

DESCRIPTION

VEHICLE POSITION MEASUREMENT DEVICE AND VEHICLE POSITION
MEASUREMENT METHOD

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TECHNICAL FIELD

[0001]

The present invention relates to a vehicle position measurement device and a vehicle position measurement method.

10 Priority is claimed on Japanese Patent Application No. 2009-131376, filed May 29, 2009, the content of which is incorporated herein by reference.

BACKGROUND ART

[0002]

15 Conventionally, a toll charging system has been proposed in which a GPS (global positioning system) is used to measure the position of a vehicle and detect that the vehicle enters a charging area, and thereby a toll is charged (see Patent Document 1). Such a system has a problem in that, when a vehicle is positioned in a location where it is difficult for the vehicle to receive radio waves from a GPS satellite, the accuracy in

20 measuring the vehicle position degrades, and thereby it becomes impossible to accurately charge a toll. For example, this problem has been found in high-rise buildings, basement parking areas, inside tunnels, under expressways, and the like.

[0003]

In the above-described locations, dead-reckoning navigation using a vehicle

25 speed signal and a gyroscope, or map matching using map data has been generally used

as alternative means for the GPS. Use of the alternative means makes it possible to measure the position of a vehicle even when the vehicle is positioned in a location where the vehicle cannot receive radio waves from a GPS satellite.

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CITATION LIST

[Patent Document]

[0004]

[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2004-326263

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DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

[0005]

However, the measurement accuracy of the conventional alternative means is lower than that of the GPS, thereby causing a problem that the measurement accuracy deteriorates with the lapse of time.

The present invention has been made in view of the above-described situations. An object of the present invention is to provide a vehicle position measurement device and a vehicle position measurement method that enables enhancing the accuracy of measuring the position of a vehicle in a location where the vehicle cannot receive radio waves from a GPS satellite.

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Means for Solving the Problems

[0006]

According to an embodiment of the present invention, a vehicle position

measurement device includes, but is not limited to: a positioning processing unit that estimates a current position of a vehicle; a positioning information storing unit that accumulates and stores the position of the vehicle estimated by the positioning processing unit in association with an estimated time; a communication unit that receives
5 a signal transmitted from a communication device installed at a fixed location, and detects, based on the signal received, a position of the vehicle at a time when the signal is received; and an updating unit that updates, based on the position of the vehicle detected by the communication unit, the position of the vehicle stored in the positioning information storing unit in association with a time at and after the time when the signal is
10 received by the communication unit.

[0007]

The updating unit may previously store a value of time lag generated at the time when the signal is received by the communication unit, and update, based on the vehicle position detected by the communication unit, the position of the vehicle stored in the
15 positioning information storing unit in association with a time at and after a time obtained by subtracting the value of the time lag from the time when the signal is received by the communication unit.

[0008]

To update the position of the vehicle, the updating unit may replace, with the
20 position of the vehicle detected by the communication unit, the position of the vehicle stored in the positioning information storing unit in association with the time obtained by subtracting the value of the time lag from the time when the signal is received by the communication unit.

[0009]

25 According to another embodiment of the present invention, a vehicle position

measurement method includes, but is not limited to: a positioning processing step of a vehicle position measurement device estimating a current position of a vehicle, the vehicle position measurement device comprising a positioning information storing unit; a positioning information storing step of the vehicle position measurement device

5 accumulating and storing the position of the vehicle estimated in the positioning processing step in association with an estimated time; a communication step of the vehicle position measurement device receiving a signal transmitted from a communication device installed at a fixed location, and detecting, based on the signal received, a position of the vehicle at a time when the signal is received; and an updating

10 step of the vehicle position measurement device updating, based on the position of the vehicle detected in the communication step, the position of the vehicle stored in the positioning information storing unit in association with a time at and after the time when the signal is received in the communication step.

15 Effects of the Invention

[0010]

According to the present invention, accuracy in measuring the position of a vehicle can be enhanced in a location where the vehicle cannot receive radio waves from a GPS satellite.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 illustrates an environment where a vehicle C mounted with a vehicle position measurement system travels.

25 FIG. 2 is a brief block diagram illustrating a functional configuration of the

vehicle position measurement system.

FIG. 3 illustrates an outline of a process for a positioning processing unit to measure the current position of the vehicle C based on coordinate values read out by a DSRC processing unit.

