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(54) **APPARATUS AND METHOD FOR DETECTING VEHICLE LOCATION IN NAVIGATION SYSTEM**

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(57) **ABSTRACT**

When a vehicle location is estimated using only detection signals from a sensor unit installed on a vehicle since the value of dilution of precision (DOP) of a navigation message received by a GPS receiver is equal to or greater than a predetermined threshold in a navigation system, the vehicle location is precisely estimated using a traveled distance, a travel angle difference, and lateral and longitudinal inclinations of the vehicle. The value of DOP of the navigation message received by the GPS receiver is compared with the predetermined threshold. If the value of DOP is less than the predetermined threshold, reference vehicle location information is set using the navigation message. If the value of DOP is equal to or greater than the predetermined threshold, the reference vehicle location information is set using vehicle location information just previously map-matched and the detection signals from the sensor unit. The vehicle location is estimated using the set reference vehicle location information and the detection signals from the sensor unit and then map-matched on a digital map stored in a map data storage unit, thereby displaying the map-matched results on a display unit.

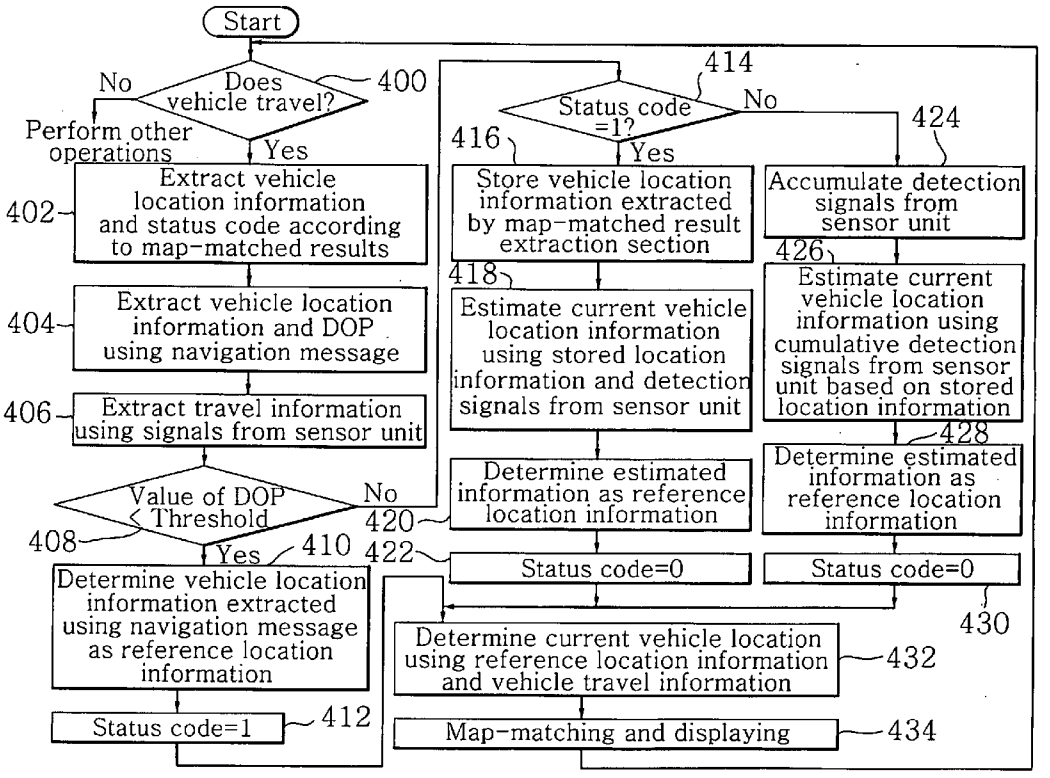


Fig. 1

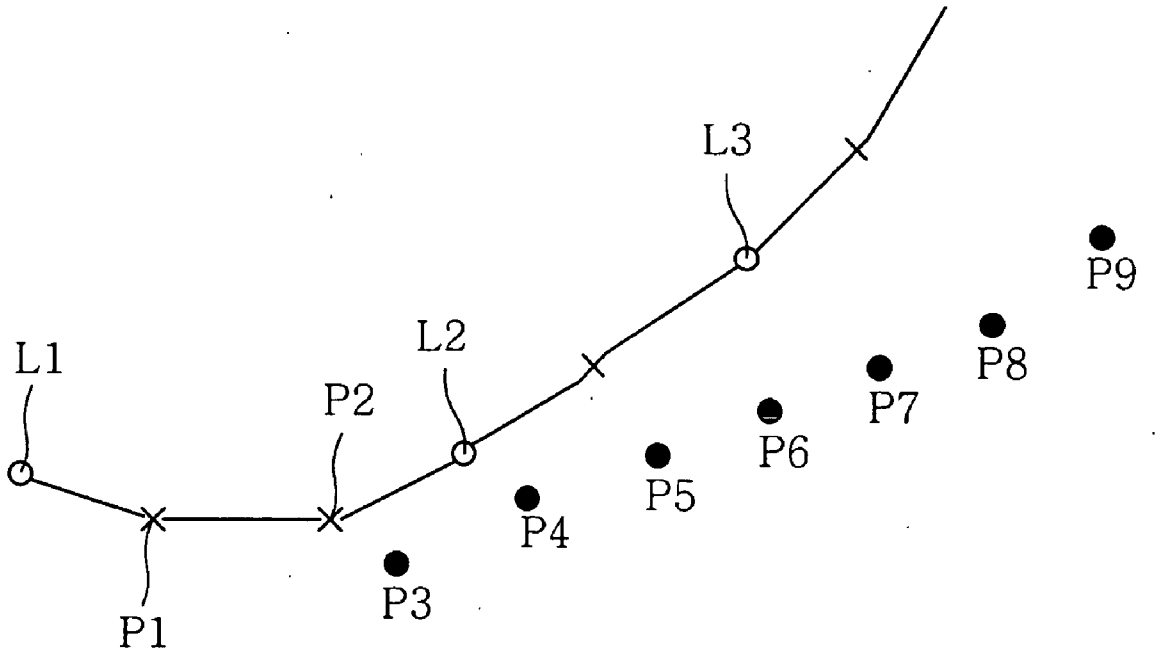


Fig.2

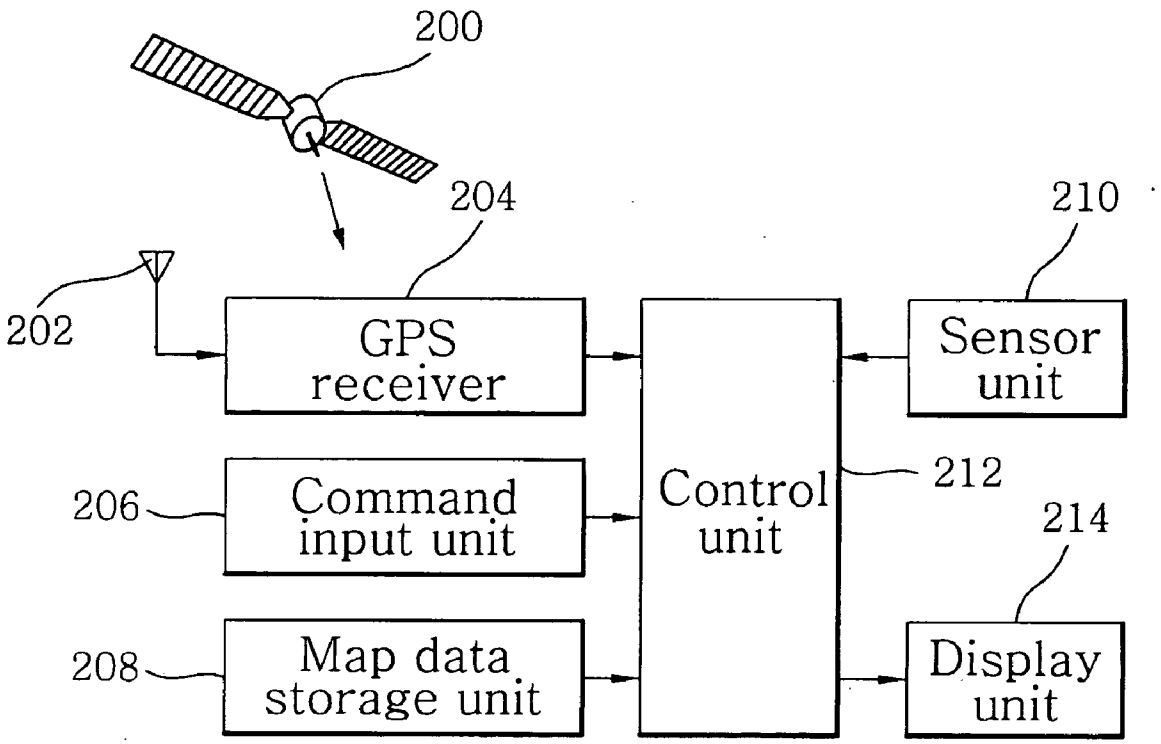

200
204
210
202
GPS receiver
Sensor unit
Command input unit
206
Control unit
212
214
208
Map data storage unit
Display unit

Fig.3

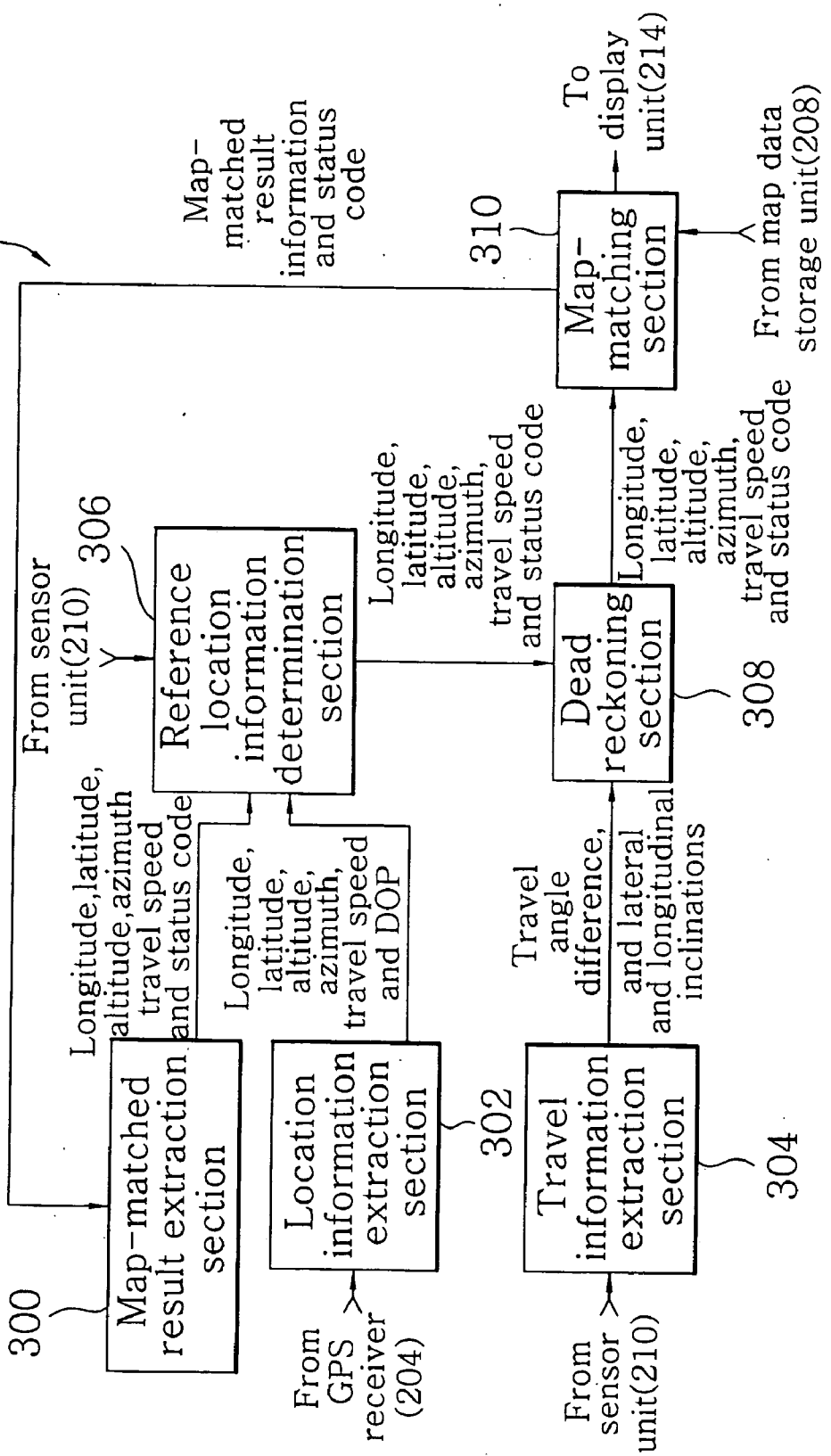

212
Map-matched result information and status code
To display unit(214)
310
Map-matching section
From map data storage unit(208)
From sensor unit(210)
306
Reference location information determination section
Longitude, latitude, altitude, azimuth, travel speed and status code
Dead reckoning section
308
Longitude, latitude, altitude, azimuth, travel speed and status code
Longitude, latitude, altitude, azimuth, travel speed and status code
Longitude, latitude, altitude, azimuth, travel speed and DOP
Travel angle difference, and lateral and longitudinal inclinations
300
Map-matched result extraction section
Location information extraction section
302
Travel information extraction section
304
From GPS receiver (204)
From sensor unit(210)

