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(54) **Method and system for providing routing guidance**

Verfahren und Vorrichtung zur Routenführung

Méthode et système de guidage

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- **PATENT ABSTRACTS OF JAPAN vol. 1999, no. 08, 30 June 1999 (1999-06-30) & JP 11 072340 A (DENSO CORP), 16 March 1999 (1999-03-16)**

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to navigation systems and more particularly the present invention relates to providing guidance when a driver deviates from a route for which route guidance was previously being provided a navigation system.

[0002] Navigation systems provide useful features, such as calculating a route to a desired destination and providing guidance for following the route. In order to provide these features, navigation systems use geographic data that include information about the locations of roads and intersections, estimated travel times along road segments, the speed limits along roads, etc. Using these kinds of geographic data, programming algorithms included in navigation systems can find an optimal (e.g, fastest or shortest) route to a specified destination.

[0003] Some navigation systems provide a feature that can detect if a vehicle has departed from a route for which route guidance was being provided (i.e., when the vehicle has gone "off-route"). Upon detecting that the vehicle has gone off-route, the navigation system calculates a new route to either the destination or back to the original route and provides guidance to the vehicle driver for following the new route. A factor that can complicate providing this feature is that the calculation of the new route may take several seconds during which time the vehicle position may change. Therefore, the point of origin from which the new route was calculated may not be valid several seconds later when the guidance for following the new route is available for the driver. Worse still, the vehicle driver may have encountered an intersection before the route guidance for following the new route was available and chosen a path leading from the intersection that was not part of the new route. If this occurs, the vehicle is off-route of the new route when the new route becomes available thereby necessitating calculation of another new route from the vehicle position to either the destination or back to the original route.

[0004] A navigation system to provide route guidance to a user when the vehicle in the navigation system goes off-route is known from EP-A-0 854 463.

SUMMARY OF THE INVENTION

[0005] According to an aspect of the invention, there is provided a method according to claim 1.

[0006] According to an aspect of the invention, there is provided a navigation system according to claim 12.

[0007] According to an aspect of the invention, there is provided a computer program according to claim 13.

[0008] To address these and other objectives, embodiments of the present invention comprise a method performed by a navigation system to provide guidance to a driver of a vehicle when the vehicle departs from a route to a destination for which route guidance was being provided by the navigation system. Intersections that can be reached by the vehicle while calculation of a new solution route to the destination is being performed are identified. For each identified intersection, cost factors associated with the possible paths leading from the identified intersection are modified to increase the likelihood that the new solution route include those paths with the least cost factors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Figure 1 is a block diagram illustrating a navigation system.

Figure 2 is a block diagram illustrating components of a road segment data record included in the geographic database of Figure 1.

Figure 3 is a block diagram illustrating components of the navigation programming shown in Figure 1.

Figure 4 is a flow chart showing steps performed by the off-route application of Figure 3.

Figure 5A depicts the vehicle of Figure 1 approaching an intersection. Figure 5A is used in a first example describing operation of the off-route application of Figure 4.

Figure 5B is a graphical representation of the intersection shown in Figure 5A.

Figure 5C shows how the turn costs of the intersection of Figure 5A are represented in the geographic database of Figure 2.

Figure 6A depicts the vehicle of Figure 1 approaching an exit ramp. Figure 6A is used in a second example describing operation of the off-route application of Figure 4.

Figure 6B is a graphical representation of the controlled access road and exit ramp shown in Figure 6A.

Figure 6C shows how the turn costs of the controlled access road and exit ramp of Figure 6A are represented in the geographic database of Figure 2.

Figure 7A depicts the vehicle of Figure 1 approaching an intersection. Figure 7A is used in a third example describing operation of the off-route application of Figure 4.

Figure 7B is a graphical representation of the intersection shown in Figure 7A.