5 FIG. 4 is a flowchart illustrating operation of the vehicle position measurement device.

BEST MODE FOR CARRYING OUT THE INVENTION

[0012]

10 Hereinafter, the present invention is explained with reference to specific embodiments. A person skilled in the art can make various types of different embodiments based on the description of the present invention. Further, the present invention is not limited to the embodiments illustrated for explanation.

[0013]

15 FIG. 1 illustrates an environment where the vehicle C mounted with a vehicle position measurement system 100 travels. Multiple communication devices A are arranged in a region where the vehicle C mounted with the vehicle position measurement system 100 travels. The vehicle position measurement system 100 communicates with a communicable communication device A (a communication device A1 located closest to
20 the vehicle C in the case of FIG. 1), and thereby measures the position of the vehicle C.

[0014]

Each of the communication devices A stores identification information (antenna ID) uniquely allocated thereto and transmits a signal containing the antenna ID by radio communication. Since a communicable range of each of the communication devices A
25 is from dozens of centimeters to several tens of meters. The communication devices A

are arranged such that the communicable ranges of the respective communication devices A do not overlap one another. Any existing technology may be applicable to a communication method used by the communication devices A. Hereinafter, a case in which each of the communication devices A is configured to execute communication by DSRC (dedicated short range communication) is explained. In addition, multiple communication devices A are arranged in a location where radio waves from a GPS satellite are less likely to or unable to reach.

[0015]

FIG. 2 is a brief block diagram showing a functional configuration of the vehicle position measurement system 100. The vehicle position measurement system 100 includes a vehicle position measurement device 1, a GPS processing unit 2, a vehicle speed measurement unit 3, and a gyrocompass 4.

[0016]

The GPS processing unit 2 includes a GPS antenna, a calculation device, and the like. The GPS processing unit 2 receives radio waves from a GPS (global positioning system) satellite and measures the current position of the vehicle C mounted with the GPS processing unit 2.

[0017]

The vehicle speed measurement unit 3 calculates the traveling speed of the vehicle C based on values such as the rotation number and the rotation speed of wheels of the vehicle C mounted with the vehicle speed measurement unit 3. Then, the vehicle speed measurement unit 3 outputs the traveling speed to the vehicle position measurement device 1. The rotation number and the rotation speed of wheels may be calculated by the vehicle speed measurement unit 3 based on signals output from sensors mounted on the wheels and axles. Alternatively, the rotation number and the rotation

speed of wheels may be calculated by a rotation number measurement device and a rotation speed measurement device different from the vehicle speed measurement unit 3. Further, the vehicle speed measurement unit 3 may measure the traveling speed of the vehicle C based on other existing technologies different from the above technology.

- 5 Moreover, when the vehicle C moves backward, the vehicle speed measurement unit 3 outputs the traveling speed together with a backward signal.

The gyrocompass 4 detects a moving direction of the vehicle C mounted with the gyrocompass 4 (a direction in which the front of the vehicle C faces).

[0018]

- 10 Then, the vehicle position measurement device 1 is explained. The vehicle position measurement device 1 includes a CPU (central processing unit), a memory, an auxiliary memory device, a communication device, and the like, which are connected via a bus. The vehicle position measurement device 1 executes a vehicle position measurement program, thereby functioning as a device including: an input/output unit
- 15 101; a DSRC processing unit 102; an antenna ID storing unit 1021; a positioning processing unit 103; a road position storing unit 1031; a positioning information storing unit 1032; a charging location storing unit 104; a determination processing unit 105; a charging basic-information storing unit 1051; a charging table storing unit 106; a charging control unit 107; an IC card processing unit 108; and a wide-area
- 20 communication processing unit 109.

[0019]

- The input/output unit 101 receives an input from a user and displays an image on an image display device. The input/output unit 101 generates, for example: a screen for displaying a charging price stored in the charging table storing unit 106 (a charging
- 25 price displaying screen); a screen for displaying a charging location stored in the

charging location storing unit 104 (a charging location displaying screen); a screen for displaying the position of the vehicle measured by the positioning processing unit 103 (a vehicle position displaying screen); and a screen for displaying a traffic congestion area based on traffic congestion information received by the wide-area communication processing unit 109 (a traffic congestion area displaying screen). Then, the input/output unit 101 displays the generated screens on the image display device. The image display device may be included in the same housing as a part of the vehicle position measurement device 1 or may be connected to the input/output unit 101 as a device of the housing different from the vehicle position measurement device 1.