Fig.4

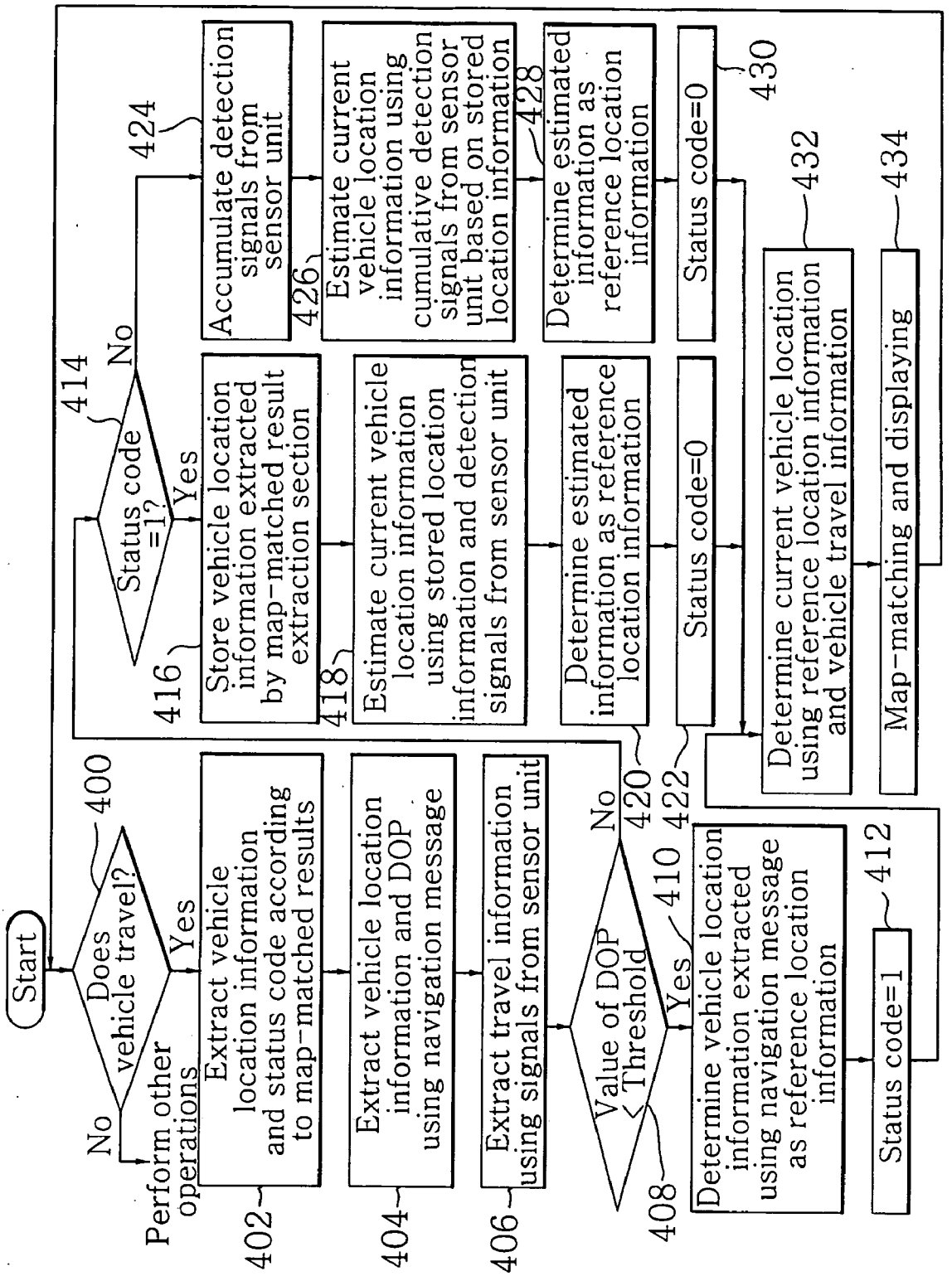

Start
Does vehicle travel?
400
No
Perform other operations
Yes
Extract vehicle location information and status code according to map-matched results
402
Extract vehicle location information and DOP using navigation message
404
Extract travel information using signals from sensor unit
406
Value of DOP < Threshold
408
No
420
Yes
410
Determine vehicle location information extracted using navigation message as reference location information
422
Status code=1
412
Status code =1?
414
No
Yes
Store vehicle location information extracted by map-matched result extraction section
416
Estimate current vehicle location information using stored location information and detection signals from sensor unit
418
Determine estimated information as reference location information
420
Status code=0
422
Accumulate detection signals from sensor unit
424
Estimate current vehicle location information using cumulative detection signals from sensor unit based on stored location information
426
Determine estimated information as reference location information
428
Status code=0
430
Determine current vehicle location using reference location information and vehicle travel information
432
Map-matching and displaying
434

Fig.5

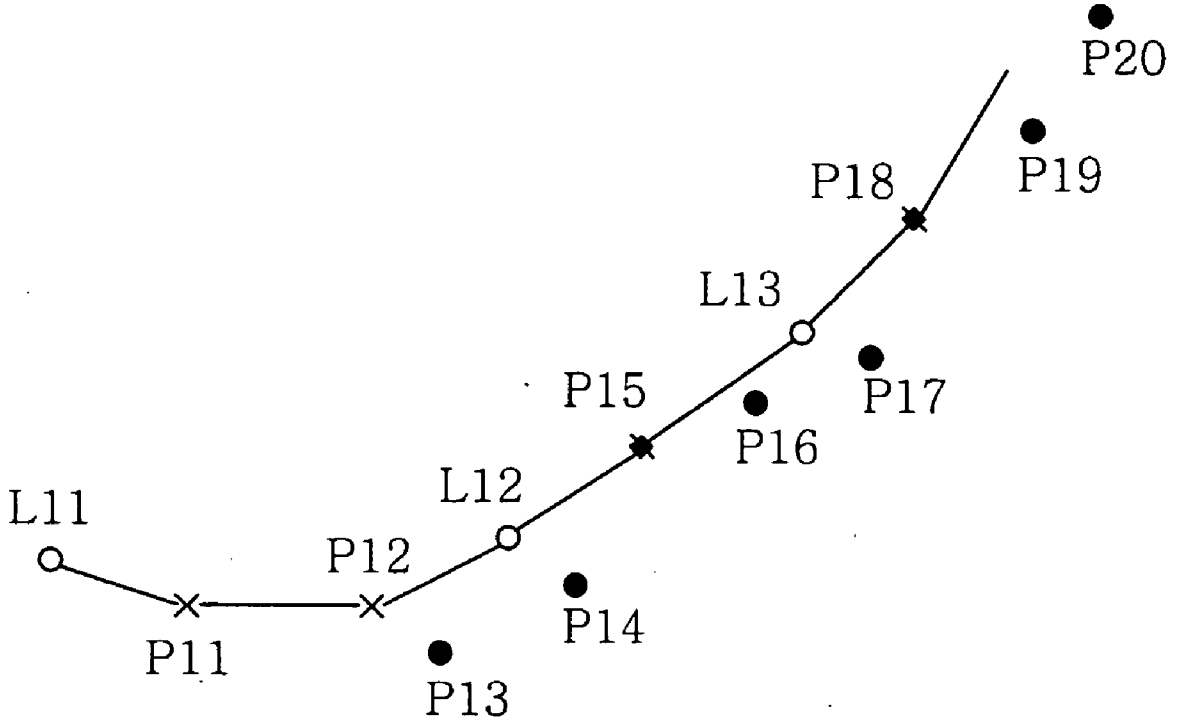


Fig.6

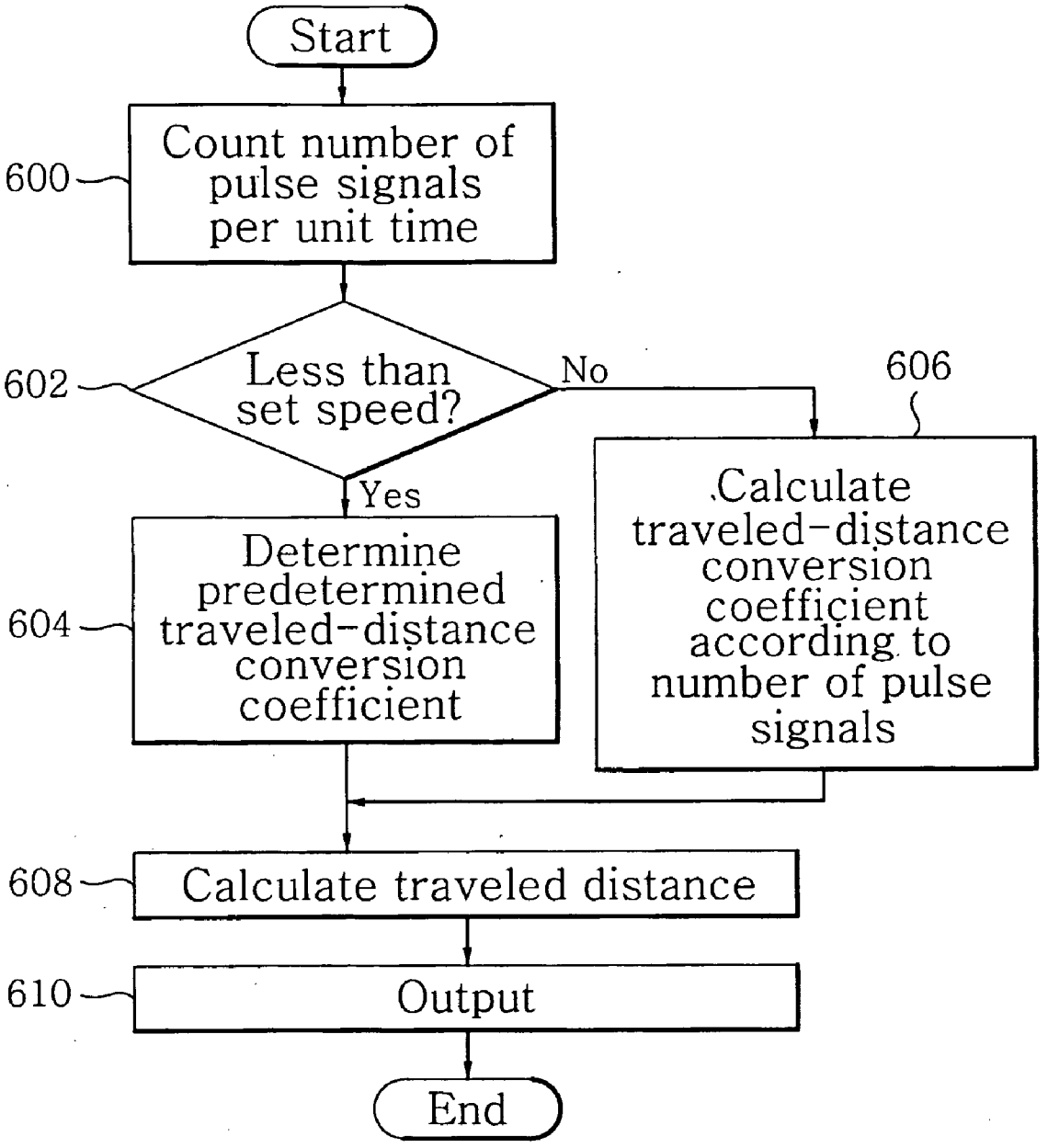

Start
600
Count number of pulse signals per unit time
602
Less than set speed?
No
606
Yes
Determine predetermined traveled-distance conversion coefficient
604
Calculate traveled-distance conversion coefficient according to number of pulse signals
608
Calculate traveled distance
610
Output
End

Fig.7

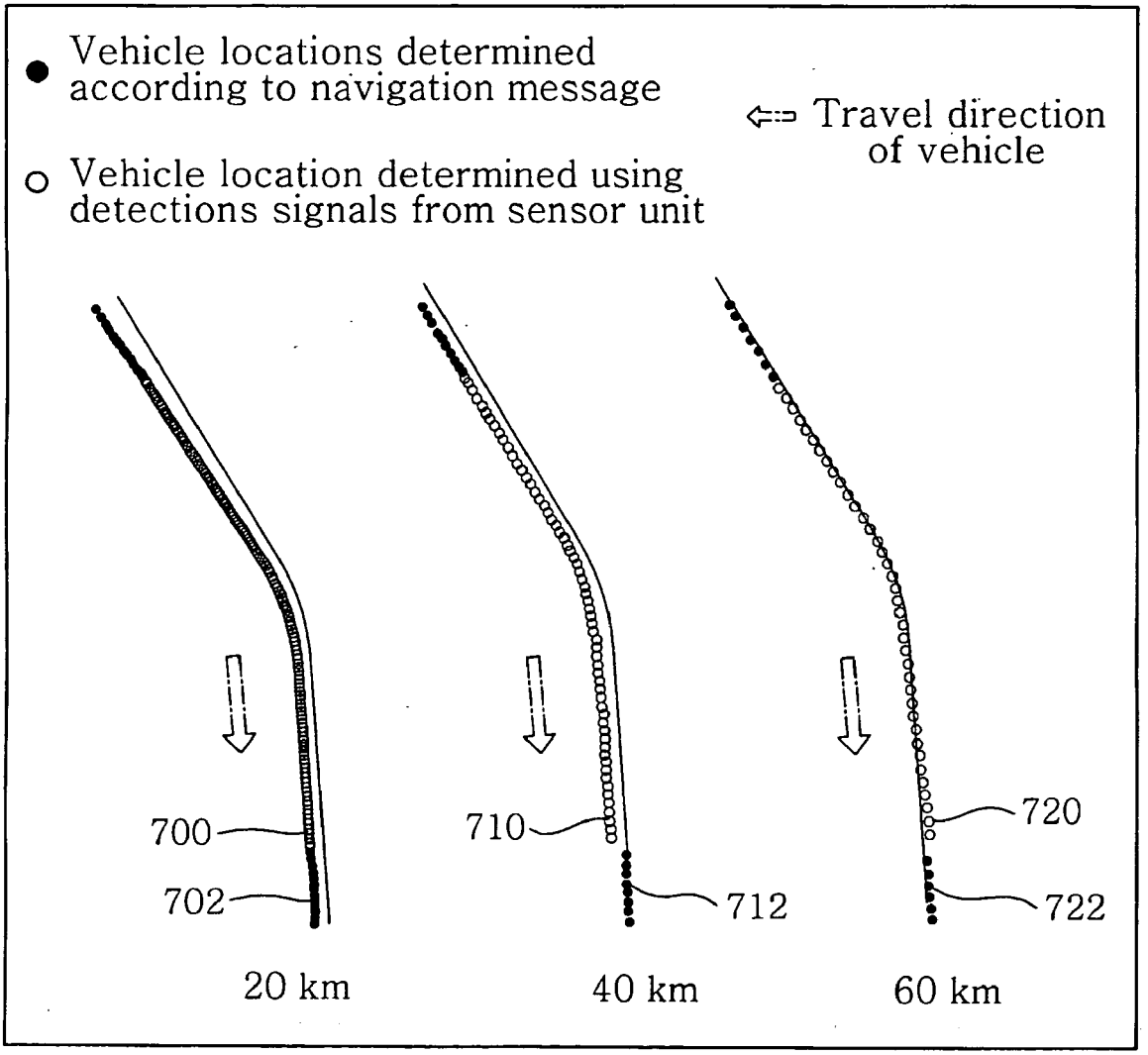

Vehicle locations determined according to navigation message
Vehicle location determined using detections signals from sensor unit
Travel direction of vehicle
700
702
710
712
720
722
20 km
40 km
60 km

