【０２６０】このように、滑走路監視レベルエリア３００ａは、滑走路３０２に対する誤進入の監視を開始するためのエリアである。また、このエリアに移動体が進入した場合に、他に滑走路３０２を占有する移動体がない場合には、その進入された移動体が滑走路３０２を占有するのである。この滑走路監視レベルエリア３００ａの範囲は、図５３に示されているように滑走路警報レベルエリア３００ｂの外側、具体的には滑走路警報レベルエリア３００ｂより広く設定する必要がある。一方、滑走路警報レベルエリア３００ｂは、アプローチにおいては進入復行が可能な限界点を含めた範囲とする必要がある。さらに進入復行可能な限界点に到達するまでに管制官からの指示を行って、それに対するパイロットのアクションを起すことが可能なだけの時間的な余裕を含めておく必要がある。また、空港面に鑑みれば、この滑走路警報レベルエリア３００ｂは滑走路３０２を十分に覆う範囲とする必要がある。

【０２６１】また、滑走路占有エリア３００の属性としては、アプローチラインを横切る航空機を警報の対象外とするため、監視の対象とするベクトル方向の範囲を保持しておく必要がある。また、使用する滑走路（使用方向も含めて考える）、出発機／進入機毎の設定が可能である。

【０２６２】以上述べたように、本実施の形態に係る空港面移動体交通監視システムにおいては滑走路の誤進入を防止するために滑走路の周囲に警報を発行するための滑走路警報レベルエリア３００ｂと、さらにそれより広い滑走路監視レベルエリア３００ａを設定した。そして、この滑走路監視レベルエリア３００ａに移動体が進入した場合には、警報は発行しないが滑走路をその進入した移動体に占有させることにより、他の移動体の進入を排除している。そして、このような排他制御により滑走路に対する誤進入を防止している。

【０２６３】滑走路の誤進入を防止するために、本システムにおいては誤進入に対し以下のような表示を管制官に対する表示部に行わせる。

【０２６４】まず、移動体が滑走路を占有した時点（移動体が滑走路監視レベルエリア３００ａ内に進入した時点）において、滑走路３０２について占有中の表示を行う。滑走路が占有中である旨の表示は、デジタルマップ上の滑走路の表示の色を変更することにより行われる。なお、図４９～図５３においては色の代りに粗いハッチングにより滑走路３０２が占有状態であることを表している。

【０２６５】さらに、現在滑走路３０２を占有している移動体に対応するデジタルターゲットについてもその旨が判断できる表示がなされる。具体的には、その滑走路３０２が占有された対象であるデジタルターゲットについてもその色を変更したり、または近傍に滑走路を占有している旨の表示や記号を表すことなどが好適である。

【０２６６】このような表示をデジタルマップ、及び空港面上を移動する各移動体の表示と共に表示することにより、空港における管制の際、誤ったクリアランスの発行を防止することが可能である。さらに、既に占有中の移動体が存在する滑走路３０２に対し、別の移動体が誤進入した場合には、誤進入した移動体に対応するデジタルターゲットについてその旨が判断できるような表示がなされる。例えば、その誤進入による移動体を表すデジタルターゲットの色が変更されたり、または管制官の注意を促すべく点滅表示などを行うのが好適である。

【０２６７】又、空港面においては、滑走路近傍に移動体が存在することを許すため、管制官が介入するだけの余裕もなく、滑走路への誤進入が発生する可能性が十分考えられる。このため、滑走路への進入誘導路に踏切などの視覚援助施設を接地するとともに、さらに個の視覚援助施設との連携オートメーションを実現することにより、安全性が向上するものと考えられる。このような例が図５４に示されている。

【０２６８】尚、衝突警報を発出するエリア範囲は警報発生から、回避開始までの所要時間に移動体が進む距離と、回避のための最低必要距離の合計距離が必要であると考えられる。

【０２６９】警報発生から回避開始までの所要時間には、計算機の処理時間、管制官の指示、パイロットのアクションなどの時間が含まれますが、このうち計算機の処理時間については、他の時間に比較した場合に、ほとんど無視することが可能である。

【０２７０】又、回避のための最低必要距離は、例えば進入機で在れば進入腹腔の限界点になると考えられる。図５５に警報発生から、回避開始までの所要時間を１０秒／２０秒／３０秒／４０秒とした場合の各々について、移動体の現在速度に対する警報発生から、回避開始までの移動体の進む距離を示す。

【０２７１】交差点誤進入監視

滑走路３０２に対する誤進入を監視すると同様な目的により、交差点の誤進入を防止する必要もある。これは、ある交差点を使用中のターゲットが既に存在する場合には、新たなターゲットが交差点に進入しないように監視を行うものである。そして、新たなターゲットが交差点に進入しようとする場合に、ターゲットは既に交差点中に存在する場合にはその進入を制限するものである。

【０２７２】図５６には、空港面における交差点の監視を行う交通監視レンジの説明図が示されている。図５６に示されているように、交差点というものは、具体的にはある点を中心とする円で表される。この円をその交差点の範囲レンジと呼ぶ。また、同じく点（交差点）を中心とする範囲レンジより広い円を交通監視レンジと読んでいる。このように、交差点は、設備属性情報テーブル２０２内部に、交通監視レンジと範囲レンジとを保持しているのである。交通監視レンジ、及び範囲レンジは、

上述したように交差点を中心にする円で表され交通監視レンジはターゲットがその円内に進入した時点で、当該交差点に関する交差点誤進入監視の対象とするレンジである。一方、範囲レンジは、当該交差点の範囲を表し、範囲レンジ内に進入するターゲットは当該交差点を占有する。

【０２７３】そして、図５６に示されているように範囲レンジに入る前に各誘導路に対しストップバー（Ｓｔｏｐ　Ｂａｒ）が設けられており、移動体が範囲レンジに入る前にその進入を阻止し得るように構成されている。

【０２７４】誘導路を走行中のターゲットが交差点の交通監視レンジに進入した場合には、当該交差点を占有するものとする。これは、上述した滑走路誤進入監視と同様である。このように、交差点の内部にターゲットが存在しない場合には、新たに交通監視レンジに進入したターゲットが当該交差点を占有するため、設備属性情報テーブル２０２の内部の占有中ターゲットの項目に当該ターゲットが設定され、現在状態を占有中に設定するのである。

【０２７５】次に、当該ターゲットがこの交差点を通過し、交通監視レンジで示される円内から脱出した場合には、設備属性情報テーブル２０２の占有中ターゲットを解除し、現在状態を使用可能に設定する。これによって、この交差点は新たにこの交差点に進入する別の移動体に使用されることが可能となる。

【０２７６】逆に、移動体が交通監視レンジに進入した場合に、既にこの交差点を占有するターゲットが存在する場合にはストップバーが閉じられ、この交差点が使用可能状態に復帰するまで移動体は範囲レンジに進入することはできない。このように、移動体を制御することにより交差点に対する誤進入を防止することが可能である。

【０２７７】

【発明の効果】第１の本発明によれば、所定のしきい値より高いか否かで警報の発行、非発行を制御しうるので、しきい値を変化させることにより、効率的に警報の抑止が行える空港面移動体交通監視装置が得られる。

【０２７８】第２の本発明によれば、各移動体に経路計画が割り当てられるので、管制官お負担を減少しうる空港面移動体交通監視装置が得られる。

【０２７９】第３の本発明によれば、各移動体の移動開始地点、及び終了地点に基づき経路計画が検索されるので、迅速な処理が可能な空港面移動体交通監視装置が得られる。

【０２８０】第４の本発明によれば、各経路計画の同時利用な移動体数を記憶保持しているため、特定の経路計画のみに割り当てが集中することを防止し、円滑な空港の運用が可能な空港面移動体交通監視装置が得られる。

【０２８１】第５の本発明によれば、各経路計画に含まれる誘導路毎に、その利用可能な移動体数を記憶、保持し、その誘導路に対する利用移動体数がこの値より大きくならないように、割り当てを行った。そのため、誘導路ごとに特に混雑してしまうことを防止し、円滑な空港の運用が可能となる。

【０２８２】第６の本発明によれば、割り当てられた経路計画が変更された場合でも、変更の前後の経路計画に基づき、新たな経路計画が作成されるので、円滑な経路計画の切替が行える。

【０２８３】第７の本発明によれば、割り当てられた経路計画が正確に履行されているか否かを効率的に監視しうる空港面移動体交通監視装置が得られる。

【０２８４】第８の本発明によれば、誘導路の共用可能移動体数を超える移動体数がその誘導路に進入しようとした場合に警報を発行するため、衝突を未然に防止可能である。

【０２８５】第９の本発明によれば、誘導路が利用されている場合に、その移動体の移動方向とは反対側からの交通ノードからの進入を制限することにより、衝突を未然に防止可能である。

【０２８６】第１０の本発明によれば、近傍に隣接して並ぶ誘導路を、同時にそれぞれ移動体が使用した場合に、これらの移動体が側面において衝突してしまうことを防止すべく、交通ノードのグループ化により、一定の交通ノードを進入禁止とする。そのため、横方向の衝突を未然に防止することが可能である。

【０２８７】第１１の本発明によれば、滑走路を排他使用することにより衝突を回避する監視装置において、監視エリアと、警報エリアの２種類の領域を設けたので円滑な排他使用が可能となる。

【０２８８】第１２の本発明によれば、上記第１１の本発明と同様の効果が奏される。

【０２８９】第１３の本発明によれば、誘導路の混雑状況が肉眼で容易に把握できるため、管制官の負担の軽減を図ることが可能な空港面移動体交通監視装置が得られる。

【図面の簡単な説明】

【図１】　本発明の好適な実施の形態である空港面移動体交通監視システムの主要な構成を表す構成ブロック図である。

【図２】　本実施の形態に係るデータの関係を表す説明図である。

【図３】　本システムにおいて、誘導路と交差点との関係を表す説明図である。

【図４】　図３と同じく誘導路と交差点との関係を表すとともに、交通ノードの関係をも表す説明図である。

【図５】　設備種別情報テーブルの内容を表す説明図である。

【図６】　設備属性情報テーブルの内容を表す説明図である。

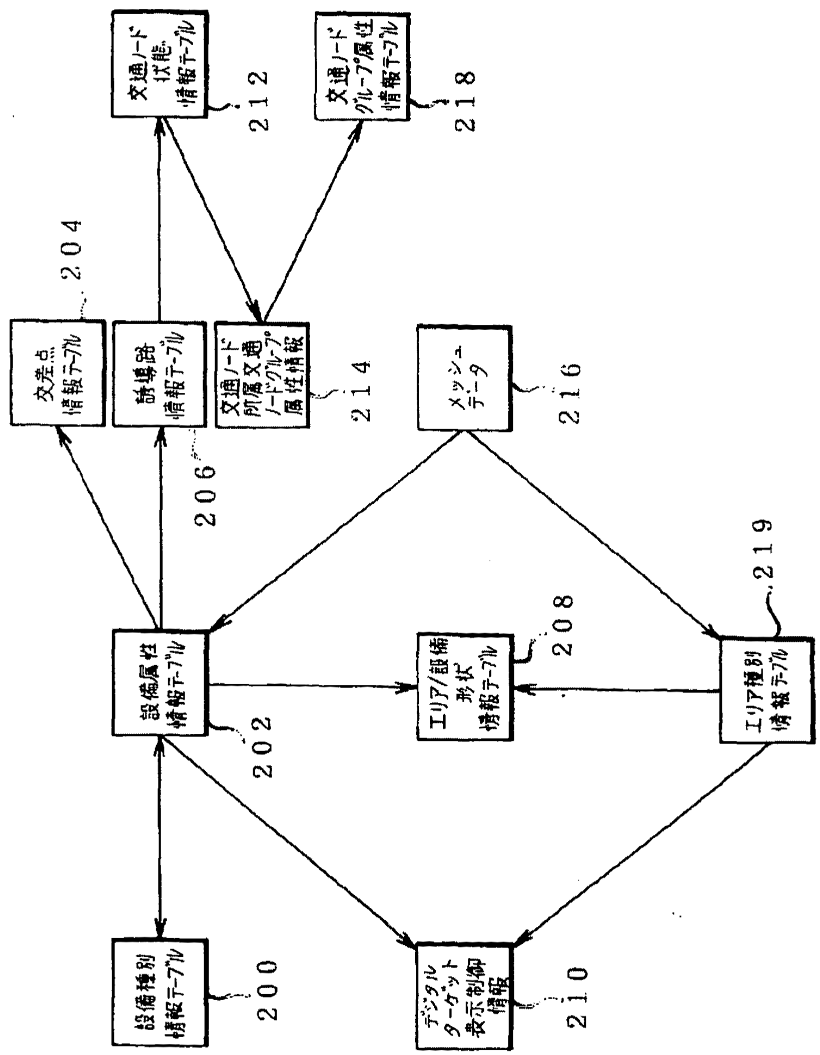
【図７】　交差点情報テーブルの内容を表す説明図であ

る。
【図８】　誘導路情報テーブルの内容を表す説明図である。
【図９】　エリア種別情報テーブルの内容を表す説明図である。
【図１０】　エリア／設備形状情報の内容を表す説明図である。
【図１１】　デジタルターゲット表示制御情報テーブルの内容を表す説明図である。
【図１２】　交通ノード状態情報テーブルの内容を表す説明図である。
【図１３】　交通ノード所属交通ノードグループ情報テーブルの内容を表す説明図である。
【図１４】　交通ノードグループ属性情報テーブルの内容を表す説明図である。
【図１５】　メッシュデータの内容を表す説明図である。
【図１６】　移動体属性情報テーブルの内容を表す説明図である。
【図１７】　航跡情報テーブルの内容を表す説明図である。
【図１８】　経路計画割当状態情報テーブルの内容を表す説明図である。
【図１９】　移動計画情報テーブルの内容を表す説明図である。
【図２０】　空港運用情報テーブルの内容を表す説明図である。
【図２１】　経路計画情報テーブルの内容を表す説明図である。
【図２２】　経路計画使用設備情報テーブルの内容を表す説明図である。
【図２３】　経路計画状態テーブルの内容を表す説明図である。
【図２４】　設備混雑状態情報テーブルの内容を表す説明図である。
【図２５】　本実施の形態に係る空港面移動体交通監視システムの画面表示の例を表す説明図である。
【図２６】　本実施の形態に係る空港面移動体交通監視システムの画面表示の例を表す説明図である。
【図２７】　本実施の形態に係る空港面移動体交通監視システムの画面表示の例を表す説明図である。
【図２８】　本実施の形態に係る空港面移動体交通監視システムの画面表示の例を表す説明図である。
【図２９】　本実施の形態に係る空港面移動体交通監視システムの画面表示の例を表す説明図である。
【図３０】　本実施の形態に係る空港面移動体交通監視システムの画面表示の例を表す説明図である。
【図３１】　本実施の形態に係る空港面移動体交通監視システムの画面表示の例を表す説明図である。
【図３２】　本実施の形態に係る空港面移動体交通監視システムの画面表示の例を表す説明図である。
【図３３】　本実施の形態に係る空港面移動体交通監視システムの画面表示の例を表す説明図である。
【図３４】　現在の移動体数を把握する動作を表すフローチャートである。
【図３５】　交通密度を監視する際の動作を表すフローチャートである。
【図３６】　交通監視を行うか否かが自動的に切り替えられる場合の切替の動作を表すフローチャートである。
【図３７】　経路Ａがあるターゲットに割り当てられている場合、経路Ｂを別のターゲットに割り当てることはできないことを表す説明図である。
【図３８】　経路計画の自動割当の具体的な動作を表すフローチャートである。
【図３９】　経路計画の移管の様子を示す説明図である。
【図４０】　各誘導路の混雑具合に応じて各誘導路の中心線の太さを変更して表示したデジタルマップを表す説明図である。
【図４１】　ターゲットが履行している経路計画に含まれる誘導路が黒線で表示される様子を表す説明図である。
【図４２】　誘導路縦方向衝突監視（１）の具体的な衝突監視の例が示されている説明図である。
【図４３】　誘導路縦方向衝突監視（２）の具体的な衝突監視の例が示されている説明図である。
【図４４】　誘導路横方向衝突監視の具体的な衝突監視の例が示されている説明図である。
【図４５】　誘導路横方向衝突監視において、３個のノードに対し１グループかなされている場合の例を表す説明図である。
【図４６】　セパレーションによる移動体同士の間隔により衝突の検知を行う方法の説明図である。
【図４７】　セパレーションによる移動体同士の間隔により衝突の検知を行う方法において誤警報が発生する可能性のある場合の説明図である。
【図４８】　滑走路誤進入監視の動作の説明図である。
【図４９】　滑走路誤進入監視の動作の説明図である。
【図５０】　滑走路誤進入監視の動作の説明図である。
【図５１】　滑走路誤進入監視の動作の説明図である。
【図５２】　滑走路誤進入監視の動作の説明図である。
【図５３】　滑走路誤進入監視の動作の説明図である。
【図５４】　滑走路誤進入監視の動作の説明図である。
【図５５】　警報発生から回避開始までの所要時間を１０秒～４０秒とした場合の移動体の進む距離を表す表の説明図である。
【図５６】　交差点における交通監視レンジの説明図である。
【図５７】　経路計画の選択において航空機型式により経路が変化する様子を表す説明図である。

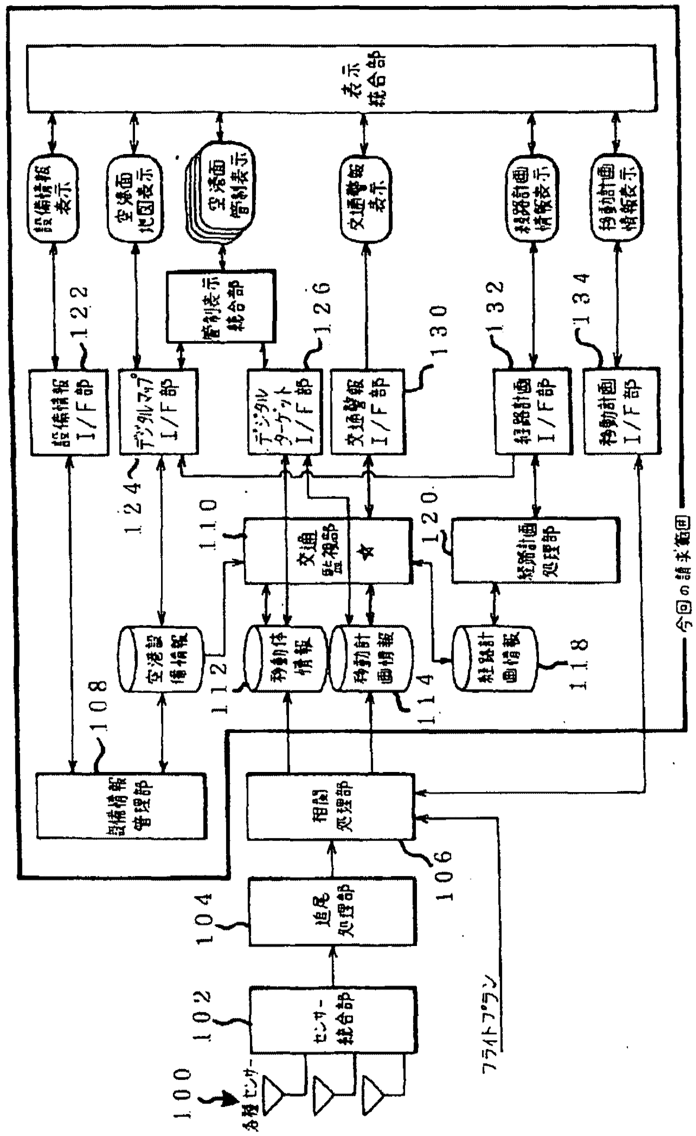
【符号の説明】

１００　各種センサー、１０２　センサー統合部、１０４　追尾処理部、１０６　相関処理部、１０８　設備情報管理部、１１０　交通監視部、１１２　移動体情報、１１４　移動計画情報、１１６　空港設備情報、１１８　経路計画情報、１２０　経路計画処理部、１２２　設備情報Ｉ／Ｆ部、１２４　デジタルマップＩ／Ｆ部、１２８　管制表示統合部、１３０　交通警報Ｉ／Ｆ部、１３２　経路計画Ｉ／Ｆ部、１３４　移動計画Ｉ／Ｆ部、２００　設備種別情報テーブル、２０２　設備属性情報テーブル、２０４　交差点情報テーブル、２０６　誘導路情報テーブル、２０８　エリア／設備形状情報テーブル、２１０　デジタルターゲット表示制御情報、２１２　交通ノード状態情報テーブル、２１４　交通ノード所属交通ノードグループ属性情報、２１６　メッシュデータ、２１８　交通ノードグループ属性情報テーブル、２１９　エリア種別情報テーブル、３００　滑走路占有エリア、３００ａ　滑走路監視レベルエリア、３００ｂ　滑走路警報レベルエリア、３０２　滑走路、３０４　進入機、３０６　出発機、３０８　地上面走行。

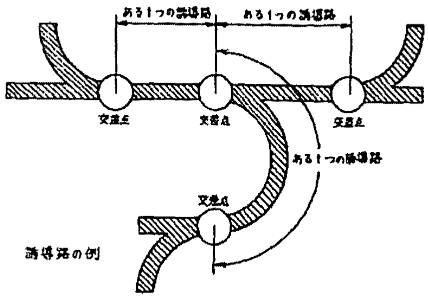
【図２】



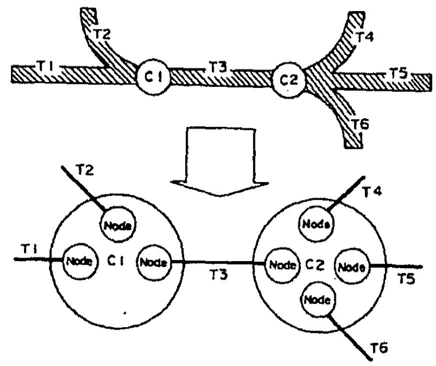
【図1】


表示統合部
設備情報表示
空港面地図表示
空港面管制表示
交通警報表示
経路計画情報表示
移動計画情報表示
管制表示統合部
設備情報I/F部
デジタルマップI/F部
デジタルターゲットI/F部
交通警報I/F部
経路計画I/F部
移動計画I/F部
交通監視部
経路計画処理部
空港設備情報
移動体情報
移動計画情報
経路計画情報
設備情報管理部
相関処理部
追尾処理部
センサー統合部
各種センサー
フライトプラン
今回の請求範囲
100
102
104
106
108
110
112
114
118
120
122
124
126
130
132
134

【図3】



【図4】



【図5】

空港設備情報

設備種別情報テーブル		
		設備種別情報テーブルは、設備種別毎の主にデジタルマップ表示に関する各種属性情報を保持し、1個の設備種別が1個のインスタンスに対応する。
*	エリア／設備種別	設備／エリアの種別をユニークに判定するための識別子である。
+	最小表示倍率	当該設備種別をデジタルマップに描画する場合のデジタルマップの最低の表示倍率を示す。デジタルマップの表示倍率を縮小した場合に、視認できる限界値であり、これ以下の倍率では、当該設備種別の表示を行なわない。
+	最大表示倍率	当該設備種別をデジタルマップに描画する場合のデジタルマップの最大の表示倍率を示す。デジタルマップの表示倍率を拡大した場合に、視認できる限界値であり、これ以上の倍率では、当該設備種別の表示を行なわない。
+	デジタルマップ表示色	デジタルマップに表示する際の表示色を示す。
+	デジタルマップ塗りつぶし区分	デジタルマップに表示する際に輪郭のみ表示するか塗りつぶすかの区分を示す。
+	表示デジタルマップ区分	表示するデジタルマップを示す。デジタルマップには、基本／セレクト／エリアマップの区分があり、どのデジタルマップに描画するかの情報を示す。

【図6】

設備属性情報テーブル		
		設備属性情報テーブルは、個々の設備毎の属性情報を示し、1個の設備が1個のインスタンスに対応し、存在する全ての設備に関する情報を保持する。
*	エリア／設備種別	設備／エリアの種別をユニークに判定するための識別子である。
*	設備識別子	個々の設備をユニークに識別するための識別子である。
+	設備名称	設備の名称であり、インスタンス生成時に運用者により名前付けされる。設備名称は、運用者、地上管制官、パイロット等により共通に認識できる名前である。
+	交通監視を行なう最低交通密度レベル	当該設備を使用中の移動体に対する交通監視を行なう最低交通密度レベルを示す。空港の交通密度レベルが本値以上となった場合に、交通監視を実施する。
+	交通監視を行なう最低視程条件レベル	当該設備を使用中の移動体に対する交通監視を行なう最低視程条件レベルを示す。空港の視程条件レベルが本値以上となった場合に、交通監視を実施する。
+	共用可能ターゲット数	共用資源を同時に使用することが可能なターゲット数を示す。
+	現在状態	当該設備の現在の状態を以下の区分で示す。 ＃占有状態 ＃使用可能状態 ＃使用不可能状態（交通監視に基づく） ＃使用不可能状態（クローズに基づく）
+	現在使用中ターゲット数	当該設備を現在使用中のターゲット数を示す。
+	経路計画自動割当て実施最大交通密度レベル	交通密度が当該レベル以上である場合は、経路計画自動割当てを行なわない。
+	経路計画自動割当て実施最大視程条件レベル	視程条件が当該レベル以上である場合は、経路計画自動割当てを行なわない。
+	デジタルターゲット表示制御情報識別子	当該設備のデジタルターゲット表示制御情報の識別子を示す。

【図７】

交差点情報テーブル		
		設備種別が交差点である設備について、設備属性情報テーブルに加えて以下の付加情報を保持する。
*	設備識別子	個々の設備をユニークに識別するための識別子である。
+	交差点位置情報	交差点の位置を基本座標系におけるＸＹ座標で示す。
+	交差点範囲レンジ	交差点の範囲を示す。交差点位置を中心とし、交差点範囲レンジを半径とする円内を当該交差点の範囲とする。交差点範囲内に存在する移動体は、その交差点を占有していなければならない。また、交差点の範囲は当該交差点に対するストップバーの内側になければならない。
+	交差点交通監視レンジ	交差点の交通監視を行う範囲を示す。当該交差点を使用する移動体が、交差点位置を中心とした交差点交通監視レンジを半径とする円内に進入した場合に、その移動体について当該交差点の交通監視を行う。交差点交通監視レンジは、交差点範囲レンジ以上の値域である必要がある。
+	占有中移動体識別子	現在当該交差点を占有しているターゲットの識別子を示す。

【図８】

誘導路情報テーブル		設備種別が誘導路である設備について、以下の付加情報を保持する。
		設備種別が誘導路である設備について、設備属性情報テーブルに加えて以下の付加情報を保持する。
*	設備識別子	個々の設備をユニークに識別するための識別子である。
+	交通ノード（１）識別子	当該誘導路に対応する交通ノードを示す。
+	交通ノード（２）識別子	当該誘導路に対応する交通ノードを示す。

【図９】

エリア種別情報テーブル		
		エリア種別に関する情報を保持する。
*	エリア／設備種別	設備／エリアの種別をユニークに判定するための識別子である。
+	エリア判定キー	当該エリアに対するＩＮ／ＯＵＴの判定を行なうためのキー情報である。エリア判定キーは、メッシュデータテーブルのエリア判定情報の当該エリアのＩＮ／ＯＵＴ情報格納位置を示す。
+	デジタルターゲット表示制御情報識別子	当該設備のデジタルターゲット表示制御情報の識別子を示す。

【図１０】

エリア／設備形状情報		
		エリア／設備の形状に関する情報は、以下に示すエリア／設備形状情報テーブルにより表現する。エリア／設備の形状は、１個以上の図形により表現し、１個のエリアや設備の形状を、複数の図形の組み合わせで構成することを可能とする。
*	エリア／設備種別	設備／エリアの種別をユニークに判定するための識別子である。
*	設備識別子	個々の設備、エリアをユニークに識別するための識別子である。
*	図形識別子	図形をユニークに識別するための識別子である。図形識別子は、エリア／設備種別識別子、及び設備識別子によりユニークに識別される１個のエリア、又は設備を構成する１個以上の図形に対してシーケンシャルな番号を付与することにより表現する。
+	図形形状区分	図形形状の区分を（１）点、（２）線分、（３）ポリライン、（４）ポリゴン、（５）矩形、（６）２レンジ２アジマス（極座標系）の別で示す。
+	図形座標情報	図形形状区分が 点の場合は１点のＸＹ座標、線分の場合は両端２点のＸＹ座標、ポリライン／ポリゴンの場合は各端点のＸＹ座標、矩形の場合は対角２点のＸＹ座標、２レンジ２アジマスの場合は、中心のＸＹ座標値、及び２個のレンジ値と２個のアジマス値により表現する。
+	有効高度上限値	エリアのインスタンスである場合に、当該エリアによる制御が有効となる移動体の高度に対する条件である。
+	有効高度下限値	エリアのインスタンスである場合に、当該エリア種別による制御が有効となる移動体の高度に対する条件である。
+	有効ヘディング	エリアのインスタンスである場合に、当該エリア種別による制御が有効となる移動体のヘディングに対する条件である。移動体のヘディングが本値から有効ヘディング誤差範囲内にある場合に、その移動体に対する当該エリアの制御が有効となる。
+	有効ヘディング誤差	エリアのインスタンスである場合に、有効ヘディングからの誤差の許容範囲値である。

【図１２】

交通ノード状態情報テーブル		
		交通ノードは、交差点において、当該交差点に接続する各誘導路に対応して自動生成する。誘導路は２つの交差点を結ぶ線分であり、ある交差点は複数の誘導路の端点となっている。誘導路から見たこの端点を交通ノードと呼ぶ。
*	対応誘導路の設備識別子	当該交通ノードに対応する誘導路を、設備識別子により示す。
*	対応交差点の設備識別子	当該交通ノードに対応する交差点を、設備識別子により示す。
@	交通ノード識別子	交通ノードをユニークに識別するための識別子であり、代替キー情報である。
+	現在状態	当該交通ノードに対応する交差点から、当該交通ノードに対応する誘導路への進入の許可／禁止状態を示す。
+	所属交通ノードグループ数	当該交通ノードが所属する交通ノードグループの個数を示す。

【図１３】

交通ノード所属交通ノードグループ情報テーブル		
		当該交通ノードが、他の交通ノードと交通ノードグループを構成する場合に、当該交通ノードが所属する交通ノードグループに関する属性情報を示す。１個の交通ノードは、複数の交通ノードグループに所属可能とする。
*	交通ノード識別子	交通ノードをユニークに識別するための識別子である。
*	所属交通ノードグループ識別子	当該交通ノードが所属する交通ノードグループをユニークに識別するための識別子である。
+	交通ノードグループ状態設定マスク値	交通ノードの現在状態変更に伴い、交通ノードグループ属性情報テーブルの交通ノードグループ状態を設定するマスク値を示す。進入許可状態から禁止状態に変更した場合に、本値を論理和設定し、進入禁止状態から許可状態に変更した場合に、本値の補数の論理積設定する。

【図11】

デジタルターゲット表示制御情報テーブル		
		設備やエリア内に存在するターゲットのデジタルターゲット表示を制御する情報である。これは、管制官に誤解を招くような表示を補正すると共に、必要とする情報のみをフィルタリングすることにより、管制のオーバロードを抑えることを目的とする。
•	デジタルターゲット表示制御情報識別子	デジタルターゲット表示情報をユニークに識別するための識別子である。
+	有効レンジスケール上限値	表示制御を行なう設備、エリアにおいて当該エリアによる制御が有効になる、デジタルマップのレンジスケール上限値である。
+	有効レンジスケール下限値	表示制御を行なう設備、エリアにおいて当該エリアによる制御が有効になる、デジタルマップのレンジスケール下限値である。
+	リーダ方向	当該設備、エリア上にある移動体のデジタルターゲット表示のリーダ方向を指定する。これにより他のデジタルターゲットのタグとの重なりを防止する。本値が無効値の場合は、既定のリーダ方向を採用する。
+	進入機タグ表示形式	当該設備、エリア内に存在する進入機移動体のデジタルターゲットタグ形式を規定する情報である。
+	出発機タグ表示形式	当該設備、エリア内に存在する出発機移動体のデジタルターゲットタグ形式を規定する情報である。
+	通過機タグ表示形式	当該設備、エリア内に存在する通過機移動体のデジタルターゲットタグ形式を規定する情報である。
+	地上移動体タグ表示形式	当該設備、エリア内に存在する地上移動体のデジタルターゲットタグ形式を規定する情報である。
+	進入機サプレス情報	当該エリア内にある進入機移動体のデジタルターゲット表示サプレスを指定する。サプレスは、シンボル、タグの各々について指定可能とする。
+	出発機サプレス情報	当該エリア内にある出発機移動体のデジタルターゲット表示サプレスを指定する。サプレスは、シンボル、タグの各々について指定可能とする。
+	通過機サプレス情報	当該エリア内にある通過機移動体のデジタルターゲット表示サプレスを指定する。サプレスは、シンボル、タグの各々について指定可能とする。
+	地上移動体サプレス情報	当該エリア内にある地上移動体のデジタルターゲット表示サプレスを指定する。サプレスは、シンボル、タグの各々について指定可能とする。
+	予測位置採用要否	当該設備、エリア内にある移動体について予測位置を採用した表示を行なうか否かを示す。予測位置採用要否が要である場合は、当該設備上にある移動体が以下に示す最低速度条件、及びヘディング条件を満たす場合に、現在位置ではなく予測位置を使用した表示を行なう。
+	ヘディング補正採用要否	当該設備、エリア内にある移動体についてヘディング補正値を採用した表示を行なうか否かを示す。本データが要である場合は、当該設備、エリア内にある移動体が以下に示すヘディング条件を満たす場合に、過去位置から算出したヘディングではなくヘディング補正値を採用する。
+	予測位置採用最低速度条件	予測位置採用要否が要である設備上で、予測位置表示を行なうためのターゲットの最低速度を示す。本速度以下の速度で移動するターゲットについては、現在位置で表示を行う。
+	予測位置採用ヘディング条件基準値	予測位置採用要否が要である設備上で、予測位置表示を行なうためのターゲットのヘディング条件を示す。ターゲットのヘディングが本値、または本値＋１８０°から次に示す予測位置採用ヘディング条件誤差範囲内に無い場合は、現在位置で表示を行う。
+	予測位置採用ヘディング条件誤差範囲	予測位置採用要否が要である設備上で、予測位置表示を行なうための予測位置採用ヘディング条件基準値に対する誤差範囲を示す。

【図14】

交通ノードグループ属性情報テーブル		
		交通ノードグループ属性情報テーブルは、交通ノードグループの属性を示す情報であり、１個の交通ノードグループが１個のインスタンスに対応する。
•	交通ノードグループ識別子	交通ノードグループをユニークに識別するための識別子である。
+	交通ノードグループ状態	交通ノードグループの状態を示す。本データは、少ない演算で交通ノードグループの状態を設定、参照するために、所属する交通ノード毎のビットマップフラグとして実装し、グループ中の進入禁止状態の交通ノードに対するビットがＯＮとなる。

【図１５】

メッシュデータ		
		メッシュデータは、空港面、及びその周辺の座標毎にインスタンスを保持し、個々の座標毎に当該座標に存在する設備識別子、及びエリアＩＮ／ＯＵＴ情報を保持する。メッシュデータは、ターゲットの現在位置における設備、エリアＩＮ／ＯＵＴ状態を知るために用いる。
*	位置座標	空港面上の位置を示す。
+	設備識別子	位置座標に対応する設備を示す。
+	エリアＩＮ／ＯＵＴ状態	位置座標に対応するエリアＩＮ／ＯＵＴ状態を保持する。

【図１６】

移動体情報

移動体属性情報テーブル		
		移動体属性情報テーブルは、移動体の現在の属性情報を示し、現在存在する移動体に対応してインスタンスを保持する。
*	移動体識別子	移動体をユニークに識別するための識別子である。
+	現在位置座標	移動体の現在位置座標を示す。
+	現在速度	移動体の現在の速度を示す。
+	現在高度	移動体の現在の高度を示す。
+	ヘディング	移動体の現在の進行方向を示す。
+	予測位置座標	移動体の一定時間後の予測位置を示す。
+	応答ビーコンコード	移動体を識別するためのコード情報を示す。
+	移動計画識別子	移動体と現在相関が取られている移動計画識別子を示す。
+	割当て経路計画数	移動計画に現在割り当てられている経路計画数を示す。
+	経路計画識別子	移動体が現在履行中の経路計画の履行順序番号を示す。
+	現在履行中経路計画移動順序番号	移動体が現在履行中の経路計画中の移動順序番号を示す。
+	現在使用中設備	移動体が現在使用中の設備の設備識別子を示す。
+	エリアＩＮ／ＯＵＴ状態	移動体の現在のエリアＩＮ／ＯＵＴ状態を示す。
+	交通監視警報状態	移動体の現在の警報状態を示す。
+	交通監視ホールド指示状態	移動体が交通監視に基づくホールド指示を受けている場合は、ホールド指示状態となる。
+	交通監視ホールド指示開始時刻	移動体が交通監視に基づくホールド指示を受けた時刻を示す。

【図１７】

航跡情報テーブル		
		航跡情報テーブルは、移動体の過去一定時間分の位置とヘディングに関する情報を示し、移動体毎に複数インスタンス保持する。本情報は、移動体の位置情報を受ける毎に追加し、更に定周期で監視して不要インスタンスをガベージする。
*	移動体識別子	移動体をユニークに識別するための識別子である。
*	過去時刻	過去の時点の時刻を示す。
+	位置座標	当該移動体の過去時刻における位置座標を示す。
+	ヘディング	当該移動体の過去時刻におけるヘディングを示す。

【図１８】

経路計画割当て状態情報テーブル		
		経路計画割当て状態情報テーブルは、移動体に対して割り当てられている経路計画を示す。１個の移動体には複数の経路計画を割り当てることが可能であり、経路計画を割り当てられている移動体毎に複数インスタンスを保持する。
*	移動体識別子	移動体をユニークに識別するための識別子である。
*	経路計画履行順序番号	経路計画の履行の順序を示すシリアル番号である。
+	経路計画識別子	経路計画履行順序番号に対応する割当経路計画識別子を示す。

【図１９】

移動計画情報

移動計画情報テーブル		
		移動計画情報テーブルは、移動計画の属性情報を示し、移動計画に対応してインスタンスを保持する。
*	移動計画識別子	移動計画をユニークに識別するための識別子である。
+	フライトプラン情報	当該移動計画がフライトプラン由来である場合に、元となるフライトプラン情報を保持する。
+	スポット情報	当該移動計画（フライトプラン）に対応するスポット情報（スポット管理システムより受け取る）が存在する場合にそのスポット情報を保持する。
+	空港面移動開始時刻	当該移動計画における空港面移動の開始予定時刻を示す。当該移動計画に対応するフライトプラン、スポット情報が存在する場合は、それらの情報より自動算出も可能である。
+	空港面移動終了時刻	当該移動計画における空港面移動の終了予定時刻を示す。当該移動計画に対応するフライトプラン、スポット情報が存在する場合は、それらの情報より自動算出も可能である。
+	空港面移動開始地点	当該移動計画における空港面移動の開始地点の設備識別子を示す。当該移動計画に対応するフライトプラン、スポット情報が存在する場合は、それらの情報より自動決定も可能である。
+	空港面移動終了地点	当該移動計画における空港面移動の終了地点の設備識別子を示す。当該移動計画に対応するフライトプラン、スポット情報が存在する場合は、それらの情報より自動決定も可能である。

【図２０】

空港運用情報

空港運用情報テーブル		
		空港運用情報テーブルは、交通監視に関係する現在の空港運用の状態に関する情報を保持する。
+	交通密度レベル	現在の交通密度レベルを３段階（レベル１からレベル３、レベル値が高いほど交通密度が高い）で示す。
+	視程条件レベル	現在の視程条件レベルを３段階（レベル１からレベル３、レベル値が高いほど視程条件が悪い）で示す。
+	現在移動体数	現在空港面上に存在する移動体の数を示す。
+	交通密度レベル２移動体数	交通密度レベル２における最低の移動体数を示す。現在移動体数が本値を越えた場合は、レベル２状態とする。
+	交通密度レベル３移動体数	交通密度レベル３における最低の移動体数を示す。現在移動体数が本値を越えた場合は、レベル３状態とする。
+	現在選択中経路計画グループ	現在の空港運用（使用滑走路等）に基づき選択されている経路計画グループを示す。

【図21】

経路計画情報

経路計画情報テーブル		
		経路計画情報テーブルは、経路計画候補の属性を示し、経路計画候補毎にインスタンスを保持する。
•	経路計画識別子	経路計画候補をユニークに識別するための識別子である。
+	経路計画名称	管制官、パイロット等が経路計画候補を認識するための名称を示す。
+	移動開始地点	経路計画候補の移動開始地点の設備識別子を示す。
+	移動終了地点	経路計画候補の移動終了地点の設備識別子を示す。
+	選択優先順位	同一移動開始地点、移動終了地点を保持する経路計画候補群中の自動選択優先順位を示す。
+	同時利用可能移動体数	当該経路計画候補を同時に割り当てることが可能な移動体の個数を示す。
+	標準走行所用時間	当該経路計画により移動開始地点から移動終了地点に移動するのにかかる標準的な走行所要時間を示す。
+	経路計画グループ識別子	当該経路計画候補が所属する経路計画グループ識別子を示す。経路計画の選択を容易にするため、その時点の空港運用状態（使用滑走路、視程条件、混雑状態等）によりグルーピングし、その時点で使用可能な経路計画候補を絞り込むことを可能とする。
+	自動割当て選択／禁止	当該経路計画がが自動割当ての対象となっているか否かを示す。経路計画には、管制官の許可無しに割り当てられる計画と管制官の許可が必要となる計画があることが想定され、管制官の許可が必要となる計画については自動割当て禁止となる。
+	自動割当て可能移動形態	自動割当て時に当該経路計画を使用可能なターゲットの移動形態（進入／出発／空港面移動等）の区分である。
+	使用可能航空機クラス上限下限	航空機クラスはクラス1～クラス3の3種類程度を持ちフライトプランの航空機形式または後方乱気流区分(ヘビー/ミディアム/ライト)から導出可能

【図22】

経路計画使用設備情報テーブル		
		経路計画使用設備情報テーブルは、経路計画候補毎に経路計画候補中で使用する誘導路設備の情報を示す。
•	経路計画識別子	経路計画候補をユニークに識別するための識別子である。
•	移動順序番号	移動する順序を示すシリアル番号である。移動順序番号は当該経路計画で使用する各誘導路設備に対して、使用する順番に番号付けする。
+	使用設備識別子	当該経路計画の移動順序番号に対応する設備識別子（誘導路）を示す。
+	進入交通ノード	当該誘導路に対する進入側の交通ノードを示す。使用設備（誘導路）設定時に内部的に自動設定する。

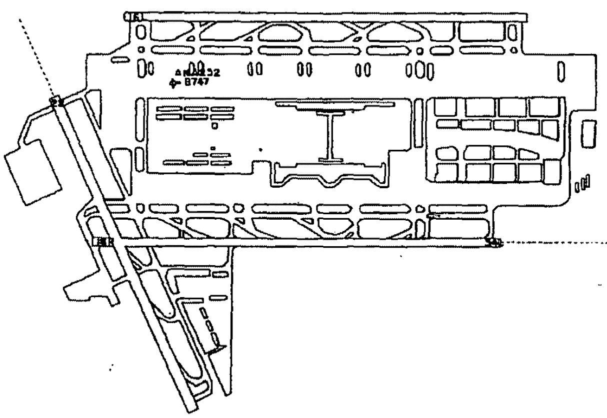
【図23】

経路計画状態テーブル		
		経路計画状態テーブルは、経路計画候補毎に、経路計画候補の移動体への現在の割当て状態の情報を保持する。
•	経路計画識別子	経路計画候補をユニークに識別するための識別子である。
+	現在使用中移動体数	当該経路計画を現在割り当てられている移動体の個数を示す。
+	直近走行所要時間	当該経路計画の現在の直近走行所要時間を示す。
+	使用可否状態	当該経路計画が使用する設備の中で、現在使用禁止状態の設備が含まれている場合には、使用不可とする。
+	使用可否最終チェック時刻	当該経路計画について使用可否状態を最後にチェックした時刻を示す。

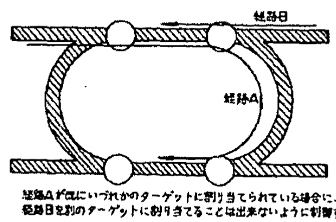
【図２４】

設備混雑状態情報テーブル		
		設備混雑状態情報テーブルは、経路計画が使用する設備について設備毎の使用状況に関する情報を保持する。
*	設備識別子	個々の設備をユニークに識別するための識別子である。
+	通過予定移動体数	当該誘導路を通過する予定のターゲット数を示す。
+	進入交通ノード	当該誘導路の現在進入側として使用中の交通ノードを示す。移動体に割り当てられた複数の経路計画は同一誘導路を使用可能であるが、進入交通ノードが異なると安全性、移動効率上好ましくない。経路計画自動割当てでは、このような状態が発生しないようにチェックする。

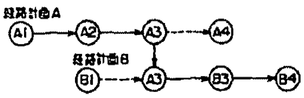
【図２５】



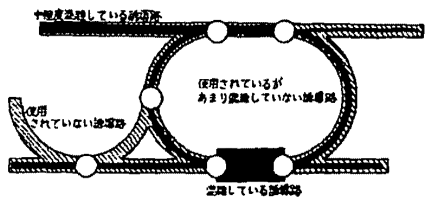
【図３７】



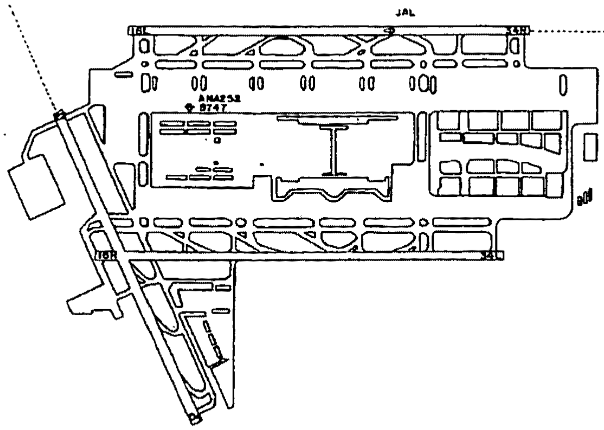
【図３９】



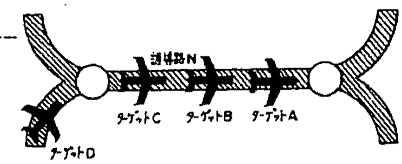
【図４０】



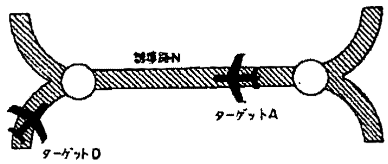
【図２６】



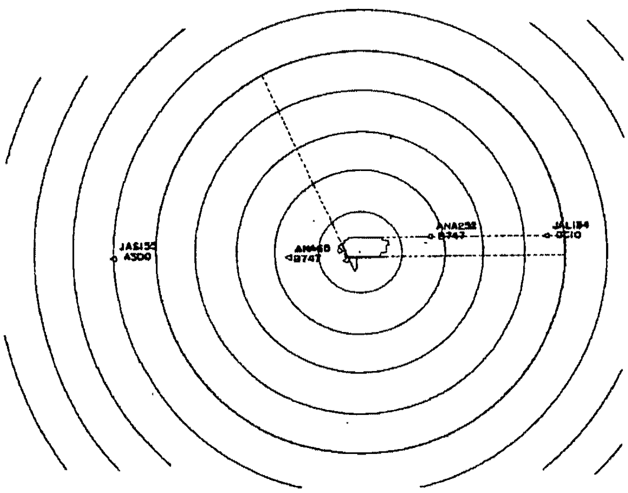
【図４２】



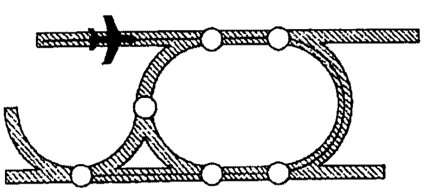
【図４３】



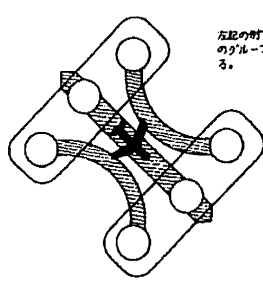
【図２７】



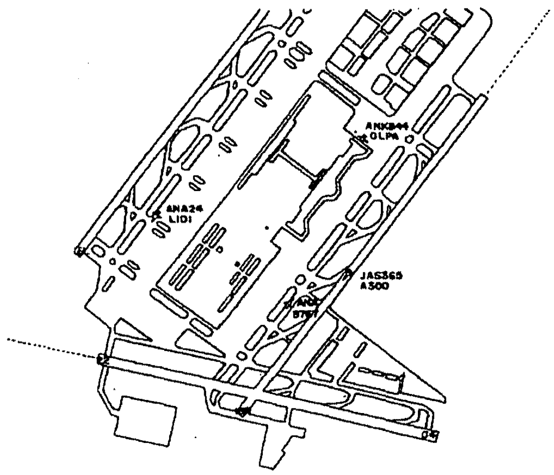
【図４１】



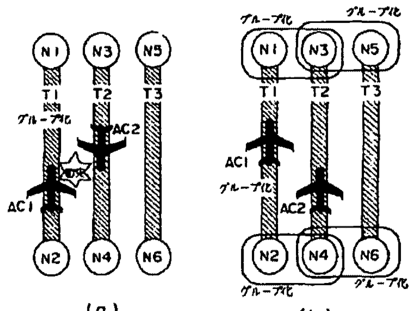
【図４５】



【図２８】

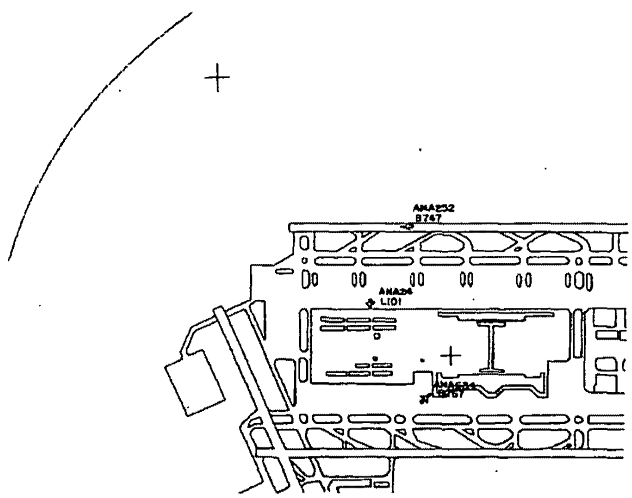


【図４４】

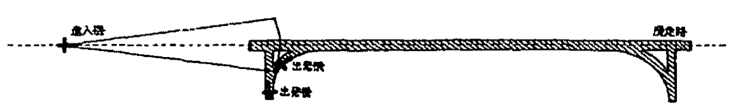


(a) 図の例では、AC1とAC2は、横方向の離隔距離を確保出来ない。
(b) 図の例では、AC1とAC2は、横方向の離隔距離を確保出来る。

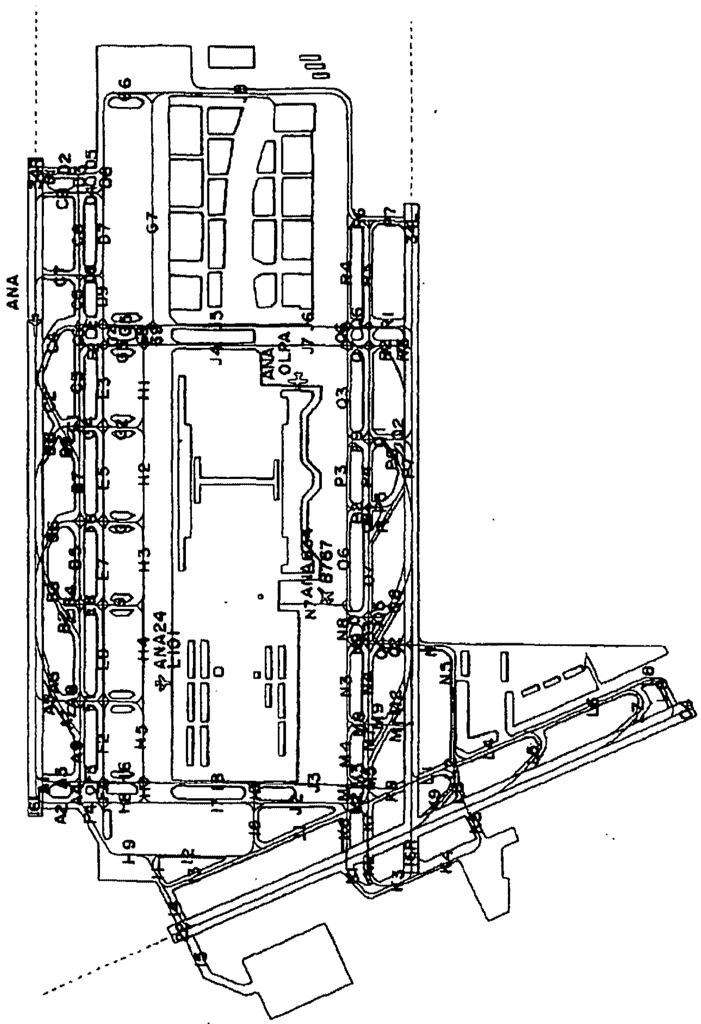
【図３１】



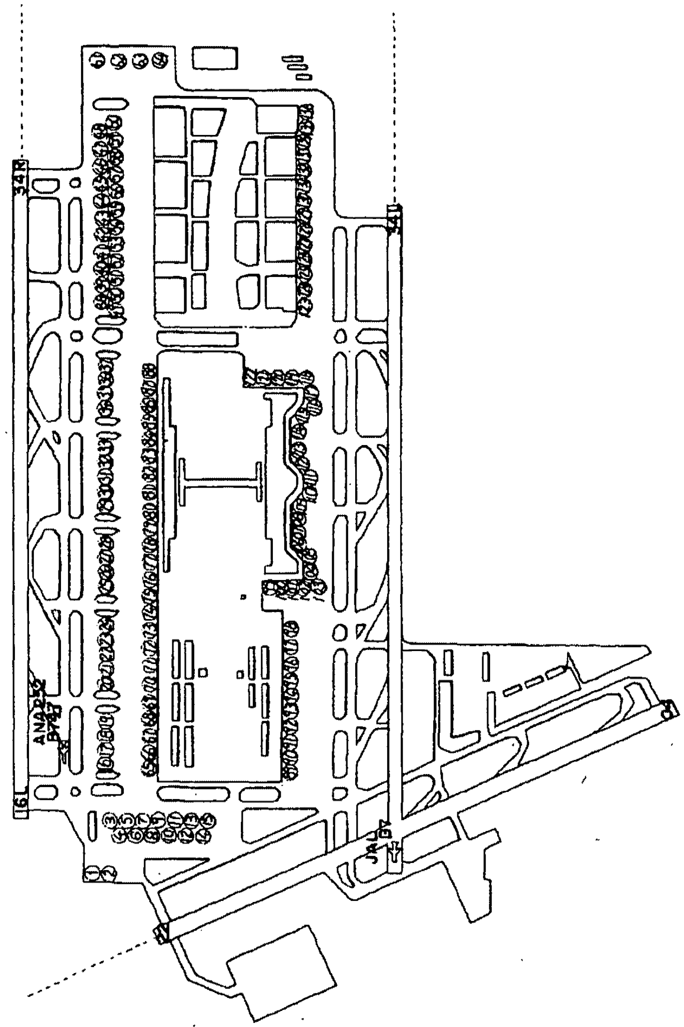
【図４７】



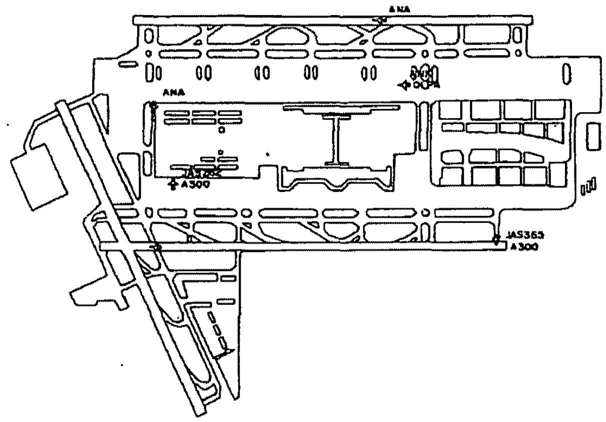
【図２９】



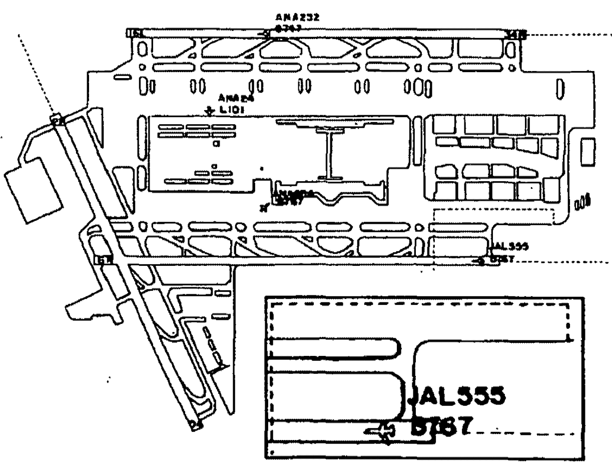
【図３０】



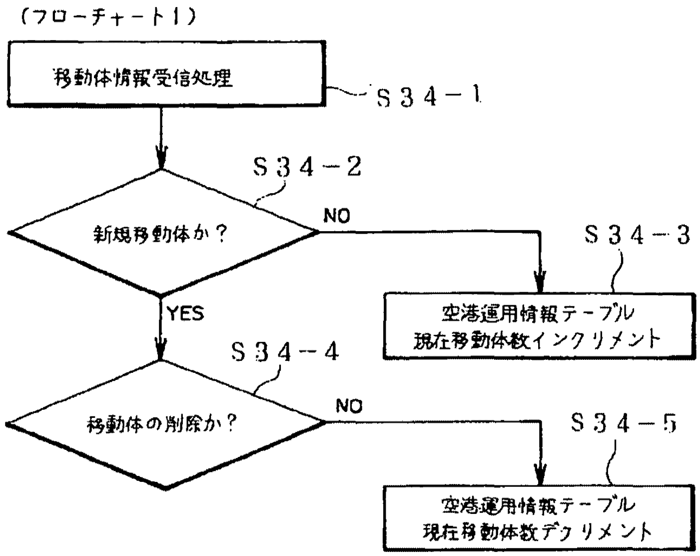
【図３２】



【図３３】

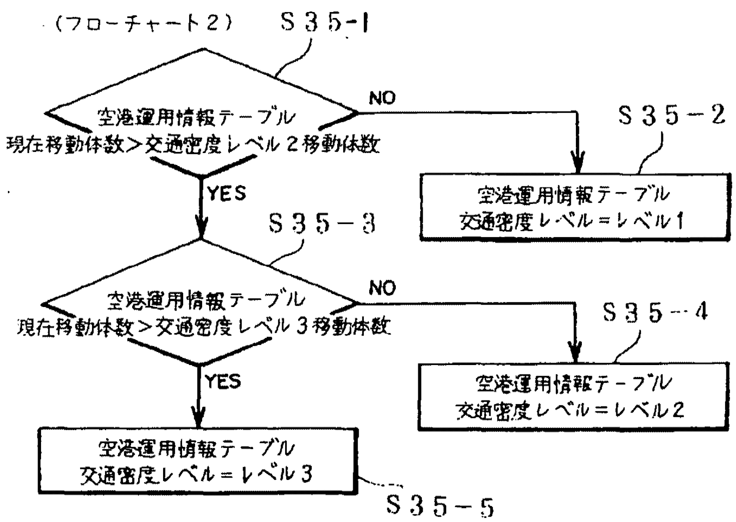


【図３４】



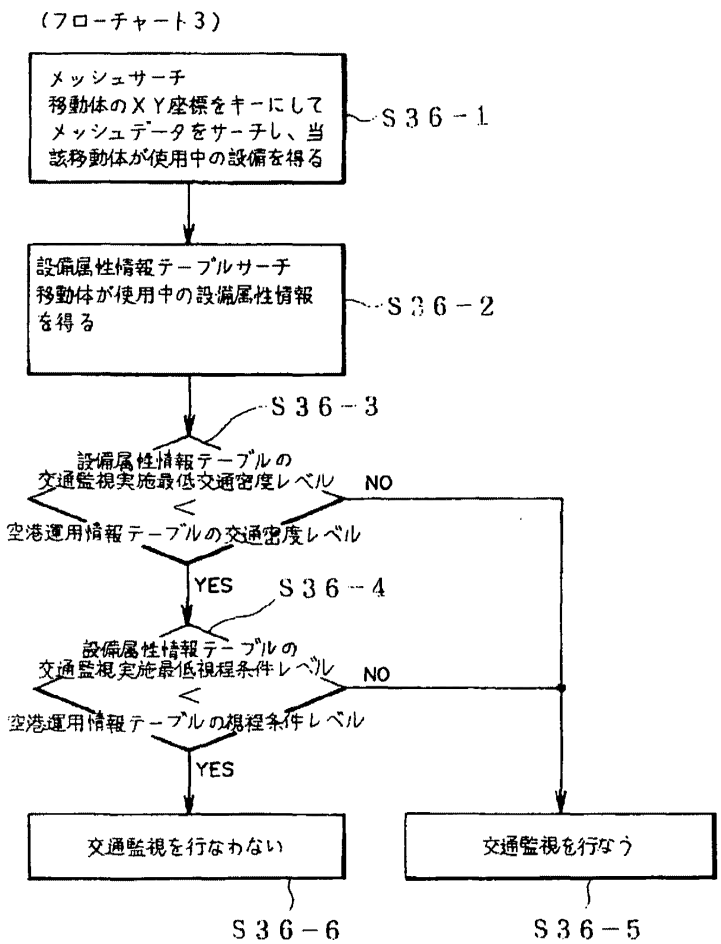
（フローチャート１）
移動体情報受信処理
S34－1
S34－2
新規移動体か？
NO
S34－3
空港運用情報テーブル
現在移動体数インクリメント
YES
S34－4
移動体の削除か？
NO
S34－5
空港運用情報テーブル
現在移動体数デクリメント

【図３５】



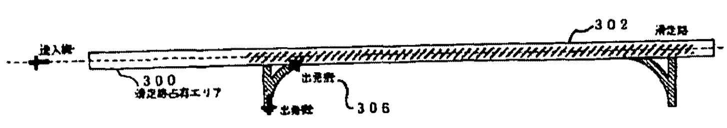
（フローチャート２）
S35-1
空港運用情報テーブル
現在移動体数＞交通密度レベル２移動体数
NO
S35－2
空港運用情報テーブル
交通密度レベル＝レベル１
YES
S35－3
空港運用情報テーブル
現在移動体数＞交通密度レベル３移動体数
NO
S35－4
空港運用情報テーブル
交通密度レベル＝レベル２
YES
空港運用情報テーブル
交通密度レベル＝レベル３
S35－5

【図３６】



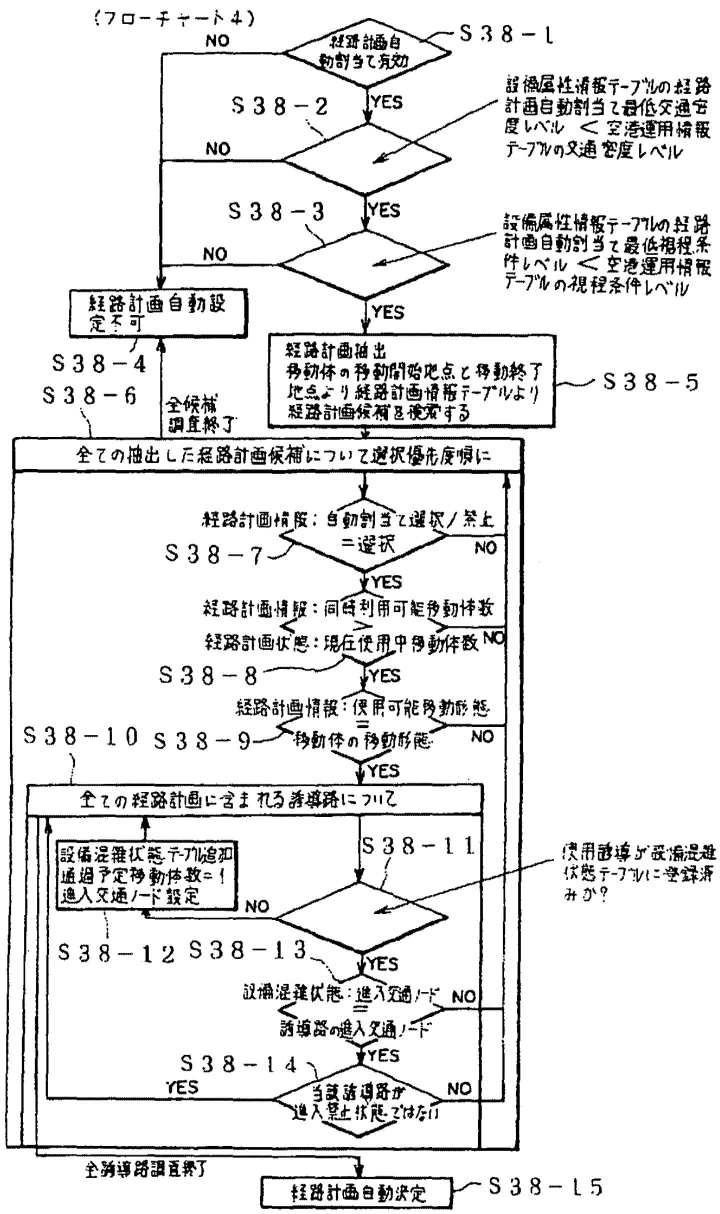
（フローチャート３）
メッシュサーチ
移動体のＸＹ座標をキーにしてメッシュデータをサーチし、当該移動体が使用中の設備を得る
S36-1
設備属性情報テーブルサーチ
移動体が使用中の設備属性情報を得る
S36-2
S36-3
設備属性情報テーブルの交通監視実施最低交通密度レベル
＜
空港運用情報テーブルの交通密度レベル
NO
YES
S36-4
設備属性情報テーブルの交通監視実施最低視程条件レベル
＜
空港運用情報テーブルの視程条件レベル
NO
YES
交通監視を行なわない
交通監視を行なう
S36-6
S36-5

【図５０】



302
滑走路
進入機
300
滑走路占有エリア
出発機
306

【図３８】


(フローチャート4)
経路計画自動割当て有効
S38-1
NO
YES
S38-2
設備属性情報テーブルの経路計画自動割当て最低交通容度レベル ＜ 空港運用情報テーブルの交通容度レベル
S38-3
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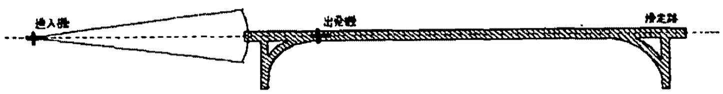
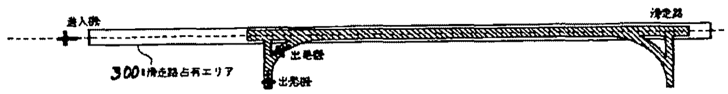
S38-15

【図４６】



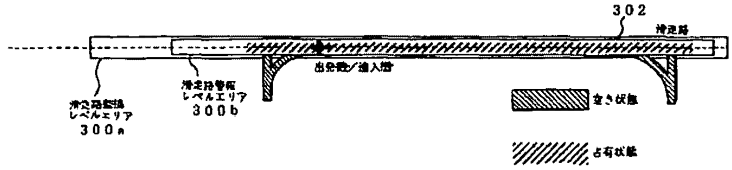
進入機
出発機
滑走路

【図４８】



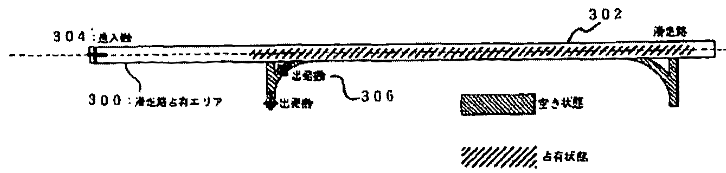
進入機
滑走路
出発機
出発機
300：滑走路占有エリア

【図５３】



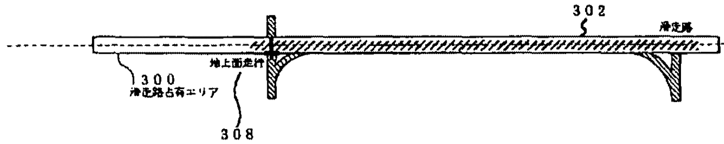
３０２
滑走路
出発機／進入機
滑走路監視
レベルエリア
３００ａ
滑走路警報
レベルエリア
３００ｂ
空き状態
占有状態

【図49】



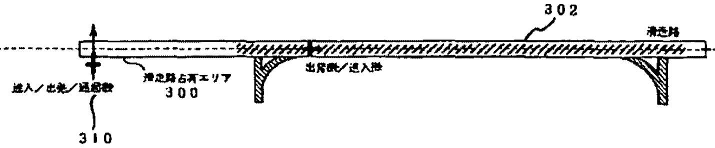
304：進入機
302
滑走路
300：滑走路占有エリア
出発機
306
空き状態
占有状態

【図51】



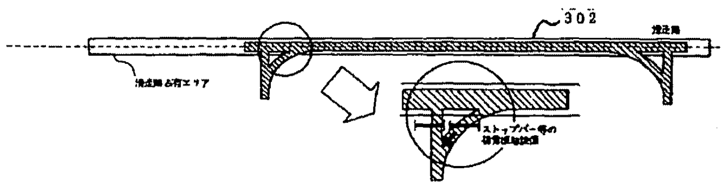
302
滑走路
地上面走行
300
滑走路占有エリア
308

【図52】

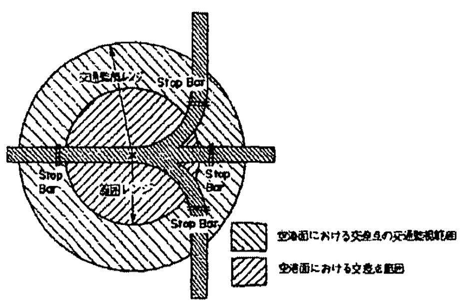


302
滑走路
出発機／進入機
滑走路占有エリア
300
310

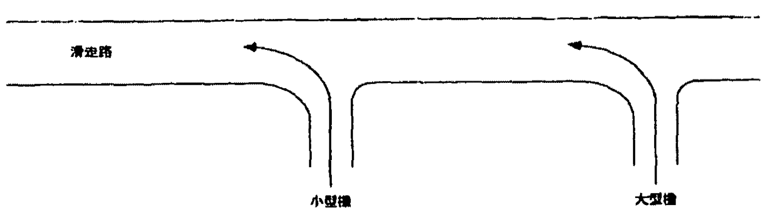
【図５４】


302
滑走路
滑走路占有エリア
ストップバー等の

【図５６】


Stop Bar
Stop Bar
Stop Bar
Stop Bar

【図５７】


滑走路
小型機
大型機

【図55】

現在速度 (km/h)	警報発生から回避開始までに進む距離 (m)				備考
	10秒後	20秒後	30秒後	40秒後	
400	1111	2222	3333	4444	
390	1083	2167	3250	4333	
380	1056	2111	3167	4222	
370	1028	2056	3083	4111	
360	1000	2000	3000	4000	
350	972	1944	2917	3889	
340	944	1889	2833	3778	
330	917	1833	2750	3667	
320	889	1778	2667	3556	
310	861	1722	2583	3444	
300	833	1667	2500	3333	
290	806	1611	2417	3222	
280	778	1556	2333	3111	
270	750	1500	2250	3000	
260	722	1444	2167	2889	
250	694	1389	2083	2778	進入機の最終進入速度
240	667	1333	2000	2667	
230	639	1278	1917	2556	
220	611	1222	1833	2444	
210	583	1167	1750	2333	
200	556	1111	1667	2222	
190	528	1056	1583	2111	
180	500	1000	1500	2000	
170	472	944	1417	1889	
160	444	889	1333	1778	
150	417	833	1250	1667	
140	389	778	1167	1556	
130	361	722	1083	1444	
120	333	667	1000	1333	
110	306	611	917	1222	
100	278	556	833	1111	
90	250	500	750	1000	
80	222	444	667	889	
70	194	389	583	778	
60	167	333	500	667	
50	139	278	417	556	
40	111	222	333	444	
30	83	167	250	333	
20	56	111	167	222	
10	28	56	83	111	
0	0	0	0	0	

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Description

The present invention relates to an automatic surveillance, guidance and fire-fighting system or installation, and concerns a system or installation whose primary purpose is to prevent accidents and, in the event that they do occur due for example to aircraft fault or pilot error, to bring about the extinction of any fires which occur, in the shortest possible time, by means of the functional integration of surface telemetry and automated fire-fighting.

In the same way that other airport systems were designed and implemented in their time (such as VASIS, ILS, CALVERT, etc.), all of which satisfactorily met the established requirements for achieving air safety, so also the present, newly designed system (RUSTEM), meets other requirements in the same field, but within the airport precincts.

In order to explain what the system comprises as well as the grounds which justify it, it is useful to set out the current state of affairs and accordingly introduce the necessary conceptual innovation in specific important aspects, being those which epitomize the characteristics of RUSTEM ("Runway Security and Taxiway Escort System").

In effect, wherever there is an aircraft in operation, the concept of air safety and the necessary means of attaining this must be present, whether the aircraft is in the air or on the ground. Thus the concept of air safety covers the whole range of air-air, air-ground, ground-ground and ground-air circumstances.

Likewise, if this approach is not taken, a gap in safety will occur in this relationship which may result in an accident, whilst the aircraft is in operation in any of the four circumstances mentioned above, transporting people, goods and fuel.

It is well-known in the air industry that from time to time serious accidents occur, although their prevention, and where necessary fire-fighting operations, have been a priority effort of the aeronautical profession. The present system is part of this effort, though in this instance it is related to the airport environment, that is the ground-ground situation.

In this context it is appropriate to recall the accident which occurred in 1983 at the airport of Barajas (Madrid), in which two aircraft collided on the ground. On this occasion, one aircraft was on its take-off run, whilst the other aircraft in taxiing and trying to head for the start of the runway to take-off in its turn, took a wrong turning and moving across a fast exit slipped into the middle of the flight path, where the collision occurred.

At this time the airport was not under minimums, but visibility was poor so that the aircraft which was taking off did not see the intruding aircraft, neither did the latter see the aircraft taking off, nor did the tower at that time see either of the aircraft, all due to the length of the runways. This occurs in certain circumstances where the airport is operative but there is not clear visibility over the full distances.

These situations, and many others, indicate conditions of a lack of air safety which require analysis and a complete solution of the problems to which they give rise.

Furthermore, an aircraft in flight is not close to the ground, whilst in take-offs, landings and taxiing, it is in contact with it and therefore is in a higher risk situation, in which safety conditions must be maximized.

Since it is possible to set up ground installations in airports which could not be set up throughout a country, and since aircraft must operate in airports, it is clearly desirable to provide a safety system on runways and taxiways capable of guaranteeing this safety. The RUSTEM system is intended to meet this requirement.

Also, the increase in modern air traffic, which leads at times to saturation in the number of operations per hour on an operative runway, has led to an increase in the risk of accidents, taking into account the poor visibility conditions which often occur. This expansion in traffic makes a built-in airport safety system increasingly urgent and necessary, as the accidents in different airports of the world confirm. The same problem occurs in military air bases, where there is the additional problem that combat aircraft may enter the base in emergency conditions, for which reason telemetric monitoring and automated fire-fighting thus become necessary. The RUSTEM system can be applied to both civil and military airport ground situations.

Two damaging effects occur in an accident: ruptures and fire.

In accidents en route, the most important factor is usually ruptures, whilst generally in airport accidents fire is the cause of the greatest damage.

This is due to the different velocity of the aircraft en route and in the airport, so that the dynamic impact is usually much greater in an accident in the air.

On the other hand, once an accident has taken place in an airport, it is obvious that there is not the least remedy in the case of ruptures, causing damage to the aircraft and the passengers. However, the fire factor develops according to a specific process, and, fire being the determining factor in causing the greatest damage in airport accidents, it may be combatted because it is a process, provided of course that there are the necessary means for this, both in extinguishing capacity and in speed of activation, since without the latter condition the fire itself will put paid to the matter.

From what has been said it emerges that the sole means of combatting the rupture factor is by avoiding the accident, as far as possible in the airport, within the present margin of possible aircraft faults or pilot error, for which reason prevention in this case lies in the area of telemetric monitoring, guidance and signalling on the ground. If, despite the measures taken, an accident occurs due to the aircraft or the pilot, the airport infrastructure must then have available an automatic fire-fighting system for eliminating fires extremely rapidly, since fire is generally the most damaging factor in airport accidents.

The research carried out in the quest for an efficient airport system which will meet these requirements, emphasized the necessity for integrating the surveillance and fire-fighting functions into one single system.

In fact, given the great speed required in fire-fighting, this had to be of an automatic nature. Since an aircraft which has had an accident may become immobilized (or its hot sections) at any point of the surface in question, it was obviously necessary to have available the x,y coordinates of the aircraft or its sections. Hence it was necessary to integrate telemetric surveillance with automated fire-fighting. Furthermore, if surface telemetry provides the x, y position of a damaged aircraft, or of its sections in the case of it being ruptured, this surface telemetry could also be used to obtain the position of normal aircraft, that is not in a state of emergency, in normal operation.

With this, the conclusion was reached that a telemetric method had to be used in our system, both for the monitoring of normal aircraft and for establishing emergencies according to the various forms and circumstances in which these could occur in each instance, as for example fuel which has leaked and is on fire. As aforementioned, the fire-fighting method has to be automatic due to the great speed demanded, since it is not just dealing with a simple fire, but with an aircraft carrying people, and loaded with highly inflammable fuel. Hence the designer's thinking has to be governed by the time-scale, taking the second as the unit.

Nevertheless, it is essential to point out that, regarding air traffic, two very different areas or environments must be considered in airports: on the one hand the flight strips (which contain the flight runways, one runway for each strip), and on the other hand the taxiways in their entirety, and the aircraft parking areas.

The vast majority of airport accidents occur in the first mentioned area, where aircraft are running at great speed. In the second area, in the taxiways, aircraft are travelling slowly in procession and able to brake quickly where necessary, as is the case in the parking areas.

This qualitative and quantitative distinction is taken into account in the present system, supplying the appropriate solution for the characteristics of each of the indicated environments.

As will be seen, the current situation is analysed and, as a result of the limitations of tanker trucks (as currently used in fire-fighting), as well as the limitations of surface radar (as used in surveillance in some airports), research into a new system which could completely solve these limitations, gave rise to the RUSTEM system, in which surveillance and fire-fighting are functionally integrated in a single operational system, constituting an innovation in the airport field.

An automatic aircraft taxi route selecting and traffic control system is disclosed in US 3706969, and may use an array of infrared sensors to detect position and/or movement of aircraft. However the system appears to be dedicated to such a function insofar as the sensors are all located adjacent runway and taxiway intersections and in areas between the intersections there seems to be no surveillance.

Furthermore EP 0117162 discloses an infra-red surveillance system for detecting fires in a forest, in which each of an array of sensors is scanned over a field of view; however in this case there appears to be no provision for tracking a moving heat source as it moves past the sensors.

In the present system, which is set out in the appended claims, an array of thermal sensors under computer control is provided which is adapted to provide both the function of tracking a moving aircraft as it passes the sensors and the function wherein each sensor scans its locality so that the position of any heat source within a locality may be determined from the outputs of adjacent detectors. Thus the present invention has the advantage that a single sensor array may be operated and used in two ways for two different and necessary purposes.

In broad outline, which will be explained in greater detail in the following pages, and taking into account the fact that statistically airport accidents occur on the flight strips in the vast majority of cases, a RUSTEM system can include the following elements:

a) Two parallel, buried lines of hydrants, one on each side of the runway. These lines, being a fixed system, extend beyond both thresholds at the heads of the runways. The hydrants only emerge in case of accidents, and have elevation, rotation and to-and-fro movement. So that when their valve is triggered they can take care of any accident occurring within the flight strip as rapidly as possible. The automatic action of the hydrants is computer-controlled. The pipes feeding them are kept filled constantly. Thus, activation of the system from the airport tower leads to their entry into operation in a matter of a few seconds.

b) As far as surveillance is concerned, there are two different zones as described earlier. The main surveillance is over the flight strips with additional surveillance over the taxiways and parking areas, by means of aircraft control and guidance.

b.1) Two parallel lines of infra-red, telemetric sensors are installed along the flight strips, capable not only of tracking the trajectory of the aircraft, but also of detecting heat sources in case of emergency, feeding this data to the automatic fire-fighting operations. Similarly, several anemometers obtain wind data. The whole flight strip is in the form of a rectangle, and the aforementioned telemetric sensors are located along the longest sides of this rectangle, monitoring the strip.

b.2) In the taxiways and parking areas the interest is in the aircraft control and guidance system, according to OACI SMGC requirements, simultaneously maintaining and monitoring minimum separation between aircraft. Thus continuous detectors are installed, as well as directional beacons along the axis, and, where necessary, directional beacons along the edges, and some airport traffic lights. Both the detectors and traffic lights are interconnected with a computer which processes taxiing and parking throughout the airport.

b.3) Aircraft movements in the taxiways and parking areas are automatically guided, each aircraft having in front of it a specific number of lit axial beacons, according to the aircraft's route. The number of beacons is always fixed, about 100 metres apart. Thus, as the aircraft moves forward it is detected by the taxiing beacons, which send signals to the computer, and the latter lights up new axial beacons in front of the aircraft according to the route it has to take, and switches off the beacons which the aircraft has left behind. The computer establishes rights of way at crossroads, where the aircraft which has to wait will see its axial beacons flashing on and off and the crossroad traffic light on red. Once the first aircraft having right of way has passed across the crossroad, the second aircraft which had to wait will have its axial beacons lit continuously to enable it to continue on its way.

Any intermittence in the guidance beacons signals the pilot to brake.

The aforementioned taxiing detectors are neutral and without electrical current throughout the airport, with the exception of those corresponding to the sensing of each aircraft. These detectors only pick up the aircraft, but purposely do not pick up other objects such as service vehicles or people. Hence cars or people, purposely not being picked up, do not distort the detection signals which correspond only to aircraft, and therefore the computer continuously guides each aircraft from an initial point to a final point, according to a route which has been laid out by the control tower. The activated detectors go on activating others in the direction of travel of the aircraft, picking it up and deactivating the previous detectors along the aircraft's taxiway.

c) A set of elements is installed in the airport tower, which amongst others consist of the following:

c.1) A main panel on which the runway computer displays the aircraft's reference both in its flight path and as it comes to a halt. In the event of an emergency, this computer on the one hand produces several alarms and on the other hand draws some emergency circles corresponding to a damaged aircraft, or its hot sections and fire sources. In the event of aircraft collision the same thing happens. Similarly, in the event that an intruding aircraft penetrates into the rectangular area of the air-strip, the alarm is automatically activated.

Likewise, the computer which controls taxiing also displays the position of the identification references corresponding to the aircraft situated in the taxiways and parking areas. In the event that an aircraft goes below its minimum distance on the taxiway with respect to the aircraft preceding it or takes a wrong route, an alarm is also provided, and at the same time the reference on the panel relating to the offending aircraft blinks intermittently.

c.2) A control console from which the whole system is controlled, both for surveillance and guidance as well as for fire-fighting, with simple and extremely sparing operations for the controllers, since the system's data processor carries out the work.

Similarly, the taxiway traffic lights are automatically activated, the internal routes for taxiing being indicated "in situ", and activated locally for each aircraft, according to whether it is on its landing run, or "en route" from the parking area to the runway and the head of its take-off exit; also indicated are the routes from the runway to the parking area, taking into account the corresponding runway head. In addition, routes from the parking area to the hangars and vice versa are shown; or from hangars to runway, and vice versa.

c.3) Computers and automatic connections.

d) Lastly, there is the installation of piping, for water and extinguishing substances, their storage tanks, pumps, dispensers, drums, autoprotection devices, connections, and other appropriate and necessary elements for the hydrant system. Also the general piping for the supply of the hydrants from one and the same line may be unique, the dispensing then being carried out at the start of the general piping. Also there is a power plant with electrical connection to the airport's supply network, and from this plant the various elements of the RUSTEM system are supplied. It is taken for granted that the whole airport has to have general emergency generating units. Furthermore, the system is adaptable to any civil airport or air base. And in the event that once installed it is decided to increase the length of a runway, the lines of hydrants and telemetric sensors of this flight lane can be extended, so that the previous installation remains operative and valid.

Statistically, 99% of airport accidents, including situations where aircraft have previously announced their emergency status, occur within flight lanes. Therefore it is both logical and necessary for automatic hydrants to be installed within the said lanes, hydrants which due to their range and their three degrees of freedom, are capable of covering any emergency, being able to act both in treating the whole runway, as well as on specific points on the damaged aircraft, colliding aircraft, or their dispersed sections, eliminating heat sources, acting globally and simultaneously on all of them.

The hydrants referred to are always without pressure and without electrical current. Thus, there is double protection against their being activated spontaneously. That is to say, if and only if, the tower activates the fire-fighting system, do the telemetric sensors along the flight lane send the position and extent of the heat sources to the computer, and the anemometers send the wind force and direction; with this data the computer system rapidly calculates the fire-fighting parameters, i.e. selects the specific hydrants which will be activated and supplies them with the operating parameters corresponding to each of them, and it is then that the selected hydrants enter into operation, in a very few seconds, launching a large discharge of extinguishing fluid and rapidly suppressing the heat sources.

While there is an aircraft in motion within the flight lane, whether in normal or emergency status, the system is locked and cannot operate. The fire-fighting operation only occurs with a motionless aircraft.

However, the hydrants can prepare the runway on the announcement of a damaged aircraft approaching the airport.

Lastly, it was evident that an installation in accordance with the invention allows the possibility that the analogue type signals originating from the surface radar installed in an airport may be processed by the computer equipment of the said installation and incorporated as an additional element with regard to airport safety. The surface radar would act as one more sensor for the installation, its signals being used as additional data for the overall safety system. To this end, the aforementioned installation can be improved in the following manner: j) for airports operating in very low visibilities, some flight lane sensors, in addition to infra-red sensing, incorporate an emitter and detector of electro-magnetic pulses, or an ultrasonic active element, capable of detecting objects within the flight lane relating to aircraft or vehicles; k) for airports with normal or average visibility, the standard sensors not only pick up the aircraft located in the flight lane, but also vehicles penetrating it; l) there is the option of installing an interface capable of processing the signals originating from the surface radar which has been installed in an airport, and introducing such signals into the computer controlling the surveillance, and with this data making an addition to the functions of the system; m) there is the option that the installation's taxiing detectors may be generally activated simultaneously, and the sensing of aircraft and other objects may be carried out simultaneously, in this case means can be incorporated for discriminating aircraft from other objects, and maintaining the logical sequence in the guidance of each aircraft in the zone of movement and parking of aircraft; and n) there is the option that the piping and pressure storage tanks for water and extinguishing agents for the flight lane are divided up into independent modules, and their discharge is attained by means of the pressure of a compressed gas connected by regulating valves to the water and extinguishing agent storage tanks.

The invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figure (1) is a representation of a "standard protected zone" (SPZ), i.e. a flight lane fitted with automated hydrants and telemetric sensors (ST) for surveillance, able to be integrated with automatic fire-fighting in emergencies. The hydrants can both treat the complete runway before the arrival of an aircraft arriving in an emergency situation, and also act in precision fire-fighting, either on one or more aircraft, or on their hot sections and other burning surfaces caused by the accident.

Figure (2) illustrates the protection of two or more crossing runways and their corresponding flight lanes (SPZ).

Figure (3) shows diagrammatically the three degrees of freedom of an extinguishing unit (hydrant), according to its three perpendicular projections.

The dispensing of the extinguishing fluid may be carried out at the foot of the hydrant, or at the start of the supply pipe (in which case it could be single).

References in this figure include:

VL	- Side view
P	- Plan
V	- View through A-A
Tr	- Trap
La	- Cannon jet
Ag	- Rubber shock absorber
Tm	- Elevating motor supply trolley
Ae	- Extinguishing agent
Ag	- Water
Mg	- Mobile base turning motor
Ro	- Bearings
Tg	- Main cover
To	- Trolley
En	- Gear
Bf	- Fixed base
Bm	- Mobile base
Me	- Elevating motor
Jr	- Rotary joint

Figure (4) graphically demonstrates the parallax error produced by standard surface radars. In the figure it is seen that as MA = MP; and RA = RA', so that OA = OA', and P does not coincide with A'. This distorts the x, y coordinates of the object when the runway has inclines.

Figure (5) represents a plan (P) and elevation (E) of a flight lane in which the variation in slope of the runway axis is seen. Also the position of the telemetric sensors is shown (not to scale), forming successive rectangles or squares along the whole length of the flight lane, the successive rectangles thus being adapted both to the slopes and to the changes in gradient allowed by the OACI standard.

Figure (6) is an illustration of the detection procedure while tracking an aircraft by means of infra-red sensors along the flight lane, thanks to the position of the colliding beams and the corresponding signals for their processing by computer.

Figure (7) is similar to the previous one, although here one sees a dangerous situation in having two aircraft within the flight lane, which could collide. One can see also the rectangles formed by each set of four telemetric sensors (STI) - "infra-red sensored areas" (ISA).

Figure (8) represents the tracking of an aircraft during the sequence of its entrance onto the runway.

Figure (9) shows the sweep mode of the telemetric sensors (ST) along the flight lane (SPZ). The sources in this case are motionless, three heat sources being represented, as well as the detection carried out by the four sensors from the four corners of the infra-red sensored area (ISA) in question, allowing the surface dimensions of each heat source to be accurately defined. The sweep mode is that used in emergencies.

Figure (10) shows an airport layout in which can be seen both the flight lane (SPZ) and the taxiways equipped with detectors (D), guidance beacons (B) and traffic lights (S). Inside the SPZ's neither detectors (D) nor traffic lights (S) are installed. However, at those points of the SPZ perimeter where taxiways impinge, the firstdetectors and traffic lights are installed, so that an aircraft is detected on leaving the runway. Full continuity in airport surveillance is thus achieved, since although an aircraft which exits from the area of the SPZ leaves behind the telemetric sensors (ST) tracking it, it will be immediately detected by the first taxiway detector (D) on entering the corresponding section of taxiway. Thus, in both cases, where the aircraft is inside the SPZ and where it is on any taxiway, it is immediately displayed on the main panel (Pn) located in the airport tower. Detectors (D), beacons (B) and traffic lights (S) have been shown in the drawing. Moreover, although automated hydrants could be sited in other zones, other than in the flight lanes, this does not seem justified in view of accident statistics.

Figure (11) represents a view of the system equipment located in the tower; panel (Pn), console (Co), computers (Or) and connections (Cn), as well as the position of the officer on watch in front of the controls. The panel (Pn) is of large dimensions and almost vertical, its angle of inclination being adjustable, for ease of observation both by the operator and by other tower personnel. Since it is necessary that all the controllers can see the aforementioned panel, it will be located in the upper part of the tower's large window, and for this purpose a small building modification will have to be made locally in the roof of the tower, allowing the panel to be housed in front of the controllers, so that the latter can both observe the panel and see through the tower's window.

Also shown in this figure are:

Tr	- Adjustable support rod
Pa	- Wall
Ca	- Cable
Gz	- Hinge

The RUSTEM system console controller directs taxiing and parking, and the remaining controllers direct flight operations on the runways and flight lanes.

The installation of the RUSTEM system does not involve alterations to the current consoles and installations, nor does it interfere with their operation or the work of the tower's flight controllers.

Figure (12) represents the main panel located in the tower. Its dimensions are those which are appropriate and necessary to reflect the resolution and definition of sources of which the flight lane telemetric sensors (ST) are capable. The operation of both the flight lane computer and the computer dealing with taxiing is displayed on the panel (Pn). When there are emergencies the telemetric sensors go into sweep mode and the reference symbols which appear directly on the panel are emergency circles. In tracking mode, the aircraft reference is seen on the panel as well as a reference which changes according to the actual path of the aircraft.

Figure (13) illustrates an airport flight lane in which an aircraft and a motor vehicle appear.

Figure (14) represents an airport layout in which the surface radar (RS) and control tower (T) are shown.

Having planned the system under the conditions described above, it is now appropriate to take stock of the current situation in airports in general, since the problem is substantially the same in all countries.

To start with the aspect of fire-fighting.

In all civil airports and air bases there is a fire station, equipped with tankers, prepared "ad hoc". This originates from the early days of aviation, as an extension of the method used by municipal fire brigades and has been evolved by trying to adapt to requirements.

Little by little, and despite the efforts made to improve it, its poor performance with regard to the special case of an aeronautical accident has become increasingly clear, as seen in practical cases.

Protests by pilots' associations and the frank pessimism of the aeronautical authorities devoted to this matter, confirm this situation in the various different countries.

For various reasons, as aircraft have been developed they have increased in volume and weight, and therefore in engine power and size of fuel tanks, and can achieve much longer flights.

This has caused airports to increase the capacity of the tankers in which water and special extinguishing agents are transported. This has already led to cases of enormous tankers, some of which have had to incorporate two engines, one in front and one behind. This would suggest that a limit has been reached in the method used.

Also, given the volume which has to be transported, there have been actual instances where the tankers have overturned, since, although smooth, there are unavoidable gradients in the airport terrain. There are thus some limitations and interactions between the load transported, speed of travel of the vehicle and stability.

