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PATENT NUMBER and  
ISSUE DATE  
**6772057**

U.S. UTILITY Patent Application

APP. NUM	FILING DATE	CLASS	SUBCLASS	GAU	EXAMINER
10302105	11/22/2002	701	45	3663	To

APPLICANTS: Ezed David; DuVall Wilbur; Johnson Wendell;

**\*\*CONTINUING DATA VERIFIED: yes /rc**  
 This application is a CIP of 10/116,808 04/05/2002 10  
 which is a CIP of 09/925,043 08/08/2001 PAT 6,507,779  
 which is a CIP of 09/765,559 01/19/2001  
 and is a CIP of 09/389,947 09/03/1999 PAT 6,393,133  
 This application 10/302,105  
 is a CIP of 09/338,019 01/20/2001 PAT 6,442,465  
 which is a CIP of 09/765,559 01/19/2001  
 which is a CIP of 09/476,255 12/30/1999 PAT 6,324,453  
 which claims benefit of 60/114,507 12/31/1998  
 and is a CIP of 09/389,947 09/03/1999 PAT 6,393,133  
 which is a CIP of 09/200,614 11/30/1998 PAT 6,141,432  
 which is a CON of 08/474,786 06/07/1995 PAT 5,845,000  
 and said 09/389,947 09/03/1999  
 claims benefit of 60/114,507 12/31/1998

**\*\* FOREIGN APPLICATIONS VERIFIED: none /rc**

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Foreign priority claimed  yes  no  
 35 USC 119 conditions met  yes  no  
 Verified and Acknowledged Examiners's initials *TC* ATTORNEY DOCKET NO  
 ATI-338

TITLE: Vehicular monitoring systems using image processing  
 U.S. DEPT. OF COMM./PAT. & TM-PTO-436L (Rev. 12-91)

*6/25/04* Formal Drawings (*19* sheets) set *L* *11/22/02*

<b>NOTICE OF ALLOWANCE MAILED</b>		<b>CLAIMS ALLOWED</b>	
<i>3/24/04</i>		Total Claims: <i>8.6</i>	Print Claim for O.G: <i>1</i>
<b>ISSUE FEE</b>		<b>DRAWING</b>	
Amount Due: <i>5965</i>	Date Paid: <i>6-18-04</i>	Sheets Drwg: <i>19</i>	Flgs Drwg: <i>22</i>
		Print Ptg: <i>8</i>	
<b>DISCLAIMER</b>		<b>Application Examiner</b>	
<b>ISSUE FILE IN FILE</b>		<b>PREPARED FOR ISSUE</b>	
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### CONTENTS

	Date Received (Incl. C. of M.) or Date Mailed	Date Received (Incl. C. of M.) or Date Mailed
1. Application <b>Prints</b> papers.		
2. <b>IDS</b>	<b>11-22-02</b>	
3. <i>05/93</i> <b>Rej (3)</b>	<b>11/3/03</b>	
4. <b>Amot A</b> <sup>cm</sup> (12/02)	<b>12/05/02</b>	
5. <b>Exr's Amot B</b>	<b>3/20/03</b>	
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(12) **United States Patent**  
**Breed et al.**

(10) **Patent No.:** **US 6,772,057 B2**  
(45) **Date of Patent:** **Aug. 3, 2004**

(54) **VEHICULAR MONITORING SYSTEMS USING IMAGE PROCESSING**

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/302,105**

(22) Filed: **Nov. 22, 2002**

(65) **Prior Publication Data**

US 2003/0125855 A1 Jul. 3, 2003

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 10/116,808, filed on Apr. 5, 2002, which is a continuation-in-part of application No. 09/925,043, filed on Aug. 8, 2001, now Pat. No. 6,507,779, which is a continuation-in-part of application No. 09/765,559, filed on Jan. 19, 2001, now Pat. No. 6,553,296, and a continuation-in-part of application No. 09/389,947, filed on Sep. 3, 1999, now Pat. No. 6,393,133, and a continuation-in-part of application No. 09/838,919, filed on Apr. 20, 2001, now Pat. No. 6,442,465, which is a continuation-in-part of application No. 09/765,559, which is a continuation-in-part of application No. 09/476,255, filed on Dec. 30, 1999, now Pat. No. 6,324,453, and a continuation-in-part of application No. 09/389,947, which is a continuation-in-part of application No. 09/200,614, filed on Nov. 30, 1998, now Pat. No. 6,141,432, which is a continuation of application No. 08/474,786, filed on Jun. 7, 1995, now Pat. No. 5,845,000.

(60) Provisional application No. 60/114,507, filed on Dec. 31, 1998.

(51) **Int. Cl.<sup>7</sup>** ..... **B60R 21/32**

(52) **U.S. Cl.** ..... **701/45; 340/573.1; 348/77; 180/271; 280/735; 382/181**

(58) **Field of Search** ..... **701/45, 36, 301; 340/461, 435, 436, 438, 815.4, 573.1; 348/148, 77, 154; 180/271; 280/735, 728.1; 382/181, 115, 190, 224, 100, 104**

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

4,496,222 A 1/1985 Shah ..... 3592/300

(List continued on next page.)

**FOREIGN PATENT DOCUMENTS**

EP 0885782 12/1998

(List continued on next page.)

**OTHER PUBLICATIONS**

"Analysis of Hidden Units in a Layered Network Trained to Classify Sonar Targets", R. Paul Gorman, et al., Neural Networks, vol. 1, pp. 75-89, 1988.

(List continued on next page.)

*Primary Examiner*—Thomas G. Black

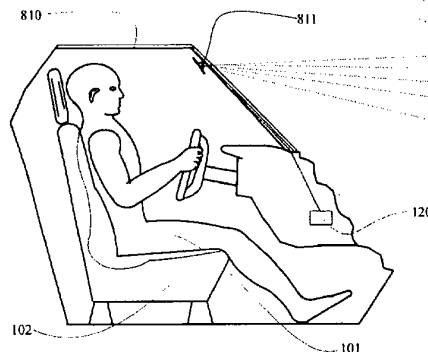
*Assistant Examiner*—Tuan C To

(74) *Attorney, Agent, or Firm*—Brian Roffe

(57) **ABSTRACT**

Vehicle monitoring arrangement for monitoring an environment of the vehicle including at least one active pixel camera for obtaining images of the environment of the vehicle and a processor coupled to the active pixel camera(s) for determining at least one characteristic of an object in the environment based on the images obtained by the active pixel camera(s). The active pixel camera can be arranged in a headliner, roof or ceiling of the vehicle to obtain images of an interior environment of the vehicle, in an A-pillar or B-pillar of the vehicle to obtain images of an interior environment of the vehicle, or in a roof, ceiling, B-pillar or C-pillar of the vehicle to obtain images of an interior environment of the vehicle behind a front seat of the vehicle. The determined characteristic can be used to enable optimal control of a reactive component, system or subsystem coupled to the processor. When the reactive component is an airbag assembly including at least one airbag, the processor can be designed to control at least one deployment parameter of the airbag(s).

**86 Claims, 19 Drawing Sheets**



US 6,772,057 B2

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U.S. PATENT DOCUMENTS

4,625,329 A	11/1986	Ishikawa et al.	382/104
4,648,052 A	3/1987	Friedman et al.	364/550
4,720,189 A	1/1988	Heynen et al.	351/210
4,768,088 A	8/1988	Ando	358/93
4,836,670 A	6/1989	Hutchinson	351/210
4,881,270 A	11/1989	Knecht et al.	382/17
4,906,940 A	3/1990	Greene et al.	382/16
4,950,069 A	8/1990	Hutchinson	351/210
4,966,388 A	10/1990	Warner et al.	280/730
5,003,166 A	3/1991	Girod	250/201.4
5,008,946 A	4/1991	Ando	382/2
5,026,153 A	6/1991	Suzuki et al.	356/1
5,060,278 A	10/1991	Fukumizu	382/157
5,062,696 A	11/1991	Oshima et al.	359/554
5,064,274 A	11/1991	Alten	359/604
5,071,160 A	12/1991	White et al.	280/735
5,074,583 A	12/1991	Fujita et al.	280/735
5,103,305 A	4/1992	Watanabe	358/105
5,118,134 A	6/1992	Mattes et al.	280/735
5,162,861 A	11/1992	Tamburino et al.	356/5.05
5,181,254 A	1/1993	Schweizer et al.	382/1
5,185,667 A	2/1993	Zimmermann	348/143
5,193,124 A	3/1993	Subbarao	382/41
5,214,744 A	5/1993	Schweizer et al.	395/21
5,227,784 A	7/1993	Masamori et al.	340/903
5,235,339 A	8/1993	Morrison et al.	342/159
5,249,027 A	9/1993	Mathur et al.	356/3.14
5,249,157 A	9/1993	Taylor	340/903
5,298,732 A	3/1994	Chen	250/203.4
5,305,012 A	4/1994	Faris	345/7
5,309,137 A	* 5/1994	Kajiwara	340/436
5,329,206 A	7/1994	Slotkowski et al.	315/159
5,330,226 A	7/1994	Gentry et al.	280/735
5,339,075 A	8/1994	Abst et al.	340/903
5,355,118 A	10/1994	Fukuhara	340/435
5,390,136 A	2/1995	Wang	364/754
5,441,052 A	8/1995	Miyajima	128/661.09
5,446,661 A	8/1995	Gioutsos et al.	364/424.05
5,454,591 A	10/1995	Mazur et al.	280/735
5,463,384 A	* 10/1995	Juds	340/903
5,473,515 A	* 12/1995	Liu	362/80.1
5,482,314 A	1/1996	Corrado et al.	280/735
5,497,305 A	* 3/1996	Pastrick et al.	362/83.1
5,528,698 A	6/1996	Kamei et al.	382/100
5,531,472 A	7/1996	Semchena et al.	280/735
5,537,003 A	7/1996	Bechtel et al.	315/82
5,550,677 A	8/1996	Schofield et al.	359/604
5,563,650 A	10/1996	Poelstra	348/36
5,653,462 A	8/1997	Breed et al.	280/735
5,706,144 A	* 1/1998	Brandin	359/843
5,785,347 A	7/1998	Adolph et al.	280/735
5,821,633 A	10/1998	Burke et al.	307/10.1
5,829,782 A	11/1998	Breed et al.	280/735
5,835,613 A	11/1998	Breed et al.	382/100
5,845,000 A	12/1998	Breed et al.	382/100
5,848,802 A	12/1998	Breed et al.	280/735
5,877,897 A	* 3/1999	Schofield et al.	359/604
5,943,295 A	8/1999	Varga et al.	367/99
5,949,331 A	* 9/1999	Schofield et al.	340/461
5,954,360 A	9/1999	Griggs, III et al.	280/735
5,959,367 A	* 9/1999	O'Farrell et al.	307/10.1
5,983,147 A	11/1999	Krumm	701/45
6,005,958 A	12/1999	Farmer et al.	382/103
6,007,095 A	12/1999	Stanley	280/735
6,020,812 A	2/2000	Thompson et al.	340/438
6,027,138 A	2/2000	Tanaka et al.	280/735

6,029,105 A	2/2000	Schweizer	701/45
6,087,953 A	* 7/2000	Deline et al.	340/815.4
6,111,517 A	8/2000	Atick et al.	340/825.34
6,113,137 A	9/2000	Mizutani et al.	280/735
6,115,552 A	9/2000	Kaneda	396/82
2002/0154379 A1	* 10/2002	Tonar et al.	359/267

FOREIGN PATENT DOCUMENTS

GB	2289332	11/1995	
JP	360166806	8/1985	
JP	3-42337	2/1991	180/273
JP	407055573 A	3/1995	
JP	2001-325700	11/2001	
WO	94/22693	10/1994	
WO	0196147	12/2001	

OTHER PUBLICATIONS

Learned Classification of Sonar Targets Using a Massively Parallel Network, R. Paul Gorman et al., IEEE Transactions on Acoustics, Speech and Signal Processing, vol. 36, No. 7, Jul., 1988, pp 1135-1140.

"How Airbags Work", David S. Breed, Presented at the Canadian Association of Road Safety Professionals, Oct. 19, 1992-Oct. 20, 1992.

Intelligent System for Video Monitoring of Vehicle Cockpit, S. Boverie et al., SAE Paper No. 980613, Feb., 1998.

Omnidirectional Vision Sensor for Intelligent Vehicles, T. Ito et al., 1998 IEEE International Conference on Intelligent Vehicles, pp. 365-370, 1998.

A 256x256 CMOS Brightness Adaptive Imaging Array with Column-Parallel Digital Output, C. Sodini et al., 1998 IEEE International Conference on Intelligent Vehicles, 1998, pp. 347-352.

Derwent Abstract of German Patent Publication No. DE 42 11 556, Oct. 7, 1993.

Derwent Abstract of Japanese patent application No. 02-051332, Nov. 13, 1991.

3D Perception for Vehicle Inner Space Monitoring, S. Boverie et al., Advanced Microsystems for Automotive Applications 2000, Apr., 2000, pp. 157-172.

Low-Cost High Speed CMOS Camera for Automotive Applications, N. Stevanovic et al., Advanced Microsystems for Automotive Applications 2000, Apr., 2000, pp. 173-180.

New Powerful Sensory Tool in Automotive Safety Systems Based on PMD-Technology, R. Schwarte et al., Advanced Microsystems for Automotive Applications 2000, Apr., 2000, pp. 181-203.

An Interior Compartment Protection System Based on Motion Detection Using CMOS Imagers, S. B. Park et al., 1998 IEEE International Conference on Intelligent Vehicles.

Sensing Automobile Occupant Position with Optical Triangulation, W. Chapelle et al., Sensors, Dec. 1995.

Intelligent System for Video Monitoring of Vehicle Cockpit, S. Boverie et al., SAE Paper No. 980613, Feb. 23-26, 1998.

A 256x256 CMOS Brightness Adaptive Imaging Array with Column-Parallel Digital Output, CG. Sodini et al., 1998 IEEE International Conference on Intelligent Vehicles.

The FERET Evaluation Methodology for Face-Recognition Algorithms, P.J. Phillips et al., NISTIR 6264, Jan. 7, 1999.

The Technology Review Ten: Biometrics, J. Atick, Jan./Feb. 2001.

\* cited by examiner

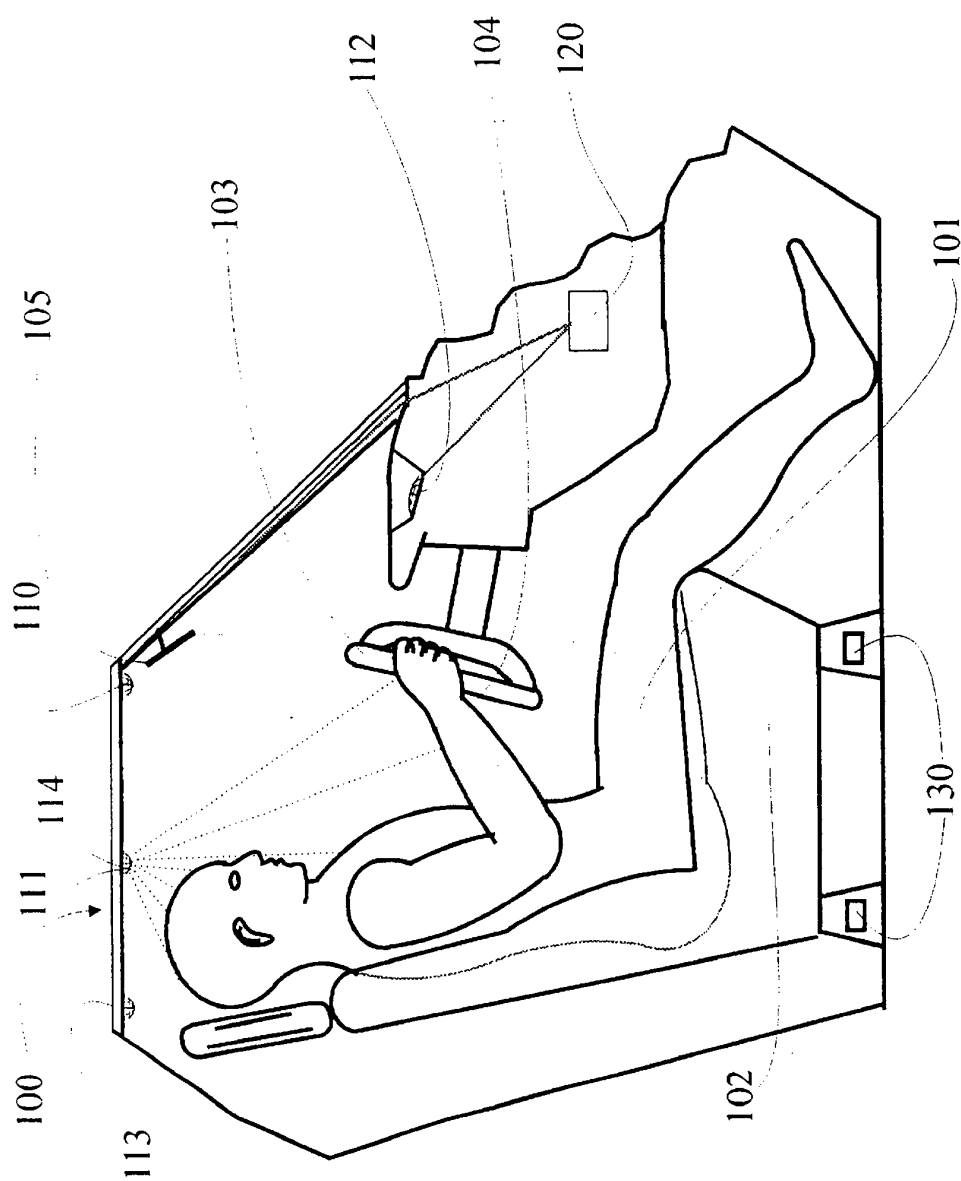


FIG. 1A

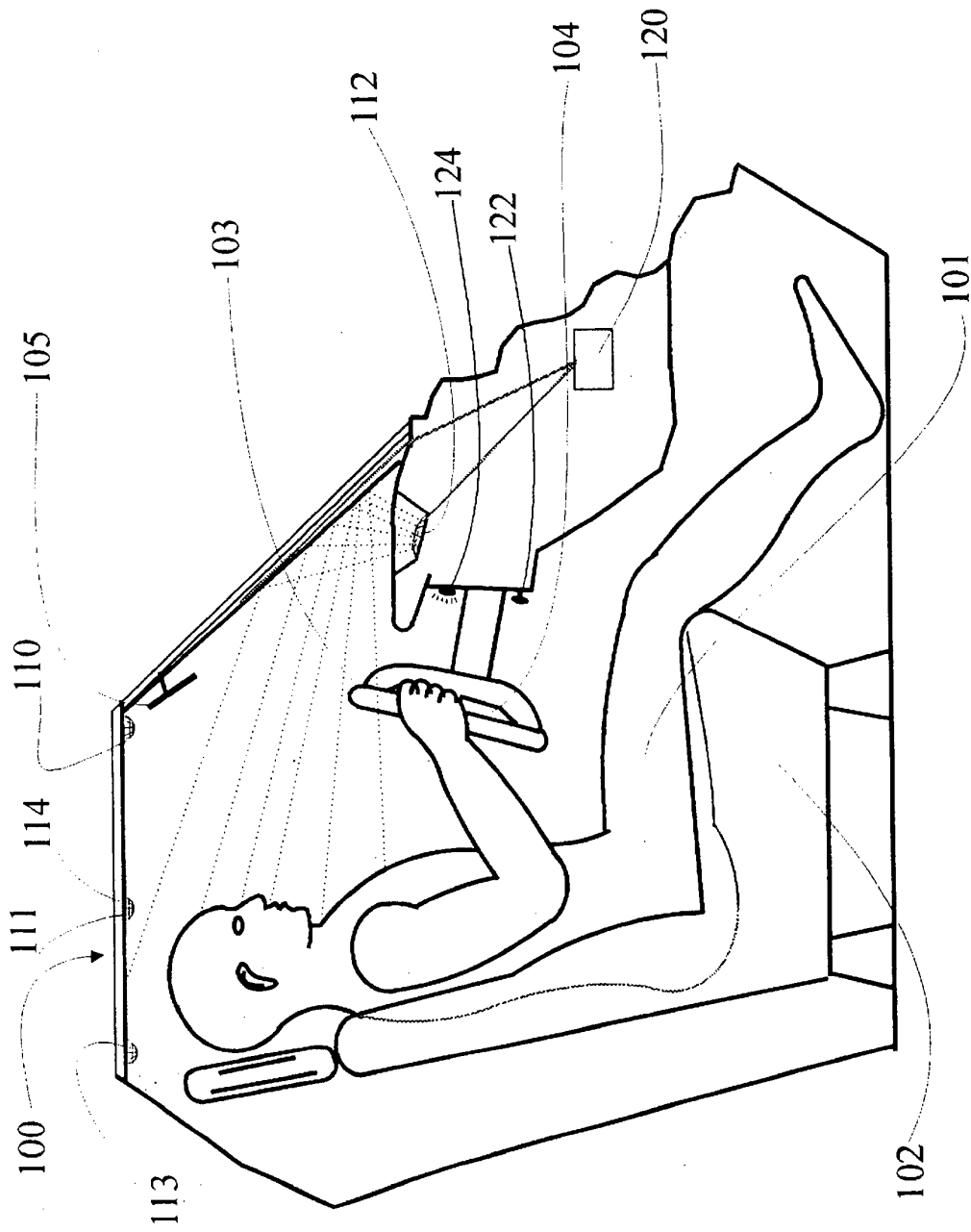


FIG. 1B



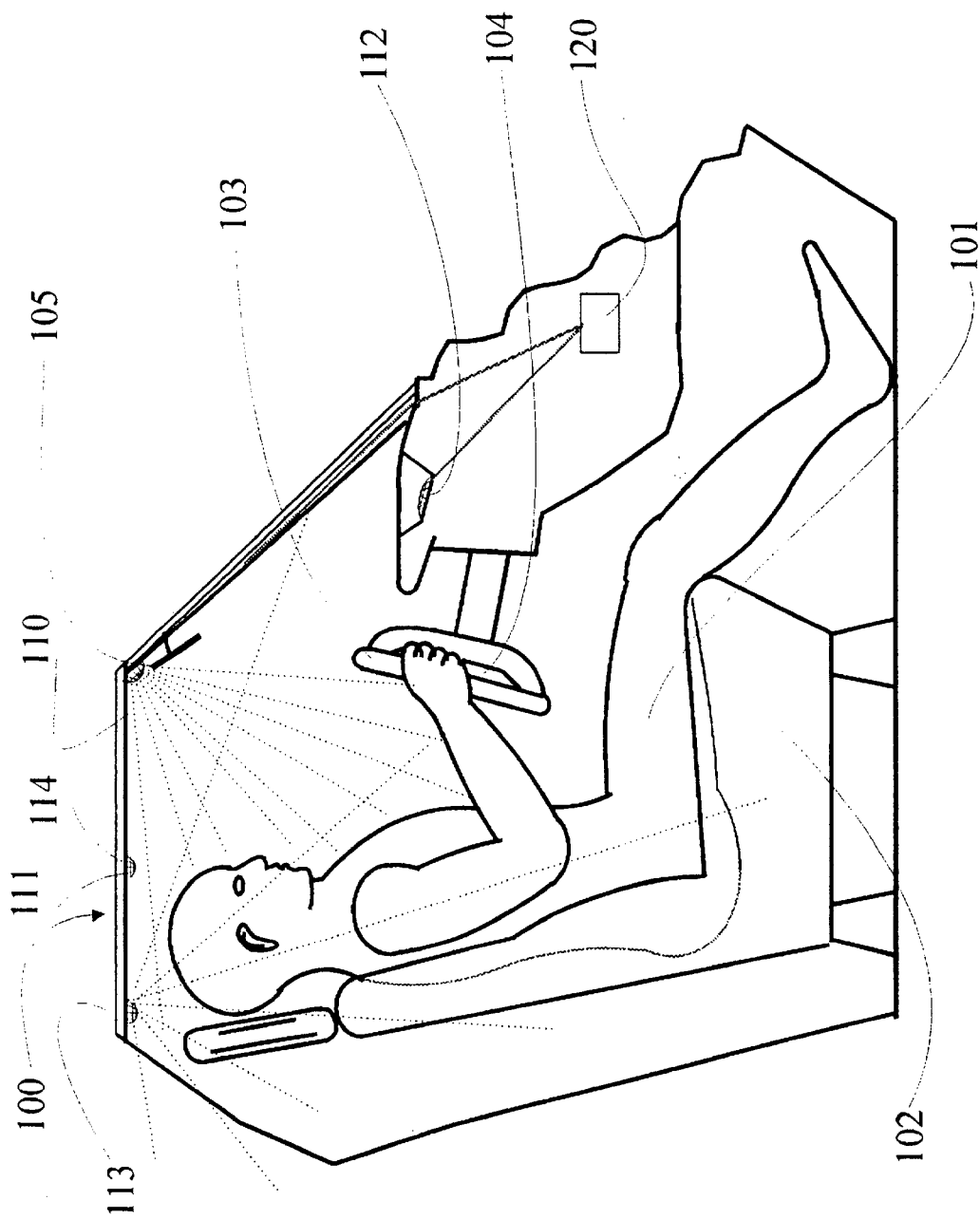


FIG. 1C

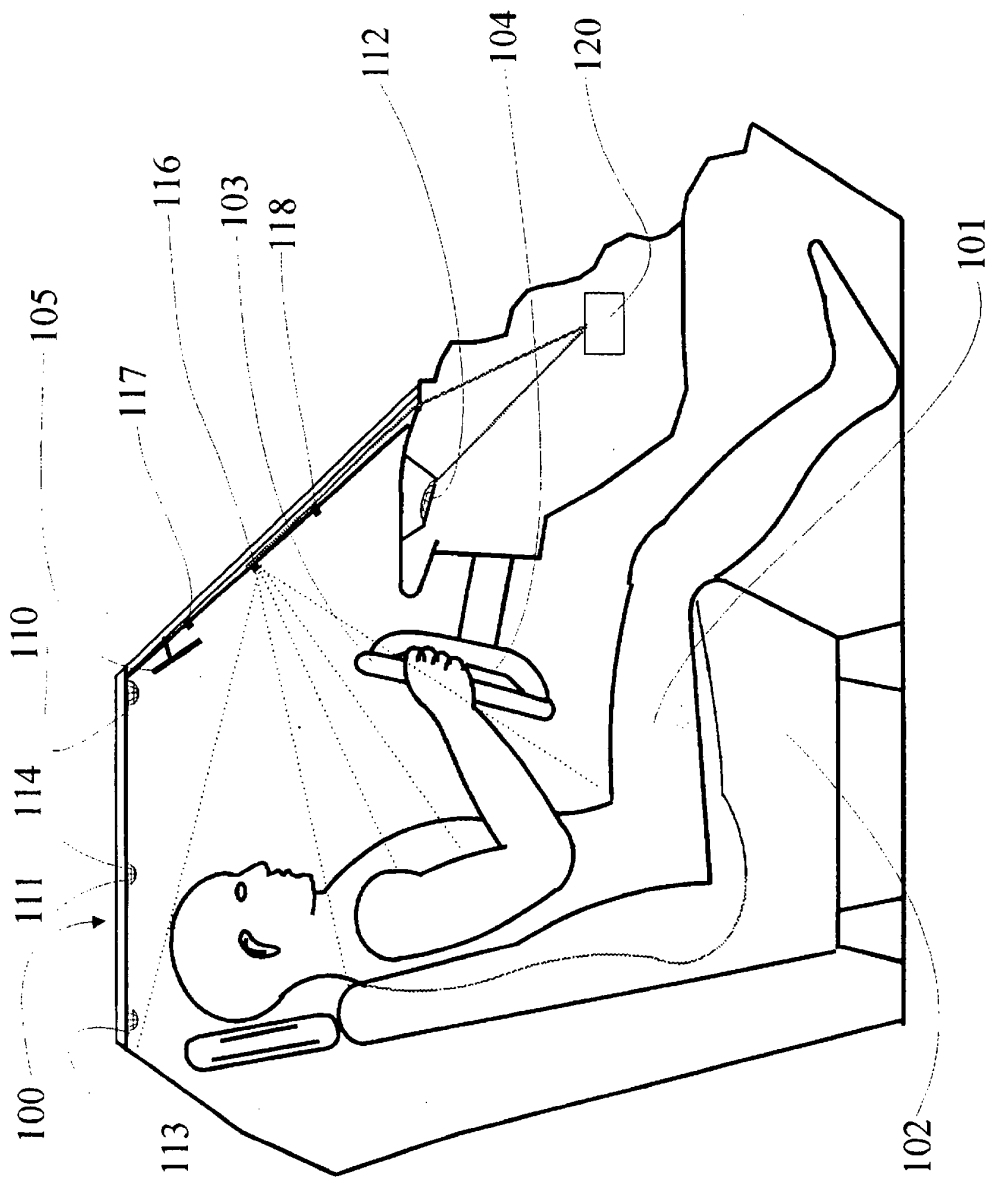


FIG. 1D

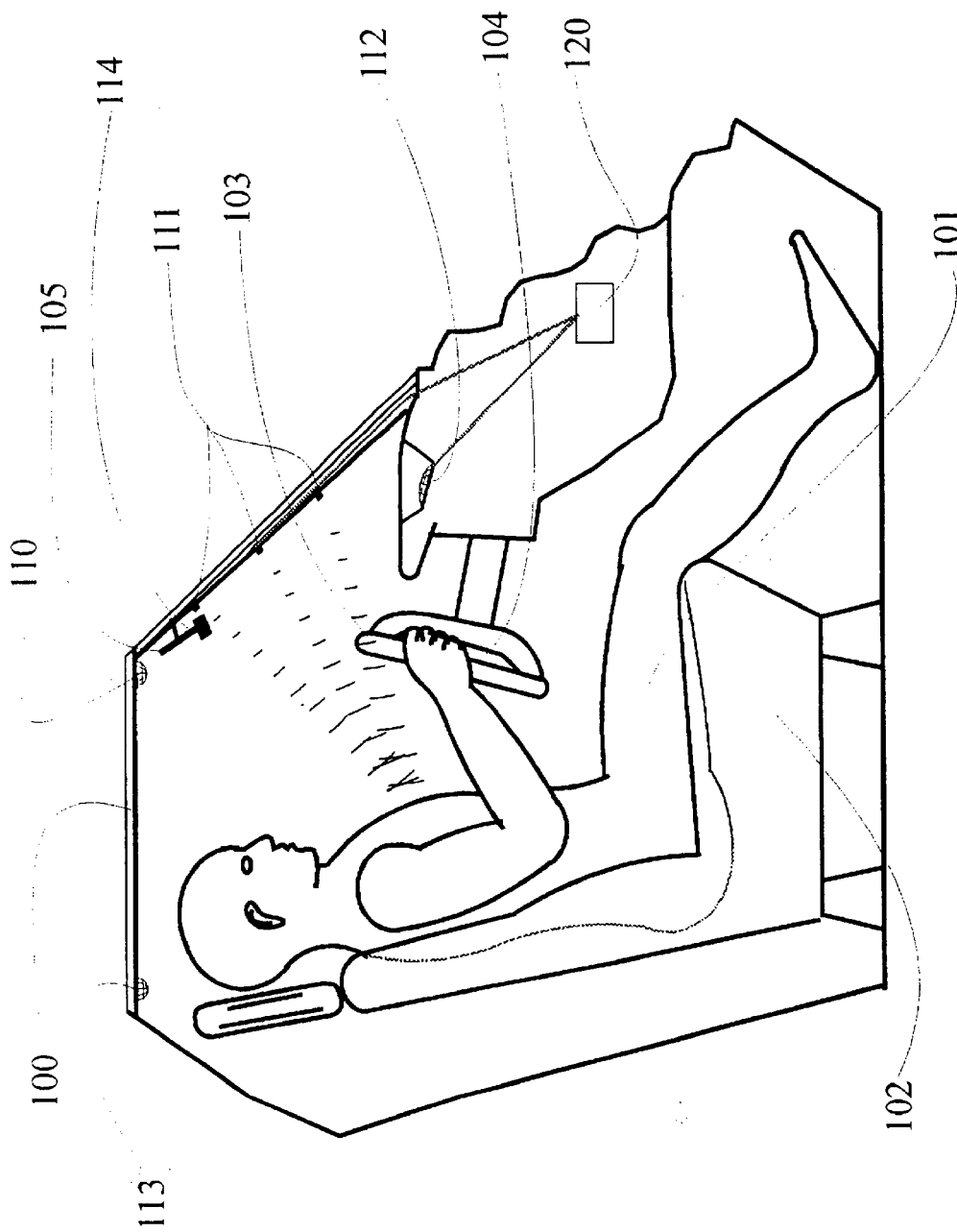


FIG. 1E

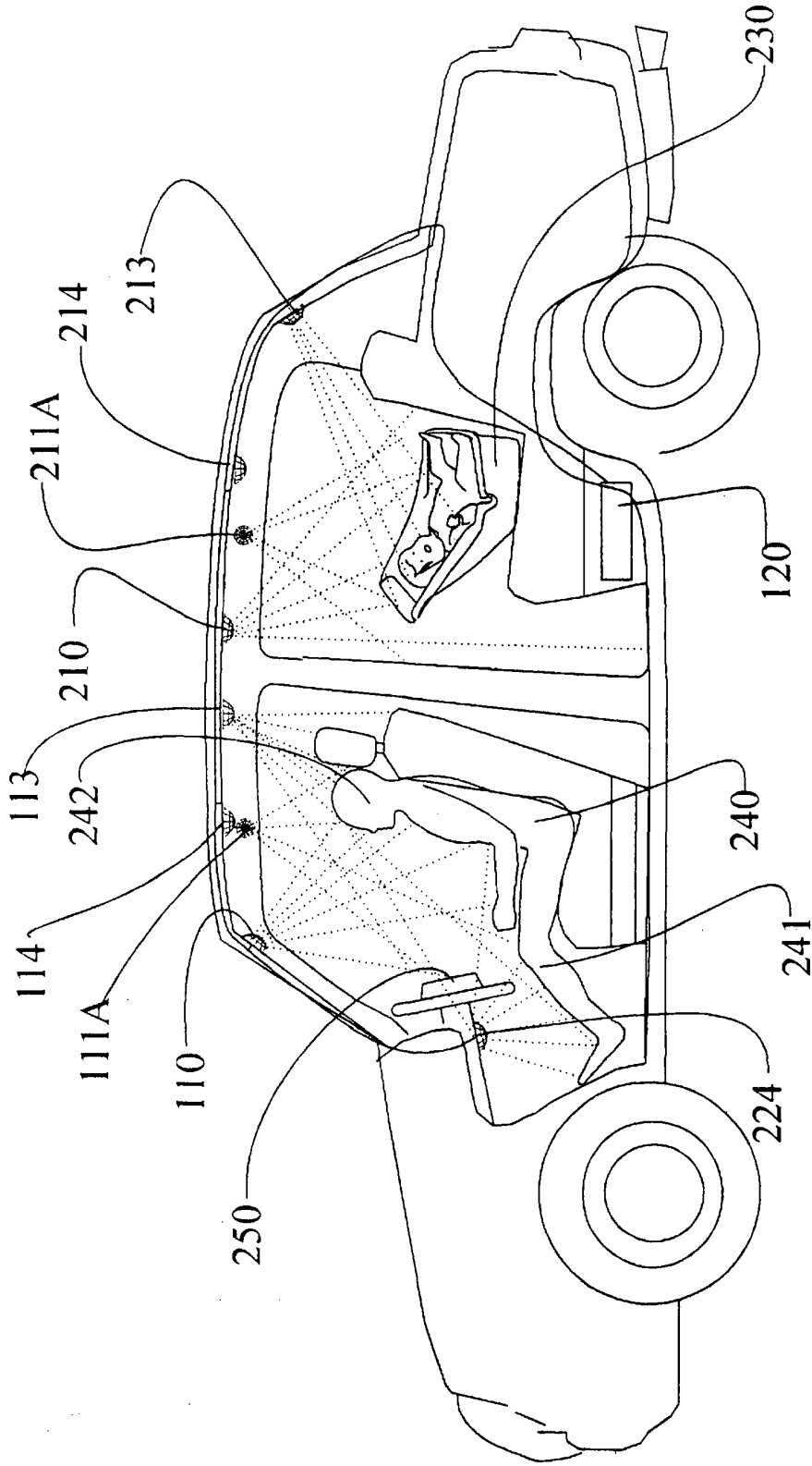


FIG. 2A

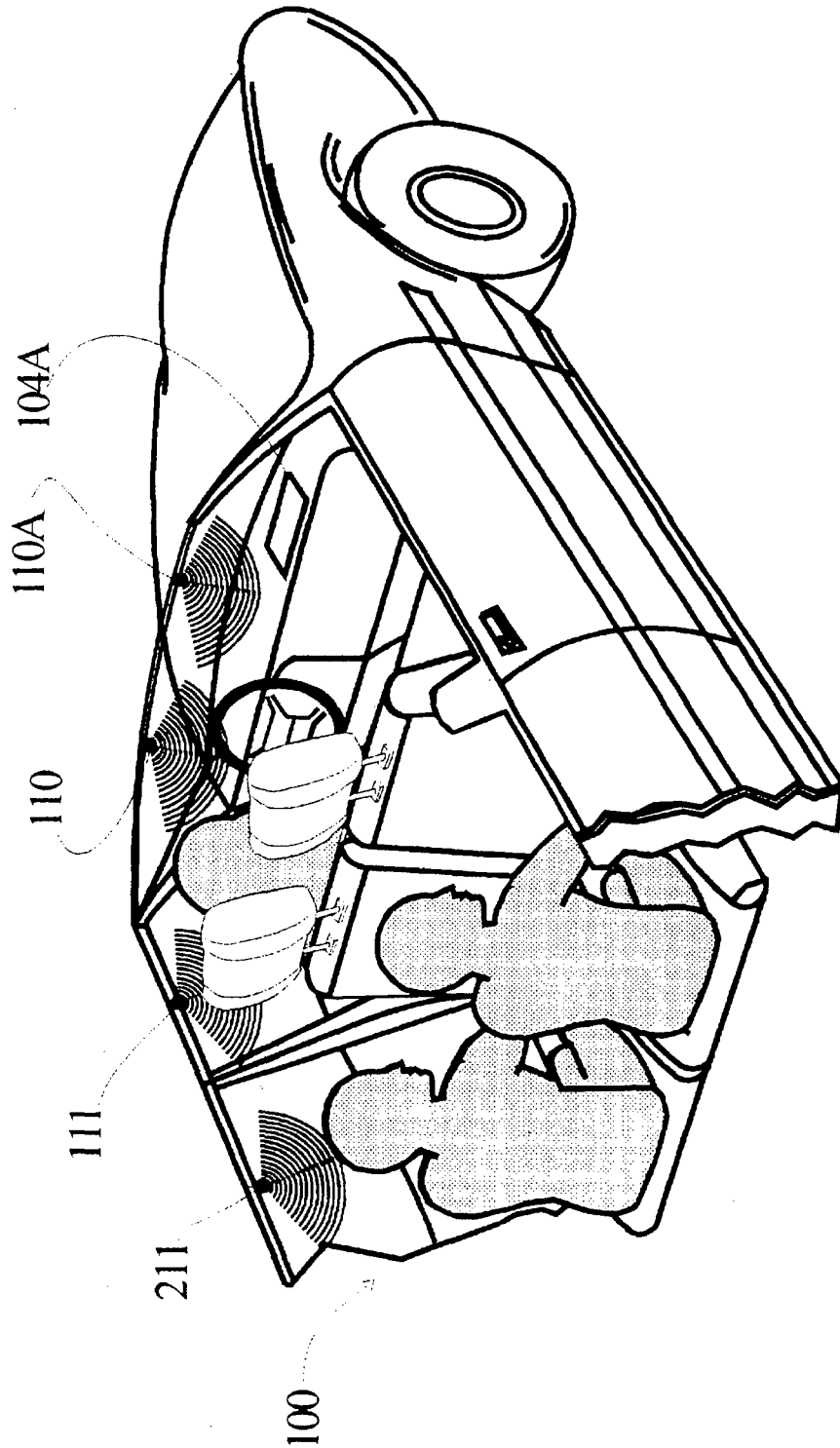


FIG. 2B

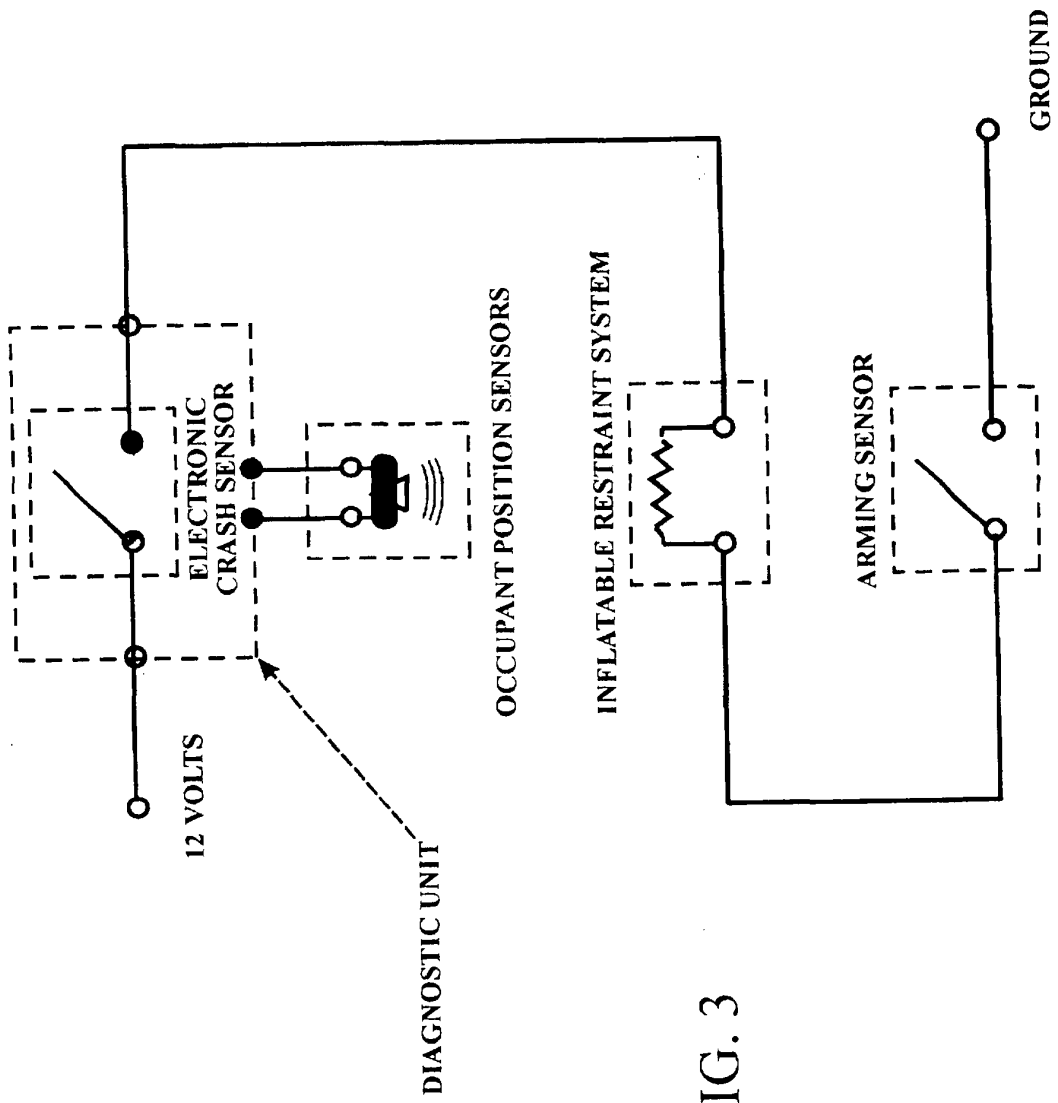


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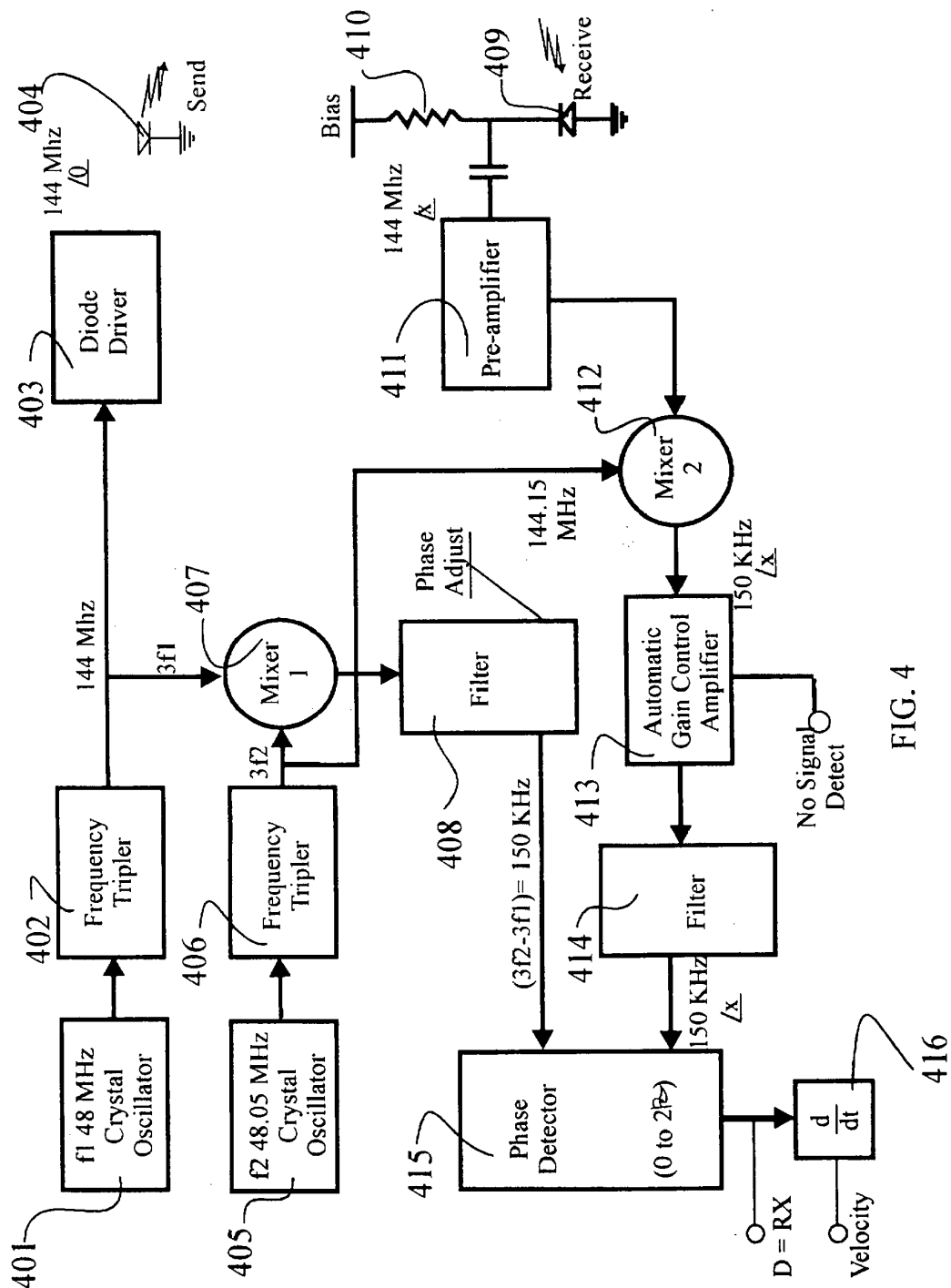


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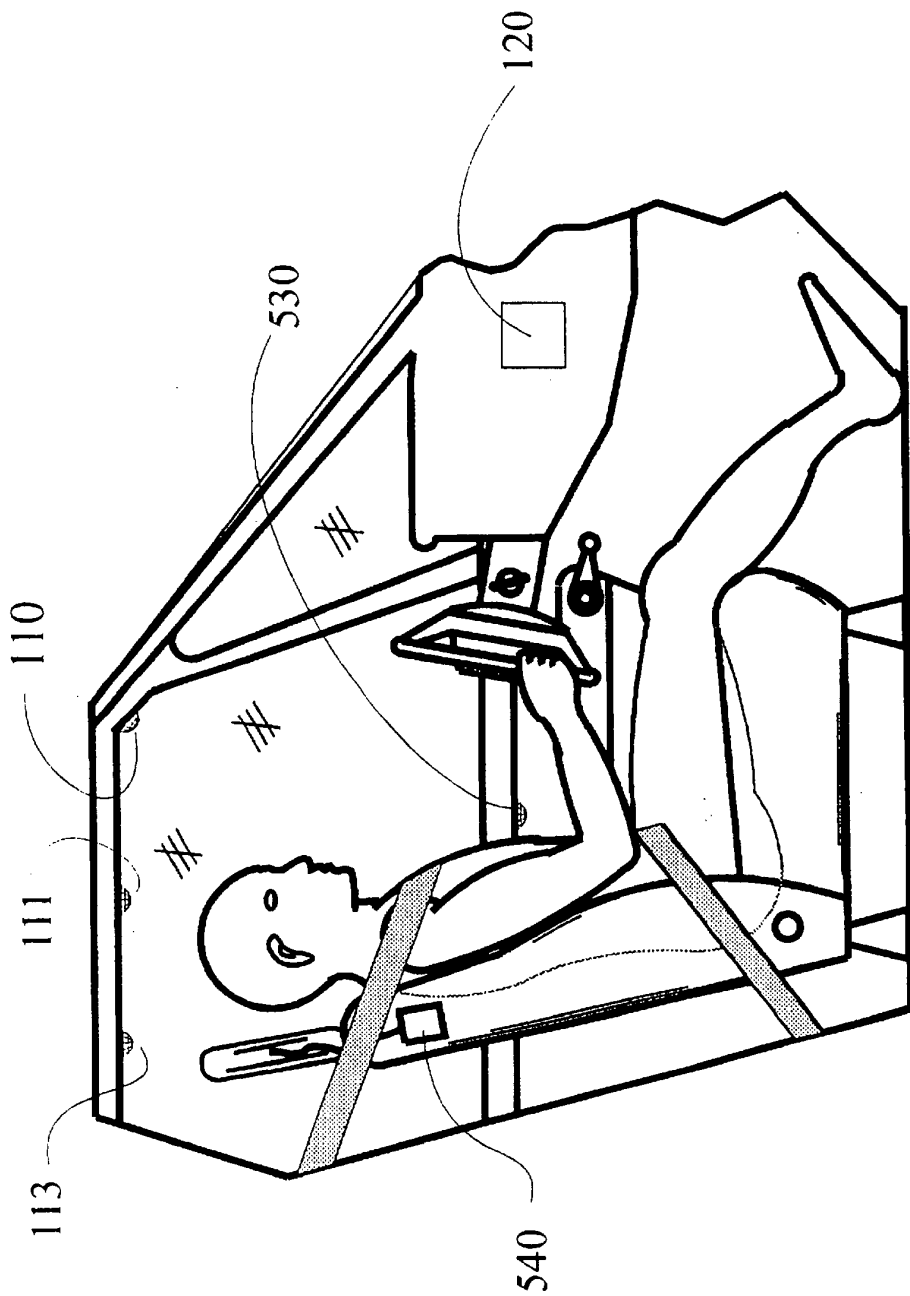


FIG. 5



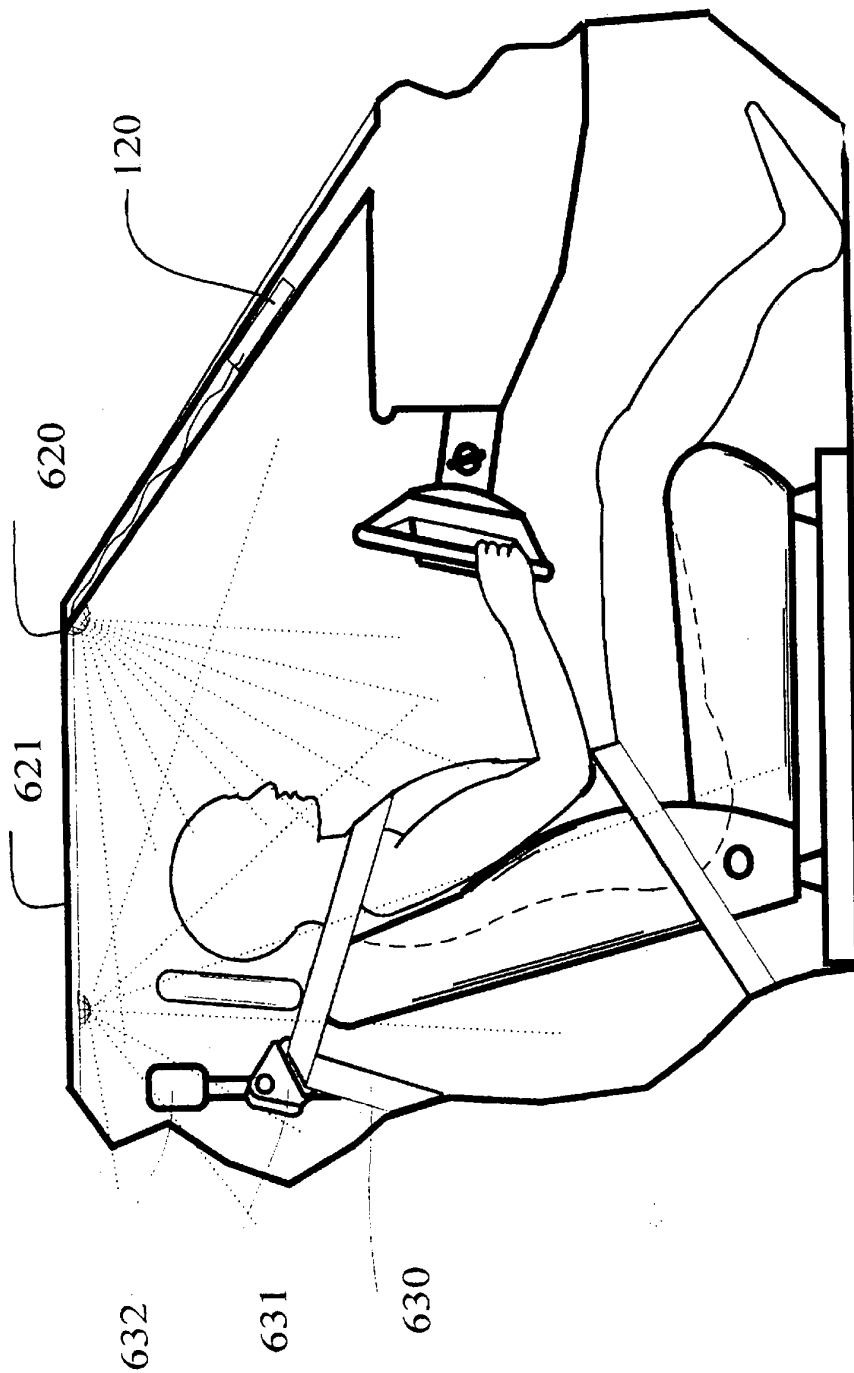


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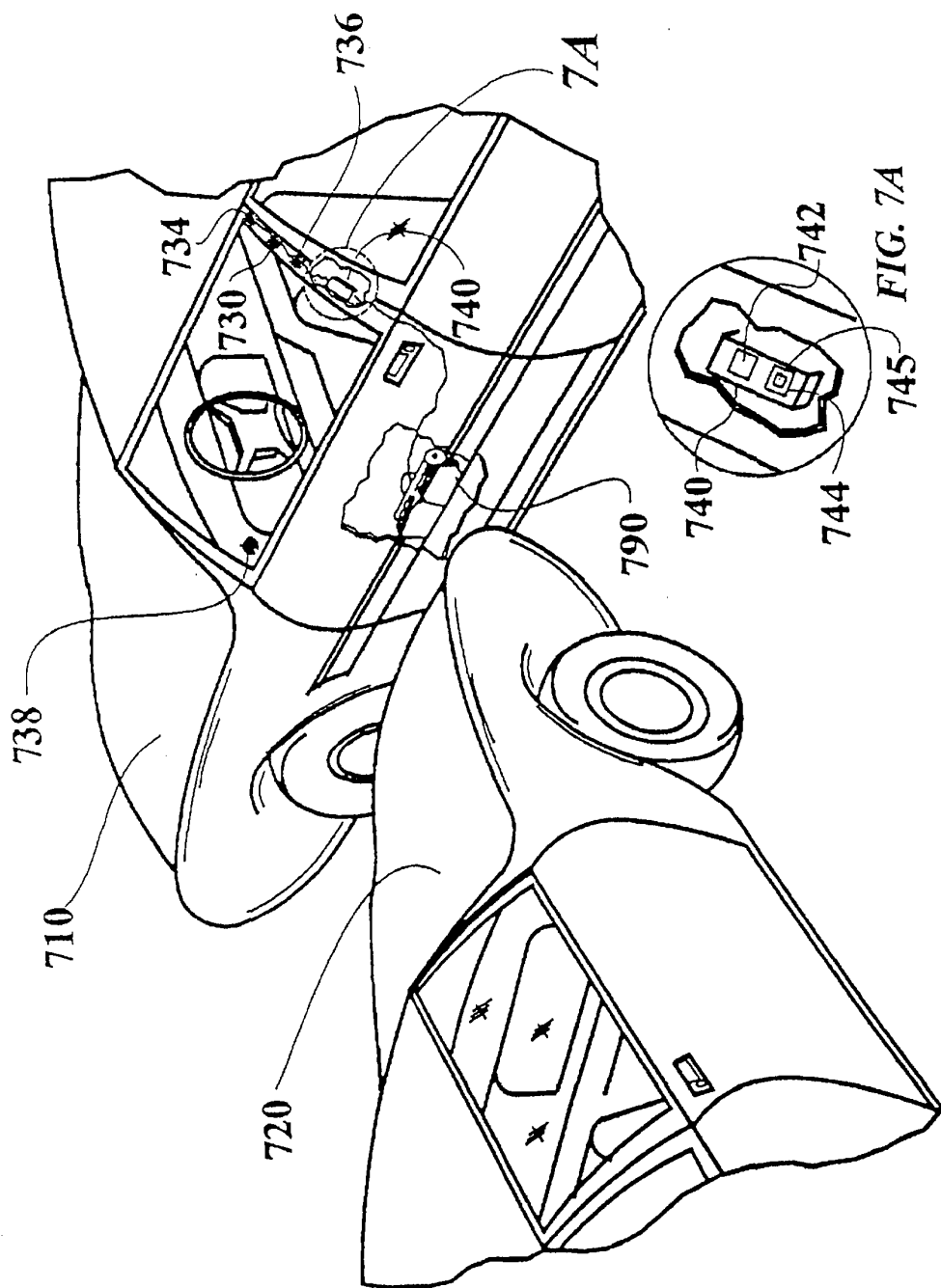


FIG. 7

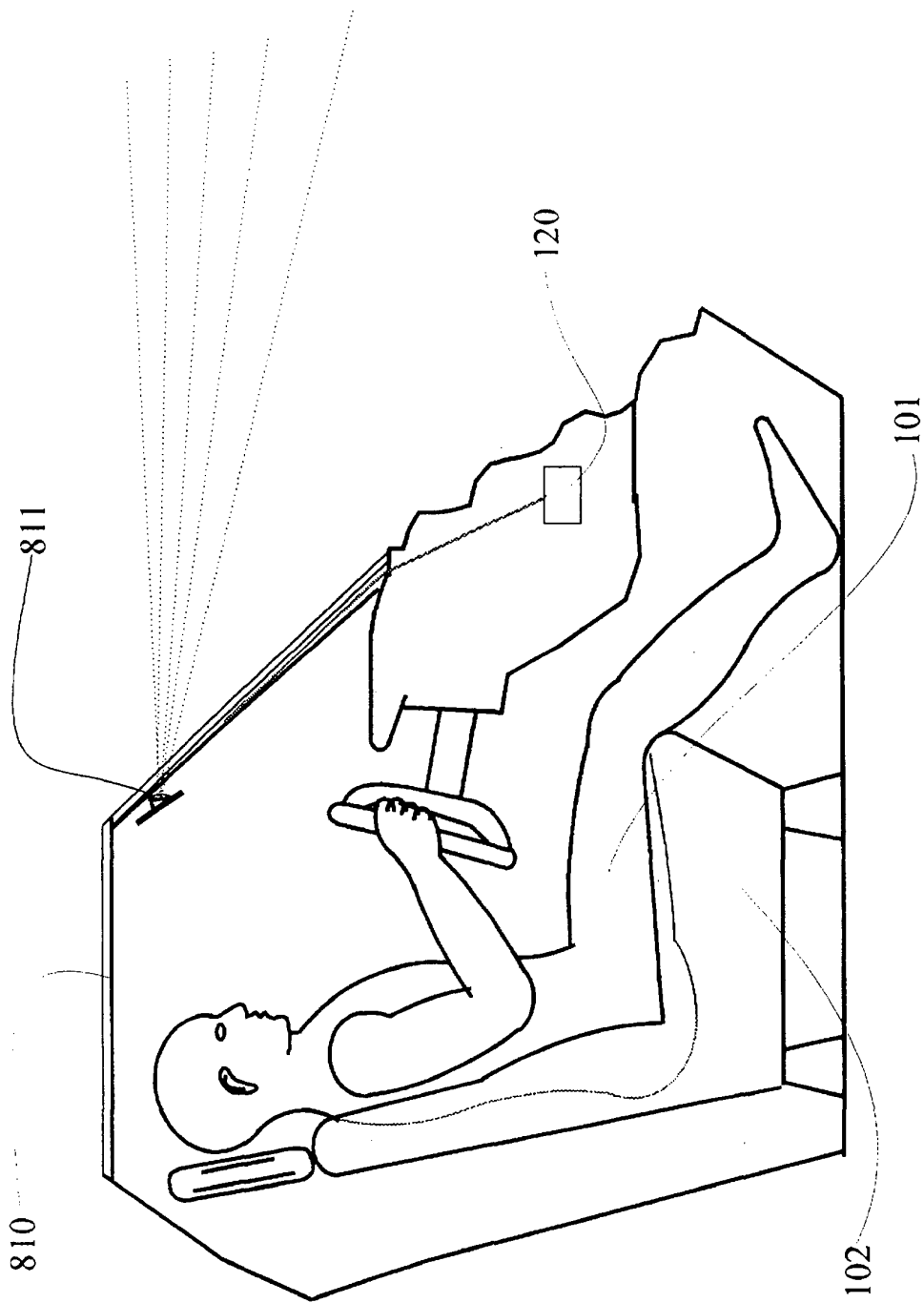


FIG. 8

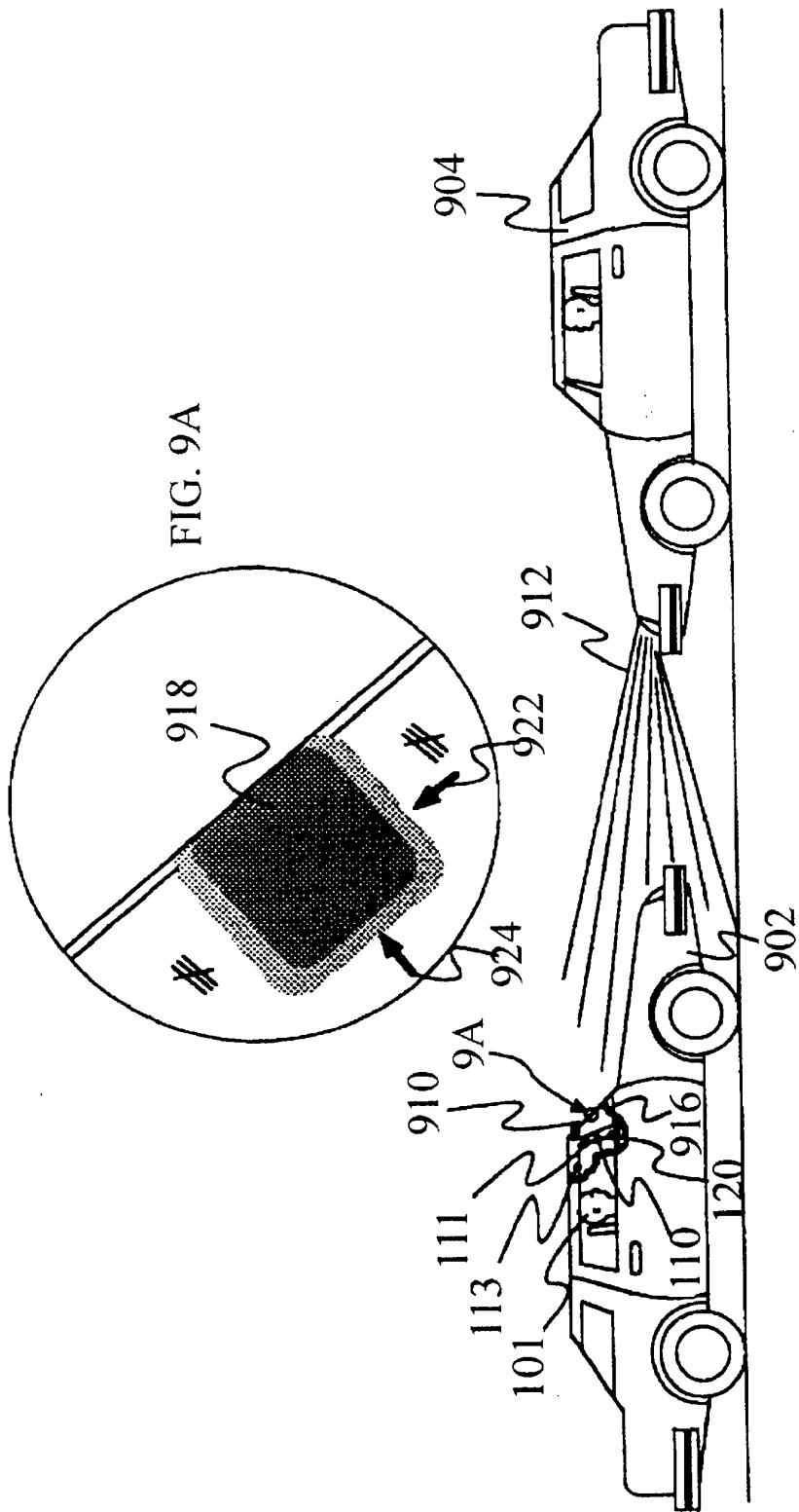


FIG. 10

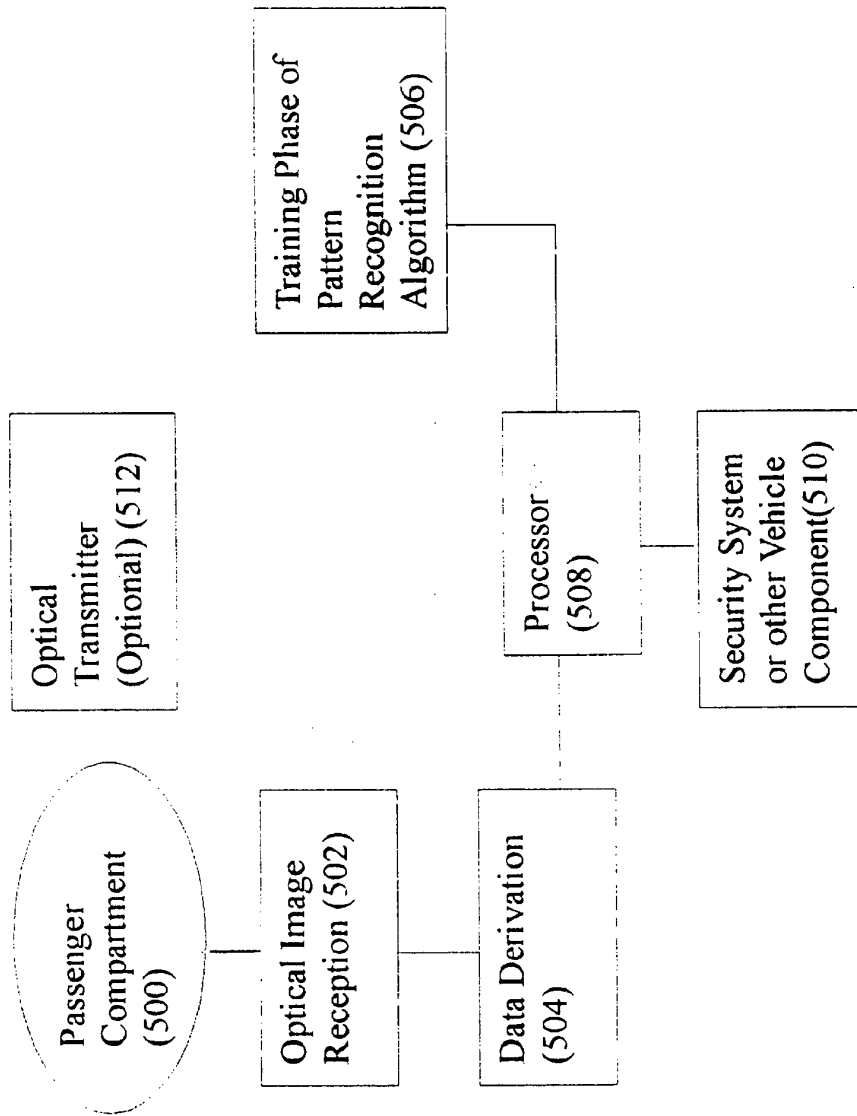
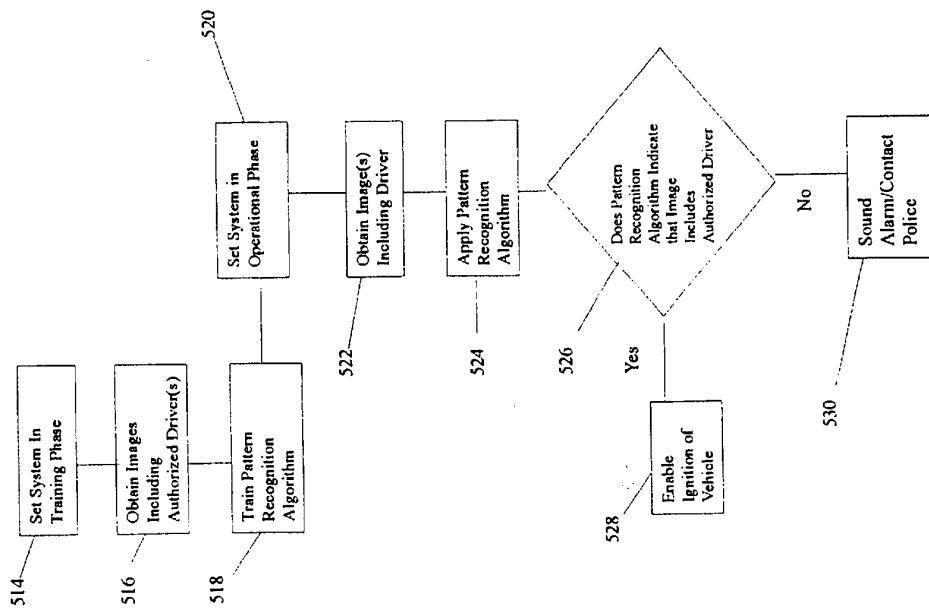


FIG. 11



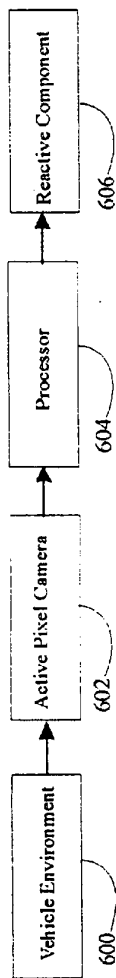


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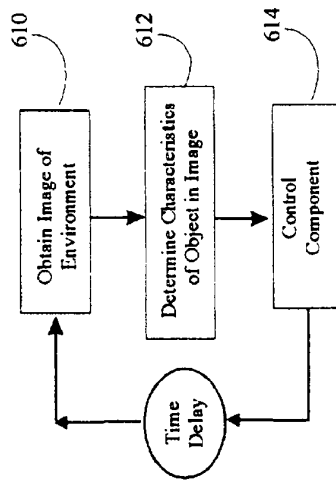


FIG. 13

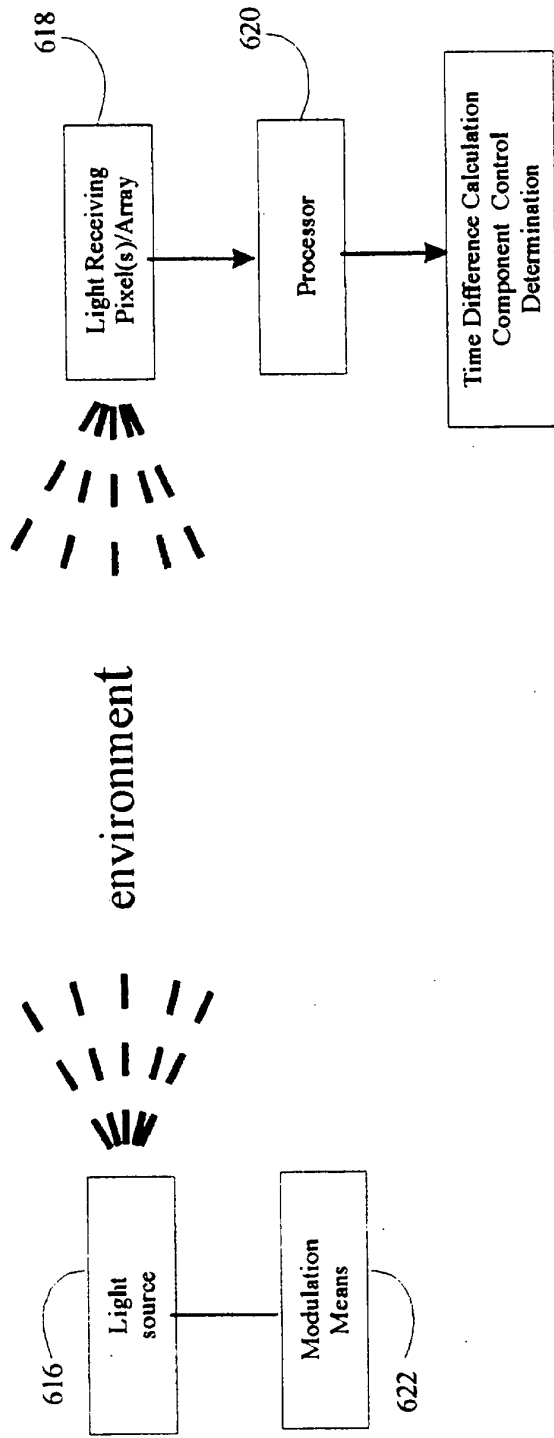
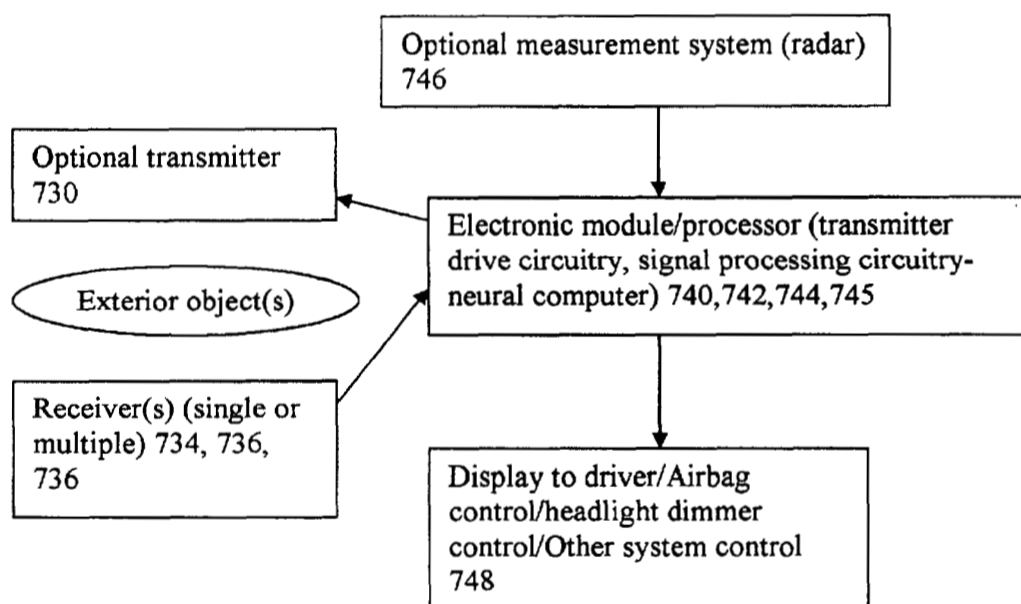


FIG. 14



FIG. 15



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## VEHICULAR MONITORING SYSTEMS USING IMAGE PROCESSING

### CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 10/116,808 filed Apr. 5, 2002 which is:

- 1) a continuation-in-part of U.S. patent application Ser. No. 09/925,043 filed Aug. 8, 2001, now U.S. Pat. No. 6,507,779, which is:
  - a) a continuation-in-part of U.S. patent application Ser. No. 09/765,559 filed Jan. 19, 2001, now U.S. Pat. No. 6,553,296; and
  - b) a continuation-in-part of U.S. patent application Ser. No. 09/389,947 filed Sep. 3, 1999, now U.S. Pat. No. 6,393,133; and
- 2) a continuation-in-part of U.S. patent application Ser. No. 09/838,919 filed Apr. 20, 2001, now U.S. Pat. No. 6,442,465, which is:
  - a) a continuation-in-part of U.S. patent application Ser. No. 09/765,559 filed Jan. 19, 2001 which is a continuation-in-part of U.S. patent application Ser. No. 09/476,255 filed Dec. 30, 1999, now U.S. Pat. No. 6,324,453, which claims priority under 35 U.S.C. §119(e) of U.S. provisional patent application Ser. No. 60/114,507 filed Dec. 31, 1998; and
  - b) a continuation-in-part of U.S. patent application Ser. No. 09/389,947 filed Sep. 3, 1999, now U.S. Pat. No. 6,393,133, which is a continuation-in-part of U.S. patent application Ser. No. 09/200,614, filed Nov. 30, 1998, now U.S. Pat. No. 6,141,432, which is a continuation of U.S. patent application Ser. No. 08/474,786 filed Jun. 7, 1995, now U.S. Pat. No. 5,845,000, all of which are incorporated by reference herein.