Fig.8

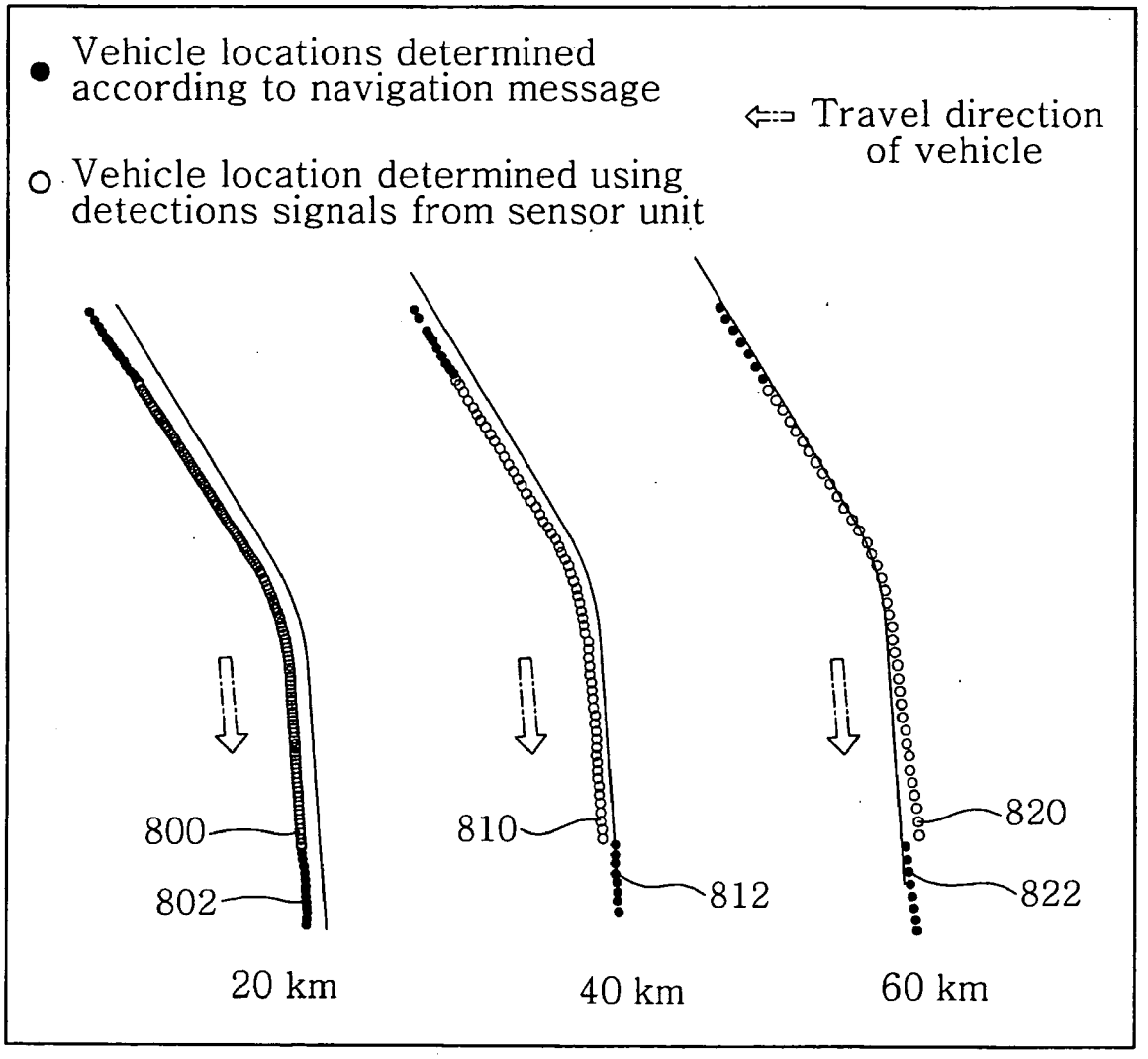

Vehicle locations determined according to navigation message
Vehicle location determined using detections signals from sensor unit
Travel direction of vehicle
800
802
810
812
820
822
20 km
40 km
60 km

Fig.9

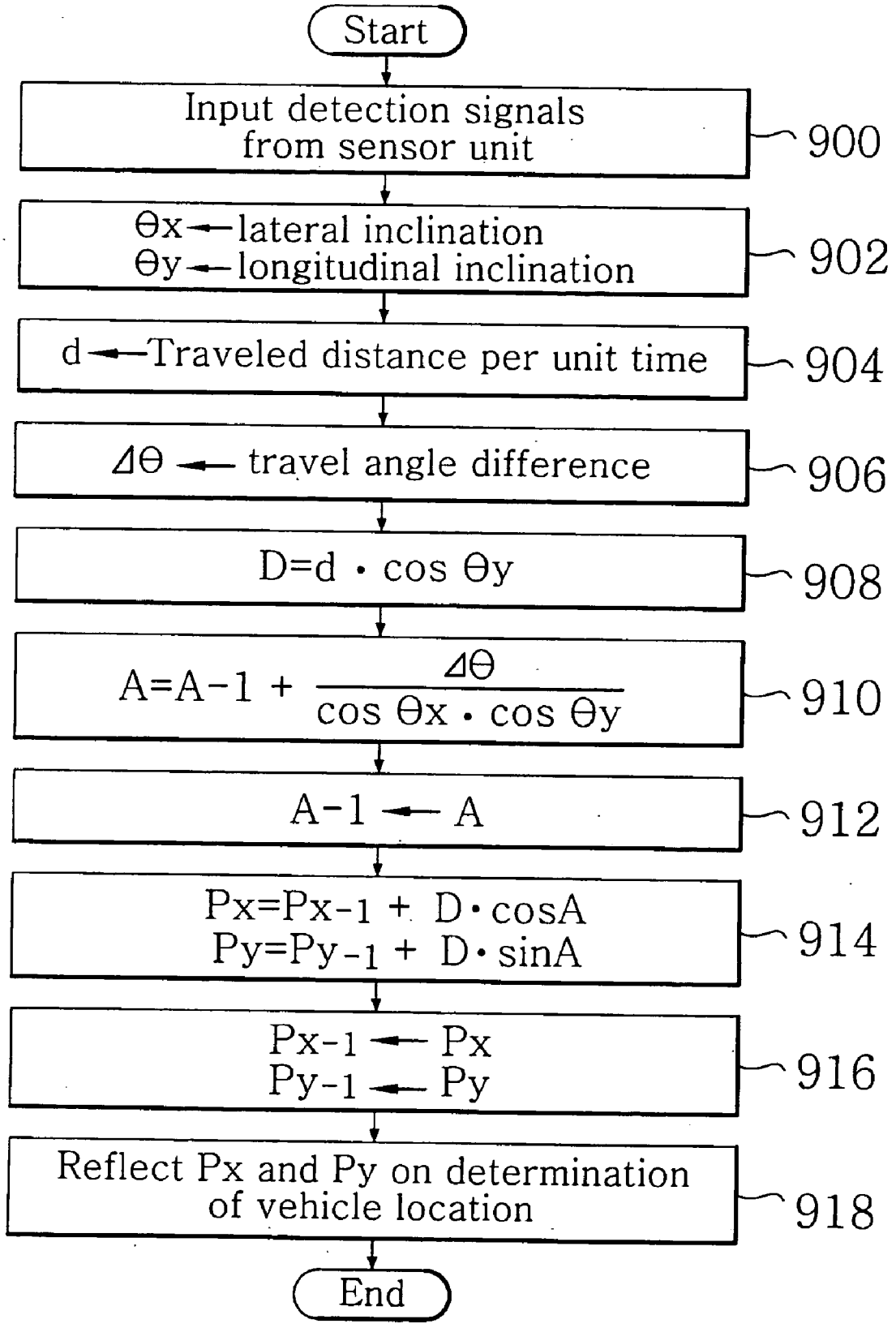

Start
Input detection signals from sensor unit
900
Θx ← lateral inclination
Θy ← longitudinal inclination
902
d ← Traveled distance per unit time
904
ΔΘ ← travel angle difference
906
D=d · cos Θy
908
A=A-1 + ΔΘ / (cos Θx · cos Θy)
910
A-1 ← A
912
Px=Px-1 + D·cosA
Py=Py-1 + D·sinA
914
Px-1 ← Px
Py-1 ← Py
916
Reflect Px and Py on determination of vehicle location
918
End