Furthermore, if an accident occurs at the head of a runway, at the far end of the start of the runway, often muddy areas and other obstacles prevent or make difficult an approach close to the said accident.

On occasion, the aeroplane or colliding aircraft, are broken into sections which are dispersed, thus requiring the said tankers to be able to attend to all the fires simultaneously and involving an increase in the fleet of trucks necessary.

Moreover, the trucks cannot act on their own, but only when the airport tower so indicates. So that as in the majority of airports the surveillance function is deficient, as the tower first has to determine whether there is an emergency or not, a question which is often difficult and uncertain due to the lack of an instrument which can rapidly verify this, especially at night or in low visibilities.

All this causes a build-up of time which weighs heavily against a hypothetical fire and rescue operation, since first the tower has to determine whether or not there is an emergency, after that it has to notify the fire brigade and this has to be mobilized; then the journey has to be made from the fire station to the site of the accident, at times far away as in the case of the heads of runways. Once the fire brigade have arrived, they have to take charge of the disaster which has occurred different each time, which is complicated in the case of dispersed sections.

Thus, there is an excessive time lag which is inconsistent with the type of accident being considered. It is thus inevitable that performances have been low, losing human lives and increasing the damage to aircraft.

When in the past, aircraft were much smaller, less global inefficiency was observed with this procedure, but currently this is continually on the increase, since it is actually the method and procedure used which have to be changed globally, both in theory and in practice.

According to OACI publications extinction must be carried out in a period of five minutes, due to the fuel, its explosive capacity, and the toxic gases which may asphyxiate the passengers trapped in the accident.

Currently, the OACI specifies between two and three minutes for starting up fast fire trucks after the alarm has been given.

This clearly shows that between the five tragic minutes available and the two or three minutes for the mobilization of the high-speed trucks, there only remain two minutes for the work of extinction, thus emphasizing the necessity for using a different method, like the RUSTEM system whose automated hydrants enter into operation in a few seconds after the fire rescue button has been pressed by the tower.

In addition to the problems and limitations described, there are other problems which also act negatively on the efficiency of fire rescue operations, this time related to the rescue personnel themselves. These may be summarized as follows:

- the fortunate rarity in the number of accidents paradoxically has a negative effect on the rescue personnel, because they become out of practice due to their enforced inactivity, leading to reduced performances when the critical time arrives of unavoidable emergencies.

Also, having arrived at the site of the accident, on the one hand they are tied to the fire tanker, and on the other the accident has managed to produce a number of fire sources. Thus, each accident being different, they have to improvise their action on the way, often leading to psychological blocks in the face of the urgency of the various sources to be extinguished and their dispersal.

- The airport fireman, moreover, in contrast to his city counterpart, in all cases without the least exception, has to deal with an aircraft which is liable to explode at any moment in its emergency state. So that the fireman's own survival instinct militates against the work he carries out, acting in a situation of fear and insecurity which logically leads to low performances.

The truth is that it is irrational and preposterous to completely, systematically and without exception, require heroism as an everyday norm for work. So that if the technician does not carry out his own self-criticism, he will continue to maintain an error of principle and with it foreseeable low performances, as demonstrated in practical instances.

It is absurd to deal with saving the life of the pilot by placing the lives of several firemen at risk in the attempt. As human beings their lives are as important as that of the pilot and to be respected equally with all others.

If this is not agreed upon, the pilot may not be saved since fear will tend to paralyse the actions of the firemen, with predictable low performances.

Thus, no matter what the quality of the fire-tankers may be at a given moment, they have to be operated by firemen, whose actions are unpredictable.

Faced with this set of problems, both in the method employed and those related to the rescue personnel, the conceptual modification intrinsic to the present system is based on the following:

a) the setting up of a fixed, buried installation on both sides of the runway, extending it to both ends beyond the thresholds (Figure 1).

b) these two lines consist of hydrants, which in the position of rest are underground, covered by a steel cover flush with the surrounding area so that if an aircraft leaves the runway and runs over the said cover it will not damage the aircraft nor the hydrant hidden underneath (Figure 3).

c) each hydrant incorporates two cannons whose elevations are generally at different angles and appropriate to every fire-fighting operation (Figure 3).

d) each hydrant (Figure 3) has a rotary base, so that it can rapidly assume any angle of azimuth, and therefore line up on the aiming position.

e) the complete hydrant is capable of to-and-fro movement for covering the damaged area.

f) the hydrant has a main trigger valve, continuously adjustable by servo-motor.

g) the hydrant's range is such that it covers the whole width of the flight lane, i.e. each line of hydrants, being rotatory, covers at least two-thirds of the said width. Thus, the runway and its two adjacent areas are covered along the length of the runway and its two ends. For instrument runways, the OACI Standards establish the permitted runway widths as being between 45 and 60 metres, so that on these runways the width of the flight lane has to be not less than 300 metres (Figure 1).

h) it happens that airport accidents occur statistically in 99% of the cases within the area defined by the flight lane, for which reason the automated hydrants are suitably located to cover any emergency in the aforesaid flight lane. The computer software does not improvise, but rationally covers all cases.

i) as the pipes which supply the hydrants are always under load, and as the hydrants cover the whole width of the flight lane, the triggering of the hydrants is extremely rapid and they cover any emergency, whatever the topographical position of the accident and its separate focal points.

j) the automatic action of the hydrants is computer-controlled, and as the buttons are pressed on the control console located in the tower, they act together in preparing the whole runway on the prior announcement of the arrival of an aircraft in an emergency, being accurately trained on the stopped aircraft, or its sections, whatever the topographical dispersal they may have. The fire-fighting takes place globally and simultaneously over all the heat sources present.

k) the position of the aircraft or its sections, in x, y coordinates, is supplied by the telemetric surveillance of the present system, as will be explained later (Figure 12).

So, concentrating for a moment on the fire-fighting method described, the following advantages may be pointed out, amongst others:

1. The automated fire-fighting system requires only a few seconds to come into operation after the button is pressed in the airport tower, thus cutting out the excessive time lag which occurs with fire tankers.
2. As both the water and the extinguishing substances are supplied under pressure to the hydrant by means of underground pipes, no transport by truck is necessary, since now the extinguishing fluid is placed "in situ" via continuously full pipes.
3. Since the water and extinguishing agent storage tanks are also fixed, they can be as large as required, with reserves, whatever the size of the aircraft or the collision in question. The pump, the dispensers, valves, connections and auto-protection devices act in fast response, each line being fitted with the necessary service pressure regulation drum. The pressure is sufficient to guarantee the maximum range of the hydrants, the pump being automatically triggered and responding as soon as there is a slight reduction in the pressure of the regulating drum.
4. The computer which controls the hydrants selects these according to each accident, in accordance with the topographical position of the aircraft, or its sections, as well as according to the force and direction of the wind.

Furthermore, once the fire-fighting operation is initiated, this computer is updated with the possible variations in both the topographical and meteorological data relating to the accident, since new heat sources may have arisen and the wind data may have changed, so that the parameters of each hydrant are altered throughout the fire-fighting operation, the latter being self-adjusted automatically according to the possible variations in the mishap, as well as to those in the prevailing wind.

5. Each hydrant releases via its two cannons a large volume of extinguishing fluid, hitting the whole accident zone. If the aircraft in the emergency does not break up into sections, several hydrants will act together on the aircraft from different angles, hitting it rapidly with a large volume flow, leading to an extremely rapid extinction.
6. The hydrants do not suffer from psychological blocks, since they do not have to think about their actions in each accident, nor are they afraid of fire or explosions, instead when the fire brigade arrives on the scene of the accident, the fire sources will already be under control and since the lives of the rescue team will remain protected, the latter will complete the operation with high success rates, in favour of both the injured and uninjured.
7. The same can be said for the runway ends, since the system is the same.
8. Due to the automation and its great speed and coverage, in the majority of the accidents there will be a high rescue success rate, both in terms of people and in preventing more damage to the aircraft, which can be salvaged.

This completes the explanation of the principal fire-fighting concepts in the present RUSTEM system.

Now consider the aspect of airport surveillance.

The current general situation can be described as follows:

Although seemingly it might be imagined that there is nothing to enquire into regarding the matter in question, the negative secondary effects which the introduction of the ILS has had on civil airports and air bases should be pointed out, negative effects which were not taken into account when the use of the ILS was introduced and extended into all airports.

This very beneficial instrument was introduced to try to maintain air traffic running inspite of poor visibility conditions on an aircraft's approach to the airport.

The ILS (instrument landing system) is, in fact, a landing instrument.

The said instrument consists of an aerial which is located on the threshold of the runway, emitting signals which are picked up by an instrument on board, indicating whether the aircraft is to the right or left of the runway axis, as well as whether the aircraft in its approach is flying above or below the correct approach path. Hence, although the pilot cannot see the runway due to cloud, he carries out the landing on instruments, gradually altering his course until he is finally on the runway, landing in the touchdown zone.

The runways which have ILS are called instrument runways, which on the ground have to meet the strictest OACI standards regarding widths, slopes...etc., with their respective flight lanes being wider (a minimum of 300 metres).

Thus, it may easily be appreciated that in the past, when there was no ILS, pilots did not land unless they had complete visibility regarding the runway. The tower also had this same visibility with respect to the aircraft trying to land. Put simply, both visibilities, that of the pilot and that of the tower were one and the same visibility.

But, if suddenly the aircraft is given some electronic eyes with which the pilot can carry out the landing, without seeing the runway with his naked eye, there is a situation in which the operating minimums of this airport have been reduced, by which the aircraft is helped to land, but at the cost of leaving the tower blind if the tower has lost visibility over the complete airport environment.

Together with this there is a situation of general risk in all ground operations, which negative effect was not taken into account when the ILS was introduced and its installation extended into all civil airports and air bases.

In fact, although initially it would appear somewhat illogical, in reality the airport accident referred to previously at Madrid airport, in which two aircraft collided, was basically due to the existence of the ILS in the said airport, since although the ILS is a landing instrument, and in that accident there had been one aircraft landing and the other taxiing, both ground operations were being carried out in conditions of poor visibility, since the introduction of the ILS has lowered the operating minimums in all the world's airports. Neither aircraft saw the other, nor did the tower see either of the two by eye, nor did the tower see the collision, nor the place where both the colliding aircraft were to come to a halt in the flight lane. All the tower saw was fog and initially not knowing what had happened, lost time in calling the fire brigade who then had to look for the site of the accident, also in poor visibility.

On this occasion, the general risk mentioned above became a disaster, with a corresponding loss of human lives and damage to the aircraft. This airport acident is symptomatic of the risk situation which has been highlighted and which it is essential to correct, because from time to time it costs the lives of passengers and pilots.

Air safety embraces the whole environment, and it therefore also includes the ground-ground area.

The ILS comes under the air-ground heading, but an airport is an organic whole as with any object in reality, so that it is connected. Accordingly, if only one part is considered without taking into account the rest, as happened with the ILS (which was aimed exclusively at aiding landing), secondary effects may be, and, in fact, have been produced, such as that quoted of leaving airport towers blind.

Aircraft in an airport cannot move without the proper instructions from the control tower, but if the latter are blind with respect to incidents occurring on the runways, the tower personnel seem to be in a contradictory situation where they have to control and direct surface traffic and at the same time are left blind and without any instrument allowing them to view incidents in the airport. This contradiction from time to time costs people's lives and must be corrected.

That is to say, this is not an attempt to eliminate the ILS, since it is very beneficial, rather an attempt to provide the tower with a suitable instrument for carrying out telemetric surveillance in the airport, despite there being poor meteorological conditions, or that it is operating at night, as is usual.

In fact, the day has arrived for so-called surface radar, which instead of directing its beam into open space directs it towards the ground, sweeping the airport.

However, this equipment is not suitable, nor is it included in the present RUSTEM system. Here the telemetric method will be something else. There are various reasons for this:

In the first place, surface radar emits its pulses from one point, the aerial.

Secondly, the runway is not flat, but has gradients, even though limited and standardized.

In addition, it should be taken into account that radar does not measure distances, but the time difference between the transmission of the pulse and the reception of its echo bounced back by the object, although since the pulse and its echo consist of electromagnetic radiation their velocity (c) is known, and since the time difference between the transmission and reception is known, the corresponding distance is obtained. But in this process, if the object located on a runway is such that this runway is horizontal, or else has gradients, the result will be that although the straight distance between both objects and the aerial is the same, nevertheless their respective coordinates with respect to runway axes will be different in x, y. This parallax effect is shown in Figure (4).

That is to say, standard surface radar falsifies the x, y coordinates of the object due to a parallax effect which appears when runways have gradients.

These gradients are smooth, but as the length of runways is relatively great, the result is that often there is a very significant difference in height (z) between one end of the runway and the other, so that, in fact, the radar falsifies the corresponding measurement of the x, y position of the objects.

These radars, which in themselves are not very economic due to their functional structure and the elements which they incorporate, would be even more expensive if an attempt were made to obtain the correct x, y coordinates, since in this case one would have to turn to a three-dimensional radar accompanied by a correcting computer. Then the output signal from the (3D) radar receiver would have to be corrected with the computer, which in turn would have to contain the topographical data of the different points of the airport. This would have to take place in real time so that this type of equipment would be more complex and more expensive, and therefore not very advisable.

There is yet another problem which is that when speaking in general of airport or in-flight surveillance, the concept persists that this telemetric surveillance will be with respect to normal aircraft, when in fact in the case of an airport, not only do the movements and stoppages of normal aircraft have to be monitored, but also the telemetric system has to supply data on emergencies and fires in case of accidents. In addition, it is vital to obtain via telemetry, the actual form of the fire sources which appear. Only in this way will the aiming and automated action of the fire-fighting operation be efficient and accurate. That is, the surveillance function and the fire-fighting function cannot be separated nor split off.

Thus, considering the case of a fuel lake in flames, the result of an accident, three (3) negative factors emerge with regard to surface radar:

a) as said earlier, if the runway has gradients (and it always has some), the x, y position of the source is displaced, and as the hydrants constitute a fixed system in which each hydrant has its respective x, y coordinates with respect to the runway axes, the position of the source would be in error with respect to the hydrants, and their action would be incorrect, due to having carried out the telemetry by means of standard surface radar.

b) but imagine a three-dimensional, computer-corrected radar, making the installation even more expensive. A second difficulty now appears, making the increased outlay practically useless. In actual fact, a burning fuel lake is seen from the radar aerial basically as a "wall" of flames and smoke. So that in any case the echo signal is going to give the position of this "wall", but is not going to give the surface dimensions of this burning lake, since the "wall" prevents the determination of the surface length of the lake, i.e. it is the straight section of the object which is used in the radar; in an airport the radar has an aerial raised at a point of proper height, and therefore the sweep carried out by the beam will come up against this "wall". Naturally if the surface extent of the source is not known, it will not be possible to operate the hydrants correctly.

c) lastly, there is another reason, which is that flames generally return a distorted radar echo and the measurement is still not reliable.

All these reasons make the use of surface radar inadvisable, since in the event of using it, these problems would distort the necessary telemetry. Furthermore, radar will give the sections of the aircraft, but in an airport accident these sections are of less interest since the rupture factor already has no remedy in this case, of greater interest instead in the telemetry of emergencies is the position of the heat sources, which will sometimes coincide with the sections and at other times not. For example, an aircraft could have its undercarriage broken off in an accident, and this part could be detected by radar. But this part is of no interest as far as the hydrants are concerned, only the fire sources which are the sole item which must be eliminated as quickly as possible after the accident has occurred. Thus, if the telemetry gives mainly the metal sections and not the heat sources, this telemetry would be completely useless and detrimental in this instance, since it would oblige the hydrants to have to act on sections and not on sources, the hydrants being "thrown off track" by a bad choice of the telemetric method used.

Radar has been a great advance, but on every occasion the correct instrument has to be used which is consistent with the function demanding solution, without confusing the uses and functional possibilities of each instrument.

Moreover, although surface radar distorts x, y positions, it is used to give a screen display which is often sufficient for surveillance exclusively. But if an automated fire-fighting system is sought, those errors and difficulties which have been pointed out are disadvantageous, and another method of telemetry must be turned to, which naturally gives the correct x, y position of normal aircraft, but which also gives accurate data in cases of emergency, that is, with one and the same method, both functions must be brought about without duplicating the elements used.

Again, it is essential to understand that an airport is divided into two zones which are completely different in function:

a) the flight lanes and the runways contained within them.

b) the taxiways and parking areas.

In fact, when an aircraft is in operation, it does not, nor cannot have any intention in the airport other than to move in one of two directions:

- from the parking area to the runway (going via the taxiways).
- from the runway to the parking area (also going via the taxiways).

In a taxiway the aircraft travels very slowly and often in procession, where some aircraft follow others.

But in the flight lanes and runways the situation is completely different, since this is the ground-air or air-ground transition area. In a taxiway an aircraft can stop sharply if necessary, but this is completely impossible on the runways.

Thus, although the airport is an organic whole and its parts are interconnected, there are basic qualitative differences in these parts, and this differentiation therefore also has to be reflected appropriately in the telemetry system and its respective consequences and functional derivations.

For example, 99% of airport disasters occur in the flight lanes, so that it makes sense for the automated hydrants to be installed in the flight lanes, but not in other airport areas. That is, although they could of course be installed, it would not make sense comparing the function/cost relationship.

The same thing occurs with the analysis of surface radar, since there are many zones of little or no conflict in the airport, and for these surface radar surveillance gives a totally disproportionate funtion/cost relationship. Hence, this is another reason for the present RUSTEM system not using surface radar.

Also, as indicated by the OACI SMGC requirements, surface radar will not be regarded as the determining element. This is due, among other reasons, to the fact that although the tower can observe the said radar screen, the pilots in the taxiway cannot see this screen. It is specified that the pilots be guided "in situ", which requires detectors, guidance beacons and traffic lights at crossings, something which surface radar does not provide.

Because of guidance and emergencies, the RUSTEM system does not make use of surface radar.

As will be explained, two different methods will be used:

1) Two parallel lines of infra-red sensors for the flight lanes (Figure 11). Each of these lines located on the longest sides of the rectangle formed by the flight lane. As for instrument runways, the flight lane has to be at least 300 metres wide, this would be the minimum distance at which both parallel lines of sensors are installed.

2) Detectors and beacons (Figure 10) for control of aircraft in the taxiways and parking areas. Reference is made here to the generic detector, the following different types of detector being able to be used: weight pickup, ultrasonic pickup, heat pickup, pickup of the metallic nature of the aircraft (magnetic or electrical fields) and so on, since it is essential in the RUSTEM system that such detectors are neutral throughout the airport, with the exception of the detectors which pick up the aircraft along its run, as the said detectors are only activated exclusively for aircraft, due to the interconnecting mechanism between each of the successive detectors.

In order that a detector can perform the pickup and send its signal to the computer it has to be activated by electric current. This activation will be such that it will occur as the aircraft itself moves. The activated detectors will "accompany" the aircraft's progress.

These detectors are installed in such a way that they allow the standard minimum distance between aircraft to be controlled. That is to say, if two aircraft on the taxiway are not closer to each other than a minimum specified distance, they are certain of not colliding.

3) A simple system of traffic lights (Figure 10) installed at the taxiway crossings. In this way the tower records for example aircraft movements on each of the internal taxiway routes in the airport, whether for aircraft going from the parking area to the operative flight lane, or for coming from the runway to the parking area, routes that are held in the memory of the computer which controls and guides each aircraft step by step.

In their turn, these traffic lights, which are seen by the pilots when taxiing, are connected to each other, with the detectors described above, and with the tower.

A general description of this aspect of the system is given below:

1) Flight lane telemetric sensors.

The flight lane is another element which is very distinct from an aircraft parking area, since it is a place of movement, so that within the flight lane all aircraft have their engines running, and thus are sources of heat.

In the case of accident, fire sources are also heat sources. Ruptures are already without remedy and what has to be extinguished are fires. Hence, the common denominator of all incidents within a flight lane is heat.

Therefore the special ingredient of the RUSTEM system's telemetric method for flight lanes is the infra-red telemetric sensors (Figures 1,6,7). These sensors are installed in rectangles, one sensor at each corner. So that each sensor in a line has its counterpart in the line opposite.

The flat area which is the flight lane, with no obstacle between the aircraft and the sensors, as well as having no obstacles between the aircraft and the hydrants, allows "sui generis" activation, difficult to repeat in other contexts, but which is totally serviceable in the case of flight lanes, the vast majority of airport accidents occur, either by sudden accident, or else through the arrival at the airport of an aircraft announcing its emergency condition.

The sensors run along the source-detector line, producing a signal which when duly converted from analogue to digital is able to be processed by computer.

As it occurs in two sensors at the same time, there are two lines of bearing whose intersection is calculated by the aforesaid computer, supplying in real time the x, y position of the source with great simplicity and accuracy.

In turn, the rectangles or squares formed by four sensors, are such that they are successively adjusted to the whole length of the flight lane and its corresponding topography, so that each set of four sensors form (with small error) a plane. Thus the three-dimensional problem substantially disappears and the telemetry is exclusively surface telemetry in x, y. This is taking into account the fact that we are not now considering aircraft in flight, but on the ground, i.e. in their landing or take-off runs and in their taxiing movements within the confines of the flight lane. The latter not only contains the runway, but also covers the part corresponding to fast exits etc, i.e. the paved junctions connecting with the runway.

The telemetric sensors of the present system can operate in two different modes:

a) Tracking.

b) Sweep.

In the first case this is the normal functional mode, tracking the paths of normal aircraft in their operations within the flight lane. It is naturally assumed that there has to be only one single aircraft within the perimeter of the flight lane, since although this is often forgotten after airport construction, the flight lane is a standard obstacle-free zone. It does not make the least sense to put great effort at the time into planning and constructing an airport, strictly observing the standard of obstacle-free zones, then afterwards, once the airport has entered into operation, aircraft are placed within the flight lane, as happens many times with threshold waiting zones.

A waiting aircraft has to be outside the flight lane, not inside it, since an aircraft inside the flight lane whilst there is another one operating on it, represents a dangerous obstacle for the aircraft which is not waiting, as it is loaded with passengers and above all fuel, so that inside the perimeter of the flight lane there must be only one aircraft if the intention is to meet the OACI standard for obstacle-free zones, which is absolutely necessary for air safety.

A chimney or an aircraft may be such an obstacle, if they are situated where they ought not to be.

So flight lane sensors will now detect it there are one or more aircraft in it, since the telemetry will of course be tracking, and this will be displayed on the main RUSTEM panel located in the tower.

When there is an emergency, the sensors leave tracking mode and change to sweep mode by the pressing of an emergency button on the control console also located in the tower.

The sweep (Figure 9) takes place from the four corners formed by four sensors, so that the surface form of the heat sources is obtained. (Surface radar only transmits from a single point, the aerial).

At the computer level this gives rise to a circle being displayed, inside which the source is recorded. If there is more than one source, they would have corresponding emergency circles.

This data, together with the wind force and direction data, is passed on to the computer which controls the hydrants, which computes the selection of hydrants and the parameters of each of those selected, thus initiating the fire-fighting operation.

That is to say, the sensors receive the emergency data and the hydrants are triggered by the computer system, all this work being done very rapidly, considering the elements involved, with the functions of telemetric surveillance and automated fire-fighting being integrated.

By pressing a single button on the console located in the tower, the process described is set off, which is measured in seconds, the response time being very fast, as demanded by the extinction operations in question.

2) The detectors located in the taxiways are in their turn connected to the computer controlling all the airport taxiing.

This is a different environment from that of the flight lanes. Here the aircraft travel more slowly, following in procession. What is of interest now is maintaining the minimum distance between aircraft. That is, the position of the aircraft has to be monitored within a taxiway, and above all the maintenance of the said distance has to be controlled for safety purposes.

In order to do this the detectors are sited in the taxiways and the guidance beacons also guarantee this minimum distance. Where there are crossings traffic lights are located at their "entrances".

In other words, this involves only having one aircraft between each two taxiing detectors, being activated by the aircraft's own progress, and not detecting other objects.

This is a similar situation to the technique used in the airways while aircraft are in flight, maintaining the distances between them. In the present case this situation is controlled on the ground by means of one of the said detectors, the aircraft being able to be quite close to each other, but not too close, since although they are travelling slowly they still have some velocity.

With this type of detector the passage of the aircraft in front of the detector as well as its direction of travel are detected.

For each new detector which picks up the aircraft's progress, the computer lights another axial beacon for this aircraft, every aircraft on the taxiway having a fixed number of axial beacons lit in front of the nose of the aircraft according to the specific route of each aircraft.

The sequence of successive activation of the detectors is produced by means of the interconnecting mechanism between adjacent detectors. An activated detector on picking up the aircraft not only sends its signal to the computer, but also activates the next detector and deactivates the previous one.

Furthermore, if there is an aircraft in a section of taxiway, which is accounted for, and another aircraft enters this same section, the record shows two aircraft in this section and another signal appears on the main panel in this section; the second signal being arranged to flash and a small alarm sounds on the console at the same time. That is to say, an infraction has been detected and the tower personnel slow down the offending aircraft, thus avoiding damage. That is, the offending aircraft would be at a lesser distance than the standard minimum distance between aircraft, causing risk and possible collision. In such cases, the appropriate computer causes the axial beacons of the offending aircraft to flash.

3) The airport traffic lights of the present system are different from those in towns, although the three lights, green, amber, red, are also used.

The traffic light has two faces with the three lights on both its faces, like the faces of a coin. Although all of this is adapted to the airport context.

In actual fact, what at one moment is given as the valid direction on a taxiway, may become the prohibited direction in another moment. For example, the airport of Las Palmas de Gran Canaria is situated in a region of the world subject to trade winds which change direction twice a year. Thus the operative head of the runway changes according to the season of the year in question. Hence, on altering the runway head the internal routes for taxiing are changed accordingly.

On the control console (Figure 12) there is a diagram of the runways and a button panel with which the internal taxiing routes are recorded at each moment: start and end point.

If a second aircraft tries to enter a taxiway crossing occupied at that time by a preceding aircraft, the pilot of the second aircraft meets with an amber light which tells him that the route he is taking on the taxiway is correct, but the amber light indicates to him that there is an aircraft in front on this section of taxiway, and therefore the second aircraft has to wait until the amber light disappears, since only then will he be able to enter this section of road. In addition, the fixed number of axial beacons flash on and off.

That is to say, not only is the taxiing control function on the part of the tower involved, as happens with surface radar, but also the pilots have clear instructions "in situ" corresponding to this control. The pilots can see the traffic lights activated "in situ", but cannot view the surface radar screen, since obviously this will only be seen by the tower personnel. For these reasons also surface radar is not suitable and is not used in the RUSTEM system.

It is a question of synchronizing the tower and the taxiing aircraft, with the dual function of instructing the pilots "in situ" and at the same time controlling taxiing from the tower, both in marking out the internal taxiing routes and in detecting infractions, thus achieving control over the minimum distance between aircraft, which is what is important for safety purposes, having an objective measurement available on all occasions.

It is as important that the tower has a display available of what is happening on the runways as it is that the pilots have the data available "in situ".

The signals corresponding to aircraft may be seen on a surface radar screen, but the pilots cannot see this "in situ", nor does it help them at all in maintaining the standard distance between aircraft.

On the main RUSTEM system panel, one can see both the aircraft in the flight lanes (due to the signals sent back by the telemetric sensors), as well as all the aircraft on the taxiways (due to the continuous detectors). Thus, radio should only be used where essential.

To summarize, where there is an ILS in operation, the operating minimums are lowered and telemetric surveillance is therefore essential. Moreover, there must be monitoring and certainty that there is only one aircraft inside the flight lane, since the obstacle-free zone standard must be met which basically affects the whole of the flight lane. Similarly, the minimum distance between aircraft in the taxiing sequence must be monitored, while at the same time all the aircraft are being guided along their taxiway.

Furthermore, telemetric surveillance must be functionally integrated with automated fire-fighting in the flight lanes.

It emerges from all this that, for the reasons explained, surface radar is not the appropriate instrument, but rather the installation of telemetric sensors, detectors, axial beacons and traffic lights, as in the case of the described RUSTEM system, which to distinguish it from other airport systems has been called this for short, standing for "runway security and taxiway escort system", in which three functions are considered: surveillance, guidance and fire-fighting. With this the tower actually recovers its functions. One could then have smaller, faster and cheaper fire tankers for taking care of possible fires in other airport zones, but used as an auxiliary measure with respect to the automated hydrant installation, as a much more powerful and faster system, as demanded by the aeronautical accident, this being able to take care of any type of emergency in the flight lanes which is where airport accidents tend to occur.

This also reduces the general installation costs and those of maintenance, simultaneously achieving a high degree of reliability, speed, and simple and secure operation on the part of the tower personnel, who would thus have a working tool which they can use whatever the meteorological conditions, night-time situation or traffic density, the RUSTEM system being adaptable to any airport.

Lastly, as shown in Figures 13 and 14, especially in Figure 13, along the sides of the flight lane will be arranged a series of standard infra-red sensors, Si, as well as some special infra-red sensors, SiA, with an additional element for transmitting and receiving electromagnetic or ultrasonic pulses. The infra-red rays, if, which leave the aircraft are picked up by both types of infra-red sensors as the aircraft passes in front of them, and the data thus obtained is sent to the central computer of the installation fitted in the control tower, T (Figure 14). The two types of infra-red detectors can pick up not only the infra-red rays originating from the aircraft, but also the infra-red rays, if, originating from any vehicle, vh, which is travelling along the flight lane.

Also, as can be seen in Figure 14, the control tower, T, is linked in with the airport's surface radar, RS, Figure 14 also illustrating the normal infra-red sensors, Si, and the taxiing and guidance detectors and beacons, D-B.

As a result of the present invention, the automatic surveillance, guidance and fire-fighting installation for airport aircraft covers the whole spectrum of safety in an airport and is thus in the optimum position to meet the different safety emergencies which may arise in airport traffic.

Claims

1. An automatic surveillance and fire fighting system in an airport having a flight lane, comprising an array of heat sensors each directed towards the flight lane and disposed at laterally of the flight lane in spaced relation substantially along its entire length, including positions between intersections of the flight lane with any other lane, and a computer operable in a first mode to receive signals from the sensors to provide an indication of movement of an aircraft as it moves along the flight lane past successive sensors, characterised in that the system further comprises an array of selectively operable hydrants arranged such that any position along the flight path may be reached by fluid from at least one of the hydrants, the computer and the sensors are adapted to operate in a second mode in response to a control signal applied to the computer in which sensors are caused to sweep their respective local areas, and the computer acts to combine the outputs of adjacent sensors to detect the position of any heat source within any such area, and to selectively activate hydrants capable of providing fire extinguishing fluid to the position of the heat source.

2. A system according to claim 1, in which the computer is also operable in a third mode to cause the hydrants to direct fire extinguishing fluid over the whole or selected areas of the flight lane.

3. A system according to claim 1 or 2 in which in the second mode the computer also derives information as to the area of each heat source from the sensor outputs.

4. A system according to any preceding claim, further comprising at least one wind speed detector arranged to provide a wind speed signal indicative of the wind velocity in the flight lane to an input of the computer, and the computer is arranged to process this wind speed information with the sensor output signals to control the direction of the fluid from the hydrants.

5. A system according to any preceding claim, in which the airport has taxiways and parking areas, further comprising position detectors for detecting the position of aircraft in the taxiways and parking areas as a function of travel and direction of travel to provide position output signals to said computer, and guidance beacons along the taxiways controlled by the computer in response to the position signals to indicate the path to be followed by an aircraft.

6. A system according to claim 5 and comprising traffic lights connected to the guidance beacons and situated at appropriate positions such

as taxiway crossings.

7. A system in accordance with any one of claims 1 to 6, in which the infra-red sensors are arranged in two parallel rows situated outside the or each runway, on both sides of the latter and at the perimeter of the flight lanes, along the latter and preferably for a suitable distance beyond the runway threshold.

8. A system in accordance with claim 7, in which the flight lane sensors are interconnected and determine the position of the aircraft situated within such a lane in an instantaneous and continuous manner, in such a way that in normal operation they supply the corresponding computer with the data from the heat sources present on the flight lane and enable the aforementioned computer to define the position of each heat source, whether at rest or in motion, in real time on the tower control panel.

9. A system in accordance with claim 7 or 8, in which the separation between each two consecutive flight lane sensors of each row is defined in such a way that it is sufficiently small for the distance between them to be approximately equal to its horizontal projection, and between each two pairs of opposing detectors a rectangle of detection is created, within which, in an emergency situation, the heat sources are accurately detected by the four corner sensors which operate in the said emergency situation in the form of a continuous sweep, in such a way that the electrical signal from the infra-red sensors contains the information relating to position and size of the different heat sources, and is passed via an analogue to digital converter for processing by the aforesaid computer, the sensors being adapted to the flight lane's own particular topography, allowing surface telemetry.

10. A system in accordance with any one of claims 5 to 9 characterised by the fact that the taxiing and parking detectors are all neutral throughout the airport, not picking up any object other than aircraft exclusively, so that other objects do not interfere with the computer which processes the monitoring and guidance of the aircraft in their respective continuous sequences of travel, between an initial point and final point, various types of detector being able to be used, such as weight sensing; pickup by ultrasonic transmission and reception; transmission and reception of light; infra-red; laser; or else of the electrical or magnetic field type, so that only the detector corresponding to the aircraft's position sends back the corresponding signal to the computer, and in such a way that as each aircraft goes on taxiing, the activated detector deactivates the previous detector and activates the following detector, the latter remaining ready to pick up the aircraft when it passes in front of it, causing the detector signals arriving at the computer to trigger the latter into lighting and extinguishing the guidance beacons.

11. A system in accordance with claim 10, in which the said taxiing and parking detectors do not constitute an obstacle for aircraft or service vehicles, but only pick-up aircraft, and the computer on being fed with the signals originating from the detectors keeps account of each detector which sends its signal, the computer holding the route of each aircraft in memory, between its starting point and end point, which causes the computer to go on lighting the guidance beacons in front of each aircraft, according to a fixed number of beacons, and in such a way that each aircraft has in front of it a fixed number of lighted beacons, whether day or night, which beacons will go on changing according to the progress of the aircraft, the pilot being guided along the whole taxiing route, and in such a way that a minimum distance between aircraft is maintained, so that should two aircraft enter a crossing the computer causes the guidance beacons of one of the aircraft to flash on and off intermittently at the same time as the crossing traffic light remains lit at red, so that this aircraft has to brake its progress, and once the other aircraft has passed the crossing, the computer will cancel the aforesaid intermittent flashing, the red traffic light will be cancelled to allow the aircraft to continue on its way.

12. A system in accordance with any one of claims 5 to 11, in which the arrangement of the flight lane telemetric sensors and the taxiing detectors is such that once an aircraft has ceased being monitored by the former, it will start to be monitored by the latter and vice versa.

13. A system in accordance with any one of claims 6 to 12, in which the traffic lights are situated only at the crossings of taxiways, in a position related to that of the detectors and are connected to the said detectors, to the guidance beacons and to the control console, the traffic lights being activated in the event of opposing routes in aircraft taxiing and in such a way that in the event that a taxiing aircraft has to return to the parking area, in order to report any fault

for example, a controller can cancel the route which had been allocated to the said aircraft and input on a keyboard a new initial and final point for the said aircraft, which is guided back on its return.

14. A system in accordance with any one of claims 4 to 13, in which the information relating to wind force and direction generated by the anemometers, is sent continously to the control console and to the hydrant computer, so that the latter may effect calculations for aiming the different hydrants in emergency situations.

15. A system in accordance with any one of the preceding claims, in which the hydrants are arranged in two or more parallel rows on the runways, one or more on each side of the latter, and within the flight lanes, in such a way that each of the hydrants is independent of the rest, is solely controlled by the hydrant computer and launches its jets of extinguishing liquid with a horizontal to-and-fro motion whose amplitude depends upon the heat source to be extinguished, and with a different elevation for each discharge outlet, the hydrants being deactivated, despite being automatic in operation, unless the fire rescue control button is pressed from the airport tower, being capable of acting to prepare the runway on the announcement of the arrival of an aircraft in emergency status, or going into operation once the aircraft in the emergency is motionless; the system remaining locked whilst the aircraft is in motion.

16. A system in accordance with claim 15, in which the hydrants are anchored and buried underground, being covered by a metal, such as steel, cover, flush with the surrounding terrain, not constituting any obstacle in the event that an aircraft on leaving the runway passes over the top of the said cover, and in the event of the hydrants being activated due to an aircraft emergency, the hydrant cannon are raised up, raising the steel cover; the hydrants having three degrees of freedom being capable of horizontally rotating through 360°, to take care of any emergency.

17. A system in accordance with any one of the preceding claims, in which the hydrants are mobile, of the previous type, as well of the fixed type with multiple pipes, according to the requirements of the airport, at certain points of the flight lane and its ends.

18. A system in accordance with claim 15, in which the hydrants are arranged in locations suited to the form of the crossings of the different flight lanes.

19. A system in accordance with any one of claims 4 to 18, in which the hydrant computer only intervenes in the event that an emergency situation arises, being inactive under normal conditions, and carries out continuous calculations of the hydrant triggering parameters, by taking account of continuous information originating from the flight lane detectors and anemometers in cases of emergency and activation of the system from the tower.

20. A system in accordance with claim 19, in which at least one hydrant computer is provided for each flight lane, and the said computers are interconnected.

21. A system in accordance with claim 19 or 20, in which the hydrants can spray the complete runway on the prior announcement of an aircraft in an emergency situation or operate accurately on the halted aircraft or its sections.

22. A system in accordance with any one of claims 4 to 21, in which the flight lane computer receives data from all the sensors and anemometers, using this to carry out calculations of aircraft positions, and the position and size of the different fire zones which already exist or which develop subsequently, transmitting this last data to the hydrant computers, and stores information in memory relating to day-to-day hazards, as well as normal movements.

23. A system in accordance with any one of claims 5 to 22, in which contained in the tower is a main panel with the representation and identification of the aircraft in the flight lanes and in the taxiways, the said representation being in a special form for aircraft in a situation of infraction, with heat sources also appearing in an emergency situation, the computer equipment producing the corresponding alarm, either for infractions or for emergencies.

24. A system in accordance with claim 23, in which the control console is fitted with infraction and emergency alarm signals, a constant display of the data from the anemometers, selection controls for taxiway courses by means of a data input keyboard, controls for selecting flight lanes and take-off direction on the latter, and fire-fighting activation controls, in expectation of an emergency in all the flight lanes; similarly, it has controls for carrying out tests with the hydrants, using only water to check the system's response at any given moment, including also the necessary measuring instruments, switches and protection devices.

25. A system in accordance with any one of the preceding claims, characterised by its operation at any time, whether in a day- or night-time situation, or with poor visibility, due to its characteristics being adaptable to any aircraft configuration, as well as to any expansion there might be at any given time, the previously fitted system being capable of being expanded according to any extension of the runways and taxiways which may be carried out.

26. A system in accordance with any one of claims 5 to 25, in which each beacon is fitted with a compressed air outlet for the removal of dust, snow or other grime which has been deposited, whose discharge is activated when the beacon is lit.

27. A system in accordance with any one of claims 5 to 26, characterised by the fact that: (j) for airports operating in very poor visibilities, in addition to infra-red sensing, some flight lane sensors incorporate a transmitter and detector of electromagnetic pulses, or else an ultrasonic active element, capable of detecting objects located inside the flight lane relating to aircraft or vehicles; (k) for airports with normal or average visibility, the normal sensors not only pickup the aircraft located in the flight lane, but also the vehicles entering it; (1) there is the option of installing an interface capable of processing the signals originating from the surface radar which an airport may have installed, and introducing such signals into the computer which controls the surveillance, and with this data making an addition to the functions of the system; (m) there is the option that the systems taxiing detectors may be simultaneously activated throughout, and the pick up of aircraft and other objects carried out simultaneously, although in this case incorporating means for discriminating aircraft from other objects, achieving the maintenance of the logical sequence in the guidance of each aircraft in the zone of movement and parking of aircraft; and (n) there is the option of the water and extinguishing agent pipes and pressurized storage tanks being divided up into independent modules, and their discharge being achieved by means of the pressure of a compressed gas connected by regulating valves to the water and extinguishing agent storage tanks.

Patentansprüche

1. Automatisches Überwachungs- und Brandbekämpfungssystem auf einem Flugplatz mit einer Start- und Landebahn, mit einer Anordnung von Wärmefühlern, die je zur Start- und Landebahn hin gerichtet und seitlich der Start- und Landebahn im wesentlichen entlang ihrer gesamten Länge mit Abstand voneinander angeordnet sind, einschließlich Orten zwischen Kreuzungen der Start- und Landebahn mit jeder anderen Bahn, und einem in einer ersten Betriebsart betreibbaren Rechner zum Empfangen von Signalen von den Fühlern, um eine Bewegungsanzeige eines Flugzeugs bereitzustellen, während es sich entlang der Start- und Landebahn an aufeinanderfolgenden Fühlern vorbeibewegt,
dadurch gekennzeichnet,
daß das System weiterhin eine Anordnung wahlweise betreibbarer Hydranten aufweist, die so angeordnet sind, daß jede Stelle entlang der Start- und Landebahn von Flüssigkeit aus zumindest einem der Hydranten erreicht werden kann, der Rechner und die Fühler als Antwort auf ein dem Rechner zugeführtes Steuersignal in einer zweiten Betriebsart betreibbar sind, in der Fühler zum Überstreichen ihrer jeweiligen lokalen Bereiche veranlaßt werden, und der Rechner tätig ist, um die Ausgangssignale benachbarter Fühler zum Ermitteln der Lage einer Wärmequelle in irgendeinem solchen Bereich zu kombinieren, und um Hydranten wahlweise zu aktivieren, die Feuerlöschflüssigkeit am Ort der Wärmequelle bereitstellen können.

2. System nach Anspruch 1, bei dem der Rechner auch in einer dritten Betriebsart betreibbar ist, um die Hydranten zu veranlassen, Feuerlöschflüssigkeit auf die gesamte oder ausgewählte Bereiche der Start- und Landebahn zu richten.

3. System nach Anspruch 1 oder 2, bei dem der Rechner in der zweiten Betriebsart aus den Ausgangssignalen der Fühler auch Information über die Fläche jeder Wärmequelle gewinnt.

4. System nach einem der vorhergehenden Ansprüche, das ferner zumindest einen Windgeschwindigkeitsmesser aufweist, der zum Liefern eines die Windgeschwindigkeit in der Start- und Landebahn anzeigenden Windgeschwindigkeitssignals an einen Eingang des Rechners angeordnet ist, wobei der Rechner dafür eingerichtet ist, diese Windgeschwindigkeitsinformation mit den Fühlerausgangssigna-

len zu verarbeiten, um die Richtung der Flüssigkeit aus den Hydranten zu steuern.

5. System nach einem der vorhergehenden Ansprüche, wobei der Flugplatz Rollbahnen und Parkflächen hat, das ferner Ortsanzeiger zum Feststellen der Position von Flugzeugen auf den Rollbahnen und Parkflächen als Funktion von Bewegung und Bewegungsrichtung aufweist, um dem genannten Rechner Positionsausgangssignale zu liefern, und Leitfeuer entlang der Rollbahnen aufweist, die in Abhängigkeit der Positionssignale vom Rechner angesteuert werden, um den von einem Flugzeug zu folgenden Weg anzuzeigen.

6. System nach Anspruch 5 mit Verkehrsampeln, die mit den Leitfeuern verbunden und an geeigneten Stellen wie z. B. Rollbahnkreuzungen angeordnet sind.

7. System nach einem der Ansprüche 1 bis 6, bei dem die Infrarotsensoren in zwei parallelen, beidseits und außerhalb der oder jeder Start- und Landebahn gelegenen Reihen, und am Rand der Anflugbahnen längs dieser und vorzugsweise eine angemessene Wegstrecke über die Start- und Landebahngrenze hinaus angeordnet sind.

8. System nach Anspruch 7, bei dem die Flugbahn-Sensoren miteinander verbunden sind und die Position des sich in solch einer Bahn befindenden Flugzeugs augenblicklich und fortwährend derart ermitteln, daß sie im Normalbetrieb den entsprechenden Rechner mit den Daten von den in der Flugbahn vorhandenen Wärmequellen versorgen und den vorgenannten Rechner in die Lage versetzen, die Position jeder Wärmequelle, ob im Stillstand oder in Bewegung, in Echtzeit auf der Anzeigetafel im Kontrollturm anzugeben.

9. System nach Anspruch 7 oder 8, bei dem der Abstand zwischen je zwei aufeinanderfolgenden Flugbahnsensoren jeder Reihe derart festgesetzt ist, daß er klein genug ist, um die Wegstrecke zwischen ihnen etwa gleich ihrer Horizontalprojektion sein zu lassen, und bei dem zwischen je zwei Paaren gegenüberliegender Fühleinrichtungen ein Erfassungsrechteck erzeugt ist, innerhalb dessen in einer Notfallsituation die Wärmequellen von den vier Ecksensoren genau erfaßt werden, die in der genannten Notfallsituation in Form einer fortlaufenden Abtastung arbeiten, derart, daß das elektrische Signal der Infrarotsensoren die Information bezüglich Position und Größe der verschiedenen Wärmequellen enthält und durch einen Analog/Digital-Wandler zum Verarbeiten durch den vorgenannten Rechner geführt wird, wobei die Sensoren an die der Flugbahn eigene, besondere Topographie angepaßt sind und Oberflächentelemetrie ermöglichen.

10. System nach einem der Ansprüche 5 bis 9, **dadurch gekennzeichnet,** daß die Rollbahn- und Parkflächen-Fühleinrichtungen auf dem gesamten Flugplatz alle indifferent sind und kein anderes Objekt als ausschließlich Flugzeuge erfassen, so daß andere Objekte den Rechner nicht stören, der die Überwachung und Leitung der Flugzeuge in ihren entsprechenden fortlaufenden Bewegungsabschnitten zwischen einem Anfangs- und Endpunkt bearbeitet, wobei unterschiedliche Arten von Fühleinrichtungen eingesetzt werden können, wie z. B. Gewichtserfassung; Erfassung durch Aussendung und Empfang von Ultraschall; Aussendung und Empfang von Licht; Infrarot; Laser; oder eine andere elektrische oder magnetische Feldart, so daß nur die der Position des Flugzeugs entsprechende Fühleinrichtung das entsprechende Signal zu dem Rechner zurücksendet, derart, daß beim Weiterrollen jedes Flugzeugs die aktivierte Fühleinrichtung die vorhergehende Fühleinrichtung deaktiviert und die nächstfolgende Fühleinrichtung aktiviert, wobei letztere bereit bleibt, das Flugzeug zu erfassen, wenn es vor ihr vorbeirollt, und bewirkt, daß die am Rechner ankommenden Signale der Fühleinrichtung letztere erleuchten und die Leitfeuer erlöschen lassen.

11. System nach Anspruch 10, bei dem die genannten Rollbahn- und Parkflächen Fühleinrichtungen kein Hindernis für Flugzeuge oder Servicefahrzeuge darstellen, sondern nur Flugzeuge erfassen, und bei dem der Rechner, während ihm die von den Fühleinrichtungen stammenden Signale zugeführt werden, Buch über jede Fühleinrichtung führt, die ihr Signal sendet, wobei der Rechner den Weg jedes Flugzeugs zwischen seinem Anfangs- und Endpunkt speichert, was den Rechner veranlaßt, eine feste Anzahl von Leitfeuern vor jedem Flugzeug aufleuchten zu lassen, derart, daß jedes Flugzeug vor sich bei Tag oder Nacht eine feste Anzahl erleuchteter Feuer hat, die entsprechend dem Vorrücken des Flugzeugs umschalten, so daß der Pilot entlang des gesamten Rollwegs geleitet wird, derart, daß ein Minimalabstand zwischen Flugzeugen eingehalten wird, so daß im Falle zweier in

eine Kreuzung einlaufender Flugzeuge der Rechner die Leitfeuer für eines der Flugzeuge während der Zeitdauer blinken läßt, in der die Kreuzungsampel rot leuchtet, so daß dieses Flugzeug sein Vorrücken bremsen muß, und der Rechner das genannte Blinken beendet und die rote Ampel ausgeschaltet wird, so bald das andere Flugzeug die Kreuzung passiert hat, um dem Flugzeug zu gestatten, seinen Weg fortzusetzen.

12. System nach einem der Ansprüche 5 bis 11, bei dem die Anordnung der Flugbahn-Telemetriesensoren und der Rollbahn-Fühleinrichtungen so ist, daß ein Flugzeug, sobald es nicht mehr von den ersteren überwacht wird, es von den letzteren überwacht wird und umgekehrt.

13. System nach einem der Ansprüche 6 bis 12, bei dem die Ampeln nur an den Kreuzungen von Rollbahnen in einer mit der Position der Fühleinrichtungen in Bezug stehenden Position angeordnet und mit den genannten Fühleinrichtungen, den Leitfeuern und dem Kontrollpult verbunden sind, wobei die Ampeln bei entgegengerichteten Rollwegen von Flugzeugen aktiviert werden, so daß bei einem rollenden Flugzeug, das zu der Parkfläche zurückkehren muß, beispielsweise um irgendeinen Fehler zu melden, ein Controller die dem genannten Flugzeug zugeteilte Wegstrecke löschen und auf einer Tastatur einen neuen Anfangs- und Endpunkt für das genannte Flugzeug eingeben kann, das bei seiner Rückkehr zurückgeleitet wird.

14. System nach einem der Ansprüche 4 bis 13, bei dem die sich auf Windstärke und -richtung beziehende, von den Windgeschwindigkeitsmessern erzeugte Information fortwährend zum Kontrollpult und zu dem Rechner für die Hydranten gesendet wird, so daß letzterer Berechnungen zum Ausrichten der verschiedenen Hydranten in Notfallsituationen ausführen kann.

15. System nach einem der vorhergehenden Ansprüche, bei dem die Hydranten in zwei oder mehr parallelen Reihen auf den Start- und Landebahnen in einer oder mehreren Reihen auf jeder Seite derselben, und innerhalb der Flugbahnen derart angeordnet sind, daß jeder der Hydranten von den übrigen unabhängig ist, nur durch den Rechner für die Hydranten gesteuert wird und seine Löschflüssigkeitsstrahlen in einer horizontalen Hin- und Herbewegung, deren Amplitude von der zu löschenden Wärmequelle abhängt, und mit einer für jede Auslaßöffnung verschiedenen Neigung ausstößt, wobei die Hydranten, trotz automatischen Betriebs, deaktiviert sind, bis der Feuerrettungsknopf vom Kontrollturm aus gedrückt wird, und in der Lage sind, die Start- und Landebahn bei Ankündigung der Ankunft eines sich in einer Notfallsituation befindenden Flugzeugs vorzubereiten oder in Betrieb zu treten, sobald das sich in Not befindende Flugzeug nicht mehr in Bewegung ist, wobei das System gesperrt bleibt, so lange das Flugzeug in Bewegung ist.

16. System nach Anspruch 15, bei dem die Hydranten unterirdisch verankert und versenkt sind und von einer Metallabdeckung, beispielsweise aus Stahl, in einer Ebene mit dem umgebenden Gelände abgedeckt sind und kein Hindernis darstellen, falls ein Flugzeug beim Verlassen der Start- und Landebahn über die Oberseite der genannten Abdeckung fährt, und bei aufgrund einer Flugzeugnotsituation aktivierter Hydranten die Hydrantenkanonen, die Stahlabdeckung anhebend, hochgefahren werden, wobei die Hydranten mit drei Freiheitsgraden in der Lage sind, horizontal um 360° zu drehen, um sich jedes Notfalls anzunehmen.

17. System nach einem der vorhergehenden Ansprüche, bei dem die Hydranten an bestimmten Punkten der Flugbahn und ihrer Enden entsprechend den Anforderungen des Flugplatzes sowohl gemäß der vorhergehenden Art bewegbar als auch vom feststehenden Typ mit Mehrfachrohren sind.

18. System nach Anspruch 15, bei dem die Hydranten an Stellen angeordnet sind, die der Kreuzungsform der verschiedenen Flugbahnen angepaßt sind.

19. System nach einem der Ansprüche 4 bis 18, bei dem der Rechner für die Hydranten nur eingreift, wenn eine Notfallsituation auftritt und unter normalen Bedingungen nicht aktiv ist, und bei Notfällen und einer Aktivierung des Systems vom Kontrollturm aus fortwährende Berechnungen der Hydranten-Auslöseparameter durch Verfolgen der von den Fühleinrichtungen der Flugbahn und den Windgeschwindigkeitsmessern stammenden kontinuierlichen Information durchführt.

20. System nach Anspruch 19, bei dem für jede Flugbahn zumindest ein Rechner für Hydranten vorgesehen ist und die genannten Rechner miteinander verbunden sind.

21. System nach Anspruch 19 oder 20, bei dem die Hydranten nach vorheriger Ankündigung eines sich in einer Notfallsituation befindenden Flugzeugs die gesamte Start- und Landebahn besprühen oder gezielt das gestoppte Flugzeug oder seine Abschnitte bearbeiten können.

22. System nach einem der Ansprüche 4 bis 21, bei dem der Rechner für die Flugbahn Daten von allen Fühleinrichtungen und Windgeschwindigkeitsmessern empfängt und diese benutzt, um Berechnungen von Flugzeugpositionen und der Lage und Größe der verschiedenen, bereits vorhandenen oder sich nach und nach entwickelnden Brandzonen durchzuführen, wobei diese letzten Daten an die Rechner für die Hydranten übertragen werden, und Informationen sowohl bezüglich tagtäglicher Gefahren als auch bezüglich normaler Bewegungen abspeichert.

23. System nach einem der Ansprüche 5 bis 22, bei dem im Kontrollturm eine Haupttafel mit der Darstellung und Kennung der Flugzeuge in den Flugbahnen und in den Rollbahnen vorhanden ist, wobei die genannte Darstellung eine besondere Form für beschädigte Flugzeuge aufweist, und wobei Wärmequellen in einer Notfallsituation ebenfalls erscheinen und die Rechneranlage den entsprechenden Alarm erzeugt, entweder für Beschädigungen oder für Notfälle.

24. System nach Anspruch 23, bei dem das Kontrollpult mit Beschädigungs- und Notfallalarmsignalen, einer dauernden Anzeige der Daten von den Windgeschwindigkeitsmessern, Wahlorganen für Rollbahnwege mittels einer Dateneingabetastatur, Organen zur Wahl von Flugbahnen und Startrichtung auf letzterer, und mit Brandbekämpfungsaktivierungsorganen versehen ist, in Erwartung eines Notfalls in allen Flugbahnen; gleichermaßen weist es Bedienungsorgane zum Durchführen von Hydrantentests und auch die notwendigen Meßinstrumente, Schalter und Schutzvorrichtungen auf, wobei zum Prüfen der Reaktion des Systems zu jedem beliebigen Zeitpunkt nur Wasser eingesetzt wird.

25. System nach einem der vorhergehenden Ansprüche,
gekennzeichnet durch
seinen Betrieb zu jeder Zeit, ob bei Tag oder bei Nacht oder bei schlechter Sicht, welches aufgrund seiner Eigenschaften sowohl an jede Flugzeugkonfiguration als auch an jede zu jedem gegebenen Zeitpunkt mögliche Erweiterung anpaßbar ist, wobei das vorher installierte System entsprechend jeder Verlängerung der Start- und Landebahnen und Rollbahnen, die möglicherweise ausgeführt wird, erweiterbar ist.

26. System nach einem der Ansprüche 5 bis 25, bei dem jedes Feuer mit einem Druckluftauslaß zur Entfernung von Staub, Schnee oder anderem Schmutz, der abgelagert worden ist, versehen ist, dessen Ausströmen aktiviert wird, wenn das Feuer aufleuchtet.

27. System nach einem der Ansprüche 5 bis 26,
dadurch gekennzeichnet,
daß: (j) für Flugplätze, die bei sehr schlechter Sicht betrieben werden, einige Flugbahnfühleinrichtungen zusätzlich zu Infrarotsensoren einen Sender und Empfänger elektromagnetischer Impulse oder ein aktives Ultraschallelement zum Erfassen von innerhalb der Flugbahn befindlichen Gegenständen in Bezug auf Flugzeuge oder Fahrzeuge aufweisen; (k) bei Flugplätzen mit normaler oder durchschnittlicher Sicht die normalen Fühleinrichtungen nicht nur das sich in der Flugbahn befindende Flugzeug, sondern auch in diese einfahrende Fahrzeuge erfassen; (1) die Wahl besteht, ein Interface zu installieren, welches in der Lage ist, die von einem Oberflächenradar stammenden Signale zu verarbeiten, welches ein Flugplatz installiert haben kann, und diese Signale dem Rechner zuzuführen, der die Überwachung steuert, und mit diesen Daten eine Funktionserweiterung des Systems vorzunehmen; (m) die Wahl besteht, daß die Rollbahnfühleinrichtungen des Systems gleichzeitig insgesamt aktiviert werden können und das Erfassen von Flugzeugen und anderen Gegenständen gleichzeitig durchgeführt wird, in diesem Fall allerdings Mittel zur Unterscheidung von Flugzeugen gegenüber anderen Gegenständen einschließend, wodurch der Erhalt der logischen Reihenfolge beim Leiten jedes Flugzeugs im Park- und Bewegungsbereich von Flugzeugen erreicht wird; und (n) die Wahl besteht, die Wasser- und Löschmittelrohre und Druckspeichertanks in unabhängige Module aufzuteilen, wobei ihr Ausströmen mittels des Drucks eines komprimierten Gases erreicht wird, das über Regelventile mit den Wasser- und Löschmittelspeichertanks verbunden ist.

Revendications

1. Dispositif automatique de surveillance et de lutte contre l'incendie dans un aéroport comportant une bande aménagée, constitué par un réseau de détecteurs de chaleur, dont chacun est orienté vers la bande aménagée, et placés de façon espacée sur les côtés de la bande aménagée sensiblement sur toute sa longueur, y compris en des emplacements entre les intersections de la bande aménagée avec une autre piste, et un ordinateur qui peut fonctionner dans un premier mode pour recevoir des signaux émis par les capteurs afin de fournir une indication du mouvement d'un avion qui se déplace le long de la bande aménagée en passant devant les capteurs successifs, **caractérisé** en ce que le dispositif comporte en outre un réseau de bouches d'incendie, qui peuvent fonctionner de façon sélective, disposées de telle sorte que l'on puisse atteindre n'importe quelle position le long de la bande aménagée avec du fluide en provenance de l'une des bouches au moins ; l'ordinateur et les capteurs sont aptes à fonctionner dans un deuxième mode en réponse à un signal de commande appliqué à l'ordinateur, mode dans lequel on fait balayer par les capteurs la région locale qui leur correspond, et l'ordinateur agit pour combiner les sorties des capteurs adjacents, afin de détecter la position de toute source de chaleur dans n'importe laquelle de ces régions, et activer de façon sélective les bouches capables d'envoyer un fluide extincteur d'incendie à l'emplacement de la source de chaleur.

2. Dispositif suivant la revendication 1, dans lequel l'ordinateur peut aussi fonctionner dans un troisième mode pour amener les bouches d'incendie à diriger le fluide extincteur d'indencie sur toute la bande aménagée ou sur des zones choisies de celle-ci.

3. Dispositif suivant la revendication 1 ou 2, dans lequel, dans le deuxième mode, l'ordinateur déduit aussi des sorties des capteurs une information sur l'étendue de chaque source de chaleur.

4. Dispositif suivant l'une quelconque des précédentes revendications, comportant en outre au moins un détecteur de la vitesse du vent placé pour fournir un signal de vitesse de vent indicateur de la vélocité du vent dans la bande aménagée à une borne d'entrée de l'ordinateur, et l'ordinateur est prévu pour traiter cette information de vitesse du vent avec les signaux de sortie des capteurs de façon à commander la direction du fluide émis par les bouches d'incendie.

5. Dispositif suivant l'une quelconque des précédentes revendications, dans lequel l'aéroport comporte des voies de circulation et des aires de stationnement, qui a en outre des détecteurs de position pour détecter la position d'un avion sur les voies de circulation et sur les aires de stationnement en fonction du trajet et de la direction de trajet, pour fournir en sortie des signaux de position audit ordinateur, et des balises de guidage le long des voies de circulation commandées par l'ordinateur en réponse aux signaux de position afin d'indiquer à l'avion le trajet à suivre.

6. Dispositif suivant la revendication 5, comportant des signaux lumineux de circulation reliés aux balises de guidage et placés en des endroits appropriés tels que les intersections de voies de circulation.

7. Dispositif suivant l'une quelconque des revendications 1 à 6, dans lequel des capteurs infrarouges sont agencés en deux rangées parallèles situées à l'extérieur de la piste, ou de chacune d'elle, sur les deux côtés de celle-ci, et au périmètre de la bande aménagée, le long de celle-ci et de préférence jusqu'à une distance appropriée au-delà du seuil de la piste.

8. Dispositif suivant la revendication 7, dans lequel les capteurs de la bande aménagée sont inter-reliés et déterminent la position de l'avion placé sur une telle piste de façon instantanée et continue, de telle manière qu'en fonctionnement normal ils fournissent à l'ordinateur correspondant les données en provenance des sources de chaleur présentes sur la bande aménagée et permettent à l'ordinateur ci-dessus mentionné de définir la position de chaque source de chaleur, qu'elle soit au repos ou en mouvement, en temps réel au tableau de la tour de contrôle.

9. Dispositif suivant la revendication 7 ou 8, dans lequel on définit l'espacement entre deux capteurs de la bande aménagée consécutifs sur chaque rangée suffisamment petit pour que la distance entre eux soit sensiblement égale à leur projection horizontale, et on définit un rectangle de détection entre chacune des deux paires de détecteurs se faisant face à l'intérieur duquel, dans une situation d'urgence, les sources de chaleur sont détectées avec précision par les quatre détecteurs d'angle qui fonctionnent dans ladite situation d'urgence sous forme d'un balayage continu, de telle sorte que le signal électrique émis par les détecteurs infrarouges contient l'information concernant la position et la taille des différentes sources de chaleur, et est envoyé via un convertisseur analogique/numérique à l'ordinateur précité

pour qu'il le traite, les capteurs étant adaptés à la topographie particulière propre à la bande aménagée concernée, permettant une télémétrie de surface.

10. Dispositif suivant l'une quelconque des revendications 5 à 9, **caractérisé** par le fait que les détecteurs pour les voies de circulation et les aires de stationnement sont tous neutres partout dans l'aéroport, ne sont sensibles à aucun autre objet qu'exclusivement un avion, de telle sorte que d'autres objets ne peuvent pas interférer avec l'ordinateur qui surveille et guide les avions en continu dans leurs séquences respectives de trajet entre un point initial et un point final, et l'on peut utiliser différents types de détecteurs, sensibles au poids, fonctionnant par transmission et réception d'ultrasons, transmission et réception de lumière, d'infrarouges, au laser, ou tout autre type à champ magnétique ou électrique, de telle sorte que seul le détecteur qui correspond à la position de l'avion renvoie un signal correspondant à l'ordinateur, et cela de telle façon que, lorsque l'avion se déplace sur la voie de circulation, le détecteur activé désactive le détecteur qui le précède et active celui qui le suit, ce dernier étant prêt à détecter l'avion lorsqu'il passera en face de lui, amenant les signaux de détecteurs qui arrivent à l'ordinateur à déclencher celui-ci pour éclairer et éteindre les balises de guidage.

11. Dispositif suivant la revendication 10, dans lequel lesdits détecteurs des voies de circulation et des aires de stationnement ne constituent pas un obstacle pour un avion ni pour les véhicules de service, mais servent seulement à suivre l'avion, et l'ordinateur, alimenté par les signaux émis par ces détecteurs, garde en compte chaque détecteur qui envoie un signal, mémorise la route de chaque avion entre son point de départ et son point d'arrivée, ce qui l'amène à allumer les balises de guidage en face de chaque avion suivant un nombre fixe de balises, de telle sorte que chaque avion a en face de lui un nombre fixe de balises allumées, qu'il fasse jour ou nuit, balises qui vont changer au fur et à mesure de la progression de l'avion, le pilote étant guidé sur tout le chemin de la voie de circulation, et de telle sorte que soit maintenue une distance minimale entre avions, si bien que si deux avions arrivent à une intersection, l'ordinateur fait clignoter de façon intermittente les balises de guidage de l'un des avions alors qu'en même temps le feu au niveau du croisement reste au rouge ce qui oblige cet avion à s'arrêter, et après que l'autre avion a traversé l'intersection l'ordinateur annule le clignotement interméttent précité, annule le feu rouge au niveau de l'intersection, pour autoriser l'avion à poursuivre sa route.

12. Dispositif suivant l'une quelconque des revendications 5 à 11, dans lequel la disposition des capteurs télémétriques de la bande aménagée et des détecteurs de la voie de circulation est telle qu'après que l'avion a cessé d'être surveillé par les premiers, il va être surveillé par les seconds et vice versa.

13. Dispositif suivant l'une quelconque des revendications 6 à 12, dans lequel les feux de circulation sont situés uniquement aux intersections des voies de circulation, dans une position reliée à celle des détecteurs et sont reliés auxdits détecteurs, aux balises de guidage et à la console de commande, les feux de circulation étant actionnés dans le cas où il y a des routes opposées pour la circulation de l'avion, et de telle sorte que, si un avion dans les voies de circulation doit retourner sur l'aire de stationnement, par exemple pour reporter une quelconque défaillance, un contrôleur peut annuler la route qui avait été allouée audit avion et entrer dans un clavier de nouveaux points initial et final pour ledit avion qui sera guidé sur son trajet de retour.

14. Dispositif suivant l'une quelconque des revendications 4 à 13, dans lequel l'information émise par les anémomètres concernant la direction et la force du vent est envoyée en continu à la console de commande et à l'ordinateur des bouches d'incendie, de telle sorte que ce dernier peut effectuer les calculs pour diriger l'orientation des bouches différentes dans des situations d'urgence.

15. Dispositif suivant l'une quelconque des précédentes revendications, dans lequel les bouches d'incendie sont disposées en deux rangées parallèles aux pistes, ou davantage, une ou plus de chaque côté de celles-ci, et à l'intérieur des bandes aménagées, de telle sorte que chaque bouche soit indépendante des autres, uniquement commandée par l'ordinateur des bouches et envoie ses jets de liquide extincteur avec un mouvement horizontal de va-et-vient dont l'amplitude dépend de la source de chaleur à éteindre, et ce, avec une hauteur différente pour chaque émission, les bouches étant désactivées, bien qu'automatiques dans leur fonctionnement, à moins que le bouton de commande d'intervention contre le

feu ne soit pressé par la tour de contrôle de l'aéroport, étant capable d'agir pour préparer la piste à l'annonce de l'arrivée d'un avion en état de détresse ou entrant en fonctionnement une fois que l'avion en détresse est immobile, le dispositif étant verrouillé tant que l'avion se déplace.

16. Dispositif suivant la revendication 15, dans lequel les bouches d'incendie sont fixées au sol et enterrées, recouvertes d'un couvercle en métal tel que de l'acier, se fondent avec le terrain environnant sans constituer quelque obstacle que ce soit dans le cas où un avion passe sur le sommet dudit couvercle au moment de quitter la piste, et dans le cas où les bouches sont activées à cause d'un avion en détresse, le canon de la bouche est soulevé en soulevant le couvercle en acier ; les bouches ont trois degrés de liberté et peuvent tourner horizontalement suivant 360° pour parer à toute situation d'urgence.

17. Dispositif suivant l'une quelconque des précédentes revendications, dans lequel les bouches d'incendie sont mobiles, du type précédent, ainsi que du type fixe avec tuyaux multiples, suivant les exigences de l'aéroport, en certains points de la bande aménagée et en ses extrémités.

18. Dispositif suivant la revendication 15, dans lequel les bouches d'incendie sont situées en des endroits appropriés à la forme des intersections des différentes bandes aménagées.

19. Dispositif suivant l'une quelconque des revendications 4 à 18, dans lequel l'ordinateur des bouches intervient uniquement dans le cas où se déclare une situation d'urgence, étant inactif en conditions normales, et effectue des calculs en continu des paramètres de déclenchement des bouches, en prenant en compte l'information continue émise par les détecteurs des bandes aménagées et les anémomètres en prévision d'une urgence et d'une activation du dispositif par la tour de contrôle.

20. Dispositif suivant la revendication 19, dans lequel au moins un ordinateur de bouche est prévu pour chaque bande aménagée, et lesdits ordinateurs sont interconnectés.

21. Dispositif suivant les revendications 19 ou 20, dans lequel les bouches d'incendie peuvent arroser l'intégralité de la piste à l'annonce d'un avion en situation de détresse, ou opérer de façon précise sur l'avion arrêté ou sur des parties de celui-ci.

22. Dispositif suivant l'une quelconque des revendications 4 à 21, dans lequel l'ordinateur de bandes aménagées reçoit des données de tous les détecteurs et anémomètres, en les utilisant pour mener à bien les calculs des positions d'avion, et la position et la taille des zones différentes de feu qui existent déjà ou qui peuvent se développer ensuite, transmettant ces dernières données aux ordinateurs de bouches, et mémorise une information se rapportant aux incidents jour après jour ainsi qu'aux mouvements normaux.

23. Dispositif suivant l'une quelconque des revendications 5 à 22, dans lequel la tour de contrôle dispose d'un panneau principal avec la représentation et l'identification des avions dans les bandes aménagées et dans les voies de circulation, ladite représentation prenant une forme spéciale pour un avion en situation d'infraction, les sources de chaleur apparaissant aussi dans une situation d'urgence, l'ordinateur produisant une alarme correspondante que ce soit pour les infractions ou pour les urgences.

24. Dispositif suivant la revendication 23, dans lequel la console de contrôle est munie de signaux d'alarme pour infraction et pour urgence, d'une visualisation constante des données en provenance des anémomètres, de commandes de sélection pour les voies de circulation au moyen d'un clavier d'entrées de données, de commandes pour le choix des pistes d'envol et de la direction de décollage sur celles-ci, et des commandes d'activation de la lutte contre l'incendie, en prévision d'une urgence dans toutes les bandes aménagées ; de même, elle a des commandes pour conduire des essais avec les bouches, utilisant seulement de l'eau pour vérifier la réponse du dispositif à tout moment, comportant aussi les instruments nécessaires aux mesures, des interrupteurs et des dispositifs de protection.

25. Dispositif suivant l'une quelconque des précédentes revendications, **caractérisé** par le fait qu'il fonctionne à tout moment, jour et nuit, en faible visibilité, qu'il est adaptable, dû à ses caractéristiques, à n'importe quelle configuration d'avion, et aussi à quelque extension qui puisse se produire à n'importe quel moment, le dispositif précédemment installé étant capable d'être agrandi en fonction de toute extension des pistes et des voies de circulation qui puisse être réalisées.

26. Dispositif suivant l'une quelconque des revendications 5 à 25, dans lequel chaque balise est munie d'une sortie d'air comprimé pour retirer la poussière, la neige ou toute autre salissure qui a été déposée, dont l'émission est activée lorsque la balise est allumée.

27. Dispositif suivant l'une quelconque des revendications 5 à 26, **caractérisé** par le fait que :

j) dans le cas d'aéroports qui fonctionnent avec une visibilité très faible, certains détecteurs de la bande aménagée, outre la détection par infrarouge, comportent un émetteur-détecteur d'impulsions électromagnétiques, ou bien un élément sensible aux ultrasons, capable de détecter des objets placés sur la bande aménagée se rapportant à un avion ou à des véhicules,

k) pour des aéroports avec une visibilité moyenne ou normale, les détecteurs normaux repèrent non seulement l'avion situé dans la bande aménagée mais aussi les véhicules qui y pénètrent,

l) il y a la possibilité d'installer une interface capable de traiter les signaux en provenance du radar de surface que l'aéroport peut avoir installé, et d'introduire de tels signaux dans l'ordinateur qui commande la surveillance, et d'ajouter, avec ces données, aux fonctions du dispositif,

m) en option, il est possible que les détecteurs des voies de circulation du dispositif soient tous actionnés en même temps et que l'on effectue en même temps la détection d'un avion et d'autres objets, avec dans ce cas des moyens pour faire la distinction entre un avion et les autres objets, tout en maintenant la séquence logique dans le guidage de chaque avion dans sa zone de déplacement et de stationnement,

(n) en option, les tuyaux d'agent d'extinction et d'eau et les réservoirs de stockage pressurisés peuvent être séparés en modules indépendants, et on peut obtenir leur émission au moyen de la pression d'un gaz comprimé relié par des valves de régulation aux réservoirs de stockage d'eau et de liquide extincteur.

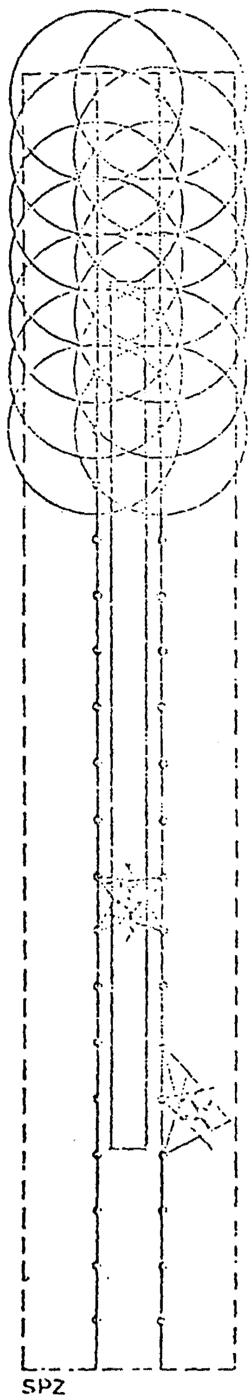


FIG. 1

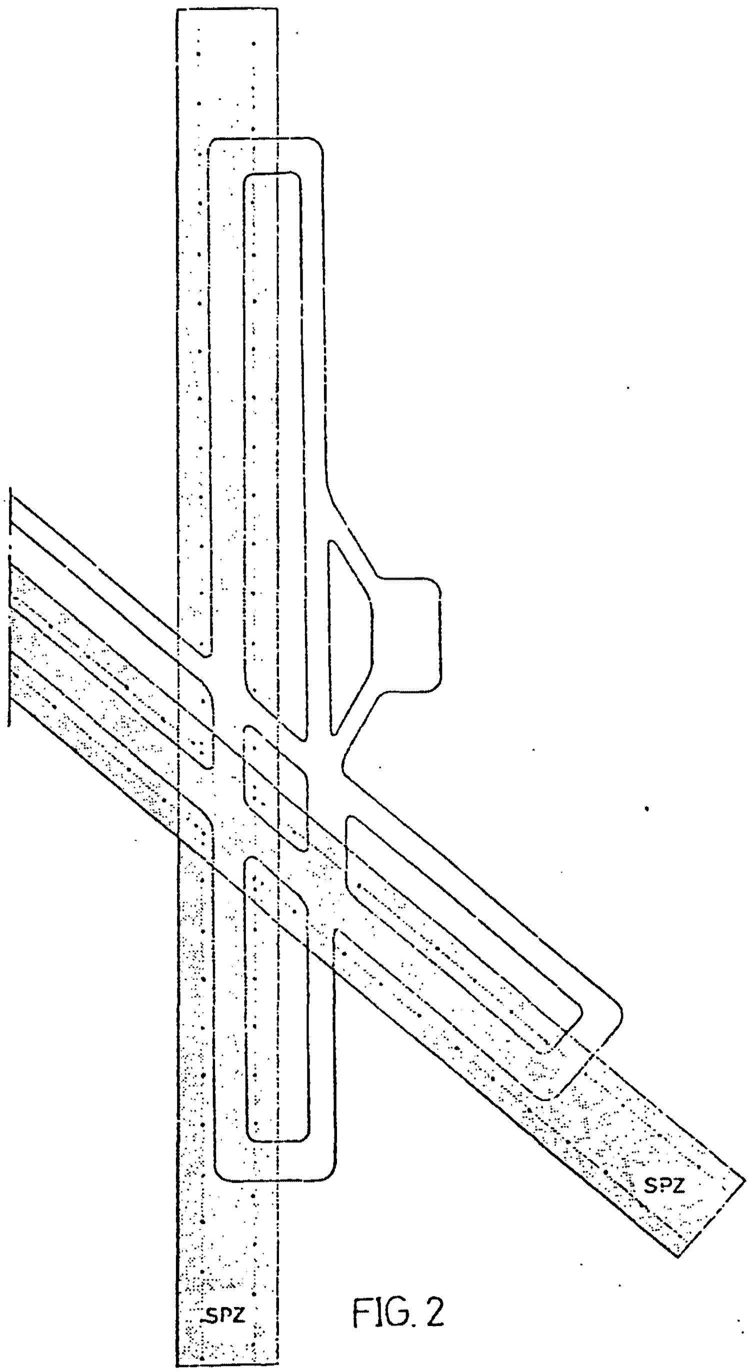


FIG. 2

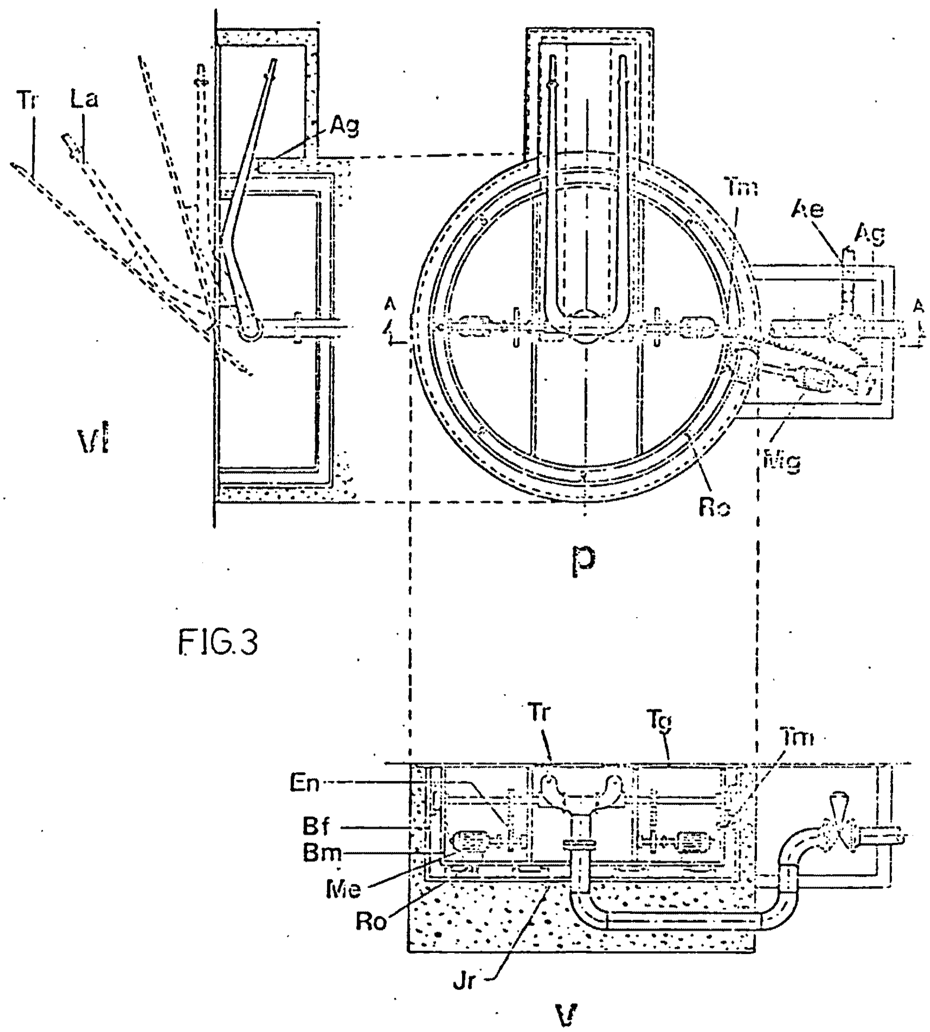


FIG.3

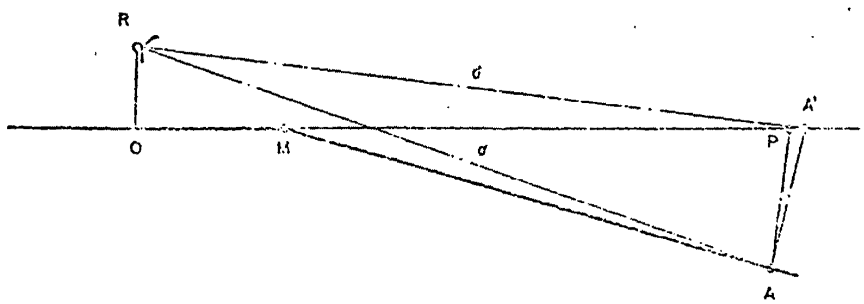


FIG.4

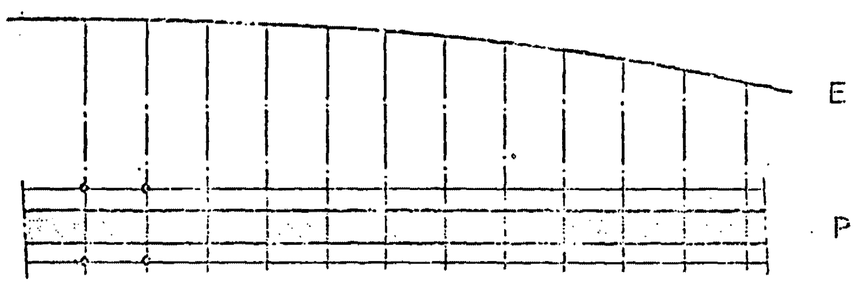


FIG.5

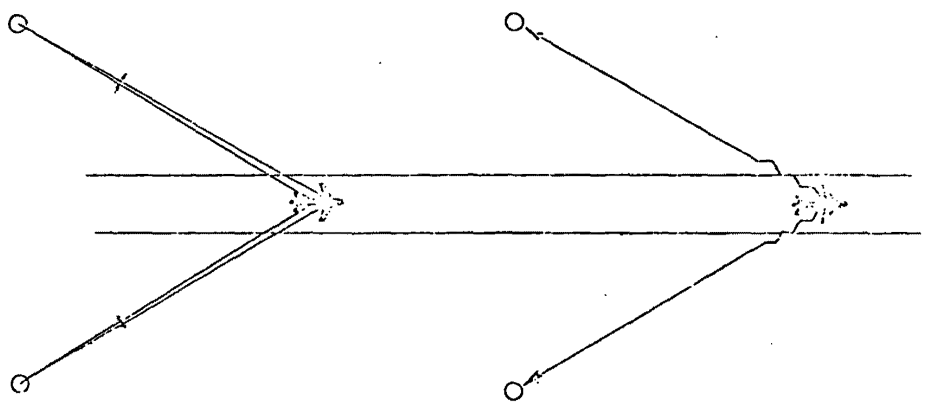


FIG.6

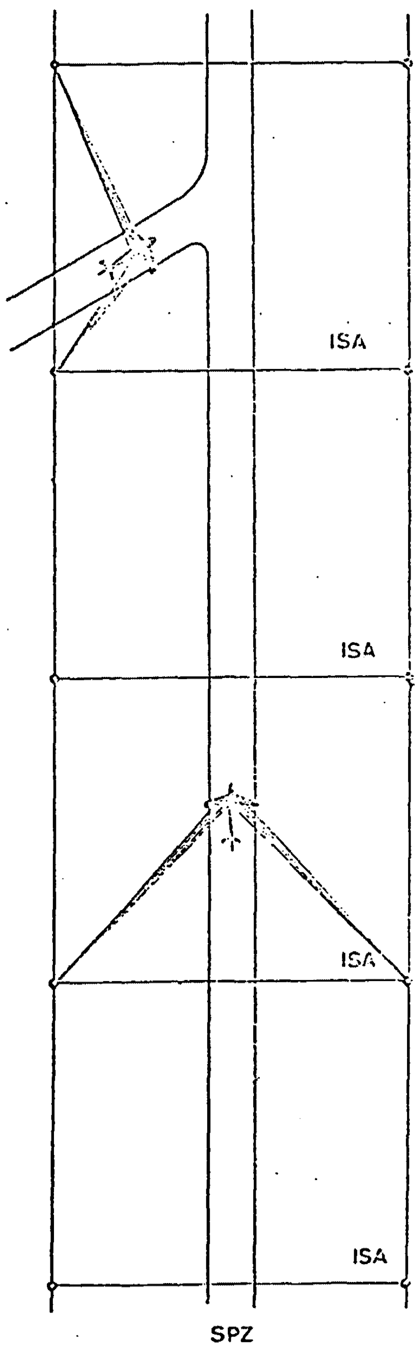


FIG.7

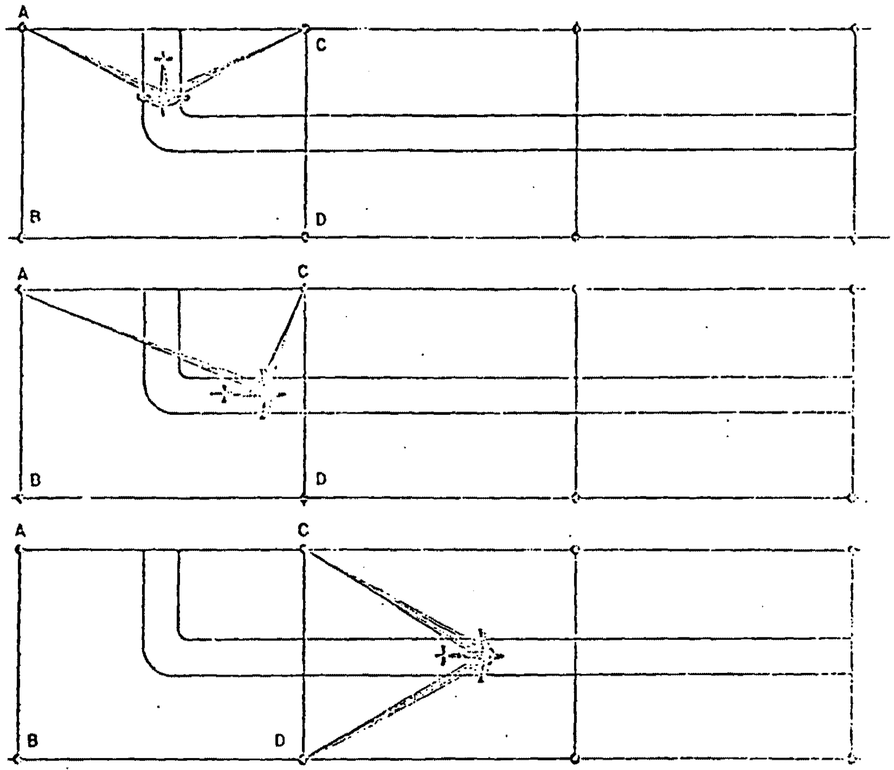


FIG.8

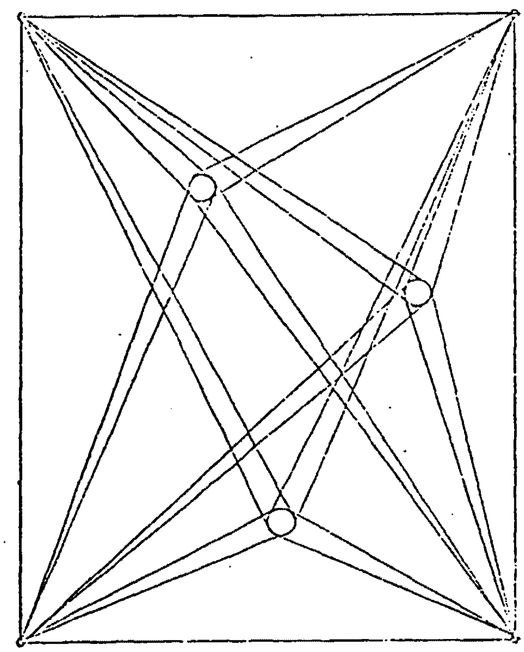
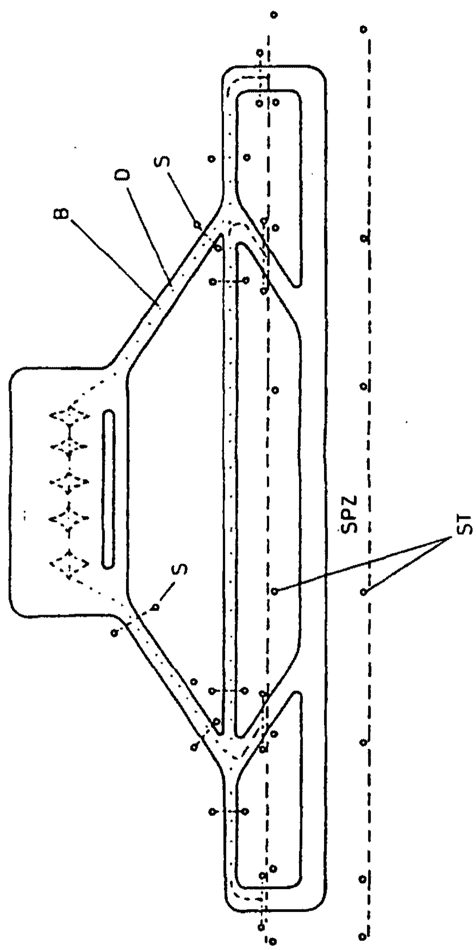


FIG.9

FIG. 10



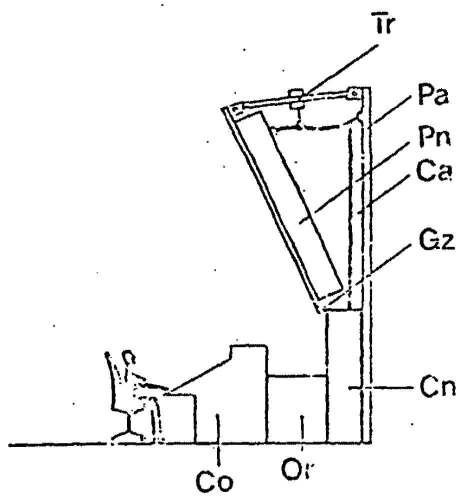


FIG.11

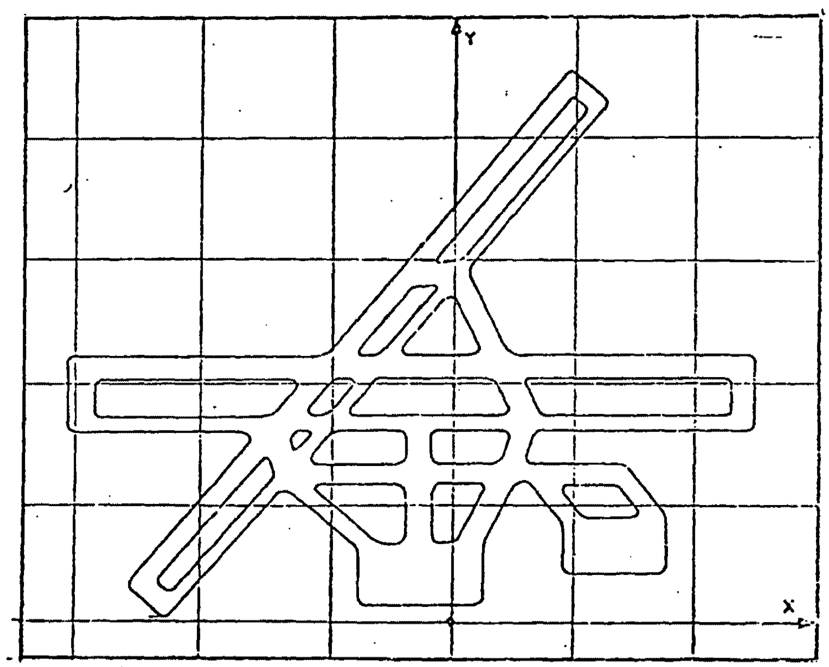


FIG.12

FIG. 13

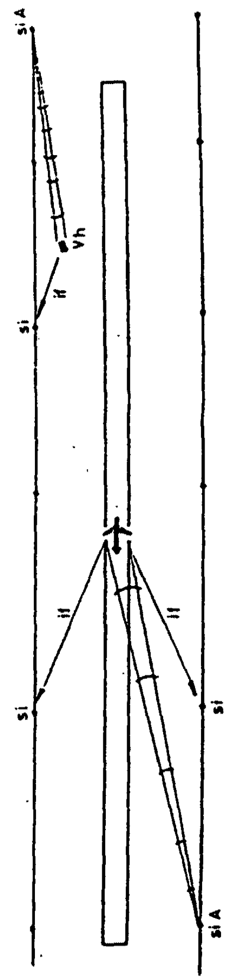
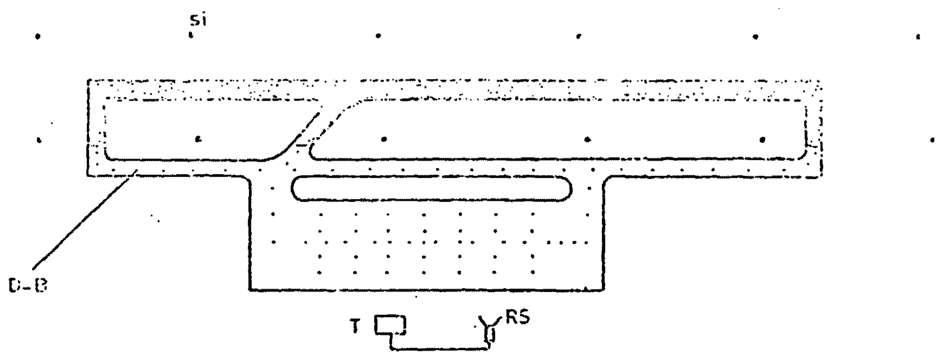


FIG. 14



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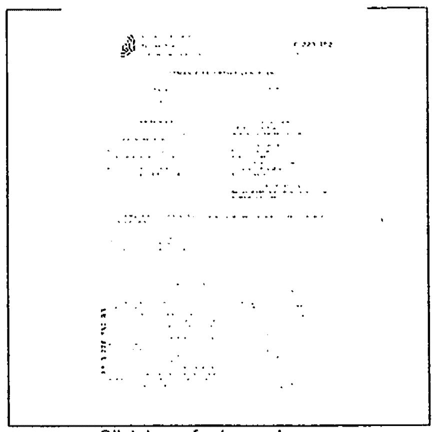
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Abstract:

Ground control method, either at night or in poor visibility, or in good visibility when it is not possible to have a good view from the control tower of the whole of the aerodrome, of all the machines, aeroplanes and vehicles, such as service and security vehicles, parked or moving on the site of the aerodrome, in particular the take-off or landing runways as well as all the access routes to these runways, and arrangement for carrying out this method.