This application claims priority under 35 U.S.C. §119(e) of U.S. provisional patent application Ser. No. 60/114,507 filed Dec. 31, 1998 through the parent applications.

### FIELD OF THE INVENTION

The present invention relates to apparatus and methods for monitoring environments in and outside of a vehicle using image processing.

The present invention also relates to arrangements for detecting the presence, type and/or position of occupants in vehicles and objects exterior of vehicles, e.g., in a driver's blind spot, primarily using optics.

The present invention also relates to apparatus and methods for determining a distance between objects in an environment in and outside of a vehicle by image processing techniques.

### BACKGROUND OF THE INVENTION

#### 1. Prior Art on Out of Position Occupants and Rear Facing Child Seats

Whereas thousands of lives have been saved by airbags, a large number of people have also been injured, some seriously, by the deploying airbag, and over 100 people have now been killed. Thus, significant improvements need to be made to airbag systems. As discussed in detail in U.S. Pat. No. 5,653,462 referenced above, for a variety of reasons vehicle occupants may be too close to the airbag before it deploys and can be seriously injured or killed as a result of the deployment thereof. Also, a child in a rear facing child seat that is placed on the right front passenger seat is in danger of being seriously injured if the passenger airbag

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deploys. For these reasons and, as first publicly disclosed in Breed, D. S. "How Airbags Work" presented at the International Conference on Seatbelts and Airbags in 1993, in Canada, occupant position sensing and rear facing child seat detection systems are required.

Initially, these systems will solve the out-of-position occupant and the rear facing child seat problems related to current airbag systems and prevent unneeded airbag deployments when a front seat is unoccupied. However, airbags are now under development to protect rear seat occupants in vehicle crashes and all occupants in side impacts. A system will therefore be needed to detect the presence of occupants, determine if they are out-of-position and to identify the presence of a rear facing child seat in the rear seat. Future automobiles are expected to have eight or more airbags as protection is sought for rear seat occupants and from side impacts. In addition to eliminating the disturbance and possible harm of unnecessary airbag deployments, the cost of replacing these airbags will be excessive if they all deploy in an accident needlessly.

Inflators now exist which will adjust the amount of gas flowing to the airbag to account for the size and position of the occupant and for the severity of the accident. The vehicle identification and monitoring system (VIMS) discussed in U.S. Pat. No. 5,829,782 will control such inflators based on the presence and position of vehicle occupants or of a rear facing child seat. As discussed more fully below, the instant invention is an improvement on that VIMS system and uses an advanced optical system comprising one or more CCD (charge coupled device) or CMOS arrays and particularly active pixel arrays plus a source of illumination preferably combined with a trained neural network pattern recognition system.

Others have observed the need for an occupant out-of-position sensor and several methods have been disclosed in U.S. patents for determining the position of an occupant of a motor vehicle. Each of these systems, however, has significant limitations. For example, in White et al. (U.S. Pat. No. 5,071,160), a single acoustic sensor and detector is described and, as illustrated, is mounted lower than the steering wheel. White et al. correctly perceive that such a sensor could be defeated, and the airbag falsely deployed, by an occupant adjusting the control knobs on the radio and thus they suggest the use of a plurality of such sensors.

Mattes et al. (U.S. Pat. No. 5,118,134) describe a variety of methods of measuring the change in position of an occupant including ultrasonic, active or passive infrared and microwave radar sensors, and an electric eye. The sensors measure the change in position of an occupant during a crash and use that information to access the severity of the crash and thereby decide whether or not to deploy the airbag. They are thus using the occupant motion as a crash sensor. No mention is made of determining the out-of-position status of the occupant or of any of the other features of occupant monitoring as disclosed in one or more of the above-referenced patents and patent applications. It is interesting to note that nowhere does Mattes et al. discuss how to use active or passive infrared to determine the position of the occupant. As pointed out in one or more of the above-referenced patents and patent applications, direct occupant position measurement based on passive infrared is probably not possible and, until very recently, was very difficult and expensive with active infrared requiring the modulation of an expensive GaAs infrared laser. Since there is no mention of these problems, the method of use contemplated by Mattes et al. must be similar to the electric eye concept where position is measured indirectly as the occupant passes by a plurality of longitudinally spaced-apart sensors.

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The object of an occupant out-of-position sensor is to determine the location of the head and/or chest of the vehicle occupant relative to the airbag since it is the impact of either the head or chest with the deploying airbag which can result in serious injuries. Both White et al. and Mattes et al. describe only lower mounting locations of their sensors in front of the occupant such as on the dashboard or below the steering wheel. Both such mounting locations are particularly prone to detection errors due to positioning of the occupant's hands, arms and legs. This would require at least three, and preferably more, such sensors and detectors and an appropriate logic circuitry which ignores readings from some sensors if such readings are inconsistent with others, for the case, for example, where the driver's arms are the closest objects to two of the sensors.

White et al. also describe the use of error correction circuitry, without defining or illustrating the circuitry, to differentiate between the velocity of one of the occupant's hands as in the case where he/she is adjusting the knob on the radio and the remainder of the occupant. Three ultrasonic sensors of the type disclosed by White et al. might, in some cases, accomplish this differentiation if two of them indicated that the occupant was not moving while the third was indicating that he or she was. Such a combination, however, would not differentiate between an occupant with both hands and arms in the path of the ultrasonic transmitter at such a location that they were blocking a substantial view of the occupant's head or chest. Since the sizes and driving positions of occupants are extremely varied, it is now believed that pattern recognition systems and preferably trained pattern recognition systems, such as neural networks, are required when a clear view of the occupant, unimpeded by his/her extremities, cannot be guaranteed.

Fujita et al., in U.S. Pat. No. 5,074,583, describe another method of determining the position of the occupant but do not use this information to suppress deployment if the occupant is out-of-position. In fact, the closer the occupant gets to the airbag, the faster the inflation rate of the airbag is according to the Fujita et al. patent, which thereby increases the possibility of injuring the occupant. Fujita et al. do not measure the occupant directly but instead determine his or her position indirectly from measurements of the seat position and the vertical size of the occupant relative to the seat (occupant height). This occupant height is determined using an ultrasonic displacement sensor mounted directly above the occupant's head.

As discussed above, the optical systems described herein are also applicable for many other sensing applications both inside and outside of the vehicle compartment such as for sensing crashes before they occur as described in U.S. Pat. No. 5,829,782, for a smart headlight adjustment system and for a blind spot monitor (also disclosed in U.S. provisional patent application Ser. No. 60/202,424).

## 2. Definitions

Preferred embodiments of the invention are described below and unless specifically noted, it is the applicants' intention that the words and phrases in the specification and claims be given the ordinary and accustomed meaning to those of ordinary skill in the applicable art(s). If the applicant intends any other meaning, he will specifically state he is applying a special meaning to a word or phrase.

Likewise, applicants' use of the word "function" here is not intended to indicate that the applicants seek to invoke the special provisions of 35 U.S.C. §112, sixth paragraph, to define their invention. To the contrary, if applicants wish to invoke the provisions of 35 U.S.C. §112, sixth paragraph, to define their invention, they will specifically set forth in the

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claims the phrases "means for" or "step for" and a function, without also reciting in that phrase any structure, material or act in support of the function. Moreover, even if applicants invoke the provisions of 35 U.S.C. §112, sixth paragraph, to define their invention, it is the applicants' intention that their inventions not be limited to the specific structure, material or acts that are described in the preferred embodiments herein. Rather, if applicants claim their inventions by specifically invoking the provisions of 35 U.S.C. §112, sixth paragraph, it is nonetheless their intention to cover and include any and all structure, materials or acts that perform the claimed function, along with any and all known or later developed equivalent structures, materials or acts for performing the claimed function.

The use of pattern recognition is important to the instant invention as well as to one or more of those disclosed in the above-referenced patents and patent applications above. "Pattern recognition" as used herein will generally mean any system which processes a signal that is generated by an object, or is modified by interacting with an object, in order to determine which one of a set of classes that the object belongs to. Such a system might determine only that the object is or is not a member of one specified class, or it might attempt to assign the object to one of a larger set of specified classes, or find that it is not a member of any of the classes in the set. The signals processed are generally electrical signals coming from transducers which are sensitive to either acoustic or electromagnetic radiation and, if electromagnetic, they can be either visible light, infrared, ultraviolet or radar or low frequency radiation as used in capacitive sensing systems.

A trainable or a trained pattern recognition system as used herein means a pattern recognition system which is taught various patterns by subjecting the system to a variety of examples. The most successful such system is the neural network. Not all pattern recognition systems are trained systems and not all trained systems are neural networks. Other pattern recognition systems are based on fuzzy logic, sensor fusion, Kalman filters, correlation as well as linear and non-linear regression. Still other pattern recognition systems are hybrids of more than one system such as neural-fuzzy systems.

A pattern recognition algorithm will thus generally mean an algorithm applying or obtained using any type of pattern recognition system, e.g., a neural network, sensor fusion, fuzzy logic, etc.

To "identify" as used herein will usually mean to determine that the object belongs to a particular set or class. The class may be one containing, for example, all rear facing child seats, one containing all human occupants, or all human occupants not sitting in a rear facing child seat depending on the purpose of the system. In the case where a particular person is to be recognized, the set or class will contain only a single element, i.e., the person to be recognized.

To "ascertain the identity of" as used herein with reference to an object will generally mean to determine the type or nature of the object (obtain information as to what the object is), i.e., that the object is an adult, an occupied rear facing child seat, an occupied front facing child seat, an unoccupied rear facing child seat, an unoccupied front facing child seat, a child, a dog, a bag of groceries, a car, a truck, a tree, a pedestrian, a deer etc.

An "occupying item" or "occupant" of a seat or "object" in a seat may be a living occupant such as a human being or a dog, another living organism such as a plant, or an inanimate object such as a box or bag of groceries.

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A "rear seat" of a vehicle as used herein will generally mean any seat behind the front seat on which a driver sits. Thus, in minivans or other large vehicles where there are more than two rows of seats, each row of seats behind the driver is considered a rear seat and thus there may be more than one "rear seat" in such vehicles. The space behind the front seat includes any number of such rear seats as well as any trunk spaces or other rear areas such as are present in station wagons.

An optical image will generally mean any type of image obtained using electromagnetic radiation including visual, infrared and radar radiation.

In the description herein on anticipatory sensing, the term "approaching" when used in connection with the mention of an object or vehicle approaching another will usually mean the relative motion of the object toward the vehicle having the anticipatory sensor system. Thus, in a side impact with a tree, the tree will be considered as approaching the side of the vehicle and impacting the vehicle. In other words, the coordinate system used in general will be a coordinate system residing in the target vehicle. The "target" vehicle is the vehicle that is being impacted. This convention permits a general description to cover all of the cases such as where (i) a moving vehicle impacts into the side of a stationary vehicle, (ii) where both vehicles are moving when they impact, or (iii) where a vehicle is moving sideways into a stationary vehicle, tree or wall.

"Out-of-position" as used for an occupant will generally mean that the occupant, either the driver or a passenger, is sufficiently close to an occupant protection apparatus (airbag) prior to deployment that he or she is likely to be more seriously injured by the deployment event itself than by the accident. It may also mean that the occupant is not positioned appropriately in order to attain the beneficial, restraining effects of the deployment of the airbag. As for the occupant being too close to the airbag, this typically occurs when the occupant's head or chest is closer than some distance such as about 5 inches from the deployment door of the airbag module. The actual distance where airbag deployment should be suppressed depends on the design of the airbag module and is typically farther for the passenger airbag than for the driver airbag.

### 3. Pattern Recognition Prior Art

Japanese Patent No. 3-42337 (A) to Ueno discloses a device for detecting the driving condition of a vehicle driver comprising a light emitter for irradiating the face of the driver and a means for picking up the image of the driver and storing it for later analysis. Means are provided for locating the eyes of the driver and then the irises of the eyes and then determining if the driver is looking to the side or sleeping. Ueno determines the state of the eyes of the occupant rather than determining the location of the eyes relative to the other parts of the vehicle passenger compartment. Such a system can be defeated if the driver is wearing glasses, particularly sunglasses, or another optical device which obstructs a clear view of his/her eyes. Pattern recognition technologies such as neural networks are not used.

U.S. Pat. No. 5,008,946 to Ando uses a complicated set of rules to isolate the eyes and mouth of a driver and uses this information to permit the driver to control the radio, for example, or other systems within the vehicle by moving his eyes and/or mouth. Ando uses natural light and analyzes only the head of the driver. He also makes no use of trainable pattern recognition systems such as neural networks, nor is there any attempt to identify the contents of the vehicle nor of their location relative to the vehicle passenger compartment. Rather, Ando is limited to control of vehicle devices by responding to motion of the driver's mouth and eyes.

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U.S. Pat. No. 5,298,732 to Chen also concentrates on locating the eyes of the driver so as to position a light filter between a light source such as the sun or the lights of an oncoming vehicle, and the driver's eyes. Chen does not explain in detail how the eyes are located but does supply a calibration system whereby the driver can adjust the filter so that it is at the proper position relative to his or her eyes. Chen references the use of automatic equipment for determining the location of the eyes but does not describe how this equipment works. In any event, there is no mention of illumination of the occupant, monitoring the position of the occupant, other than the eyes, determining the position of the eyes relative to the passenger compartment, or identifying any other object in the vehicle other than the driver's eyes. Also, there is no mention of the use of a trainable pattern recognition system.

U.S. Pat. No. 5,305,012 to Faris also describes a system for reducing the glare from the headlights of an oncoming vehicle. Faris locates the eyes of the occupant utilizing two spaced apart infrared cameras using passive infrared radiation from the eyes of the driver. Again, Faris is only interested in locating the driver's eyes relative to the sun or oncoming headlights and does not identify or monitor the occupant or locate the occupant relative to the passenger compartment or the airbag. Also, Faris does not use trainable pattern recognition techniques such as neural networks. Faris, in fact, does not even say how the eyes of the occupant are located but refers the reader to a book entitled *Robot Vision* (1991) by Berthold Horn, published by MIT Press, Cambridge, Mass. A review of this book did not appear to provide the answer to this question. Also, Faris uses the passive infrared radiation rather than illuminating the occupant with active infrared radiation or in general electromagnetic radiation.

The use of neural networks as the pattern recognition technology is important to several of the implementations of this invention since it makes the monitoring system robust, reliable and practical. The resulting algorithm created by the neural network program is usually only a few hundred lines of code written in the C or C++ computer language as opposed to typically many hundreds of lines when the techniques of the above patents to Ando, Chen and Faris are implemented. As a result, the resulting systems are easy to implement at a low cost, making them practical for automotive applications. The cost of the CCD and CMOS arrays, for example, have been prohibitively expensive until recently, rendering their use for VIMS impractical. Similarly, the implementation of the techniques of the above referenced patents requires expensive microprocessors while the implementation with neural networks and similar trainable pattern recognition technologies permits the use of low cost microprocessors typically costing less than \$10 in large quantities.

The present invention preferably uses sophisticated trainable pattern recognition capabilities such as neural networks. Usually the data is preprocessed, as discussed below, using various feature extraction techniques. An example of such a pattern recognition system using neural networks on sonar signals is discussed in two papers by Gorman, R. P. and Sejnowski, T. J. "Analysis of Hidden Units in a Layered Network Trained to Classify Sonar Targets", *Neural Networks*, Vol. 1. pp. 75-89, 1988, and "Learned Classification of Sonar Targets Using a Massively Parallel Network", *IEEE Transactions on Acoustics, Speech, and Signal Processing*, Vol. 36, No. 7, July 1988. Examples of feature extraction techniques can be found in U.S. Pat. No. 4,906,940 entitled "Process and Apparatus for the Automatic

Detection and Extraction of Features in Images and Displays" to Green et al. Examples of other more advanced and efficient pattern recognition techniques can be found in U.S. Pat. No. 5,390,136 entitled "Artificial Neuron and Method of Using Same" and U.S. Pat. No. 5,517,667 entitled "Neural Network and Method of Using Same" to S. T. Wang. Other examples include U.S. Pat. Nos. 5,235,339 (Morrison et al.), 5,214,744 (Schweizer et al), 5,181,254 (Schweizer et al), and 4,881,270 (Knecht et al). All of the above references are incorporated herein by reference. Neural networks as used herein include all types of neural networks including modular neural networks, cellular neural networks and support vector machines and all combinations as described in detail in U.S. Pat. No. 6,445,988, which is incorporated herein by reference in its entirety, and referred to therein as "combination neural networks".

#### 4. Optics

Optics can be used in several configurations for monitoring the interior of a passenger compartment or exterior environment of an automobile. In one known method, a laser optical system uses a GaAs infrared laser beam to momentarily illuminate an object, occupant or child seat, in the manner as described and illustrated in FIG. 8 of U.S. Pat. No. 5,829,782 referenced above. The receiver can be a charge-coupled device or CCD (a type of TV camera), or a CMOS imager to receive the reflected light. The laser can either be used in a scanning mode, or, through the use of a lens, a cone of light can be created which covers a large portion of the object. In these configurations, the light can be accurately controlled to only illuminate particular positions of interest within or around the vehicle. In the scanning mode, the receiver need only comprise a single or a few active elements while in the case of the cone of light, an array of active elements is needed. The laser system has one additional significant advantage in that the distance to the illuminated object can be determined as disclosed in the commonly owned '462 patent as also described below. When a single receiving element is used, a PIN or avalanche diode is preferred.

In a simpler case, light generated by a non-coherent light emitting diode (LED) device is used to illuminate the desired area. In this case, the area covered is not as accurately controlled and a larger CCD or CMOS array is required. Recently, however, the cost of CCD and CMOS arrays has dropped substantially with the result that this configuration may now be the most cost-effective system for monitoring the passenger compartment as long as the distance from the transmitter to the objects is not needed. If this distance is required, then the laser system, a stereographic system, a focusing system, a combined ultrasonic and optic system, or a multiple CCD or CMOS array system as described herein is required. Alternately, a modulation system such as used with the laser distance system can be used with a CCD or CMOS camera and distance determined on a pixel by pixel basis.

A mechanical focusing system, such as used on some camera systems can determine the initial position of an occupant but is too slow to monitor his/her position during a crash. Although the example of an occupant is used herein as an example, the same or similar principles apply to objects exterior to the vehicle. A distance measuring system based on focusing is described in U.S. Pat. No. 5,193,124 (Subbarao) which can either be used with a mechanical focusing system or with two cameras, the latter of which would be fast enough. Although the Subbarao patent provides a good discussion of the camera focusing art and is therefore incorporated herein by reference, it is a more

complicated system than is needed for the practicing the instant invention. In fact, a neural network can also be trained to perform the distance determination based on the two images taken with different camera settings or from two adjacent CCD's and lens having different properties as the cameras disclosed in Subbarao making this technique practical for the purposes of this instant invention. Distance can also be determined by the system disclosed in U.S. Pat. No. 5,003,166 (Girod) by the spreading or defocusing of a pattern of structured light projected onto the object of interest. Distance can also be measured by using time of flight measurements of the electromagnetic waves or by multiple CCD or CMOS arrays as is a principle teaching of this invention.

In each of these cases, regardless of the distance measurement system used, a trained pattern recognition system, as defined above, is used in the instant invention to identify and classify, and in some cases to locate, the illuminated object and its constituent parts.

#### 5. Optics and Acoustics

The laser systems described above are expensive due to the requirement that they be modulated at a high frequency if the distance from the airbag to the occupant, for example, needs to be measured. Alternately, modulation of another light source such as an LED can be done and the distance measurement accomplished using a CCD or CMOS array on a pixel by pixel basis.

Both laser and non-laser optical systems in general are good at determining the location of objects within the two dimensional plane of the image and a pulsed laser radar system in the scanning mode can determine the distance of each part of the image from the receiver by measuring the time of flight through range gating techniques. It is also possible to determine distance with the non-laser system by focusing as discussed above, or stereographically if two spaced apart receivers are used and, in some cases the mere location in the field of view can be used to estimate the position relative to the airbag, for example. Finally, a recently developed pulsed quantum well diode laser also provides inexpensive distance measurements as discussed below.

Acoustic systems are additionally quite effective at distance measurements since the relatively low speed of sound permits simple electronic circuits to be designed and minimal microprocessor capability is required. If a coordinate system is used where the z axis is from the transducer to the occupant, acoustics are good at measuring z dimensions while simple optical systems using a single CCD are good at measuring x and y dimensions. The combination of acoustics and optics, therefore, permits all three measurements to be made from one location with low cost components as discussed in commonly assigned U.S. Pat. Nos. 5,845,000 and 5,835,613.

One example of a system using these ideas is an optical system which floods the passenger seat with infrared light coupled with a lens and CCD or CMOS array which receives and displays the reflected light and an analog to digital converter (ADC), or frame grabber, which digitizes the output of the CCD or CMOS and feeds it to a feature extraction algorithm (such as an edge detector) and then to an Artificial Neural Network (ANN) or other pattern recognition system for analysis. This system uses an ultrasonic transmitter and receiver for measuring the distances to the objects located in the passenger seat. The receiving transducer feeds its data into an ADC and from there the converted data is directed into the ANN. The same ANN can be used for both systems thereby providing full three-

dimensional data for the ANN to analyze. This system, using low cost components, will permit accurate identification and distance measurements. If a phased array system is added to the acoustic part of the system, the optical part can determine the location of the driver's ears, for example, and the phased array can direct a narrow beam to the location and determine the distance to the occupant's ears.

Although the use of ultrasound for distance measurement has many advantages, it also has some drawbacks. First, the speed of sound limits the rate at which the position of the occupant can be updated to approximately 10 milliseconds, which though sufficient for most cases, is marginal if the position of the occupant is to be tracked during a vehicle crash. Second, ultrasound waves are diffracted by changes in air density that can occur when the heater or air conditioner is operated or when there is a high-speed flow of air past the transducer. Third, the resolution of ultrasound is limited by its wavelength and by the transducers, which are high Q tuned devices. Typically, the resolution of ultrasound is on the order of about 2 to 3 inches. Finally, the fields from ultrasonic transducers are difficult to control so that reflections from unwanted objects or surfaces add noise to the data.

#### 6. Applications

The applications for this technology are numerous as described in the patents and patent applications listed above. They include: (i) the monitoring of the occupant for safety purposes to prevent airbag deployment induced injuries, (ii) the locating of the eyes of the occupant (driver) to permit automatic adjustment of the rear view mirror(s), (iii) the location of the seat to place the occupant's eyes at the proper position to eliminate the parallax in a heads-up display in night vision systems, (iv) the location of the ears of the occupant for optimum adjustment of the entertainment system, (v) the identification of the occupant for security reasons, (vi) the determination of obstructions in the path of a closing door or window, (vii) the determination of the position of the occupant's shoulder so that the seat belt anchorage point can be adjusted for the best protection of the occupant, (viii) the determination of the position of the rear of the occupant's head so that the headrest can be adjusted to minimize whiplash injuries in rear impacts, (ix) anticipatory crash sensing, (x) blind spot detection, (xi) smart headlight dimmers, (xii) sunlight and headlight glare reduction and many others. In fact, over forty products alone have been identified based on the ability to identify and monitor objects and parts thereof in the passenger compartment of an automobile or truck. In addition, there are many applications of the apparatus and methods described herein for monitoring the environment exterior to the vehicle.

#### 7. Other Prior Art

European Patent Application No. 98110617.2 (Publication No. 0 885 782 A1), corresponding to U.S. patent application Ser. No. 08/872,836 filed Jun. 11, 1997, describes a purportedly novel motor vehicle control system including a pair of cameras which operatively produce first and second images of a passenger area. A distance processor determines the distances that a plurality of features in the first and second images are from the cameras based on the amount that each feature is shifted between the first and second images. An analyzer processes the determined distances and determines the size of an object on the seat. Additional analysis of the distance also may determine movement of the object and the rate of movement. The distance information also can be used to recognize predefined patterns in the images and this identify objects. An air bag controller utilizes the determined object characteristics in controlling deployment of the air bag.

A paper entitled "Sensing Automobile Occupant Position with Optical Triangulation" by W. Chappelle, Sensors, December 1995, describes the use of optical triangulation techniques for determining the presence and position of people or rear-facing infant seats in the passenger compartment of a vehicle in order to guarantee the safe deployment of an air bag. The paper describes a system called the "Takata Safety Shield" which purportedly makes high-speed distance measurements from the point of air bag deployment using a modulated infrared beam projected from an LED source. Two detectors are provided, each consisting of an imaging lens and a position-sensing detector.

A paper entitled "An Interior Compartment Protection System based on Motion Detection Using CMOS Imagers" by S. B. Park et al., 1998 IEEE International Conference on Intelligent Vehicles, describes a purportedly novel image processing system based on a CMOS image sensor installed at the car roof for interior compartment monitoring including theft prevention and object recognition. One disclosed camera system is based on a CMOS image sensor and a near infrared (NIR) light emitting diode (LED) array.

A paper entitled "A 256x256 CMOS Brightness Adaptive Imaging Array with Column-Parallel Digital Output" by C. Sodini et al., 1988 IEEE International Conference on Intelligent Vehicles, describes a CMOS image sensor for intelligent transportation system applications such as adaptive cruise control and traffic monitoring. Among the purported novelties is the use of a technique for increasing the dynamic range in a CMOS imager by a factor of approximately 20, which technique is based on a previously described technique for CCD imagers.

A paper entitled "Intelligent System for Video Monitoring of Vehicle Cockpit" by S. Boverie et al., SAE Technical Paper Series No. 980613, Feb. 23-26, 1998, describes the installation of an optical/retina sensor in the vehicle and several uses of this sensor. Possible uses are said to include observation of the driver's face (eyelid movement) and the driver's attitude to allow analysis of the driver's vigilance level and warn him/her about critical situations and observation of the front passenger seat to allow the determination of the presence of somebody or something located on the seat and to value the volumetric occupancy of the passenger for the purpose of optimizing the operating conditions for air bags.

Ishikawa et al. (U.S. Pat. No. 4,625,329) describes an image analyzer (M5 in FIG. 1) for analyzing the position of driver including an infrared light source which illuminates the driver's face and an image detector which receives light from the driver's face, determines the position of facial feature, e.g., the eyes in three dimensions, and thus determines the position of the driver in three dimensions. A pattern recognition process is used to determine the position of the facial features and entails converting the pixels forming the image to either black or white based on intensity and conducting an analysis based on the white area in order to find the largest contiguous white area and the center point thereof. Based on the location of the center point of the largest contiguous white area, the driver's height is derived and a heads up display is adjusted so information is within driver's field of view. The pattern recognition process can be applied to detect the eyes, mouth, or nose of the driver based on the differentiation between the white and black areas.

Ando (U.S. Pat. No. 5,008,946) describes a system which recognizes an image and specifically ascertains the position of the pupils and mouth of the occupant to enable movement of the pupils and mouth to control electrical devices installed in the automobile. The system includes a camera which

takes a picture of the occupant and applies algorithms based on pattern recognition techniques to analyze the picture, converted into an electrical signal, to determine the position of certain portions of the image, namely the pupils and mouth.

Masamori (U.S. Pat. No. 5,227,784) describes a system which is based on radar, specifically it is a collision avoidance system aimed at detecting vehicles which are at some distance from the vehicle.

Suzuki et al. (U.S. Pat. No. 5,026,153) describes a vehicle tracking control for continuously detecting the distance and direction to a preceding vehicle irrespective of background dark/light distribution. In this system, every vehicle must have a light on its rear that emits a constant or time varying signal and two photoelectric sensors that zero in on the light emitted from the preceding vehicle are used and thereby determine both the distance and angular position of the preceding vehicle.

Krumm (U.S. Pat. No. 5,983,147) describes a system for determining the occupancy of a passenger compartment including a pair of cameras mounted so as to obtain binocular stereo images of the same location in the passenger compartment. A representation of the output from the cameras is compared to stored representations of known occupants and occupancy situations to determine which stored representation the output from the cameras most closely approximates. The stored representations include that of the presence or absence of a person or an infant seat in the front passenger seat.

Farmer et al. (U.S. Pat. No. 6,005,958) describes a method and system for detecting the type and position of a vehicle occupant utilizing a single camera unit. The single camera unit is positioned at the driver or passenger side A-pillar in order to generate data of the front seating area of the vehicle. The type and position of the occupant is used to optimize the efficiency and safety in controlling deployment of an occupant protection device such as an air bag.

A paper by Rudolf Schwarte, et al. entitled "New Powerful Sensory Tool in Automotive Safety Systems Based on PMD-Technology", Eds. S. Krueger, W. Gessner, *Proceedings of the AMAA 2000 Advanced Microsystems for Automotive Applications 2000*, Springer Verlag; Berlin, Heidelberg, N.Y., ISBN 3-540-67087-4, describes an implementation of the teachings of the instant invention wherein a modulated light source is used in conjunction with phase determination circuitry to locate the distance to objects in the image on a pixel by pixel basis. This camera is an active pixel camera the use of which for internal and external vehicle monitoring is also a teaching of this invention. The novel feature of the PMD camera is that the pixels are designed to provide a distance measuring capability within each pixel itself. This then is a novel application of the active pixel and distance measuring teachings of the instant invention.

The instant invention as described in the above-referenced commonly assigned patents and patent applications, teaches the use of modulating the light used to illuminate an object and to determine the distance to that object based on the phase difference between the reflected radiation and the transmitted radiation. The illumination can be modulated at a single frequency when short distances such as within the passenger compartment are to be measured. Typically, the modulation wavelength would be selected such that one wave would have a length of approximately one meter or less. This would provide resolution of 1 cm or less. For larger vehicles, a longer wavelength would be desirable. For measuring longer distances, the illumination can be modu-

lated at more than one frequency to eliminate cycle ambiguity if there is more than one cycle between the source of illumination and the illuminated object. This technique is particularly desirable when monitoring objects exterior to the vehicle to permit accurate measurements of devices that are hundreds of meters from the vehicle as well as those that are a few meters away. Naturally, there are other modulation methods that eliminate the cycle ambiguity such as modulation with a code that is used with a correlation function to determine the phase shift or time delay. This code can be a pseudo random number in order to permit the unambiguous monitoring of the vehicle exterior in the presence of other vehicles with the same system. This is sometimes known as noise radar, noise modulation (either of optical or radar signals), ultra wideband (UWB) or the techniques used in Micropower impulse radar (MIR).

Although a simple frequency modulation scheme has been disclosed so far, it is also possible to use other coding techniques including the coding of the illumination with one of a variety of correlation patterns including a pseudo-random code. Similarly, although frequency and code domain systems have been described, time domain systems are also applicable wherein a pulse of light is emitted and the time of flight measured. Additionally, in the frequency domain case, a chirp can be emitted and the reflected light compared in frequency with the chirp to determine by frequency difference the distance to the object. Although each of these techniques is known to those skilled in the art, they have heretofore not been applied for monitoring objects within or outside of a vehicle.

#### OBJECTS AND SUMMARY OF THE INVENTION

Principle objects and advantages of the optical sensing system in accordance with the invention are:

1. To provide a system for monitoring the environment exterior of a vehicle in order to determine the presence and classification, identification and/or location of objects in the exterior environment.
2. To provide a blind spot detector which detects and categorizes an object in the driver's blind spot or other location in the vicinity of the vehicle, and warns the driver in the event the driver begins to change lanes, for example, or continuously informs the driver of the state of occupancy of the blind spot.
3. To provide a camera system for interior and exterior monitoring, which can adjust on a pixel by pixel basis for the intensity of the received light.
4. To provide for the use of an active pixel camera for interior and exterior vehicle monitoring.
5. To recognize the presence of a human on a particular seat of a motor vehicle and to use this information to affect the operation of another vehicle system such as the airbag, heating and air conditioning, or entertainment systems, among others.
6. To recognize the presence of a human on a particular seat of a motor vehicle and then to determine his/her position and to use this position information to affect the operation of another vehicle system.
7. To determine the position, velocity or size of an occupant in a motor vehicle and to utilize this information to control the rate of gas generation, or the amount of gas generated by an airbag inflator system.
8. To determine the presence or position of rear seated occupants in the vehicle and to use this information to

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- affect the operation of a rear seat protection airbag for frontal, side and/or rear impacts.
9. To recognize the presence of a rear facing child seat on a particular seat of a motor vehicle and to use this information to affect the operation of another vehicle system such as the airbag system.
  10. To determine the approximate location of the eyes of a driver and to use that information to control the position of one or more of the rear view mirrors of the vehicle.
  11. To monitor the position of the head of the vehicle driver and determine whether the driver is falling asleep or otherwise impaired and likely to lose control of the vehicle and to use that information to affect another vehicle system.
  12. To provide an occupant position sensor which reliably permits, and in a timely manner, a determination to be made that the occupant is out-of-position, or will become out-of-position, and likely to be injured by a deploying airbag and to then output a signal to suppress the deployment of the airbag.
  13. To provide an anticipatory sensor that permits accurate identification of the about-to-impact object in the presence of snow and/or fog whereby the sensor is located within the vehicle.
  14. To provide a smart headlight dimmer system which senses the headlights from an oncoming vehicle or the tail lights of a vehicle in front of the subject vehicle and identifies these lights differentiating them from reflections from signs or the road surface and then sends a signal to dim the headlights.
  15. To provide an occupant position determination in a sufficiently short time that the position of an occupant can be tracked during a vehicle crash.
  16. To provide an occupant vehicle interior monitoring system which is not affected by temperature or thermal gradients.
  17. To provide an occupant vehicle interior monitoring system which has high resolution to improve system accuracy and permits the location of body parts of the occupant to be determined.
  18. To provide an occupant vehicle interior monitoring system which reduces the glare from sunlight and headlights by imposing a filter between the eyes of an occupant and the light source.
  19. To provide a system for recognizing the identity of a particular individual in the vehicle.
  20. To use the principles of time of flight to measure the distance to an occupant or object exterior to the vehicle.
  21. To obtain a three dimensional image from a device at one location on a vehicle.
  22. To use pattern recognition techniques for analyzing three-dimensional image data of occupants of a vehicle and objects exterior to the vehicle.
  23. To provide a system of frequency domain modulation of the illumination of an object interior or exterior of a vehicle.
  24. To utilize code modulation such as with a pseudo random code to permit the unambiguous monitoring of the vehicle exterior in the presence of other vehicles with the same system.
  25. To use a chirp frequency modulation technique to aid in determining the distance to an object interior or exterior of a vehicle.

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26. To utilize a correlation pattern modulation in a form of code division modulation for determining the distance of an object interior or exterior of a vehicle.

These and other objects and advantages will become apparent from the following description of the preferred embodiments of the vehicle identification and monitoring system of this invention.

Briefly, in order to achieve at least one of the objects and possibly others, a monitoring arrangement for monitoring an environment exterior of a vehicle comprises at least one receiver arranged to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves, and a processor coupled to the receiver(s) and comprising pattern recognition means for processing the signal to provide a classification, identification and/or location of the exterior object. The pattern recognition means, such as a neural computer or neural network and the like, apply a pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects. In this manner, one or more systems in the vehicle may be coupled to the processor such that the operation the system(s) is/are affected in response to the classification, identification and/or location of the exterior object.

This affected system may be a display viewable by the driver and arranged to show an image or icon of the exterior object or objects. The affected system may also be an internally deployed or externally deployed airbag, deployment of which is controlled based on the identification of the exterior object.

A pair of receivers spaced apart from one another may be used and the receiver may be arranged to receive infrared waves. If a transmitter is provided to transmit waves into the environment exterior of the vehicle, then the receiver is arranged to receive waves transmitted by the transmitter and reflected by any exterior objects.

A measurement system may be provided to measure a distance between the exterior object and the vehicle. The measurement system may be a radar or laser radar system.

Another monitoring arrangement for monitoring an environment exterior of a vehicle in accordance with the invention comprises at least one CCD array positioned to obtain images of the environment exterior of the vehicle and a processor coupled to the CCD array(s) and comprising pattern recognition means for processing the images obtained by the CCD array(s) to provide a classification, identification and/or location of the exterior object. In this manner, one or more systems in the vehicle may be coupled to the processor such that the operation the system(s) is/are affected in response to the classification, identification and/or location of the exterior object. Optionally, the pattern recognition means apply a pattern recognition algorithm generated from data of possible exterior objects and images from the CCD array(s) of the possible exterior objects. The same enhancements described for the arrangement above can be used in this arrangement as well.

In another embodiment of the invention, at least one receiver is arranged on a rear view mirror of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves and a processor is coupled to the receiver(s) and arranged to classify, identify and/or locate the exterior object based on the signal. As such, the operation of one or more systems in the vehicle, coupled to the processor, can be affected in response to the classification, identification and/



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or location of the exterior object. The same enhancements described for the arrangements above can be used in this embodiment as well.

Instead of being arranged on the rear view mirror, the receiver can be arranged on a B-pillar of the vehicle to receive waves from the environment exterior of and on the side of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves. In addition, the receiver could be arranged in a door window trim panel of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves. Other mounting locations include in a rear window and in a C-pillar of the vehicle.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings are illustrative of embodiments of the invention and are not meant to limit the scope of the invention as encompassed by the claims.

FIG. 1A is a side planar view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing several preferred mounting locations of interior vehicle monitoring sensors shown particularly for sensing the vehicle driver illustrating the wave pattern from a CCD or CMOS optical position sensor mounted along the side of the driver or centered above his or her head.

FIG. 1B is a view as in FIG. 1A illustrating the wave pattern from an optical system using an infrared light source and a CCD or CMOS array receiver using the windshield as a reflection surface and showing schematically the interface between the vehicle interior monitoring system of this invention and an instrument panel mounted inattentiveness warning light or buzzer and reset button.

FIG. 1C is a view as in FIG. 1A illustrating the wave pattern from an optical system using an infrared light source and a CCD or CMOS array receiver where the CCD or CMOS array receiver is covered by a lens permitting a wide angle view of the contents of the passenger compartment.

FIG. 1D is a view as in FIG. 1A illustrating the wave pattern from a pair of small CCD or CMOS array receivers and one infrared transmitter where the spacing of the CCD or CMOS arrays permits an accurate measurement of the distance to features on the occupant.

FIG. 1E is a view as in FIG. 1A illustrating the wave pattern from a set of ultrasonic transmitter/receivers where the spacing of the transducers and the phase of the signal permits an accurate focusing of the ultrasonic beam and thus the accurate measurement of a particular point on the surface of the driver.

FIG. 2A is a side view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing preferred mounting locations of optical interior vehicle monitoring sensors

FIG. 2B is a perspective view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing some preferred mounting locations of optical interior vehicle monitoring sensors.

FIG. 3 is a circuit schematic illustrating the use of the vehicle interior monitoring sensor used as an occupant position sensor in conjunction with the remainder of the inflatable restraint system.

FIG. 4 is a schematic illustrating the circuit of an occupant position-sensing device using a modulated infrared signal, beat frequency and phase detector system.

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FIG. 5 is a side planer view with parts cutaway and removed of a vehicle showing the passenger compartment containing a driver and a preferred mounting location for an optical occupant position sensor for use in side impacts and also of an optical rear of occupant's head locator for use with a headrest adjustment system to reduce whiplash injuries in rear impact crashes.

FIG. 6 is a side plan view of the interior of an automobile, with portions cut away and removed, with two optical occupant height measuring sensors, one mounted into the headliner above the occupant's head and the other mounted onto the A-pillar and also showing a seatbelt associated with the seat where the seatbelt has an adjustable upper anchorage point which is automatically adjusted corresponding to the height of the occupant.

FIG. 7 is a perspective view of a vehicle about to impact the side of another vehicle showing the location of the various parts of the anticipatory sensor system of this invention.

FIG. 7A is an enlarged view of the section designated 7A in FIG. 7.

FIG. 8 is a side planar view, with certain portions removed or cut away, of a portion of the passenger compartment illustrating a sensor for sensing the headlights of an oncoming vehicle and/or the taillights of a leading vehicle used in conjunction with an automatic headlight dimming system.

FIG. 9 is a side planar view with parts cutaway and removed of a subject vehicle and an oncoming vehicle, showing the headlights of the oncoming vehicle and the passenger compartment of the subject vehicle, containing detectors of the driver's eyes and detectors for the headlights of the oncoming vehicle and the selective filtering of the light of the approaching vehicle's headlights through the use of a liquid crystal filter in the windshield.

FIG. 9A is an enlarged view of the section designated 9A in FIG. 9.

FIG. 10 is a schematic illustration of a system for controlling operation of a vehicle or a component thereof based on recognition of an authorized individual.

FIG. 11 is a schematic illustration of a method for controlling operation of a vehicle based on recognition of an individual.

FIG. 12 is a schematic illustration of the environment monitoring in accordance with the invention.

FIG. 13 is a flow chart of the environment monitoring in accordance with the invention.

FIG. 14 is a schematic illustration of the position measuring in accordance with the invention.

FIG. 15 is a schematic illustration of the exterior monitoring system in accordance with the invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings wherein the same reference numerals refer to the same or similar elements, a section of the passenger compartment of an automobile is shown generally as **100** in FIGS. 1A-1D. A driver **101** of a vehicle sits on a seat **102** behind a steering wheel **103**, which contains an airbag assembly **104**. Airbag assembly **104** may be integrated into the steering wheel assembly or coupled to the steering wheel **103**. Five transmitter and/or receiver assemblies **110**, **111**, **112**, **113** and **114** are positioned at various places in the passenger compartment (the specific locations of which are set forth below) to determine the location of various parts of the driver, e.g., the head, chest

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and torso, relative to the airbag and to otherwise monitor the interior of the passenger compartment. Monitoring of the interior of the passenger compartment can entail detecting the presence or absence of the driver and passengers, differentiating between animate and inanimate objects, detecting the presence of occupied or unoccupied child seats, rear-facing or forward-facing, and identifying and ascertaining the identity of the occupying items in the passenger compartment. Processor means such as control circuitry 120 is connected to the transmitter/receiver assemblies 110-114 and controls the transmission from the transmitters, if a transmission component is present in the assemblies, and captures the return signals from the receivers, if a receiver component is present in the assemblies. Control circuitry 120 usually contains analog to digital converters (ADCs) or a frame grabber, a microprocessor containing sufficient memory and appropriate software including pattern recognition algorithms, and other appropriate drivers, signal conditioners, signal generators, etc. Usually, in any given implementation, only three or four of the transmitter/receiver assemblies would be used depending on their mounting locations as described below.

With respect to the connection between the transmitter/receiver assemblies 110-114 and the control circuitry 120, a portion of this connection is shown as wires. It should be understood that all of the connections between the transmitter/receiver assemblies 110-114 and the control circuitry 120 may be wires, either individual wires leading from the control circuitry 120 to each of the transmitter/receiver assemblies 110-114 or one or more wire buses.

With respect to the position of the control circuitry 120 in the dashboard of the vehicle, this position is for illustration purposes only and does not limit the location of the control circuitry 120. Rather, the control circuitry 120 may be located anywhere convenient or desired in the vehicle.

It is contemplated that a system and method in accordance with the invention can include a single transmitter and multiple receivers, each at a different location. Thus, each receiver would not be associated with a transmitter forming transmitter/receiver assemblies. Rather, for example, with reference to FIG. 1A, only element 110 would constitute a transmitter/receiver assembly and elements 111, 112, 113, 114 would be receivers only.

On the other hand, it is conceivable that in some implementations, a system and method in accordance with the invention include a single receiver and multiple transmitters. Thus, each transmitter would not be associated with a receiver forming transmitter/receiver assemblies. Rather, for example, with reference to FIG. 1A, only element 110 would constitute a transmitter/receiver assembly and elements 111, 112, 113, 114 would be transmitters only.

FIG. 1A illustrates a typical wave pattern of transmitted infrared waves from transmitter/receiver assembly 111, which is mounted on the side of the vehicle passenger compartment above the front, driver's side door. Transmitter/receiver assembly 114, shown overlaid onto transmitter/receiver 111, is actually mounted in the center headliner of the passenger compartment (and thus between the driver's seat and the front passenger seat), near the dome light, and is aimed toward the driver. Typically there will be symmetrical installation for the passenger side of the vehicle. That is, a transmitter/receiver assembly would be arranged above the front, passenger side door and another transmitter/receiver assembly would be arranged in the center headliner, near the dome light, and aimed toward the front, passenger side door.

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In a preferred embodiment, each transmitter/receiver assembly 111, 114 comprises an optical transducer that will generally be used in conjunction with another optical transmitter/receiver assembly such as shown at 110, 112 and 113, which act in a similar manner. These optical transmitter/receiver assemblies are comprised of an optical transmitter, which may be an infrared LED (or possibly a near infrared (NIR) LED), a laser with a diverging lens or a scanning laser assembly, and a receiver such as a CCD or CMOS array and particularly an active pixel CMOS camera or array or a HDRL or HDRC camera or array as discussed below. The transducer assemblies map the location of the occupant(s), objects and features thereof, in a two or three-dimensional image as will now be described in more detail.

An active pixel camera is a special camera which has the ability to adjust the sensitivity of each pixel of the camera similar to the manner in which an iris adjusts the sensitivity of a camera. Thus, the active pixel camera automatically adjusts to the incident light on a pixel-by-pixel basis. An active pixel camera differs from an active infrared sensor in that an active infrared sensor, such as of the type envisioned by Mattes et al. (discussed above), is generally a single pixel sensor that measures the reflection of infrared light from an object. In some cases, as in the HDRC camera, the output of each pixel is a logarithm of the incident light thus giving a high dynamic range to the camera. This is similar to the technique used to suppress the effects of thermal gradient distortion of ultrasonic signals as described in the above cross-referenced patents. Thus if the incident radiation changes in magnitude by 1,000,000, for example, the output of the pixel may change by a factor of only 6.

A dynamic pixel camera is a camera having a plurality of pixels and which provides the ability to pick and choose which pixels should be observed, as long as they are contiguous.

An HDRC camera is a type of active pixel camera where the dynamic range of each pixel is considerably broader. An active pixel camera manufactured by the Photobit Corporation has a dynamic range of 70 db while an IMS Chips camera, an HDRC camera manufactured by another manufacturer, has a dynamic range of 120 db. Thus, the HDRC camera has a 100,000 times greater range of light sensitivity than the Photobit camera.

In a preferred implementation, four transducer assemblies are positioned around the seat to be monitored, each comprising an LED with a diverging lens and a CMOS array. Although illustrated together, the illuminating source in many cases will not be co-located with the receiving array. The LED emits a controlled angle, 120° for example, diverging cone of infrared radiation that illuminates the occupant from both sides and from the front and rear. This angle is not to be confused with the field angle used in ultrasonic systems. With ultrasound, extreme care is required to control the field of the ultrasonic waves so that they will not create multipath effects and add noise to the system. With infrared, there is no reason, in the implementation now being described, other than to make the most efficient use of the infrared energy, why the entire vehicle cannot be flooded with infrared energy either from many small sources or from a few bright ones.

The image from each array is used to capture two dimensions of occupant position information, thus, the array of assembly 110 positioned on the A-pillar, which is approximately 25% of the way laterally across the headliner in front of the driver, provides a both vertical and transverse information on the location of the driver. A similar view from the

rear is obtained from the array of assembly 113 positioned behind the driver on the roof of the vehicle and above the seatback portion of the seat 102. As such, assembly 113 also provides both vertical and transverse information on the location of the driver. Finally, arrays of assemblies 111 and 114 provide both vertical and longitudinal driver location information. Another preferred location is the headliner centered directly above the seat of interest. The position of the assemblies 110-114 may differ from that shown in the drawings. In the invention, in order that the information from two or more of the assemblies 110-114 may provide a three-dimensional image of the occupant, or portion of the passenger compartment, the assemblies should not be arranged side-by-side. A side-by-side arrangement as used in several prior art references discussed above, will provide two essentially identical views with the difference being a lateral shift. This does not enable a complete three-dimensional view of the occupant.

If each receiving array of assemblies 110, 111, 113, 114 contains a matrix of 100 by 100 pixels, then 40,000 (4x100x100) pixels or data elements of information will be created each time the system interrogates the driver seat, for example. There are many pixels of each image that can be eliminated as containing no useful information. This typically includes the corner pixels, back of the seat and other areas where an occupant cannot reside. This pixel pruning can typically reduce the number of pixels by up to 50 percent resulting in approximately 20,000 remaining pixels. The output from each array is then compared with a series of stored arrays representing different unoccupied positions of the seat, seatback, steering wheel etc. For each array, each of the stored arrays is subtracted from the acquired array and the results analyzed to determine which subtraction resulted in the best match. The best match is determined by such things as the total number of pixels reduced below the threshold level, or the minimum number of remaining detached pixels, etc. Once this operation is completed for all four images, the position of the movable elements within the passenger compartment has been determined. This includes the steering wheel angle, telescoping position, seatback angle, headrest position, and seat position. This information can be used elsewhere by other vehicle systems to eliminate sensors that are currently being used to sense such positions of these complements. Alternately, the sensors that are currently on the vehicle for sensing these complement positions can be used to simplify processes described above.

Each receiving array may also be a 256x256 CMOS pixel array as described in the paper by C. Sodini et al. referenced above.

An alternate technique of differentiating between the occupant and the vehicle is to use motion. If the images of the passenger seat are compared over time, reflections from fixed objects will remain static whereas reflections from vehicle occupants will move. This movement can be used to differentiate the occupant from the background.

Following the subtraction process described above, each image now consists of typically as many as 50 percent fewer pixels leaving a total of approximately 10,000 pixels remaining. The resolution of the images in each array can now be reduced by combining adjacent pixels and averaging the pixel values. This results in a reduction to a total pixel count of approximately 1000. The matrices of information that contains the pixel values is now normalized to place the information in a location in the matrix which is independent of the seat position. The resulting normalized matrix of 1000 pixel values is now used as input into an artificial neural network and represents the occupancy of the seat independent of the position of the occupant.

The neural network has been previously trained on a significant number of occupants of the passenger compartment. The number of such occupants depends strongly on whether the driver or the passenger seat is being analyzed. The variety of seating states or occupancies of the passenger seat is vastly greater than that of the driver seat. For the driver seat, a typical training set will consist of approximately 100 different vehicle occupancies. For the passenger seat, this number can exceed 1000. These numbers are used for illustration purposes only and will differ significantly from vehicle model to vehicle model.

The neural network is now used to determine which of the stored occupancies most closely corresponds to the measured data. The output of the neural network is an index of the setup that was used during training that most closely matches the current measured state. This index is used to locate stored information from the matched trained occupancy. Information that has been stored for the trained occupancy typically includes the locus of the centers of the chest and head of the driver, as well as the approximate radius of pixels which is associated with this center to define the head area, for example. For the case of FIG. 1A, it is now known from this exercise where the head, chest, and perhaps the eyes and ears, of the driver are most likely to be located and also which pixels should be tracked in order to know the precise position of the driver's head and chest. What has been described above is the identification process.

The normalization process conducted above created a displacement value for each of the CCD or CMOS arrays in the four assemblies 110, 111, 113, 114 which can now be used in reverse to find the precise location of the driver's head and chest or chest, for example, relative to the known location of the airbag. From the vehicle geometry, and the head and chest location information, a choice can now be made as to whether to track the head or chest for dynamic out-of-position.

Tracking of the motion of the occupant's head or chest can be done using a variety of techniques. One preferred technique is to use differential motion, that is, by subtracting the current image from the previous image to determine which pixels have changed in value and by looking at the leading edge of the changed pixels and the width of the changed pixel field, a measurement of the movement of the pixels of interest, and thus the driver, can be readily accomplished. Alternately, a correlation function can be derived which correlates the pixels in the known initial position of the head, for example, with pixels that were derived from the latest image. The displacement of the center of the correlation pixels would represent the motion of the head of the occupant. Naturally, a wide variety of other techniques will be now obvious to those skilled in the art.

There are many mathematical techniques that can be applied to simplify the above process. One technique used in military pattern recognition, for example, uses the Fourier transform of particular areas in an image to match with known Fourier transforms of known images. In this manner, the identification and location can be determined simultaneously. There is even a technique used for target identification whereby the Fourier transforms are compared optically. Other techniques utilize thresholding to limit the pixels that will be analyzed by any of these processes. Other techniques search for particular features and extract those features and concentrate merely on the location of certain of these features. (See for example the Kage et al. artificial retina publication referenced above which, together with the references cited therein, is incorporated herein by reference.)

Generally, the pixel values are not directly fed into a pattern recognition system but rather the image is prepro-

cessed through a variety of feature extraction techniques such as an edge detection algorithm. Once the edges are determined, a vector is created containing the location of the edges and their orientation and that vector is fed into the neural network, for example, which performs the pattern

recognition. The principal used in this preferred implementation of the invention is to use images of different views of the occupant to correlate with known images that were used to train a neural network for vehicle occupancy. Then carefully measured positions of the known images are used to locate particular parts of the occupant such as his or her head, chest, eyes, ears, mouth, etc. An alternate approach is to make a three-dimensional map of the occupant and to precisely locate these features using neural networks, sensor fusion, fuzzy logic or other rules. One method of obtaining a three-dimensional map is to utilize a scanning laser radar system where the laser is operated in a pulse mode and the distance from the object being illuminated is determined using range gating in a manner similar to that described in various patents on micropower impulse radar to McEwan. (See, for example, U.S. Pat. Nos. 5,457,394 and 5,521,600).

The scanning portion of the pulse laser radar device can be accomplished using rotating mirrors, mechanical motors, or preferably, a solid state system, for example one utilizing  $\text{TeO}_2$  as an optical diffraction crystal with lithium niobate crystals driven by ultrasound (although other solid state systems not necessarily using  $\text{TeO}_2$  and lithium niobate crystals could also be used). An alternate method is to use a micromachined mirror, which is supported at its center and caused to deflect by miniature coils. Such a device has been used to provide two-dimensional scanning to a laser. This has the advantage over the  $\text{TeO}_2$ -lithium niobate technology in that it is inherently smaller and lower cost and provides two-dimensional scanning capability in one small device. The maximum angular deflection that can be achieved with this process is on the order of about 10 degrees. Thus, a diverging lens will be needed for the scanning system.

An alternate method of obtaining three-dimensional information from a scanning laser system is to use multiple arrays to replace the single arrays used in FIG. 1A. In the case, the arrays are displaced from each other and, through triangulation, the location of the reflection from the illumination by a laser beam of a point on the object can be determined in a manner that is understood by those skilled in the art.

One important point concerns the location and number of optical assemblies. It is possible to use fewer than four such assemblies with a resulting loss in accuracy. The number of four was chosen so that either a forward or rear assembly or either of the side assemblies can be blocked by a newspaper, for example, without seriously degrading the performance of the system. Since drivers rarely are reading newspapers while driving, fewer than four arrays are usually adequate for the driver side.

The particular locations of the optical assemblies were chosen to give the most accurate information as to the locations of the occupant. This is based on an understanding of what information can be best obtained from a visual image. There is a natural tendency on the part of humans to try to gauge distance from the optical sensors directly. This, as can be seen above, is at best complicated involving focusing systems, stereographic systems, multiple arrays and triangulation, time of flight measurement, etc. What is not intuitive to humans is to not try to obtain this distance directly from apparatus or techniques associated with the

mounting location. Whereas ultrasound is quite good for measuring distances from the transducer (the z-axis), optical systems are better at measuring distances in the vertical and lateral directions (the x and y-axes). Since the precise locations of the optical transducers are known, that is, the geometry of the transducer locations is known relative to the vehicle, there is no need to try to determine the displacement of an object of interest from the transducer (the z-axis) directly. This can more easily be done indirectly by another transducer. That is, the z-axis to one transducer is the x-axis to another.

Ultrasonic transducers are relatively good at measuring the distance along a radius to a reflective object. An optical array, such as disclosed herein, on the other hand, can get accurate measurements in two dimensions, the lateral and vertical dimensions relative to the transducer. If we assume that the optical array has dimensions of 100 by 100 as compared to an ultrasonic sensor that has a single dimension of 100, an optical array can give therefore 100 times as much information as the ultrasonic array. Most importantly, this vastly greater amount of information does not cost significantly more to obtain than the information from the ultrasonic sensor.

As illustrated in FIGS. 1A-1D, the optical sensors are typically located at the positions where the desired information is available with the greatest resolution. These positions are typically in the center front and center rear of the occupancy seat and at the center on each side and top. This is in contrast to the optimum location for ultrasonic sensors, which are the corners of such a rectangle that outlines the seated volume.

Systems based on ultrasonics and neural networks have been very successful in analyzing the seated state of both the passenger and driver seats of automobiles. Such systems are now going into production for preventing airbag deployment when a rear facing child seat or and out-of-position occupant is present. The ultrasonic systems, however, suffer from certain natural limitations that prevent the system accuracy from getting better than about 99 percent. These limitations relate to the fact that the wavelength of ultrasound is typically between 3 and 8 mm. As a result, unexpected results occur which are due partially to the interference of reflections from different surfaces. Additionally, commercially available ultrasonic transducers are tuned devices that require several cycles before they transmit significant energy and similarly require several cycles before they effectively receive the reflected signals. This requirement has the effect of smearing the resolution of the ultrasound to the point that, for example, using a conventional 40 kHz transducer, the resolution of the system is approximately three inches.

In contrast, the wavelength of infrared is less than one micron and no significant interferences occur. Similarly, the system is not tuned and therefore is theoretically sensitive to a very few cycles. As a result, resolution of the optical system is determined by the pixel spacing in the CCD or CMOS arrays. For this application, typical arrays have been chosen to be 100 pixels by 100 pixels and therefore the space being imaged can be broken up into pieces that are significantly less than 1 cm in size. Naturally, if greater resolution is required arrays having larger numbers of pixels are readily available. Another advantage of optical systems is that special lenses can be used to magnify those areas where the information is most critical and operate at reduced resolution where this is not the case. For example, the area closest to the at-risk zone in front of the airbag can be magnified. This is not possible with ultrasonic systems.

To summarize, although ultrasonic neural network systems are operating with high accuracy, they do not totally

eliminate the problem of deaths and injuries caused by airbag deployments. Optical systems, on the other hand, at little increase in cost, have the capability of virtually 100 percent accuracy. Additional problems of ultrasonic systems arise from the slow speed of sound and diffraction caused by variations in air density. The slow sound speed limits the rate at which data can be collected and thus eliminates the possibility of tracking the motion of an occupant during a high speed crash.

In the case of FIG. 1A, transmitter/receiver assemblies 110-114 emit infrared waves that reflect off of the head and chest of the driver and return thereto. Periodically, the device, as commanded by control circuitry 120, transmits a pulse of infrared waves and the reflected signal is detected by the same or a different device. The transmitters can either transmit simultaneously or sequentially. An associated electronic circuit and algorithm in control circuitry 120 processes the returned signals as discussed above and determines the location of the occupant in the passenger compartment. This information is then sent to the crash sensor and diagnostic circuitry, which may also be resident in control circuitry 120 (programmed within a control module), which determines if the occupant is close enough to the airbag that a deployment might, by itself, cause injury which exceeds that which might be caused by the accident itself. In such a case, the circuit disables the airbag system and thereby prevents its deployment. In an alternate case, the sensor algorithm assesses the probability that a crash requiring an airbag is in process and waits until that probability exceeds an amount that is dependent on the position of the occupant. Thus, for example, the sensor might decide to deploy the airbag based on a need probability assessment of 50%, if the decision must be made immediately for an occupant approaching the airbag, but might wait until the probability rises to 95% for a more distant occupant. In the alternative, the crash sensor and diagnostic circuitry optionally resident in control circuitry 120 may tailor the parameters of the deployment (time to initiation of deployment, rate of inflation, rate of deflation, deployment time, etc.) based on the current position and possibly velocity of the occupant, e.g., a depowered deployment.

Although a driver system has been illustrated, the front and rear seat passenger systems would be similar.

In another implementation, the sensor algorithm may determine the rate that gas is generated to affect the rate that the airbag is inflated. In all of these cases, the position of the occupant is used to affect the deployment of the airbag as to whether or not it should be deployed at all, the time of deployment and/or the rate of inflation.

It should be understood that although the above description mentions that the airbag system can be controlled by the control circuitry 120, any vehicular system, component or subsystem can be controlled based on the information or data obtained by transmitter/receiver assemblies 110-114. Control circuitry 120 can be programmed or trained, if for example a neural network is used, to control heating an air-conditioning systems based on the presence of occupants in certain positions so as to optimize the climate control in the vehicle. The entertainment system can also be controlled to provide sound only to locations at which occupants are situated. There is no limit to the number and type of vehicular systems, components and subsystems that can be controlled using the image analysis techniques described herein.

Furthermore, if multiple vehicular systems are to be controlled by control circuitry 120, then these systems can

be controlled by the control circuitry 120 based on the status of particular components of the vehicle. For example, an indication of whether a key is in the ignition can be used to direct the control circuitry 120 to either control an airbag system (when the key is present in the ignition) or an anti-theft system (when the key is not present in the ignition). Control circuitry 120 would thus be responsive to the status of the ignition of the motor vehicle to perform one of a plurality of different functions. More particularly, the pattern recognition algorithm, such as the neural network described herein, could itself be designed to perform in a different way depending on the status of a vehicular component such as the detected presence of a key in the ignition. It could provide one output to control an anti-theft system when a key is not present and another output when a key is present using the same inputs from the transmitter/receiver assemblies 110-114.

The algorithm in control circuitry 120 can also be designed to determine the location of the occupant's eyes either directly or indirectly through a determination of the location of the occupant and an estimation of the position of the eyes therefrom. As such, the position of the rear view mirror 105 can be adjusted to optimize the driver's use thereof.

Weight sensors 130 are also included in the system shown in FIG. 1A. Although strain gage type sensors are schematically illustrated mounted to the supporting structure of the seat 102, any other type of weight sensor can be used. Strain gage weight sensors are described in detail in U.S. patent application Ser. No. 09/193,209 that is incorporated herein by reference as if it were entirely set forth herein. Weight can be used to confirm the occupancy of the seat, i.e., the presence or absence of an occupant as well as whether the seat is occupied by a light or heavy object. In the latter case, a measured weight of less than 60 pounds is often determinative of the presence of a child seat whereas a measured weight of greater than 60 pounds is often indicative of the absence of a child seat. The weight sensors 130 can also be used to determine the weight distribution of the occupant of the seat and thereby ascertain whether the occupant is moving and the position of the occupant. As such, the weight sensors 130 could be used to confirm the position of the occupant. The measured weight or distribution thereof can also be used in combination with the data from the transmitter/receiver assemblies 110-114 to provide an identification of the occupants in the seat.

The accuracy of the optical occupant sensor is critically dependent upon the accuracy of the camera. The dynamic range of light within a vehicle exceeds 120 decibels. When a car is driving at night, for example, very little light is available whereas when driving in a bright sunlight, especially in a convertible, the light intensity can overwhelm most cameras. Additionally, the camera must be able to adjust rapidly to changes and light caused by, for example, the emergence of the vehicle from tunnel, or passing by other obstructions such as trees, buildings, other vehicles, etc. which temporarily block the sun and cause a strobing effect at frequencies approaching 1 kHz.

Recently, improvements have been made to CMOS cameras that have significantly increased their dynamic range. New logarithmic high dynamic range technology such as developed by IMS Chips of Stuttgart, Germany, is now available in HDRC (High Dynamic Range CMOS) cameras. This technology provides a 120 dB dynamic intensity response at each pixel in a mono chromatic mode. The technology has a 1 million to one dynamic range at each pixel. This prevents blooming, saturation and flaring nor-

mally associated with CMOS and CCD camera technology. This solves a problem that will be encountered in an automobile when going from a dark tunnel into bright sunlight. Such a range would even exceed the 120 dB intensity.

There is also significant infrared radiation from bright sunlight and from incandescent lights within the vehicle. Such situations may even exceed the dynamic range of the HDRC camera and additional filtering may be required. Changing the bias on the receiver array, the use of a mechanical iris, or of electrochromic glass or liquid crystal can provide this filtering on a global basis but not at a pixel level. Filtering can also be used with CCD arrays, but the amount of filtering required is substantially greater than for the HDRC camera. A notch filter can be used to block significant radiation from the sun, for example. This notch filter can be made as a part of the lens through the placement of various coatings onto the lens surface.

Liquid crystals operate rapidly and give as much as a dynamic range of 10,000 to 1 but may create a pixel interference affect. Electrochromic glass operates more slowly but more uniformly thereby eliminating the pixel affect. The pixel effect arises whenever there is one pixel device in front of another. This results in various aliasing, Moire patterns and other ambiguities. One way of avoiding this is to blur the image. Another solution is to use a large number of pixels and combine groups of pixels to form one pixel of information and thereby to blur the edges to eliminate some of the problems with aliasing and Moire patterns.

One straightforward approach is the use of a mechanical iris. Standard cameras already have response times of several tens of milliseconds range. They will switch, for example, in a few frames on a typical video camera (1 frame=0.033 seconds). This is sufficiently fast for categorization but much too slow for dynamic out-of-position tracking.

An important feature of the IMS Chips HDRC camera is that the full dynamic range is available at each pixel. Thus, if there are significant variations in the intensity of light within the vehicle, and thereby from pixel to pixel, such as would happen when sunlight streams and through a window, the camera can automatically adjust and provide the optimum exposure on a pixel by pixel basis. The use of the camera having this characteristic is very beneficial to the invention described herein and contributes significantly to system accuracy. CCDs have a rather limited dynamic range due to their inherent linear response and consequently cannot come close to matching the performance of human eyes. A key advantage of the IMS Chips HDRC camera is its logarithmic response which comes closest to matching that of the human eye.