Fig.10a

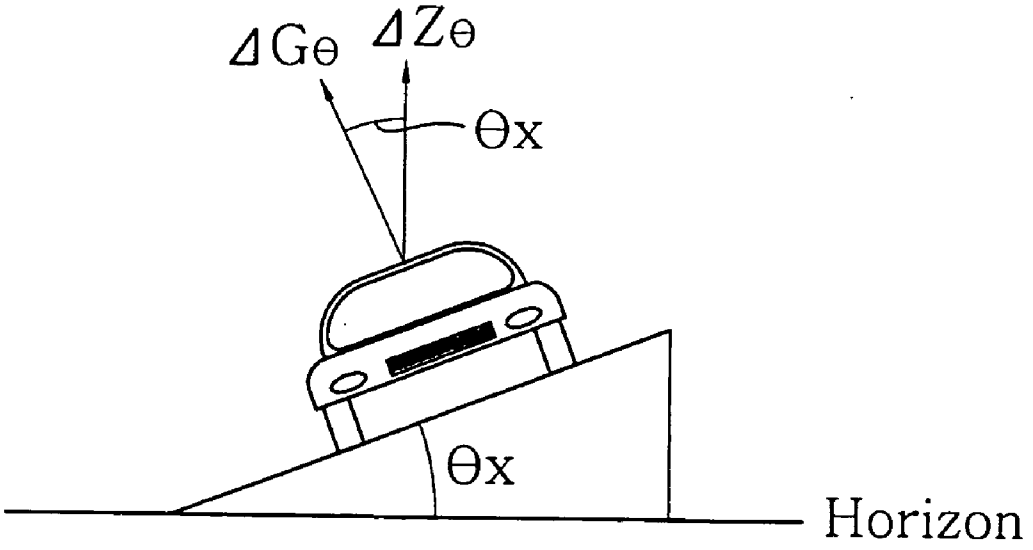


Fig.10b

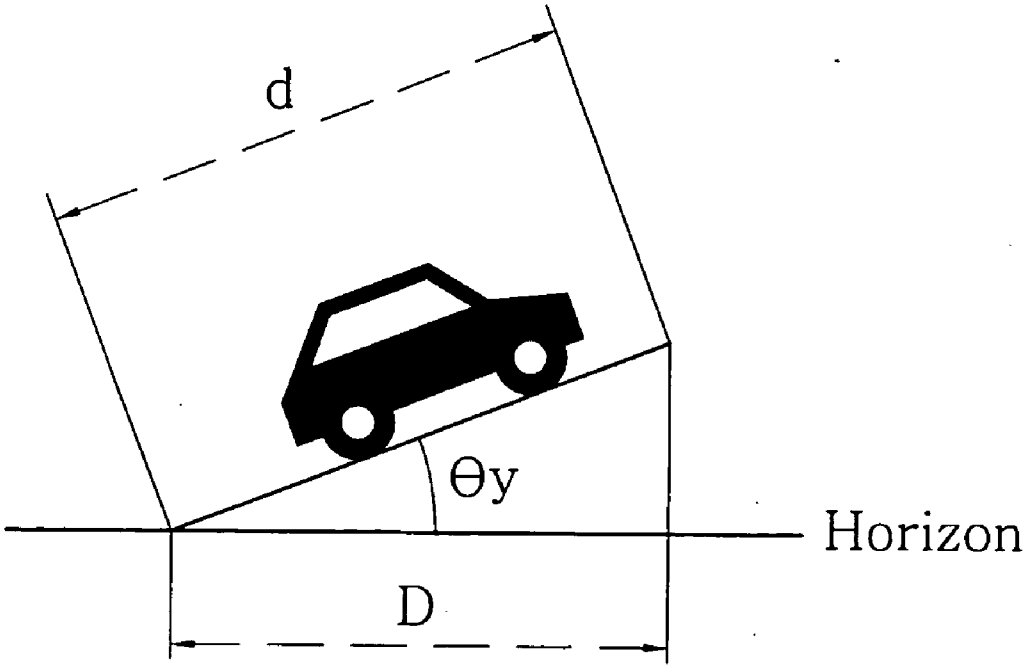


Fig.11a

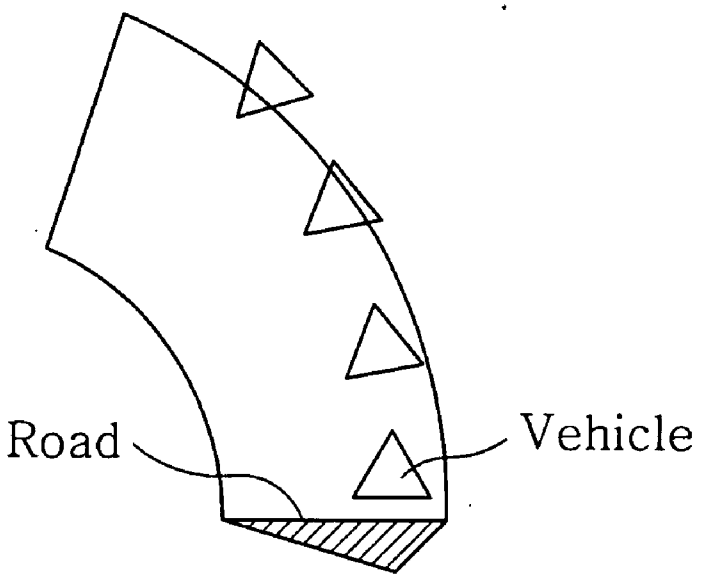


Fig.11b

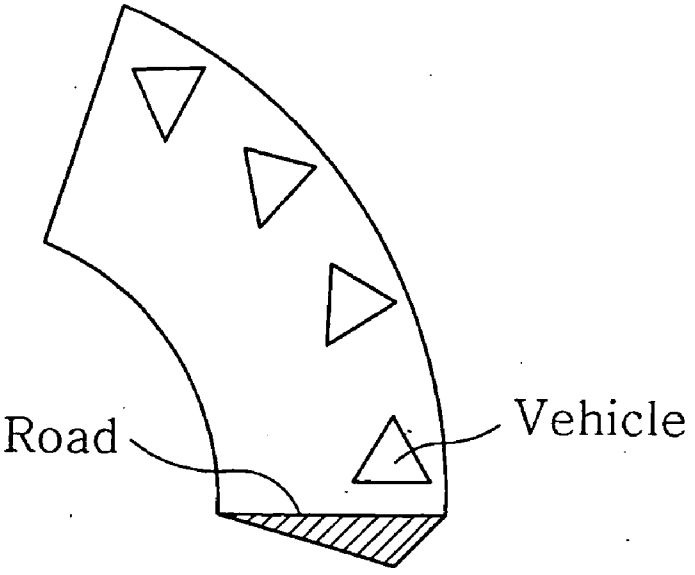


Fig.12

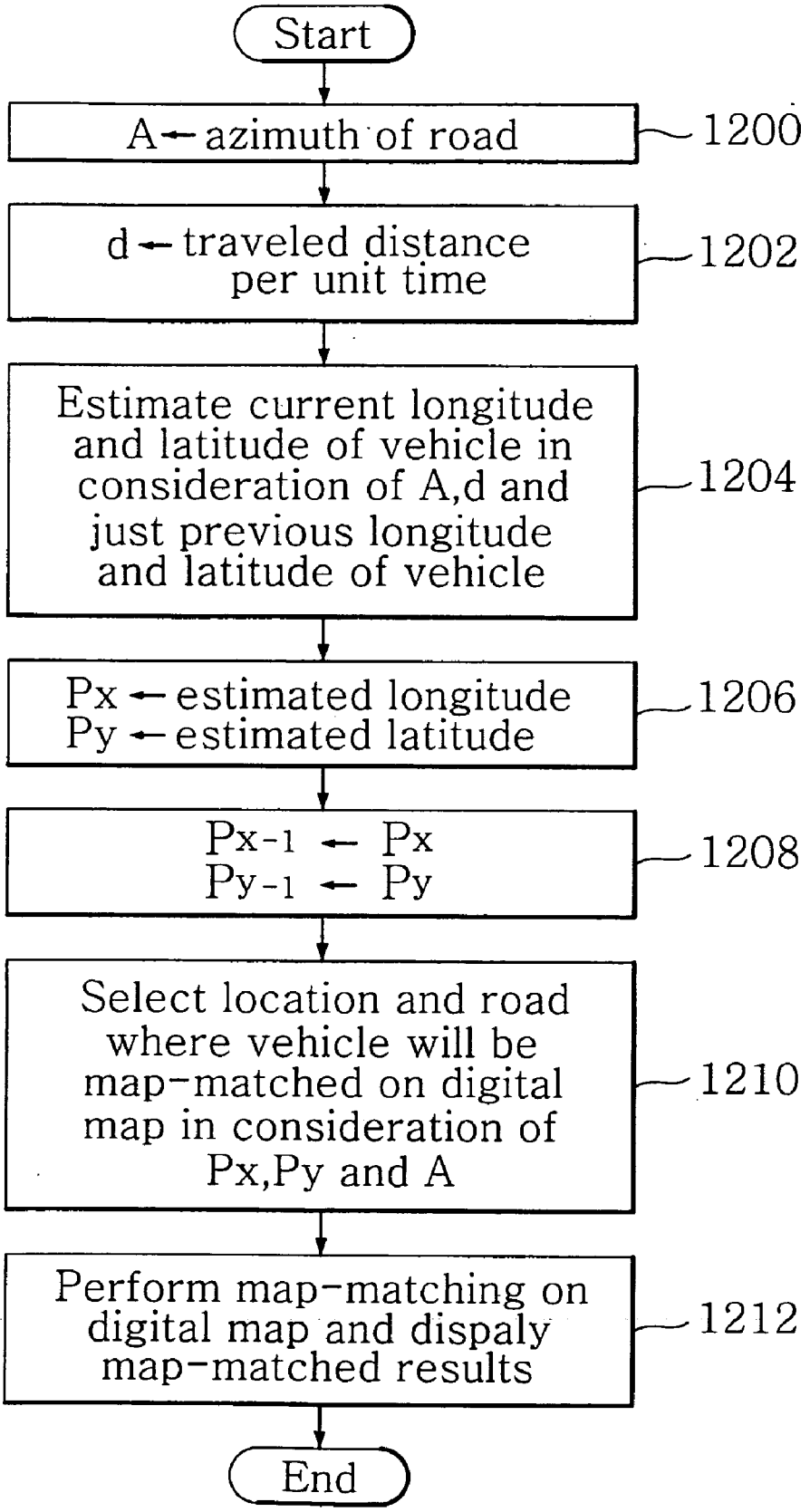

Start
A ← azimuth of road
1200
d ← traveled distance per unit time
1202
Estimate current longitude and latitude of vehicle in consideration of A,d and just previous longitude and latitude of vehicle
1204
Px ← estimated longitude
Py ← estimated latitude
1206
Px-1 ← Px
Py-1 ← Py
1208
Select location and road where vehicle will be map-matched on digital map in consideration of Px,Py and A
1210
Perform map-matching on digital map and dispaly map-matched results
1212
End

Fig.13a

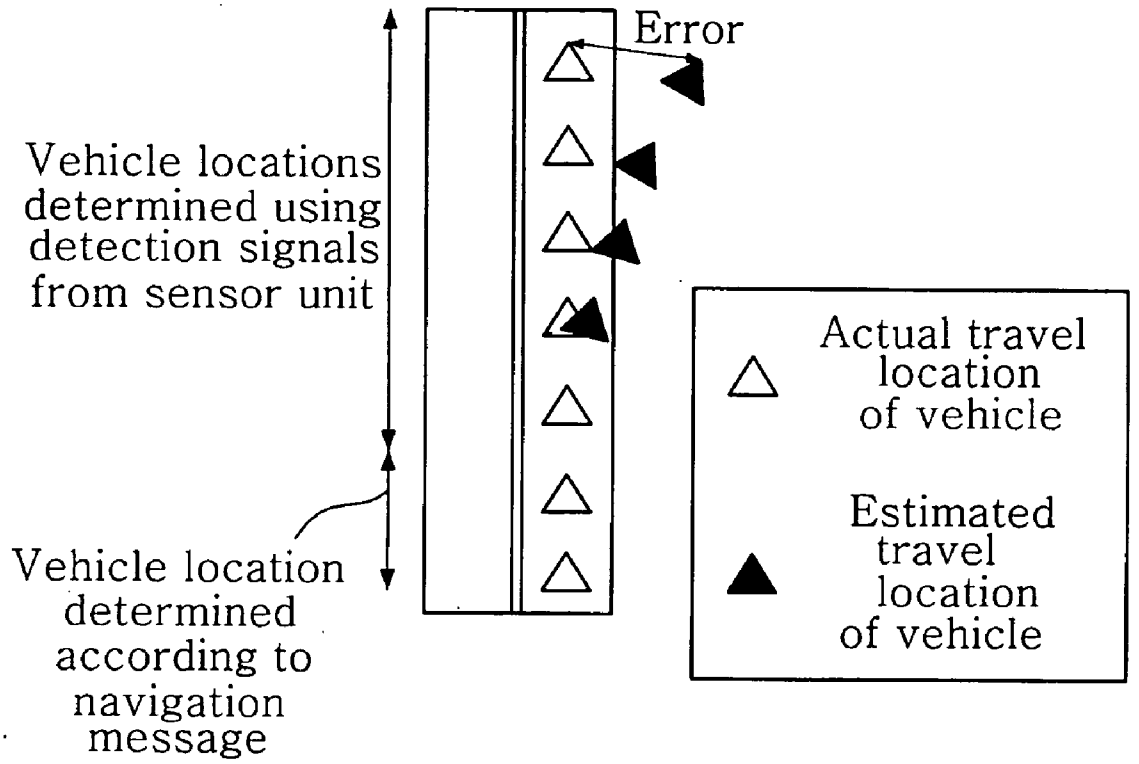

Error
Vehicle locations determined using detection signals from sensor unit
Vehicle location determined according to navigation message
Actual travel location of vehicle
Estimated travel location of vehicle

Fig.13b

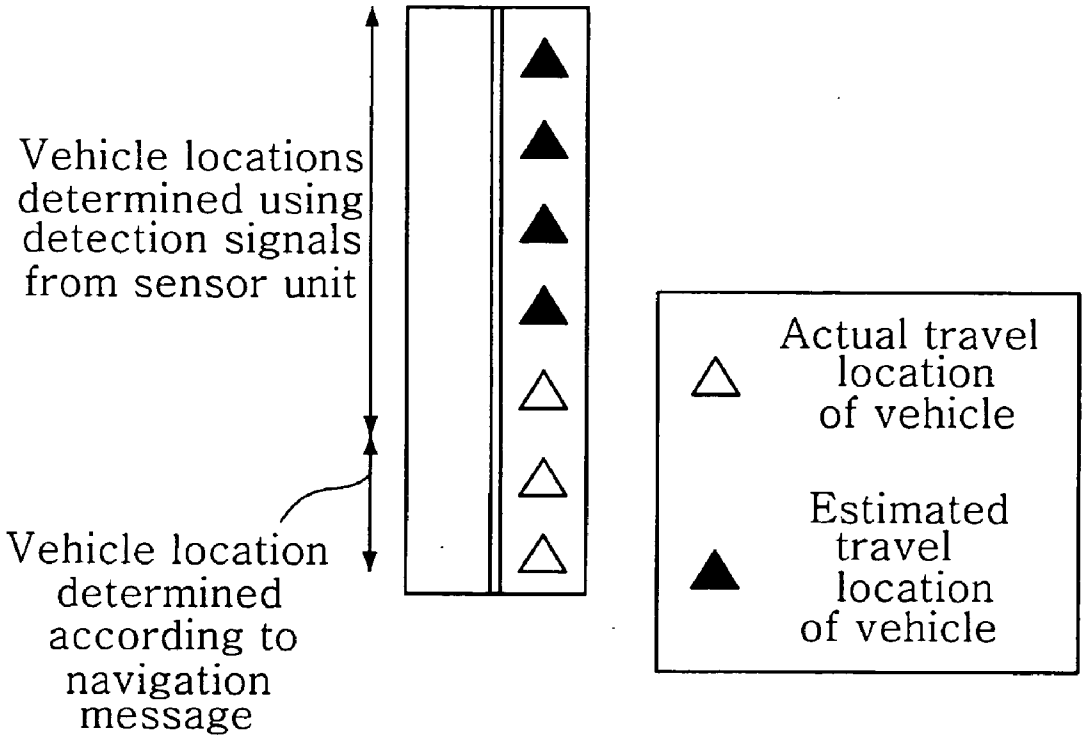
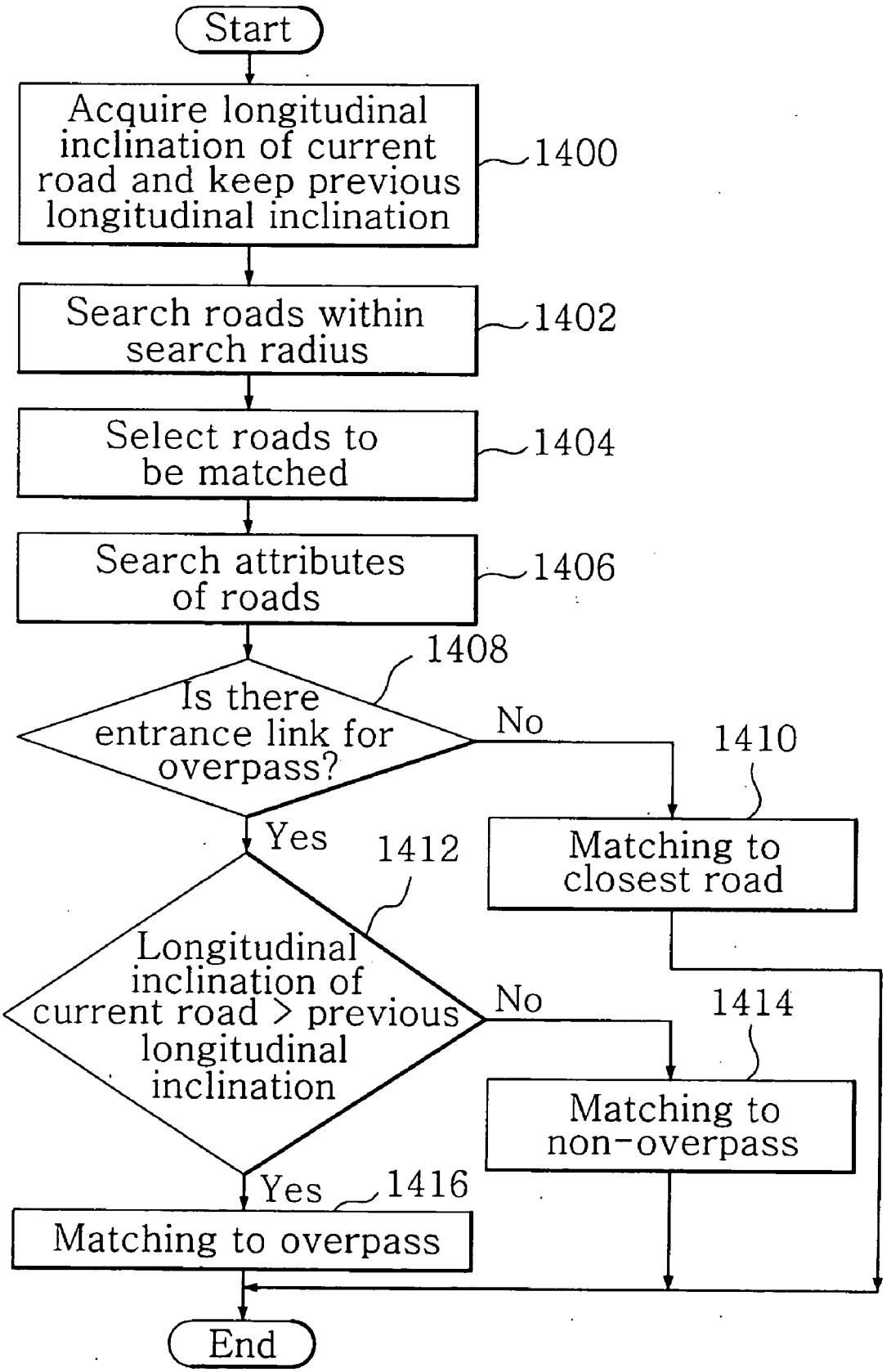

Vehicle locations determined using detection signals from sensor unit
Vehicle location determined according to navigation message
Actual travel location of vehicle
Estimated travel location of vehicle

Fig.14


Start
Acquire longitudinal inclination of current road and keep previous longitudinal inclination
1400
Search roads within search radius
1402
Select roads to be matched
1404
Search attributes of roads
1406
1408
Is there entrance link for overpass?
No
1410
Matching to closest road
Yes
1412
Longitudinal inclination of current road > previous longitudinal inclination
No
1414
Matching to non-overpass
Yes
1416
Matching to overpass
End

APPARATUS AND METHOD FOR DETECTING VEHICLE LOCATION IN NAVIGATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Pursuant to 35 U.S.C. §119(a), this application claims the benefit of earlier filing date and right of priority to Korean Patent Application Nos. 10-2003-49855, 10-2003-101284, 10-2004-4477, 10-2004-28386, 28387, filed on Jul. 21, 2003, December 31, Jan. 20, 2004, 2003, Apr. 23, 2004, Apr. 24, 2004, and Apr. 24, 2004 respectively, the contents of which are hereby incorporated by reference herein in their entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an apparatus and method for detecting a vehicle location in a navigation system, wherein a vehicle location can be precisely estimated using detection signals from sensors installed at a vehicle and then map-matched on a digital map so as to be displayed on a display screen.

[0004] 2. Description of the Related Art

[0005] As the number of vehicles such as cars continuously increases, traffic congestion becomes more critical. Particularly, there is a serious problem in that the rate of increase in the number of vehicles is much higher than the rate at which roads and other infrastructures are being expanded. One recent study found that, in the major urban areas of the United States, the total cost of traffic congestion exceeds $47.5 billion per year. Traffic congestion wastes more than 14.35 billion liters of fuel and 2.7 billion hours of work time per year. These numbers have continued to increase by 5% to 10% per year through the 1990s.

[0006] As one of solutions to such traffic congestion, attention has been paid to a navigation system for guiding a travel path of a vehicle using a global positioning system (GPS). GPS is a satellite-based navigation system developed by the U.S. Department of Defense, wherein a plurality of GPS satellites arranged on geostationary orbits over the Earth transmit navigation messages, respectively, and a GPS receiver receives navigation messages transmitted by at least four GPS satellites among the navigation messages transmitted by the plurality of GPS satellites, so as to detect the distance between the GPS satellites and the GPS receiver and position vectors of the GPS satellites using the received navigation messages and to calculate a position vector of the GPS receiver. That is, it is possible to precisely detect 3D coordinates of the receiver that receives the navigation messages from the GPS satellites anywhere over the world.

