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(54) **DETERMINATION DEVICE, DETERMINATION METHOD, AND DETERMINATION SYSTEM**

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(57) **ABSTRACT**

There is provided a determination device comprising a determination section configured to determine an area where a portable device is positioned, on a basis of wireless communication between a plurality of first wireless communication devices installed at different portions of a mobile object and a second wireless communication device installed in a portable device, in conformity with a designated communication standard, wherein the determination section determines the area where the portable device is positioned, by using different determination expressions depending on the respective first wireless communication devices, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device through wireless communication compliant with the designated communication standard and a determination target area.

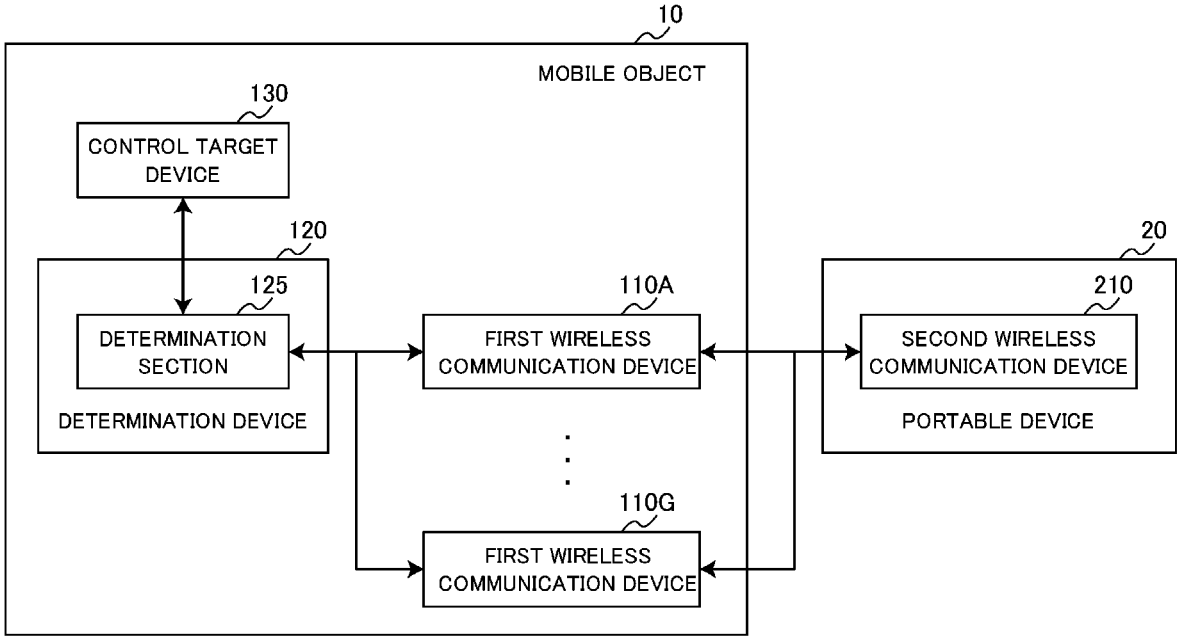


FIG. 1

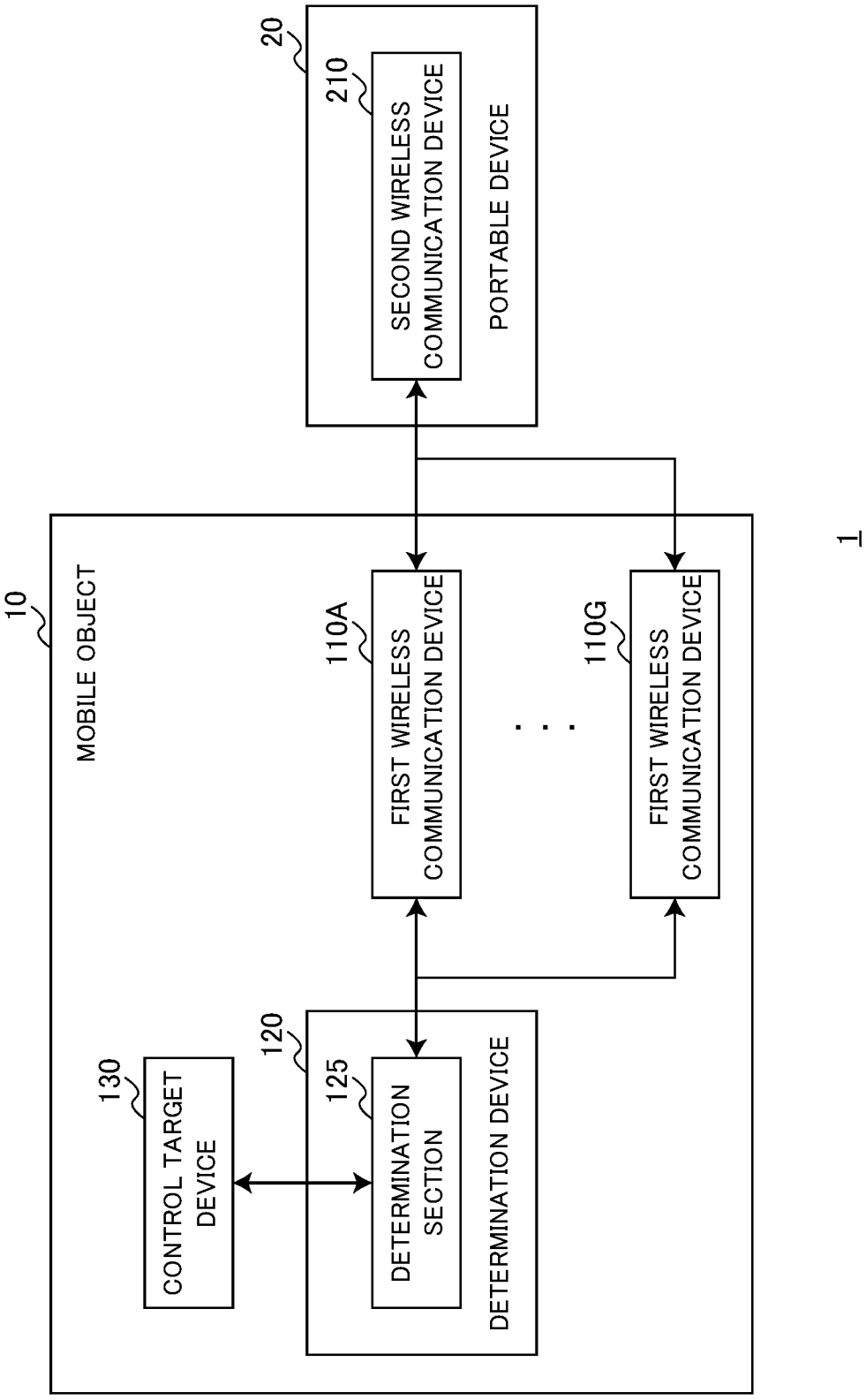

1
10
MOBILE OBJECT
20
PORTABLE DEVICE
210
SECOND WIRELESS COMMUNICATION DEVICE
110A
FIRST WIRELESS COMMUNICATION DEVICE
110G
FIRST WIRELESS COMMUNICATION DEVICE
120
DETERMINATION DEVICE
125
DETERMINATION SECTION
130
CONTROL TARGET DEVICE