Another approach, which is applicable in some vehicles, is to record an image without the infrared illumination and then a second image with the infrared illumination and to then subtract the first image from the second image. In this manner, illumination caused by natural sources such as sunlight or even from light bulbs within the vehicle can be subtracted out. Naturally, using the logarithmic pixel system of the IMS Chips camera care must be taken to include the logarithmic effect during the subtraction process. For some cases, natural illumination such as from the sun, light bulbs within the vehicle, or radiation emitted by the object itself can be used alone without the addition of a special source of infrared illumination.

Other imaging systems such as CCD arrays can also of course be used with this invention. However, the techniques

will be quite different since the camera is very likely to saturate when bright light is present and to require the full resolution capability when the light is dim. Generally when practicing this invention the interior of the passenger compartment will be illuminated with infrared radiation.

There are other bright sources of infrared that must be accounted for. These include the sun and any light bulbs that may be present inside the vehicle. This lack of a high dynamic range inherent with the CCD technology requires the use of an iris, liquid crystal, or electrochromic glass filter to be placed between the camera and the scene. Even with these filters however, some saturation will take place with CCD cameras under bright sun or incandescent lamp exposure. This saturation reduces the accuracy of the image and therefore the accuracy of the system. In particular the training regimen that must be practiced with CCD cameras is more severe since all of the saturation cases must be considered since the camera is unable to appropriately adjust. Thus, although CCD cameras can be use, HDRC logarithmic cameras such as manufactured by IMS Chips are preferred. They not only provide a significantly more accurate image but also significantly reduce the amount of training effort and associated data collection that must be undertaken during the development of the neural network algorithm or other computational intelligence system. In some applications, it is possible to use other more deterministic image processing or pattern recognition systems than neural networks.

Another very important feature of the HDRC camera from IMS Chips is that the shutter time is constant at less than 100 ns irrespective of brightness of the scene. The pixel data arrives at constant rate synchronous with the internal imager clock. Random access to each pixel facilitates high-speed intelligent access to any sub-frame (block) size or sub-sampling ratio and a trade-off of frame speed and frame size therefore results. For example, a scene with 128 K pixels per frame can be taken at 120 frames per second, or about 8 milliseconds per frame, whereas a sub-frame can be taken in run at as high as 4000 frames per second with 4 K pixels per frame. This combination allows the maximum resolution for the identification and classification part of the occupant sensor problem while permitting a concentration on those particular pixels which track the head or chest, as described above, for dynamic out-of-position tracking. In fact the random access features of these cameras can be used to track multiple parts of the image simultaneously while ignoring the majority of the image, and do so at very high speed. For example, the head can be tracked simultaneously with the chest by defining two separate sub-frames that need not be connected. This random access pixel capability, therefore, is optimally suited or recognizing and tracking vehicle occupants. It is also suited for monitoring the environment outside of the vehicle for purposes of blind spot detection, collision avoidance and anticipatory sensing. Photobit Corporation of 135 North Los Robles Ave., Suite 700, Pasadena, Calif. 91101 manufactures another camera with some characteristics similar to the IMS Chips camera. Other competitive cameras can be expected to appear on the market.

Photobit refers to their Active Pixel Technology as APS. According to Photobit, in the APS, both the photodetector and readout amplifier are part of each pixel. This allows the integrated charge to be converted into a voltage in the pixel that can then be read out over X-Y wires instead of using a charge domain shift register as in CCDs. This column and row addressability (similar to common DRAM) allows for window of interest readout (windowing) which can be utilized for on chip electronic pan/tilt and zoom. Windowing

provides added flexibility in applications, such as disclosed herein, needing image compression, motion detection or target tracking. The APS utilizes intra-pixel amplification in conjunction with both temporal and fixed pattern noise suppression circuitry (i.e. correlated double sampling), which produces exceptional imagery in terms of wide dynamic range (~75 dB) and low noise (~15 e-rms noise floor) with low fixed pattern noise (<0.15% sat). Unlike CCDs, the APS is not prone to column streaking due to blooming pixels. This is because CCDs rely on charge domain shift registers that can leak charge to adjacent pixels when the CCD registers overflows. Thus, bright lights "bloom" and cause unwanted streaks in the image. The active pixel can drive column busses at much greater rates than passive pixel sensors and CCDs. On-chip analog-to-digital conversion (ADC) facilitates driving high speed signals off chip. In addition, digital output is less sensitive to pickup and crosstalk, facilitating computer and digital controller interfacing while increasing system robustness. A high speed APS recently developed for a custom binary output application produced over 8,000 frames per second, at a resolution of 128x128 pixels. It is possible to extend this design to a 1024x1024 array size and achieve greater than 1000 frames per second for machine vision. All of these features are important to many applications of this invention.

These advanced cameras, as represented by the HDRC and the APS cameras, now make it possible to more accurately monitor the environment in the vicinity of the vehicle. Heretofore, the large dynamic range of environmental light has either blinded the cameras when exposed to bright light or else made them unable to record images when the light level was low. Even the HDRC camera with its 120 dB dynamic range may be marginally sufficient to handle the fluctuations in environmental light that occur. Thus, the addition of an electrochromic, liquid crystal, or other similar filter may be necessary. This is particularly true for cameras such as the Photobit APS camera with its 75 dynamic range.

At about 120 frames per second, these cameras are adequate for cases where the relative velocity between vehicles is low. There are many cases, however, where this is not the case and a much higher monitoring rate is required. This occurs for example, in collision avoidance and anticipatory sensor applications. The HDRC camera is optimally suited for handling these cases since the number of pixels that are being monitored can be controlled resulting in a frame rate as high as about 4000 frames per second with a smaller number of pixels.

Another key advantage of the HDRC camera is that it is quite sensitive to infrared radiation in the 0.8 to 1 micrometer wavelength range. This range is generally beyond visual range for humans permitting this camera to be used with illumination sources that are not visible to the human eye. Naturally, a notch filter is frequently used with the camera to eliminate unwanted wavelengths. These cameras are available from the Institute for Microelectronics (IMS Chips), Allamndring 30a, D-70569 Stuttgart, Germany with a variety of resolutions ranging from 512 by 256 to 720 by 576 pixels and can be custom fabricated for the resolution and response time required.

An optical infrared transmitter and receiver assembly is shown generally at 112 in FIG. 1B and is mounted onto the instrument panel facing the windshield. Assembly 112 can either be recessed below the upper face of the instrument panel or mounted onto the upper face of the instrument panel. Assembly 112, shown enlarged, comprises a source of infrared radiation, or another form of electromagnetic

radiation, and a CCD or CMOS array of typically 160 pixels by 160 pixels. In this embodiment, the windshield is used to reflect the illumination light provided by the infrared radiation toward the objects in the passenger compartment and also reflect the light being reflected back by the objects in the passenger compartment, in a manner similar to the "heads-up" display which is now being offered on several automobile models. The "heads-up" display, of course, is currently used only to display information to the driver and is not used to reflect light from the driver to a receiver. Once again, unless one of the distance measuring systems as described below is used, this system alone cannot be used to determine distances from the objects to the sensor. Its main purpose is object identification and monitoring. Depending on the application, separate systems can be used for the driver and for the passenger. In some cases, the cameras located in the instrument panel which receive light reflected off of the windshield can be co-located with multiple lenses whereby the respective lenses aimed at the driver and passenger seats respectively.

Assembly 112 is actually about two centimeters in diameter and is shown greatly enlarged in FIG. 1B. Also, the reflection area on the windshield is considerably smaller than illustrated and special provisions are made to assure that this area of the windshield is flat and reflective as is done generally when heads-up displays are used. For cases where there is some curvature in the windshield, it can be at least partially compensated for by the CCD optics.

When using the surface of the windshield as a reflector of infrared radiation, care must be taken to assure that the desired reflectivity at the frequency of interest is achieved. Mirror materials, such as metals and other special materials manufactured by Eastman Kodak, have a reflectivity for infrared frequencies that is substantially higher than at visible frequencies. They are thus candidates for coatings to be placed on the windshield services for this purpose. If two spaced apart CCD arrays are used, then the distance to the various objects within the passenger compartment can be found by using a triangulation algorithm which locates similar features on both images and determines their relative location on the images. An alternate method is to use a lens with a short focal length. In this case, the lens is mechanically focused, e.g., automatically, directly or indirectly, by the control circuitry 120, to determine the clearest image and thereby obtain the distance to the object. This is similar to certain camera auto-focusing systems such as one manufactured by Fuji of Japan. Naturally, other methods can be used as described in the patents and patent applications referenced above.

Instead of focusing the lens, the lens could be moved relative to the array to thereby adjust the image on the array. Instead of moving the lens, the array could be moved to achieve the proper focus. In addition, it is also conceivable that software could be used to focus the image without moving the lens or the array.

Once a vehicle interior monitoring system employing a sophisticated pattern recognition system, such as a neural network, is in place, it is possible to monitor the motions of the driver over time, and his/her response to various stimuli, and determine if he or she is falling asleep, has become incapacitated or otherwise unable to operate the vehicle. In such an event, the vehicle can be caused to respond in a number of different ways. One such system is illustrated in FIG. 1B and consists of a monitoring system having the transducer assembly 112 coupled to a microprocessor in control circuitry 120 which is programmed to compare the motions of the driver over time and trained to recognize

changes in behavior representative of becoming incapacitated, e.g., the eyes blinking erratically and remaining closed for ever longer periods of time. If the system determines that there is a reasonable probability that the driver has fallen asleep, for example, then it can activate an alarm, e.g., turn on a warning light shown here as **124** or send a warning sound. If the driver fails to respond to the warning by pushing a button **122**, for example, then the horn and lights of the vehicle can be operated in a manner to warn other vehicles and the vehicle may be brought to a stop. Naturally, other responses can also be programmed and other tests of driver attentiveness can be used without resorting to attempting to monitor the motions of the driver's eyes.

The use of the windshield as a reflector is particularly useful when monitoring the eyes of the driver. The reflections from the cornea are highly directional as every driver knows whose lights have reflected off the eyes of an animal on the roadway. For this to be effective, the eyes of the driver must be looking at the radiation source. Since the driver is presumably looking through the windshield, the source of the radiation must also come from the windshield and the reflections from the driver's eyes must also be in the direction of the windshield. Using this technique, the time that the driver spends looking through the windshield can be monitored and if that time drops below some threshold value it can be presumed that the driver is not attentive and may be sleeping or otherwise incapacitated.

An even more sophisticated system of monitoring the behavior of the driver is to track the driver's eye motions using such techniques as are described in: Freidman et al., U.S. Pat. No. 4,648,052 entitled "Eye Tracker Communication System"; Heyner et al., U.S. Pat. No. 4,720,189 entitled "Eye Position Sensor"; Hutchinson, U.S. Pat. No. 4,836,670 entitled "Eye Movement Detector"; and Hutchinson, U.S. Pat. No. 4,950,069 entitled "Eye Movement Detector With Improved Calibration and Speed", all of which are incorporated herein by reference as well as U.S. Pat. Nos. 5,008,946 and 5,305,012 referenced above. The detection of the impaired driver in particular can be best determined by these techniques. These systems make use of pattern recognition techniques plus, in many cases, the transmitter and CCD receivers must be appropriately located so that the reflection off of the cornea of the driver's eyes can be detected as discussed in the above referenced patents. The size of the CCD arrays used herein permits their location, sometimes in conjunction with a reflective windshield, where this corneal reflection can be detected with some difficulty. Sunglasses or other items can interfere with this process.

The location of the eyes of the driver, for this application, is greatly facilitated by the teachings of this invention as described above. Although others have suggested the use of eye motions and corneal reflections for drowsiness determination, up until now there has not been a practical method for locating the driver's eyes with sufficient precision and reliability as to render this technique practical. Also, although sunglasses might defeat such a system, most drowsiness caused accidents happen at night where it is less likely that sunglasses are worn.

The eye tracker systems discussed above are facilitated by the instant invention since one of the main purposes of determining the location of the driver's eyes either by directly locating them with trained pattern recognition technology or by inferring their location from the location of the driver's head, is so that the seat can be automatically positioned to place the driver's eyes into the "eye-ellipse".

The eye-ellipse is the proper location for the driver's eyes to permit optimal operation of the vehicle and for the location of the mirrors etc. Thus, if the location of the driver's eyes are known, then the driver can be positioned so that his or her eyes are precisely situated in the eye ellipse and the reflection off of the eye can be monitored with a small eye tracker system. Also, by ascertaining the location of the driver's eyes, a rear view mirror positioning device can be controlled to adjust the mirror **105** to an optimal position.

In addition to finding the location of the eyes, the location of the ears is becoming more important. Many automobile accidents are now being caused by driver's holding on and talking into cellular phones. Vehicle noise significantly deteriorates the quality of the sound heard by the driver from speakers. This problem can be solved through the use of hypersound and by knowing the location of the ears of the driver. Hypersound permits the precise focusing of sound waves along a line from the speaker with little divergence of the sound field. Thus, if the locations of the ears of the driver are known, the sound can be projected to them directly thereby overcoming much of the vehicle noise. In addition to the use of hypersound, directional microphones are well known in the microphone art which are very sensitive to sound coming from a particular direction. If the driver has been positioned so that his eyes are in the eye ellipse, then the location of the driver's mouth is also accurately known and a fixed position directional microphone can be used to selectively sense sound emanating from the mouth of the driver. In many cases, the sensitivity of the microphone can be designed to include a large enough area such that most motions of the driver's head can be tolerated. Alternately the direction of the microphone can be adjusted using motors or the like. Systems of noise cancellation now also become possible if the ear locations are precisely known and noise canceling microphones as described in U.S. provisional patent application Serial No. 60/110,973, which is incorporated herein by reference, if the location of the driver's mouth is known.

Infrared waves are shown coming from the front and back transducer assemblies **110** and **113** in FIG. 1C.

FIG. 1D illustrates two optical systems each having a source of infrared radiation and a CCD or CMOS array receiver. The price of such arrays has dropped dramatically recently making them practical for interior and exterior vehicle monitoring. In this embodiment, transducers **110** and **113** are CMOS arrays having 160 pixels by 160 pixels covered by a lens. In some applications, this can create a "fisheye" effect whereby light from a wide variety of directions can be captured. One such transducer placed by the dome light or other central position in the vehicle headliner, such as the transducer designated **113**, can monitor the entire vehicle interior with sufficient resolution to determine the occupancy of the vehicle, for example. CCD's such as those used herein are available from Marshall Electronics Inc. of Culver City, Calif. A fisheye lens is ". . . a wide-angle photographic lens that covers an angle of about 180°, producing a circular image with exaggerated foreshortening in the center and increasing distortion toward the periphery". (*The American Heritage Dictionary of the English Language, Third Edition, 1992* by Houghton Mifflin Company). This distortion of a fisheye lens can be substantially changed by modifying the shape of the lens to permit particular portions of the interior passenger compartment to be observed. Also, in many cases the full 180° is not desirable and a lens which captures a smaller angle may be used. Although primarily spherical lenses are illustrated herein, it is understood that the particular lens design will



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depend on the location in the vehicle and the purpose of the particular receiver.

CCD arrays are in common use in television cameras, for example, to convert an image into an electrical signal. For the purposes herein, a CCD will be defined to include all devices, including CMOS arrays, APS arrays, artificial retinas and particularly HDRC arrays, which are capable of converting light frequencies, including infrared, visible and ultraviolet, into electrical signals. The particular CCD array used for many of the applications disclosed herein is implemented on a single chip that is less than two centimeters on a side. Data from the CCD array is digitized and sent serially to an electronic circuit (at times designated 120 herein) containing a microprocessor for analysis of the digitized data. In order to minimize the amount of data that needs to be stored, initial processing of the image data takes place as it is being received from the CCD array, as discussed in more detail above. In some cases, some image processing can take place on the chip such as described in the Kage et al. artificial retina article referenced above.

One method of determining distance to an object directly without resorting to range finders, which require multiple arrays, is to use a mechanical focusing system. However, the use of such an apparatus is cumbersome, expensive, and slow and has questionable reliability. An alternative is to use the focusing systems described in the above referenced U.S. Pat. Nos. 5,193,124 and 5,003,166, however, such systems require expensive hardware and/or elaborate algorithms. Another alternative is illustrated in FIG. 1D where transducer 116 is an infrared source having a wide transmission angle such that the entire contents of the front driver's seat is illuminated. Receiving CCD transducers 117 and 118 are shown spaced apart so that a stereographic analysis can be made by the control circuitry 120. This circuitry 120 contains a microprocessor with appropriate pattern recognition algorithms along with other circuitry as described above. In this case, the desired feature to be located is first selected from one of the two returned images from either CCD transducer 117 or 118. The software then determines the location of the same feature, through correlation analysis or other methods, on the other image and thereby, through analysis familiar to those skilled in the art, determines the distance of the feature from the transducers.

Transducers 116-118 are illustrated mounted onto the A-pillar of the vehicle, however, since these transducers are quite small, typically approximately 2 cm on a side, they could alternately be mounted onto the windshield itself, or other convenient location which provides a clear view of the portion of the passenger compartment being monitored. Other preferred mounting locations include the headliner above and also the side of the seat.

With respect to the connection between the transducers 110-114 and 116-118 and the control circuitry 120, a portion of this connection is shown as wires. It should be understood that all of the connections between the transducers 110-114 and 116-118 and the control circuitry 120 may be wires, either individual wires leading from the control circuitry 120 to each of the transducers 110-114 and 116-118 or one or more wire buses.

With respect to the position of the control circuitry 120 in the dashboard of the vehicle, this position is for illustration purposes only and does not limit the location of the control circuitry 120. Rather, the control circuitry 120 may be located anywhere convenient or desired in the vehicle.

A new class of laser range finders has particular application here. This product, as manufactured by Power Spectra,

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Inc. of Sunnyvale, Calif., is a GaAs pulsed laser device which can measure up to 30 meters with an accuracy of <2 cm and a resolution of <1 cm. This system is implemented in combination with transducer 116 and one of the receiving transducers 117 or 118 may thereby be eliminated. Once a particular feature of an occupying item of the passenger compartment has been located, this device is used in conjunction with an appropriate aiming mechanism to direct the laser beam to that particular feature. The distance to that feature is then known to within 2 cm and with calibration even more accurately. In addition to measurements within the passenger compartment, this device has particular applicability in anticipatory sensing and blind spot monitoring applications exterior to the vehicle. An alternate technology using range gating to measure the time of flight of electromagnetic pulses with even better resolution can be developed based on the teaching of the McEwan patents listed above and incorporated herein by reference.

A more accurate acoustic system for determining the distance to a particular object, or a part thereof, in the passenger compartment is exemplified by transducers 111A in FIG. 1E. In this case, three ultrasonic transmitter/receivers are shown spaced apart mounted onto the A-pillar of the vehicle. The A-pillar is the forward most roof support pillar and also supports the windshield. Due to the wavelength, it is difficult to get a narrow beam using ultrasonics without either using high frequencies that have limited range or a large transducer. A commonly available 40 kHz transducer, for example, is about 1 cm in diameter and emits a sonic wave that spreads at about a sixty-degree angle. To reduce this angle requires making the transducer larger in diameter. An alternate solution is to use several transducers and to phase the transmissions so that they arrive at the intended part of the target in phase. Reflections from the selected part of the target are then reinforced whereas reflections from adjacent parts encounter interference with the result that the distance to the brightest portion within the vicinity of interest can be determined. By varying the phase of transmission from the three transducers 111A, the location of a reflection source on a curved line can be determined. In order to locate the reflection source in space, at least one additional transmitter/receiver is required which is not co-linear with the others. The accuracy of the measurement can be determined by those skilled in the art of phased array radar as the relevant equations are applicable here. The waves shown in FIG. 1E coming from the three transducers 111A are actually only the portions of the waves which arrive at the desired point in space together in phase. The effective direction of these wave streams can be varied by changing the transmission phase between the three transmitters. A determination of the approximate location of a point of interest on the occupant is accomplished by the CCD array and appropriate analysis and the phasing of the ultrasonic transmitters is determined so that the distance to the desired point can be determined.

FIG. 2A is a side view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing preferred mounting locations of optical interior vehicle monitoring sensors (transmitter/receiver assemblies or transducers) 110, 111A, 113, 114, 210, 211A, 213, 214, and 224. Each of these sensors is illustrated as having a lens and is shown enlarged in size for clarity. In a typical actual device, the diameter of the lens is approximately 2 cm and it protrudes from the mounting surface by approximately 1 cm. This small size renders these devices almost unnoticeable by vehicle occupants. Since these sensors are optical, it is important that the lens surface remains

relatively clean. Control circuitry 120, which is coupled to each transducer, contains a self-diagnostic feature where the image returned by a transducer is compared with a stored image and the existence of certain key features is verified. If a receiver fails this test, a warning is displayed to the driver which indicates that cleaning of the lens surface is required. The technology illustrated in FIG. 2A can be used for numerous purposes relating to monitoring of the space in the passenger compartment behind the driver including: (i) the determination of the presence and position of objects in the rear seat(s), (ii) the determination of the presence, position and orientation of child seats 230 in the rear seat, (iii) the monitoring of the rear of an occupant's head 242, (iv) the monitoring of the position of occupant 240, (v) the monitoring of the position of the occupant's knees 241, (vi) the monitoring of the occupant's position relative to the airbag 250, (vii) the measurement of the occupant's height, as well as other monitoring functions as described elsewhere herein.

Information relating to the space behind the driver can be obtained by processing the data obtained by the sensors 210, 211A, 213 and 214, which data would be in the form of images if optical sensors are used as in the preferred embodiment. Such information can be the presence of a particular occupying item or occupant, e.g., a rear facing child seat 230 as shown in FIG. 2A, as well as the location or position of occupying items. Additional information obtained by the optical sensors can include an identification of the occupying item. The information obtained by the control circuitry by processing the information from sensors 210, 211A, 213 and 214 may be used to affect any other system in the vehicle in a similar manner as the information from the sensors which monitor the front seat is used as described herein, such as the airbag system. Processing of the images obtained by the sensors to determine the presence, position and/or identification of any occupants or occupying item can be effected using a pattern recognition algorithm in any of the ways discussed herein, e.g., a trained neural network.

Sensors 210, 211A, 213, 214 can also be microwave radar sensors which transmit and receive radar waves. As such, it is possible to determine the presence of an object in the rear seat and the distance between the object and the sensors. Using multiple radar sensors, it would be possible to determine the contour of an object in the rear seat and thus using pattern recognition techniques, the classification or identity of the object. Motion of objects in the rear seat can also be determined using radar sensors. For example, if the radar sensors are directed toward a particular area and/or are provided with the ability to detect motion in a predetermined frequency range, they can be used to determine the presence of children or pets left in the vehicle, i.e., by detecting heartbeats or other body motions such as movement of the chest cavity.

FIG. 2B is a perspective view corresponding to the embodiment shown in FIG. 2A illustrating some of the transducer mounting locations (including sensor 110A). The passenger side airbag module is designated 104A and is mounted in the dashboard or instrument panel of the vehicle.

The occupant position sensor in any of its various forms is integrated into the airbag system circuitry as shown schematically in FIG. 3. In this example, the occupant position sensors are used as an input to a smart electronic sensor and diagnostic system. The electronic sensor determines whether one or more of the airbags should be deployed based on the vehicle acceleration crash pulse, or crush zone mounted crash sensors, or a combination thereof, and the occupant position sensor determines whether the

occupant is too close to any of the airbags and therefore that the deployment should not take place. In FIG. 3, the electronic crash sensor located within the sensor and diagnostic unit determines whether the crash is of such severity as to require deployment of one or more of the airbags. The occupant position sensors determine the location of the vehicle occupants relative to the airbags and provide this information to the sensor and diagnostic unit that then determines whether it is safe to deploy each airbag and/or whether the deployment parameters should be adjusted. The arming sensor, if one is present, also determines whether there is a vehicle crash occurring. In such a case, if the sensor and diagnostic unit and the arming sensor both determine that the vehicle is undergoing a crash requiring one or more airbags and the position sensors determine that the occupants are safely away from the airbag(s), the airbag(s), or inflatable restraint system, is deployed.

A particular implementation of an occupant position sensor having a range of from 0 to 2 meters (corresponding to an occupant position of from 0 to 1 meter since the signal must travel both to and from the occupant) using infrared is illustrated in the block diagram schematic of FIG. 4. The operation is as follows. A 48 MHz signal, f1, is generated by a crystal oscillator 401 and fed into a frequency tripler 402 which produces an output signal at 144 MHz. The 144 MHz signal is then fed into an infrared diode driver 403 which drives the infrared diode 404 causing it to emit infrared light modulated at 144 MHz and a reference phase angle of zero degrees. The infrared diode 404 is directed at the vehicle occupant. A second signal f2 having a frequency of 48.05 MHz, which is slightly greater than f1, is similarly fed from a crystal oscillator 405 into a frequency tripler 406 to create a frequency of 144.15 MHz. This signal is then fed into a mixer 407 which combines it with the 144 MHz signal from frequency tripler 402. The combined signal from the mixer 407 is then fed to filter 408 which removes all signals except for the difference, or beat frequency, between 3 times f1 and 3 times f2, of 150 kHz. The infrared signal which is reflected from the occupant is received by receiver 409 and fed into pre-amplifier 411, a resistor 410 to bias being coupled to the connection between the receiver 409 and the pre-amplifier 411. This signal has the same modulation frequency, 144 MHz, as the transmitted signal but now is out of phase with the transmitted signal by an angle x due to the path that the signal took from the transmitter to the occupant and back to the receiver. The output from pre-amplifier 411 is fed to a second mixer 412 along with the 144.15 MHz signal from the frequency tripler 406. The output from mixer 412 is then amplified by an automatic gain amplifier 413 and fed into filter 414. The filter 414 eliminates all frequencies except for the 150 kHz difference, or beat, frequency, in a similar manner as was done by filter 408. The resulting 150 kHz frequency, however, now has a phase angle x relative to the signal from filter 408. Both 150 kHz signals are now fed into a phase detector 415 which determines the magnitude of the phase angle x. It can be shown mathematically that, with the above values, the distance from the transmitting diode to the occupant is  $x/345.6$  where x is measured in degrees and the distance in meters. The velocity can also be obtained using the distance measurement as represented by 416. An alternate method of obtaining distance information, as discussed above, is to use the teachings of the McEwan patents discussed above.

Although the embodiment in FIG. 4 uses infrared, it is possible to use other frequencies of energy without deviating from the scope of the invention.

The applications described herein have been illustrated using the driver of the vehicle. The same systems of deter-

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mining the position of the occupant relative to the airbag apply to front and rear seated passengers, sometimes requiring minor modifications. It is likely that the sensor required triggering time based on the position of the occupant will be different for the driver than for the passenger. Current systems are based primarily on the driver with the result that the probability of injury to the passenger is necessarily increased either by deploying the airbag too late or by failing to deploy the airbag when the position of the driver would not warrant it but the passenger's position would. With the use of occupant position sensors for both the passenger and driver, the airbag system can be individually optimized for each occupant and result in further significant injury reduction. In particular, either the driver or passenger system can be disabled if either the driver or passenger is out-of-position or if the passenger seat is unoccupied.

There is almost always a driver present in vehicles that are involved in accidents where an airbag is needed. Only about 30% of these vehicles, however, have a passenger. If the passenger is not present, there is usually no need to deploy the passenger side airbag. The occupant monitoring system, when used for the passenger side with proper pattern recognition circuitry, can also ascertain whether or not the seat is occupied, and if not, can disable the deployment of the passenger side airbag and thereby save the cost of its replacement. The same strategy applies also for monitoring the rear seat of the vehicle. Also, a trainable pattern recognition system, as used herein, can distinguish between an occupant and a bag of groceries, for example. Finally, there has been much written about the out-of-position child who is standing or otherwise positioned adjacent to the airbag, perhaps due to pre-crash braking. The occupant position sensor described herein can prevent the deployment of the airbag in this situation as well as in the situation of a rear facing child seat as described above.

The use of trainable pattern recognition technologies such as neural networks is an important part of the instant invention, although other non-trained pattern recognition systems such as fuzzy logic, correlation, Kalman filters, and sensor fusion (a derivative of fuzzy logic) can also be used. These technologies are implemented using computer programs to analyze the patterns of examples to determine the differences between different categories of objects. These computer programs are derived using a set of representative data collected during the training phase, called the training set. After training, the computer programs output a computer algorithm containing the rules permitting classification of the objects of interest based on the data obtained after installation in the vehicle. These rules, in the form of an algorithm, are implemented in the system that is mounted onto the vehicle. The determination of these rules is central to the pattern recognition techniques used in this invention. Artificial neural networks using back propagation are thus far the most successful of the rule determination approaches, however, research is underway to develop systems with many of the advantages of back propagation neural networks, such as learning by training, without the disadvantages, such as the inability to understand the network and the possibility of not converging to the best solution. In particular, back propagation neural networks will frequently give an unreasonable response when presented with data that is not within the training data. It is well known that neural networks are good at interpolation but poor at extrapolation. A combined neural network fuzzy logic system, on the other hand, can substantially solve this problem. Additionally, there are many other neural network systems in addition to back propagation. In fact, one type of

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neural network may be optimum for identifying the contents of the passenger compartment and another for determining the location of the object dynamically.

In some implementations of this invention, such as the determination that there is an object in the path of a closing window as described below, the rules are sufficiently obvious that a trained researcher can look at the returned optical signals and devise an algorithm to make the required determinations. In others, such as the determination of the presence of a rear facing child seat or an occupant, artificial neural networks are frequently used to determine the rules. One such set of neural network software for determining the pattern recognition rules, is available from the NeuralWare Corporation of Pittsburgh, Pa. Numerous books and articles, including more than 500 U.S. patents, describe neural networks in great detail and thus the theory and application of this technology is well known and will not be repeated here. Except in a few isolated situations where neural networks have been used to solve particular problems limited to engine control, for example, they have not heretofore been applied to automobiles and trucks.

The system generally used in the instant invention, therefore, for the determination of the presence of a rear facing child seat, an occupant, or an empty seat is the artificial neural network or a neural-fuzzy system. In this case, the network operates on the returned signals from the CCD array as sensed by transducers 110, 111, 113 and 114 (not shown) in FIG. 5, for example. For the case of the front passenger seat, for example, through a training session, the system is taught to differentiate between the three cases. This is done by conducting a large number of experiments where available child seats are placed in numerous positions and orientations on the front passenger seat of the vehicle. Similarly, a sufficiently large number of experiments are run with human occupants and with boxes, bags of groceries and other objects. As many as 1,000,000 such experiments are run before the neural network is sufficiently trained so that it can differentiate among the three cases and output the correct decision with a very high probability.

Once the network is determined, it is possible to examine the result to determine, from the algorithm created by the NeuralWare software, the rules that were finally arrived at by the trial and error training technique. In that case, the rules can then be programmed into a microprocessor. Alternately, a neural computer can be used to implement the net directly. In either case, the implementation can be carried out by those skilled in the art of pattern recognition using neural networks. If a microprocessor is used, a memory device is also required to store the data from the analog to digital converters which digitize the data from the receiving transducers. On the other hand, if a neural network computer is used, the analog signal can be fed directly from the transducers to the neural network input nodes and an intermediate memory is not required. Memory of some type is needed to store the computer programs in the case of the microprocessor system and if the neural computer is used for more than one task, a memory is needed to store the network specific values associated with each task.

There are several methods measuring the height of the driver for use in automatically adjusting the seat or for adjusting the seatbelt anchorage point. Some alternatives are shown in FIG. 5, which is a side plan view of the front portion of the passenger compartment showing three height measuring transducers or sensors 110, 111, 113, all of which are mounted on or near the headliner. These transducers may already be present because of other implementations of the vehicle interior identification and monitoring system

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described herein. The combination of four transducers can determine, by the methods described above, the location of the head with great accuracy.

Optical transducers using CCD arrays are now becoming price competitive and, as mentioned above, will soon be the technology of choice for interior vehicle monitoring. A single CCD array of 160 by 160 pixels, for example, coupled with the appropriate trained pattern recognition software, can be used to form an image of the head of an occupant and accurately locate the head for some of the purposes of this invention.

The position of the rear of the head can also be known once the locus of the head has been determined. This information can be used to determine the distance from the headrest to the rearmost position of the occupant's head and to control the position of the headrest so that it is properly positioned behind the occupant's head to offer optimum support in the event of a rear impact. Although the headrest of most vehicles is adjustable, it is rare for an occupant to position it properly, if at all. Each year, there are in excess of 400,000 whiplash injuries in vehicle impacts approximately 90,000 of which are from rear impacts (source: National Highway Traffic Safety Administration, (NHTSA)). A properly positioned headrest could substantially reduce the frequency of such injuries that can be accomplished by the head detector of this invention. The head detector is connected to the headrest control mechanism and circuitry 540. This mechanism is capable of moving the headrest up and down and, in some cases, rotating it fore and aft. Thus, the control circuitry 120 may be coupled to headrest control mechanism and circuitry 540 to adjust the headrest based on the determined location of the rear of the occupant's head.

An occupant position sensor for side impacts used with a door mounted airbag system is illustrated at 530 in FIG. 5. This sensor has the particular task of monitoring the space adjacent to the door-mounted airbag. Sensor 530 may also be coupled to control circuitry 120 which can process and use the information provided by sensor 530 in the determination of the location or identity of the occupant or location of a part of the occupant.

Seatbelts are most effective when the upper attachment point to the vehicle is positioned vertically close to the shoulder of the occupant being restrained. If the attachment point is too low, the occupant experiences discomfort from the rubbing of the belt on his or her shoulder. If it is too high, the occupant may experience discomfort due to the rubbing of the belt against his or her neck and the occupant will move forward by a greater amount during a crash which may result in his or her head striking the steering wheel. For these reasons, it is desirable to have the upper seatbelt attachment point located slightly above the occupant's shoulder. To accomplish this for various sized occupants, the location of the occupant's shoulder must be known, which can be accomplished by the vehicle interior monitoring system described herein.

Such a system is illustrated in FIG. 6, which is a side planer view of a seatbelt anchorage adjustment system. In this system, infrared transmitter and CCD array receivers 620 and 621 are positioned in a convenient location proximate the occupant's shoulder, such as in connection with the headliner, above and usually to the outside of the occupant's shoulder. An appropriate pattern recognition system, as may be resident in control circuitry 120 to which the receivers 620, 621 are coupled, as described above is then used to determine the location and position of the shoulder. This

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information is provided by control circuitry 120 to the seatbelt anchorage height adjustment system 632 (through a conventional coupling arrangement), shown schematically, which moves the attachment point 631 of the seatbelt 630 to the optimum vertical location for the proper placement of the seatbelt 630.

FIG. 7 is an angular perspective overhead view of a vehicle 710 about to be impacted in the side by an approaching vehicle 720, where vehicle 710 is equipped with an anticipatory sensor system showing a transmitter 730 transmitting electromagnetic, such as infrared, waves toward vehicle 720. This is one example of many of the uses of the instant invention for exterior monitoring. The transmitter 730 is connected to an electronic module 740. Module 740 contains circuitry 742 to drive transmitter 730 and circuitry 744 to process the returned signals from receivers 734 and 736 which are also coupled to module 740. Circuitry 744 contains a processor such as a neural computer 745, which performs the pattern recognition determination based on signals from receivers 734 and 736 (FIG. 7A). Receivers 734 and 736 are mounted onto the B-Pillar of the vehicle and are covered with a protective transparent cover. An alternate mounting location is shown as 738 which is in the door window trim panel where the rear view mirror (not shown) is frequently attached. One additional advantage of this system is the ability of infrared to penetrate fog and snow better than visible light which makes this technology particularly applicable for blind spot detection and anticipatory sensing applications. Although it is well known that infrared can be significantly attenuated by both fog and snow, it is less so than visual light depending on the frequency chosen. (See for example L. A. Klein, *Millimeter-Wave and Infrared Multisensor Design and Signal Processing*, Artech House, Inc, Boston 1997, ISBN 0-89006-764-3 which is incorporated herein by reference).

The same system can also be used for the detection of objects in the blind spot of the vehicle and the image or an icon representative thereof displayed for the operator to see (display 748 discussed below with reference to FIG. 15), or a warning system activated, if the operator attempts to change lanes, for example. In this case, the mounting location must be chosen to provide a good view of the blind spot along the side of the vehicle in order to pick up vehicles which are about to pass vehicle 710. Each of the locations 734, 736 and 730 provide sufficient field of view for this application although the space immediately adjacent to the vehicle could be missed. Alternate locations include mounting onto the outside rear view mirror or the addition of a unit in the rear window or C-Pillar, in which case, the contents of areas other than the side of the vehicle would be monitored. Using several receivers in various locations as disclosed above would provide for a monitoring system which monitors all of the areas around the vehicle. The mirror location, however, does leave the device vulnerable to being covered with ice, snow and dirt.

In many cases, neural networks are used to identify objects exterior of the vehicle and then an icon is displayed on a heads-up display, for example, which provides core control over the brightness of the image and permits the driver to more easily recognize the object.

In both cases of the anticipatory sensor and blind spot detector, the infrared transmitter and CCD array system provides mainly image information to permit recognition of the object in the vicinity of vehicle 710, whether the object is alongside the vehicle, in a blind spot of the driver, in front of the vehicle or behind the vehicle, the position of the object being detected being dependent on the position and orien-

tation of the receiver(s). To complete the process, distance information is also required as well as velocity information, which can in general be obtained by differentiating the position data. This can be accomplished by any one of the several methods discussed above, such as with a pulsed laser radar system, as well as with a radar system.

Radar systems, which may not be acceptable for use in the interior of the vehicle, are now commonly used in sensing applications exterior to the vehicle, police radar being one well-known example. Miniature radar systems are now available which are inexpensive and fit within the available space. Such systems are disclosed in the McEwan patents described above. Another advantage of radar in this application is that it is easy to get a transmitter with a desirable divergence angle so that the device does not have to be aimed. One particularly advantageous mode of practicing the invention for these cases, therefore, is to use radar and a second advantageous mode is the pulsed laser radar system, along with a CCD array, although the use of two CCD arrays or the acoustical systems are also good choices. The acoustical system has the disadvantage of being slower than the laser radar device and must be mounted outside of the vehicle where it may be affected by the accumulation of deposits onto the active surface.

In a preferred implementation, transmitter 730 is an infrared transmitter and receivers 734, 736 and 738 are CCD transducers that receive the reflected infrared waves from vehicle 720. In the implementation shown in FIG. 7, an exterior airbag 790 is shown which deploys in the event that a side impact is about to occur as described in U.S. patent application Ser. No. 08/247,760.

Referring now to FIG. 15, a schematic of the use of one or more receivers 734, 736, 738 to affect another system in the vehicle is shown. The general exterior monitoring system, or blind spot monitoring system if the environment exterior of the vehicle is not viewable by the driver in the normal course of driving the vehicle, includes one or more receivers 734, 736, 738 positioned at various locations on the vehicle for the purpose of receiving waves from the exterior environment. Instead of waves, and to the extent different than waves, the receivers 734, 736, 738 could be designed to receive energy or radiation.

The waves received by receivers 734, 736, 738 contain information about the exterior objects in the environment, such waves either having been generated by or emanating from the exterior objects or reflected from the exterior objects such as is the case when the optional transmitter 730 is used. The electronic module/processor 740 contains the necessary circuitry 742, 744 and trained pattern recognition means (neural computer 745) to drive the transmitter 730 when present and process the received waves to provide a classification, identification and/or location of the exterior object. The classification, identification and/or location is then used to show an image or icon on a display 748 viewable to the driver. Also, the classification, identification and/or location of the objects could be used for airbag control, i.e., control of the deployment of the exterior airbag 790 (or any other airbags for that matter), for the control of the headlight dimmers (as discussed below with reference to FIG. 8), or in general, for any other system whose operation might be changed based on the presence of exterior objects.

FIG. 8 illustrates the exterior monitoring system for use in detecting the headlights of an oncoming vehicle or the taillights of a vehicle in front of vehicle 810. In this embodiment, the CCD array is designed to be sensitive to visible light and a separate source of illumination is not

used. Once again for some applications, the key to this technology is the use of trained pattern recognition algorithms and particularly the artificial neural network. Here, as in the other cases above and in the patents and patent applications referenced above, the pattern recognition system is trained to recognize the pattern of the headlights of an oncoming vehicle or the tail lights of a vehicle in front of vehicle 810 and to then dim the headlights when either of these conditions is sensed. It is also trained to not dim the lights for other reflections such as reflections off of a sign post or the roadway. One problem is to differentiate taillights where dimming is desired from distant headlights where dimming is not desired. Three techniques are used: (i) measurement of the spacing of the light sources, (ii) determination of the location of the light sources relative to the vehicle, and (iii) use of a red filter where the brightness of the light source through the filter is compared with the brightness of the unfiltered light. In the case of the taillight, the brightness of the red filtered and unfiltered light is nearly the same while there is a significant difference for the headlight case. In this situation, either two CCD arrays are used, one with a filter, or a filter which can be removed either electrically, such as with a liquid crystal, or mechanically.

The headlights of oncoming vehicles frequently make it difficult for the driver of a vehicle to see the road and safely operate the vehicle. This is a significant cause of accidents and much discomfort. The problem is especially severe during bad weather where rain can cause multiple reflections. Visors are now used to partially solve this problem but they do so by completely blocking the view through a large portion of the window and therefore cannot be used to cover the entire windshield. Similar problems happen when the sun is setting or rising and the driver is operating the vehicle in the direction of the sun. The vehicle interior monitoring system of this invention can contribute to the solution of this problem by determining the position of the driver's eyes as discussed above. If separate sensors are used to sense the direction of the light from the on-coming vehicle or the sun and through the use of electrochromic glass or a liquid crystal assembly, a portion of the windshield can be darkened to impose a filter between the eyes of the driver and the light source. Electrochromic glass is a material where the color of the glass can be changed through the application of an electric current. By dividing the windshield into a controlled grid or matrix of contiguous areas and through feeding the current into the windshield from orthogonal directions, selective portions of the windshield can be darkened as desired using either the electrochromic, liquid crystal or a similar technology. There are other technologies currently under development that perform in a similar manner as liquid crystals. The term "liquid crystal" as used herein, therefore, will be used to represent the class of all such materials where the optical transmissibility can be varied electrically or electronically. Electrochromic products are available from Gentex of Zeeland, Mich., and Donnelly of Holland, Mich.

FIG. 9 illustrates how such a system operates. A sensor 910 located on vehicle 902 determines the direction of the light from the headlights of oncoming vehicle 904. Sensor 910 is comprised of a lens and a CCD array with appropriate electronic circuitry which determines which elements of the CCD array are being most brightly illuminated. An algorithm stored in control circuitry 120 then calculates the direction of the light from the oncoming headlights based on the information from the CCD array. Transducers 110, 111, 113 and 114 determine the probable location of the eyes of the operator 101 of vehicle 902 in a manner such as

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described above. In this case, however, the determination of the probable locus of the driver's eyes is made with an accuracy of a diameter for each eye of about 3 inches (7.5 cm). This calculation sometimes will be in error and provision is made for the driver to make an adjustment to correct for this error as described below.

The windshield 916 of vehicle 902 comprises a liquid crystal, or similar technology, and is selectively darkened at area 918 due to the application of a current along perpendicular directions 922 and 924 of windshield 916 (See FIG. 9A). The particular portion of the windshield to be darkened is determined by control circuitry 120. Once the direction of the light from the oncoming vehicle is known and the locations of the driver's eyes are known, it is a matter of simple trigonometry to determine which areas of the windshield matrix should be darkened to impose a filter between the headlights and the driver's eyes. This is accomplished by control circuitry 120. A separate control system, not shown, located on the instrument panel, or at some other convenient location, allows the driver to select the amount of darkening accomplished by the system from no darkening to maximum darkening. In this manner, the driver can select the amount of light which is filtered to suit his particular physiology. The sensor 910 can either be designed to respond to a single light source or to multiple light sources to be sensed and thus multiple portions of the vehicle windshield to be darkened.

As mentioned above, the calculations of the location of the driver's eyes may be in error and therefore provision can be made to correct for this error. One such system permits the driver to adjust the center of the darkened portion of the windshield to correct for such errors through a knob on the instrument panel, steering wheel or other convenient location. Another solution permits the driver to make the adjustment by slightly moving his head. Once a calculation as to the location of the driver's eyes has been made, that calculation is not changed even though the driver moves his head slightly. It is assumed that the driver will only move his head to center the darkened portion of the windshield to optimally filter the light from the oncoming vehicle. The monitoring system will detect this initial head motion and make the correction automatically for future calculations.

In the applications discussed and illustrated above, the source and receiver of the electromagnetic radiation have been mounted in the same package. This is not necessary and in some implementations, the illumination source will be mounted elsewhere. For example, a laser beam can be used which is directed along an axis which bisects the angle between the center of the seat volume and two of the arrays. Such a beam may come from the A-Pillar, for example. The beam, which may be supplemental to the main illumination system, provides a point reflection from the occupying item that, in most cases, can be seen by two receivers. Triangulation thereafter can precisely determine the location of the illuminated point. This point can be moved to provide more information. In another case where it is desired to track the head of the occupant, for example, several such beams can be directed at the occupant's head during pre-crash braking or even during a crash to provide the fastest information as to the location of the head of the occupant for the fastest tracking of the motion of the occupant's head. Since only a few pixels are involved, even the calculation time is minimized.

In most of the applications above the assumption has been made that either a uniform field of light or a scanning spot of light will be provided. This need not be the case. The light that is emitted or transmitted to illuminate the object can be structured light. Structured light can take many forms start-

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ing with, for example, a rectangular or other macroscopic pattern of light and dark can be superimposed on the light by passing it through a filter. If a similar pattern is interposed between the reflections and the camera, a sort of pseudo-interference pattern can result sometimes known as Moire patterns. A similar effect can be achieved by polarizing transmitted light so that different parts of the object that is being illuminated are illuminated with light of different polarization. Once again by viewing the reflections through a similarly polarized array, information can be obtained as to where the source of light came from which is illuminating a particular object. Thus, any of the transmitter/receiver assemblies or transducers in any of the embodiments above using optics can be designed to use structured light.

One consideration when using structured light is that the source of structured light cannot be exactly co-located with the array because in this case, the pattern projected will not change as a function of the distance between the array and the object and thus the distance between the array and the object cannot be determined. Thus, it is usually necessary to provide a displacement between the array and the light source. For example, the light source can surround the array, be on top of the array or on one side of the array. The light source can also have a different virtual source, i.e., it can appear to come from behind of the array or in front of the array.

The goal is to determine the direction that a particular ray of light had when it was transmitted from the source. Then by knowing which pixels were illuminated by the reflected light ray along with the geometry of the vehicle, the distance to the point of reflection off of the object can be determined. This is particularly effective if the light source is not collocated with the CCD array. If a particular light ray, for example, illuminates an object surface which is near to the source then the reflection off of that surface will illuminate a pixel at a particular point on the CCD array. If the reflection of the same ray however occurs from a more distant surface, then a different pixel will be illuminated in the CCD array. In this manner the distance from the surface of the object to the CCD can be determined by triangulation formulas. Similarly if a given pixel is illuminated in the CCD from a reflection of a particular ray of light from the transmitter, and if we know the direction that that ray of light was sent from the transmitter, then the distance to the object at the point of reflection can be determined. If each ray of light is individually recognizable and therefore can be correlated to the angle at which it was transmitted, then a full three-dimensional image can be obtained of the object that simplifies the identification problem.

The coding of the light rays coming from the transmitter can be accomplished in many ways. One method is to polarize the light by passing the light through a filter whereby the polarization is a combination of the amount and angle of the polarization. This gives two dimensions that can therefore be used to fix the angle that the light was sent. Another method is to superimpose an analog or digital signal onto the light which could be done, for example, by using an addressable light valve, such as a liquid crystal filter, electrochromic filter, or, preferably, a garnet crystal array. Each pixel in this array would be coded such that it could be identified at the CCD.

The technique described above is dependent upon either changing the polarization or using the time domain to identify particular transmission angles with particular reflections. Spatial patterns can also be imposed on the transmitted light which generally goes under the heading of structured light. The concept is that if a pattern is identifiable then

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either the direction of transmitted light can be determined or, if the transmission source is collocated with the receiver, then the pattern expands as it travels toward the object and then, by determining the size of the received pattern, the distance to the object can be determined. In some cases Moier pattern techniques are utilized.

When the illumination source is not placed at the same location as the receiving array, it is typically placed at an angle such as 45 degrees. At least two other techniques can be considered. One is to place the illumination source at 90 degrees to the CCD array. In this case only those surface elements that are closer to the receiving array than previous surfaces are illuminated. Thus significant information can be obtained as to the profile of the object. In fact, if no object is occupying the seat, then there will be no reflections except from the seat itself. This provides a very powerful technique for determining whether the seat is occupied and where the initial surfaces of the occupying item are located.

The particular radiation field of the transmitting transducer can also be important to some implementations of this invention. In some techniques the object which is occupying the seat is the only part of the vehicle which is illuminated. Extreme care is exercised in shaping the field of light such that this is true. For example, the objects are illuminated in such a way that reflections from the door panel do not occur. Ideally if only the items which occupy the seat can be illuminated then the problem of separating the occupant from the interior vehicle passenger compartment surfaces can be more easily accomplished.

Another variant on the invention is to use no illumination source at all. In this case, the entire visible and infrared spectrum will be used. CMOS arrays are now available with very good night vision capabilities making it possible to see and image an occupant in very low light conditions.

A further consideration to this invention is to use the motion of the occupant, as determined from successive differential arrays, for example, to help identify that there is in fact a living object occupying the seat, or for other purposes.

FIG. 10 shows a schematic illustration of a system for controlling operation of a vehicle based on recognition of an authorized individual in accordance with the invention. One or more images of the passenger compartment 500 are received at 502 and data derived therefrom at 504. Multiple image receivers may be provided at different locations. The data derivation may entail any one or more of numerous types of image processing techniques such as those described in U.S. patent application Ser. No. 09/474,147 incorporated by reference herein, including those designed to improve the clarity of the image. A pattern recognition algorithm, e.g., a neural network, is trained in a training phase 506 to recognize authorized individuals. The training phase can be conducted upon purchase of the vehicle by the dealer or by the owner after performing certain procedures provided to the owner, e.g., entry of a security code or key. In the training phase for a theft prevention system, the authorized driver(s) would sit themselves in the passenger seat and optical images would be taken and processed to obtain the pattern recognition algorithm. A processor 508 is embodied with the pattern recognition algorithm thus trained to identify whether a person is the individual by analysis of subsequently obtained data derived from optical images 504. The pattern recognition algorithm in processor 508 outputs an indication of whether the person in the image is an authorized individual for which the system is trained to identify. A security system 510 enable operations of the

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vehicle when the pattern recognition algorithm provides an indication that the person is an individual authorized to operate the vehicle and prevents operation of the vehicle when the pattern recognition algorithm does not provide an indication that the person is an individual authorized to operate the vehicle.

Optionally, an optical transmitting unit 512 is provided to transmit electromagnetic energy into the passenger compartment such that electromagnetic energy transmitted by the optical transmitting unit is reflected by the person and received by the optical image reception device 502.

As noted above, several different types of optical reception devices can be used including a CCD array, a CMOS array, any type of two-dimensional image receiver, any type of three-dimensional image receiver, an active pixel camera and an HDRC camera.

The processor 508 can also be trained to determine the position of the individuals included in the images obtained by the optical image reception device, as well as the distance between the optical image reception devices and the individuals.

Instead of a security system, another component in the vehicle can be affected or controlled based on the recognition of a particular individual. For example, the rear view mirror, seat, seat belt anchorage point, headrest, pedals, steering wheel, entertainment system, air-conditioning/ventilation system can be adjusted.

FIG. 11 is a schematic illustration of a method for controlling operation of a vehicle based on recognition of a person as one of a set of authorized individuals. Although the method is described and shown for permitting or preventing ignition of the vehicle based on recognition of an authorized driver, it can be used to control for any vehicle component, system or subsystem based on recognition of an individual.

Initially, the system is set in a training phase 514 in which images including the authorized individuals are obtained by means of at least one optical receiving unit 516 and a pattern recognition algorithm is trained based thereon 518, usually after application of one or more image processing techniques to the images. The authorized individual(s) occupy the passenger compartment and have their picture taken by the optical receiving unit to enable the formation of a database on which the pattern recognition algorithm is trained. Training can be performed by any known method in the art.

The system is then set in an operational phase 520 wherein an image is obtained 522, including the driver when the system is used for a security system. If the system is used for component adjustment, then the image would include any passengers or other occupying items in the vehicle. The obtained image, or images if multiple optical receiving units are used, are input into the pattern recognition algorithm 524, preferably after some image processing, and a determination is made whether the pattern recognition algorithm indicates that the image includes an authorized driver 526. If so, ignition of the vehicle is enabled 528, or the vehicle may actually be started automatically. If not, an alarm is sounded and/or the police may be contacted 530.

The image processing techniques may be, when each image is constituted by an array of pixels, elimination of pixels from the images which are present in multiple images and/or comparing the images with stored arrays of pixels and eliminating pixels from the images which are present in the stored arrays of pixels.

FIG. 12 shows the components of the manner in which an environment of the vehicle, designated 600, is monitored.

The environment may either be an interior environment, the entire passenger compartment or only a part thereof, or an exterior environment. An active pixel camera 602 obtains images of the environment and provides the images or a representation thereof, or data derived from, to a processor 604. The processor 604 determines at least one characteristic of an object in the environment based on the images obtained by the active pixel camera 602, e.g., the presence of an object in the environment, the type of object in the environment, the position of an object in the environment and the velocity of an object in the environment. Several active pixel cameras can be provided, each focusing on a different area of the environment, although some overlap is desired. Instead of an active pixel camera or array, a single light-receiving pixel can be used.

An active pixel camera can be arranged in various locations in the vehicle including in a headliner, roof, ceiling, an A-pillar, a B-pillar and a C-pillar. Images of the front seat area or the rear seat area can be obtained by proper placement and orientation of the cameras.

Once a characteristic of the object is obtained, it can be used for numerous purposes. For example, the processor can be programmed to control a reactive component, system or subsystem 606 based on the determined characteristic of the object. When the reactive component is an airbag assembly including one or more airbags, the processor can control one or more deployment parameters of the airbag(s).

As to the manner in which the apparatus operates, reference is made to FIG. 13, wherein as a first step 610, one or more images of the environment are obtained. One or more characteristics of objects in the images are determined at 612, using, for example, pattern recognition techniques, and then one or more components are controlled at 614 based on the determined characteristics. The process of obtaining and processing the images, or the processing of data derived from the images or data representative of the images, is periodically continued at least throughout the operation of the vehicle.

FIG. 14 shows the components for measuring the position of an object in an environment of or about the vehicle. A light source 616 directs modulated light into the environment and at least one light-receiving pixel or an array of pixels 618 receives the modulated light after reflection by any objects in the environment. A processor 620 determines the distance between any objects from which the modulated light is reflected and the light source based on the reception of the modulated light by the pixel(s) 618. To provide the modulated light, a device or component for modulating a frequency of the light 622 are provided. Also, a device for providing a correlation pattern in a form of code division modulation of the light can be used. The pixel may be a photo diode such as a PIN or avalanche diode.

The processor 620 includes appropriate circuitry to determine the distance between any objects from which any pulse of light is reflected and the light source 616. For example, the processor 620 can determine this distance based on a difference in time between the emission of a pulse of light by the light source 616 and the reception of light by the pixel 618.

Thus, one method described above for determining the identification and position of objects in a passenger compartment of a vehicle in accordance with the invention comprises the steps of transmitting electromagnetic waves (optical or non-optical) into the passenger compartment from one or more locations, obtaining a plurality of images of the interior of the passenger compartment from several

locations, and comparing the images of the interior of the passenger compartment with stored images representing different arrangements of objects in the passenger compartment to determine which of the stored images match most closely to the images of the interior of the passenger compartment such that the identification of the objects and their position is obtained based on data associated with the stored images. The electromagnetic waves may be transmitted from transmitter/receiver assemblies positioned at different locations around a seat such that each assembly is situated in a middle of a side of the ceiling surrounding the seat or in the middle of the headliner directly above the seat. The method would thus be operative to determine the identification and/or position of the occupants of that seat. Each assembly may comprise an optical transmitter (such as an infrared LED, an infrared LED with a diverging lens, a laser with a diverging lens and a scanning laser assembly) and an optical array (such as a CCD array and a CMOS array). The optical array is thus arranged to obtain the images of the interior of the passenger compartment represented by a matrix of pixels. To enhance the method, prior to the comparison of the images, each obtained image or output from each array may be compared with a series of stored images or arrays representing different unoccupied states of the passenger compartment, such as different positions of the seat when unoccupied, and each stored image or array is subtracted from the obtained image or acquired array. Another way to determine which stored image matches most closely to the images of the interior of the passenger compartment is to analyze the total number of pixels of the image reduced below a threshold level, and analyze the minimum number of remaining detached pixels. Preferably, a library of stored images is generated by positioning an object on the seat, transmitting electromagnetic waves into the passenger compartment from one or more locations, obtaining images of the interior of the passenger compartment, each from a respective location, associating the images with the identification and position of the object, and repeating the positioning step, transmitting step, image obtaining step and associating step for the same object in different positions and for different objects in different positions. If the objects include a steering wheel, a seat and a headrest, the angle of the steering wheel, the telescoping position of the steering wheel, the angle of the back of the seat, the position of the headrest and the position of the seat may be obtained by the image comparison. One advantage of this implementation is that after the identification and position of the objects are obtained, one or more systems in the vehicle, such as an occupant restraint device or system, a mirror adjustment system, a seat adjustment system, a steering wheel adjustment system, a pedal adjustment system, a headrest positioning system, a directional microphone, an air-conditioning/heating system, an entertainment system, may be affected based on the obtained identification and position of at least one of the objects. The image comparison may entail inputting the images or a form thereof into a neural network which provides for each image of the interior of the passenger compartment, an index of a stored image that most closely matches the image of the interior of the passenger compartment. The index is thus utilized to locate stored information from the matched image including, inter alia, a locus of a point representative of the position of the chest of the person, a locus of a point representative of the position of the head of the person, one or both ears of the person, one or both eyes of the person and the mouth of the person. Moreover, the position of the person relative to at least one airbag or other occupant



restraint system of the vehicle may be determined so that deployment of the airbag(s) or occupant restraint system is controlled based on the determined position of the person. It is also possible to obtain information about the location of the eyes of the person from the image comparison and adjust the position of one or more of the rear view mirrors based on the location of the eyes of the person. Also, the location of the eyes of the person may be obtained such that an external light source may be filtered by darkening the windshield of the vehicle at selective locations based on the location of the eyes of the person. Further, the location of the ears of the person may be obtained such that a noise cancellation system in the vehicle is operated based on the location the ears of the person. The location of the mouth of the person may be used to direct a directional microphone in the vehicle. In addition, the location of the locus of a point representative of the position of the chest or head (e.g., the probable center of the chest or head) over time may be monitored by the image comparison and one or more systems in the vehicle controlled based on changes in the location of the locus of the center of the chest or head over time. This monitoring may entail subtracting a most recently obtained image from an immediately preceding image and analyzing a leading edge of changes in the images or deriving a correlation function which correlates the images with the chest or head in an initial position with the most recently obtained images. In one particularly advantageous embodiment, the weight applied onto the seat is measured and one or more systems in the vehicle are affected (controlled) based on the measured weight applied onto the seat and the identification and position of the objects in the passenger compartment.

In another method disclosed above for determining the identification and position of objects in a passenger compartment of a vehicle in accordance with the invention, electromagnetic waves are transmitted into the passenger compartment from one or more locations, a plurality of images of the interior of the passenger compartment are obtained, each from a respective location, a three-dimensional map of the interior of the passenger compartment is created from the images, and a pattern recognition technique is applied to the map in order to determine the identification and position of the objects in the passenger compartment. The pattern recognition technique may be a neural network, fuzzy logic or an optical correlator or combinations thereof. The map may be obtained by utilizing a scanning laser radar system where the laser is operated in a pulse mode and determining the distance from the object being illuminated using range gating. (See, for example, H. Kage, W. Freeman, Y. Miyke, E. Funtsu, K. Tanaka, K. Kyuma "Artificial retina chips as on-chip image processors and gesture-oriented interfaces", *Optical Engineering*, December, 1999, Vol. 38, Number 12, ISSN 0091-3286)

In a method disclosed above for tracking motion of a vehicular occupant's head or chest in accordance with the invention, electromagnetic waves are transmitted toward the occupant from at least one location, a first image of the interior of the passenger compartment is obtained from each location, the first image being represented by a matrix of pixels, and electromagnetic waves are transmitted toward the occupant from the same location(s) at a subsequent time and an additional image of the interior of the passenger compartment is obtained from each location, the additional image being represented by a matrix of pixels. The additional image is subtracted from the first image to determine which pixels have changed in value. A leading edge of the changed pixels and a width of a field of the changed pixels

is determined to thereby determine movement of the occupant from the time between which the first and additional images were taken. The first image is replaced by the additional image and the steps of obtaining an additional image and subtracting the additional image from the first image are repeated such that progressive motion of the occupant is attained.

A method disclosed above for controlling deployment of an occupant restraint system in a vehicle comprises the steps of transmitting electromagnetic waves toward an occupant seated in a passenger compartment of the vehicle from one or more locations, obtaining a plurality of images of the interior of the passenger compartment, each from a respective location, analyzing the images to determine the distance between the occupant and the occupant restraint system, and controlling deployment of the occupant restraint system based on the determined distance between the occupant and the occupant restraint system. The images may be analyzed by comparing the images of the interior of the passenger compartment with stored images representing different arrangements of objects in the passenger compartment to determine which of the stored images match most closely to the images of the interior of the passenger compartment, each stored image having associated data relating to the distance between the occupant in the image and the occupant restraint system. The image comparison step may entail inputting the images or a form thereof into a neural network which provides for each image of the interior of the passenger compartment, an index of a stored image that most closely matches the image of the interior of the passenger compartment. In a particularly advantageous embodiment, the weight of the occupant on a seat is measured and deployment of the occupant restraint system is controlled based on the determined distance between the occupant and the occupant restraint system and the measured weight of the occupant.

In another method disclosed above for determining the identification and position of objects in a passenger compartment of a vehicle, a plurality of images of the interior of the passenger compartment, each from a respective location and of radiation emanating from the objects in the passenger compartment, and the images of the radiation emanating from the objects in the passenger compartment are compared with stored images of radiation emanating from different arrangements of objects in the passenger compartment to determine which of the stored images match most closely to the images of the interior of the passenger compartment such that the identification of the objects and their position is obtained based on data associated with the stored images. In this embodiment, there is no illumination of the passenger compartment with electromagnetic waves. Nevertheless, the same processes described above may be applied in conjunction with this method, e.g., affecting another system based on the position and identification of the objects, a library of stored images generated, external light source filtering, noise filtering, occupant restraint system deployment control and the utilization of weight for occupant restraint system control.

Thus, disclosed above is a system to identify, locate and monitor occupants, including their parts, and other objects in the passenger compartment and objects outside of a motor vehicle, such as an automobile or truck, by illuminating the contents of the vehicle and/or objects outside of the vehicle with electromagnetic radiation, and specifically infrared radiation, or using radiation naturally emanating from the object, and using one or more lenses to focus images of the contents onto one or more arrays of charge coupled devices

(CCD's) or CMOS arrays. Outputs from the CCD or CMOS arrays are analyzed by appropriate computational means employing trained pattern recognition technologies, to classify, identify or locate the contents and/or external objects. In general, the information obtained by the identification and monitoring system may be used to affect the operation of at least one other system in the vehicle.

When the vehicle interior monitoring system in accordance with some embodiments of this invention is installed in the passenger compartment of an automotive vehicle equipped with a passenger protective device, such as an inflatable airbag, and the vehicle is subjected to a crash of sufficient severity that the crash sensor has determined that the protective device is to be deployed, the system determines the position of the vehicle occupant relative to the airbag and disables deployment of the airbag if the occupant is positioned so that he/she is likely to be injured by the deployment of the airbag. In the alternative, the parameters of the deployment of the airbag can be tailored to the position of the occupant relative to the airbag, e.g., a depowered deployment.

In some implementations of the invention, several CCD or CMOS arrays are placed in such a manner that the distance from, and the motion of the occupant toward, the airbag can be monitored as a transverse motion across the field of the array. In this manner, the need to measure the distance from the array to the object is obviated. In other implementations, the source of infrared light is a pulse modulated laser which permits an accurate measurement of the distance to the point of reflection through the technique of range gating to measure the time of flight of the radiation pulse.

In some applications, a trained pattern recognition system, such as a neural network, sensor fusion or neural-fuzzy system, is used to identify the occupancy of the vehicle or an object exterior to the vehicle. In some of these cases, the pattern recognition system determines which of a library of images most closely matches the seated state of a particular vehicle seat and thereby the location of certain parts of an occupant can be accurately estimated from the matched images, thus removing the requirement for the pattern recognition system to locate the head of an occupant, for example.

Also disclosed above is an arrangement for determining vehicle occupant position relative to a fixed structure within the vehicle which comprises an array structured and arranged to receive an image of a portion of the passenger compartment of the vehicle in which the occupant is likely to be situated, a lens arranged between the array and the portion of the passenger compartment, adjustment means for changing the image received by the array, and processor means coupled to the array and the adjustment means. The processor means determine, upon changing by the adjustment means of the image received by the array, when the image is clearest whereby a distance between the occupant and the fixed structure is obtainable based on the determination by the processor means when the image is clearest. The image may be changed by adjusting the lens, e.g., adjusting the focal length of the lens and/or the position of the lens relative to the array, by adjusting the array, e.g., the position of the array relative to the lens, and/or by using software to perform a focusing process. The array may be arranged in several advantageous locations on the vehicle, e.g., on an A-pillar of the vehicle, above a top surface of an instrument panel of the vehicle and on an instrument panel of the vehicle and oriented to receive an image reflected by a windshield of the vehicle. The array may be a CCD array

with an optional liquid crystal or electrochromic glass filter coupled to the array for filtering the image of the portion of the passenger compartment. The array could also be a CMOS array. In a preferred embodiment, the processor means are coupled to an occupant protection device and control the occupant protection device based on the distance between the occupant and the fixed structure. For example, the occupant protection device could be an airbag whereby deployment of the airbag is controlled by the processor means. The processor means may be any type of data processing unit such as a microprocessor. This arrangement could be adapted for determining distance between the vehicle and exterior objects, in particular, objects in a blind spot of the driver. In this case, such an arrangement would comprise an array structured and arranged to receive an image of an exterior environment surrounding the vehicle containing at least one object, a lens arranged between the array and the exterior environment, adjustment means for changing the image received by the array, and processor means coupled to the array and the adjustment means. The processor means determine, upon changing by the adjustment means of the image received by the array, when the image is clearest whereby a distance between the object and the vehicle is obtainable based on the determination by the processor means when the image is clearest. As before, the image may be changed by adjusting the lens, e.g., adjusting the focal length of the lens and/or the position of the lens relative to the array, by adjusting the array, e.g., the position of the array relative to the lens, and/or by using software to perform a focusing process. The array may be a CCD array with an optional liquid crystal or electrochromic glass filter coupled to the array for filtering the image of the portion of the passenger compartment. The array could also be a CMOS array. In a preferred embodiment, the processor means are coupled to an occupant protection device and control the occupant protection device based on the distance between the occupant and the fixed structure. For example, the occupant protection device could be an airbag whereby deployment of the airbag is controlled by the processor means. The processor means may be any type of data processing unit such as a microprocessor.

Also, at least one of the above-listed objects is achieved by an arrangement for determining vehicle occupant presence, type and/or position relative to a fixed structure within the vehicle, the vehicle having a front seat and an A-pillar. The arrangement comprises a first array mounted on the A-pillar of the vehicle and arranged to receive an image of a portion of the passenger compartment in which the occupant is likely to be situated, and processor means coupled to the first array for determining the presence, type and/or position of the vehicle occupant based on the image of the portion of the passenger compartment received by the first array. The processor means preferably are arranged to utilize a pattern recognition technique, e.g., a trained neural network, sensor fusion, fuzzy logic. The processor means can determine the vehicle occupant presence, type and/or position based on the image of the portion of the passenger compartment received by the first array. In some embodiments, a second array is arranged to receive an image of at least a part of the same portion of the passenger compartment as the first array. The processor means are coupled to the second array and determine the vehicle occupant presence, type and/or position based on the images of the portion of the passenger compartment received by the first and second arrays. The second array may be arranged at a central portion of a headliner of the vehicle between sides of the vehicle. The determination of the occupant presence,

type and/or position can be used in conjunction with a reactive component, system or subsystem so that the processor means control the reactive component, system or subsystem based on the determination of the occupant presence, type and/or position. For example, if the reactive component, system or subsystem is an airbag assembly including at least one airbag, the processor means control one or more deployment parameters of the airbag(s). The arrays may be CCD arrays with an optional liquid crystal or electrochromic glass filter coupled to the array for filtering the image of the portion of the passenger compartment. The arrays could also be CMOS arrays, active pixel cameras and HDRC cameras.

Another embodiment disclosed above is an arrangement for obtaining information about a vehicle occupant within the vehicle which comprises transmission means for transmitting a structured pattern of light, e.g., polarized light, into a portion of the passenger compartment in which the occupant is likely to be situated, an array arranged to receive an image of the portion of the passenger compartment, and processor means coupled to the array for analyzing the image of the portion of the passenger compartment to obtain information about the occupant. The transmission means and array are proximate one another and the information obtained about the occupant is a distance from the location of the transmission means and the array. The processor means obtain the information about the occupant utilizing a pattern recognition technique. The information about of the occupant can be used in conjunction with a reactive component, system or subsystem so that the processor means control the reactive component, system or subsystem based on the determination of the occupant presence, type and/or position. For example, if the reactive component, system or subsystem is an airbag assembly including at least one airbag, the processor means control one or more deployment parameters of the airbag(s).

Another invention disclosed above is a system for controlling operation of a vehicle based on recognition of an authorized individual comprises a processor embodying a pattern recognition algorithm, as defined above, trained to identify whether a person is the individual by analyzing data derived from images and one or more optical receiving units for receiving an optical image including the person and deriving data from the image. Each optical receiving unit is coupled to the processor to provide the data to the pattern recognition algorithm to thereby obtain an indication from the pattern recognition algorithm whether the person is the individual. A security system is arranged to enable operation of the vehicle when the pattern recognition algorithm provides an indication that the person is an individual authorized to operate the vehicle and prevent operation of the vehicle when the pattern recognition algorithm does not provide an indication that the person is an individual authorized to operate the vehicle. An optional optical transmitting unit is provided in the vehicle for transmitting electromagnetic energy and is arranged relative to the optical receiving unit(s) such that electromagnetic energy transmitted by the optical transmitting unit is reflected by the person and received by at least one of the optical receiving units. The optical receiving units may be selected from a group consisting of a CCD array, a CMOS array, an active pixel camera and an HDRC camera. Other types of two or three-dimensional cameras can also be used.

Instead of a security system, the individual recognition system can be used to control vehicular components, such as the mirrors, the seat, the anchorage point of the seatbelt, the airbag deployment parameters including inflation rate and

pressure, inflation direction, deflation rate, time of inflation, the headrest, the steering wheel, the pedals, the entertainment system and the air-conditioning/ventilation system. In this case, the system includes control means coupled to the component for affecting the component based on the indication from the pattern recognition algorithm whether the person is the individual.