Figure 7C shows how the turn costs of the intersection of Figure 7A are represented in the geographic database of Figure 2.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

I. EXEMPLARY NAVIGATION SYSTEM PLATFORM

A. Overview

[0010] Referring to Figure 1, there is a diagram illustrating an exemplary embodiment of a navigation system 110. In the embodiment shown in Figure 1, the navigation system 110 is located in a vehicle 111, such as an automobile, truck, or bus. The navigation system 110 is a combination of hardware and software components. The hardware components of the navigation system 110 may include a processor 112, memory 120, and so on. In the embodiment of Figure 1, the navigation system 110 also includes a positioning system 124 that determines the position of the vehicle 111 in which it is installed. The positioning system 124 may include sensors 125 or other components that sense the speed, orientation, direction, angular acceleration, and so on, of the vehicle 111. The positioning system 124 may also include a GPS system.

[0011] The navigation system 110 also includes a user interface 131. The user interface 131 includes appropriate means 127 for receiving instructions and/or input from an end user of the navigation system. The instruction receiving means 127 may include a keyboard, keypad, or other type of input panel 127(P), a microphone 127 (M), as well as other means for accepting end-user input, such as voice recognition software, and so on, through which the end user may request navigation information and services. The user interface 131 also includes appropriate means 129 for providing information back to the end user. The information providing means 129 may include a display 129(D) and speakers 129(S) (including speech synthesis hardware and software) through which the end user can be provided with information and services from the navigation system 110.

[0012] All of the components described above may be conventional (or other than conventional) and the manufacture and use of these components are known to those of skill in the art

B. The geographic database

[0013] In order to provide navigation features to an end user, the navigation system 110 uses geographic data 140. The geographic data 140 include information about one or more geographic regions or coverage areas. The geographic data 140 may be stored in the vehicle 11 1 or alternatively, the geographic data 140 may be stored remotely and made available to the navigation system 110 in the vehicle 111 through a wireless communication system which may be part of the navigation system 110. In another alternative, a portion of the geographic data 140 may be stored in the vehicle 111 and a portion of the geographic data 140 may be stored in a remote location and made available to the navigation system 110 in the vehicle 111 over a wireless communication system from the remote location.

[0014] In the embodiment shown in Figure 1, some or all of the geographic data 140 are stored on a medium 132 which is located in the vehicle 111. Accordingly, the navigation system 110 includes a drive 114 (or other suitable peripheral device) into which the medium 132 can be installed and accessed. In one embodiment, the storage medium 132 is a CD-ROM disk. In another alternative embodiment, the storage medium 132 may be a PCMCIA card in which case the drive 114 would be substituted with a PCMCIA slot. Various other storage media may be used, including fixed or hard disks, DVD disks or other currently available storage media, as well as storage media that may be developed in the future.

[0015] The geographic data 140 include data specifying the positions of the roads in the covered geographic region(s). The geographic data 140 also include data relating to the roads, such as restrictions on directions of travel along the roads (e.g., one-way streets), street addresses along the roads, street names, speed limits along the roads, turn restrictions at intersections, and so on. The geographic data 140 may also include information about points of interest in the geographic area, such as hotels, restaurants, museums, stadiums, offices, automobile dealerships, auto repair shops, etc. The geographic data 140 may also include information about places, such as cities, towns, or other communities. The geographic data 140 may include other kinds of data about the geographic area.

[0016] The geographic data 140 may take a variety of different forms. In one embodiment, the geographic data 140 are in the form of one or more computer-readable data files or databases 141. Methods for forming and organizing a geographic database are disclosed in U.S. Pat. Nos. 5,953,722 and 5,974,419 and copending patent application Ser. No. 08/740,295, the disclosures of which are incorporated herein by reference. In one embodiment, the geographic database 141 contains a plurality of road segment data records. Each road segment data record represents a portion (or segment) of a navigable road in the geographic region. In one type of geographic database, there is at least one database entry (also referred to as "entity" or "record") for each represented road segment in a geographic region. Each physical road segment has two nodes associated with it, one at each of the endpoints of the road segment. In this embodiment, the geographic database also includes a plurality of data entities that represent these nodes. (The terms "segment" and "node" represent only one terminology for describing these physical geographic features and other terminology for these features is intended to be encompassed within the scope of these concepts.)

[0017] Data attributes are associated with each road segment data record to describe features or characteristics of the represented road segment. The various attributes associated with a road segment may be included in a single road segment record, or may be included in more than one type of record which are cross-referenced to each other.