FIG. 2

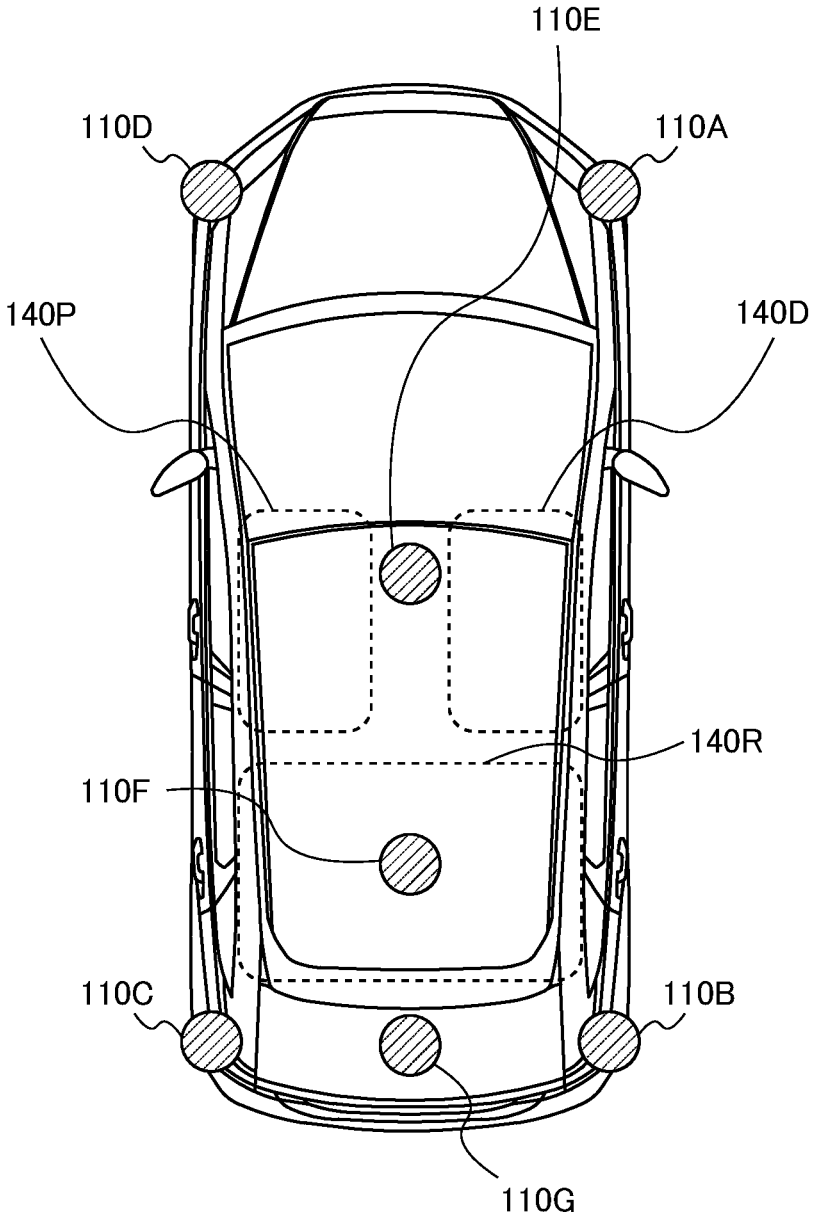


FIG. 3

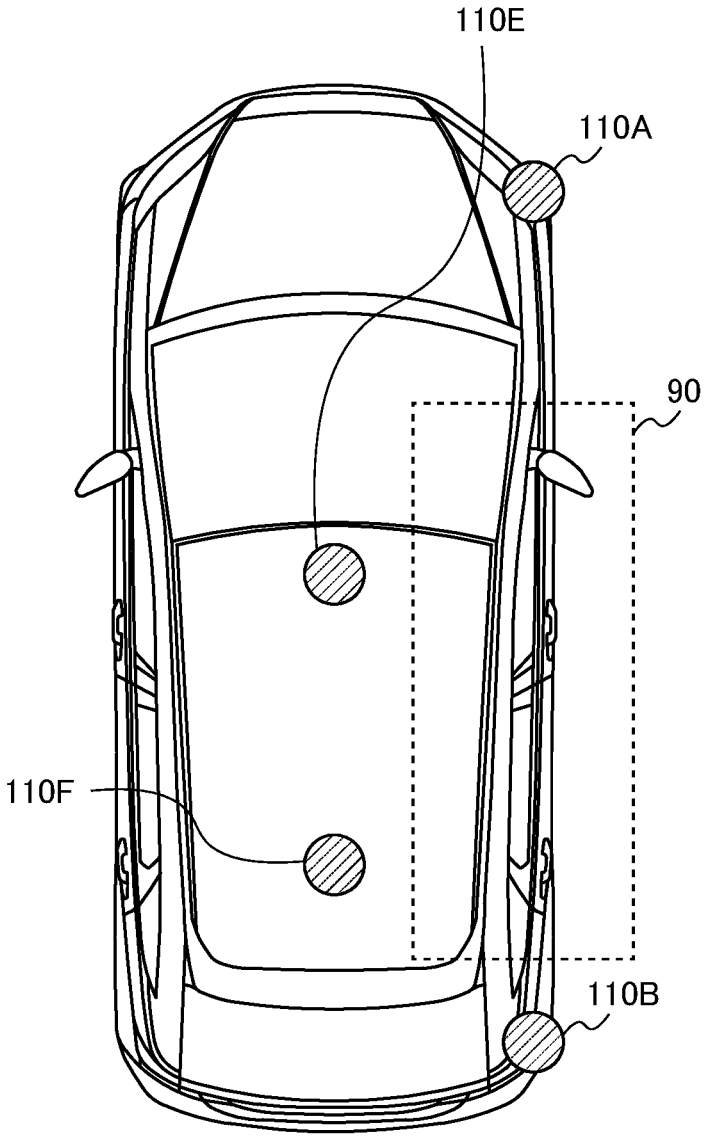


FIG. 4

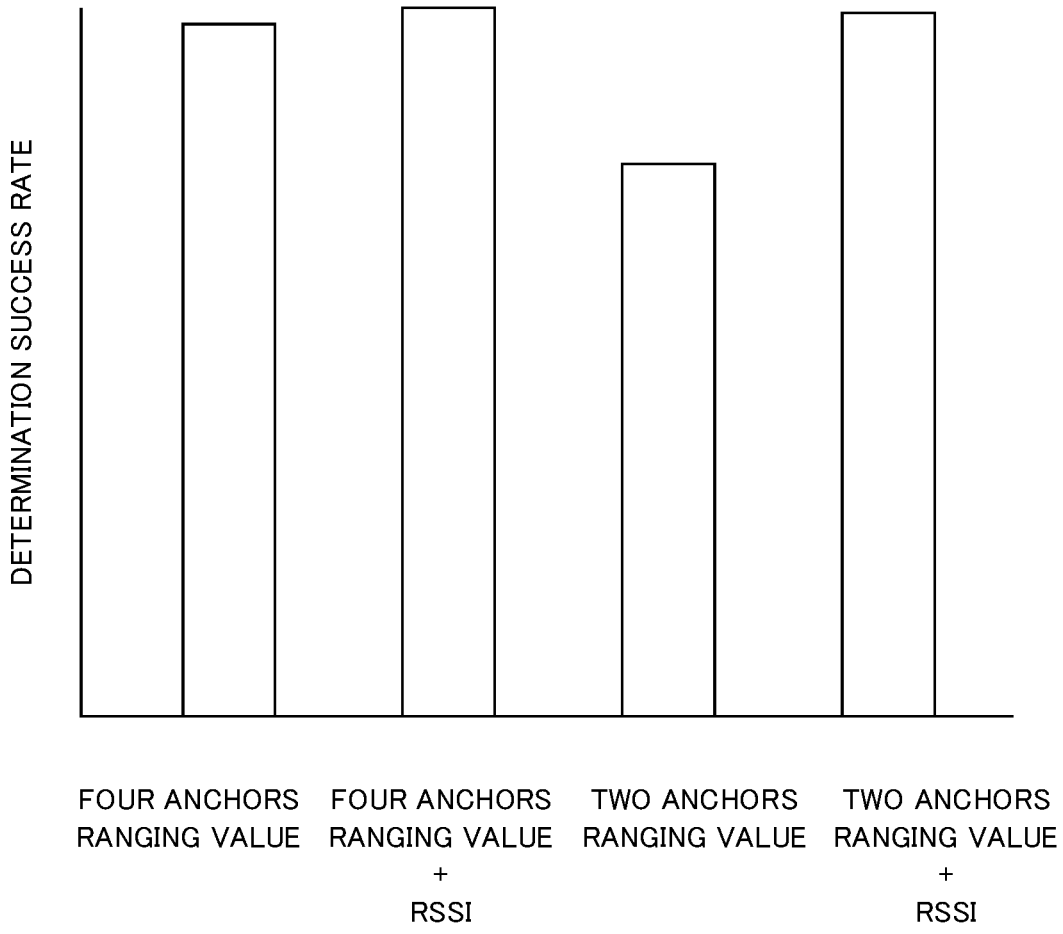

DETERMINATION SUCCESS RATE
FOUR ANCHORS RANGING VALUE
FOUR ANCHORS RANGING VALUE + RSSI
TWO ANCHORS RANGING VALUE
TWO ANCHORS RANGING VALUE + RSSI