A method for controlling operation of a vehicle based on recognition of a person as one of a set of authorized individuals comprises the steps of obtaining images including the authorized individuals by means of one or more optical receiving unit, deriving data from the images, training a pattern recognition algorithm on the data derived from the images which is capable of identifying a person as one of the individuals, then subsequently obtaining images by means of the optical receiving unit(s), inputting data derived from the images subsequently obtained by the optical receiving unit(s) into the pattern recognition algorithm to obtain an indication whether the person is one of the set of authorized individuals, and providing a security system which enables operation of the vehicle when the pattern recognition algorithm provides an indication that the person is one of the set of individuals authorized to operate the vehicle and prevents operation of the vehicle when the pattern recognition algorithm does not provide an indication that the person is one of the set of individuals authorized to operate the vehicle. The data derivation from the images may entail any number of image processing techniques including eliminating pixels from the images which are present in multiple images and comparing the images with stored arrays of pixels and eliminating pixels from the images which are present in the stored arrays of pixels. The method can also be used to control a vehicular component based on recognition of a person as one of a predetermined set of particular individuals. This method includes the step of affecting the component based on the indication from the pattern recognition algorithm whether the person is one of the set of individuals. The components may be one or more of the following: the mirrors, the seat, the anchorage point of the seatbelt, the airbag deployment parameters including inflation rate and pressure, inflation direction, deflation rate, time of inflation, the headrest, the steering wheel, the pedals, the entertainment system and the air-conditioning/ventilation system.

There has thus been shown and described, among other things, a monitoring system for monitoring both the interior and the exterior of the vehicle using an optical system, for example, with one or more CCD arrays or CMOS arrays, and other associated equipment which fulfills all the objects and advantages sought after.

Lastly, it is possible to use a modulated scanning beam of radiation and a single pixel receiver, PIN or avalanche diode, in the inventions described above. Any form of energy or radiation used above may be in the infrared or radar spectrums, to the extent possible, and may be polarized and filters may be used in the receiver to block out sunlight etc. These filters may be notch filters as described above and may be made integral with the lens as one or more coatings on the lens surface as is well known in the art.

Also disclosed above is a vehicle including a monitoring arrangement for monitoring an environment of the vehicle which comprises at least one active pixel camera for obtaining images of the environment of the vehicle and a processor coupled to the active pixel camera(s) for determining at least one characteristic of an object in the environment based on the images obtained by the active pixel camera(s). The active pixel camera can be arranged in a headliner, roof or ceiling of the vehicle to obtain images of an interior envi-

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ronment of the vehicle, in an A-pillar or B-pillar of the vehicle to obtain images of an interior environment of the vehicle, or in a roof, ceiling, B-pillar or C-pillar of the vehicle to obtain images of an interior environment of the vehicle behind a front seat of the vehicle. These mounting locations are exemplary only and not limiting.

The determined characteristic can be used to enable optimal control of a reactive component, system or subsystem coupled to the processor. When the reactive component is an airbag assembly including at least one airbag, the processor can be designed to control at least one deployment parameter of the airbag(s).

Another monitoring arrangement comprises an imaging device for obtaining three-dimensional images of the environment (internal and/or external) and a processor embodying a pattern recognition technique for processing the three-dimensional images to determine at least one characteristic of an object in the environment based on the three-dimensional images obtained by the imaging device. The imaging device can be arranged at locations throughout the vehicle as described above. Control of a reactive component is enabled by the determination of the characteristic of the object.

Another arrangement for monitoring objects in or about a vehicle comprises a generating device for generating a first signal having a first frequency in a specific radio range, a wave transmitter arranged to receive the signal and transmit waves toward the objects, a wave-receiver arranged relative to the wave transmitter for receiving waves transmitted by the wave transmitter after the waves have interacted with an object, the wave receiver being arranged to generate a second signal based on the received waves at the same frequency as the first signal but shifted in phase, and a detector for detecting a phase difference between the first and second signals, whereby the phase difference is a measure of a property of the object. The phase difference is a measure of the distance between the object and the wave receiver and the wave transmitter. The wave transmitter may comprise an infrared driver and the receiver comprises an infrared diode.

A vehicle including an arrangement for measuring position of an object in an environment of or about the vehicle comprises a light source capable of directing modulated light into the environment, at least one light-receiving pixel arranged to receive the modulated light after reflection by any objects in the environment and a processor for determining the distance between any objects from which the modulated light is reflected and the light source based on the reception of the modulated light by the pixel(s). The pixels can constitute an array. Components for modulating a frequency of the light being directed by the light source into the environment and for providing a correlation pattern in a form of code division modulation of the light being directed by the light source into the environment can be provided. The pixel can also be a photo diode such as a PIN or avalanche diode.

Another measuring position arrangement comprises a light source capable of directing individual pulses of light into the environment, at least one array of light-receiving pixels arranged to receive light after reflection by any objects in the environment and a processor for determining the distance between any objects from which any pulse of light is reflected and the light source based on a difference in time between the emission of a pulse of light by the light source and the reception of light by the array. The light source can be arranged at various locations in the vehicle as

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described above to direct light into external and/or internal environments, relative to the vehicle.

Many changes, modifications, variations and other uses and applications of the subject invention will, however, become apparent to those skilled in the art after considering this specification and the accompanying drawings which disclose the preferred embodiments thereof. All such changes, modifications, variations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the following claims.

We claim:

1. A monitoring arrangement for monitoring an environment exterior of a vehicle, comprising:

at least one receiver arranged to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and comprising trained pattern recognition means for processing the signal to provide a classification, identification or location of the exterior object, said trained pattern recognition means being structured and arranged to apply a trained pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects to provide the classification, identification or location of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

2. The arrangement of claim 1, wherein said at least one receiver comprises a pair of receivers spaced apart from one another.

3. The arrangement of claim 1, wherein said at least one receiver is arranged to receive infrared waves.

4. The arrangement of claim 1, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said at least one receiver is arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

5. The arrangement of claim 1, wherein said trained pattern recognition means comprise a neural computer.

6. The arrangement of claim 1, wherein said trained pattern recognition means comprise a neural network.

7. The arrangement of claim 1, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

8. The arrangement of claim 1, wherein said at least one receiver is a CCD array.

9. The arrangement of claim 1, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

10. The arrangement of claim 9, wherein said measurement means comprise a radar or laser radar system.

11. The arrangement of claim 1, wherein the another system is an airbag, said pattern recognition means being structured and arranged to apply the pattern recognition algorithm to provide the identification of the exterior object, deployment of said airbag being controlled based on the identification of the exterior object.

12. The arrangement of claim 11, wherein the airbag is an externally deployed airbag.

13. The arrangement of claim 1, wherein said processor is arranged to provide the classification of the exterior object.

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14. The arrangement of claim 1, wherein said processor is arranged to provide the identification of the exterior object.

15. The arrangement of claim 1, wherein said processor is arranged to provide the location of the exterior object.

16. A monitoring arrangement for monitoring an environment exterior of a vehicle, comprising:

at least one CCD array positioned to obtain images of the environment exterior of the vehicle; and

a processor coupled to said at least one CCD array and comprising trained pattern recognition means for processing the images obtained by said at least one CCD array to provide a classification, identification or location of the exterior object,

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

17. The arrangement of claim 16, wherein said pattern recognition means are structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and images from said at least one CCD array of the possible exterior objects.

18. The arrangement of claim 16, wherein said at least one CCD array comprises a pair of CCD arrays spaced apart from one another.

19. The arrangement of claim 16, wherein the monitoring arrangement further comprises a transmitter for transmitting infrared waves into the environment exterior of the vehicle.

20. The arrangement of claim 16, wherein said pattern recognition means comprise a neural computer.

21. The arrangement of claim 16, wherein said pattern recognition means comprise a neural network.

22. The arrangement of claim 16, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

23. The arrangement of claim 16, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

24. The arrangement of claim 23, wherein said measurement means comprise a radar or laser radar system.

25. The arrangement of claim 16, wherein the another system is an airbag, said trained pattern recognition means being structured and arranged to process the images obtained by said at least one CCD array to provide the identification of the exterior object, deployment of said airbag being controlled based on the identification of the exterior object.

26. The arrangement of claim 25, wherein the airbag is an externally deployed airbag.

27. The arrangement of claim 16, wherein said processor is arranged to provide the classification of the exterior object.

28. The arrangement of claim 16, wherein said processor is arranged to provide the identification of the exterior object.

29. The arrangement of claim 16, wherein said processor is arranged to provide the location of the exterior object.

30. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged on a rear view mirror of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and arranged to classify or identify the exterior object based

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on the signal and thereby provide the classification or identification of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification or identification of the exterior object.

31. The vehicle of claim 30, wherein said processor comprises trained pattern recognition means for processing the signal to provide the classification or identification of the exterior object, said trained pattern recognition means being structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects.

32. The vehicle of claim 30, wherein said at least one receiver comprises a pair of receivers spaced apart from one another.

33. The vehicle of claim 30, wherein said at least one receiver is arranged to receive infrared waves.

34. The vehicle of claim 30, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said at least one receiver is arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

35. The vehicle of claim 31, wherein said trained pattern recognition means comprise a neural computer.

36. The vehicle of claim 31, wherein said trained pattern recognition means comprise a neural network.

37. The vehicle of claim 30, wherein said at least one receiver is a CCD array.

38. The vehicle of claim 30, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

39. The vehicle of claim 38, wherein said measurement means comprise a radar or laser radar system.

40. A monitoring arrangement for monitoring an environment exterior of a vehicle, comprising:

a plurality of receivers arranged apart from one another and to receive waves from different parts of the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said receivers and arranged to classify, identify or locate the exterior object based on the signals generated by said receivers and thereby provide the classification identification or location of the exterior object,

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

41. The arrangement of claim 40, wherein said processor comprises trained pattern recognition means for processing the signal to provide the classification, identification or location of the exterior object, said trained pattern recognition means being structured and arranged to apply a trained pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects.

42. The arrangement of claim 40, wherein said receivers are arranged to receive infrared waves.

43. The arrangement of claim 40, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said receivers are arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

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44. The arrangement of claim 41, wherein said trained pattern recognition means comprise a neural computer.

45. The arrangement of claim 41, wherein said trained pattern recognition means comprise a neural network.

46. The arrangement of claim 40, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

47. The arrangement of claim 40, wherein said receivers are CCD arrays.

48. The arrangement of claim 40, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

49. The arrangement of claim 48, wherein said measurement means comprise a radar or laser radar system.

50. The arrangement of claim 40, wherein the another system is an airbag, said processor being arranged to identify the exterior object to provide an identification of the exterior object, said output means being arranged to control deployment of said airbag based on the identification of the exterior object.

51. The arrangement of claim 50, wherein the airbag is an externally deployed airbag.

52. The monitoring arrangement of claim 40, wherein said processor is arranged to classify or identify the exterior object based on the signals generated by said receivers and thereby provide the classification or identification of the exterior object.

53. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged on a B-pillar of the vehicle to receive waves from the environment exterior of and on the side of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and arranged to classify, identify or locate the exterior object based on the signal and thereby provide the classification, identification or location of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

54. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged in a door window trim panel of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and arranged to classify, identify or locate the exterior object based on the signal and thereby provide the classification, identification or location of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

55. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged on a rear view mirror of the vehicle to receive waves from the environment exterior

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of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves;

a processor coupled to said at least one receiver and arranged to at least one of classify, identify and locate the exterior object based on the signal and thereby provide at least one of the classification, identification and location of the exterior object; and

a display viewable by the driver; said display being coupled to and controlled by said processor to cause the display the presence and at least one of the classification, identification and location of the exterior object on said display.

56. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and comprising trained pattern recognition means for processing the signal to provide a classification, identification or location of the exterior object, said trained pattern recognition means being structured and arranged to apply a trained pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects to provide the classification, identification or location of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

57. The vehicle of claim 56, wherein said at least one receiver is arranged on a B-pillar of the vehicle to receive waves from a side of the vehicle.

58. The vehicle of claim 56, wherein said at least one receiver is arranged in a door window trim panel.

59. The vehicle of claim 56, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said at least one receiver is arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

60. The vehicle of claim 56, wherein said at least one receiver is arranged to receive waves from a blind spot of the vehicle.

61. The vehicle of claim 56, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

62. The vehicle of claim 56, wherein said at least one receiver is mounted on a rear view mirror or in a rear window.

63. The vehicle of claim 56, wherein said at least one receiver is mounted in a C-pillar of the vehicle.

64. The vehicle of claim 56, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

65. The vehicle of claim 56, wherein the another system is an airbag, said trained pattern recognition means being structured and arranged to apply the pattern recognition algorithm to provide the identification of the exterior object, deployment of said airbag being controlled based on the identification of the exterior object.

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66. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one CCD array positioned to obtain images of the environment exterior of the vehicle; and

a processor coupled to said at least one CCD array and comprising trained pattern recognition means for processing the images obtained by said at least one CCD array to provide a classification, identification or location of the exterior object, said trained pattern recognition means being structured and arranged to apply a trained pattern recognition algorithm generated from data of possible exterior objects and images obtained by said at least one CCD array from the possible exterior objects to provide the classification, identification or location of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

67. The vehicle of claim 66, wherein said at least one CCD array is arranged on a B-pillar of the vehicle to obtain images from a side of the vehicle.

68. The vehicle of claim 66, wherein said at least one CCD array is arranged in a door window trim panel.

69. The vehicle of claim 66, wherein said at least one CCD array comprises a pair of CCD arrays spaced apart from one another.

70. The vehicle of claim 66, wherein the monitoring arrangement further comprises a transmitter for transmitting infrared waves into the environment exterior of the vehicle.

71. The vehicle of claim 66, wherein said at least one CCD array is arranged to obtain images from a blind spot of the vehicle.

72. The vehicle of claim 66, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

73. The vehicle of claim 66, wherein said at least one CCD array is mounted on a rear view mirror or in a rear window.

74. The vehicle of claim 66, wherein said at least one CCD array is mounted in a C-pillar of the vehicle.

75. The vehicle of claim 66, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

76. The vehicle of claim 66, wherein the another system is an airbag, said trained pattern recognition means being arranged to process the images obtained by said at least one CCD array to provide the identification of the exterior object, deployment of said airbag being controlled based on the identification of the exterior object.

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77. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

a plurality of receivers arranged apart from one another and to receive waves from different parts of the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said receivers and arranged to classify, identify or locate the exterior object based on the signals generated by said receivers to provide the classification, identification or location of the exterior object,

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

78. The vehicle of claim 77, wherein said processor comprises trained pattern recognition means for processing the signal to provide the classification, identification or location of the exterior object, said pattern recognition means being structured and arranged to apply a pattern recognition algorithm generated.

79. The vehicle of claim 77, wherein said receivers are arranged on a B-pillar of the vehicle to receive waves from a side of the vehicle.

80. The vehicle of claim 77, wherein said receivers are arranged to receive infrared waves.

81. The vehicle of claim 77, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said receivers are arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

82. The vehicle of claim 77, wherein said receivers are arranged to receive waves from a blind spot of the vehicle.

83. The vehicle of claim 77, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

84. The vehicle of claim 77, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

85. The vehicle of claim 77, wherein the another system is an airbag, said processor being arranged to identify the exterior object to provide the identification of the exterior object, said output means being arranged to control deployment of said airbag based on the identification of the exterior object.

86. The vehicle of claim 77, wherein said processor is arranged to classify or identify the exterior object based on the signals generated by said receivers and thereby provide the classification or identification of the exterior object.

\* \* \* \* \*

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PTO/SB/05 (03-01)

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<b>UTILITY PATENT APPLICATION TRANSMITTAL</b> <small>(Only for new nonprovisional applications under 37 CFR 1.53(b))</small>	<b>Attorney Docket No.</b>	ATI-338
	<b>First Inventor</b>	David S. Breed
	<b>Title</b>	Vehicular Monitoring Systems Using Image...
	<b>Express Mail Label No.</b>	EF162696266US

<b>APPLICATION ELEMENTS</b> <small>See MPEP chapter 600 concerning utility patent application contents.</small>	<b>ADDRESS TO:</b> Assistant Commissioner for Patents Box Patent Application Washington, DC 20231
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1.  Fee Transmittal Form (e.g., PTO/SB/17)  
(Submit an original and a duplicate for fee processing)
2.  Applicant claims small entity status.  
See 37 CFR 1.27.
3.  Specification [Total Pages 73]  
(preferred arrangement set forth below)
  - Descriptive title of the invention
  - Cross Reference to Related Applications
  - Statement Regarding Fed sponsored R & D
  - Reference to sequence listing, a table, or a computer program listing appendix
  - Background of the Invention
  - Brief Summary of the Invention
  - Brief Description of the Drawings (if filed)
  - Detailed Description
  - Claim(s)
  - Abstract of the Disclosure
4.  Drawing(s) (35 U.S.C. 113) [ Total Sheets 19 ]
5.  Oath or Declaration [ Total Pages 6 ]
  - a.  Newly executed (original or copy)  
Copy from a prior application (37 CFR 1.63 (d))
  - b.  (for continuation/divisional with Box 18 completed)
    - i.  **DELETION OF INVENTOR(S)**  
Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6.  Application Data Sheet. See 37 CFR 1.76

7.  CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
  - a.  Computer Readable Form (CRF)
  - b. Specification Sequence Listing on:
    - i.  CD-ROM or CD-R (2 copies); or
    - ii.  paper
  - c.  Statements verifying identity of above copies

<b>ACCOMPANYING APPLICATION PARTS</b>	
9. <input checked="" type="checkbox"/> Assignment Papers (cover sheet & document(s))	
10. <input type="checkbox"/> 37 CFR 3.73(b) Statement <input type="checkbox"/> Power of Attorney <small>(when there is an assignee)</small>	
11. <input type="checkbox"/> English Translation Document <small>(if applicable)</small>	
12. <input checked="" type="checkbox"/> Information Disclosure Statement (IDS)/PTO-1449 <input checked="" type="checkbox"/> Copies of IDS Citations	
13. <input type="checkbox"/> Preliminary Amendment	
14. <input checked="" type="checkbox"/> Return Receipt Postcard (MPEP 503) <small>(Should be specifically itemized)</small>	
15. <input type="checkbox"/> Certified Copy of Priority Document(s) <small>(if foreign priority is claimed)</small>	
16. <input type="checkbox"/> Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.	
17. <input type="checkbox"/> Other: .....	

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

Continuation  Divisional  Continuation-in-part (CIP) of prior application No.: 10, 116,808

Prior application information: Examiner: \_\_\_\_\_ Group Art Unit: 3663

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

<b>19. CORRESPONDENCE ADDRESS</b>			
<input checked="" type="checkbox"/> Customer Number or Bar Code Label	22846 <small>(Insert Customer No. or Attach bar code label here)</small>	or	<input type="checkbox"/> Correspondence address below
Name			
Address			
City	State	Zip Code	
Country	Telephone	Fax	

Name (Print/Type)	Brian Roffe	Registration No. (Attorney/Agent)	35,336
Signature	<i>Brian Roffe</i>	Date	11/22/2002

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231.

J11046 U.S. PTO

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PTO/SB/17 (10-01)  
 Approved for use through 10/31/2002. OMB 0651-0032  
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<h2 style="margin: 0;">FEE TRANSMITTAL for FY 2002</h2> <p style="font-size: small; margin: 5px 0;">Patent fees are subject to annual revision.</p>	<b>Complete if Known</b>	
	Application Number	
	Filing Date	11/22/2002
	First Named Inventor	David S. Breed
	Examiner Name	
	Group Art Unit	
<b>TOTAL AMOUNT OF PAYMENT</b>	(\$)	1289.00
	Attorney Docket No.	ATI-338

<p style="text-align: center;"><b>METHOD OF PAYMENT</b></p> <p>1. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:</p> <p>Deposit Account Number: <input type="text" value="50-0266"/>          Deposit Account Name: <input type="text" value="Automotive Technologies International Inc."/></p> <p><input checked="" type="checkbox"/> Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17  <input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27</p> <p>2. <input type="checkbox"/> Payment Enclosed:  <input type="checkbox"/> Check   <input type="checkbox"/> Credit card   <input type="checkbox"/> Money Order   <input type="checkbox"/> Other</p> <p style="text-align: center;"><b>FEE CALCULATION</b></p> <p><b>1. BASIC FILING FEE</b></p> <table border="1" style="width: 100%; font-size: x-small;"> <thead> <tr> <th>Large Entity Code</th> <th>Large Entity Fee (\$)</th> <th>Small Entity Code</th> <th>Small Entity Fee (\$)</th> <th>Fee Description</th> <th>Fee Paid</th> </tr> </thead> <tbody> <tr><td>101</td><td>740</td><td>201</td><td>370</td><td>Utility filing fee</td><td style="text-align: center;">370.00</td></tr> <tr><td>106</td><td>330</td><td>206</td><td>165</td><td>Design filing fee</td><td></td></tr> <tr><td>107</td><td>510</td><td>207</td><td>255</td><td>Plant filing fee</td><td></td></tr> <tr><td>108</td><td>740</td><td>208</td><td>370</td><td>Reissue filing fee</td><td></td></tr> <tr><td>114</td><td>160</td><td>214</td><td>80</td><td>Provisional filing fee</td><td></td></tr> <tr><td colspan="5" style="text-align: right;"><b>SUBTOTAL (1)</b></td><td style="text-align: center;"><b>(\$)</b> 370.00</td></tr> </tbody> </table> <p><b>2. EXTRA CLAIM FEES</b></p> <table border="1" style="width: 100%; font-size: x-small;"> <tr> <td>Total Claims</td> <td style="text-align: center;">85</td> <td>-20** =</td> <td style="text-align: center;">65</td> <td>X</td> <td style="text-align: center;">Fee from below 9.00</td> <td>=</td> <td style="text-align: center;">585.00</td> </tr> <tr> <td>Independent Claims</td> <td style="text-align: center;">10</td> <td>-3** =</td> <td style="text-align: center;">7</td> <td>X</td> <td style="text-align: center;">42.00</td> <td>=</td> <td style="text-align: center;">294.00</td> </tr> <tr> <td>Multiple Dependent</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>=</td> <td></td> </tr> </table> <table border="1" style="width: 100%; font-size: x-small;"> <thead> <tr> <th>Large Entity Code</th> <th>Large Entity Fee (\$)</th> <th>Small Entity Code</th> <th>Small Entity Fee (\$)</th> <th>Fee Description</th> <th>Fee Paid</th> </tr> </thead> <tbody> <tr><td>103</td><td>18</td><td>203</td><td>9</td><td>Claims in excess of 20</td><td></td></tr> <tr><td>102</td><td>84</td><td>202</td><td>42</td><td>Independent claims in excess of 3</td><td></td></tr> <tr><td>104</td><td>280</td><td>204</td><td>140</td><td>Multiple dependent claim, if not paid</td><td></td></tr> <tr><td>109</td><td>84</td><td>209</td><td>42</td><td>** Reissue independent claims over original patent</td><td></td></tr> <tr><td>110</td><td>18</td><td>210</td><td>9</td><td>** Reissue claims in excess of 20 and over original patent</td><td></td></tr> <tr><td colspan="5" style="text-align: right;"><b>SUBTOTAL (2)</b></td><td style="text-align: center;"><b>(\$)</b> 879.00</td></tr> </tbody> </table> <p style="font-size: x-small;">**or number previously paid, if greater; For Reissues, see above</p>	Large Entity Code	Large Entity Fee (\$)	Small Entity Code	Small Entity Fee (\$)	Fee Description	Fee Paid	101	740	201	370	Utility filing fee	370.00	106	330	206	165	Design filing fee		107	510	207	255	Plant filing fee		108	740	208	370	Reissue filing fee		114	160	214	80	Provisional filing fee		<b>SUBTOTAL (1)</b>					<b>(\$)</b> 370.00	Total Claims	85	-20** =	65	X	Fee from below 9.00	=	585.00	Independent Claims	10	-3** =	7	X	42.00	=	294.00	Multiple Dependent						=		Large Entity Code	Large Entity Fee (\$)	Small Entity Code	Small Entity Fee (\$)	Fee Description	Fee Paid	103	18	203	9	Claims in excess of 20		102	84	202	42	Independent claims in excess of 3		104	280	204	140	Multiple dependent claim, if not paid		109	84	209	42	** Reissue independent claims over original patent		110	18	210	9	** Reissue claims in excess of 20 and over original patent		<b>SUBTOTAL (2)</b>					<b>(\$)</b> 879.00	<p><b>3. ADDITIONAL FEES</b></p> <table border="1" style="width: 100%; font-size: x-small;"> <thead> <tr> <th>Large Entity Fee Code (\$)</th> <th>Large Entity Fee (\$)</th> <th>Small Entity Fee Code (\$)</th> <th>Small Entity Fee (\$)</th> <th>Fee Description</th> <th>Fee Paid</th> </tr> </thead> <tbody> <tr><td>105</td><td>130</td><td>205</td><td>65</td><td>Surcharge - late filing fee or oath</td><td></td></tr> <tr><td>127</td><td>50</td><td>227</td><td>25</td><td>Surcharge - late provisional filing fee or cover sheet</td><td></td></tr> <tr><td>139</td><td>130</td><td>139</td><td>130</td><td>Non-English specification</td><td></td></tr> <tr><td>147</td><td>2,520</td><td>147</td><td>2,520</td><td>For filing a request for <i>ex parte</i> reexamination</td><td></td></tr> <tr><td>112</td><td>920*</td><td>112</td><td>920*</td><td>Requesting publication of SIR prior to Examiner action</td><td></td></tr> <tr><td>113</td><td>1,840*</td><td>113</td><td>1,840*</td><td>Requesting publication of SIR after Examiner action</td><td></td></tr> <tr><td>115</td><td>110</td><td>215</td><td>55</td><td>Extension for reply within first month</td><td></td></tr> <tr><td>116</td><td>400</td><td>216</td><td>200</td><td>Extension for reply within second month</td><td></td></tr> <tr><td>117</td><td>920</td><td>217</td><td>460</td><td>Extension for reply within third month</td><td></td></tr> <tr><td>118</td><td>1,440</td><td>218</td><td>720</td><td>Extension for reply within fourth month</td><td></td></tr> <tr><td>128</td><td>1,960</td><td>228</td><td>980</td><td>Extension for reply within fifth month</td><td></td></tr> <tr><td>119</td><td>320</td><td>219</td><td>160</td><td>Notice of Appeal</td><td></td></tr> <tr><td>120</td><td>320</td><td>220</td><td>160</td><td>Filing a brief in support of an appeal</td><td></td></tr> <tr><td>121</td><td>280</td><td>221</td><td>140</td><td>Request for oral hearing</td><td></td></tr> <tr><td>138</td><td>1,510</td><td>138</td><td>1,510</td><td>Petition to institute a public use proceeding</td><td></td></tr> <tr><td>140</td><td>110</td><td>240</td><td>55</td><td>Petition to revive - unavoidable</td><td></td></tr> <tr><td>141</td><td>1,280</td><td>241</td><td>640</td><td>Petition to revive - unintentional</td><td></td></tr> <tr><td>142</td><td>1,280</td><td>242</td><td>640</td><td>Utility issue fee (or reissue)</td><td></td></tr> <tr><td>143</td><td>460</td><td>243</td><td>230</td><td>Design issue fee</td><td></td></tr> <tr><td>144</td><td>620</td><td>244</td><td>310</td><td>Plant issue fee</td><td></td></tr> <tr><td>122</td><td>130</td><td>122</td><td>130</td><td>Petitions to the Commissioner</td><td></td></tr> <tr><td>123</td><td>50</td><td>123</td><td>50</td><td>Processing fee under 37 CFR-1.17(q)</td><td></td></tr> <tr><td>126</td><td>180</td><td>126</td><td>180</td><td>Submission of Information Disclosure Stmt</td><td></td></tr> <tr><td>581</td><td>40</td><td>581</td><td>40</td><td>Recording each patent assignment per property (times number of properties)</td><td style="text-align: center;">40.00</td></tr> <tr><td>146</td><td>740</td><td>246</td><td>370</td><td>Filing a submission after final rejection (37 CFR § 1.129(a))</td><td></td></tr> <tr><td>149</td><td>740</td><td>249</td><td>370</td><td>For each additional invention to be examined (37 CFR § 1.129(b))</td><td></td></tr> <tr><td>179</td><td>740</td><td>279</td><td>370</td><td>Request for Continued Examination (RCE)</td><td></td></tr> <tr><td>169</td><td>900</td><td>169</td><td>900</td><td>Request for expedited examination of a design application</td><td></td></tr> <tr><td colspan="5">Other fee (specify) _____</td><td></td></tr> <tr><td colspan="5" style="text-align: right;"><b>SUBTOTAL (3)</b></td><td style="text-align: center;"><b>(\$)</b> 40.00</td></tr> </tbody> </table> <p style="font-size: x-small;">*Reduced by Basic Filing Fee Paid</p>	Large Entity Fee Code (\$)	Large Entity Fee (\$)	Small Entity Fee Code (\$)	Small Entity Fee (\$)	Fee Description	Fee Paid	105	130	205	65	Surcharge - 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Name (Print/Type)	Brian Roffe	Registration No. (Attorney/Agent)	35,336
Signature		Telephone	516 295-1394
		Date	11/22/2002

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1.0303.005 - 1.1.2202

Attorney Docket No. ATI-338

**VEHICULAR MONITORING SYSTEMS USING IMAGE PROCESSING**

**5 CROSS REFERENCE TO RELATED APPLICATIONS**

This application is a continuation-in-part of U.S. patent application Ser. No. 10/116,808 filed April 5, 2002 which is:

TC 13/5/04 031 1) a continuation-in-part of U.S. patent application Ser. No. 09/925,043 filed Aug. 8, 2001, which is:

10 a) a continuation-in-part of U.S. patent application Ser. No. 09/765,559 filed Jan.

C 115/04 032 19, 2001; and

b) a continuation-in-part of U.S. patent application Ser. No. 09/389,947 filed Sep. 3, 1999, now U.S. Pat. No. 6,393,133; and

15 2) a continuation-in-part of U.S. patent application Ser. No. 09/838,919 filed Apr. 20, 2001, now U.S. Pat. No. 6,442,465, which is:

a) a continuation-in-part of U.S. patent application Ser. No. 09/765,559 filed Jan. 19, 2001 which is a continuation-in-part of U.S. patent application Ser. No. 09/476,255 filed Dec. 30, 1999, now U.S. Pat. No. 6,324,453, which claims priority under 35 U.S.C. §119(e) of U.S. provisional patent application Ser. No. 60/114,507 filed Dec. 31, 1998; and

20 b) a continuation-in-part of U.S. patent application Ser. No. 09/389,947 filed Sep. 3, 1999, now U.S. Pat. No. 6,393,133, which is a continuation-in-part of U.S. patent application Ser. No. 09/200,614, filed Nov. 30, 1998, now U.S. Pat. No. 6,141,432, which is a continuation of U.S. patent application Ser. No. 08/474,786 filed Jun. 7, 1995, now U.S. Pat. No. 5,845,000, all of which are incorporated by reference herein.

25 This application claims priority under 35 U.S.C. §119(e) of U.S. provisional patent application Ser. No. 60/114,507 filed Dec. 31, 1998 through the parent applications.

**FIELD OF THE INVENTION**

30 The present invention relates to apparatus and methods for monitoring environments in and outside of a vehicle using image processing.

The present invention also relates to arrangements for detecting the presence, type and/or position of occupants in vehicles and objects exterior of vehicles, e.g., in a driver's blind spot, primarily using optics.

The present invention also relates to apparatus and methods for determining a distance between objects in an environment in and outside of a vehicle by image processing techniques.

## BACKGROUND OF THE INVENTION

### 5 1. *Prior Art on Out of position occupants and rear facing child seats*

Whereas thousands of lives have been saved by airbags, a large number of people have also been injured, some seriously, by the deploying airbag, and over 100 people have now been killed. Thus, significant improvements need to be made to airbag systems. As discussed in detail in U.S. Pat. No. 5,653,462 referenced above, for a variety of reasons vehicle occupants may be too close to the airbag  
10 before it deploys and can be seriously injured or killed as a result of the deployment thereof. Also, a child in a rear facing child seat that is placed on the right front passenger seat is in danger of being seriously injured if the passenger airbag deploys. For these reasons and, as first publicly disclosed in Breed, D. S. "How Airbags Work" presented at the International Conference on Seatbelts and Airbags in 1993, in Canada, occupant position sensing and rear facing child seat detection systems are required.

15 Initially, these systems will solve the out-of-position occupant and the rear facing child seat problems related to current airbag systems and prevent unneeded airbag deployments when a front seat is unoccupied. However, airbags are now under development to protect rear seat occupants in vehicle crashes and all occupants in side impacts. A system will therefore be needed to detect the presence of occupants, determine if they are out-of-position and to identify the presence of a rear facing child seat in  
20 the rear seat. Future automobiles are expected to have eight or more airbags as protection is sought for rear seat occupants and from side impacts. In addition to eliminating the disturbance and possible harm of unnecessary airbag deployments, the cost of replacing these airbags will be excessive if they all deploy in an accident needlessly.

Inflators now exist which will adjust the amount of gas flowing to the airbag to account for the  
25 size and position of the occupant and for the severity of the accident. The vehicle identification and monitoring system (VIMS) discussed in U.S. Pat. No. 5,829,782 will control such inflators based on the presence and position of vehicle occupants or of a rear facing child seat. As discussed more fully below, the instant invention is an improvement on that VIMS system and uses an advanced optical system comprising one or more CCD (charge coupled device) or CMOS arrays and particularly active pixel  
30 arrays plus a source of illumination preferably combined with a trained neural network pattern recognition system.

Others have observed the need for an occupant out-of-position sensor and several methods have been disclosed in U.S. patents for determining the position of an occupant of a motor vehicle. Each of these systems, however, has significant limitations. For example, in White et al. (U.S. Pat. No.

5,071,160), a single acoustic sensor and detector is described and, as illustrated, is mounted lower than the steering wheel. White et al. correctly perceive that such a sensor could be defeated, and the airbag falsely deployed, by an occupant adjusting the control knobs on the radio and thus they suggest the use of a plurality of such sensors.

5 Mattes et al. (U.S. Pat. No. 5,118,134) describe a variety of methods of measuring the change in position of an occupant including ultrasonic, active or passive infrared and microwave radar sensors, and an electric eye. The sensors measure the change in position of an occupant during a crash and use that information to assess the severity of the crash and thereby decide whether or not to deploy the airbag. They are thus using the occupant motion as a crash sensor. No mention is made of determining the out-  
 10 of-position status of the occupant or of any of the other features of occupant monitoring as disclosed in one or more of the above-referenced patents and patent applications. It is interesting to note that nowhere does Mattes et al. discuss how to use active or passive infrared to determine the position of the occupant. As pointed out in one or more of the above-referenced patents and patent applications, direct occupant position measurement based on passive infrared is probably not possible and, until very recently, was  
 15 very difficult and expensive with active infrared requiring the modulation of an expensive GaAs infrared laser. Since there is no mention of these problems, the method of use contemplated by Mattes et al. must be similar to the electric eye concept where position is measured indirectly as the occupant passes by a plurality of longitudinally spaced-apart sensors.

The object of an occupant out-of-position sensor is to determine the location of the head and/or  
 20 chest of the vehicle occupant relative to the airbag since it is the impact of either the head or chest with the deploying airbag which can result in serious injuries. Both White et al. and Mattes et al. describe only lower mounting locations of their sensors in front of the occupant such as on the dashboard or below the steering wheel. Both such mounting locations are particularly prone to detection errors due to positioning of the occupant's hands, arms and legs. This would require at least three, and preferably more, such  
 25 sensors and detectors and an appropriate logic circuitry which ignores readings from some sensors if such readings are inconsistent with others, for the case, for example, where the driver's arms are the closest objects to two of the sensors.

White et al. also describe the use of error correction circuitry, without defining or illustrating the circuitry, to differentiate between the velocity of one of the occupant's hands as in the case where he/she  
 30 is adjusting the knob on the radio and the remainder of the occupant. Three ultrasonic sensors of the type disclosed by White et al. might, in some cases, accomplish this differentiation if two of them indicated that the occupant was not moving while the third was indicating that he or she was. Such a combination, however, would not differentiate between an occupant with both hands and arms in the path of the ultrasonic transmitter at such a location that they were blocking a substantial view of the occupant's head

or chest. Since the sizes and driving positions of occupants are extremely varied, it is now believed that pattern recognition systems and preferably trained pattern recognition systems, such as neural networks, are required when a clear view of the occupant, unimpeded by his/her extremities, cannot be guaranteed.

5 Fujita et al., in U.S. Pat. No. 5,074,583, describe another method of determining the position of the occupant but do not use this information to suppress deployment if the occupant is out-of-position. In fact, the closer the occupant gets to the airbag, the faster the inflation rate of the airbag is according to the Fujita et al. patent, which thereby increases the possibility of injuring the occupant. Fujita et al. do not measure the occupant directly but instead determine his or her position indirectly from measurements of the seat position and the vertical size of the occupant relative to the seat (occupant height). This occupant  
10 height is determined using an ultrasonic displacement sensor mounted directly above the occupant's head.

As discussed above, the optical systems described herein are also applicable for many other sensing applications both inside and outside of the vehicle compartment such as for sensing crashes before they occur as described in U.S. Pat. No. 5,829,782, for a smart headlight adjustment system and for a blind spot monitor (also disclosed in U.S. provisional patent application Ser. No. 60/202,424).

15 2. *Definitions*

Preferred embodiments of the invention are described below and unless specifically noted, it is the applicants' intention that the words and phrases in the specification and claims be given the ordinary and accustomed meaning to those of ordinary skill in the applicable art(s). If the applicant intends any other meaning, he will specifically state he is applying a special meaning to a word or phrase.

20 Likewise, applicants' use of the word "function" here is not intended to indicate that the applicants seek to invoke the special provisions of 35 U.S.C. §112, sixth paragraph, to define their invention. To the contrary, if applicants wish to invoke the provisions of 35 U.S.C. §112, sixth paragraph, to define their invention, they will specifically set forth in the claims the phrases "means for" or "step for" and a function, without also reciting in that phrase any structure, material or act in support of the function.  
25 Moreover, even if applicants invoke the provisions of 35 U.S.C. §112, sixth paragraph, to define their invention, it is the applicants' intention that their inventions not be limited to the specific structure, material or acts that are described in the preferred embodiments herein. Rather, if applicants claim their inventions by specifically invoking the provisions of 35 U.S.C. §112, sixth paragraph, it is nonetheless their intention to cover and include any and all structure, materials or acts that perform the claimed  
30 function, along with any and all known or later developed equivalent structures, materials or acts for performing the claimed function.

The use of pattern recognition is important to the instant invention as well as to one or more of those disclosed in the above-referenced patents and patent applications above. "Pattern recognition" as used herein will generally mean any system which processes a signal that is generated by an object, or is

modified by interacting with an object, in order to determine which one of a set of classes that the object belongs to. Such a system might determine only that the object is or is not a member of one specified class, or it might attempt to assign the object to one of a larger set of specified classes, or find that it is not a member of any of the classes in the set. The signals processed are generally electrical signals coming from transducers which are sensitive to either acoustic or electromagnetic radiation and, if electromagnetic, they can be either visible light, infrared, ultraviolet or radar or low frequency radiation as used in capacitive sensing systems.

A trainable or a trained pattern recognition system as used herein means a pattern recognition system which is taught various patterns by subjecting the system to a variety of examples. The most successful such system is the neural network. Not all pattern recognition systems are trained systems and not all trained systems are neural networks. Other pattern recognition systems are based on fuzzy logic, sensor fusion, Kalman filters, correlation as well as linear and non-linear regression. Still other pattern recognition systems are hybrids of more than one system such as neural-fuzzy systems.

A pattern recognition algorithm will thus generally mean an algorithm applying or obtained using any type of pattern recognition system, e.g., a neural network, sensor fusion, fuzzy logic, etc.

To "identify" as used herein will usually mean to determine that the object belongs to a particular set or class. The class may be one containing, for example, all rear facing child seats, one containing all human occupants, or all human occupants not sitting in a rear facing child seat depending on the purpose of the system. In the case where a particular person is to be recognized, the set or class will contain only a single element, i.e., the person to be recognized.

To "ascertain the identity of" as used herein with reference to an object will generally mean to determine the type or nature of the object (obtain information as to what the object is), i.e., that the object is an adult, an occupied rear facing child seat, an occupied front facing child seat, an unoccupied rear facing child seat, an unoccupied front facing child seat, a child, a dog, a bag of groceries, a car, a truck, a tree, a pedestrian, a deer etc.

An "occupying item" or "occupant" of a seat or "object" in a seat may be a living occupant such as a human being or a dog, another living organism such as a plant, or an inanimate object such as a box or bag of groceries.

A "rear seat" of a vehicle as used herein will generally mean any seat behind the front seat on which a driver sits. Thus, in minivans or other large vehicles where there are more than two rows of seats, each row of seats behind the driver is considered a rear seat and thus there may be more than one "rear seat" in such vehicles. The space behind the front seat includes any number of such rear seats as well as any trunk spaces or other rear areas such as are present in station wagons.

An optical image will generally mean any type of image obtained using electromagnetic radiation including visual, infrared and radar radiation.

In the description herein on anticipatory sensing, the term "approaching" when used in connection with the mention of an object or vehicle approaching another will usually mean the relative motion of the object toward the vehicle having the anticipatory sensor system. Thus, in a side impact with a tree, the tree will be considered as approaching the side of the vehicle and impacting the vehicle. In other words, the coordinate system used in general will be a coordinate system residing in the target vehicle. The "target" vehicle is the vehicle that is being impacted. This convention permits a general description to cover all of the cases such as where (i) a moving vehicle impacts into the side of a stationary vehicle, (ii) where both vehicles are moving when they impact, or (iii) where a vehicle is moving sideways into a stationary vehicle, tree or wall.

"Out-of-position" as used for an occupant will generally mean that the occupant, either the driver or a passenger, is sufficiently close to an occupant protection apparatus (airbag) prior to deployment that he or she is likely to be more seriously injured by the deployment event itself than by the accident. It may also mean that the occupant is not positioned appropriately in order to attain the beneficial, restraining effects of the deployment of the airbag. As for the occupant being too close to the airbag, this typically occurs when the occupant's head or chest is closer than some distance such as about 5 inches from the deployment door of the airbag module. The actual distance where airbag deployment should be suppressed depends on the design of the airbag module and is typically farther for the passenger airbag than for the driver airbag.

3. *Pattern recognition prior art*

Japanese Patent No. 3-42337 (A) to Ueno discloses a device for detecting the driving condition of a vehicle driver comprising a light emitter for irradiating the face of the driver and a means for picking up the image of the driver and storing it for later analysis. Means are provided for locating the eyes of the driver and then the irises of the eyes and then determining if the driver is looking to the side or sleeping. Ueno determines the state of the eyes of the occupant rather than determining the location of the eyes relative to the other parts of the vehicle passenger compartment. Such a system can be defeated if the driver is wearing glasses, particularly sunglasses, or another optical device which obstructs a clear view of his/her eyes. Pattern recognition technologies such as neural networks are not used.

U.S. Pat. No. 5,008,946 to Ando uses a complicated set of rules to isolate the eyes and mouth of a driver and uses this information to permit the driver to control the radio, for example, or other systems within the vehicle by moving his eyes and/or mouth. Ando uses natural light and analyzes only the head of the driver. He also makes no use of trainable pattern recognition systems such as neural networks, nor is there any attempt to identify the contents of the vehicle nor of their location relative to the vehicle

passenger compartment. Rather, Ando is limited to control of vehicle devices by responding to motion of the driver's mouth and eyes.

U.S. Pat. No. 5,298,732 to Chen also concentrates on locating the eyes of the driver so as to position a light filter between a light source such as the sun or the lights of an oncoming vehicle, and the driver's eyes. Chen does not explain in detail how the eyes are located but does supply a calibration  
5 system whereby the driver can adjust the filter so that it is at the proper position relative to his or her eyes. Chen references the use of automatic equipment for determining the location of the eyes but does not describe how this equipment works. In any event, there is no mention of illumination of the occupant, monitoring the position of the occupant, other than the eyes, determining the position of the eyes relative  
10 to the passenger compartment, or identifying any other object in the vehicle other than the driver's eyes. Also, there is no mention of the use of a trainable pattern recognition system.

U.S. Pat. No. 5,305,012 to Faris also describes a system for reducing the glare from the headlights of an oncoming vehicle. Faris locates the eyes of the occupant utilizing two spaced apart infrared cameras using passive infrared radiation from the eyes of the driver. Again, Faris is only interested in  
15 locating the driver's eyes relative to the sun or oncoming headlights and does not identify or monitor the occupant or locate the occupant relative to the passenger compartment or the airbag. Also, Faris does not use trainable pattern recognition techniques such as neural networks. Faris, in fact, does not even say how the eyes of the occupant are located but refers the reader to a book entitled Robot Vision (1991) by Berthold Horn, published by MIT Press, Cambridge, Mass. A review of this book did not appear to  
20 provide the answer to this question. Also, Faris uses the passive infrared radiation rather than illuminating the occupant with active infrared radiation or in general electromagnetic radiation.

The use of neural networks as the pattern recognition technology is important to several of the implementations of this invention since it makes the monitoring system robust, reliable and practical. The resulting algorithm created by the neural network program is usually only a few hundred lines of code  
25 written in the C or C++ computer language as opposed to typically many hundreds of lines when the techniques of the above patents to Ando, Chen and Faris are implemented. As a result, the resulting systems are easy to implement at a low cost, making them practical for automotive applications. The cost of the CCD and CMOS arrays, for example, have been prohibitively expensive until recently, rendering their use for VIMS impractical. Similarly, the implementation of the techniques of the above referenced  
30 patents requires expensive microprocessors while the implementation with neural networks and similar trainable pattern recognition technologies permits the use of low cost microprocessors typically costing less than \$10 in large quantities.

The present invention preferably uses sophisticated trainable pattern recognition capabilities such as neural networks. Usually the data is preprocessed, as discussed below, using various feature extraction



techniques. An example of such a pattern recognition system using neural networks on sonar signals is discussed in two papers by Gorman, R. P. and Sejnowski, T. J. "Analysis of Hidden Units in a Layered Network Trained to Classify Sonar Targets", *Neural Networks*, Vol. 1. pp. 75-89, 1988, and "Learned Classification of Sonar Targets Using a Massively Parallel Network", *IEEE Transactions on Acoustics, Speech, and Signal Processing*, Vol. 36, No. 7, July 1988. Examples of feature extraction techniques can be found in U.S. Pat. No. 4,906,940 entitled "Process and Apparatus for the Automatic Detection and Extraction of Features in Images and Displays" to Green et al. Examples of other more advanced and efficient pattern recognition techniques can be found in U.S. Pat. No. 5,390,136 entitled "Artificial Neuron and Method of Using Same" and U.S. Pat. No. 5,517,667 entitled "Neural Network and Method of Using Same" to S.T. Wang. Other examples include U.S. Pat. Nos. 5,235,339 (Morrison et al.), 5,214,744 (Schweizer et al), 5,181,254 (Schweizer et al), and 4,881,270 (Knecht et al). All of the above references are incorporated herein by reference. Neural networks as used herein include all types of neural networks including modular neural networks, cellular neural networks and support vector machines and all combinations as described in detail in U.S. Pat. No. 6,445,988, which is incorporated herein by reference in its entirety, and referred to therein as "combination neural networks".

#### 4. Optics

Optics can be used in several configurations for monitoring the interior of a passenger compartment or exterior environment of an automobile. In one known method, a laser optical system uses a GaAs infrared laser beam to momentarily illuminate an object, occupant or child seat, in the manner as described and illustrated in FIG. 8 of U.S. Pat. No. 5,829,782 referenced above. The receiver can be a charge-coupled device or CCD (a type of TV camera), or a CMOS imager to receive the reflected light. The laser can either be used in a scanning mode, or, through the use of a lens, a cone of light can be created which covers a large portion of the object. In these configurations, the light can be accurately controlled to only illuminate particular positions of interest within or around the vehicle. In the scanning mode, the receiver need only comprise a single or a few active elements while in the case of the cone of light, an array of active elements is needed. The laser system has one additional significant advantage in that the distance to the illuminated object can be determined as disclosed in the commonly owned '462 patent as also described below. When a single receiving element is used, a PIN or avalanche diode is preferred.

In a simpler case, light generated by a non-coherent light emitting diode (LED) device is used to illuminate the desired area. In this case, the area covered is not as accurately controlled and a larger CCD or CMOS array is required. Recently, however, the cost of CCD and CMOS arrays has dropped substantially with the result that this configuration may now be the most cost-effective system for monitoring the passenger compartment as long as the distance from the transmitter to the objects is not

needed. If this distance is required, then the laser system, a stereographic system, a focusing system, a combined ultrasonic and optic system, or a multiple CCD or CMOS array system as described herein is required. Alternately, a modulation system such as used with the laser distance system can be used with a CCD or CMOS camera and distance determined on a pixel by pixel basis.

5 A mechanical focusing system, such as used on some camera systems can determine the initial position of an occupant but is too slow to monitor his/her position during a crash. Although the example of an occupant is used herein as an example, the same or similar principles apply to objects exterior to the vehicle. A distance measuring system based on focusing is described in U.S. Pat. No. 5,193,124 (Subbarao) which can either be used with a mechanical focusing system or with two cameras, the latter of  
10 which would be fast enough. Although the Subbarao patent provides a good discussion of the camera focusing art and is therefore incorporated herein by reference, it is a more complicated system than is needed for the practicing the instant invention. In fact, a neural network can also be trained to perform the distance determination based on the two images taken with different camera settings or from two adjacent CCD's and lens having different properties as the cameras disclosed in Subbarao making this  
15 technique practical for the purposes of this instant invention. Distance can also be determined by the system disclosed in U.S. Pat. No. 5,003,166 (Girod) by the spreading or defocusing of a pattern of structured light projected onto the object of interest. Distance can also be measured by using time of flight measurements of the electromagnetic waves or by multiple CCD or CMOS arrays as is a principle teaching of this invention.

20 In each of these cases, regardless of the distance measurement system used, a trained pattern recognition system, as defined above, is used in the instant invention to identify and classify, and in some cases to locate, the illuminated object and its constituent parts.

#### 5. *Optics and acoustics*

The laser systems described above are expensive due to the requirement that they be modulated at  
25 a high frequency if the distance from the airbag to the occupant, for example, needs to be measured. Alternately, modulation of another light source such as an LED can be done and the distance measurement accomplished using a CCD or CMOS array on a pixel by pixel basis.

Both laser and non-laser optical systems in general are good at determining the location of objects within the two dimensional plane of the image and a pulsed laser radar system in the scanning mode can  
30 determine the distance of each part of the image from the receiver by measuring the time of flight through range gating techniques. It is also possible to determine distance with the non-laser system by focusing as discussed above, or stereographically if two spaced apart receivers are used and, in some cases the mere location in the field of view can be used to estimate the position relative to the airbag, for example.

Finally, a recently developed pulsed quantum well diode laser also provides inexpensive distance measurements as discussed below.

Acoustic systems are additionally quite effective at distance measurements since the relatively low speed of sound permits simple electronic circuits to be designed and minimal microprocessor capability is required. If a coordinate system is used where the z axis is from the transducer to the occupant, acoustics are good at measuring z dimensions while simple optical systems using a single CCD are good at measuring x and y dimensions. The combination of acoustics and optics, therefore, permits all three measurements to be made from one location with low cost components as discussed in commonly assigned U.S. Pat. Nos. 5,845,000 and 5,835,613.

One example of a system using these ideas is an optical system which floods the passenger seat with infrared light coupled with a lens and CCD or CMOS array which receives and displays the reflected light and an analog to digital converter (ADC), or frame grabber, which digitizes the output of the CCD or CMOS and feeds it to a feature extraction algorithm (such as an edge detector) and then to an Artificial Neural Network (ANN) or other pattern recognition system for analysis. This system uses an ultrasonic transmitter and receiver for measuring the distances to the objects located in the passenger seat. The receiving transducer feeds its data into an ADC and from there the converted data is directed into the ANN. The same ANN can be used for both systems thereby providing full three-dimensional data for the ANN to analyze. This system, using low cost components, will permit accurate identification and distance measurements. If a phased array system is added to the acoustic part of the system, the optical part can determine the location of the driver's ears, for example, and the phased array can direct a narrow beam to the location and determine the distance to the occupant's ears.

Although the use of ultrasound for distance measurement has many advantages, it also has some drawbacks. First, the speed of sound limits the rate at which the position of the occupant can be updated to approximately 10 milliseconds, which though sufficient for most cases, is marginal if the position of the occupant is to be tracked during a vehicle crash. Second, ultrasound waves are diffracted by changes in air density that can occur when the heater or air conditioner is operated or when there is a high-speed flow of air past the transducer. Third, the resolution of ultrasound is limited by its wavelength and by the transducers, which are high Q tuned devices. Typically, the resolution of ultrasound is on the order of about 2 to 3 inches. Finally, the fields from ultrasonic transducers are difficult to control so that reflections from unwanted objects or surfaces add noise to the data.

#### 6. *Applications*

The applications for this technology are numerous as described in the patents and patent applications listed above. They include: (i) the monitoring of the occupant for safety purposes to prevent airbag deployment induced injuries, (ii) the locating of the eyes of the occupant (driver) to permit

automatic adjustment of the rear view mirror(s), (iii) the location of the seat to place the occupant's eyes at the proper position to eliminate the parallax in a heads-up display in night vision systems, (iv) the location of the ears of the occupant for optimum adjustment of the entertainment system, (v) the identification of the occupant for security reasons, (vi) the determination of obstructions in the path of a closing door or window, (vii) the determination of the position of the occupant's shoulder so that the seat belt anchorage point can be adjusted for the best protection of the occupant, (viii) the determination of the position of the rear of the occupants head so that the headrest can be adjusted to minimize whiplash injuries in rear impacts, (ix) anticipatory crash sensing, (x) blind spot detection, (xi) smart headlight dimmers, (xii) sunlight and headlight glare reduction and many others. In fact, over forty products alone have been identified based on the ability to identify and monitor objects and parts thereof in the passenger compartment of an automobile or truck. In addition, there are many applications of the apparatus and methods described herein for monitoring the environment exterior to the vehicle.

7. *Other Prior Art*

European Patent Application No. 98110617.2 (Publication No. 0 885 782 A1), corresponding to U.S. patent application Ser. No. 08/872,836 filed Jun. 11, 1997, describes a purportedly novel motor vehicle control system including a pair of cameras which operatively produce first and second images of a passenger area. A distance processor determines the distances that a plurality of features in the first and second images are from the cameras based on the amount that each feature is shifted between the first and second images. An analyzer processes the determined distances and determines the size of an object on the seat. Additional analysis of the distance also may determine movement of the object and the rate of movement. The distance information also can be used to recognize predefined patterns in the images and this identify objects. An air bag controller utilizes the determined object characteristics in controlling deployment of the air bag.

A paper entitled "Sensing Automobile Occupant Position with Optical Triangulation" by W. Chappelle, *Sensors*, December 1995, describes the use of optical triangulation techniques for determining the presence and position of people or rear-facing infant seats in the passenger compartment of a vehicle in order to guarantee the safe deployment of an air bag. The paper describes a system called the "Takata Safety Shield" which purportedly makes high-speed distance measurements from the point of air bag deployment using a modulated infrared beam projected from an LED source. Two detectors are provided, each consisting of an imaging lens and a position-sensing detector.

A paper entitled "An Interior Compartment Protection System based on Motion Detection Using CMOS Imagers" by S.B. Park et al., 1998 IEEE International Conference on Intelligent Vehicles, describes a purportedly novel image processing system based on a CMOS image sensor installed at the car roof for interior compartment monitoring including theft prevention and object recognition. One

disclosed camera system is based on a CMOS image sensor and a near infrared (NIR) light emitting diode (LED) array.

5 A paper entitled "A 256x256 CMOS Brightness Adaptive Imaging Array with Column-Parallel Digital Output" by C. Sodini et al., 1988 IEEE International Conference on Intelligent Vehicles, describes a CMOS image sensor for intelligent transportation system applications such as adaptive cruise control and traffic monitoring. Among the purported novelties is the use of a technique for increasing the dynamic range in a CMOS imager by a factor of approximately 20, which technique is based on a previously described technique for CCD imagers.

10 A paper entitled "Intelligent System for Video Monitoring of Vehicle Cockpit" by S. Boverie et al., SAE Technical Paper Series No. 980613, February 23-26, 1998, describes the installation of an optical/retina sensor in the vehicle and several uses of this sensor. Possible uses are said to include observation of the driver's face (eyelid movement) and the driver's attitude to allow analysis of the driver's vigilance level and warn him/her about critical situations and observation of the front passenger seat to allow the determination of the presence of somebody or something located on the seat and to value  
15 the volumetric occupancy of the passenger for the purpose of optimizing the operating conditions for air bags.

Ishikawa et al. (U.S. Pat. No. 4,625,329) describes an image analyzer (M5 in Fig. 1) for analyzing the position of driver including an infrared light source which illuminates the driver's face and an image detector which receives light from the driver's face, determines the position of facial feature, e.g., the  
20 eyes in three dimensions, and thus determines the position of the driver in three dimensions. A pattern recognition process is used to determine the position of the facial features and entails converting the pixels forming the image to either black or white based on intensity and conducting an analysis based on the white area in order to find the largest contiguous white area and the center point thereof. Based on the location of the center point of the largest contiguous white area, the driver's height is derived and a heads  
25 up display is adjusted so information is within driver's field of view. The pattern recognition process can be applied to detect the eyes, mouth, or nose of the driver based on the differentiation between the white and black areas.

Ando (U.S. Pat. No. 5,008,946) describes a system which recognizes an image and specifically ascertains the position of the pupils and mouth of the occupant to enable movement of the pupils and  
30 mouth to control electrical devices installed in the automobile. The system includes a camera which takes a picture of the occupant and applies algorithms based on pattern recognition techniques to analyze the picture, converted into an electrical signal, to determine the position of certain portions of the image, namely the pupils and mouth.

Masamori (U.S. Pat. No. 5,227,784) describes a system which is based on radar, specifically it is a collision avoidance system aimed at detecting vehicles which are at some distance from the vehicle.

5 Suzuki et al. (U.S. Pat. No. 5,026,153) describes a vehicle tracking control for continuously detecting the distance and direction to a preceding vehicle irrespective of background dark/light distribution. In this system, every vehicle must have a light on its rear that emits a constant or time  
5 varying signal and two photoelectric sensors that zero in on the light emitted from the preceding vehicle are used and thereby determine both the distance and angular position of the preceding vehicle.

10 Krumm (U.S. Pat. No. 5,983,147) describes a system for determining the occupancy of a passenger compartment including a pair of cameras mounted so as to obtain binocular stereo images of the same location in the passenger compartment. A representation of the output from the cameras is compared to stored representations of known occupants and occupancy situations to determine which  
10 stored representation the output from the cameras most closely approximates. The stored representations include that of the presence or absence of a person or an infant seat in the front passenger seat.

15 Farmer et al. (U.S. Pat. No. 6,005,958) describes a method and system for detecting the type and position of a vehicle occupant utilizing a single camera unit. The single camera unit is positioned at the driver or passenger side A-pillar in order to generate data of the front seating area of the vehicle. The type and position of the occupant is used to optimize the efficiency and safety in controlling deployment of an occupant protection device such as an air bag.

20 A paper by Rudolf Schwarte, et al. entitled "New Powerful Sensory Tool in Automotive Safety Systems Based on PMD-Technology", Eds. S. Krueger, W. Gessner, Proceedings of the AMAA 2000 Advanced Microsystems for Automotive Applications 2000, Springer Verlag; Berlin, Heidelberg, New York, ISBN 3-540-67087-4, describes an implementation of the teachings of the instant invention wherein a modulated light source is used in conjunction with phase determination circuitry to locate the distance to objects in the image on a pixel by pixel basis. This camera is an active pixel camera the use of  
25 which for internal and external vehicle monitoring is also a teaching of this invention. The novel feature of the PMD camera is that the pixels are designed to provide a distance measuring capability within each pixel itself. This then is a novel application of the active pixel and distance measuring teachings of the instant invention.

30 The instant invention as described in the above-referenced commonly assigned patents and patent applications, teaches the use of modulating the light used to illuminate an object and to determine the distance to that object based on the phase difference between the reflected radiation and the transmitted radiation. The illumination can be modulated at a single frequency when short distances such as within the passenger compartment are to be measured. Typically, the modulation wavelength would be selected such that one wave would have a length of approximately one meter or less. This would provide

resolution of 1 cm or less. For larger vehicles, a longer wavelength would be desirable. For measuring longer distances, the illumination can be modulated at more than one frequency to eliminate cycle ambiguity if there is more than one cycle between the source of illumination and the illuminated object. This technique is particularly desirable when monitoring objects exterior to the vehicle to permit accurate measurements of devices that are hundreds of meters from the vehicle as well as those that are a few meters away. Naturally, there are other modulation methods that eliminate the cycle ambiguity such as modulation with a code that is used with a correlation function to determine the phase shift or time delay. This code can be a pseudo random number in order to permit the unambiguous monitoring of the vehicle exterior in the presence of other vehicles with the same system. This is sometimes known as noise radar, noise modulation (either of optical or radar signals), ultra wideband (UWB) or the techniques used in Micropower impulse radar (MIR).

Although a simple frequency modulation scheme has been disclosed so far, it is also possible to use other coding techniques including the coding of the illumination with one of a variety of correlation patterns including a pseudo-random code. Similarly, although frequency and code domain systems have been described, time domain systems are also applicable wherein a pulse of light is emitted and the time of flight measured. Additionally, in the frequency domain case, a chirp can be emitted and the reflected light compared in frequency with the chirp to determine by frequency difference the distance to the object. Although each of these techniques is known to those skilled in the art, they have heretofore not been applied for monitoring objects within or outside of a vehicle.

## OBJECTS AND SUMMARY OF THE INVENTION

Principle objects and advantages of the optical sensing system in accordance with the invention are:

1. To provide a system for monitoring the environment exterior of a vehicle in order to determine the presence and classification, identification and/or location of objects in the exterior environment.
2. To provide a blind spot detector which detects and categorizes an object in the driver's blind spot or other location in the vicinity of the vehicle, and warns the driver in the event the driver begins to change lanes, for example, or continuously informs the driver of the state of occupancy of the blind spot.
3. To provide a camera system for interior and exterior monitoring, which can adjust on a pixel by pixel basis for the intensity of the received light.
4. To provide for the use of an active pixel camera for interior and exterior vehicle monitoring.

5. To recognize the presence of a human on a particular seat of a motor vehicle and to use this information to affect the operation of another vehicle system such as the airbag, heating and air conditioning, or entertainment systems, among others.

6. To recognize the presence of a human on a particular seat of a motor vehicle and then to determine his/her position and to use this position information to affect the operation of another vehicle system.

7. To determine the position, velocity or size of an occupant in a motor vehicle and to utilize this information to control the rate of gas generation, or the amount of gas generated by an airbag inflator system.

8. To determine the presence or position of rear seated occupants in the vehicle and to use this information to affect the operation of a rear seat protection airbag for frontal, side and/or rear impacts.

9. To recognize the presence of a rear facing child seat on a particular seat of a motor vehicle and to use this information to affect the operation of another vehicle system such as the airbag system.

10. To determine the approximate location of the eyes of a driver and to use that information to control the position of one or more of the rear view mirrors of the vehicle.

11. To monitor the position of the head of the vehicle driver and determine whether the driver is falling asleep or otherwise impaired and likely to lose control of the vehicle and to use that information to affect another vehicle system.

12. To provide an occupant position sensor which reliably permits, and in a timely manner, a determination to be made that the occupant is out-of-position, or will become out-of-position, and likely to be injured by a deploying airbag and to then output a signal to suppress the deployment of the airbag.

13. To provide an anticipatory sensor that permits accurate identification of the about-to-impact object in the presence of snow and / or fog whereby the sensor is located within the vehicle.

14. To provide a smart headlight dimmer system which senses the headlights from an oncoming vehicle or the tail lights of a vehicle in front of the subject vehicle and identifies these lights differentiating them from reflections from signs or the road surface and then sends a signal to dim the headlights.

15. To provide an occupant position determination in a sufficiently short time that the position of an occupant can be tracked during a vehicle crash.

16. To provide an occupant vehicle interior monitoring system which is not affected by temperature or thermal gradients.



17. To provide an occupant vehicle interior monitoring system which has high resolution to improve system accuracy and permits the location of body parts of the occupant to be determined.

18. To provide an occupant vehicle interior monitoring system which reduces the glare from sunlight and headlights by imposing a filter between the eyes of an occupant and the light source.

5 19. To provide a system for recognizing the identity of a particular individual in the vehicle.

20. To use the principles of time of flight to measure the distance to an occupant or object exterior to the vehicle.

21. To obtain a three dimensional image from a device at one location on a vehicle.

10 22. To use pattern recognition techniques for analyzing three-dimensional image data of occupants of a vehicle and objects exterior to the vehicle.

23. To provide a system of frequency domain modulation of the illumination of an object interior or exterior of a vehicle.

24. To utilize code modulation such as with a pseudo random code to permit the unambiguous monitoring of the vehicle exterior in the presence of other vehicles with the same system.

15 25. To use a chirp frequency modulation technique to aid in determining the distance to an object interior or exterior of a vehicle.

26. To utilize a correlation pattern modulation in a form of code division modulation for determining the distance of an object interior or exterior of a vehicle.

20 These and other objects and advantages will become apparent from the following description of the preferred embodiments of the vehicle identification and monitoring system of this invention.

Briefly, in order to achieve at least one of the objects and possibly others, a monitoring arrangement for monitoring an environment exterior of a vehicle comprises at least one receiver arranged to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves, and a processor coupled to the receiver(s) and comprising pattern recognition means for processing the signal to provide a classification, identification and/or location of the exterior object. The pattern recognition means, such as  
25 a neural computer or neural network and the like, apply a pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects. In this manner, one or more systems in the vehicle may be coupled to the processor such that the operation the system(s) is/are affected in response to the classification, identification and/or location of the exterior  
30 object.

This affected system may be a display viewable by the driver and arranged to show an image or icon of the exterior object or objects. The affected system may also be an internally deployed or

externally deployed airbag, deployment of which is controlled based on the identification of the exterior object.

5 A pair of receivers spaced apart from one another may be used and the receiver may be arranged to receive infrared waves. If a transmitter is provided to transmit waves into the environment exterior of the vehicle, then the receiver is arranged to receive waves transmitted by the transmitter and reflected by any exterior objects.

A measurement system may be provided to measure a distance between the exterior object and the vehicle. The measurement system may be a radar or laser radar system.

10 Another monitoring arrangement for monitoring an environment exterior of a vehicle in accordance with the invention comprises at least one CCD array positioned to obtain images of the environment exterior of the vehicle and a processor coupled to the CCD array(s) and comprising pattern recognition means for processing the images obtained by the CCD array(s) to provide a classification, identification and/or location of the exterior object. In this manner, one or more systems in the vehicle may be coupled to the processor such that the operation the system(s) is/are affected in response to the classification, identification and/or location of the exterior object. Option-  
15 ally, the pattern recognition means apply a pattern recognition algorithm generated from data of possible exterior objects and images from the CCD array(s) of the possible exterior objects. The same enhancements described for the arrangement above can be used in this arrangement as well.

In another embodiment of the invention, at least one receiver is arranged on a rear view mirror of  
20 the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves and a processor is coupled to the receiver(s) and arranged to classify, identify and/or locate the exterior object based on the signal. As such, the operation of one or more systems in the vehicle, coupled to the processor, can be affected in response to the classification, identification and/or location of the exterior object. The same  
25 enhancements described for the arrangements above can be used in this embodiment as well.

Instead of being arranged on the rear view mirror, the receiver can be arranged on a B-pillar of the vehicle to receive waves from the environment exterior of and on the side of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves. In addition, the receiver could be arranged in a door window trim panel of the vehicle to receive waves  
30 from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves. Other mounting locations include in a rear window and in a C-pillar of the vehicle.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The following drawings are illustrative of embodiments of the invention and are not meant to limit the scope of the invention as encompassed by the claims.

5 FIG. 1A is a side planar view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing several preferred mounting locations of interior vehicle monitoring sensors shown particularly for sensing the vehicle driver illustrating the wave pattern from a CCD or CMOS optical position sensor mounted along the side of the driver or centered above his or her head.

10 FIG. 1B is a view as in FIG. 1A illustrating the wave pattern from an optical system using an infrared light source and a CCD or CMOS array receiver using the windshield as a reflection surface and showing schematically the interface between the vehicle interior monitoring system of this invention and an instrument panel mounted inattentiveness warning light or buzzer and reset button.

15 FIG. 1C is a view as in FIG. 1A illustrating the wave pattern from an optical system using an infrared light source and a CCD or CMOS array receiver where the CCD or CMOS array receiver is covered by a lens permitting a wide angle view of the contents of the passenger compartment.

FIG. 1D is a view as in FIG. 1A illustrating the wave pattern from a pair of small CCD or CMOS array receivers and one infrared transmitter where the spacing of the CCD or CMOS arrays permits an accurate measurement of the distance to features on the occupant.

20 FIG. 1E is a view as in FIG. 1A illustrating the wave pattern from a set of ultrasonic transmitter/receivers where the spacing of the transducers and the phase of the signal permits an accurate focusing of the ultrasonic beam and thus the accurate measurement of a particular point on the surface of the driver.

25 FIG. 2A is a side view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing preferred mounting locations of optical interior vehicle monitoring sensors

FIG. 2B is a perspective view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing some preferred mounting locations of optical interior vehicle monitoring sensors.

30 FIG. 3 is a circuit schematic illustrating the use of the vehicle interior monitoring sensor used as an occupant position sensor in conjunction with the remainder of the inflatable restraint system.

FIG. 4 is a schematic illustrating the circuit of an occupant position-sensing device using a modulated infrared signal, beat frequency and phase detector system.

FIG. 5 is a side planer view with parts cutaway and removed of a vehicle showing the passenger compartment containing a driver and a preferred mounting location for an optical occupant position

sensor for use in side impacts and also of an optical rear of occupant's head locator for use with a headrest adjustment system to reduce whiplash injuries in rear impact crashes.

FIG. 6 is a side plan view of the interior of an automobile, with portions cut away and removed, with two optical occupant height measuring sensors, one mounted into the headliner above the occupant's head and the other mounted onto the A-pillar and also showing a seatbelt associated with the seat where  
5 the seatbelt has an adjustable upper anchorage point which is automatically adjusted corresponding to the height of the occupant.

FIG. 7 is a perspective view of a vehicle about to impact the side of another vehicle showing the location of the various parts of the anticipatory sensor system of this invention.

10 FIG. 7A is an enlarged view of the section designated 7A in Fig. 7.

FIG. 8 is a side planar view, with certain portions removed or cut away, of a portion of the passenger compartment illustrating a sensor for sensing the headlights of an oncoming vehicle and/or the taillights of a leading vehicle used in conjunction with an automatic headlight dimming system.

FIG. 9 is a side planar view with parts cutaway and removed of a subject vehicle and an  
15 oncoming vehicle, showing the headlights of the oncoming vehicle and the passenger compartment of the subject vehicle, containing detectors of the driver's eyes and detectors for the headlights of the oncoming vehicle and the selective filtering of the light of the approaching vehicle's headlights through the use of a liquid crystal filter in the windshield.

FIG. 9A is an enlarged view of the section designated 9A in FIG. 9.

20 FIG. 10 is a schematic illustration of a system for controlling operation of a vehicle or a component thereof based on recognition of an authorized individual.

FIG. 11 is a schematic illustration of a method for controlling operation of a vehicle based on recognition of an individual.

FIG. 12 is a schematic illustration of the environment monitoring in accordance with the  
25 invention.

FIG. 13 is a flow chart of the environment monitoring in accordance with the invention.

FIG. 14 is a schematic illustration of the position measuring in accordance with the invention.

FIG. 15 is a schematic illustration of the exterior monitoring system in accordance with the  
invention.