10 [0020]

The antenna ID storing unit 1021 is configured with memory devices such as a semiconductor memory device and a magnetic hard-disk device. The antenna ID storing unit 1021 stores an antenna ID of each of the communication devices A in association with a coordinate value which indicates an installation location of each of the communication devices A. In addition, the antenna ID storing unit 1021 may be configured to store a coordinate value which indicates a position on the road closest to each of the communication devices A, instead of a location at which each of the communication devices A is installed.

[0021]

20 The DSRC processing unit 102 receives a signal transmitted from a communication device A through DSRC communication, and obtains an antenna ID of the communication device A contained in the received signal. Then, the DSRC processing unit 102 reads out, from the antenna ID storing unit 1021, a coordinate value corresponding to the obtained antenna ID. Further, when the signal is received from the communication device A, the DSRC processing unit 102 detects the time at which the

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signal is received.

[0022]

The road position information storing unit 1031 is configured with memory devices such as a semiconductor memory device and a magnetic hard-disk device. The road position information storing unit 1031 stores coordinate values which indicate positions at which a road is laid out.

The positioning processing unit 103 measures the current position of the vehicle C based on the current position received from the GPS processing unit 2, a traveling speed received from the vehicle speed measurement unit 3, a moving direction received from the gyrocompass 4, and a coordinate value received from the DSRC processing unit 102. Specifically, the positioning processing unit 103 measures the current position of the vehicle C based on the current position received from the GPS processing unit 2 when radio waves can be received from a GPS satellite (hereinafter, this measurement process is referred to as a “GPS positioning process”). When no radio waves can be received from the GPS satellite, the positioning processing unit 103 uses existing dead-reckoning navigation based on the traveling speed and the moving direction, and thereby estimates the current position of the vehicle C (hereinafter, this measurement process is referred to as a “dead-reckoning navigation positioning process.” Further, when the DSRC processing unit 102 receives a signal from a communication device A, the positioning processing unit 103 performs a recalculation process based on coordinate values read out by the DSRC processing unit 102, and thereby updates coordinate values written into the positioning information storing unit 1032 (hereinafter, this process is referred to as a “recalculation process”).

[0023]

The positioning information storing unit 1032 is configured with memory

devices such as a semiconductor memory device and a magnetic hard-disk device. The positioning information storing unit 1032 stores a log which indicates results of the measurement performed by the positioning processing unit 103. Specifically, the positioning information storing unit 1032 stores a coordinate value which indicates the current position of the vehicle C calculated by the positioning processing unit 103 in association with the time when the vehicle C is positioned at the coordinate value (time when the coordinate value is measured).

[0024]

The charging location storing unit 104 is configured with memory devices such as a semiconductor memory device and a magnetic hard-disk device. The charging location storing unit 104 stores coordinate values which indicate a road for which a toll is charged (hereinafter, referred to as "charging target road"). The charging target road is a road for which a toll is charged to an owner or a driver of the vehicle C when the vehicle C enters the road.

[0025]

The determination processing unit 105 generates charging basic information based on the position of the vehicle C measured by the positioning processing unit 103 and the coordinate values stored in the charging location storing unit 104. The charging basic information is information that is required when the charging control unit 107 performs a charging process. The charging basic information differs depending on a charging method to be adopted. For example, when a toll is charged in accordance with a traveling distance, the determination processing unit 105 calculates a total value of distances which the vehicle C travels on the charging target road, and writes the value into the charging basic-information storing unit 1051 as the charging basic information. Further, when a toll is charged in accordance with a period of stay, the determination

processing unit 105 calculates a total value of a period for which the vehicle C stays on the charging target road, and writes the value into the charging basic-information storing unit 1051 as the charging basic information.

[0026]

5 The charging basic-information storing unit 1051 is configured with memory devices such as a semiconductor memory device, and a magnetic hard disk device. The charging basic-information storing unit 1051 stores charging basic information.

