

DESCRIPTION

LOCATION IDENTIFICATION DEVICE, LOCATION IDENTIFICATION METHOD,
AND PROGRAM

5

TECHNICAL FIELD

[0001]

The present invention relates to a location identification device, a location
identification method, and a program for identifying a location where the device itself is
10 present.

Priority is claimed on Japanese Patent Application No. 2011-210715, filed
September 27, 2011, the contents of which are incorporated herein by reference.

BACKGROUND ART

15 [0002]

In recent years, attention has been drawn to services that are provided for a
vehicle based on the location of the vehicle, such as information provision services,
alerting services, and intervention control services. A vehicle location is identified by a
location identification device such as a car navigation system, based on a GPS (Global
20 Positioning System) and/or dead reckoning. Moreover, in order to enhance the precision
of a vehicle location, there has been used a method of correcting a vehicle location by
receiving a signal on a carrier wave such as a radio wave or a light, from a beacon provided
on a road side, and correcting the location where the communication is established, to the
beacon location (for example, refer to Patent Document 1).

25 [Prior Art Documents]

[Patent Documents]

[0003]

[Patent Document 1] Japanese Unexamined Patent Application, First Publication
No. 2009-026056

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SUMMARY OF INVENTION

[Technical Problem]

[0004]

However, in order to reliably communicate with the location identification device,
10 a beacon emits a carrier wave for a predetermined range (for example, a range of 10 meters
width in the traveling direction). Consequently, in location information estimated by the
location identification device based on the location where a signal is received from the
beacon, an error occurs in the size of the carrier wave emission range.

[0005]

15 The present invention takes into consideration the above problem with an object
of providing a location identification device, a location identification method, and a
program for reducing errors due to a range of a carrier wave emission performed by a
beacon, in order to identify a location where the device itself is present.

[Solution to Problem]

20 [0006]

A first aspect of the present invention is a location identification device including:
a location estimation unit configured to estimate a location of the device itself; a beacon
location acquisition unit configured to acquire a beacon location based on a signal received
from a beacon that emits a carrier wave carrying the signal, the beacon location being a
25 location within a range of a carrier wave emission performed by the beacon; and a location

identification unit configured to calculate a location indicated by a weighted average of an estimated location, which is a location estimated by the location estimation unit, and the beacon location, while taking a weighted value which becomes greater as a range of the carrier wave emission performed by the beacon becomes narrower, as a weight of the beacon location acquired by the beacon location acquisition unit, and to identify the location indicated by the weighted average as a location of the device itself.

[0007]

Moreover, in the first aspect of the present invention, the location identification unit may be configured to calculate a location indicated by the weighted average of the estimated location and the beacon location, while taking a weighted value which becomes greater as an error range of a location estimation performed by the location estimation unit becomes narrower, as a weight of the estimated location.

[0008]

Furthermore, in the first aspect of the present invention, the beacon location may be a matrix that indicates a location within the range of the carrier wave emission performed by the beacon in a predetermined orthogonal coordinate system. The estimated location may be a matrix that indicates a location where the device itself is estimated to be present in the orthogonal coordinate system. The weight of the beacon location may be a variance-covariance matrix that indicates a variance of a location in the orthogonal coordinate system where the signal from the beacon is receivable normally.

[0009]

Moreover, in the first aspect of the present invention, the weight of the beacon location may become smaller as an installation height of the device itself becomes higher.

[0010]

Furthermore, in the first aspect of the present invention, the location identification

device may further include: a road identification unit configured to identify a road on which the device itself is present, based on the estimated location estimated by the location estimation unit; and a beacon weight acquisition unit configured to acquire a weight of a beacon location corresponding to the road identified by the road identification unit. The location identification unit may be configured to use the weight acquired by the beacon weight acquisition unit to identify a location of the device itself.

[0011]

Moreover, in the first aspect of the present invention, the beacon location acquisition unit may be configured to estimate the beacon location upon completion of normal signal reception, based on an intensity of the carrier wave of the signal, and on a relationship between the beacon location and the intensity of the carrier wave.

[0012]

Furthermore, in the first aspect of the present invention, the location identification device may further include a carrier wave intensity recording unit configured to sequentially record an intensity of the carrier wave from the beacon in a carrier wave intensity memory unit while associating the intensity with a location where the carrier wave is received. The beacon location acquisition unit may be configured to estimate a location associated with a maximum value of the intensity of the carrier wave recorded in the carrier wave intensity memory unit, as a beacon location in a road extending direction.

[0013]

Moreover, in the first aspect of the present invention, the beacon location acquisition unit may be configured to estimate a beacon location in a direction orthogonal to the road extending direction, based on the maximum value of the intensity of the carrier wave recorded in the carrier wave intensity memory unit, and on a relationship between a beacon location in the direction orthogonal to the road extending direction and the

intensity of the carrier wave.