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#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Referring now to the drawings wherein the same reference numerals refer to the same or similar elements, a section of the passenger compartment of an automobile is shown generally as 100 in FIGS. 1A-1D. A driver 101 of a vehicle sits on a seat 102 behind a steering wheel 103, which contains an

airbag assembly 104. Airbag assembly 104 may be integrated into the steering wheel assembly or coupled to the steering wheel 103. Five transmitter and/or receiver assemblies 110, 111, 112, 113 and 114 are positioned at various places in the passenger compartment (the specific locations of which are set forth below) to determine the location of various parts of the driver, e.g., the head, chest and torso, relative to the airbag and to otherwise monitor the interior of the passenger compartment. Monitoring of the interior of the passenger compartment can entail detecting the presence or absence of the driver and passengers, differentiating between animate and inanimate objects, detecting the presence of occupied or unoccupied child seats, rear-facing or forward-facing, and identifying and ascertaining the identity of the occupying items in the passenger compartment. Processor means such as control circuitry 120 is connected to the transmitter/receiver assemblies 110-114 and controls the transmission from the transmitters, if a transmission component is present in the assemblies, and captures the return signals from the receivers, if a receiver component is present in the assemblies. Control circuitry 120 usually contains analog to digital converters (ADCs) or a frame grabber, a microprocessor containing sufficient memory and appropriate software including pattern recognition algorithms, and other appropriate drivers, signal conditioners, signal generators, etc. Usually, in any given implementation, only three or four of the transmitter/receiver assemblies would be used depending on their mounting locations as described below.

With respect to the connection between the transmitter/receiver assemblies 110-114 and the control circuitry 120, a portion of this connection is shown as wires. It should be understood that all of the connections between the transmitter/receiver assemblies 110-114 and the control circuitry 120 may be wires, either individual wires leading from the control circuitry 120 to each of the transmitter/receiver assemblies 110-114 or one or more wire buses.

With respect to the position of the control circuitry 120 in the dashboard of the vehicle, this position is for illustration purposes only and does not limit the location of the control circuitry 120. Rather, the control circuitry 120 may be located anywhere convenient or desired in the vehicle.

It is contemplated that a system and method in accordance with the invention can include a single transmitter and multiple receivers, each at a different location. Thus, each receiver would not be associated with a transmitter forming transmitter/receiver assemblies. Rather, for example, with reference to FIG. 1A, only element 110 would constitute a transmitter/receiver assembly and elements 111, 112, 113, 114 would be receivers only.

On the other hand, it is conceivable that in some implementations, a system and method in accordance with the invention include a single receiver and multiple transmitters. Thus, each transmitter would not be associated with a receiver forming transmitter/receiver assemblies. Rather, for example, with reference to FIG. 1A, only element 110 would constitute a transmitter/receiver assembly and elements 111, 112, 113, 114 would be transmitters only.

FIG. 1A illustrates a typical wave pattern of transmitted infrared waves from transmitter/receiver assembly 111, which is mounted on the side of the vehicle passenger compartment above the front, driver's side door. Transmitter/receiver assembly 114, shown overlaid onto transmitter/receiver 111, is actually mounted in the center headliner of the passenger compartment (and thus between the driver's seat and the front passenger seat), near the dome light, and is aimed toward the driver. Typically there will be symmetrical installation for the passenger side of the vehicle. That is, a transmitter/receiver assembly would be arranged above the front, passenger side door and another transmitter/receiver assembly would be arranged in the center headliner, near the dome light, and aimed toward the front, passenger side door.

In a preferred embodiment, each transmitter/receiver assembly 111,114 comprises an optical transducer that will generally be used in conjunction with another optical transmitter/receiver assembly such as shown at 110, 112 and 113, which act in a similar manner. These optical transmitter/receiver assemblies are comprised of an optical transmitter, which may be an infrared LED (or possibly a near infrared (NIR) LED), a laser with a diverging lens or a scanning laser assembly, and a receiver such as a CCD or CMOS array and particularly an active pixel CMOS camera or array or a HDRL or HDRC camera or array as discussed below. The transducer assemblies map the location of the occupant(s), objects and features thereof, in a two or three-dimensional image as will now be described in more detail.

An active pixel camera is a special camera which has the ability to adjust the sensitivity of each pixel of the camera similar to the manner in which an iris adjusts the sensitivity of a camera. Thus, the active pixel camera automatically adjusts to the incident light on a pixel-by-pixel basis. An active pixel camera differs from an active infrared sensor in that an active infrared sensor, such as of the type envisioned by Mattes et al. (discussed above), is generally a single pixel sensor that measures the reflection of infrared light from an object. In some cases, as in the HDRC camera, the output of each pixel is a logarithm of the incident light thus giving a high dynamic range to the camera. This is similar to the technique used to suppress the effects of thermal gradient distortion of ultrasonic signals as described in the above cross-referenced patents. Thus if the incident radiation changes in magnitude by 1,000,000, for example, the output of the pixel may change by a factor of only 6.

A dynamic pixel camera is a camera having a plurality of pixels and which provides the ability to pick and choose which pixels should be observed, as long as they are contiguous.

An HDRC camera is a type of active pixel camera where the dynamic range of each pixel is considerably broader. An active pixel camera manufactured by the Photobit Corporation has a dynamic range of 70 db while an IMS Chips camera, an HDRC camera manufactured by another manufacturer, has a dynamic range of 120 db. Thus, the HDRC camera has a 100,000 times greater range of light sensitivity than the Photobit camera.

In a preferred implementation, four transducer assemblies are positioned around the seat to be monitored, each comprising an LED with a diverging lens and a CMOS array. Although illustrated together, the illuminating source in many cases will not be co-located with the receiving array. The LED emits a controlled angle, 120° for example, diverging cone of infrared radiation that illuminates the occupant from both sides and from the front and rear. This angle is not to be confused with the field angle used in ultrasonic systems. With ultrasound, extreme care is required to control the field of the ultrasonic waves so that they will not create multipath effects and add noise to the system. With infrared, there is no reason, in the implementation now being described, other than to make the most efficient use of the infrared energy, why the entire vehicle cannot be flooded with infrared energy either from many small sources or from a few bright ones.

The image from each array is used to capture two dimensions of occupant position information, thus, the array of assembly 110 positioned on the A-pillar, which is approximately 25% of the way laterally across the headliner in front of the driver, provides a both vertical and transverse information on the location of the driver. A similar view from the rear is obtained from the array of assembly 113 positioned behind the driver on the roof of the vehicle and above the seatback portion of the seat 102. As such, assembly 113 also provides both vertical and transverse information on the location of the driver. Finally, arrays of assemblies 111 and 114 provide both vertical and longitudinal driver location information. Another preferred location is the headliner centered directly above the seat of interest. The position of the assemblies 110-114 may differ from that shown in the drawings. In the invention, in order that the information from two or more of the assemblies 110-114 may provide a three-dimensional image of the occupant, or portion of the passenger compartment, the assemblies should not be arranged side-by-side. A side-by-side arrangement as used in several prior art references discussed above, will provide two essentially identical views with the difference being a lateral shift. This does not enable a complete three-dimensional view of the occupant.

If each receiving array of assemblies 110,111,113,114 contains a matrix of 100 by 100 pixels, then 40,000 (4 x 100 x 100) pixels or data elements of information will be created each time the system interrogates the driver seat, for example. There are many pixels of each image that can be eliminated as containing no useful information. This typically includes the corner pixels, back of the seat and other areas where an occupant cannot reside. This pixel pruning can typically reduce the number of pixels by up to 50 percent resulting in approximately 20,000 remaining pixels. The output from each array is then compared with a series of stored arrays representing different unoccupied positions of the seat, seatback, steering wheel etc. For each array, each of the stored arrays is subtracted from the acquired array and the results analyzed to determine which subtraction resulted in the best match. The best match is determined by such things as the total number of pixels reduced below the threshold level, or the minimum number of

remaining detached pixels, etc. Once this operation is completed for all four images, the position of the movable elements within the passenger compartment has been determined. This includes the steering wheel angle, telescoping position, seatback angle, headrest position, and seat position. This information can be used elsewhere by other vehicle systems to eliminate sensors that are currently being used to sense such positions of these complements. Alternately, the sensors that are currently on the vehicle for sensing these complement positions can be used to simplify processes described above.

Each receiving array may also be a 256x256 CMOS pixel array as described in the paper by C. Sodini et al. referenced above.

An alternate technique of differentiating between the occupant and the vehicle is to use motion. If the images of the passenger seat are compared over time, reflections from fixed objects will remain static whereas reflections from vehicle occupants will move. This movement can be used to differentiate the occupant from the background.

Following the subtraction process described above, each image now consists of typically as many as 50 percent fewer pixels leaving a total of approximately 10,000 pixels remaining. The resolution of the images in each array can now be reduced by combining adjacent pixels and averaging the pixel values. This results in a reduction to a total pixel count of approximately 1000. The matrices of information that contains the pixel values is now normalized to place the information in a location in the matrix which is independent of the seat position. The resulting normalized matrix of 1000 pixel values is now used as input into an artificial neural network and represents the occupancy of the seat independent of the position of the occupant.

The neural network has been previously trained on a significant number of occupants of the passenger compartment. The number of such occupants depends strongly on whether the driver or the passenger seat is being analyzed. The variety of seating states or occupancies of the passenger seat is vastly greater than that of the driver seat. For the driver seat, a typical training set will consist of approximately 100 different vehicle occupancies. For the passenger seat, this number can exceed 1000. These numbers are used for illustration purposes only and will differ significantly from vehicle model to vehicle model.

The neural network is now used to determine which of the stored occupancies most closely corresponds to the measured data. The output of the neural network is an index of the setup that was used during training that most closely matches the current measured state. This index is used to locate stored information from the matched trained occupancy. Information that has been stored for the trained occupancy typically includes the locus of the centers of the chest and head of the driver, as well as the approximate radius of pixels which is associated with this center to define the head area, for example. For the case of FIG. 1A, it is now known from this exercise where the head, chest, and perhaps the eyes and



ears, of the driver are most likely to be located and also which pixels should be tracked in order to know the precise position of the driver's head and chest. What has been described above is the identification process.

The normalization process conducted above created a displacement value for each of the CCD or CMOS arrays in the four assemblies 110,111,113,114 which can now be used in reverse to find the precise location of the driver's head and chest or chest, for example, relative to the known location of the airbag. From the vehicle geometry, and the head and chest location information, a choice can now be made as to whether to track the head or chest for dynamic out-of-position.

Tracking of the motion of the occupant's head or chest can be done using a variety of techniques. One preferred technique is to use differential motion, that is, by subtracting the current image from the previous image to determine which pixels have changed in value and by looking at the leading edge of the changed pixels and the width of the changed pixel field, a measurement of the movement of the pixels of interest, and thus the driver, can be readily accomplished. Alternately, a correlation function can be derived which correlates the pixels in the known initial position of the head, for example, with pixels that were derived from the latest image. The displacement of the center of the correlation pixels would represent the motion of the head of the occupant. Naturally, a wide variety of other techniques will be now obvious to those skilled in the art.

There are many mathematical techniques that can be applied to simplify the above process. One technique used in military pattern recognition, for example, uses the Fourier transform of particular areas in an image to match with known Fourier transforms of known images. In this manner, the identification and location can be determined simultaneously. There is even a technique used for target identification whereby the Fourier transforms are compared optically. Other techniques utilize thresholding to limit the pixels that will be analyzed by any of these processes. Other techniques search for particular features and extract those features and concentrate merely on the location of certain of these features. (See for example the Kage et al. artificial retina publication referenced above which, together with the references cited therein, is incorporated herein by reference.)

Generally, the pixel values are not directly fed into a pattern recognition system but rather the image is preprocessed through a variety of feature extraction techniques such as an edge detection algorithm. Once the edges are determined, a vector is created containing the location of the edges and their orientation and that vector is fed into the neural network, for example, which performs the pattern recognition.

The principal used in this preferred implementation of the invention is to use images of different views of the occupant to correlate with known images that were used to train a neural network for vehicle occupancy. Then carefully measured positions of the known images are used to locate particular parts of

the occupant such as his or her head, chest, eyes, ears, mouth, etc. An alternate approach is to make a three-dimensional map of the occupant and to precisely locate these features using neural networks, sensor fusion, fuzzy logic or other rules. One method of obtaining a three-dimensional map is to utilize a scanning laser radar system where the laser is operated in a pulse mode and the distance from the object being illuminated is determined using range gating in a manner similar to that described in various patents on micropower impulse radar to McEwan. (See, for example, U.S. Pat. Nos. 5,457,394 and 5,521,600).

The scanning portion of the pulse laser radar device can be accomplished using rotating mirrors, mechanical motors, or preferably, a solid state system, for example one utilizing  $\text{TeO}_2$  as an optical diffraction crystal with lithium niobate crystals driven by ultrasound (although other solid state systems not necessarily using  $\text{TeO}_2$  and lithium niobate crystals could also be used). An alternate method is to use a micromachined mirror, which is supported at its center and caused to deflect by miniature coils. Such a device has been used to provide two-dimensional scanning to a laser. This has the advantage over the  $\text{TeO}_2$  - lithium niobate technology in that it is inherently smaller and lower cost and provides two-dimensional scanning capability in one small device. The maximum angular deflection that can be achieved with this process is on the order of about 10 degrees. Thus, a diverging lens will be needed for the scanning system.

An alternate method of obtaining three-dimensional information from a scanning laser system is to use multiple arrays to replace the single arrays used in FIG. 1A. In the case, the arrays are displaced from each other and, through triangulation, the location of the reflection from the illumination by a laser beam of a point on the object can be determined in a manner that is understood by those skilled in the art.

One important point concerns the location and number of optical assemblies. It is possible to use fewer than four such assemblies with a resulting loss in accuracy. The number of four was chosen so that either a forward or rear assembly or either of the side assemblies can be blocked by a newspaper, for example, without seriously degrading the performance of the system. Since drivers rarely are reading newspapers while driving, fewer than four arrays are usually adequate for the driver side.

The particular locations of the optical assemblies were chosen to give the most accurate information as to the locations of the occupant. This is based on an understanding of what information can be best obtained from a visual image. There is a natural tendency on the part of humans to try to gauge distance from the optical sensors directly. This, as can be seen above, is at best complicated involving focusing systems, stereographic systems, multiple arrays and triangulation, time of flight measurement, etc. What is not intuitive to humans is to not try to obtain this distance directly from apparatus or techniques associated with the mounting location. Whereas ultrasound is quite good for measuring distances from the transducer (the z-axis), optical systems are better at measuring distances in the vertical and lateral directions (the x and y-axes). Since the precise locations of the optical transducers

are known, that is, the geometry of the transducer locations is known relative to the vehicle, there is no need to try to determine the displacement of an object of interest from the transducer (the z-axis) directly. This can more easily be done indirectly by another transducer. That is, the z-axis to one transducer is the x-axis to another.

5           Ultrasonic transducers are relatively good at measuring the distance along a radius to a reflective object. An optical array, such as disclosed herein, on the other hand, can get accurate measurements in two dimensions, the lateral and vertical dimensions relative to the transducer. If we assume that the optical array has dimensions of 100 by 100 as compared to an ultrasonic sensor that has a single dimension of 100, an optical array can give therefore 100 times as much information as the ultrasonic  
10 array. Most importantly, this vastly greater amount of information does not cost significantly more to obtain than the information from the ultrasonic sensor.

As illustrated in FIGS. 1A-1D, the optical sensors are typically located at the positions where the desired information is available with the greatest resolution. These positions are typically in the center front and center rear of the occupancy seat and at the center on each side and top. This is in contrast to  
15 the optimum location for ultrasonic sensors, which are the corners of such a rectangle that outlines the seated volume.

Systems based on ultrasonics and neural networks have been very successful in analyzing the seated state of both the passenger and driver seats of automobiles. Such systems are now going into production for preventing airbag deployment when a rear facing child seat or an out-of-position  
20 occupant is present. The ultrasonic systems, however, suffer from certain natural limitations that prevent the system accuracy from getting better than about 99 percent. These limitations relate to the fact that the wavelength of ultrasound is typically between 3 and 8 mm. As a result, unexpected results occur which are due partially to the interference of reflections from different surfaces. Additionally, commercially available ultrasonic transducers are tuned devices that require several cycles before they transmit  
25 significant energy and similarly require several cycles before they effectively receive the reflected signals. This requirement has the effect of smearing the resolution of the ultrasound to the point that, for example, using a conventional 40 kHz transducer, the resolution of the system is approximately three inches.

In contrast, the wavelength of infrared is less than one micron and no significant interferences occur. Similarly, the system is not tuned and therefore is theoretically sensitive to a very few cycles. As  
30 a result, resolution of the optical system is determined by the pixel spacing in the CCD or CMOS arrays. For this application, typical arrays have been chosen to be 100 pixels by 100 pixels and therefore the space being imaged can be broken up into pieces that are significantly less than 1 cm in size. Naturally, if greater resolution is required arrays having larger numbers of pixels are readily available. Another advantage of optical systems is that special lenses can be used to magnify those areas where the

information is most critical and operate at reduced resolution where this is not the case. For example, the area closest to the at-risk zone in front of the airbag can be magnified. This is not possible with ultrasonic systems.

To summarize, although ultrasonic neural network systems are operating with high accuracy, they do not totally eliminate the problem of deaths and injuries caused by airbag deployments. Optical systems, on the other hand, at little increase in cost, have the capability of virtually 100 percent accuracy. Additional problems of ultrasonic systems arise from the slow speed of sound and diffraction caused by variations in air density. The slow sound speed limits the rate at which data can be collected and thus eliminates the possibility of tracking the motion of an occupant during a high speed crash.

In the case of FIG. 1A, transmitter/receiver assemblies 110-114 emit infrared waves that reflect off of the head and chest of the driver and return thereto. Periodically, the device, as commanded by control circuitry 120, transmits a pulse of infrared waves and the reflected signal is detected by the same or a different device. The transmitters can either transmit simultaneously or sequentially. An associated electronic circuit and algorithm in control circuitry 120 processes the returned signals as discussed above and determines the location of the occupant in the passenger compartment. This information is then sent to the crash sensor and diagnostic circuitry, which may also be resident in control circuitry 120 (programmed within a control module), which determines if the occupant is close enough to the airbag that a deployment might, by itself, cause injury which exceeds that which might be caused by the accident itself. In such a case, the circuit disables the airbag system and thereby prevents its deployment. In an alternate case, the sensor algorithm assesses the probability that a crash requiring an airbag is in process and waits until that probability exceeds an amount that is dependent on the position of the occupant. Thus, for example, the sensor might decide to deploy the airbag based on a need probability assessment of 50%, if the decision must be made immediately for an occupant approaching the airbag, but might wait until the probability rises to 95% for a more distant occupant. In the alternative, the crash sensor and diagnostic circuitry optionally resident in control circuitry 120 may tailor the parameters of the deployment (time to initiation of deployment, rate of inflation, rate of deflation, deployment time, etc.) based on the current position and possibly velocity of the occupant, e.g., a depowered deployment.

Although a driver system has been illustrated, the front and rear seat passenger systems would be similar.

In another implementation, the sensor algorithm may determine the rate that gas is generated to affect the rate that the airbag is inflated. In all of these cases, the position of the occupant is used to affect the deployment of the airbag as to whether or not it should be deployed at all, the time of deployment and/or the rate of inflation.

It should be understood that although the above description mentions that the airbag system can be controlled by the control circuitry 120, any vehicular system, component or subsystem can be controlled based on the information or data obtained by transmitter/receiver assemblies 110-114. Control circuitry 120 can be programmed or trained, if for example a neural network is used, to control heating and air-conditioning systems based on the presence of occupants in certain positions so as to optimize the climate control in the vehicle. The entertainment system can also be controlled to provide sound only to locations at which occupants are situated. There is no limit to the number and type of vehicular systems, components and subsystems that can be controlled using the image analysis techniques described herein.

Furthermore, if multiple vehicular systems are to be controlled by control circuitry 120, then these systems can be controlled by the control circuitry 120 based on the status of particular components of the vehicle. For example, an indication of whether a key is in the ignition can be used to direct the control circuitry 120 to either control an airbag system (when the key is present in the ignition) or an antitheft system (when the key is not present in the ignition). Control circuitry 120 would thus be responsive to the status of the ignition of the motor vehicle to perform one of a plurality of different functions. More particularly, the pattern recognition algorithm, such as the neural network described herein, could itself be designed to perform in a different way depending on the status of a vehicular component such as the detected presence of a key in the ignition. It could provide one output to control an antitheft system when a key is not present and another output when a key is present using the same inputs from the transmitter/receiver assemblies 110-114.

The algorithm in control circuitry 120 can also be designed to determine the location of the occupant's eyes either directly or indirectly through a determination of the location of the occupant and an estimation of the position of the eyes therefrom. As such, the position of the rear view mirror 105 can be adjusted to optimize the driver's use thereof.

Weight sensors 130 are also included in the system shown in FIG. 1A. Although strain gage type sensors are schematically illustrated mounted to the supporting structure of the seat 102, any other type of weight sensor can be used. Strain gage weight sensors are described in detail in U.S. patent application Ser. No. 09/193,209 that is incorporated herein by reference as if it were entirely set forth herein. Weight can be used to confirm the occupancy of the seat, i.e., the presence or absence of an occupant as well as whether the seat is occupied by a light or heavy object. In the latter case, a measured weight of less than 60 pounds is often determinative of the presence of a child seat whereas a measured weight of greater than 60 pounds is often indicative of the absence of a child seat. The weight sensors 130 can also be used to determine the weight distribution of the occupant of the seat and thereby ascertain whether the occupant is moving and the position of the occupant. As such, the weight sensors 130 could be used to confirm the position of the occupant. The measured weight or distribution thereof can also be used in

combination with the data from the transmitter/receiver assemblies 110-114 to provide an identification of the occupants in the seat.

The accuracy of the optical occupant sensor is critically dependent upon the accuracy of the camera. The dynamic range of light within a vehicle exceeds 120 decibels. When a car is driving at night, for example, very little light is available whereas when driving in a bright sunlight, especially in a convertible, the light intensity can overwhelm most cameras. Additionally, the camera must be able to adjust rapidly to changes and light caused by, for example, the emergence of the vehicle from tunnel, or passing by other obstructions such as trees, buildings, other vehicles, etc. which temporarily block the sun and cause a strobing effect at frequencies approaching 1 kHz.

Recently, improvements have been made to CMOS cameras that have significantly increased their dynamic range. New logarithmic high dynamic range technology such as developed by IMS Chips of Stuttgart, Germany, is now available in HDRC (High Dynamic Range CMOS) cameras. This technology provides a 120 dB dynamic intensity response at each pixel in a mono chromatic mode. The technology has a 1 million to one dynamic range at each pixel. This prevents blooming, saturation and flaring normally associated with CMOS and CCD camera technology. This solves a problem that will be encountered in an automobile when going from a dark tunnel into bright sunlight. Such a range would even exceed the 120 dB intensity.

There is also significant infrared radiation from bright sunlight and from incandescent lights within the vehicle. Such situations may even exceed the dynamic range of the HDRC camera and additional filtering may be required. Changing the bias on the receiver array, the use of a mechanical iris, or of electrochromic glass or liquid crystal can provide this filtering on a global basis but not at a pixel level. Filtering can also be used with CCD arrays, but the amount of filtering required is substantially greater than for the HDRC camera. A notch filter can be used to block significant radiation from the sun, for example. This notch filter can be made as a part of the lens through the placement of various coatings onto the lens surface.

Liquid crystals operate rapidly and give as much as a dynamic range of 10,000 to 1 but may create a pixel interference affect. Electrochromic glass operates more slowly but more uniformly thereby eliminating the pixel affect. The pixel effect arises whenever there is one pixel device in front of another. This results in various aliasing, Moire patterns and other ambiguities. One way of avoiding this is to blur the image. Another solution is to use a large number of pixels and combine groups of pixels to form one pixel of information and thereby to blur the edges to eliminate some of the problems with aliasing and Moire patterns.

One straightforward approach is the use of a mechanical iris. Standard cameras already have response times of several tens of milliseconds range. They will switch, for example, in a few frames on a

typical video camera (1 frame = .033 seconds). This is sufficiently fast for categorization but much too slow for dynamic out-of-position tracking.

An important feature of the IMS Chips HDRC camera is that the full dynamic range is available at each pixel. Thus, if there are significant variations in the intensity of light within the vehicle, and thereby from pixel to pixel, such as would happen when sunlight streams and through a window, the camera can automatically adjust and provide the optimum exposure on a pixel by pixel basis. The use of the camera having this characteristic is very beneficial to the invention described herein and contributes significantly to system accuracy. CCDs have a rather limited dynamic range due to their inherent linear response and consequently cannot come close to matching the performance of human eyes. A key advantage of the IMS Chips HDRC camera is its logarithmic response which comes closest to matching that of the human eye.

Another approach, which is applicable in some vehicles, is to record an image without the infrared illumination and then a second image with the infrared illumination and to then subtract the first image from the second image. In this manner, illumination caused by natural sources such as sunlight or even from light bulbs within the vehicle can be subtracted out. Naturally, using the logarithmic pixel system of the IMS Chips camera care must be taken to include the logarithmic effect during the subtraction process. For some cases, natural illumination such as from the sun, light bulbs within the vehicle, or radiation emitted by the object itself can be used alone without the addition of a special source of infrared illumination.

Other imaging systems such as CCD arrays can also of course be used with this invention. However, the techniques will be quite different since the camera is very likely to saturate when bright light is present and to require the full resolution capability when the light is dim. Generally when practicing this invention the interior of the passenger compartment will be illuminated with infrared radiation.

There are other bright sources of infrared that must be accounted for. These include the sun and any light bulbs that may be present inside the vehicle. This lack of a high dynamic range inherent with the CCD technology requires the use of an iris, liquid crystal, or electrochromic glass filter to be placed between the camera and the scene. Even with these filters however, some saturation will take place with CCD cameras under bright sun or incandescent lamp exposure. This saturation reduces the accuracy of the image and therefore the accuracy of the system. In particular the training regimen that must be practiced with CCD cameras is more severe since all of the saturation cases must be considered since the camera is unable to appropriately adjust. Thus, although CCD cameras can be use, HDRC logarithmic cameras such as manufactured by IMS Chips are preferred. They not only provide a significantly more accurate image but also significantly reduce the amount of training effort and associated data collection

that must be undertaken during the development of the neural network algorithm or other computational intelligence system. In some applications, it is possible to use other more deterministic image processing or pattern recognition systems than neural networks.

Another very important feature of the HDRC camera from IMS Chips is that the shutter time is constant at less than 100ns irrespective of brightness of the scene. The pixel data arrives at constant rate synchronous with the internal imager clock. Random access to each pixel facilitates high-speed intelligent access to any sub-frame (block) size or sub-sampling ratio and a trade-off of frame speed and frame size therefore results. For example, a scene with 128 K pixels per frame can be taken at 120 frames per second, or about 8 milliseconds per frame, whereas a sub-frame can be taken in run at as high as 4000 frames per second with 4 K pixels per frame. This combination allows the maximum resolution for the identification and classification part of the occupant sensor problem while permitting a concentration on those particular pixels which track the head or chest, as described above, for dynamic out-of-position tracking. In fact the random access features of these cameras can be used to track multiple parts of the image simultaneously while ignoring the majority of the image, and do so at very high speed. For example, the head can be tracked simultaneously with the chest by defining two separate sub-frames that need not be connected. This random access pixel capability, therefore, is optimally suited for recognizing and tracking vehicle occupants. It is also suited for monitoring the environment outside of the vehicle for purposes of blind spot detection, collision avoidance and anticipatory sensing. Photobit Corporation of 135 North Los Robles Ave., Suite 700, Pasadena, California 91101 manufactures another camera with some characteristics similar to the IMS Chips camera. Other competitive cameras can be expected to appear on the market.

Photobit refers to their Active Pixel Technology as APS. According to Photobit, in the APS, both the photodetector and readout amplifier are part of each pixel. This allows the integrated charge to be converted into a voltage in the pixel that can then be read out over X-Y wires instead of using a charge domain shift register as in CCDs. This column and row addressability (similar to common DRAM) allows for window of interest readout (windowing) which can be utilized for on chip electronic pan/tilt and zoom. Windowing provides added flexibility in applications, such as disclosed herein, needing image compression, motion detection or target tracking. The APS utilizes intra-pixel amplification in conjunction with both temporal and fixed pattern noise suppression circuitry (i.e. correlated double sampling), which produces exceptional imagery in terms of wide dynamic range (~75 dB) and low noise (~15 e- rms noise floor) with low fixed pattern noise (<0.15% sat). Unlike CCDs, the APS is not prone to column streaking due to blooming pixels. This is because CCDs rely on charge domain shift registers that can leak charge to adjacent pixels when the CCD registers overflows. Thus, bright lights "bloom" and cause unwanted streaks in the image. The active pixel can drive column busses at much greater rates than



passive pixel sensors and CCDs. On-chip analog-to-digital conversion (ADC) facilitates driving high speed signals off chip. In addition, digital output is less sensitive to pickup and crosstalk, facilitating computer and digital controller interfacing while increasing system robustness. A high speed APS recently developed for a custom binary output application produced over 8,000 frames per second, at a resolution of 128 x 128 pixels. It is possible to extend this design to a 1024 x 1024 array size and achieve greater than 1000 frames per second for machine vision. All of these features are important to many applications of this invention.

These advanced cameras, as represented by the HDRC and the APS cameras, now make it possible to more accurately monitor the environment in the vicinity of the vehicle. Heretofore, the large dynamic range of environmental light has either blinded the cameras when exposed to bright light or else made them unable to record images when the light level was low. Even the HDRC camera with its 120 dB dynamic range may be marginally sufficient to handle the fluctuations in environmental light that occur. Thus, the addition of an electrochromic, liquid crystal, or other similar filter may be necessary. This is particularly true for cameras such as the Photobit APS camera with its 75 dynamic range.

At about 120 frames per second, these cameras are adequate for cases where the relative velocity between vehicles is low. There are many cases, however, where this is not the case and a much higher monitoring rate is required. This occurs for example, in collision avoidance and anticipatory sensor applications. The HDRC camera is optimally suited for handling these cases since the number of pixels that are being monitored can be controlled resulting in a frame rate as high as about 4000 frames per second with a smaller number of pixels.

Another key advantage of the HDRC camera is that it is quite sensitive to infrared radiation in the 0.8 to 1 micrometer wavelength range. This range is generally beyond visual range for humans permitting this camera to be used with illumination sources that are not visible to the human eye. Naturally, a notch filter is frequently used with the camera to eliminate unwanted wavelengths. These cameras are available from the Institute for Microelectronics (IMS Chips), Allamndring 30a, D-70569 Stuttgart, Germany with a variety of resolutions ranging from 512 by 256 to 720 by 576 pixels and can be custom fabricated for the resolution and response time required.

An optical infrared transmitter and receiver assembly is shown generally at 112 in FIG. 1B and is mounted onto the instrument panel facing the windshield. Assembly 112 can either be recessed below the upper face of the instrument panel or mounted onto the upper face of the instrument panel. Assembly 112, shown enlarged, comprises a source of infrared radiation, or another form of electromagnetic radiation, and a CCD or CMOS array of typically 160 pixels by 160 pixels. In this embodiment, the windshield is used to reflect the illumination light provided by the infrared radiation toward the objects in the passenger compartment and also reflect the light being reflected back by the objects in the passenger

compartment, in a manner similar to the "heads-up" display which is now being offered on several automobile models. The "heads-up" display, of course, is currently used only to display information to the driver and is not used to reflect light from the driver to a receiver. Once again, unless one of the distance measuring systems as described below is used, this system alone cannot be used to determine  
5 distances from the objects to the sensor. Its main purpose is object identification and monitoring. Depending on the application, separate systems can be used for the driver and for the passenger. In some cases, the cameras located in the instrument panel which receive light reflected off of the windshield can be co-located with multiple lenses whereby the respective lenses aimed at the driver and passenger seats respectively.

10 Assembly 112 is actually about two centimeters in diameter and is shown greatly enlarged in FIG. 1B. Also, the reflection area on the windshield is considerably smaller than illustrated and special provisions are made to assure that this area of the windshield is flat and reflective as is done generally when heads-up displays are used. For cases where there is some curvature in the windshield, it can be at least partially compensated for by the CCD optics.

15 When using the surface of the windshield as a reflector of infrared radiation, care must be taken to assure that the desired reflectivity at the frequency of interest is achieved. Mirror materials, such as metals and other special materials manufactured by Eastman Kodak, have a reflectivity for infrared frequencies that is substantially higher than at visible frequencies. They are thus candidates for coatings to be placed on the windshield services for this purpose. If two spaced apart CCD arrays are used, then  
20 the distance to the various objects within the passenger compartment can be found by using a triangulation algorithm which locates similar features on both images and determines their relative location on the images. An alternate method is to use a lens with a short focal length. In this case, the lens is mechanically focused, e.g., automatically, directly or indirectly, by the control circuitry 120, to determine the clearest image and thereby obtain the distance to the object. This is similar to certain  
25 camera auto-focusing systems such as one manufactured by Fuji of Japan. Naturally, other methods can be used as described in the patents and patent applications referenced above.

Instead of focusing the lens, the lens could be moved relative to the array to thereby adjust the image on the array. Instead of moving the lens, the array could be moved to achieve the proper focus. In addition, it is also conceivable that software could be used to focus the image without moving the lens or  
30 the array.

Once a vehicle interior monitoring system employing a sophisticated pattern recognition system, such as a neural network, is in place, it is possible to monitor the motions of the driver over time, and his/her response to various stimuli, and determine if he or she is falling asleep, has become incapacitated or otherwise unable to operate the vehicle. In such an event, the vehicle can be caused to respond in a

number of different ways. One such system is illustrated in FIG. 1B and consists of a monitoring system having the transducer assembly 112 coupled to a microprocessor in control circuitry 120 which is programmed to compare the motions of the driver over time and trained to recognize changes in behavior representative of becoming incapacitated, e.g., the eyes blinking erratically and remaining closed for ever  
5 longer periods of time. If the system determines that there is a reasonable probability that the driver has fallen asleep, for example, then it can activate an alarm, e.g., turn on a warning light shown here as 124 or send a warning sound. If the driver fails to respond to the warning by pushing a button 122, for example, then the horn and lights of the vehicle can be operated in a manner to warn other vehicles and the vehicle may be brought to a stop. Naturally, other responses can also be programmed and other tests of driver  
10 attentiveness can be used without resorting to attempting to monitor the motions of the driver's eyes.

The use of the windshield as a reflector is particularly useful when monitoring the eyes of the driver. The reflections from the cornea are highly directional as every driver knows whose lights have reflected off the eyes of an animal on the roadway. For this to be effective, the eyes of the driver must be looking at the radiation source. Since the driver is presumably looking through the windshield, the source  
15 of the radiation must also come from the windshield and the reflections from the driver's eyes must also be in the direction of the windshield. Using this technique, the time that the driver spends looking through the windshield can be monitored and if that time drops below some threshold value it can be presumed that the driver is not attentive and may be sleeping or otherwise incapacitated.

An even more sophisticated system of monitoring the behavior of the driver is to track the  
20 driver's eye motions using such techniques as are described in: Freidman et al., U.S. Pat. No. 4,648,052 entitled "Eye Tracker Communication System"; Heyner et al., U.S. Pat. No. 4,720,189 entitled "Eye Position Sensor"; Hutchinson, U.S. Pat. No. 4,836,670 entitled "Eye Movement Detector"; and Hutchinson, U.S. Pat. No. 4,950,069 entitled "Eye Movement Detector With Improved Calibration and Speed", all of which are incorporated herein by reference as well as U.S. Pat. Nos. 5,008,946 and  
25 5,305,012 referenced above. The detection of the impaired driver in particular can be best determined by these techniques. These systems make use of pattern recognition techniques plus, in many cases, the transmitter and CCD receivers must be appropriately located so that the reflection off of the cornea of the driver's eyes can be detected as discussed in the above referenced patents. The size of the CCD arrays used herein permits their location, sometimes in conjunction with a reflective windshield, where this  
30 corneal reflection can be detected with some difficulty. Sunglasses or other items can interfere with this process.

The location of the eyes of the driver, for this application, is greatly facilitated by the teachings of this invention as described above. Although others have suggested the use of eye motions and corneal reflections for drowsiness determination, up until now there has not been a practical method for locating

the driver's eyes with sufficient precision and reliability as to render this technique practical. Also, although sunglasses might defeat such a system, most drowsiness caused accidents happen at night where it is less likely that sunglasses are worn.

5 The eye tracker systems discussed above are facilitated by the instant invention since one of the main purposes of determining the location of the driver's eyes either by directly locating them with trained pattern recognition technology or by inferring their location from the location of the driver's head, is so that the seat can be automatically positioned to place the driver's eyes into the "eye-ellipse". The eye-ellipse is the proper location for the driver's eyes to permit optimal operation of the vehicle and for the location of the mirrors etc. Thus, if the location of the driver's eyes are known, then the driver can be positioned so that his or her eyes are precisely situated in the eye ellipse and the reflection off of the eye can be monitored with a small eye tracker system. Also, by ascertaining the location of the driver's eyes, a rear view mirror positioning device can be controlled to adjust the mirror 105 to an optimal position.

15 In addition to finding the location of the eyes, the location of the ears is becoming more important. Many automobile accidents are now being caused by driver's holding on and talking into cellular phones. Vehicle noise significantly deteriorates the quality of the sound heard by the driver from speakers. This problem can be solved through the use of hypersound and by knowing the location of the ears of the driver. Hypersound permits the precise focusing of sound waves along a line from the speaker with little divergence of the sound field. Thus, if the locations of the ears of the driver are known, the sound can be projected to them directly thereby overcoming much of the vehicle noise. In addition to the use of hypersound, directional microphones are well known in the microphone art which are very sensitive to sound coming from a particular direction. If the driver has been positioned so that his eyes are in the eye ellipse, then the location of the driver's mouth is also accurately known and a fixed position directional microphone can be used to selectively sense sound emanating from the mouth of the driver. In many cases, the sensitivity of the microphone can be designed to include a large enough area such that most motions of the driver's head can be tolerated. Alternately the direction of the microphone can be adjusted using motors or the like. Systems of noise cancellation now also become possible if the ear locations are precisely known and noise canceling microphones as described in U.S. provisional patent application Serial No. 60/110,973, which is incorporated herein by reference, if the location of the driver's mouth is known.

25 30 Infrared waves are shown coming from the front and back transducer assemblies 110 and 113 in FIG. 1C.

FIG. 1D illustrates two optical systems each having a source of infrared radiation and a CCD or CMOS array receiver. The price of such arrays has dropped dramatically recently making them practical for interior and exterior vehicle monitoring. In this embodiment, transducers 110 and 113 are CMOS

arrays having 160 pixels by 160 pixels covered by a lens. In some applications, this can create a "fisheye" effect whereby light from a wide variety of directions can be captured. One such transducer placed by the dome light or other central position in the vehicle headliner, such as the transducer designated 113, can monitor the entire vehicle interior with sufficient resolution to determine the occupancy of the vehicle, for example. CCD's such as those used herein are available from Marshall Electronics Inc. of Culver City, CA. A fisheye lens is "... a wide-angle photographic lens that covers an angle of about 180°, producing a circular image with exaggerated foreshortening in the center and increasing distortion toward the periphery". (*The American Heritage Dictionary of the English Language, Third Edition, 1992 by Houghton Mifflin Company*). This distortion of a fisheye lens can be substantially changed by modifying the shape of the lens to permit particular portions of the interior passenger compartment to be observed. Also, in many cases the full 180° is not desirable and a lens which captures a smaller angle may be used. Although primarily spherical lenses are illustrated herein, it is understood that the particular lens design will depend on the location in the vehicle and the purpose of the particular receiver.

CCD arrays are in common use in television cameras, for example, to convert an image into an electrical signal. For the purposes herein, a CCD will be defined to include all devices, including CMOS arrays, APS arrays, artificial retinas and particularly HDRC arrays, which are capable of converting light frequencies, including infrared, visible and ultraviolet, into electrical signals. The particular CCD array used for many of the applications disclosed herein is implemented on a single chip that is less than two centimeters on a side. Data from the CCD array is digitized and sent serially to an electronic circuit (at times designated 120 herein) containing a microprocessor for analysis of the digitized data. In order to minimize the amount of data that needs to be stored, initial processing of the image data takes place as it is being received from the CCD array, as discussed in more detail above. In some cases, some image processing can take place on the chip such as described in the Kage et al. artificial retina article referenced above.

One method of determining distance to an object directly without resorting to range finders, which require multiple arrays, is to use a mechanical focusing system. However, the use of such an apparatus is cumbersome, expensive, and slow and has questionable reliability. An alternative is to use the focusing systems described in the above referenced U.S. Pat. Nos. 5,193,124 and 5,003,166, however, such systems require expensive hardware and/or elaborate algorithms. Another alternative is illustrated in FIG. 1D where transducer 116 is an infrared source having a wide transmission angle such that the entire contents of the front driver's seat is illuminated. Receiving CCD transducers 117 and 118 are shown spaced apart so that a stereographic analysis can be made by the control circuitry 120. This circuitry 120 contains a microprocessor with appropriate pattern recognition algorithms along with other circuitry as

described above. In this case, the desired feature to be located is first selected from one of the two returned images from either CCD transducer 117 or 118. The software then determines the location of the same feature, through correlation analysis or other methods, on the other image and thereby, through analysis familiar to those skilled in the art, determines the distance of the feature from the transducers.

5 Transducers 116-118 are illustrated mounted onto the A-pillar of the vehicle, however, since these transducers are quite small, typically approximately 2 cm on a side, they could alternately be mounted onto the windshield itself, or other convenient location which provides a clear view of the portion of the passenger compartment being monitored. Other preferred mounting locations include the headliner above and also the side of the seat.

10 With respect to the connection between the transducers 110-114 and 116-118 and the control circuitry 120, a portion of this connection is shown as wires. It should be understood that all of the connections between the transducers 110-114 and 116-118 and the control circuitry 120 may be wires, either individual wires leading from the control circuitry 120 to each of the transducers 110-114 and 116-118 or one or more wire buses.

15 With respect to the position of the control circuitry 120 in the dashboard of the vehicle, this position is for illustration purposes only and does not limit the location of the control circuitry 120. Rather, the control circuitry 120 may be located anywhere convenient or desired in the vehicle.

A new class of laser range finders has particular application here. This product, as manufactured by Power Spectra, Inc. of Sunnyvale, California, is a GaAs pulsed laser device which can measure up to  
 20 30 meters with an accuracy of < 2 cm and a resolution of < 1 cm. This system is implemented in combination with transducer 116 and one of the receiving transducers 117 or 118 may thereby be eliminated. Once a particular feature of an occupying item of the passenger compartment has been located, this device is used in conjunction with an appropriate aiming mechanism to direct the laser beam to that particular feature. The distance to that feature is then known to within 2 cm and with calibration  
 25 even more accurately. In addition to measurements within the passenger compartment, this device has particular applicability in anticipatory sensing and blind spot monitoring applications exterior to the vehicle. An alternate technology using range gating to measure the time of flight of electromagnetic pulses with even better resolution can be developed based on the teaching of the McEwan patents listed above and incorporated herein by reference.

30 A more accurate acoustic system for determining the distance to a particular object, or a part thereof, in the passenger compartment is exemplified by transducers 111A in FIG. 1E. In this case, three ultrasonic transmitter/receivers are shown spaced apart mounted onto the A-pillar of the vehicle. The A-pillar is the forward most roof support pillar and also supports the windshield. Due to the wavelength, it is difficult to get a narrow beam using ultrasonics without either using high frequencies that have limited

range or a large transducer. A commonly available 40 kHz transducer, for example, is about 1 cm. in diameter and emits a sonic wave that spreads at about a sixty-degree angle. To reduce this angle requires making the transducer larger in diameter. An alternate solution is to use several transducers and to phase the transmissions so that they arrive at the intended part of the target in phase. Reflections from the selected part of the target are then reinforced whereas reflections from adjacent parts encounter interference with the result that the distance to the brightest portion within the vicinity of interest can be determined. By varying the phase of transmission from the three transducers 111A, the location of a reflection source on a curved line can be determined. In order to locate the reflection source in space, at least one additional transmitter/receiver is required which is not co-linear with the others. The accuracy of the measurement can be determined by those skilled in the art of phased array radar as the relevant equations are applicable here. The waves shown in FIG. 1E coming from the three transducers 111A are actually only the portions of the waves which arrive at the desired point in space together in phase. The effective direction of these wave streams can be varied by changing the transmission phase between the three transmitters. A determination of the approximate location of a point of interest on the occupant is accomplished by the CCD array and appropriate analysis and the phasing of the ultrasonic transmitters is determined so that the distance to the desired point can be determined.

FIG. 2A is a side view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing preferred mounting locations of optical interior vehicle monitoring sensors (transmitter/receiver assemblies or transducers) 110, 111A, 113, 114, 210, 211A, 213, 214, and 224. Each of these sensors is illustrated as having a lens and is shown enlarged in size for clarity. In a typical actual device, the diameter of the lens is approximately 2 cm and it protrudes from the mounting surface by approximately 1 cm. This small size renders these devices almost unnoticeable by vehicle occupants. Since these sensors are optical, it is important that the lens surface remains relatively clean. Control circuitry 120, which is coupled to each transducer, contains a self-diagnostic feature where the image returned by a transducer is compared with a stored image and the existence of certain key features is verified. If a receiver fails this test, a warning is displayed to the driver which indicates that cleaning of the lens surface is required. The technology illustrated in FIG. 2A can be used for numerous purposes relating to monitoring of the space in the passenger compartment behind the driver including: (i) the determination of the presence and position of objects in the rear seat(s), (ii) the determination of the presence, position and orientation of child seats 230 in the rear seat, (iii) the monitoring of the rear of an occupant's head 242, (iv) the monitoring of the position of occupant 240, (v) the monitoring of the position of the occupant's knees 241, (vi) the monitoring of the occupant's position relative to the airbag 250, (vii) the measurement of the occupant's height, as well as other monitoring functions as described elsewhere herein.

Information relating to the space behind the driver can be obtained by processing the data obtained by the sensors 210,211A,213 and 214, which data would be in the form of images if optical sensors are used as in the preferred embodiment. Such information can be the presence of a particular occupying item or occupant, e.g., a rear facing child seat 230 as shown in FIG. 2A, as well as the location or position of occupying items. Additional information obtained by the optical sensors can include an identification of the occupying item. The information obtained by the control circuitry by processing the information from sensors 210,211A,213 and 214 may be used to affect any other system in the vehicle in a similar manner as the information from the sensors which monitor the front seat is used as described herein, such as the airbag system. Processing of the images obtained by the sensors to determine the presence, position and/or identification of any occupants or occupying item can be effected using a pattern recognition algorithm in any of the ways discussed herein, e.g., a trained neural network.

Sensors 210,211A,213,214 can also be microwave radar sensors which transmit and receive radar waves. As such, it is possible to determine the presence of an object in the rear seat and the distance between the object and the sensors. Using multiple radar sensors, it would be possible to determine the contour of an object in the rear seat and thus using pattern recognition techniques, the classification or identity of the object. Motion of objects in the rear seat can also be determined using radar sensors. For example, if the radar sensors are directed toward a particular area and/or are provided with the ability to detect motion in a predetermined frequency range, they can be used to determine the presence of children or pets left in the vehicle, i.e., by detecting heartbeats or other body motions such as movement of the chest cavity.

FIG. 2B is a perspective view corresponding to the embodiment shown in FIG. 2A illustrating some of the transducer mounting locations (including sensor 110A). The passenger side airbag module is designated 104A and is mounted in the dashboard or instrument panel of the vehicle.

The occupant position sensor in any of its various forms is integrated into the airbag system circuitry as shown schematically in FIG. 3. In this example, the occupant position sensors are used as an input to a smart electronic sensor and diagnostic system. The electronic sensor determines whether one or more of the airbags should be deployed based on the vehicle acceleration crash pulse, or crash zone mounted crash sensors, or a combination thereof, and the occupant position sensor determines whether the occupant is too close to any of the airbags and therefore that the deployment should not take place. In FIG. 3, the electronic crash sensor located within the sensor and diagnostic unit determines whether the crash is of such severity as to require deployment of one or more of the airbags. The occupant position sensors determine the location of the vehicle occupants relative to the airbags and provide this information to the sensor and diagnostic unit that then determines whether it is safe to deploy each airbag and/or whether the deployment parameters should be adjusted. The arming sensor, if one is present, also



determines whether there is a vehicle crash occurring. In such a case, if the sensor and diagnostic unit and the arming sensor both determine that the vehicle is undergoing a crash requiring one or more airbags and the position sensors determine that the occupants are safely away from the airbag(s), the airbag(s), or inflatable restraint system, is deployed.

5 A particular implementation of an occupant position sensor having a range of from 0 to 2 meters (corresponding to an occupant position of from 0 to 1 meter since the signal must travel both to and from the occupant) using infrared is illustrated in the block diagram schematic of FIG. 4. The operation is as follows. A 48 MHz signal, f1, is generated by a crystal oscillator 401 and fed into a frequency tripler 402 which produces an output signal at 144 MHz. The 144 MHz signal is then fed into an infrared diode driver 403 which drives the infrared diode 404 causing it to emit infrared light modulated at 144 MHz and  
10 a reference phase angle of zero degrees. The infrared diode 404 is directed at the vehicle occupant. A second signal f2 having a frequency of 48.05 MHz, which is slightly greater than f1, is similarly fed from a crystal oscillator 405 into a frequency tripler 406 to create a frequency of 144.15 MHz. This signal is then fed into a mixer 407 which combines it with the 144 MHz signal from frequency tripler 402. The  
15 combined signal from the mixer 407 is then fed to filter 408 which removes all signals except for the difference, or beat frequency, between 3 times f1 and 3 times f2, of 150 kHz. The infrared signal which is reflected from the occupant is received by receiver 409 and fed into pre-amplifier 411, a resistor 410 to bias being coupled to the connection between the receiver 409 and the pre-amplifier 411. This signal has the same modulation frequency, 144 MHz, as the transmitted signal but now is out of phase with the  
20 transmitted signal by an angle  $x$  due to the path that the signal took from the transmitter to the occupant and back to the receiver. The output from pre-amplifier 411 is fed to a second mixer 412 along with the 144.15 MHz signal from the frequency tripler 406. The output from mixer 412 is then amplified by an automatic gain amplifier 413 and fed into filter 414. The filter 414 eliminates all frequencies except for the 150 kHz difference, or beat, frequency, in a similar manner as was done by filter 408. The resulting  
25 150 kHz frequency, however, now has a phase angle  $x$  relative to the signal from filter 408. Both 150 kHz signals are now fed into a phase detector 415 which determines the magnitude of the phase angle  $x$ . It can be shown mathematically that, with the above values, the distance from the transmitting diode to the occupant is  $x/345.6$  where  $x$  is measured in degrees and the distance in meters. The velocity can also be obtained using the distance measurement as represented by 416. An alternate method of obtaining  
30 distance information, as discussed above, is to use the teachings of the McEwan patents discussed above.

Although the embodiment in FIG. 4 uses infrared, it is possible to use other frequencies of energy without deviating from the scope of the invention.

The applications described herein have been illustrated using the driver of the vehicle. The same systems of determining the position of the occupant relative to the airbag apply to front and rear seated

passengers, sometimes requiring minor modifications. It is likely that the sensor required triggering time based on the position of the occupant will be different for the driver than for the passenger. Current systems are based primarily on the driver with the result that the probability of injury to the passenger is necessarily increased either by deploying the airbag too late or by failing to deploy the airbag when the position of the driver would not warrant it but the passenger's position would. With the use of occupant position sensors for both the passenger and driver, the airbag system can be individually optimized for each occupant and result in further significant injury reduction. In particular, either the driver or passenger system can be disabled if either the driver or passenger is out-of-position or if the passenger seat is unoccupied.

There is almost always a driver present in vehicles that are involved in accidents where an airbag is needed. Only about 30% of these vehicles, however, have a passenger. If the passenger is not present, there is usually no need to deploy the passenger side airbag. The occupant monitoring system, when used for the passenger side with proper pattern recognition circuitry, can also ascertain whether or not the seat is occupied, and if not, can disable the deployment of the passenger side airbag and thereby save the cost of its replacement. The same strategy applies also for monitoring the rear seat of the vehicle. Also, a trainable pattern recognition system, as used herein, can distinguish between an occupant and a bag of groceries, for example. Finally, there has been much written about the out-of-position child who is standing or otherwise positioned adjacent to the airbag, perhaps due to pre-crash braking. The occupant position sensor described herein can prevent the deployment of the airbag in this situation as well as in the situation of a rear facing child seat as described above.

The use of trainable pattern recognition technologies such as neural networks is an important part of the instant invention, although other non-trained pattern recognition systems such as fuzzy logic, correlation, Kalman filters, and sensor fusion (a derivative of fuzzy logic) can also be used. These technologies are implemented using computer programs to analyze the patterns of examples to determine the differences between different categories of objects. These computer programs are derived using a set of representative data collected during the training phase, called the training set. After training, the computer programs output a computer algorithm containing the rules permitting classification of the objects of interest based on the data obtained after installation in the vehicle. These rules, in the form of an algorithm, are implemented in the system that is mounted onto the vehicle. The determination of these rules is central to the pattern recognition techniques used in this invention. Artificial neural networks using back propagation are thus far the most successful of the rule determination approaches, however, research is underway to develop systems with many of the advantages of back propagation neural networks, such as learning by training, without the disadvantages, such as the inability to understand the network and the possibility of not converging to the best solution. In particular, back propagation neural

networks will frequently give an unreasonable response when presented with data than is not within the training data. It is well known that neural networks are good at interpolation but poor at extrapolation. A combined neural network fuzzy logic system, on the other hand, can substantially solve this problem. Additionally, there are many other neural network systems in addition to back propagation. In fact, one  
5 type of neural network may be optimum for identifying the contents of the passenger compartment and another for determining the location of the object dynamically.

In some implementations of this invention, such as the determination that there is an object in the path of a closing window as described below, the rules are sufficiently obvious that a trained researcher can look at the returned optical signals and devise an algorithm to make the required determinations. In  
10 others, such as the determination of the presence of a rear facing child seat or an occupant, artificial neural networks are frequently used to determine the rules. One such set of neural network software for determining the pattern recognition rules, is available from the NeuralWare Corporation of Pittsburgh, Pennsylvania. Numerous books and articles, including more than 500 U.S. patents, describe neural networks in great detail and thus the theory and application of this technology is well known and will not  
15 be repeated here. Except in a few isolated situations where neural networks have been used to solve particular problems limited to engine control, for example, they have not heretofore been applied to automobiles and trucks.

The system generally used in the instant invention, therefore, for the determination of the presence of a rear facing child seat, an occupant, or an empty seat is the artificial neural network or a  
20 neural-fuzzy system. In this case, the network operates on the returned signals from the CCD array as sensed by transducers 110, 111, 113 and 114 (not shown) in FIG. 5, for example. For the case of the front passenger seat, for example, through a training session, the system is taught to differentiate between the three cases. This is done by conducting a large number of experiments where available child seats are placed in numerous positions and orientations on the front passenger seat of the vehicle. Similarly, a  
25 sufficiently large number of experiments are run with human occupants and with boxes, bags of groceries and other objects. As many as 1,000,000 such experiments are run before the neural network is sufficiently trained so that it can differentiate among the three cases and output the correct decision with a very high probability.

Once the network is determined, it is possible to examine the result to determine, from the  
30 algorithm created by the NeuralWare software, the rules that were finally arrived at by the trial and error training technique. In that case, the rules can then be programmed into a microprocessor. Alternately, a neural computer can be used to implement the net directly. In either case, the implementation can be carried out by those skilled in the art of pattern recognition using neural networks. If a microprocessor is used, a memory device is also required to store the data from the analog to digital converters which

digitize the data from the receiving transducers. On the other hand, if a neural network computer is used, the analog signal can be fed directly from the transducers to the neural network input nodes and an intermediate memory is not required. Memory of some type is needed to store the computer programs in the case of the microprocessor system and if the neural computer is used for more than one task, a  
5 memory is needed to store the network specific values associated with each task.

There are several methods measuring the height of the driver for use in automatically adjusting the seat or for adjusting the seatbelt anchorage point. Some alternatives are shown in FIG. 5, which is a side plan view of the front portion of the passenger compartment showing three height measuring transducers or sensors 110,111,113, all of which are mounted on or near the headliner. These transducers  
10 may already be present because of other implementations of the vehicle interior identification and monitoring system described herein. The combination of four transducers can determine, by the methods described above, the location of the head with great accuracy.

Optical transducers using CCD arrays are now becoming price competitive and, as mentioned above, will soon be the technology of choice for interior vehicle monitoring. A single CCD array of 160  
15 by 160 pixels, for example, coupled with the appropriate trained pattern recognition software, can be used to form an image of the head of an occupant and accurately locate the head for some of the purposes of this invention.

The position of the rear of the head can also be known once the locus of the head has been determined. This information can be used to determine the distance from the headrest to the rearmost  
20 position of the occupant's head and to control the position of the headrest so that it is properly positioned behind the occupant's head to offer optimum support in the event of a rear impact. Although the headrest of most vehicles is adjustable, it is rare for an occupant to position it properly, if at all. Each year, there are in excess of 400,000 whiplash injuries in vehicle impacts approximately 90,000 of which are from rear impacts (source: National Highway Traffic Safety Administration, (NHTSA)). A properly positioned  
25 headrest could substantially reduce the frequency of such injuries that can be accomplished by the head detector of this invention. The head detector is connected to the headrest control mechanism and circuitry 540. This mechanism is capable of moving the headrest up and down and, in some cases, rotating it fore and aft. Thus, the control circuitry 120 may be coupled to headrest control mechanism and circuitry 540 to adjust the headrest based on the determined location of the rear of the occupant's head.

An occupant position sensor for side impacts used with a door mounted airbag system is  
30 illustrated at 530 in FIG. 5. This sensor has the particular task of monitoring the space adjacent to the door-mounted airbag. Sensor 530 may also be coupled to control circuitry 120 which can process and use the information provided by sensor 530 in the determination of the location or identity of the occupant or location of a part of the occupant.

Seatbelts are most effective when the upper attachment point to the vehicle is positioned vertically close to the shoulder of the occupant being restrained. If the attachment point is too low, the occupant experiences discomfort from the rubbing of the belt on his or her shoulder. If it is too high, the occupant may experience discomfort due to the rubbing of the belt against his or her neck and the occupant will move forward by a greater amount during a crash which may result in his or her head striking the steering wheel. For these reasons, it is desirable to have the upper seatbelt attachment point located slightly above the occupant's shoulder. To accomplish this for various sized occupants, the location of the occupant's shoulder must be known, which can be accomplished by the vehicle interior monitoring system described herein.

Such a system is illustrated in FIG. 6, which is a side planer view of a seatbelt anchorage adjustment system. In this system, infrared transmitter and CCD array receivers 620 and 621 are positioned in a convenient location proximate the occupant's shoulder, such as in connection with the headliner, above and usually to the outside of the occupant's shoulder. An appropriate pattern recognition system, as may be resident in control circuitry 120 to which the receivers 620,621 are coupled, as described above is then used to determine the location and position of the shoulder. This information is provided by control circuitry 120 to the seatbelt anchorage height adjustment system 632 (through a conventional coupling arrangement), shown schematically, which moves the attachment point 631 of the seatbelt 630 to the optimum vertical location for the proper placement of the seatbelt 630.

FIG. 7 is an angular perspective overhead view of a vehicle 710 about to be impacted in the side by an approaching vehicle 720, where vehicle 710 is equipped with an anticipatory sensor system showing a transmitter 730 transmitting electromagnetic, such as infrared, waves toward vehicle 720. This is one example of many of the uses of the instant invention for exterior monitoring. The transmitter 730 is connected to an electronic module 740. Module 740 contains circuitry 742 to drive transmitter 730 and circuitry 744 to process the returned signals from receivers 734 and 736 which are also coupled to module 740. Circuitry 744 contains a processor such as a neural computer 745, which performs the pattern recognition determination based on signals from receivers 734 and 736 (FIG. 7A). Receivers 734 and 736 are mounted onto the B-Pillar of the vehicle and are covered with a protective transparent cover. An alternate mounting location is shown as 738 which is in the door window trim panel where the rear view mirror (not shown) is frequently attached. One additional advantage of this system is the ability of infrared to penetrate fog and snow better than visible light which makes this technology particularly applicable for blind spot detection and anticipatory sensing applications. Although it is well known that infrared can be significantly attenuated by both fog and snow, it is less so than visual light depending on the frequency chosen. (See for example L. A. Klein, Millimeter-Wave and Infrared Multisensor Design

and Signal Processing, Artech House, Inc, Boston 1997, ISBN 0-89006-764-3 which is incorporated herein by reference).

The same system can also be used for the detection of objects in the blind spot of the vehicle and the image or an icon representative thereof displayed for the operator to see (display 748 discussed below with reference to FIG. 15), or a warning system activated, if the operator attempts to change lanes, for example. In this case, the mounting location must be chosen to provide a good view of the blind spot along the side of the vehicle in order to pick up vehicles which are about to pass vehicle 710. Each of the locations 734, 736 and 730 provide sufficient field of view for this application although the space immediately adjacent to the vehicle could be missed. Alternate locations include mounting onto the outside rear view mirror or the addition of a unit in the rear window or C-Pillar, in which case, the contents of areas other than the side of the vehicle would be monitored. Using several receivers in various locations as disclosed above would provide for a monitoring system which monitors all of the areas around the vehicle. The mirror location, however, does leave the device vulnerable to being covered with ice, snow and dirt.

In many cases, neural networks are used to identify objects exterior of the vehicle and then an icon is displayed on a heads-up display, for example, which provides core control over the brightness of the image and permits the driver to more easily recognize the object.

In both cases of the anticipatory sensor and blind spot detector, the infrared transmitter and CCD array system provides mainly image information to permit recognition of the object in the vicinity of vehicle 710, whether the object is alongside the vehicle, in a blind spot of the driver, in front of the vehicle or behind the vehicle, the position of the object being detected being dependent on the position and orientation of the receiver(s). To complete the process, distance information is also required as well as velocity information, which can in general be obtained by differentiating the position data. This can be accomplished by any one of the several methods discussed above, such as with a pulsed laser radar system, as well as with a radar system.

Radar systems, which may not be acceptable for use in the interior of the vehicle, are now commonly used in sensing applications exterior to the vehicle, police radar being one well-known example. Miniature radar systems are now available which are inexpensive and fit within the available space. Such systems are disclosed in the McEwan patents described above. Another advantage of radar in this application is that it is easy to get a transmitter with a desirable divergence angle so that the device does not have to be aimed. One particularly advantageous mode of practicing the invention for these cases, therefore, is to use radar and a second advantageous mode is the pulsed laser radar system, along with a CCD array, although the use of two CCD arrays or the acoustical systems are also good choices. The acoustical system has the disadvantage of being slower than the laser radar device and must be

mounted outside of the vehicle where it may be affected by the accumulation of deposits onto the active surface.

In a preferred implementation, transmitter 730 is an infrared transmitter and receivers 734, 736 and 738 are CCD transducers that receive the reflected infrared waves from vehicle 720. In the implementation shown in FIG. 7, an exterior airbag 790 is shown which deploys in the event that a side impact is about to occur as described in U.S. patent application Ser. No. 08/247,760.

Referring now to FIG. 15, a schematic of the use of one or more receivers 734, 736, 738 to affect another system in the vehicle is shown. The general exterior monitoring system, or blind spot monitoring system if the environment exterior of the vehicle is not viewable by the driver in the normal course of driving the vehicle, includes one or more receivers 734,736,738 positioned at various locations on the vehicle for the purpose of receiving waves from the exterior environment. Instead of waves, and to the extent different than waves, the receivers 734, 736, 738 could be designed to receiver energy or radiation.

The waves received by receivers 734, 736, 738 contain information about the exterior objects in the environment, such waves either having been generated by or emanating from the exterior objects or reflected from the exterior objects such as is the case when the optional transmitter 730 is used. The electronic module/processor 740 contains the necessary circuitry 742,744 and trained pattern recognition means (neural computer 745) to drive the transmitter 730 when present and process the received waves to provide a classification, identification and/or location of the exterior object. The classification, identification and/or location is then used to show an image or icon on a display 748 viewable to the driver. Also, the classification, identification and/or location of the objects could be used for airbag control, i.e., control of the deployment of the exterior airbag 790 (or any other airbags for that matter), for the control of the headlight dimmers (as discussed below with reference to FIG. 8), or in general, for any other system whose operation might be changed based on the presence of exterior objects.

FIG. 8 illustrates the exterior monitoring system for use in detecting the headlights of an oncoming vehicle or the taillights of a vehicle in front of vehicle 810. In this embodiment, the CCD array is designed to be sensitive to visible light and a separate source of illumination is not used. Once again for some applications, the key to this technology is the use of trained pattern recognition algorithms and particularly the artificial neural network. Here, as in the other cases above and in the patents and patent applications referenced above, the pattern recognition system is trained to recognize the pattern of the headlights of an oncoming vehicle or the tail lights of a vehicle in front of vehicle 810 and to then dim the headlights when either of these conditions is sensed. It is also trained to not dim the lights for other reflections such as reflections off of a sign post or the roadway. One problem is to differentiate taillights where dimming is desired from distant headlights where dimming is not desired. Three techniques are used: (i) measurement of the spacing of the light sources, (ii) determination of the location of the light

sources relative to the vehicle, and (iii) use of a red filter where the brightness of the light source through the filter is compared with the brightness of the unfiltered light. In the case of the taillight, the brightness of the red filtered and unfiltered light is nearly the same while there is a significant difference for the headlight case. In this situation, either two CCD arrays are used, one with a filter, or a filter which can be removed either electrically, such as with a liquid crystal, or mechanically.

The headlights of oncoming vehicles frequently make it difficult for the driver of a vehicle to see the road and safely operate the vehicle. This is a significant cause of accidents and much discomfort. The problem is especially severe during bad weather where rain can cause multiple reflections. Visors are now used to partially solve this problem but they do so by completely blocking the view through a large portion of the window and therefore cannot be used to cover the entire windshield. Similar problems happen when the sun is setting or rising and the driver is operating the vehicle in the direction of the sun. The vehicle interior monitoring system of this invention can contribute to the solution of this problem by determining the position of the driver's eyes as discussed above. If separate sensors are used to sense the direction of the light from the on-coming vehicle or the sun and through the use of electrochromic glass or a liquid crystal assembly, a portion of the windshield can be darkened to impose a filter between the eyes of the driver and the light source. Electrochromic glass is a material where the color of the glass can be changed through the application of an electric current. By dividing the windshield into a controlled grid or matrix of contiguous areas and through feeding the current into the windshield from orthogonal directions, selective portions of the windshield can be darkened as desired using either the electrochromic, liquid crystal or a similar technology. There are other technologies currently under development that perform in a similar manner as liquid crystals. The term "liquid crystal" as used herein, therefore, will be used to represent the class of all such materials where the optical transmissibility can be varied electrically or electronically. Electrochromic products are available from Gentex of Zeeland, MI, and Donnelly of Holland, MI.

FIG. 9 illustrates how such a system operates. A sensor 910 located on vehicle 902 determines the direction of the light from the headlights of oncoming vehicle 904. Sensor 910 is comprised of a lens and a CCD array with appropriate electronic circuitry which determines which elements of the CCD array are being most brightly illuminated. An algorithm stored in control circuitry 120 then calculates the direction of the light from the oncoming headlights based on the information from the CCD array. Transducers 110, 111, 113 and 114 determine the probable location of the eyes of the operator 101 of vehicle 902 in a manner such as described above. In this case, however, the determination of the probable locus of the driver's eyes is made with an accuracy of a diameter for each eye of about 3 inches (7.5 cm). This calculation sometimes will be in error and provision is made for the driver to make an adjustment to correct for this error as described below.



The windshield 916 of vehicle 902 comprises a liquid crystal, or similar technology, and is selectively darkened at area 918 due to the application of a current along perpendicular directions 922 and 924 of windshield 916 (See FIG. 9A). The particular portion of the windshield to be darkened is determined by control circuitry 120. Once the direction of the light from the oncoming vehicle is known and the locations of the driver's eyes are known, it is a matter of simple trigonometry to determine which areas of the windshield matrix should be darkened to impose a filter between the headlights and the driver's eyes. This is accomplished by control circuitry 120. A separate control system, not shown, located on the instrument panel, or at some other convenient location, allows the driver to select the amount of darkening accomplished by the system from no darkening to maximum darkening. In this manner, the driver can select the amount of light which is filtered to suit his particular physiology. The sensor 910 can either be designed to respond to a single light source or to multiple light sources to be sensed and thus multiple portions of the vehicle windshield to be darkened.

As mentioned above, the calculations of the location of the driver's eyes may be in error and therefore provision can be made to correct for this error. One such system permits the driver to adjust the center of the darkened portion of the windshield to correct for such errors through a knob on the instrument panel, steering wheel or other convenient location. Another solution permits the driver to make the adjustment by slightly moving his head. Once a calculation as to the location of the driver's eyes has been made, that calculation is not changed even though the driver moves his head slightly. It is assumed that the driver will only move his head to center the darkened portion of the windshield to optimally filter the light from the oncoming vehicle. The monitoring system will detect this initial head motion and make the correction automatically for future calculations.

In the applications discussed and illustrated above, the source and receiver of the electromagnetic radiation have been mounted in the same package. This is not necessary and in some implementations, the illumination source will be mounted elsewhere. For example, a laser beam can be used which is directed along an axis which bisects the angle between the center of the seat volume and two of the arrays. Such a beam may come from the A-Pillar, for example. The beam, which may be supplemental to the main illumination system, provides a point reflection from the occupying item that, in most cases, can be seen by two receivers. Triangulation thereafter can precisely determination the location of the illuminated point. This point can be moved to provide more information. In another case where it is desired to track the head of the occupant, for example, several such beams can be directed at the occupant's head during pre-crash braking or even during a crash to provide the fastest information as to the location of the head of the occupant for the fastest tracking of the motion of the occupant's head. Since only a few pixels are involved, even the calculation time is minimized.

In most of the applications above the assumption has been made that either a uniform field of light or a scanning spot of light will be provided. This need not be the case. The light that is emitted or transmitted to illuminate the object can be structured light. Structured light can take many forms starting with, for example, a rectangular or other macroscopic pattern of light and dark can be superimposed on the light by passing it through a filter. If a similar pattern is interposed between the reflections and the camera, a sort of pseudo-interference pattern can result sometimes known as Moire patterns. A similar effect can be achieved by polarizing transmitted light so that different parts of the object that is being illuminated are illuminated with light of different polarization. Once again by viewing the reflections through a similarly polarized array, information can be obtained as to where the source of light came from which is illuminating a particular object. Thus, any of the transmitter/receiver assemblies or transducers in any of the embodiments above using optics can be designed to use structured light.

One consideration when using structured light is that the source of structured light cannot be exactly co-located with the array because in this case, the pattern projected will not change as a function of the distance between the array and the object and thus the distance between the array and the object cannot be determined. Thus, it is usually necessary to provide a displacement between the array and the light source. For example, the light source can surround the array, be on top of the array or on one side of the array. The light source can also have a different virtual source, i.e., it can appear to come from behind of the array or in front of the array.

The goal is to determine the direction that a particular ray of light had when it was transmitted from the source. Then by knowing which pixels were illuminated by the reflected light ray along with the geometry of the vehicle, the distance to the point of reflection off of the object can be determined. This is particularly effective if the light source is not collocated with the CCD array. If a particular light ray, for example, illuminates an object surface which is near to the source then the reflection off of that surface will illuminate a pixel at a particular point on the CCD array. If the reflection of the same ray however occurs from a more distant surface, then a different pixel will be illuminated in the CCD array. In this manner the distance from the surface of the object to the CCD can be determined by triangulation formulas. Similarly if a given pixel is illuminated in the CCD from a reflection of a particular ray of light from the transmitter, and if we know the direction that that ray of light was sent from the transmitter, then the distance to the object at the point of reflection can be determined. If each ray of light is individually recognizable and therefore can be correlated to the angle at which it was transmitted, then a full three-dimensional image can be obtained of the object that simplifies the identification problem.