[0018] Figure 2 illustrates some of the components of a road segment data record 222 included in the geographic database 141. The road segment data record 222 includes a segment ID 222(1) by which the record can be identified in the geographic database. The road segment data record 222 includes data fields 222(2) for various attributes of the represented road segment. These attributes include the speed limit along the road (or a speed limit range), the type of road (e.g., controlled access, ramp, bridge, tunnel, toll road, ferry, and so on), a functional rank, a permitted direction of travel, an address range, a name, a highway designation of the road of which the road segment is a part, and so on.

[0019] The road segment data record 222 includes data 222(3) identifying the endpoints of the road segment. In one embodiment, these data 222(3) include references 222(3)(1)(L) and 222(3)(1)(R) to node data records 223 (1) and 223(2) defined for the nodes corresponding to the endpoints of the represented road segment.

[0020] Also associated with the road segment data record 222 are data 222(3)(2)(L) and 222(3)(2)(R) indicating valid successor segments (if any) at each of the endpoints of the represented road segment. A valid successor segment is a road segment to which vehicular travel is legally permitted from the represented road segment. Also associated with the road segment data record 222 are data 222(3)(3)(L) and 222(3)(3)(R) indicating invalid successor segments (if any) at each of the endpoints of the represented road segment. An invalid successor segment is a road segment to which vehicular travel is not legally permitted from the represented road segment.

[0021] Associated with the data indicating each identified successor segment are data 222(4) indicating a turn cost. The turn cost data 222(4) indicate a cost associated with travel from the represented segment onto the successor segment via the common node (intersection) connecting the represented segment and the successor segment. The turn cost data 222(4) are used by functions in the navigation system (e.g., the route calculation function 250 in Figure 3) to evaluate and compare different possible travel paths in order to ascertain which travel path takes the least time. In the embodiment of Figure 2, the turn cost data 222(4) represent an estimate of the actual travel time it take to traverse the intersection between a represented segment and a successor segment. For example, if the successor segment is reached by a left turn from the represented segment at the common node, the turn cost data 222(4) represent an estimation of the time (in seconds) it takes to make the left turn from the represented segment onto to the successor segment.

[0022] The turn cost data 222(4) are used to represent the time it takes to travel onto a successor segment even if no turn is required to reach the successor segment. For example, if a successor segment is reached from the represented segment by traveling straight ahead across the common intersection, the turn cost data 222(4) represent the cost (e.g., travel time) to cross straight ahead across the intersection. The turn cost data 222(4) can also be used to represent invalid successor segments. Invalid successor segments have an infinite (or very high) travel cost value.

[0023] In one embodiment, the geographic data are provided by Navigation Technologies Corporation of Rosemont, Illinois. However it is understood that the inventive concepts disclosed herein are not restricted to any particular source of data.

C. <u>The navigation programming.</u>

[0024] Referring again to Figure 1, in addition to the hardware components and geographic database, the navigation system 110 includes or uses navigation programming 228. The navigation programming 228 includes the software that provides for the functions and/or features performed by the navigation system 110. The navigation programming 228 uses the geographic data 140 in conjunction with input from the end user via the user interface 131, and possibly in conjunction with outputs from the positioning system 124, to provide various navigation-related features and/or functions.

[0025] The navigation programming 228 may be stored in a non-volatile storage medium 229 in the navigation system 110. Alternatively, the navigation programming 228 and the geographic data 140 may be stored together on a single storage device or medium. Alternatively, the navigation programming 228 may be located at a remote location and may be provided to or accessed by the navigation system 110 over a communications system.

[0026] In one embodiment, the navigation programming 228 is written in the C programming language although in alternative embodiments other programming languages may be used, such as C++, Java, Visual Basic, and so on.

[0027] The navigation programming 228 may be formed of separate component applications (also referred to as programs, subprograms, routines, or tools). The component applications of the navigation programming 228 work together through defined programming interfaces. Figure 3 shows a block diagram illustrating some of the component applications for one embodiment of the navigation programming 228 included in the navigation system 110 of Figure 1. In addition to the component programs shown in Figure 3, the navigation programming 228 may include other component sub-routines or programs.