[0014]

A second aspect of the present invention is a location identification method that uses a location identification device that identifies a location where the device itself is present, the method including: estimating the location of the device itself using a location estimation unit; acquiring a beacon location using a beacon location acquisition unit, based on a signal received from a beacon that emits a carrier wave carrying the signal, the beacon location being a location within a range of a carrier wave emission performed by the beacon; and calculating, using a location identification unit, a location indicated by a weighted average of an estimated location, which is a location estimated by the location estimation unit, and the beacon location, while taking a weighted value which becomes greater as a range of the carrier wave emission performed by the beacon becomes narrower, as a weight of the beacon location acquired by the beacon location acquisition unit, and identifying the location indicated by the weighted average as a location of the device itself.

[0015]

A third aspect of the present invention is a program that causes a location identification device that identifies a location where the device itself is present, to function as: a location estimation unit that estimates the location of the device itself; a beacon location acquisition unit that acquires a beacon location based on a signal received from a beacon, the beacon emitting a carrier wave carrying the signal, the beacon location being a location within a range of a carrier wave emission performed by the beacon; and a location identification unit that calculates a location indicated by a weighted average of an estimated location, which is a location estimated by the location estimation unit, and the beacon location, while taking a weighted value which becomes greater as a range of the carrier wave emission performed by the beacon becomes narrower, as a weight of the

beacon location acquired by the beacon location acquisition unit, and identifies the location indicated by the weighted average as a location of the device itself.

[Advantageous Effects of Invention]

[0016]

5 According to the present invention, the location identification unit calculates a location indicated by a weighted average of an estimated location and a beacon location, as a location of the device itself. Thereby, it is possible to reduce errors due to a range of carrier wave emission performed by the beacon, and to identify a location where the device itself is present.

10

BRIEF DESCRIPTION OF DRAWINGS

[0017]

FIG. 1 is a schematic block diagram showing a configuration of a location identification device according to a first embodiment of the present invention.

15 FIG. 2 is a diagram showing a vehicle location identification method according to the first embodiment of the present invention.

FIG. 3 is a flowchart showing an operation of the location identification device according to the first embodiment of the present invention.

20 FIG. 4 is a diagram showing an example of a beacon error stored in a beacon, according to a second embodiment of the present invention.

FIG. 5 is a schematic block diagram showing a configuration of a location identification device according to the second embodiment of the present invention.

FIG. 6 is a diagram showing an example of a state of a road intersection where a beacon is installed.

25 FIG. 7 is a diagram showing an example of a beacon error stored in a beacon,

according to a third embodiment of the present invention.

FIG. 8 is a schematic block diagram showing a configuration of a location identification device according to the third embodiment of the present invention.

FIG. 9 is a diagram showing a relationship between traveling locations and carrier
5 wave intensities in a case where a beacon location is present on a road side.

DESCRIPTION OF EMBODIMENTS

[0018]

<<First Embodiment>>

10 Hereinafter, a first embodiment of the present invention is described in detail, with reference to the drawings.

FIG. 1 is a schematic block diagram showing a configuration of a location identification device according to the first embodiment of the present invention.

The location identification device is a device that is mounted on a vehicle and that
15 identifies a location where the device itself is present. The location identification device includes; a location estimation unit 1, a location memory unit 2, an estimation error calculation unit 3, a beacon signal receiver unit 4, a beacon location acquisition unit 5, a beacon error acquisition unit 6, a location identification unit 7, and a location output unit 8.

[0019]

20 The location estimation unit 1 estimates a location of the device itself based on GPS and dead reckoning, and records an estimated location P_e that indicates the estimated location, in the location memory unit 2, while associating the estimated location P_e with an estimation time. The estimated location P_e is a matrix illustrated by Equation (1).

[0020]

25 [Equation 1]

$$P_c = \begin{pmatrix} x_c \\ y_c \end{pmatrix} \quad \cdot \cdot \cdot (1)$$

[0021]

where x_c and y_c are values that respectively indicate a latitude and a longitude of an estimated location.

5 [0022]

The location memory unit 2 stores location information that indicates a location of the device itself that is estimated by the location estimation unit 1 or identified by the location identification unit 7.

The estimation error calculation unit 3 calculates an estimation error R_c , which is
 10 a variance-covariance matrix that indicates an error in the latitude line direction and longitude line direction of the estimated location P_c estimated by the location estimation unit 1, based on a history of estimated locations P_c accumulated in the location memory unit 2 and a GPS estimation precision of the location estimation unit 1. The estimation error R_c is a matrix illustrated by Equation (2).