The coding of the light rays coming from the transmitter can be accomplished in many ways. One method is to polarize the light by passing the light through a filter whereby the polarization is a combination of the amount and angle of the polarization. This gives two dimensions that can therefore be

used to fix the angle that the light was sent. Another method is to superimpose an analog or digital signal onto the light which could be done, for example, by using an addressable light valve, such as a liquid crystal filter, electrochromic filter, or, preferably, a garnet crystal array. Each pixel in this array would be coded such that it could be identified at the CCD.

5           The technique described above is dependent upon either changing the polarization or using the time domain to identify particular transmission angles with particular reflections. Spatial patterns can also be imposed on the transmitted light which generally goes under the heading of structured light. The concept is that if a pattern is identifiable then either the direction of transmitted light can be determined or, if the transmission source is collocated with the receiver, then the pattern expands as it travels toward  
10 the object and then, by determining the size of the received pattern, the distance to the object can be determined. In some cases Moier pattern techniques are utilized.

          When the illumination source is not placed at the same location as the receiving array, it is typically placed at an angle such as 45 degrees. At least two other techniques can be considered. One is to place the illumination source at 90 degrees to the CCD array. In this case only those surface elements  
15 that are closer to the receiving array than previous surfaces are illuminated. Thus significant information can be obtained as to the profile of the object. In fact, if no object is occupying the seat, then there will be no reflections except from the seat itself. This provides a very powerful technique for determining whether the seat is occupied and where the initial surfaces of the occupying item are located.

          The particular radiation field of the transmitting transducer can also be important to some  
20 implementations of this invention. In some techniques the object which is occupying the seat is the only part of the vehicle which is illuminated. Extreme care is exercised in shaping the field of light such that this is true. For example, the objects are illuminated in such a way that reflections from the door panel do not occur. Ideally if only the items which occupy the seat can be illuminated then the problem of separating the occupant from the interior vehicle passenger compartment surfaces can be more easily  
25 accomplished.

          Another variant on the invention is to use no illumination source at all. In this case, the entire visible and infrared spectrum will be used. CMOS arrays are now available with very good night vision capabilities making it possible to see and image an occupant in very low light conditions.

          A further consideration to this invention is to use the motion of the occupant, as determined from  
30 successive differential arrays, for example, to help identify that there is in fact a living object occupying the seat, or for other purposes.

          Fig. 10 shows a schematic illustration of a system for controlling operation of a vehicle based on recognition of an authorized individual in accordance with the invention. One or more images of the passenger compartment 500 are received at 502 and data derived therefrom at 504. Multiple image

receivers may be provided at different locations. The data derivation may entail any one or more of numerous types of image processing techniques such as those described in U.S. patent application ser. No. 09/474,147 incorporated by reference herein, including those designed to improve the clarity of the image. A pattern recognition algorithm, e.g., a neural network, is trained in a training phase 506 to recognize authorized individuals. The training phase can be conducted upon purchase of the vehicle by the dealer or by the owner after performing certain procedures provided to the owner, e.g., entry of a security code or key. In the training phase for a theft prevention system, the authorized driver(s) would sit themselves in the passenger seat and optical images would be taken and processed to obtain the pattern recognition algorithm. A processor 508 is embodied with the pattern recognition algorithm thus trained to identify whether a person is the individual by analysis of subsequently obtained data derived from optical images 504. The pattern recognition algorithm in processor 508 outputs an indication of whether the person in the image is an authorized individual for which the system is trained to identify. A security system 510 enable operations of the vehicle when the pattern recognition algorithm provides an indication that the person is an individual authorized to operate the vehicle and prevents operation of the vehicle when the pattern recognition algorithm does not provide an indication that the person is an individual authorized to operate the vehicle.

Optionally, an optical transmitting unit 512 is provided to transmit electromagnetic energy into the passenger compartment such that electromagnetic energy transmitted by the optical transmitting unit is reflected by the person and received by the optical image reception device 502.

As noted above, several different types of optical reception devices can be used including a CCD array, a CMOS array, any type of two-dimensional image receiver, any type of three-dimensional image receiver, an active pixel camera and an HDRC camera.

The processor 508 can also be trained to determine the position of the individuals included in the images obtained by the optical image reception device, as well as the distance between the optical image reception devices and the individuals.

Instead of a security system, another component in the vehicle can be affected or controlled based on the recognition of a particular individual. For example, the rear view mirror, seat, seat belt anchorage point, headrest, pedals, steering wheel, entertainment system, air-conditioning/ventilation system can be adjusted.

FIG. 11 is a schematic illustration of a method for controlling operation of a vehicle based on recognition of a person as one of a set of authorized individuals. Although the method is described and shown for permitting or preventing ignition of the vehicle based on recognition of an authorized driver, it can be used to control for any vehicle component, system or subsystem based on recognition of an individual.

Initially, the system is set in a training phase 514 in which images including the authorized individuals are obtained by means of at least one optical receiving unit 516 and a pattern recognition algorithm is trained based thereon 518, usually after application of one or more image processing techniques to the images. The authorized individual(s) occupy the passenger compartment and have their picture taken by the optical receiving unit to enable the formation of a database on which the pattern recognition algorithm is trained. Training can be performed by any known method in the art.

The system is then set in an operational phase 520 wherein an image is obtained 522, including the driver when the system is used for a security system. If the system is used for component adjustment, then the image would include any passengers or other occupying items in the vehicle. The obtained image, or images if multiple optical receiving units are used, are input into the pattern recognition algorithm 524, preferably after some image processing, and a determination is made whether the pattern recognition algorithm indicates that the image includes an authorized driver 526. If so, ignition of the vehicle is enabled 528, or the vehicle may actually be started automatically. If not, an alarm is sounded and/or the police may be contacted 530.

The image processing techniques may be, when each image is constituted by an array of pixels, elimination of pixels from the images which are present in multiple images and/or comparing the images with stored arrays of pixels and eliminating pixels from the images which are present in the stored arrays of pixels.

FIG. 12 shows the components of the manner in which an environment of the vehicle, designated 600, is monitored. The environment may either be an interior environment, the entire passenger compartment or only a part thereof, or an exterior environment. An active pixel camera 602 obtains images of the environment and provides the images or a representation thereof, or data derived from, to a processor 604. The processor 604 determines at least one characteristic of an object in the environment based on the images obtained by the active pixel camera 602, e.g., the presence of an object in the environment, the type of object in the environment, the position of an object in the environment and the velocity of an object in the environment. Several active pixel cameras can be provided, each focusing on a different area of the environment, although some overlap is desired. Instead of an active pixel camera or array, a single light-receiving pixel can be used.

An active pixel camera can be arranged in various locations in the vehicle including in a headliner, roof, ceiling, an A-pillar, a B-pillar and a C-pillar. Images of the front seat area or the rear seat area can be obtained by proper placement and orientation of the cameras.

Once a characteristic of the object is obtained, it can be used for numerous purposes. For example, the processor can be programmed to control a reactive component, system or subsystem 606 based on the determined characteristic of the object. When the reactive component is an airbag assembly

including one or more airbags, the processor can control one or more deployment parameters of the airbag(s).

As to the manner in which the apparatus operates, reference is made to FIG. 13, wherein as a first step 610, one or more images of the environment are obtained. One or more characteristics of objects in the images are determined at 612, using, for example, pattern recognition techniques, and then one or more components are controlled at 614 based on the determined characteristics. The process of obtaining and processing the images, or the processing of data derived from the images or data representative of the images, is periodically continued at least throughout the operation of the vehicle.

Fig. 14 shows the components for measuring the position of an object in an environment of or about the vehicle. A light source 616 directs modulated light into the environment and at least one light-receiving pixel or an array of pixels 618 receives the modulated light after reflection by any objects in the environment. A processor 620 determines the distance between any objects from which the modulated light is reflected and the light source based on the reception of the modulated light by the pixel(s) 618. To provide the modulated light, a device or component for modulating a frequency of the light 622 are provided. Also, a device for providing a correlation pattern in a form of code division modulation of the light can be used. The pixel may be a photo diode such as a PIN or avalanche diode.

The processor 620 includes appropriate circuitry to determine the distance between any objects from which any pulse of light is reflected and the light source 616. For example, the processor 620 can determine this distance based on a difference in time between the emission of a pulse of light by the light source 616 and the reception of light by the pixel 618.

Thus, one method described above for determining the identification and position of objects in a passenger compartment of a vehicle in accordance with the invention comprises the steps of transmitting electromagnetic waves (optical or non-optical) into the passenger compartment from one or more locations, obtaining a plurality of images of the interior of the passenger compartment from several locations, and comparing the images of the interior of the passenger compartment with stored images representing different arrangements of objects in the passenger compartment to determine which of the stored images match most closely to the images of the interior of the passenger compartment such that the identification of the objects and their position is obtained based on data associated with the stored images. The electromagnetic waves may be transmitted from transmitter/receiver assemblies positioned at different locations around a seat such that each assembly is situated in a middle of a side of the ceiling surrounding the seat or in the middle of the headliner directly above the seat. The method would thus be operative to determine the identification and/or position of the occupants of that seat. Each assembly may comprise an optical transmitter (such as an infrared LED, an infrared LED with a diverging lens, a laser with a diverging lens and a scanning laser assembly) and an optical array (such as a CCD array and a

CMOS array). The optical array is thus arranged to obtain the images of the interior of the passenger compartment represented by a matrix of pixels. To enhance the method, prior to the comparison of the images, each obtained image or output from each array may be compared with a series of stored images or arrays representing different unoccupied states of the passenger compartment, such as different positions of the seat when unoccupied, and each stored image or array is subtracted from the obtained image or acquired array. Another way to determine which stored image matches most closely to the images of the interior of the passenger compartment is to analyze the total number of pixels of the image reduced below a threshold level, and analyze the minimum number of remaining detached pixels. Preferably, a library of stored images is generated by positioning an object on the seat, transmitting electromagnetic waves into the passenger compartment from one or more locations, obtaining images of the interior of the passenger compartment, each from a respective location, associating the images with the identification and position of the object, and repeating the positioning step, transmitting step, image obtaining step and associating step for the same object in different positions and for different objects in different positions. If the objects include a steering wheel, a seat and a headrest, the angle of the steering wheel, the telescoping position of the steering wheel, the angle of the back of the seat, the position of the headrest and the position of the seat may be obtained by the image comparison. One advantage of this implementation is that after the identification and position of the objects are obtained, one or more systems in the vehicle, such as an occupant restraint device or system, a mirror adjustment system, a seat adjustment system, a steering wheel adjustment system, a pedal adjustment system, a headrest positioning system, a directional microphone, an air-conditioning/heating system, an entertainment system, may be affected based on the obtained identification and position of at least one of the objects. The image comparison may entail inputting the images or a form thereof into a neural network which provides for each image of the interior of the passenger compartment, an index of a stored image that most closely matches the image of the interior of the passenger compartment. The index is thus utilized to locate stored information from the matched image including, inter alia, a locus of a point representative of the position of the chest of the person, a locus of a point representative of the position of the head of the person, one or both ears of the person, one or both eyes of the person and the mouth of the person. Moreover, the position of the person relative to at least one airbag or other occupant restraint system of the vehicle may be determined so that deployment of the airbag(s) or occupant restraint system is controlled based on the determined position of the person. It is also possible to obtain information about the location of the eyes of the person from the image comparison and adjust the position of one or more of the rear view mirrors based on the location of the eyes of the person. Also, the location of the eyes of the person may be obtained such that an external light source may be filtered by darkening the windshield of the vehicle at selective locations based on the location of the eyes of the person. Further, the location of

the ears of the person may be obtained such that a noise cancellation system in the vehicle is operated based on the location the ears of the person. The location of the mouth of the person may be used to direct a directional microphone in the vehicle. In addition, the location of the locus of a point representative of the position of the chest or head (e.g., the probable center of the chest or head) over time  
5 may be monitored by the image comparison and one or more systems in the vehicle controlled based on changes in the location of the locus of the center of the chest or head over time. This monitoring may entail subtracting a most recently obtained image from an immediately preceding image and analyzing a leading edge of changes in the images or deriving a correlation function which correlates the images with the chest or head in an initial position with the most recently obtained images. In one particularly  
10 advantageous embodiment, the weight applied onto the seat is measured and one or more systems in the vehicle are affected (controlled) based on the measured weight applied onto the seat and the identification and position of the objects in the passenger compartment.

In another method disclosed above for determining the identification and position of objects in a passenger compartment of a vehicle in accordance with the invention, electromagnetic waves are  
15 transmitted into the passenger compartment from one or more locations, a plurality of images of the interior of the passenger compartment are obtained, each from a respective location, a three-dimensional map of the interior of the passenger compartment is created from the images, and a pattern recognition technique is applied to the map in order to determine the identification and position of the objects in the passenger compartment. The pattern recognition technique may be a neural network, fuzzy logic or an  
20 optical correlator or combinations thereof. The map may be obtained by utilizing a scanning laser radar system where the laser is operated in a pulse mode and determining the distance from the object being illuminated using range gating. (See, for example, H. Kage, W. Freeman, Y. Miyke, E. Funtsu, K. Tanaka, K. Kyuma "Artificial retina chips as on-chip image processors and gesture-oriented interfaces", Optical Engineering, December, 1999, Vol. 38, Number 12, ISSN 0091-3286)

25 In a method disclosed above for tracking motion of a vehicular occupant's head or chest in accordance with the invention, electromagnetic waves are transmitted toward the occupant from at least one location, a first image of the interior of the passenger compartment is obtained from each location, the first image being represented by a matrix of pixels, and electromagnetic waves are transmitted toward the occupant from the same location(s) at a subsequent time and an additional image of the interior of the  
30 passenger compartment is obtained from each location, the additional image being represented by a matrix of pixels. The additional image is subtracted from the first image to determine which pixels have changed in value. A leading edge of the changed pixels and a width of a field of the changed pixels is determined to thereby determine movement of the occupant from the time between which the first and additional images were taken. The first image is replaced by the additional image and the steps of



obtaining an additional image and subtracting the additional image from the first image are repeated such that progressive motion of the occupant is attained.

5 A method disclosed above for controlling deployment of an occupant restraint system in a vehicle comprises the steps of transmitting electromagnetic waves toward an occupant seated in a passenger compartment of the vehicle from one or more locations, obtaining a plurality of images of the interior of the passenger compartment, each from a respective location, analyzing the images to determine the distance between the occupant and the occupant restraint system, and controlling deployment of the occupant restraint system based on the determined distance between the occupant and the occupant restraint system. The images may be analyzed by comparing the images of the interior of the passenger compartment with stored images representing different arrangements of objects in the passenger compartment to determine which of the stored images match most closely to the images of the interior of the passenger compartment, each stored image having associated data relating to the distance between the occupant in the image and the occupant restraint system. The image comparison step may entail inputting the images or a form thereof into a neural network which provides for each image of the interior of the passenger compartment, an index of a stored image that most closely matches the image of the interior of the passenger compartment. In a particularly advantageous embodiment, the weight of the occupant on a seat is measured and deployment of the occupant restraint system is controlled based on the determined distance between the occupant and the occupant restraint system and the measured weight of the occupant.

20 In another method disclosed above for determining the identification and position of objects in a passenger compartment of a vehicle, a plurality of images of the interior of the passenger compartment, each from a respective location and of radiation emanating from the objects in the passenger compartment, and the images of the radiation emanating from the objects in the passenger compartment are compared with stored images of radiation emanating from different arrangements of objects in the passenger compartment to determine which of the stored images match most closely to the images of the interior of the passenger compartment such that the identification of the objects and their position is obtained based on data associated with the stored images. In this embodiment, there is no illumination of the passenger compartment with electromagnetic waves. Nevertheless, the same processes described above may be applied in conjunction with this method, e.g., affecting another system based on the position and identification of the objects, a library of stored images generated, external light source filtering, noise filtering, occupant restraint system deployment control and the utilization of weight for occupant restraint system control.

30 Thus, disclosed above is a system to identify, locate and monitor occupants, including their parts, and other objects in the passenger compartment and objects outside of a motor vehicle, such as an

automobile or truck, by illuminating the contents of the vehicle and/or objects outside of the vehicle with electromagnetic radiation, and specifically infrared radiation, or using radiation naturally emanating from the object, and using one or more lenses to focus images of the contents onto one or more arrays of charge coupled devices (CCD's) or CMOS arrays. Outputs from the CCD or CMOS arrays are analyzed by  
5 appropriate computational means employing trained pattern recognition technologies, to classify, identify or locate the contents and/or external objects. In general, the information obtained by the identification and monitoring system may be used to affect the operation of at least one other system in the vehicle.

When the vehicle interior monitoring system in accordance with some embodiments of this invention is installed in the passenger compartment of an automotive vehicle equipped with a passenger  
10 protective device, such as an inflatable airbag, and the vehicle is subjected to a crash of sufficient severity that the crash sensor has determined that the protective device is to be deployed, the system determines the position of the vehicle occupant relative to the airbag and disables deployment of the airbag if the occupant is positioned so that he/she is likely to be injured by the deployment of the airbag. In the alternative, the parameters of the deployment of the airbag can be tailored to the position of the occupant  
15 relative to the airbag, e.g., a depowered deployment.

In some implementations of the invention, several CCD or CMOS arrays are placed in such a manner that the distance from, and the motion of the occupant toward, the airbag can be monitored as a transverse motion across the field of the array. In this manner, the need to measure the distance from the array to the object is obviated. In other implementations, the source of infrared light is a pulse modulated  
20 laser which permits an accurate measurement of the distance to the point of reflection through the technique of range gating to measure the time of flight of the radiation pulse.

In some applications, a trained pattern recognition system, such as a neural network, sensor fusion or neural-fuzzy system, is used to identify the occupancy of the vehicle or an object exterior to the vehicle. In some of these cases, the pattern recognition system determines which of a library of images  
25 most closely matches the seated state of a particular vehicle seat and thereby the location of certain parts of an occupant can be accurately estimated from the matched images, thus removing the requirement for the pattern recognition system to locate the head of an occupant, for example.

Also disclosed above is an arrangement for determining vehicle occupant position relative to a fixed structure within the vehicle which comprises an array structured and arranged to receive an image of  
30 a portion of the passenger compartment of the vehicle in which the occupant is likely to be situated, a lens arranged between the array and the portion of the passenger compartment, adjustment means for changing the image received by the array, and processor means coupled to the array and the adjustment means. The processor means determine, upon changing by the adjustment means of the image received by the array, when the image is clearest whereby a distance between the occupant and the fixed structure is obtainable

based on the determination by the processor means when the image is clearest. The image may be changed by adjusting the lens, e.g., adjusting the focal length of the lens and/or the position of the lens relative to the array, by adjusting the array, e.g., the position of the array relative to the lens, and/or by using software to perform a focusing process. The array may be arranged in several advantageous  
5 locations on the vehicle, e.g., on an A-pillar of the vehicle, above a top surface of an instrument panel of the vehicle and on an instrument panel of the vehicle and oriented to receive an image reflected by a windshield of the vehicle. The array may be a CCD array with an optional liquid crystal or electrochromic glass filter coupled to the array for filtering the image of the portion of the passenger compartment. The array could also be a CMOS array. In a preferred embodiment, the processor means  
10 are coupled to an occupant protection device and control the occupant protection device based on the distance between the occupant and the fixed structure. For example, the occupant protection device could be an airbag whereby deployment of the airbag is controlled by the processor means. The processor means may be any type of data processing unit such as a microprocessor. This arrangement could be adapted for determining distance between the vehicle and exterior objects, in particular, objects in a blind  
15 spot of the driver. In this case, such an arrangement would comprise an array structured and arranged to receive an image of an exterior environment surrounding the vehicle containing at least one object, a lens arranged between the array and the exterior environment, adjustment means for changing the image received by the array, and processor means coupled to the array and the adjustment means. The processor means determine, upon changing by the adjustment means of the image received by the array, when the  
20 image is clearest whereby a distance between the object and the vehicle is obtainable based on the determination by the processor means when the image is clearest. As before, the image may be changed by adjusting the lens, e.g., adjusting the focal length of the lens and/or the position of the lens relative to the array, by adjusting the array, e.g., the position of the array relative to the lens, and/or by using software to perform a focusing process. The array may be a CCD array with an optional liquid crystal or  
25 electrochromic glass filter coupled to the array for filtering the image of the portion of the passenger compartment. The array could also be a CMOS array. In a preferred embodiment, the processor means are coupled to an occupant protection device and control the occupant protection device based on the distance between the occupant and the fixed structure. For example, the occupant protection device could be an airbag whereby deployment of the airbag is controlled by the processor means. The processor  
30 means may be any type of data processing unit such as a microprocessor.

Also, at least one of the above-listed objects is achieved by an arrangement for determining vehicle occupant presence, type and/or position relative to a fixed structure within the vehicle, the vehicle having a front seat and an A-pillar. The arrangement comprises a first array mounted on the A-pillar of the vehicle and arranged to receive an image of a portion of the passenger compartment in which the

occupant is likely to be situated, and processor means coupled to the first array for determining the presence, type and/or position of the vehicle occupant based on the image of the portion of the passenger compartment received by the first array. The processor means preferably are arranged to utilize a pattern recognition technique, e.g., a trained neural network, sensor fusion, fuzzy logic. The processor means can  
5 determine the vehicle occupant presence, type and/or position based on the image of the portion of the passenger compartment received by the first array. In some embodiments, a second array is arranged to receive an image of at least a part of the same portion of the passenger compartment as the first array. The processor means are coupled to the second array and determine the vehicle occupant presence, type and/or position based on the images of the portion of the passenger compartment received by the first and  
10 second arrays. The second array may be arranged at a central portion of a headliner of the vehicle between sides of the vehicle. The determination of the occupant presence, type and/or position can be used in conjunction with a reactive component, system or subsystem so that the processor means control the reactive component, system or subsystem based on the determination of the occupant presence, type and/or position. For example, if the reactive component, system or subsystem is an airbag assembly  
15 including at least one airbag, the processor means control one or more deployment parameters of the airbag(s). The arrays may be CCD arrays with an optional liquid crystal or electrochromic glass filter coupled to the array for filtering the image of the portion of the passenger compartment. The arrays could also be CMOS arrays, active pixel cameras and HDRC cameras.

Another embodiment disclosed above is an arrangement for obtaining information about a vehicle  
20 occupant within the vehicle which comprises transmission means for transmitting a structured pattern of light, e.g., polarized light, into a portion of the passenger compartment in which the occupant is likely to be situated, an array arranged to receive an image of the portion of the passenger compartment, and processor means coupled to the array for analyzing the image of the portion of the passenger compartment to obtain information about the occupant. The transmission means and array are proximate one another  
25 and the information obtained about the occupant is a distance from the location of the transmission means and the array. The processor means obtain the information about the occupant utilizing a pattern recognition technique. The information about of the occupant can be used in conjunction with a reactive component, system or subsystem so that the processor means control the reactive component, system or subsystem based on the determination of the occupant presence, type and/or position. For example, if the  
30 reactive component, system or subsystem is an airbag assembly including at least one airbag, the processor means control one or more deployment parameters of the airbag(s).

Another invention disclosed above is a system for controlling operation of a vehicle based on recognition of an authorized individual comprises a processor embodying a pattern recognition algorithm, as defined above, trained to identify whether a person is the individual by analyzing data derived from

images and one or more optical receiving units for receiving an optical image including the person and deriving data from the image. Each optical receiving unit is coupled to the processor to provide the data to the pattern recognition algorithm to thereby obtain an indication from the pattern recognition algorithm whether the person is the individual. A security system is arranged to enable operation of the vehicle  
5 when the pattern recognition algorithm provides an indication that the person is an individual authorized to operate the vehicle and prevent operation of the vehicle when the pattern recognition algorithm does not provide an indication that the person is an individual authorized to operate the vehicle. An optional optical transmitting unit is provided in the vehicle for transmitting electromagnetic energy and is arranged relative to the optical receiving unit(s) such that electromagnetic energy transmitted by the optical  
10 transmitting unit is reflected by the person and received by at least one of the optical receiving units. The optical receiving units may be selected from a group consisting of a CCD array, a CMOS array, an active pixel camera and an HDRC camera. Other types of two or three-dimensional cameras can also be used.

Instead of a security system, the individual recognition system can be used to control vehicular components, such as the mirrors, the seat, the anchorage point of the seatbelt, the airbag deployment  
15 parameters including inflation rate and pressure, inflation direction, deflation rate, time of inflation, the headrest, the steering wheel, the pedals, the entertainment system and the air-conditioning/ventilation system. In this case, the system includes control means coupled to the component for affecting the component based on the indication from the pattern recognition algorithm whether the person is the individual.

20 A method for controlling operation of a vehicle based on recognition of a person as one of a set of authorized individuals comprises the steps of obtaining images including the authorized individuals by means of one or more optical receiving unit, deriving data from the images, training a pattern recognition algorithm on the data derived from the images which is capable of identifying a person as one of the individuals, then subsequently obtaining images by means of the optical receiving unit(s), inputting data  
25 derived from the images subsequently obtained by the optical receiving unit(s) into the pattern recognition algorithm to obtain an indication whether the person is one of the set of authorized individuals, and providing a security system which enables operation of the vehicle when the pattern recognition algorithm provides an indication that the person is one of the set of individuals authorized to operate the vehicle and prevents operation of the vehicle when the pattern recognition algorithm does not provide an indication  
30 that the person is one of the set of individuals authorized to operate the vehicle. The data derivation from the images may entail any number of image processing techniques including eliminating pixels from the images which are present in multiple images and comparing the images with stored arrays of pixels and eliminating pixels from the images which are present in the stored arrays of pixels. The method can also be used to control a vehicular component based on recognition of a person as one of a predetermined set

of particular individuals. This method includes the step of affecting the component based on the indication from the pattern recognition algorithm whether the person is one of the set of individuals. The components may be one or more of the following: the mirrors, the seat, the anchorage point of the seatbelt, the airbag deployment parameters including inflation rate and pressure, inflation direction, deflation rate, time of inflation, the headrest, the steering wheel, the pedals, the entertainment system and the air-conditioning/ventilation system.

There has thus been shown and described, among other things, a monitoring system for monitoring both the interior and the exterior of the vehicle using an optical system, for example, with one or more CCD arrays or CMOS arrays, and other associated equipment which fulfills all the objects and advantages sought after.

Lastly, it is possible to use a modulated scanning beam of radiation and a single pixel receiver, PIN or avalanche diode, in the inventions described above. Any form of energy or radiation used above may be in the infrared or radar spectrums, to the extent possible, and may be polarized and filters may be used in the receiver to block out sunlight etc. These filters may be notch filters as described above and may be made integral with the lens as one or more coatings on the lens surface as is well known in the art.

Also disclosed above is a vehicle including a monitoring arrangement for monitoring an environment of the vehicle which comprises at least one active pixel camera for obtaining images of the environment of the vehicle and a processor coupled to the active pixel camera(s) for determining at least one characteristic of an object in the environment based on the images obtained by the active pixel camera(s). The active pixel camera can be arranged in a headliner, roof or ceiling of the vehicle to obtain images of an interior environment of the vehicle, in an A-pillar or B-pillar of the vehicle to obtain images of an interior environment of the vehicle, or in a roof, ceiling, B-pillar or C-pillar of the vehicle to obtain images of an interior environment of the vehicle behind a front seat of the vehicle. These mounting locations are exemplary only and not limiting.

The determined characteristic can be used to enable optimal control of a reactive component, system or subsystem coupled to the processor. When the reactive component is an airbag assembly including at least one airbag, the processor can be designed to control at least one deployment parameter of the airbag(s).

Another monitoring arrangement comprises an imaging device for obtaining three-dimensional images of the environment (internal and/or external) and a processor embodying a pattern recognition technique for processing the three-dimensional images to determine at least one characteristic of an object in the environment based on the three-dimensional images obtained by the imaging device. The imaging device can be arranged at locations throughout the vehicle as described above. Control of a reactive component is enabled by the determination of the characteristic of the object.

Another arrangement for monitoring objects in or about a vehicle comprises a generating device for generating a first signal having a first frequency in a specific radio range, a wave transmitter arranged to receive the signal and transmit waves toward the objects, a wave-receiver arranged relative to the wave transmitter for receiving waves transmitted by the wave transmitter after the waves have interacted with  
5 an object, the wave receiver being arranged to generate a second signal based on the received waves at the same frequency as the first signal but shifted in phase, and a detector for detecting a phase difference between the first and second signals, whereby the phase difference is a measure of a property of the object. The phase difference is a measure of the distance between the object and the wave receiver and the wave transmitter. The wave transmitter may comprise an infrared driver and the receiver comprises  
10 an infrared diode.

A vehicle including an arrangement for measuring position of an object in an environment of or about the vehicle comprises a light source capable of directing modulated light into the environment, at least one light-receiving pixel arranged to receive the modulated light after reflection by any objects in the environment and a processor for determining the distance between any objects from which the modulated  
15 light is reflected and the light source based on the reception of the modulated light by the pixel(s). The pixels can constitute an array. Components for modulating a frequency of the light being directed by the light source into the environment and for providing a correlation pattern in a form of code division modulation of the light being directed by the light source into the environment can be provided. The pixel can also be a photo diode such as a PIN or avalanche diode.

Another measuring position arrangement comprises a light source capable of directing individual pulses of light into the environment, at least one array of light-receiving pixels arranged to receive light after reflection by any objects in the environment and a processor for determining the distance between any objects from which any pulse of light is reflected and the light source based on a difference in time  
20 between the emission of a pulse of light by the light source and the reception of light by the array. The light source can be arranged at various locations in the vehicle as described above to direct light into external and/or internal environments, relative to the vehicle.

Many changes, modifications, variations and other uses and applications of the subject invention will, however, become apparent to those skilled in the art after considering this specification and the accompanying drawings which disclose the preferred embodiments thereof. All such changes,  
30 modifications, variations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the following claims.

CLAIMS:

We Claim:

1. A monitoring arrangement for monitoring an environment exterior of a vehicle, comprising:

at least one receiver arranged to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and comprising pattern recognition means for processing the signal to provide a classification, identification or location of the exterior object, said pattern recognition means being structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects;

whereby a system in the vehicle is coupled to said processor such that the operation the system is affected in response to the classification, identification or location of the exterior object.

2. The arrangement of claim 1, wherein said at least one receiver comprises a pair of receivers spaced apart from one another.

3. The arrangement of claim 1, wherein said at least one receiver is arranged to receive infrared waves.

4. The arrangement of claim 1, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said at least one receiver is arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

5. The arrangement of claim 1, wherein said pattern recognition means comprise a neural computer.

6. The arrangement of claim 1, wherein said pattern recognition means comprise a neural network.

7. The arrangement of claim 1, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.



8. The arrangement of claim 1, wherein said at least one receiver is a CCD array.

9. The arrangement of claim 1, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

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10. The arrangement of claim 9, wherein said measurement means comprise a radar or laser radar system.

11. The arrangement of claim 1, wherein the another system is an airbag, deployment of said airbag being controlled based on the identification of the exterior object.

10

12. The arrangement of claim 11, wherein the airbag is an externally deployed airbag.

13. The arrangement of claim 1, wherein said processor is arranged to provide the classification of the exterior object.

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14. The arrangement of claim 1, wherein said processor is arranged to provide the identification of the exterior object.

15. The arrangement of claim 1, wherein said processor is arranged to provide the location of the exterior object.

20

16. A monitoring arrangement for monitoring an environment exterior of a vehicle, comprising:

25

at least one CCD array positioned to obtain images of the environment exterior of the vehicle; and a processor coupled to said at least one CCD array and comprising pattern recognition means for processing the images obtained by said at least one CCD array to provide a classification, identification or location of the exterior object,

30

whereby a system in the vehicle is coupled to said processor such that the operation the system is affected in response to the classification, identification or location of the exterior object.

17. The arrangement of claim 16, wherein said pattern recognition means are structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and images from said at least one CCD array of the possible exterior objects.

18. The arrangement of claim 16, wherein said at least one CCD array comprises a pair of CCD arrays spaced apart from one another.

5 19. The arrangement of claim 16, wherein the monitoring arrangement further comprises a transmitter for transmitting infrared waves into the environment exterior of the vehicle.

20. The arrangement of claim 16, wherein said pattern recognition means comprise a neural computer.

10

21. The arrangement of claim 16, wherein said pattern recognition means comprise a neural network.

15

22. The arrangement of claim 16, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

23. The arrangement of claim 16, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

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24. The arrangement of claim 23, wherein said measurement means comprise a radar or laser radar system.

25. The arrangement of claim 16, wherein the another system is an airbag, deployment of said airbag being controlled based on the identification of the exterior object.

25

26. The arrangement of claim 25, wherein the airbag is an externally deployed airbag.

27. The arrangement of claim 16, wherein said processor is arranged to provide the classification of the exterior object.

30

28. The arrangement of claim 16, wherein said processor is arranged to provide the identification of the exterior object.

29. The arrangement of claim 16, wherein said processor is arranged to provide the location of the exterior object.

5 30. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged on a rear view mirror of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

10 a processor coupled to said at least one receiver and arranged to classify, identify or locate the exterior object based on the signal.

whereby a system in the vehicle is coupled to said processor such that the operation the system is affected in response to the classification, identification or location of the exterior object.

15 31. The vehicle of claim 30, wherein said processor comprises pattern recognition means for processing the signal to provide the classification, identification or location of the exterior object, said pattern recognition means being structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects.

20 32. The vehicle of claim 30, wherein said at least one receiver comprises a pair of receivers spaced apart from one another.

25 33. The vehicle of claim 30, wherein said at least one receiver is arranged to receive infrared waves.

34. The vehicle of claim 30, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said at least one receiver is arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

30 35. The vehicle of claim 30, wherein said pattern recognition means comprise a neural computer.

36. The vehicle of claim 30, wherein said pattern recognition means comprise a neural network.

37. The vehicle of claim 30, wherein said at least one receiver is a CCD array.

5 38. The vehicle of claim 30, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

39. The vehicle of claim 38, wherein said measurement means comprise a radar or laser radar system.

10 40. A monitoring arrangement for monitoring an environment exterior of a vehicle, comprising:

a plurality of receivers arranged apart from one another and to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

15 a processor coupled to said receivers and arranged to classify, identify or locate the exterior object based on the signals generated by said receivers,

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

20 41. The arrangement of claim 40, wherein said processor comprises pattern recognition means for processing the signal to provide the classification, identification or location of the exterior object, said pattern recognition means being structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects.

25 42. The arrangement of claim 40 wherein said receivers are arranged to receive infrared waves.

30 43. The arrangement of claim 40, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said receivers are arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

44. The arrangement of claim 40, wherein said pattern recognition means comprise a neural computer.

45. The arrangement of claim 40, wherein said pattern recognition means comprise a neural network.

5 46. The arrangement of claim 40, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

47. The arrangement of claim 40, wherein said receivers are CCD arrays.

10 48. The arrangement of claim 40, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

49. The arrangement of claim 48, wherein said measurement means comprise a radar or laser radar system.

15 50. The arrangement of claim 40, wherein the another system is an airbag, said output means being arranged to control deployment of said airbag based on the identification of the exterior object.

51. The arrangement of claim 50, wherein the airbag is an externally deployed airbag.

20 52. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged on a B-pillar of the vehicle to receive waves from the environment exterior of and on the side of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

25 a processor coupled to said at least one receiver and arranged to classify, identify or locate the exterior object based on the signal;

whereby a system in the vehicle is coupled to said processor such that the operation the system is affected in response to the classification, identification or location of the exterior object.

30 53. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged in a door window trim panel of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and arranged to classify, identify or locate the exterior object based on the signal;

whereby a system in the vehicle is coupled to said processor such that the operation the system is affected in response to the classification, identification or location of the exterior object.

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54. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged on a rear view mirror of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves;

10

a processor coupled to said at least one receiver and arranged to classify, identify or locate the exterior object based on the signal; and

a display viewable by the driver; said display being coupled to said processor such that the presence and classification, identification or location of the exterior object is displayed on said display.

15

55. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

20

a processor coupled to said at least one receiver and comprising pattern recognition means for processing the signal to provide a classification, identification or location of the exterior object, said pattern recognition means being structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects;

25

whereby a system in the vehicle is coupled to said processor such that the operation the system is affected in response to the classification, identification or location of the exterior object.

56. The vehicle of claim 55, wherein said at least one receiver is arranged on a B-pillar of the vehicle to receive waves from a side of the vehicle.

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57. The vehicle of claim 55, wherein said at least one receiver is arranged in a door window trim panel.

58. The vehicle of claim 55, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said at least one receiver is arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

5 59. The vehicle of claim 55, wherein said at least one receiver is arranged to receive waves from a blind spot of the vehicle.

60. The vehicle of claim 55, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

10 61. The vehicle of claim 55, wherein said at least one receiver is mounted on a rear view mirror or in a rear window.

15 62. The vehicle of claim 55, wherein said at least one receiver is mounted in a C-pillar of the vehicle.

63. The vehicle of claim 55, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

20 64. The vehicle of claim 55, wherein the another system is an airbag, deployment of said airbag being controlled based on the identification of the exterior object.

65. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

25 at least one CCD array positioned to obtain images of the environment exterior of the vehicle; and a processor coupled to said at least one CCD array and comprising pattern recognition means for processing the images obtained by said at least one CCD array to provide a classification, identification or location of the exterior object,

30 whereby a system in the vehicle is coupled to said processor such that the operation the system is affected in response to the classification, identification or location of the exterior object.

66. The vehicle of claim 65, wherein said pattern recognition means are structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and images from said at least one CCD array of the possible exterior objects.

67. The vehicle of claim 65, wherein said at least one CCD array is arranged on a B-pillar of the vehicle to obtain images from a side of the vehicle.

5 68. The vehicle of claim 65, wherein said at least one CCD array is arranged in a door window trim panel.

69. The vehicle of claim 65, wherein said at least one CCD array comprises a pair of CCD arrays spaced apart from one another.

10 70. The vehicle of claim 65, wherein the monitoring arrangement further comprises a transmitter for transmitting infrared waves into the environment exterior of the vehicle.

15 71. The vehicle of claim 65, wherein said at least one CCD array is arranged to obtain images from a blind spot of the vehicle.

72. The vehicle of claim 65, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

20 73. The vehicle of claim 65, wherein said at least one CCD array is mounted on a rear view mirror or in a rear window.

74. The vehicle of claim 65, wherein said at least one CCD array is mounted in a C-pillar of the vehicle.

25 75. The vehicle of claim 65, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

30 76. The vehicle of claim 65, wherein the another system is an airbag, deployment of said airbag being controlled based on the identification of the exterior object.

77. A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:



a plurality of receivers arranged apart from one another and to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

5 a processor coupled to said receivers and arranged to classify, identify or locate the exterior object based on the signals generated by said receivers,

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

10 78. The vehicle of claim 77, wherein said processor comprises pattern recognition means for processing the signal to provide the classification, identification or location of the exterior object, said pattern recognition means being structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects.

15 79. The vehicle of claim 77, wherein said receivers are arranged on a B-pillar of the vehicle to receive waves from a side of the vehicle.

80. The vehicle of claim 77, wherein said receivers are arranged to receive infrared waves.

20 81. The vehicle of claim 77, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said receivers are arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

25 82. The vehicle of claim 77, wherein said receivers are arranged to receive waves from a blind spot of the vehicle.

83. The vehicle of claim 77, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

30 84. The vehicle of claim 77, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

85. The vehicle of claim 77, wherein the another system is an airbag, said output means being arranged to control deployment of said airbag based on the identification of the exterior object.

**ABSTRACT OF THE DISCLOSURE**

Vehicular monitoring arrangement for monitoring an environment of the vehicle including at least one active pixel camera for obtaining images of the environment of the vehicle and a processor coupled to the active pixel camera(s) for determining at least one characteristic of an object in the environment based on the images obtained by the active pixel camera(s). The active pixel camera can be arranged in a headliner, roof or ceiling of the vehicle to obtain images of an interior environment of the vehicle, in an A-pillar or B-pillar of the vehicle to obtain images of an interior environment of the vehicle, or in a roof, ceiling, B-pillar or C-pillar of the vehicle to obtain images of an interior environment of the vehicle behind a front seat of the vehicle. The determined characteristic can be used to enable optimal control of a reactive component, system or subsystem coupled to the processor. When the reactive component is an airbag assembly including at least one airbag, the processor can be designed to control at least one deployment parameter of the airbag(s).

## DECLARATION FOR PATENT APPLICATION

Attorney Docket Number: ATI-338

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Vehicular Monitoring Systems Using Image Processing

the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability as defined in 37 C.F.R. §1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT International filing date of the continuation-in-part application.

I hereby claim foreign or domestic priority benefits under Title 35, United States Code, §119 of any foreign and/or provisional U.S. application(s) for patent or inventor's certificate listed below and have also identified below any foreign and provisional U.S. application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Application(s)	U.S.	31 December 1998	Priority Claimed	
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
60/114,507	U.S.	31 December 1998	X	

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

10/116,808	Apr. 5, 2002	Pending
09/925,043	August 8, 2001	Pending
09/838,919	April 20, 2001	Pending
09/765,559	January 19, 2001	Pending
09/476,255	December 30, 1999	Patented
09/389,947	September 3, 1999	Patented
09/200,614	November 30, 1998	Patented
08/474,786	June 7, 1995	Patented
(Application Serial No.)	(Filing Date)	(Status - patented, pending, abandoned)

10302105 112202

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Brian Roffe, Reg. No. 35,336, Customer Number 22846

Telephone number: (516) 295-1394; Facsimile Number: (516) 295-0318

Address: Brian Roffe, Esq., 366 Longacre Avenue, Woodmere, New York 11598-2417

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of first joint inventor, (given name, family name) David S. Breed

Inventor's signature \_\_\_\_\_ Date \_\_\_\_\_

Residence Boonton Township, Morris County, New Jersey Citizenship U S A

Post Office Address 48 Hillcrest Road, Boonton Township, Morris County, New Jersey 07005

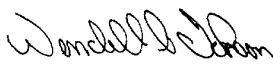
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Full name of second joint inventor, (given name, family name) Wilbur E. DuVall

Inventor's signature \_\_\_\_\_ Date \_\_\_\_\_

Residence Kimberling City, MO Citizenship U S A

Post Office Address 57 Northwoods Drive, Kimberling City, MO 65686

-----  
Full name of third joint inventor, (given name, family name) Wendell C. Johnson

  
Inventor's signature \_\_\_\_\_ Date 11/20/2002

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Full name of second joint inventor, (given name, family name) Wilbur E. DuVall

Inventor's signature Wilbur E. DuVall Date 11-20-2007

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Inventor's signature \_\_\_\_\_ Date \_\_\_\_\_

Residence Signal Hill, CA Citizenship U S A

Post Office Address 2675 Junipero Avenue, Suite 100, Signal Hill, CA 90806







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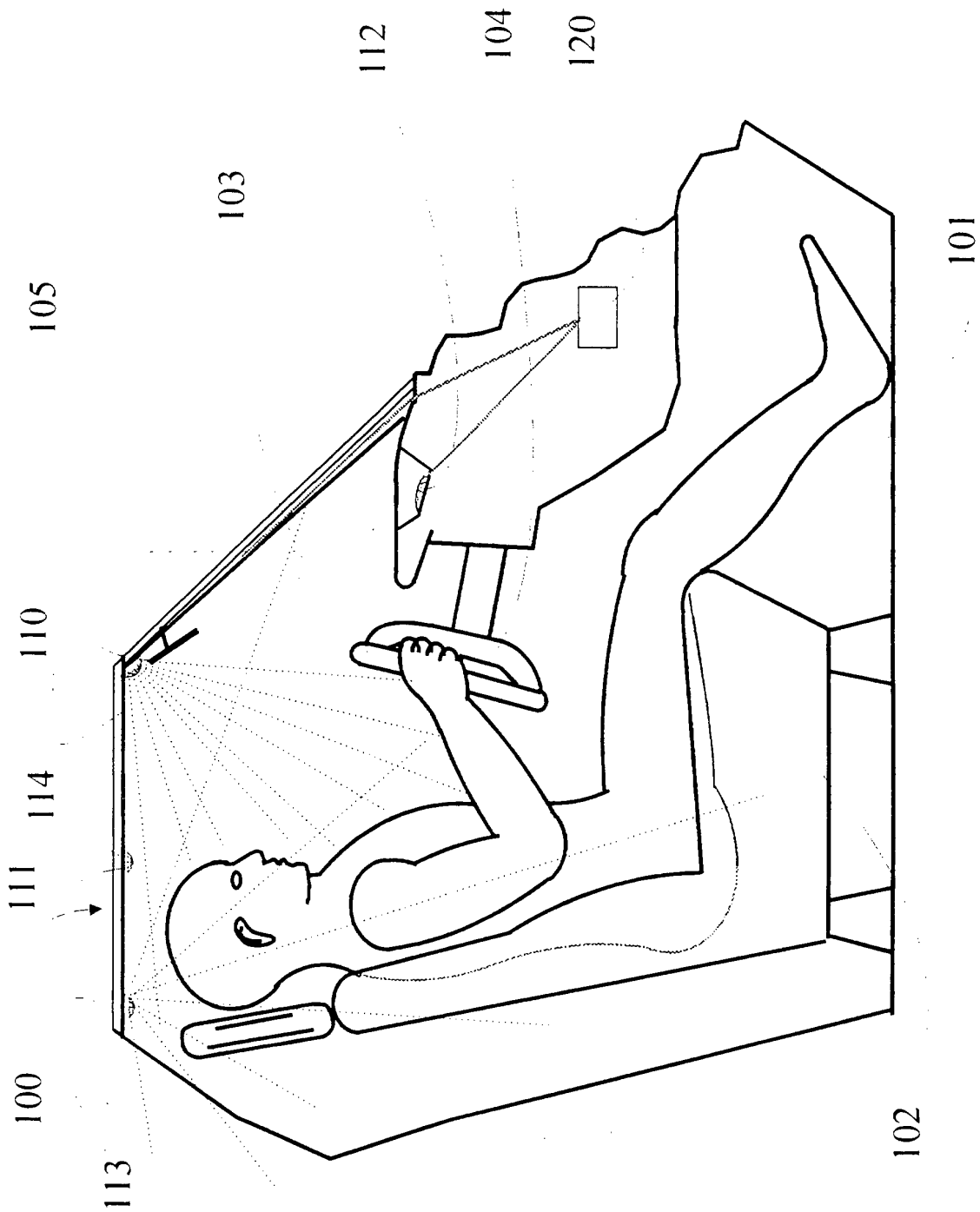


FIG. 1C

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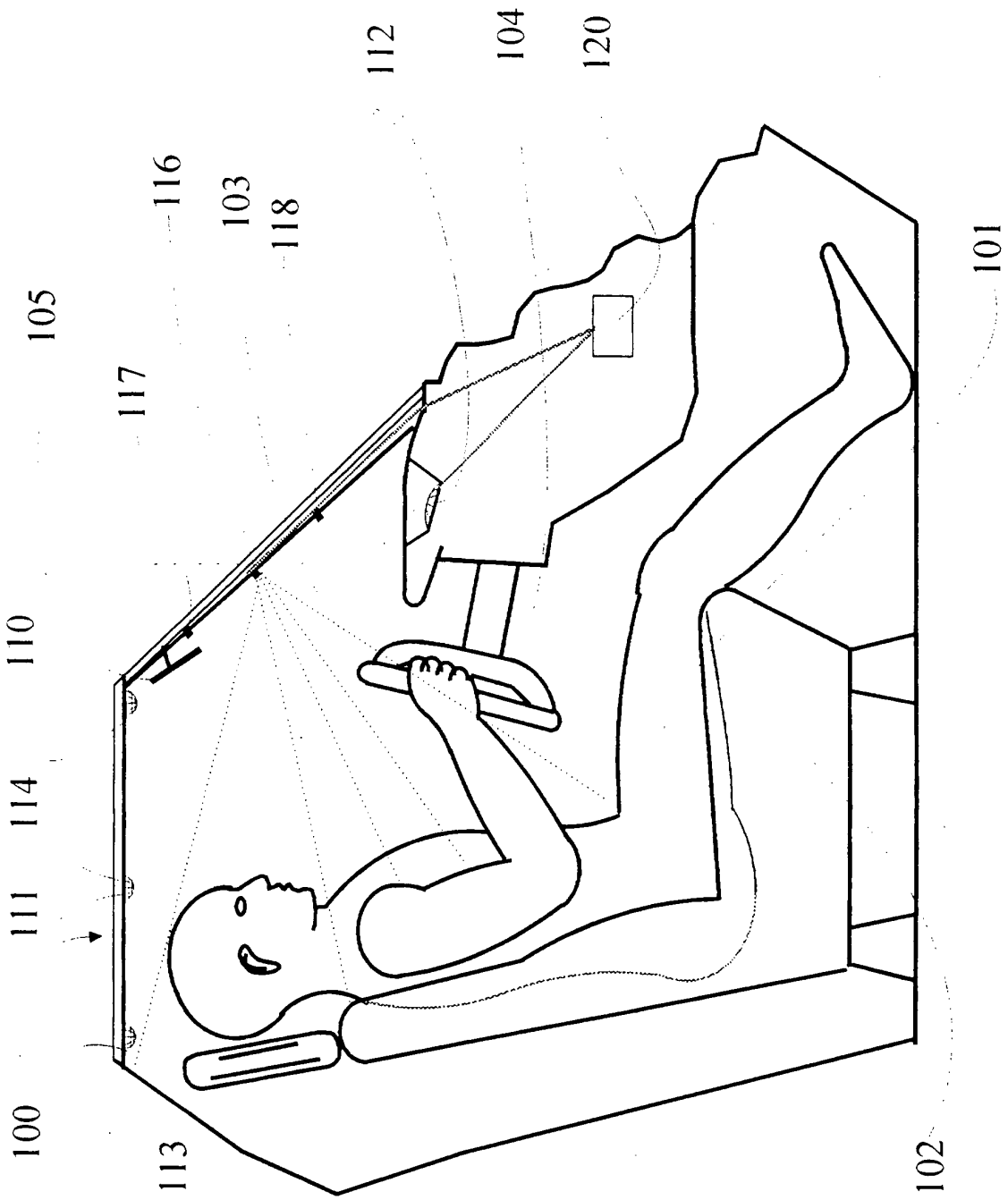


FIG. 1D

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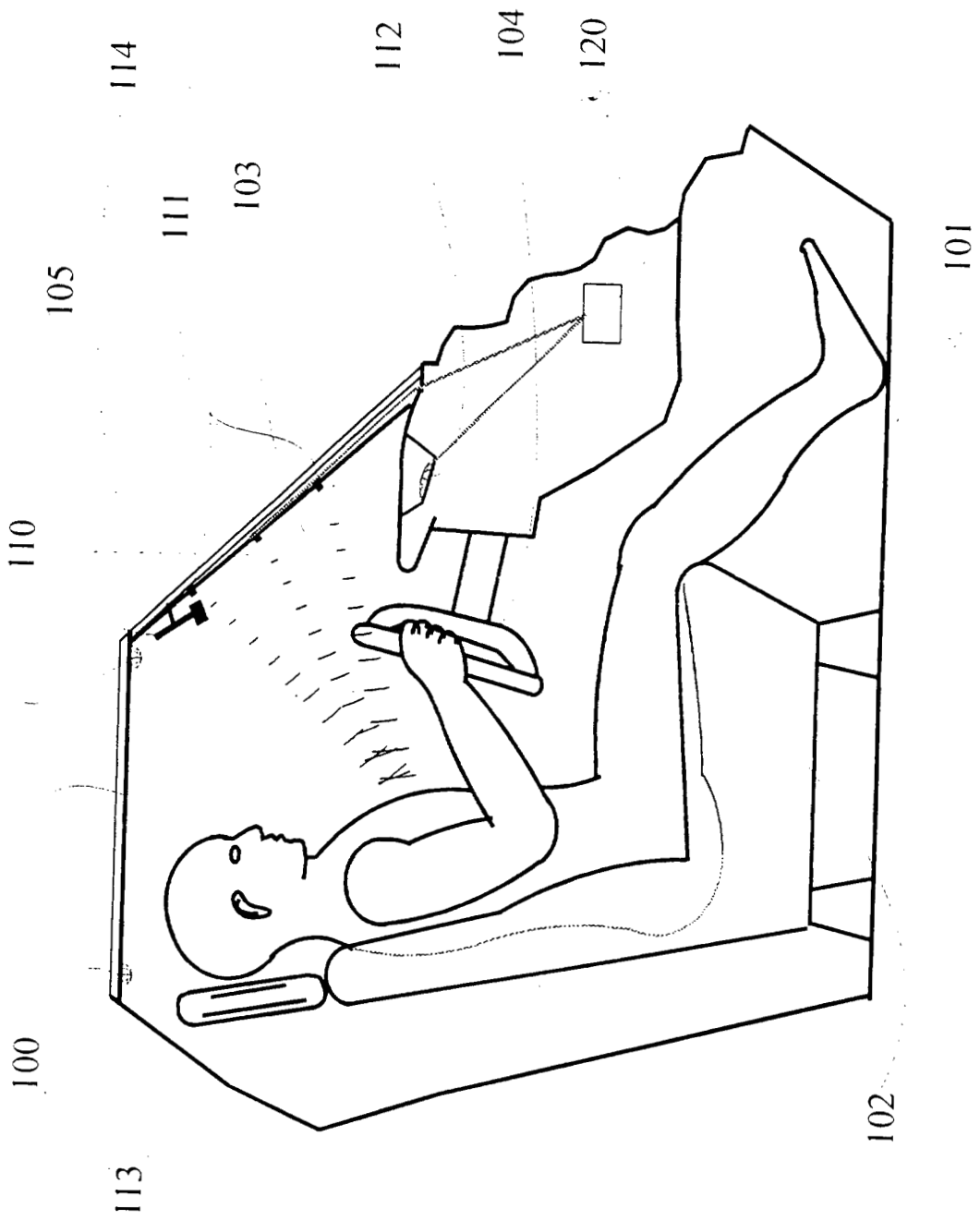


FIG. 1E

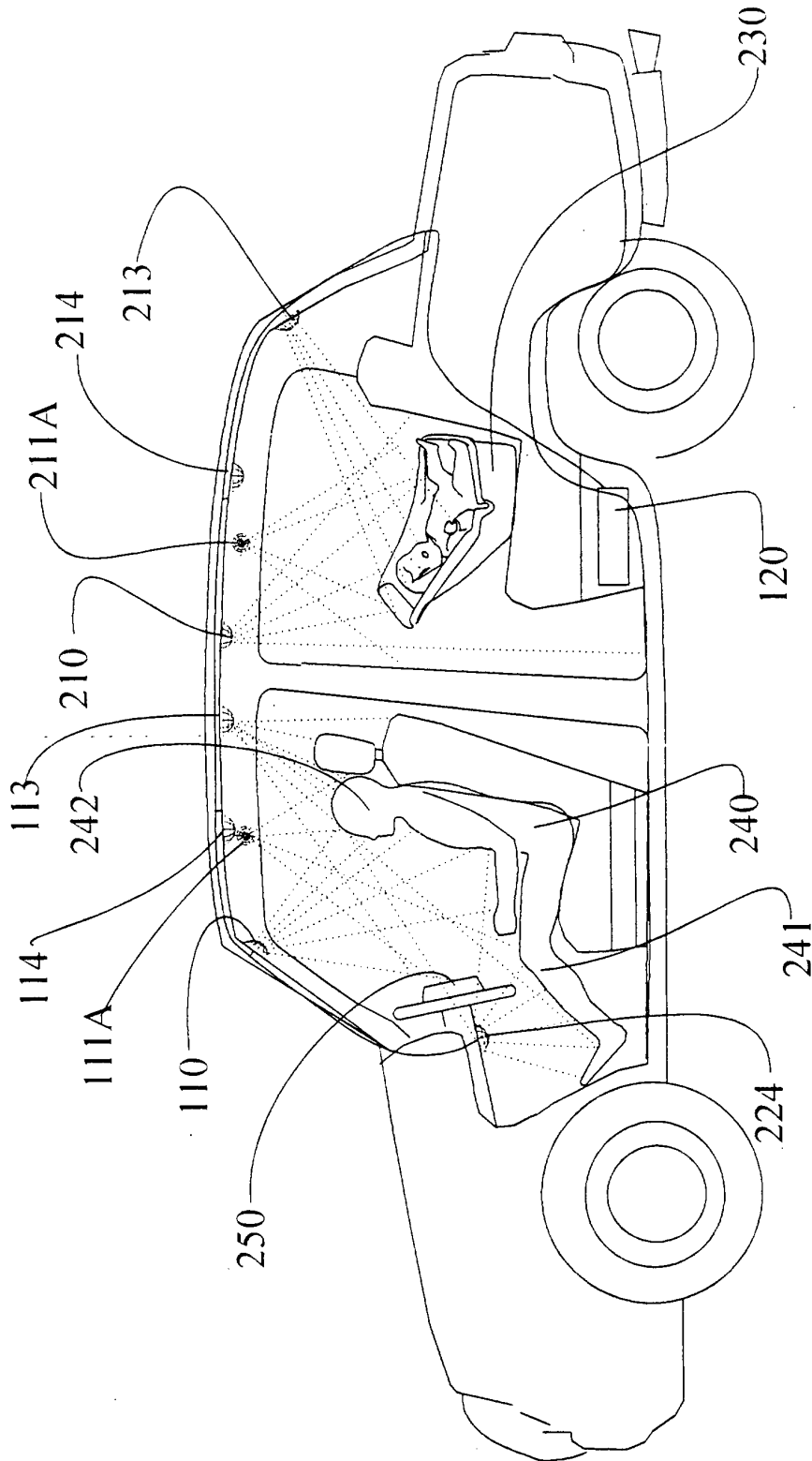


FIG. 2A

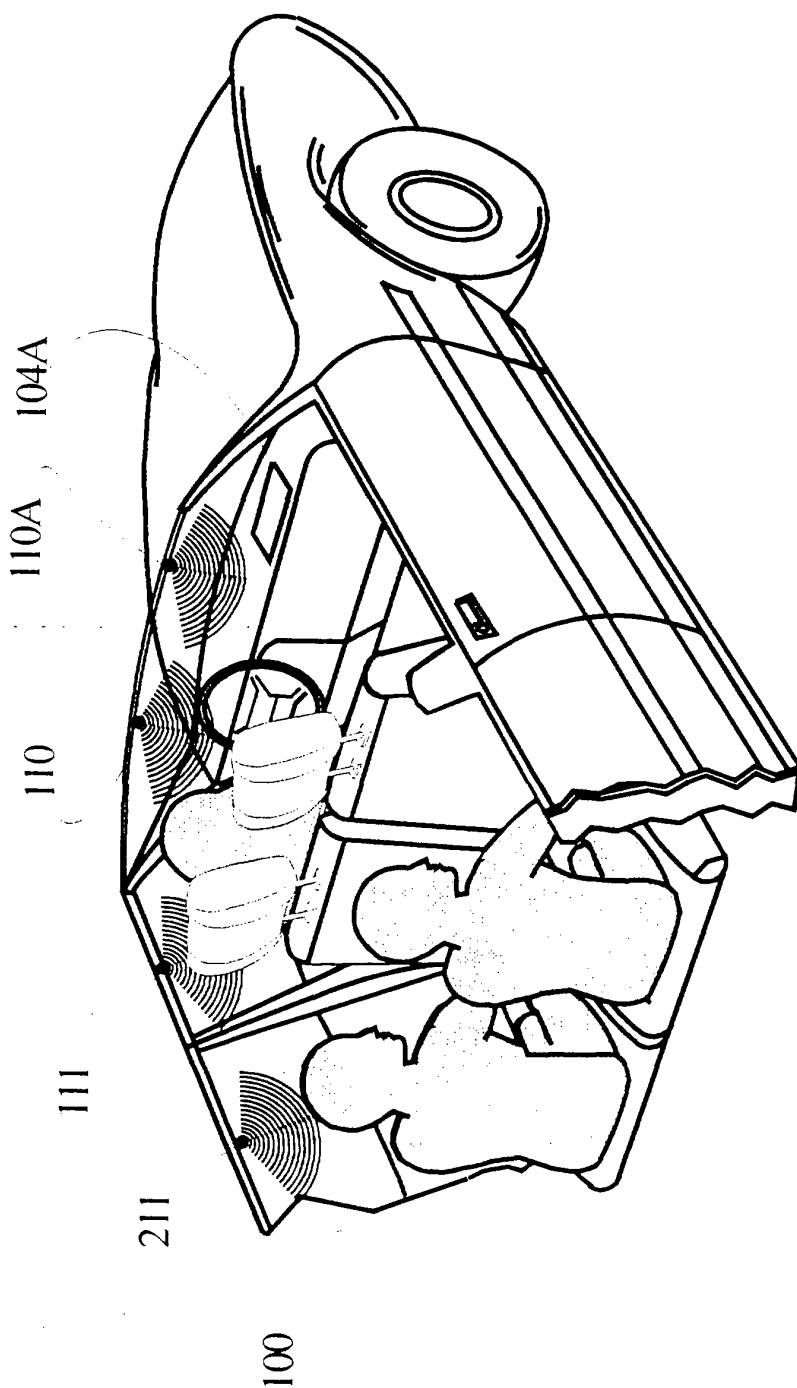


FIG. 2B

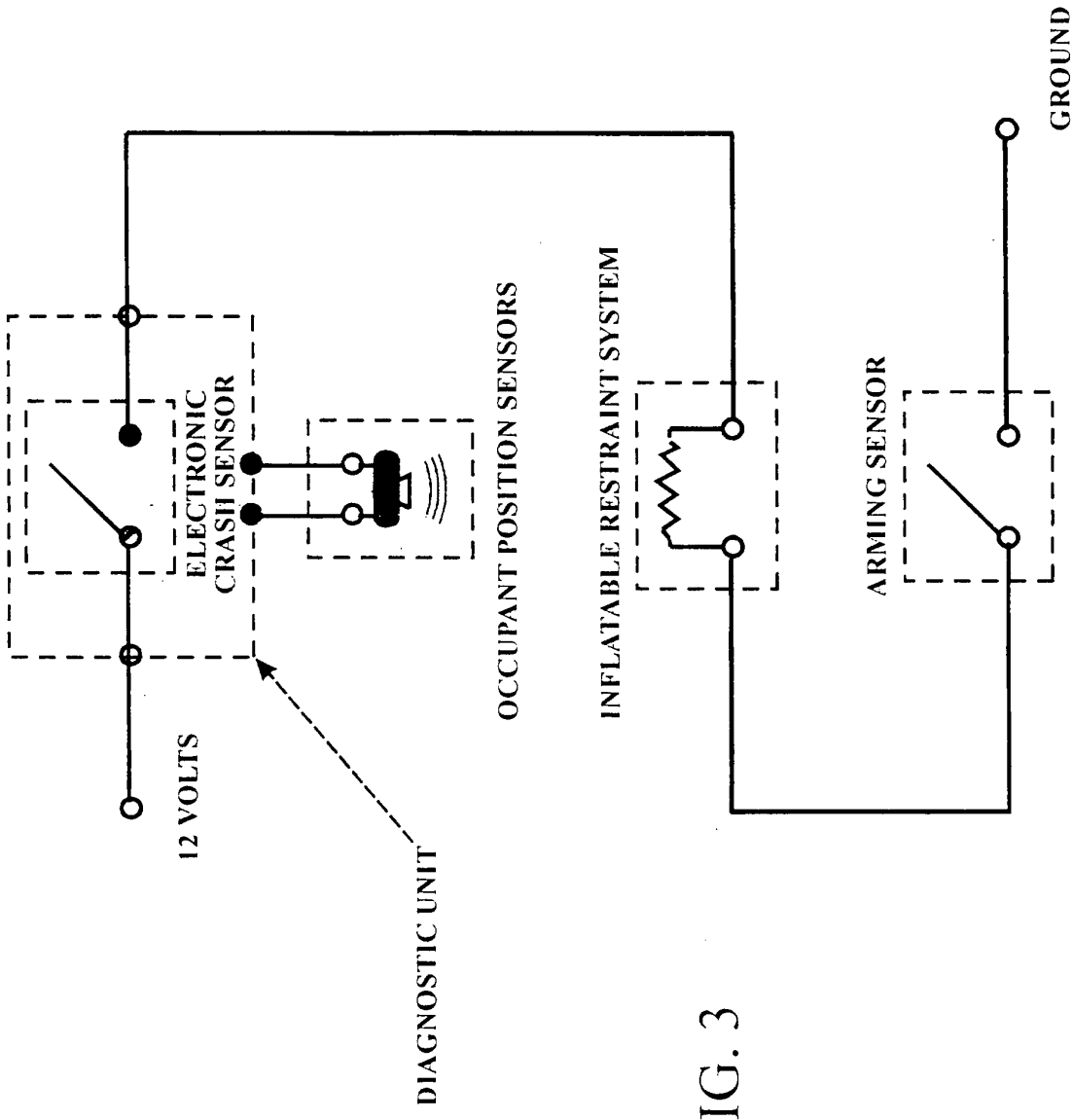


FIG. 3



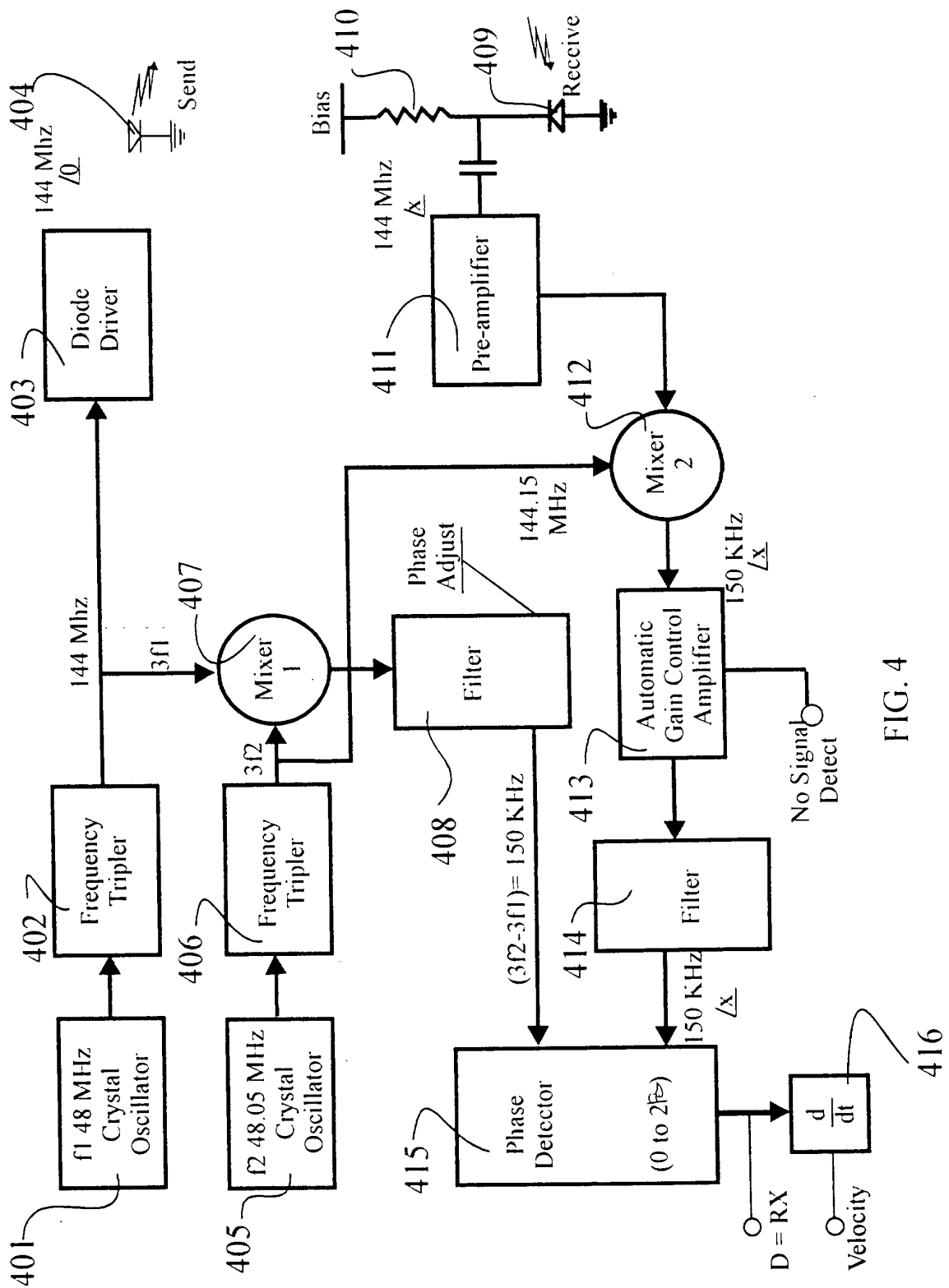


FIG. 4

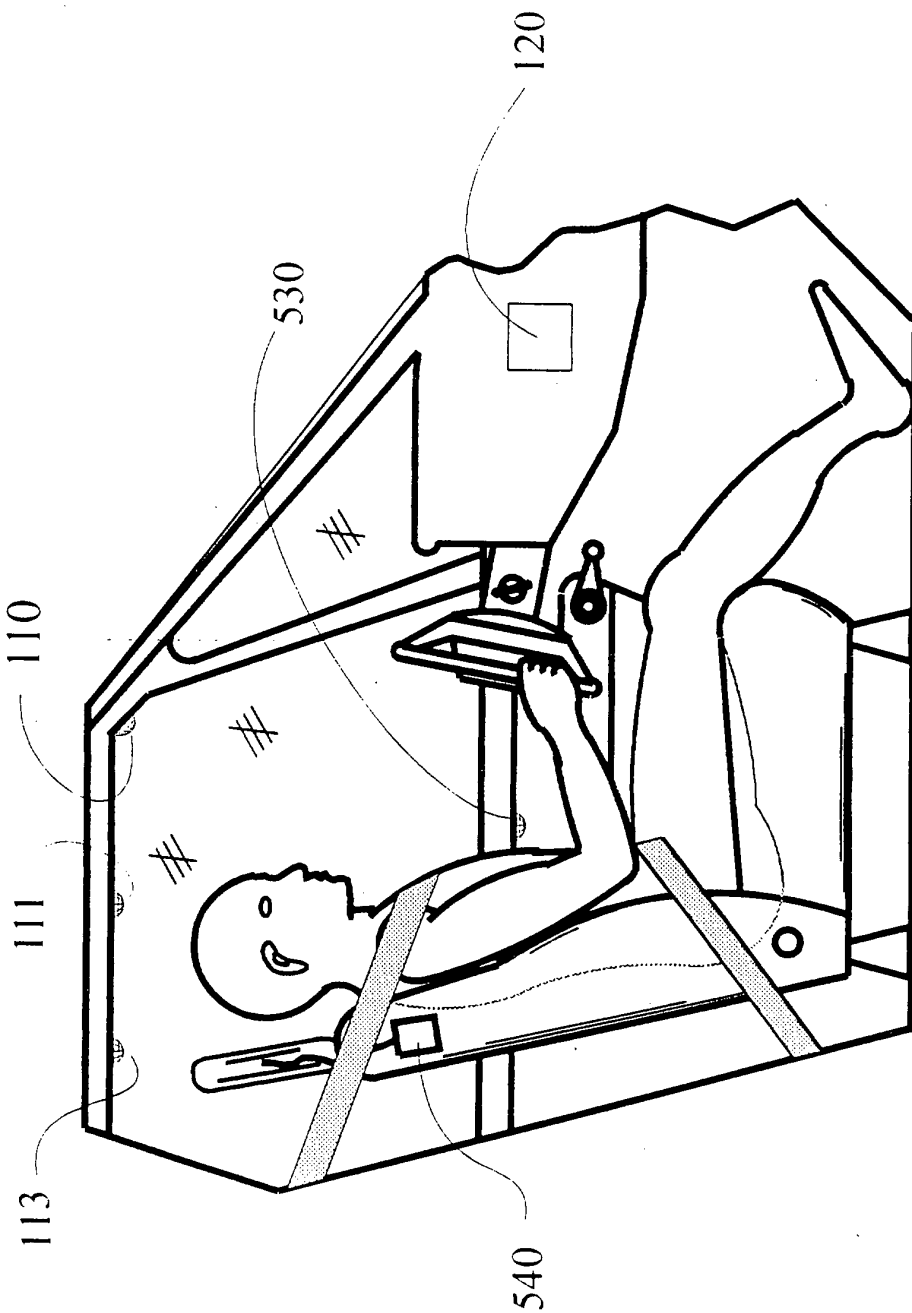


FIG. 5

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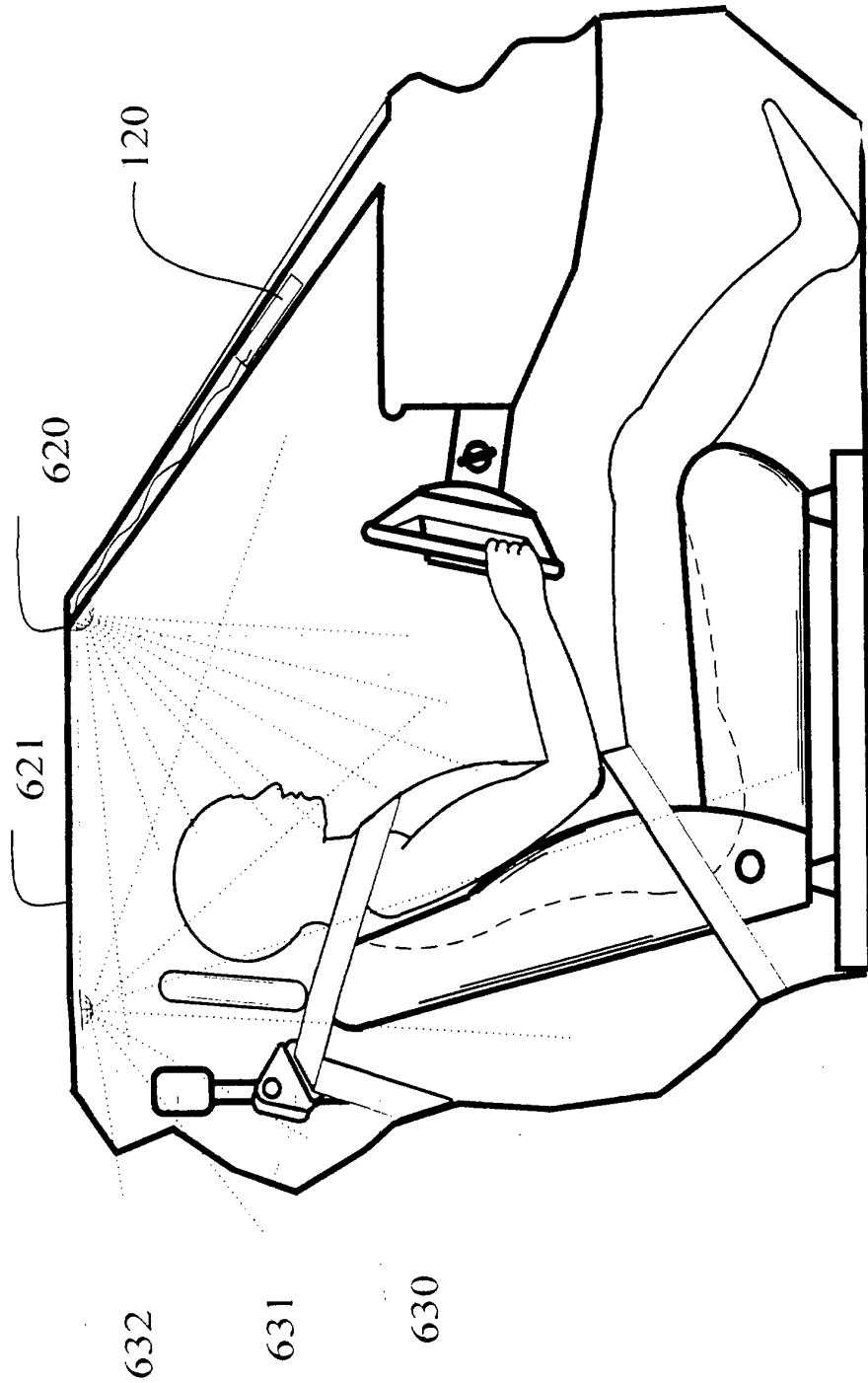