 The charging table storing unit 106 is configured with memory devices such as a semiconductor memory device, and a magnetic hard-disk device. The charging table
10 storing unit 106 stores a charging table which is information for charging. For example, when a toll is charged in accordance with a traveling distance, the charging table storing unit 106 stores a charging table in which a charging price is associated with each total value of the traveling distance. Further, when a toll is charged in accordance with a period of stay, the charging table storing unit 106 stores a charging table in which a
15 charging price is associated with each total value of a period of stay.

[0027]

 The charging control unit 107 calculates a charging price for the vehicle C based on the charging basic information stored in the charging basic-information storing unit 1051 and the charging table stored in the charging table storing unit 106.

20 The IC card processing unit 108 writes the charging price calculated by the charging control unit 107 into an IC card (integrated circuit card).

[0028]

 The wide-area communication processing unit 109 transmits a charging price calculated by the charging control unit 107 to a charging price management server via a
25 wide-area communication network by radio communication. Further, the wide-area

communication processing unit 109 receives traffic congestion information from the traffic congestion information management server via the wide-area communication network.

[0029]

5 FIG. 3 illustrates an outline of a process for the positioning processing unit 103 to measure the current position of the vehicle C based on coordinate values read out by the DSRC processing unit 102. Pp_n indicates a position of the vehicle C calculated by the positioning processing unit 103 based on the GPS positioning process or the dead-reckoning navigation positioning process at the time of Tn. RVp is a vector which
10 indicates a road direction detected by the positioning processing unit 103 based on a coordinate value of Pp_n and a moving direction of the vehicle C. The positioning processing unit 103 detects a road closest to the coordinate value of Pp_n and also detects a unit vector extending in the moving direction of the vehicle C along the detected road as RVp. Pp_n+1 indicates a position of the vehicle C calculated by the
15 positioning processing unit 103 based on the GPS positioning process or the dead-reckoning navigation positioning process at the time of Tn+1.

[0030]

 Pd_n indicates a coordinate value read out by the DSRC processing unit 102 at the time of Tn. Pr_n indicates the results of a recalculation process at the position of the
20 vehicle C at the time of Tn (recalculation value). At the time of Tn when a signal is received by the DSRC processing unit 102, the coordinate value (Pd_n) read out by the DSRC processing unit 102 matches a recalculation value (Pr_n). In other words, the positioning processing unit 103 regards a recalculation value at the time of Tn when the DSRC processing unit 102 receives the signal as a coordinate value read out based on an
25 antenna ID received at the same time of Tn.

[0031]

RVr is a vector in which a starting point of the vector of RVp is substituted for Pd_n. This is a vector which indicates a road direction detected by the positioning processing unit 103 based on the coordinate value of Pp_n and a moving direction of the vehicle C. Pt_{n+1} indicates a position of the vehicle C at the time of T_{n+1} obtained by the dead-reckoning navigation positioning process performed based on a recalculation value at the previous time (T_n). A vector connecting Pp_n with Pp_{n+1} matches a vector connecting Pd_n with Pt_{n+1} in terms of magnitude and direction. Pr_{n+1} is a point at which a perpendicular line drawn down from Pt_{n+1} to RVr intersects with RVr, and indicates a recalculation value at the time of T_{n+1}.

[0032]

The positioning processing unit 103 stores a predetermined value of a time lag. The value of the time lag is a value determined previously by experiments and simulation. The value of the time lag indicates a time lag from the time when the vehicle C comes closest to a communication device A to the time when DSRC communication is completed in a case where the DSRC processing unit 102 mounted on the vehicle C traveling at a general traveling speed (for example, 50 km per hour) communicates with the communication device A. When the DSRC processing unit 102 receives a signal from the communication device A, the positioning processing unit 103 detects the time closest to the time obtained by subtracting the value of the time lag from the time when the signal is received, from among the times stored in the positioning information storing unit 1032 (hereinafter, referred to as "processing target time"), and thereby reads out a coordinate value corresponding to the processing target time as Pp_n. Then, the positioning processing unit 103 replaces the coordinate value stored in the positioning

information storing unit 1032 in association with the processing target time with the coordinate value read out by the DSRC processing unit 102. Then, the positioning processing unit 103 performs the recalculation process on the coordinate values stored in the positioning information storing unit 1032 in association with respective times at and
 5 after the processing target time, and thereby calculates and rewrites a recalculation value.
 [0033]