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French Title: Procédé pour le contrôle au sol des mobiles sur un aéroport et installation pour la mise en oeuvre de ce procédé

French Abstract:

Procédé pour le contrôle au sol, soit de nuit ou par mauvaise visibilité, soit par bonne visibilité lorsqu'il n'est pas possible d'avoir de la tour de contrôle une bonne vue d'ensemble de l'aéroport, de tous les engins, avions et véhicules, tels que véhicules de service et de sécurité, stationnant ou circulant sur le site de l'aéroport, en particulier les pistes d'envol ou d'atterrissage ainsi que toutes les voies d'accès à ces pistes, ledit procédé consistant à disposer, au moins le long des pistes et à leurs extrémités ainsi qu'aux intersections éventuelles de toutes les voies d'accès aux pistes, des systèmes de contrôle différents fournissant chacun des informations distinctes relatives au moins aux mobiles, à l'arrêt ou en mouvement, se trouvant sur le site, à analyser toutes les informations susdites par ordinateur dont les mémoires contiennent les caractéristiques des mobiles circulant sur le site, à activer, à partir de l'ordinateur, d'une part, des écrans cathodiques et/ou synoptiques permettant aux contrôleurs de visualiser les pistes et accès ainsi que tous les éléments, en particulier les mobiles, à l'arrêt ou en mouvement, présents sur ces pistes et accès avec des caractéristiques d'identification, et, d'autre part, des moyens de signalisation prévus sur le site et destinés à donner des indications quant aux libertés et interdictions de circuler et des moyens d'alarme associés aux écrans activés quand une interdic-tion n'est pas respectée.

German Title: Verfahren zur Steuerung beweglicher Koerper am Boden auf einem

Flughafen und Einrichtung zur Durchfuehrung dieses Verfahrens

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(54) **Procédé pour le contrôle au sol des mobiles sur un aéroport et installation pour la mise en oeuvre de ce procédé.**

(57) Procédé pour le contrôle au sol, soit de nuit ou par mauvaise visibilité, soit par bonne visibilité lorsqu'il n'est pas possible d'avoir de la tour de contrôle une bonne vue d'ensemble de l'aéroport, de tous les engins, avions et véhicules, tels que véhicules de service et de sécurité, stationnant ou circulant sur le site de l'aéroport, en particulier les pistes d'envol ou d'atterrissage ainsi que toutes les voies d'accès à ces pistes, et installation pour la mise en oeuvre de ce procédé.

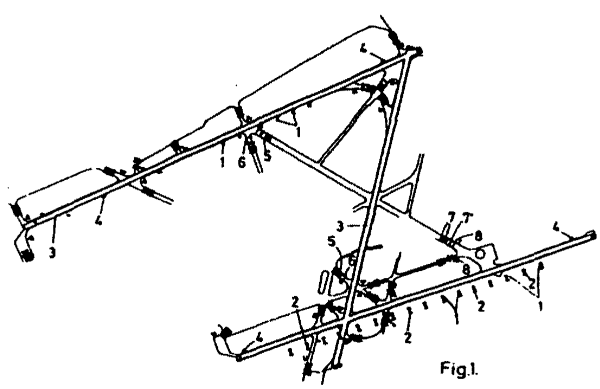

Fig.1.

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"Procédé pour le contrôle au sol des mobiles sur un aéroport et installation pour la mise en oeuvre de ce procédé".

La présente invention a pour objet un procédé pour le contrôle au sol, soit de nuit ou par mauvaise visibilité, soit par bonne visibilité lorsqu'il n'est pas possible d'avoir de la tour de contrôle une bonne vue d'ensemble de l'aéroport, de tous les engins, avions et véhicules, tels que véhicules de service et de sécurité, stationnant ou circulant sur le site de l'aéroport, en particulier les pistes d'envol ou d'atterrissage ainsi que toutes les voies d'accès à ces pistes. En général, lorsque la visibilité est bonne, le personnel de la tour de contrôle assure, à vue, le guidage au sol des avions et véhicules divers se déplaçant sur l'ensemble des pistes et voies d'accès de l'aérodrome, car il peut suivre et contrôler la circulation globale et donner, par liaison radio, les indications aux opérateurs des avions et véhicules pour le bon déroulement des opérations.

Il n'en est plus de même lorsque la visibilité à partir de la tour de contrôle est réduite et que le personnel de la tour n'a plus à sa disposition que les liaisons radio avec les avions et véhicules au sol alors que les informations fournies quant à la localisation précise de chacun des mobiles au sol peuvent être sujettes à caution. En effet, en ce qui concerne la position au sol des avions, qui est donnée par les pilotes, celle-ci ne peut être contrôlée de manière absolue par le personnel de la tour et un doute peut subsister quant à la position réelle des avions surtout lorsque les informations sont fournies par des pilotes peu familiarisés avec l'aéroport où ils font escale. Cette situation s'est encore aggravée depuis que les avions commerciaux décollent et atterrissent avec une visibilité de 100 à 150 mètres.

Par mauvaise visibilité, on dispose, sur un nombre réduit d'aéroports pour lesquels l'investissement très important a pu être consenti, de radars de sol et radars de veille qui, s'ils permettent d'améliorer la situation, présentent encore des inconvénients sérieux. En effet, les informations fournies par ces radars ne sont pas parfaitement fiables. Par exemple, lorsque le personnel de la tour autorise un avion à décoller et qu'il est dans l'impossibilité de suivre à vue cet avion, il ne pourra suivre sur les radars les diverses phases du décollage. Si l'avion autorisé à décoller ne prend pas son envol, le personnel de la tour restera dans l'incertitude tant qu'une liaison radio n'aura pas été établie avec le pilote de l'avion. Ces radars restent donc dans certains cas tributaires des liaisons radio, avec tous les aléas précités attachés à ces dernières. De plus, ces radars ne permettent pas d'identifier les mobiles en mouvement ou à l'arrêt sur l'aéroport, ils ne peuvent que constater leur présence. En outre, ces radars font essentiellement appel à l'appréciation des informations fournies par le personnel de la tour, d'où possibilité de défaillance humaine et ce, d'autant plus qu'un individu ne peut contrôler qu'environ 50 points lumineux différents et que la permanence rétinienne peut encore entrer en jeu lors du passage d'un écran à un autre.

L'invention a pour but de remédier à ces inconvénients et de procurer un procédé et une installation pouvant renseigner le personnel de la tour de contrôle sur la situation des mobiles au sol, de manière fiable et précise, avec identification desdits mobiles, et ce, sans avoir recours aux liaisons radios.

A cet effet, suivant l'invention, le procédé consiste à disposer, au moins le long des pistes et à leurs extrémités ainsi qu'aux intersections éventuelles de toutes les voies d'accès aux pistes, des systèmes de contrôle différents fournissant chacun des informations distinctes relatives au moins aux mobiles, à l'arrêt ou en mouvement, se trouvant sur le site, à analyser toutes les informations susdites par ordinateur dont les mémoires contiennent les caractéristiques des mobiles circulant sur le site, à activer, à partir de l'ordinateur, d'une part, des écrans cathodiques et/ou synoptiques permettant aux contrôleurs de visualiser les pistes et accès ainsi que tous les éléments, en particulier les mobiles, à l'arrêt ou en mouvement, présents sur ces pistes et accès avec des caractéristiques d'identification, et, d'autre part, des moyens de signalisation prévus sur le site et destinés à donner des indications quant aux libertés et interdictions de circuler et des moyens d'alarme associés aux écrans activés quand une interdiction n'est pas respectée.

Suivant une forme avantageuse de l'invention, sur base des informations traitées par l'ordinateur et dès que le contrôlleur autorise la circulation d'un avion sur une voie ou piste donnée, l'ordinateur crée le long de celle-ci une zone de protection.

L'installation suivant l'invention comprend au moins des moyens de contrôle associés aux pistes d'envol et d'atterrissage et agencés pour détecter tout élément situé sur ces pistes, en particulier les mobiles à l'arrêt ou en mouvement, des moyens de contrôle associés aux voies d'accès éventuelles et à toutes les intersections de ces dernières avec les pistes et agencés pour détecter tout mobile à l'arrêt ou en mouvement sur lesdites voies d'accès à proximité de ces intersections, des moyens pour transmettre les informations en provenance des moyens de contrôle à un ordinateur agencé pour comparer les informations reçues des moyens de contrôle précités à des informations mises en mémoire et concernant les divers mobiles autorisés à se déplacer sur les pistes et voies d'accès, des écrans cathodiques et/ou synoptiques disposés au moins dans la tour de contrôle et activés par l'ordinateur pour visualiser, d'une part, les pistes et voies d'accès à celles-ci et, d'autre part, les éléments et en particulier les mobiles, à l'arrêt ou en mouvement sur ces voies et pistes munies de moyens de contrôle, avec leurs caractéristiques d'identification, des moyens de signalisation optiques et/ou sonores associés aux pistes et voies d'accès pour renseigner les opérateurs des mobiles au sujet des libertés et interdictions de circuler dans les zones protégées par les moyens de contrôle et des moyens d'alarme associés aux écrans précités et agencés pour être activés par l'ordinateur quand une interdiction de circuler n'est pas respectée.

D'autres détails et particularités de l'invention ressortiront de la description des dessins annexés au présent mémoire et qui représentent, à titre d'exemple non limitatif, une forme de réalisation particulière de l'installation et illustrent le procédé suivant l'invention.

La figure 1 est une vue schématique, en plan, d'un aéroport équipé de l'installation précitée.

La figure 2 est une vue analogue à la figure 1 montrant un détail de ladite installation.

Dans les différentes figures, les mêmes signes de référence désignent des éléments identiques.

Il est évident que le procédé et l'installation suivant l'invention devront être adoptés en fonction des caractéristiques propres de chacun des aéroports concernés et que la multiplicité des moyens de contrôle nécessaires pour assurer une sécurité automatique maximum, au sol, de la circulation des mobiles dépendra essentiellement du nombre de pistes à protéger et de l'interpénétration de ces pistes entre elles et avec un nombre plus ou moins élevé de voies d'accès aux pistes. Pour des aéroports qui ne posséderaient qu'une ou plusieurs pistes ne se croisant pas et n'étant pas recoupées par des voies d'accès, il suffirait, pour obtenir une excellente sécurité, de munir la ou chacune des pistes de moyens de contrôle constatant la présence ou l'absence d'éléments, en particulier mobiles, sur les pistes. Dans ce cas, la sécurité pourrait être accrue en contrôlant également l'accès en bout de chacune des pistes.

Pour les aéroports dont les pistes et les voies d'accès se croisent, il conviendra, pour atteindre le niveau de sécurité équivalent à celui obtenu ci-dessus, de créer à chaque point d'intersection, en plus des moyens de contrôle des pistes, une zone protégée surveillée par un ou plusieurs moyens de contrôle propres à ces intersections.

Dans l'un et l'autre cas, la sécurité pourra être encore accrue en munissant au moins les véhicules de service de moyens optiques ou sonores renseignant automatiquement les opérateurs des dangers que peut présenter l'endroit où lesdits véhicules se trouvent ou vont aborder.

Il est également intéressant de pouvoir vérifier si les véhicules d'intervention, pompiers et ambulances, occupent leurs emplacements, qui sont bien déterminés sur l'aéroport. Dans ce but, des moyens sont prévus auxdits emplacements et dans les véhicules pour fournir les informations requises.

Dans tous les cas, les informations recueillies sont transmises à un ordinateur qui active des moyens audio-visuels situés au moins dans la tour de contrôle. De tels moyens peuvent en effet également être prévus à l'emplacement réservé aux véhicules d'intervention.

Dans tous les cas, l'ordinateur est agencé pour traiter les informations reçues des divers moyens et déclencher automatiquement tous les signaux optiques ou sonores assurant la sécurité de circulation. L'ordinateur est également agencé pour refuser une commande en conflit avec les informations provenant des différents moyens de contrôle.

Dans le cas où on ne surveille que la ou les pistes de l'aéroport, le scénario général consiste à acquérir des informations fournies par les moyens de contrôle, à traiter ces informations par ordinateur, à visualiser ces informations, à suivre l'atterrissage ou le décollage, à ramener en position d'attente après décollage ou atterrissage.

Pour obtenir un résultat valable, il est impératif d'incorporer dans le système, des moyens de contrôle alimentés par des réseaux indépendants pour des raisons tant électriques que techniques - (parasites,effets de réverbérations, radars).

Deux moyens de contrôle différents minimum sont nécessaires pour obtenir une sécurité totale.

Ces moyens de contrôle seront constitués par deux types de radars 1 et 2, des radars 1 à faisceau étroit le long des pistes 3 et des radars 2 à faisceau large répartis également à des distances variables le long desdites pistes 3. Les radars 1 seront installés tous les 150 m sur le bord de la piste à la hauter prescrite et ce en un alignement parallèle aux lampes de balisage des pistes et à ± 1 m de celles-ci. Chacun des radars à faisceau étroit 1 fonction ne sur une fréquence de 9,9 gigaHz et est utilisé pour analyser le déplacement des avions sur la piste. L'effet doppler permet ce contrôle quel que soit le sens de déplacement de l'avion. Placés transversalement et de préférence perpendiculairement à l'axe de la piste 3 de façon à bénéficier au maximum de l'effet doppler, le champ de vision avoisine les 9 degrés.

Les radars 2 à faisceau large seront répartis le long de la piste 3, un radar sera installé en début de piste afin de couvrir un large espace comprenant entre autres la zone d'attente des avions avant le décollage. Aux endroits de décollage ou d'atterrissage possibles et en fin de piste, les radars 2 seront dotés d'une inclinaison adéquate permettant de suivre l'avion en vol. Des caméras de télévision 4 seront également prévues pour compléter les informations fournies par les radars 1 et 2, elles fonctionneront avec des luminosités excessivement faibles (tubes infrarouges) et seront placées aux endroits stratégiques de façon que le contrôleur puisse visualiser différents paramètres (type d'avion ou d'autre mobile, arrêt ou mouvement de celui-ci). Les différents radars 1, à faisceau étroit, échelonnés à 150 le long de la piste 3, détectent le passage de l'avion et mesurent le temps que mettra celui-ci pour sortir du faisceau. Le radar 2, à faisceau large, en début de piste, vu la conception de sa cavité et de ses circuits, déterminera le début du processus de traitement. Au fur et à mesure de sa progression, l'avion coupera le faisceau des différents radars 1 et ce de plus en plus vite vu qu'il sera en accélération constante. Le radar 2 de fin de piste ou situé à l'endroit de décollage le détectera en altitude et ce pendant un laps de temps plus important. La non détection par les radars 2 permettra d'être certain que l'avion a bien décollé. L'ordinateur recevant les données ou informations des radars permettra par comparaison de suivre l'accélération, mais, comme les angles des faisceaux ne sont jamais rigoureusement identiques, il calculera la vitesse instantannée pour le passage à chaque radar et vérifiera ainsi les données de comparaison. Le programme est également prévu pour éliminer les détections parasites dues aux oiseaux et aux lièvres se déplaçant sur le site. Ce qui est énoncé pour le décollage est vrai pour l'atterrissage. Les caméras 4 permettront de visualiser l'avion en attente de décollage ainsi que lors de son trajet sur la piste 3. L'ordinateur numérise et mémorise les images reçues; il les compare aux modules de sa bibliothèque et identifie donc le mobile. Le module objet est intégré et positionné sur un écran cathodique et/ou synoptique pour que son déplacement soit pour le contrôleur une visualisation réelle de ce qui se passe sur la piste 3. Lorsque le contrôleur a autorisé le pilote à se mettre en bout de piste 3, il met en fonction par un commutateur le programme de gestion de la piste, ce qui active les caméras 4 et les systèmes radars 1 et 2. Sur les écrans grand format, le contrôleur voit apparaître la piste et le module objet de l'avion. Une fenêtre clignotante lui signale que le radar 2 en début de piste a également pris en charge l'appareil. Le contrôleur peut ainsi donner l'ordre de décollage qui sera suivi par les caméras 4 jusqu'à la limite de leur champ d'action. Lors du passage de l'avion dans le champ d'un radar 1, la fenêtre correspondant à celui-ci s'illumine et la représentation de l'avion se déplace sur l'écran synoptique permettant de suivre sa progression sur la piste. La caméra de bout de piste ou d'endroit de décollage transmet les données à l'ordinateur qui analyse les images reçues et qui active l'affichage sur l'écran du module objet de l'avion décollé. Le radar 2 le plus proche de l'endroit de décollage détecte l'avion en vol et permet à l'ordinateur d'analyser l'état des radars 1 qui sont inactifs vu que l'avion est en vol. Soit après un temps préprogrammé, soit par une action du contrôleur, la mise au repos du système permet à l'ordinateur de passer en phase statistique, ce qui engendrera éventuellement une impulsion des informations compilées du décollage.

Lorsque les pistes sont recoupées par d'autres pistes ou par des voies d'accès, le contrôle des intersections se décompose en deux fonctions bien distinctes, à savoir :

-la signalisation donnée au pilote d'avion ou au conducteur d'un véhicule arrivant à une intersection,

-l'acquisition de la donnée, son traitement et le transfert vers le contrôleur des résultantes données par l'ordinateur.

La signalisation sera réalisée au moyen de deux bandeaux 5 à base de fibres optiques (figure 2) figurant le "STOP". Ces bandeaux forment une signalisation vraiment efficace vu la disposition particulière des fibres optiques et la puissance lumineuse rayonnée par celles-ci. Lorsque le système est en position d'attente, le contrôleur peut remplacer l'émission de lumière rouge correspondant toujours à cette position d'attente par un rayonnement vert lorsqu'il décide d'autoriser l'accès de la piste. Un troisième bandeau optique 6 situé environ à 5 m en aval de la zone de contrôle, constituée notamment par les bandeaux 5, se mettra à clignoter au rouge si un mobile franchit intempestivement lesdits bandeaux de sécurité 5.

L'acquisition des données se fera de deux façons:

-par boucles magnétiques 7 et

- par radar 8.

Deux boucles magnétiques 7 seront installées dans le sol et permettront de détecter le passage de tous les mobiles qui les franchissent ainsi que leur sens de circulation. Au-delà des bandeaux 5, une troisième boucle magnétique 7' permettra de contrôler le respect des consignes fournies par ces bandeaux 5 et de donner une alerte à la tour de contrôle. Ces données seront affichées sur un synoptique par l'ordinateur qui tiendra compte des différents mouvements à l'approche des zones dangereuses.

Le radar 8 a pour but de contrôler par un autre canal les mesures effectuées par les boucles 7 et 7'. Il donnera les informations d'arrêt et de démarrage des mobiles. Ce radar 8 peut également être un élément générateur d'hyperfréquence qui influencerait des détecteurs prévus sur les mobiles et provoquerait l'émission de signaux optiques et/ou sonores pour avertir leur opérateur du danger.

Lorsqu'un avion a été autorisé à quitter son aire d'attente pour prendre place en bout de piste 3 en vue du décollage, le contrôleur fait passer la zone correspondant à cette piste au rouge ce qui a pour conséquence d'activer automatiquement tous les moyens de contrôle et de prévention. Il est évident que les actions prévues en cas de décollage s'appliquent également pour les atterrissages qui sont parfois imbriqués sur la même piste. Il est alors intéressant de créer une zone de sécurité automatique autour des points de conflit que sont les intersections de pistes avec les voies d'accès et les chemins utilisés par le personnel chargé d'éloigner les oiseaux des aires de décollage, etc.

Pour ce faire, on équipe d'un récepteur hyperfréquence un maximum de mobiles. Ce récepteur reçoit les informations émises par le dispositif zone rouge et donne une information auditive et visuelle à l'opérateur lorsqu'il pénètre dans la zone dangereuse.

Il faut considérer que les avions sur un aéroport sont prioritaires et que tout doit être fait pour ne pas déranger leurs évolutions.

Le but du système suivant l'invention est donc de prévenir toute circulation intempestive qui mettrait en danger les mobiles en présence.

Tous les véhicules de service sont équipés d'un récepteur hyperfréquence qui signalera immédiatement au conducteur qu'il s'engage dans une zone en activité ou qu'il va franchir une limite où

-une attention soutenue est de rigueur

-une autorisation de la tour est nécessaire.

Les véhicules étrangers à l'aéroport qui, pour des prestations, doivent circuler sur le site, recevront avantageusement un module portatif leur permettant ainsi d'avoir leur attention attirée à l'approche des zones dangereuses.

Sur les aéroports, les véhicules d'interventions occupent généralement un emplacement fixe et dédicacé. Un émetteur miniature hyperfréquence monté sur les véhicules permet de contrôler instantanément la présence desdits véhicules sur leur aire de stationnement vu qu'un récepteur y est incorporé.

Dans la tour de contrôle et éventuellement à l'emplacement des véhicules d'intervention, le personnel aura à sa disposition une unité du type audiovisuel. Elle sera composée d'un pupitre de commande, d'un écran synoptique et de deux ou trois écrans cathodiques. Pour que la visualisation soit efficace et puisse se percevoir sans réflexion, les états représentés aux écrans apparaîtront comme une rupture dans l'affichage général.

La représentation réelle des pistes et de leurs accès sera donc visualisée sur l'écran synoptique suivant le système de pavé, système similaire à celui utilisé à la SNCV dans les gares de triage, et ce à une échelle efficace.

Les données acquises par les différents moyens de contrôle et les résultats de leur traitement par l'ordinateur seront visualisées sur les écrans synoptique et cathodique. L'écran synoptique permettra de positionner et de suivre avec grande précision le déplacement des mobiles, l'écran cathodique, de préférence couleur, reprendra chacune des pistes et informera le contrôleur des opérations en cours.

Afin de bien préciser l'ensemble des opérations, les différentes phases d'un décollage, la piste étant au repos, von être décrites:

L'ensemble des signalisations est au rouge - (état de repos normal). Des véhicules circulent sur le site. Les véhicules de service sont sur leur aire de stationnement. L'écran synoptique est actif, car l'ordinateur tient en permanence compte des mobiles entrant et sortant des pistes, les écrans cathodiques passant automatiquement en position repos sont inactifs.

Lors d'une demande d'accès à la piste, un avion ayant quitté son terminal se dirige vers l'aire d'attente de la piste 3. Le contrôleur enclenche le processus de gestion du site. A ce moment, l'écran synoptique répercutera en clignotant la présence éventuelle d'un véhicule et émettra une signalisation optique et/ou sonore. La piste 3 passera en zone rouge et tous les véhicules se trouvant dans cette zone recevront sur leur récepteur hyperfréquence le signal optique et/ou sonore de zone dangereuse.

Lorsque le contrôleur le jugera utile, il donnera l'autorisation d'accès à la piste. Il sera informé à chaque instant de la situation vu que les données sont transmises en temps réel. De plus, afin de parer à une défaillance humaine et de manière à lui permettre de superviser le reste de l'aéroport, l'ordinateur l'avertira, en activant une alarme, si un conflit se présentait.

Le contrôleur, au moyen du module objet défini par la caméra, s'assure du type d'appareil qui est en instance de décollage et donne le feu vert. Au cas où il donne l'autorisation de décollage en présence d'un conflit, le système émet un signal d'avertissement et bloque les signalisations au rouge. Une commande de sécurité permet, après un laps de temps déterminé, de demander au système un nouvel essai.

L'avion se mettant en branle sur la piste 3 sera accompagné par une des caméras 4 et les radars de piste 1 et 2 qui permettront à l'ordinateur de suivre le décollage et de renseigner de façon continue le contrôleur sur l'accélération continue du mobile, grâce à l'écran synoptique. L'avion ayant décollé sera pris par le radar à large faisceau 2 susdit et l'ordinateur ne recevant aucune information des radars 1 affichera sur l'écran synoptique l'état décollé. La caméra de bout de piste confirmera la disparition de l'avion.

Le contrôleur au moyen de cette caméra pourra en cas de non décollage de l'avion suivre les évolutions de l'appareil en difficulté et déterminer de visu les interventions que la situation requiert car il sera averti par l'ordinateur dès que l'avion subira une décélération significative.

Le contrôleur, ayant constaté la bonne exécution de la manoeuvre, mettra le système en veilleuse ce qui déterminera pour le calculateur l'action statistique et l'impression des paramètres du décollage.

Il doit être entendu que l'invention n'est nullement limitée à la forme de réalisation décrite et que bien des modifications peuvent être apportées à cette dernière sans sortir du cadre du présent brevet.

C'est ainsi que l'on pourrait prévoir un rayon laser émis d'une extrémité de chaque piste 3 suivant l'axe de celle-ci et capté à l'autre extrémité pour que ce faisceau soit interrompu par un avion situé sur la piste. Ce dispositif pourrait compléter les radars 2 ou se substituer à ces derniers.

Pour parfaire l'identification d'un véhicule avec certitu de, le véhicule qui se présente à une barrière de sécurité, on prévoit sur lui un émetteur, statique ou non, générateur d'une hyperfréquence codée qui permettra une identification infaillible pour le système du véhicule considéré. Une plaque magnétique codée propre à chaque véhicule remplacera, dans certains cas, le générateur avec un même résultat.

On pourrait encore prévoir, le long des pistes 3 et soit en combinaison avec les radars 1 à faisceau étroit, soit en remplacement de ces radars 1, une rangée d'émetteurs de rayon laser équidistants disposée, le long d'un des bords longitudinaux de la piste 3 et parallèlement à cette dernière, pour que les rayons soient sensiblement parallèles entre eux, parallèles au sol et transversaux à l'axe de la piste et à une hauteur telle qu'ils soient interceptés par un véhicule ou avion à l'arrêt ou en mouvement sur la piste. Le long de l'autre bord longitudinal de la piste, on prévoit une rangée de récepteurs de rayon équidistants disposée parallèlement à la piste. Les récepteurs, dont le nombre est égal à celui des émetteurs et qui sont destinés chacun à recevoir le rayon émis par l'émetteur correspondant, sont alors connectés chacun à l'ordinateur pour fournir à celui-ci une information lorsqu'il n'est plus activé par le rayon laser. Les rayons laser émis par les émetteurs susdits sont avantageusement perpendiculaires à l'axe de la piste, la distance qui sépare deux de ces rayons voisins étant comprise entre 50 et 150 m, la distance des rayons du sol étant comprise entre 0,25 et 1 m et les rangées d'émetteurs et de récepteurs étant disposées à au moins 1 m en retrait des lampes de balisage de la piste.

Revendications

1. Procédé pour le contrôle au sol, soit de nuit ou par mauvaise visibilité, soit par bonne visibilité lorsqu'il n'est pas possible d'avoir de la tour de contrôle une bonne vue d'ensemble de l'aéroport, de tous les engins, avions et véhicules, tels que véhicules de service et de sécurité, stationnant ou circulant sur le site de l'aéroport, en particulier les pistes d'envol ou d'atterrissage ainsi que toutes les voies d'accès à ces pistes, ledit procédé étant caractérisé en ce qu'il consiste à disposer, au moins le long des pistes et à leurs extrémités ainsi qu'aux intersections éventuelles de toutes les voies d'accès aux pistes, des systèmes de contrôle différents fournissant chacun des informations distinctes relatives au moins aux mobiles, à l'arrêt ou en mouvement, se trouvant sur le site, à analyser toutes les informations susdites par ordinateur dont les mémoires contiennent les caractéristiques des mobiles circulant sur le site, à activer, à partir de l'ordinateur, d'une part, des écrans cathodiques et/ou synoptiques permettant aux contrôleurs de visualiser les pistes et accès ainsi que tous les éléments, en particulier les mobiles, à l'arrêt ou en mouvement, présents sur ces pistes et accès avec des caractéristiques d'identification, et, d'autre part, des moyens de signalisation prévus sur le site et destinés à donner des indications quant aux libertés et interdictions de circuler et des moyens d'alarme associés aux écrans activés quand une interdiction n'est pas respectée.

2. Procédé suivant la revendication 1, caractérisé en ce qu'on équipe au moins une partie des mobiles, appelés à circuler sur le site de l'aéroport, de moyens d'avertissement pour les

opérateurs desdits mobiles les informant d'une interdiction ou d'un danger associé à la zone qu'ils occupent.

3. Procédé suivant l'une ou l'autre des revendications 1 et 2, caractérisé en ce que, sur base des informations traitées par l'ordinateur et dès que le contrôleur autorise la circulation d'un avion sur une voie ou piste donnée, l'ordinateur crée le long de celle-ci une zone de protection.

4. Procédé suivant la revendication 3, caractérisé en ce que l'ordinateur détermine toutes les intersections de la voie ou piste empruntée par l'avion avec les autres voies ou pistes de l'aéroport et crée à chacune de ces intersections une zone de protection.

5. Procédé suivant l'une quelconque des revendications 1 à 4, caractérisé en ce que l'ordinateur analyse les informations provenant de moyens de contrôle disposés à intervalles réguliers le long des pistes d'envol ou d'atterrissage pour indiquer sur les écrans susdits la progression et la vitesse de circulation d'un avion se déplaçant sur ces pistes.

6. Procédé suivant l'une quelconque des revendications 1 à 5, caractérisé en ce que l'ordinateur analyse les informations provenant de moyens de contrôle associés aux pistes pour indiquer sur les écrans précités le moment où un avion circulant sur ces pistes quitte le sol.

7. Procédé suivant l'une quelconque des revendications 1 à 6, caractérisé en ce que l'ordinateur analyse conjointement les informations provenant des moyens de contrôle au sol et celles provenant du contrôle du trafic aérien pour indiquer toute éventuelle situation de conflit.

8. Installation pour la mise en oeuvre du procédé suivant l'une quelconque des revendications 1 à 7, caractérisée en ce qu'elle comprend au moins des moyens de contrôle associés aux pistes d'envol et d'atterrissage et agencés pour détecter tout élément situé sur ces pistes, en particulier les mobiles à l'arrêt ou en mouvement, des moyens de contrôle associés aux voies d'accès éventuelles et à toutes les intersections de ces dernières avec les pistes agencés pour détecter tout mobile à l'arrêt ou en mouvement sur lesdites voies d'accès à proximité de ces intersections, des moyens pour transmettre les informations en provenance des moyens de contrôle à un ordinateur agencé pour comparer les informations reçues des moyens de contrôle précités à des informations mises en mémoire et concernant les divers mobiles autorisés à se déplacer sur les pistes et voies d'accès, des écrans cathodiques et/ou synoptiques disposés au moins dans la tour de contrôle et activés par l'ordinateur pour visualiser, d'une part, les pistes et voies d'accès à celles-ci et, d'autre part, les éléments et en particulier les mobiles, à l'arrêt ou en mouvement sur ces voies et pistes munies de moyens de contrôle, avec leurs caractéristiques d'indentification, des moyens de signalisation optiques et/ou sonores associés aux pistes et voies d'accès pour renseigner les opérateurs des mobiles au sujet des libertés et interdictions de circuler dans les zones protégées par les moyens de contrôle et des moyens d'alarme associés aux écrans précités et agencés pour être activés par l'ordinateur quand une interdiction de circuler n'est pas respectée.

9. Installation suivant la revendication 8, caractérisée en ce que les moyens de contrôle associés à chacune des pistes surveillées sont constitués par une rangée de radars (1) équidistants à faisceau étroit disposée parallèlement à la piste - (3) pour que les faisceaux soient sensiblement parallèles et transversaux à l'axe de la piste, par un radar (2) à faisceau large installé en début de piste et couvrant la zone de stationnement des avions en instance de décollage,et par des radars à faisceau large échelonnés le long de la piste aux endroits de décollage ou d'atterrissage des différents types d'avions et dont les faisceaux sont orientés pour suivre un avion en mouvement.

10. Installation suivant la revendication 9, caractérisée en ce que les faisceaux de radars (1) à faisceau étroit sont perpendiculaires à l'axe de la piste (3), la distance qui sépare deux de ces radars (1) voisins est de l'ordre de 150 m, le champ de vision desdits radars, qui fonctionnent sur une fréquence de 9,9 gigaHz, est de l'ordre de 9°, la distance des radars du sol est fonction de leurs caractéristiques et la rangée desdits radars est disposée à environ 1 m en retrait des lampes de balisage de la piste.

11. Installation suivant l'une quelconque des revendications 8 à 10, caractérisée en ce que les moyens de contrôle associés à chacune des pistes surveillées comprennent, le long d'un des bords longitudinaux de la piste, une rangée d'émetteurs de rayon laser équidistants disposées parallèlement à la piste pour que les rayons soient sensiblement parallèles entre eux, parallèles au sol et transversaux à l'axe de la piste et à une hauteur qu'ils soient interceptés par un véhicule ou avion à l'arrêt ou en mouvement sur la piste et, le long de l'autre bord longitudinal de la piste, une rangée de récepteurs de rayon équidistants disposée parallèlement à la piste, les récepteurs, dont le nombre est égal à celui des émetteurs et qui sont destinés chacun à recevoir le rayon émis par l'émetteur correspondant, étant connectés chacun à l'ordinateur pour fournir à celui-ci une information lorsqu'il n'est plus activé par le rayon laser.

12. Installation suivant la revendication 11, caractérisée en ce que les rayons laser émis par les émetteurs susdits sont perpendiculaires à l'axe de

la piste, la distance qui sépare deux de ces rayons voisins étant comprise entre 50 et 150 m, la distance des rayons du sol étant comprise entre 0,25 et 1 m et les rangées d'émetteurs et de récepteurs étant disposées à au moins 1 m en retrait des lampes de balisage de la piste.

13. Installation suivant l'une quelconque des revendications 8 à 12, caractérisée en ce qu'elle comprend au moins deux caméras de télévision - (4) orientables, prévues pour fonctionner avec des luminosités extrêmement faibles, disposées en début et en fin de chacune des pistes (3), ces caméras (4) étant reliées à l'ordinateur qui numérise et mémorise les images reçues pour les comparer ensuite aux modules mis en mémoire et identifier le mobile filmé par les caméras, le module objet étant intégré et positionné sur les écrans cathodiques et/ou synoptiques précités.

14. Installation suivant l'une quelconque des revendications 8 a 13, caractérisé en ce qu'elle comprend, à une des extrémités de la piste (3), un émetteur de rayon laser agencé pour que ce rayon soit dans l'axe de la piste et à une hauteur telle qu'il soit intercepté par un avion à l'arrêt ou en mouvement sur la piste, un récepteur de ce rayon étant disposé à l'autre extrémité de la piste et connecté à l'ordinateur pour fournir à celui-ci une information lorsqu'il n'est plus activé par le rayon laser.

15. Installation suivant l'une quelconque des revendications 8 à 14, caractérisée en ce que les moyens de contrôle associés à chaque voie d'accès et à chacune des intersections de ces dernières avec les pistes (3) comprennent au moins deux boucles magnétiques (7) installées dans le revêtement des voies d'accès, en amont des pistes (3), et agencées pour détecter le passage d'un mobile et définir son sens de circulation, ces boucles magnétiques (7) étant associées à l'ordinateur pour que, suite aux informations fournies par ces boucles et par les moyens de contrôle de piste, ledit ordinateur active au moins un signal (5, 6) optique et/ou sonore autorisant ou interdisant l'accès à la piste.

16. Installation suivant la revendication 15, caractérisée en ce que les moyens de contrôle susdits associés à chaque voie d'accès aux pistes (3) comprend, en aval du signal (5) optique et/ou sonore précité, une troisième boucle magnétique (7') noyée dans le revêtement, les informations transmises à l'ordinateur par cette troisième boucle (7') étant analysées conjointement avec l'état du signal (5) optique et/ou sonore, l'ordinateur étant agencé pour activer une alarme, au moins dans la tour de contrôle, si cette troisième boucle (7') est franchie alors que le signal (5) indique une interdiction de passage.

17. Installation suivant l'une ou l'autre des revendications 15 et 16, caractérisée en ce que les moyens de contrôle, associés à chacune des voies d'accès aux pistes, comprend un radar (8) dont le faisceau est orienté vers les boucles magnétiques - (7) et qui est connecté à l'ordinateur pour fournir à ce dernier des informations qu'il analyse conjointement aux informations fournies par les boucles magnétiques (7), ledit ordinateur activant, en cas de conflit, les moyens d'alarme précités.

18. Installation suivant l'une quelconque des revendications 8 à 17, caractérisé en ce qu'elle comprend, aux abords des intersections de pistes et de voies d'accès, des générateurs hyperfréquence, les mobiles circulant sur ces pistes et voies étant équipés de récepteurs hyperfréquence agencés pour activer un signal auditif et/ou lumineux renseignant l'opérateur à l'approche de la zone dans laquelle émettent ces générateurs.

19. Installation suivant l'une quelconque des revendications 8 à 18, caractérisée en ce que, à chacun des emplacements déterminés occupés par les véhicules d'intervention, tels que pompes et ambulances, elle comprend un récepteur hyperfréquence, chacun des véhicules d'intervention étant pourvu d'un émetteur hyperfréquence, les récepteurs susdits étant connectés à l'ordinateur qui, après analyse des informations, active les écrans cathodiques et/ou synoptiques pour que les véhicules d'intervention puissent être visualisés lorsqu'ils occupent leurs emplacements déterminés.

20. Installation suivant l'une quelconque des revendications 8 à 19, caractérisée en ce que la signalisation optique met en oeuvre des fibres optiques.

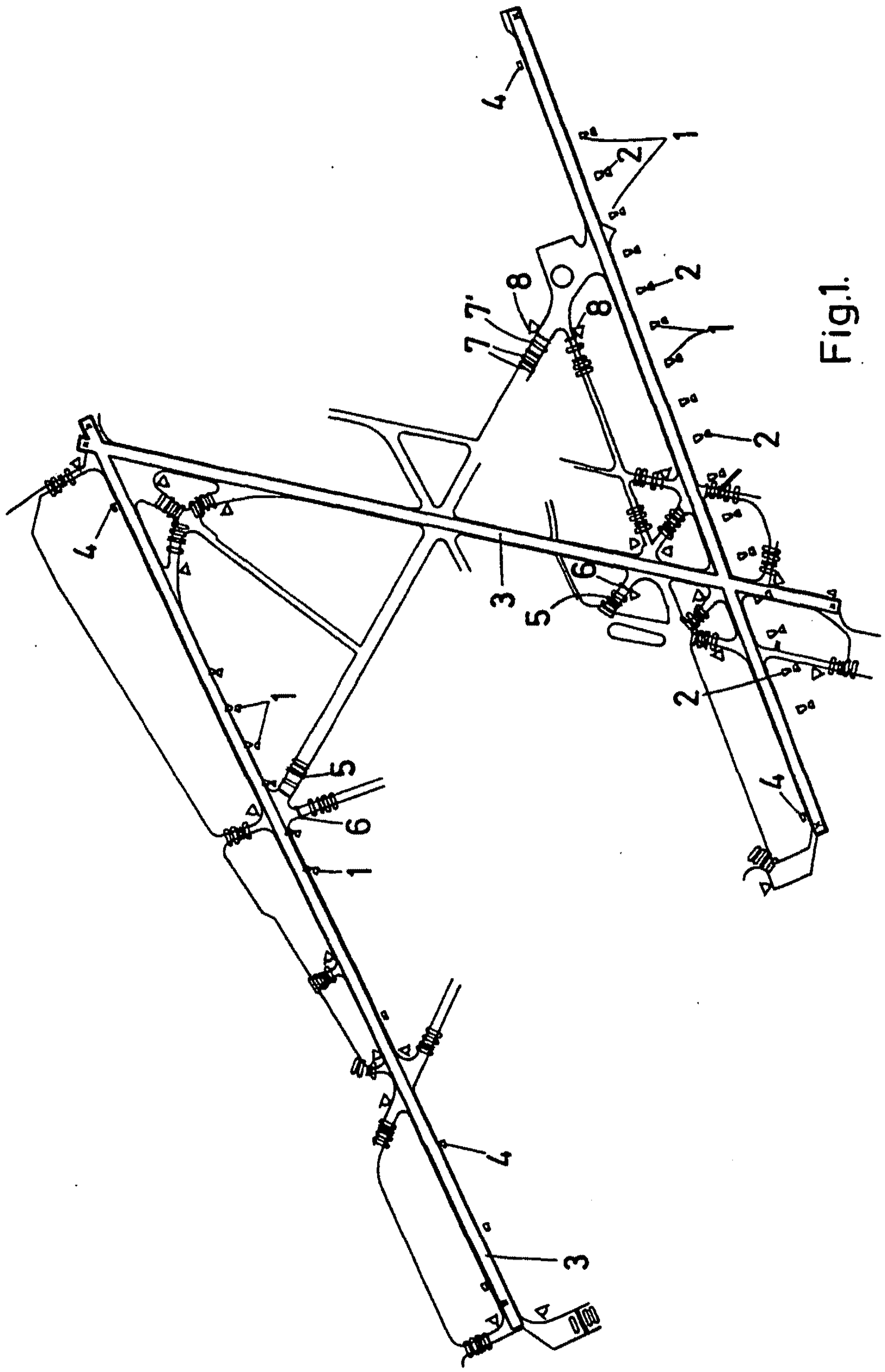

Fig.1.

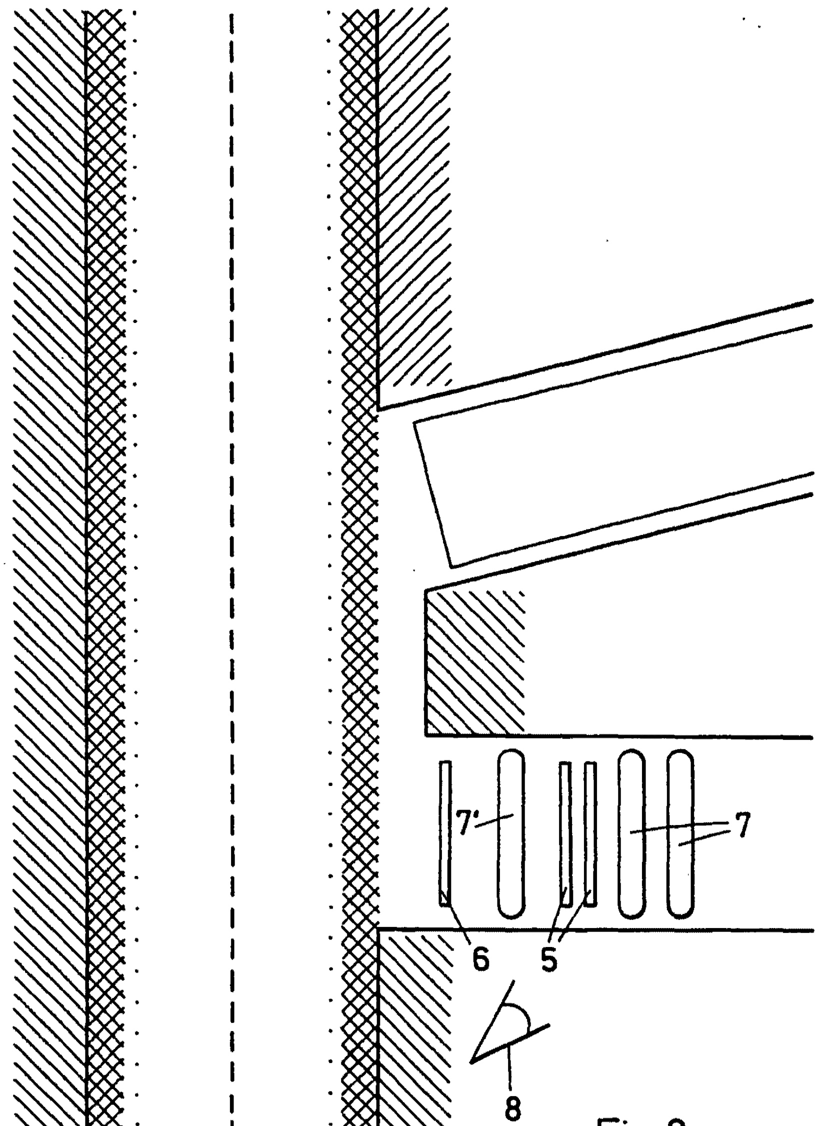

Fig.2.

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(54) **Airport incursion avoidance system.**

(57) An airport incursion avoidance sy stem for detection of aircraft and other vehicles utilizes edge lights [20] along taxiways and runways by having a sensor [50] co-located with each edge light, the sensor output being coupled to a central computer system [12] via the airport's edge light power lines [21]. The detection system comprises infrared sensors. The output of each sensor [50] is fed into a microprocessor [44] within an edge light assembly [20] and then to a power line modem [54] for transmission to the central computer system [12] which includes a display [30] at the airport tower for showing the airport and all traffic thereon. Data from each sensor [50] along taxiways and runways is received at the central computer system [12] and processed to provide vehicle tracking and control of all ground traffic on the airport taxiways and runways to avoid an airport incursion.

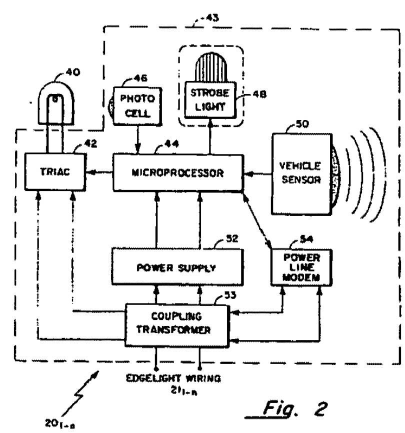

Fig. 2

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Background of the Invention

This invention relates to an airport ground collision avoidance system and in particular to an apparatus and method for monitoring, controlling and predicting aircraft or other vehicle movement primarily on airport taxiways and runways to avoid runway incursions.

Currently, ground control of aircraft at an airport is done visually by the air traffic controller in the tower. Low visibility conditions sometimes make it impossible for the controller to see all parts of the field. Ground surface radar can help in providing coverage during low visibility conditions; it plays an important part in the solution of the runway incursion problem but cannot solve the entire problem. A runway incursion is defined as "any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing, or intending to land." The U.S. Federal Administration Agency (FAA) has estimated that it can only justify the cost of ground surface radar at 29 of the top 100 airports in the United States. However, such radar only provides location information; it cannot alert the controller to possible conflicts between aircraft.

In the prior art, an airport control and monitoring system has been used to sense when an airplane reaches a certain point on a taxiway and controls switching lights on and off to indicate to the pilot when he may proceed on to a runway. Such a system sends microwave sensor information to a computer in the control tower. The computer comprises software for controlling the airport lighting and for providing fault information on the airport lighting via displays or a control panel to an operator. Such a system is described in sales information provided on a Bidirectional Series 7 Transceiver (BRITEE) produced by ADB-ALNACO, Inc., A Siemens Company, of Columbus, Ohio. However, such a system does not show the location of all vehicles on an airfield and is not able to detect and avoid a possible vehicle incursion.

A well known approach to airport surface traffic control has been the use of scanning radars operating at high frequencies such as K-band in order to obtain adequate definition and resolution. An existing airport ground traffic control equipment of that type is known in the art as Airport Surface Detection Equipment (ASDE). However, such equipment provides surveillance only, no discrete identification of aircraft on the surface being available. Also there is a need for a relatively high antenna tower and a relatively large rotation antenna system thereon.

Another approach to airport ground surveillance is a system described in U. S. Patent No. 3,872,474, issued March 18, 1974, to Arnold M. Levine and assigned to International Telephone and Telegraph Corporation, New York, NY, referred to as LOCAR (Localized Cable Radar) which comprises a series of small, lower powered, narrow pulses, transmitting radars having limited range and time sequenced along opposite sides of a runway ramp or taxiway. In another U. S. Patent No. 4,197,536, issued on April 8, 1980, to Amold M. Levine, an airport surface identification and control system is described for aircraft equipped with ATCRBS (Air Traffic Control Radio Beacon System) and ILS (Instrument Landing System). However, these approaches are expensive, require special cabling and for identification purposes require expensive equipment to be included on the aircraft and other vehicles.

Another approach to vehicle identification such as types of aircraft by identifying the unique characteristic of the "footprint" presented by the configuration of wheels unique to a particular type of vehicle is described in U.S. Patent No. 3,872,283, issued March 18, 1975, to Gerald R. Smith et al. and assigned to The Cadre Corporation of Atlanta Georgia.

An automatic system for surveillance, guidance and fire-fighting at airports using infrared sensors is described in U. S. Patent No. 4,845,629, issued July 4, 1989 to Maria V. Z. Murga. The infrared sensors are arranged along the flight lanes and their output signals are processed by a computer to provide information concerning the aircraft movements along the flight lanes. Position detectors are provided for detecting the position of aircraft in the taxiways and parking areas. However, such system does not teach the use of edge lights along the runways and taxiways along with their associated wiring and it is not able to detect and avoid a possible vehicle incursion.

The manner in which the invention deals with the disadvantages of the prior art to provide a low cost airport incursion avoidance system will be evident as the description proceeds.

Summary of the Invention

Accordingly, it is therefore an object of this invention to provide a system that detects a possible aircraft or vehicle incursion at an airport.

It is also an object of this invention to provide a low cost airport incursion avoidance system using edge light assemblies and associated wiring along runways and taxiways.

It is another object of this invention to provide an airport incursion avoidance system that generates a graphic display of the airport showing the location of all ground traffic including direction and velocity data.

It is a further object of this invention to provide an airport incursion avoidance system that generates a verbal alert to an air traffic controller or an aircraft pilot.

The objects are further accomplished by providing an airport incursion avoidance system comprising a plurality of light circuits on an airport, each of the light circuits comprises a plurality of light assembly means, means for providing power to each of the plurality of light circuits and to each of the light assembly means, means in each of the light assembly means for sensing ground traffic on the airport, means for processing data received from each of the light assembly means, means for providing data communication between each of the light assembly means and the processing means, the processing means comprises means for providing a graphic display of the airport including symbols representing the ground traffic, each of the symbols having direction and velocity data displayed, the processing means further comprises means for predicting an occurrence of an airport incursion in accordance with the data received from the sensing means, and means for alerting an airport controller or aircraft pilot of the predicted airport incursion. Each of the light circuits are located along the edges of a taxiway or a runway on the airport. The sensing means comprises infrared detectors. The light assembly means comprises light means coupled to the lines of the power providing means for lighting the airport, the infrared detectors sensing means, microprocessor means coupled to the light means, the sensing means, and the data communication means for providing processing, communication and control for the light assembly means, the microprocessor controlling a plurality of lighting patterns of the light means on the airport, and the data communication means being coupled to the microprocessor means and the lines of the power providing means. The light assembly means further comprises a photocell means coupled to the microprocessor means for detecting the light intensity of the light means. The light assembly means further comprises a strobe light coupled to the microprocessor means. The processing means comprises redundant computers for fault tolerance operation. The symbols representing the ground traffic comprise icons having a shape indicating type of aircraft or vehicle. The processing means determines the locations of the symbols on the graphic display of the airport in accordance with the data receive from the light assembly means. The processing means further determines a future path of the ground traffic based on a ground clearance command, the future path being shown on the graphic display. The processing means for predicting an occurrence of an airport incursion comprises means for comparing position, direction and velocity of the ground traffic to predetermined separation minimums for the airport. The power providing means comprises constant current power means for providing a separate line to each of the plurality of light circuits, and network bridge means coupled to the constant current power means for providing a communication channel to the processing means for each line of the constant current power means. The alerting means comprises a speech synthesis unit connected to a speaker, and the alerting means also comprises a speech synthesis unit connected to a radio transmitter.

The objects are further accomplished by a method of providing an airport incursion avoidance system comprising the steps of providing a plurality of light circuits on the airport, each of the light circuits comprises a plurality of light assembly means, providing power to each of the plurality of light circuits, sensing ground traffic on the airport with means in each of the light assembly means, processing data received from each of the light assembly means in computer means, providing a graphic display of the airport comprising symbols representing the ground traffic, each of the symbols having direction and velocity data displayed, providing data communication between the computer means and each of the light assembly means, predicting an occurrence of an airport incursion in accordance with the data received from the sensing means, and alerting an airport controller or aircraft pilot of the predicted airport incursion. The step of sensing the ground traffic on the airport comprises the steps of lighting the airport with a light means coupled to the microprocessor means and the power lines, providing infrared detectors for sensing the ground traffic, performing processing, communication and control within the light assembly means with a microprocessor means coupled to the light means, the sensing means and data communication means, and coupling the data communication means between the microprocessor means and the power lines. The step of processing data comprises the step of operating redundant computers for fault tolerance. The step of providing power comprises the steps of providing a separate line to each of the plurality of light circuits with a constant current power means, and providing a communication channel to the computer means for each line of the constant current power means using a network bridge means. The step of providing a graphic display comprising symbols representing the ground traffic comprise the step of indicating a type of aircraft or vehicle with icons of various shapes. The step of processing the data from each of the light assembly means comprises the step of determining a location of the symbols on the graphic display of the airport in accordance with the data. The step of predicting an occurrence of an airport incursion comprises the step of determining a future path of the ground traffic in accordance with a ground clearance command and showing the future path on the graphic display.

Brief Description of the Drawings

Other and further features of the invention will become apparent in connection with the accompanying drawings wherein:

FIG. 1 is a block diagram of the invention of an airport vehicle incursion avoidance system;

FIG. 2 is a block diagram of an edge light assembly showing a sensor electronics unit coupled to an edge light of an airfield lighting system;

FIG. 3 is a pictorial diagram of the edge light assembly showing the edge light positioned above the sensor electronics unit;

FIG. 4 is a diagram of an airfield runway or taxiway having a plurality of edge light assemblies positioned along each side of the runway or taxiway for detecting various size aircraft as shown;

FIG. 5 is a block diagram of the central computer system shown in FIG. 1;

FIG. 6 shows eleven network variables used in programming the microprocessor of an edge light assembly to interface with a sensor, a light and a strobe light;

FIG. 7 is a block diagram showing an interconnection of network variables for a plurality of edge light assemblies located on both sides of a runway, each comprising a sensor electronics unit 10 positioned along a taxiway or runway;

FIG. 8 shows a graphic display of a typical taxiway/runway on a portion of an airport as seen by an operator in a control tower, the display showing the location of vehicles as they are detected by the sensors mounted in the edge light assemblies located along taxiways and runways; and

FIG. 9 is a block diagram of the data flow within the system shown in FIG. 1 and FIG. 5.

Description of the Preferred Embodiment

Referring to FIG. 1 a block diagram of the invention of an airport vehicle incursion avoidance system 10 is shown comprising a plurality of light circuits 18_{1-n}, each of said light circuits 18_{1-n} comprises a plurality of edge light assemblies 20_{1-n} connected via wiring 21_{1-n} to a lighting vault 16 which is connected to a central computer system 12 via a wide area network 14. Each of the edge light assemblies 20_{1-n} comprises an infrared (IR) detector vehicle sensor 50 (FIG. 2).

The edge light assemblies 20_{1-n} are generally located along side the runways and taxiways of the airport with an average 100 foot spacing and are interconnected to the lighting vault 16 by single conductor series edge light wiring 21_{1-n}. Each of the edge light circuits 18_{1-n} is powered via the wiring 21_{1-n} by a constant current supply 24_{1-n} located in the lighting vault 16.

Referring now to FIG. 1 and FIG. 2, communication between the edge light assemblies 20_{1-n} and the central computer system 12 is accomplished with LON Bridges 22_{1-n} interconnecting the edge light wiring 21_{1-n} with the Wide Area Network 14. Information from a microprocessor 44 located in edge light assembly 20_{1-n} is coupled to the edge light wiring 21_{1-n} via a power line modem 54. The LON bridges 22_{1-n} transfers message information from the edge light circuits 18_{1-n} via the wiring 21_{1-n} to the wide area network 14. The wide area network 14 provides a transmission path to the central computer system 12. These circuit components also provide the return path communications link from the central computer system 12 to the microprocessor 44 in each edge light assembly 20_{1-n}. Other apparatus and methods, known to one of ordinary skill in the art, for data communication between the edge light assemblies 20_{1-n} and the central computer system 12 may be employed, such as radio techniques, but the present embodiment of providing data communication on the edge light wiring 21_{1-n} provides a low cost system for present airports. The LON Bridge 22 may be embodied by devices manufactured by Echelon Corporation of Palo Alto, California. The wide area network 14 may be implemented by one of ordinary skill in the art using standard Ethernet or Fiber Distributed Data Interface (FDDI) components. The constant current supply 24 may be embodied by devices manufactured by Crouse-Hinds of Winslow, Connecticut.

Referring now to FIG. 2 and FIG. 3, FIG. 3 shows a pictorial diagram of the edge light assembly 20_{1-n}. The edge light assembly 20_{1-n} comprises a bezel including an incandescent lamp 40 and an optional strobe light assembly 48 (FIG. 2) which are mounted above an electronics enclosure 43 comprising the vehicle sensor 50. The electronics enclosure 43 sits on the top of a tubular shaft extending from a base support 56. The light assembly bezel with lamp 40 and base support 56 may be embodied by devices manufactured by Crouse-Hinds of Winslow, Connecticut.

A block diagram of the contents of the electronics enclosure 43 is shown in FIG. 2 which comprises a coupling transformer 53 connected to the edge light wiring 21_{1-n}. The coupling transformer 53 provides power to both the incandescent lamp 40 via the lamp control triac 42 and the microprocessor power supply 52; in addition, the coupling transformer 53 provides a data communication path between the power line modem 54 and the LON Bridges 22_{1-n} via the edge light wiring 21_{1-n}. The microprocessor 44 provides the computational power to run the internal software program that controls the edge light assemblies 20_{1-n}. The microprocessor 44 is powered by the microprocessor power supply 52. Also connected to the microprocessor 44 is the lamp control triac 42, a lamp monitoring photo cell 46, the optional strobe light assembly 48, the vehicle sensor 50, and the data communications modem 54. The microprocessor 44 is used to control the incandescent edge light 40 intensity and optional strobe light assembly 48. The use of the microprocessor 44 in each light assembly 20_{1-n} allows complete addressable control over every light on the field. The microprocessor 44 may be embodied by a VLSI device manufactured by Echelon Corporation of Palo Alto, California 94304, called the Neuron® chip.

Still referring to FIG. 2, the sensor 50 in the present embodiment comprises an infrared (IR) detector and in other embodiments may comprise other devices such as proximity detectors, CCD cameras, microwave motion detectors, inductance loops, or laser beams. The program in the microprocessor 44 is responsible for the initial filtering of the sensor data received from the sensor 50 and responsible for the transmission of such data to the,central computer system 12. The sensor 50 must perform the following functions: detect a stationary object, detect a moving object, have a range at least half the width of the runway or taxiway, be low power and be immune to false alarms. This system design does not rely on just one type of sensor. Since sensor fusion functions are performed within the central computer system 12, data inputs from all different types of sensors are acceptable. Each sensor relays a different view of what is happening on the airfield and the central computer system 12 combines them. There are a wide range of sensors that may be used in this system. As a new sensor type becomes available, it can be integrated into this system with a minimum of difficulty. The initial sensor used is an IR proximity detector based around a piezoelectric strip. These are the kind of sensors you use at home to turn on your flood lights when heat and/or movement is detected. When the sensor output provides an analog signal, an analog-to-digital converter readily known in the art may be used to interface with the microprocessor 44.

Another proximity detector that can be used is based around a microwave Gunn diode oscillator. These are currently in use in such applications as Intrusion Alarms, Door Openers, Distance Measurement, Collision Warning, Railroad Switching, etc. These types of sensors have a drawback because they are not passive devices and care needs to be taken to select frequencies that would not interfere with other airport equipment. Finally, in locations such as the hold position lines on taxiways, solid state laser and detector combinations could be used between adjacent taxiway lights. These sensor systems create a beam that when broken would identify the location of the front wheel of the airplane. This type of detector would be used in those locations where the absolute position of a vehicle was needed. The laser beam would be modulated by the microprocessor 44 to avoid the detector being fooled by any other stray radiation.

Referring to FIG. 2 and FIG. 4, a portion of an airport runway 64 or taxiway is shown having a plurality of edge light assemblies 20_{1-8} positioned along each side of the runway or taxiway for detecting various size airplanes or vehicles 60, 62. The dashed lines represent the coverage area of the sensors 50 located in each edge light assembly 20_{1-8} positioned along each side of the runway 64 or taxiway to insure detection of any airplane 60, 62 or other vehicles traveling on such runway 64 or taxiway. The edge light assemblies 20_{1-n} comprising the sensor 50 are logically connected together in such a way that an entire airport is sensitized to the movement of vehicles. Node to node communication takes place to verify and identify the location of the vehicles. Once this is done a message is sent to the central computer system 12 reporting the vehicles location. Edge light assemblies (without a sensor electronics unit 43) and taxiway power wiring currently exist along taxiways, runways and open areas of airports, therefore, the sensor electronics unit 43 is readily added to existing edge lights and existing taxiway power wiring without the inconvenience and expense of closing down runways and taxiways while installing new cabling.

Referring now to FIG. 1, FIG. 5, FIG. 8 and FIG. 9, the central computer system 12 is generally located at a control tower or terminal area of an airport and is interconnected to the LON Bridges 22_{1-n} located in the lighting vault 16 with a Wide Area Network 14. The central computer system 12 comprises two redundant computers, computer #1 26 and computer #2 28 for fault tolerance, the display 30, speech synthesis units 29 & 31, alert lights 34, keyboard 27 and a speech recognition unit 33, all of these elements being interconnected by the wide area network 14 for the transfer of information. The two computers 26 and 28 communicate with the microprocessors 44 located in the edge light assemblies 20_{1-n}. Data received from the edge light assembly 20_{1-n} microprocessors 44 are used as an input to a sensor fusion software module 101 (FIG. 9) run on the redundant computers 26 and 28. The output of the sensor fusion software module 101 operating in the computers 26, 28 is used to drive the CRT display 30 which displays the location of each vehicle on the airport taxiway and runways as shown in FIG. 8. The central computer system 12 may be embodied by devices manufactured by IBM Corporation of White Plains, New York. The Wide Area Network 14 may be embodied by devices manufactured by 3Com Corporation of Santa Clara, California. The speech synthesis units 29, 31 and the speech recognition unit 33 may be embodied by devices manufactured by BBN of Cambridge, Massachusetts.

The speech synthesis unit 29 is coupled to a speaker 32. Limited information is sent to the speech synthesis unit 29 via the wide area network 14 to provide the capability to give an air traffic controller a verbal alert. The speech synthesis unit 31 is coupled to a radio 37 having an antenna 39 to provide the capability to give the pilots a verbal alert. The voice commands from the air traffic controller to the pilots are captured by microphone 35 and sent to the pilots via radio 36 and antenna 38. In the present embodiment a tap is made and the speech information is sent to both the radio 36 and the speech recognition unit 33 which is programmed to recognize the limited air traffic control vocabulary used by a controller. This includes airline names, aircraft type, the numbers 0-9, the name of the taxiways and runways and various short phrases such as "hold short", "expedite" and "give way to." The output of the speech recognition unit 33 is fed to the computers 26, 28.

Referring again to FIG. 2, the power line modem 54 provides a data communication path over the edge light wiring 21_{1-n} for the microprocessor 44. This two way path is used for the passing of command and control information between the various edge light assemblies 20_{1-n} and the central computer system 12. A power line transceiver module in the power line modem 54 is used to provide a data channel. These modules use a carrier current approach to create the data channel. Power line modems that operate at carrier frequencies in the 100 to 450 Khz band are available from many manufacturers. These modems provide digital communication paths at data rates of up to 10,000 bits per second utilizing direct sequence spread spectrum modulation. They conform to FCC power line carrier requirements for conducted emissions, and can work with up to 55 dB of power line attenuation. The power line modem 54 may be embodied by a device manufactured by Echelon Corporation of Palo Alto, California 94304, called the PLT-10 Power Line Transceiver Module.

The data channel provides a transport layer or lowest layer of the open system interconnection (OSI) protocol used in the data network. The Neuron® chip which implements the microprocessor 44 contains all of the firmware required to implement a 7 layer OSI protocol. When interconnected via an appropriate medium the Neuron® chips automatically communicate with one another using a robust Collision Sense Multiple Access (CSMA) protocol with forward error corrections, error checking and automatic retransmission of missed messages (ARQ).

The command and control information is placed in data packets and sent over the network in accordance with the 7 Layer OSI protocol. All messages generated by the microprocessor 44 and destined for the central computer system 12 are received by the network bridge 22 via the power lines 21_{1-n} and routed to the central computer system 12 over the wide area network 14.

The Neuron® chip of the microprocessor 44 comprises three processors (not shown) and the firmware required to support a full 6 layer open systems interconnection (OSI) protocol. The user is allocated one of the processors for the application code. The other two processors give the application program access to all of the other Neuron® chips in the network. This access creates a Local Operating Network or LON. A LON can be thought of as a high level local area network LAN. The use of the Neuron® chip for the implementation of this invention, reduces the amount of custom hardware and software that otherwise would have to be developed.

Data from the sensor electronic unit 43 of the edge light assemblies 20_{1-n} is coupled to the central computer system 12 via the existing airport taxiway lighting power wiring 21. Using the existing edge light power line to transfer the sensor data into a LON network has many advantages. As previously pointed out, the reuse of the existing edge lights eliminates the inconvenience and expense of closing down runways and taxiways while running new cable and provides for a low cost system.

The Neuron® chip allows the edge light assemblies 20_{1-n} to automatically communicate with each other at the applications level. This is accomplished through network variables which allow individual Neuron® chips to pass data between themselves. Each Neuron® 'C' program comprises both local and network variables. The local variables are used by the Neuron® program as a scratch pad memory. The network variables are used by the Neuron® program in one of two ways, either as a network output variables or a network input variables. Both kinds of variables can be initialized, evaluated and modified locally. The difference comes into play in that once a network output variable is modified, network messages are automatically sent to each network input variable that is linked to that output variable. This variable linking is done at installation time. As soon as a new value of a network input variable is received by a Neuron® chip, the code is vectored off to take appropriate action based upon the value of the network input variable. The advantage to the program is that this message passing scheme is entirely transparent since the message passing code is part of the embedded Neuron® operating system.

Referring now to FIG. 6, eleven network variables have been identified for a sensor program in each microprocessor 44 of the edge light assemblies 20_{1-n}. The sensor 50 function has two output variables: prelim_detect 70 and confirmed_detect 72. The idea here is to have one output trigger whenever the sensor 50 detects movement. The other output does not trigger unless the local sensor and the sensor on the edge light across the runway both spot movement. Only when the detection is confirmed will the signal be fed back to the central computer system 12. This technique of confirmation helps to reduce false alarms in order to implement this technique the adjacent sensor 50 has an input variable called adj_prelim_detect 78 that is used to receive the other sensors prelim_detect output 70. Other input variables are upstream_detect 74 and downstream_detect 76 which are used when chaining adjacent sensors together. Also needed is a detector_sensitivity 80 input that is used by the central computer system 12 to control the detection ability of the sensor 50.

The incandescent light 40 requires two network variables, one input and the other an output variable. The input variable light_level 84 would be used to control the light's brightness. The range would be OFF or 0% all the way to FULL ON or 100%. This range from 0% to 100% would be made in 0.5% steps. Since the edge light assembly 20_{1-n} also contains the photocell 46, an output variable light_failure 84 is created to signal that the lamp did not obtain the desired brightness.

The strobe light 48 requires three input variables. The strobe-mode 86 variable is used to select either the OFF, SEQUENTIAL, or ALTERNATE flash modes. Since the two flash modes require a distinct pattern to be created, two input variables active_delay 88 and flash_delay 90 are used to time align the strobe flashes. By setting these individual delay factors and then addressing the Neuron® chips as a group, allows the creation of a field strobe pattern with just one command.

Referring now to FIG. 7, a block diagram of an interconnection of network variables for a plurality of edge light assemblies 20_{1-n} located on both sides of a runway is shown, each of the edge light assemblies 20_{1-n} comprising a microprocessor 44. Each Neuron® program in the microprocessor 44 is designed with certain network input and output variables. The user writes the code for the Neurone® chips in the microprocessor 44 assuming that the inputs are supplied and that the outputs are used. To create an actual network the user has to "wire up" the network by interconnecting the individual nodes with a software linker. The resulting distributed process is best shown in schematic form, and a portion of the network interconnect matrix is shown in Figure 7. The prelim_detect 70 output of a sensor node 44_1 is connected to the adj_primary_detect 92 input of the sensor node 44_4 across the taxiway. This is used as a means to verify actual detections and eliminate false reports. The communications link between these two nodes 44_1 and 44_4 is part of the distributed processing. The two nodes communicate among themselves without involving the central computer system 12. If in the automatic mode or if instructed by the controller, the system will also alert the pilots via audio and visual indications.

Referring again to FIG. 1 and FIG. 4, the central computer system 12 tracks the movement of vehicles as they pass from the sensor 50 to sensor 50 in each edge light assembly 20_{1-n}. Using a variation of a radar automatic track algorithm, the system can track position, velocity and heading of all aircraft or vehicles based upon the sensor 50 readings. New vehicles are entered into the system either upon leaving a boarding gate or landing. Unknown vehicles are also tracked automatically. Since taxiway and runway lights are normally across from each other on the pavement (as shown in FIG. 4 and FIG. 7), the microprocessor 44 in each edge lights assembly 20_{1-n} is programmed to combine their sensor 50 inputs and agree before reporting a contact. A further refinement is to have the microprocessor 44 check with the edge light assemblies 20_{1-n} on either side of them to see if their sensors 50 had detected the vehicle. This allows a vehicle to be handed off from sensor electronic unit 43 to sensor electronic unit 43 of each edge light assembly 20_{1-n} as it travels down the taxiway. This also assures that vehicle position reports remain consistent. Vehicle velocity may also be calculated by using the distance between sensors, the sensor pattern and the time between detections.

Referring to FIG. 5 and FIG. 8, the display 30 is a color monitor which provides a graphical display of the airport, a portion of which is shown in FIG. 8. This is accomplished by storing a map of the airport in the redundant computers 26 and 28 in a digital format. The display 30 shows the location of airplanes or vehicles as they are detected by the sensors 50 mounted in the edge light assemblies 20_{1-n} along each taxiway and runway or other airport surface areas. All aircraft or vehicles on the airport surface are displayed as icons, with the shape of the icons being determined by the vehicle type. Vehicle position is shown by the location of the icon on the screen. Vehicle direction is shown by either the orientation of the icon or by an arrow emanating from the icon. Vehicle status is conveyed by the color of the icon. The future path of the vehicle as provided by the ground clearance command entered via the controllers microphone 35 is shown as a colored line on the display 30. The status of all field lights including each edge light 20_{1-n} in each edge light circuit 18_{1-n} is shown via color on the display 30.

Use of object orientated software provides the basis for building a model of an airport. The automatic inheritance feature allows a data structure to be defined once for each object and then replicated automatically for each instance of that object. Automatic flow down assures that elements of the data base are not corrupted due to typing errors. It also assures that the code is regular and structured. Rule based object oriented programming makes it difficult to create unintelligible "spaghetti code." Object oriented programming allows the runways, taxiways, aircraft and sensors, to be decoded directly as objects. Each of these objects contains attributes. Some of these attributes are fixed like runway 22R or flight UA347, and some are variable like vehicle status and position.

In conventional programming we describe the attributes of an object in data structures and then describe the behaviors of the object as procedures that operate on those data structures. Object oriented programming shifts the emphasis and focuses first on the data structure and only secondarily on the procedures. More importantly, object oriented programming allows us to analyze and design programs in a natural manner. We can think in terms of runways and aircraft instead of focusing on either the behavior or the data structures of the runways and aircraft.

Table 1 shows a list of objects with corresponding attributes. Each physical object that is important to the runway incursion problem is modeled. The basic airplane or vehicle tracking algorithm is shown in Table 2 in a Program Design Language (PDL). The algorithm which handles sensor fusion, incursion avoidance and safety alerts is shown in a single program even though it is implemented as distributed system using both the central computer system 12 and the sensor microprocessors 44.

TABLE 1

OBJECT	ATTRIBUTE	DESCRIPTION
Sensor	Location	X & Y coordinates of sensor
	Circuit	AC wiring circuit name & number
	Unique_address	Net address for this sensor and its mate
	Lamp_intensity	0% to 100% in 0.5% steps
	Strobe_status	Blink rate/off
	Strobe-delay	From start signal
	Sensor_status	Detect/no detect
	Sensor_type	IR, laser, proximity, etc.
Runway	Name	22R, 27, 33L, etc.
	Location	X & Y coordinates of start of center line
	Length	In feet
	Width	In feet
	Direction	In degrees from north
	Status	Not_active, active_takeoff, active_landing, alarm
	Sensors (MV)	List of lights/sensors along this runway
	Intersections (MV)	List of intersections
	Vehicles	List of vehicles on the runway
Taxiway	Name	Name of taxiway
	Location	X & Y coordinates of start of center line
	Length	In feet
	Width	In feet
	Direction	In degrees from north
	Status	Not active, active, alarm
	Sensors (MV)	List of intersections
	Hold_Locations	List of holding locations
	Vehicles (MV)	List of vehicles on the runway

Intersection	Name	Intersection Name
	Location	Intersection of two center lines
	Status	Vacant/Occupied
	Sensors (MV)	List of sensors creating intersection border
Aircraft	Airline	United
	Model	727-200
	Tail-number	N32742
	Empty_weight	9.5 tons
	Freight_weight	2.3 tons
	Fuel_weight	3.2 tons
	Top_speed	598 mph
	V1_speed	100 mph
	V2_speed	140 mph
	Acceleration	0.23 g's
	Deceleration	0.34 g's

MV = Multi-variable or array

Table 2

```
while (forever)
| if (edge light shows a detection)
| | if (adjacent light also shows a detection sensor fusion)
| | | /* CONFIRMED DETECTION */
| | | if (previous block showed a detection)
| | | | /* ACCEPT HANDOFF */
| | | | Update aircraft position and speed
| | | else
| | | | /* MAY BE AN ANIMAL OR SERVICE TRUCK */
| | | | Alert operator to possible incursion
| | | | /* MAY BE AN AIRCRAFT ENTERING THE SYSTEM */
| | | | Start a new track
| | else
| | | Request status from adjacent light
| | | if (Adjacent light is OK)
```

```
|   |   |   |  /* NON CONFIRMED DETECTION */
|   |   |  else
|   |   |   |  Flag adjacent light for repair
|   |   |  endif
|   |  endif
|  endif
|  if (Edge light loses a detection AND status is OK)
|   |  if (Next block showed a detection)
|   |   |     /* PROPER HANDOFF */
|   |  else
|   |   |  if (vehicle speed > = takeoff)
|   |   |   |  Handoff to departure control
|   |   |  else
|   |   |   |  /* MISSING HANDOFF */
|   |   |   |  Alert operator to possible incursion
|   |   |  endif
|   |  endif
|  endif
|  /* CHECK FOR POSSIBLE COLLISIONS */
|  for (all tracked aircraft)
|   |  Plot future position
|   |  if (position conflict)
|   |   |     Alert operator to possible incursion
|   |  endif
|  endif
|  Update display
endwhile
```

Referring again to FIG. 1 and FIG. 2, the control of taxiway lighting intensity is usually done by placing all the lights on the same series circuit and then regulating the current in that circuit. In the present embodiment the intensity of the lamp 40 is controlled by sending a message with the light intensity value to the microprocessor 44 located within the light assembly 20_{1-n}. The message allows for intensity settings in the range of 0 to 100% in 0.5% steps. The use of photocell 46 to check the light output allows a return message to be sent if the bulb does not respond. This in turn generates a maintenance report on the light. The strobe light 48 provides an additional optional capability under program control of the microprocessor 44. Each of the microprocessors 44 in the edge light assemblies 20 is individually addressable. This means every lamp on the field is controlled individually by the central computer system 12.

The system 10 can be programmed to provide an Active Runway Indicator by using the strobe lights 48 in those edge light assemblies 20_{1-n} located on the runway 64 to continue the approach light "rabbit" strobe pattern all the way down the runway. This lighting pattern could be turned-on as a plane is cleared for landing and then turned-off after the aircraft has touched down. A pilot approaching the runway along an intersecting taxiway would be alerted in a clear and unambiguous way that the runway was active and should not be crossed.

If an incursion was detected the main computers 26, 28 could switch the runway strobe lights 48 from the "rabbit" pattern to a pattern that alternatively flashes either side of the runway in a wig-wag fashion. A switch to this pattern would be interpreted by the pilot of an arriving aircraft as a wave off and a signal to go around. The abrupt switch in the pattern of the strobes would be instantaneously picked up by the air crew in time for them to initiate an aborted landing procedure.

During Category III weather conditions both runway and taxiway visibility are very low. Currently radio based landing systems are used to get the aircraft from final approach to the runway. Once on the runway it is not always obvious which taxiways are to be used to reach the airport terminal. In system 10 the main computers 26,28 can control the taxiway lamps 40 as the means for guiding aircraft on the ground during CAT III conditions. Since the intensity of the taxiway lamps 40 can be controlled remotely, the lamps just in front of an aircraft could be intensified or flashed as a means of guiding it to the terminal.

Alternatively, a short sequence of the "rabbit" pattern may be programmed into the taxiway strobes just in front of the aircraft. At intersections, either the unwanted paths may have their lamps turned off or the entrance to the proper section of taxiway may flash directing the pilot to head in that direction. Of course in a smart system only those lights directly in front of a plane would be controlled, all other lamps on the field would remain in their normal mode.

Referring now to FIG. 9, a block diagram is shown of the data flow within the system 10 (as shown in FIG. 1 and FIG. 5). The software modules are shown that are used to process the data within the computers 26, 28 of the central computer system 12. The tracking of aircraft and other vehicles on the airport operates under the control of a sensor fusion software module 101 which resides in the computers 26, 28. The sensor fusion software module 101 receives data from the plurality of sensors 50, a sensor 50 being located in each edge light assembly 20_{1-n} which reports the heat level detected, and this software module 101 combines this information through the use of rule based artificial intelligence to create a complete picture of all ground traffic at the airport on a display 30 of the central computer system 12.

The tracking algorithm starts a track upon the first report of a sensor 50 detecting a heat level that is above the ambient background level of radiation. This detection is then verified by checking the heat level reported by the sensor directly across the pavement from the first reporting sensor. This secondary reading is used to confirm the vehicle detected and to eliminate false alarms. After a vehicle has been confirmed the sensors adjacent to the first reporting sensor are queried for changes in their detected heat level. As soon as one of the adjacent sensors detects a rise in heat level a direction vector for the vehicle can be established. This process continues as the vehicle is handed off from sensor to sensor in a bucket brigade fashion as shown in FIG. 7. Vehicle speed can be roughly determined by calculating the time between vehicle detection by adjacent sensors. This information is combined with information from a system data base on the location of each sensor to calculate the velocity of the target. Due to hot exhaust or jet blast, the sensors behind the vehicle may not return to a background level immediately. Because of these condition, the algorithm only uses the first four sensors (two on either side of the taxiway) to calculate the vehicles position. The vehicle is always assumed to be on the centerline of the pavement and between the first four reporting sensors.

Vehicle identification can be added to the track either manually or automatically by an automated source that can identify a vehicle by its position. An example would be prior knowledge of the next aircraft to land on a particular runway. Tracks are ended when a vehicle leaves the detection system. This can occur in one of two ways. The first way is that the vehicle leaves the area covered by the sensors 50. This is determined by a vehicle track moving in the direction of a gateway sensor and then a lack of detection after the gateway sensor has lost contact. A second way to leave the detection system is for a track to be lost in the middle of a sensor array. This can occur when an aircraft departs or a vehicle runs onto the grass. Takeoff scenarios can be determined by calculating the speed of the vehicle just before detection was lost. If the vehicle speed was increasing and above rotation speed then the aircraft is assumed to have taken off. If not then the vehicle is assumed to have gone on to the grass and an alarm is sounded.

Referring to FIG. 5 and FIG. 9, the ground clearance routing function is performed by the speech recognition unit 33 along with the ground clearance compliance verifier software module 103 running on the computers 26, 28. This software module 103 comprises a vehicle identification routine, clearance path routing, clearance checking routine and a path checking routine.

The vehicle identification routine is used to receive the airline name and flight number (i.e. "Delta 374") from the speech recognition unit 33 and it highlights the icon of that aircraft on the graphic display of the airport on display 30.

The clearance path routine takes the remainder of the controller's phrase (i.e. "outer taxiway to echo, hold short of runway 15 Left") and provides a graphical display of the clearance on the display 30 showing the airport.

The clearance checking routine checks the clearance path for possible conflict with other clearances and vehicles. If a conflict is found the portion of the path that would cause an incursion is highlighted in a blinking red and an audible indication is given to the controller via speaker 32.

The path checking routine checks the actual path of the vehicle as detected by the sensors 50 after the clearance path has been entered into the computers 26, 28 and it monitors the actual path for any deviation. If this routine detects that a vehicle has strayed from the assigned course, the vehicle icon on the graphic display of the airport flashes and an audible indicator is given to the controller via speaker 32 and optionally the vehicle operator via radio 37.

The airport vehicle incursion avoidance system 10 operates under the control of safety logic routines which reside in the collision detection software module 104 running on computers 26, 28. The safety logic routines receive data from the sensor fusion software module 101 via the tracker software module 102 location program and interpret this information through the use of rule based artificial intelligence to predict possible collisions or runway incursions. This information is then used by the central computer system 12 to alert tower controllers, aircraft pilots and truck operators to the possibility of a runway incursion. The tower controllers are alerted by the display 30 along with a computer synthesized voice message via speaker 32. Ground traffic is alerted by a combination of traffic lights, flashing lights, stop bars and other alert lights 34, lamps 40 and 48, and computer generated voice commands broadcast via radio 36.

Knowledge based problems are also called fuzzy problems and their solutions depend upon both program logic and an interface engine that can dynamically create a decision tree, selecting which heuristics are most appropriate for the specific case being considered. Rule based systems broaden the scope of possible applications. They allow designers to incorporate judgement and experience, and to take a consistent solution approach across an entire problem set.

The programming of the rule based incursion detections software is very straight forward. The rules are written in English allowing the experts, in this case the tower personnel and the pilots, to review the system at an understandable level. Another feature of the rule based system is that the rules stand alone. They can be added, deleted or modified without affecting the rest of the code. This is almost impossible to do with code that is created from scratch. An example of a rule we might use is:

```
If (Runway_Status = Active)
        then (Stop_Bar_Lights = RED).
```

This is a very simple and straight forward rule. It stands alone requiring no extra knowledge except how Runway_Status is created. So let's make some rules affecting Runway_Status.

```
If (Departure = APPROVED) or (Landing = IMMINENT),
        then (Runway_Status = ACTIVE).
```

For incursion detection, another rule is:

```
If (Runway_Status = ACTIVE) and (Intersection = OCCUPIED),
        then (Runway_Incursion = TRUE).
```

Next, detect that an intersection of a runway and taxiway are occupied by the rules:

```
If (Intersection_Sensors = DETECT),
        then (Intersection = OCCUPIED).
```

To predict that an aircraft will run a Hold Position stop, the following rule is created:

```
If (Aircraft_Stopping_Distance > Distance_to_Hold_Position),
        then (Intersection = OCCUPIED).
```

In order to show that rules can be added without affecting the reset of the program, assume that after a demonstration of the system 10 to tower controllers, they decided that they wanted a "Panic Button" in the tower to override the rule based software in case they spot a safety violation on the ground. Besides installing the button, the only other change would be to add this extra rule.

```
If (Panic_button = PRESSED),
        then (Runway_Incursion = TRUE).
```

It is readily seen that the central rule based computer program is very straight forward to create, understand and modify. As types of incursions are defined, the system 10 can be upgraded by adding more rules.

Referring again to FIG. 9, the block diagram shows the data flow between the functional elements within the system 10 (FIG. 1). Vehicles are detected by the sensor 50 in each of the edge light assemblies 20_{1-n}. This information is passed over the local operating network (LON) via edge light wiring 21_{1-n} to the LON bridges 22_{1-n}. The individual message packets are then passed to the redundant computers 26 and 28 over the wide area network (WAN) 14 to the WAN interface 108. After arriving at the redundant computers 26 and 28, the message packet is checked and verified by a message parser software module 100. The contents of the message are then sent to the sensor fusion software module 101. The sensor fusion software module 101 is used to keep track of the status of all the sensors 50 on the airport; it filters and verifies the data from the airport and stores a representative picture of the sensor array in a memory. This information is used directly by the display 30 to show which sensors 50 are responding and used by the tracker software module 102. The tracker software module 102 uses the sensor status information to determine which sensor 50 reports correspond to actual vehicles. In addition, as the sensor reports and status change, the tracker software module 102 identifies movement of the vehicles and produces a target location and direction output. This information is used by the display 30 in order to display the appropriate vehicle icon on the screen.

The location and direction of the vehicle is also used by the collision detection software module 104. This module checks all of the vehicles on the ground and plots their expected course. If any two targets are on intersecting paths, this software module generates operator alerts by using the display 30, the alert lights 34, the speech synthesis unit 29 coupled to the associated speaker 32, and the speech synthesis unit 31 coupled to radio 37 which is coupled to antenna 39.

Still referring to FIG. 9, another user of target location and position data is the ground clearance compliance verifier software module 103. This software module 103 receives the ground clearance commands from the controller's microphone 35 via the speech recognition unit 33. Once the cleared route has been determined, it is stored in the ground clearance compliance verifier software module 103 and used for comparison to the actual route taken by the vehicle. If the information received from the tracker software module 102 shows that the vehicle has deviated from its assigned course, this software module 103 generates operator alerts by using the display 30, the alert lights 34, the speech synthesis unit 29 coupled to speaker 32, and the speech synthesis unit 31 coupled to radio 37 which is coupled to antenna 39.

The keyboard 27 is connected to a keyboard parser software module 109. When a command has been verified by the keyboard parser software module 109, it is used to change display 30 options and to reconfigure the sensors and network parameters. A network configuration data base 106 is updated with these reconfiguration commands. This information is then turned into LON message packets by the command message generator 107 and sent to the edge light assemblies 20_{1-n} via the WAN interface 108 and the LON bridges 22_{1-n}.

This concludes the description of the preferred embodiment. However, many modifications and alterations will be obvious to one of ordinary skill in the art without departing from the spirit and scope of the inventive concept. Therefore, it is intended that the scope of this invention be limited only by the appended claims.

Claims

1. An airport incursion avoidance system comprising:

   a plurality of light circuits on an airport, each of said light circuits comprises a plurality of light assembly means;

   means for providing power to each of said plurality of light circuits and to each of said light assembly means;

   means in each of said light assembly means for sensing ground traffic on said airport;

   means for processing data received from each of said light assembly means;

   means for providing data communication between each of said light assembly means and said processing means;

   said processing means comprises means for providing a graphic display of said airport comprising symbols representing said ground traffic, each of said symbols having direction and velocity data displayed;

   said processing means comprises means for predicting an occurrence of an airport incursion in accordance with the data received from said sensing means; and

   means for alerting an airport controller or aircraft pilot of said predicted airport incursion.

2. The airport incursion avoidance system as recited in Claim 1 wherein:

   each of said light circuits being located along the edges of a taxiway or a runway on said airport.

3. The airport incursion avoidance system as recited in Claim 1 wherein:

   said sensing means comprises infrared detectors.

4. The airport incursion avoidance system as recited in Claim 1 wherein said light assembly means comprises:

   light means coupled to said lines of said power providing means for lighting said airport;

said sensing means;

microprocessor means coupled to said light means, said sensing means, and said data communication means for providing processing, communication and control for said light assembly means, said microprocessor controlling a plurality of lighting patterns of said light means on said airport; and

said data communication means being coupled to said microprocessor means and said lines of said power providing means.

5. The airport incursion avoidance system as recited in Claim 4 wherein:

said light assembly means further comprises a photocell means coupled to said microprocessor means for detecting the light intensity of said light means.

6. The airport incursion avoidance system as recited in Claim 4 wherein:

said light assembly means further comprises a strobe light coupled to said microprocessor means.

7. The airport incursion avoidance system as recited in Claim 1 wherein:

said processing means comprises redundant computers for fault tolerance operation.

8. The airport incursion avoidance system as recited in Claim 1 wherein:

said symbols representing said ground traffic comprise icons having a shape indicating type of aircraft or vehicle.

9. The airport incursion avoidance system as recited in Claim 1 wherein:

said processing means determines a location of said symbols on said graphic display of said airport in accordance with said data receive from said light assembly means.

10. The airport incursion avoidance system as recited in Claim 1 wherein:

said processing means determines a future path of said ground traffic based on a ground clearance command, said future path being shown on said graphic display.

11. The airport incursion avoidance system as recited in Claim 1 wherein:

said processing means for predicting an occurrence of an airport incursion comprises means for comparing position, direction and velocity of said ground traffic to predetermined separation minimums for said airport.

12. The airport incursion avoidance system as recited in Claim 1 wherein said power providing means comprises:

constant current power means for providing a separate line to each of said plurality of light circuits; and

network bridge means coupled to said constant current power means for providing a communication channel to said processing means for each line of said constant current power means.

13. The airport incursion avoidance system as recited in Claim 1 wherein:

said alerting means comprises a speech synthesis umit connected to a speaker.

14. The airport incursion avoidance system as recited in Claim 1 wherein:

said alerting means comprises a speech synthesis unit connected to a radio transmitter.

15. An airport incursion avoidance system comprising:

a plurality of light circuits on an airport, each of said light circuits comprises a plurality of light assembly means;

constant current power means for providing a separate line to each of said plurality of light circuits;

network bridge means coupled to said constant current power means for providing a communication channel to said processing means for each of said constant current power means;

infrared detector means in each of said light assembly means for sensing ground traffic on said airport;

means for processing ground traffic data received from each of said light assembly means;

means for providing data communication on lines of said power providing means between each of said light assembly means and said processing means;

said processing means comprises means for providing a graphic display of said airport comprising symbols representing said ground traffic located in accordance with said ground traffic data received from said light assembly means, each of said symbols having direction and velocity data displayed;

said processing means comprises means for predicting an occurrence of an airport incursion in accordance with said ground traffic data received from said sensing means including comparing position, direction aand velocity of said ground traffic data to predetermined separation minimums for said airport; and

means for alerting an airport controller or aircraft pilot of said predicted airport incursion.

16. The airport incursion avoidance system as recited in Claim 15 wherein:

each of said light circuits being located along the edges of a taxiway or a runway on said airport.

17. The airport incursion avoidance system as recited in Claim 15 wherein said light assembly means comprises:

light means coupled to said lines of said power providing means for lighting said airport;

said infrared detector sensing means;

microprocessor means coupled to said light means, said sensing means, and said data communication means for providing processing, communication and control for said light assembly means, said microprocessor controlling a plurality of lighting patterns of said light means on said airport; and

said data communication means being coupled to said microprocessor means and said lines of said constant current power providing means.

18. The airport incursion avoidance system as recited in Claim 17 wherein:

said light assembly means further comprises a photocell means coupled to said microprocessor means for detecting the light intensity of said light means.

19. The airport incursion avoidance system as recited in Claim 17 wherein:

said light assembly means further comprises a strobe light coupled to said microprocessor means.

20. The airport incursion avoidance system as recited in Claim 15 wherein:

said processing means comprises redundant computers for fault tolerance operation.

21. The airport incursion avoidance system as recited in Claim 15 wherein:

said symbols representing said ground traffic comprise icons having a shape indicating type of aircraft or vehicle.

22. The airport incursion avoidance system as recited in Claim 15 wherein:

said processing means determines a future path of said ground traffic based on a ground clearance command, said future path being shown on said graphic display.

23. The airport incursion avoidance system as recited in Claim 15 wherein:

said alerting means comprises a speech synthesis umit connected to a speaker.

24. The airport incursion avoidance system as recited in Claim 15 wherein:

said alerting means comprises a speech synthesis unit connected to a radio transmitter.

25. A method of providing an airport incursion avoidance system comprising the steps of:

providing a plurality of light circuits on said airport, each of said light circuits comprises a plurality of light assembly means;

providing power to each of said plurality of light circuits;

sensing ground traffic on said airport with means in each of said light assembly means;

processing data received from each of said light assembly means in computer means;

providing a graphic display of said airport comprising symbols representing said ground traffic, each of said symbols having direction and velocity data displayed;

providing data communication between said computer means and each of said light assembly means;

predicting an occurrence of an airport incursion in accordance with the data received from said sensing means; and

alerting an airport controller or aircraft pilot of said predicted airport incursion.

26. The method as recited in Claim 25 wherein said step of sensing said ground traffic on said airport comprises the steps of:

lighting said airport with a light means coupled to said microprocessor means and said power lines;

providing a sensing means;

performing processing, communication and control within said light assembly means with a microprocessor means coupled to said light means, said sensing means and data communication means; and

coupling said data communication means between said microprocessor means and said power lines.

27. The method recited in Claim 25 wherein said step of processing data comprises the step of operating redundant computers for fault tolerance.

28. The method as recited in Claim 25 wherein said step of providing power comprises the steps of:

providing a separate line to each of said plurality of light circuits with a constant current power means; and

providing a communication channel to said computer means for each line of said constant current power means using a network bridge means.

29. The method as recited in Claim 25 wherein said step of providing a graphic display comprising symbols representing said ground traffic comprises the step of indicating a type of aircraft or vehicle with icons of various shapes.

30. The method as recited in Claim 25 wherein said step of processing said data from each of said light assembly means comprises the step of determining a location of said symbols on said graphic display of said airport in accordance with said data.