FIG. 6

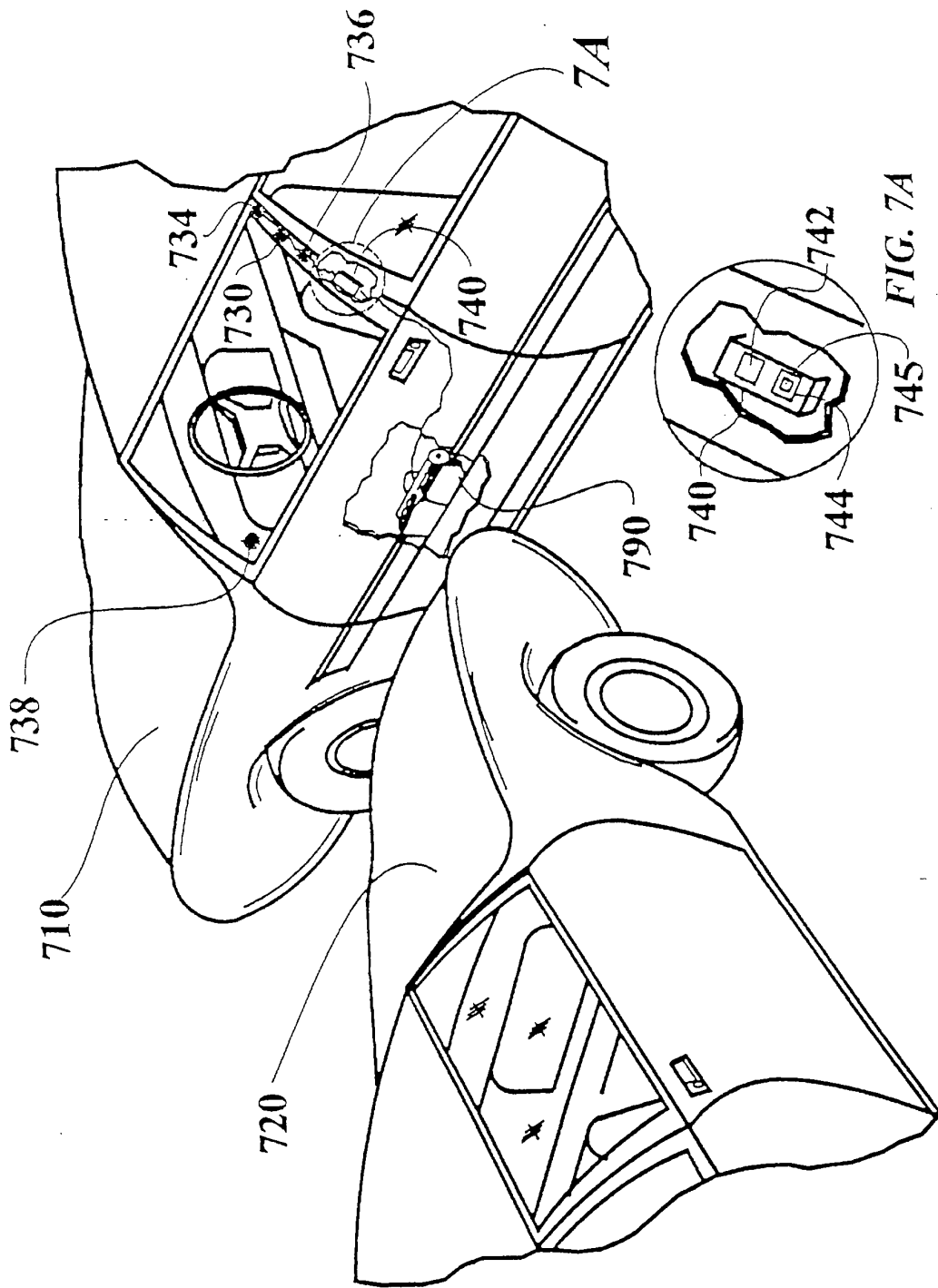


FIG. 7

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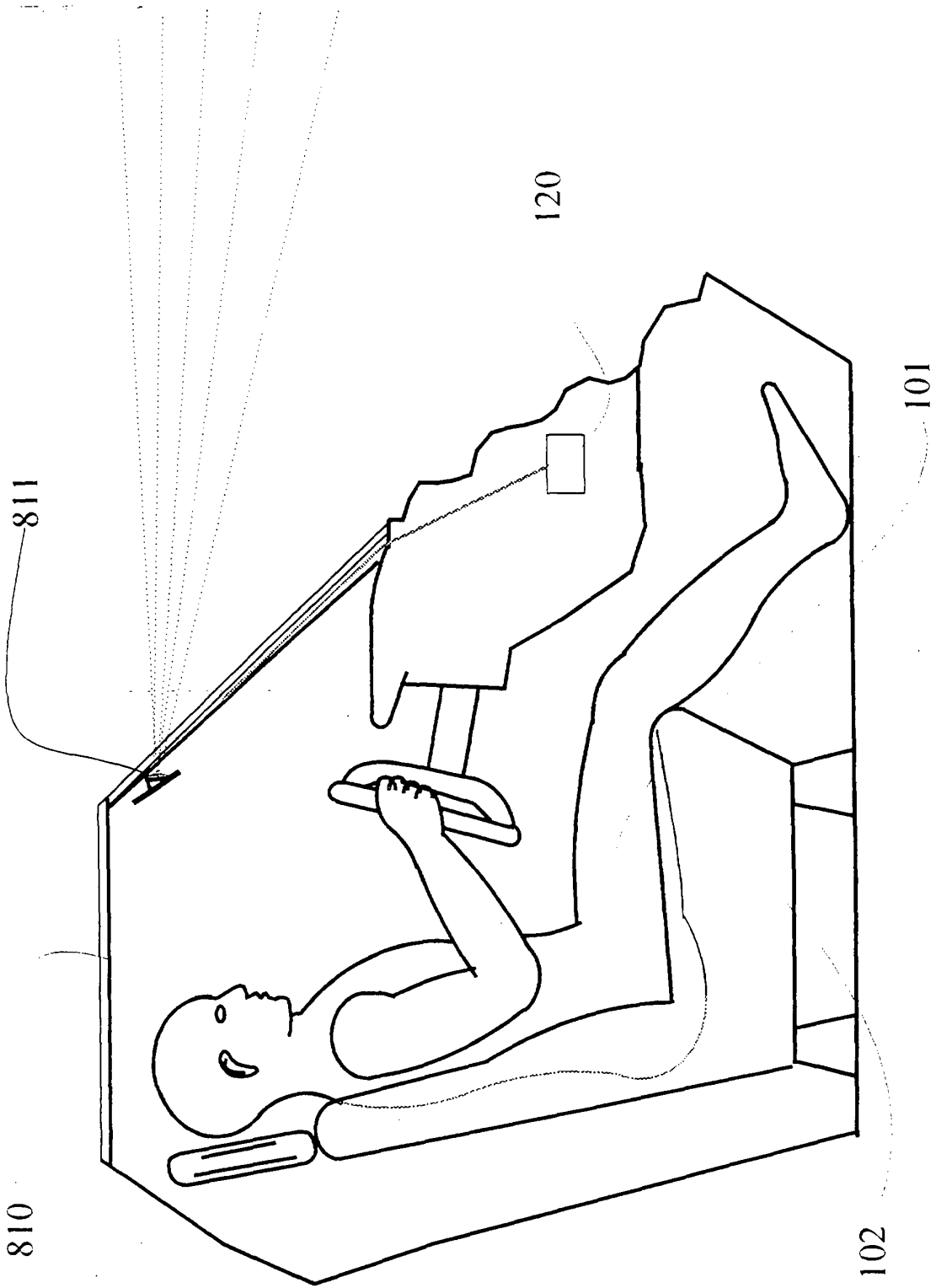


FIG. 8

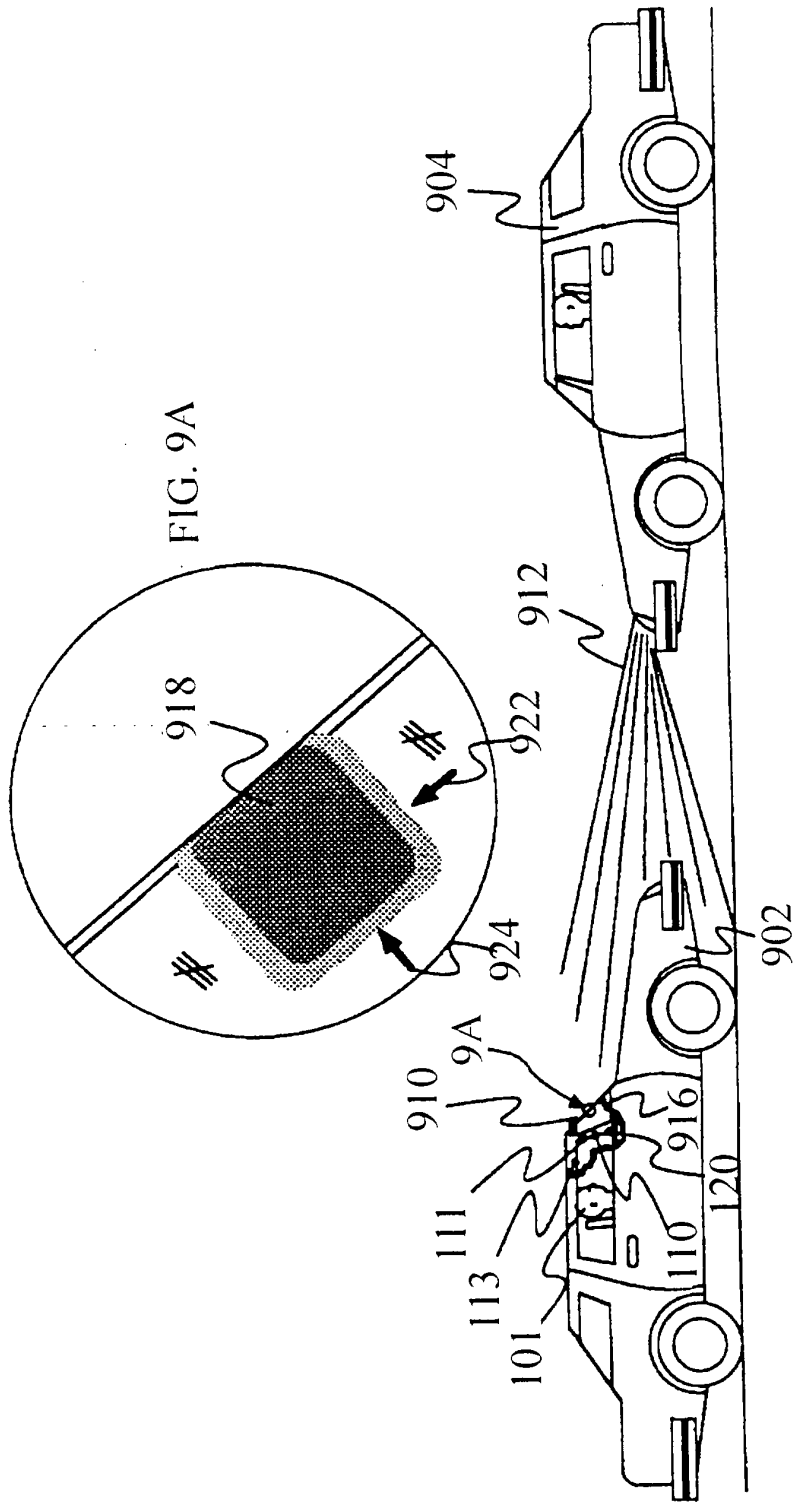


FIG. 9

FIG. 10

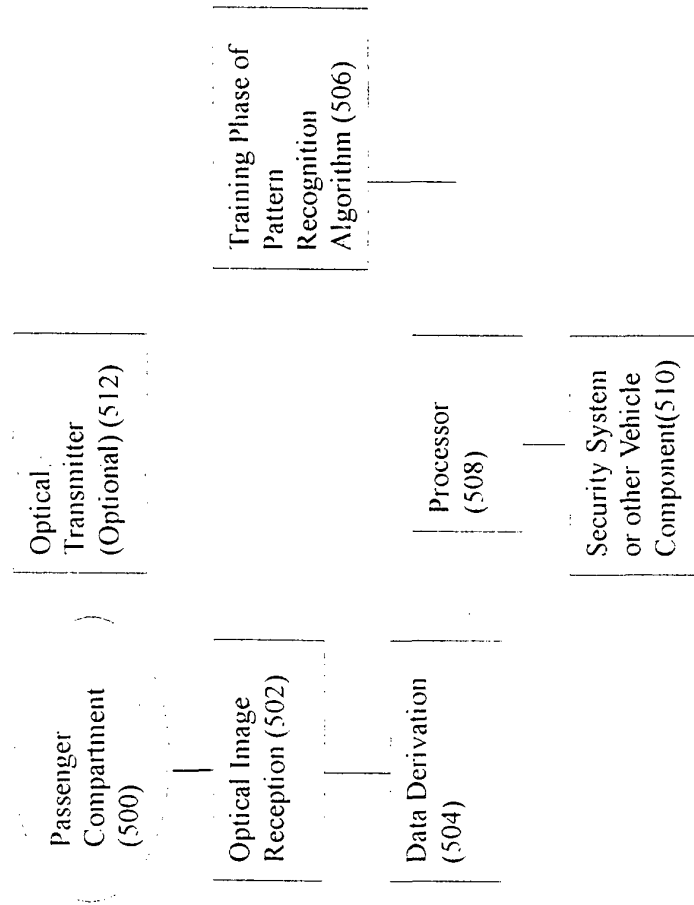
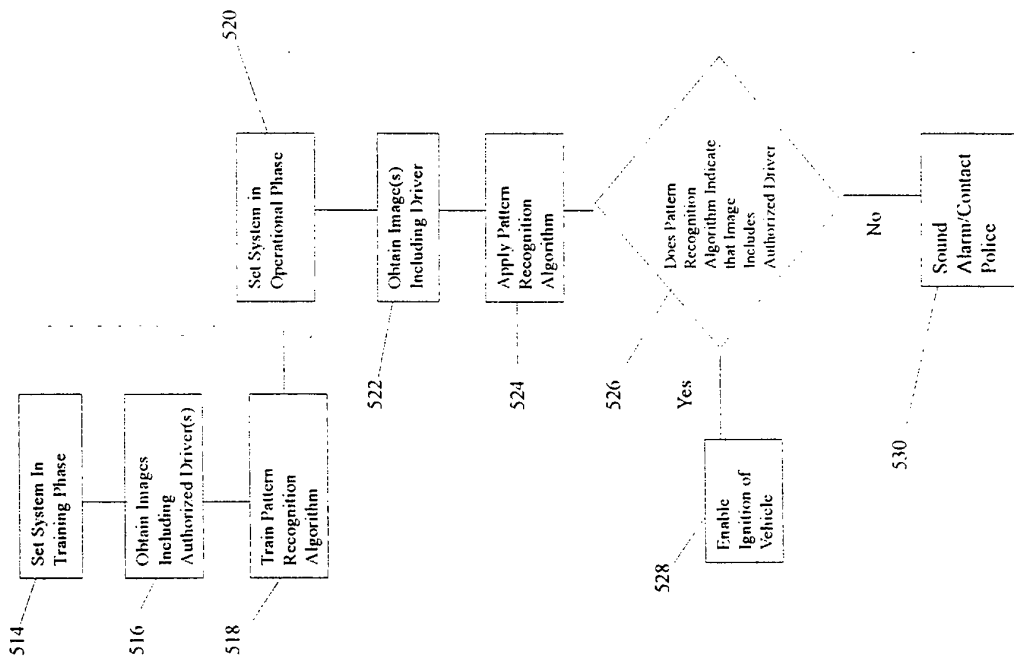


FIG. 11





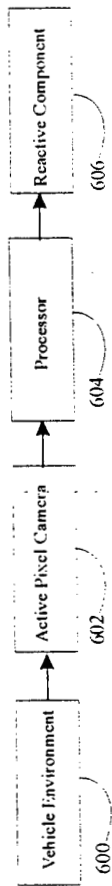


FIG. 12

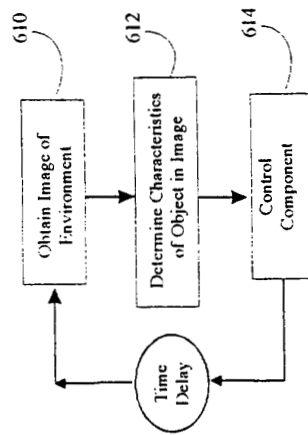


FIG. 13

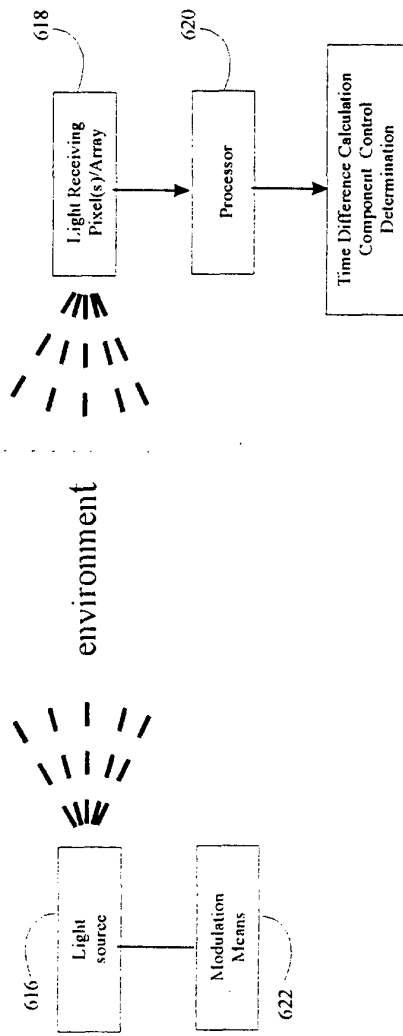
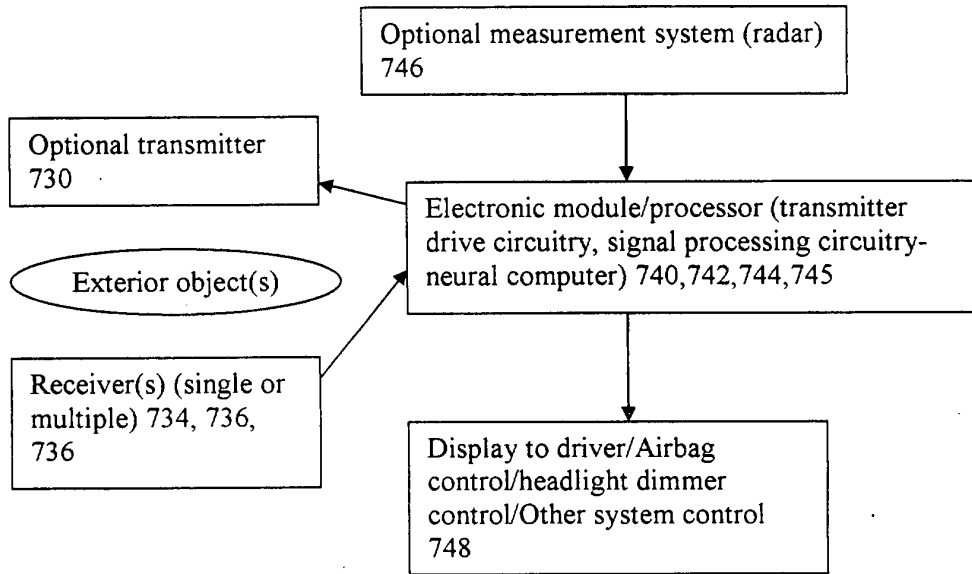


FIG. 14

FIG. 15



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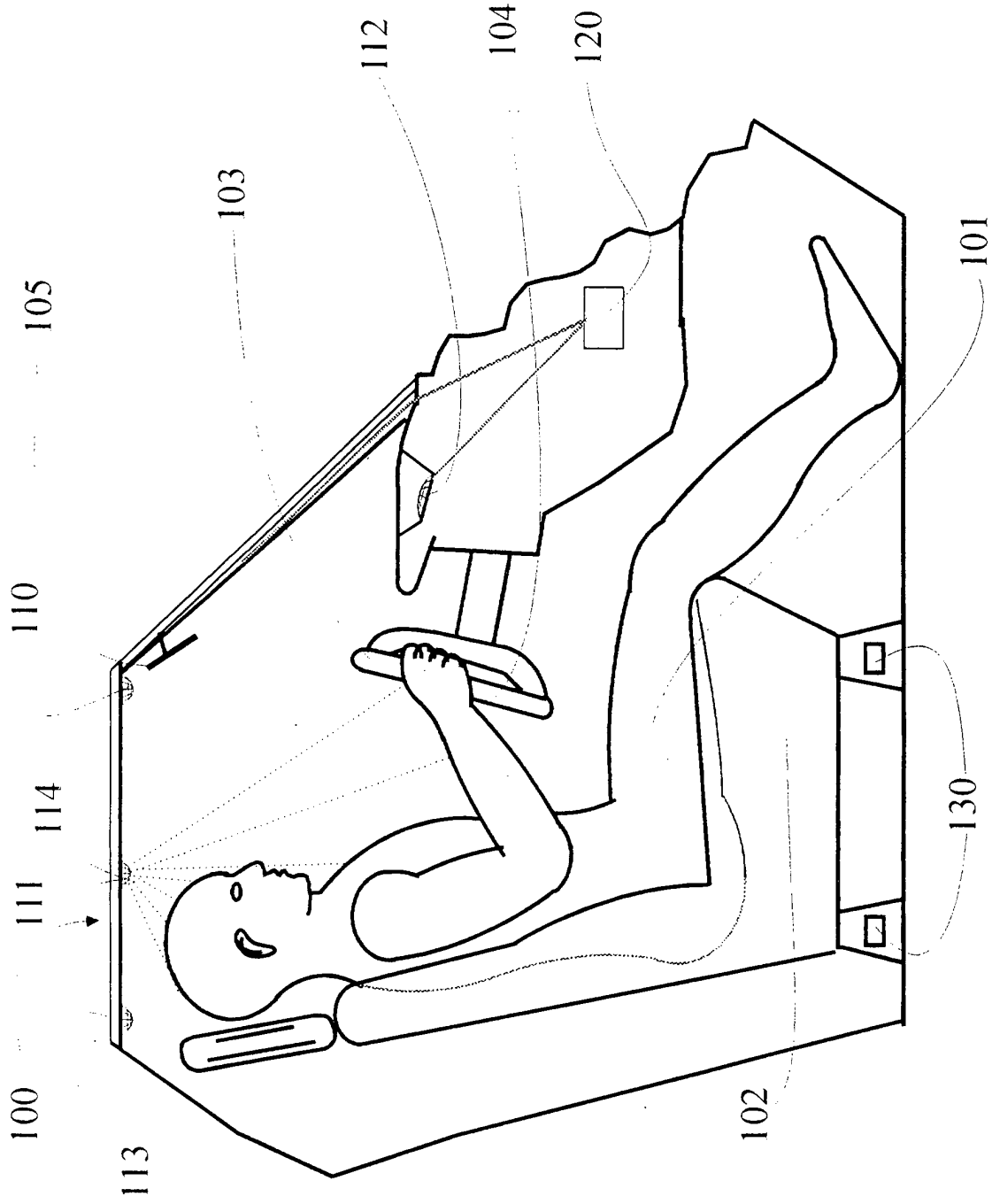


FIG. 1A

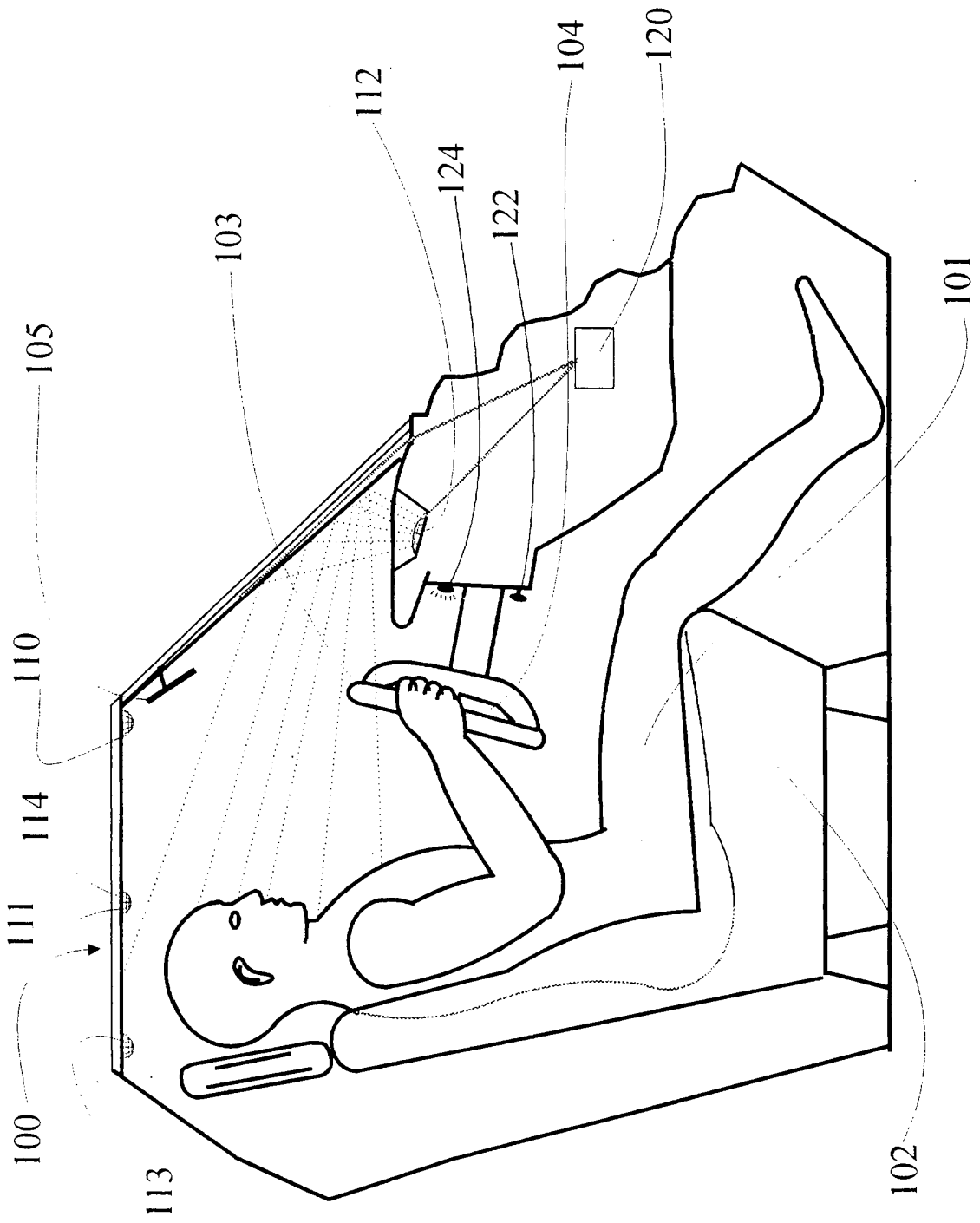


FIG. 1B



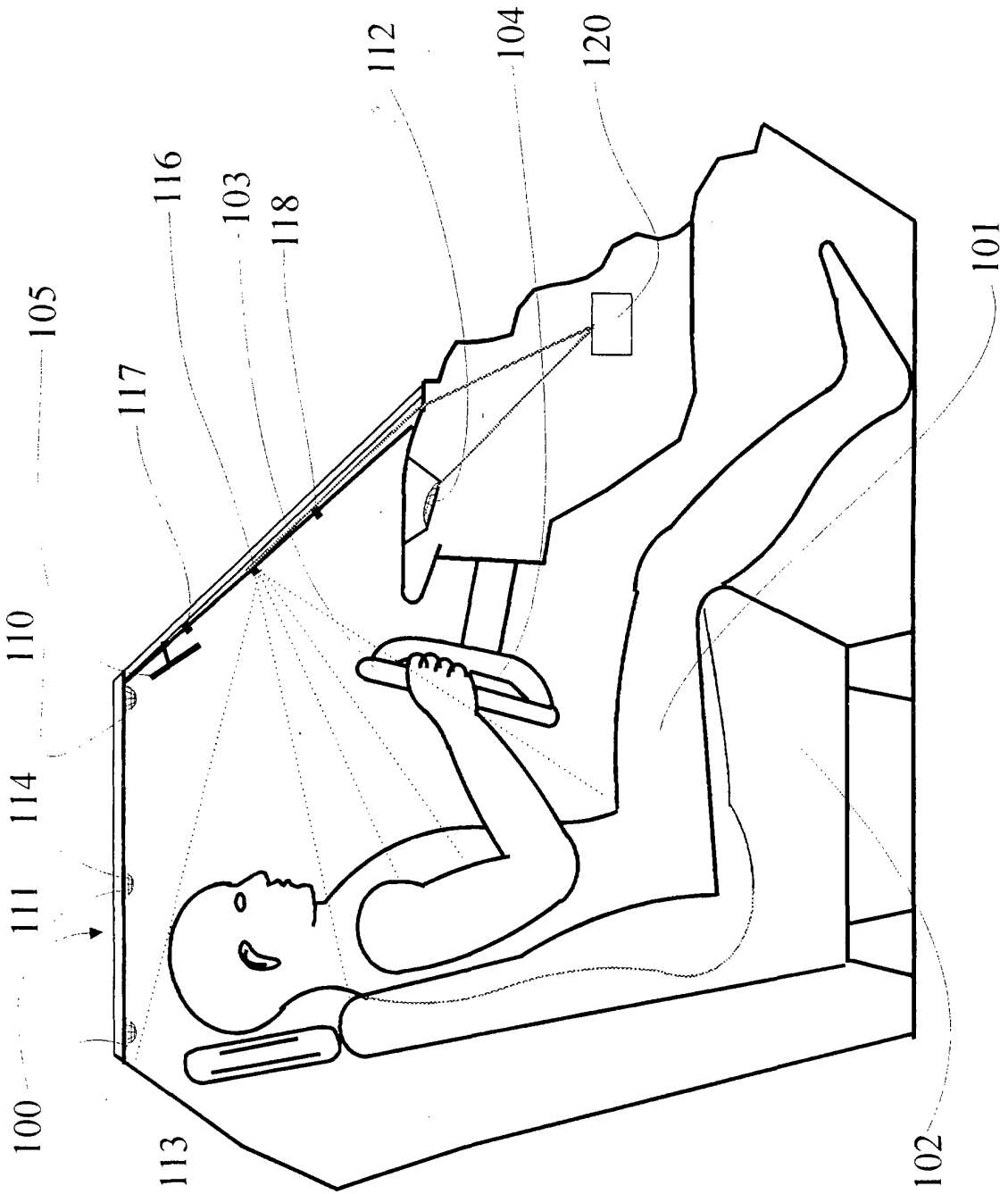


FIG. 1D

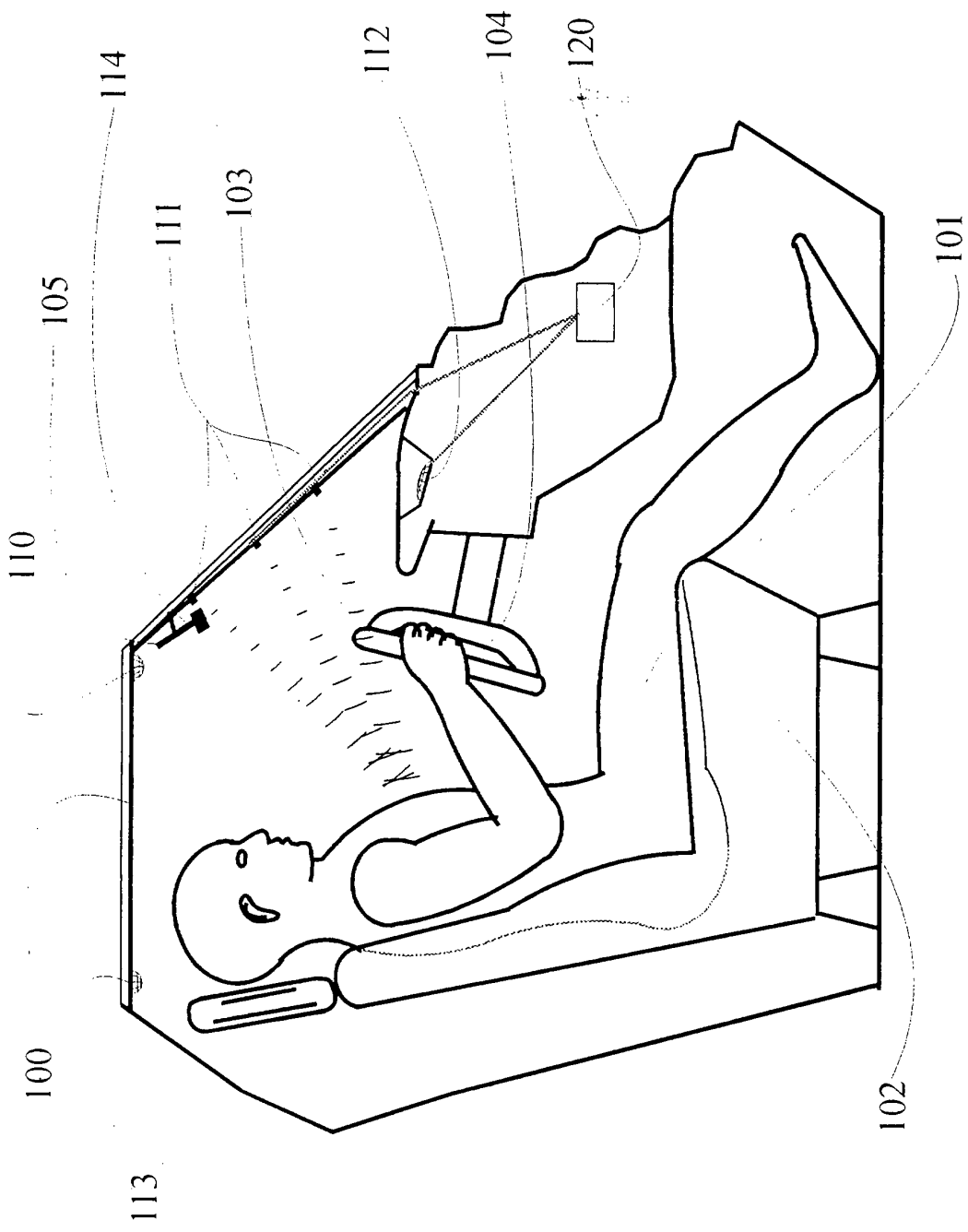


FIG. 1E



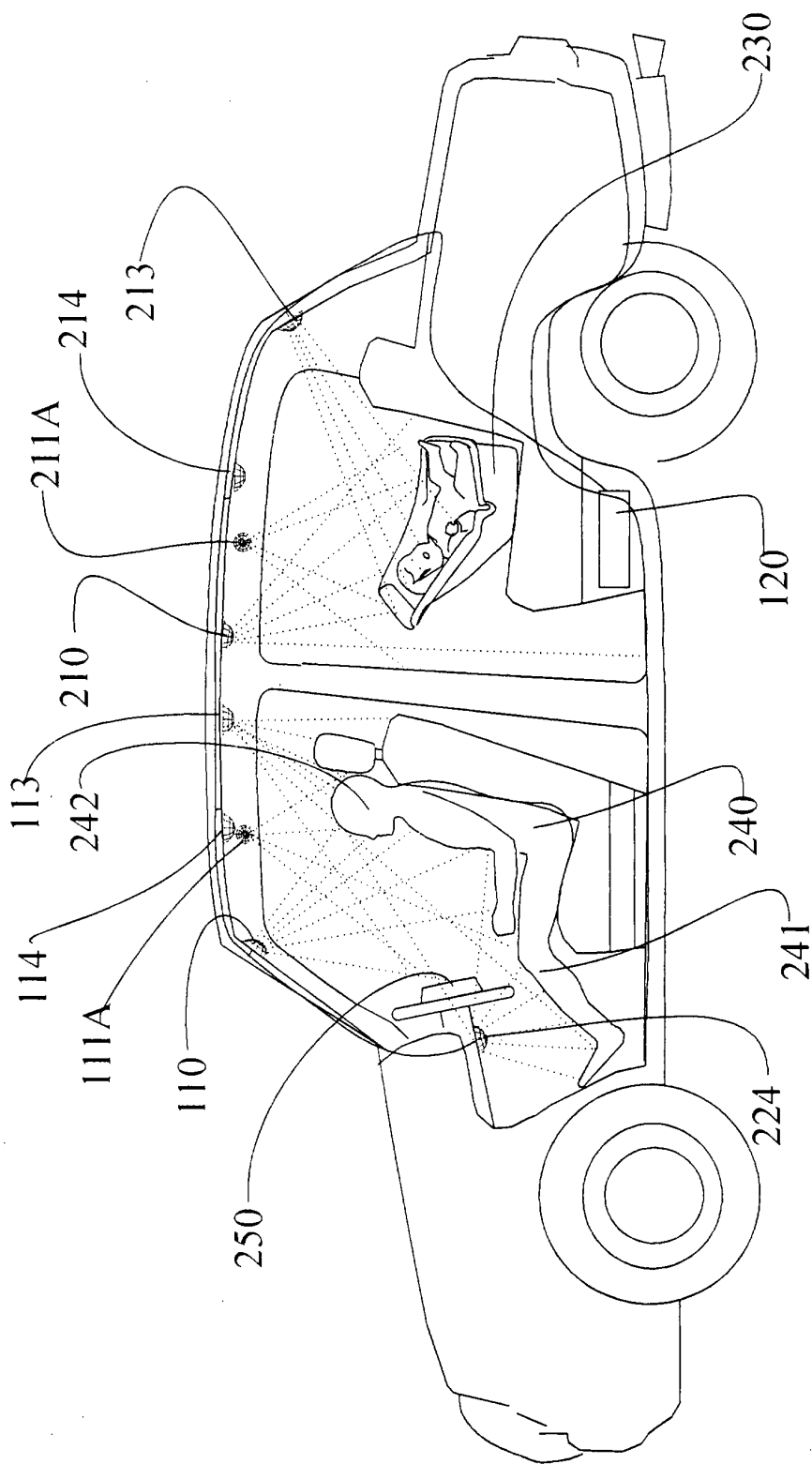


FIG. 2A

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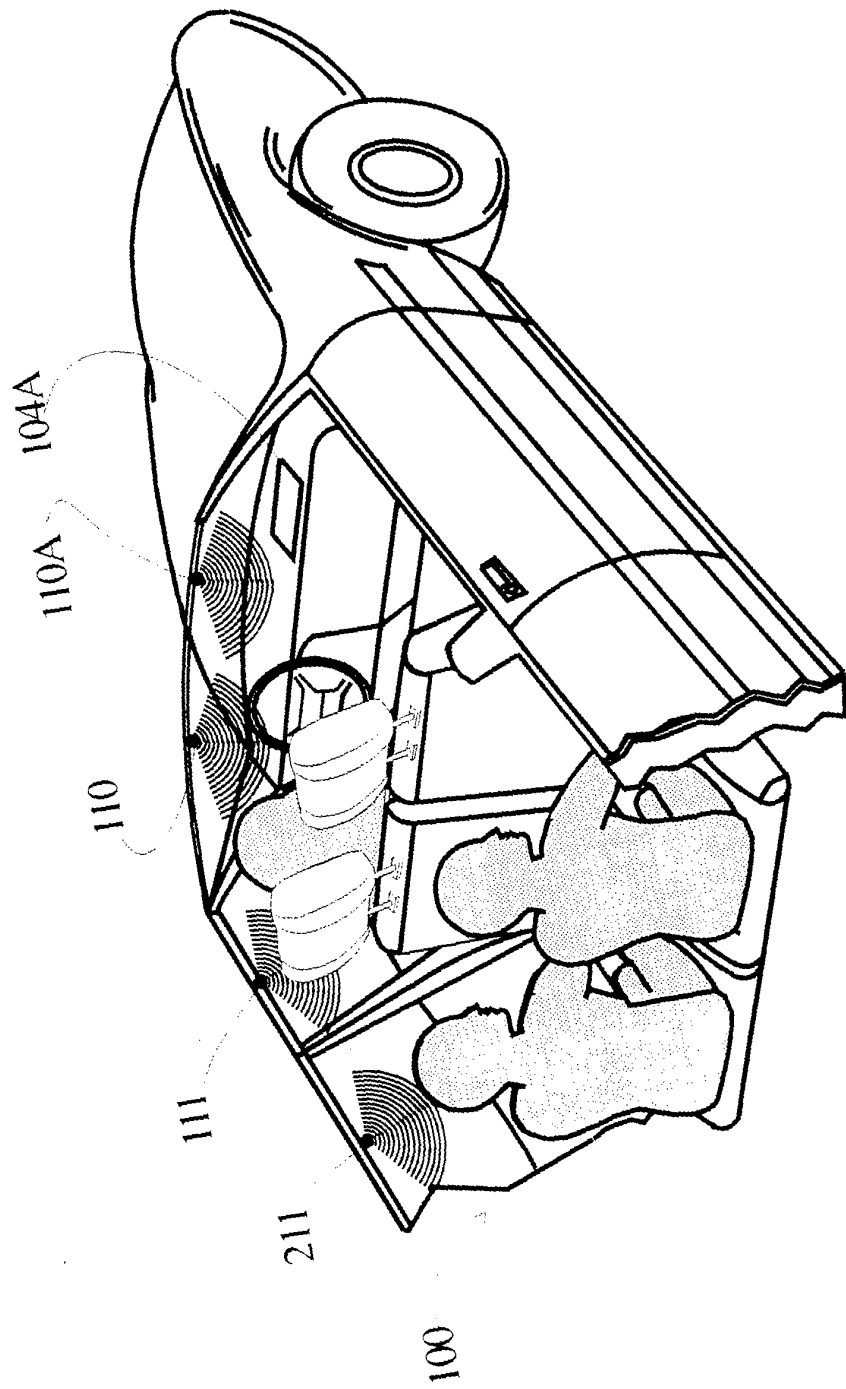


FIG. 2B

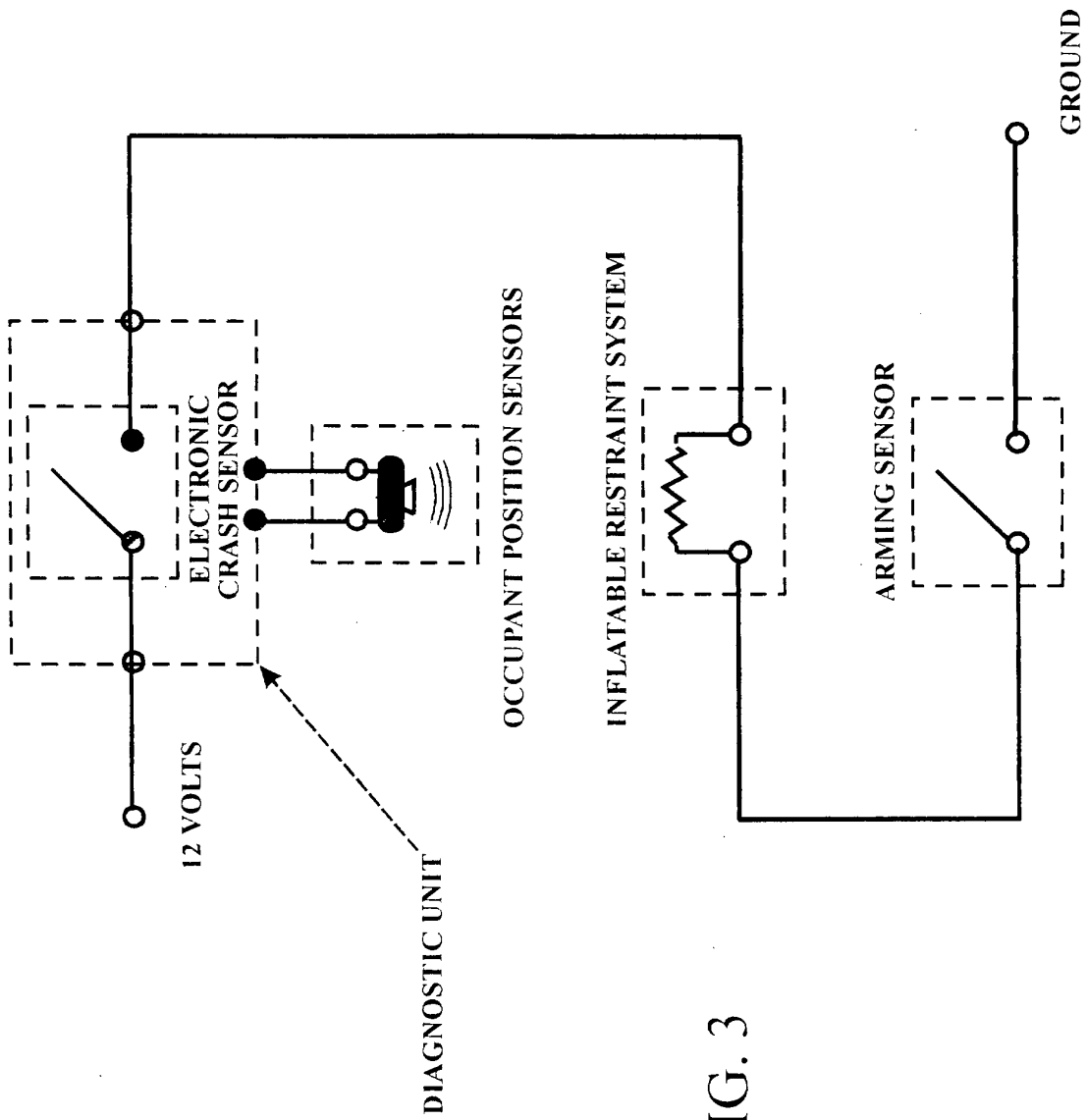


FIG. 3

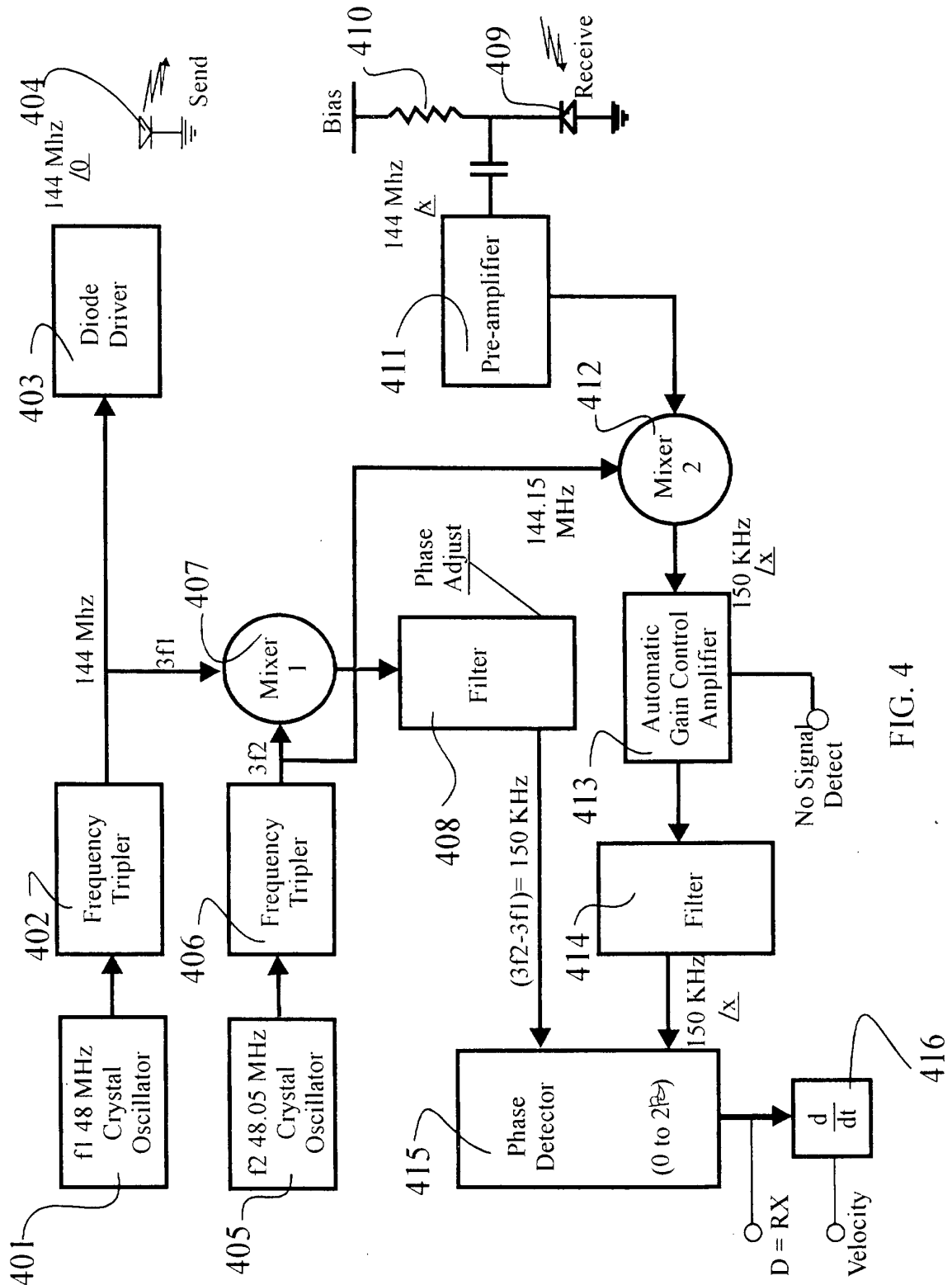


FIG. 4

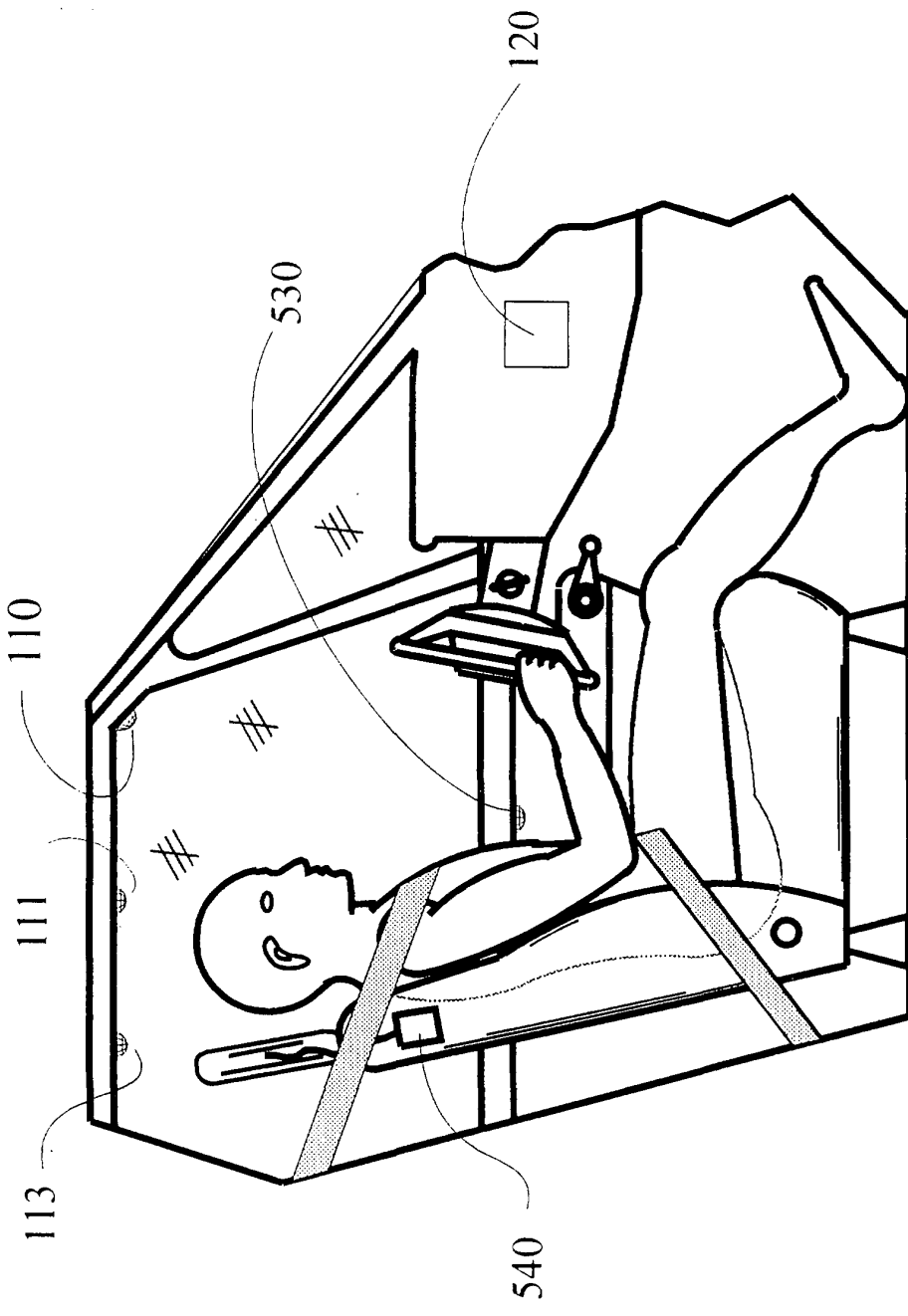


FIG. 5

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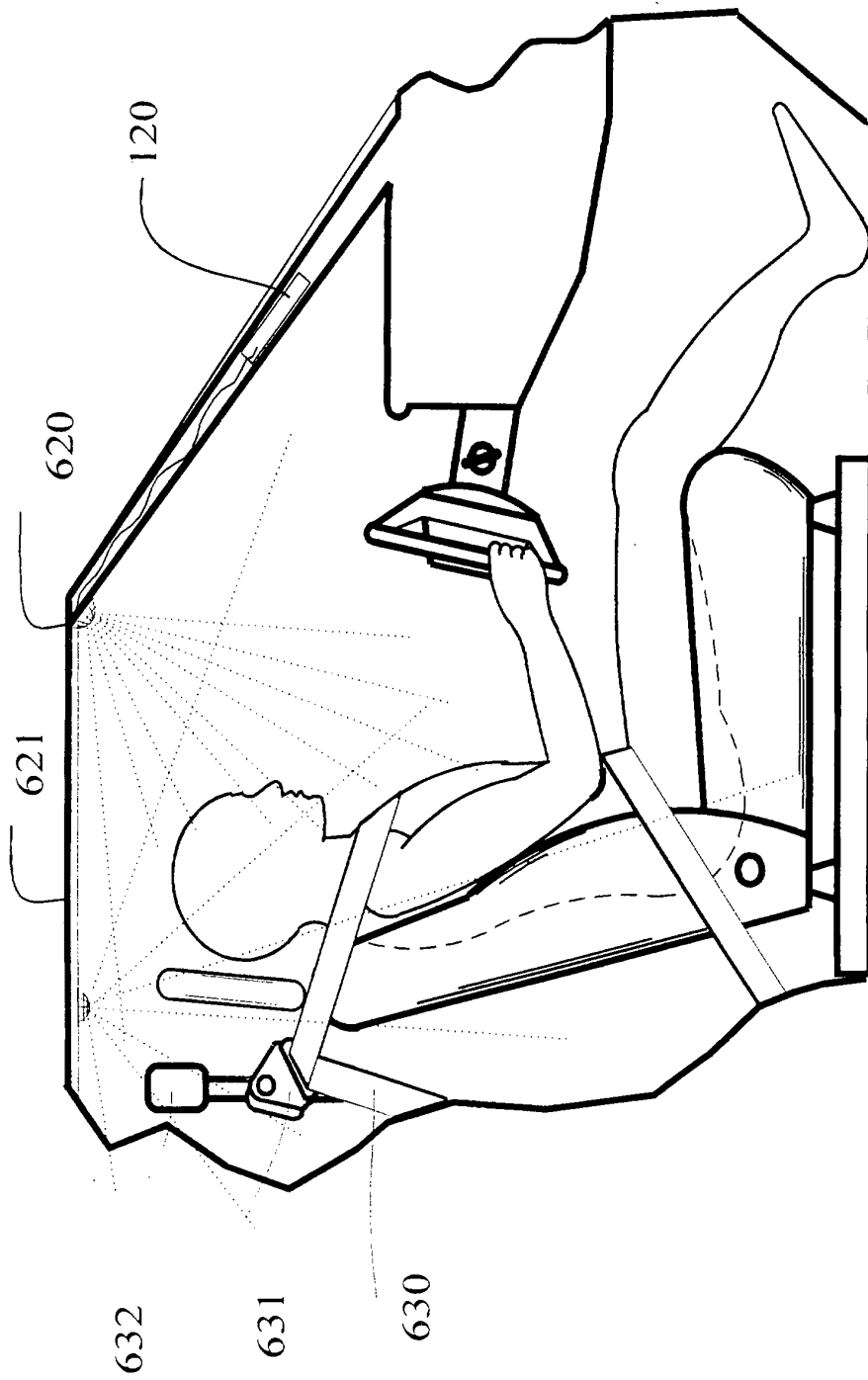


FIG. 6

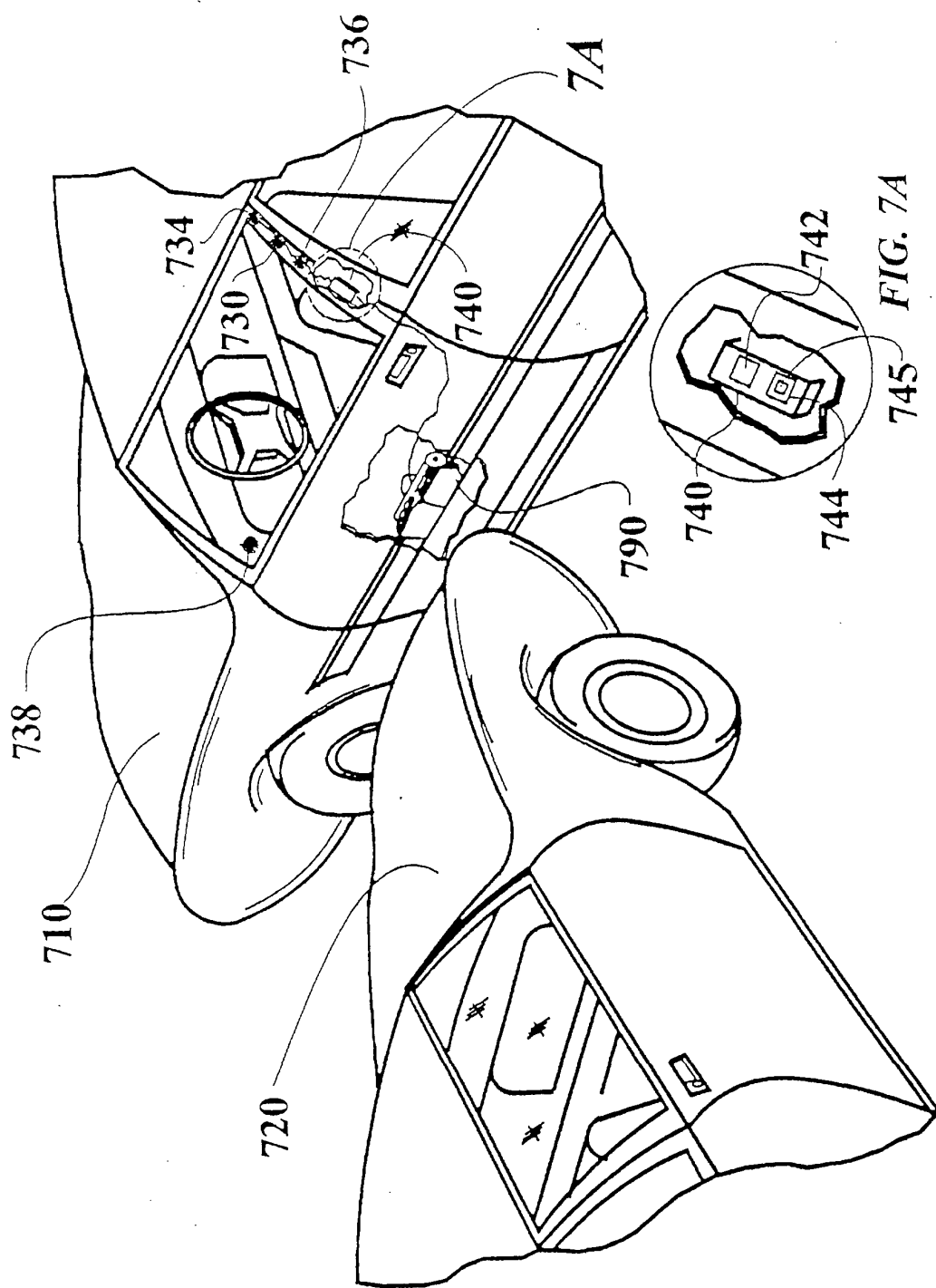


FIG. 7

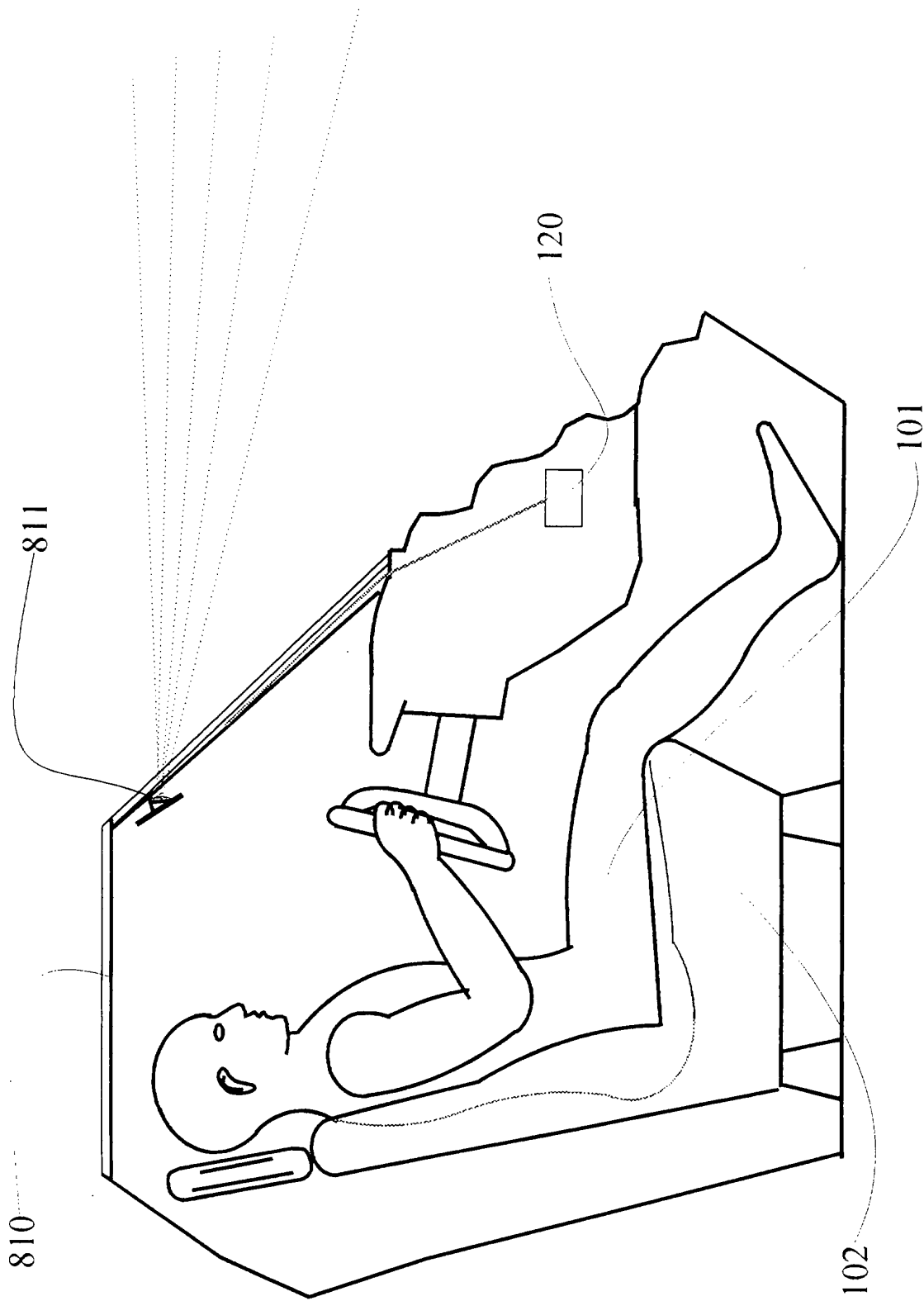


FIG. 8



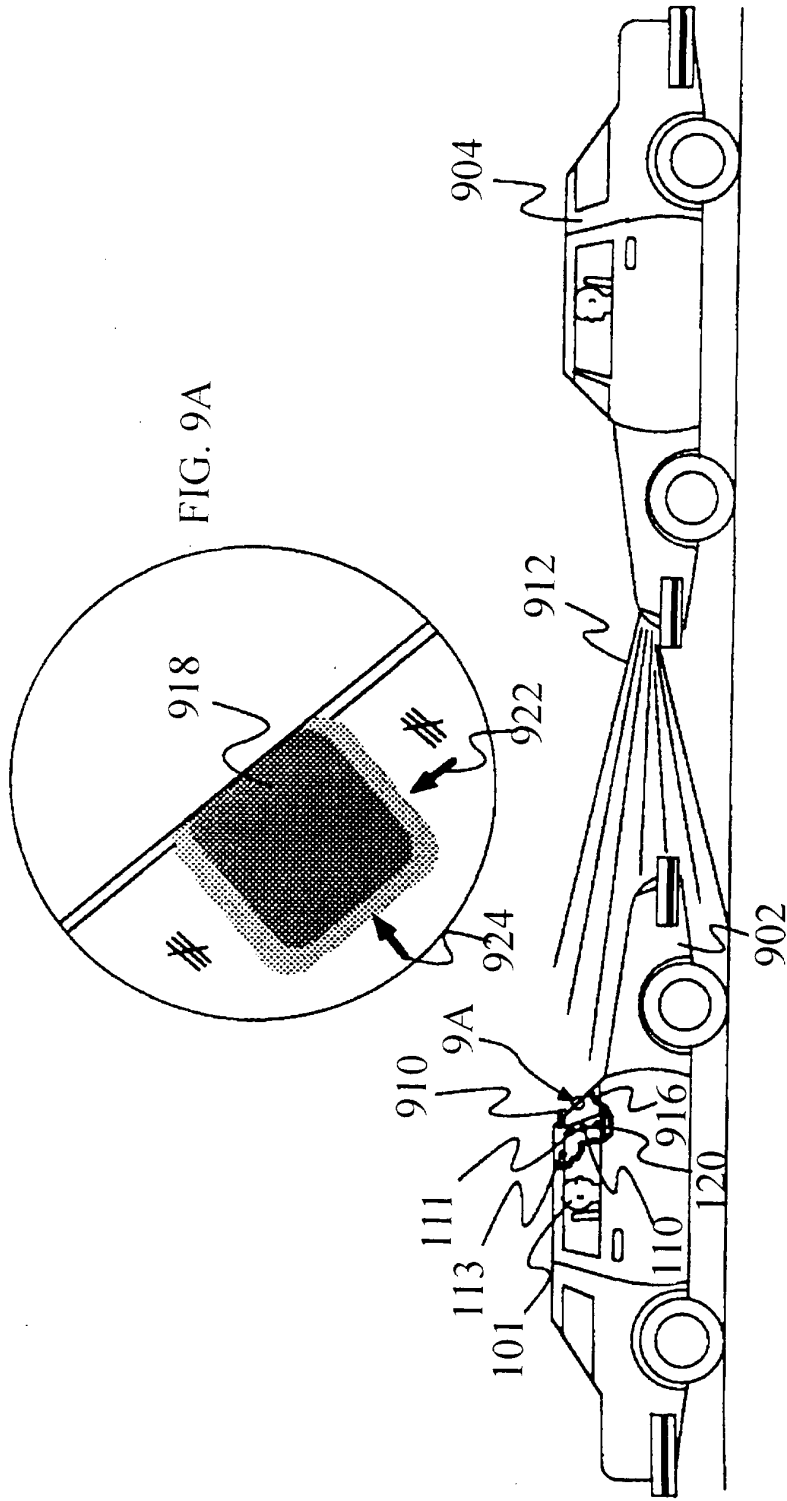


FIG. 9

FIG. 10

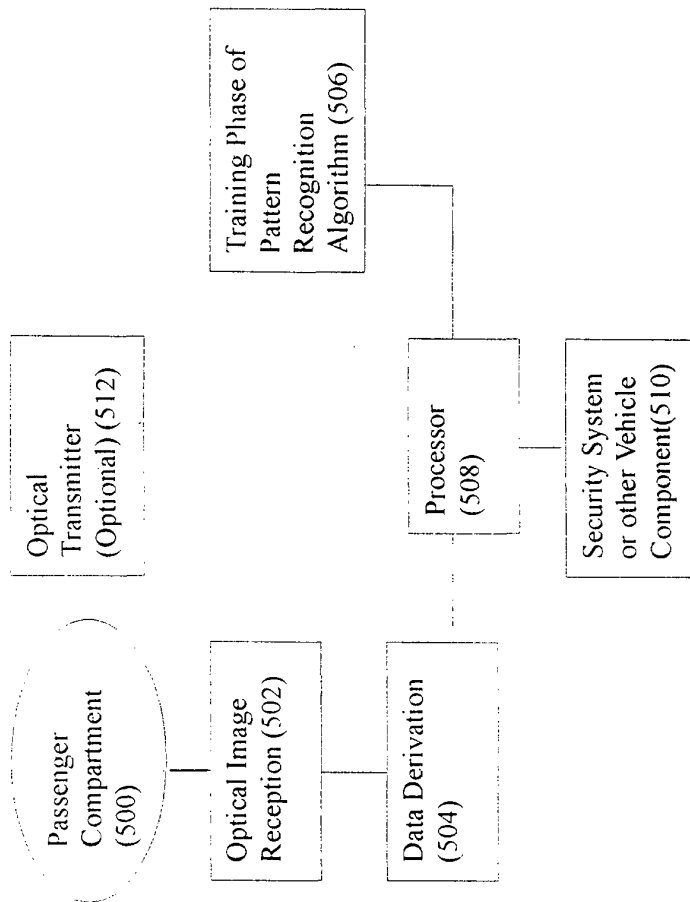
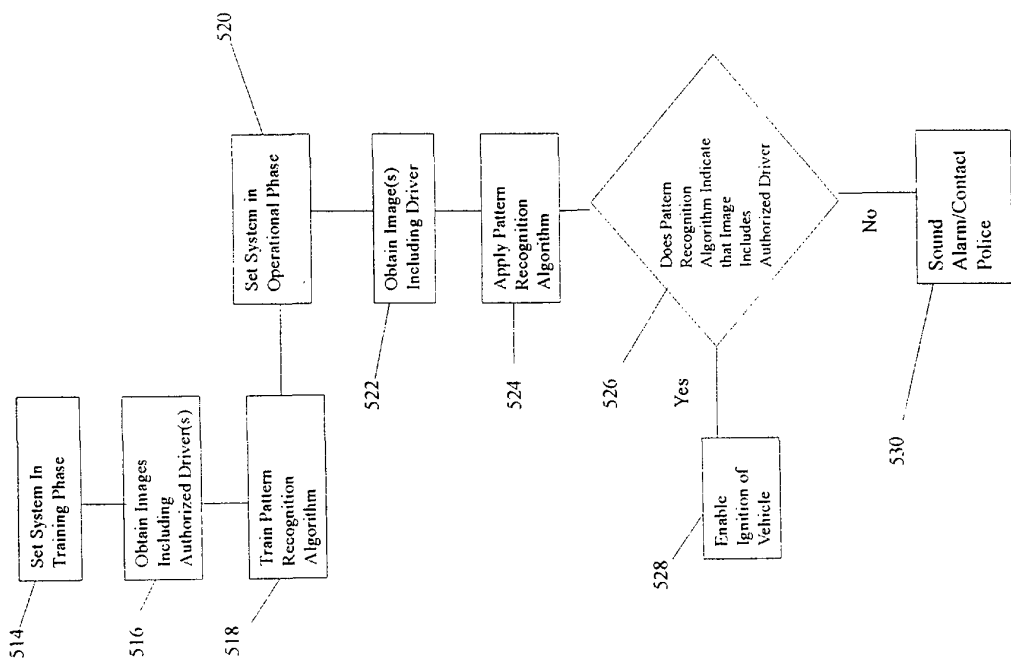


FIG. 11



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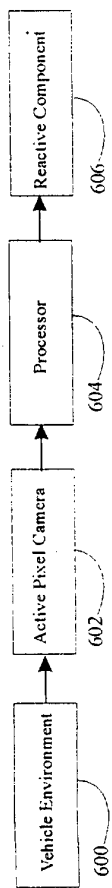


FIG. 12

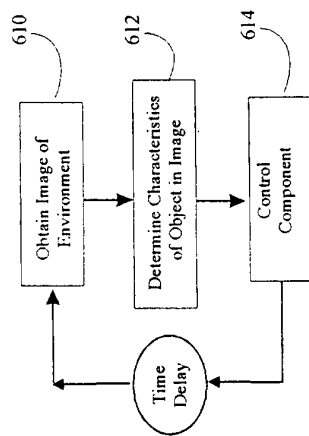


FIG. 13

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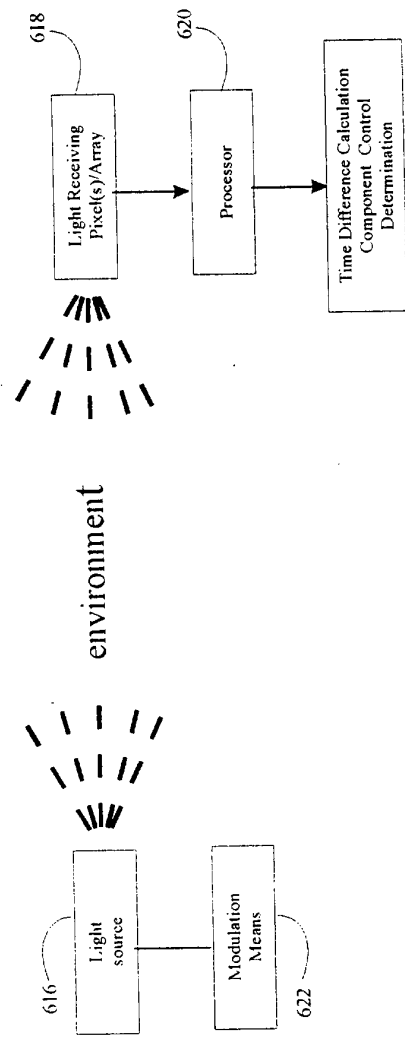
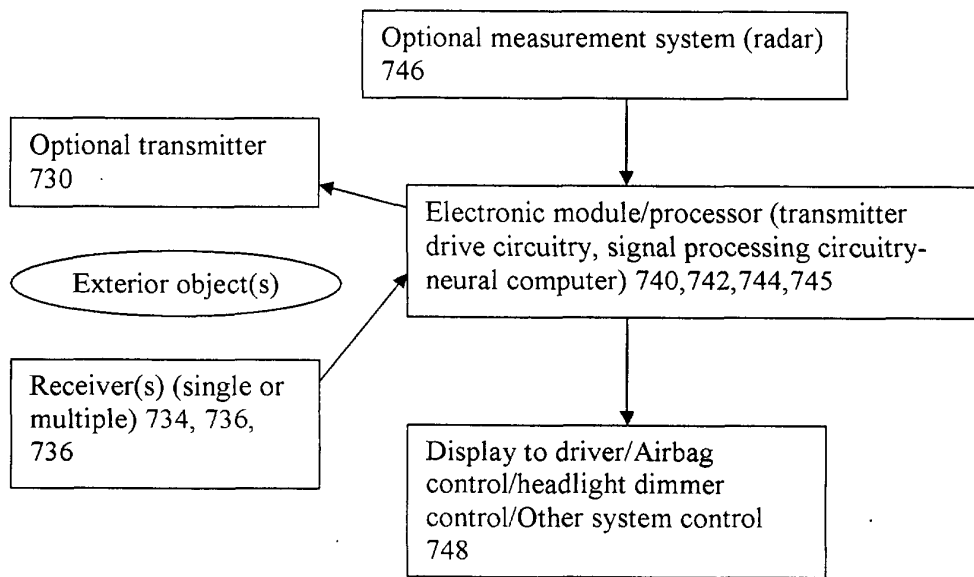


FIG. 14

FIG. 15

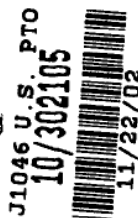


Attorney Docket No. ATI-338

**UNITED STATES PATENT AND TRADEMARK OFFICE**

Re: Application of: David S. Breed et al.  
Serial No.: Not yet known  
Filed: November 22, 2002  
For: VEHICULAR MONITORING SYSTEMS  
USING IMAGE PROCESSING

# 2  
3-18-02  
DRS



**INFORMATION DISCLOSURE STATEMENT**

Honorable Commissioner for Patents  
Washington, D.C. 20231

November 22, 2002

Sir:

Applicants herewith submit a list of references including those cited during the prosecution of the parent applications, U.S. patent application Serial Nos. 10/116,808, 09/925,043, 09/838,919, 09/765,559, 09/476,255, 09/389,947, 09/200,614 and 08/474,786, those cited in the specification and other references of which one or more of the applicants is aware. A copy of each of the references can be found in one or more of the parent applications or is enclosed herewith.