15 [0023]

[Equation 2]

$$R_c = \begin{pmatrix} \sigma_{c_xx}^2 & \sigma_{c_xy}^2 \\ \sigma_{c_xy}^2 & \sigma_{c_yy}^2 \end{pmatrix} \quad \cdot \cdot \cdot (2)$$

[0024]

where σ_{c_xx} is a value that indicates a variance of an estimated location in the
 20 latitude line direction. Moreover, σ_{c_yy} is a value that indicates a variance of an estimated location in the longitude line direction. σ_{c_xy} is a value that indicates a covariance of an

estimated location in the latitude line direction and longitude line direction. That is to say, a value of each element of an estimation error R_e becomes greater as an error range of a location estimation performed by the location estimation unit 1 becomes wider.

[0025]

5 The beacon signal receiver unit 4 captures a carrier wave output by a beacon provided on a road side, and extracts a signal from the carrier wave to thereby receive the signal.

 The beacon location acquisition unit 5 reads a beacon location P_b that indicates a location within a range of a carrier wave emission performed by the beacon, from the
10 signal received by the beacon signal receiver unit 4. Here, as a beacon location P_b , a location where the beacon is installed or a location where the radio wave intensity is the highest within the emission range is set. The beacon location P_b is a matrix illustrated by Equation (3).

[0026]

15 [Equation 3]

$$P_b = \begin{pmatrix} x_b \\ y_b \end{pmatrix} \quad \cdot \cdot \cdot (3)$$

[0027]

 where x_b and y_b are values that respectively indicate a latitude and a longitude of a beacon location.

20 [0028]

 The beacon error acquisition unit 6 reads from the signal received by the beacon signal receiver unit 4, a beacon error R_b , which is a variance-covariance matrix that indicates a carrier wave emission range with the beacon location P_b being the center

thereof. The beacon error R_b is a matrix illustrated by Equation (4).

[0029]

[Equation 4]

$$R_b = \begin{pmatrix} \sigma_{b_xx}^2 & \sigma_{b_xy}^2 \\ \sigma_{b_xy}^2 & \sigma_{b_yy}^2 \end{pmatrix} \cdot \cdot \cdot (4)$$

5 [0030]

where σ_{b_xx} is a value that indicates a variance in the latitude line direction at a location where a signal emitted from the beacon is received. Moreover, σ_{b_yy} is a value that indicates a variance in the longitude line direction at a location where a signal emitted from the beacon is received. σ_{b_xy} is a value that indicates a covariance in the longitude line direction and latitude line direction at a location where a signal emitted from the beacon is received. That is to say, a value of each element of the beacon error R_b becomes greater as a range of carrier wave emission performed by the beacon becomes wider.

[0031]

Taking the estimation error R_e calculated by the estimation error calculation unit 3 as a weight of the beacon location P_b acquired by the beacon location acquisition unit 5, and the beacon error R_b acquired by the beacon error acquisition unit 6 as a weight of the estimated location P_e stored in the location memory unit 2, the location identification unit 7 calculates a weighted average of the beacon location P_b and the estimated location P_e , and identifies an acquired location P as a location of the device itself. Specifically, the location identification unit 7 solves Equation (5) to thereby identify the location P of the device itself. Moreover, the location identification unit 7 overwrites the estimated location stored in the location memory unit 2, with the identified location P .

[0032]

[Equation 5]

$$P = (R_c P_b + R_b P_c)(R_b + R_c)^{-1} \quad \cdot \cdot \cdot (5)$$

[0033]

where X^{-1} indicates an inverse matrix of a matrix X .

5 In the present embodiment, the estimation error R_c calculated by the estimation error calculation unit 3 is taken as a weight of the beacon location P_b acquired by the beacon location acquisition unit 5, and the beacon error R_b acquired by the beacon error acquisition unit 6 is taken as a weight of the estimated location P_c stored in the location memory unit 2. That is to say, the weight R_b of the estimated location P_c indicates a value
10 relatively greater than the weight R_c of the beacon location P_b as a range of location estimation error becomes narrower. Similarly, the weight R_c of the beacon location P_b indicates a value relatively greater than the weight R_b of the estimated location P_c as a beacon communication range becomes narrower.

[0034]

15 FIG. 2 is a diagram showing a vehicle location identification method according to the first embodiment of the present invention.

 In the present embodiment, the estimation error R_c and the beacon error R_b are indicated by a 2×2 variance-covariance matrix. Accordingly, when projecting these errors on a two-dimensional plane with the latitude line and longitude line serving as the
20 axes thereof, errors spread in an elliptical shape as shown in FIG. 2.

[0035]

 The location output unit 8 outputs location information stored in the location memory unit 2 to a display.