31. The method as recited in Claim 25 wherein said step of predicting an occurrence of an airport incursion comprises the step of determining a future path of said ground traffic in accordance with a ground clearance command and showing said future path on said graphic display.

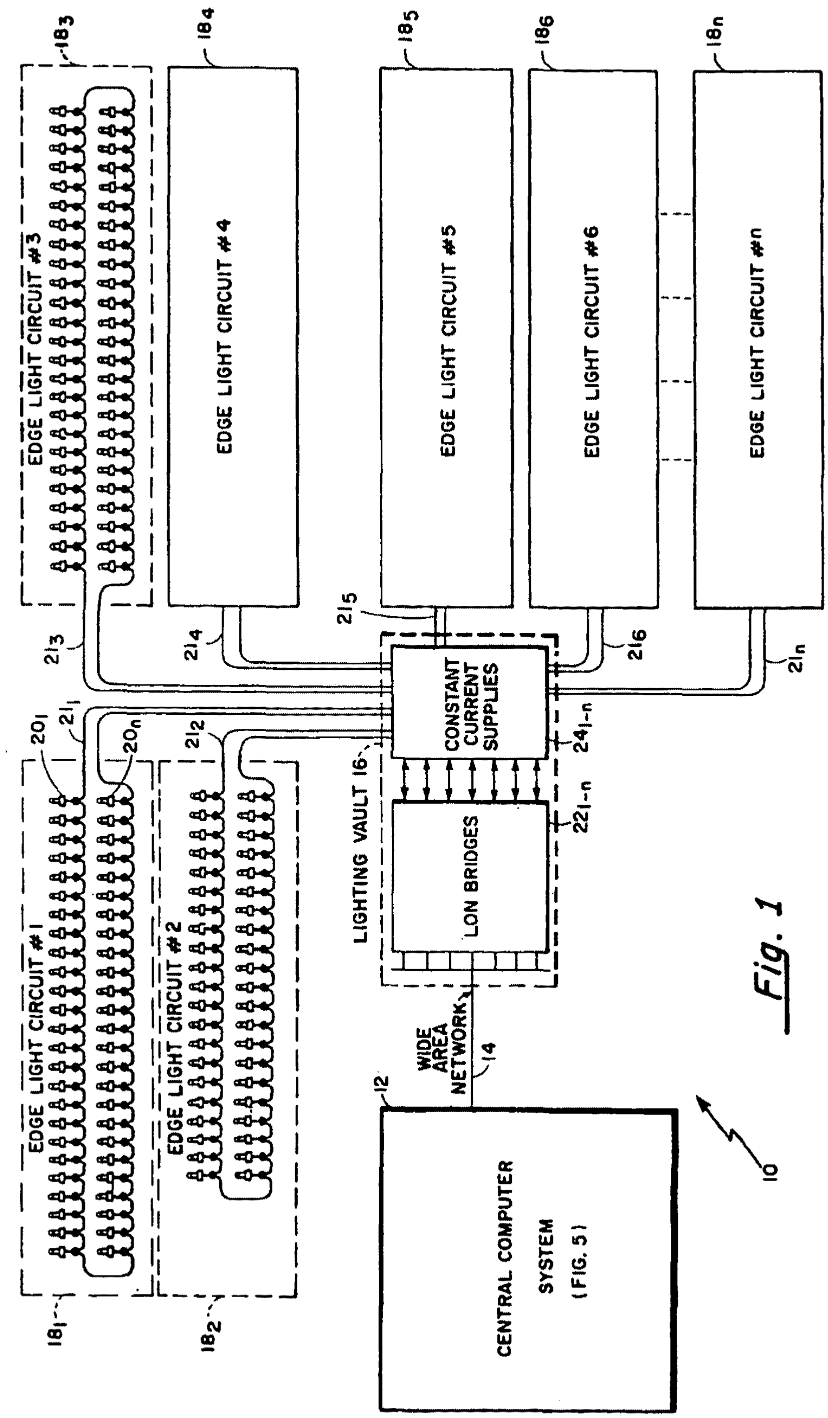

EDGE LIGHT CIRCUIT #1
EDGE LIGHT CIRCUIT #2
EDGE LIGHT CIRCUIT #3
EDGE LIGHT CIRCUIT #4
EDGE LIGHT CIRCUIT #5
EDGE LIGHT CIRCUIT #6
EDGE LIGHT CIRCUIT #n
CONSTANT CURRENT SUPPLIES
LON BRIDGES
LIGHTING VAULT 16
WIDE AREA NETWORK
14
12
CENTRAL COMPUTER SYSTEM (FIG. 5)
10

Fig. 1

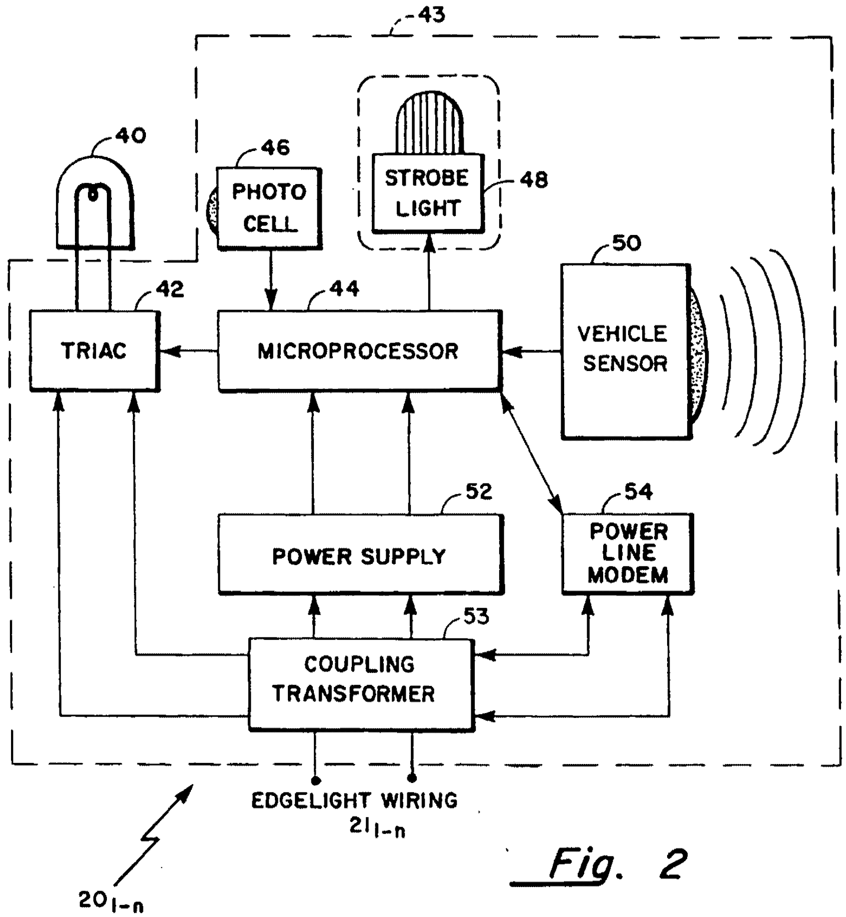

43
40
46
PHOTO CELL
STROBE LIGHT
48
50
42
44
TRIAC
MICROPROCESSOR
VEHICLE SENSOR
52
54
POWER SUPPLY
POWER LINE MODEM
53
COUPLING TRANSFORMER
EDGELIGHT WIRING
21_{1-n}
20_{1-n}

Fig. 2

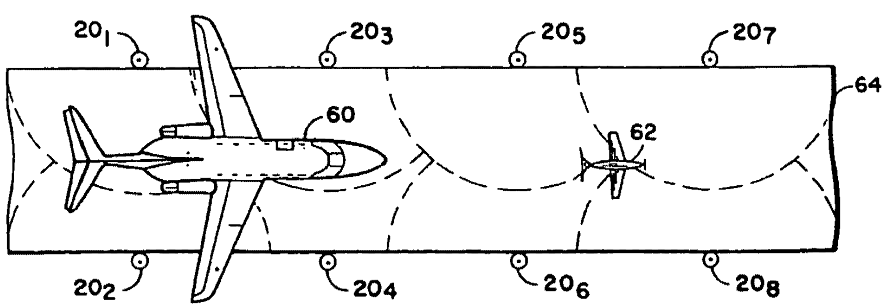

20_1
20_3
20_5
20_7
64
60
62
20_2
20_4
20_6
20_8

Fig. 4

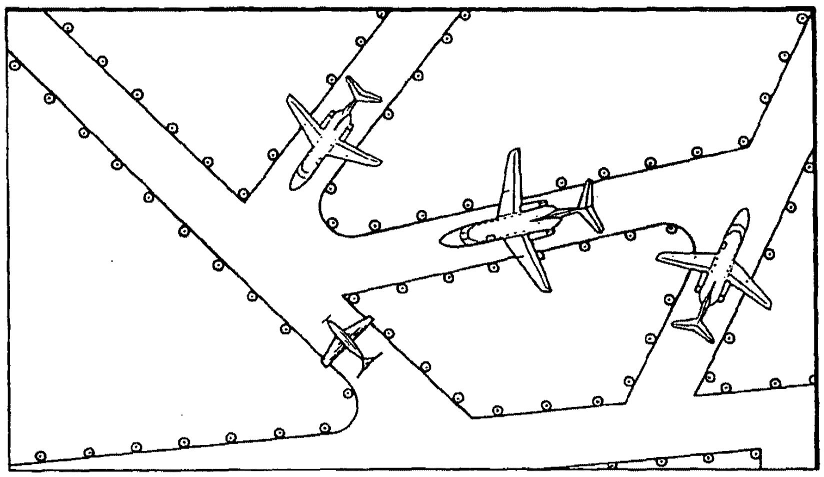


Fig. 8

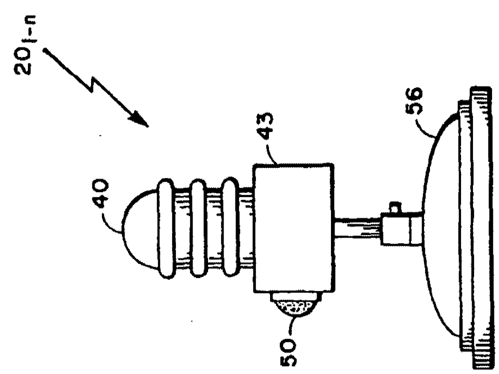


Fig. 3

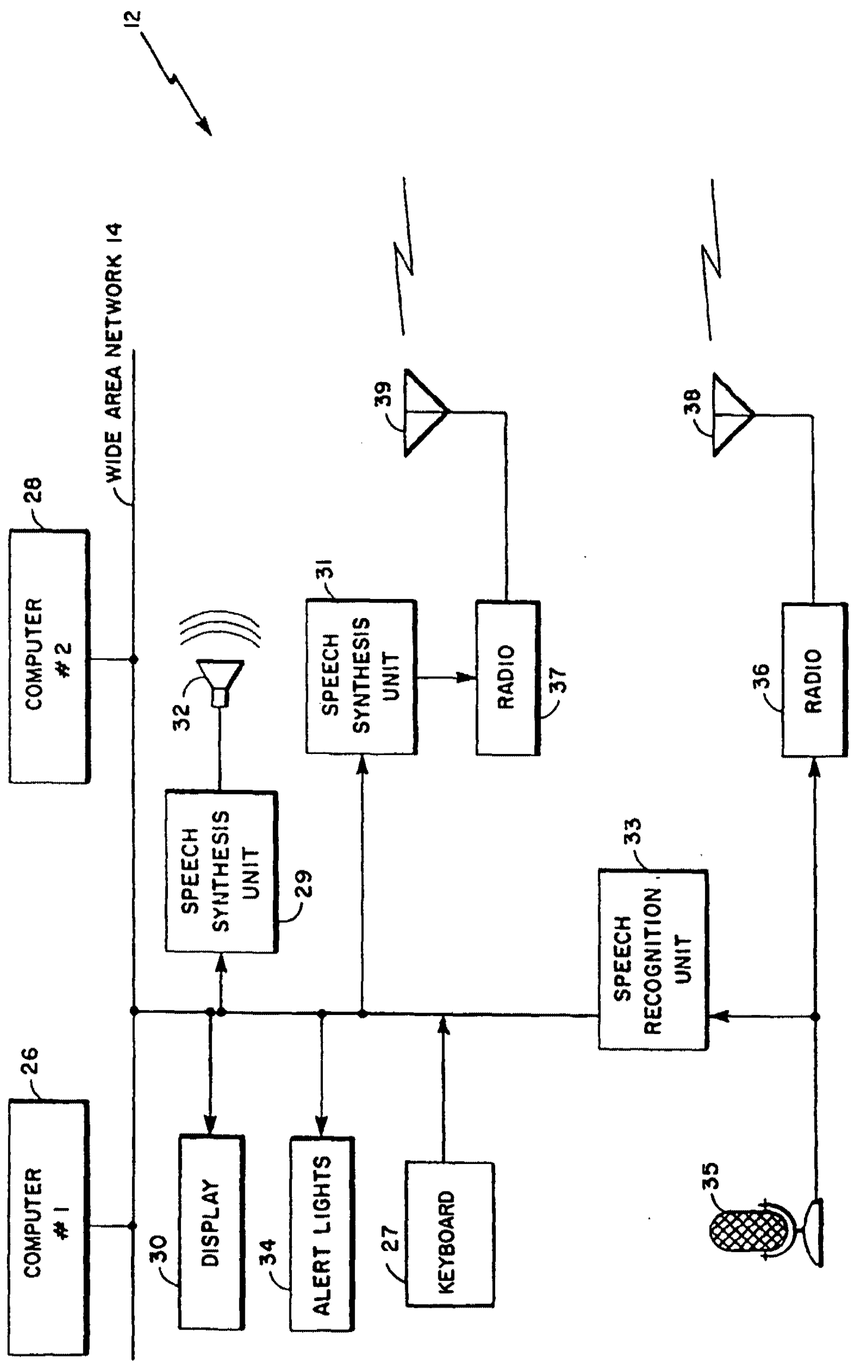
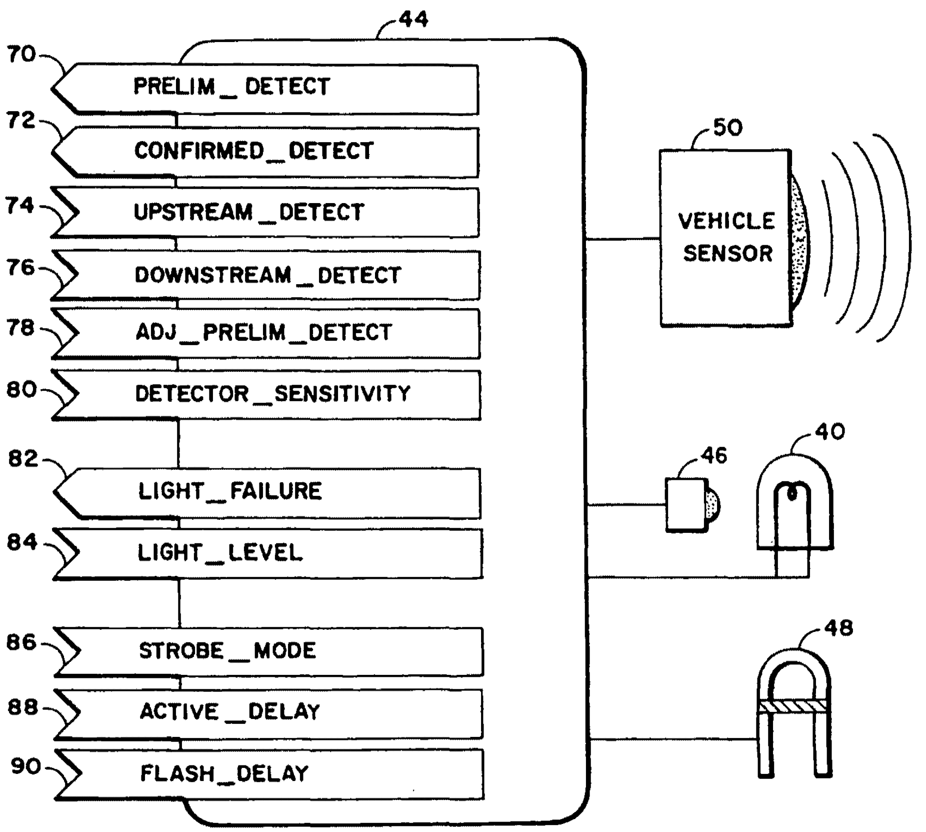

12
COMPUTER # 1
26
COMPUTER # 2
28
WIDE AREA NETWORK 14
DISPLAY
30
ALERT LIGHTS
34
KEYBOARD
27
SPEECH SYNTHESIS UNIT
29
32
SPEECH SYNTHESIS UNIT
31
RADIO
37
39
SPEECH RECOGNITION UNIT
33
RADIO
36
38
35

Fig. 5


44
70
PRELIM_DETECT
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CONFIRMED_DETECT
74
UPSTREAM_DETECT
76
DOWNSTREAM_DETECT
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ADJ_PRELIM_DETECT
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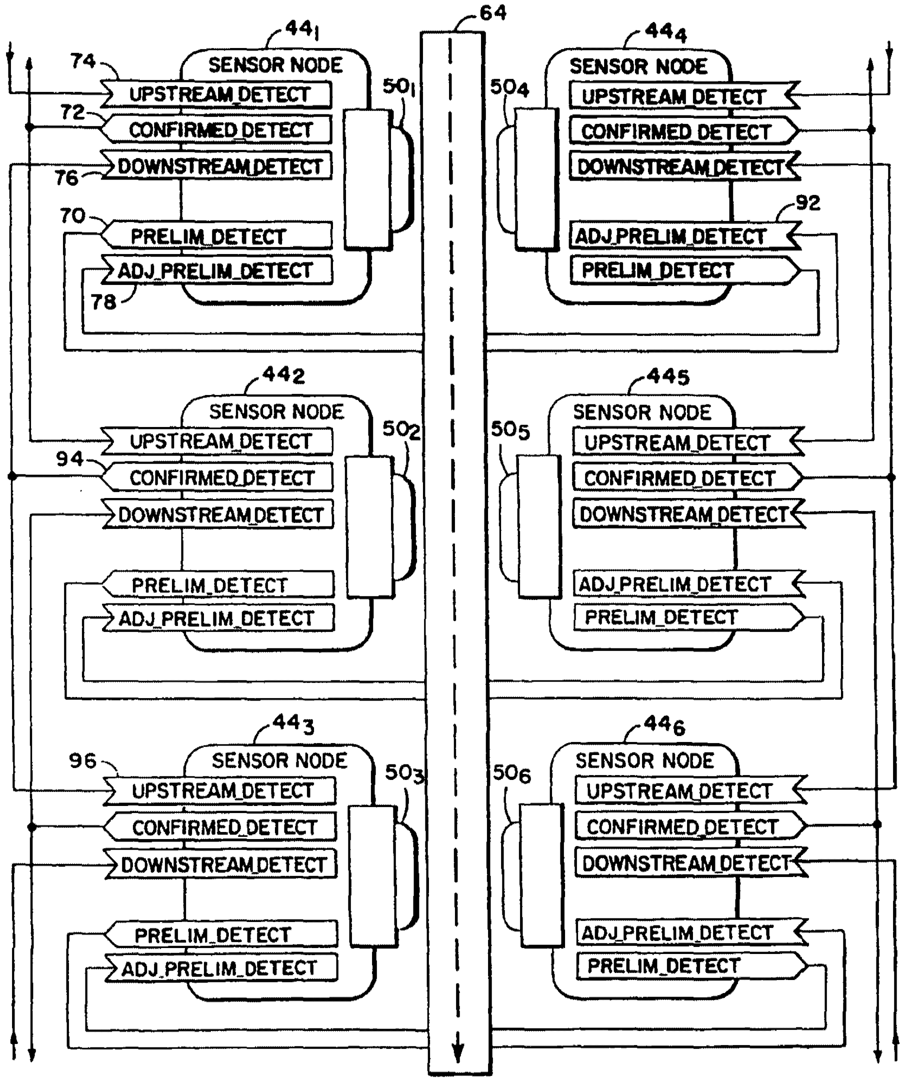
DETECTOR_SENSITIVITY
82
LIGHT_FAILURE
84
LIGHT_LEVEL
86
STROBE_MODE
88
ACTIVE_DELAY
90
FLASH_DELAY
50
VEHICLE SENSOR
46
40
48

Fig. 6


64
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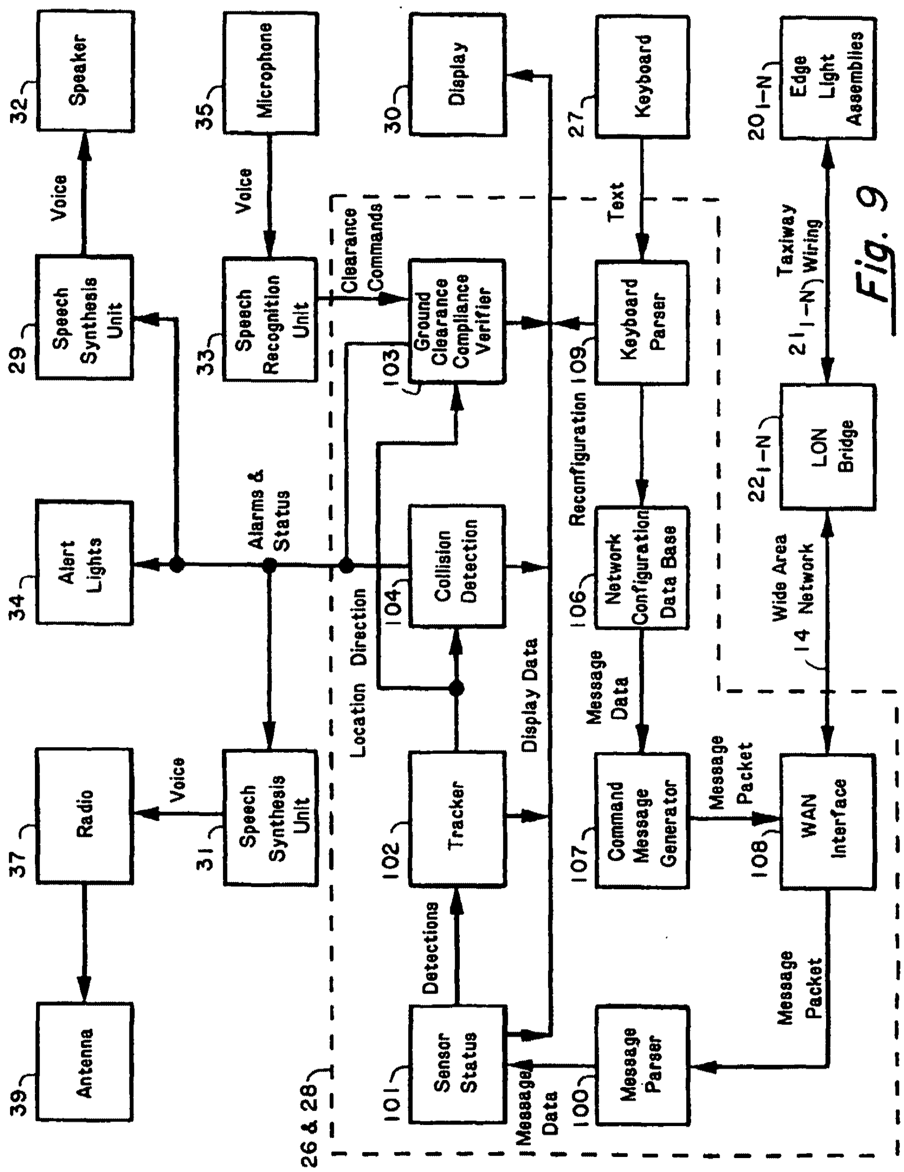
SENSOR NODE
74
UPSTREAM DETECT
72
CONFIRMED DETECT
DOWNSTREAM DETECT
76
70
PRELIM DETECT
ADJ PRELIM DETECT
78
50₁
50₄
44₄
SENSOR NODE
UPSTREAM DETECT
CONFIRMED DETECT
DOWNSTREAM DETECT
92
ADJ PRELIM DETECT
PRELIM DETECT
44₂
SENSOR NODE
UPSTREAM DETECT
94
CONFIRMED DETECT
DOWNSTREAM DETECT
PRELIM DETECT
ADJ PRELIM DETECT
50₂
50₅
44₅
SENSOR NODE
UPSTREAM DETECT
CONFIRMED DETECT
DOWNSTREAM DETECT
ADJ PRELIM DETECT
PRELIM DETECT
44₃
SENSOR NODE
96
UPSTREAM DETECT
CONFIRMED DETECT
DOWNSTREAM DETECT
PRELIM DETECT
ADJ PRELIM DETECT
50₃
50₆
44₆
SENSOR NODE
UPSTREAM DETECT
CONFIRMED DETECT
DOWNSTREAM DETECT
ADJ PRELIM DETECT
PRELIM DETECT

Fig. 7



32
Speaker
Voice
29
Speech Synthesis Unit
34
Alert Lights
Alarms & Status
37
Radio
Voice
31
Speech Synthesis Unit
39
Antenna
35
Microphone
Voice
33
Speech Recognition Unit
Clearance Commands
30
Display
103
Ground Clearance Compliance Verifier
104
Collision Detection
Location
Direction
102
Tracker
Detections
101
Sensor Status
Display Data
Message Data
26 & 28
27
Keyboard
Text
109
Keyboard Parser
Reconfiguration
106
Network Configuration Data Base
Message Data
107
Command Message Generator
Message Packet
100
Message Parser
20 1-N
Edge Light Assemblies
Taxiway Wiring
21 1-N
22 1-N
LON Bridge
Wide Area Network
14
108
WAN Interface
Message Packet

Fig. 9

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 1262

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
Y	US-A-3 706 969 (PAREDES) * the whole document * ---	1-31	G08G5/06
Y	WO-A-90 04242 (SWEDISH AIRPORT TECHNOLOGY HB) * the whole document * ---	1-12, 15-22, 25-31	
Y	US-A-4 093 937 (HABINGER) * column 2, line 3 - line 33 * ---	6,19	
Y	US-A-4 455 551 (LEMELSON) * abstract * ---	13,14, 23,24	
A	EP-A-0 209 397 (GENERAL INVESTIGACION Y DESARROLLO S.A.) * claims 1,5-13,23,27 *	1-3, 8-11,15, 21,22, 25,26, 29-31	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
D	& US-A-4 845 629 (MURGA ET AL.) ---		G08G
A	EP-A-0 220 752 (D.R.I.M. LIMITED) * claims * -----	1,10,11, 15,22, 25,26,31	G08B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 June 1994	Reekmans, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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(54) Airport surveillance system.

(57) An airport surveillance system for detection of aircraft or other vehicles having a sensor co-located with edge lights (20_{1-N}) along taxiways, runways and other surface areas, the sensor output being coupled to a central computer system (26,28) via the airport's edge light power lines (21_{1-N}). The detection system comprises infrared sensors (50, Fig. 2). The output of each sensor (50) is fed into a microprocessor (44) within an edge light assembly (20) and then to a power line modem (54) for transmission to the central computer (26,28) which includes a display system (30) at the airport tower for displaying the airport and all traffic thereon. Data from each sensor (50) along taxiways and runways is received at the central computer system (26,8) and processed to provide comprehensive vehicle tracking and control of all ground traffic on the airport.

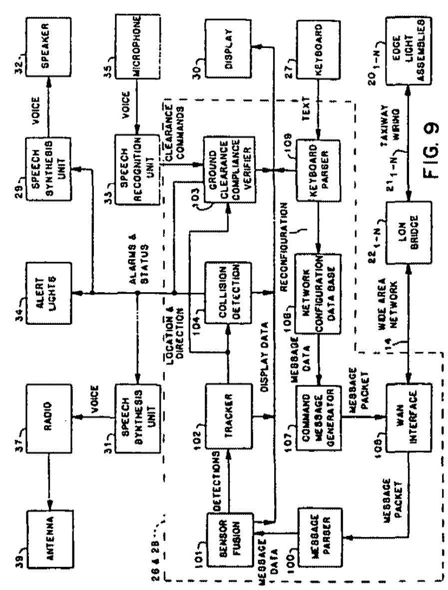

FIG. 9

EP 0 613 111 A1

Jouve, 18, rue Saint-Denis, 75001 PARIS

Background of the Invention

This invention relates to an airport ground surveillance system and in particular to an apparatus and method for monitoring and controlling aircraft or other vehicle movement primarily on airport taxiways, runways and other surface areas.

Currently, ground control of aircraft at an airport is done visually by the air traffic controller in the tower. Low visibility conditions sometimes make it impossible for the controller to see all parts of the field. Ground surface radar can help in providing coverage during low visibility conditions; it plays an important part in the solution of the runway incursion problem but cannot solve the entire problem. A runway incursion is defined as "any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing, or intending to land." The U.S. Federal Administration Agency (FAA) has estimated that it can only justify the cost of ground surface radar at 29 of the top 100 airports in the United States. However, such radar only provides location information; it cannot alert the controller to possible conflicts between aircraft.

In the prior art, an airport control and monitoring system has been used to sense when an airplane reaches a certain point on a taxiway and controls switching lights on and off to indicate to the pilot when he may proceed on to a runway. Such a system sends microwave sensor information to a computer in the control tower. The computer comprises software for controlling the airport lighting and for providing fault information on the airport lighting via displays or a control panel to an operator. Such a system is described in sales information provided on a Bi-directional Series 7 Transceiver (BRITEE) produced by ADB-ALNACO, Inc., A Siemens Company, of Columbus, Ohio. However, such a system does not show the location of all vehicles on an airfield and is not able to detect and avoid a possible vehicle incursion.

A well known approach to airport surface traffic control has been the use of scanning radars operating at high frequencies such as K-band in order to obtain adequate definition and resolution. An existing airport ground traffic control equipment of that type is known in the art as Airport Surface Detection Equipment (ASDE). However, such equipment provides surveillance only, no discrete identification of aircraft on the surface being available. Also there is a need for a relatively high antenna tower and a relatively large rotation antenna system thereon.

Another approach to airport ground surveillance is a system described in U. S. Patent No. 3,872,474, issued March 18, 1974, to Arnold M. Levine and assigned to International Telephone and Telegraph Corporation, New York, NY, referred to as LOCAR (Localized Cable Radar) comprises a series of small, lower powered, narrow pulses, transmitting radars having limited range and time sequenced along opposite sides of a runway ramp or taxiway. In another U. S. Patent No. 4,197,536, issued on April 8, 1980, to Arnold M. Levine, an airport surface identification and control system is described for aircraft equipped with ATCRBS (Air Traffic Control Radio Beacon System) and ILS (Instrument Landing System). However, these approaches are expensive, require special cabling and for identification purposes require expensive equipment to be included on the aircraft and other vehicles.

Another approach to vehicle identification such as types of aircraft by identifying the unique characteristic of the "footprint" presented by the configuration of wheels unique to a particular type of vehicle is described in U.S. Patent No. 3,872,283, issued March 18, 1975, to Gerald R. Smith et al. and assigned to The Cadre Corporation of Atlanta Georgia.

An automatic system for surveillance, guidance and fire-fighting at airports using infrared sensors is described in U. S. Patent No. 4,845,629, issued July 4, 1989 to Maria V. Z. Murga. The infrared sensors are arranged along the flight lanes and their output signals are processed by a computer to provide information concerning the aircraft movements along the flight lanes. Position detectors are provided for detecting the position of aircraft in the taxiways and parking areas. However, such system does not teach the use of edge lights along the runways and taxiways along with their associated wiringand it is not able to detect and avoid a possible vehicle incursion.

The manner in which the invention deals with the disadvantages of the prior art to provide a low cost airport surveillance system, will be evident as the description proceeds.

Summary of the Invention

Accordingly, it is therefore an object of this invention to provide an airport surveillance system for detecting and monitoring all ground traffic on runways and taxiways and other surface areas.

It is also an object of this invention to provide a low cost airport surveillance system using edge light assemblies and associated wiring along runways and taxiways.

It is another object of this invention to provide a low cost airport surveillance system comprising infrared detectors.

It is a further object of this invention to provide an airport surveillance system that generates a graphic display of the airport showing the location of all ground traffic including direction and velocity data.

The objects are further accomplished by providing an airport surveillance system comprising a plurality of light circuits on an airport, each of the light circuits comprises a plurality of light assembly means, means for providing power to each of the plurality of light circuits and to each of the light assembly means, means in each of the light assembly means for sensing ground traffic on the airport, means for processing data received from each of the light assembly means, means for providing data communication between each of the light assembly means and the processing means, and the processing means comprises means for providing a graphic display of the airport, the graphic display having symbols representing the ground traffic, each of the symbols having direction and velocity data displayed. Each of the light circuits are located along the edges of a taxiway or a runway on the airport. The light assembly means comprises light means coupled to the lines of the power providing means for lighting the airport, sensing means which comprises infrared detectors, microprocessor means coupled to the light means, the sensing means, and the data communication means for providing processing, communication and control for the light assembly means, the microprocessor controlling a plurality of lighting patterns of the light means on the airport, and the data communication means are coupled to the microprocessor means and the lines of the power providing means. The light assembly means further comprises a photocell means coupled to the microprocessor means for detecting the light intensity of the light means. The light assembly means further comprises a strobe light coupled to the microprocessor means. The processing means comprises redundant computers for fault tolerance operation. The symbols representing the ground traffic comprise icons having a shape indicating the type of airplane or vehicle. The processing means determines a location of the symbols on the graphic display of the airport in accordance with the data receive from the light assembly means. The processing means determines a future path of the ground traffic based on a ground clearance command, the future path being shown on the graphic display. The power providing means comprises constant current power means for providing a separate line to each of the plurality of light circuits, and network bridge means coupled to the constant current power means for providing a communication channel to the processing means for each line of the constant current power means.

The objects are further accomplished by a method of providing an airport surveillance system comprising the steps of providing a plurality of light circuits on the airport, each of the light circuits comprises a plurality of light assembly means, providing power to each of the plurality of light circuits, sensing ground traffic on the airport with means in each of the light assembly means, processing data received from each of the light assembly means in computer means, providing a graphic display of the airport comprising symbols representing the ground traffic, each of the symbols having direction and velocity data displayed, and providing data communication between the computer means and each of the light assembly means. The step of sensing the ground traffic on the airport comprises the steps of lighting the airport with a light means coupled to the power lines, providing infrared detectors for sensing ground traffic, performing processing, communication and control within the light assembly means with a microprocessor means coupled to the light means, the sensing means and data communication means, and coupling the data communication means between the microprocessor means and the power lines. The step of processing data comprises the steps of operating redundant computers for fault tolerance. The step of providing power comprises the steps of providing a separate line to each of the plurality of light circuits with a constant current power means, and providing a communication channel to the computer means for each line of the constant current power means using a network bridge means. The step of providing a graphic display comprising symbols representing the ground traffic comprises the step of indicating a type of aircraft or vehicle with icons of various shapes. The step of processing the data from each of the light assembly means comprises the step of determining a location of the symbols on the graphic display of the airport in accordance with the data.

Brief Description of the Drawings

Other and further features of the invention will become apparent in connection with the accompanying drawings wherein:

FIG. 1 is a block diagram of the invention of an airport vehicle detection system;

FIG. 2 is a block diagram of an edge light assembly showing a sensor electronics unit coupled to an edge light of an airfield lighting system;

FIG. 3 is a pictorial diagram of the edge light assembly showing the edge light positioned above the sensor electronics unit;

FIG. 4 is a diagram of an airfield runway or taxiway having a plurality of edge light assemblies positioned along each side of the runway or taxiway for detecting various size aircraft as shown;

FIG. 5 is a block diagram of the central computer system shown in FIG. 1;

FIG. 6 shows eleven network variables used in programming the microprocessor of an edge light assembly to interface with a sensor, a light and a strobe light;

FIG. 7 is a block diagram showing an interconnection of network variables for a plurality of edge light assemblies located on both sides of a runway, each comprising a sensor electronics unit 10 positioned along a taxiway or runway;

FIG. 8 shows a graphic display of a typical taxiway/runway on a portion of an airport as seen by an operator in a control tower, the display showing the location of vehicles as they are detected by the sensors mounted in the edge light assemblies located along taxiways and runways; and

FIG. 9 is a block diagram of the data flow within the system shown in FIG. 1 and FIG. 5.

Description of the Preferred Embodiment

Referring to FIG. 1 a block diagram of the invention of an airport vehicle detection system 10 is shown comprising a plurality of light circuits 18_{1-n}, each of said light circuits 18_{1-n} comprises a plurality of edge light assemblies 20_{1-n} connected via wiring 21_{1-n} to a lighting vault 16 which is connected to a central computer system 12 via a wide area network 14. Each of the edge light assemblies 20_{1-n} comprises an infrared (IR) detector vehicle sensor 50 (FIG. 2).

The edge light assemblies 20_{1-n} are generally located alongside the runways and taxiways of the airport with an average 100 foot spacing and are interconnected to the lighting vault 16 by single conductor series edge light wiring 21_{1-n}. Each of the edge light circuits 18_{1-n} is powered via the wiring 21_{1-n} by a constant current supply 24_{1-n} located in the lighting vault 16.

Referring now to FIG. 1 and FIG. 2, communication between the edge light assemblies 20_{1-n} and the central computer system 12 is accomplished with LON Bridges 22_{1-n} interconnecting the edge light wiring 21_{1-n} with the Wide Area Network 14. Information from a microprocessor 44 located in each edge light assembly 20_{1-n} is coupled to the edge light wiring 21_{1-n} via a power line modem 54. The LON bridges 22_{1-n} transfers message information from the edge light circuits 18_{1-n} via the wiring 21_{1-n} to the wide area network 14. The wide area network 14 provides a transmission path to the central computer system 12. These circuit components also provide the return path communications link from the central computer system 12 to the microprocessor 44 in each edge light assembly 20_{1-n}. Other apparatus and methods, known to one of ordinary skill in the art, for data communication between the edge light assemblies 20_{1-n} and the central computer system 12 may be employed, such as radio techniques, but the present embodiment of providing data communication on the edge light wiring 21_{1-n} provides a low cost system for present airports. The LON Bridge 22 may be embodied by devices manufactured by Echelon Corporation of Palo Alto, California. The wide area network 14 may be implemented by one of ordinary skill in the art using standard Ethernet or Fiber Distributed Data Interface (FDDI) components. The constant current supply 24 may be embodied by devices manufactured by Crouse-Hinds of Winslow, Connecticut.

Referring now to FIG. 2 and FIG. 3, FIG. 3 shows a pictorial diagram of the edge light assembly 20_{1-n}. The edge light assembly 20_{1-n} comprises a bezel including an incandescent lamp 40 and an optional strobe light assembly 48 (FIG. 2) which are mounted above an electronics enclosure 43 comprising the vehicle sensor 50. The electronics enclosure 43 sits on the top of a tubular shaft extending from a base support 56. The light assembly bezel with lamp 40 and base support 56 may be embodied by devices manufactured by Crouse-Hinds of Winslow, Connecticut.

A block diagram of the contents of the electronics enclosure 43 is shown in FIG. 2 which comprises a coupling transformer 53 connected to the edge light wiring 21_{1-n}. The coupling transformer 53 provides power to both the incandescent lamp 40 via the lamp control triac 42 and the microprocessor power supply 52; in addition, the coupling transformer 53 provides a data communication path between the power line modem 54 and the LON Bridges 22_{1-n} via the edge light wiring 21_{1-n}. The microprocessor 44 provides the computational power to run the internal software program that controls the edge light assemblies 20_{1-n}. The microprocessor 44 is powered by the microprocessor power supply 52. Also connected to the microprocessor 44 is the lamp control triac 42, a lamp monitoring photo cell 46, the optional strobe light assembly 48, the vehicle sensor 50, and the data communications modem 54. The microprocessor 44 is used to control the incandescent edge light 40 intensity and optional strobe light assembly 48. The use of the microprocessor 44 in each light assembly 20_{1-n} allows complete addressable control over every light on the field. The microprocessor 44 may be embodied by a VLSI device manufactured by Echelon Corporation of Palo Alto, California 94304, called the Neuron® chip.

Still referring to FIG. 2, the sensor 50 in the present embodiment comprises an infrared (IR) detector and in other embodiments may comprise other devices such as proximity detectors, CCD cameras, microwave motion detectors, inductance loops, or laser beams. The program in the microprocessor 44 is responsible for the initial filtering of the sensor data received from the sensor 50 and responsible for the transmission of such data to the central computer system 12. The sensor 50 must perform the following functions: detect a stationary object, detect a moving object, have a range at least half the width of the runway or taxiway, be low power and be immune to false alarms. This system design does not rely on just one type of sensor. Since sensor fusion functions are performed within the central computer system 12, data inputs from all different types of sensors are acceptable. Each sensor relays a different view of what is happening on the airfield and the central computer system 12 combines them. There are a wide range of sensors that may be used in this system. As a new sensor type becomes available, it can be integrated into this system with a minimum of difficulty. The initial sensor used is an IR proximity detector based around a piezoelectric strip. These are the kind of sensors you use at home to turn on your flood lights when heat and/or movement is detected. When the sensor output provides an analog signal, an analog-to-digital converter readily known in the art may be used to interface with the microprocessor 44.

Another proximity detector that can be used is based around a microwave Gunn diode oscillator. These are currently in use in such applications as Intrusion Alarms, Door Openers, Distance Measurement, Collision Warning, Railroad Switching, etc. These types of sensors have a drawback because they are not passive devices and care needs to be taken to select frequencies that would not interfere with other airport equipment. Finally, in locations such as the hold position lines on taxiways, solid state laser and detector combinations could be used between adjacent taxiway lights. These sensor systems create a beam that when broken would identify the location of the front wheel of the airplane. This type of detector would be used in those locations where the absolute position of a vehicle was needed. The laser beam would be modulated by the microprocessor 44 to avoid the detector being fooled by any other stray radiation.

Referring to FIG. 2 and FIG. 4, a portion of an airport runway 64 or taxiway is shown having a plurality of edge light assemblies 20_{1-8} positioned along each side of the runway or taxiway for detecting various size airplanes or vehicles 60, 62. The dashed lines represent the coverage area of the sensors 50 located in each edge light assembly 20_{1-8} positioned along each side of the runway 64 or taxiway to insure detection of any airplane 60, 62 or other vehicles traveling on such runway 64 or taxiway. The edge light assemblies 20_{1-n} comprising the sensor 50 are logically connected together in such a way that an entire airport is sensitized to the movement of vehicles. Node to node communication takes place to verify and identify the location of the vehicles. Once this is done a message is sent to the central computer system 12 reporting the vehicles location. Edge light assemblies (without a sensor electronics unit 43) and taxiway power wiring currently exist along taxiways, runways and open areas of airports; therefore, the sensor electronics unit 43 is readily added to existing edge lights and existing taxiway power wiring without the inconvenience and expense of closing down runways and taxiways while installing new cabling.

Referring now to FIG. 1, FIG. 5, FIG. 8 and FIG. 9, the central computer system 12 is generally located at a control tower or terminal area of an airport and is interconnected to the LON Bridges 22_{1-n} located in the lighting vault 16 with a Wide Area Network 14. The central computer system 12 comprises two redundant computers, computer #1 26 and computer #2 28 for fault tolerance, the display 30, speech synthesis units 29 & 31, alert lights 34, keyboard 27 and a speech recognition unit 33, all of these elements being interconnected by the wide area network 14 for the transfer of information. The two computers 26 and 28 communicate with the microprocessors 44 located in the edge light assemblies 20_{1-n}. Data received from the edge light assembly 20_{1-n} microprocessors 44 are used as an input to a sensor fusion software module 101 (FIG. 9) run on the redundant computers 26 and 28. The output of the sensor fusion software module 101 operating in the computers 26, 28 is used to drive the CRT display 30 which displays the location of each vehicle on the airport taxiway and runways as shown in FIG. 8. The central computer system 12 may be embodied by devices manufactured by IBM Corporation of White Plains, New York. The Wide Area Network 14 may be embodied by devices manufactured by 3Com Corporation of Santa Clara, California. The speech synthesis units 29, 31 and the speech recognition unit 33 may be embodied by devices manufactured by BBN of Cambridge, Massachusetts.

The speech synthesis unit 29 is coupled to a speaker 32. Limited information is sent to the speech synthesis unit 29 via the wide area network 14 to provide the capability to give an air traffic controller a verbal alert. The speech synthesis unit 31 is coupled to a radio 37 having an antenna 39 to provide the capability to give the pilots a verbal alert. The voice commands from the air traffic controller to the pilots are captured by microphone 35 and sent to the pilots via radio 36 and antenna 38. In the present embodiment a tap is made and the speech information is sent to both the radio 36 and the speech recognition unit 33 which is programmed to recognize the limited air traffic control vocabulary used by a controller. This includes airline names, aircraft type, the numbers 0-9, the name of the taxiways and runways and various short phrases such as "hold short", "expedite" and "give way to." The output of the speech recognition unit 33 is fed to the computers 26, 28.

Referring again to FIG. 2, the power line modem 54 provides a data communication path over the edge light wiring 21_{1-n} for the microprocessor 44. This two way path is used for the passing of command and control information between the various edge light assemblies 20_{1-n} and the central computer system 12. A power line transceiver module in the power line modem 54 is used to provide a data channel. These modules use a carrier current approach to create the data channel. Power line modems that operate at carrier frequencies in the 100 to 450 Khz band are available from many manufacturers. These modems provide digital communication paths at data rates of up to 10,000 bits per second utilizing direct sequence spread spectrum modulation. They conform to FCC power line carrier requirements for conducted emissions, and can work with up to 55 dB of power line attenuation. The power line modem 54 may be embodied by a device manufactured by Echelon Corporation of Palo Alto, California 94304, called the PLT-10 Power Line Transceiver Module.

The data channel provides a transport layer or lowest layer of the open system interconnection (OSI) protocol used in the data network. The Neuron® chip which implements the microprocessor 44 contains all of the firmware required to implement a 7 layer OSI protocol. When interconnected via an appropriate medium the Neuron® chips automatically communicate with one another using a robust Collision Sense Multiple Access (CSMA) protocol with forward error corrections, error checking and automatic retransmission of missed messages (ARQ).

The command and control information is placed in data packets and sent over the network in accordance with the 7 Layer OSI protocol. All messages generated by the microprocessor 44 and destined for the central computer system 12 are received by the network bridge 22 via the power lines 21_{1-n} and routed to the central computer system 12 over the wide area network 14.

The Neuron® chip of the microprocessor 44 comprises three processors (not shown) and the firmware required to support a full 6 layer open systems interconnection (OSI) protocol. The user is allocated one of the processors for the application code. The other two processors give the application program access to all of the other Neuron® chips in the network. This access creates a Local Operating Network or LON. A LON can be thought of as a high level local area network LAN. The use of the Neuron® chip for the implementation of this invention, reduces the amount of custom hardware and software that otherwise would have to be developed.

Data from the sensor electronic unit 43 of the edge light assemblies 20_{1-n} is coupled to the central computer system 12 via the existing airport taxiway lighting power wiring 21. Using the existing edge light power line to transfer the sensor data into a LON network has many advantages. As previously pointed out, the reuse of the existing edge lights eliminates the inconvenience and expense of closing down runways and taxiways while running new cable and provides for a low cost system.

The Neuron® chip allows the edge light assemblies 20_{1-n} to automatically communicate with each other at the applications level. This is accomplished through network variables which allow individual Neuron® chips to pass data between themselves. Each Neuron® 'C' program comprises both local and network variables. The local variables are used by the Neuron® program as a scratch pad memory. The network variables are used by the Neuron® program in one of two ways, either as a network output variables or a network input variables. Both kinds of variables can be initialized, evaluated and modified locally. The difference comes into play in that once a network output variable is modified, network messages are automatically sent to each network input variable that is linked to that output variable. This variable linking is done at installation time. As soon as a new value of a network input variable is received by a Neuron® chip, the code is vectored off to take appropriate action based upon the value of the network input variable. The advantage to the program is that this message passing scheme is entirely transparent since the message passing code is part of the embedded Neuron® operating system.

Referring now to FIG. 6, eleven network variables have been identified for a sensor program in each microprocessor 44 of the edge light assemblies 20_{1-n}. The sensor 50 function has two output variables: prelim_detect 70 and confirmed_detect 72. The idea here is to have one output trigger whenever the sensor 50 detects movement. The other output does not trigger unless the local sensor and the sensor on the edge light across the runway both spot movement. Only when the detection is confirmed will the signal be fed back to the central computer system 12. This technique of confirmation helps to reduce false alarms in order to implement this technique the adjacent sensor 50 has an input variable called adj_prelim_detect 78 that is used to receive the other sensors prelim_detect output 70. Other input variables are upstream_detect 74 and downstream_detect 76 which are used when chaining adjacent sensors together. Also needed is a detectQr_sensitivity 80 input that is used by the central computer system 12 to control the detection ability of the sensor 50.

The incandescent light 40 requires two network variables, one input and the other an output variable. The input variable light_level 84 would be used to control the light's brightness. The range would be OFF or 0% all the way to FULL ON or 100%. This range from 0% to 100% would be made in 0.5% steps. Since the edge light assembly 20_{1-n} also contains the photocell 46, an output variable light_failure 84 is created to signal that the lamp did not obtain the desired brightness.

The strobe light 48 requires three input variables. The strobe-mode 86 variable is used to select either the OFF, SEQUENTIAL, or ALTERNATE flash modes. Since the two flash modes require a distinct pattern to be created, two input variables active_delay 88 and flash_delay 90 are used to time align the strobe flashes. By setting these individual delay factors and then addressing the Neuron® chips as a group, allows the creation of a field strobe pattern with just one command.

Referring now to FIG. 7, a block diagram of an interconnection of network variables for a plurality of edge light assemblies 20_{1-n} located on both sides of a runway is shown, each of the edge light assemblies 20_{1-n} comprising a microprocessor 44. Each Neuron® program in the microprocessor 44 is designed with certain network input and output variables. The user writes the code for the Neuron® chips in the microprocessor 44 assuming that the inputs are supplied and that the outputs are used. To create an actual network the user has to "wire up" the network by interconnecting the individual nodes with a software linker. The resulting distributed process is best shown in schematic form, and a portion of the network interconnect matrix is shown in Figure 7. The prelim_detect 70 output of a sensor node 441 is connected to the adj_primary_detect 92 input of the sensor node 44_4 across the taxiway. This is used as a means to verify actual detections and eliminate false reports. The communications link between these two nodes 44_1 and 44_4 is part of the distributed processing. The two nodes communicate among themselves without involving the central computer system 12. If in the automatic mode or if instructed by the controller, the system will also alert the pilots via audio and visual indications.

Referring again to FIG. 1 and FIG. 4, the central computer system 12 tracks the movement of vehicles as they pass from the sensor 50 to sensor 50 in each edge light assembly 20_{1-n}. Using a variation of a radar automatic track algorithm, the system can track position, velocity and heading of all aircraft or vehicles based upon the sensor 50 readings. New vehicles are entered into the system either upon leaving a boarding gate or landing. Unknown vehicles are also tracked automatically. Since taxiway and runway lights are normally across from each other on the pavement (as shown in FIG. 4 and FIG. 7), the microprocessor 44 in each edge lights assembly 20_{1-n} is programmed to combine their sensor 50 inputs and agree before reporting a contact. A further refinement is to have the microprocessor 44 check with the edge light assemblies 20_{1-n} on either side of them to see if their sensors 50 had detected the vehicle. This allows a vehicle to be handed off from sensor electronic unit 43 to sensor electronic unit 43 of each edge light assembly 20_{1-n} as it travels down the taxiway. This also assures that vehicle position reports remain consistent. Vehicle velocity may also be calculated by using the distance between sensors, the sensor pattern and the time between detections.

Referring to FIG. 5 and FIG. 8, the display 30 is a color monitor which provides a graphical display of the airport, a portion of which is shown in FIG. 8. This is accomplished by storing a map of the airport in the redundant computers 26 and 28 in a digital format. The display 30 shows the location of airplanes or vehicles as they are detected by the sensors 50 mounted in the edge light assemblies 20_{1-n} along each taxiway and runway or other airport surface areas. All aircraft or vehicles on the airport surface are displayed as icons, with the shape of the icons being determined by the vehicle type. Vehicle position is shown by the location of the icon on the screen. Vehicle direction is shown by either the orientation of the icon or by an arrow emanating from the icon. Vehicle status is conveyed by the color of the icon. The future path of the vehicle as provided by the ground clearance command entered via the controllers microphone 35 is shown as a colored line on the display 30. The status of all field lights including each edge light 20_{1-n} in each edge light circuit 18_{1-n} is shown via color on the display 30.

Use of object orientated software provides the basis for building a model of an airport. The automatic inheritance feature allows a data structure to be defined once for each object and then replicated automatically for each instance of that object. Automatic flow down assures that elements of the data base are not corrupted due to typing errors. It also assures that the code is regular and structured. Rule based object oriented programming makes it difficult to create unintelligible "spaghetti code." Object oriented programming allows the runways, taxiways, aircraft and sensors, to be decoded directly as objects. Each of these objects contains attributes. Some of these attributes are fixed like runway 22R or flight UA347, and some are variable like vehicle status and position.

In conventional programming we describe the attributes of an object in data structures and then describe the behaviors of the object as procedures that operate on those data structures. Object oriented programming shifts the emphasis and focuses first on the data structure and only secondarily on the procedures. More importantly, object oriented programming allows us to analyze and design programs in a natural manner. We can think in terms of runways and aircraft instead of focusing on either the behavior or the data structures of the runways and aircraft.

Table 1 shows a list of objects with corresponding attributes. Each physical object that is important to the runway incursion problem is modeled. The basic airplane or vehicle tracking algorithm is shown in Table 2 in a Program Design Language (PDL). The algorithm which handles sensor fusion, incursion avoidance and safety alerts is shown in a single program even though it is implemented as distributed system using both the central computer system 12 and the sensor microprocessors 44.

TABLE 1

OBJECT	ATTRIBUTE	DESCRIPTION
Sensor	Location	X & Y coordinates of sensor
	Circuit	AC wiring circuit name & number
	Unique_address	Net address for this sensor and its mate
	Lamp_intensity	0% to 100% in 0.5% steps
	Strobe_status	Blink rate/off
	Strobe-delay	From start signal
	Sensor_status	Detect/no detect
	Sensor_type	IR, laser, proximity, etc.
Runway	Name	22R, 27, 33L, etc.
	Location	X & Y coordinates of start of center line
	Length	In feet
	Width	In feet
	Direction	In degrees from north
	Status	Not_active, active_takeoff, active_landing, alarm
	Sensors (MV)	List of lights/sensors along this runway
	Intersections (MV)	List of intersections
	Vehicles	List of vehicles on the runway
Taxiway	Name	Name of taxiway
	Location	X & Y coordinates of start of center line
	Length	In feet
	Width	In feet
	Direction	In degrees from north
	Status	Not active, active, alarm
	Sensors (MV)	List of intersections
	Hold_Locations	List of holding locations
	Vehicles (MV)	List of vehicles on the runway

Intersection	Name	Intersection Name
	Location	Intersection of two center lines
	Status	Vacant/Occupied
	Sensors (MV)	List of sensors creating intersection border
Aircraft	Airline	United
	Model	727-200
	Tail-number	N3274Z
	Empty_weight	9.5 tons
	Freight_weight	2.3 tons
	Fuel_weight	3.2 tons
	Top_speed	598 mph
	V1_speed	100 mph
	V2_speed	140 mph
	Acceleration	0.23 g's
	Deceleration	0.34 g's

MV = Multi-variable or array

Table 2

```
while (forever)
|  if (edge light shows a detection)
|  |  if (adjacent light also shows a detection sensor fusion)
|  |  |  /* CONFIRMED DETECTION */
|  |  |  if (previous block showed a detection)
|  |  |  |  /* ACCEPT HANDOFF */
|  |  |  |  Update aircraft position and speed
|  |  |  else
|  |  |  |  /* MAY BE AN ANIMAL OR SERVICE TRUCK */
|  |  |  |  Alert operator to possible incursion
|  |  |  |  /* MAY BE AN AIRCRAFT ENTERING THE SYSTEM */
|  |  |  |  Start a new track
|  |  else
|  |  |  Request status from adjacent light
```

```
|   |   |   if (Adjacent light is OK)
|   |   |   |   /* NON CONFIRMED DETECTION */
|   |   |   else
|   |   |   |   Flag adjacent light for repair
|   |   |   endif
|   |   endif
|   endif
|   if (Edge light loses a detection AND status is OK)
|   |   if (Next block showed a detection)
|   |   |       /* PROPER HANDOFF */
|   |   else
|   |   |   if (vehicle speed > = takeoff)
|   |   |   |   Handoff to departure control
|   |   |   else
|   |   |   |   /* MISSING HANDOFF */
|   |   |   |   Alert operator to possible incursion
|   |   |   endif
|   |   endif
|   endif
|   /* CHECK FOR POSSIBLE COLLISIONS */
|   for (all tracked aircraft)
|   |   Plot future position
|   |   if (position conflict)
|   |   |       Alert operator to possible incursion
|   |   endif
|   endif
|   Update display
endwhile
```

Referring again to FIG. 1 and FIG. 2, the control of taxiway lighting intensity is usually done by placing all the lights on the same series circuit and then regulating the current in that circuit. In the present embodiment the intensity of the lamp 40 is controlled by sending a message with the light intensity value to the microprocessor 44 located within the light assembly 20_{1-n}. The message allows for intensity settings in the range of 0 to 100% in 0.5% steps. The use of photocell 46 to check the light output allows a return message to be sent if the bulb does not respond. This in turn generates a maintenance report on the light. The strobe light 48 provides an additional optional capability under program control of the microprocessor 44. Each of the microprocessors 44 in the edge light assemblies 20 is individually addressable. This means every lamp on the field is controlled individually by the central computer system 12.

The system 10 can be programmed to provide an Active Runway Indicator by using the strobe lights 48 in those edge light assemblies 20_{1-n} located on the runway 64 to continue the approach light "rabbit" strobe pattern all the way down the runway. This lighting pattern could be turned-on as a plane is cleared for landing and then turned-off after the aircraft has touched down. A pilot approaching the runway along an intersecting taxiway would be alerted in a clear and unambiguous way that the runway was active and should not be crossed.

If an incursion was detected the main computers 26, 28 could switch the runway strobe lights 48 from the "rabbit" pattern to a pattern that alternatively flashes either side of the runway in a wig-wag fashion. A switch to this pattern would be interpreted by the pilot of an arriving aircraft as a wave off and a signal to go around. The abrupt switch in the pattern of the strobes would be instantaneously picked up by the air crew in time for them to initiate an aborted landing procedure.

During Category III weather conditions both runway and taxiway visibility are very low. Currently radio based landing systems are used to get the aircraft from final approach to the runway. Once on the runway it is not always obvious which taxiways are to be used to reach the airport terminal. In system 10 the main computers 26,28 can control the taxiway lamps 40 as the means for guiding aircraft on the ground during CAT III conditions. Since the intensity of the taxiway lamps 40 can be controlled remotely, the lamps just in front of an aircraft could be intensified or flashed as a means of guiding it to the terminal.

Alternatively, a short sequence of the "rabbit" pattern may be programmed into the taxiway strobes just in front of the aircraft. At intersections, either the unwanted paths may have their lamps turned off or the entrance to the proper section of taxiway may flash directing the pilot to head in that direction. Of course in a smart system only those lights directly in front of a plane would be controlled, all other lamps on the field would remain in their normal mode.

Referring now to FIG. 9, a block diagram is shown of the data flow within the system 10 (as shown in FIG. 1 and FIG. 5). The software modules are shown that are used to process the data within the computers 26, 28 of the central computer system 12. The tracking of aircraft and other vehicles on the airport operates under the control of a sensor fusion software module 101 which resides in the computers 26, 28. The sensor fusion software module 101 receives data from the plurality of sensors 50, a sensor 50 being located in each edge light assembly 20_{1-n} which reports the heat level detected, and this software module 101 combines this information through the use of rule based artificial intelligence to create a complete picture of all ground traffic at the airport on a display 30 of the central computer system 12.

The tracking algorithm starts a track upon the first report of a sensor 50 detecting a heat level that is above the ambient background level of radiation. This detection is then verified by checking the heat level reported by the sensor directly across the pavement from the first reporting sensor. This secondary reading is used to confirm the vehicle detected and to eliminate false alarms. After a vehicle has been confirmed the sensors adjacent to the first reporting sensor are queried for changes in their detected heat level. As soon as one of the adjacent sensors detects a rise in heat level a direction vector for the vehicle can be established. This process continues as the vehicle is handed off from sensor to sensor in a bucket brigade fashion as shown in FIG. 7. Vehicle speed can be roughly determined by calculating the time between vehicle detection by adjacent sensors. This information is combined with information from a system data base on the location of each sensor to calculate the velocity of the target. Due to hot exhaust or jet blast, the sensors behind the vehicle may not return to a background level immediately. Because of these condition, the algorithm only uses the first four sensors (two on either side of the taxiway) to calculate the vehicles position. The vehicle is always assumed to be on the centerline of the pavement and between the first four reporting sensors.

Vehicle identification can be added to the track either manually or automatically by an automated source that can identify a vehicle by its position. An example would be prior knowledge of the next aircraft to land on a particular runway. Tracks are ended when a vehicle leaves the detection system. This can occur in one of two ways. The first way is that the vehicle leaves the area covered by the sensors 50. This is determined by a vehicle track moving in the direction of a gateway sensor and then a lack of detection after the gateway sensor has lost contact. A second way to leave the detection system is for a track to be lost in the middle of a sensor array. This can occur when an aircraft departs or a vehicle runs onto the grass. Takeoff scenarios can be determined by calculating the speed of the vehicle just before detection was lost. If the vehicle speed was increasing and above rotation speed then the aircraft is assumed to have taken off. If not then the vehicle is assumed to have gone on to the grass and an alarm is sounded.

Referring to FIG. 5 and FIG. 9, the ground clearance routing function is performed by the speech recognition unit 33 along with the ground clearance compliance verifier software module 103 running on the computers 26, 28. This software module 103 comprises a vehicle identification routine, clearance path routing, clearance checking routine and a path checking routine.

The vehicle identification routine is used to receive the airline name and flight number (i.e. "Delta 374") from the speech recognition unit 33 and it highlights the icon of that aircraft on the graphic display of the airport on display 30.

The clearance path routine takes the remainder of the controller's phrase (i.e. "outer taxiway to echo, hold short of runway 15 Left") and provides a graphical display of the clearance on the display 30 showing the airport.

The clearance checking routine checks the clearance path for possible conflict with other clearances and vehicles. If a conflict is found the portion of the path that would cause an incursion is highlighted in a blinking red and an audible indication is given to the controller via speaker 32.

The path checking routine checks the actual path of the vehicle as detected by the sensors 50 after the clearance path has been entered into the computers 26, 28 and it monitors the actual path for any deviation. If this routine detects that a vehicle has strayed from the assigned course, the vehicle icon on the graphic display of the airport flashes and an audible indicator is given to the controller via speaker 32 and optionally the vehicle operator via radio 37.

The airport system 10 operates in a vehicle detection mode under the control of safety logic routines which reside in the collision detection software module 104 running on computers 26, 28. The safety logic routines receive data from the sensor fusion software module 101 via the tracker software module 102 location program and interpret this information through the use of rule based artificial intelligence to predict possible collisions or runway incursions. This information is then used by the central computer system 12 to alert tower controllers, aircraft pilots and truck operators to the possibility of a runway incursion. The tower controllers are alerted by the display 30 along with a computer synthesized voice message via speaker 32. Ground traffic is alerted by a combination of traffic lights, flashing lights, stop bars and other alert lights 34, lamps 40 and 48, and computer generated voice commands broadcast via radio 36.

Knowledge based problems are also called fuzzy problems and their solutions depend upon both program logic and an interface engine that can dynamically create a decision tree, selecting which heuristics are most appropriate for the specific case being considered. Rule based systems broaden the scope of possible applications. They allow designers to incorporate judgement and experience, and to take a consistent solution approach across an entire problem set.

The programming of the rule based incursion detections software is very straight forward. The rules are written in English allowing the experts, in this case the tower personnel and the pilots, to review the system at an understandable level. Another feature of the rule based system is that the rules stand alone. They can be added, deleted or modified without affecting the rest of the code. This is almost impossible to do with code that is created from scratch. An example of a rule we might use is:

```
If (Runway_Status = Active)
    then (Stop_Bar_Lights = RED).
```

This is a very simple and straight forward rule. It stands alone requiring no extra knowledge except how Runway_Status is created. So let's make some rules affecting Runway_Status.

```
If (Departure = APPROVED) or (Landing = IMMINENT),
    then (Runway_Status = ACTIVE).
```

For incursion detection, another rule is:

```
If (Runway_Status = ACTIVE) and (Intersection = OCCUPIED),
    then (Runway_Incursion = TRUE).
```

Next, detect that an intersection of a runway and taxiway are occupied by the rules:

```
If (Intersection_Sensors = DETECT),
    then (Intersection = OCCUPIED).
```

To predict that an aircraft will run a Hold Position stop, the following rule is created:

```
If (Aircraft_Stopping_Distance > Distance_to_Hold_Position),
    then (Intersection = OCCUPIED).
```

In order to show that rules can be added without affecting the reset of the program, assume that after a demonstration of the system 10 to tower controllers, they decided that they wanted a "Panic Button" in the tower to override the rule based software in case they spot a safety violation on the ground. Besides installing the button, the only other change would be to add this extra rule.

```
If (Panic_button = PRESSED),
    then (Runway_Incursion = TRUE).
```

It is readily seen that the central rule based computer program is very straight forward to create, understand and modify. As types of incursions are defined, the system 10 can be upgraded by adding more rules.

Referring again to FIG. 9, the block diagram shows the data flow between the functional elements within the system 10 (FIG. 1). Vehicles are detected by the sensor 50 in each of the edge light assemblies 20_{1-n}. This information is passed over the local operating network (LON) via edge light wiring 21_{1-n} to the LON bridges 22_{1-n}. The individual message packets are then passed to the redundant computers 26 and 28 over the wide area network (WAN) 14 to the WAN interface 108. After arriving at the redundant computers 26 and 28, the message packet is checked and verified by a message parser software module 100. The contents of the message are then sent to the sensor fusion software module 101. The sensor fusion software module 101 is used to keep track of the status of all the sensors 50 on the airport; it filters and verifies the data from the airport and stores a representative picture of the sensor array in a memory. This information is used directly by the display 30 to show which sensors 50 are responding and used by the tracker software module 102. The tracker software module 102 uses the sensor status information to determine which sensor 50 reports correspond to actual vehicles. In addition, as the sensor reports and status change, the tracker software module 102 identifies movement of the vehicles and produces a target location and direction output. This information is used by the display 30 in order to display the appropriate vehicle icon on the screen.

The location and direction of the vehicle is also used by the collision detection software module 104. This module checks all of the vehicles on the ground and plots their expected course. If any two targets are on intersecting paths, this software module generates operator alerts by using the display 30, the alert lights 34, the speech synthesis unit 29 coupled to the associated speaker 32, and the speech synthesis unit 31 coupled to radio 37 which is coupled to antenna 39.

Still referring to FIG. 9, another user of target location and position data is the ground clearance compliance verifier software module 103. This software module 103 receives the ground clearance commands from the controller's microphone 35 via the speech recognition unit 33. Once the cleared route has been determined, it is stored in the ground clearance compliance verifier software module 103 and used for comparison to the actual route taken by the vehicle. If the information received from the tracker software module 102 shows that the vehicle has deviated from its assigned course, this software module 103 generates operator alerts by using the display 30, the alert lights 34, the speech synthesis unit 29 coupled to speaker 32, and the speech synthesis unit 31 coupled to radio 37 which is coupled to antenna 39.

The keyboard 27 is connected to a keyboard parser software module 109. When a command has been verified by the keyboard parser software module 109, it is used to change display 30 options and to reconfigure the sensors and network parameters. A network configuration data base 106 is updated with these reconfiguration commands. This information is then turned into LON message packets by the command message generator 107 and sent to the edge light assemblies 20_{1-n} via the WAN interface 108 and the LON bridges 22_{1-n}.

This concludes the description of the preferred embodiment. However, many modifications and alterations will be obvious to one of ordinary skill in the art without departing from the spirit and scope of the inventive concept. Therefore, it is intended that the scope of this invention be limited only by the appended claims.

Claims

1. An airport surveillance system comprising:
   a plurality of light circuits on an airport, each of said light circuits comprises a plurality of light assembly means;
   means for providing power to each of said plurality of light circuits and to each of said light assembly means;
   means in each of said light assembly means for sensing ground traffic on said airport;
   means for processing data received from each of said light assembly means;
   means for providing data communication between each of said light assembly means and said processing means; and
   said processing means comprises means for providing a graphic display of said airport comprising symbols representing said ground traffic, each of said symbols having direction and velocity data displayed.

2. The airport surveillance system as recited in Claim 1 wherein:
   each of said light circuits being located along the edges of a taxiway or a runway on said airport.

3. The airport surveillance system as recited in Claim 1 wherein said light assembly means comprises:
   light means coupled to said lines of said power providing means for lighting said airport;
   said sensing means;
   microprocessor means coupled to said light means, said sensing means, and said data communication means for providing processing, communication and control for said light assembly means, said microprocessor controlling a plurality of lighting patterns of said light means on said airport; and
   said data communication means being coupled to said microprocessor means and said lines of said power providing means.

4. The airport surveillance system as recited in Claim 3 wherein: said sensing means comprises an infrared detector.

5. The airport surveillance system as recited in Claim 3 wherein: said light assembly means further comprises a photocell means coupled to said microprocessor means for detecting the light intensity of said light means.

6. The airport surveillance system as recited in Claim 3 wherein: said light assembly means further comprises a strobe light coupled to said microprocessor means.

7. The airport surveillance system as recited in Claim 1 wherein: said processing means comprises redundant computers for fault tolerance operation.

8. The airport surveillance system as recited in Claim 1 wherein: said symbols representing said ground traffic comprise icons having a shape indicating type of airplane or vehicle.

9. The airport surveillance system as recited in Claim 1 wherein: said processing means determines a location of said symbols on said graphic display of said airport in accordance with said data receive from said light assembly means.

10. The airport surveillance system as recited in Claim 1 wherein: said processing means determines a future path of said ground traffic based on a ground clearance command, said future path being shown on said graphic display.

11. The airport surveillance system as recited in Claim 1 wherein said power providing means comprises: constant current power means for providing a separate line to each of said plurality of light circuits; and

network bridge means coupled to said constant current power means for providing a communication channel to said processing means for each line of said constant current power means.

12. An airport surveillance system comprising:

a plurality of light circuits on an airport, each of said light circuits comprises a plurality of light assembly means;

means for providing power to each of said plurality of light circuits and to each of said light assembly means;

means in each of said light assembly means for sensing ground traffic on said airport;

means in each of said light assembly means coupled to said sensing means for providing communication and control for said light assembly means;

means for processing data received from each of said light assembly means;

means for providing data communication between each of said light assembly means and said processing means; and

said processing means comprises means for providing a graphic display of said airport comprising symbols representing said ground traffic in accordance with said data received from each of said light assembly means, each of said symbols having direction and velocity data displayed.

13. The airport surveillance system as recited in Claim 12 wherein: said sensing means comprises an infrared detector.

14. The airport surveillance system as recited in Claim 12 wherein: each of said light circuits being located along the edges of a taxiway or a runway on said airport.

15. The airport surveillance system as recited in Claim 12 wherein: said light assembly means further comprises a photocell means coupled to said communication and control providing means for detecting a light intensity of said light assembly means.

16. The airport surveillance system as recited in Claim 12 wherein: said light assembly means further comprises a strobe light coupled to said communication and control providing means.

17. The airport surveillance system as recited in Claim 12 wherein:
said processing means comprises redundant computers for fault tolerance operation.

18. The airport surveillance system as recited in Claim 12 wherein:
said symbols representing said ground traffic comprise icons having a shape indicating type of airplane or vehicle.

19. The airport surveillance system as recited in Claim 12 wherein:
said processing means determines a future path of said ground traffic based on a ground clearance command, said future path being shown on said graphic display.

20. The airport surveillance system as recited in Claim 12 wherein said power providing means comprises:
constant current power means for providing a separate line to each of said plurality of light circuits; and
network bridge means coupled to said constant current power means for providing a communication channel to said processing means for each line of said constant current power means.

21. A method of providing an airport surveillance system comprising the steps of:
providing a plurality of light circuits on said airport, each of said light circuits comprises a plurality of light assembly means;
providing power to each of said plurality of light circuits;
sensing ground traffic on said airport with means in each of said light assembly means;
processing data received from each of said light assembly means in computer means;
providing a graphic display of said airport comprising symbols representing said ground traffic, each of said symbols having direction and velocity data displayed; and
providing data communication between said computer means and each of said light assembly means.

22. The method as recited in Claim 21 wherein said step of sensing said ground traffic on said airport comprises the steps of:
lighting said airport with a light means coupled to said power lines;
providing infrared detectors for sensing ground traffic;
performing processing, communication and control within said light assembly means with a microprocessor means coupled to said light means, said infrared detectors and data communication means; and
coupling said data communication means between said microprocessor means and said power lines.

23. The method recited in Claim 21 wherein said step of processing data comprises the step of operating redundant computers for fault tolerance.

24. The method as recited in Claim 21 wherein said step of providing power comprises the steps of:
providing a separate line to each of said plurality of light circuits with a constant current power means; and
providing a communication channel to said computer means for each line of said constant current power means using a network bridge means.

25. The method as recited in Claim 21 wherein said step of providing a graphic display comprising symbols representing said ground traffic comprises the step of indicating a type of aircraft or vehicle with icons of various shapes.

26. The method as recited in Claim 21 wherein said step of processing said data from each of said light assembly means comprises the step of determining a location of said symbols on said graphic display of said airport in accordance with said data.

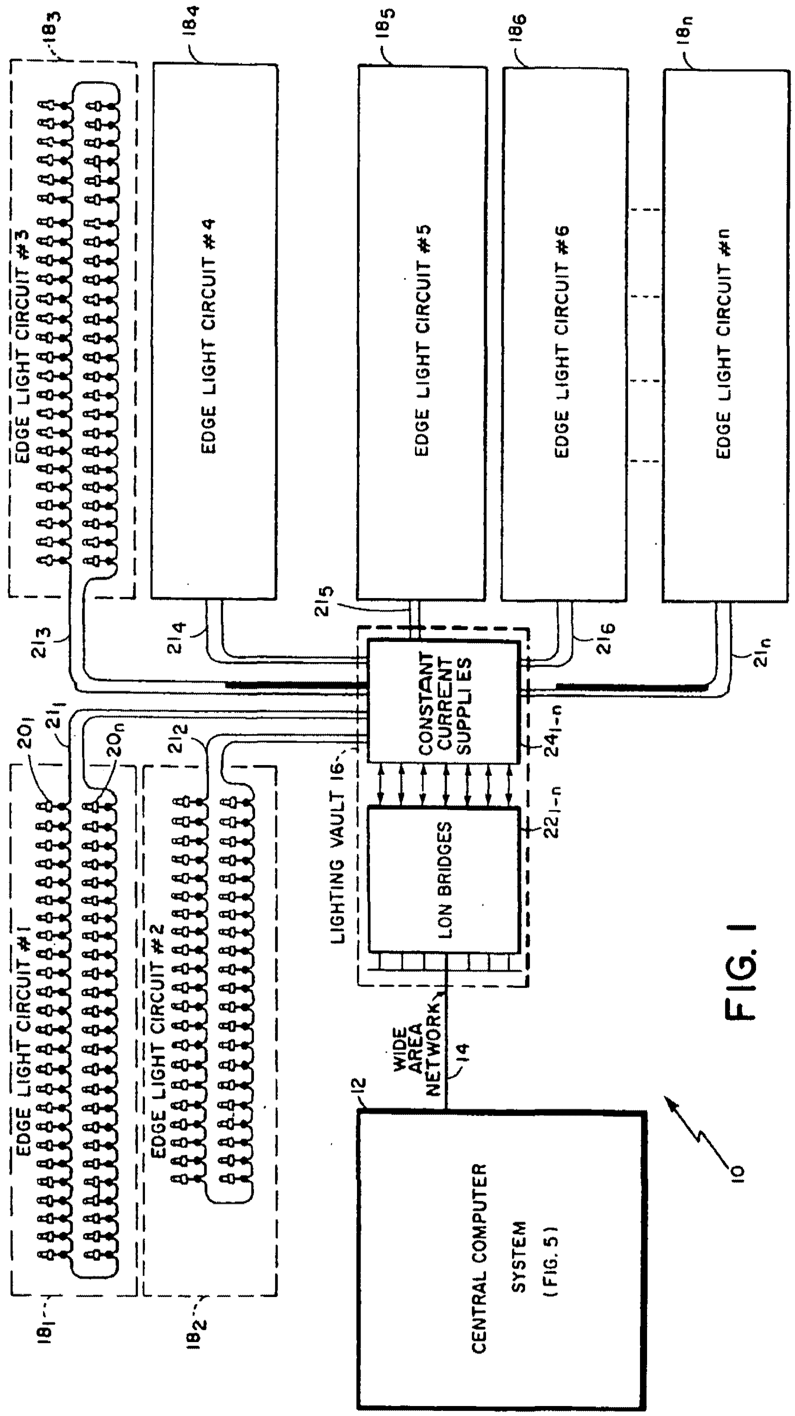
EDGE LIGHT CIRCUIT #1
EDGE LIGHT CIRCUIT #2
EDGE LIGHT CIRCUIT #3
EDGE LIGHT CIRCUIT #4
EDGE LIGHT CIRCUIT #5
EDGE LIGHT CIRCUIT #6
EDGE LIGHT CIRCUIT #n
CONSTANT CURRENT SUPPLIES
LON BRIDGES
LIGHTING VAULT 16
WIDE AREA NETWORK
14
12
CENTRAL COMPUTER SYSTEM (FIG. 5)
10
18₁
18₂
18₃
18₄
18₅
18₆
18ₙ
20₁
20ₙ
21₁
21₂
21₃
21₄
21₅
21₆
21ₙ
22₁₋ₙ
24₁₋ₙ

FIG. I

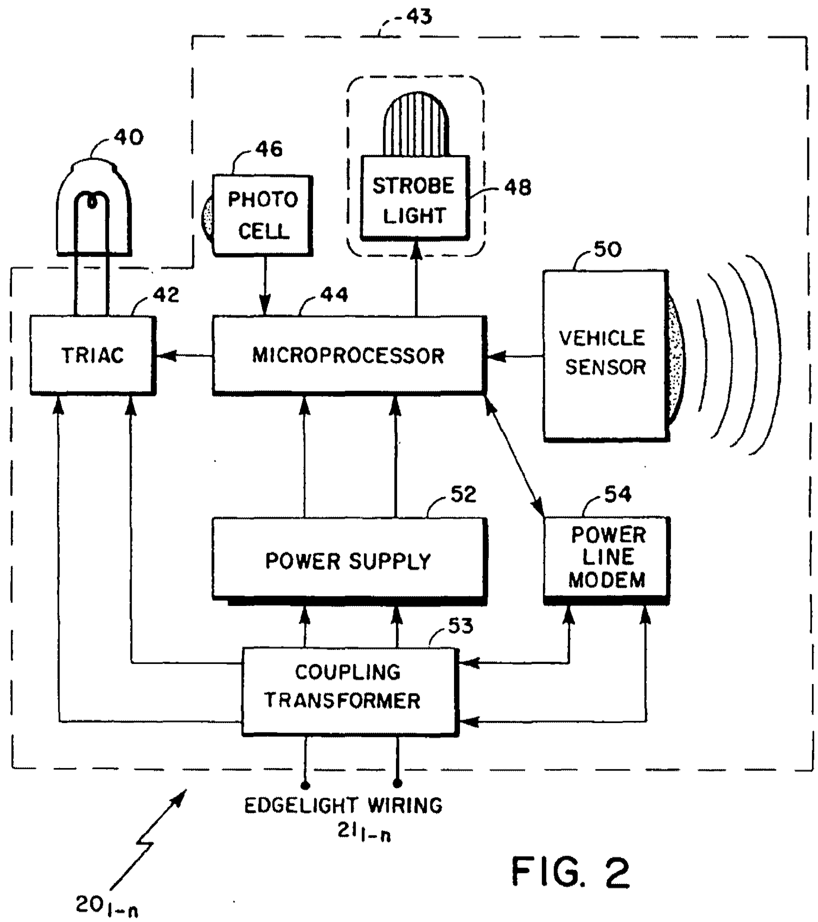
43
40
46
PHOTO CELL
STROBE LIGHT
48
50
42
44
TRIAC
MICROPROCESSOR
VEHICLE SENSOR
52
54
POWER SUPPLY
POWER LINE MODEM
53
COUPLING TRANSFORMER
EDGELIGHT WIRING
21_{1-n}
20_{1-n}

FIG. 2

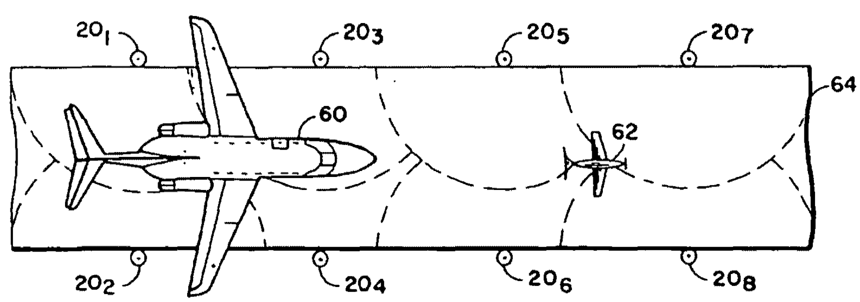
20_1
20_3
20_5
20_7
64
60
62
20_2
20_4
20_6
20_8

FIG. 4

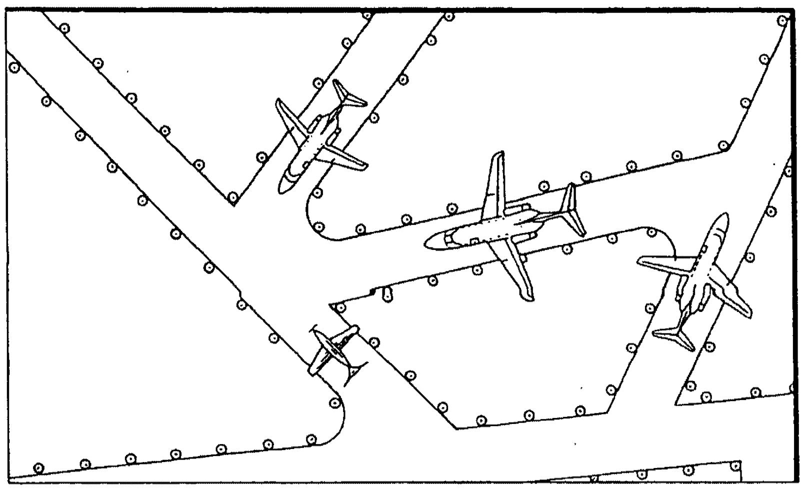

FIG. 8

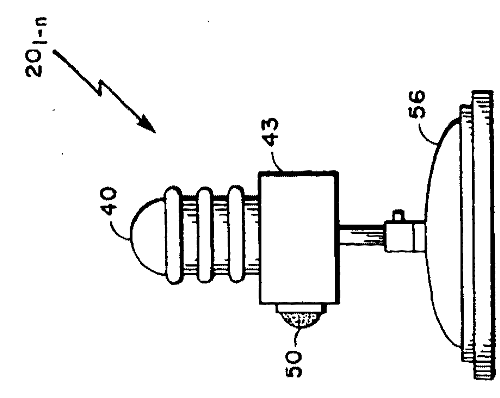

FIG. 3

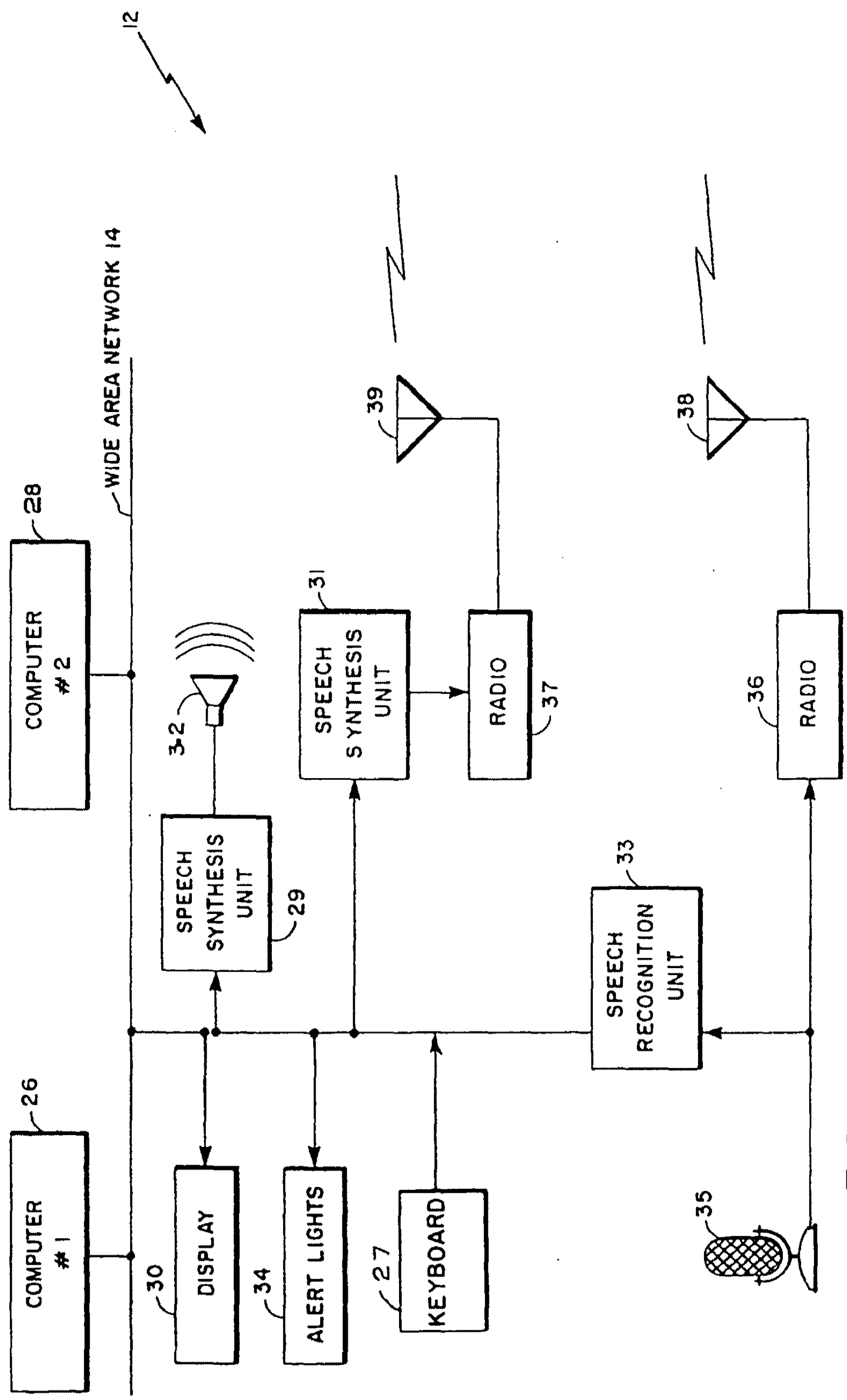
12
WIDE AREA NETWORK 14
COMPUTER # 2
28
COMPUTER # 1
26
SPEECH SYNTHESIS UNIT
29
32
SPEECH SYNTHESIS UNIT
31
RADIO
37
39
RADIO
36
38
SPEECH RECOGNITION UNIT
33
DISPLAY
30
ALERT LIGHTS
34
KEYBOARD
27
35

FIG. 5

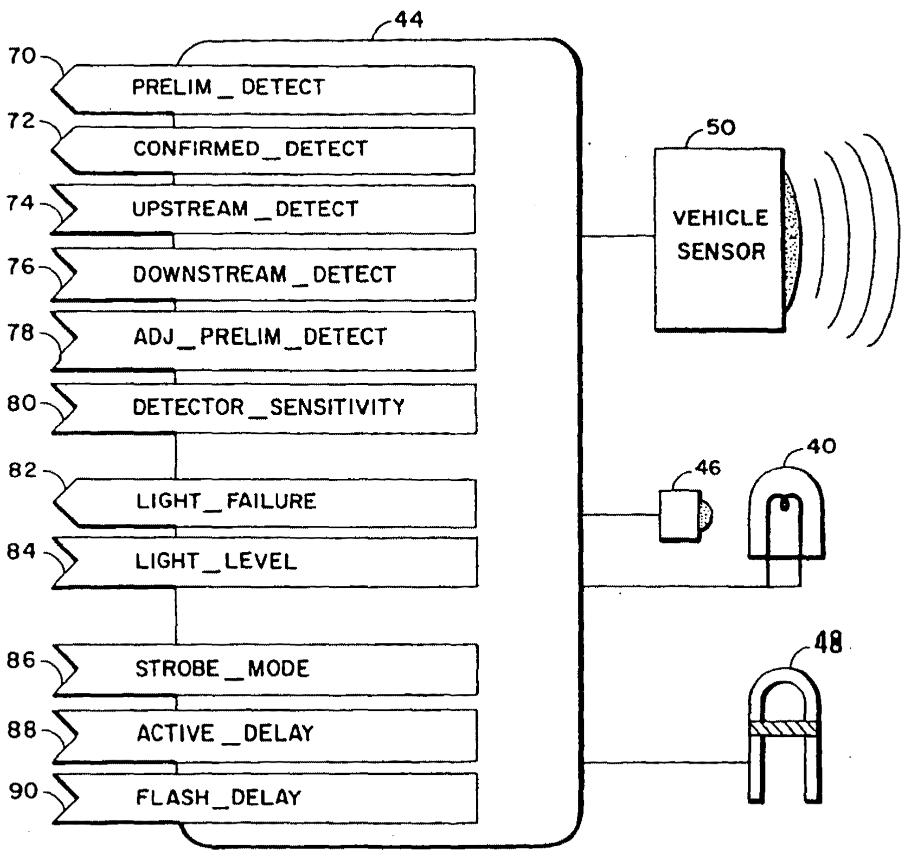
44
70
PRELIM _ DETECT
72
CONFIRMED _ DETECT
74
UPSTREAM _ DETECT
76
DOWNSTREAM _ DETECT
78
ADJ _ PRELIM _ DETECT
80
DETECTOR _ SENSITIVITY
82
LIGHT _ FAILURE
84
LIGHT _ LEVEL
86
STROBE _ MODE
88
ACTIVE _ DELAY
90
FLASH _ DELAY
50
VEHICLE SENSOR
46
40
48

FIG. 6

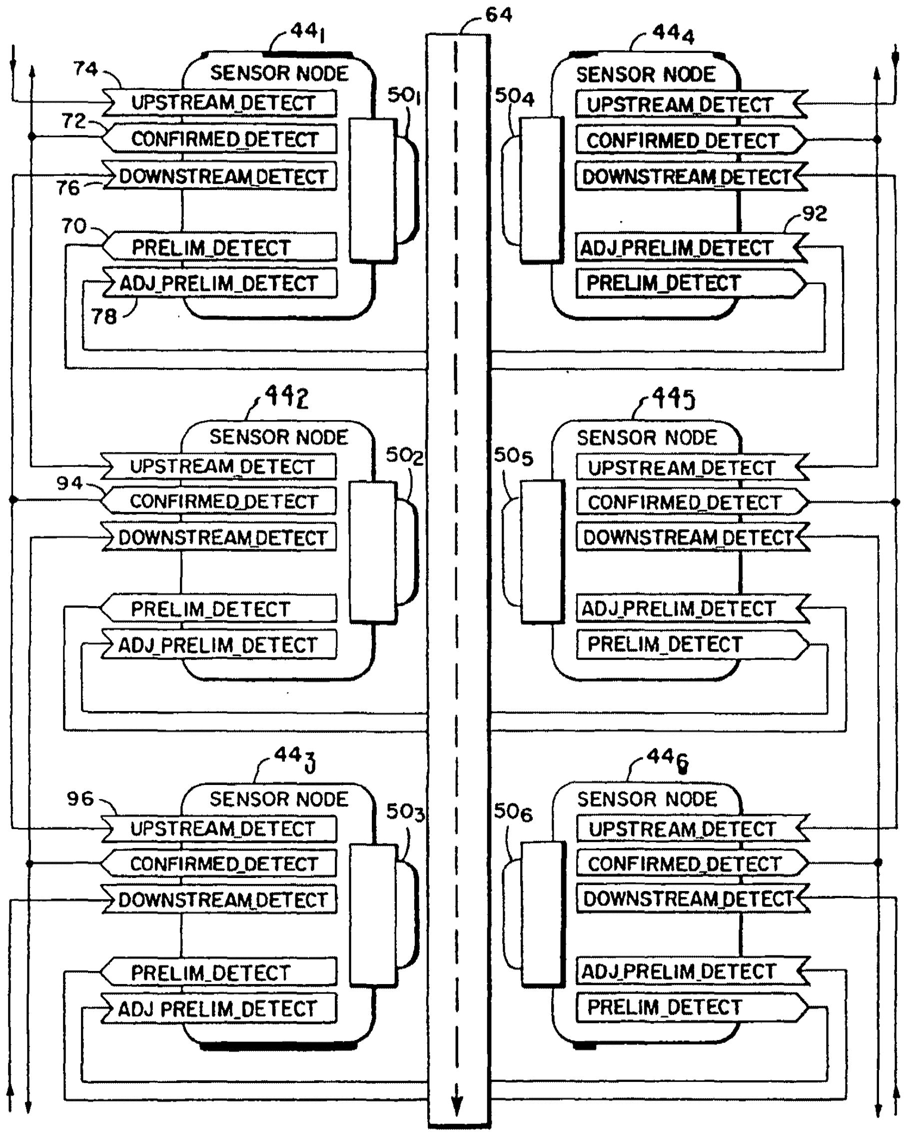
64
44₁
SENSOR NODE
74
UPSTREAM DETECT
72
CONFIRMED DETECT
76
DOWNSTREAM DETECT
70
PRELIM DETECT
ADJ PRELIM DETECT
78
50₁
50₄
44₄
SENSOR NODE
UPSTREAM DETECT
CONFIRMED DETECT
DOWNSTREAM DETECT
92
ADJ PRELIM DETECT
PRELIM DETECT
44₂
SENSOR NODE
UPSTREAM DETECT
94
CONFIRMED DETECT
DOWNSTREAM DETECT
PRELIM DETECT
ADJ PRELIM DETECT
50₂
50₅
44₅
SENSOR NODE
UPSTREAM DETECT
CONFIRMED DETECT
DOWNSTREAM DETECT
ADJ PRELIM DETECT
PRELIM DETECT
44₃
SENSOR NODE
96
UPSTREAM DETECT
CONFIRMED DETECT
DOWNSTREAM DETECT
PRELIM DETECT
ADJ PRELIM DETECT
50₃
50₆
44₆
SENSOR NODE
UPSTREAM DETECT
CONFIRMED DETECT
DOWNSTREAM DETECT
ADJ PRELIM DETECT
PRELIM DETECT

FIG. 7

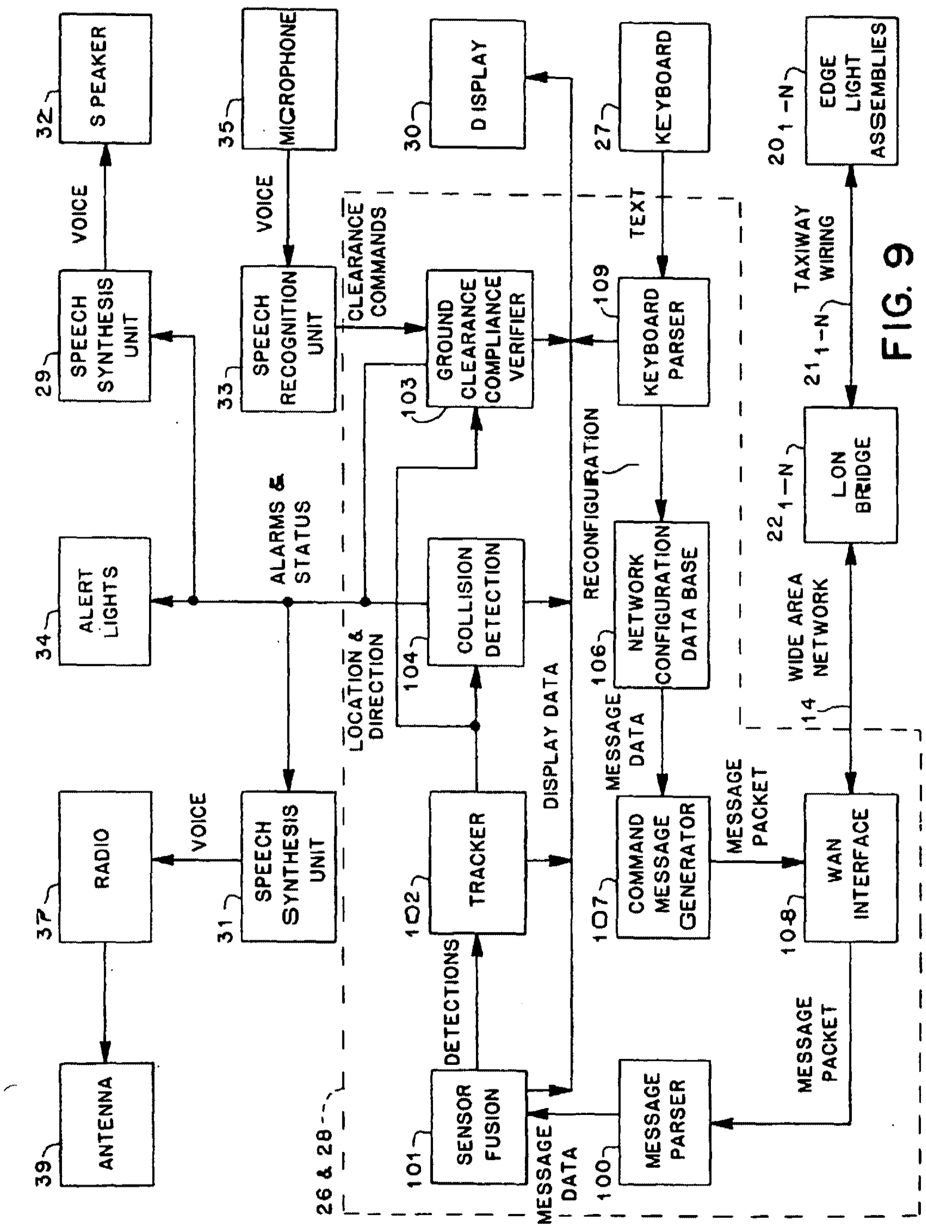
SPEAKER
32
VOICE
SPEECH SYNTHESIS UNIT
29
MICROPHONE
35
VOICE
SPEECH RECOGNITION UNIT
33
CLEARANCE COMMANDS
GROUND CLEARANCE COMPLIANCE VERIFIER
103
DISPLAY
30
KEYBOARD
27
TEXT
KEYBOARD PARSER
109
EDGE LIGHT ASSEMBLIES
20 1-N
TAXIWAY WIRING
21 1-N
LON BRIDGE
22 1-N
ALERT LIGHTS
34
ALARMS & STATUS
COLLISION DETECTION
104
RECONFIGURATION
NETWORK CONFIGURATION DATA BASE
106
WIDE AREA NETWORK
14
RADIO
37
VOICE
SPEECH SYNTHESIS UNIT
31
LOCATION & DIRECTION
TRACKER
102
DISPLAY DATA
MESSAGE DATA
COMMAND MESSAGE GENERATOR
107
MESSAGE PACKET
WAN INTERFACE
108
ANTENNA
39
DETECTIONS
SENSOR FUSION
101
26 & 28
MESSAGE DATA
MESSAGE PARSER
100
MESSAGE PACKET

FIG. 9

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 1263

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	WO-A-90 04242 (SWEDISH AIRPORT TECHNOLOGY HB)	1-3,5,7, 11-15, 17,20-24	G08G5/06
Y	* the whole document *	4,6, 8-10,16, 18,19, 25,26	
Y	US-A-3 706 969 (PAREDES) * column 6, line 53 - line 56 *	4	
Y	* column 3, line 18 - column 4, line 59 *	10,19	
Y	EP-A-0 209 397 (GENERAL DE INVESTIGACION Y DESARROLLO S.A.) * claims 1,5-13,23,27 *	8,9,18, 25,26	
D	& US-A-4 845 629 (MURGA ET AL.)		
Y	US-A-4 093 937 (HABINGER) * column 2, line 3 - line 33 *	6,16	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

G08G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 June 1994	Reekmans, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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(54) Airport surface monitoring and runway incursion warning system

(57) An airport runway incursion warning system (10) for monitoring air and ground traffic at an airport. The system (10) is optimally used with an aircraft (12) that has an electronic tag (21) or interrogation system (21) that stores identification information regarding the aircraft (12), and an RF transponder (22) for receiving interrogation signals and for transmitting the identification information in response thereto. A radar system (41, 20) comprises a plurality of radar sensor units (13) disposed at predetermined installation sites adjacent to a runway (11). Each radar sensor unit (13) typically has an interface processor (42, 14) and telemetry electronics (43, 14a) for communication, although hard-wired communication paths may be used. An RF/telemetry interface (43, 18) is provided for communicating with the radar sensor units (13) when the interface processor (42, 14) and telemetry electronics (43, 14a) are used. The RF/telemetry interface (43, 18) is also used to transmit the interrogation signals to the aircraft (12) and receive the identification information therefrom. A central processing unit (44, 16) is coupled to the radar sensor units (13) for receiving and integrating radar data produced by each the radar sensor units (13) to produce a map of the runway (11) that identifies authorization objects (26) and aircraft (12) that do not constitute intrusion threats, and intruding objects that do constitute intrusion threats to the runway (11). The central processing unit (44, 16) is optionally coupled to the RF/telemetry interface (43, 18) for transmitting signals to and from the aircraft (12), and in this case, the central processing unit (44, 16) processes identification information received from the aircraft (12) to integrate the identification information into to generate a displayed image. An operator display (45, 17) is coupled to the central processing unit (44, 16) for displaying the map and identification information generated thereby for use by an operator.