The relevance of some of the references is discussed in the background of the invention section of the application.

This submission does not represent that a search has been made or that no better prior art exists. While the term "reference" is used in citing each of the publications called to the Examiner's attention herein, applicants do not make any admission that each or all of them are "prior art" references within the meaning of the statutory and case law.

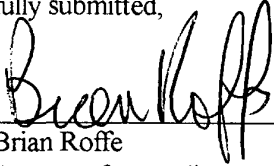
Applicants reserve the right to contend, where appropriate, that a reference asserted against any claim of the present application is not prior art under the facts and the law.

Applicants also reserve the right to present appropriate arguments and/or evidence to establish patentability over the references, should one or more of the references be applied against the claims of the present application.

Applicants respectfully request that the Examiner independently determine those items that the Examiner would consider the most pertinent of all the references cited herein.

It is respectfully requested that these references be considered and made of record.

Respectfully submitted,

By:   
Brian Roffe  
Attorney for Applicants  
Reg. No. 35,336

Brian Roffe, Esq.  
366 Longacre Avenue  
Woodmere, New York 11598-2417  
Tel.: (516) 295-1394  
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Enclosures  
PTO-1449 (3 pages)  
1 Reference





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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/302,105	11/22/2002	David S. Breed	ATI-338	2206

22846 7590 09/03/2003

BRIAN ROFFE, ESQ  
11 SUNRISE PLAZA, SUITE 303  
VALLEY STREAM, NY 11580-6170

EXAMINER

TO, TUAN C

ART UNIT PAPER NUMBER

3663

DATE MAILED: 09/03/2003

Please find below and/or attached an Office communication concerning this application or proceeding.



**DETAILED ACTION**

***Claim Rejections - 35 USC § 102***

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for a patent.

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

(e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraphs (1), (2), and (4) of section 371(c) of this title before the invention thereof by the applicant for patent.

**Claims 1-6, 13-15, 30-36, 40-44, 54, 55, 58, 59, 61, 62, 70, 77, 80, and 81 are rejected under 35 U.S.C. 102(b) as being anticipated by Schofield et al. (US 5877897A).**

Claims 1, 30, 40, 54, 55, and 77: The U.S reference to Schofield et al. has been cited as disclosing a system and method for controlling a plurality of reflectance mirrors, including not only a rear view mirror but also the side view mirrors (See figure 2, 4, and 5). Schofield et al. teach that the photo sensor array acts like a receiver as claimed in claim1 to receive waves from the environment exterior of the vehicle. Said photo sensor array 32 is used by the logic and control circuit 34 (see figure 6A of Schofield et al.) to determine the presence of a vehicle or other object within the field of view of the photo sensor array 32. Based on the teaching of Schofield et al., the processing unit 34 (figure 6A) is coupled with the photo sensor array 32 using a pattern recognition means

(see column 11, lines 45-64). In addition, in response to the appearance of an object or vehicle in the field of view, a visual signal or an audible signal warning is provided.

Claims 2 and 32: As clearly explained in the patent, the photo sensor array 32 monitors the vehicle interior or compartment in a vehicle interior if it is located at the rear view mirror, and also the photo sensor array 32 monitors the vehicle exterior or outside view of the vehicle if said sensor array is located at the side view mirrors 4 and 5 as shown in figure 2 of the patent. Thus, each photo sensor arrays located at each side view mirror is spaced apart from one another.

Claims 3, 33, 42, and 80: The photo sensor array 32 as mentioned in the patent is able to receive the infrared waves.

Claims 4, 34, 43, 58, 59, 70, and 81: The photo sensor array 32 performs the act of transmitting the signal to and receiving the signal from the exterior object or other vehicle that is in the field of view of the photo sensor array.

Claims 5, 6, 35, 36, and 44: In column 11, lines 32-44, Schofield et al teach that the photo sensor array 32 involves using a pattern recognition means.

Claims 13-15, 31, 41: Referring to figure 6 of Schofield et al, there is shown a processor 34 for processing the input signals from the photo sensor arrays 32.

Claims 61 and 62: In the Schofield et al's, the photo sensor arrays could be located at the rear view mirror or the side view mirrors.

***Claim Rejections - 35 USC § 103***

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(f) or (g) prior art under 35 U.S.C. 103(a).

**Claims 7, 9, 10, 38, 39, 46, 48, 49, 60, 63, 72, 82, and 84 are rejected under 35 U.S.C. 103(a) as being unpatentable over Schofield et al. (US 5877897A) and in view of Schofield et al. (US 5949331A).**

Claims 7, 46, 60, 72, and 83: Schofield et al. ('897A) disclose all of the limitation recited in claim 1 except for the display viewable by the driver and arranged to show an image or icon of the exterior object. Schofield et al. ('331A) is provided to overcome the missing features from Schofield et al. ('897A) by teaching a vision system that includes an image capture device. And a display informs the user about the image of the

exterior object. It would have been obvious to one having ordinary skill in the art at the time the invention was made to combine the teachings of both Schofield et al. in order to notify the driver about the appearance of an object that may be at the warning distance from the vehicle.

Claims 9, 10, 38, 39, 48, 49, 63, and 84: In column 11, lines 17-27, Schofield et al. ('331A) teach that a separate distance-measuring system may be used for measuring the distance between the exterior object and the vehicle. Such the distance-measuring system may include radar, ultrasonic sensing.

**Claims 8, 16-21, 27-29, 33, 47, 65, 66, 69, and 73 are rejected under 35 U.S.C. 103(a) as being unpatentable over Schofield et al. (US 5877897A) and in view of DeLine et al. (US 6087953A).**

Claims 8, 16-18, 37, 47, 65, 66, and 69: As discussed in the previous paragraph, Schofield et al. reference discloses all features as claimed except for the teaching of CCD array. The secondary reference to Deline et al. has been cited for disclosing the image sensor array could be a CCD array, which can be incorporated within the rear view mirror assembly. It would have been obvious to one having ordinary skill in the art at the time the invention was made to substitute the CCD array to the photo sensor array of Schofield in order to detect the images of an object or the images of a vehicle in the field of view of the array as a detector.

Claim 19: The photo sensor array 32 performs the act of transmitting the signal to and receiving the signal from the exterior object or other vehicle that is in the field of view of the photo sensor array.

Claims 20 and 21: In column 11, lines 32-44, Schofield et al teach that the photo sensor array 32 involves using a pattern recognition means.

Claims 27-29: Referring to figure 6 of Schofield et al, there is shown a processor 34 for processing the input signals from the photo sensor arrays 32.

Claims 73: In the Schofield et al's, the photo sensor arrays could be located at the rear view mirror or located at the side view mirrors.

**Claims 11, 12, 50, 51, 64, and 85 are rejected under 35 U.S.C. 103(a) as being unpatentable over Schofield et al. (US 5877897A) and in view of Cho (US 5959552A).**

With respect to the subject matter of said claims, the Cho reference has been cited as teaching the restraint system to minimize the damage and personal injury. The system of Cho is provided to fill the gap of the Schofield et al. According to Cho, the airbag system is deployed properly in order to protect the vehicle occupants from injury. It would have been obvious to one having ordinary skill in the art at the time the invention was made to combine the teachings of Schofield et al. and Cho to provide the safety for driver and passengers when the vehicle is traveling on the road.

**Claims 22-24, and 75 are rejected under 35 U.S.C. 103(a) as being unpatentable over Schofield et al. (US 5877897A), DeLine et al. (US 6087953A), and further in view of Schofield et al. (US 5949331A).**

Claim 22: As shown above, the combination of Schofield et al. ('897A) and Deline et al. discloses all of the limitation recited in claim 16 except for the display viewable by the driver and arranged to show an image or icon of the exterior object. Schofield et al.

('331A) is provided to overcome the missing features from said combination by teaching a vision system that includes an image capture device. And a display informs the user about the image of the exterior object. It would have been obvious to one having ordinary skill in the art at the time the invention was made to combine the teachings of both Schofield et al. in order to notify the driver about the appearance of an object that may be at the warning distance from the vehicle.

Claims 23, 24, and 75: In column 11, lines 17-27, Schofield et al. ('331A) teach that a separate distance-measuring system may be used for measuring the distance between the exterior object and the vehicle. Such the distance-measuring system may include radar, ultrasonic sensing.

**Claims 25, 26, and 76 are rejected under 35 U.S.C. 103(a) as being unpatentable over Schofield et al. (US 5877897A), DeLine et al. (US 6087953A), and further in view of Cho (US 5959552A).**

With respect to the subject matter of claims 25, 26, and 76, the U.S Patent No. '552A to Cho has been cited as teaching the restraint system to minimize the damage and personal injury. The system of Cho is provided to fill the gap of the Schofield et al. and Deline et al. combination. According to Cho, the airbag system is deployed properly in order to protect the vehicle occupants from injury. It would have been obvious to one having ordinary skill in the art at the time the invention was made to combine the teachings of Schofield et al. and Cho to provide the safety for driver and passengers when the vehicle is traveling on the road.



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Art Unit: 3663

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**Allowable Subject Matter**

Due to none of the references has been found teaches or fairly suggests the monitoring arrangement for monitoring an environment exterior of the vehicle, comprising at least one receiver arranged on a B-pillar of the vehicle to receive waves from the environment exterior of and on the side of the vehicle as claimed. Thus, claims 52, and 53 are allowable.

Claims 56, 57, 67, 68, 71, 74, 79, and 82 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

*Thomas M. [Signature]*  
T. M. [Signature]  
SUPERVISOR [Signature]  
GROUP 2600

<b>Notice of References Cited</b>	Application/Control No. 10/302,105	Applicant(s)/Patent Under Reexamination BREED ET AL.	
	Examiner Tuan C To	Art Unit 3663	Page 1 of 1

**U.S. PATENT DOCUMENTS**

*	Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
A	US-5959367A	09-1999	O'Farrell et al.	307/10.1
B	US-5877897A	03-1999	Schofield et al.	359/604
C	US-5949331A	09-1999	Schofield et al.	340/461
D	US-5497305A	03-1996	Pastrick et al.	362/83.1
E	US-5309137A	05-1994	Kajiwara	340/436
F	US-5463384A	10-1995	Juds	340/903
G	US-5473515A	12-1995	Liu	362/80.1
H	US-5706144	01-1998	Brandin	359/843
I	US-20020154379A1	10-2002	Tonar et al.	359/267
J	US-6087953A	07-2000	Deline et al.	340/815.4
K	US-			
L	US-			
M	US-			

**FOREIGN PATENT DOCUMENTS**

*	Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
N					
O					
P					
Q					
R					
S					
T					

**NON-PATENT DOCUMENTS**

*	Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
U	
V	
W	
X	

\*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)  
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

LIST OF REFERENCES CITED

Page 1 of 3

Attorney Docket No.

ATI-338

Serial No.:

Examiner: *TRAV C TD*

Filed:

November 22, 2002

Inventors:

David S. Breed et al.

Title:

Vehicular Monitoring Systems Using Image Processing

J11046 U.S. PTO  
10/302105  
11/22/02

Check		Patent No.	Date	Name	Class	Subclass
<input checked="" type="checkbox"/>	AA	4,496,222	1/1985	Shah	3592	300
<input type="checkbox"/>	AB	4,625,329	11/1986	Ishikawa et al.	382	104
<input type="checkbox"/>	AC	4,648,052	3/1987	Friedman et al.	364	550
<input type="checkbox"/>	AD	4,720,189	1/1988	Heynen et al.	351	210
<input type="checkbox"/>	AE	4,768,088	8/1988	Ando	358	93
<input type="checkbox"/>	AF	4,836,670	6/1989	Hutchinson	351	210
<input type="checkbox"/>	AG	4,881,270	11/1989	Knecht et al.	382	17
<input type="checkbox"/>	AH	4,906,940	3/1990	Greene et al.	382	16
<input type="checkbox"/>	AI	4,950,069	8/1990	Hutchinson	351	210
<input type="checkbox"/>	AJ	4,966,388	10/1990	Warner et al.	280	730
<input type="checkbox"/>	AK	5,003,166	3/1991	Girod	250	201.4
<input type="checkbox"/>	AL	5,008,946	4/1991	Ando	382	2
<input type="checkbox"/>	AM	5,026,153	6/1991	Suzuki et al.	356	1
<input type="checkbox"/>	AN	5,060,278	10/1991	Fukumizu	382	157
<input type="checkbox"/>	AO	5,062,696	11/1991	Oshima et al.	359	554
<input type="checkbox"/>	AP	5,064,274	11/1991	Alten	359	604
<input type="checkbox"/>	AQ	5,071,160	12/1991	White et al.	280	735
<input type="checkbox"/>	AR	5,074,583	12/1991	Fujita et al.	280	735
<input type="checkbox"/>	AS	5,103,305	4/1992	Watanabe	358	105
<input type="checkbox"/>	AT	5,118,134	6/1992	Mattes et al.	280	735
<input type="checkbox"/>	AU	5,162,861	11/1992	Tamburino et al.	356	5.05
<input type="checkbox"/>	AV	5,181,254	1/1993	Schweizer et al.	382	1
<input type="checkbox"/>	AW	5,185,667	2/1993	Zimmermann	348	143
<input type="checkbox"/>	AX	5,193,124	3/1993	Subbarao	382	41
<input type="checkbox"/>	AY	5,214,744	5/1993	Schweizer et al.	395	21
<input type="checkbox"/>	AZ	5,227,784	7/1993	Masamori et al.	340	903
<input type="checkbox"/>	BA	5,235,339	8/1993	Morrison et al.	342	159
<input type="checkbox"/>	BB	5,249,027	9/1993	Mathur et al.	356	3.14
<input type="checkbox"/>	BC	5,249,157	9//1993	Taylor	340	903
<input type="checkbox"/>	BD	5,298,732	3/1994	Chen	250	203.4
<input type="checkbox"/>	BE	5,305,012	4/1994	Faris	345	7
<input type="checkbox"/>	BF	5,309,137	5/3/1994	Kajiwara	340	436
<input type="checkbox"/>	BG	5,329,206	7/1994	Slotkowski et al.	315	159
<input type="checkbox"/>	BH	5,330,226	7/1994	Gentry et al.	280	735
<input type="checkbox"/>	BI	5,339,075	8/16/1994	Abst et al.	340	903
<input checked="" type="checkbox"/>	BJ	5,355,118	10/1994	Fukuhara	340	435

LIST OF REFERENCES CITED

Attorney Docket No. ATI-338  
 Serial No.:  
 Examiner: *TUAN C TO*  
 Filed: November 22, 2002  
 Inventors: David S. Breed et al.  
 Title: Vehicular Monitoring Systems Using Image Processing

U.S. PATENT DOCUMENTS

Check	Patent No.	Date	Name	Class	Subclass
- ✓ -	BK	5,390,136	2/1995	Wang	364 754
-   -	BL	5,441,052	8/1995	Miyajima	128 661.09
-   -	BM	5,446,661	8/1995	Gioutsos et al.	364 424.05
-   -	BN	5,454,591	10/1995	Mazur et al.	280 735
-   -	BO	5,482,314	1/1996	Corrado et al.	280 735
-   -	BP	5,528,698	6/1996	Kamei et al.	382 100
-   -	BQ	5,531,472	7/1996	Semchena et al.	280 735
-   -	BR	5,537,003	7/1996	Bechtel et al.	315 82
-   -	BS	5,550,677	8/1996	Schofield et al.	359 604
-   -	BT	5,563,650	10/1996	Poelstra	348 36
-   -	BU	5,653,462	8/1997	Breed et al.	280 735
-   -	BV	5,785,347	7/1998	Adolph et al.	280 735
-   -	BW	5,821,633	10/1998	Burke et al.	307 10.1
-   -	BX	5,829,782	11/1998	Breed et al.	280 735
-   -	BY	5,835,613	11/1998	Breed et al.	382 100
-   -	BZ	5,845,000	12/1998	Breed et al.	382 100
-   -	CA	5,848,802	12/1998	Breed et al.	280 735
-   -	CB	5,943,295	8/1999	Varga et al.	367 99
-   -	CC	5,954,360	9/1999	Griggs, III et al.	280 735
-   -	CD	5,983,147	11/1999	Krumm	701 45
-   -	CE	6,005,958	12/1999	Farmer et al.	382 103
-   -	CF	6,007,095	12/1999	Stanley	280 735
-   -	CG	6,020,812	2/2000	Thompson et al.	340 438
-   -	CH	6,027,138	2/2000	Tanaka et al.	280 735
-   -	CI	6,029,105	2/2000	Schweizer	701 45
-   -	CJ	6,111,517	8/2000	Atick et al.	340 825.34
-   -	CK	6,113,137	9/2000	Mizutani et al.	280 735
-   -	CL	6,115,552	9/2000	Kaneda	396 82

Foreign Patent Documents

	Number	Date	Country	Class	Subclass
-   -	CM	3-42337	2/1991	Japan	180 273
-   -	CN	94/22693	10/1994	W.I.P.O.	
-   -	CO	2289332	11/1995	Great Britain	
-   -	CP	0885782	12/1998	E.P.O.	
-   -	CQ	JP-360166806	8/1985	Japan-Ishikawa	
-   -	CR	JP-407055573A	3/1995	Japan-Hashimoto	
-   -	CS	0196147	12/2001	WIPO	
- ✓ -	CT	2001-325700	11/2001	Japan	

LIST OF REFERENCES CITED

Page 3 of 3

Attorney Docket No. ATI-338  
 Serial No.  
 Examiner: *THAN C TO*  
 Filed: November 22, 2002  
 Inventors: David S. Breed et al.  
 Title: Vehicular Monitoring systems Using Image Processing

Other Prior Art

- DA "Analysis of Hidden Units in a Layered Network Trained to Classify Sonar Targets", R. Paul Gorman, et al., Neural Networks, Vol. 1, pp.75-89, 1988.
- DB "Learned Classification of Sonar Targets Using a Massively Parallel Network, R. Paul Gorman et al., IEEE Transactions on Acoustics, Speech and Signal Processing, Vol. 36, No. 7, July, 1988, pp1135-1140.
- DC "How Airbags Work", David S. Breed, Presented at the Canadian Association of Road Safety Professionals, 10/19/92-10/20/92.
- DD Intelligent System for Video Monitoring of Vehicle Cockpit, S. Boverie et al., SAE Paper No. 980613, February, 1998.
- DE Omnidirectional Vision Sensor for Intelligent Vehicles, T. Ito et al., 1998 IEEE International Conference on Intelligent Vehicles, pages 365-370, 1998.
- DF A 256x256 CMOS Brightness Adaptive Imaging Array with Column-Parallel Digital Output, C. Sodini et al., 1998 IEEE International Conference on Intelligent Vehicles, 1998, pages 347-352.
- DG Derwent Abstract of German Patent Publication No. DE 42 11 556, October 7, 1993.
- DH Derwent Abstract of Japanese Patent Application No. 02-051332, November 13, 1991
- DI 3D Perception for Vehicle Inner Space Monitoring, S. Boverie et al., Advanced Microsystems for Automotive Applications 2000, April, 2000, pages 157-172.
- DJ Low-Cost High Speed CMOS Camera for Automotive Applications, N. Stevanovic et al., Advanced Microsystems for Automotive Applications 2000, April, 2000, pages 173-180.
- DK New Powerful Sensory Tool in Automotive Safety Systems Based on PMD-Technology, R. Schwarte et al., Advanced Microsystems for Automotive Applications 2000, April, 2000, pages 181-203.
- DL An Interior Compartment Protection System Based on Motion Detection Using CMOS Imagers, S. B. Park et al., 1998 IEEE International Conference on Intelligent Vehicles.
- DM Sensing Automobile Occupant Position with Optical Triangulation, W. Chapelle et al., Sensors, December 1995.
- DN Intelligent System for Video Monitoring of Vehicle Cockpit, S. Boverie et al., SAE Paper No. 980613, February 23-26, 1998.
- DO A 256x256 CMOS Brightness Adaptive Imaging Array with Column-Parallel Digital Output, CG. Sodini et al., 1998 IEEE International Conference on Intelligent Vehicles.
- DP The FERET Evaluation Methodology for Face-Recognition Algorithms, P.J. Phillips et al., NISTIR 6264, January 7, 1999.
- DQ The Technology Review Ten: Biometrics, J. Atick, January/February 2001



Amend A 3663  
C. Burns  
01/07/04

Attorney Docket No. ATI-338

**UNITED STATES PATENT AND TRADEMARK OFFICE**

Examiner: To, Tuan C.	Art Unit: 3663
Re: Application of:	David S. Breed et al.
Serial No.:	10/302,105
Confirmation No.:	2206
Filed:	November 22, 2002
For:	Vehicular Monitoring Systems Using Image Processing
Customer No.:	22846

**RECEIVED**  
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**GROUP 3600**

**AMENDMENT**

Mail Stop With Fee Amendment  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

December 3, 2003

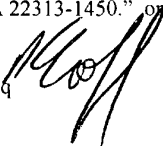
Dear Sir:

In response to the Office Action dated September 3, 2003 which set a three month shortened statutory period for reply expiring on December 3, 2003, please amend the above-identified application as follows:

**Amendments to the claims** are reflected in the listing of claims which begins on page 2 of this paper.

**Remarks/Arguments** begin on page 15 of this paper.

I hereby certify that this correspondence and/or fee is being deposited as first class mail with the United States Postal Service in a postage-paid envelope addressed to "Mail Stop With Fee Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450." on December 3, 2003.

Brian Roffe, Esq 

Appl. No. 10/302,105  
Amdt. dated December 3, 2003  
Reply to Office Action of September 3, 2003

**Amendments to the claims**

Please replace the previous listing of claims with the following listing of claims.

**Listing of Claims:**

1. (Currently Amended) A monitoring arrangement for monitoring an environment exterior of a vehicle, comprising:

at least one receiver arranged to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and comprising trained pattern recognition means for processing the signal to provide a classification, identification or location of the exterior object, said trained pattern recognition means being structured and arranged to apply a trained pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects to provide the classification, identification or location of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

2. (Original) The arrangement of claim 1, wherein said at least one receiver comprises a pair of receivers spaced apart from one another.

3. (Original) The arrangement of claim 1, wherein said at least one receiver is arranged to receive infrared waves.

4. (Original) The arrangement of claim 1, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said at least one receiver is arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

5. (Currently Amended) The arrangement of claim 1, wherein said trained pattern recognition means comprise a neural computer.

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Reply to Office Action of September 3, 2003

6. (Original) The arrangement of claim 1, wherein said trained pattern recognition means comprise a neural network.

7. (Original) The arrangement of claim 1, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

8. (Original) The arrangement of claim 1, wherein said at least one receiver is a CCD array.

9. (Original) The arrangement of claim 1, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

10. (Original) The arrangement of claim 9, wherein said measurement means comprise a radar or laser radar system.

AI  
control  
11. (Currently Amended) The arrangement of claim 1, wherein the another system is an airbag, said pattern recognition means being structured and arranged to apply the pattern recognition algorithm to provide the identification of the exterior object, deployment of said airbag being controlled based on the identification of the exterior object.

12. (Original) The arrangement of claim 11, wherein the airbag is an externally deployed airbag.

13. (Original) The arrangement of claim 1, wherein said processor is arranged to provide the classification of the exterior object.

14. (Original) The arrangement of claim 1, wherein said processor is arranged to provide the identification of the exterior object.

15. (Original) The arrangement of claim 1, wherein said processor is arranged to provide the location of the exterior object.



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16. (Currently Amended) A monitoring arrangement for monitoring an environment exterior of a vehicle, comprising:

at least one CCD array positioned to obtain images of the environment exterior of the vehicle;  
and

a processor coupled to said at least one CCD array and comprising trained pattern recognition means for processing the images obtained by said at least one CCD array to provide a classification, identification or location of the exterior object,

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

17. (Original) The arrangement of claim 16, wherein said pattern recognition means are structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and images from said at least one CCD array of the possible exterior objects.

18. (Original) The arrangement of claim 16, wherein said at least one CCD array comprises a pair of CCD arrays spaced apart from one another.

19. (Original) The arrangement of claim 16, wherein the monitoring arrangement further comprises a transmitter for transmitting infrared waves into the environment exterior of the vehicle.

20. (Original) The arrangement of claim 16, wherein said pattern recognition means comprise a neural computer.

21. (Original) The arrangement of claim 16, wherein said pattern recognition means comprise a neural network.

22. (Original) The arrangement of claim 16, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

23. (Original) The arrangement of claim 16, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

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24. (Original) The arrangement of claim 23, wherein said measurement means comprise a radar or laser radar system.

25. (Currently Amended) The arrangement of claim 16, wherein the another system is an airbag, said trained pattern recognition means being structured and arranged to process the images obtained by said at least one CCD array to provide the identification of the exterior object, deployment of said airbag being controlled based on the identification of the exterior object.

26. (Original) The arrangement of claim 25, wherein the airbag is an externally deployed airbag.

27. (Original) The arrangement of claim 16, wherein said processor is arranged to provide the classification of the exterior object.

28. (Original) The arrangement of claim 16, wherein said processor is arranged to provide the identification of the exterior object.

29. (Original) The arrangement of claim 16, wherein said processor is arranged to provide the location of the exterior object.

30. (Currently Amended) A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged on a rear view mirror of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and arranged to classify [[,]] or identify ~~or locate~~ the exterior object based on the signal and thereby provide the classification or identification of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification [[,]] or identify ~~or location~~ of the exterior object.

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31. (Currently Amended) The vehicle of claim 30, wherein said processor comprises trained pattern recognition means for processing the signal to provide the classification [[,]] or identification ~~or location~~ of the exterior object, said trained pattern recognition means being structured and arranged to apply a pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects.

32. (Original) The vehicle of claim 30, wherein said at least one receiver comprises a pair of receivers spaced apart from one another.

33. (Original) The vehicle of claim 30, wherein said at least one receiver is arranged to receive infrared waves.

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34. (Original) The vehicle of claim 30, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said at least one receiver is arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

35. (Original) The vehicle of claim [[30]] 31, wherein said trained pattern recognition means comprise a neural computer.

36. (Original) The vehicle of claim [[30]] 31, wherein said trained pattern recognition means comprise a neural network.

37. (Original) The vehicle of claim 30, wherein said at least one receiver is a CCD array.

38. (Original) The vehicle of claim 30, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

39. (Original) The vehicle of claim 38, wherein said measurement means comprise a radar or laser radar system.

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40. (Currently Amended) A monitoring arrangement for monitoring an environment exterior of a vehicle, comprising:

a plurality of receivers arranged apart from one another and to receive waves from different parts of the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said receivers and arranged to classify, identify or locate the exterior object based on the signals generated by said receivers and thereby provide the classification, identification or location of the exterior object,

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

41. (Currently Amended) The arrangement of claim 40, wherein said processor comprises trained pattern recognition means for processing the signal to provide the classification, identification or location of the exterior object, said trained pattern recognition means being structured and arranged to apply a trained pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects.

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42. (Original) The arrangement of claim 40, wherein said receivers are arranged to receive infrared waves.

43. (Original) The arrangement of claim 40, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said receivers are arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

44. (Currently Amended) The arrangement of claim ~~[[40]]~~ 41, wherein said trained pattern recognition means comprise a neural computer.

45. (Currently Amended) The arrangement of claim ~~[[40]]~~ 41, wherein said trained pattern recognition means comprise a neural network.

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46. (Original) The arrangement of claim 40, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

47. (Original) The arrangement of claim 40, wherein said receivers are CCD arrays.

48. (Original) The arrangement of claim 40, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

49. (Original) The arrangement of claim 48, wherein said measurement means comprise a radar or laser radar system.

50. (Currently Amended) The arrangement of claim 40, wherein the another system is an airbag, said processor being arranged to identify the exterior object to provide an identification of the exterior object, said output means being arranged to control deployment of said airbag based on the identification of the exterior object.

51. (Original) The arrangement of claim 50, wherein the airbag is an externally deployed airbag.

52. (Currently Amended) A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged on a B-pillar of the vehicle to receive waves from the environment exterior of and on the side of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and arranged to classify, identify or locate the exterior object based on the signal and thereby provide the classification, identification or location of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

53. (Currently Amended) A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

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at least one receiver arranged in a door window trim panel of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and arranged to classify, identify or locate the exterior object based on the signal and thereby provide the classification, identification or location of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

<sup>55</sup>  
54. (Currently Amended) A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged on a rear view mirror of the vehicle to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves;

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a processor coupled to said at least one receiver and arranged to at least one of classify, identify [[or]] and locate the exterior object based on the signal and thereby provide at least one of the classification, identification and location of the exterior object; and

a display viewable by the driver; said display being coupled to and controlled by said processor ~~such that~~ to cause the display the presence and at least one of the classification, identification [[or]] and location of the exterior object is displayed on said display.

<sup>56</sup>  
55. (Currently Amended) A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one receiver arranged to receive waves from the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said at least one receiver and comprising trained pattern recognition means for processing the signal to provide a classification, identification or location of the exterior object, said trained pattern recognition means being structured and arranged to apply a trained pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects to provide the classification, identification or location of the exterior object;

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whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

56. (Original) The vehicle of claim 55, wherein said at least one receiver is arranged on a B-pillar of the vehicle to receive waves from a side of the vehicle.

57. (Original) The vehicle of claim 55, wherein said at least one receiver is arranged in a door window trim panel.

58. (Original) The vehicle of claim 55, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said at least one receiver is arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

59. (Original) The vehicle of claim 55, wherein said at least one receiver is arranged to receive waves from a blind spot of the vehicle.

60. (Original) The vehicle of claim 55, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

61. (Original) The vehicle of claim 55, wherein said at least one receiver is mounted on a rear view mirror or in a rear window.

62. (Original) The vehicle of claim 55, wherein said at least one receiver is mounted in a C-pillar of the vehicle.

63. (Original) The vehicle of claim 55, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

64. (Currently Amended) The vehicle of claim 55, wherein the another system is an airbag, said trained pattern recognition means being structured and arranged to apply the pattern

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recognition algorithm to provide the identification of the exterior object, deployment of said airbag being controlled based on the identification of the exterior object.

<sup>66</sup>65. (Currently Amended) A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

at least one CCD array positioned to obtain images of the environment exterior of the vehicle;  
and

a processor coupled to said at least one CCD array and comprising trained pattern recognition means for processing the images obtained by said at least one CCD array to provide a classification, identification or location of the exterior object, said trained pattern recognition means being structured and arranged to apply a trained pattern recognition algorithm generated from data of possible exterior objects and images obtained by said at least one CCD array from the possible exterior objects to provide the classification, identification or location of the exterior object;

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

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66. (Canceled)

<sup>67</sup>67. (Original) The vehicle of claim <sup>65</sup>65, wherein said at least one CCD array is arranged on a B-pillar of the vehicle to obtain images from a side of the vehicle.

<sup>68</sup>68. (Original) The vehicle of claim <sup>65</sup>65, wherein said at least one CCD array is arranged in a door window trim panel.

<sup>69</sup>69. (Original) The vehicle of claim <sup>65</sup>65, wherein said at least one CCD array comprises a pair of CCD arrays spaced apart from one another.

<sup>70</sup>70. (Original) The vehicle of claim <sup>65</sup>65, wherein the monitoring arrangement further comprises a transmitter for transmitting infrared waves into the environment exterior of the vehicle.

<sup>71</sup>71. (Original) The vehicle of claim <sup>65</sup>65, wherein said at least one CCD array is arranged to obtain images from a blind spot of the vehicle.



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72. (Original) The vehicle of claim <sup>65</sup>65, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

73. (Original) The vehicle of claim <sup>65</sup>65, wherein said at least one CCD array is mounted on a rear view mirror or in a rear window.

74. (Original) The vehicle of claim <sup>65</sup>65, wherein said at least one CCD array is mounted in a C-pillar of the vehicle.

75. (Original) The vehicle of claim <sup>65</sup>65, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

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76. (Currently Amended) The vehicle of claim <sup>65</sup>65, wherein the another system is an airbag, said trained pattern recognition means being arranged to process the images obtained by said at least one CCD array to provide the identification of the exterior object, deployment of said airbag being controlled based on the identification of the exterior object.

77. (Currently Amended) A vehicle including a monitoring arrangement for monitoring an environment exterior of the vehicle, the monitoring arrangement comprising:

a plurality of receivers arranged apart from one another and to receive waves from different parts of the environment exterior of the vehicle which contain information on any objects in the environment and generate a signal characteristic of the received waves; and

a processor coupled to said receivers and arranged to classify, identify or locate the exterior object based on the signals generated by said receivers to provide the classification, identification or location of the exterior object,

whereby a system in the vehicle is coupled to said processor such that the operation of the system is affected in response to the classification, identification or location of the exterior object.

78. (Currently Amended) The vehicle of claim 77, wherein said processor comprises trained pattern recognition means for processing the signal to provide the classification, identification or

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location of the exterior object, said pattern recognition means being structured and arranged to apply a pattern recognition algorithm generated.

79. (Original) The vehicle of claim 77, wherein said receivers are arranged on a B-pillar of the vehicle to receive waves from a side of the vehicle.

80. (Original) The vehicle of claim 77, wherein said receivers are arranged to receive infrared waves.

81. (Original) The vehicle of claim 77, wherein the monitoring arrangement further comprises a transmitter for transmitting waves into the environment exterior of the vehicle whereby said receivers are arranged to receive waves transmitted by said transmitter and reflected by any exterior objects.

82. (Original) The vehicle of claim 77, wherein said receivers are arranged to receive waves from a blind spot of the vehicle.

83. (Original) The vehicle of claim 77, wherein the another system is a display viewable by the driver and arranged to show an image or icon of the exterior object.

84. (Original) The vehicle of claim 77, further comprising measurement means for measuring a distance between the exterior object and the vehicle.

85. (Currently Amended) The vehicle of claim 77, wherein the another system is an airbag, said processor being arranged to identify the exterior object to provide the identification of the exterior object, said output means being arranged to control deployment of said airbag based on the identification of the exterior object.

86. (New) The monitoring arrangement of claim 40, wherein said processor is arranged to classify or identify the exterior object based on the signals generated by said receivers and thereby provide the classification or identification of the exterior object.

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87. (New) The vehicle of claim 77, wherein said processor is arranged to classify or identify the exterior object based on the signals generated by said receivers and thereby provide the classification or identification of the exterior object.

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**REMARKS/ARGUMENTS**

Entry of this amendment and reconsideration of the present application as amended is respectfully requested.

Claims 1-65, 67-85 and new claims 86 and 87 are pending in this application, claim 66 having been canceled. Claims 1-51, 54, 55, 58-66, 69, 70, 72, 73, 75-78, 80, 81 and 83-85 are rejected. Claims 52 and 53 are allowed. Claims 56, 57, 67, 68, 71, 74, 79 and 82 are objected to but would be allowable if rewritten in independent form.

Claims 1, 5, 11, 16, 25, 30, 31, 40, 41, 44, 45, 50, 52-55, 64, 65, 76-78 and 85 are amended to clarify the invention. Unless an argument is made below relating to a specific change to one or more of these claims, the changes do not relate to patentability.

**Rejection under 35 U.S.C. §102**

Claims 1-6, 13-15, 30-36, 40-44, 54, 55, 58, 59, 61, 62, 70, 77, 80 and 81 were rejected under 35 U.S.C. §102(b) as being anticipated by Schofield et al. (U.S. Pat. No. 5,877,897). (Note that claim 70 depends from claim 65 which was not included in this rejection.)

The rejection is respectfully traversed, in part, in view of amendments to the claims.

With respect to claims 1-6, 55, 58, 59, 61 and 62, independent claims 1 and 55 are amended to specify that the processor comprises "trained pattern recognition means" which apply a trained pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects to provide the classification, identification or location of the exterior object. An essential feature of these embodiments of the invention is the trained pattern recognition system which is defined in the specification at page 5, lines 8-13 as a pattern recognition system which is taught various patterns by subjecting the system to a variety of examples. The manner in which a pattern recognition system is trained is described in the specification at page 41, line 21 to page 2, line 6.

One manner to form a trained pattern recognition system is to locate one possible exterior object in a first position relative to the receiver(s) and patterns of waves received by the receiver(s) are associated with the classification, identification and location of the object. The same object is moved to different positions and waves are received and associated with the classification, identification and location of the object. Then, the same procedure is repeated with different objects. The data obtained is entered into a pattern recognition generating program, such as a neural network generating program, to obtain as output, the "trained" pattern recognition system.

The use of such a trained pattern recognition system or trained neural network is described in the specification at page 15, lines 7-23 with reference to Fig. 15 (see in particular, lines 15-18).

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Schofield et al. describes a system for controlling the reflectance of mirrors which includes, among other things, a system which detects the presence of a vehicle or other object within the field of view of a photosensor array 32 (col. 14, lines 1-7). Mention is made that when using a larger photosensor array 32, a pattern recognition means is utilized to determine the appropriate centerline of the vehicle so that an appropriate portion of the photosensor array 32 may be selected depending on whether the rearview mirror system 20 is installed in a left or right hand system (col. 1, lines 38-44).

In contrast to the embodiments now set forth in claims 1 and 55, Schofield et al. does not disclose trained pattern recognition means which apply a trained pattern recognition algorithm generated from data of possible exterior objects and patterns of received waves from the possible exterior objects to provide the classification, identification or location of the exterior object. There is no disclosure of training the pattern recognition means in Schofield et al., i.e., using data of possible exterior objects for the purpose of determining the appropriate centerline of the vehicle. Moreover, the pattern recognition means of Schofield et al. are used only to determine the vehicle centerline when a larger photosensor array 32 is used. They are not used to provide a classification, identification or location of an exterior object.

In view of the absence of all of the features of claims 1 and 55 in Schofield et al., Schofield et al. cannot anticipate the embodiments of the invention set forth in claims 1-6, 13-15, 55, 58, 59, 61 and 62.

With respect to claims 30-36, independent claim 36 is amended to specify that the processor is arranged to classify or identify the exterior object based on the signal and thereby provide the classification or identification of the exterior object, the operation of a system in the vehicle being affected in response to the classification or identification of the exterior object.

In these embodiments, the classification or identification of the exterior objects is extremely useful in determining how the operation of the system should be affected. For example, if reflections from an exterior object at a distance from the vehicle are received (with the distance therebetween shrinking) is classified or identified as a sign post, which is usually stationary, then an airbag system will not typically be deployed because it will be assumed that the sign post is stationary and the road curves. Although the vehicle would be in a path to hit the sign post, the road will most likely curve away from the sign post so that the vehicle will not actually hit the sign post and deployment of the airbag is not desired. On the other hand, if the exterior object is classified or identified as a vehicle, then the airbag system will be readied for deployment if the reflections continue in a direction toward the vehicle.

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As can be seen from this relatively simple example, the classification or identification of the exterior object is important when considering how they affect a system in the vehicle because different objects will require different responses.

Schofield et al. describes providing information regarding the location and intensity of headlights of following vehicles (col. 28, lines 49-58). As such, Schofield et al. assumes that the objects providing light whose reflectance is appearing on the photosensor array 32 are headlights of a following vehicle. However, this may be entirely incorrect and the objects may be considerably different in which case, a different response may be required, e.g., not to activate the visual signal warning or audible warning (see col. 14, lines 1-7).

Thus, in contrast to the embodiment now set forth in claim 30, Schofield et al. does not disclose a processor arranged to classify or identify the exterior object based on the signal and thereby provide the classification or identification of the exterior object and therefore cannot anticipate the embodiments of the invention set forth in claims 30-36.

With respect to claims 40-44, 77, 81 and 81, independent claims 40 and 77 are amended to specify that a plurality of receivers are arranged apart from one another and to receive waves from "different parts of" the environment exterior of the vehicle.

In these embodiments, the multiple receivers are arranged apart from one another on the vehicle, with each receiver obtaining waves from a different part of the exterior environment.

Schofield et al. describes a single photosensor array 32 which receives waves from the vicinity of the vehicle. It is stated that the single photosensor array can be located in any of the mirrors on the vehicle to extend the effective field of view of the driver. Also, the photosensor array 32 can replace one or more of the side view mirrors 4,5. Thus, Schofield contemplates a single photosensor array 32 which allows for the elimination of one or both of the side view mirrors 4, 5 which allows for the reduction in aerodynamic drag (see col. 13, lines 62-67).

Schofield does not contemplate multiple receivers each arranged to obtain waves from a different part of the exterior environment, i.e., non-overlapping fields of view.

In view of the absence of all of the features of claims 40 and 77 in Schofield et al., Schofield et al. cannot anticipate the embodiments of the invention set forth in claims 40-44, 77, 81 and 82.

With respect to independent claim 54, this claim recites a display viewable by the driver and coupled to and controlled by the processor to cause the display of the presence and at least one of the classification, identification and location of the exterior object (as determined by the processor) thereon.

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For example, a display 748 is provided which can show an icon or image of the classified or identified exterior object at its determined location (as described in the specification at page 46, lines 18-20).

Schofield et al. describes the formation of a visual display signal such as through a display panel when the presence of a vehicle within a field of view is detected (col. 14, lines 1-7). In contrast to the embodiment of claim 54, in Schofield et al., the visual display signal is a simple warning light, e.g., on the dashboard, which is illuminated when the presence of a vehicle is detected which satisfies the parameters, e.g., distance and speed. There is no disclosure of displaying, in addition to the presence of the object, the classification, identification or location of the object on a display panel.

In view of the absence of all of the features of claim 54 in Schofield et al., Schofield et al. cannot anticipate the embodiment of the invention set forth in this claim.

Rejections under 35 U.S.C. §103

Claims 7, 9, 10, 38, 39, 46, 48, 49, 60, 63, 72, 82 and 84 were rejected under 35 U.S.C. §103(a) as being unpatentable over Schofield et al. '897 in view of Schofield et al. (U.S. Pat. No. 5,949,331). (Clarification that this rejection applies to claim 83 instead of claim 82 is respectfully requested as claim 82 was indicated as containing allowable subject matter.)

Schofield et al. '331 does not disclose features of the independent claims upon which claims 7, 9, 10, 38, 39, 46, 48, 49, 60, 63, 72, 83 and 84 depend, such as trained pattern recognition means for providing a classification, identification or location of an exterior object. Rather, Schofield et al. '331 describes only the display of the objects on a display without any processing of the objects to obtain their classification or identification.

Thus, one skilled in the art could not have combined any purported teachings of Schofield et al. '897 and Schofield et al. '331 and arrived at the embodiments of the invention set forth in the rejected claims.

Claims 8, 16-21, 27-29, 33, 47, 65, 66, 69 and 73 were rejected under 35 U.S.C. §103(a) as being unpatentable over Schofield et al. '897 in view of DeLine et al. (U.S. Pat. No. 6,087,953).

DeLine et al. does not disclose features of the independent claims upon which claims 8, 16-21, 27-29, 33 and 47 depend, such as the trained pattern recognition means for providing a classification, identification or location of an exterior object.

With respect to claims 65, 66, 69 and 73, independent claim 65 has been amended to recite that the processor comprises trained pattern recognition means which are structured and arranged to apply a trained pattern recognition algorithm generated from data of possible exterior objects and images obtained by the CCD array(s) from the possible exterior objects to provide the classification,

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identification or location of the exterior object. A description of the training of a pattern recognition system is discussed above.

DeLine et al. does not disclose trained pattern recognition means for providing a classification, identification or location of an exterior object.

Thus, one skilled in the art could not have combined any purported teachings of Schofield et al. '897 and DeLine et al. and arrived at the embodiments of the invention set forth in the rejected claims.

Claims 11, 12, 50, 51, 64 and 85 were rejected under 35 U.S.C. §103(a) as being unpatentable over Schofield et al. '897 in view of Cho (U.S. Pat. No. 5,959,552).

Cho does not disclose features of the independent claims upon which claims 11, 12, 50, 51, 64 and 85 depend, such as the trained pattern recognition means for providing a classification, identification or location of an exterior object. Thus, one skilled in the art could not have combined any purported teachings of Schofield et al. '897 and Cho and arrived at the embodiments of the invention set forth in the rejected claims.

Claims 22-24 and 75 were rejected under 35 U.S.C. §103(a) as being unpatentable over Schofield et al. '897, DeLine et al. and Schofield et al. '331.

Schofield et al. '897, DeLine et al. and Schofield et al. '331, taken either individually or in combination, do not disclose, teach or suggest features of the independent claims upon which claims 22-24 and 75 depend. Thus, one skilled in the art could not have combined any purported teachings of Schofield et al. '897, DeLine et al. and Schofield et al. '331 and arrived at the embodiments of the invention set forth in the rejected claims.

Claims 25, 26 and 76 were rejected under 35 U.S.C. §103(a) as being unpatentable over Schofield et al. '897, DeLine et al. and Cho.

Schofield et al. '897, DeLine et al. and Cho, taken either individually or in combination, do not disclose, teach or suggest features of the independent claims upon which claims 25, 26 and 76 depend. Thus, one skilled in the art could not have combined any purported teachings of Schofield et al. '897, DeLine et al. and Cho and arrived at the embodiments of the invention set forth in the rejected claims.

In view of the foregoing, it is respectfully submitted that the Examiner's rejections of the claims have been overcome and should be removed.

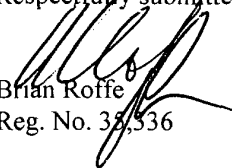
If the Examiner should determine that minor changes to the claims to obviate informalities are necessary to place the application in condition for allowance, the Examiner is respectfully requested to contact the undersigned to discuss the same.



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An early and favorable action on the merits is earnestly solicited.

FOR THE APPLICANTS  
Respectfully submitted,



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EXAMINER

ART UNIT	PAPER
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5

DATE MAILED:

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner for Patents

**Notice of Allowability**

<b>Application No.</b>	<b>Applicant(s)</b>	
10/302,105	BREED ET AL.	
<b>Examiner</b>	<b>Art Unit</b>	
Tuan C To	3663	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--  
 All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1.  This communication is responsive to 12/08/2003.
2.  The allowed claim(s) is/are 1-65 and 67-87.
3.  The drawings filed on 22 November 2002 are accepted by the Examiner.
4.  Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
  - a)  All   b)  Some\*   c)  None   of the:
    1.  Certified copies of the priority documents have been received.
    2.  Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
    3.  Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

\* Certified copies not received: \_\_\_\_\_.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.  
**THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.**

5.  A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
6.  CORRECTED DRAWINGS ( as "replacement sheets") must be submitted.
  - (a)  including changes required by the Notice of Draftsperson's Patent Drawing Review ( PTO-948) attached
    - 1)  hereto or 2)  to Paper No./Mail Date \_\_\_\_\_.
  - (b)  including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date \_\_\_\_\_.

Identifying Indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
7.  DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

**Attachment(s)**

- |   |   |
|---|---|
| 1. <input type="checkbox"/> Notice of References Cited (PTO-892)  | 5. <input type="checkbox"/> Notice of Informal Patent Application (PTO-152)           |
| 2. <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948)                                | 6. <input type="checkbox"/> Interview Summary (PTO-413),<br>Paper No./Mail Date _____ |
| 3. <input type="checkbox"/> Information Disclosure Statements (PTO-1449 or PTO/SB/08),<br>Paper No./Mail Date _____ | 7. <input checked="" type="checkbox"/> Examiner's Amendment/Comment <b>B</b>          |
| 4. <input type="checkbox"/> Examiner's Comment Regarding Requirement for Deposit<br>of Biological Material          | 8. <input checked="" type="checkbox"/> Examiner's Statement of Reasons for Allowance  |
|   | 9. <input type="checkbox"/> Other _____   |

*Thomas L. Black*  
 THOMAS L. BLACK  
 PERMISSORY PATENT EXAMINER  
 GROUP 3600

Application/Cor. l Number: 10/302,105  
Art Unit: 3663

Page 2

### EXAMINER'S AMENDMENT **B**

An informal examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

In the "Cross Reference to Related Applications" section, line 8, after "Ser. No. 09/925,043 filed Aug. 8, 2001" ~~-,now U.S. Pat. No. 6,507,779,--~~ has been ]

**B1** inserted. On lines 10 and 11, after "Ser. No. 09/765,559 filed Jan. 19, 2001", --

**B2** ,now U.S Pat. No. 6,553,296--has been inserted.]

### EXAMINER'S STATEMENT OF REASONS FOR ALLOWANCE

This communication is an Examiner's reasons for allowance in response to application filed on 12/08/2003, assigned serial 10/302,105 and titled "Vehicular Monitoring Systems Using Image Processing."

The following is the Examiner's statement of reasons for the indication of allowable subject matter:

The prior art closest to the subject matter of the independent claims 1, 16, 30, 40, 52, 53, 54, 55, 65, and 77 is the reference of Schofield et al. (US 5877897A), which discloses a system and method for controlling a plurality of reflectance mirrors, including a rear view mirror and side view mirrors. Although Schofield et al. teaches the photo sensor array having a field of view encompassing a vehicle interior, said photo sensor array would not be similar to the typical receiver as claimed, wherein said receiver is arranged to classify or

identify the exterior object based on the signal and thereby provide the classification or identification of the exterior object. In addition, after carefully reviewing the cited prior art of record, the examiner has found neither Schofield et al. nor other prior art fairly suggests that "a processor coupled to said at least one receiver and comprising trained pattern recognition means for processing the signal to provide classification, identification, or location of the exterior object..."

For the reason set forth above said independent claims are now set in a condition for allowance as well as the claims dependent on said claims. Claim 65 is cancelled by the applicant.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to examiner Tuan To, whose telephone number is (703) 308-6273. The examiner can normally be reached on Monday-Friday from 8:00 AM-4:30 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thomas Black, can be reached on (703) 305-8233.

**Any response to this action should be mailed to:**

Commissioner of Patents and Trademarks

Washington, D.C. 20231

**or faxed to:**

(703) 305-7687, (for informal or draft communications, please label

"PROPOSED" or "DRAFT")

Hand-delivered responses should be brought to Crystal Park V, 2451

Crystal Drive, Arlington, VA, Seventh Floor (Receptionist).

Application/Cor. # Number: 10/302,105  
Art Unit: 3663

Page 4

/tc

March 15, 2004

  
THOMAS G. BEARD  
INTERVENOR/OPPOSITION  
GROUP 3663



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

22846 7590 03/24/2004

BRIAN ROFFE, ESQ
11 SUNRISE PLAZA, SUITE 303
VALLEY STREAM, NY 11580-6170

EXAMINER

TO, TUAN C

ART UNIT PAPER NUMBER

3663

DATE MAILED: 03/24/2004

Table with 5 columns: APPLICATION NO., FILING DATE, FIRST NAMED INVENTOR, ATTORNEY DOCKET NO., CONFIRMATION NO.
10/302,105 11/22/2002 David S. Breed ATI-338 2206

TITLE OF INVENTION: VEHICULAR MONITORING SYSTEMS USING IMAGE PROCESSING

Table with 6 columns: APPLN. TYPE, SMALL ENTITY, ISSUE FEE, PUBLICATION FEE, TOTAL FEE(S) DUE, DATE DUE
nonprovisional YES \$665 \$300 \$965 06/24/2004

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE REFLECTS A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE APPLIED IN THIS APPLICATION. THE PTOL-85B (OR AN EQUIVALENT) MUST BE RETURNED WITHIN THIS PERIOD EVEN IF NO FEE IS DUE OR THE APPLICATION WILL BE REGARDED AS ABANDONED.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

- A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.
B. If the status is changed, pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above and notify the United States Patent and Trademark Office of the change in status, or

If the SMALL ENTITY is shown as NO:

- A. Pay TOTAL FEE(S) DUE shown above, or
B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check the box below and enclose the PUBLICATION FEE and 1/2 the ISSUE FEE shown above.
[ ] Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

II. PART B - FEE(S) TRANSMITTAL should be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). Even if the fee(s) have already been paid, Part B - Fee(s) Transmittal should be completed and returned. If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

**PART B - FEE(S) TRANSMITTAL**

Complete and send this form, together with applicable fee(s), to: **Mail** **Mail Stop ISSUE FEE**  
**Commissioner for Patents**  
**P.O. Box 1450**  
**Alexandria, Virginia 22313-1450**  
**or Fax (703) 746-4000**

**INSTRUCTIONS:** This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

22846 7590 03/24/2004

**BRIAN ROFFE, ESQ**  
**11 SUNRISE PLAZA, SUITE 303**  
**VALLEY STREAM, NY 11580-6170**

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

**Certificate of Mailing or Transmission**

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO, on the date indicated below.

_____ (Depositor's name)
_____ (Signature)
_____ (Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/302,105	11/22/2002	David S. Breed	ATI-338	2206

TITLE OF INVENTION: VEHICULAR MONITORING SYSTEMS USING IMAGE PROCESSING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	\$665	\$300	\$965	06/24/2004

EXAMINER	ART UNIT	CLASS-SUBCLASS
TO, TUAN C	3663	701-045000

<p>1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.563).</p> <p><input type="checkbox"/> Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.</p> <p><input type="checkbox"/> "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.</p>	<p>2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.</p> <p>1 _____</p> <p>2 _____</p> <p>3 _____</p>
--	---

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE \_\_\_\_\_ (B) RESIDENCE: (CITY and STATE OR COUNTRY) \_\_\_\_\_

Please check the appropriate assignee category or categories (will not be printed on the patent);  individual  corporation or other private group entity  government

<p>4a. The following fee(s) are enclosed:</p> <p><input type="checkbox"/> Issue Fee</p> <p><input type="checkbox"/> Publication Fee</p> <p><input type="checkbox"/> Advance Order - # of Copies _____</p>	<p>4b. Payment of Fee(s):</p> <p><input type="checkbox"/> A check in the amount of the fee(s) is enclosed.</p> <p><input type="checkbox"/> Payment by credit card. Form PTO-2038 is attached.</p> <p><input type="checkbox"/> The Director is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).</p>
---	---

Director for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) \_\_\_\_\_ (Date) \_\_\_\_\_

**NOTE:** The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Alexandria, Virginia 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Alexandria, Virginia 22313-1450.**

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TRANSMIT THIS FORM WITH FEE(S)





UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/302,105	11/22/2002	David S. Breed	ATI-338	2206
22846	7590	03/24/2004	EXAMINER	
BRIAN ROFFE, ESQ 11 SUNRISE PLAZA, SUITE 303 VALLEY STREAM, NY 11580-6170			TO, TUAN C	
			ART UNIT	PAPER NUMBER
			3663	

DATE MAILED: 03/24/2004

**Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)**  
(application filed on or after May 29, 2000)

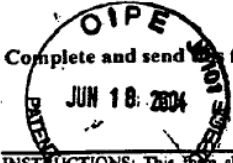
The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) system (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (703) 305-1383. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (703) 305-8283.

**PART B - FEE(S) TRANSMITTAL**



Complete and send this form, together with applicable fee(s), to: Mail  
or Fax

Mail Stop ISSUE FEE  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
(703) 746-4000

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless directed below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

22846 7590 03/24/2004

BRIAN ROFFE, ESQ  
11 SUNRISE PLAZA, SUITE 303  
VALLEY STREAM, NY 11580-6170

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission  
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO, on the date indicated below.

Brian Roffe	(Depositor's name)
<i>[Signature]</i>	
June 16, 2004	

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/302,105	11/22/2002	David S. Breed	ATI-338	2206

TITLE OF INVENTION: VEHICULAR MONITORING SYSTEMS USING IMAGE PROCESSING

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1. Brian Roffe  
2. \_\_\_\_\_  
3. \_\_\_\_\_

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: AUTOMOTIVE TECHNOLOGIES INTERNATIONAL, INC.  
(B) RESIDENCE: (CITY AND STATE OR COUNTRY): DENVILLE, NEW JERSEY

Please check the appropriate assignee category or categories (will not be printed on the patent):  individual  corporation or other private group entity  government

4a. The following fee(s) are enclosed:

- Issue Fee
- Publication Fee
- Advance Order - # of Copies 1

4b. Payment of Fee(s):

- A check in the amount of the fee(s) is enclosed.
- Payment by credit card. Form PTO-2038 is attached.
- The Director is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number 50-0266 (enclose an extra copy of this form).

Director for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) *[Signature]* (Date) 6/16/2004

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant, a registered attorney or agent, or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Alexandria, Virginia 22313-1450.

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06/22/2004 AHONDAF2 0000023 500266 10302105

01 FC:2501 665.00 DA  
02 FC:1504 300.00 DA  
03 FC:8001 3.00 DA

TRANSMIT THIS FORM WITH FEE(S)

DRS

PATENT APPLICATION SERIAL NO. \_\_\_\_\_

U.S. DEPARTMENT OF COMMERCE  
PATENT AND TRADEMARK OFFICE  
FEE RECORD SHEET

11/26/2002 EHAILE1 00000025 500266 10302105

01 FC:2001	370.00 CH
02 FC:2201	294.00 CH
03 FC:2202	585.00 CH

PTO-1556  
(5/87)

**PATENT APPLICATION FEE DETERMINATION RECORD**  
Effective October 1, 2001

Application or Docket Number

*A 71-338*

**CLAIMS AS FILED - PART I**

	(Column 1)	(Column 2)
TOTAL CLAIMS	<i>85</i>	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	<i>85</i> minus 20= *	<i>65</i>
INDEPENDENT CLAIMS	<i>10</i> minus 3 = *	<i>7</i>
MULTIPLE DEPENDENT CLAIM PRESENT <input type="checkbox"/>		

\* If the difference in column 1 is less than zero, enter "0" in column 2

**CLAIMS AS AMENDED - PART II**

	(Column 1)	(Column 2)	(Column 3)
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	* <i>86</i>	Minus ** <i>85</i>	= <i>1</i>
Independent	* <i>10</i>	Minus *** <i>10</i>	= <i>-</i>
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <input type="checkbox"/>			

	(Column 1)	(Column 2)	(Column 3)
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	*	Minus **	=
Independent	*	Minus ***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <input type="checkbox"/>			

	(Column 1)	(Column 2)	(Column 3)
AMENDMENT C	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	*	Minus **	=
Independent	*	Minus ***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <input type="checkbox"/>			

• If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."

\*\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1

SMALL ENTITY TYPE

OR OTHER THAN SMALL ENTITY

RATE	FEE
BASIC FEE	370.00
X\$ 9=	
X42=	
+140=	
TOTAL	

RATE	FEE
BASIC FEE	740.00
X\$18=	
X84=	
+280=	
TOTAL	

RATE	ADDITIONAL FEE
X\$ 9=	<i>9</i>
X42=	
+140=	
TOTAL ADDIT. FEE	<i>9</i>

RATE	ADDITIONAL FEE
X\$18=	
X84=	
+280=	
TOTAL ADDIT. FEE	

RATE	ADDITIONAL FEE
X\$ 9=	
X42=	
+140=	
TOTAL ADDIT. FEE	

RATE	ADDITIONAL FEE
X\$18=	
X84=	
+280=	
TOTAL ADDIT. FEE	

RATE	ADDITIONAL FEE
X\$ 9=	
X42=	
+140=	
TOTAL ADDIT. FEE	

RATE	ADDITIONAL FEE
X\$18=	
X84=	
+280=	
TOTAL ADDIT. FEE	

# CLAIMS ONLY

SERIAL NO.  
10302105

FILING DATE

APPLICANT(S)

## CLAIMS

	AS FILED		AFTER 1st AMENDMENT		AFTER 2nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
1	1					
2						
3						
4						
5						
6						
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40	1					
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48						
49						
50						
TOTAL IND.		↓		↓		↓
TOTAL DEP.		←		←		←
TOTAL CLAIMS						

	*		*		*	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
51		1				
52	1					
53						
54	1					
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93						
94						
95						
96						
97						
98						
99						
100						
TOTAL IND.	10	↓		↓		↓
TOTAL DEP.	75	←		←		←
TOTAL CLAIMS	85					

\* MAY BE USED FOR ADDITIONAL CLAIMS OR ADMENDMENTS

ISSUE SLIP STAPLE AREA (for additional cross-references)

ISSUING CLASSIFICATION			
ORIGINAL		CROSS REFERENCE(S)	
CLASS	SUBCLASS	CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)
701	45	340	573.1
INTERNATIONAL CLASSIFICATION		348	77
		180	221
B 6 D R	21132	280	735
	1	382	181
	1		
	1		
	1		

^ Continued on Issue Slip Inside File Jacket

INDEX OF CLAIMS

✓ ..... Rejected - (Through numeral) ... Canceled N ..... Non-elected A ..... Appeal  
 = ..... Allowed + ..... Restricted I ..... Interference O ..... Objected

Claim	Date	Claim	Date	Claim	Date
1		51		101	
2		52		102	
3		53		103	
4		54		104	
5		55		105	
6		56		106	
7		57		107	
8		58		108	
9		59		109	
10		60		110	
11		61		111	
12		62		112	
13		63		113	
14		64		114	
15		65		115	
16		66		116	
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886  
 305  
 3/11/5

If more than 150 claims or 9 actions staple additional sheet here

## SEARCH

Class	Sub.	Date	Exmr.
701	45	08/14/03	TC
340	461, 435		
	436, 438		
	815.4		
348	148	02/14/03	TC
701	36, 301	03/14/04	TC
340	573.1		
348	77 154		
180	271		
280	735 728.1		
382	181, 115 190, 224 100, 104	03/15/04	TC

## SEARCH NOTES

(List databases searched. Attach search strategy inside.)

	Date	Exmr.
East search logic attached	04/25/03	TC
search logic attached	03/15/04	TC

### INTERFERENCE SEARCHED

Class	Sub.	Date	Exmr.
701	45	03/15/04	TC
340	573.1		
348	77, 154		
180	271		
280	735		
382	181	03/15/04	TC