FIG. 5

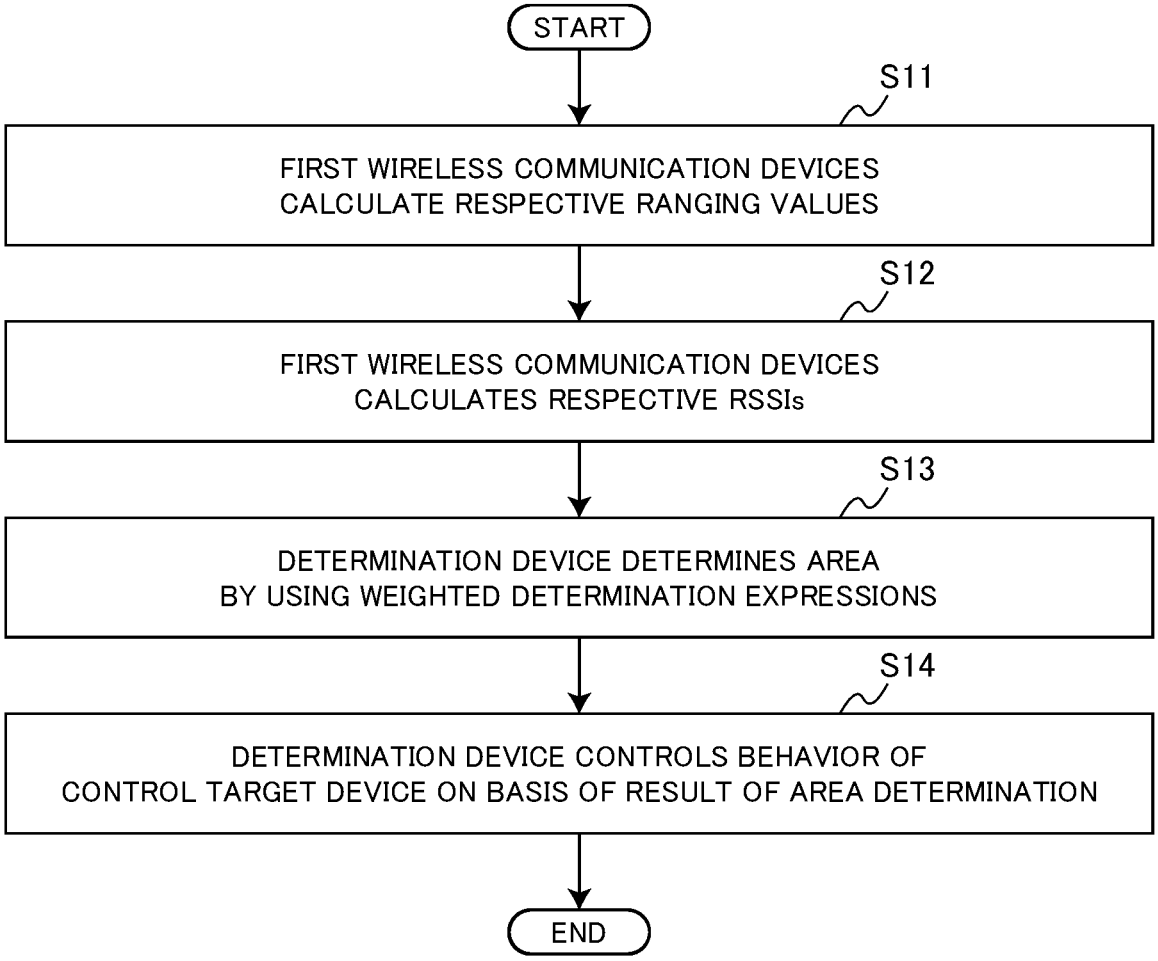

START
S11
FIRST WIRELESS COMMUNICATION DEVICES CALCULATE RESPECTIVE RANGING VALUES
S12
FIRST WIRELESS COMMUNICATION DEVICES CALCULATES RESPECTIVE RSSIs
S13
DETERMINATION DEVICE DETERMINES AREA BY USING WEIGHTED DETERMINATION EXPRESSIONS
S14
DETERMINATION DEVICE CONTROLS BEHAVIOR OF CONTROL TARGET DEVICE ON BASIS OF RESULT OF AREA DETERMINATION
END