[0036]

In the present embodiment, the beacon includes a memory unit for storing a beacon location P_b and a beacon error R_b , and outputs a signal indicating information stored in the memory unit through a carrier wave within a predetermined emission range. The beacon error R_b may be a value that is preliminarily decided when designing the beacon, or it may be a value that is acquired by making the vehicle travel and actually measuring a beacon error R_b .

[0037]

Next, an operation of the location identification device according to the present embodiment is described.

FIG. 3 is a flowchart showing an operation of the location identification device according to the first embodiment of the present invention.

First, when the location identification device is activated, the location estimation unit 1 estimates, by means of GPS or dead reckoning, a location of the device itself, that is, a location of the vehicle with the device mounted thereon (step S1). The location estimation unit 1 includes a Kalman filter that estimates a current location based on past location information history stored in the location memory unit 2, and the location acquired by means of GPS or dead reckoning, and the location estimation unit 1 outputs an output value of the Kalman filter as an estimated location P_e . Then, the location estimation unit 1 records the estimated location P_e into the location memory unit 2 (step S2).

[0038]

Moreover, the location estimation unit 1 calculates an estimation error R_e of the estimated location (step S3). Specifically, in the case where the location estimation unit 1 performs a location estimation by means of GPS in step S1, a DOP (dilution of precision) value is calculated based on directional vectors of GPS satellites used for location estimation, and an estimation error R_e is calculated based on the DOP value. On the other

hand, in the case where the location estimation unit 1 performs a location estimation by means of dead reckoning in step S1, an error learned in the Kalman filter of the location estimation unit 1 is taken as the estimation error R_e .

[0039]

5 Next, the beacon signal receiver unit 4 determines whether or not a signal has been received from the beacon (step S4). The beacon signal receiver unit 4 determines that the beacon signal receiver unit 4 has received a signal from the beacon when signal reception is completed without errors. If the beacon signal receiver unit 4 determines that the beacon signal receiver unit 4 has received a signal from the beacon (step S4: YES), the
10 beacon location acquisition unit 5 acquires information that indicates a beacon location P_b included in the signal received by the beacon signal receiver unit 4 (step S5). Furthermore, the beacon error acquisition unit 6 acquires a beacon error R_b included in the signal received by the beacon signal receiver unit 4 (step S6).

[0040]

15 Next, the location identification unit 7 solves Equation (5) above using the estimated location P_e , the estimation error R_e , the beacon location P_b , and the beacon error R_b to thereby identify a vehicle location P (step S7). According to Equation (5), a weight can be dynamically decided depending on the resulting magnitude of error. Moreover, the weight R_e of the beacon location P_b becomes smaller as the error range of location
20 estimation becomes narrower (as estimation precision becomes higher), and therefore, the vehicle position P to be identified is located in proximity to the estimated location P_e . Similarly, the weight R_b of the estimated location P_e becomes smaller as the beacon communication range becomes narrower, and therefore, the vehicle position P to be identified is located in proximity to the beacon location P_b .

25 Next, the location identification unit 7 records the identified vehicle location into

the location memory unit 2 to overwrite the estimated location recorded in step S2 (step S8).

[0041]

If the vehicle location is overwritten in step S8, or if the beacon signal receiver
 5 unit 4 determines in step S4 that no signal has been received from the beacon (step S4: NO), the location output unit 8 outputs the last recorded vehicle position in the location memory unit 2 to the display (step S9).

Next, the location identification device determines whether or not a process end request has been input from outside through a user operation, an interrupt process, or the
 10 like (step S10). If the location identification device determines that no process end request is input from outside (step S10: NO), the process returns to step S1 and a vehicle location is estimated. On the other hand, if the location identification device determines that a process end request is input from outside (step S10: YES), the location identification device ends the process.

15 [0042]

As described above, according to the present embodiment, a location indicated by a weighted average of the estimated location P_e and the beacon location P_b is calculated while taking the weight value R_e , which becomes greater as a range of carrier wave emission performed by the beacon becomes narrower, as the weight of the beacon location
 20 P_b , and the location is identified as a location of the device itself. Thereby, in the case where the range of carrier wave emission performed by the beacon is narrow, that is, where the beacon location P_b is reliable, a location in proximity to the beacon location P_b is identified as the vehicle location P . Also, in the case where the range of carrier wave emission performed by the beacon is wide, that is, where the beacon location P_b is
 25 unreliable, a location, which is closer to the estimated location P_e than the beacon location

P_b , is identified as the vehicle location P . Thereby, it is possible to reduce errors due to a range of carrier wave emission performed by the beacon, and to identify a location where the device itself is present.