[0007] In a navigation system using GPS, a GPS receiver receives navigation messages transmitted by a plurality of GPS satellites so as to detect a location at which the navigation messages are received, i.e. a vehicle location, using the received navigation messages, and the detected vehicle location is map-matched on a digital map so that the digital map and the vehicle location can be displayed on a display screen.

[0008] Therefore, a vehicle user can check a current vehicle location, a shortest path from the current location to a destination, and the like using the navigation system. Further, under the guidance of the navigation system, the vehicle user can beforehand plan a travel path along which a vehicle travels and be guided so that he/she moves the vehicle along the planned travel path, resulting in efficient use of road systems.

[0009] However, the navigation system can precisely detect a vehicle location only at an area where the GPS receiver can correctly receive the navigation messages transmitted by the GPS satellites. That is, since GPS detects a vehicle location using the GPS receiver that receives the navigation messages transmitted by the GPS satellites, it may not detect coordinates of a vehicle location or merely can obtain very incorrect results of detection of the coordinates at areas, including the interiors of tunnels, thickly-wooded forests or downtown areas surrounded by skyscrapers, where the GPS receiver cannot correctly receive the navigation messages transmitted by the GPS satellites.

[0010] Thus, a deduced reckoning system for deducing a vehicle location by detecting the travel distance and direction of a vehicle has been employed at areas where a vehicle location cannot be calculated since a GPS receiver cannot correctly receive navigation messages from GPS satellites.

[0011] The deduced reckoning system continues to measure the travel distance and direction of the vehicle from its initial location by using sensors including an odometer for detecting the number of revolutions of a driving wheel of the vehicle, and a gyroscope for detecting a travel angle difference of the vehicle. The vehicle location is consecutively estimated from the distance traveled and the travel direction by continuously integrating the number of revolutions of the driving wheel and the travel angle difference that have been measured. Since such a deduced reckoning system should initially know the coordinates of a reference location of the vehicle, it is also called "dead-reckoning."

[0012] However, the deduced reckoning system has disadvantages in that the initial location of the vehicle should be set correctly, and an estimated location of the vehicle is incorrect due to an accumulation of measurement errors inherent to the sensors if the vehicle travels for a long time during a process of deducing the vehicle location using the deduced reckoning system.

[0013] To solve these problems, there has been developed a hybrid navigation system. The hybrid navigation system comprises a GPS receiver for receiving a navigation message, and sensors installed on a vehicle, such as a gyroscope and an odometer for detecting the travel angle difference and traveled distance of the vehicle. If the value of dilution of precision (DOP) of the navigation message received by the GPS receiver is less than a predetermined threshold, a vehicle location is detected based on the received navigation message and the detection signals from the sensors. If the value of dilution of precision (DOP) of the navigation message received by the GPS receiver is equal to or greater than the predetermined threshold, the vehicle location is detected by using only the detection signals from the sensors without using the received navigation message.

[0014] When the GPS receiver detects a vehicle location by receiving navigation messages transmitted by a plurality of GPS satellites, DOP as a geometrical error is produced according to the relationship of arrangement between the

GPS satellites, which have transmitted the navigation messages received by the GPS receiver, with respect to the position of the GPS receiver. The value of DOP becomes small if the GPS satellites are arranged uniformly with respect to the position of the GPS receiver, but large if the GPS satellites are not arranged uniformly. The GPS receiver detects the value of DOP according to the relationship of arrangement between the relevant GPS satellites from which the GPS receiver receives the navigation messages. If the value of DOP according to the relationship of arrangement between the relevant GPS satellites from which the GPS receiver receives the navigation messages is less than 2, this is an excellent case. If the value of DOP ranges from 2 to 3, this is a good case. If the value of DOP ranges from 4 to 5, this is a regular case. If the value of DOP is equal to or greater than 6, this cannot be utilized due to many errors in the position of the GPS receiver detected from the received navigation messages.

[0015] The hybrid navigation system determines based on the value of DOP whether the navigation messages received by the GPS receiver are used. If the value of DOP is less than a predetermined threshold, e.g., 5, the vehicle location is detected using both the received navigation messages and the detection signals from the sensors installed on the vehicle. If the value of DOP is equal to or greater than 5, the vehicle location is detected using only the detection signals from the sensors without using the received navigation messages.

[0016] However, in the case where the hybrid navigation system detects a current vehicle location using only the detection signals from the sensors since the value of DOP of a navigation message received by the GPS receiver is equal to or greater than the predetermined threshold, the detection of the current vehicle location is iterated using a vehicle location, which has been detected using just previous detection signals from the sensors, as a reference location. Thus, errors in the vehicle location detected using the detection signals from the sensors are continuously accumulated. Accordingly, there is a problem in that the difference between an actual vehicle location and a vehicle location detected using the detection signals from the sensors increases continuously with time.

[0017] That is, on the assumption that a vehicle travels along links between nodes L1, L2 and L3 as shown in **FIG. 1**, vehicle locations P1 and P2 are precisely detected using navigation messages with the values of DOP less than a predetermined threshold received by a GPS receiver, and vehicle locations are then detected using only detection signals from sensors installed on the vehicle after the values of DOP of received navigation messages become equal to or greater than the threshold, location P2 is detected and current vehicle location P3 is then detected using the detection signals from the sensors with respect to location P2. Thereafter, current vehicle location P4 is detected with respect to vehicle location P3 that has been detected just previously. Iteration of such processes results in detection of locations P5, P6, P7, P8 and P9.

[0018] However, the detection of a vehicle location using only the detection signals from the sensors, i.e. a travel angle difference and traveled distance, contains a little error in the detected vehicle location in view of characteristics of the sensors. Such a prior art has a problem in that since a current vehicle location is detected with respect to a just previously detected vehicle location, errors in vehicle locations detected using the detection signals from the sensors are continuously accumulated and thus the difference between an actual vehicle location and a detected vehicle location increases with time.

[0019] Further, when the traveled distance of the vehicle is estimated from the detection signals from the sensors in the prior art, the distance traveled per unit time is estimated by multiplying the number of pulse signals, which are generated from an odometer depending on a travel of the vehicle irrespective of a travel speed of the vehicle, by a predetermined distance conversion coefficient. Thus, there is a large difference between an actual vehicle location and a detected vehicle location according to the travel speed of the vehicle.

[0020] That is, when the vehicle travels, different frictional forces are produced between driving wheels and a road according to the travel speed of the vehicle. Due to this phenomenon, even though the vehicle travels by an identical distance, the number of pulse signals generated by the odometer varies according to the travel speed of the vehicle.

[0021] However, since the traveled distance of the vehicle is estimated by multiplying the number of pulse signals, which are generated from the odometer, by only the predetermined distance conversion coefficient in the prior art, a large difference occurs between an actual vehicle location and a detected vehicle location according to the travel speed of the vehicle.

[0022] Further, the travel angle difference of the vehicle detected by an output signal from the gyroscope cannot correctly reflect a 3D gradient of a road on which the vehicle travels. Moreover, the traveled distance of the vehicle detected by the odometer cannot also reflect a fore-and-aft gradient of a road on which the vehicle travels. These become causes of the occurrence of errors in the determination of a vehicle location, resulting in a large difference between the traveled distance and a traveled distance on a plane of an actual map.

[0023] Although there has been proposed a method using a cumulative inclinometer to reduce such errors, measurement errors are continuously accumulated in the cumulative inclinometer. Thus, an estimated vehicle location becomes incorrect with time. Further, at a junction of an overpass and a surface street, what road a vehicle enters or exits from cannot be correctly determined. Therefore, there is a problem in that errors occur in performing map-matching of a vehicle location on a digital map.

SUMMARY OF THE INVENTION

[0024] Accordingly, a first object of the present invention is to provide an apparatus and method for detecting a vehicle location in a navigation system, wherein the vehicle location can be precisely detected in such a manner that an error included in a detected vehicle location will not be accumulated on the next detected vehicle location in a case where the value of DOP of a navigation message received from a GPS satellite is equal to or greater than a predetermined threshold and thus the vehicle location is detected using only detection signals from sensors installed on a vehicle.

[0025] A second object of the present invention is to provide a method of detecting a vehicle location in a

navigation system, wherein the vehicle location can be precisely detected irrespective of a moving speed of a vehicle by differently setting a traveled-distance conversion coefficient according to the moving speed of the vehicle in a case where the vehicle location is estimated using detection signals from sensors.

[0026] A third object of the present invention is to provide a method of detecting a vehicle location in a navigation system, wherein the vehicle location can be precisely detected by installing a biaxial inclinometer on a vehicle, detecting a lateral inclination in a right and left direction and a longitudinal inclination in a fore and aft direction with respect to a travel direction of a vehicle, and correcting a traveled distance and a travel angle difference of the vehicle based on the detected lateral and longitudinal inclinations.

[0027] A fourth object of the present invention is to provide a method of detecting a vehicle location in a navigation system, wherein the vehicle location can be precisely detected by positively utilizing the azimuth of a road on which a vehicle travels.

[0028] A fifth object of the-present invention is to provide a method of detecting a vehicle location in a navigation system, wherein the vehicle location can be precisely estimated using a gradient of a road on which a vehicle travels at a junction of an overpass and a surface street.

[0029] In an apparatus for detecting a vehicle location in a navigation system for achieving the first object, a GPS receiver receives a navigation message transmitted by a GPS satellite, a map data storage unit stores in advance a digital map data therein, and a sensor unit detects a travel angle difference and a traveled distance of a vehicle and lateral and longitudinal inclinations of a road on which the vehicle travels. A control unit of the apparatus compares the value of DOP of the navigation message received by the GPS receiver with a predetermined threshold. If the value of DOP is less than the predetermined threshold, the control unit sets reference vehicle location information from vehicle location information detected using the navigation message. If the value of DOP is equal to or greater than the predetermined threshold, the control unit determines the reference vehicle location information by storing vehicle location information map-matched to the digital map data when the just previous value of DOP was less than the predetermined threshold, by accumulating detection signals from the sensor unit, and by using the stored vehicle location information and the accumulated detection signals from the sensor unit. The control unit estimates the vehicle location using the determined reference vehicle location information and the detection signals from the sensor unit, map-matches the estimated vehicle location to the digital map data stored in the map data storage unit, and outputs the map-matched results to display the map-matched digital map data and vehicle location on a screen of a display unit.

[0030] In the control unit, a map-matched result extraction section extracts the vehicle location information according to results of the map-matching of the vehicle location to the digital map data, and also extracts a status code for notifying whether the extracted vehicle location information is location information determined using the navigation message. A location information extraction section extracts the vehicle location information and the DOP using the navigation message received by the GPS receiver. A travel information extraction section extracts vehicle travel information using the detection signals from the sensor unit. According to the extracted value of DOP, a reference location information determination section determines the reference vehicle location information using the vehicle location information extracted by the location information extraction section, or determines the reference vehicle location information using the vehicle location information extracted by the map-matched result extraction section and the detection signals from the sensor unit, and generates a status code for notifying whether the determined reference vehicle location information has been determined using the navigation message. A dead reckoning section detects current vehicle location information by performing dead-reckoning using the reference vehicle location information determined by the reference location information determination section and the vehicle travel information extracted by the travel information extraction section. A map-matching section map-matches the vehicle location information detected by the dead reckoning section to the digital map data stored in the map data storage unit, outputting the map-matched results to the display unit, and providing information on the map-matched results to the map-matched result extraction section to extract the vehicle location information according to the map-matching.

[0031] A method of detecting a vehicle location in a navigation system for achieving the first object comprises the steps of: extracting, by a map-matched result extraction section, vehicle location information by receiving vehicle location information map-matched to digital map data from a map-matching section, extracting, by a location information extraction section, vehicle location information and DOP using a navigation message received by a GPS receiver, and extracting, by a travel information extraction section, vehicle travel information using detection signals from a sensor unit installed on a vehicle; determining the vehicle location information extracted by the location information extraction section as reference vehicle location information, or determining the reference vehicle location information using the vehicle location information extracted by the map-matched result extraction section and the detection signals from the sensor unit, according to the extracted value of DOP; performing, by a dead reckoning section, dead reckoning using the extracted vehicle travel information and the determined reference vehicle location information to extract current vehicle location information; and map-matching, by the map-matching section, the extracted current vehicle location information to the digital map data, displaying the map-matched results on a display unit, and providing the map-matched results to the map-matched result extraction section.

[0032] The step of determining the reference vehicle location information comprises the steps of: comparing the value of DOP with a predetermined threshold; if it is determined from the comparison that the value of DOP is less than the predetermined threshold, determining the vehicle location information extracted by the location information extraction section as the reference vehicle location information; and if it is determined from the comparison that the value of DOP is equal to or greater than the predetermined threshold, storing the vehicle location information extracted by the map-matched result extraction section at an initial stage where the value of DOP becomes equal to or greater than the predetermined threshold, accumulating the detection signals

from the sensor unit, and determining the reference vehicle location information using the stored vehicle location information and the accumulated detection signals from the sensor unit.

[0033] A method of determining a vehicle location in a navigation system for achieving the second object comprises the steps of: determining a travel speed of a vehicle using the number of pulse signals per unit time generated by an odometer of a sensor unit according to travel of the vehicle; determining a traveled-distance conversion coefficient varying according to the determined travel speed of the vehicle, and calculating a traveled distance per unit time of the vehicle.

[0034] The step of determining the traveled-distance conversion coefficient comprises the steps of: determining whether the travel speed of the vehicle is not equal to or greater than a predetermined speed; if it is determined that the travel speed of the vehicle is not equal to or greater than a predetermined speed, determining a predetermined constant as the traveled-distance conversion coefficient; and if it is determined that the travel speed of the vehicle is equal to or greater than the predetermined speed, determining the traveled-distance conversion coefficient through calculation using a predetermined logarithmic function including the number of pulse signals per unit time generated by the odometer.

[0035] A method of detecting a vehicle location in a navigation system for achieving the third object comprises the steps of: receiving a travel angle difference and a traveled distance of a vehicle, and lateral and longitudinal inclinations of a road on which the vehicle travels from a sensor unit; calculating a traveled distance per unit time using the received traveled distance; correcting the travel angle difference and the traveled distance per unit time of the vehicle using the received lateral and longitudinal inclinations of the road; and determining a current vehicle location from a previous vehicle location using the corrected angle difference and the traveled distance per unit time.

[0036] A method of detecting a vehicle location in a navigation system for achieving the fourth object comprises the steps of: extracting, by a control unit, an azimuth of a road on which a vehicle currently travels from a digital map, and extracting a traveled distance per unit time of the vehicle using the number of pulse signals output from an odometer of a sensor unit according to travel of the vehicle; estimating current longitude and latitude coordinates of the vehicle using the extracted azimuth of the road, the extracted traveled distance per unit time of the vehicle, and just previously estimated longitude and latitude coordinates of the vehicle; determining a location and a road where the vehicle will be matched on the digital map using the extracted azimuth of the road and the estimated longitude and latitude coordinates of the vehicle; and matching the vehicle at the determined location and road and displaying the matched results.