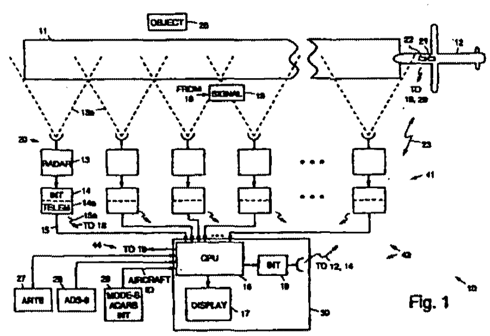


Fig. 1

EP 0 744 630 A2

Description

BACKGROUND

The present invention relates to radar systems, and more particularly, to a radar system that is used to provide surface monitoring and runway incursion for airports.

The prevention of runaway incursions has been an issue of increasing concern and has resulted in the development of the Airport Surface Detection Equipment (ASDE-3), the Airport Movement Area System (AMASS), and the Airport Surface Traffic Automation Program (ASTA).

The most relevant prior art relating to the present invention, and airport surface monitoring and runway incursion systems in particular is the ASDE-3 radar system which is a single high power Ku-Band real aperture radar that is located on a tower adjacent to an airport. The ASDE-3 system experiences shadowing and multiple reflections that seriously affect the its performance, which is a consequence of the fact that it is a single radar system. The ASDE-3 radar system does not have the ability to interrogate vehicles or aircraft monitored by the system. The ASDE-3 radar system is also relatively expensive.

Therefore, it is an objective of the present invention to provide for an improved radar system that may be used to monitor surface and runway incursion at airports, and the like, and which improves upon the currently-used ASDE-3 radar system.

SUMMARY OF THE INVENTION

In order to meet the above and other objectives, the present invention is a runway incursion warning system for monitoring a runway of an airport and for displaying data indicative of unauthorized intrusion onto the runway to an operator. A radar system is provided that comprises a plurality of radar sensor units that are disposed at predetermined installation sites adjacent to selected runways of the airport. Each radar sensor unit associated with a particular runway generates a radar beam that typically overlaps the adjacent radar beam to provide complete coverage of a runway. Each radar sensor unit is coupled to a collocated interface processor and telemetry electronics that interface between the radar sensor unit and a central processing unit. Communication between each radar sensor unit and the central processing unit may be by physical electrical interconnection and/or RF communication using the telemetry electronics. The physical electrical interconnection may be provided by way of existing cabling normally for runway lights to provide power and the communication link for each of the radar sensor units.

The central processing unit is coupled to an operator display that processed data derived from each of the radar sensor units and displays the data on the operator display. The central processing unit is coupled to an RF/telemetry interface that is used to communicate with the radar sensor units and to aircraft having an electronic tag or transponder system. The central processing unit also integrates and causes the display of data derived from other systems coupled to it, such as the ARTS, ASDE-3, MODE-S or ACARS systems, for example. The central processing unit also generates a display showing the airport runways along with moving and non-moving physical objects that are in the vicinity of the runway. Such objects include departing and arriving aircraft, buildings, and vehicles that are in the vicinity of the runway. Thus, the present system provides a complete display of the runway environment to an operator.

The system may be used with non-cooperative objects or vehicles, or with aircraft or vehicles that have the electronic tag or RF transponder (transmitter and receiver) system. The electronic tag or RF transponder system contains identification information regarding the aircraft, vehicle, or object. The tag or RF transponder receives interrogation signals and transmits the identification information, and other additional information, if desired, in response to the interrogation signals.

The interface processor and telemetry electronics at each radar sensor unit and the RF/telemetry interface provide a communication link between the radar sensor units and the central processing unit. The RF/telemetry interface transmits the interrogation signals and receives the identification information from the aircraft and other cooperative objects or vehicles. Alternatively, the identification information may be received by a central receiver at the airport while the RF/telemetry interface only transmits interrogation signals in conformance with existing aircraft equipment, such as MODE-S or ACARS systems, for example. Multiple interrogation signals sent by different sensor units are separated and identified on the basis of timing, for example, for reception of identifications signals or GPS position information contained in the identification signals themselves.

The telemetry electronics receives data produced by the radar sensor units and the central processing unit integrates the data derived from the radar sensor units and the electronic tag or transponder system in the aircraft. The central processing unit processes data derived from the radar system and identification information received from the electronic tag to produce a map of the airport that identifies authorization objects and aircraft that are not intrusion threats, and intruding objects that are intrusion threats. The operator display displays the map generated by the central processing unit.

The central processing unit generates warning signals in response to intrusion threats that are detected by the system and wherein the warning signals are transmitted to the aircraft by means of the RF/telemetry interface and the RF transponder system. The central processing unit generates an image of the runways that identifies objects, aircraft that are landing and taking off from the runways, and identifying information associated with interrogated aircraft derived from the electronic tag or transponder system. The central processing unit may also produce data that is displayed on the map that includes priority alert information indicating aircraft that may impose a possible runway incursion, a list of arriving and departing aircraft, and displays that show landing and take-off patterns of arriving and departing aircraft.

The system thus provides for a distributed system of relatively low-cost radars disposed adjacent the runways. Each radar has limited angular coverage and the complete system provides coverage of the entire airport runway area. The present system provides a surface map of aircraft and surface vehicles and point interrogation of aircraft for identification purposes using the electronic tags or transponder system.

The present runway incursion warning system is considerably less expensive than the ASDE-3 radar system, and does not suffer from the shadowing and multiple reflection problems experienced by the ASDE-3 system. The system is scalable to provide monitoring of different size airports. The system provides high range resolution and velocity information, and may be used to interrogate electronic tags or transponder systems disposed on vehicles and aircraft to provide identification information to aircraft traffic controllers that operate the system. The system provides a real-time display of airport surface traffic and warnings of runway incursion.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of the present invention may be more readily understood with reference to the following detailed description taken in conjunction with the accompanying drawing, wherein like reference numerals designate like structural elements, and in which:

Fig. 1 illustrates a system block diagram of a runway incursion warning system in accordance with the principles of the present invention; and

Fig. 2 illustrates a typical video display produced by the runway incursion warning system of Fig. 1.

DETAILED DESCRIPTION

Referring to the drawing figure, Fig. 1 illustrates a system block diagram of a runway incursion warning system 10 in accordance with the principles of the present invention. The system 10 includes a radar system 20 that is comprised of a plurality of radar sensor units 13, such as millimeter wave radar sensor units 13, for example, disposed at predetermined installation sites on the ground adjacent to a runway 11, or runways 11, of an airport. Each radar sensor unit 13 associated with a particular runway 11 generates a radar beam 13a that typically overlaps the adjacent radar beam 13a to provide complete coverage of a runway 11, although this is not absolutely required. Each radar sensor unit 13 is coupled to an interface processor (INT) 14 and telemetry electronics (TELEM) 14a that permit communication with a processing center 30 located in an airport control tower, for example. Intelligent processing may be performed at each installation site in the interface processor 14 to reduce the data rate of telemetered data and perform confidence tests. Existing cabling 15 for airport lights provide power and a communication link for each of the plurality of radar sensor units 13, interface processor 14, and telemetry electronics 14a. Alternatively, a dedicated RF communications link 15a may be employed.

A central processing unit (CPU) 16 integrates the data received from the plurality of radar sensor units 13, and maintains a map of authorized targets 26, such as fixed objects 26 or buildings 26 that do not constitute intrusion threats. The central processing unit 16 may also collect input data from an ARTS or ASDE-3 system 27 and available identification reports derived therefrom. The ARTS and ASDE-3 systems provide information regarding aircraft approaching the airport. Data that is derived from an ASDE-3 radar 28, if available, may also be integrated by the central processing unit 16, and a dynamic real-time situation display 17 is provided to an aircraft controller, in graphic format, that is clear and easy to interpret. A sample image on the video display 17 that is presented to an operator of the system 10 is shown in Fig. 2.

The aircraft 12 includes an electronic tag or interrogation system 21 such as a MODE-S or ACARS transponder system 21, for example, that provides identification information regarding the aircraft, and an RF transponder system 22. Warning signals may be transmitted to the aircraft 12 by means of the RF/telemetry interface 18 and the RF transponder system 22 over an RF communications link 23. Warning signals may also be displayed to arriving and departing aircraft 12 using ground signals 19 such as lights or beacons disposed adjacent the runway 11. In addition, the electronic tag or interrogation system 21 may be interrogated by the system 10 using the RF/telemetry interface 18 and the RF transponder system 22. Interrogation signals are transmitted to the aircraft 12 by way of the communication link 23, and the electronic tag or interrogation system 21 on the aircraft 12 responds by outputting information stored therein that is returned to the central processing unit 16 by way of the RF communications link 23.

As shown in Fig. 1, the system 10 is comprised of five major subsystems 41-45. The first subsystem 41 comprises the radar system 20 including the plurality of radar sensor units 13 and electronic components installed at each installation site. The second subsystem 42 comprises the interface processor 14 that is coupled to the radar sensor units 13 and that is located at each remote installation site. The third subsystem 43 comprises a telemetry subsystem and includes the telemetry electronics 14a installed at the installation sites and an RF/telemetry interface 18 that is coupled to the central processing unit 16 at the central processor site. The fourth subsystem 44 comprises the central processing unit 16. The fifth subsystem 45 comprises the operator display 17 that includes a conventional display and control terminal. Each of the subsystems 41-45 employed in the present invention are well-known and their interconnection and operation is routine to those skilled in the art.

The operator display 17 used in the runway incursion warning system 10 displays information for use by an airport traffic planner or aircraft traffic controller. The data presented on the operator display 17 optimizes the available data while minimizing the need for physical interaction with the system 10. Fig. 2 illustrates a typical video image displayed on the operator display 17 by the runway incursion warning system 10. Referring to Fig. 2, the display 17 shows an image of the runways 11 of the airport and identifies the locations of buildings 26 and other stationary objects 26, aircraft 12 that are landing and taking off from the runways 11, including data 47 from the transponders 21 from interrogated aircraft 12. Typically the data 47 from each transponder system 21 indicates the aircraft number or flight number, as is indicated by the alphanumeric identifiers in the boxes shown on the display 17. Additional data may be displayed including information provided in a system area 51 that provides data regarding the instrument landing system (ILS) system, the time and other relevant system parameters, priority alert information 52 indicating objects 26 or aircraft 12 that are determined to be runway incursions, a list 53 of arriving and departing aircraft 12, and displays 34 that provide real-time images showing the landing and take-off of arriving and departing aircraft 12.

A preliminary proof-of-concept demonstration model of the present system 10 was constructed and data collection was performed at Los Angeles International Airport (LAX) using a test version of a millimeter-wave radar (radar sensor units 13) developed by the assignee of the present invention. Test results show that the system 10 works as expected and provides superior performance over the ASDE-3 radar system.

In summary, there is disclosed an airport runway incursion warning system 10 for monitoring air and ground traffic at an airport. The system 10 is optimally used with an aircraft 12 that has an electronic tag 21 or interrogation system 21 that stores identification information regarding the aircraft 12, and an RF transponder 22 for receiving interrogation signals and for transmitting the identification information in response thereto. A radar system 41, 20 comprises a plurality of radar sensor units 13 disposed at predetermined installation sites adjacent to a runway 11. Each radar sensor unit 13 typically has an interface processor 42, 14 and telemetry electronics 43, 14a for communication, although hardwired communication paths may be used. An RF/telemetry interface 43, 18 is provided for communicating with the radar sensor units 13 when the interface processor 42, 14 and telemetry electronics 43, 14a are used. The RF/telemetry interface 43, 18 is also used to transmit the interrogation signals to the aircraft 12 and receive the identification information therefrom. A central processing unit 44, 16 is coupled to the radar sensor units 13 for receiving and integrating radar data produced by each the radar sensor units 13 to produce a map of the runway 11 that identifies authorization objects 26 and aircraft 12 that do not constitute intrusion threats, and intruding objects that do constitute intrusion threats to the runway 11. The central processing unit 44, 16 is optionally coupled to the RF/telemetry interface 43, 18 for transmitting signals to and from the aircraft 12, and in this case, the central processing unit 44, 16 processes identification information received from the aircraft 12 to integrate the identification information into to generate a displayed image. An operator display 45, 17 is coupled to the central processing unit 44, 16 for displaying the map and identification information generated thereby for use by an operator.

Thus there has been described a new and improved radar system for providing surface monitoring and runway incursion for airports. It is to be understood that the above-described embodiments are merely illustrative of some of the many specific embodiments that represent applications of the principles of the present invention.

Clearly, numerous and other arrangements can be readily devised by those skilled in the art without departing from the scope of the invention.

Claims

1. An airport runway incursion warning system (10) for monitoring air and ground traffic in the vicinity of a runway (11) of an airport, said system (10) characterized by:

   a radar system (41, 20) comprising of a plurality of radar sensor units (13) disposed at predetermined installation sites adjacent to the runway (11) and wherein the plurality of radar sensor units (13) generate adjacent or substantially overlapping radar beams (13a) that illuminate the runway (11);

   a central processing unit (44, 16) coupled to the plurality of radar sensor units (13), for receiving radar data produced by the plurality of radar sensor units (13), and for processing the radar data to produce a map of the runway (11) that identify objects (26) and aircraft (12) in the vicinity thereof;

   an operator display (45, 17) coupled to the central processing unit (44, 16) for displaying the map of the runway (11), objects (26) and aircraft (12) generated by the central processing unit (44, 16).

2. The system (10) of Claim 1, characterized in that each radar sensor unit (13) is coupled to an interface processor (42, 14) for processing radar data generated by the radar sensor unit (13), wherein

each interface processor (42, 14) is coupled to RF telemetry electronics (43, 14a) for transmitting the radar data to the central processing unit (44, 16), and wherein the central processing unit (44, 16) is coupled to an RF/telemetry interface (43, 18) for receiving the radar data transmitted from the radar sensor unit (13) by the RF telemetry electronics (43, 14a).

3. The system (10) of Claim 2, characterized in that the aircraft (12) comprises an electronic tag (21) that stores identification information regarding the aircraft (12), and comprises an RF transponder (22) coupled to the electronic tag (21) for receiving interrogation signals generated by the central processing unit (44, 16) and for transmitting the identification information in response to the interrogation signals;

and wherein the interrogation signals generated by the central processing unit (44, 16) are transmitted to the aircraft (12) by way of the RF/telemetry interface (43, 18), and the identification information is received from the RF transponder (22) by way of the RF/telemetry interface (43, 18) and wherein the central processing unit (44, 16) generates signals for display on the operator display (45, 17) that identifies the aircraft (12).

4. The system (10) of Claim 2 or 3, characterized in that the central processing unit (44, 16) is coupled to the plurality of radar sensor units (13) by way of a RF communications link (43, 15a) for communicating radar to the central processing unit (44, 16) by way of the RF/telemetry interface (43, 18).

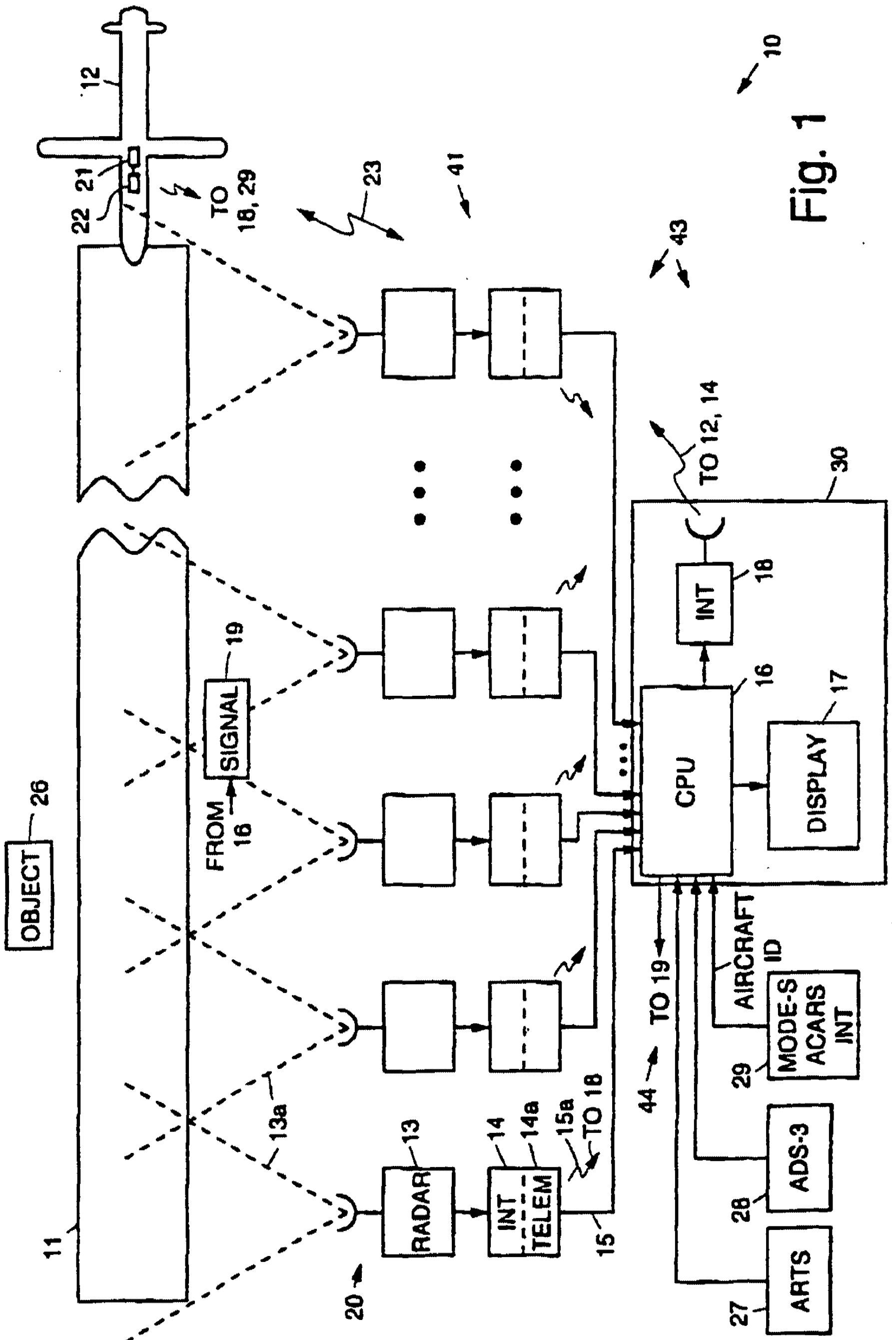
5. The system (10) of any of Claims 1-4, characterized further by an ARTS system (27) coupled to the central processing unit (44, 16), and wherein the central processing unit (44, 16) processes data and identification reports derived from the ARTS system (27) and integrates them into the map that is displayed on the operator display (45, 17).

6. The system (10) of any of Claims 1-5, further characterized by an ASDE-3 radar (28) coupled to the central processing unit (44, 16) and wherein the central processing unit (44, 16) integrates data derived from the ASDE-3 radar (28) into the map that is displayed on the operator display (45, 17).

7. The system (10) of any of Claims 3-6, characterized in that the central processing unit (44, 16) generates an image of the runway (11) that identifies objects (26), aircraft (12) that are landing and taking off from the runway (11), and identifying information (47) associated with interrogated aircraft (12) derived from the transponder (21).

8. The system (10) of any of Claims 3-7, characterized in that the central processing unit (44, 16) produces data for display that includes priority alert information (51) indicating aircraft (12) that are runway incursions, a list (53) of arriving and departing aircraft (12), and displays (54) that show landing and take-off patterns of arriving and departing aircraft (12).

9. The system (10) of any of Claims 3-8, characterized in that the central processing unit (44, 16) generates warning signals (19) in response to intrusion threats that are detected and wherein the warning signals (19) are transmitted to the aircraft (12) by means of the RF/telemetry interface (43, 18) and the RF transponder (22).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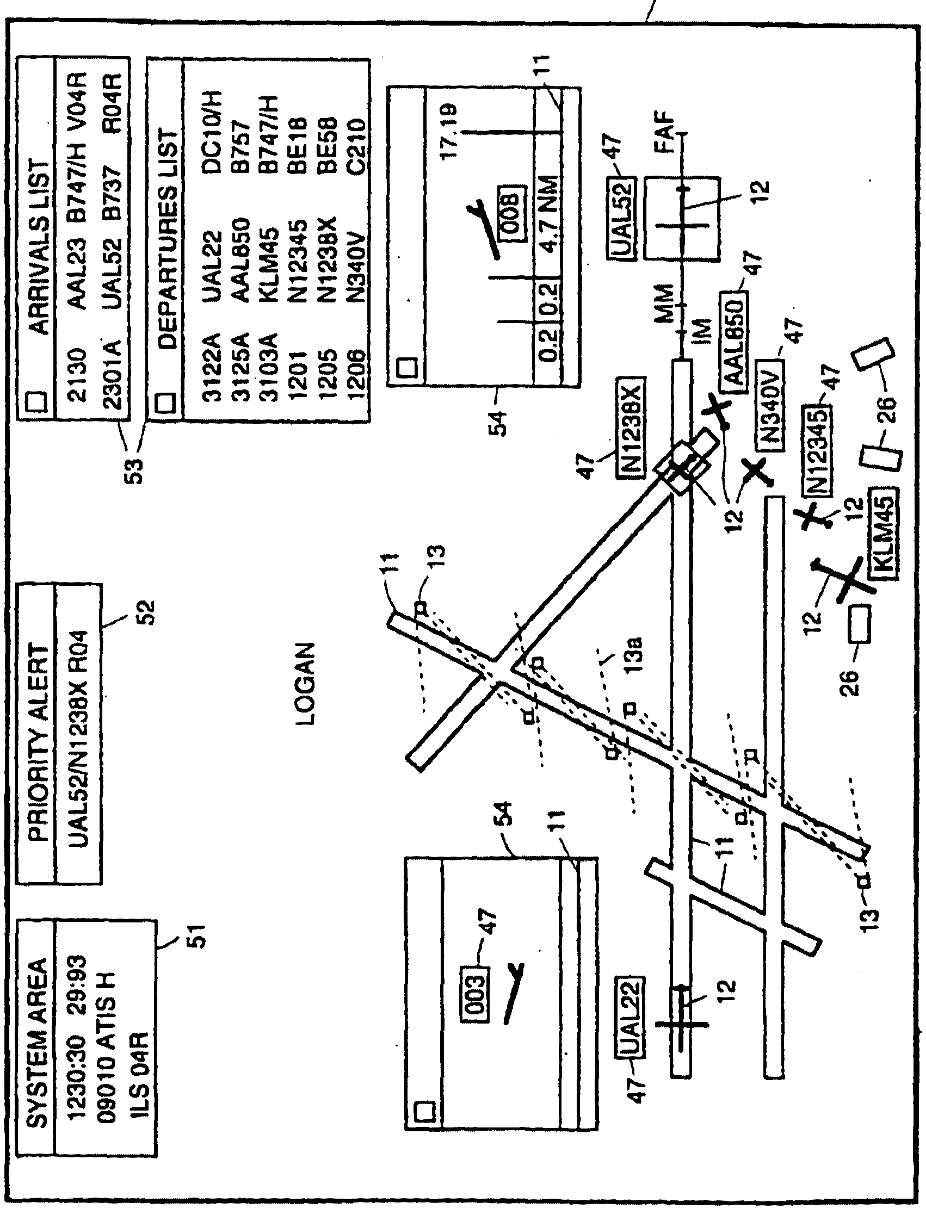
ARTS

Fig. 1

Fig. 2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3103A KLM45 B747/H
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(54) **Airport surface monitoring and runway incursion warning system**

(57) An airport runway incursion warning system (10) for monitoring air and ground traffic at an airport. The system (10) is optimally used with an aircraft (12) that has an electronic tag (21) or interrogation system (21) that stores identification information regarding the aircraft (12), and an RF transponder (22) for receiving interrogation signals and for transmitting the identification information in response thereto. A radar system (41, 20) comprises a plurality of radar sensor units (13) disposed at predetermined installation sites adjacent to a runway (11). Each radar sensor unit (13) typically has an interface processor (42, 14) and telemetry electronics (43, 14a) for communication, although hard-wired communication paths may be used. An RF/telemetry interface (43, 18) is provided for communicating with the radar sensor units (13) when the interface processor (42, 14) and telemetry electronics (43, 14a) are used. The RF/telemetry interface (43, 18) is also used to transmit the interrogation signals to the aircraft (12) and receive the identification information therefrom. A central processing unit (44, 16) is coupled to the radar sensor units (13) for receiving and integrating radar data produced by each the radar sensor units (13) to produce a map of the runway (11) that identifies authorization objects (26) and aircraft (12) that do not constitute intrusion threats, and intruding objects that do constitute intrusion threats to the runway (11).

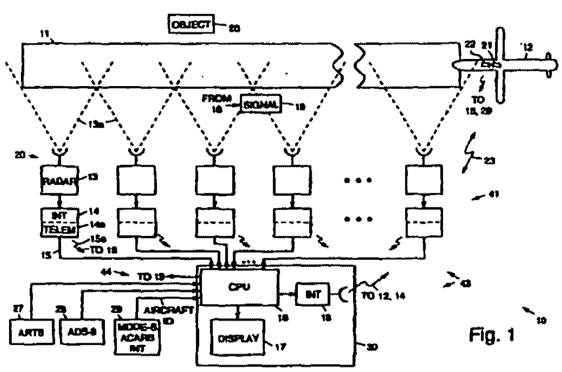

Fig. 1

EP 0 744 630 A3

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EP 96 10 8293

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	ATUL JAIN: "APPLICATIONS OF MILLIMETER-WAVE RADARS TO AIRPORT SURFACE SURVEILLANCE" DIGITAL AVIONICS SYSTEMS CONFERENCE, PHOENIX, OCT. 30 - NOV. 3, 1994, no. CONF. 13, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 528-533, XP000512920 * page 528, left-hand column - page 531, left-hand column * * page 533, left-hand column - right-hand column; figures * ---	1-6 7-9	G01S13/91 G01S13/93 G01S7/06 G08G5/00 G08G5/06
Y	US 5 374 932 A (WYSCHOGROD DANIEL ET AL) 20 December 1994 * column 6 - column 7 * * column 10 - column 34 * ---	7,8	
Y	GO G ET AL: "ENHANCED AIRPORT SURFACE SURVEILLANCE RADAR" DIGITAL AVIONICS SYSTEMS CONFERENCE, PHOENIX, OCT. 30 - NOV. 3, 1994, no. CONF. 13, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 544-551, XP000512923 * page 550 * ---	9	**TECHNICAL FIELDS SEARCHED (Int.Cl.6)** G01S G08G
A	EP 0 220 752 A (DRIM LTD) 6 May 1987 * column 4 - column 9; figures * ---	1-9	
A	DE 36 40 401 A (SIEMENS) 9 June 1988 * column 11, line 36 - line 51 * * column 2 - column 3 * ---	1	
A	US 3 872 474 A (LEVINE) 18 March 1975 * abstract; figures * --- -/--	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	15 October 1997	Devine, J

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EUROPEAN SEARCH REPORT

Application Number
EP 96 10 8293

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 466 239 A (HAAN FRANS HERMAN DE) 15 January 1992 -----		
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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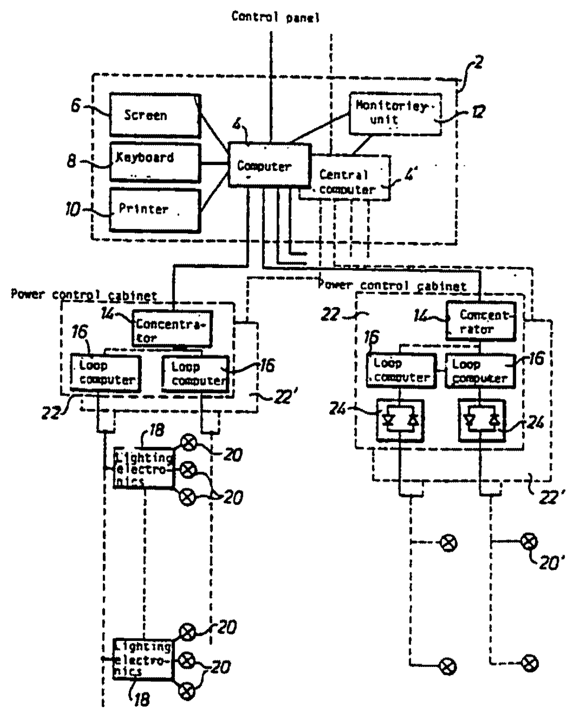
(54) Title: SUPERVISION AND CONTROL OF AIRPORT LIGHTING AND GROUND MOVEMENTS

(57) Abstract

In a method and plant for supervising and controlling field lighting (20) at an airport, a regulator provided with a monitoring unit for power supply and monitoring the lighting fitting is arranged individually for each lighting (18, 20), such as to regulate the light intensity of the lighting and for receiving information as to its operational status. Each lighting in the plant is provided with a lighting electronic unit including a regulator, monitoring unit and modem for power supply to the light source and monitoring the operation of the lighting, each lighting being individually addressable from a control central for the airport. In the method and plant in accordance with the above, a ground traffic control system can be integrated in the field lighting system by connecting suitable presence detectors to the system.



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Supervision and Control of Airport Lighting and Ground Movements.

The present invention relates to a method and a plant for supervising and controlling field lighting at an airport, and which optionally include presence detectors.

The traditional implementation of a system for field lights is as follows.

High-intensive and low-intensive lightings along approach paths, runways and taxiways are supplied from one or more supply points, so-called cabinets or stations situated in the airport field, usually two for a field with one runway. These supply points are fed with high voltage unregulated electricity which is transformed down to 380/320 V and the supply points contain regulator equipment, thyristor or transducer regulators or regulating transformers for converting the unregulated electricity into controlled, requlated electric power for supplying the light units, which takes place via several power supply loops. Supply takes place in two principally different ways, i.e. by series of parallel feed to the lightings. Each lifhting is provided with a transformer for retransforming the electricity to a suitable low voltage for supplying the lighting with power, in addition, the supply points also contain a supervisory system which monitors the status of the field lighting plant, e.g. such as to ensure that a sufficiently large number of light units function, that the intensity of the light units is correct etc. The supply points, i.e. the cabinets, communicate via a communication link, inter alia with the traffic control tower supervising and operating panel, from which the regulating and supervisory systems are controlled, and at which information from the systems is received. This communication takes place via separate wire pairs for each function, or with time multiplex transmission on wires or optical fibres.

The object of the present invention is to present a new method for supervising and controlling field lighting, and to provide a new field lighting plant, where each individual lighting is addressable and includes a communicating local regulator and a monitoring unit for supplying power to, and monitoring the lighting. Thus each lighting or subsystem of lightings can be controlled individually, irrespective of the sections into which the power cabling is divided.

This object is achieved with a method according to claim 1 and a plant according to claim 9.

Furthermore, the invention enables a presence indication system for detecting vehicle and aircraft movements on the ground to be integrated in the field lighting system implemented in accordance with the present invention.

Communication between the traffic control tower supervision and operating panel takes place via a central computer to a so-called concentrator and loop computer. The communication signals can be in the form of time multiplexed electrical or optical signals on signal cables or optical fibre cables.

A plurality of advantages are achieved by the present invention compared with the already known state of the airport lighting art.

In the implementation of a traditional field lighting system, the different power supply loops are fed via a regulator centrally connected to each loop for regulating the intensity of the lightings connected to the loop. For reasons of safety, the differrent lighting configurations such as approach lighting, runway edge lighting, glidepath beacons, threshold lighting and taxiway lighting must be fed by several loops in case there should be a regulator or cable fault. A large number of centrally placed regulators are therefore required for controlling the field lighting system, and these occupy large spaces which must often be specially built. With the present invention, on the other hand, each lighting is provided with a local regulator which is placed at the light fitting or in a so-called fitting well associated therewith. At the supply point there will only be a so-called concentrator, sling computer, contactor and modem. This results in less voluminous equipment, which gives savings in space and cost compared with the implementation carried out in a conventional way. In addition, the necessary redundance is obtained automatically with the method of implementation in accordance with the invention.

With a conventional method of implementation there is further required one or more lamp transformers at each lighting. These are heavy and take up considerable space. With the present invention, one or more of these transformers can be replaced by a small and light electronic unit on the fitting for intensity regulation and monitoring each individual lighting.

Since, in accordance with the present invention, each lighting can communicate and is addressable with the aid of its electronic unit, and is thus provided with local intelligence, a lighting with several individual illumination points can control these separately in spite of the supply taking place merely over a single phase or a common cable. The necessary amount of power cable can thus be substantially reduced.

Field lighting plant for airports in accordance with the invention can advantageously be made up of certain modules, namely the lighting electronic unit (hereinafter denoted the AE unit), loop computer, concentrator and modem, where the concentrator and loop computer are realized with the same hardware but with different software, the plant being completed by a central computer and a supervising and operating unit in the traffic control tower (hereinafter denoted TWR). This simple, modular implementation method reduces the hardware costs for a given field lighting plant as well as design costs for a given lighting configuration. Since an ordinary-sized airport has several hundred lightings, the size of the AE unit manufacturing series will be considerable, which considerably reduces the manufacturing cost of each AE unit.

The modular method of implementation means that service and maintenance are facilitated. If an individual lighting does not light, this can either be due to the lamp or the corresponding AE unit failing, or both. In the great majority of cases, it is the lamp that fails, and therefore it is changed first. If a section coupled to a loop computer does not light, this can only be due to failing of the loop computer and modem, and this unit is then changed. Service and maintenance work will thus be extremely simplified, which is an advantage from the time, cost and personnel expects.

With conventionally implemented field lighting systems, there must be an ocular inspection of the field lighting at least once a day to determine which light units are defect. For airports with heavy traffic this must take place at night, since the runway system is not available for inspection during daytime. This results in increased costs. With the present invention this inspection is eliminated, since each lighting is individually monitored and a presentation of the status of each one can be obtained via the sling computer, concentrator and central computer, either on a display or printed out on a printer. In addition, monitoring can take place without the field lighting being lit up, since the AE unit only needs to drive a minimum amount of current through the lamp in order to decide whether it is failing or not. This method saves energy. Each AE unit can furthermore be implemented to enable measuring of the operating time of the light source to which it is connected. Since the average life (illumination time) of the lamps in question is well known, this individual information as to lamp status, namely illumination time and functioning/failing enables planned maintenance of the field lighting plant, which gives better status of the plant and more effective utilization of maintenance personnel. The total illumination time of each light source is suitably continuosly registered at e.g. the central computer.

According to an advantageous embodiment of the plant in accordance with the invention, each lighting includes two separate light sources, the lighting configurations of which are identical. Only one light source is in service at a time, but should it fail the other light source is automatically connected, and information is sent that there is no reserve lamp for the lighting.

Since each lighting is addressable in accordance with the present invention, there is the possibility of guiding aircrafts, using parts of the field lighting system, for taxiing to and from runways, i.e., to arrange a so-called taxiway guidance system. This can be arranged by the lighting system along the central line of a taxiway being sectioned so that a given section is given a group address. This section can then either have its own operating button in a control tower panel where the section is lit when the appropriate button is pressed, or the central computer in the system can select a path with given input values for the taxiing path of the aircraft, taking into consideration any maintenance work on the taxiway, or to other aircraft movements etc. The decided path can either be lit up simultaneously in its entirety or successively in front of the aircraft. In existing plants this sectioning has been achieved by each section being provided with a separate power supply. With the present invention, the sectioning is performed, with the aid of the AE units' addresses, in the software, which drastically reduces the installation costs for a guidance system, and simplifies any future changes in the section configuration.

The invention can also be used for detecting vehicle and aircraft movements on the ground, i.e. it can form a so-called ground traffic detection system. In airports with heavy traffic, the collision risk between aircraft/aircraft and aircraft/vehicle is namely a great problem in poor visibility conditions. Since the inventive lighting system includes "intelligent" and addressable AE units at each point where there is a lighting, every taxiway and runway can be divided into frequent identification blocks. This inventive implementation of the plant, supplemented with a presence detector allocated to each fitting the complete field lighting system or parts thereof enables detection and supervision of aircraft and vehicle movements along the rolling way system or parts thereof. The signals from the ground traffic detectors are taken up by the AE units and transmitted together with other lighting information via loop computer and concentrator to the central computer, which depicts the ground traffic on a display. The central computer, or a special supervisory computer, can give an alarm for situations where unpermitted ground traffic situations occur. This ground traffic detection system integrated with the field lighting system is very cost-effective compared with existing ground radar systems. The present invention moreover permits that only those parts of the rolling way system selectively chosen from the safety aspect are provided with ground traffic detection capacity, whereby further cost savings can be made.

In accordance with a further advantageous development of the invention, the guidance system is integrated with the ground traffic detection system such that the centre line lights included in the guidance system are lit up or extinguished or change lighting colour in front of and after the taxiing aircraft, respectively, lighting up and extinguishing the centre line lights taking place individually or in sections with the aid of control signals from the presence detection of the aircraft.

According to another embodiment of the plant, each lighting position where an AE unit is to be connected is provided with an unique address, which is automatically transferred to the AE unit when the unit is connected, such that this address is tied to its location and is not lost if an AE unit were to be changed.

An advantageous method of realizing an address which is not tied to the AE unit but to its position is to arrange a plurality of permanent magnets in the AE unit mounting such that these magnets have a unique combination of north and south pole orientation, giving the position in question an unique address which is automatically transferred to the AE unit by magnetic field-sensitive elements when the unit is connected. An eight bit address can be realized using eight magnets, for example.

According to a still further advantageous embodiment of the plant, and via the AE unit, the lightings are made for three-phase supply enabling the supply to be dimensioned to cope with a phase failure up to a predetermined current or voltage level. Up to this level all lightings light with no change if there is a phase failure. The central computer can be programmed such as to increase the number of lightings which are extinguished with an increasing modulation in order that the maximum transmitted power for two phases is not exceeded.

Examples of the invention will now be described in more detail, with reference to the accompanying drawings, where Fig. 1 illustrates the two systems in use today for controlling field lighting at an airport, Fig. 2 illustrates the principle implementation of an embodiment of the plant in accordance with the invention, Fig. 3 illustrates the principle system implementation of an embodiment of the plant in accordance with the invention, Fig. 4 illustrates an embodiment of the lighting electronics in the inventive plant, Fig. 5 illustrates an example of the realization of a unique address for each fitting, Fig. 6 illustrates the principle of ground traffic detection in the inventive plant, Fig. 7 illustrates an embodiment of the plant in accordance with the invention for microwave-based ground traffic detection, Fig. 8 illustrates a system with stop lights having automatic re-illumination for controlling ground traffic, Fig. 9 is an idealized depiction of vehicle and aircraft ground movements and Fig. 10 illustrates a guidance system in a conventional construction and a system which may be realized with the plant in accordance with the invention.

Fig. 1 illustrates the two different systems used today for controlling the field lighting at an airport. The internationally most usual form is the so-called series system. The power supply line is here fed with a constant current which can be set at different levels. The lightings 20 on the field are connected via a so-called series transformer 50 in series with each other. Two or more such loops are required for supplying each lighting system such as runway edge lighting, approach lighting, glidepath beacons, centre line lighting, taxiing lighting etc. Since the lightings 20 are in series there is most often required high secondary voltage at the main transformer 51. The regulator 24 is connected on the primary side. In fig. 1 it is illustrated as a thyristor regulator 46, 48 but it can also be a transductor regulator or a regulating transformer.

The power supply system most usual in Sweden is the so-called parallel system. In this case the lightings 20 are connected in parallel to each other via their individual transformers 21 along the power supply loop. Transducer regulators or regulator transformers are used here as well, apart from thyristor regulators 24, 46, 48. The control and monitoring equipment, (the equipment to the left of the dashed line in Fig. 1), is often placed in so-called cabinets or stations in the field for these systems. For a medium-sized airport there are usually about 10-15 such regulator units for supplying the different power supply loops included in the field lighting system.

Fig. 2 illustrates in principle the implementation of an embodiment of a plant in accordance with the invention. The power supply loop is here formed of the ordinary power supply, and connected to each lighting 20 there is a so-called lighting electronic unit 18, denoted AE.

Fig. 3 illustrates the principle system implementation of a plant according to an embodiment of the invention.

Field lighting installations (existing and future) are controlled and monitored from an operating panel in the airport control tower (TWR). In the invention, a so-called central computer 4 senses the status of the different functions of the operating panel and sends control signals via its control program to one or more so-called concentrators 14. These are most often placed in a so-called power control cabinet 22 at the power supply points for the field lighting. This communication between the central computer 4, most often placed in the apparatus room of the control tower, and the concentrator 14 may be by a time multiplexed signal on cable or optical fibre. Radio signalling can also be used. The concentrator 14 sends its control signals further to one or more loop computers 16. Via a modem communication each loop computer 16 looks after the AE units 18 which are connected to the associated power supply loop. One loop computer can at present communicate with a maximum of 127 AE units, with retention of the necessary rapidity in the system. Communication between the loop computer 16 and the respective AE units 18 along the loop can either take place with digital signals superposed on the power supply loop or via separate signal cable. The most advantageous embodiment appears to be communication via the power cables, no special signal cable thus being required.

Each AE unit 18 monitors the status of the lighting fitting 20 and sends this information to the loop computer 16 in question, for further transmission via the concentrator 14 to the central computer 4, which co-ordinates the information and gives an alarm when so required. As will be seen from Fig. 3, the status of the plant can also be depicted on a screen 6 with associated keyboard 8 or a printer 10 in the so-called operational supervision centre. As is further apparent from Fig. 3, this embodiment of the plant in accordance with the invention, with supply to the lightings 20 via AE units 18, permits this new control and monitoring method to be mixed with the conventional technique using series of parallel supply by the power supply loops. The loop computer 16 thus provides a centrally placed regulator 24 with the necessary control signals (criterion values) and it also monitors the regulator 24 so that the right intensity is set and the right load connected to the loop. This possibility of combining conventional power supply methods with the new technique in accordance with the invention makes the system very flexible.

For meeting functional reliability requirements, the central computer 4 and the power control cabinets 22 can be doubled, as indicated in Fig. 3 by dashed lines. When the central computer 4, 4' and the power control cabinets 22, 22' are doubled, all the cables between the operating panel and the power control cabinets 22,22' are similarly doubled.

A monitoring unit 12, e.g. of the so-called watchdog type, is connected to both the central computers 4, 4' for monitoring the function of the plant.

Fig. 4 illustrates an embodiment of the AE unit in the plant in accordance with the invention. This comprises a modem 36 for receiving control signals which are either carried on separate signal cables or are digital signals superposed on the power cabling. The AE unit further includes a lamp control unit 35 with a microprocessor and associated interfaces 37 and power semiconductors 39 for regulating the power supply to the light sources 20. The microprocessor of the lamp control unit 35 also looks after monitoring of the operation so that if incorrect light intensity is set, or if a lamp 20 fails, the AE unit sends information on this to the loop computer 16, c.f. Fig. 3.

Power control in the AE unit can take place according to several different principle methods. Fig. 4 illustrates so-called primary switching, with which, while using high switching frequency, there is obtained extremely small lamp transformers and thereby a very compact construction. Ideally, the transformer decreases in size inversely proportional to the frequency. The frequency is determined here by the construction of the lamp control unit 35 and control can take place, e.g.

by pulse length modulation, i.e. the pulse length in the "on position" is greater for higher output effect, and for lower output effect this pulse length becomes shorter, the switching frequency being constant the whole time.

A voltage regulator 41 is illustrated in Fig. 4 for supplying the electronics. the fitting electronics also includes a rectifier bridge 43 and a filter 45 for preventing noise from the fittings and electronics to propagate to the network.

By each lighting having its individual regulator, at least certain lightings can advantageously be fitted with battery backup, so that for voltage failure the lamp in the lighting continues to light with predetermined intensity.

Each AE unit has its unique address, as mentioned above. There is thus obtained a possibility of individual control and monitoring of each lighting 20 or section of lightings. Fig. 5 illustrates an advantageous method of achieving this. Permanently situated on the lighting there is a magnetic strip 1 containing the necessary number of permanent magnets 3. The magnets 3 are made as reversible magnet plugs to enable pole reversing. The AE unit contains magnetosensitive elements 2, for sensing the orientation of the north and south poles of the magnets, this orientation enabling a binary address code to be obtained, at 4 in Fig. 5. When the AE unit is positioned it automatically obtains its address, which is permanently associated with the location. This means that each AE unit can be used anywhere in the field lighting system, as far as addressing is concerned, which is advantageous from the point of view of service and maintenance. The embodiment illustrated in Fig. 5 shows how the magnetic field 5 connects the address code from the permanently installed address code transmitter B to an address code decoder A in the lighting electronic unit without galvanic contacts, a signal converter and address transmission unit 6 being connected to the decoder.

It is obviously possible to implement this memory so that the input address is also retained when there is no current, the input taking place with the aid of a special command to start with.

With the technique in accordance with the invention for controlling and monitoring the field lighting using addressable local regulators there is obtained the field system divided into unique addressing blocks a_i, as is illustrated in Fig. 6. By providing the field system with the required number of presence detectors 72, c.f. Fig. 4, a system for detecting vehicle and aircraft ground traffic can be achieved, integrated with the field lighting system. In such a case the presence detector can be placed on a lighting fitting, as illustrated in Fig. 7. Since each fitting has a unique address to which the presence detector signal is correlated, vehicle and aircraft movements on the field can be supervised with the aid of this procedure.

In the illustrated embodiment, the presence detector 72 comprises a microwave based detector. The microwave signals are transmitted and received via an antenna unit 71 and are evaluated at 74. However, the detector can be based on other physical measuring principles using such as supersonics, infrared rays, eddy current etc.

In order to control the ground traffic, above all in airports with heavy traffic, stop lights are required at the entrances to runways, and also at crossings between taxiways. Such an arrangement is illustrated in Fig. 8, the stoplights 11 are usually sunk lightings arranged across the taxiway 80, where it is suitable to stop the traffic. The stoplights 11 comprise a line of at least 5 light units sunk into the taxiway and providing directed, steady red lights solely for the traffic which is to be stopped. Light ramps included in the stop light system must be enabled for separate operation in the control tower, and the installation of the stop lights should be carried out so that not all light units in such a ramp are extinguished at the same time for failure in the supply system.

The stop lights 11 are controlled such that when an aircraft 82 approaches an illuminated ramp of stop lights, the pilot stops the aircraft and calls the control tower to obtain permission to pass the stoplights. The flying controller gives a clearance sign for passage by extinguishing the stop lights. When the aircraft 82 has passed the lights, they shall be illuminated once again with red light as soon as possible to prevent further aircrafts from unintentionally crossing them. This re-illumination takes place either manually or automatically. For configurating a stop light ramp with automatic re-illumination, and using the technique known up to now, there are required at least two centrally placed current regulators in order to obtain the separate operation required according to the above, and also to obtain the necessary redundance.

In apparatus of this kind known up to now, the automatic re-illumination is controlled by a separate traffic signal system which, with separate current supply and with separate control signal cables, is connected to the regulator units for the lighting in question. This is an expensive way of controlling and automatically re-illuminating only five light units, for example.

A configuration in accordance with the present invention is illustrated in Fig. 8. Each lighting in the stop lights 11 is provided with an electronic unit AE, which is controlled via the power cables from the loop computer/concentrator 13, 14. Supply can take place as illustrated in the figure, e.g. it can be three-phase supply to obtain great redundance in the supply. The same power supply which is used, e.g. for surrounding illuminated signs, can be used for supplying the stop lights and thus considerably reducing cable costs. A presence detection system is integrated into the configuration for obtaining the automatic re-illumination. In fig. 8 there is illustrated a microwave-based presence detector 12 with a transmitter ND/S and a receiver ND/M. A fitting electronics unit 17 is connected to the receiver for looking after the signal from the receiver. The signal from the receiver is sent on the cable 18 to the associated loop computer 13, which in turn sends the re-illumination signal to the fitting electronic units of the stop lights. Also schematically illustrated in the figure are the necessary modem 15, way edge lighting 16, a power point 19 and signal cable 21 to an operating and display panel 10 in the control tower.

The described configuration for controlling and automatically re-illuminating the stop lights 11 for aircraft at an airport is substantially cheaper than the configuration according to previously known technique, with regard to hardware cost and cable cost. In addition there is automatically obtained great redundance, which is important from the safety aspect, a possibility of being able to regulate the intensity of the stop lights being obtained as well.

The system permits vehicle and aircraft movements to be depicted on a monitor in the control tower or at another desired place, see Fig. 9. The described method of detecting ground traffic is very cost effective compared with today's ground radar systems. Such systems also have the disadvantage that in heavy rain and snowfall they cause high background noise, thus causing difficulties in effective supervision. Another advantage with the solution in accordance with this invention is that if the field movement supervision is only desired or required for a small part of the runway system, this can be advantageously achieved.

At airports with the most heavy traffic in the world today, so-called guidance systems have been built up to guide aircraft when taxiing to and from runways, see Fig. 10. The lower part of the figure illustrates how such a system is built up today. This is done by the power supply to the lightings in question being sectioned so that each section can be lit up and extinguished individually. A large amount of cable is required for this, as well as many centrally placed regulators. With the present invention having addressable regulators the sectioning is done in the software. Different sections of lightings can thus be connected to the same power supply cable, and merely by defining what lighting addresses are associated with a certain section the section in question can be lit up and extinguished individually. This configuration results in large cost savings, see the upper part of Fig. 10.

Claims

1. Method of supervising and controlling field lighting at an airport, c h a r a c t e r i z e d in that each lighting has a regulator with associated monitoring unit for power supply to and monitoring of said lighting, which is addressed individually for controlling the light intensity of the lighting and for receiving information as to the operational status of the lighting.

2. Method as claimed in claim 1, communication between a traffic control tower and the lightings taking place via a so-called loop computer and modem, c h a r a c t e r i z e d in that communication between the loop computer and lightings is expedited over existing power cables, and superposed on the existing power supply.

3. Method as claimed in claim 1, communication between a traffic control tower and the lightings taking place via a so-called loop computer and modem, c h a r a c t e r i z e d in that communication between loop computer and lightings is expedited via a special signal cable.

4. Method as claimed in either of claims 2 or 3, c h a r a c t e r i z e d in that the lightings along one or more power supply loops are addressed from a loop computer individually or in groups.

5. Method as claimed in any one of claims 1-4, c h a r a c t e r i z e d in that the central line lighting on a taxiway is lit up successively, individually or sectionally, in front of a taxiing aircraft for indicating the route of the aircraft when it is taxiing home or out, the necessary electric sectioning being determined in the software of a central computer via the addresses of the lighting electronic unit, and lighting being controlled by the taxiing route determined in the central computer.

6. Method as claimed in claim 5, c h a r a c t e r i z e d in that the extent of lighting up, extinguishing or changing colour of the light is controlled via a presence detecting system.

7. Method as claimed in any one of claims 1-6, c h a r a c t e r i z e d in that said output effect of each lighting for a given intensity level is changed by reprogramming via a centrally placed computer using the lighting electronics unit in situ.

8. Method as claimed in any one of claims 1-7, c h a r a c t e r i z e d in that the total illumination time of each light source is automatically and individually registered.

9. Plant for supervising and controlling field lighting at an airport, c h a r a c t e r i z e d in that each lighting is provided with an electronic unit controlling a regulator, monitoring unit and modem for power supply to the light source of the lighting, and for monitoring the operation of the lighting, each lighting being individually addressable from a control central for the airport.

10. Plant as claimed in claim 9, c h a r a c t e r i z e d in that a selected plurality of the electronic units of the lightings are each allotted a presence detector for forming a ground traffic detection system for detecting the ground movements of aircraft and vehicles, said detector including transducers based on supersonics, optics, magnetism, eddy currents, or microwaves.

11. Plant as claimed in claim 9 or 10, c h a r a c t e r i z e d in that each lighting electronic unit includes a unique address block, permanently mounted on the lighting, or its associated lighting well, such that when said unit is put in place the lighting is automatically given its unique address.

12. Plant as claimed in claim 11, c h a r a c t e r i z e d in that the address block includes permanent magnets, the north and south pole orientation of which gives a unique digital address, the lighting electronic unit containing magnetism-sensitive elements for sensing the north and south pole orientation of the magnets.

13. Plant as claimed in claim 10, c h a r a c t e r i z e d in that at least certain lightings are arranged to form so-called stop lights, each lighting of these stoplights including an individual electronic unit, and in that a presence detection system connected to said stop lights is arranged for automatically giving a re-illumination signal to the lightings of the stop lights as a reply to the passage of an aircraft or other vehicle past the stop lights.

14. Plant as claimed in any one of claims 9-13, c h a r a c t e r i z e d in that a given number of lightings are provided with battery backup, so that should there be a voltage failure the light intensity of the lamp is regulated to a previously determined value.

15. Plant as claimed in any one of claims 9-14, c h a r a c t e r i z e d in that the power supply to the lighting electronic unit is three-phase connected, and disposed such that should a phase fail, all the light units continue to light up with unaltered intensity unless the light intensity exceeds a predetermined value, at which a predetermined number of lightings are adapted such as to be extinguished.

16. Plant as claimed in any one of claims 9-15, c h a r a c t e r i z e d in that each lighting includes two separate light sources, the light configurations of these sources being identical, it only being intended that one light source is connected at a time, and in that the lighting electronic unit is adapted such that for a failure of one light source it automatically connects the other and gives an alarm for the failed light source.

Fig. 1

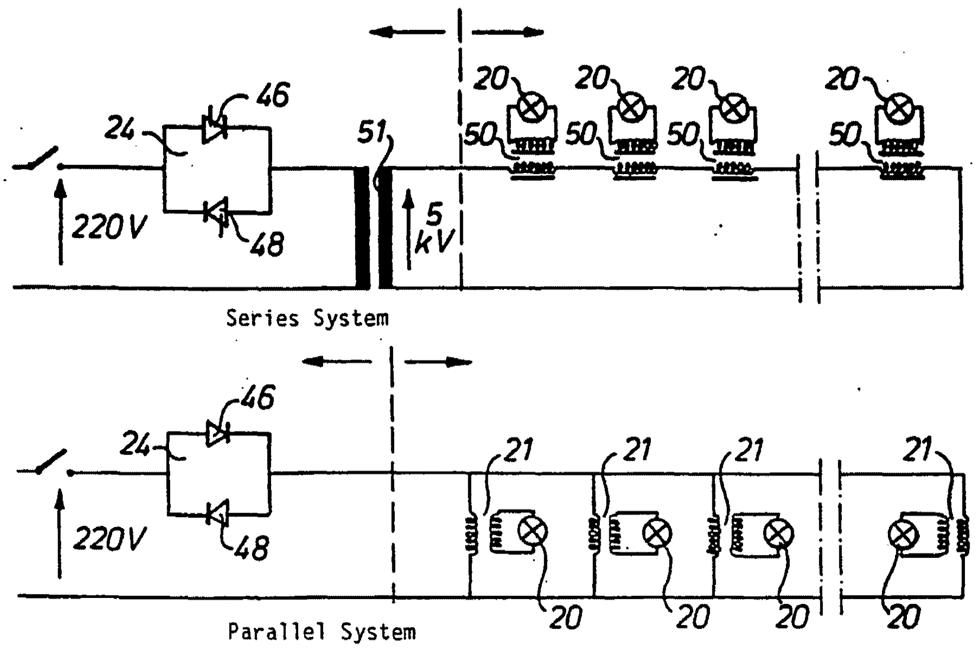

20
50
51
46
24
48
220V
5
kV
Series System
46
24
48
21
220V
20
Parallel System

Fig. 2

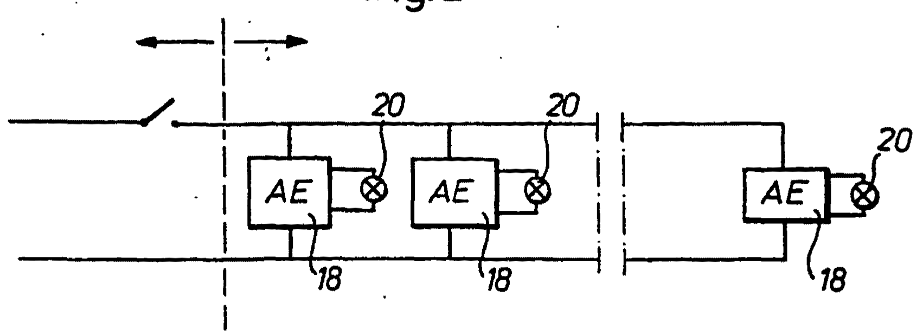

20
AE
18

Fig.3

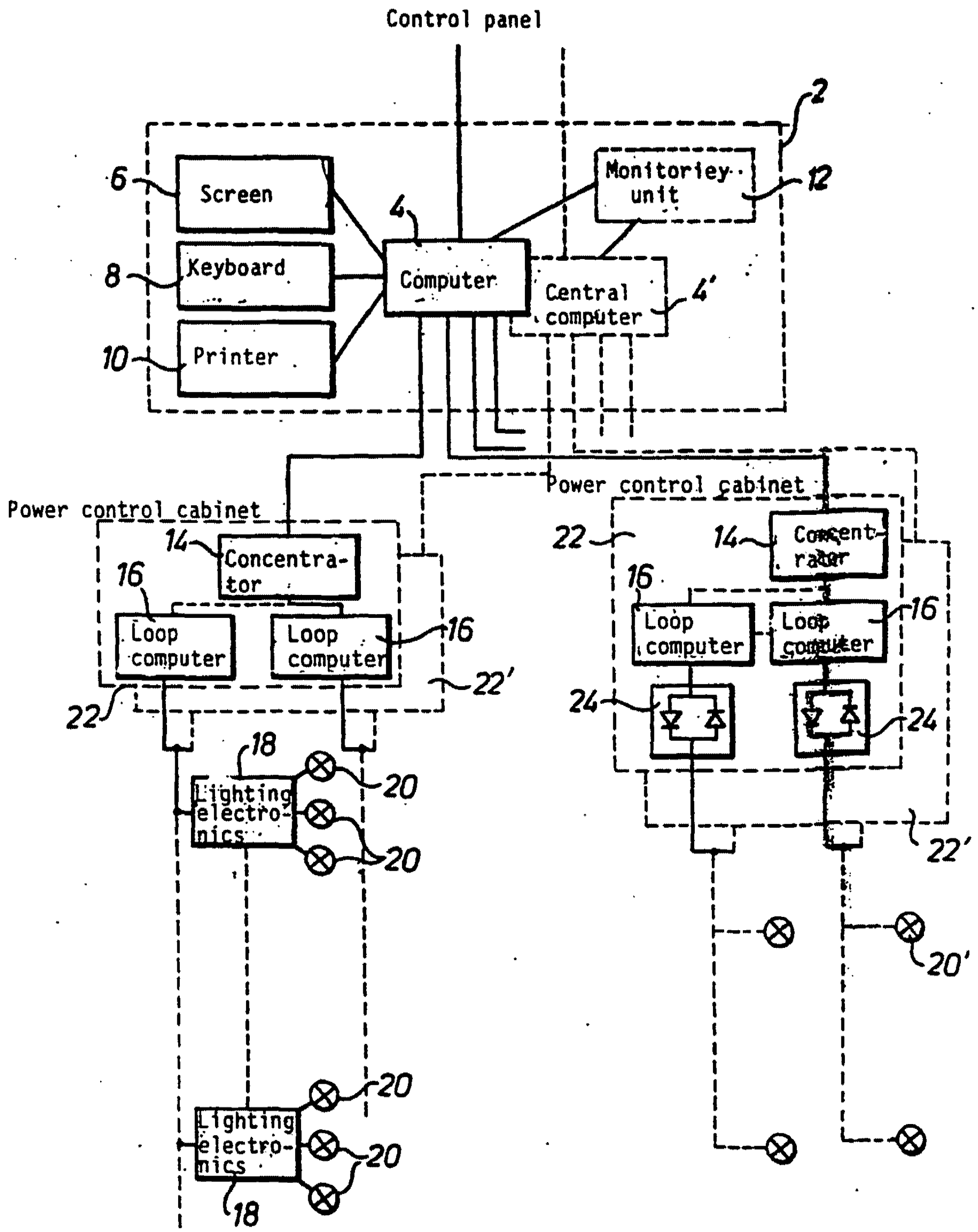

Control panel
2
Screen
Keyboard
Printer
Computer
Monitoriey unit
Central computer
6
8
10
4
4'
12
Power control cabinet
Concentrator
Loop computer
Loop computer
14
16
22
22'
18
Lighting electronics
20
24
20'

Fig. 4

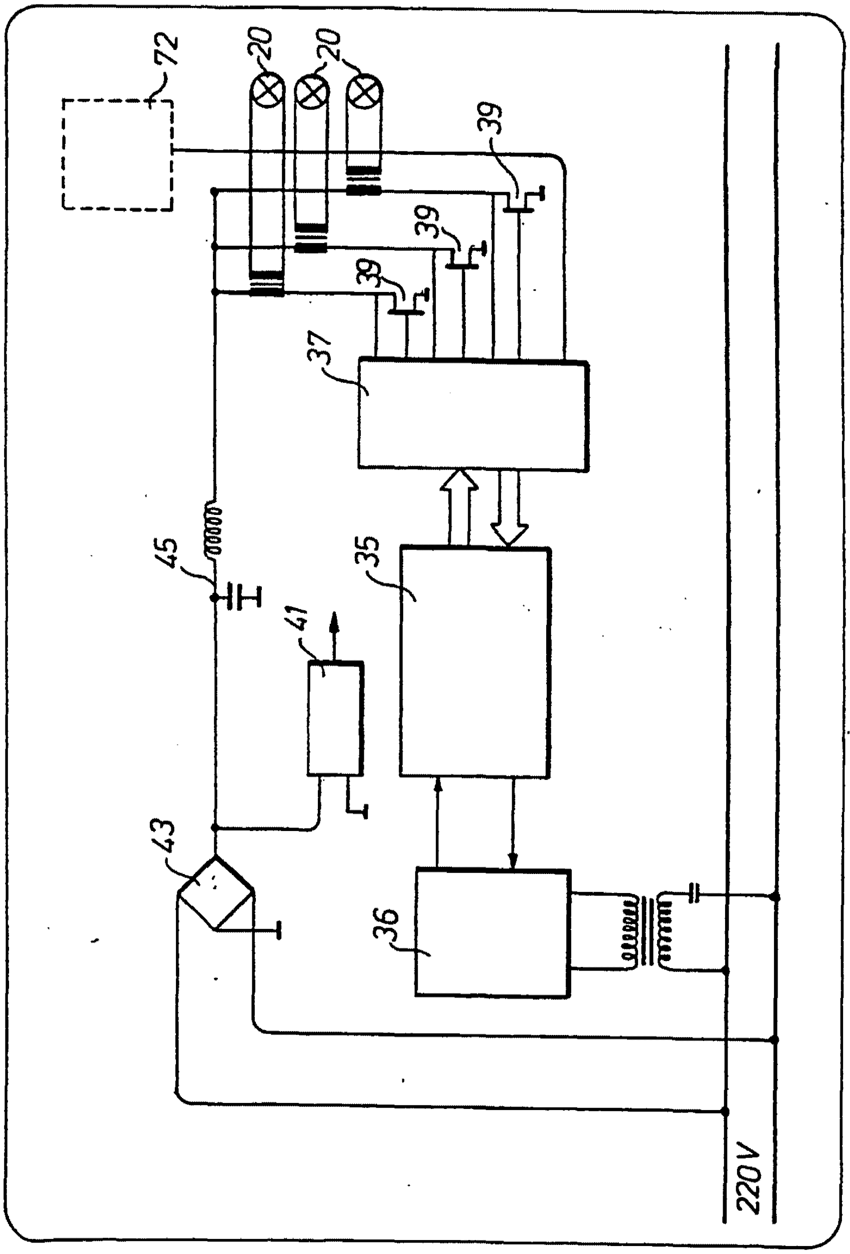


Fig.5

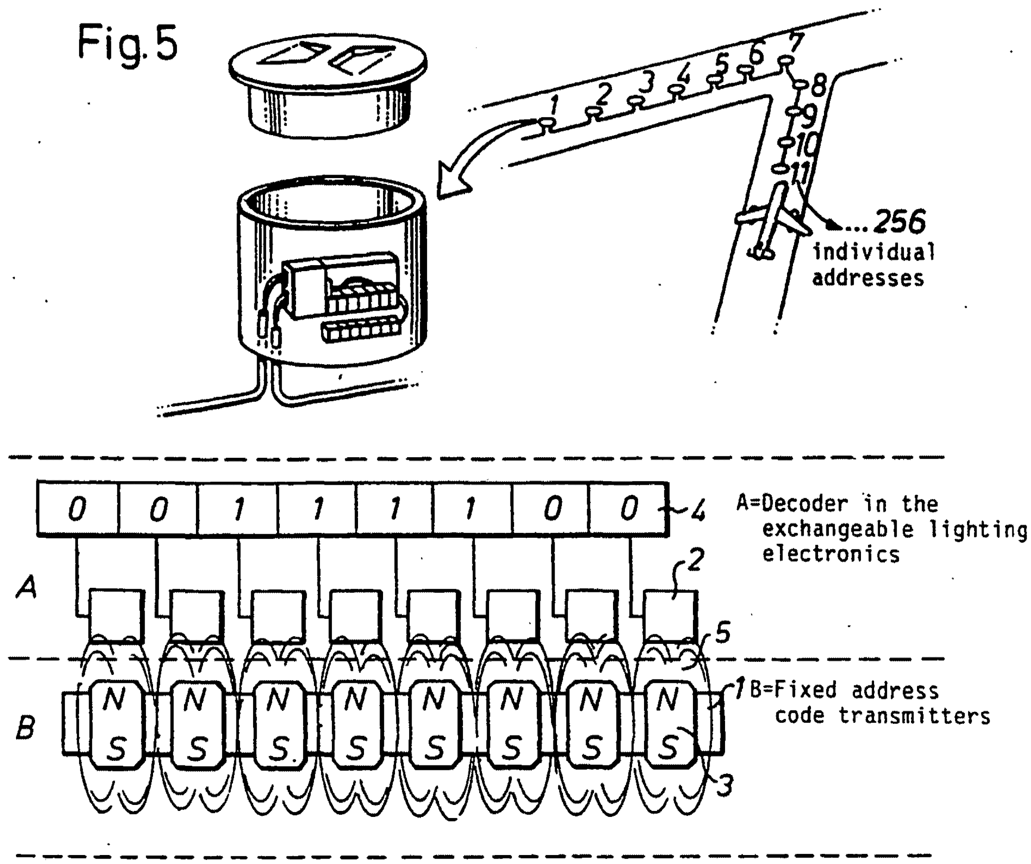
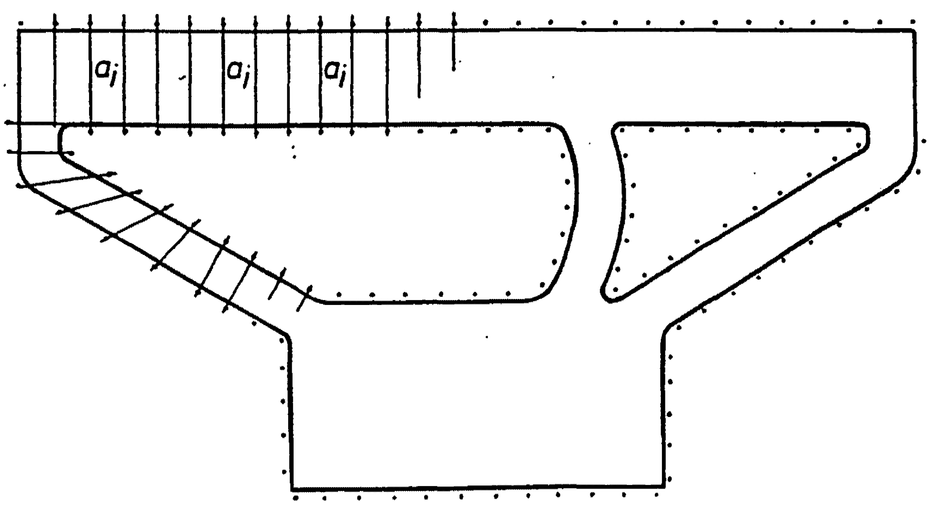

1
2
3
4
5
6
7
8
9
10
11
...256
individual
addresses
0 0 1 1 1 1 0 0
4
A=Decoder in the
exchangeable lighting
electronics
2
A
5
N
S
1
B=Fixed address
code transmitters
B
3

Fig. 6


a_i
a_i
a_i

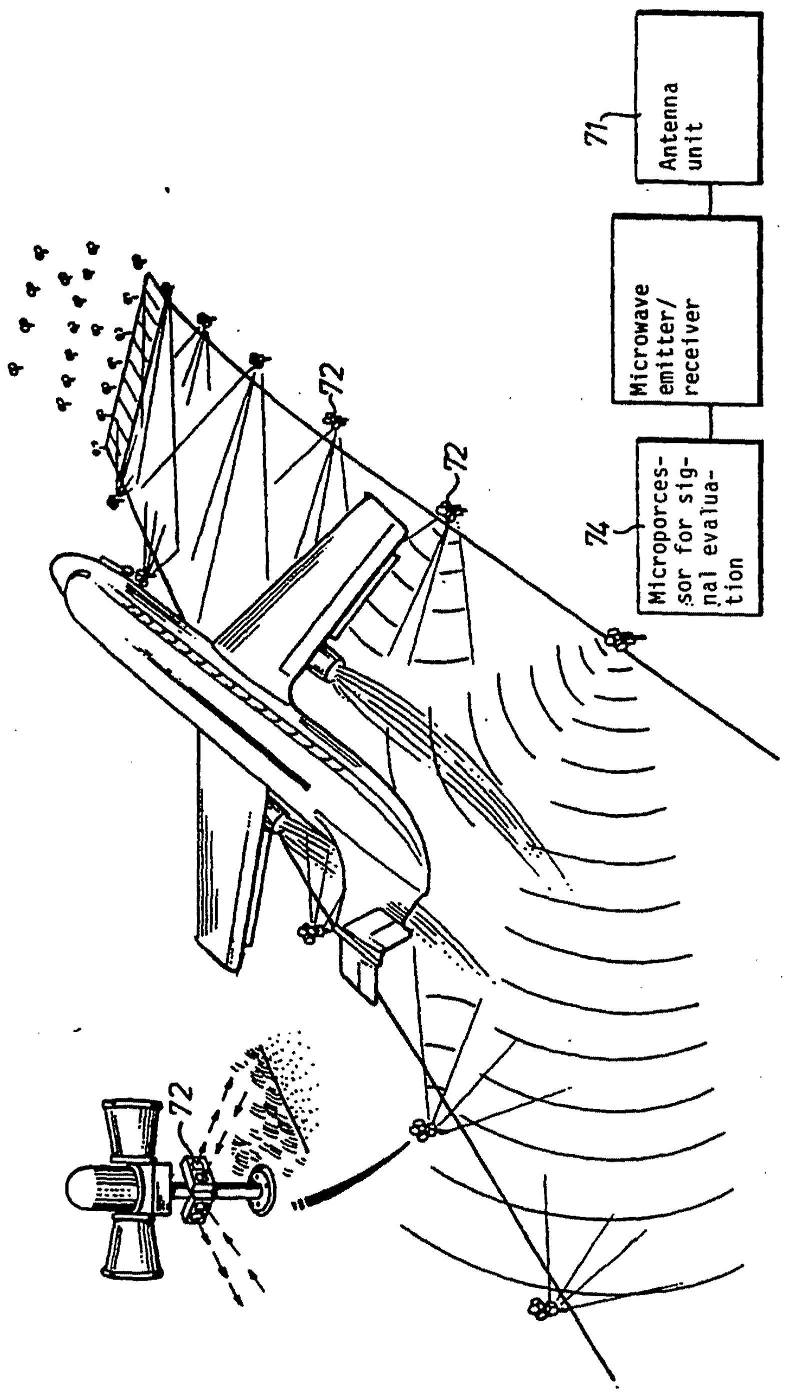
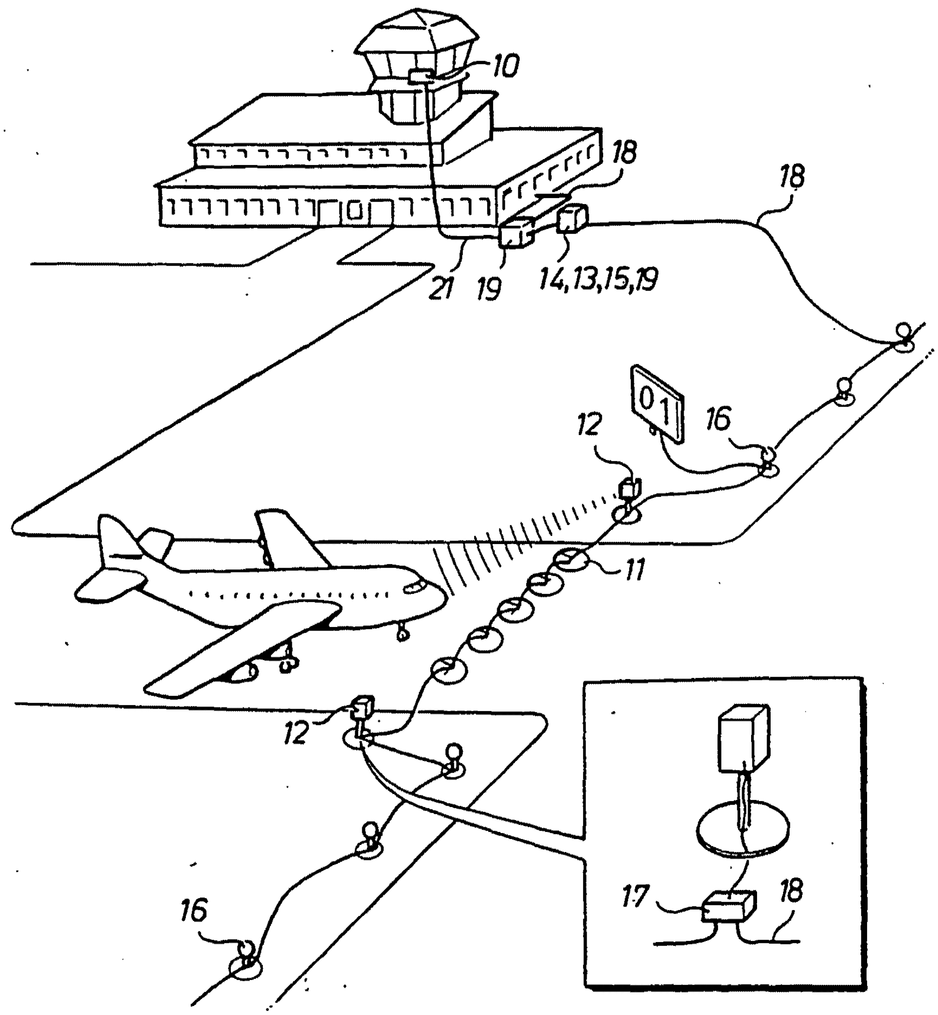

71
Antenna unit
Microwave emitter/ receiver
74
Microporces- sor for sig- nal evalua- tion
72
72
72

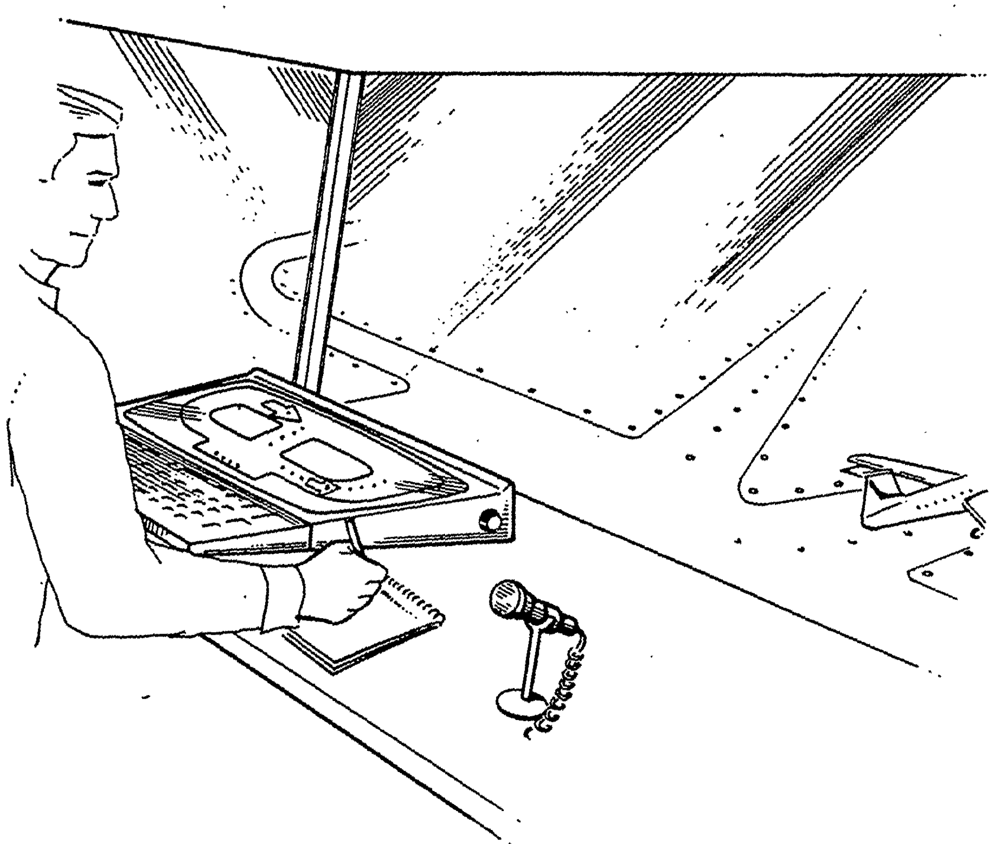
Fig. 7

Fig.8



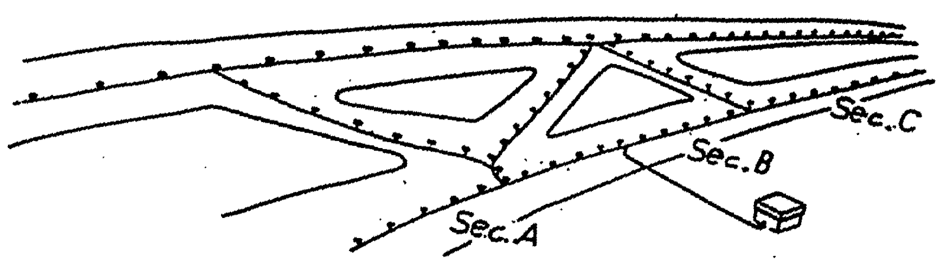
SUBSTITUTE SHEET

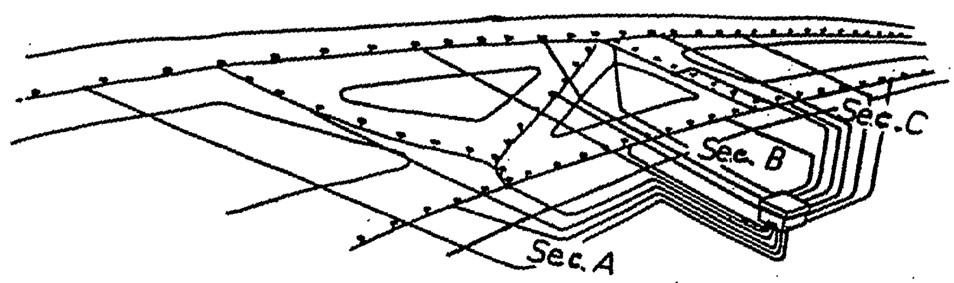
Fig. 9



SUBSTITUTE SHEET

Fig. 10





INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 89/00546

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC
IPC4: G 08 G 5/00, H 05 B 37/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC4	B 64 F, F 21 P, G 05 D, G 08 G, H 05 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
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Y	US, A, 4095139 (A.P. SYMONDS ET AL) 13 June 1978, see abstract --	1-7,9, 10,14,
Y	EP, A1, 0060068 (VARI-LITE) 15 September 1982, see abstract --	1-7,9, 10,14,
Y	EP, A1, 0069470 (PITTWAY CORPORATION) 12 January 1983, see abstract --	1-7,9, 10,14,
Y	GB, A, 2174852 (TANN ELECTRONICS LTD) 12 November 1986, see the whole document --	1-7,9, 10,14, 16

* Special categories of cited documents: [10]
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
14th December 1989	1989 -12- 27
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	Bertil Nordenberg

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

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ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. PCT/SE 89/00546

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DE-A1- 3635682	28/04/88	NONE	
US-A- 3771120	06/11/73	NONE	
US-A- 3531765	29/09/70	NONE	

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

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(51) International Patent Classification 6 : G08G 5/06

A1

(11) International Publication Number: **WO 98/52174**

(43) International Publication Date: 19 November 1998 (19.11.98)

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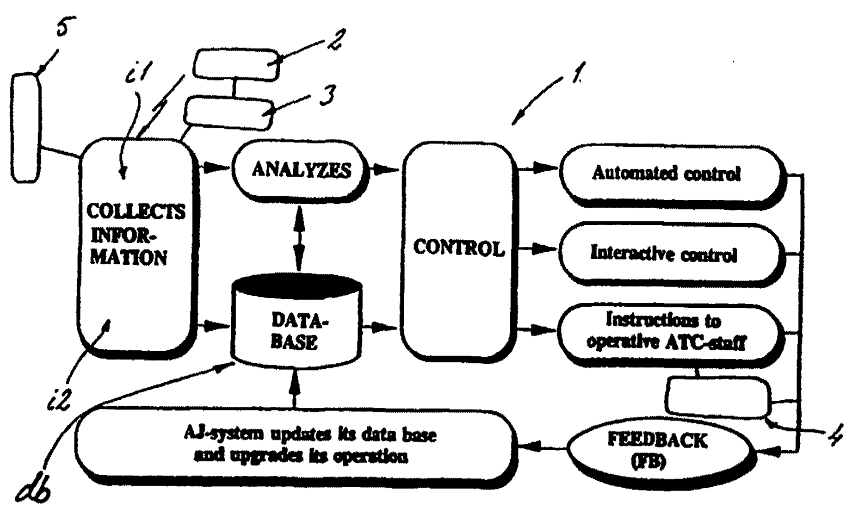
(54) Title: METHOD AND CONTROL SYSTEM FOR OPERATIVE TRAFFIC



(57) Abstract

The invention relates to a method for operative traffic, said traffic, such as operative ground traffic associated with air traffic, being controlled by means of a real–time and preferably so–called self–learning expert system (1), at least substantially all operative units, such as aircraft, field, maintenance, and upkeep equipment, vehicles or the like, as well as preferably also persons and groups of persons, present in an operative traffic area, being at least in an information transmitting communication therewith at least for the identification and substantially continuous positioning of the latter. The invention relates also to a control system applying the method.

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Method and control system for operative traffic

A method for operative traffic, said operative traffic, especially operative ground traffic associated with air traffic, being controlled by means of a real-time and automated data processing unit, at least some of the operative units, such as aircraft, field, maintenance, and upkeep equipment, vehicles or the like, present in an operative traffic area, being at least in an information transmitting communication therewith at least for the identification and positioning of the latter.

It is possible to apply a method of the invention in a wide variety of applications, e.g. for safely controlling operative traffic occurring on the ground, in water and/or in the air. One of the key applications for a method of the invention is the control of operative ground traffic associated especially with air traffic.

It is prior known that the ground traffic, especially one associated with air traffic, is run by using quite traditional methods and arrangements, each airport being always provided with an air traffic control tower, which is the base for controlling all airport operations involving both ground and air traffic activities by using conventional radar and monitor systems. However, the traditional control methods are largely based on visual monitoring performed by air traffic controllers, whereby, especially in adverse weather conditions, such as in fog, snowfall, or the like, the conditions may cause major setbacks and interruptions for air traffic. A principal reason for this is that it is not possible in all circumstances to visually make sure in a sufficiently reliable fashion e.g. the condition of a required runway door the equipment possibly present in such runway.

Therefore, e.g. after a snowplowing operation, it is generally necessary to wait at least an hour before it is possible to re-commission a runway to its primary applications. Snowy conditions are particularly inconvenient for traditional air traffic control methods since, as a result of sufficiently long runway standstill required as a safety precaution, there is time for fresh snow to gather thereon prior to the next commissioning of the runway, and this necessitates another pawing operation very shortly, leading to a continuing delay in air traffic as snowfall continues.

In addition, the traditional control system is not capable of controlling and guiding e.g. a landed aircraft to a terminal best suited for a given situation but, in principle, it is necessary to always stick with operating plans decided a long time before. Thus, e.g. occasional malfunctions, equipment breakdowns etc. often cause lengthy downtimes, resulting in a confusion in terms of preplanned timetables and arrangements. Furthermore, so-called "last-minute tune-ups" in traditional inflexible control systems frequently cause danger situations since, with manual arrangements, it is not possible to account for a sufficient number of factors even in minor changes of operating plan.

The prior art is described in US Patent 4,827,418, relating to an expert system which relies on so-called artificially intelligence based data processing for controlling the altitude and heading of especially airborne aircraft in order to avoid collisions. Such solutions make use particularly of LISP-programming or the like which, however, from the viewpoint of a person skilled in the art, does not have any significant equivalence to the processing solutions of the present invention. Thus, the system disclosed in the cited patent is indeed primarily intended for air traffic control, which can also be used as an air control simulator. Moreover, in the cited solution, e.g. the positioning is carried out conventionally by means of a radar. It should further be noted that the mere LISP-programming represents quite traditional processing in terms of technology and, hence, the (at present virtually "out-of-use") LISP-programming is not even close to being sufficiently powerful in terms of solving problems equivalent to those addressed by the present invention.