[0043]

5 Moreover, according to the present embodiment, a location indicated by a weighted average of the estimated location P_e and the beacon location P_b is calculated while taking the value R_b , which becomes greater as an error range of location estimation made by the location estimation unit 1 becomes narrower, as the weight of the estimated location P_e . Thereby, in the case where the error in location estimation is small, that is, 10 where the estimated location P_e is reliable, a location in proximity to the estimated location P_e is identified as the vehicle location P . Also, in the case where the error in location estimation is large, that is, where the estimated location P_e is unreliable, a location, which is closer to the beacon location P_b than the estimated location P_e is identified as the vehicle location. As a result, it is possible to identify the location where the device itself is present, 15 while taking into account the influence of the estimation error.

[0044]

 Furthermore, according to the present embodiment, the estimation error R_e and the beacon error R_b are respectively indicated by a 2×2 variance-covariance matrix. With use of the matrix, it is possible, in a two-dimensional orthogonal coordinate space shown 20 with latitudes and longitudes, to identify a vehicle location with use of the weights R_e and R_b that spread in an elliptical shape. Moreover, not only in the case where axes orthogonal to the latitude line direction and longitude line direction are taken as the major axis and minor axis as shown in FIG. 2, but also in the case where axes which intersect with the latitude line direction and longitude line direction are taken as the major axis and minor 25 axis, the errors can be expressed by a variance-covariance matrix. Most ranges of carrier

wave emission performed by the beacon can be approximated to an elliptical shape with the major axis along the road extending direction. On the other hand, the road extending direction does not always match the latitude line direction or longitude line direction. For this reason, by using a matrix for the weighted value as practiced in the present

5 embodiment, it is possible to identify a vehicle location with use of a weight suitable for the shape of the range of carrier wave emission performed by the beacon.

[0045]

<<Second Embodiment>>

Next, a second embodiment of the present invention is described in detail, with

10 reference to the drawings.

The second embodiment is of a configuration in which a signal transmitted from a beacon of the first embodiment includes a beacon error R_b for each vehicle type.

[0046]

FIG. 4 is a diagram showing an example of a beacon error stored in the beacon,

15 according to the second embodiment of the present invention.

The beacon stores as a passenger vehicle beacon error R_b^v , a bus beacon error R_b^b , and a motorcycle beacon error R_b^m as beacon errors R_b , and transmits a signal including the respective beacon errors R_b through a carrier wave.

The passenger vehicle beacon error R_b^v stored in the beacon is a value greater than

20 that of the bus beacon error R_b^b . This is because the installation height of the location identification device on a passenger vehicle is normally positioned lower than the installation height of the location identification device on a bus, and therefore, the location identification device installed on the bus is closer to an antenna than the location identification device installed on the passenger vehicle, and the range of carrier wave

25 emission for the bus is smaller than that for the passenger vehicle.

As described above, the beacon error R_b stored in the beacon becomes smaller as an installation height of the location identification device becomes higher.

[0047]

FIG. 5 is a schematic block diagram showing a configuration of the location
5 identification device according to the second embodiment of the present invention.

The location identification device according to the second embodiment is such that a vehicle type information acquisition unit 9 is further provided for the location identification device of the first embodiment, and the operation of the beacon error acquisition unit 6 is different from that the first embodiment.

10 The vehicle type information acquisition unit 9 acquires, from an on-vehicle device, vehicle type information of a vehicle in which the device itself is installed.

[0048]

The beacon error acquisition unit 6 acquires a beacon error R_b that is associated with the vehicle type information acquired by the vehicle type information acquisition unit
15 9, among the beacon errors R_b included in the signal received by the beacon signal receiver unit 4.

As a result, by using the beacon error R_b according to the installation height of the device itself, the location identification unit 7 can more precisely identify the vehicle location.

20 [0049]

<<Third Embodiment>>

Next, a third embodiment of the present invention is described in detail, with reference to the drawings.

The third embodiment is of a configuration in which a signal transmitted from a
25 beacon of the first embodiment includes a beacon error R_b for each road.

[0050]

FIG. 6 is a diagram showing an example of a state of a road intersection where a beacon is installed.

The beacon carrier wave emission range may differ in some cases, depending on
5 the environment that surrounds the beacon installation place. The example illustrated in
FIG. 6 is an example of a road intersection where a road 3 is provided in the extending
direction of a road 1, a road 4 is provided in the extending direction of a road 2, and the
roads 1 and 3 intersect with the roads 2 and 4. Here, at the road intersection shown in FIG.
6, the widths of the roads 1 and 3 are wider than the widths of the roads 2 and 4. Clear
10 spaces are present on both adjacent sides of the road 2. Building structures are present on
both adjacent sides of the road 4. Moreover, a beacon is installed so that the location of the
beacon is positioned at the center of the road intersection.

[0051]

In the example shown in FIG. 6, the roads 1 and 3 are wider than the roads 2 and 4,
15 and therefore, the carrier wave emission range in the widthwise direction of the roads 1 and
3 is wider than the carrier wave emission range of the roads 2 and 4. Furthermore, since
there are building structures on both adjacent sides of the road 4, the carrier wave emission
range in the road extending direction is narrower than that of the road 2 with the clear
spaces on both adjacent sides thereof.