[0037] A method of detecting a vehicle location in a navigation system for achieving the fifth object comprises the steps of: acquiring, by a control unit, a current vehicle location using hybrid navigation; acquiring an inclination of a road on which a vehicle travels using detection signals from a sensor unit; searching roads within a search radius set from the acquired current vehicle location using digital map data, extracting roads on which the vehicle location will be matched, and searching attributes of the extracted roads; if it is determined from the search results of the road attributes that there is no entrance link for an overpass, the current vehicle location is matched on a road closest thereto; if there is an entrance link for an overpass, comparing the acquired inclination of the road on which the vehicle currently travels with an inclination of a previous road on which the vehicle has traveled; if it is determined from the comparison that the inclination of the current road is larger than that of the previous road, matching the vehicle location on an overpass; and if the inclination of the current road is not larger than that of the previous road, matching the vehicle location on a closest road among roads except overpasses.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] The above and other objects, features and advantages of the present invention will become apparent from the following description of preferred embodiments given in conjunction with the accompanying drawings, in which:

[0039] **FIG. 1** is a diagram illustrating an accumulation of errors in vehicle locations estimated on the basis of detection signals from sensors in a conventional hybrid navigation system;

[0040] **FIG. 2** is a block diagram showing a configuration of a detection apparatus of the present invention;

[0041] **FIG. 3** is a block diagram showing an inner configuration of a control unit of **FIG. 2**;

[0042] **FIG. 4** is a flowchart illustrating a detection method of the present invention;

[0043] **FIG. 5** is a diagram showing a trajectory of current vehicle locations detected according to the detection apparatus and method of the present invention;

[0044] **FIG. 6** is a flowchart illustrating an embodiment in which a vehicle location is determined according to a travel speed of a vehicle in the detection method of the present invention;

[0045] **FIGS. 7 and 8** are diagrams showing results displayed by calculating a traveled distance of a vehicle, estimating a vehicle location, and map-matching the vehicle location on a digital map-in accordance with a conventional detection method and the detection method of the present invention, respectively;

[0046] **FIG. 9** is a flowchart showing an embodiment in which a vehicle location is determined according to lateral and longitudinal inclinations of a road in the detection method of the present invention;

[0047] **FIG. 10*a*** is a diagram illustrating a principle for correcting a travel angle difference of a vehicle in the detection method of the present invention in a case where the vehicle travels on a curvilinear road with a lateral inclination;

[0048] **FIG. 10*b*** is a diagram illustrating a principle for correcting a traveled distance of a vehicle in the detection method of the present invention in a case where the vehicle travels on a straight road with a longitudinal inclination;

[0049] **FIGS. 11*a*** and **11*b*** are diagrams showing vehicle locations on a curvilinear road with a lateral inclination,

which are determined according to a conventional detection method and the detection method of the present invention, respectively;

[0050] **FIG. 12** is a flowchart illustrating an embodiment in which a vehicle location is detected using information on the azimuth of a road in the detection method of the present invention;

[0051] **FIGS. 13***a* and **13***b* are diagrams showing vehicle locations detected according to a conventional detection method and the detection method of the present invention, respectively; and

[0052] **FIG. 14** is a flowchart illustrating an embodiment in which a road on which a vehicle location is matched is determined according to an inclination of a road on which a vehicle travels in the detection method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0053] Hereinafter, a method of detecting a vehicle location in a navigation system according to the present invention will be described in detail with reference to accompanying drawings.

[0054] **FIG. 2** is a block diagram showing a configuration of an apparatus for detecting a vehicle location according to the present invention. As shown in the figure, the apparatus comprises a GPS receiver **204** for receiving a navigation message, which has been transmitted by a GPS satellite **200**, through an antenna **202**; a command input unit **206** for inputting an operation command corresponding to a user's manipulation; a map data storage unit **208** for storing a digital map data therein; a sensor unit **210**, including a gyroscope, an odometer, a biaxial inclinometer for detecting lateral and longitudinal inclinations of a vehicle, and the like installed on a vehicle, to detect a travel angle difference, a traveled distance, and lateral and longitudinal inclinations of the vehicle; a control unit **212** for controlling detection of the value of DOP of the navigation message received by the GPS receiver **204**, detection of the vehicle location using the navigation message received by the GPS receiver **204** and detection signals from the sensor unit **210** if the detected value of DOP is less than a predetermined threshold or using the detection signals from the sensor unit **210** if the value of DOP is equal to or greater than the predetermined threshold, map-matching of the detected vehicle location to digital map data stored in the map data storage unit **208**, and displaying of the map-matched digital map data and vehicle location; and a display unit **214** for displaying the digital map data and vehicle location on a screen thereof under the control of the control unit **212**.

[0055] As shown in **FIG. 3**, the control unit **212** comprises a map-matched result extraction section **300** for extracting vehicle location information from information on results of the map-matching of the vehicle location to the digital map data, and extracting a status code for notifying whether the extracted vehicle location information is location information determined using the navigation message; a location information extraction section **302** for extracting the vehicle location information and the DOP using the navigation message received by the GPS receiver **204**; a travel information extraction section **304** for extracting vehicle travel information using the detection signals from the sensor unit **210**; a reference location information determination section **306** for determining, according to the value of DOP extracted by the location information extraction section **302**, a reference vehicle location information using the vehicle location information extracted by the location information extraction section **302** or using the vehicle location information extracted by the map-matched result extraction section **300** and the detection signals from the sensor unit **210**, and for generating a status code for notifying whether the determined reference location information is determined using the navigation message; a dead reckoning section **308** for detecting current vehicle location information by performing dead-reckoning using the reference vehicle location information determined by the reference location information determination section **306** and the vehicle travel information extracted by the travel information extraction section **304**; and a map-matching section **310** for map-matching the vehicle location information detected by the dead reckoning section **308** to the digital map data stored in the map data storage unit **208**, outputting the map-matched results to the display unit **214**, and providing information on the map-matched results to the map-matched result extraction section **300** to extract the vehicle location information according to the map-matching.

[0056] The vehicle location detection apparatus of the present invention constructed as above receives the navigation message, which has been transmitted by the GPS satellite **200**, through the antenna **202**, and outputs the received navigation message to the location information extraction section **302** of the control unit **212**.

[0057] As the vehicle travels, the sensor unit **210** detects the vehicle travel information, i.e. the travel angle difference, traveled distance, and lateral and longitudinal inclinations of the vehicle, and outputs the detected vehicle travel information to the travel information extraction section **304** of the control unit **212**.

[0058] Then, the location information extraction section **302** extracts the longitude, latitude, altitude, azimuth and travel speed of the vehicle and the value of DOP using the navigation message received by the GPS receiver **204**. The travel information extraction section **304** extracts the travel angle difference, traveled distance, and lateral and longitudinal inclinations of the vehicle using the detection signals from the sensor unit **210**.

[0059] Meanwhile, the map-matched result extraction section **300** receives the information on the results of the map-matching of the vehicle location to the digital map data from the map-matching section **310**, and extracts the location information, such as the longitude, latitude, altitude, azimuth and speed obtained through the map-matching of the vehicle location to the digital map data, and the status code.

[0060] In such a state, the reference location information determination section **306** determines whether the value of DOP extracted by the location information extraction section **302** is less than, or equal to or greater than the predetermined threshold. If it is determined that the value of DOP is less than the predetermined threshold, the reference location information such as the longitude, latitude, altitude, azimuth and speed of the vehicle is determined using the vehicle location information extracted by the location infor-

mation extraction section **302**. Further, an output signal of the location information extraction section **302**, i.e. the status code for notifying that the reference location information has been determined using the navigation message, is generated. If it is determined that the value of DOP is equal to or greater than the predetermined threshold, the status code extracted by the map-matched result extraction section **300** is determined.

[**0061**] If it is determined from the status code that the reference location information is determined using a just previous navigation message, the location information extracted by the map-matched result extraction section **304** is stored, the vehicle location information is estimated using the stored reference location information and the detection signals from the sensor unit and then determined as the reference location information, and a status code for notifying that the reference location information has not been determined using the navigation message is generated.

[**0062**] If it is determined from the status code that reference location information determined just previously was not determined using a navigation message, the reference location information determination section **306** estimates current vehicle location information using the stored location information, i.e. location information extracted and stored by the map-matched result extraction section **304** at an initial stage where the value of DOP is equal to or greater than the predetermined threshold, and a cumulative detection signal obtained through accumulation of the detection signals from the sensor unit **210**. The reference location information determination section **306** determines the estimated vehicle location information as the reference location information, and then consecutively generates the status code for notifying that the reference location information has not been determined using the navigation message.

[**0063**] When the reference location information on the vehicle is determined in such a manner, the dead reckoning section **308** performs dead reckoning using the determined reference location information and the vehicle travel information extracted by the travel information extraction section **304**, i.e. the travel angle difference, traveled distance, and lateral and longitudinal inclinations of the vehicle, so as to detect a current vehicle location. The map-matching section **310** map-matches the detected vehicle location to the digital map data stored in the map data storage unit **208** and causes the map-matched results to be displayed on the display unit **214** by outputting them thereto. Further, the map-matched results are provided to the map-matched result extraction section **300** in order to extract vehicle location information according to the map-matched results.

[**0064**] In the meantime, **FIG. 4** is a flowchart illustrating a method of detecting a vehicle location according to the present invention. As shown in the figure, the control unit **212** determines whether a vehicle travels (step **400**). If the vehicle travels, the map-matched result extraction section **300** of the control unit **212** extracts vehicle location information map-matched to digital map data using information on map-matched results of the map-matching section **310** (step **402**). That is, the longitude, latitude, altitude, azimuth and speed of the vehicle and a status code are extracted.

[**0065**] The location information extraction section **302** of the control unit **212** extracts location information, such as the longitude, latitude, altitude, azimuth and speed of the vehicle, and DOP using a navigation message received by the GPS receiver **204** (step **404**). The travel information extraction section **304** extracts the travel angle difference, traveled distance, and lateral and longitudinal inclinations of the vehicle using the detection signals from the sensor unit **210** (step **406**).

[**0066**] When the vehicle location information obtained using the map-matched results, the vehicle location information obtained using the received navigation message, and the vehicle travel information obtained using the detection signals from the sensor unit **210** are extracted, the reference location information determination section **305** of the control unit **212** compares the value of DOP extracted by the location information extraction section **302** with a predetermined threshold (step **408**). If it is determined from the comparison in step **408** that the value of DOP is less than the predetermined threshold, the reference location information determination section **305** determines the location information extracted by the location information extraction section **302**, i.e. the location information extracted using the received navigation message, as the reference location information (step **410**). Then, the reference location information determination section **305** generates a status code for notifying that the location information extracted using the navigation message has been determined as the reference location information (step **412**).

[**0067**] Here, assume that the value of the status code becomes 1 if an output signal of the location information extraction section **302** using the navigation message is determined as the reference location information, whereas it becomes 0 if the reference location information is not determined using the navigation message.

[**0068**] If it is determined in step **408** that the value of DOP is equal to or greater than the threshold, the reference location information determination section **305** of the control unit **212** determines the value of the status code output from the map-matched result extraction section **300** (step **414**).

[**0069**] If it is determined in step **414** that the value of the status code is '1' and the reference location information has been determined using location information extracted using a just previous navigation message, the reference location information determination section **306** stores the vehicle location information extracted by the map-matched result extraction section **300**, i.e. previous location information on map-matching of the vehicle location to the digital map data (step **416**). Then, the reference location information determination section **306** estimates current vehicle location information using the stored location information and the detection signals from the sensor unit **210** (step **418**), and generates a status code for notifying that the location information extracted using the navigation message has not been determined as the reference location information (step **422**).

[**0070**] Meanwhile, if it is determined in step **414** that the value of the status code is '0', i.e. the reference location information has not been determined using the location information extracted from the just previous navigation message, the reference location information determination section **305** accumulates the detection signals from the sensor unit **210** (step **424**), estimates current vehicle location information using the cumulative detection signals from the sensor unit **210** based on the stored location information

(step **426**), determines the estimated location information as the reference location information (step **428**), and consecutively generates the status code for notifying that the location information extracted using the navigation message has not been determined as the reference location information (step **430**).

[**0071**] When the reference location information is determined in such a manner, the dead reckoning section **308** performs dead reckoning using the determined reference location information and the vehicle travel information extracted by the travel information extraction section **304** and thus determines a current vehicle location (step **432**). The map-matching section **310** performs map-matching of the determined current vehicle location to the digital map stored in the map data storage unit **208** and outputs the map-matched results to the display unit **214** to be displayed thereon (step **434**). Then, the procedure returns to step **400** in which determination is made as to whether the vehicle travels. If the vehicle travels, the aforementioned procedure is repeated to continuously detect and display vehicle locations.

[**0072**] In the present invention, assuming that the vehicle travels along links between nodes L**11**, L**12** and L**13** as shown in **FIG. 5**, vehicle locations P**11** and P**12** are precisely detected using navigation messages with the values of DOP of navigation messages received by the GPS receiver **204** less than a predetermined threshold, and a current vehicle location is detected using detection signals from sensor unit **210** after the values of DOP of navigation messages received by the GPS receiver **204** become equal to or greater than the threshold, the detection signals from the sensor unit **210** are continuously accumulated after the detection of location P**12** and vehicle locations P**13**, P**14**, P**15** . . . are then detected using the cumulative detection signal from the sensor unit **210** based on location P**12**. Thus, errors produced in detected respective locations P**13**, P**14**, P**15** . . . are not accumulated on the next detected location, resulting in precise detection of a current vehicle location.

[**0073**] **FIG. 6** is a flowchart illustrating an embodiment in which a traveled distance is differently determined according to the travel speed of a vehicle upon determination of a vehicle location using the detection signals from the sensor unit **210**. As shown in the figure, the travel information extraction section **304** of the control unit **212** counts the number of pulse signals per unit time, which are generated by an odometer of the sensor unit **212** according to travel of the vehicle, for example, at a time interval of 1 sec (step **600**). In step **602**, determination is made as to whether the travel speed of the vehicle is less than a predetermined speed, e.g., 20 km/h, using the number of pulse signals counted.

[**0074**] If it is determined in step **602** that the travel speed of the vehicle is less than the predetermined speed, the travel information extraction section **304** determines a predetermined constant as a traveled-distance conversion coefficient (step **604**). If it is determined in step **602** that the vehicle does not travel at a speed less than the predetermined speed, the travel information extraction section **304** calculates a traveled-distance conversion coefficient according to the number of pulse signals per unit time, for example, using formula 1 as follows (step **606**):

$$\text{Traveled-distance conversion coefficient} = a + \frac{\log(\text{number of pulse signals per unit time})}{b} \quad (1)$$

[**0075**] where a and b are empirical constants.

[**0076**] When the traveled-distance conversion coefficient according to the travel speed of the vehicle is determined in such a manner, the travel information extraction section **304** calculates a traveled distance per unit time of the vehicle, for example, from formula 2 using the determined traveled-distance conversion coefficient as follows (step **608**):

$$\text{Traveled distance per unit time} = (\text{number of pulse signals per unit time}) \times (\text{traveled-distance conversion coefficient}). \quad (2)$$

[**0077**] When the traveled distance per unit time of the vehicle is calculated in such a manner, the traveled distance per unit time calculated is output to the dead reckoning section **308** to be used for estimating a vehicle location (step **610**).