[0028] In Figure 3, the navigation programming 228 is shown to include a navigation application manager 240. The navigation application manager 240 is a program or routine that provides for overall management of the functions of the navigation system 110. The navigation application manager 240 may also include support for and interfaces to the navigation system hardware, such as the positioning system 124 and the user interface 131. The navigation application manager 240 includes user interface functions 242 to interface with the user interface hardware 131. These user interface functions 242 may provide for presenting a menu to the end user on the screen display 129(D) of the user interface hardware 131, accepting inputs from the end user via the input devices 127 of the user interface hardware 131, displaying results to the end user on the screen display 129(D) of the user interface hardware 131, and so on.

[0029] The navigation programming 228 includes sub-programs or routines that interface with the navigation application manager 240 and that provide for specific navigation-related features or functions to be performed by the navigation system. These sub-programs include a route calculation application 250, a route guidance application 252, a map display application 253, and a vehicle positioning application 256. The navigation programming 228 may include other navigation applications in addition to these.

Example of operation of the navigation system.

[0030] The route calculation application 250 receives a request to calculate a route to a desired destination. The request may originate with the end user. The request is received via the user interface 131, the user interface functions 242 and the manager application 240. The request may be in the form of an identification of a starting location and a desired destination location. The identification of these locations may include the geographic coordinates of these locations. The route calculation application may also be provided with other data or parameters, such as driving preferences (e.g., avoid toll roads).

[0031] Given at least the identification of a starting location and a desired destination location, the route calculation application 250 attempts to determine one or more solution routes between the starting location and the destination location. A solution route is formed of a series of connected road segments over which a vehicle can travel from the starting location to the destination location. When the route calculation application 250 calculates a route, it accesses the geographic data 140 and obtains road segment data records 222 that represent road segments around and between the starting location and the destination location. The route calculation application 250 uses the information in the road segment data records 222 to attempt to determine at least one valid solution route from the starting location to the destination location. The route calculation application 250 may use various means or algorithms in determining solution routes. In determining a valid solution route for a vehicle to travel, the route calculation program 250 uses the data attributes associated with the road segment data records to account for direction of travel restrictions (e.g., one-way streets), turn restrictions at intersections (e.g., no left turns), and so on. The route calculation application 250 may attempt to find a solution route that takes the least time to travel, that covers the least distance, or that meets some other specifiable criteria.

[0032] The route calculation application 250 provides an output. In the embodiment of Figure 3, the output of the route calculation application 250 is in the form of an ordered list 254 identifying a plurality of road segments. The plurality of road segments form the continuous navigable route between the origin and the destination that had been calculated by the route calculation application 250. (The route calculation application 250 may calculate more than one solution route.)

[0033] The list 254 of road segments determined by the route calculation application 250 is provided to the route guidance application 252. The route guidance application 252 uses the information in the list 254, as well as additional information from the geographic database 141, to provide instructions and advice to the end user to travel the route defined by the list 254 output by the route calculation application 250. The route guidance application 252 may include functions that identify locations along the calculated route at which maneuvering instructions may be provided to the end user. The route guidance application 252 may also include functions that formulate the maneuvering instructions for visual output and/or audio output. The route guidance application 252 may provide the maneuvering instructions all at once, or alternatively, the route guidance application 252 may provide the maneuvering instructions one at a time as the vehicle is traveling. In one embodiment, each maneuvering instruction is provided separately (or in small groups of combined maneuvering instructions) in advance of when the specific maneuver is required to be taken so that the end user can prepare to make the required maneuver.

[0034] In order to provide maneuvering instructions at appropriate times and/or locations, the navigation system 110 uses data from the positioning system 124. The positioning system 124 determines the position of the vehicle as it is traveling. The vehicle positioning application 256 in the navigation programming 228 compares the vehicle position determined by the positioning system 124 to the positions of the road segments in the solution driving route 254. Using this comparison, the maneuver instructions, which are related to positions along the solution route, can be provided at appropriates times as these positions are approached.

[0035] The list 254 of road segments from the route calculation application 250 may also be provided to the map display application 253. The map display application 253 uses the information in the list 254, as well as additional information from the geographic database 140, to provide graphical maps on the display (129(D) in Figure 1) of the user interface 131. The graphical maps illustrate the areas through which the calculated route passes. The path of the calculated route may be highlighted on the displayed maps. The map display application 253 interfaces with the navigation application manager 240 so that the display maps are provided as the vehicle is

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