20 As described above, the carrier wave spreads in a different manner depending on
the road, and therefore, it is preferable that the beacon error R_b is made different for each
road.

[0052]

FIG. 7 is a diagram showing an example of a beacon error stored in the beacon,
25 according to the third embodiment of the present invention.

The beacon stores as a beacon error R_b , a beacon error for each road (in the example of FIG. 6, a beacon error R_b^1 of the road 1, a beacon error R_b^2 of the road 2, a beacon error R_b^3 of the road 3, and a beacon error R_b^4 of the road 4), and transmits a signal including each beacon error R_b through a carrier wave.

5 [0053]

FIG. 8 is a schematic block diagram showing a configuration of the location identification device according to the third embodiment of the present invention.

The location identification device according to the third embodiment is such that a road identification unit 10 is further provided for the location identification device of the first embodiment, and the operation of the beacon error acquisition unit 6 is different from that of the first embodiment.

The road identification unit 10 identifies a road on which the vehicle is currently present, based on the vehicle location stored in the location memory unit 2.

[0054]

15 The beacon error acquisition unit 6 acquires a beacon error R_b that is associated with the road identified by the road identification unit 10, among the beacon errors R_b included in the signal received by the beacon signal receiver unit 4. As a result, by using the beacon error R_b that is associated with the road on which the device itself is present, the location identification unit 7 can more precisely identify the vehicle location.

20 [0055]

<<Fourth Embodiment>>

Next, a fourth embodiment of the present invention is described in detail.

The fourth embodiment is of a configuration in which a beacon location P_b is identified with a method different from that of the first embodiment.

25 In the first embodiment, the case where a beacon location is included in a signal

transmitted from a beacon, and the beacon location acquisition unit 5 reads and acquires the beacon location from the signal has been described. In the fourth embodiment, a configuration is described in which a beacon location is estimated from an intensity of a carrier wave at the time of receiving a signal from a beacon.

5 [0056]

When the location of signal reception becomes further from the beacon location, the intensity of the carrier wave at the time of signal reception becomes lower. Therefore, with knowledge of the signal reception location and carrier wave intensity, and the relationship between the reception location and the intensity, the location identification
10 device can estimate a beacon location.

The beacon according to the fourth embodiment stores, instead of a beacon location, information that indicates a relationship between the radio wave intensity and the distance from the reception location to the beacon location, and the beacon transmits a signal including this information through a carrier wave.

15 The beacon location acquisition unit 5 of the location identification device according to the fourth embodiment reads the carrier wave intensity at the time when the beacon signal receiver unit 4 receives the signal, as well as information included in the received signal. Next, the beacon location acquisition unit 5 reads, from the read information, the distance to the beacon location that is associated with the carrier wave
20 intensity at the time of the signal reception. Then, the read distance is added to the current estimated location stored in the location memory unit 2 in the road extending direction (or vehicle traveling direction) to thereby calculate the beacon location.

[0057]

As described above, according to the present embodiment, it is possible to
25 calculate a beacon location based on a carrier wave reception intensity at the time of signal

reception from the beacon.

[0058]

<<Fifth Embodiment>>

Next, a fifth embodiment of the present invention is described in detail.

5 The fifth embodiment is of a configuration in which a beacon location P_b is identified with a method different from that of each of the first embodiment and the fourth embodiment.

10 In the first embodiment, the case where a beacon location is included in a signal transmitted from a beacon, and the beacon location acquisition unit 5 reads and acquires the beacon location from the signal has been described. Moreover, in the fourth embodiment, the case where a beacon location is estimated from an intensity of a carrier wave at the time of receiving a signal from a beacon has been described. In the fifth embodiment, a configuration is described in which a beacon location is estimated based on a peak value of an intensity of a carrier wave from a beacon.

15 [0059]

20 When the location identification device and the beacon location become closer to each other, the intensity of the received carrier wave becomes higher. Therefore, it is possible to estimate a point where the intensity of the carrier wave received by the location identification device is peaked when the location identification device passes by the beacon location, as being a beacon location.

25 A beacon location acquisition unit 5 of the location identification device according to the fifth embodiment associates an estimated location of the location identification device with a carrier wave intensity detected at the estimated location by a beacon signal receiver unit 4, and sequentially stores them. Next, when the carrier wave intensity detected by the beacon signal receiver unit 4 has passed its peak point, the beacon

location acquisition unit 5 reads the estimated location associated with the peak intensity as a beacon location.

[0060]

As described above, according to the present embodiment, it is possible to
5 calculate a beacon location based on a carrier wave reception intensity at the time of signal reception from the beacon.