Specifically, the positioning processing unit 103 calculates a vector connecting both points based on the coordinate values Pp_n and Pp_n+1 at the processing target time and the next time ($Tn+1$) obtained by the GPS positioning process or the dead-reckoning
 10 navigation positioning process. Then, the positioning processing unit 103 sets a vector which is equal in magnitude and direction to a vector calculated by regarding a coordinate value Pd_n (Pr_n) read out by the DSRC processing unit 102 at the processing target time as a starting point, and thereby calculates an ending point of the vector as Pt_n+1 . Then, the positioning processing unit 103 calculates a recalculation value
 15 (Pr_n+1) at the time of $Tn+1$ based on RVr and Pt_n+1 . Thereafter, the positioning processing unit 103 handles a value of Pt_n+1 as the aforementioned Pt_n , and also handles a value of Pt_n+2 as the aforementioned Pt_n+1 , and thereby calculates a recalculation value at each time at and after the processing target time.

[0034]

20 FIG. 4 is a flowchart illustrating operation of the vehicle position measurement device 1. First, the positioning processing unit 103 executes a positioning process (the GPS positioning process or the dead-reckoning navigation positioning process) (Step S101). Then, the positioning processing unit 103 associates the time when a coordinate value has been measured (positioning time) with the coordinate value, and writes the

time and the coordinate value into the positioning information storing unit 1032 (Step S102). The determination processing unit 105 totals traveling distances and the period of stay based on the information written into the positioning information storing unit 1032, and thereby calculates the charging basic information (Step S301). The DSRC processing unit 102 constantly executes idling and stands ready until a signal is received from a communication device A (Step S201, Step S202-NO). Upon receipt of the signal transmitted from the communication device A (Step S202-YES), the DSRC processing unit 102 obtains an antenna ID from the signal received (Step S203). The DSRC processing unit 102 reads out a coordinate value based on the obtained antenna ID (Step S204). Then, the DSRC processing unit 102 notifies the positioning processing unit 103 of the coordinate value and communication time read out (Step S205).

[0035]

The positioning processing unit 103 repeatedly executes the processes of Step S101 and Step S102 until being notified from the DSRC processing unit 102 (Step S103-NO). On the other hand, when being notified from the DSRC processing unit 102 (Step S103-YES), the positioning processing unit 103 executes a recalculation process based on the communication time and the coordinate value notified (Step S104), and thereby updates the content stored in the positioning information storing unit 1032 by using a recalculation value (Step S105). Then, the positioning processing unit 103 notifies the determination processing unit 105 of the fact that the recalculation process has been executed (Step S106).

[0036]

The determination processing unit 105 repeatedly executes the process of Step S301 until being notified of the fact that the recalculation process has been executed from the positioning processing unit 103 (Step S302-NO). On the other hand, when being

notified of the fact that the recalculation process has been executed from the positioning processing unit 103 (Step S302-YES), the determination processing unit 105 totals the traveling distances and the period of stay based on the updated content stored in the positioning information storing unit 1032, and thereby updates the content stored in the charging basic-information storing unit 1051.

[0037]

In the vehicle position measurement device 1 and the vehicle position measurement system 100 having the above configuration, the positioning processing unit 103 measures the current position of the vehicle C based on a signal received from a communication device A. In this instance, a coordinate value which indicates the position of the communication device A is accurate. Therefore, accuracy of the measurement process based on the position of the communication device A is higher than that of the conventional dead-reckoning navigation positioning process. For this reason, according to the vehicle position measurement device 1 and the vehicle position measurement system 100, it is possible to enhance the measurement accuracy of the current position of the vehicle C even when the vehicle C is positioned in a location where it is difficult for the vehicle C to receive radio waves from a GPS satellite.

[0038]

Further, the positioning processing unit 103 executes the positioning process based on a time lag in the communication process between a communication device A and the DSRC processing unit 102. Therefore, it is possible to enhance the accuracy of measuring the current position of the vehicle C.

[0039]

(Modified Example)

In place of calculating RVr based on RVp as described above, the positioning

processing unit 103 may calculate RVr based on a coordinate value of Pd_n and a moving direction of the vehicle C on calculating RVr. Specifically, the positioning processing unit 103 may detect a road closest to the coordinate value of Pd_n, and then detect a vector extending along the detected road in a moving direction of the vehicle C as RVr.