On the other hand, unlike both the above-cited and the present invention, the reference publication EP 613,109 encompasses infrared-radiation based transmitters and receivers for the identification and positioning of aircraft in a ground traffic area. In the cited solution, the positioning is largely based on monitoring the field temperature levels, whereby sensors mounted on the field detect a new aircraft on the basis of an increase in temperature. Thereafter, the heading of this particular aircraft is determined as soon as some other heat identification unit has detected the elevated temperature caused by this aeroplane. Then, it is possible to determine mathematically the heading/acceleration/speed etc. of the aircraft, e.g. by the application of vector mathematics or the like.

From the viewpoint of a person skilled in the art, the cited solution is also essentially different from the present invention since, first of all, it is based on IR radiation. On the other hand, the positioning of aircraft as well represents quite traditional technology, especially in light of the present invention, nor does it function with reliability that would be even nearly equal to that of the present invention. Neither is the cited type of arrangement by any means such that it could be utilised, at least not with a sufficient reliability, for monitoring the movements of persons/groups of persons working within a ground traffic area.

Thus, the cited solution is only capable of performing a fraction of what can be done with the present invention. Moreover, especially the use of IR radiation in this connection is unfavourable particularly for the following reasons:

- restricted in terms of its range/power
- necessitates a physical contact
- a limited number of channels
- out-of-date technology
- few practical applications, and even those in not absolutely crucial circumstances.

Hence, what the cited solution has in common with the present invention is primarily that it is intended for monitoring the position of aircraft or the like currently within a ground traffic area for avoiding collisions or the like by means of computer-assisted processing.

An object of a method of the invention is to provide a decisive improvement in terms of the above problems and hence to raise substantially the available prior art. In order to achieve this object, a method of the invention is principally characterized in that an expert system is informed about each unit on commission within an operative traffic area, preferably including also persons or groups of persons within the operative traffic area, by means of a radio-frequency operated transmitter system as well as by means of an antenna system enabling a substantially continuous-action positioning, the operative traffic being monitored and controlled by means of a comprehensive expert system, preferably making use of so-called soft computing technology, such as a sum logic, a neural network, a neuro-sum logic, chaos theory, genetic algorithms and/or the like for enabling its adaptive or self-learning operation.

The most important benefits gained by a method of the invention include simplicity, reliability in operation, and a remarkable improvement in the safety of operative traffic, the method making it possible to safely control for example all operative traffic associated with aviation while eliminating safety hazards and risk factors in the ground traffic within an airfield perimeter all the way from the landing of an aircraft to its take-off. A method of the invention also improves the speed and reliability of decision-making especially in abnormal situations, the method making it possible to eliminate unnecessary operation stoppages as well as congestions. Thus, a method of the invention provides a substantial improvement in the flexibility of especially ground and air traffic control, thereby producing a significant increase in the capacity of airfield traffic and in the economy of the entire airport operation. One further advantage gained especially by so-called soft computing technology over the prior art-technology is that, first of all, e.g. the neuro-sum logic provides a system which is distinctly more inexpensive, speedier, and simpler than those described above and which requires significantly fewer rules. In addition, the deduction-making is significantly speedier, with possibly more than 1000-fold differences in favour of the presentinvention.

The non-independent claims directed to a method disclose preferred applications for a method of the invention.

The invention relates also to a control system operating in accordance with the method. The control system is defined in more detail in the preamble of an independent claim directed thereto. The principal characterizing features of the control system are set forth in the characterizing clause of the same claim.

When correctly implemented, the control system of the invention is trouble-free, operates in real time, and self-learning, in addition to which it can be coupled, e.g. in the afore-mentioned aviation, e.g. interactively with ground radar, surveillance, or e.g. meteorological systems or the like. Since it is also possible to connect the operative staff to an integral, intelligent coding and information system, controlled by an expert system and further secured preferably with arrangements based e.g. on biothermal identification for preventing e.g. the passage of unauthorized persons within operative areas, the control system of the invention is capable of providing a significant improvement especially in terms of the safety and efficiency of aviation by eliminating major safety hazards and risk factors associated with traditional aviation. Thus, the control system of the invention can be used for controlling all activities within the operative ground traffic area of an airport from the moment an aircraft has touched down on runway all the way to the moment said aircraft has safely taxied to its designated terminal lot or vice versa.

The non-independent claims directed to a control system disclose preferred embodiments for a control system of the invention. The invention will now be described in detail with reference made to the accompanying drawings, in which fig. 1 shows basically a general operating principle for a control system applying a method of the invention,

fig. 2 shows further a method of the invention, applying a so-called diffuse spectrum-radio positioning system based on GSM-technology.

A method for operative traffic, said operative traffic, especially operative ground traffic associated with air traffic, being controlled by means of a real-time, automated data processing system, at least some of the operative units present in an operative traffic area, such as aircraft, field, maintenance, and upkeep equipment, vehicles or the like, being at least in an information transmitting communication therewith at least for the identification and positioning of the latter. An expert system 1 is informed about each unit on commission within an operative traffic area, preferably including also persons or groups of persons within the operative traffic area, by means of a radio-frequency operated transmitter system 2 as well as by means of an antenna system 3 enabling a substantially continuous-action positioning, the operative traffic being monitored and controlled by means of a comprehensive expert system 1, preferably making use of so-called soft computing technology, such as a sum logic, a neural network, a neuro-sum logic, chaos theory, genetic algorithms and/or the like for enabling its adaptive or self-learning operation.

In one preferred application of a method of the invention, the expert system 1 is supplied not only with collected real-time information i1, such as that regarding said operative units, but also with information i2 regarding the conditions of an operative traffic area, such as wind, ice, snow, water, temperature and/or the like factors, for anticipating hazardous situations, such as collision situations or the like, by means of operating models db pre-programmed therein.

In reference to traditional solutions, it is naturally preferable to control operative traffic also by means of guide boards, one preferred application of a method of the invention comprising the use of luminous, such as optical fiber, LCD-, LED-matrix displays 4 and/or the like, which are controlled integrally by means of the expert system 1 especially for providing an active guidance optimally compatible with the situation of each controlled unit.

In a further preferred application of the method, each unit present in an operative traffic area is identified and/or positioned by means of a unit-specific and/or personal detector system 5, such as through the intermediary of remote identification and/or preferably the antenna system 3 or, respectively, by means of a transponder system (TIRIS) enabling the positioning, a fingertip, eyeground identification system and/or the like, based on biometric identification, especially for making use of unit-specific clearances, restrictions, priorities and/or the like programmed in the expert system 1.

In a particularly preferred application of the method, each unit present in an operative traffic area is identified and positioned most preferably by means of a cellular network principle, such as a mobile communicator system included in a mobile communication network consisting of cells containing a base station, the positioning being effected by using a diffuse spectrum-radio positioning system 2, 3, 5 based on so-called GSM-technology. Fig. 2 illustrates one particular lay-out example for setting up the afore-mentioned diffuse spectrum-radio positioning system. 3', 5' represents in fig. 2 a taxiway shoulder light and a positioning beacon connected therewith. Respectively, 3", 5" represents a runway shoulder light and a positioning beacon connected therewith. kx represents a runway mid-line light. In a type of solution depicted in the figure, each moving/stationary object, or in this example an aircraft fp, fitted with a diffuse-spectrum transmitter 2' emitting an identification code. At this juncture, the runway shoulder lights present in the runway area and the taxiway shoulder lights receive and identify various diffuse-spectral transmissions, operating in accordance with the above-described logic as so-called positioning beacons. In this context, the radio path is provided by a system 2400 - 2450 GHz operating on ISM (Industrial & Scientifical & Medical) frequencies, having a frequency band of 50 MHz and a transmission capacity of < 10 mW. In this type of solution, at the object speed of 0 - 100 m/s, the coordinates are obtained at the accuracy of 0,1 - 10 meters. The scope of surveillance provides a possibility of monitoring all aircraft, vehicles moving in the area, maintenance people walking within the field area etc. In addition, the number of objects within the operating range of a single positioning analyzer may always be as high as 15 objects, whose activated identifications are included in the system data base.

For example, the above-mentioned TIRIS-system is based on an identifier (transponder), which is identifiable and preferably also attachable to an object to be positioned, and on a reader, which in this case is arranged in communication with the position-defining antenna system 2. In terms of technology, the TIRIS-system is constructed in such a way that the identifier is provided with an antenna element, a micro-circuit containing an identification code, and a capacitor. When subjected to a magnetic field from the reader, the passive identifier is charged and transmits the message contained in the identifier. The identifications are either previously encoded or to be updated in the field of a reader. The identifier receives its necessary operating energy preferably from an electromagnetic field (radio waves) and, thus, it needs no battery or other source of energy.

Referring particularly to the preferred operating principle depicted in the drawing, the control system of the invention comprises a transmitter system 2, operating on radio frequencies and informing an expert system 1 about each unit operating within an operative traffic area, including preferably also persons and groups of persons present in the operative traffic area, as well as an antenna system 3 enabling a substantially continuous-action positioning, the surveillance and control of operative traffic in the control system being effected by means of the expert system 1, making use of so-called soft computing technology, such as a sum logic, a neural network, a neuro-sum logic, a chaos theory, genetic algorithms and/or the like, enabling its adaptive or self-learning operation.

The control system is further preferably based on a self-learning expert system 1, whose information and control channels are preferably constituted by apparatus-specifically encoded high-frequency transmitters 2, and further on an antenna system 3, required for positioning and detecting a set of coordinates to be positioned, and on an active and luminous display board arrangement 4, controlling an operative field area preferably through the intermediary of a so-called intelligent optical network and based e.g. on an optical fiber/LCD-, LED-matrix.

In a further preferred application, the operative units/persons are linked to the system also by means of a unit-specific/personal detector system 5, such as a transponder system (TIRIS) enabling remote identification and the positioning preferably through the intermediary of the antenna system 3, a fingertip, eyeground identification system based on biometric identification, and/or the like. This enables making use of unit-specific clearances, restrictions, priorities and/or the like programmed especially in the expert system 1.

In a preferred application, the control system includes a diffuse spectrum-radio positioning system 2,3,5, which is preferably based on GSM-technology and whereby each unit present in an operative traffic area is identified and positioned preferably on a cellular network principle, such as a mobile communicator system included in a mobile communicator network consisting of cells that contain a base station.

In an intended application as described above, the control system monitors and controls automatically as well as transmits information independently about all operative traffic action within a field area and, by virtue of this, provides air traffic control and aviators with significantly improved possibilities of taking correct decisions and measures required by a given situation. In addition, the above type of control system increases substantially the capacity of operative field action (landing, take-off, surface traffic, flight maintenance) especially in foul weather conditions, as it is capable of composing an overall picture of all surveillance and sensor points simultaneously. The accuracy is further enhanced, as the control system is capable of determining and deciding continuously and in real-time all situations and by constantly simulating both mathematically and empirically such situations before they are likely to occur. Thus, an expert system included in the control system is capable of identifying also completely unpredictable events e.g. by alarming the operative staff automatically and by describing the problem as well as by also presenting preferably e.g. graphic and safe, i.e. previously simulated and tested model solutions.

One further advantage offered by the control system of the invention in this context is that it relieves the air traffic control of all control measures regarding aircraft present on the ground and in a normal condition as well as other surface traffic. Hence, the control system concentrates the decision-making especially in a crisis situation on the air traffic control, the expert system, as well as on other monitoring systems associated preferably interactively with the control system, e.g. as depicted in the chart of the drawing. Hence, an expert system of the invention operates as part of the control system by delivering continuous, real-time, graphic information, solution models and suggestions, while leaving, whenever necessary, the actual decision-making to the air traffic control. According to the chart depicted in the drawing, the control system thus collects the real-time information, compares it to a safe decision compatible with the condition of the expert system 1, and produces an alarm about immediate or anticipated discrepancies. The analyzed surveillance information is stored automatically in the data base db.

In certain type of cases, the expert system 1 included in the control system operates automatically by deciding and performing all conventional and non-hazardous control duties. In addition, it is possible to monitor thereby that the air traffic control performs correctly the ground traffic control operations assigned thereto.

The method and control system of the invention can be further exploited in such a manner that all relevant travelling paths within an operative area are also provided with guiding tapes or the like, controlled in real time by the expert system, whereby e.g. an advancing light or sound effect is used to guide each controlled unit to its proper destination.

It is naturally obvious that a method of the invention can be applied not only in the above-mentioned and -described applications but in the most diverse of contexts, i.e. in addition to ground traffic application, e.g. in a harbour area for controlling and monitoring the passage of boats/ships. Naturally, the operating chart depicted by way of example only represents generally the operating principle for a method of the invention, as it is of course possible to link directly therewith, in addition to the above-mentioned supplementary functions, e.g. an air traffic control radar and monitor info, air traffic control preference decisions, weather observations, etc. Also naturally, e.g. the above-described TIRIS-system can be active as well, whereby, when fitted with a current supply, it will be capable of independently communicating with the expert system, e.g. for the continuous positioning of a moving vehicle.

Claims:

1. A method for operative traffic, said operative traffic, especially operative ground traffic associated with air traffic, being controlled by means of a real-time and automated data processing unit, at least some of the operative units, such as aircraft, field, maintenance, and upkeep equipment, vehicles or the like, present in an operative traffic area, being at least in an information transmitting communication therewith at least for the identification and positioning of the latter, characterized in that an expert system (1) is informed about each unit on commission within an operative traffic area, preferably including also persons or groups of persons within the operative traffic area, by means of a radio-frequency operated transmitter system (2) as well as by means of an antenna system (3) enabling a substantially continuous-action positioning, the operative traffic being monitored and controlled by means of the comprehensive expert system (1), preferably making use of so-called soft computing technology, such as a sum logic, a neural network, a neuro-sum logic, chaos theory, genetic algorithms and/or the like for enabling its adaptive or self-learning operation.

2. A method as set forth in claim 1, characterized in, that the expert system (1) is supplied not only with collected real-time information (i1), such as that regarding said operative units, but also with information (i2) regardin the conditions of an operative traffic area, such as wind, ice, snow, water, temperature and/or the like factors, for anticipating hazardous situations, such as collision situations or the like, by means of operating models (db) pre-programmed therein.

3. A method as set forth in claim 1 or 2, wherein the operative traffic is controlled by means of guide boards present at least in an operative traffic area, characterized in that said guidance is effected by using luminous, such as optical fiber, LCD-, LED-matrix displays (4) and/or the like, which are controlled integrally by means of the expert system (1) especially for providing an active guidance optimally compatible with the situation of each controlled unit.

4. A method as set forth in any of the preceding claims 1-3, characterized in that each unit present in an operative traffic area is identified and/or positioned by means of a unit-specific and/or personal detector system (5), such as through the intermediary of remote identification and/or preferably the antenna system (3) or, respectively, by means of a transponder system (TIRIS) enabling the positioning, a fingertip, eyeground identification system and/or the like, based on biometric identification, especially for making use of unit-specific clearances, restrictions, priorities and/or the like programmed in the expert system (1).

5. A method as set forth in any of the preceding claims 1-4, characterized in that each unit present in an operative traffic area is identified and positioned most preferably by means of a cellular network principle, such as a mobile communicator system included in a mobile communication network consisting of cells containing a base station, the positioning being effected by using a diffuse spectrum-radio positioning system (2,3,5), most preferably based on GSM-technology.

6. A control system for operative traffic, said control system intended for controlling operative traffic, especially operative ground traffic

associated with air traffic, being implemented by means of a real-time and automated data processing unit, at least some of the operative units, such as aircraft, field, maintenance, and upkeep equipment, vehicles or the like, present in an operative traffic area being at least in an information transmitting communication therewith at least for the identification and positioning of the latter, characterized in that the control system comprises a transmitter system (2), operating on radio frequencies and informing an expert system (1) about each unit operating within an operative traffic area, including preferably also persons and groups of persons present in the operative traffic area, as well as an antenna system (3) enabling a substantially continuous-action positioning, the surveillance and control of operative traffic in the control system being effected by means of the expert system (1), making use of so-called soft computing technology, such as a sum logic, a neural network, a neuro-sum logic, a chaos theory, genetic algorithms and/or the like, enabling its adaptive or self-learning operation.

7. A control system as set forth in claim 6, characterized in that the expert system (1) is adapted to process not only real-time information (i1) collected therein and regarding said operative units, but also information (i2) regarding the conditions of an operative traffic area, such as wind, ice, snow, water, temperature and/or the like factors, for anticipating hazardous situations, such as collision situations or the like, by means of operating models (db) pre-programmed therein.

8. A control system as set forth in claim 6 or 7, including guide boards present at least in an operative traffic area for guiding said operative traffic, characterized in that said guidance is

provided by means of luminous, such as optical fiber, LCD-, LED-matrix displays (4) and/or the like, which are adapted to be integrally controlled by means of the expert system (1) especially for providing an active guidance optimally compatible with the situation of each controlled unit.

9. A control system as set forth in any of the preceding claims 6-8, characterized in that, for identifying and/or positioning each unit present in an operative traffic area, said control system includes a unit-specific and/or personal detector system (5), such as a transponder system (TIRIS) enabling the positioning through the intermediary of remote identification and/or preferably the antenna system (3) or, respectively, a fingertip, eyeground identification system and/or the like, based on biometric identification, especially for making use of unit-specific clearances, restrictions, priorities and/or the like programmed in the expert system (1).

10. A control system as set forth in any of the preceding claims 6-9, characterized in that it includes a diffuse spectrum-radio positioning system (2,3,5), most preferably based on GSM-technology, for identifying and positioning each unit present in an operative traffic area most preferably on a cellular network principle, such as by means of a mobile communicator system included in a mobile communication network consisting of cells containing a base station.

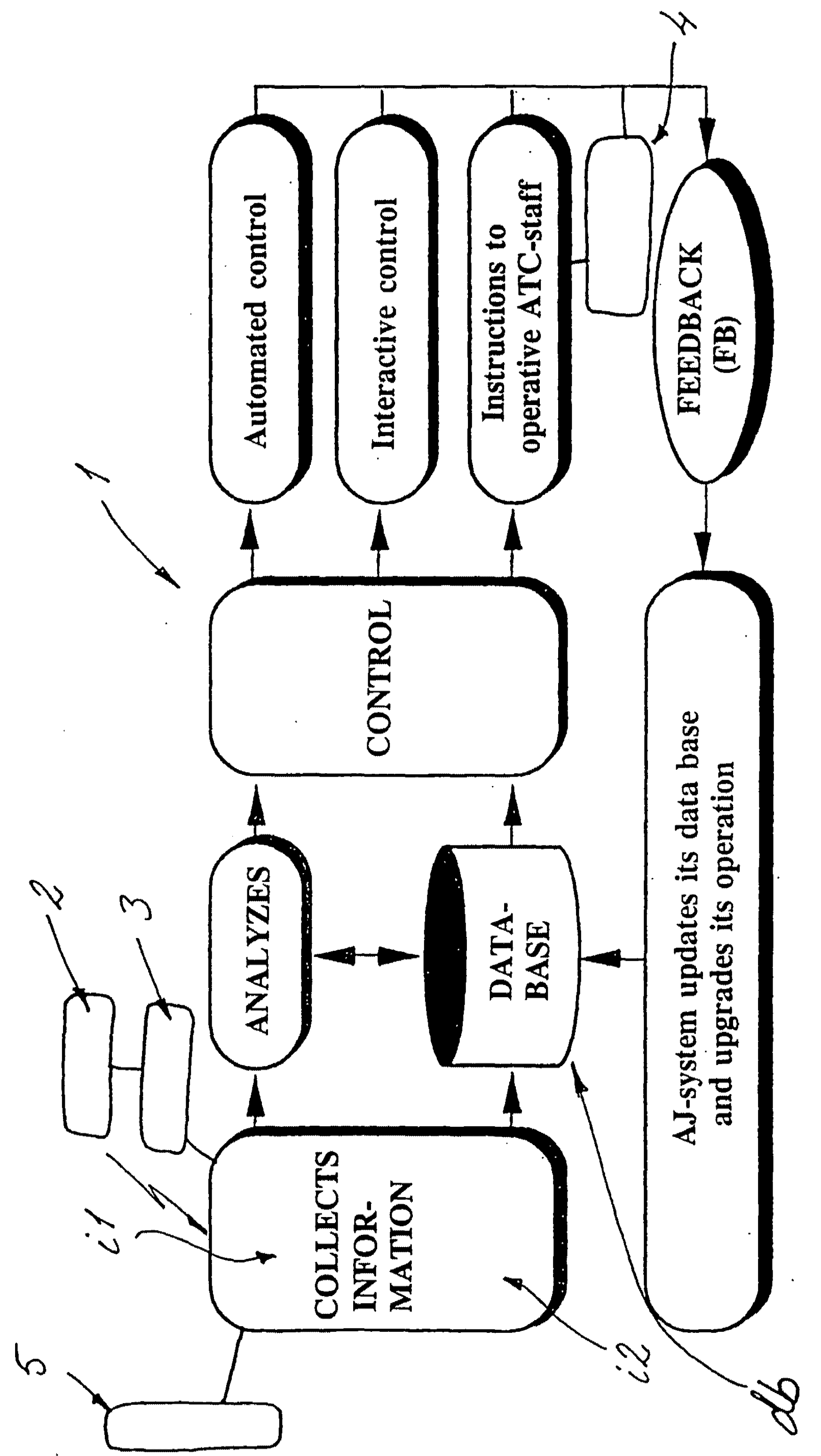
COLLECTS INFOR-MATION
ANALYZES
DATA-BASE
CONTROL
Automated control
Interactive control
Instructions to operative ATC-staff
FEEDBACK (FB)
AJ-system updates its data base and upgrades its operation
1
2
3
4
5
i1
i2
db

FIG.1

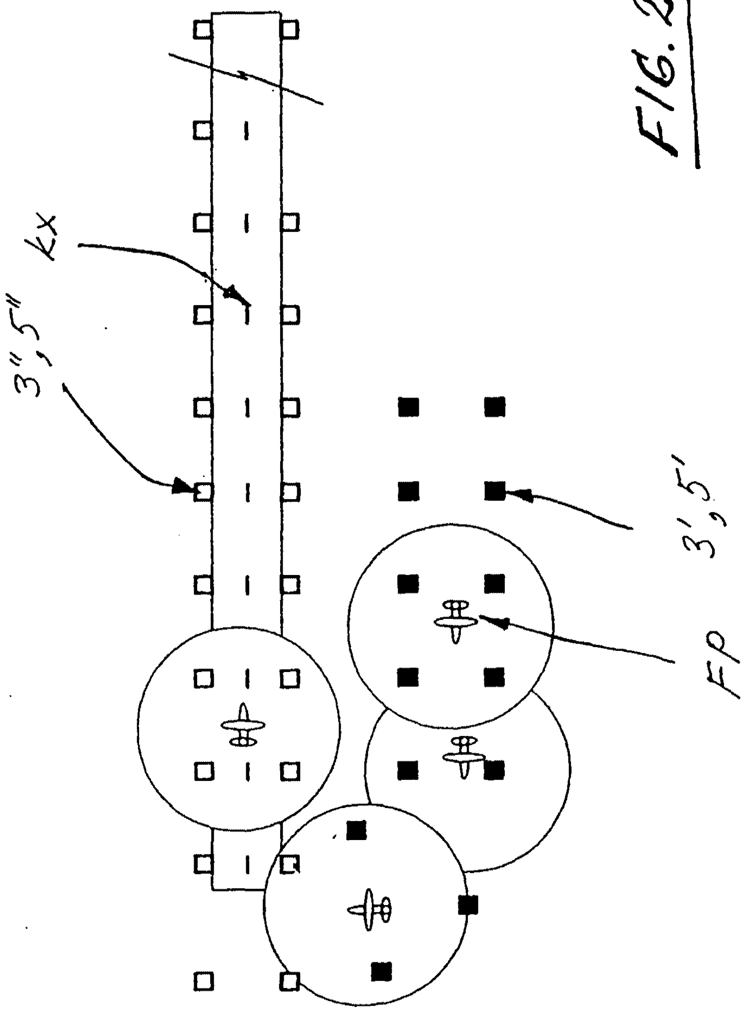

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 97/00281

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G08G 5/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G08G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Electrical Communication, Volume, January 1993, Monzel F.-G. et al, "Surface Movement Guidance and Control System", page 51 - page 59, see the whole document --	1-10
A	US 4827418 A (ARTHUR GERSTENFELD), 2 May 1989 (02.05.89), abstract --	1,6
A	EP 0613109 A1 (RAYTHEON COMPANY), 31 August 1994 (31.08.94) -- --------	4,9

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 February 1998	16 -02- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Göran Magnusson Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT
Information on patent family members

03/02/98

International application No.
PCT/FI 97/00281

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4827418 A	02/05/89	US 4949267 A	14/08/90
		US 4979137 A	18/12/90
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		JP 6301899 A	28/10/94
		NO 940626 A	29/08/94

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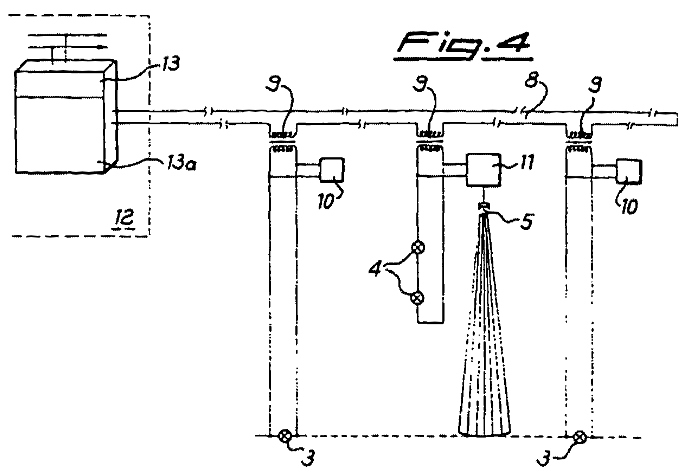
(54) **Automatic equipment for controlling and guiding the movement of aircraft travelling on the ground.**

(57) Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground on taxi strips (1b), comprising illumination devices (3) disposed at predetermined intervals along the longitudinal axis of the taxi strips (1b); light signalling devices (4) spaced equally apart in such a way that each successive pair of signalling devices (4) defines, in the longitudinal direction, consecutive segments (2) of the taxi strip (1b); devices (5) for detecting the passage of aircraft (6) capable of sending a signal to corresponding means of controlling (10, 13, 14) and displaying (15) the actuation of the sequence of lighting and extinguishing of the illumination and guiding (3) devices and of the light signalling devices (4) of the various segments (2, 102) of the taxi strip (1b).

Fig.4



EP 0 532 110 A2

The present invention relates to equipment for controlling and guiding the movement of aircraft travelling on the ground on taxi strips for access to and exit from the runway and parking and standing areas of airports.

It is known that one of the principal problems relating to the operational management of airports is constituted by the necessity of moving aircraft as rapidly as possible, but in conditions of complete safety, in their transit from the parking area to the take-off runway and from the landing runway to the parking area.

Among the known methods of providing the aircraft pilot with signals permitting proceeding and guiding on predetermined routes of exit from and/or entry to the runways, particular mention may be made of those based on direct visual observation by the pilot of signs located on the ground, manually operated on sight by the control tower operator, and those based on surface radar devices installed at predetermined points at the airport; such devices, however, have numerous disadvantages, including the total lack of control of ground traffic in case of failure or disabling of the device for maintenance operations, or incorrect signalling and/or interpretation of the signalling due to high reflection levels caused by irregularities of the ground, the presence of obstacles, driving rain and the like, image splitting and the like.

Such problems are also significantly increased in critical operating conditions such as those arising with high traffic flows, adverse meteorological conditions and poor visibility.

Consequently there is a technical problem of providing automatic equipment which is capable of signalling to and guiding aircraft during their transit on the ground on sections of taxi and connecting strips, and which is able to ensure a specified safe distance between the aircraft, permitting or refusing their access to sections of taxi strip, and operating reliably in any weather and traffic density conditions, and with a signalling speed proportional to the actual requirements related to the real traffic density in such a way as to cause no significant decrease of the operating capacity of the airport.

The equipment must also be such that correct operation is ensured even in case of failure and/or during ordinary maintenance operations, and such that it may be applied both at new airports and at airports already in operation, by making use, in the latter case, of auxiliary services and transmission lines which may already be in existence.

These results are achieved by the present invention, which provides automatic equipment for controlling and guiding the movement of aircraft travelling on the ground on taxi strips to and from the runways and to and from the standing and parking areas, this equipment comprising in combination illumination devices disposed at predetermined intervals along the longitudinal axis of the taxi strips; light signalling devices spaced equally apart in such a way that each successive pair of signalling devices defines, in the longitudinal direction, consecutive segments of the taxi strip; devices for detecting the transit of aircraft and capable of sending a signal to corresponding means of controlling and displaying the actuation of the sequence of lighting and extinguishing of the illumination and guiding devices and of the light signalling devices of the various segments of the taxi strip, for corresponding permission for or prohibition of the advance of the aircraft along successive segments.

More particularly, it is specified that the said light signalling devices consist of pairs of lights disposed at the lateral edges of the taxi strip on the transverse axes of the segments and that the said detection devices preferably consist of sensors of the microwave and infrared type and consequently that the said sensors illuminate the respective signalling devices when any detection of the passage of the aircraft has ceased.

A further characteristic of the invention consists in the fact that the said control units comprise local control units disposed next to the segments, substation control units disposed inside electrical equipment substations, and central control units disposed in the control tower; in particular, the said substation control units are capable of receiving signals from a central unit and of operating local control units to light and extinguish the axial illumination devices and to extinguish the signalling devices, while the local control units are capable of receiving signals confirming the passage of an aircraft from the sensors and of autonomously causing the lighting of the signalling devices.

In particular, each unilluminated segment is delimited by illuminated red light signals to prevent the access of an aircraft to the said segment.

According to the invention, the automatic equipment may also be used with illumination devices each of which comprises a signalling light and a sensor, each illumination device being capable of operating in this mode, and also as a segment end light, in which case each segment has a minimum length which may be varied as required, and is determined by the lighting of the illumination device with a red light.

For the better use of the equipment it is also specified that the central control unit only controls the intersections delimiting sections of taxi strip and that the local and substation control units directly control the segments into which each of the said taxi strip sections, delimited by consecutive nodes, is divided.

Further details may be obtained from the following description, with reference to the attached drawings, which show:

in Fig. 1:

a partial schematic plan of an airport;

in Fig. 2:

a plan view of a section of taxi strip equipped with signalling devices according to the invention;

in Fig. 3:

a schematic diagram of the local electrical power supply and control circuit of the signalling equipment;

in Fig. 4:

a schematic diagram of the circuit connecting the taxi strip equipment to the substation control unit;

in Fig. 5:

a block diagram of the system of connection of the substation control unit to the central control unit;

in Figs. 6a, 6b, 6c:

the operating sequence of the control and signalling equipment according to the invention;

in Fig. 7:

a view of the device displaying the current state of the ground traffic situation;

in Fig. 8:

an alternative division of the taxi strips into sections delimited by intersections.

As shown in Fig. 1, the map of an airport 1 is normally divided into landing and take-off runways 1a, taxi strips 1b comprising links and intersections 1c, and standing and parking areas 1d.

In order for the aircraft to be guided automatically from the moment at which they leave the landing runway 1a until they stop in the parking area 1d, and vice versa, the taxi strips 1b are, according to the invention, ideally divided into segments 2 adjacent to each other and physically delimited by lighting elements whose lighting and extinguishing are monitored and controlled by programmed control units which receive signals from sensors associated with the lighting elements and send lighting or extinguishing commands to local control units which are in communication with a central unit installed in the control tower.

In greater detail, each segment 2 (Fig. 2) is provided with illuminating elements 3 disposed at predetermined intervals, as will be more clearly specified subsequently, along the longitudinal axis of the segment 2 which is delimited by two opposite theoretical transverse lines 2a constituting the axis of alignment of stop lights 4 associated with sensors 5 capable of detecting the passage of an aircraft 6 and of lighting the stop lights 4 through the local control unit 11, which in turn sends a confirmation signal to a substation control unit 13 located near the taxi strip in corresponding substations 12 (Fig. 4).

The minimum length of a segment 2 is determined on the basis of certain parameters which affect the whole design of the equipment and include the photometric properties of the illuminating elements 3, the characteristic category of authorization for landing, the geometry of the electrical circuits of the light fittings and the dimensions of the aircraft; the power of the lamps and their spacing along the segment, together with the length of the segment itself, will be calculated from these parameters.

As is more clearly shown in Fig. 3, the axial illuminating elements 3 are connected to the series power supply circuits 8 disposed along the taxi strip 1b at its edges, each pair of illuminating elements 3 formed in this way being connected to isolation transformers 9 in parallel to which are connected local control units 10 in order to implement the lighting and extinguishing commands received from the substation control unit 13.

As has been stated, two pairs of stop lights 4 are also installed at each transverse axis of the start and end of a segment 2 near the edge of the taxi strip, these lights also being supplied from the mains 8 through transformers 9, in parallel with which are connected sensors 5 to detect the passage of the aircraft, these sensors also being supplied from the mains 8 through isolation transformers 9.

According to the invention (Fig. 4), the terminals of the electrical circuits are connected to constant current regulators 13a housed in the electrical substations 12, which in turn are connected to substation control units 13 for connection (Fig. 5) to the central control unit 14 which is located in the control tower and substantially consists of a pair of electronic computers 14a arranged in parallel, a monitoring unit 14b capable of determining the priority of operation between the two computers, a data compression unit 14c and an intermediate register 14d for the temporary storage of signals from and to the substation control units 13, installed in the individual substations 12, which operate at a different rate from the central unit 14.

The operating sequence of the equipment is as follows (Fig. 6a): when an aircraft 6a passes through a given segment 2a, all the axial lights 3a of the segment 2a are illuminated to guide the aeroplane and at the same time the red stop lights 4'a, defining the start of segment 2a, are illuminated to prevent any access to the same segment by another aeroplane. During such a phase the axial lights 3b of segment 2b, behind and adjacent to the occupied segment 2a, are extinguished, since the presence of an aeroplane 6, which would be too close to the one in front, is not permitted in this segment.

If the two segments 2c, 2d following segment 2a are free, the stop lights 4"a disposed next to the transverse end axis of segment 2a permit free passage, being extinguished, and allow the aeroplane 6a to proceed on its way, guided by the corresponding axial lights 3c which will be lighted.

At the same time, a second aeroplane 6b travelling along the same taxi strip behind the aeroplane 6a would find the axial lights 3e of its segment 2e illuminated and the rear stop lights 4'e and forward stop lights 4"e illuminated with red lights to prevent the advance of the aeroplane 6b to the following segment 2b, which would be immediately adjacent to the segment 2a already occupied by the aeroplane 6a and which, in turn, has axial lights 3b extinguished as stated previously.

When the first aeroplane 6a passes the sensor 5a (Fig 6b), the latter, detecting the interruption of the beam, changes state and sends a signal to the substation control unit 13 which, by a dialogue with the central control unit 14, enables the latter to send signals to the local control unit 10 to modify the situation as follows: illumination of the axial lights 3d of segment 2d to allow aeroplane 6a to proceed on its way, on completion of the passage of which in front of the sensors 5'a the situation is further changed as follows (Fig. 6c): axial lights 3c, 3d of the adjacent segments 2c, 2d illuminated and stop lights 4"c extinguished to allow aeroplane 6a to proceed on its way; axial lights 3a of segment 2a to the rear and adjacent extinguished and stop lights 4'a, 4"a illuminated with a red light to prevent access of a second aeroplane to segment 2a, stop lights 4"e extinguished and axial lights 3b of segment 2b illuminated to permit the advance of aeroplane 6b to segment 2b following that being passed through.

Consequently the control of the illumination of consecutive adjacent segments as described above enables the advance of a number of aeroplanes to be guided, while simultaneously ensuring the maintenance of the desired safety distance between one aeroplane and the other, this distance always being measured in multiples of segments 2 of a minimum predetermined length as described above.

The equipment according to the invention is completed by a device for the display of the complete ground traffic situation of the airport, which enables the operators to identify on a video screen 15 (Fig. 7) fixed areas 15a for identification of particular aeroplanes, distinguished for example by their own flight numbers, such fixed areas being associated with a broken line 15b or the like to graphically link the identification area 15a with the segment 2 of taxi strip occupied by the aeroplane and represented on the screen within the map of the airport; as the aeroplane moves along the taxi strip to take off or, in the opposite direction, to the parking area 1d, the identification number will occupy successive fixed areas and change its position on the screen.

Many constructional and dimensional modifications may be introduced into the embodiment of the various components of the equipment without thereby departing from the scope of the invention in its general characteristics; in particular, it is possible to specify the connection of stop light 4 and of the sensor 5 inside each axial illuminating element 3, which in this case will be designed to emit either a green light or a red light, providing, by means of appropriate processing of the data carried out by the corresponding units, continuous control of the whole airport area with the further important possibility of freely modifying the minimum length of segment 2 according to necessity and/or convenience, for example as a result of a decrease in visibility which necessitates a greater safety distance.

It is also possible (Fig. 8) to theoretically divide the map of the airport into sections 102 located between two consecutive intersections, known as nodes, 101c, additionally dividing the tasks of the various control units in such a way that the substation control units 13 have the task of guiding the aeroplane in the individual segments 102 until the final sensor 105 indicates that the aeroplane is entering a node 101c, at which point control passes to the central control unit 14, which is informed of the presence or absence of the other segments leading to this particular intersection, and which may establish the order of precedence of access to the intersection or may divert a machine to other segments; with such a configuration it would be possible to make considerable savings of transmission time, since the data traffic relating to the control of the advance of the aircraft 6 in segments 102 would be limited to the substation control units situated near the taxi strips, while only the data concerning the actual position of each aeroplane would be sent to the central control unit (14).

Claims

1. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground on taxi strips (1b) from and to the runways (1a) and to and from the standing and parking areas (1d), characterized in that it comprises in combination illumination devices (3) disposed at predetermined intervals along the longitudinal axis of the taxi strips (1b); light signalling devices (4) spaced equally apart, in such a way that each pair of successive signalling devices (4) defines, in the longitudinal direction, consecutive segments (2) of taxi strip

(1b); devices (5) for detecting the transit of aircraft (6), capable of sending a signal to corresponding means of control (10, 13, 14) and display (15) of the actuation of the illumination and extinguishing sequence of the illumination and guiding devices (3) and of the light signalling devices (4) of the various segments (2, 102) of the taxi strip (1b), for the corresponding permission for or prohibition of the advance of the aircraft through successive segments (2).

2. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground on taxi strips (1b) according to claim 1, characterized in that the said light signalling devices (4) consist of pairs of lights disposed at the lateral edges of the taxi strip (1b) next to the transverse axes (2a) of the segments (2) del imitating the length of the segments.

3. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground on taxi strips (1b) according to claim 1, characterized in that the said detection devices preferably consist of sensors (5) of the microwave and infrared type, and in that the said sensors illuminate the corresponding signalling devices (4) when any detection of the passage of the aircraft (6) has ceased.

4. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground according to claim 1, characterized in that the said control units comprise local control units (10, 11) disposed next to the segments (2), substation control units (13) disposed inside electrical equipment substations (12), and central control units (14) disposed in the control tower.

5. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground according to claim 1, characterized in that the said substation control units (13) are capable of receiving signals from a central unit (14) and of actuating local control units (10, 11) to illuminate and extinguish the axial illumination devices (3) and to extinguish the signalling devices (4), and in that the said local control units (11) are capable of receiving signals confirming the passage of an aircraft (6) from sensors (5) and of autonomously causing the illumination of the signalling devices (4).

6. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground according to claim 1, characterized in that the said central control unit (14) controls the illumination and extinguishing of the first pair of signalling lights (4) disposed near the accesses to the taxi strip (1b), thus specifying the taxi strip along which the aeroplane has to travel.

7. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground according to claim 1, characterized in that each of the said illumination devices (3) comprises a signalling light (4) and a sensor (5), each illumination device (5) being capable of operating in this mode, and also as a segment end light (2).

8. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground according to claims 1 and 7, characterized in that each segment (2) has a minimum length which may be varied as necessary and is determined by the illumination with red light of the illumination device (3).

9. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground according to claim 1, characterized in that each unilluminated segment is delimited by illuminated red signal lights (4) to prevent the access of an aircraft to this segment.

10. Automatic equipment for controlling and guiding the movement of aircraft (6) travelling on the ground according to claim 1, characterized in that the central control unit (14) controls only the intersections (101c) delimiting sections of the taxi strip (1b), and in that the local control units (10) and substation control units (11) directly control the segments (102) into which each of the said sections of taxi strip delimited by consecutive nodes (101c) is divided.

Fig. 1

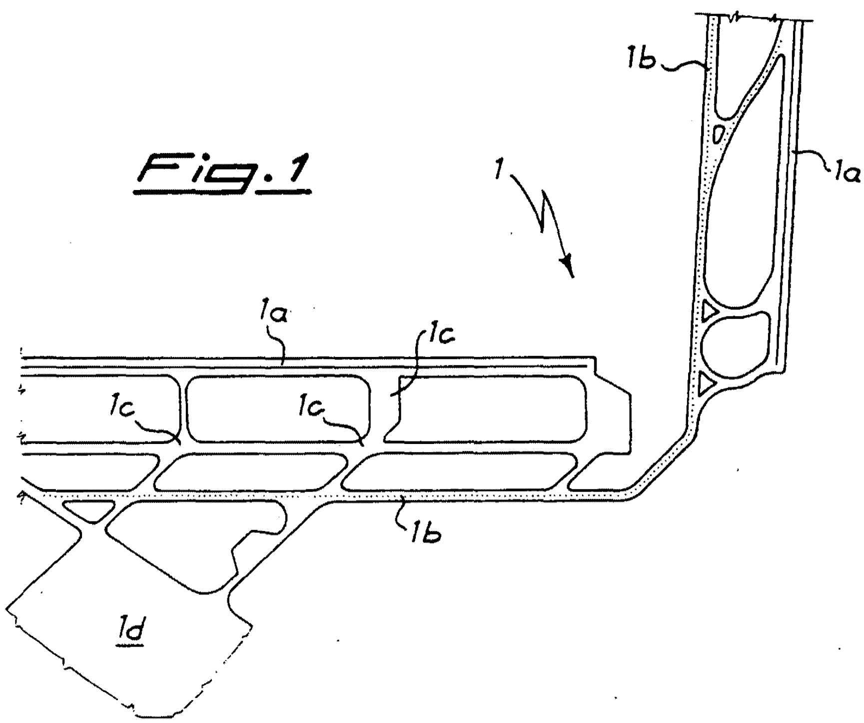
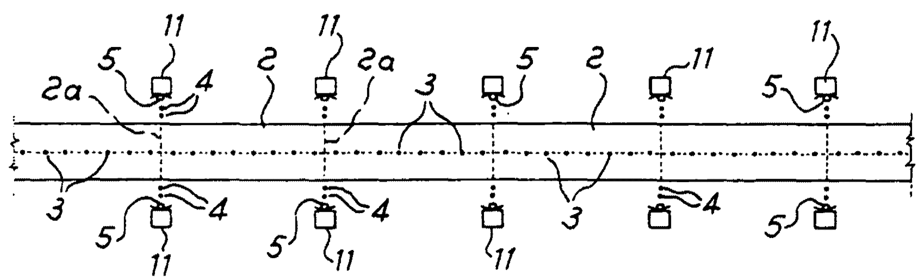


Fig. 2



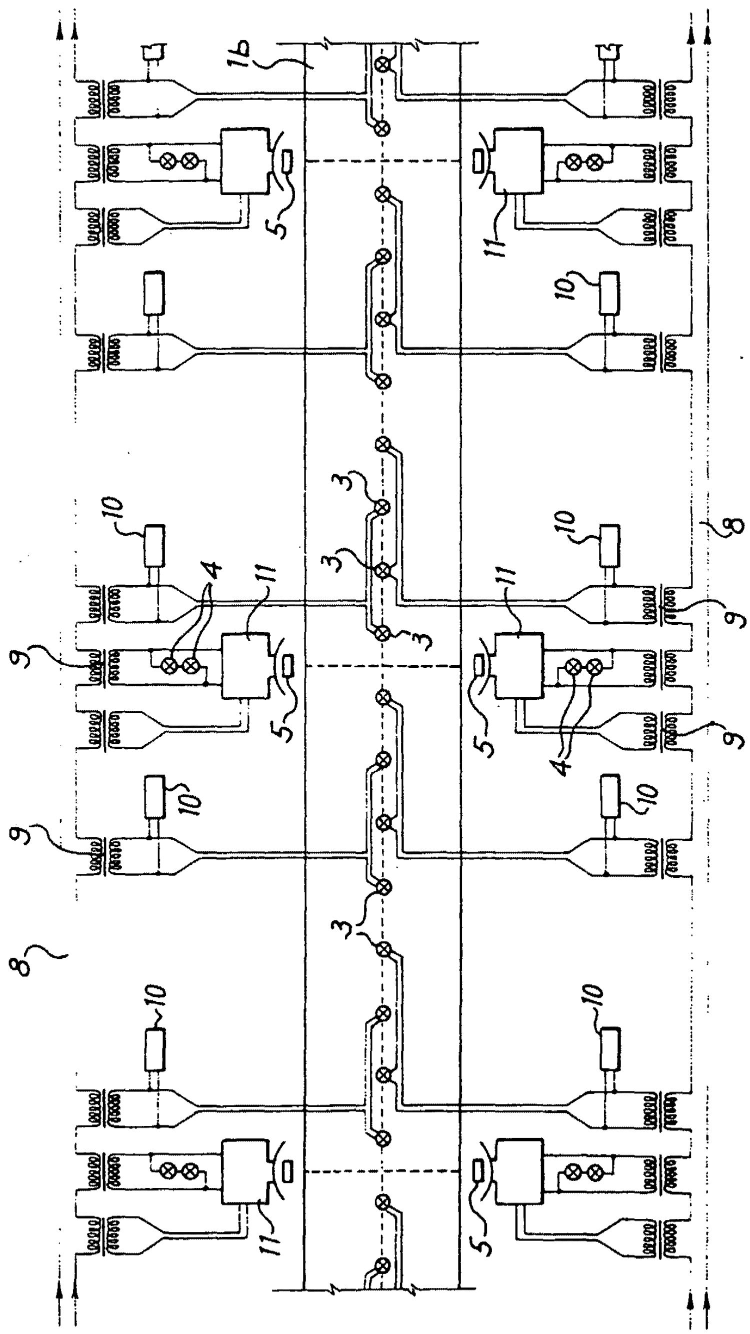


Fig.3

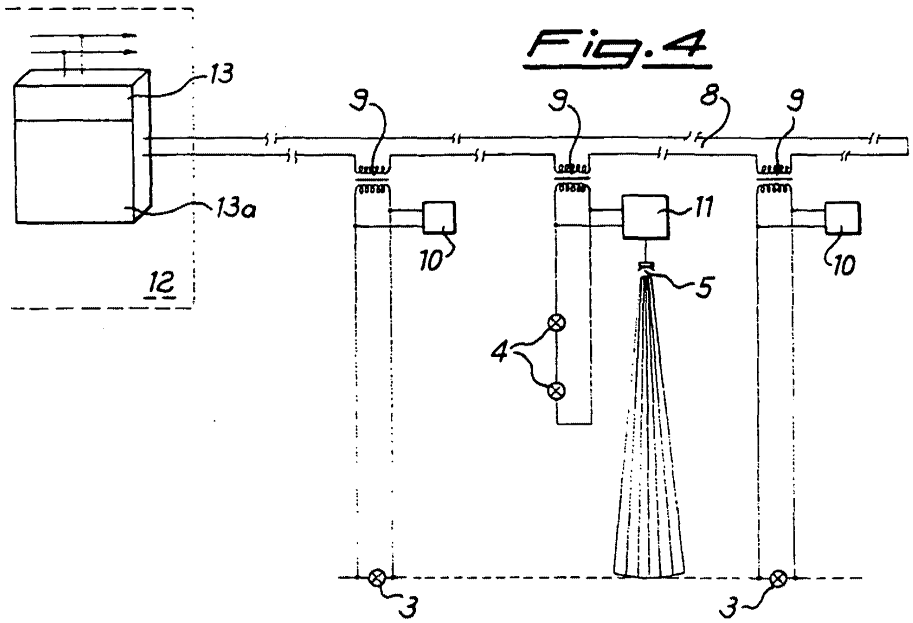


Fig.4
13
13a
12
9
9
8
9
10
11
5
10
4
3
3

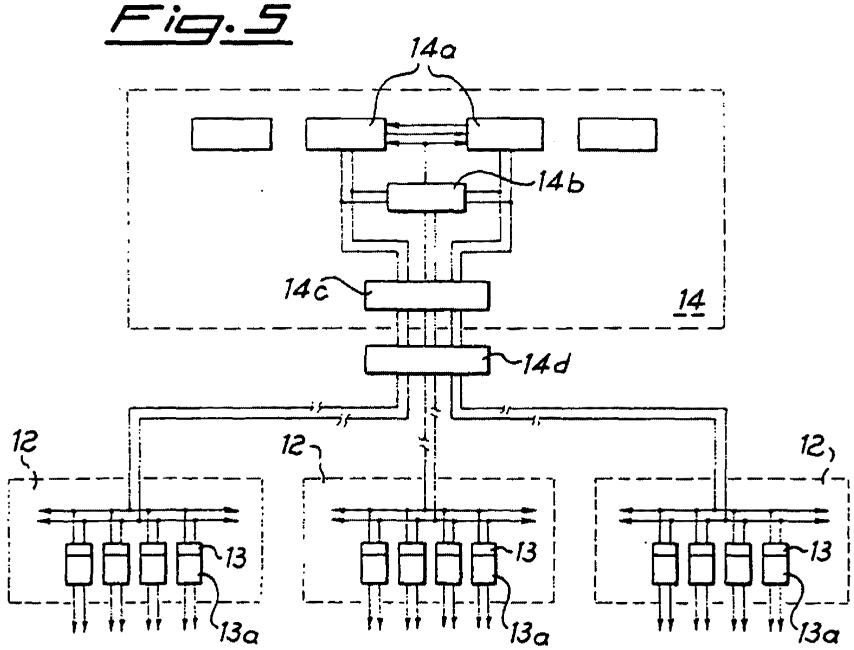


Fig.5
14a
14b
14c
14
14d
12
12
12
13
13
13
13a
13a
13a

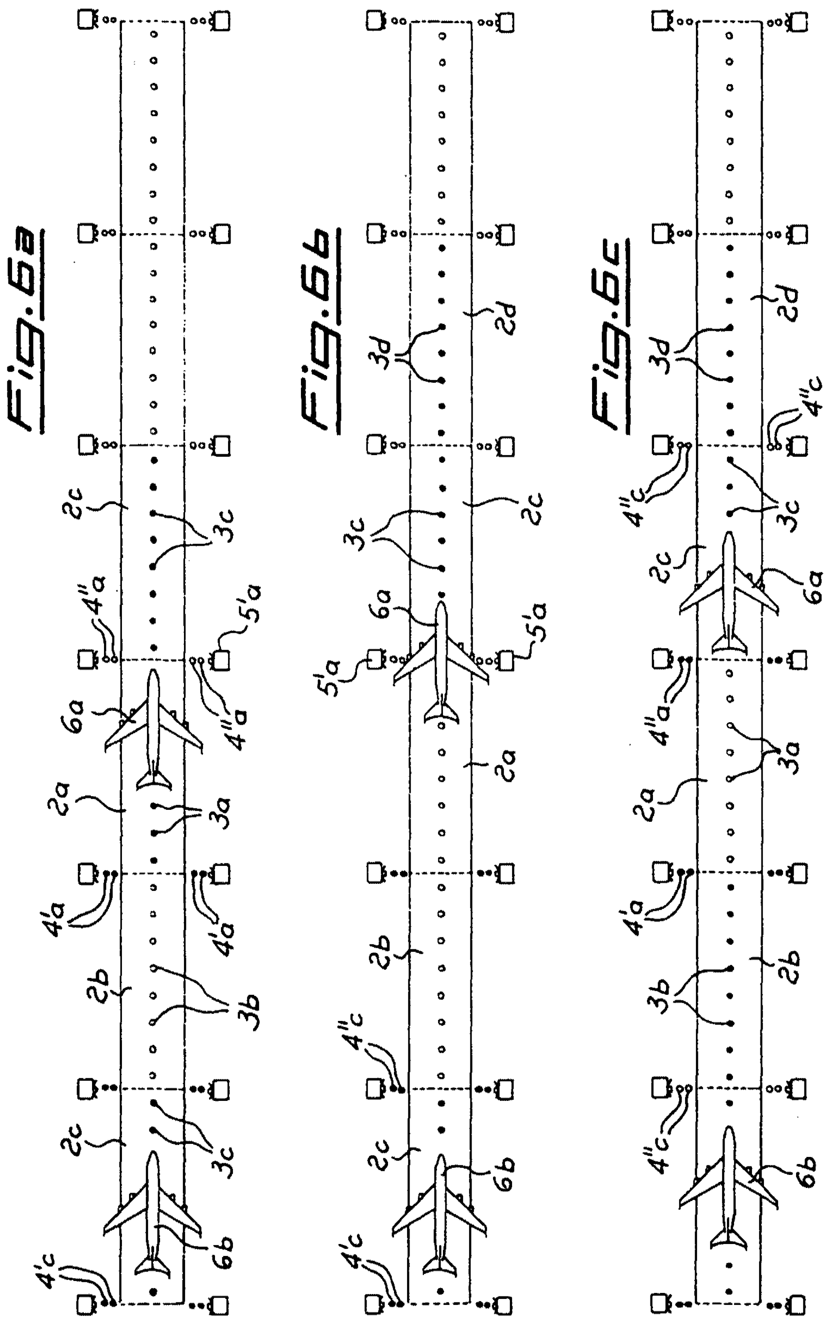


Fig.6a

Fig.6b

Fig.6c

Fig.7

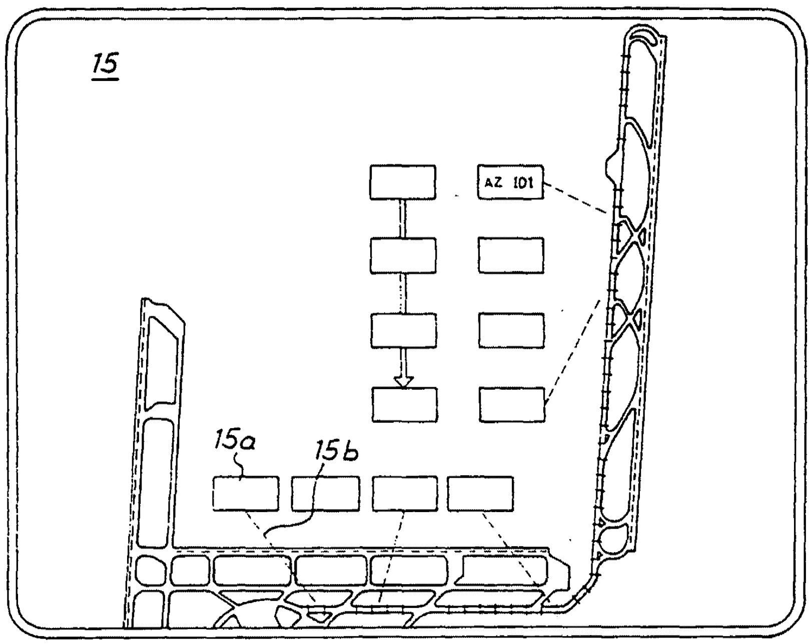
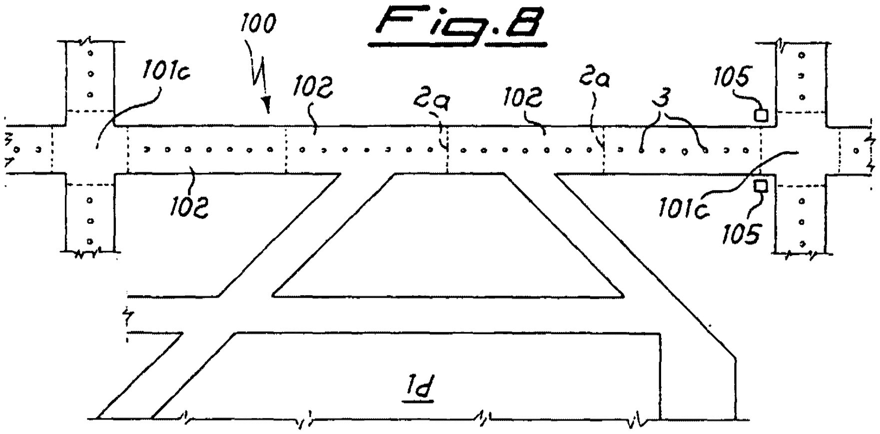


Fig.8



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(54) **Airport surface traffic monitoring system**

(57) An airport surface traffic monitoring system includes a plurality of sensors suitable to detect signals from the airport surface. The signals are sent to a signal and sensor image processing unit suitable to provide in output the exact location of aircraft, moving or stationary vehicles, and of obstacles for controlling traffic on the airport surface.

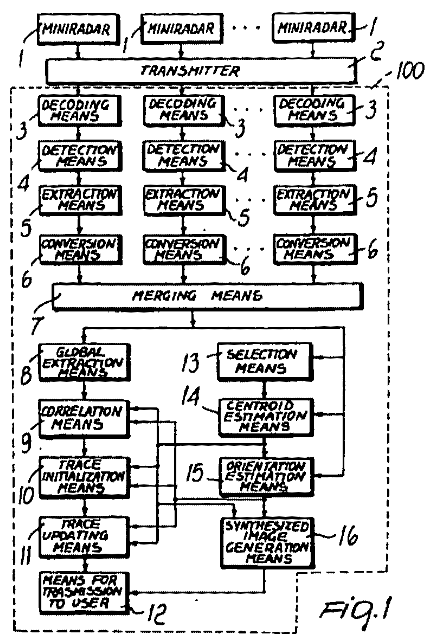


Fig.1

EP 0 785 536 A1

Description

The present invention relates to an airport surface traffic monitoring system.

In particular, the invention relates to airport surface movement guidance and control systems, for the safety and efficiency of airport ground traffic. More particularly, the invention is in the field of the monitoring function.

Airports worldwide are currently affected by an amount of air traffic which is often close to the maximum limit of their capacity and is further increased by the corresponding traffic flow of all the support vehicles which are indispensable in order to ensure the operation of the airport. Accordingly, ground traffic management is becoming increasingly difficult and subject to a considerable risk of accidents.

In most airports, monitoring is currently performed substantially by means of direct visual observation carried out by the controllers from the control tower, complemented by the position reports sent by the pilots and by the drivers of the various vehicles which are present on the airport surface.

In poor visibility conditions, typically at nighttime or in bad weather, in some airports the controller is assisted by a radar sensor for surface movement control, known as SMR (Surface Movement Radar) or ASDE (Airport Surface Detection Equipment) which operates at frequencies below 40 GHz.

The information provided by this kind of radar, which has a relatively long range capable of covering the entire surface involved but is not able to identify the detected objects, must be interpreted by the controller.

Especially in poor visibility conditions, the controller must mentally visualize a "picture" of the situation of the traffic on the airport surface in addition of course to planning the flow of the traffic. Obviously, such a task is extremely demanding due to the large number of trucks, vehicles, and the like which are present on the airport surface in addition to the aircraft.

Current radar monitoring systems are heavily hindered by the poor resolution and poor precision of the radar sensor, by masking effects caused by the inevitable presence of obstacles in the area of interest, and by difficulties in promptly identifying the targets for safety purposes, particularly as regards the danger of collisions between vehicles or between vehicles and obstacles.

Furthermore, the position and movement information dictated by controllers to the individual aircraft and trucks that move on the airport surface are currently sent by radio, using channels which are already overloaded.

The document "Sistema di guida e controllo del movimento a terra", F.G. Monzel, A. Bories, Prospettive di telecomunicazioni - 1st quarter 1993 describes a control system which should partly solve these problems; however, even this system has insufficient resolution in addition to being complicated and expensive.

The aim of the present invention is to provide an airport surface traffic monitoring system which is capable of ensuring safe, orderly and efficient traffic flow even in poor visibility conditions and in bad weather.

Within the scope of this aim, an object of the invention is to provide an airport surface traffic monitoring system which allows to locate the aircraft and the other vehicles and occasional obstacles, eliminating the effects of interference.

A further object of the present invention is to provide an airport surface traffic monitoring system which allows to cover the airport surface with a better resolution than conventional systems.

A further object of the invention is to provide an airport surface traffic monitoring system which is capable of using radar images to clearly locate and identify the various aircraft and vehicles.

A further object of the present invention is to provide an airport surface traffic monitoring system which is simple to manufacture and highly reliable and has a competitive cost.

This aim, these objects, and others which will become apparent hereinafter are achieved by an airport surface traffic monitoring system, characterized in that it comprises a plurality of sensors which are suitable to detect signals from the airport surface, the signals being sent to devices for processing signals and images of the sensors, which are suitable to provide in output the exact location of aircraft, moving or stationary vehicles and of obstacles in order to control the traffic on the airport surface.

Further characteristics and advantages will become apparent from the description of a preferred but not exclusive embodiment of the invention, illustrated only by way of non-limitative example in the accompanying drawings, wherein:

Figure 1 is a block diagram of the system according to the present invention; and

Figure 2 is a block diagram of one of the miniradars used in the block diagram of Figure 1.

With reference to the above figures, the system according to the invention includes a plurality of sensors which are connected to a subsystem for processing the signals and data of the sensors over high-capacity communications channels, advantageously provided by means of optical fibers.

The sensors that are used are small radars 1 (miniradars), which are characterized by small dimensions with respect to the state of the art and by low weight and cost, which can be achieved by using millimeter waves with higher frequencies than those used by existing systems (<40 GHz). These miniradars 1 are placed in elevated locations (buildings, pylons) in the airport area or in the immediate vicinity. The number of these miniradars typically varies from 1 to 5, depending on the structure of the particular airport in which they are used.

By way of example and for the sake of greater clarity, Figure 1 illustrates the block diagram of the system according to the invention in the case in which there are three miniradars 1.

The miniradars 1 have a range which is shorter than the dimensions of the airport surface and are organized like a network so as to ensure optimum coverage of the airport surface.

The miniradars 1 use millimeter frequencies both during reception and during transmission in order to have small antennas.

The use of these millimeter frequencies prevents electromagnetic compatibility problems in the operating environment and minimizes the effects caused by ground reflections.

Frequencies around 95 GHz are used in a preferred embodiment.

The miniradars 1 are connected to the processing subsystem by means of a transmission means 2, which is advantageously constituted by optical fibers.

The transmission means 2 connects each miniradar 1 to a means 100 for processing the signals and the data of the miniradars.

In particular, the transmission means 2 connects each miniradar 1 to a corresponding demodulation and decoding means conveniently constituted by a demodulator decoder 3 which is suitable to convert the signal into a numeric representation.

The signal in output from each demodulator decoder 3 enters a signal processing and detection means 4 suitable to eliminate the effects of the interference caused by unwanted echoes and by noise.

A local radar data extraction means 5 is cascade-connected to the signal processing and detection means and is suitable to provide, in output, data in polar-coordinate form, which are sent to a converter means 6 suitable to convert the polar representation into an X-Y representation.

The outputs of the various conversion means 6, one for each miniradar 1, are sent to a radar data merging means 7.

A global radar data extraction means 8 is cascade-connected to the merging means 7 and is suitable to generate numeric messages which indicate the presence and the position of the objects of interest.

The output of the global extraction means 8 is sent to a correlation means 9, suitable to correlate the numeric messages that indicate the presence and position of objects of interest with summary indications of moving vehicles with their corresponding path and, if available, their identification (hereinafter termed "traces").

The output of the correlation means 9 is sent to a trace initialization means 10, which initializes a new trace if the comparison performed by the correlation means 9 does not yield a match between the numeric message (hereinafter referenced as "plot") and an existing trace.

The output of the initialization means 10 is sent to a trace updating means 11, which sends its output to a transmission means 12 suitable to display the result to the controller assigned to airport surface traffic monitoring.

The output signal from the merging means 7 is sent not only to the global extraction means but also to an image processing means. The image processing means includes an area selection means 13, a centroid estimation means 14, an orientation estimation means 15, and a synthesized image generation means 16.

The area selection means 13 is suitable to select a specific area which includes a single target of interest for transfer to a subsequent means 14 for estimating the centroid of the target and its extension.

The output of the centroid estimation means 14 is sent to the correlation means 9, to the trace initialization means 10, and to the trace updating means 11.

The same output of the merging means 7 and the output of the centroid estimation means 14 are sent to a target orientation estimation means 15, whose output is sent on the one hand to a synthesized image generation means 16 and on the other hand to the correlation means 9, to the trace initialization means 10, and to the trace updating means 11.

The synthesized image generation means then sends its output to the means 12 for transmission to the user.

In detail, as shown in Figure 2, each miniradar 1 includes a transmission and reception means constituted by a solid-state transceiver, an antenna, and a circuit for encoding and modulating the raw signals produced by the miniradar to transmit them to the processing subsystem.

The entire miniradar revolves about a vertical axis at a typical rate of one revolution per second.

More particularly, each miniradar 1 includes a reflector-type antenna 22 which provides the optimum radiation pattern for the applications being considered, particularly a lobe that is very narrow in the azimuth plane so as to achieve the necessary high angular discrimination, and is shaped in the vertical plane so as to receive, for a set target, an echo power that is independent of the distance of the object of interest in the range of the radar.

The antenna 22, in addition to having a linear polarization, has a circular polarization in order to increase the signal ratio between the useful signal and rain echo.

A duplexer 21 provides the connection between the antenna 22 on one side and the receiver and transmitter on the other side, according to techniques which are well-known to the persons skilled in the art and are described for example in the book by M.I. Skonlik "Introduction to the radar system", McGraw-Hill, 2nd edition, chapter 9, pages 359-366.

The transmitter is of the solid-state type, which can be used in this case by virtue of the low power that is required, but it might also be of the amplifier-tube or oscillator type without altering the subject of the present invention.

In a preferred embodiment, described hereinafter, it is essentially composed of a stable millimeter-band oscillator 17 whose radio-frequency signal, before being transmitted to the antenna 22 through the duplexer 21, passes through a first up-converter 18 so as to vary the transmitted frequency from pulse to pulse or from one group of pulses to the next, and then through a second up-converter 19, to allow medium-frequency conversion, and through a millimeter-band power amplifier with solid-state technology 20, where the transmitted pulse is generated; the pulse has a very short duration so as to allow high distance discrimination.

In order to achieve the two up-conversions of the transmitted frequency, by means of the two converters 18 and 19, and still ensure the stability of the millimeter-band oscillator 17, an intermediate reference frequency generator 29 is used for the unequivocal synchronization of all the frequencies of the miniradar 1.

The receiver of the miniradar 1 is of the superheterodyne type (a type which is well-known to the persons skilled in the art) and is composed of a first down-converter 23, which is required in order to take into account the variation of the transmitted frequency from one pulse or group of pulses to the next, of an intermediate-frequency signal amplifier 24, of a second down-converter 25 to obtain the video signal, and finally of a detector stage 26 to obtain the amplitude information of the received echo signal.

The final part of the receiver is constituted by a stage 27 for converting the received echo amplitude signal from the analog format to the digital one, and finally by an encoding and modulation stage 28 to adapt the signal to the transmission thereof over the communications channel 2 towards the central processing system, which is provided by virtue of optical fibers in the preferred embodiment.

With reference to the above figures, the operation of the system according to the invention is as follows.

The raw signals that arrive from the miniradars 1 represent the amplitude of the radar echo by means of an appropriate representation scale; they are sent to the processing subsystem over the transmission means 2, which in the preferred embodiment is constituted by optical fibers and can also be constituted by radio links of adequate capacity.

At the processing subsystem, the signal that arrives from each miniradar 1 is input to the demodulator decoder 3, where it is converted to the numeric representation that is most suited to the subsequent processing operations, according to methods that are well-known to the persons skilled in the art.

The signal then enters the signal processing and detection means 4, which has the purpose of eliminating the effects of the interference produced by unwanted echoes and noise and of providing in output the indications of the presence of echoes originating from targets of interest (aircraft, vehicles, obstacles).

In particular, the signal processing and detection means 4 internally include a detection threshold of the "time integration" type, which provides an estimate of the average interference level for each resolving cell of the radar.

This estimate, multiplied by a suitable parameter, provides the detection threshold used for the particular resolving cell.

In the present invention, the multiplying parameter takes on two separate values: the first one, which is higher, is used before echo detection occurs, whereas the second one, which is lower, is used after detection of an echo, so as to avoid compromising the detection of slow and/or large targets.

For the same reason, the time constant of time integration is provided so that it can vary between two separate values, the first one to be applied before detection of the target and the second one to be applied after detection of the target.

Detection indications are transferred to the local radar data extraction means 5, which correlates these indications with the current distance and azimuth indications, providing in output data in polar-coordinate form, which are sent to the subsequent coordinate conversion means 6 which, by using algorithms that are well-known to the persons skilled in the art, performs real-time conversion from polar coordinates to X-Y coordinates, according to an X-Y reference system which is rigidly linked to the monitoring area and is therefore common to all the miniradars 1.

The outputs of the various coordinate conversion means 6, one for each miniradar, are sent to the radar data merging means 7, which in the above mentioned common reference system merges the information from the various miniradars, generating unique detections by virtue of elementary logic operations that are well-known to the persons skilled in the art.

The resulting detections are transferred to the global radar data extraction means 8 which, by virtue of techniques that are well-known to the persons skilled in the art, generates numeric messages, known as "plots", which indicate the presence and position of the objects of interest (aircraft, vehicles, occasional obstacles).

The plots are sent to the subsequent radar tracking subsystem, which is constituted by the following functions:

-- correlation between the plot and the trace (provided by the correlation means 9), in which a check whether each plot can be ascribed or not to an existing trace is performed by comparing the position of the plots and the summary indications of moving vehicles with their corresponding path and, if available, their identification, that is to say, the so-called "traces";

-- initialization of a trace (provided by the initialization means 10), by virtue of which the plots that do not correlate with existing traces produce new traces by means of appropriate logic systems;

-- updating of the trace (11), by virtue of which, as a function of the localization of the plot that correlates with the trace and of the extrapolated trace with the current trace, the optimum estimate of the position, orientation, and speed of the object of interest is produced.

These functions, in a preferred embodiment of the present invention, are made more accurate and effective by virtue of information which originates from the image processing subsystem, whose functions are described hereafter.

The outputs of the radar data merging means 7 are transferred to the area selection means 13, which on command from an operator or from the general airport traffic management system extract the outputs of the merging means that belong to a rectangular window within the above mentioned reference system rigidly linked to the surface of interest.

The dimensions and position of the window are such as to include a single target of interest for transfer to the subsequent centroid estimation means 14, wherein, by means of weighted-average algorithms, the centroid of the radar image of the target and its size are estimated.

The same output of the merging means 7 and the output of the centroid estimation means 14 are sent to the orientation estimation means 15, in which the orientation angle of the target, that is to say, the direction of its front end with respect to the north, is estimated.

The outputs of the centroid estimation means 14 and of the orientation estimation means 15 are sent to the correlation means 9, to the trace initialization means 10, and to the trace updating means 11 in order to produce significant improvements in the correlation between the plot and the trace, in trace initialization, and in trace updating, by virtue of the considerable increase in the amount of information on the target provided by the image processing performed in the centroid estimation means 14 and in the orientation estimation means 15.

The information obtained by the radar image processing performed by the means 14 and 15 is used in the tracking process, performed by the trace correlation means 9, the trace initialization means 10, and the trace updating means 11 by means of an optimum nonlinear filtering or by means of a linearized filtering (Kalman filter techniques).

Finally, the outputs of the centroid estimation means 14 and of the orientation estimation means 15 are sent to the synthesized image generation means 16 which, by means of techniques well-known to the persons skilled in the art, prepares the radar information for display by virtue of a commercial-type display system.

The means 12 for transmission to the user receives the outputs of the trace updating means 11 and of the synthesized image generation means 16 and transmits them to the user for the traffic monitoring purposes of the present invention.

In practice it has been observed that the system according to the invention achieves the intended aim and objects, since it allows to monitor the entire airport surface by virtue of a network of small, low-cost radars 1 and of a subsystem for processing the data produced by the radars 1 which has a high resolution and is capable of identifying the various targets which are present in the area of interest.

In this manner, the controller assigned to monitoring the traffic on the airport surface has a system which is capable of locating the aircraft and the other vehicles, as well as occasional obstacles, eliminating the effects of various kinds of interference.

Furthermore, the system according to the invention also uses the radar images of the aircraft provided by virtue of the high spatial resolution of each one of the miniradars 1.

The airport surface traffic monitoring system can be used by modern control, monitoring, and guidance systems known to airport traffic control experts as SMGCS (Surface Movement Guidance and Control System) with new functions for processing and displaying the radar images with high resolution in order to provide more effective automatic or controller-dependent solving of possible conflicts between vehicles and occasional obstacles.

The system according to the invention can also be applied to the radar monitoring of sea and river ports or of traffic in other confined spaces.

The system according to the invention is susceptible of numerous modifications and variations, all of which are within the scope of the claims; all the details may be replaced with other technically equivalent elements.

The materials employed, as well as the dimensions, may of course be any according to the requirements and the state of the art.

Claims

1. Airport surface traffic monitoring system, characterized in that it comprises a plurality of sensors (1) adapted to detect signals from the airport surface, said signals being send to a means (100) for processing the signals of said sensors which provides in output the exact location of aircraft, stationary or moving vehicles, and obstacles in order to control traffic on the airport surface.

2. System according to claim 1, characterized in that said sensors comprise mini radars (1).

3. System according to claim 2, characterized in that each of said mini radars has a range that is shorter than the airport surface to be covered.

4. System according to claim 2, characterized in that said mini radars are arranged so as to cover the entire airport surface together.

5. System according to claim 2, characterized in that said mini radars use millimeter frequencies for both transmission and reception.

6. System according to claim 2, characterized in that each of said radars (1) comprises a transmission and reception means, an antenna (22), and a means for encoding and modulating the raw signals produced by said radars for transmission to the signal processing means.

7. System according to claim 2, characterized in that said radars are connected to said signal processing means by optical fibers.

8. System according to claim 2, characterized in that said radars are connected to said signal processing means by high-capacity radio channels.

9. System according to claim 6, characterized in that said antenna is a millimeter-band reflector antenna.

10. System according to claim 6, characterized in that said transmission and reception means of said radars comprises a solid-state transmitter and a superheterodyne receiver.

11. System according to claim 6, characterized in that said transmitter of said radars is an amplifier-tube transmitter.

12. System according to claim 6, characterized in that said transmitter of said radars is an oscillator-type transmitter.

13. System according to claim 10, characterized in that said transmission and reception means of said radars is connected to said antenna by a duplexer.

14. System according to claim 10, characterized in that said transmission means of said radars comprises a stable oscillator in the millimeter band, said oscillator being adapted to generate a radio-frequency signal, a first up-converter adapted to vary the transmitted frequency from pulse to pulse or from one group of pulses to the next, a second up-converter adapted to perform medium-frequency conversion, and a power amplifier.

15. System according to claim 14, characterized in that it comprises an intermediate-frequency generator having an output connected to said first and second up-converters, said intermediate-frequency generator being adapted to maintain the stability of said oscillator.

16. System according to claim 10, characterized in that said reception means of said radars comprises a first down-converter, an intermediate-frequency signal amplifier, a second down-converter, and a detection stage adapted to detect the amplitude of the echo signal received by said reception means.

17. System according to claim 16, characterized in that it comprises a conversion means connected to the output of said detection stage, said conversion means being adapted to convert said received echo amplitude signal into a digital signal.

18. System according to claim 17, characterized in that said encoding and modulation means is connected to the output of said conversion means and is adapted to prepare said received echo amplitude signal for transmission to said signal processing means.

19. System according to claim 2, characterized in that said signal and radar data processing means comprises, for each one of said radars, a demodulation and decoding means adapted to demodulate and decode the input signal into a numeric representation; a processing and detection means adapted to provide in output a detection threshold; a local extraction means adapted to provide position data in polar-coordinate form; and a conversion means adapted to convert said position data from polar coordinates to X-Y coordinates according to a single reference which is common to all of said radars.

20. System according to claim 19, characterized in that said signal and radar data processing means furthermore comprises a merging means adapted to merge the signals that originate from said radars, in order to obtain a single position data item for each target detected by said radars together.

21. System according to claim 19, characterized in that said processing and detection means is of the time integration type and is adapted to provide an estimate of the average level of the interference for each resolving cell of said radars; said estimate, multiplied by a parameter, providing the detection threshold used for the particular resolving cell.

22. System according to claim 21, characterized in that said multiplying parameter assumes a first value and a second value in two separate moments, said first value being used before the detection of an echo, said second value being used after the detection of said echo, said first value being higher than said second value.

23. System according to claim 21, characterized in that the time constant of the time integration of said processing and detection means can vary between a first value and a second value, said first value being applied before the detection of an echo, said second value being applied after the detection of

said echo.

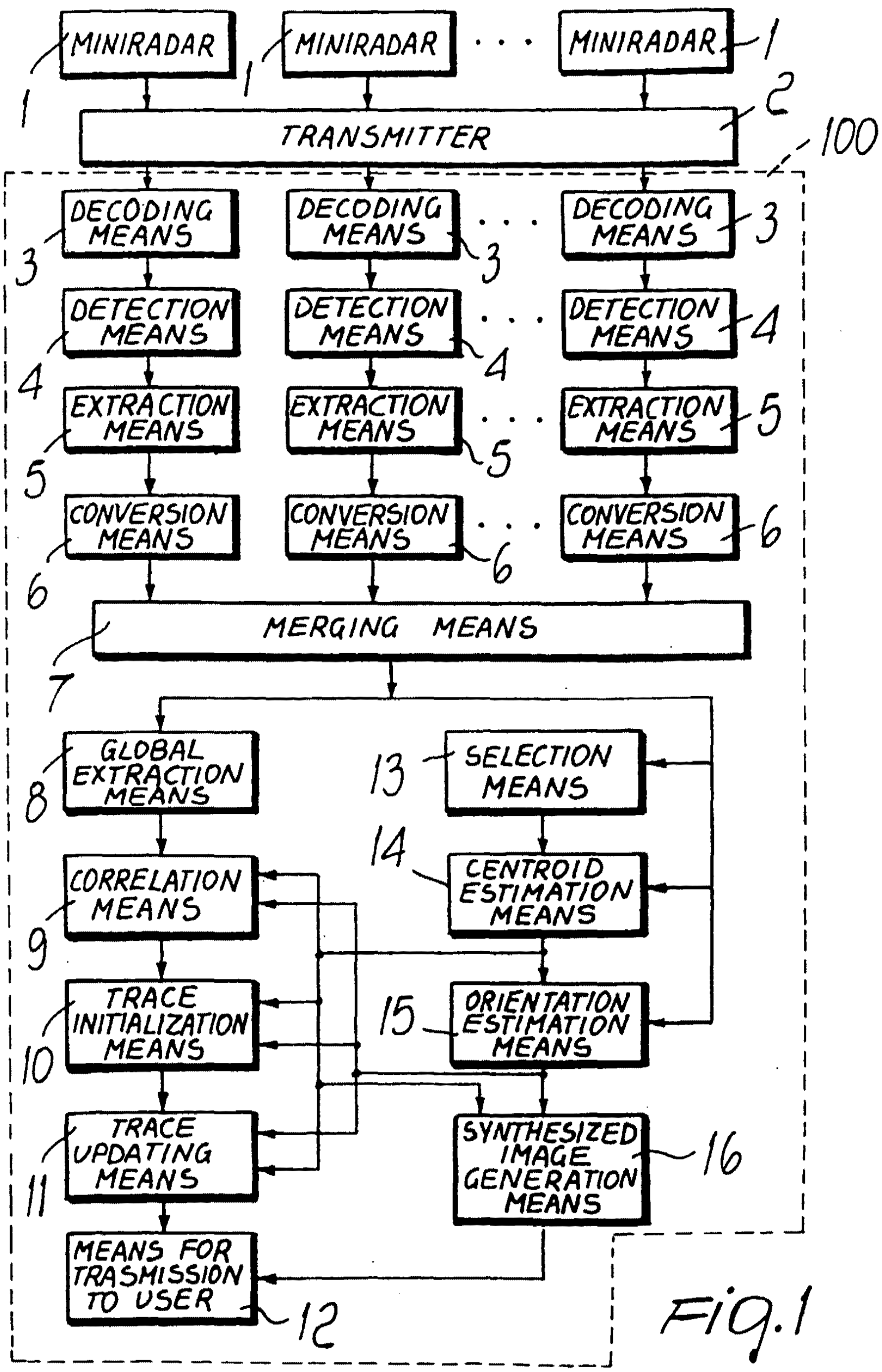
24. System according to claim 2, characterized in that said signal and radar data processing means furthermore comprises a global extraction means adapted to generate numeric messages which indicate the position of targets of interest, a correlation means adapted to perform a position comparison between said numeric messages and existing paths of moving targets, a path initialization means adapted to initialize a new path following a failed comparison in said correlation means, a path updating means, and a means for transmission to the user.

25. System according to one or more of the preceding claims, characterized in that the output of said merging means is sent to said image processing means.

26. System according to claim 25, characterized in that said image processing means comprises an area selection means adapted to select an area of the airport surface which contains a single target of interest, a means for estimating the centroid of the radar image adapted to estimate the centroid of said target of interest, and an orientation estimation means adapted to estimate the orientation angle of the target with respect to the magnetic north.

27. System according to claim 26, characterized in that it furthermore comprises a means for generating synthesized images which are cascade-connected to said orientation estimation means and is adapted to prepare the resulting radar images for display.

28. System according to claim 26, characterized in that the output of said centroid estimation means and the output of said orientation estimation means are sent to the correlation means, to the path initialization means, and to the path updating means.


MINIRADAR
MINIRADAR
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1
TRANSMITTER
2
100
DECODING MEANS
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EXTRACTION MEANS
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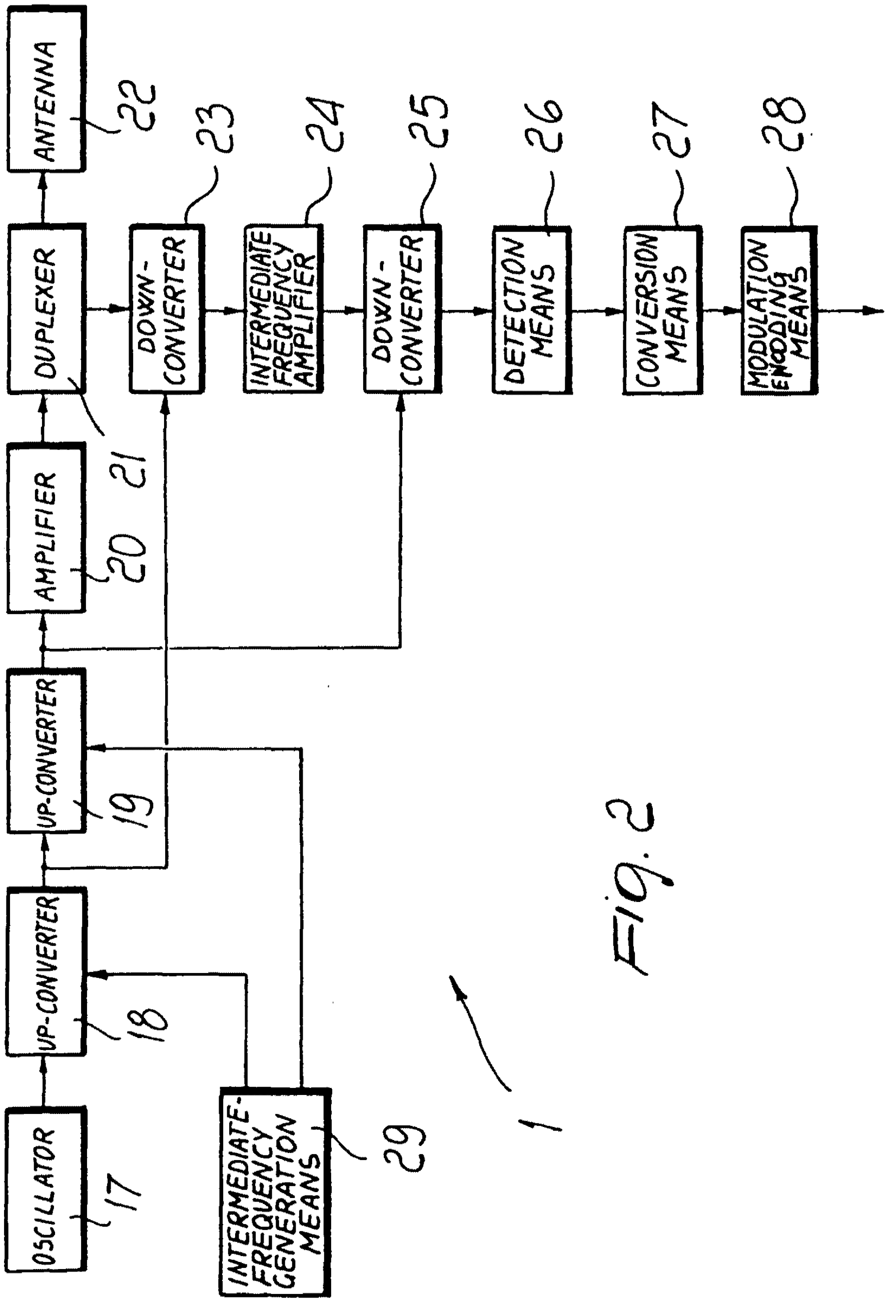
CONVERSION MEANS
6
MERGING MEANS
7
GLOBAL EXTRACTION MEANS
8
CORRELATION MEANS
9
TRACE INITIALIZATION MEANS
10
TRACE UPDATING MEANS
11
MEANS FOR TRASMISSION TO USER
12
SELECTION MEANS
13
CENTROID ESTIMATION MEANS
14
ORIENTATION ESTIMATION MEANS
15
SYNTHESIZED IMAGE GENERATION MEANS
16

Fig.1


OSCILLATOR
17
UP-CONVERTER
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UP-CONVERTER
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DUPLEXER
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ANTENNA
22
DOWN-CONVERTER
23
INTERMEDIATE FREQUENCY AMPLIFIER
24
DOWN-CONVERTER
25
DETECTION MEANS
26
CONVERSION MEANS
27
MODULATION ENCODING MEANS
28
INTERMEDIATE-FREQUENCY GENERATION MEANS
29
1

Fig. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 10 0509

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	INTERNATIONAL RADAR CONFERENCE, ALEXANDRIA, MAY 8 - 11, 1995, 8 May 1995, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 505-510, XP000529139 SCHROTH A ET AL: "THE DLR NEAR-RANGE EXPERIMENTAL RADAR SYSTEM FOR AIRPORT SURFACE MOVEMENT GUIDANCE AND CONTROL" * the whole document *	1-3	G08G5/06
A		4-28	

Y	PROCEEDINGS OF THE DIGITAL AVIONICS SYSTEMS CONFERENCE, SEATTLE, OCT. 5 - 8, 1992, no. CONF. 11, 5 October 1992, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 549-552, XP000366735 WATNICK M ET AL: "AIRPORT MOVEMENT AREA SAFETY SYSTEM" * figures 2-4 *	1-3	
A		4-28	TECHNICAL FIELDS SEARCHED (Int.Cl.6)

Y	FR 2 307 320 A (INTERNATIONAL STANDARD ELECTRIC CORPORATION) 5 November 1976 * the whole document *	1-3	G08G G01S
A		4-28	

A	US 5 400 031 A (FITTS RICHARD A) 21 March 1995 * column 2, line 1 - column 3, line 13 *	1-28	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 April 1997	Crechet, P

CATEGORY OF CITED DOCUMENTS

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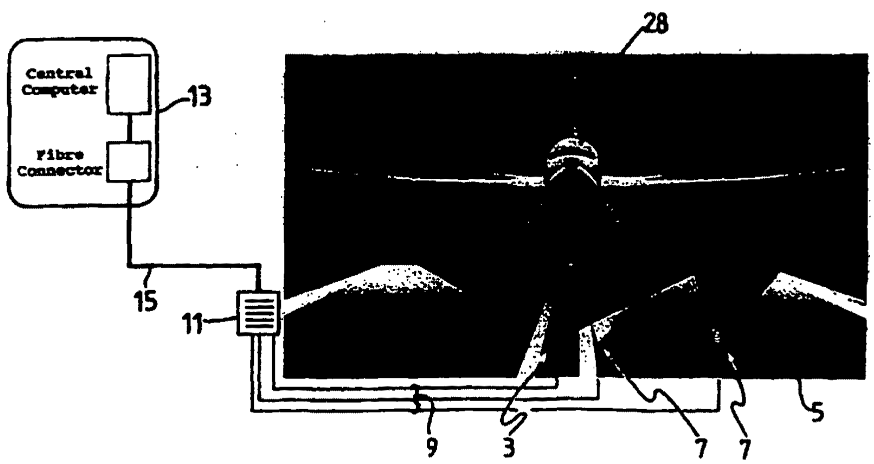

(57) Abstract

An object detection system including passive sensors (3) for receiving electromagnetic radiation from a moving object (28) and generating intensity signals representative of the received radiation, and a processing system for subtracting the intensity signals to obtain a differential signature representative of the position of the moving object. An image acquisition system including at least one camera (7) for acquiring an image of at least part of a moving object, in response to a trigger signal, and an analysis system for processing the image to locate a region in the image including markings identifying the object and processing the region to extract the markings for optical recognition.

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AN AIRCRAFT DETECTION SYSTEM

The present invention relates to an object detection system and, in particular to an aircraft detection system.

The International Civil Aviation Organisation (ICAO) has established regulations which require all civil aircraft to have registration markings beneath the port wing to identify an aircraft. The markings denote the nationality of an aircraft and its registration code granted by the ICAO. In some countries, airline operators do not follow the regulations and the markings appear on an aircraft's fuselage. Owners of aircraft are charged for airport use, but a satisfactory system has not been developed to automatically detect aircraft and then, if necessary, administer a charge to the owner. Microwave signals for detecting an aircraft can interfere with microwave frequencies used for airport communications and, similarly, radar signals can interfere with those used for aircraft guidance systems. A system which can be used to detect an aircraft using unobtrusive passive technology is desired.

In accordance with the present invention there is provided an object detection system including:

passive sensing means for receiving electromagnetic radiation from a moving object and generating intensity signals representative of the received radiation; and

processing means for subtracting said intensity signals to obtain a differential signature representative of the position of said moving object.

The present invention also provides an image acquisition system including:

at least one camera for acquiring an image of at least part of a moving object, in response to a trigger signal, and analysis means for processing said image to locate a region in said image including markings identifying said object and processing said region to extract said markings for a recognition process.

The present invention also provides an object detection method including:

passively sensing electromagnetic radiation received from a moving object;

generating intensity signals representative of the received radiation; and

subtracting said intensity signals to obtain a differential signature representative of the position of said moving object.

The present invention also provides an image acquisition method including:

acquiring an image of at least part of a moving object, in response to a trigger signal, using at least one camera, and

processing said image to locate a region in said image including markings identifying said object and processing said region to extract said markings for a recognition process.

Preferred embodiments of the present invention are hereinafter described, by way of example only, with reference to the accompanying drawings, wherein:

Figure 1 is a block diagram of a preferred embodiment of an aircraft detection system;

Figure 2 is a schematic diagram of a preferred embodiment of the aircraft detection system;

Figure 3 is a block diagram of a connection arrangement for components of the aircraft detection system;

Figure 4 is a more detailed block diagram oi a proximity detector and a tracking system for the aircraft detection system;

Figure 5 is a coordinate system used for the proximity detector;

Figures 6(a) and 6(b) are underneath views of discs of sensors of the tracking system;

Figure 7 is a schematic diagram of an image obtained by the tracking system;

Figures 8 and 9 are images obtained from a first embodiment of the tracking system;

Figure 10 is a graph of a pixel row sum profile for an image obtained by the tracking system;

Figure 11 is a graph of a difference profile obtained by subtracting successive row sum profiles;

Figure 12 is a diagram of a coordinate system for images obtained by the tracking system;

Figure 13 is a diagram of a coordinate system for the aircraft used for geometric correction of the images obtained by the tracking system;

Figure 14 is a diagram of a coordinate system used for predicting a time to generate an acquisition signal;

Figure 15 is a graph of aircraft position in images obtained by the tracking system over successive frames;

Figure 16 is a graph of predicted trigger frame number over successive image frames obtained by the tracking system;

Figure 17 is a schematic diagram of a pyroelectric sensor used in a second embodiment of the tracking system;

Figure 18 is graphs of differential signatures obtained using the second embodiment of the tracking system;

Figures 19 and 20 are images obtained of an aircraft by high resolution cameras of an acquisition system of the aircraft detection system;

Figure 21 is a schematic diagram of an optical sensor system used for exposure control of the acquisition cameras;

Figure 22 is a flow diagram of a preferred character location process executed on image data obtained by the high resolution cameras;

Figure 23 is a diagram of images produced during the character location process; and

Figure 24 is a flow diagram of a character recognition process executed on a binary image of the characters extracted from an image obtained by one of the high resolution cameras.

An aircraft detection system 2, as shown in Figure 1, includes a proximity detector 4, a tracking sensor system 6, an image processing system 8, an image acquisition system 10 and an analysis system 12. A control system 14 can be included to control the image acquisition system 10 on the basis of signals provided by the image processing system 8, and also control an illumination unit 16.