[0061]

<<Sixth Embodiment>>

Next, a sixth embodiment of the present invention is described in detail.

10 In the fifth embodiment, the method of deciding a beacon location based on a peak intensity of a carrier wave has been described. However, while this method enables identification of a beacon location in the road extending direction, it is unable to identify a beacon location in the road width direction. Consequently, in a case where the location of a beacon is not in the center of the road and the beacon is installed on a road side, a method
15 described in the sixth embodiment is used to identify the beacon location, and thereby identify the beacon location in the road extending direction as well as in the road width direction.

[0062]

FIG. 9 is a diagram showing a relationship between traveling locations and carrier
20 wave intensities in a case where a beacon location is present on a road side.

When the location of signal reception becomes further from the beacon location, the intensity of the carrier wave at the time of signal reception becomes lower. Therefore, as shown in FIG. 9, at a point of the peak intensity of the carrier wave, in a case where a vehicle is traveling at a location close to the beacon location in the road width direction, the
25 carrier wave reception intensity is higher than that in the case of traveling at a location that

is further from the beacon location. That is to say, with knowledge of the peak intensity of the carrier wave and the relationship between the beacon location in the road width direction and the peak intensity, the location identification device can estimate a beacon location.

5 [0063]

The beacon according to the sixth embodiment stores, instead of a beacon location, information that indicates a relationship between the peak intensity of the carrier wave and the beacon location in the road width direction, and the beacon transmits a signal including this information through a carrier wave.

10 The beacon location acquisition unit 5 of the location identification device according to the sixth embodiment reads the peak intensity of the carrier wave detected by the beacon signal receiver unit 4, as well as information included in the received signal. Next, the beacon location acquisition unit 5 reads, from the read information, the beacon location in the road width direction that is associated with the peak intensity of the carrier
15 wave.

As a result, according to the present embodiment, it is possible to calculate a beacon location in the road extending direction and in the road width direction, based on a carrier wave reception intensity at the time of signal reception from the beacon.

[0064]

20 The above is a detailed description of one embodiment of the present invention with reference to the drawings. However, the specific configuration of the invention is not limited to that described above, and various design modifications or the like may be made without departing from the scope of the invention.

For example, in the above embodiments, the case where a beacon outputs signals
25 indicating a beacon location P_b and a beacon error R_b has been described. However, it is

not limited to this, and the location identification device may preliminarily store a beacon location P_b and a beacon error R_b of the beacon while associating them with identification information of each beacon.

[0065]

5 Moreover, in the above embodiments, the case where a vehicle location is estimated using an estimation error R_c calculated by the estimation error calculation unit and a beacon error R_b acquired by the beacon error acquisition unit 6 has been described. However, it is not limited to this, and the estimation error R_c may be a fixed value.

[0066]

10 Furthermore, in the above embodiments, the case where the estimation error R_c is used as the weight of the beacon location P_b and the beacon error R_b is used as the weight of the estimated location P_c has been described. However, it is not limited to this, and, for example, an inverse of the estimation error R_c may be used as the weight of the estimated location P_c and an inverse of the beacon error R_b may be used as the weight of the beacon
15 location P_b .

[0067]

 Moreover, in the above embodiments, the case where a matrix is used as the weight values R_b and R_c has been described. However, it is not limited to this, and scalar values may be used as weight values.

20 Furthermore, in the above embodiments, the case where a variance-covariance matrix is used as the weight values R_b and R_c has been described. However, it is not limited to this, and another scattering degree such as a standard deviation or a range of the beacon location may be used, or a representative value such as an average value and median value of the distance from a reception location to a beacon location may be used.

25 [0068]

The above location identification device has a computer system thereinside. The operations of the respective processing units described above are stored in a program format on a computer-readable recording medium, and the above processes are performed by the computer reading and executing of this program. The "computer-readable recording medium" here refers to a magnetic disc, a magnetic-optical disc, a CD-ROM, a DVD-ROM, a semiconductor memory, or the like. Moreover, this computer program may be distributed through a communication line, and a computer that receives this distribution may execute the program.

[0069]

Furthermore, the above program may realize part of the functions described above.

Moreover, the program may be a program capable of realizing the above functions in combination with a preliminarily recorded program on a computer system, that is, a so-called differential file (differential program).

15

INDUSTRIAL APPLICABILITY

[0070]

The present invention is such that in a location identification device, a location identification method, and a program for identifying a location where the device itself is present, a location identification unit calculates a location indicated by a weighted average of an estimated location and a beacon location, as a location of the device itself. Thereby, it is possible to reduce errors due to a range of carrier wave emission performed by the beacon, and to identify a location where the device itself is present.