5 [0040]

The positioning processing unit 103 may store a value of a time lag in association with each of the communication devices A. In this instance, the positioning processing unit 103 reads out the value of the time lag stored in association with an antenna ID of a signal received by the DSRC processing unit 102, and thereby executes
10 the recalculation process.

Further, the positioning processing unit 103 may store a value of a time lag in association with each traveling speed. In this instance, the positioning processing unit 103 reads out the value of the time lag corresponding to the current traveling speed of the vehicle C, and thereby executes the recalculation process.

15 [0041]

The positioning processing unit 103 may be configured to write, when a calculated coordinate value is written into the positioning information storing unit 1032, the coordinate value in association with an identifier which indicates whether the coordinate value is a value calculated by the GPS positioning process, a value calculated
20 by the dead-reckoning navigation positioning process, or a recalculation value. Then, the positioning processing unit 103 may be configured so as not to recalculate a value calculated by the GPS positioning process, but to recalculate and update only a value calculated by the dead-reckoning navigation positioning process in the recalculation process.

25 [0042]

The details of the embodiments of the present invention have been explained with reference to the accompanying drawings. Specific configurations of the present invention are not limited to the above-described embodiments, and may include change in design and the like without departing from the scope of the present invention.

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INDUSTRIAL APPLICABILITY

[0043]

The present invention is applicable, for example, to measurement of the position of a vehicle in a location where the vehicle cannot receive radio waves from a GPS

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satellite.

DESCRIPTION OF REFERENCE NUMERALS

[0044]

1: vehicle position measurement device

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2: GPS processing unit

3: vehicle speed measurement unit

101: input/output unit

102: DSRC processing unit

103: positioning processing unit (positioning processing unit, update unit)

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104: charging location storing unit

105: determination processing unit

106: charging table storing unit

107: charging control unit

108: IC card processing unit

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109: wide-area communication processing unit

A: communication device

C: vehicle

CLAIMS

1. A vehicle position measurement device comprising:
 - a positioning processing unit that estimates a position of a vehicle at each of a processing target time and a next time to the processing target time, estimates a vector based on the estimated position of the vehicle, and estimates a road direction based on the position and a moving direction of the vehicle at the processing target time;
 - a positioning information storing unit that accumulates and stores the position of the vehicle estimated by the positioning processing unit in association with an estimated time;
 - a communication unit that receives a signal transmitted from a communication device installed at a fixed location, and detects, based on the signal received, a position of the vehicle at a time when the signal is received; and
 - an updating unit that updates, based on the position of the vehicle detected by the communication unit and the vector and the road direction estimated by the positioning processing unit, the position of the vehicle stored in the positioning information storing unit in association with a time at and after the time when the signal is received by the communication unit.
2. The vehicle position measurement device according to claim 1, wherein the updating unit previously stores a value of time lag generated at the time when the signal is received by the communication unit, and updates, based on the vehicle position detected by the communication unit, the position of the vehicle stored in the positioning information storing unit in association with a time at and after a time obtained by subtracting the value of the time lag from the time when the signal is received by the communication unit.
3. The vehicle position measurement device according to claim 2, wherein to update the position of the vehicle, the updating unit replaces, with the position of the vehicle detected by the communication unit, the position of the vehicle stored in the positioning information storing unit in association with the time obtained by subtracting the value of the time lag from the time when the signal is received by the communication unit.
4. A vehicle position measurement method comprising:
 - a positioning processing step of a vehicle position measurement device estimating a position of a vehicle at each of a processing target time and a next time to the processing

target time, estimating a vector based on the estimated position of the vehicle, and estimating a road direction based on the position and a moving direction of the vehicle at the processing target time, the vehicle position measurement device comprising a positioning information storing unit;

a positioning information storing step of the vehicle position measurement device accumulating and storing the position of the vehicle estimated in the positioning processing step in association with an estimated time;

a communication step of the vehicle position measurement device receiving a signal transmitted from a communication device installed at a fixed location, and detecting, based on the signal received, a position of the vehicle at a time when the signal is received; and

an updating step of the vehicle position measurement device updating, based on the position of the vehicle detected in the communication step and the vector and the road direction estimated by the positioning processing unit, the position of the vehicle stored in the positioning information storing unit in association with a time at and after the time when the signal is received in the communication step.