The proximity detector 4 and the tracking sensor system 6 includes sensors 3 which may be placed on or near an aircraft runway 5 to detect the presence of an aircraft 28 using visual or thermal imaging or aural sensing techniques. Also located on or near the runway 5 is at least one high resolution camera 7 of the image acquisition system 10. The sensors 3 and the acquisition camera 7 are connected by data and power lines 9 to an instrument rack 11, as shown in Figure 2, which may be located adjacent or near the runway 5. The instrument rack 11 may alternatively be powered by its own independent supply which may be charged by solar power. The instrument rack 11 includes control circuitry and image processing circuitry which is able to control activation of the sensors 3 and the camera 7 and perform image processing, as required. The instrument rack 11, the data and power lines 9, the sensors 3 and the acquisition camera 7 can be considered to form a runway module which may be located at the end of each runway of an airport. A runway module can be connected back to a central control system 13 using an optical fibre or other data link 15. Images provided by the sensors 3 may be processed and passed to the central system 13 for further processing, and the central system 13 would control triggering of the acquisition cameras 7. Alternatively image processing for determining triggering of the acquisition camera 7 may be performed by each instrument rack 11. The central control system 13 includes the analysis system 12. One method of configuring connection of the instrument racks 11 to the central control system 13 is illustrated in Figure 3. The optical fibre link 15 may include dedicated optical fibres 17 for transmitting video signals to the central control system 13 and other optical fibres 19 dedicated to transmitting data to and receiving data from the central control system 13 using the Ethernet protocol or direct serial data communication. A number of different alternatives can be used for connecting the runway modules to the central control system 13. For example, the runway modules and the control system 13 may be connected as a Wide Area Network (WAN) using Asynchronous Transfer Mode (ATM) or Synchronous Digital Hierarchy (SDH) links. The runway modules and the central control system 13 may also be connected as a Local Area Network (LAN) using a LAN protocol, such as Ethernet. Physical connections may be made between the runway modules and the central control system 13 or alternatively wireless transmission techniques may be used, such as using infrared or microwave signals for communication.

The proximity detector 4 determines when an aircraft is within a predetermined region, and then on detecting the presence of an aircraft activates the tracking sensor system 6. The proximity detector 4, as shown in Figure 4, may include one or more pyroelectric devices 21, judiciously located at an airport, and a signal processing unit 23 and trigger unit 25 connected thereto in order to generate an activation signal to the tracking sensor system 6 when the thermal emission of an approaching aircraft exceeds a predetermined threshold. The proximity detector 4 may use one or more pyroelectric point sensors that detect the infrared radiation emitted from the aircraft 28. A mirror system can be employed with a point sensor 70 to enhance its sensitivity to the motion of the aircraft 28. The point sensor 70 may consist of two or more pyroelectric sensors configured in a geometry and with appropriate electrical connections so as to be insensitive to the background infrared radiation and slowly moving objects. With these sensors the rate of motion of the image of the aircraft 28 across the sensor 70 is important. The focal length of the mirror 72 is chosen to optimise the motion of the image across the sensor 70 at the time of detection. As an example, if the aircraft at altitude H with glide slope angle θ_{GS} moves with velocity V and passes overhead at time t_0, as shown in Figure 5, then the position h of the image of the aircraft 28 on the sensor 70 is

$$h = f\left(\frac{H}{V(t_o - t)} + \tan\theta_{GS}\right) \qquad (1)$$

where f is the focal length of a cylindrical mirror.

If the rate of motion of the image *dh/dt* is required to have a known value, then the focal length of the mirror 72 should be chosen to satisfy

$$f = v\frac{(t_o - t)^2}{H}\frac{dh}{dt} \tag{2}$$

where $t_0 - t$ is the time difference between the time t_0 at which the aircraft is overhead and the time t at which it is to be detected. Alternatively, the proximity detector 4 may include different angled point sensors to determine when an aircraft enters the monitored region and is about to land or take-off. In response to the activation signal, the tracking sensor system 6 exposes the sensor 3 to track the aircraft. Use of the proximity detector 4 allows the sensor 3 to be sealed in a housing when not in use and protected from damaging environmental conditions, such as hailstorms and blizzards or fuel. The sensor 3 is only exposed to the environment for a short duration whilst an aircraft is in the vicinity of the sensor 3. If the tracking system 6 is used in conditions where the sensor 3 can be permanently exposed to the environment or the sensor 3 can resist the operating conditions, then the proximity detector 4 may not be required. The activation signal generated by the proximity detector 4 can also be used to cause the instrument rack 11 and the central control system 13 to adjust the bandwidth allocated on the link 15 so as to provide an adequate data transfer rate for transmission of video signals from the runway module to the central system 13. If the bandwidth is fixed at an acceptable rate or the system 2 only uses local area network communications and only requires a reduced bandwidth, then again the proximity detector 4 may not be required.

The tracking sensor system 6 includes one or more tracking or detection cameras 3 which obtain images of an aircraft as it approaches or leaves a runway. From a simple image of the aircraft, aspect ratios, such as the ratio of the wingspan to the fuselage length can be obtained. The tracking camera 3 used is a thermal camera which monitors thermal radiation received in the 10 to 14 μm wavelength range and is not dependent on lighting conditions for satisfactory operation. Use of the thermal cameras is also advantageous as distribution of temperatures over the observed surfaces of an aircraft can be obtained, together with signatures of engine exhaust emissions and features in the fuselage or engines. The tracking camera 3 can obtain an instantaneous two-dimensional image I_n using all of the sensors in a CCD array of the camera, or alternatively one row of the array perpendicular to the direction of motion of the aircraft can be used to obtain a linear image at each scan and the linear image is then used to build up a two-dimensional image I_n for subsequent processing.

To allow operation of the tracking and acquisition cameras 3 and 7 in rain, a rotating disc system is employed. The use of a rotating disc for removing water drops from windows is used on marine vessels. A reflective or transparent disc is rotated at high speed in front of the window that is to be kept clear. Water droplets falling on the disk experience a large shear force related to the rotation velocity. The shear force is sufficient to atomise the water drop, thereby removing it from the surface of the disc. A transparent disc of approximate diameter 200 mm is mounted to an electric motor and rotated to a frequency of 60 Hz. A camera with a 4.8 mm focal length lens was placed below a glass window which in turn was beneath the rotating disc. The results of inserting the rotating disc are illustrated in Figure 6(a), which shows the surface of a camera housing without the rotating disc, and in Figure 6(b), which shows the surface of a camera housing with the rotating disc activated and in rain conditions.

The image processing system 8 processes the digital images provided by the tracking sensor system 6 so as to extract in real-time information concerning the features and movement of the aircraft. The images provided to the image processing system, depending on the tracking cameras employed, provide an underneath view of the aircraft, as shown in Figure 7. The tips of the wings or wingspan points 18 of the aircraft are tracked by the image processor system 8 to determine when the image acquisition system 10 should be activated so as to obtain the best image of the registration markings on the port wing 20 of the aircraft. The image processing system 8 generates an acquisition signal using a trigger logic circuit 39 to trigger the camera of the image acquisition system 10. The image processing system 8 also determines and stores data concerning the wingspan 22 of the aircraft and other details concerning the size, shape and ICAO category (A to G) of the aircraft. The image processing system 8 classifies the aircraft on the basis of the size which can be used subsequently when determining the registration markings on the port wing 20. The data obtained can also be used for evaluation of the aircraft during landing and/or take-off.

Alternatively a pyroelectric sensor 27 can be used with a signal processing wing detection unit 29 to provide a tracking system 1 which also generates the acquisition signal using the trigger logic circuit 39, as shown in Figure 4 and described later.

Detecting moving aircraft in the field of view of the sensor 3 or 27 is based on forming a profile or signature of the aircraft, $P(y,t)$, that depends on a spatial coordinate y and time t. To eliminate features in the field of view that are secondary or slowly moving, a difference profile $\Delta P(y,t)$ is formed. The profile or signature can be differenced in time or in space because these differences are equivalent for moving objects. If the intensity of the light or thermal radiation from the object is not changing then the time derivative of the profile obtained from this radiation is zero. A time derivative of a moving field can be written as a convective derivative involving partial derivatives, which gives the equation

$$\frac{dP(y,t)}{dt} = \frac{\partial P(y,t)}{\partial t} + v\,\frac{\partial P(y,t)}{\partial y} = 0 \qquad \textbf{(3)}$$

where v is the speed of the object as observed in the profile. After rearranging equation (3), gives

$$\frac{\partial P(y,t)}{\partial t} = -v\,\frac{\partial P(y,t)}{\partial y} \qquad \textbf{(4)}$$

which shows that the difference in the profile in time is equivalent to the difference in the profile in space. This only holds for moving objects, when $v \neq 0$. Equation (4) also follows from the simple fact that if the profile has a given value $P(y_0,t_0)$ at the coordinate (y_0,t_0), then it will have this same value along the line

$$y = y_0 + v(t - t_0) \qquad \textbf{(5)}$$

To detect and locate a moving feature that forms an extremum in the profile, such as an aircraft wing, the profile can be differenced in space $\Delta_y P(y,t)$. Then an extremum in the profile $P(y,t)$ will correspond to a point where the difference profile $\Delta_y P(y,t)$ crosses zero.

In one method for detecting a feature on the aircraft, a profile $P(y,t)$ is formed and a difference profile $\Delta_t P(y,t)$ is obtained by differencing in time, as described below. According to equation (4) this is equivalent to a profile of a moving object that is differenced in space. Therefore the position y_p of the zero crossing point of $\Delta_t P(y,t)$ at time t is also the position of the zero crossing point of $\Delta_y P(y,t)$ which locates an extremum in $P(y,t)$.

In another method for detecting a feature on the aircraft, the difference between the radiation received by a sensor 27 from two points in space is obtained as a function of time, $\Delta_y S(t)$, as described below. If there are no moving features in the field of view, then the difference is constant. If any object in the field of view is moving, then the position of a point on the object is related to time using equation (5). This allows a profile or signature differenced in space to be constructed

$$\Delta_y P(y(t),t) = \Delta_y S(t) \qquad \textbf{(6)}$$

and, as described above, allows an extremum corresponding to an aircraft wing to be located in the profile from the zero crossing point in the differential signature.

The image acquisition system 10 includes at least one high resolution camera 7 to obtain images of the aircraft when triggered. The images are of sufficient resolution to enable automatic character recognition of the registration code on the port wing 20 or elsewhere. The illumination unit 16 is also triggered simultaneously to provide illumination of the aircraft during adverse lighting conditions, such as at night or during inclement weather.

The acquired images are passed to the analysis system 12 which performs Optical Character Recognition (OCR) on the images to obtain the registration code. The registration code corresponds to aircraft type and therefore the aircraft classification determined by the image processing system 8 can be used to assist to the recognition process, particularly when characters of the code are obscured in an acquired image. The registration code extracted and any other information concerning the aircraft can be then passed to other systems via a network connection 24.

Once signals received from the pyroelectric sensors 21 indicate the aircraft 28 is within the field of view of the sensors 3 of the tracking sensor system 6, the tracking system 1 is activated by the proximity detector 4. The proximity detector 4 is usually the first stage detection system to determine when the aircraft is in the proximity of the more precise tracking system 1. The tracking system 1 includes the tracking sensor system 6 and the image processing system 8 and according to one embodiment the images from the detection cameras 3 of the sensor system 6 are used by the image processing system 8 to provide a trigger for the image acquisition system when some point in the image of the aircraft reaches a predetermined pixel position. One or more detection cameras 3 are placed in appropriate locations near the airport runway such that the aircraft passes within the field of view of the cameras 3. A tracking camera 3 provides a sequence of images, $\{I_n\}$. The image processing system 8 subtracts a background image from each image I_n of the sequence. The background image represents an average of a number of preceding images. This yields an image ΔI_n that contains only those objects that have moved during the time interval between images. The image ΔI_n is thresholded at appropriate values to yield a binary image, i.e. one that contains only two levels of brightness, such that the pixels comprising the edges of the aircraft are clearly distinguishable. The pixels at the extremes of the aircraft in the direction perpendicular to the motion of the aircraft will correspond to the edges 18 of the wings of the aircraft. After further processing, described below, when it is determined the pixels comprising the port edge pass a certain position in the image corresponding to the acquisition point, the acquisition system 10 is triggered, thereby obtaining an image of the registration code beneath the wing 20 of the aircraft.

Imaging the aircraft using thermal infrared wavelengths and detecting the aircraft by its thermal radiation renders the aircraft self-luminous so that it can be imaged both during the day and night primarily without supplementary illumination. Infrared (IR) detectors are classified as either photon detectors (termed cooled sensors herein), or thermal detectors (termed uncooled sensors herein). Photon detectors (photoconductors or photodiodes) produce an electrical response directly as the result of absorbing IR radiation. These detectors are very sensitive, but are subject to noise due to ambient operating temperatures. It is usually necessary to cryogenically cool (80°K) these detectors to maintain high sensitivity. Thermal detectors experience a temperature change when they absorb IR radiation, and an electrical response results from temperature dependence of the material property. Thermal detectors are not generally as sensitive as photon detectors, but perform well at room temperature.

Typically, the cooled sensing devices are formed from Mercury Cadmium Telluride offer far greater sensitivity than uncooled devices, which may be formed from Barium Strontium Titanate. Their Net Equivalent Temperature Difference (NETD) is also superior. However, with the uncooled sensor a chopper can be used to provide temporal modulation of the scene. This permits AC coupling of the output of each pixel to remove the average background. This minimises the dynamic range requirements for the processing electronics and amplifies only the temperature differences. This is an advantage for resolving differences between cloud, the sun, the aircraft and the background. The advantage of differentiation between objects is that it reduced the load on subsequent image processing tasks for segmenting the aircraft from the background and other moving objects such as the clouds.

Both a cooled and uncooled thermal infrared imaging system 6 has been used during day, night and foggy conditions. The system 6 produced consistent images of the aircraft in all these conditions, as shown in Figures 8 and 9. In particular, the sun in the field of view produced no saturation artefacts or flaring in the lens. At night, the entire aircraft was observable, not just the lights.

The image processing system 8 uses a background subtraction method in an attempt to eliminate slowly moving or stationary objects from the image, leaving only the fast moving objects. This is achieved by maintaining a background image that is updated after a certain time interval elapses. The update is an incremental one based on the difference between the current image and the background. The incremental change is such that the background image can adapt to small intensity variations in the scene but takes some time to respond to large variations. The background image is subtracted from the current image, a modulus is taken and a threshold applied. The result is a binary image containing only those differences from the background that exceed the threshold.

One problem with this method is that some slow moving features, such as clouds, still appear in the binary image. The reason for this is that the method does not select on velocity but on a combination of velocity and intensity gradients. If the intensity in the image is represented by $I(x,y,t)$, where x and y represent the position in rows and columns, respectively, and t represents the image frame number (time) and if the variation in the intensity due to ambient conditions is very small then it can be shown that the time variation of the intensity in the image due to a feature moving with velocity v is given by

$$\frac{\partial I(x,y,t)}{\partial t} = -v.\nabla I(x,y,t) \tag{7}$$

In practice, the time derivative in equation (7) is performed by taking the difference between the intensity at (x,y) at different times. Equation (7) shows that the value of this difference depends on the velocity v of the feature at (x,y) and the intensity gradient. Thus a fast moving feature with low contrast relative to the background is identical to a slow moving feature with a large contrast. This is the situation with slowly moving clouds that often have very bright edges and therefore large intensity gradients there, and are not eliminated by this method. Since features in a binary image have the same intensity gradients, better velocity selection is obtained using the same method but applied to the binary image. In this sense, the background-subtraction method is applied twice, once to the original grey-scale image to produce a binary image as described above, and again to the subsequent binary image, as described below.

The output from the initial image processing hardware is a binary image $B(x,y,t)$ where $B(x,y,t) = 1$ if a feature is located at (x,y) at time t, and $B(x,y,t) = 0$ represents the background. Within this image the fast moving features belong to the aircraft. To deduce the aircraft wing position the two-dimensional binary image can be compressed into one dimension by summing along each pixel row of the binary image,

$$P(y,t) = \int B(x,y,t)\, dx \qquad \textbf{(8)}$$

where the aircraft image moves in the direction of the image columns. This row-sum profile is easily analysed in real time to determine the location of the aircraft. An example of a profile is shown in Figure 10 where the two peaks 30 and 31 of the aircraft profile correspond to the main wings (large peak 30) and the tail wings (smaller peak 31).

In general, there are other features present, such as clouds, that must be identified or filtered from the profile. To do this, differences between profiles from successive frames are taken, which is equivalent to a time derivative of the profile. Letting $A(x,y,t)$ be the aircraft where $A(x,y,t) = 1$ if (x,y) lies within the aircraft and 0 otherwise and letting $C(x,y,t)$ represent clouds or other slowly moving objects, then it can be shown that the time derivative of the profile is given by

$$\begin{aligned}\frac{\partial P(y,t)}{\partial t} &= \int \frac{\partial A(x,y,t)}{\partial t}dx + \int \frac{\partial C(x,y,t)}{\partial t}dx - \int \frac{\partial}{\partial t}[A(x,y,t)C(x,y,t)]dx \\ &= \int \frac{\partial A(x,y,t)}{\partial t}[1 - C(x,y,t)]dx + \varepsilon(C)\end{aligned} \qquad \textbf{(9)}$$

where $\varepsilon(C) \approx 0$ is a small error term due to the small velocity of the clouds. Equation (9) demonstrates an obvious fact that the time derivative of a profile gives information on the changes (such as motion) of feature A only when the changes in A do not overlap features C. In order to obtain the best measure of the location of a feature, the overlap between features must be minimised. This means that $C(x,y,t)$ must cover as small an area as possible. If the clouds are present but do not overlap the aircraft, then apart from a small error term, the time difference between profiles gives the motion of the aircraft. The difference profile corresponding to Figure 10 is shown in Figure 11 where the slow moving clouds have been eliminated. The wing positions occur at the zero-crossing points 33 and 34. Note that the clouds have been removed, apart from small error terms.

The method is implemented using a programmable logic circuit of the image processing system 8 which is programmed to perform the row sums on the binary image and to output these as a set of integers after each video field. When taking the difference between successive profiles the best results were obtained using differences between like fields of the video image, i.e. even-even and odd-odd fields.

The difference profile is analysed to locate valid zero crossing points corresponding to the aircraft wing positions. A valid zero crossing is one in which the difference profile initially rises above a threshold I_T for a minimum distance y_T and falls through zero to below $-I_T$ for a minimum distance y_T. The magnitude of the threshold I_T is chosen to be greater than the error term $\varepsilon(C)$ which is done to discount the affect produced by slow moving features, such as clouds.

In addition, the peak value of the profile, corresponding to the aircraft wing, can be obtained by summing the difference values when they are valid up to the zero crossing point. This method removes the contributions to the peak from the non-overlapping clouds. It can be used as a guide to the wing span of the aircraft.

The changes in position of the aircraft in the row-sum profile are used to determine a velocity for the aircraft that can be used for determining the image acquisition or trigger time, even if the aircraft is not in view. This situation may occur if the aircraft image moves into a region on the sensor that is saturated, or if the trigger point is not in the field of view of the camera 3. However, to obtain a reliable estimate of the velocity, geometric corrections to the aircraft position are required to account for the distortions in the image introduced by the camera lens. These are described below using the coordinate systems (x,y,z) for the image and (X,Y,Z) for the aircraft as shown in Figures 12 and 13, respectively.

For an aircraft at distance Z and at a constant altitude Y_0, the angle from the horizontal to the aircraft in the vertical plane is

$$\tan\theta_y = \frac{Y_0}{Z} \qquad (10)$$

Since Y_0 is approximately constant, a normalised variable $Z_N = Z/Y_0$ can be used. If y_0 is the coordinate of the centre of the images, f is the focal length of the lens and θ_c is the angle of the camera from the horizontal in the vertical plane, then

$$\frac{y_0 - y}{f} = \tan(\theta_y - \theta_c) = \frac{\tan\theta_y - \tan\theta_c}{1 + \tan\theta_y \tan\theta_c} \qquad (11)$$

where the tangent has been expanded using a standard trigonometric identity. Using (10) and (11) an expression for the normalised distance Z_N is obtained

$$Z_N(y) = \frac{1 + \beta(y - y_0)\tan\theta_c}{\tan\theta_c - \beta(y - y_0)} \qquad (12)$$

where $\beta = 1/f$. This equation allows a point in the image at y to be mapped onto a true distance scale, Z_N. Since the aircraft altitude is unknown, the actual distance cannot be determined. Instead, all points in the image profile are scaled to be equivalent to a specific point, y_1, in the profile. This point is chosen to be the trigger line or image acquisition line. The change in the normalised distance $Z_N(y_1)$ at y_1 due to an increment in pixel value Δy_1 is $\Delta Z_N(y_1) = Z_N(y_1 + \Delta y_1) - Z_N(y_1)$. The number of such increments over a distance $Z_N(y_2) - Z_N(y_1)$ is $M = (Z_N(y_2) - Z_N(y_1))/\Delta Z_N(y_1)$. Thus the geometrically corrected pixel position at y_2 is

$$y_{c2} = y_1 + M\Delta y_1 = y_1 + \frac{Z_N(y_2) - Z_N(y_1)}{\Delta Z_N(y_1)} \Delta y_1 \tag{13}$$

For an aircraft at distance Z and at altitude Y_0, a length X on it in the X direction subtends an angle in the horizontal plane of

$$\tan\theta_x = \frac{X}{\sqrt{Y_0^2 + Z^2}} = \frac{X_N}{\sqrt{1 + Z_N^2}} \tag{14}$$

where normalised values have been used. If x_0 is the location of the centre of the image and f is the focal length of the lens, then

$$\frac{x - x_0}{f} = \tan\theta_x \tag{15}$$

Using (12), (14) and (15), the normalised distance X_N can be obtained in terms of x and y

$$X_N = \frac{(x - x_0)}{f}\sqrt{1 + Z_N^2(y)} \tag{16}$$

As with the y coordinate, the x coordinate is corrected to a value at y_1. Since X_N should be independent of position, then a length $x_2 - x_0$ at y_2 has a geometrically corrected length of

$$\begin{aligned} x_{c2} - x_0 &= (x_2 - x_0)\frac{\sqrt{1 + Z_N^2(y_2)}}{\sqrt{1 + Z_N^2(y_1)}} \\ &= (x_2 - x_0)\frac{\sqrt{1 + \beta^2(y_2 - y_0)^2}}{\sin\theta_c - \beta(y_2 - y_0)\cos\theta_c}\frac{\sin\theta_c - \beta(y_1 - y_0)\cos\theta_c}{\sqrt{1 + \beta^2(y_1 - y_0)^2}} \end{aligned} \tag{17}$$

The parameter $\beta = 1/f$ is chosen so that x and y are measured in terms of pixel numbers. If y_0 is the centre of the camera centre and it is equal to half the total number of pixels, and if θ_{FOV} is the vertical field of view of the camera, then

$$\beta = \frac{\tan(\theta_{FOV}/2)}{y_0} \qquad \textbf{(18)}$$

This relation allows β to be calculated without knowing the lens focal length and the dimensions of the sensor pixels.

The velocity of a feature is expressed in terms of the number of pixels moved between image fields (or frames). Then if the position of the feature in frame n is y_n, the velocity is given by $v_n = y_n - y_{n-1}$. Over N frames, the average velocity is then

$$\langle v\rangle = \frac{1}{N}\sum_{n=1}^{N} v_n = \frac{1}{N}\sum_{n=1}^{N}\left(y_n - y_{n-1}\right) = \frac{1}{N}\left(y_N - y_0\right) \qquad \textbf{(19)}$$

which depends only on the start and finish points of the data. This is sensitive to errors in the first and last values and takes no account of the positions in between. The error in the velocity due to an error δy_N in the value y_N is

$$\varepsilon(\langle v\rangle) = \frac{\delta y_N}{N} \qquad \textbf{(20)}$$

A better method of velocity estimation uses all the position data obtained between these values. A time t is maintained which represents the current frame number. Then the current position is given by

$$y = y_0 - vt \qquad \textbf{(21)}$$

where y_0 is the unknown starting point and v is the unknown velocity. The number n of valid positions y_n measured from the feature are each measured at time t_n. Minimising the mean square error

$$\chi^2 = \frac{1}{N}\sum_{n=1}^{N}\left(y_n - y_0 + vt_n\right)^2 \qquad \textbf{(22)}$$

with respect to v and y_0 gives two equations for the unknown quantities y_0 and v. Solving for v yields

$$v = \frac{\sum_{n=1}^{N} y_n \sum_{n=1}^{N} t_n - N \sum_{n=1}^{N} y_n t_n}{N \sum_{n=1}^{N} t_n^2 - \sum_{n=1}^{N} t_n \sum_{n=1}^{N} t_n} \tag{23}$$

This solution is more robust in the sense that it takes account of all the motions of the feature, rather than the positions at the beginning and at the end of the observations. If the time is sequential, so that $t_n = n\Delta t$ where $t_n = 1$ is the time interval between image frames, then the error in the velocity due to an error δy_n in the value y_n is

$$\varepsilon(\langle v \rangle) = \frac{\delta y_n}{N} \left\{ \frac{6(N + 1 - 2n)}{(N + 1)(N - 1)} \right\} \tag{24}$$

which, for the same error δy_N in (19), gives a smaller error than (21) for $N > 5$. In general, the error in (24) varies as $1/N^2$ which is less sensitive to uncertainties in position than (19).

If the aircraft is not in view, then the measurement of the velocity v can be used to estimate the trigger time. If y_l is the position of a feature on the aircraft that was last seen at a time t_l, then the position at any time t is estimated from

$$y = y_l - v(t - t_l) \tag{25}$$

Based on this estimate of position, the aircraft will cross the trigger point located at y_T at a time t_T estimated by

$$t_T = t_l - \frac{y_T - y_l}{v} \tag{26}$$

An alternative method of processing the images obtained by the camera 3 to determine the aircraft position, which also automatically accounts for geometric corrections, is described below. The method is able to predict the time for triggering the acquisition system 10 based on observations of the position of the aircraft 28.

To describe the location of an aircraft 28 and its position, a set of coordinates are defined such that the $\hat{x}$ axis points vertically upwards, the $\hat{z}$ axis points horizontally along the runway towards the approaching aircraft, and $\hat{y}$ is horizontal and perpendicular to the runway. The image 66 of the aircraft is located in the digitised image by pixel values (x_p, y_p), where x_p is defined to be the vertical pixel value and y_p the horizontal value. The lens on the camera inverts the image so that a light ray from the aircraft strikes the sensor at position $(-x_p, -y_p, 0)$, where the sensor is located at the coordinate origin. Figure 14 shows a ray 68 from an object, such as a point on the aircraft, passing through a lens of a focal length f, and striking the imaging sensor at a point $(-x_p, -y_p)$, where x_p and y_p are the pixel values. The equation locating a point on the ray is given by

$$\boldsymbol{r} = x_p(z/f - 1)\hat{\boldsymbol{x}}_c + y_p(z/f - 1)\hat{\boldsymbol{y}}_c + z\hat{\boldsymbol{z}}_c \qquad \textbf{(27)}$$

where z is the horizontal distance along the ray, and the subscript c refers to the camera coordinates. The camera axis $\hat{z}_c$ is collinear with the lens optical axis. It will be assumed that $z/f \gg 1$, which is usually the case.

Assuming the camera is aligned so that $\hat{y}_c = \hat{y}$ is aligned with the runway coordinate, but the camera is tilted from the horizontal by angle θ. Then

$$\begin{aligned} \hat{\boldsymbol{x}}_c &= \hat{\boldsymbol{x}} \cos\theta - \hat{\boldsymbol{z}} \sin\theta \\ \hat{\boldsymbol{z}}_c &= \hat{\boldsymbol{x}} \sin\theta + \hat{\boldsymbol{z}} \cos\theta \end{aligned} \qquad \textbf{(28)}$$

and a point on the ray from the aircraft to its image is given by

$$\boldsymbol{r} = z\left[\left(x_p \cos\theta / f + \sin\theta\right) \hat{\boldsymbol{x}} + \left(y_p / f\right) \hat{\boldsymbol{y}} + \left(\cos\theta - x_p \sin\theta / f\right) \hat{\boldsymbol{z}}\right] \qquad \textbf{(29)}$$

Letting the aircraft trajectory be given by

$$\boldsymbol{r}(t) = \left(z(t) \tan\theta_{GS} + x_0\right) \hat{\boldsymbol{x}} + y_0\hat{\boldsymbol{y}} + z(t)\hat{\boldsymbol{z}} \qquad \textbf{(30)}$$

where $z(t)$ is the horizontal position of the aircraft at time t, θ_{GS} is the glide-slope angle, and the aircraft is at altitude x_0 and has a lateral displacement y_0 at $z(t_0) = 0$. Here, $t = t_0$ is the time at which the image acquisition system 10 is triggered, i.e. when the aircraft is overhead with respect to the cameras 7.

Comparing equations (29) and (30) allows z to be written in terms of $z(t)$ and gives the pixel positions as

$$x_p(t) = f\left(\frac{z(t)\left[\cos\theta\ \tan\theta_{GS} - \sin\theta\right] + x_0 \cos\theta}{z(t)\left[\sin\theta\ \tan\theta_{GS} + \cos\theta\right] + x_0 \sin\theta}\right) \quad \textbf{(31)}$$

and

$$y_p(t) = \frac{f y_0}{z(t)\left[\sin\theta\ \tan\theta_{GS} + \cos\theta\right] + x_0 \sin\theta} \quad \textbf{(32)}$$

Since $z_p(t)$ is the vertical coordinate and its value controls the acquisition trigger, the following discussion will be centred on equation (31). The aircraft position is given by

$$z(t) = v(t_0 - t) \quad \textbf{(33)}$$

where v is the speed of the aircraft along the $\hat{z}$ axis.

The aim is to determine t_0 from a series of values of $z_p(t)$ at t determined from the image of the aircraft. For this purpose, it is useful to rearrange (31) into the following form

$$c - t + ax_p - btx_p = 0 \quad \textbf{(34)}$$

where

$$a = \frac{vt_0\left(\tan\theta_{GS} + \cot\theta\right) + x_0}{fv\left(1 - \tan\theta_{GS}\cot\theta\right)} \quad \textbf{(35)}$$

$$b = \frac{\tan\theta_{GS} + \cot\theta}{f\left(1 - \tan\theta_{GS}\cot\theta\right)} \quad \textbf{(36)}$$

and

$$c = t_0 - \frac{x_T x_0}{fv(1 - \tan\theta_{GS} \cot\theta)} \tag{37}$$

The pixel value corresponding to the trigger point vertically upwards is $x_T = f \cot\theta$. The trigger time, t_0, can be expressed in terms of the parameters a, b and c

$$t_0 = \frac{c + ax_T}{1 + bx_T} \tag{38}$$

The parameters a, b and c are unknown since the aircraft glide slope, speed, altitude and the time at which the trigger is to occur are unknown. However, it is possible to estimate these using equation (34) by minimising the chi-square statistic. Essentially, equation (34) is a prediction of the relationship between the measured values x_p and t, based on a simple model of the optical system of the detection camera 3 and the trajectory of the aircraft 28. The parameters a, b and c are to be chosen so as to minimise the error of the model fit to the data, i.e. make equation (34) be as close to zero as possible.

Let x_n be the location of the aircraft in the image, i.e. pixel value, obtained at time t_n. Then the chi-square statistic is

$$\chi^2 = \sum_{n=1}^{N} (c - t_n + ax_n - bt_n x_n)^2 \tag{39}$$

for N pairs of data points. The optimum values of the parameters are those that minimise the chi-square statistic, i.e. those that satisfy equation (34).

For convenience, the following symbols are defined

$$X = \sum_{n=1}^{N} x_n, \quad T = \sum_{n=1}^{N} t_n, \quad P = \sum_{n=1}^{N} x_n t_n, \quad Y = \sum_{n=1}^{N} x_n^2, \\ = \sum_{n=1}^{N} x_n^2 t_n, \quad R = \sum_{n=1}^{N} x_n t_n^2, \quad S = \sum_{n=1}^{N} x_n^2 t_n^2. \tag{40}$$

Then the values of a, b and c that minimise equation (39) are given by

$$a = \frac{(NP - XT)(P^2 - NS) - (NR - PT)(PX - NQ)}{(NY - X^2)(P^2 - NS) + (PX - NQ)^2} \quad (41)$$

$$b = \frac{(NP - XT)(PX - NQ) + (NR - PT)(NY - X^2)}{(NY - X^2)(P^2 - NS) + (PX - NQ)^2} \quad (42)$$

and

$$c = \frac{T + bP - aX}{N} \quad (43)$$

On obtaining a, b and c from equations (41) to (43), then t_0 can be obtained from equation (38).

Using data obtained from video images of an aircraft landing at Melbourne airport, a graph of aircraft image position as a function of image frame number is shown in Figure 15. The data was processed using equations (41) to (43) and (38) to yield the predicted value for the trigger frame number $t_0 = 66$ corresponding to trigger point 70. The predicted point 70 is shown in Figure 16 as a function of frame number. The predicted value is $t_0 = 66 \pm 0.5$ after 34 frames. In this example, the aircraft can be out of the view of the camera 3 for up to 1.4 seconds and the system 2 can still trigger the acquisition camera 7 to within 40 milliseconds of the correct time. For an aircraft travelling at 62.5 m/s, the system 2 captures the aircraft to within 2.5 metres of the required position.

The tracking system 6, 8 may also use an Area-Parameter Accelerator (APA) digital processing unit, as discussed in International Publication No. WO 93/19441, to extract additional information, such as the aspect ratio of the wing span to the fuselage length of the aircraft and the location of the centre of the aircraft.

The tracking system 1 can also be implemented using one or more pyroelectric sensors 27 with a signal processing wing detection unit 29. Each sensor 27 has two adjacent pyroelectric sensing elements 40 and 42, as shown in Figure 17, which are electrically connected so as to cancel identical signals generated by each element. A plate 44 with a slit 46 is placed above the sensing elements 40 and 42 so as to provide the elements 40 and 42 with different fields of view 48 and 50. The fields of view 48 and 50 are significantly narrower than the field of view of a detection camera discussed previously. If aircraft move above the runway in the direction indicated by the arrow 48, the first element 40 has a front field of view 48 and the second element 42 has a rear field of view 50. As an aircraft 28 passes over the sensor 27 the first element 40 detects the thermal radiation of the aircraft before the second element 42, the aircraft 28 will then be momentarily in both fields of view 48 and 50, and then only detectable by the second element 42. An example of the difference signals generated by two sensors 27 is illustrated in Figure 18 where the graph 52 is for a sensor 27 which has a field of view that is directed at 90° to the horizontal and a sensor 27 which is directed at 75° to the horizontal. Graph 54 is an expanded view of the centre of graph 52. The zero crossing points of peaks 56 in the graphs 52 and 54 correspond to the point at which the aircraft 28 passes the sensor 27. Using the known position of the sensor 27 the time at which the aircraft passes, and the speed of the aircraft 28, a time can be determined for generating an acquisition signal to trigger the high resolution acquisition cameras 7. The speed can be determined from movement of the zero crossing points over time, in a similar manner to that described previously.

The image acquisition system 10, as mentioned previously, acquires an image of the aircraft with sufficient resolution for the aircraft registration characters to be obtained using optical character recognition. According to one embodiment of the acquisition system 10, the system 10 includes two high resolution cameras 7 each comprising a lens and a CCD detector array. Respective images obtained by the two cameras 7 are shown in Figures 19 and 20.

The minimum pixel dimension and the focal length of the lens determine the spatial resolution in the image. If the dimension of a pixel is L_p, the focal length f and the altitude of the aircraft is h, then the dimension of a feature W_{min} on the aircraft that is mapped onto a pixel is

$$W_{\min} = \frac{L_p h}{f} \quad \text{or} \quad f = \frac{L_p h}{W_{\min}} \qquad (44)$$

The character recognition process used requires each character stroke to be mapped onto at least four pixels with contrast levels having at least 10% difference from the background. The width of a character stroke in the aircraft registration is regulated by the ICAO. According to the ICAO Report, Annex 7, sections 4.2.1 and 5.3, the character height beneath the port wing must be at least 50 centimetres and the character stroke must be 1/6th the character height. Therefore, to satisfy the character recognition criterion, the dimension of the feature on the aircraft that is mapped onto a pixel should be $W_{\min} = 2$ centimetres, or less. Once the CCD detector is chosen, L_p is fixed and the focal length of the system 10 is determined by the maximum altitude of the aircraft at which the spatial resolution $W_{\min} = 2$ centimetres is required.

The field of view of the system 10 at altitude h is determined by the spatial resolution $W_{\min}$ chosen at altitude $h_{\max}$ and the number of pixels N_{pl} along the length of the CCD,

$$W_{FOV} = \frac{N_{pl} W_{\min} h}{h_{\max}} \qquad (45)$$

For $h = h_{\max}$ and $N_{pl} = 1552$ the field of view is $W_{FOV} = 31.04$ metres.

To avoid blurring due to motion of the aircraft, the image moves a distance less than the size of a pixel during the exposure. If the aircraft velocity is v, then the time to move a distance equal to the required spatial resolution $W_{\min}$ is

$$t = \frac{W_{\min}}{v} \qquad (46)$$

The maximum aircraft velocity that is likely to be encountered on landing or take-off is v = 160 knots = 82 ms $^{-1}$. With W_{min} = 0.02 m, the exposure time to avoid excessive blurring is t < 240 μs.

The focal length of the lens in the system 10 can be chosen to obtain the required spatial resolution at the maximum altitude. This fixes the field of view. Alternatively, the field of view may be varied by altering the focal length according to the altitude of the aircraft. The range of focal lengths required can be calculated from equation (44).

The aircraft registration, during daylight conditions, is illuminated by sunlight or scattered light reflected from the ground. The aircraft scatters the light that is incident, some of which is captured by the lens of the imaging system. The considerable amount of light reflected from aluminium fuselages of an aircraft can affect the image obtained, and is taken into account. The light power falling onto a pixel of the CCD is given by

$$P_p = L_\lambda \Delta\lambda \Omega_{sun} \frac{R_{gnd} R_A A_p}{8f\#^2} \qquad \textbf{(47)}$$

where L_λ is the solar spectral radiance, $\Delta\lambda$ is the wavelength bandpass of the entire configuration, Ω_{sun} is the solid angle subtended by the sun, R_{gnd} is the reflectivity of the ground, R_A is the reflectivity of the aircraft, A_p is the area of a pixel in the CCD detector and $f\#$ is the lens f-number.

The solar spectral radiance L_λ varies markedly with wavelength λ. The power falling on a pixel will therefore vary over a large range. This can be limited by restricting the wavelength range $\Delta\lambda$ passing to the sensor and optimally choosing the centre wavelength of this range. The optimum range and centre wavelength are chosen to match the characteristics of the imaging sensor.

In one embodiment, the optimum wavelength range and centre wavelength are chosen in the near infrared waveband, 0.69 to 2.0 microns. This limits the variation in light power on a pixel in the sensor to within the useable limits of the sensor. A KODAK™ KAF-1600L imaging sensor (a monolithic silicon sensor with lateral overflow anti-blooming) was chosen that incorporated a mechanism to accommodate a thousandfold saturation of each pixel, giving a total acceptable range of light powers in each pixel of 10^5. This enables the sensor to produce a useful image of an aircraft when very bright light sources, for example the sun, are in its field of view.

The correct choice of sensor and the correct choice of wavelength range and centre wavelength enables an image to be obtained within a time interval that arrests the motion of the aircraft and that provides an image with sufficient contrast on the aircraft registration to enable digital image processing and recognition of the registration characters.

In choosing the wavelength range and centre wavelength, it was important to avoid dazzling light from the supplementary illumination of the illumination unit 16. The optimum wavelength range was therefore set to between 0.69 μm and 2.0 μm.

The power of sunlight falling onto a pixel directly from the sun is

$$P_{p\text{-sun}} = L_{\lambda} \Delta\lambda \frac{A_p \pi}{4 f\#^2} \qquad \textbf{(48)}$$

The relative light powers from the sun and from the aircraft registration falling onto a single pixel is

$$\frac{P_{p\text{-sun}}}{P_p} = \frac{2\pi}{\Omega_{sun} R_{gnd} R_A} \qquad \textbf{(49)}$$

With $\Omega_{sun} = 6.8 \times 10^{-5}$ steradians, $R_{gnd} \approx 0.2$ and $R_A = 1$, the ratio is $P_{p\text{-sun}}/P_p = 4.6 \times 10^5$. This provides an estimate of the relative contrast between the image of the sun and the image of the underneath of the aircraft on a CCD pixel. The CCD sensor and system electronics are chosen to accommodate this range of light powers.

In poor lighting conditions, the aircraft registration requires additional illumination from the illumination unit 16. The light source of the unit 16 needs to be sufficient to illuminate the aircraft at its maximum altitude. If the source is designed to emit light into a solid angle that just covers the field of view of the imaging system then the light power incident onto a pixel of the imaging system 10 due to light emitted from the source and reflected from the aircraft is given by

$$P_p = P_s \frac{R_A}{8A_A} \frac{A_p}{N_{ptot} f\#^2} \qquad \textbf{(50)}$$

where A_A is the area on the aircraft imaged onto a pixel of area A_p, P_s is the light power of the source, R_A is the aircraft reflectivity, N_{ptot} is the total number of pixels in the CCD sensor and $f\#$ is the f-number of the lens. The power of the source required to match the daytime reflected illumination is estimated by setting $P_p = 7.3 \times 10^{-11}$ W, $R_A = 1$, $A_p = 81\ \mu m^2$, $N_{ptot} = 1552 \times 1032$, $f\# = 1.8$ and noting that $A_A = W_{min}^2$ where $W_{min} = 0.02$ m. Then $P_s = 1.50 \times 10^4$ W. For a Xenon flash lamp, the flash time is typically $t = 300\ \mu s$ which compares favourably with the exposure time to minimise motion blurring. Then the source must deliver an energy of $E_s = P_s t = 4.5$ J. This is the light energy in a wavelength band $\Delta\lambda = 0.1\ \mu m$. Xenon flash lamps typically have 10% of their light energy within this bandpass centred around $\lambda = 0.8\ \mu m$. Furthermore, the flash lamp may only be 50% efficient. Thus the electrical energy required is approximately 90 J. Flash lamps that deliver energies of 1500 J in 300 μs are readily available. Illumination with such a flash lamp during the day reduces the contrast between the direct sun and the aircraft registration, thereby relaxing the requirement for over-exposure tolerance of the CCD sensor. This result depends on the flash lamp directing all of its energy into the field of view only and that the lens focal length is optimally chosen to image the region of dimension $W_{min} = 0.02$ m onto a single pixel.

In one embodiment, the aperture of the lens on the acquisition camera 7 is automatically adjusted to control the amount of light on the imaging sensor in order to optimise the image quality for digital processing. In the image obtained, the intensity level of the registration characters relative to the underside of the aircraft needs to be maintained to provide good contrast between the two for OCR. The power P_s of the flash 16 is automatically adjusted in accordance with the aperture setting f# of the acquisition camera 7 to optimise the image quality and maintain the relative contrast between the registration characters and the underside of the aircraft, in accordance with the relationship expressed in equation (50). For example, during the day the aperture of the lens may be very small and the power of the flash may be increased to provide additional illumination of the underside, whereas during night conditions, the aperture may be fully opened and the power of the flash reduced considerably as additional illumination is not required. As an alternative, or in addition, the electrical gain of the electronic circuits connected to an acquisition camera 7 is adjusted automatically to optimise the image quality.

To appropriately set the camera aperture and/or gain one or more point optical sensors 60, 62, as shown in Figure 21, are used to measure the ambient lighting conditions. The electrical output signals of the sensors 60, 62 are processed by the acquisition system 10 to produce the information required to control the camera aperture and/or gain. Two point sensors 60, 62 sensitive to the same optical spectrum as the acquisition cameras 7 can be used. One sensor 60 receives light from the sky that passes through a diffusing plate 64 onto the sensor 60. The diffusing plate 64 collects light from many different directions and allows it to reach the sensor 60. The second sensor 62 is directed towards the ground to measure the reflected light from the ground.

The high resolution images obtained of the aircraft by the acquisition system 10 are submitted, as described previously, to the analysis system 12 which performs optical character recognition on the images to extract the registration codes of the aircraft.

The analysis system 12 processes the aircraft images obtained by a high resolution camera 7 according to an image processing procedure 100, as shown in

Figure 22, which is divided into two parts 102 and 104. The first part 102 operates on a sub-sampled image 105, as shown in Figure 23, to locate regions that contain features that may be registration characters, whereas the second part 104 executes a similar procedure but is done using the full resolution of the original image and is executed only on the regions identified by the first part 102. The sub-sampled image 105 is the original image with one pixel in four removed in both row and column directions, resulting in a one in sixteen sampling ratio. Use of the sub-sampled image improves processing time sixteen-fold.

The first part 102 receives the sub-sampled image at step 106 and filters the image to remove features which are larger than the expected size of the registration characters (b) at step 108. Step 108 executes a morphological operation of linear closings applied to a set of lines angled between 0 and 180°. The operation passes a kernel or window across the image 105 to extract lines which exceed a predetermined length and are at a predetermined angle. The kernel or window is passed over the image a number of times and each time the predetermined angle is varied. The lines extracted from all of the passes are then subtracted from the image 105 to provide a filtered difference image 109. The filtered difference image 109 is then thresholded or binarised at step 110 to convert it from a grey scale image to a binary scale image 111. This is done by setting to 1 all image values that are greater than a threshold and setting to 0 all other image values. The threshold at a given point in the image is determined from a specified multiple of standard deviations from the mean calculated from the pixel values within a window centred on the given point. The binarised image 111 is then filtered at step 112 to remove all features that have pixel densities in a bounding box that are smaller or larger than the expected pixel density for a bounded registration character. The image 111 is then processed at step 114 to remove all features which are not clustered together like registration characters. Step 114 achieves this by grouping together features that have similar sizes and that are close to one another. Groups of features that are smaller than a specified size are removed from the image to obtain a cleaned image 113. The cleaned image 113 is then used at step 116 to locate regions of interest. Regions of interest are obtained in step 116 from the location and extents of the groups remaining after step 114. Step 116 produces regions of interest which include the registration characters and areas of the regions are bounded above and below, as for the region 115 shown in Figure 23.

The regions of interest obtained by the first part 102 of the procedure 100 are further processed individually using the full resolution of the original image and the second part 104 of the procedure. The second part 104 takes a region of interest 115 from the original image at step 120 and for that region filters out features larger than the expected character sizes at step 122, using the same morphological operation of linear closings applied to a set of lines angled between 0 and 180°, followed by image subtraction, as described above, to obtain image 117. The filtered image 117 is then binarised at step 124 by selecting a filter threshold that is representative of the pixel values at the edges of features. To distinguish the registration characters from the aircraft wing or body the filter threshold needs to be set correctly. A mask image of significant edges in image 117 is created by calculating edge-strengths at each point in image 117 and setting to 1 all points that have edge-strengths greater than a mask threshold and setting to 0 all other points. An edge-strength is determined by taking at each point pixel gradients in two directions, Δx and Δy, and calculating $\sqrt{\Delta x^2 + \Delta y^2}$ to give the edge-strength at that point. The mask threshold at a given point is determined from a specified multiple of standard deviations from the mean calculated from the edge-strengths within a window centred on the given point. The filter threshold for each point in image 117 is then determined from a specified multiple of standard deviations from the mean calculated from the pixel values at all points within a window centred on the given point that correspond to non-zero values in the mask image. The binarised image 118 is then filtered at step 126 to remove features that are smaller than the expected character sizes. Features are clustered together at step 128 that have similar sizes, that are near to one another and that are associated with similar image values in image 117. At step 130 the correctly clustered features that have sizes, orientations and relative positions that deviate too much from the averages for the clusters are filtered out to leave features that form linear chains. Then at step 132, if the number of features remaining in the image produced by step 130 is greater than 3, then a final image is created by rotating image 118 to align the linear chain of features with the image rows and by masking out features not belonging to the linear chain. The final image is passed to a character recognition process 200 to determine whether the features are registration characters and, if so, which characters.

The final image undergoes a standard optical character recognition process 200, as shown in Figure 24, to generate character string data which represents the ICAO characters on the port wing. The process 200 includes receiving the final image at step 202, which is produced by step 132 of the image processing procedure 100, and separating the characters of the image at step 204. The size of the characters are normalised at step 206 and at step 208 correction for the alignment of the characters is made and further normalisation occurs. Character features are extracted at step 210 and an attempt made to classify the features of the characters extracted at step 212. Character rules are applied to the classified features at step 214 so as to produce a binary string representative of the registration characters at step 216.

Although the system 2 has been described above as being one which is particularly suitable for detecting an aircraft, it should be noted that many features of the system can be used for detecting and identifying other moving objects. For example, the embodiments of the tracking system 1 may be used for tracking land vehicles. The system 2 may be employed to acquire images of and identify automobiles at tollway points on a roadway.

Many modifications will be apparent to those skilled in the art without departing from the scope of the present invention as hereinbefore described with reference to the accompanying drawings.

CLAIMS:

1. An object detection system including:

passive sensing means for receiving electromagnetic radiation from a moving object and generating intensity signals representative of the received radiation; and

processing means for subtracting said intensity signals to obtain a differential signature representative of the position of said moving object.

2. An object detection system as claimed in claim 1, wherein said processing means generates an image acquisition signal on the basis of said differential signature.

3. An object detection system as claimed in claim 2, including acquisition means, responsive to said acquisition signal, for acquiring an image of at least part of said moving object; and

analysis means for processing said image to identify said moving object.

4. An object detection system as claimed in claim 3, wherein said analysis system processes said acquired image to extract markings to identify said moving object.

5. An object detection system as claimed in claim 1, 2, 3 or 4, wherein said moving object is an aircraft.

6. An object detection system as claimed in claim 5, wherein said aircraft is in flight.

7. An object detection system as claimed in claim 5, wherein said electromagnetic radiation is thermal radiation.

8. An object detection system as claimed in claim 5, including proximity detecting means for detecting the presence of said aircraft within a predetermined region and, in response thereto, generating an activation signal for said passive sensing means.

9. An object detection system as claimed in claim 1, wherein said passive sensing means includes imaging means for obtaining images of said radiation at successive periods of time, and

said processing means generates respective profiles of pixel values for said images and a difference profile, generated from the difference between successive profiles, which includes said differential signature.

10. An object detection system as claimed in claim 9, wherein said position corresponds to a zero crossing point in said difference profile where said difference profile has risen above a first predetermined threshold for at least a first predetermined distance and then falls to below a second predetermined threshold for a second predetermined distance.

11. An object detection system as claimed in claim 10, wherein said processing means monitors the movement of said position in successive ones of said difference profile and determines the time for generation of an image acquisition signal.

12. An object detection system as claimed in claim 11, wherein said processing means generates a background image from successive images obtained by said imaging means and subtracts said background image from images of said radiation before generating said profiles.

13. An object detection system as claimed in claim 1, wherein said passive sensing means includes pyroelectric sensors with different fields of view and said intensity signals include at least first and second signals representative of the thermal radiation present in said views, respectively, and

said processing means subtracts said first and second signals to obtain a differential signal including said differential signature.

14. An object detection system as claimed in claim 13, wherein said processing means determines a time for generation of an image acquisition signal on the basis of the position of said passive sensing means, the time of generation of said differential signature and the speed of said moving object.

15. An object detection system as claimed in claim 14, wherein said time of generation and said speed are determined from a zero crossing point of said differential signature.

16. An image acquisition system including:

at least one camera for acquiring an image of at least part of a moving object, in response to a trigger signal, and

analysis means for processing said image to locate a region in said image including markings identifying said object and processing said region to extract said markings for a recognition process.

17. An image acquisition system as claimed in claim 16, wherein said camera images received radiation between 0.69 to 2.0 μm.

18. An image acquisition system as claimed in claim 17, wherein said camera has an exposure time of $<$ 240 μs.

19. An image acquisition system as claimed in claim 17, including an infrared flash having its power adjusted on the basis of the aperture setting of said camera.

20. An image acquisition system as claimed in claim 17, including optical sensor means positioned to obtain measurements of ambient direct light and reflected light for the field of view of said camera and adjust settings of said camera on the basis of said measurements.

21. An image acquisition system as claimed in claim 16, wherein said analysis means sub-samples said image, extracts lines exceeding a predetermined length and at predetermined angles, binarises the image, removes features smaller or larger than said markings, removes features not clustered as said markings, and locates said region using the remaining features.

22. An image acquisition system as claimed in claim 21, wherein said analysis means extracts said region from said image and processes said region by removing features larger than expected marking sizes, binarising said region, removing features smaller than expected marking sizes, removing features not clustered as identifying markings, and passing the remaining image for optical recognition if including more than a predetermined number of markings.

23. An image acquisition system as claimed in claim 17, wherein said moving object is an aircraft.

24. An image acquisition system as claimed in claim 23, wherein said aircraft is in flight.

25. An object detection system as claimed in claim 2, including an image acquisition system as claimed in any one of claims 16 to 24, wherein said trigger signal is said image acquisition signal.

26. An object detection method including:

passively sensing electromagnetic radiation received from a moving object;

generating intensity signals representative of the received radiation; and

subtracting said intensity signals to obtain a differential signature representative of the position of said moving object.

27. An object detection method as claimed in claim 26, including generating an image acquisition signal on the basis of said differential signature.

28. An object detection method as claimed in claim 27, including acquiring an image of at least part of said moving object in response to said acquisition signal; and

processing said image to identify said moving object.

29. An object detection method as claimed in claim 28, including processing said acquired image to extract markings identifying said moving object.

30. An object detection method as claimed in claim 26, 27, 28 or 29, wherein said moving object is an aircraft.

31. An object detection method as claimed in claim 30, wherein said aircraft is in flight.

32. An object detection method as claimed in claim 30, wherein said electromagnetic radiation is thermal radiation.

33. An object detection method as claimed in claim 30, including detecting the presence of said aircraft within a predetermined region and, in response thereto, generating an activation signal to execute said passive sensing step.

34. An object detection method as claimed in claim 26, wherein said passive sensing includes imaging said radiation at successive periods of time, and

said subtracting includes generating respective profiles of pixel values for images of said radiation and generating a difference profile, from the difference between successive profiles, which includes said differential signature.

35. An object detection method as claimed in claim 34, wherein said position corresponds to a zero crossing point in said difference profile where said difference profile has risen above a first predetermined threshold for at least a first predetermined distance and then falls to below a second predetermined threshold for a second predetermined distance.

36. An object detection method as claimed in claim 35, including monitoring the movement of said position in successive ones of said difference profile and determining the time for generation of an image acquisition signal.

37. An object detection method as claimed in claim 36, wherein said subtracting includes generating a background image from successive images of said radiation imaging means and subtracting said background image from images of said radiation before generating said profiles.

38. An object detection method as claimed in claim 26, wherein said passive sensing includes pyroelectric sensing with different fields of view and said intensity signals include at least first and second signals representative of the thermal radiation present in said views, respectively, and

said subtracting includes subtracting said first and second signals to obtain a differential signal including said differential signature.

39. An object detection method as claimed in claim 38, including determining a time for generation of an image acquisition signal on the basis of the position of passive sensors, the time of generation of said differential signature and the speed of said moving object.

40. An object detection method as claimed in claim 39, wherein said time of generation and speed are determined from a zero crossing point of said differential signature.

41. An image acquisition method including:

acquiring an image of at least part of a moving object, in response to a trigger signal, using at least one camera, and

processing said image to locate a region in said image including markings identifying said object and processing said region to extract said markings for a recognition process.

42. An image acquisition method as claimed in claim 41, wherein said camera images received radiation between 0.69 to 2.0 μm.

43. An image acquisition method as claimed in claim 42, wherein said camera has an exposure time of < 240 μs.

44. An image acquisition method as claimed in claim 42, including adjusting the power of an infrared flash for said camera on the basis of the aperture setting of said camera.

45. An image acquisition method as claimed in claim 42, including obtaining automatic measurements of ambient direct light and reflected light for the field of view of said camera and adjusting settings of said camera on the basis of said measurements.

46. An image acquisition method as claimed in claim 41, wherein said image processing includes sub-sampling said image, extracting lines exceeding a predetermined length and at predetermined angles, binarising the image, removing features smaller or larger than said markings, removing features not clustered as said markings, and locating said region using the remaining features.

47. An image acquisition method as claimed in claim 46, wherein said region processing includes extracting said region from said image, removing features larger than expected marking sizes, binarising said region, removing features with areas smaller or larger than expected marking areas, removing features not clusterec as identifying markings, and passing the remaining image for optical recognition if including more than a predetermined number of markings.

48. An image acquisition method as claimed in claim 42, wherein said moving object is an aircraft.

49. An image acquisition method as claimed in claim 48, wherein said aircraft is in flight.

50. An object detection method as claimed in claim 27, including an image acquisition method as claimed in any one of claims 41 to 49, wherein said trigger signal is said image acquisition signal.

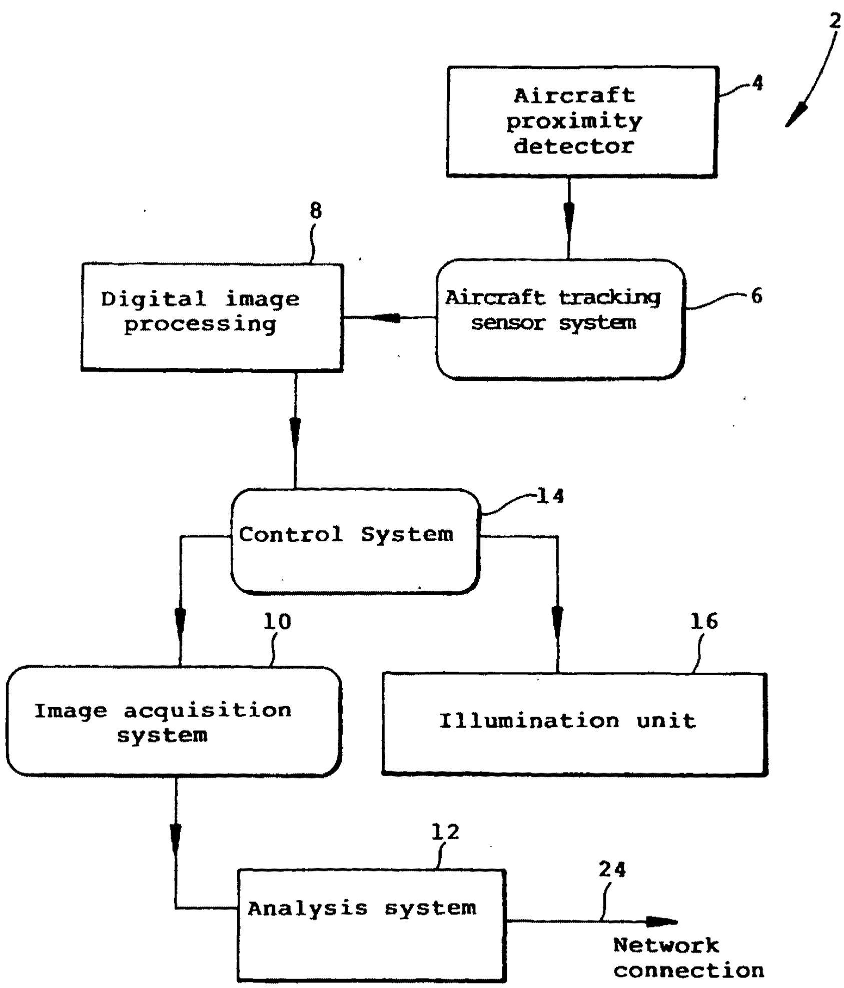

2
Aircraft proximity detector
4
8
Digital image processing
Aircraft tracking sensor system
6
Control System
14
10
16
Image acquisition system
Illumination unit
12
24
Analysis system
Network connection

FIGURE 1

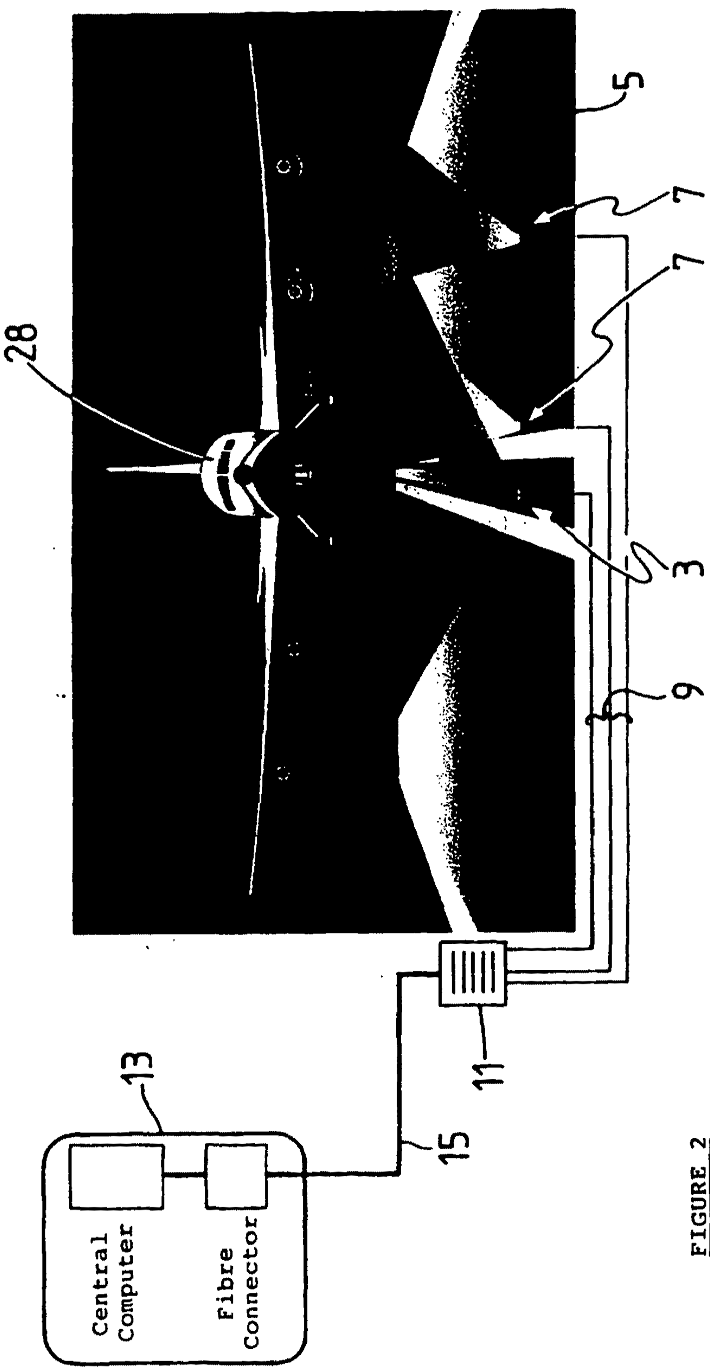


FIGURE 2

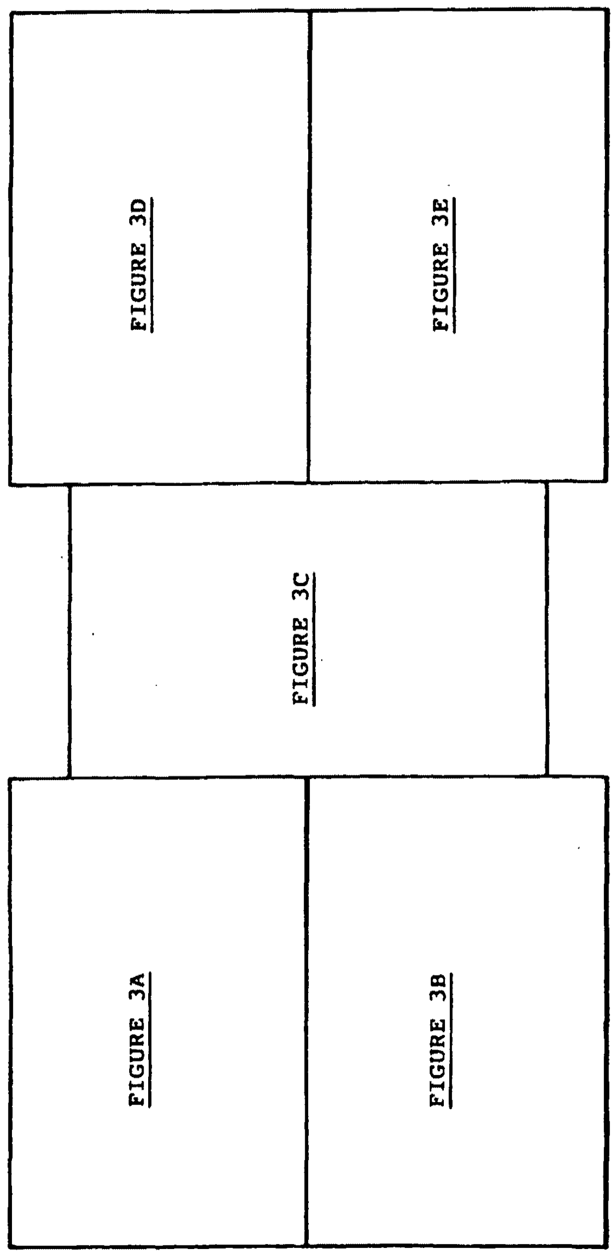


FIGURE 3

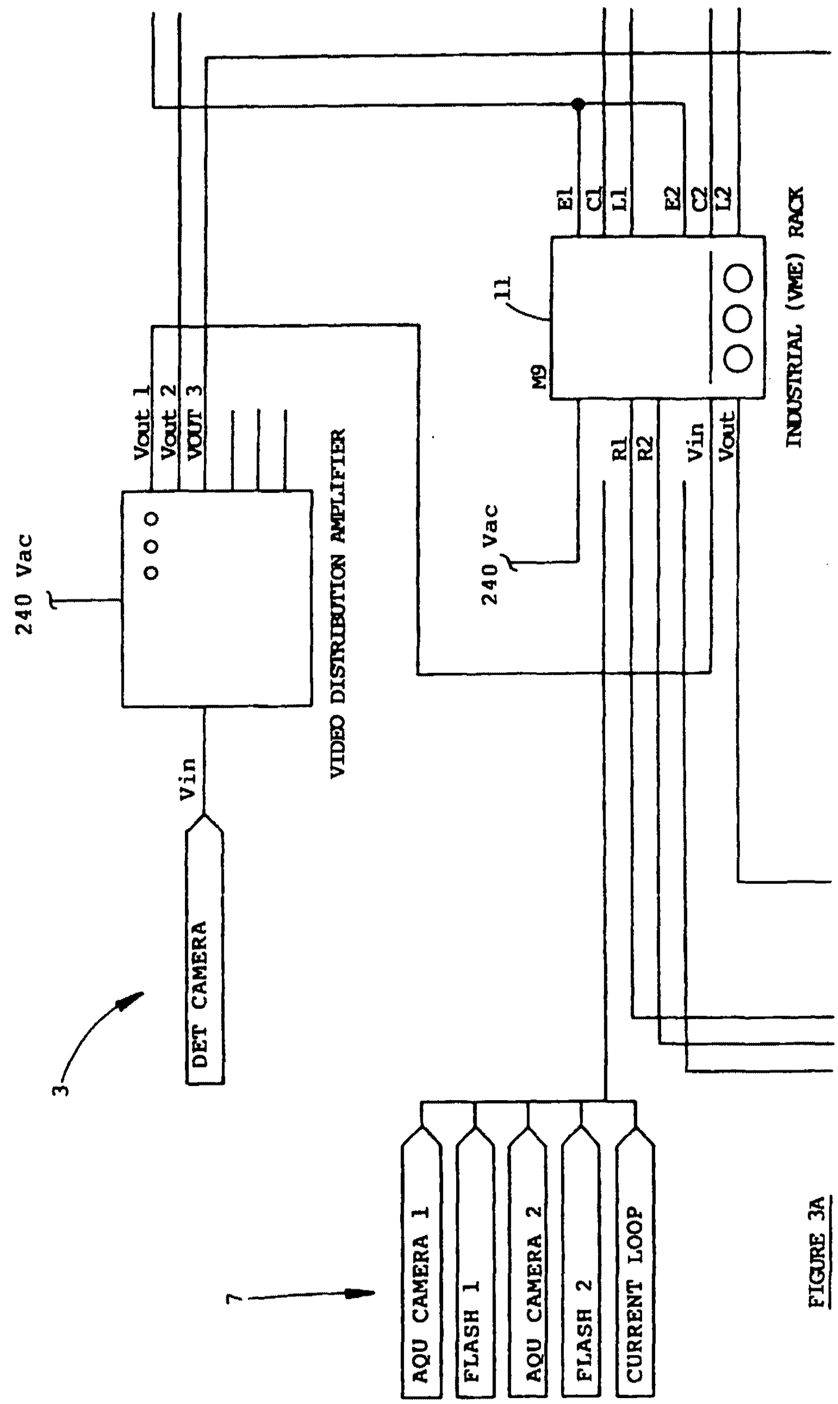

Vout 1
Vout 2
VOUT 3
240 Vac
VIDEO DISTRIBUTION AMPLIFIER
Vin
DET CAMERA
3
E1
C1
L1
E2
C2
L2
11
M9
INDUSTRIAL (VME) RACK
R1
R2
Vin
Vout
240 Vac
7
AQU CAMERA 1
FLASH 1
AQU CAMERA 2
FLASH 2
CURRENT LOOP

FIGURE 3A

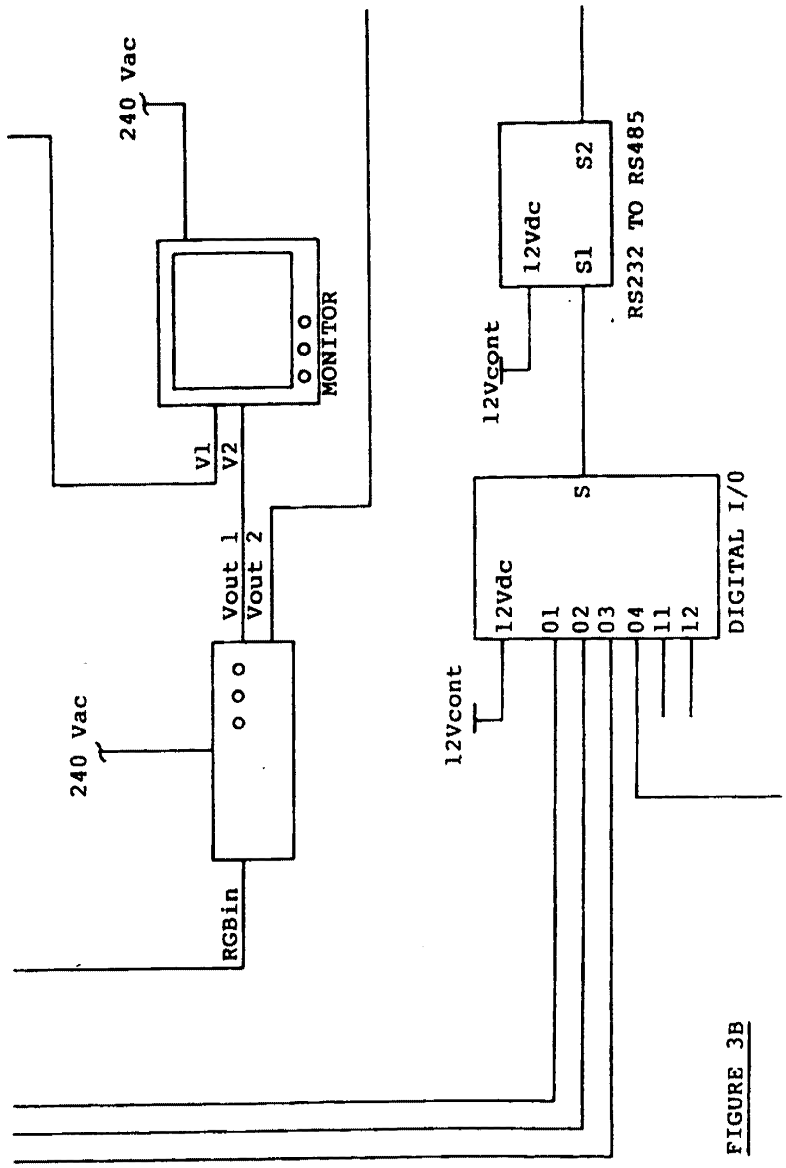
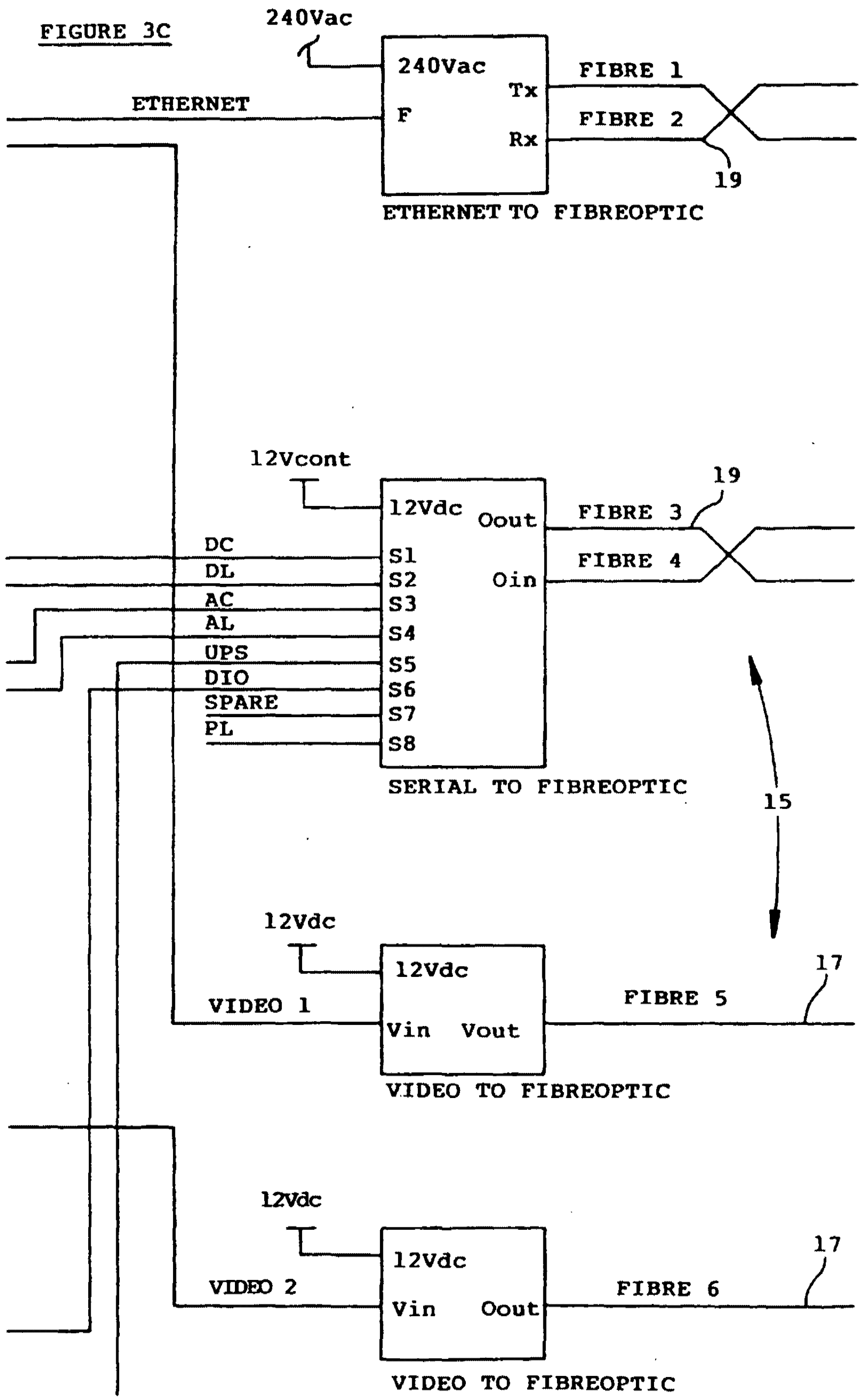

240 Vac
MONITOR
V1
V2
Vout 1
Vout 2
240 Vac
RGBin
12Vdc
S1
S2
RS232 TO RS485
12Vcont
S
12Vdc
01
02
03
04
11
12
DIGITAL I/O
12Vcont

FIGURE 3B

FIGURE 3C


240Vac
240Vac
ETHERNET
F
Tx
Rx
FIBRE 1
FIBRE 2
19
ETHERNET TO FIBREOPTIC
12Vcont
12Vdc
Oout
Oin
FIBRE 3
FIBRE 4
19
DC
DL
AC
AL
UPS
DIO
SPARE
PL
S1
S2
S3
S4
S5
S6
S7
S8
SERIAL TO FIBREOPTIC
15
12Vdc
12Vdc
VIDEO 1
Vin
Vout
FIBRE 5
17
VIDEO TO FIBREOPTIC
12Vdc
12Vdc
VIDEO 2
Vin
Oout
FIBRE 6
17
VIDEO TO FIBREOPTIC

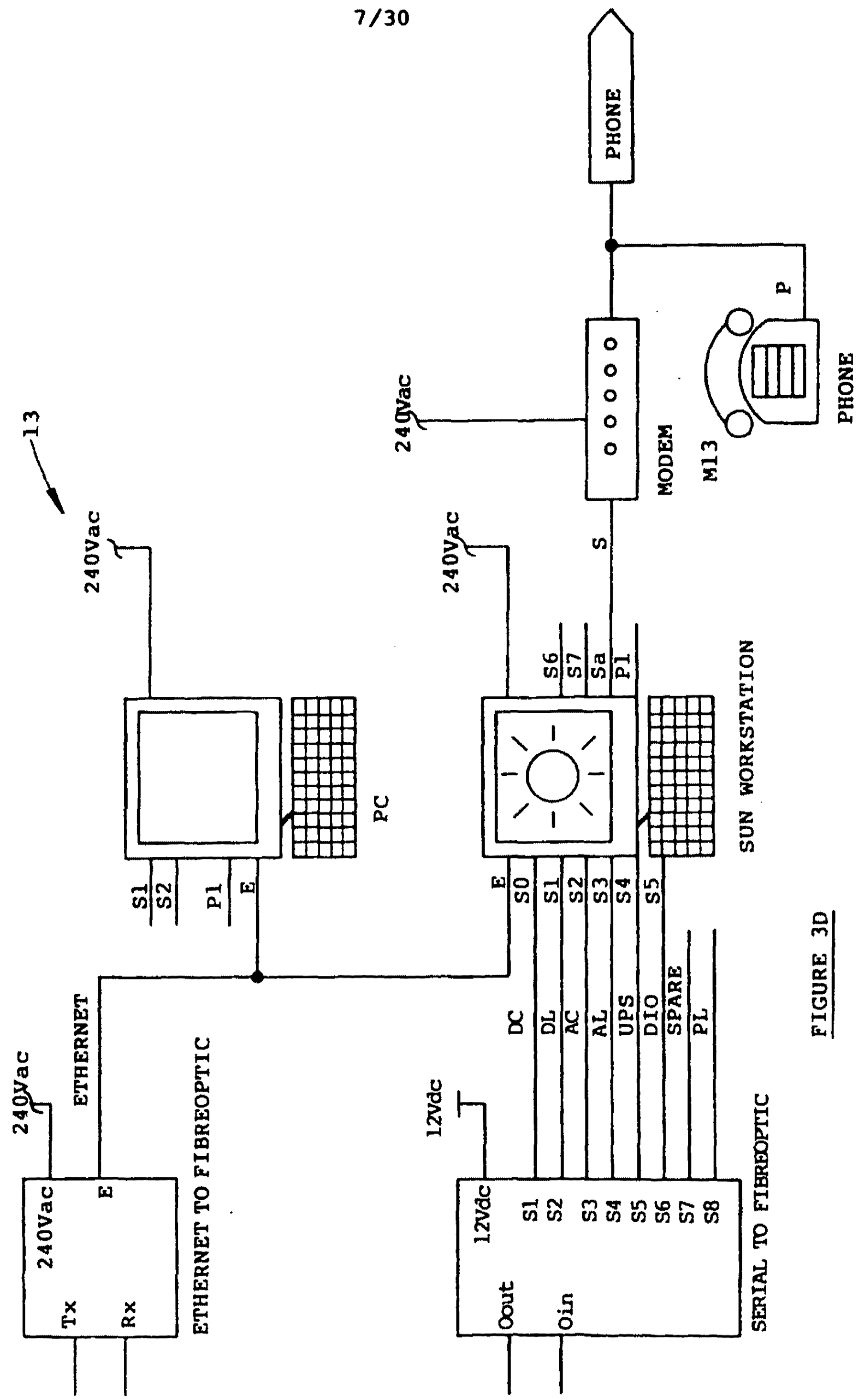

13
240Vac
PC
S1
S2
P1
E
240Vac
ETHERNET
240Vac
E
Tx
Rx
ETHERNET TO FIBREOPTIC
240Vac
SUN WORKSTATION
S6
S7
Sa
P1
E
S0
S1
S2
S3
S4
S5
S
240Vac
MODEM
M13
PHONE
P
PHONE
DC
DL
AC
AL
UPS
DIO
SPARE
PL
12Vdc
12Vdc
S1
S2
S3
S4
S5
S6
S7
S8
Oout
Oin
SERIAL TO FIBREOPTIC

FIGURE 3D

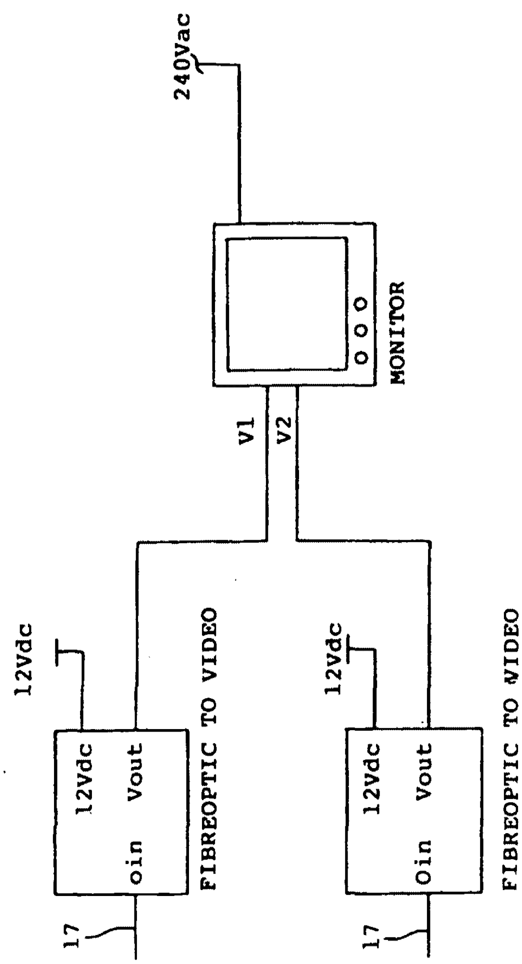

240Vac
MONITOR
V1
V2
12Vdc
12Vdc
Vout
oin
FIBREOPTIC TO VIDEO
17
12Vdc
12Vdc
Vout
oin
FIBREOPTIC TO VIDEO
17

FIGURE 3E

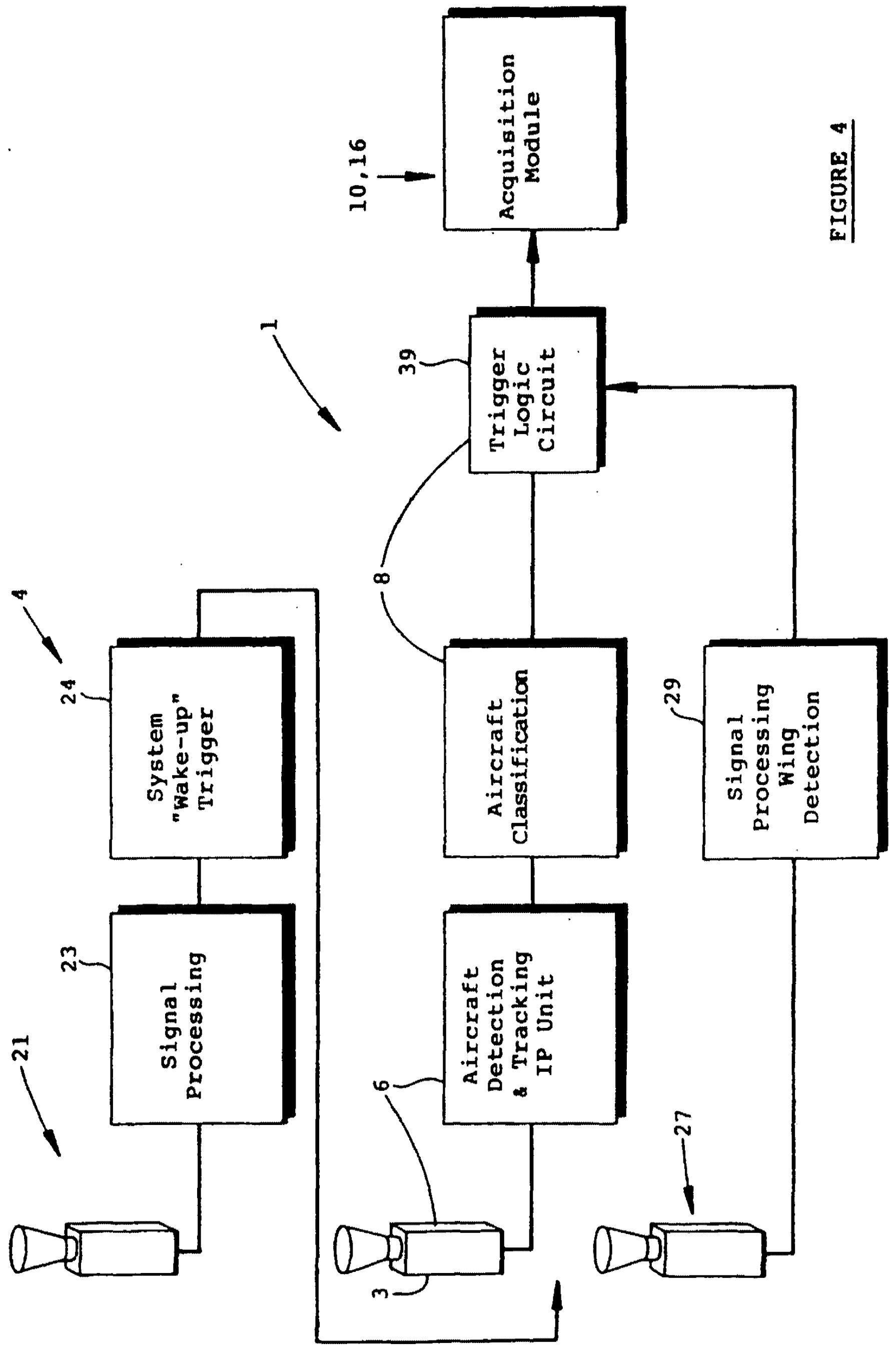

Acquisition Module
10,16
Trigger Logic Circuit
39
1
8
System "Wake-up" Trigger
24
4
Aircraft Classification
Signal Processing Wing Detection
29
Signal Processing
23
21
Aircraft Detection & Tracking IP Unit
6
27
3

FIGURE 4

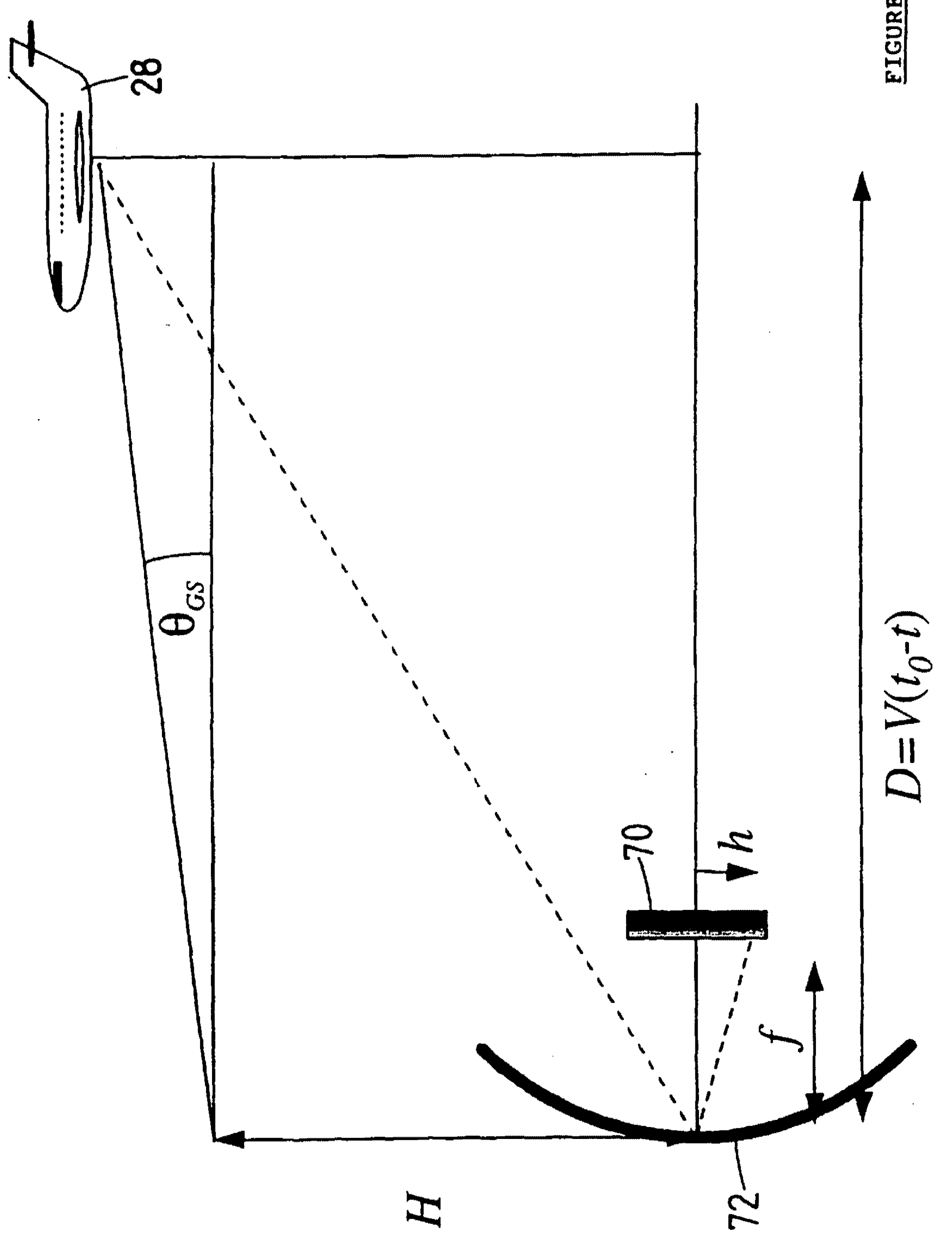


FIGURE 5

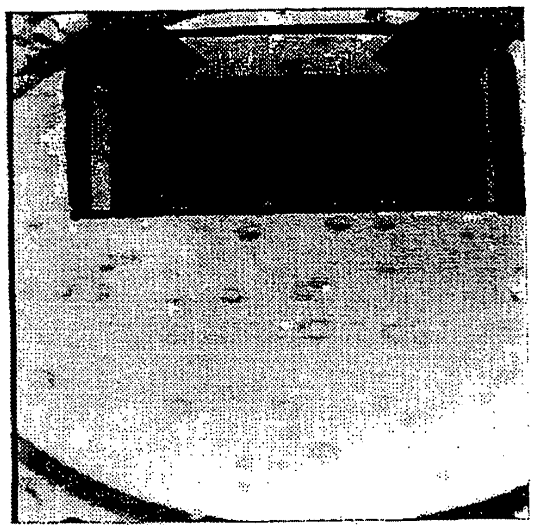


Figure 6a

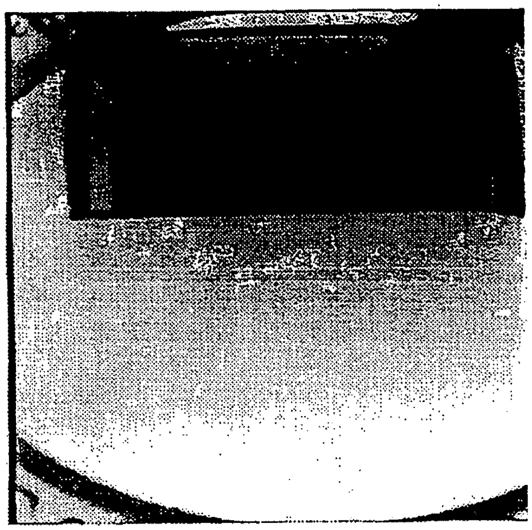


Figure 6b

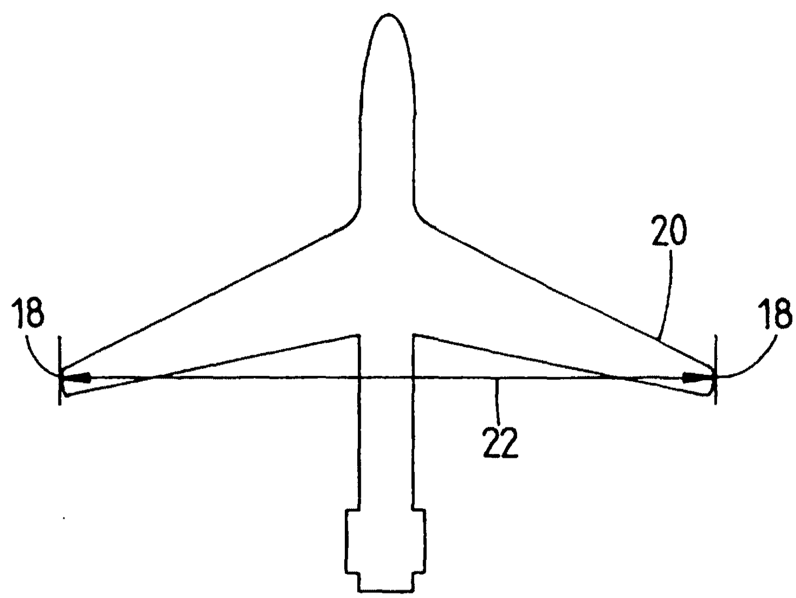


FIGURE 7

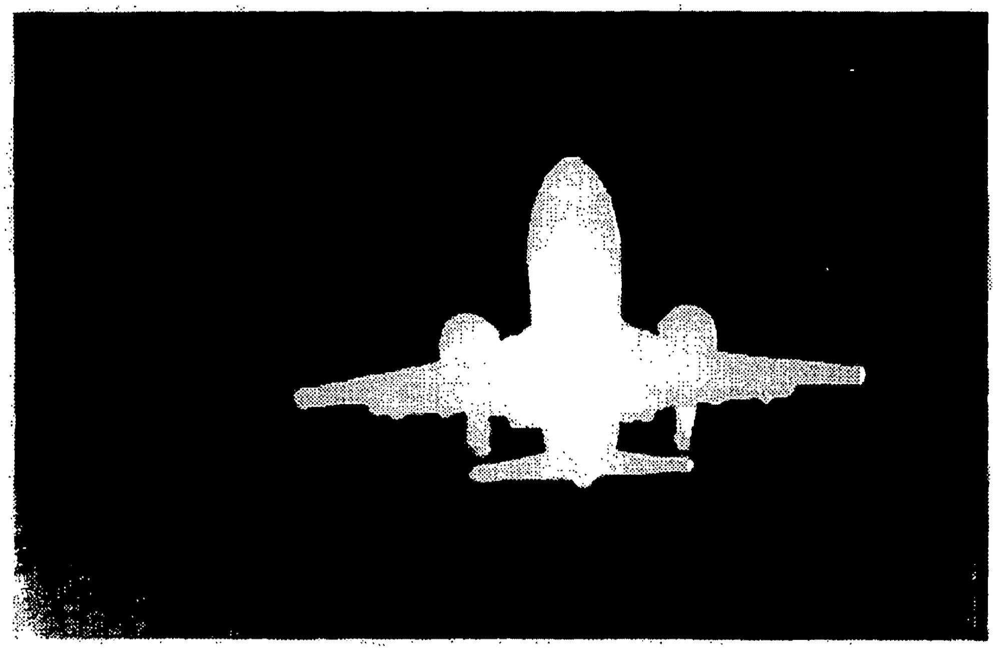


Figure 8

SUBSTITUTE SHEET (RULE 26)