[Reference Signs List]

25 [0071]

- 1 Location estimation unit
- 2 Location memory unit
- 3 Estimation error calculation unit
- 4 Beacon signal receiver unit
- 5 5 Beacon location acquisition unit
- 6 Beacon error acquisition unit
- 7 Location identification unit
- 8 Location output unit
- 9 Vehicle type information acquisition unit
- 10 10 Road identification unit

CLAIMS

1. A location identification device comprising:

a location estimation unit configured to estimate a location of the device itself;

5 a beacon location acquisition unit configured to acquire a beacon location based on a signal received from a beacon that emits a carrier wave carrying the signal, the beacon location being a location within a range of a carrier wave emission performed by the beacon; and

a location identification unit configured to calculate a location indicated by a weighted average of an estimated location, which is a location estimated by the location estimation unit, and the beacon location, while taking a weighted value which becomes greater as a range of the carrier wave emission performed by the beacon becomes narrower, as a weight of the beacon location acquired by the beacon location acquisition unit, and to identify the location indicated by the weighted average as a location of the device itself.

15

2. The location identification device according to claim 1, wherein the location identification unit is configured to calculate a location indicated by the weighted average of the estimated location and the beacon location, while taking a weighted value which becomes greater as an error range of a location estimation performed by the location estimation unit becomes narrower, as a weight of the estimated location.

20

3. The location identification device according to claim 1 or 2, wherein:

the beacon location is a matrix that indicates a location within the range of the carrier wave emission performed by the beacon in a predetermined orthogonal coordinate system;

25

the estimated location is a matrix that indicates a location where the device itself is estimated to be present in the orthogonal coordinate system; and

the weight of the beacon location is a variance-covariance matrix that indicates a variance of a location in the orthogonal coordinate system where the signal from the beacon is receivable normally.

4. The location identification device according to claim 2, wherein the weight of the beacon location becomes smaller as an installation height of the device itself becomes higher.

5. The location identification device according to any one of claims 1 to 4, further comprising:

a road identification unit configured to identify a road on which the device itself is present, based on the estimated location estimated by the location estimation unit; and

a beacon weight acquisition unit configured to acquire a weight of a beacon location corresponding to the road identified by the road identification unit,

wherein the location identification unit is configured to uses the weight acquired by the beacon weight acquisition unit to identify a location of the device itself.

6. The location identification device according to any one of claims 1 to 5, wherein the beacon location acquisition unit is configured to estimate the beacon location upon completion of normal signal reception, based on an intensity of the carrier wave of the signal, and on a relationship between the beacon location and the intensity of the carrier wave.

7. The location identification device according to any one of claims 1 to 5, further comprising a carrier wave intensity recording unit configured to sequentially record an intensity of the carrier wave from the beacon in a carrier wave intensity memory unit while associating the intensity with a location where the carrier wave is received,

5 wherein the beacon location acquisition unit is configured to estimate a location associated with a maximum value of the intensity of the carrier wave recorded in the carrier wave intensity memory unit, as a beacon location in a road extending direction.

8. The location identification device according to claim 7, wherein the beacon
10 location acquisition unit is configured to estimate a beacon location in a direction orthogonal to the road extending direction, based on the maximum value of the intensity of the carrier wave recorded in the carrier wave intensity memory unit, and on a relationship between a beacon location in the direction orthogonal to the road extending direction and the intensity of the carrier wave.

15

9. A location identification method that uses a location identification device that identifies a location where the device itself is present, the method comprising:

estimating the location of the device itself using a location estimation unit;

acquiring a beacon location using a beacon location acquisition unit, based on a
20 signal received from a beacon that emits a carrier wave carrying the signal, the beacon location being a location within a range of a carrier wave emission performed by the beacon; and

calculating, using a location identification unit, a location indicated by a weighted
average of an estimated location, which is a location estimated by the location estimation
25 unit, and the beacon location, while taking a weighted value which becomes greater as a

range of the carrier wave emission performed by the beacon becomes narrower, as a weight of the beacon location acquired by the beacon location acquisition unit, and identifying the location indicated by the weighted average as a location of the device itself.

- 5 10. A program that causes a location identification device that identifies a location where the device itself is present, to function as:

 a location estimation unit that estimates the location of the device itself;

- a beacon location acquisition unit that acquires a beacon location based on a signal received from a beacon, the beacon emitting a carrier wave carrying the signal, the
10 beacon location being a location within a range of a carrier wave emission performed by the beacon; and

- a location identification unit that calculates a location indicated by a weighted average of an estimated location, which is a location estimated by the location estimation unit, and the beacon location, while taking a weighted value which becomes greater as a
15 range of the carrier wave emission performed by the beacon becomes narrower, as a weight of the beacon location acquired by the beacon location acquisition unit, and identifies the location indicated by the weighted average as a location of the device itself.