[**0078**] Tests for determining vehicle locations were performed while the speed of a vehicle was changed to 20 km/h, 40 km/h and 60 km/h, respectively, by applying traveled distances of the vehicle, which were calculated by means of the method of the present invention and a conventional method, to the vehicle.

[**0079**] **FIG. 7** is a diagram showing a displayed state obtained through estimation of vehicle locations and map-matching thereof on a digital map by applying the traveled distances of the vehicle calculated by means of the conventional method while the speed of the vehicle was changed to 20 km/h, 40 km/h and 60 km/h, respectively. As shown in the figure, when the vehicle travels at a speed of 20 km/h, the conventional method of estimating a vehicle location by setting a predetermined constant as the traveled-distance conversion coefficient irrespective of the travel speed of the vehicle hardly has an error between a final vehicle location **700** estimated using the output signals from the sensor unit **210** and an initial vehicle location **702** determined according to a received navigation message due to the value of DOP less than a predetermined threshold, thereby relatively precisely estimating a vehicle location, map-matching the estimated vehicle location on the digital map, and displaying the map-matched results.

[**0080**] However, when the vehicle travels at a speed of 40 km/h, there is a little error between a final vehicle location **710** estimated using the output signals from the sensor unit **210** and an initial vehicle location **712** determined according to a received navigation message due to the value of DOP less than the predetermined threshold. When the vehicle travels at a speed of 60 km/h, it can be seen that there is a large error between a final vehicle location **720** estimated using the output signals from the sensor unit **210** and an initial vehicle location **722** determined according to a received navigation message due to the value of DOP less than the predetermined threshold.

[**0081**] **FIG. 8** is a diagram showing a displayed state obtained through estimation of vehicle locations and map-

matching thereof on a digital map by applying the traveled distances of the vehicle calculated by means of the method of the present invention while the speed of the vehicle was changed to 20 km/h, 40 km/h and 60 km/h, respectively. As shown in the figure, when the vehicle travels at a speed of 20 km/h, the method of estimating a traveled distance of the vehicle by setting a predetermined constant as a traveled-distance conversion coefficient according to the present invention hardly has an error between a final vehicle location **800** estimated using the output signals from the sensor unit **210** and an initial vehicle location **810** determined according to a received navigation message due to the value of DOP less than a predetermined threshold, thereby precisely estimating a vehicle location, map-matching the estimated vehicle location on the digital map, and displaying the map-matched results.

[**0082**] When the vehicle travels at speeds of 40 km/h and 60 km/h, respectively, the method of calculating a traveled-distance conversion coefficient from aforementioned formula 1 and estimating the traveled distance of the vehicle using the calculated traveled-distance conversion coefficient according to the present invention hardly has an error between final vehicle locations **810** and **820** estimated using the output signals from the sensor unit **210** and initial vehicle locations **812** and **822** determined according to received navigation messages due to the values of DOP less than a predetermined threshold. Therefore, it can be seen that the vehicle location is determined to substantially conform to an actual vehicle location.

[**0083**] **FIG. 9** is a flowchart illustrating an embodiment in which a vehicle location is determined according to lateral and longitudinal inclinations of a road. As shown in the figure, the dead reckoning section **308** receives vehicle travel information extracted by the travel information extraction section **304** (step **900**). A lateral inclination θ_x of a road on which a vehicle travels and a longitudinal inclination θ_y of the road are determined using the received travel information (step **902**). A traveled distance d per unit time of the vehicle is determined in step **904**, and a travel angle difference $\Delta\theta$ of the vehicle is determined in step **906**.

[**0084**] Then, a corrected traveled distance D per unit time of the vehicle on a digital map is calculated from formula 3 using the longitudinal inclination θ_y and the traveled distance d per unit time as follows (step **908**):

$$D=d\times\cos\theta_y. \tag{3}$$

[**0085**] A current travel angle A of the vehicle is calculated from formula 4 using a travel angle A_{-1} of the vehicle previously detected, the determined current travel angle difference $\Delta\theta$ of the vehicle, and the lateral and longitudinal inclinations θ_x and θ_y of the road as follows (step **910**):

$$A = A_{-1} + \frac{\Delta\theta}{\cos\theta_x \times \cos\theta_y} \tag{4}$$

[**0086**] When the current travel angle A of the vehicle is calculated, the calculated travel angle A substitutes for the previous travel angle A_{-1} (step **912**). Longitude and latitude coordinates P_x and P_y according to travel of the vehicle are calculated from formula 5 as follows (step **914**):

$$P_x=P_{x-1}+D\times\cos A$$
$$P_y=P_{y-1}+D\times\sin A \tag{5}$$

[**0087**] When the longitude and latitude coordinates P_x and P_y according to travel of the vehicle are calculated in step **914**, the longitude and latitude coordinates P_x and P_y substitute for previous longitude and latitude coordinates P_{x-1} and P_{y-1} so that they can be used for the next determination of a vehicle location (step **916**). A vehicle location is determined by reflecting the longitude and latitude coordinates P_x and P_y on the determination of the vehicle location (step **908**).

[**0088**] A principle for correcting a travel angle of a vehicle using lateral and longitudinal axes when the vehicle travels on a laterally inclined curvilinear road, and a principle for correcting a traveled distance of the vehicle using an inclination when the vehicle travels on a longitudinally inclined linear road in accordance with the present invention will be described in greater detail below.

[**0089**] **FIG. 10***a* is a diagram illustrating a principle for correcting a turn angle in the method of determining a vehicle location according to the present invention when a vehicle turns on a laterally inclined curvilinear road with a lateral inclination of θ_x. As shown in the figure, since a biaxial inclinometer of the sensor unit **210** is installed on the vehicle to detect lateral and longitudinal inclinations of a road on which the vehicle travels, a travel angle difference of the vehicle detected by a gyroscope on a laterally inclined road is $\Delta\theta$. When the detected travel angle difference $\Delta\theta$ of the vehicle is converted into an angular rate based on a vertical axis (Z-axis), it is possible to precisely obtain a travel angle of the vehicle on a digital map.

[**0090**] In **FIG. 10***a*, since an orientation angle difference ΔG_θ of the vehicle is $\Delta Z_\theta\times\cos\theta_x$, a travel angle difference θZ_θ of the vehicle becomes $\Delta G_\theta/\cos\theta_x$. The previously detected travel angle A−1 of the vehicle is added to the travel angle difference ΔZ_θ of the vehicle ($\Delta Z_\theta=\Delta G_\theta/\cos\theta_x$) to calculate the current travel angle A of the vehicle (step **910**).

[**0091**] **FIG. 10***b* is a diagram illustrating a principle for correcting a traveled distance of a vehicle in the method of the present invention when the vehicle travels on a longitudinally inclined linear road with a longitudinal inclination of θ_y. As shown in the figure, when the vehicle travels on an inclined linear road, a traveled distance D on a digital map is shorter than an actual traveled distance d of the vehicle.

[**0092**] Therefore, if the traveled distance on the digital map is not corrected with respect to the traveled distance of the vehicle according to the inclination of the road when the vehicle travels on the inclined linear road, an error occurs in proportion to the inclination of the road, resulting in incorrect determination of a vehicle location.

[**0093**] Thus, when the vehicle travels on the inclined linear road, the traveled distance D of the vehicle is corrected using formula 6 in the present invention as follows:

$$D=d\times\cos\theta_y. \tag{6}$$

[**0094**] At this time, if a longitudinal inclination of the vehicle is θ_y, the traveled distance D of the vehicle is corrected with $d\times\cos\theta_y$ in the same manner as step **908**.

[**0095**] Vehicle locations were determined in the following by employing the method of the present invention and a conventional method when a vehicle travels on an inclined curvilinear road.

[0096] In the conventional method of determining a vehicle location using only detection signals from a gyroscope and an odometer installed on the vehicle, there was an error by which the vehicle was determined as traveling on a location deviating from the road as shown in **FIG. 11***a*. However, according to the present invention, a vehicle location is determined by correcting the detection signals from the gyroscope using lateral inclination of the road. Therefore, as shown in **FIG. 11***b*, the vehicle was precisely determined as normally traveling along the road.

[0097] **FIG. 12** is a flowchart illustrating an embodiment in which a vehicle location is detected using azimuth information on a road in the detection method of the present invention. As shown in the figure, the control unit **212** extracts an azimuth of a road with a just previous vehicle location matched thereto from a digital map data and stores the extracted azimuth as variable A (step **1200**). A traveled distance per unit time of the vehicle is detected by using a detection signal from the odometer, i.e. by multiplying the number of pulse signals generated by the odometer upon travel of the vehicle by the aforementioned traveled-distance conversion coefficient, and then stored as variable d (step **1202**). At this time, the traveled-distance conversion coefficient is differently set according to a travel speed of the vehicle as described above.

[0098] Then, current longitude and latitude coordinates of the traveling vehicle are estimated in consideration of the azimuth A of the road, the traveled distance d per unit time of the vehicle, and longitude and latitude coordinates of the vehicle just previously detected (step **1204**). The estimated longitude and latitude coordinates are stored as variables P_x and P_y, respectively (step **1206**).

[0099] When the current longitude and latitude coordinates of the vehicle and the azimuth of the road on which the vehicle travels are extracted in such a manner, the control unit **212** stores the longitude and latitude coordinates of the vehicle, which have been stored as variables P_x and P_y, as variables P_{x-1} and P_{y-1} so that they can be used for the next detection of a vehicle location (step **1208**).

[0100] Then, a location and a road where the vehicle will be matched on a digital map are selected in consideration of the extracted longitude and latitude coordinates of the vehicle and the azimuth of the road (step **1210**). The vehicle is matched to the selected location and road on the digital map and the matched results are displayed on the screen of the display unit **214** (step **1212**).

[0101] **FIG. 13***a* is a view showing results of estimation of a vehicle location according to a conventional method in which an azimuth of a road is not reflected on the estimation of the vehicle location using the detection signals from the sensor unit **210** since the value of DOP of a navigation message received by the GPS receiver **204** is greater than a predetermined threshold. As shown in the figure, it can be seen that in the conventional method, the estimation of the vehicle location using the detection signals from the sensor unit **210** results in a cumulative error integrated through integration of output signals of the gyroscope as a vehicle travels and thus errors between actual vehicle locations and estimated vehicle locations are consecutively accumulated.

[0102] However, according to the present invention in which the azimuth of the road is reflected, it can be seen that an error hardly occurs between actual vehicle locations and estimated vehicle locations since the azimuth of the road on which the vehicle travels is reflected even though the integrated error resulting from the integration of the output signals of the gyroscope during the travel of the vehicle is consecutively accumulated, as shown in **FIG. 13***b*.

[0103] **FIG. 14** is a flowchart illustrating an embodiment in which a road on which a vehicle location is matched is determined according to an inclination of a road on which a vehicle travels in the detection method of the present invention. As shown in the figure, the control unit **212** acquires a longitudinal inclination of a road on which the vehicle travels currently and keeps a longitudinal inclination of a road on which the vehicle has traveled just previously. Then, the control unit **212** searches all roads existing within a predetermined search radius centered on a current vehicle location using digital map data (step **1402**).

[0104] The control unit **212** extracts roads with high possibilities of matching of the vehicle location thereon among the roads existing within the search radius (step **1404**), searches attributes of the extracted roads (step **1406**), and determines whether there is an entrance link for an overpass (step **1408**).

[0105] If it is determined in step **1408** that there is no entrance link for an overpass, one road closest to the current vehicle location is selected from the extracted roads and the current vehicle location is matched on the selected road (step **1410**).

[0106] If it is determined in step **1408** that there is an entrance link for an overpass, the longitudinal inclination of the road on which the vehicle travels currently is compared with that of the road on which the vehicle has traveled previously (step **1412**).

[0107] If it is determined in step **1412** that the inclination of the current road is not greater than that of the previous road, a non-overpass closest to the current vehicle location is selected and the current vehicle location is matched on the selected non-overpass (step **1414**).

[0108] If it is determined in step **1412** that the inclination of the current road is greater than that of the previous road, this state corresponds to a state where the vehicle enters an entrance link for an overpass and thus the control unit **212** matches the vehicle location on the overpass (step **1416**).

[0109] Generally, at a junction of an overpass and a surface street, it is impossible to precisely determine whether a vehicle location is matched on the overpass or surface street. In such a case, the possibility of matching of the vehicle location on a correct road becomes 50%. If the vehicle location is not matched on a correct road, errors occur in a guidance and search of a path, and the like.

[0110] Therefore, in the present invention, the performance of an entire system is improved due to reduction of errors in location estimation and a guidance and search of a path by detecting an inclination of a road at a junction of an overpass and a surface street, selecting the overpass or surface street according to the detected inclination of the road, and precisely matching a vehicle location on the selected road.

[0111] According to the present invention described above, vehicle location information just previously map-

matched to digital map data is stored at an initial stage where the value of DOP becomes equal to or greater than a predetermined threshold, detection signals from the sensor unit are accumulated, and a current vehicle location is estimated using the stored vehicle location information and the accumulated detection signals from the sensor unit. Accordingly, errors in the vehicle location information estimated using the detection signals from the sensor unit are not accumulated, resulting in precise estimation of a current vehicle location.

[0112] Further, a vehicle location can be more precisely estimated by differently setting the traveled-distance conversion coefficient according to a travel speed of the vehicle, and reflecting lateral and longitudinal inclinations and an actual azimuth of a road on which the vehicle travels. By using an inclination of the vehicle at a junction of an overpass and a surface street, the vehicle location can be precisely map-matched on the overpass or surface street.

[0113] Although the present invention has been illustrated and described in connection with the preferred embodiments, it will be readily understood by those skilled in the art that various adaptations and changes can be made thereto without departing from the spirit and scope of the present invention defined by the appended claims.

What is claimed is:

1. An apparatus for detecting a vehicle location in a navigation system, comprising:

a GPS receiver for receiving a navigation message transmitted by a GPS satellite;

a map data storage unit for storing a digital map data therein;

a sensor unit for detecting a travel direction and a traveled distance of a vehicle and lateral and longitudinal inclinations of a road on which the vehicle travels;

a control unit for comparing the value of DOP of the navigation message received by the GPS receiver with a predetermined threshold, setting reference vehicle location information from vehicle location information detected using the navigation message if the value of DOP is less than the predetermined threshold, or determining the reference vehicle location information by storing vehicle location information map-matched to the digital map data when the just previous value of DOP was less than the predetermined threshold, by accumulating detection signals from the sensor unit, and by using the stored vehicle location information and the accumulated detection signals from the sensor unit if the value of DOP is equal to or greater than the predetermined threshold, estimating the vehicle location using the determined reference vehicle location information and the detection signals from the sensor unit, and map-matching the estimated vehicle location to the digital map data stored in the map data storage unit; and

a display unit for displaying the digital map data and vehicle location map-matched by the control unit on a screen thereof.