Figure 9

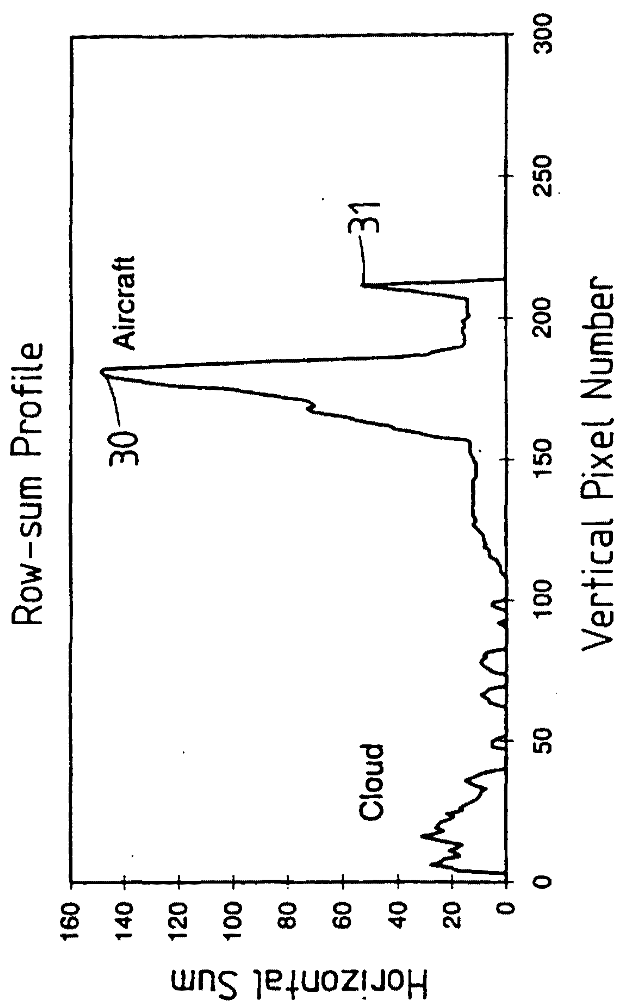

Row-sum Profile
Aircraft
Cloud
30
31
Vertical Pixel Number
Horizontal Sum
0
50
100
150
200
250
300
0
20
40
60
80
100
120
140
160

FIGURE 10

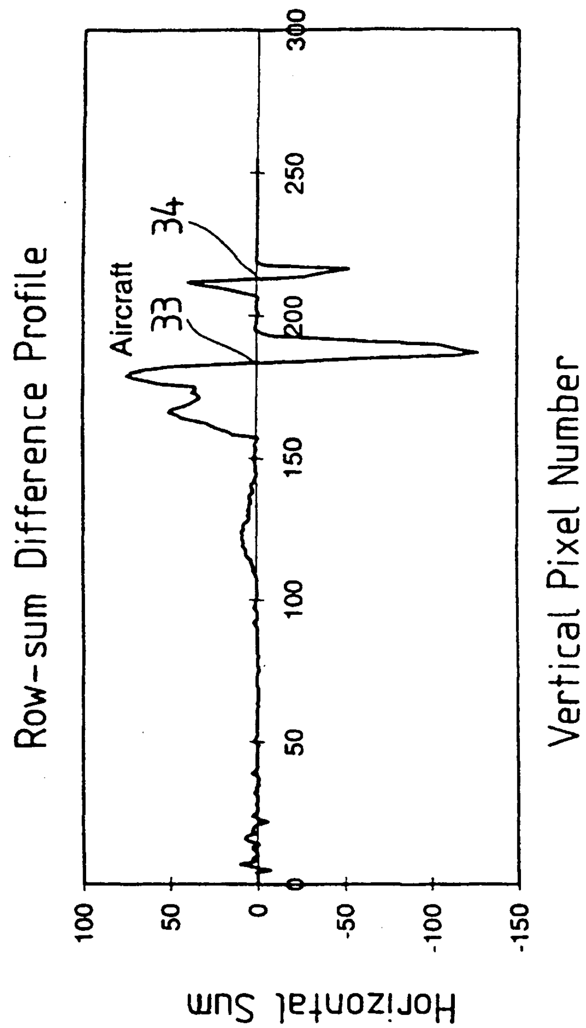

Row-sum Difference Profile
Aircraft
33
34
Horizontal Sum
Vertical Pixel Number
100
50
0
-50
-100
-150
0
50
100
150
200
250
300

FIGURE 11

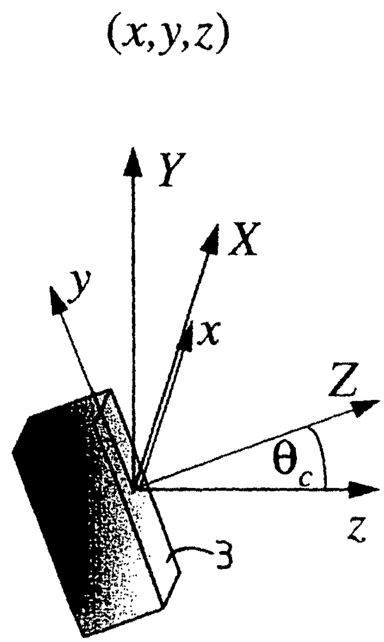


FIGURE 12

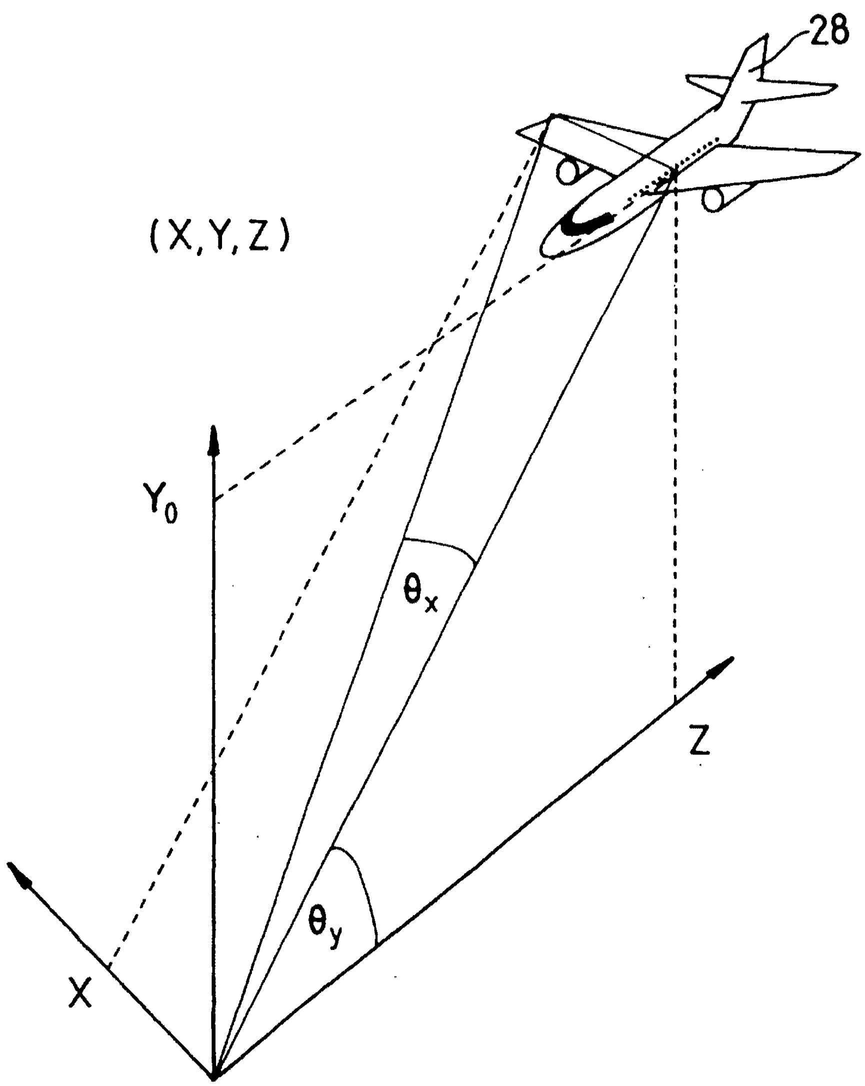


FIGURE 13

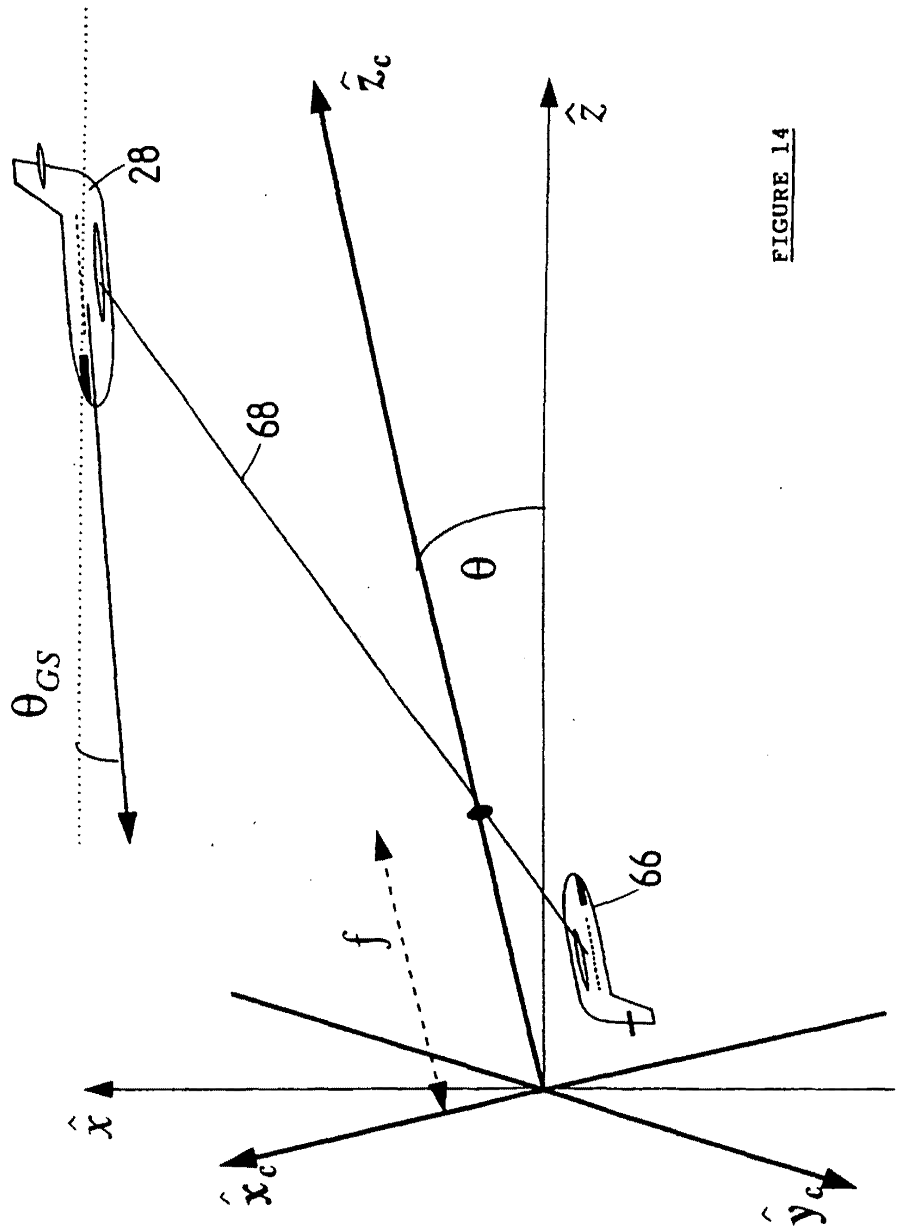


FIGURE 14

FIGURE 15

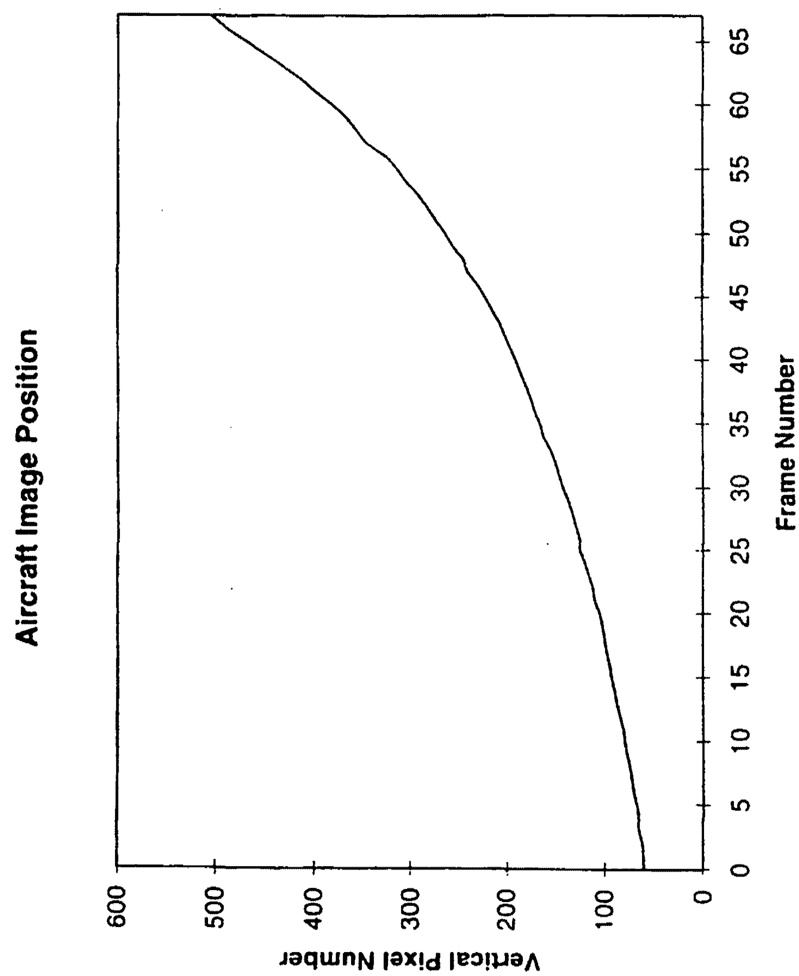
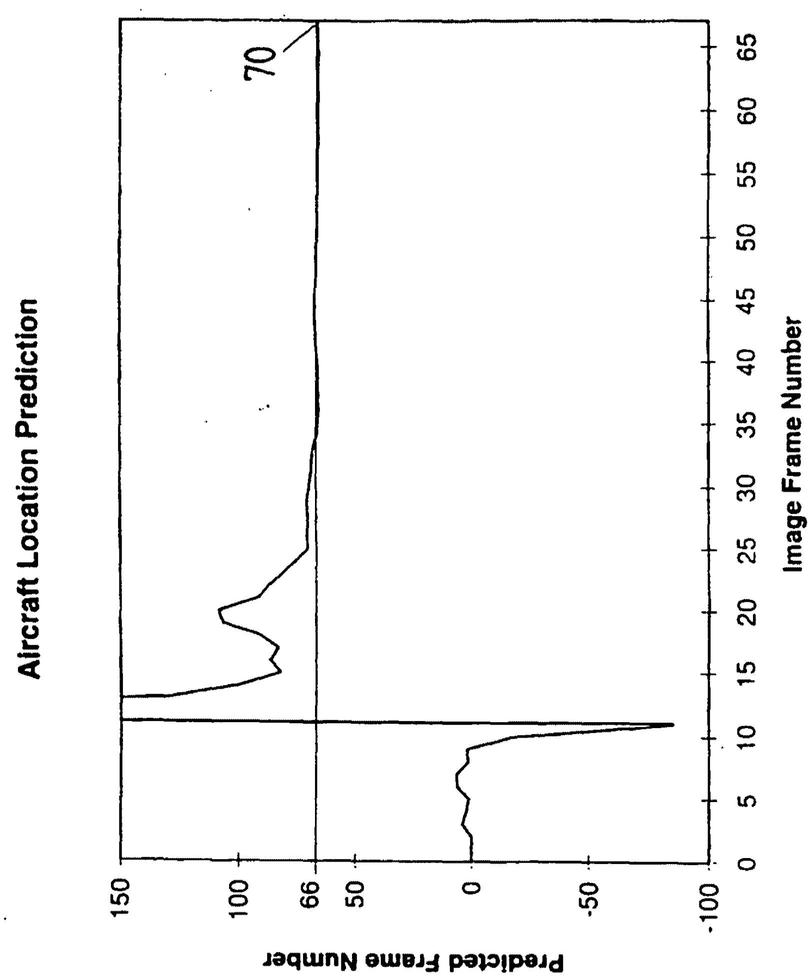

Aircraft Image Position
Vertical Pixel Number
600
500
400
300
200
100
0
Frame Number
0
5
10
15
20
25
30
35
40
45
50
55
60
65

FIGURE 16


Aircraft Location Prediction
Predicted Frame Number
Image Frame Number
150
100
66
50
0
-50
-100
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70

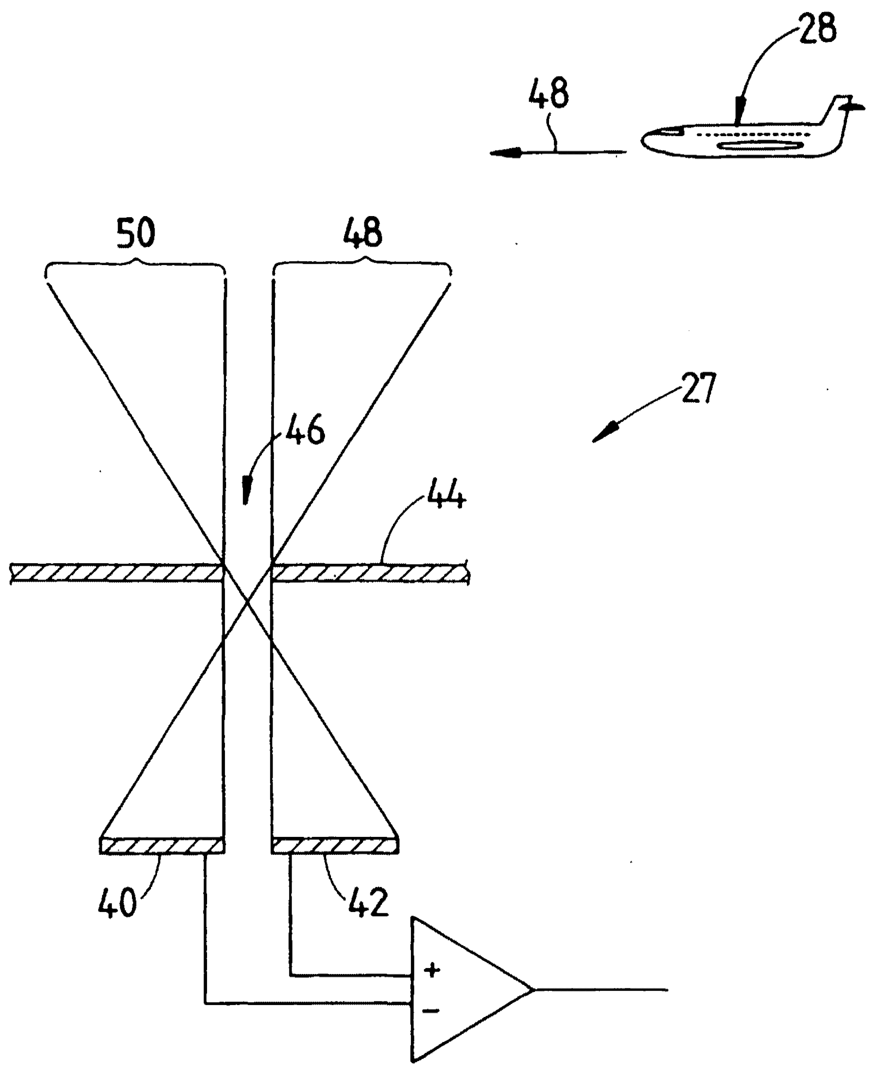


FIGURE 17

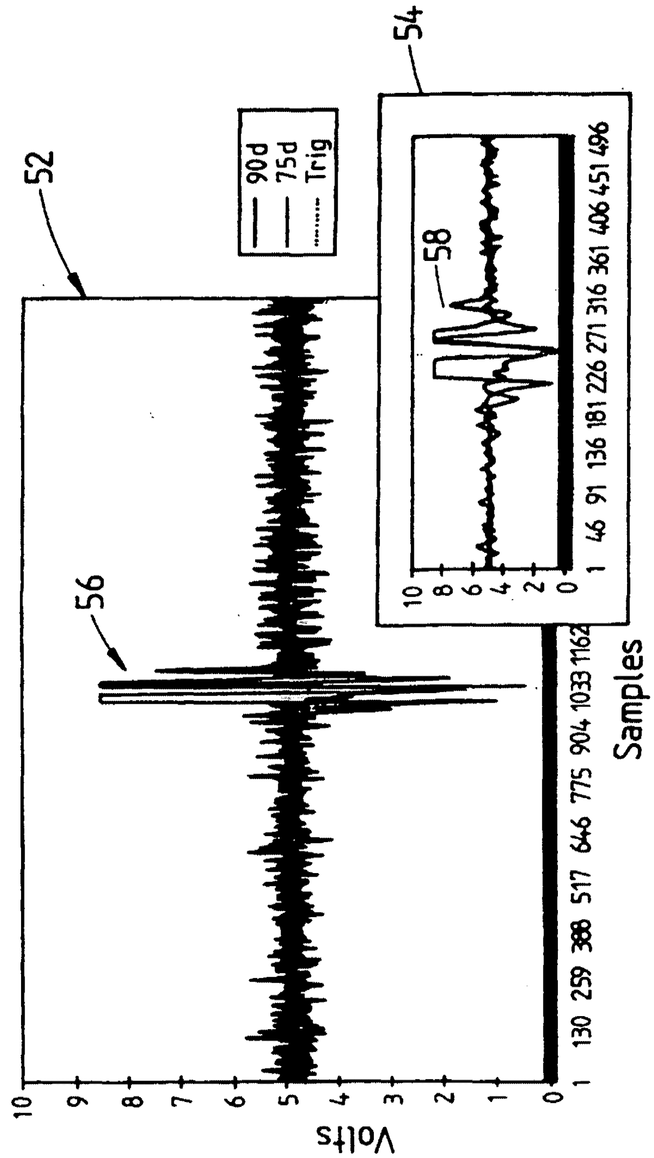

52
54
56
58
90d
75d
Trig
Volts
Samples
0 1 2 3 4 5 6 7 8 9 10
1 130 259 388 517 646 775 904 1033 1162
0 2 4 6 8 10
1 46 91 136 181 226 271 316 361 406 451 496

FIGURE 18

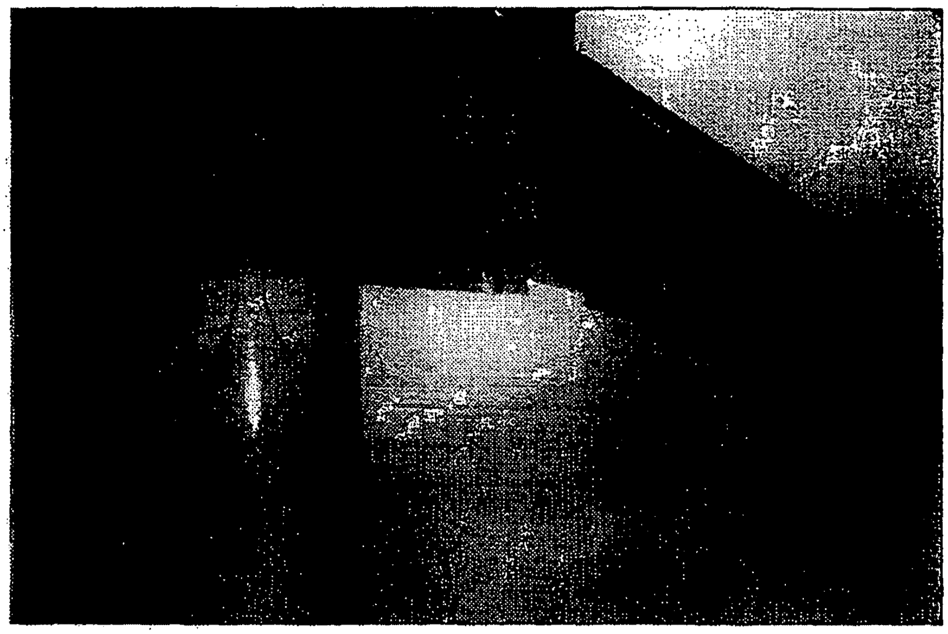


Figure 19

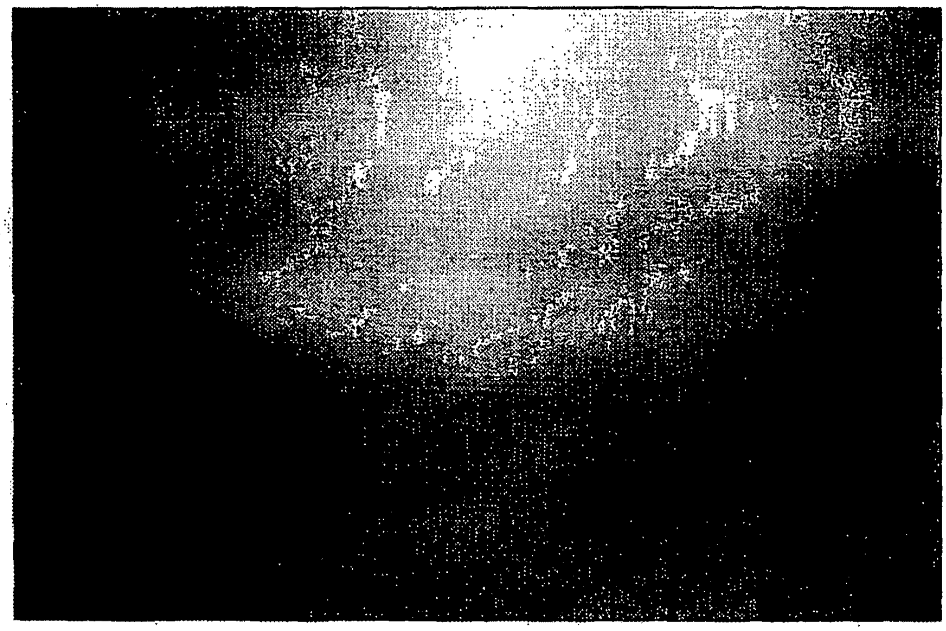


Figure 20

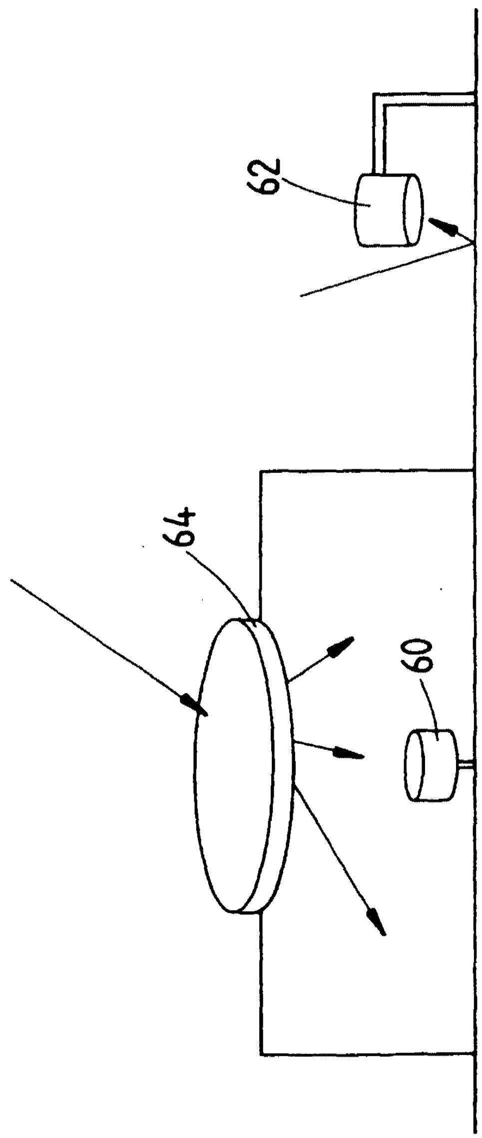


FIGURE 21

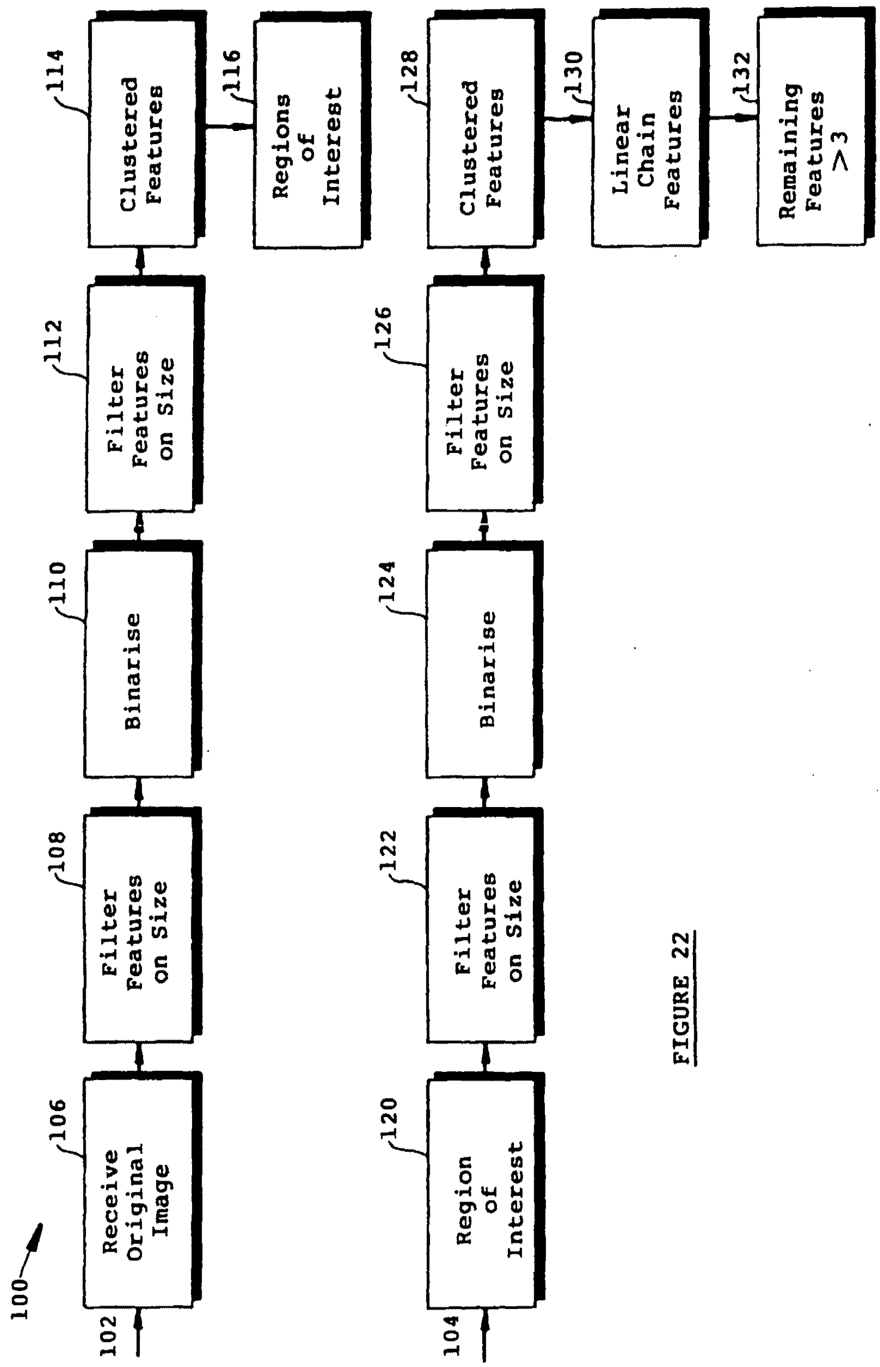
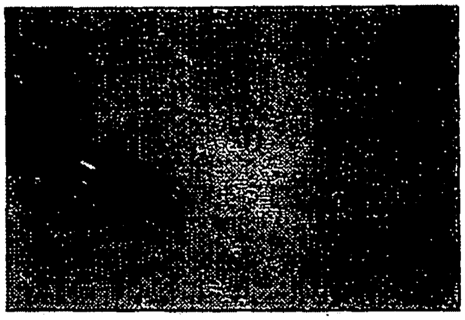
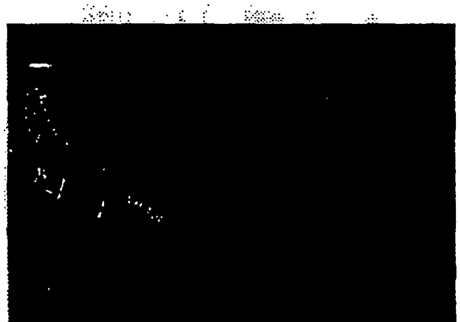

100
102
106
Receive Original Image
108
Filter Features on Size
110
Binarise
112
Filter Features on Size
114
Clustered Features
116
Regions of Interest
104
120
Region of Interest
122
Filter Features on Size
124
Binarise
126
Filter Features on Size
128
Clustered Features
130
Linear Chain Features
132
Remaining Features > 3

FIGURE 22

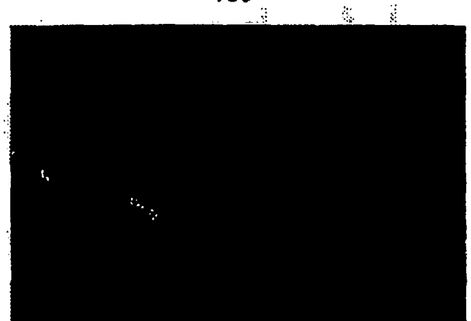


105

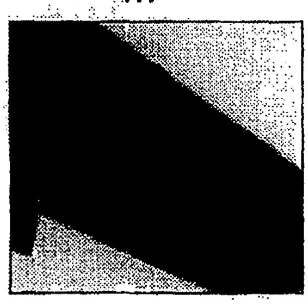
109



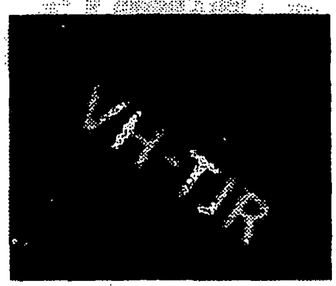
111



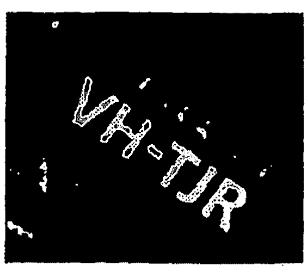
113



115



117



118

Figure 23

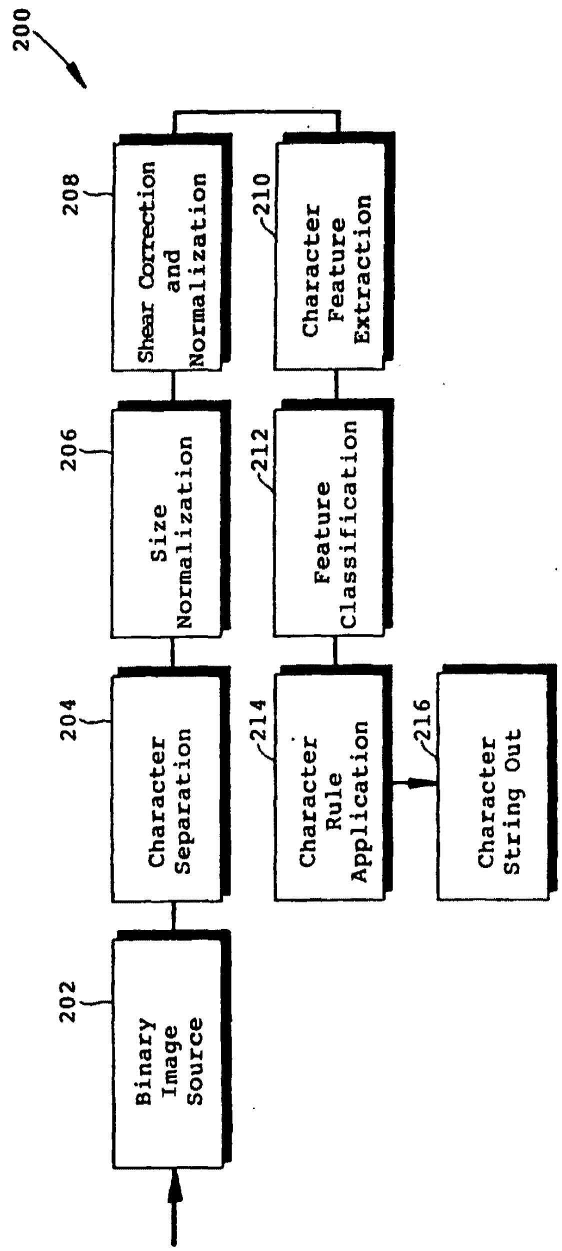

200
Binary Image Source
202
Character Separation
204
Size Normalization
206
Shear Correction and Normalization
208
Character Feature Extraction
210
Feature Classification
212
Character Rule Application
214
Character String Out
216

FIGURE 24

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 97/00198

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl^{6}: G08G 5/00, G01P 3/38, G06T 7/20, G06K 9/78, 9/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC as above

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT, INSC (IMAG:; OBJECT:; DETECT:; POSITION:; MARK, ID:)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 686943- A2 (Matsushita Electric Industrial Co. Ltd.) 13 December 1995, whole document	1, 26, 9, 34
X	US 5,406,501 (U.S. Philips Corp.) 11 April 1995, whole document	1, 7, 9, 32, 34
X	WO 93/19441 (Commonwealth Scientific and Industrial Research Organisation) 30 September 1993 whole document	1-4, 16, 17, 19, 20 26-29, 41, 42, 44, 45

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 May 1997	21 MAY 1997

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (06) 285 3929	**Dale Siver** Telephone No.: (06) 283 2196

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 97/00198

C (Continuation)	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5,243,418 (K.K. Toshiba, Kawasaki) 7 September 1993, whole document	1, 26, 9, 34 10, 35
X Y	AU-35311/93-B (Iconix Pty Ltd) 8 July 1993, whole document especially page 21, lines 11-26	16, 41 21, 46
X	US 5, 134, 472 (K.K. Toshiba) 28 July 1992, whole document	1, 9, 26, 34
X Y	GB 2,227,589 A (Image Recognition Equipment Corp.) 1 August 1990 Abstract, Summary pages 1-4, Figures	16, 41 21, 46
X	WO 90/01706 (Hughes Aircraft Co.) 22 February 1990, whole document	1, 5, 6, 9, 10, 26, 30, 31, 34, 35
Y	WO 93/21617 (Traffic Technology Ltd.) 28 October 1993, whole document	1, 2, 26, 27
A	WO 96/12265 (Airport Technology in Scandinavia) 25 April 1996, Abstract Figures	5, 23, 26, 48

International Application No.
PCT/AU 97/00198

Box 1 Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. An object detection system using passive sensor to obtain a differential signature representative of the position of moving object. (No image acquisition or analysis.) Claims 1, 5-10, 26, 34, 35, 38.

2. An image acquisition system and analysis system to locate a region in an image including markings identifying said object and processing said region to extract said markings for recognition. (No position or movement detection.) Claims 16-22, 41-47.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/AU 97/00198

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
EP	686943	CA	2151079	JP	7336694	US	5606376
US	5406501	EP	492724	FR	2670978	JP	4307681
WO	9319441	AU	37402/93	EP	631683	JP	7505966
		NZ	249799				
US	5243418	JP	4192781	JP	5046771		
AU	35311/93	AU	37398/93	WO	9319429		
US	5134472	JP	2207381	JP	2214989		
GB	2227589	FR	2642542	JP	2282881	US	4958064
WO	9001706	AU	44005/89	CA	1313704	DE	68910498
		EP	380658	ES	2016049	IL	90898
		JP	3502018	NO	901560	TR	25266
		US	4937878				
WO	9321617	AU	39599/93	GB	2266398		
WO	9612265	AU	11251/95				

END OF ANNEX

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 232 031**
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 87300392.5

(22) Date of filing: 16.01.87

(51) Int. Cl.4: **G 08 B 13/18**

(30) Priority: 03.02.86 GB 8602575

(43) Date of publication of application:
12.08.87 Bulletin 87/33

(84) Designated Contracting States:
AT BE CH DE ES FR GR IT LI LU NL SE

(71) Applicant: SAYZEN LIMITED
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Southfields London SW18 5BQ (GB)

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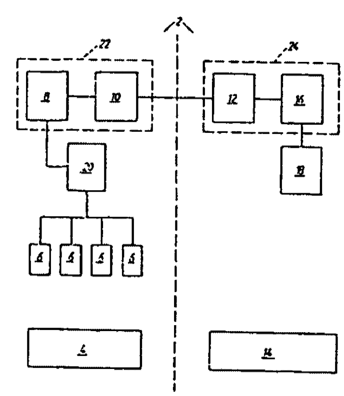
53 Brookwood Road
Southfields London, SW18 5BQ (GB)

(74) Representative: Jones, Graham H.
Graham Jones & Company 77 Beaconsfield Road
Blackheath
London SE3 7LG (GB)

(54) An aircraft surveillance system.

(57) An aircraft surveillance system (2) comprising an aircraft (4), at least one closed circuit slow scan television camera (6) which is positioned in the aircraft (4) and which is for surveying a predetermined area, first transducer means (8) which is positioned in the aircraft (4) and which is for converting video signals from the camera (6) into audio signals, first transceiver means (10) which is positioned in the aircraft (4) and which is for transmitting the audio signals from the first transducer means (8) and for receiving command signals, second transceiver means (12) which is positioned in a command base (14) remote from the aircraft (4) and which is for receiving the audio signals from the first transceiver means (10) and for sending the command signals, second transducer means (16) which is positioned in the command base (14) and which is for converting the audio signals received from the second transceiver means (12) into video signals, and at least one television monitor (18) for providing a visual display consequent upon receiving the video signals from the second transducer means (16).



EP 0 232 031 A2

Description

AN AIRCRAFT SURVEILLANCE SYSTEM

This invention relates to an aircraft surveillance system.

It is an aim of the present invention to provide an aircraft surveillance system which can be used to survey the inside of an aircraft during an emergency such for example as a hijack or which can be used to survey land or objects outside the aircraft such for example as a border sheltering terrorists.

Accordingly, this invention provides an aircraft surveillance system comprising an aircraft, at least one closed circuit slow scan television camera which is positioned in the aircraft and which is for surveying a predetermined area, first transducer means which is positioned in the aircraft and which is for converting video signals from the camera into audio signals, first transceiver means which is positioned in the aircraft and which is for transmitting the audio signals from the first transducer means and for receiving command signals, second transceiver means which is positioned in a command base remote from the aircraft and which is for receiving the audio signals from the first transceiver means and for sending the command signals, second transducer means which is positioned in the command base and which is for converting the audio signals received by the second transceiver means into video signals, and at least one television monitor for providing a visual display consequent upon receiving the video signals from the second transducer means.

The aircraft surveillance system of the invention is especially useful for surveying the inside of an aircraft during a hijack. When a hijack occurs, the hijackers invariably inform ground control that they have hijacked the aircraft and, with the surveillance system of the present invention, it is only necessary for the ground control to issue an appropriate command signal to cause the camera to operate and to cause pictures of the hijack to be transmitted back to a television monitor in ground control. The transmitted pictures can be enlarged as may be desired, for example to ascertain the identity of a hijacker and/or whether or not the hijacker has a real gun, grenade or the like or whether the gun, grenade or the like is an imitation device. It will thus be apparent, that by the time the aircraft is forced to land at its destination determined by the hijacker, ground control will be in a good position to know exactly what action to take.

The aircraft surveillance system of the invention is also of a special use for surveying land. In this case, the aircraft will usually be a slow flying aircraft such for example as a helicopter, as opposed to a passenger flying aircraft. Pictures of the land can be relayed to a command base and the pictures may help to establish the position of terrorists, escaped prisoners or the like on the land.

The pictures can be displayed as black and white or colour pictures.

The command base will usually be a ground command base but, if desired, the command base could be in another aircraft, a ship or a vehicle.

The command signals will usually be start-up signals for initiating operation of the aircraft surveillance system. However, if desired, the start-up signals may be other signals for actuating the commencement of other desired functions.

The first and the second transceiver means may be substantially identical pieces of equipment.

The first transducer means will usually convert the video signals from the camera to audio signals on cassette tape. The audio signals will usually be transmitted from the aircraft to the command base as radio signals. For example, the audio signals may be transmitted on normal aircraft radio frequencies such for example as the aircraft Mayday frequency.

Advantageously, the first transducer means and the first transceiver means are housed together in a single piece of equipment. Similarly, the second transducer means and the second transceiver means are also advantageously housed together in a single piece of equipment. Such single pieces of equipment can be arranged to be mobile or static.

The transducer means and the transceiver means are advantageously in the form of a single piece of equipment known as IBSONSCAN II. The IBSONSCAN II is manufactured and sold by Ibsonmain Limited, of Uxbridge, Middlesex, England. Other equipment can of course by used if desired.

Preferably, the first and the second transceiver means record on to tape so that they have a playback facility for helping repeated surveillance of an area or an object in that area.

Usually, the first and the second transceiver means will have a rewind facility.

Any appropriate camera may be employed. Examples of cameras that may be employed are those manufactured by Ademco,Philips and Norbane. The cameras may be positioned where desired and appropriate in the aircraft. For example, for a passenger aircraft there will usually be one camera positioned in the cockpit together with a number of other cameras positioned in the passenger, accommodation of the aircraft, the actual number of cameras employed being dependent upon the size of the passenger accommodation. For a jumbo jet, it is envisaged that at least four cameras will be required for the passenger accommodation, whilst it is envisaged that a minimum of two cameras will be required for the passenger accommodation of a Boeing 737 or a Boeing 757.

The cameras will usually be connected to the aircraft TPU power circuit to ensure that the power to the cameras cannot easily be switched off. Indeed, it is desirable that the entire aircraft surveillance system is such that it cannot by switched on or off or otherwise generally interferred with by aircraft personnel so that, in the event that the hijackers should know that they are being filmed, they cannot instruct the aircraft personnel to switch off the aircraft surveillance system.

The cameras can be positioned at random

positions in the same type of aircraft if desired in order that hijackers cannot easilly know the location of the cameras. The cameras can also be concealed where possible, for example in overhead compartments, again so that their presence cannot easily be established.

Preferably, the aircraft surveillance system is such that the TV monitor has a picture hold facility.

The aircraft surveillance system may be one which has a visual display facility only, the signals passing from the aircraft to the command base then being signals which are only for permitting the visual display. Alternatively, the aircraft surveillance system may be one which has a visual display facility and also a speech facility, the signals passing from the aircraft to the command base then being first signals which permit the visual display and second signals which permit the speech.

An embodiment of the invention will now be described solely by way of example and with reference to the accompanying drawing which shows in diagrammatic form an aircraft surveillance system.

Referring to the drawing, there is shown an aircraft surveillance system 2 comprising an aircraft 4 and four closed circuit slow scan television cameras 6 which are positioned in the aircraft 4 and which are for surveying predetermined areas in the aircraft 4 such for example as the cockpit area and the passenger areas. One camera 6 will be employed for surveying each predetermined area.

The aircraft surveillance system 2 also comprises first transducer means 8 which is positioned in the aircraft 4 and which is for converting video signals from the cameras 6 into audio signals. First transceiver means 10 is positioned in the aircraft 4 and is for transmitting the audio signals from the first transducer means 8 and for receiving command signals.

The aircraft surveillance system 2 also comprises second transceiver means 12 which is positioned in a command base 14 remote from the aircraft 4 and which is for receiving audio signals from the first transceiver means 10 and for sending the command signals. The command base 14 is also provided with second transducer means 16 which is for converting the audio signals received by the second transceiver means 12 into video signals. A television monitor 18 is linked to the second transducer means 16 for providing a visual display consequent upon receiving the video signals from the second transducer means 16.

The cameras 6 are controlled by a control device 20 which is activated by receiving appropriate control signals from the first transducer means 8. The control device 20 can be used to make the cameras 6 pan, tilt, zoom or perform other functions. The control device 20 can also be used to activate lights or perform other control functions.

The first transducer means 8 and the first transceiver means 10 are advantageously formed together in a single housing as a single piece of equipment 22. Similarly, the second transceiver means 12 and the second transducer means 16 are advantageously formed together in a single housing as a single piece of equipment 24. The equipment 22,24 is advantageously the equipment referred to above and known as IBSONSCAN II. The equipment 22,24 is such that it enables the pictures to be set as a continuous series of still pictures, updated every twenty two seconds, through standard voice frequency radio channels. The equipment 22 is able to take a television frame from the television cameras 6, convert the video signals to audio signals, record then, dial the command base 14, make a security check, and send the pictures, if desired accompanied by the time, date, source and any other required information. The equipment 24 is able to receive the signals from the equipment 22, make a security check, accept the signals, and record the signals. The equipment 24 contemporaneously restores the signal to a video mode and allows the picture to be displayed on the television monitor 18, together with any other transmitted information such for example as the above mentioned time, date and source.

The equipment 22,24 can control the entire aircraft surveillance system 2 and the transmitting equipment by sending up to sixty four separate instructions. If a poor connection is made, the equipment 22 can be instructed to rewind and replay its recording of an entire sequence. The equipment 24 can receive an entire transmission and it also has the facility to enable a single frame to be held on the television monitor 18. An entire transmission can be played back later for analysis and hard copying if desired.

It is envisaged that the aircraft surveillance system 2 will be especially useful for dealing with hijack situations and also for enabling aircraft border patrols to spot terroriste.

It is to be appreciated that the embodiment of the invention described above with reference to the accompanying drawing has been given by way of example only and that modifications may be effected. Thus, for example, more or less than the illustrated four cameras 6 may be employed, and more than one television monitor 18 may also be employed. Also, the cameras 6 could be directed outside an aircraft to survey a predetermined area such as a border or a coastline.

Claims

1. An aircraft surveillance system comprising an aircraft, at least one closed circuit slow scan television camera which is positioned in the aircraft and which is for surveying a predetermined area, first transducer means which is positioned in the aircraft and which is for converting video signals from the camera into audio signals, first transceiver means which is positioned in the aircraft and which is for transmitting the audio signals from the first transducer means and for receiving command signals, second transceiver means which is positioned in a command base remote from the aircraft and which is for receiving the audio signals from the first transceiver means and for

sending the command signals, second transducer means which is positioned in the command base and which is for converting the audio signals received by the second transceiver means into video signals, and at least one television monitor for providing a visual display consequent upon receiving the video signals from the second transducer means.

2. An aircraft surveillance system according to claim 1 in which the first transducer means is for converting the video signals from the camera to audio signals on cassette tape.

3. An aircraft surveillance system according to claim 1 or claim 2 in which the first transducer means and the first transceiver means are housed together in a single piece of equipment, and in which the second transducer means and the second transceiver means are also housed together in a single piece of equipment.

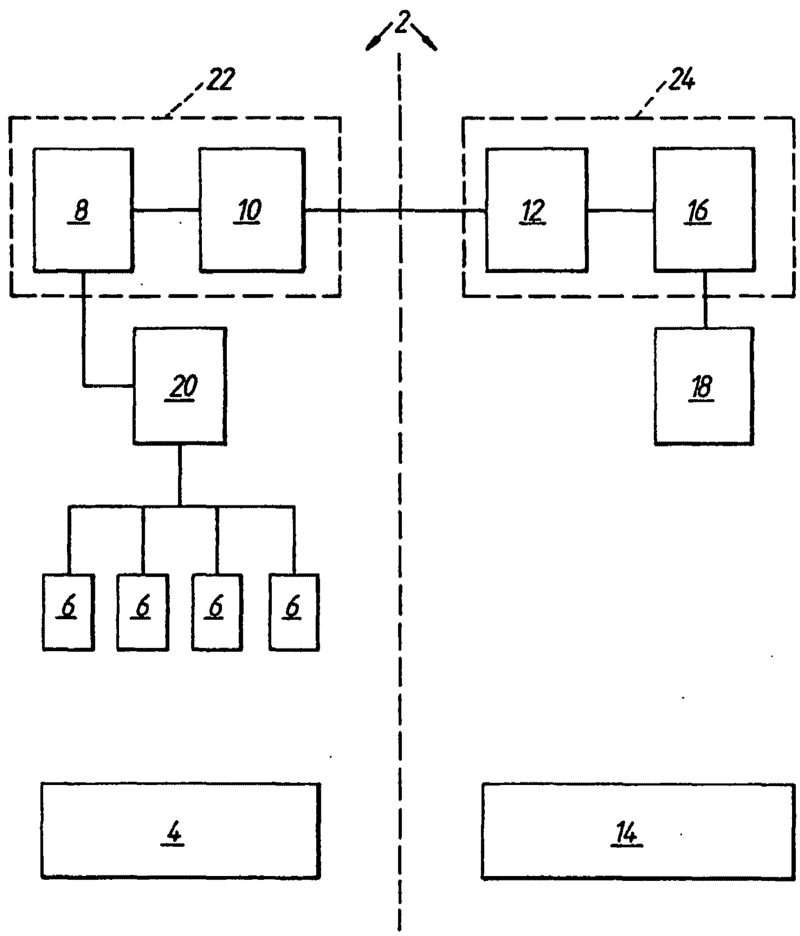
4. An aircraft surveillance system according to any one of the preceding claims in which the first and the second transceiver means record on to tape so that they have a play back facility for helping repeated surveillance of an area of an object in that area.

5. An aircraft surveillance system according to any one of the preceding claims in which the first and the second transceiver means have a rewind facility.

6. An aircraft surveillance system according to any one of the preceding claims in which the television monitor has a picture hold facility.

7. An aircraft surveillance system according to any one of the preceding claims and which has a visual display facility only, the signals passing from the aircraft to the command base then being signals which are only for permitting the visual display.

8. An aircraft surveillance system according to any one of claims 1 - 6 and which has a visual display facility and also a speech facility, the signals passing from the aircraft to the command base then being first signals which permit the visual display and second signals which permit the speech.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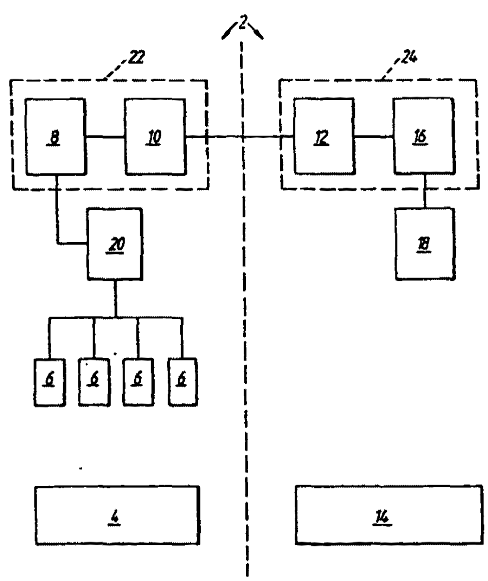
(54) **An aircraft surveillance system.**

(57) An aircraft surveillance system (2) comprising an aircraft (4), at least one closed circuit slow scan television camera (6) which is positioned in the aircraft (4) and which is for surveying a predetermined area, first transducer means (8) which is positioned in the aircraft (4) and which is for converting video signals from the camera (6) into audio signals, first transceiver means (10) which is positioned in the aircraft (4) and which is for transmitting the audio signals from the first transducer means (8) and for receiving command signals, second transceiver means (12) which is positioned in a command base (14) remote from the aircraft (4) and which is for receiving the audio signals from the first transceiver means (10) and for sending the command signals, second transducer means (16) which is positioned in the command base (14) and which is for converting the audio signals received from the second transceiver means (12) into video signals, and at least one television monitor (18) for providing a visual display consequent upon receiving the video signals from the second transducer means (16).



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EUROPEAN SEARCH REPORT

Application Number

EP 87 30 0392

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	EP-A-0 137 320 (ATIS) * Page 3, line 33 - page 4, line 33; figure 1 * ---	1-7	G 08 B 13/18
Y	EP-A-0 028 933 (ASCOTTS LTD) * Page 4, line 23 - page 5, line 29; figure 1 * ---	1-7	
A	CH-A- 651 984 (DUCROT) * Whole document * ---	1,8	
A	FR-A-2 551 240 (ARPHI) * Abstract * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			G 08 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22-11-1988	SGURA S.

CATEGORY OF CITED DOCUMENTS

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(54) Infrared vehicle identification system.

(57) An infrared vehicle identification system [109] comprising a microprocessor controlled infrared (IR) transmnitter [112] located on an aircraft nose wheel landing strut [111] and an infrared receiver [128] including a microprocessor [44] enclosed in a plurality of edge light assemblies [20] located along surface pathways of an airport including runways and taxiways. The infrared transmitter [112] comprises an array of light emitting diodes [120] (LEDs) arranged in a semicircle within the horizontal plane. The transmitter [112] emits a plurality of fields [121, Fig.13] of encoded data to provide vehicle identification and position information. One field [122] comprises a steady stream of pulses that allows the IR receiver [128] to calculate the baud rate of the transmitter [112] and automatically adjust its internal timing. The other fields include a unique word [123] for marking the beginning of a message, the number [124] of characters in the message, the' vehicle identification number [125], the vehicle position [126] and a checksum [127]. The latter [127] ensures that a complete and correct message has been received. If the transmitted message is interrupted for any reason, the checksum [127] will detect it and the messages will be voided. The IR receiver [128] relays a valid message of vehicle identification [125] and position [126] to a central computer system [12, Fig.1] at the airport control tower via the edge light assembly power wiring [21, Fig.1].

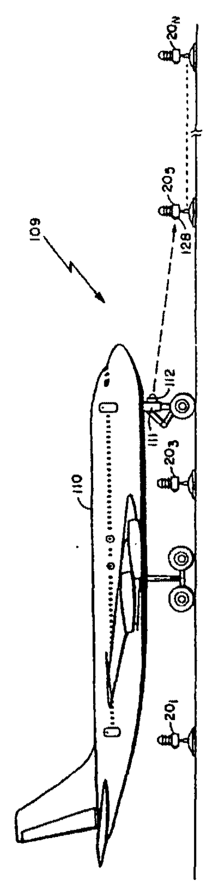

FIG. 10

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Background of the Invention

This invention relates to identification of airport surface traffic and in particular to an apparatus and method for detecting and identifying aircraft or other vehicle movement on airport taxiways, runways and other surface areas.

Currently, ground control of aircraft at an airport is done visually by the air traffic controller in the tower. Low visibility conditions sometimes make it impossible for the controller to see all parts of the field. Ground surface radar can help in providing coverage during low visibility conditions; it plays an important part in the solution of the runway incursion problem but cannot solve the entire problem. A runway incursion is defined as "any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing, or intending to land." The U.S. Federal Administration Agency (FAA) has estimated that it can only justify the cost of ground surface radar at 29 of the top 100 airports in the United States. However, such radar only provides location information; it cannot alert the controller to possible conflicts between aircraft.

In the prior art, an airport control and monitoring system has been used to sense when an airplane reaches a certain point on a taxiway and controls switching lights on and off to indicate to the pilot when he may proceed on to a runway. Such a system sends microwave sensor information to a computer in the control tower. The computer comprises software for controlling the airport lighting and for providing fault information on the airport lighting via displays or a control panel to an operator. Such a system is described in sales information provided on a Bi-directional Series 7 Transceiver (BRITEE) produced by ADB-ALNACO, Inc., A Siemens Company, of Columbus, Ohio. However, such a system does not show the location of all vehicles on an airfield and is not able to detect and avoid a possible vehicle incursion.

A well known approach to airport surface traffic control has been the use of scanning radars operating at high frequencies such as K-band in order to obtain adequate definition and resolution. An existing airport ground traffic control equipment of that type is known in the art as Airport Surface Detection Equipment (ASDE). However, such equipment provides surveillance only, no discrete identification of aircraft on the surface being available. Also there is a need for a relatively high antenna tower and a relatively large rotation antenna system thereon.

Another approach to airport ground surveillance is a system described in U. S. Patent No. 3,872,474, issued March 18, 1974, to Arnold M. Levine and assigned to International Telephone and Telegraph Corporation, New York, NY, referred to as LOCAR (Localized Cable Radar) which comprises a series of small, lower powered, narrow pulses, transmitting radars having limited range and time sequenced along opposite sides of a runway ramp or taxiway. In another U. S. Patent No. 4,197,536, issued on April 8, 1980, to Arnold M. Levine, an airport surface identification and control system is described for aircraft equipped with ATCRBS (Air Traffic Control Radio Beacon System) and ILS (Instrument Landing System). However, these approaches are expensive, require special cabling and for identification purposes require expensive equipment to be included on the aircraft and other vehicles.

Another approach to vehicle identification such as types of aircraft by identifying the unique characteristic of the "footprint" presented by the configuration of wheels unique to a particular type of vehicle is described in U.S. Patent No. 3,872,283, issued March 18, 1975, to Gerald R. Smith et al. and assigned to The Cadre Corporation of Atlanta Georgia.

An automatic system for surveillance, guidance and fire-fighting at airports using infrared sensors is described in U. S. Patent No. 4,845,629, issued July 4, 1989 to Maria V. Z. Murga. The infrared sensors are arranged along the flight lanes and their output signals are processed by a computer to provide information concerning the aircraft movements along the flight lanes. Position detectors are provided for detecting the position of aircraft in the taxiways and parking areas. However, such system does not teach the use of edge lights along the runways and taxiways along with their associated wiring and it is not able to detect and avoid a possible vehicle incursion.

The manner in which the invention deals with the disadvantages of the prior art to provide a low cost infrared vehicle identification system will be evident as the description proceeds.

Summary of the Invention

Accordingly, it is therefore an object of this invention to provide a low cost infrared system that identifies aircraft or other vehicles on airport taxiways and runways.

It is also an object of this invention to provide at an airport a low cost aircraft or vehicle identification system using existing edge light assemblies and associated wiring along runways and taxiways.

It is another object of this invention to provide an infrared vehicle identification system that generates a graphic display of the airport showing the location of all ground traffic including direction and velocity data and identifies such ground traffic.

The objects are further accomplished by providing a vehicle identification system for identifying aircraft and other vehicles on surface pathways including runways and other areas of an airport comprising means disposed on the aircraft and other vehicles for transmitting identification message data, means disposed in each of a plurality of light assembly means on the airport for receiving and decoding the message data from the transmitting means, means for providing power to each of the plurality of light assembly means, means for processing the decoded identification message data generated by the receiving and decoding means in each of the plurality of light assembly means, means for providing data communication between each of the light assembly means and the processing means, and the processing means comprises means for providing a graphic display of the airport comprising symbols representing the aircraft and other vehicles, each of the symbols having the identification message data displayed. The transmitting means comprises means for creating unique message data which includes aircraft and flight identification, and infrared means coupled to the message creating means for transmitting a coded stream of the message data. The message data further includes position information. The receiving and decoding means comprises an infrared sensor. The receiving and decoding means comprises microprocessor means coupled to the infrared sensor for decoding the message data. The plurality of light assembly means are arranged in two parallel rows along runways and taxiways of the airport. The light assembly means comprises light means coupled to the lines of the power providing means for lighting the airport, vehicle sensing means for detecting aircraft or other vehicles on the airport, microprocessor means coupled to the receiving and decoding means, the light means, the vehicle sensing means and the data communication means for decoding the identification message data, and the data communication means being coupled to the microprocessor means and the lines of the power providing means. The symbols representing aircraft and other vehicles comprise icons having a shape indicating type of aircraft or vehicle. The processing means determines a location of the symbols on the graphic display of the airport in accordance with data received from the light assembly means.

The objects are further accomplished by a vehicle identification system for surveillance and identification of aircraft and other vehicles on an airport comprising a plurality of light circuits on the airport, each of the light circuits comprises a plurality of light assembly means, means for providing power to each of the plurality of light circuits and to each of the light assembly means, means in each of the light assembly means for sensing ground traffic on the airport, means disposed on the aircraft and other vehicles for transmitting identification message data, means disposed in each of the light assembly means for receiving and decoding the message data from the transmitting means, means for processing ground traffic data from the sensing means and decoded message data from each of the light assembly means for presentation on a graphic display of the airport, means for providing data communication between each of the light assembly means and the processing means, the processing means comprises means for providing such graphic display of the airport comprising symbols representing the ground traffic, each of the symbols having direction, velocity and the identification message data displayed. Each of the light circuits are located along the edges of taxiways or runways on the airport. The sensing means comprises infrared detectors. The transmitting means comprises means for creating unique message data which includes aircraft and flight identification, and infrared means coupled to the message creating means for transmitting a coded stream of the message data. The message data further comprises position information. The receiving and decoding means comprises an infrared sensor. The receiving and decoding means comprises microprocessor means coupled to the infrared sensor for decoding the message data. The plurality of light assembly means of the light circuits being arranged in two parallel rows along runways and taxiways of the airport. The light assembly means comprises light means coupled to the lines of the power providing means for lighting the airport, the ground traffic sensing means for detecting aircraft or other vehicles on the airport, microprocessor means coupled to the receiving and decoding means, the light means, the ground traffic sensing means and the data communication means for decoding the identification message data and processing a detection signal from the ground traffic sensing means, and the data communication means being coupled to the microprocessor means and the lines of the power providing means. The light assembly means further comprises a photocell means coupled to the microprocessor means for detecting the light intensity of the light means. The light assembly means further comprises a strobe light coupled to the microprocessor means. The processing means comprises redundant computers for fault tolerance operation. The symbols representing the ground traffic comprise icons having a shape indicating type of aircraft or vehicle. The processing means determines a location of the symbols on the graphic display of the airport in accordance with the data receive from the light assembly means. The processing means determines a future path of the ground traffic based on a ground clearance command, the future path being shown on the graphic display. The processing means further comprises means for predicting an airport incursion. The power providing means comprises constant current power means for providing a separate line to each of the plurality of light circuits, and network bridge means coupled to the constant current power means for providing a communication channel to the processing means for each line of the constant current power means.

The objects are further accomplished by providing a method of providing a vehicle identification system for identifying aircraft and other vehicles on surface pathways including runways and other areas of an airport comprising the steps of transmitting identification message data with means disposed on the aircraft and other vehicles, receiving and decoding the message data from the transmitting means with means disposed in each of a plurality of light assembly means on the airport, providing power to each of the plurality of light assembly means, processing the decoded identification message data generated by the receiving and decoding means in each of the plurality of light assembly means, providing data communication between each of the light assembly means and the processing means, and providing a graphic display of the airport with the processing means comprising symbols representing the aircraft and other vehicles, each of the symbols having the identification message data displayed. The step of transmitting identification message data comprises the steps of creating unique message data which includes aircraft and flight identification, and transmitting a coded stream of the message data with infrared means coupled to the message creating means. The step of transmitting message data further includes transmitting position information. The step of receiving and decoding the message data includes using an infrared sensor. The step of receiving and decoding the message data further comprises the step of coupling microprocessor means to the infrared sensor for decoding the message data. The step of receiving and decoding the message data with means disposed in the plurality of light assembly means further comprises the step of arranging the plurality of light assembly means in two parallel rows along runways and taxiways of the airport. The step of providing a graphic display comprising symbols representing aircraft and other vehicles further comprises the step of providing icons having a shape indicating type of aircraft or vehicle. The step of providing a graphic display comprises the step of determining a location of the symbols on the graphic display of the airport in accordance with data received from the light assembly means.

Brief Description of the Drawings

Other and further features of the invention will become apparent in connection with the accompanying drawings wherein:

FIG. 1 is a block diagram of an airport vehicle incursion avoidance system;

FIG. 2 is a block diagram of an edge light assembly showing a sensor electronics unit coupled to an edge light of an airfield lighting system;

FIG. 3 is a pictorial diagram of the edge light assembly showing the edge light positioned above the sensor electronics unit;

FIG. 4 is a diagram of an airfield runway or taxiway having a plurality of edge light assemblies positioned along each side of the runway or taxiway for detecting various size aircraft as shown;

FIG. 5 is a block diagram of the central computer system shown in FIG. 1;

FIG. 6 shows eleven network variables used in programming the microprocessor of an edge light assembly to interface with a sensor, a light and a strobe light;

FIG. 7 is a block diagram showing an interconnection of network variables for a plurality of edge light assemblies located on both sides of a runway, each comprising a sensor electronics unit 10 positioned along a taxiway or runway;

FIG. 8 shows a graphic display of a typical taxiway/runway on a portion of an airport as seen by an operator in a control tower, the display showing the location of vehicles as they are detected by the sensors mounted in the edge light assemblies located along taxiways and runways;

FIG. 9 is a block diagram of the data flow within the system shown in FIG. 1 and FIG. 5;

FIG. 10 is a pictorial diagram of an infrared identification system showing an IR transmitter mounted on an airplane wheel strut and an IR receiver mounted in an edge light assembly of an airport lighting system;

FIG. 11 is a block diagram of an IR transmitter of an IR vehicle identification system;

FIG. 12 shows a top view of the IR transmitter mounted on an airplane wheel strut providing a 195° area of coverage generated by an IR light emitting diode array in the IR transmitter;

FIG. 13 shows data fields of a coded data stream transmitted by the IR transmitter;

FIG. 14 is a block diagram of an IR receiver of the IR vehicle identification system;

FIG. 15 is a flow chart of an IR message routine which is a communication protocol continuously performed in an IR receiver microprocessor; and

FIG. 16 is a flow chart of a vehicle sensor routine which is continuously performed in an IR receiver microprocessor.

Description of the Preferred Embodiment

Referring to FIG. 1 a block diagram of an airport vehicle incursion avoidance system 10 is shown comprising a plurality of light circuits 18_{1-n}, each of said light circuits 18_{1-n} comprises a plurality of edge light assemblies 20_{1-n} connected via wiring 21_{1-n} to a lighting vault 16 which is connected to a central computer system 12 via a wide area network 14. Each of the edge light assemblies 20_{1-n} comprises an infrared (IR) detector vehicle sensor 50 (FIG. 2).

The edge light assemblies 20_{1-n} are generally located along side the runways and taxiways of the airport with an average 100 foot spacing and are interconnected to the lighting vault 16 by single conductor series edge light wiring 21_{1-n}. Each of the edge light circuits 18_{1-n} is powered via the wiring 21_{1-n} by a constant current supply 24_{1-n} located in the lighting vault 16.

Referring now to FIG. 1 and FIG. 2, communication between the edge light assemblies 20_{1-n} and the central computer system 12 is accomplished with LON Bridges 22_{1-n} interconnecting the edge light wiring 21_{1-n} with the Wide Area Network 14. Information from a microprocessor 44 located in each edge light assembly 20_{1-n} is coupled to the edge light wiring 21_{1-n} via a power line modem 54. The LON bridges 22_{1-n} transfers message information from the edge light circuits 18_{1-n} via the wiring 21_{1-n} to the wide area network 14. The wide area network 14 provides a transmission path to the central computer system 12. These circuit components also provide the return path communications link from the central computer system 12 to the microprocessor 44 in each edge light assembly 20_{1-n}. Other apparatus and methods, known to one of ordinary skill in the art, for data communication between the edge light assemblies 20_{1-n} and the central computer system 12 may be employed, such as radio techniques, but the present embodiment of providing data communication on the edge light wiring 21_{1-n} provides a low cost system for present airports. The LON Bridge 22 may be embodied by devices manufactured by Echelon Corporation of Palo Alto, California. The wide area network 14 may be implemented by one of ordinary skill in the art using standard Ethernet or Fiber Distributed Data Interface (FDDI) components. The constant current supply 24 may be embodied by devices manufactured by Crouse-Hinds of Winslow, Connecticut.

Referring now to FIG. 2 and FIG. 3, FIG. 3 shows a pictorial diagram of the edge light assembly 20_{1-n}. The edge light assembly 20_{1-n} comprises a bezel including an incandescent lamp 40 and an optional strobe light assembly 48 (FIG. 2) which are mounted above an electronics enclosure 43 comprising a vehicle sensor 50. The electronics enclosure 43 sits on the top of a tubular shaft extending from a base support 56. The light assembly bezel with lamp 40 and base support 56 may be embodied by devices manufactured by Crouse-Hinds of Winslow, Connecticut.

A block diagram of the contents of the electronics enclosure 43 is shown in FIG. 2 which comprises a coupling transformer 53 connected to the edge light wiring 21_{1-n}. The coupling transformer 53 provides power to both the incandescent lamp 40 via the lamp control triac 42 and the microprocessor power supply 52; in addition, the coupling transformer 53 provides a data communication path between the power line modem 54 and the LON Bridges 22_{1-n} via the edge light wiring 21_{1-n}. The microprocessor 44 provides the computational power to run the internal software program that controls the edge light assemblies 20_{1-n}. The microprocessor 44 is powered by the microprocessor power supply 52. Also connected to the microprocessor 44 is the lamp control triac 42, a lamp monitoring photo cell 46, the optional strobe light assembly 48, the vehicle sensor 50, and the data communications modem 54. The microprocessor 44 is used to control the incandescent edge light 40 intensity and optional strobe light assembly 48. The use of the microprocessor 44 in each light assembly 20_{1-n} allows complete addressable control over every light on the field. The microprocessor 44 may be embodied by a VLSI device manufactured by Echelon Corporation of Palo Alto, California 94304, called the Neuron® chip.

Still referring to FIG. 2, the sensor 50 in the present embodiment comprises an infrared (IR) detector and in other embodiments may comprise other devices such as proximity detectors, CCD cameras, microwave motion detectors, inductance loops, or laser beams. The program in the microprocessor 44 is responsible for the initial filtering of the sensor data received from the sensor 50 and responsible for the transmission of such data to the central computer system 12. The sensor 50 must perform the following functions: detect a stationary object, detect a moving object, have a range at least half the width of the runway or taxiway, be low power and be immune to false alarms. This system design does not rely on just one type of sensor. Since sensor fusion functions are performed within the central computer system 12, data inputs from all different types of sensors are acceptable. Each sensor relays a different view of what is happening on the airfield and the central computer system 12 combines them. There are a wide range of sensors that may be used in this system. As a new sensor type becomes available, it can be integrated into this system with a minimum of difficulty. The initial sensor used is an IR proximity detector based around a piezoelectric strip. These are the kind of sensors you use at home to turn on your flood lights when heat and/or movement is detected. When the sensor output provides an analog signal, an analog-to-digital converter readily known in the art may be used to interface with the microprocessor 44.

Another proximity detector that can be used is based around a microwave Gunn diode oscillator. These are currently in use in such applications as Intrusion Alarms, Door Openers, Distance Measurement, Collision Warning, Railroad Switching, etc. These types of sensors have a drawback because they are not passive devices and care needs to be taken to select frequencies that would not interfere with other airport equipment. Finally, in locations such as the hold position lines on taxiways, solid state laser and detector combinations could be used between adjacent taxiway lights. These sensor systems create a beam that when broken would identify the location of the front wheel of the airplane. This type of detector would be used in those locations where the absolute position of a vehicle was needed. The laser beam would be modulated by the microprocessor 44 to avoid the detector being fooled by any other stray radiation.

Referring to FIG. 2 and FIG. 4, a portion of an airport runway 64 or taxiway is shown having a plurality of edge light assemblies 20_{1-8} positioned along each side of the runway or taxiway for detecting various size airplanes or vehicles 60, 62. The dashed lines represent the coverage area of the sensors 50 located in each edge light assembly 20_{1-8} positioned along each side of the runway 64 or taxiway to insure detection of any airplane 60, 62 or other vehicles traveling on such runway 64 or taxiway. The edge light assemblies 20_{1-n} comprising the sensor 50 are logically connected together in such a way that an entire airport is sensitized to the movement of vehicles. Node to node communication takes place to verify and identify the location of the vehicles. Once this is done a message is sent to the central computer system 12 reporting the vehicles location. Edge lights assemblies (without a sensor electronics unit 43) and taxiway power wiring currently exist along taxiways, runways and open areas of airports, therefore, the sensor electronics unit 43 is readily added to existing edge lights and existing taxiway power wiring without the inconvenience and expense of closing down runways and taxiways while installing new cabling.

Referring now to FIG. 1, FIG. 5, FIG. 8 and FIG. 9, the central computer system 12 is generally located at a control tower or terminal area of an airport and is interconnected to the LON Bridges 22_{1-n} located in the lighting vault 16 with a Wide Area Network 14. The central computer system 12 comprises two redundant computers, computer #1 26 and computer #2 28 for fault tolerance, the display 30, speech synthesis units 29 & 31, alert lights 34, keyboard 27 and a speech recognition unit 33, all of these elements being interconnected by the wide area network 14 for the transfer of information. The two computers 26 and 28 communicate with the microprocessors 44 located in the edge light assemblies 20_{1-n}. Data received from the edge light assembly 20_{1-n} microprocessors 44 are used as an input to a sensor fusion software module 101 (FIG. 9) run on the redundant computers 26 and 28. The output of the sensor fusion software module 101 operating in the computers 26, 28 is used to drive the CRT display 30 which displays the location of each vehicle on the airport taxiway and runways as shown in FIG. 8. The central computer system 12 may be embodied by devices manufactured by IBM Corporation of White Plains, New York. The Wide Area Network 14 may be embodied by devices manufactured by 3Com Corporation of Santa Clara, California. The speech synthesis units 29, 31 and the speech recognition unit 33 may be embodied by devices manufactured by BBN of Cambridge, Massachusetts.

The speech synthesis unit 29 is coupled to a speaker 32. Limited information is sent to the speech synthesis unit 29 via the wide area network 14 to provide the capability to give an air traffic controller a verbal alert. The speech synthesis unit 31 is coupled to a radio 37 having an antenna 39 to provide the capability to give the pilots a verbal alert. The voice commands from the air traffic controller to the pilots are captured by microphone 35 and sent to the pilots via radio 36 and antenna 38. In the present embodiment a tap is made and the speech information is sent to both the radio 36 and the speech recognition unit 33 which is programmed to recognize the limited air traffic control vocabulary used by a controller. This includes airline names, aircraft type, the numbers 0-9, the name of the taxiways and runways and various short phrases such as "hold short", "expedite" and "give way to." The output of the speech recognition unit 33 is fed to the computers 26, 28.

Referring again to FIG. 2, the power line modem 54 provides a data communication path over the edge light wiring 21_{1-n} for the microprocessor 44. This two way path is used for the passing of command and control information between the various edge light assemblies 20_{1-n} and the central computer system 12. A power line transceiver module in the power line modem 54 is used to provide a data channel. These modules use carrier current approach to create the data channel. Power line modems that operate at carrier frequencies in the 100 to 450 Khz band are available from many manufacturers. These modems provide digital communication paths at data rates of up to 10,000 bits per second utilizing direct sequence spread spectrum modulation. They conform to FCC power line carrier requirements for conducted emissions, and can work with up to 55 dB of power line attenuation. The power line modem 54 may be embodied by a device manufactured by Echelon Corporation of Palo Alto, California 94304, called the PLT-10 Power Line Transceiver Module.

The data channel provides a transport layer or lowest layer of the open system interconnection (OSI) protocol used in the data network. The Neuron® chip which implements the microprocessor 44 contains all of the firmware required to implement a 7 layer OSI protocol. When interconnected via an appropriate medium the Neuron® chips automatically communicate with one another using a robust Collision Sense Multiple Access (CSMA) protocol with forward error corrections, error checking and automatic retransmission of missed messages (ARQ).

The command and control information is placed in data packets and sent over the network in accordance with the 7 Layer OSI protocol. All messages generated by the microprocessor 44 and destined for the central computer system 12 are received by the network bridge 22 via the power lines 21_{1-n} and routed to the central computer system 12 over the wide area network 14.

The Neuron® chip of the microprocessor 44 comprises three processors (not shown) and the firmware required to support a full 6 layer open systems interconnection (OSI) protocol. The user is allocated one of the processors for the application code. The other two processors give the application program access to all of the other Neuron® chips in the network. This access creates a Local Operating Network or LON. A LON can be thought of as a high level local area network LAN. The use of the Neuron® chip for the implementation of this invention, reduces the amount of custom hardware and software that otherwise would have to be developed.

Data from the sensor electronic unit 43 of the edge light assemblies 20_{1-n} is coupled to the central computer system 12 via the existing airport taxiway lighting power wiring 21. Using the existing edge light power line to transfer the sensor data into a LON network has many advantages. As previously pointed out, the reuse of the existing edge lights eliminates the inconvenience and expense of closing down runways and taxiways while running new cable and provides for a low cost system.

The Neuron® chip allows the edge light assemblies 20_{1-n} to automatically communicate with each other at the applications level. This is accomplished through network variables which allow individual Neuron® chips to pass data between themselves. Each Neuron® 'C' program comprises both local and network variables. The local variables are used by the Neuron® program as a scratch pad memory. The network variables are used by the Neuron® program in one of two ways, either as a network output variables or a network input variables. Both kinds of variables can be initialized, evaluated and modified locally. The difference comes into play in that once a network output variable is modified, network messages are automatically sent to each network input variable that is linked to that output variable. This variable linking is done at installation time. As soon as a new value of a network input variable is received by a Neuron® chip, the code is vectored off to take appropriate action based upon the value of the network input variable. The advantage to the program is that this message passing scheme is entirely transparent since the message passing code is part of the embedded Neuron® operating system.

Referring now to FIG. 6, eleven network variables have been identified for a sensor program in each microprocessor 44 of the edge light assemblies 20_{1-n}. The sensor 50 function has two output variables: prelim_detect 70 and confirmed_detect 72. The idea here is to have one output trigger whenever the sensor 50 detects movement. The other output does not trigger unless the local sensor and the sensor on the edge light across the runway both spot movement. Only when the detection is confirmed will the signal be fed back to the central computer system 12. This technique of confirmation helps to reduce false alarms in order to implement this technique the adjacent sensor 50 has an input variable called adj_prelim_detect 78 that is used to receive the other sensors prelim_detect output 70. Other input variables are upstream_detect 74 and downstream_detect 76 which are used when chaining adjacent sensors together. Also needed is a detector_sensitivity 80 input that is used by the central computer system 12 to control the detection ability of the sensor 50.

The incandescent light 40 requires two network variables, one input and the other an output variable. The input variable light_level 84 would be used to control the light's brightness. The range would be OFF or 0% all the way to FULL ON or 100%. This range from 0% to 100% would be made in 0.5% steps. Since the edge light assembly 20_{1-n} also contains the photocell 46, an output variable light_failure 84 is created to signal that the lamp did not obtain the desired brightness.

The strobe light 48 requires three input variables. The strobe-mode 86 variable is used to select either the OFF, SEQUENTIAL, or ALTERNATE flash modes. Since the two flash modes require a distinct pattern to be created, two input variables active_delay 88 and flash_delay 90 are used to time align the strobe flashes. By setting these individual delay factors and then addressing the Neuron® chips as a group, allows the creation of a field strobe pattern with just one command.

Referring now to FIG. 7, a block diagram of an interconnection of network variables for a plurality of edge light assemblies 20_{1-n} located on both sides of a runway is shown, each of the edge light assemblies 20_{1-n} comprising a microprocessor 44. Each Neuron® program in the microprocessor 44 is designed with certain network input and output variables. The user writes the code for the Neuron® chips in the microprocessor 44 assuming that the inputs are supplied and that the outputs are used. To create an actual network the user has to "wire up" the network by interconnecting the individual nodes with a software linker. The resulting distributed process is best shown in schematic form, and a portion of the network interconnect matrix is shown in Figure 7. The prelim_detect 70 output of a sensor node 44_1 is connected to the adj_primary_detect 92 input of the sensor node 44_4 across the taxiway. This is used as a means to verify actual detections and eliminate false reports. The communications link between these two nodes 44_1 and 44_4 is part of the distributed processing. The two nodes communicate among themselves without involving the central computer system 12. If in the automatic mode or if instructed by the controller, the system will also alert the pilots via audio and visual indications.

Referring again to FIG. 1 and FIG. 4, the central computer system 12 tracks the movement of vehicles as they pass from the sensor 50 to sensor 50 in each edge light assembly 20_{1-n}. Using a variation of a radar automatic track algorithm, the system can track position, velocity and heading of all aircraft or vehicles based upon the sensor 50 readings. New vehicles are entered into the system either upon leaving a boarding gate or landing. Unknown vehicles are also tracked automatically. Since taxiway and runway lights are normally across from each other on the pavement (as shown in FIG. 4 and FIG. 7), the microprocessor 44 in each edge lights assembly 20_{1-n} is programmed to combine their sensor 50 inputs and agree before reporting a contact. A further refinement is to have the microprocessor 44 check with the edge light assemblies 20_{1-n} on either side of them to see if their sensors 50 had detected the vehicle. This allows a vehicle to be handed off from sensor electronic unit 43 to sensor electronic unit 43 of each edge light assembly 20_{1-n} as it travels down the taxiway. This also assures that vehicle position reports remain consistent. Vehicle velocity may also be calculated by using the distance between sensors, the sensor pattern and the time between detections.

Referring to FIG. 5 and FIG. 8, the display 30 is a color monitor which provides a graphical display of the airport, a portion of which is shown in FIG. 8. This is accomplished by storing a map of the airport in the redundant computers 26 and 28 in a digital format. The display 30 shows the location of airplanes or vehicles as they are detected by the sensors 50 mounted in the edge light assemblies 20_{1-n} along each taxiway and runway or other airport surface areas. All aircraft or vehicles on the airport surface are displayed as icons, with the shape of the icons being determined by the vehicle type. Vehicle position is shown by the location of the icon on the screen. Vehicle direction is shown by either the orientation of the icon or by an arrow emanating from the icon. Vehicle status is conveyed by the color of the icon. The future path of the vehicle as provided by the ground clearance command entered via the controllers microphone 35 is shown as a colored line on the display 30. The status of all field lights including each edge light 20_{1-n} in each edge light circuit 18_{1-n} is shown via color on the display 30.

Use of object orientated software provides the basis for building a model of an airport. The automatic inheritance feature allows a data structure to be defined once for each object and then replicated automatically for each instance of that object. Automatic flow down assures that elements of the data base are not corrupted due to typing errors. It also assures that the code is regular and structured. Rule based object oriented programming makes it difficult to create unintelligible "spaghetti code." Object oriented programming allows the runways, taxiways, aircraft and sensors, to be decoded directly as objects. Each of these objects contains attributes. Some of these attributes are fixed like runway 22R or flight UA347, and some are variable like vehicle status and position.

In conventional programming we describe the attributes of an object in data structures and then describe the behaviors of the object as procedures that operate on those data structures. Object oriented programming shifts the emphasis and focuses first on the data structure and only secondarily on the procedures. More importantly, object oriented programming allows us to analyze and design programs in a natural manner. We can think in terms of runways and aircraft instead of focusing on either the behavior or the data structures of the runways and aircraft.

Table 1 shows a list of objects with corresponding attributes. Each physical object that is important to the runway incursion problem is modeled. The basic airplane or vehicle tracking algorithm is shown in Table 2 in a Program Design Language (PDL). The algorithm which handles sensor fusion, incursion avoidance and safety alerts is shown in a single program even though it is implemented as distributed system using both the central computer system 12 and the sensor microprocessors 44.

TABLE 1

OBJECT	ATTRIBUTE	DESCRIPTION
Sensor	Location	X & Y coordinates of sensor
	Circuit	AC wiring circuit name & number
	Unique_address	Net address for this sensor and its mate
	Lamp_intensity	0% to 100% in 0.5% steps
	Strobe_status	Blink rate/off
	Strobe-delay	From start signal
	Sensor_status	Detect/no detect
	Sensor_type	IR, laser, proximity, etc.
Runway	Name	22R, 27, 33L, etc.
	Location	X & Y coordinates of start of center line
	Length	In feet
	Width	In feet
	Direction	In degrees from north
	Status	Not_active, active_takeoff, active_landing, alarm
	Sensors (MV)	List of lights/sensors along this runway
	Intersections (MV)	List of intersections
	Vehicles	List of vehicles on the runway
Taxiway	Name	Name of taxiway
	Location	X & Y coordinates of start of center line
	Length	In feet
	Width	In feet
	Direction	In degrees from north
	Status	Not active, active, alarm
	Sensors (MV)	List of intersections
	Hold_Locations	List of holding locations
	Vehicles (MV)	List of vehicles on the runway

Intersection	Name	Intersection Name
	Location	Intersection of two center lines
	Status	Vacant/Occupied
	Sensors (MV)	List of sensors creating intersection border
Aircraft	Airline	United
	Model	727-200
	Tail-number	N32742
	Empty_weight	9.5 tons
	Freight_weight	2.3 tons
	Fuel_weight	3.2 tons
	Top_speed	598 mph
	V1_speed	100 mph
	V2_speed	140 mph
	Acceleration	0.23 g's
	Deceleration	0.34 g's

MV = Multi-variable or array

Table 2

```
while (forever)
| if (edge light shows a detection)
| | if (adjacent light also shows a detection sensor fusion)
| | | /* CONFIRMED DETECTION */
| | | if (previous block showed a detection)
| | | | /* ACCEPT HANDOFF */
| | | | Update aircraft position and speed
| | | else
| | | | /* MAY BE AN ANIMAL OR SERVICE TRUCK */
| | | | Alert operator to possible incursion
| | | | /* MAY BE AN AIRCRAFT ENTERING THE SYSTEM */
| | | | Start a new track
| | else
| | | Request status from adjacent light
```

```
|   |   |   if (Adjacent light is OK)
|   |   |   |   /* NON CONFIRMED DETECTION */
|   |   |   else
|   |   |   |   Flag adjacent light for repair
|   |   |   endif
|   |   endif
|   endif
|   if (Edge light loses a detection AND status is OK)
|   |   if (Next block showed a detection)
|   |   |       /* PROPER HANDOFF */
|   |   else
|   |   |   if (vehicle speed > = takeoff)
|   |   |   |   Handoff to departure control
|   |   |   else
|   |   |   |   /* MISSING HANDOFF */
|   |   |   |   Alert operator to possible incursion
|   |   |   endif
|   |   endif
|   endif
|   /* CHECK FOR POSSIBLE COLLISIONS */
|   for (all tracked aircraft)
|   |   Plot future position
|   |   if (position conflict)
|   |   |       Alert operator to possible incursion
|   |   endif
|   endif
|   Update display
endwhile
```

Referring again to FIG. 1 and FIG. 2, the control of taxiway lighting intensity is usually done by placing all the lights on the same series circuit and then regulating the current in that circuit. In the present embodiment the intensity of the lamp 40 is controlled by sending a message with the light intensity value to the microprocessor 44 located within the light assembly 20_{1-n}. The message allows for intensity settings in the range of 0 to 100% in 0.5% steps. The use of photocell 46 to check the light output allows a return message to be sent if the bulb does not respond. This in turn generates a maintenance report on the light. The strobe light 48 provides an additional optional capability under program control of the microprocessor 44. Each of the microprocessors 44 in the edge light assemblies 20 is individually addressable. This means every lamp on the field is controlled individually by the central computer system 12.

The system 10 can be programmed to provide an Active Runway Indicator by using the strobe lights 48 in those edge light assemblies 20_{1-n} located on the runway 64 to continue the approach light "rabbit" strobe