2. The apparatus as claimed in claim 1, wherein the control unit comprises:

a map-matched result extraction section for extracting the vehicle location information on results of the map-matching of the vehicle location to the digital map data, and extracting a status code for notifying whether the extracted vehicle location information is location information determined using the navigation message;

a location information extraction section for extracting the vehicle location information and the DOP using the navigation message received by the GPS receiver;

a travel information extraction section for extracting vehicle travel information using the detection signals from the sensor unit;

a reference location information determination section for determining the reference vehicle location information using the vehicle location information extracted by the location information extraction section if the value of DOP extracted by the location information extraction section is less than the predetermined threshold, or determining the reference vehicle location information by storing the vehicle location information extracted by the map-matched result extraction section when the just previous value of DOP was less than the predetermined threshold, by accumulating the detection signals from the sensor unit, and by using the stored vehicle location information and the accumulated detection signals from the sensor unit if the extracted value of DOP is equal to or greater than the predetermined threshold, and for generating a status code for notifying whether the determined reference vehicle location information is location information determined using the navigation message;

a dead reckoning section for detecting current vehicle location information by performing dead-reckoning using the reference vehicle location information determined by the reference location information determination section and the vehicle travel information extracted by the travel information extraction section; and

a map-matching section for map-matching the vehicle location information detected by the dead reckoning section to the digital map data stored in the map data storage unit, outputting the map-matched results to the display unit, and providing information on the map-matched results to the map-matched result extraction section to extract the vehicle location information according to the map-matching.

3. The apparatus as claimed in claim 2, wherein the travel information extracted by the travel information extraction section includes a travel angle difference, a traveled distance, and lateral and longitudinal inclinations of the vehicle.

4. A method for detecting a vehicle location in a navigation system, comprising the steps of:

extracting, by a map-matched result extraction section, vehicle location information by receiving vehicle location information map-matched to digital map data from a map-matching section, extracting, by a location information extraction section, vehicle location information and DOP using a navigation message received by a GPS receiver, and extracting, by a travel information

extraction section, vehicle travel information using detection signals from a sensor unit installed on a vehicle;

determining the vehicle location information extracted by the location information extraction section as reference vehicle location information, or determining the reference vehicle location information by storing the vehicle location information extracted by the map-matched result extraction section, accumulating the detection signals from the sensor unit, and using the stored vehicle location information and the accumulated detection signals from the sensor unit, according to the extracted value of DOP;

performing, by a dead reckoning section, dead reckoning using the vehicle travel information extracted by the travel information extraction section and the determined reference vehicle location information to extract current vehicle location information; and

map-matching, by the map-matching section, the current vehicle location information extracted by the dead reckoning section to the digital map data, displaying the map-matched results on a display unit, and providing the map-matched results to the map-matched result extraction section to extract the map-matched vehicle location information.

5. The method as claimed in claim 4, wherein the step of determining the reference vehicle location information comprises the steps of:

comparing the value of DOP with a predetermined threshold;

if it is determined from the comparison that the value of DOP is less than the predetermined threshold, determining the vehicle location information extracted by the location information extraction section as the reference vehicle location information; and

if it is determined from the comparison that the value of DOP is equal to or greater than the predetermined threshold, storing the vehicle location information extracted by the map-matched result extraction section when the just previous value of DOP was less than the predetermined threshold, accumulating the detection signals from the sensor unit, and determining the reference vehicle location information using the stored vehicle location information and the accumulated detection signals from the sensor unit.

6. The method as claimed in claim 4, wherein the travel information extracted by the travel information extraction section includes a travel angle difference, a traveled distance, and lateral and longitudinal inclinations of the vehicle.

7. The method as claimed in claim 6, wherein the extraction of a traveled distance from the vehicle travel information is performed by the steps of determining a travel speed of the vehicle using the number of pulse signals per unit time generated by an odometer of the sensor unit according to travel of the vehicle, determining a traveled-distance conversion coefficient varying according to the determined travel speed, and calculating a traveled distance per unit time of the vehicle.

8. The method as claimed in claim 7, wherein the step of determining the traveled-distance conversion coefficient comprises the steps of:

determining whether the travel speed of the vehicle is equal to or greater than a predetermined speed;

if it is determined that the travel speed of the vehicle is not equal to or greater than the predetermined speed, determining a predetermined constant as the traveled-distance conversion coefficient; and

if it is determined that the travel speed of the vehicle is equal to or greater than the predetermined speed, determining the traveled-distance conversion coefficient through calculation using a predetermined logarithmic function including the number of pulse signals per unit time generated by the odometer.

9. The method as claimed in claim 8, wherein the traveled-distance conversion coefficient is calculated using formula 1 as follows:

$$\text{Traveled-distance conversion coefficient} = a + \frac{\log(\text{number of pulse signals per unit time})}{b} \quad (1)$$

where a and b are empirical constants.

10. The method as claimed in claim 7, wherein the traveled distance per unit time of the vehicle is calculated by multiplying the number of pulse signals per unit time generated by the odometer by the traveled-distance conversion coefficient.

11. The method as claimed in claim 6, wherein the extraction of the current vehicle location information is performed by the steps of:

receiving a travel angle difference and the traveled distance of the vehicle, and lateral and longitudinal inclinations of a road on which the vehicle travels from the sensor unit;

calculating a traveled distance per unit time using the received traveled distance;

correcting the travel angle of the vehicle using the received travel angle difference and the received lateral and longitudinal inclinations;

correcting the traveled distance per unit time using the received lateral and longitudinal inclinations; and

determining a current vehicle location from a previous vehicle location using the corrected travel angle and the corrected traveled distance per unit time.

12. The method as claimed in claim 11, wherein the travel angle of the vehicle is corrected using formula 4 as follows:

$$A = A_{-1} + \frac{\Delta\theta}{\cos\theta_x \times \cos\theta_y} \quad (4)$$

where A is a corrected current travel angle of the vehicle, A_{-1} is a previous travel angle, $\Delta\theta$ is a travel angle difference of the vehicle detected by the sensor unit, and θ_x and θ_y are lateral and longitudinal inclinations of the road on which the vehicle travels.

13. The method as claimed in claim 11, wherein the traveled distance per unit time is corrected using formula 3 as follows:

$$D=d\times\cos\theta_y \quad (3)$$

where D is a corrected traveled distance per unit time of the vehicle, d is the traveled distance per unit time, and θ_y is a longitudinal inclination of the road on which the vehicle travels.

14. The method as claimed in claim 11, wherein the current vehicle location is determined using formula 5 as follows:

$$P_x=P_{x-1}+D\times\cos A$$
$$P_y=P_{y-1}+D\times\sin A \quad (5)$$

where P_x and P_y are corrected current longitude and latitude coordinates of the vehicle, P_{x-1} and P_{y-1} are longitude and latitude coordinates of the vehicle detected prior to the unit time, D is a corrected traveled distance per unit time of the vehicle, and A is a corrected travel angle of the vehicle.

15. The method as claimed in claim 4, wherein the extraction of the current vehicle location information is performed by the steps of:

extracting an azimuth of a road on which the vehicle travels from the digital map data, and calculating a traveled distance per unit time of the vehicle;

estimating current longitude and latitude coordinates of the vehicle using the azimuth of the road, the traveled distance per unit time of the vehicle, and just previously estimated longitude and latitude coordinates of the vehicle;

selecting a location and a road where the vehicle will be matched on a digital map using the extracted azimuth of the road and the estimated longitude and latitude coordinates of the vehicle; and

matching the vehicle at the selected location and road and displaying the matched results.

16. The method as claimed in claim 15, wherein the calculation of the traveled distance per unit time of the vehicle is performed by the steps of determining a travel speed of the vehicle using the number of pulse signals per unit time generated by an odometer of the sensor unit according to the travel of the vehicle, determining a traveled-distance conversion coefficient varying according to the determined travel speed, and calculating the traveled distance per unit time.

17. The method as claimed in claim 16, wherein the step of determining the traveled-distance conversion coefficient comprises the steps of:

determining whether the travel speed of the vehicle is equal to or greater than a predetermined speed;

if it is determined that the travel speed of the vehicle is not equal to or greater than the predetermined speed, determining a predetermined constant as the traveled-distance conversion coefficient; and

if it is determined that the travel speed of the vehicle is equal to or greater than the predetermined speed, determining the traveled-distance conversion coefficient through calculation using a predetermined logarithmic function including the number of pulse signals per unit time generated by the odometer.

18. The method as claimed in claim 17, wherein the traveled-distance conversion coefficient is calculated using formula 1 as follows:

$$\text{Traveled-distance conversion coefficient} = a+\frac{\log(\text{number of pulse signals per unit time})}{b} \quad (1)$$

where a and b are empirical constants.

19. The method as claimed in claim 16, wherein the step of calculating the traveled distance per unit time of the vehicle comprises the step of making correction using formula 3 as follows:

$$D=d\times\cos\theta_y \quad (3)$$

where D is a corrected traveled distance per unit time of the vehicle, d is the traveled distance per unit time, and θ_y is a longitudinal inclination of the road on which the vehicle travels.

20. The method as claimed in claim 15, wherein the step of selecting the location and the road where the vehicle will be matched comprises the steps of:

acquiring an inclination of the road on which the vehicle travels using the detection signals from the sensor unit;

searching roads within a search radius set with respect to a current vehicle location, extracting roads on which the vehicle location will be matched, and searching attributes of the extracted roads;

if it is determined from the search results of the road attributes that there is no entrance link for an overpass, the current vehicle location is matched on a road closest thereto;

if it is determined from the search results of the road attributes that there is an entrance link for an overpass, comparing the acquired inclination of the road on which the vehicle currently travels with an inclination of a road on which the vehicle has traveled previously;

if it is determined from the comparison that the inclination of the current road is larger than that of the previous road, matching the vehicle location on an overpass; and

if it is determined from the comparison that the inclination of the current road is not larger than that of the previous road, matching the vehicle location on a closest road among roads except overpasses.

21. A method for determining a vehicle location, comprising the steps of:

determining a travel speed of a vehicle using the number of pulse signals per unit time generated by an odometer of a sensor unit according to travel of the vehicle;

setting a traveled-distance conversion coefficient varying according to the determined travel speed of the vehicle, and calculating a traveled distance per unit time of the vehicle; and

determining the vehicle location by performing dead reckoning using the calculated traveled distance per unit time.

22. The method as claimed in claim 21, wherein the step of calculating the traveled distance per unit time comprises the steps of:

if it is determined that the travel speed of the vehicle is not equal to or greater than a predetermined speed, determining a predetermined constant as the traveled-distance conversion coefficient;

if it is determined that the travel speed of the vehicle is equal to or greater than the predetermined speed, determining the traveled-distance conversion coefficient through calculation using a predetermined logarithmic function including the number of pulse signals per unit time generated by the odometer; and

calculating the traveled distance per unit time of the vehicle using the determined traveled-distance conversion coefficient.

23. The method as claimed in claim 21, wherein the traveled-distance conversion coefficient is calculated using formula 1 as follows:

$$\text{Traveled-distance conversion coefficient} = a + \frac{\log(\text{number of pulse signals per unit time})}{b} \quad (1)$$

where a and b are empirical constants.

24. The method as claimed in claim 20, wherein the traveled distance per unit time of the vehicle is calculated by multiplying the number of pulse signals per unit time generated by the odometer by the traveled-distance conversion coefficient.

25. The method as claimed in claim 20, wherein the step of calculating the traveled distance per unit time of the vehicle comprises the step of making correction using formula 3 as follows:

$$D=d\times\cos\theta_y \quad (3)$$

where D is a corrected traveled distance per unit time of the vehicle, d is the traveled distance per unit time, and θ_y is a longitudinal inclination of the road on which the vehicle travels.

26. A method of detecting a vehicle location in a navigation system, comprising the steps of:

receiving, by a control unit, a travel angle difference and a traveled distance of a vehicle, and lateral and longitudinal inclinations of a road on which the vehicle travels from a sensor unit;

calculating a traveled distance per unit time using the received traveled distance;

correcting a travel angle of the vehicle using the received lateral and longitudinal inclinations of the road;

correcting the traveled distance per unit time using the received lateral and longitudinal inclinations of the road; and

estimating a current vehicle location from a previous vehicle location using the corrected travel angle and the corrected traveled distance per unit time.

27. The method as claimed in claim 26, wherein the travel angle of the vehicle is corrected using formula 4 as follows:

$$A = A_{-1} + \frac{\Delta\theta}{\cos\theta_x \times \cos\theta_y} \quad (4)$$

where A is a corrected current travel angle of the vehicle, A_{-1} is a previous travel angle, $\Delta\theta$ is a travel angle difference of the vehicle detected by the sensor unit, and θ_x and θ_y are lateral and longitudinal inclinations of the road on which the vehicle travels.

28. The method as claimed in claim 26, wherein the traveled distance per unit time of the vehicle is corrected using formula 3 as follows:

$$D=d\times\cos\theta_y \quad (3)$$

where D is a corrected traveled distance per unit time of the vehicle, d is the traveled distance per unit time, and θ_y is a longitudinal inclination of the road on which the vehicle travels.

29. The method as claimed in claim 26, wherein the current vehicle location is estimated using formula 5 as follows:

$$P_x=P_{x-1}+D\times\cos A$$
$$P_y=P_{y-1}+D\times\sin A \quad (5)$$

where P_x and P_y are corrected current longitude and latitude coordinates of the vehicle, P_{x-1} and P_{y-1} are longitude and latitude coordinates of the vehicle detected prior to the unit time, D is a corrected traveled distance per unit time of the vehicle, and A is a corrected travel angle of the vehicle.

30. A method for detecting a vehicle location in a navigation system, comprising the steps of:

extracting, by a control unit, an azimuth of a road on which a vehicle currently travels from a digital map data, and extracting a traveled distance per unit time of the vehicle using the number of pulse signals output from an odometer of a sensor unit according to travel of the vehicle;

estimating current longitude and latitude coordinates of the vehicle using the extracted azimuth of the road, the extracted traveled distance per unit time of the vehicle, and just previously estimated longitude and latitude coordinates of the vehicle;

determining a location and a road where the vehicle will be matched on the digital map using the extracted-azimuth of the road and the estimated longitude and latitude coordinates of the vehicle; and

matching the vehicle at the determined location and road and displaying the matched results.

31. A method for detecting a vehicle location in a navigation system, comprising the steps of:

acquiring, by a control unit, a current vehicle location using hybrid navigation;

acquiring an inclination of a road on which a vehicle travels using detection signals from a sensor unit;

searching roads within a search radius set from the acquired current vehicle location using digital map data, extracting roads on which the vehicle location will be matched, and searching attributes of the extracted roads;

if it is determined from the search results of the road attributes that there is no entrance link for an overpass, the current vehicle location is matched on a road closest thereto;

if it is determined from the search results of the road attributes that there is an entrance link for an overpass, comparing the acquired inclination of the road on which the vehicle currently travels with an inclination of a previous road on which the vehicle has traveled;

if it is determined from the comparison that the inclination of the current road is larger than that of the previous road, matching the vehicle location on an overpass; and

if it is determined from the comparison that the inclination of the current road is not larger than that of the previous road, matching the vehicle location on a closest road among roads except overpasses.

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