FIG. 6

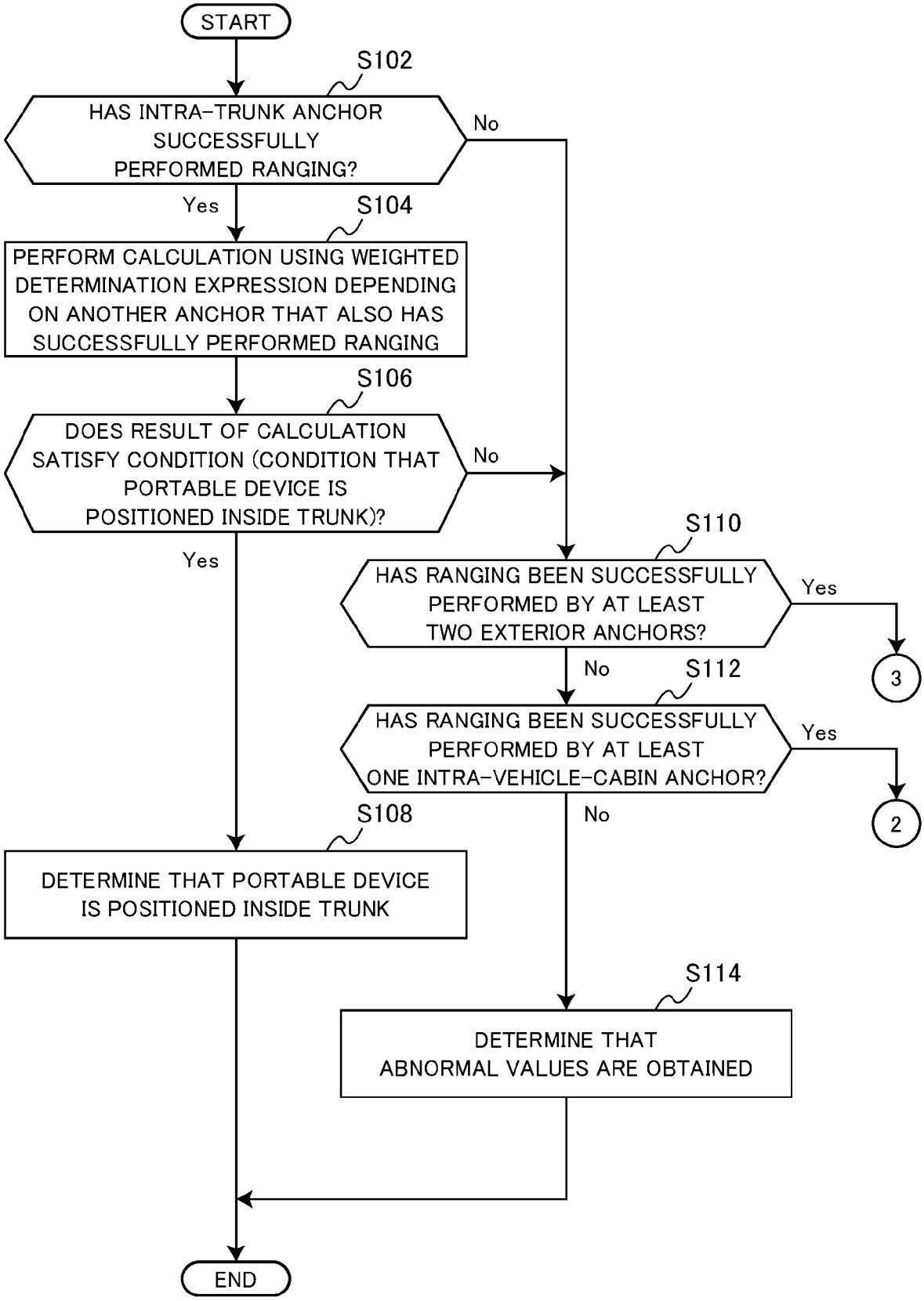

START
S102
HAS INTRA-TRUNK ANCHOR SUCCESSFULLY PERFORMED RANGING?
No
Yes
S104
PERFORM CALCULATION USING WEIGHTED DETERMINATION EXPRESSION DEPENDING ON ANOTHER ANCHOR THAT ALSO HAS SUCCESSFULLY PERFORMED RANGING
S106
DOES RESULT OF CALCULATION SATISFY CONDITION (CONDITION THAT PORTABLE DEVICE IS POSITIONED INSIDE TRUNK)?
No
Yes
S110
HAS RANGING BEEN SUCCESSFULLY PERFORMED BY AT LEAST TWO EXTERIOR ANCHORS?
Yes
3
No
S112
HAS RANGING BEEN SUCCESSFULLY PERFORMED BY AT LEAST ONE INTRA-VEHICLE-CABIN ANCHOR?
Yes
2
No
S108
DETERMINE THAT PORTABLE DEVICE IS POSITIONED INSIDE TRUNK
S114
DETERMINE THAT ABNORMAL VALUES ARE OBTAINED
END

FIG. 7

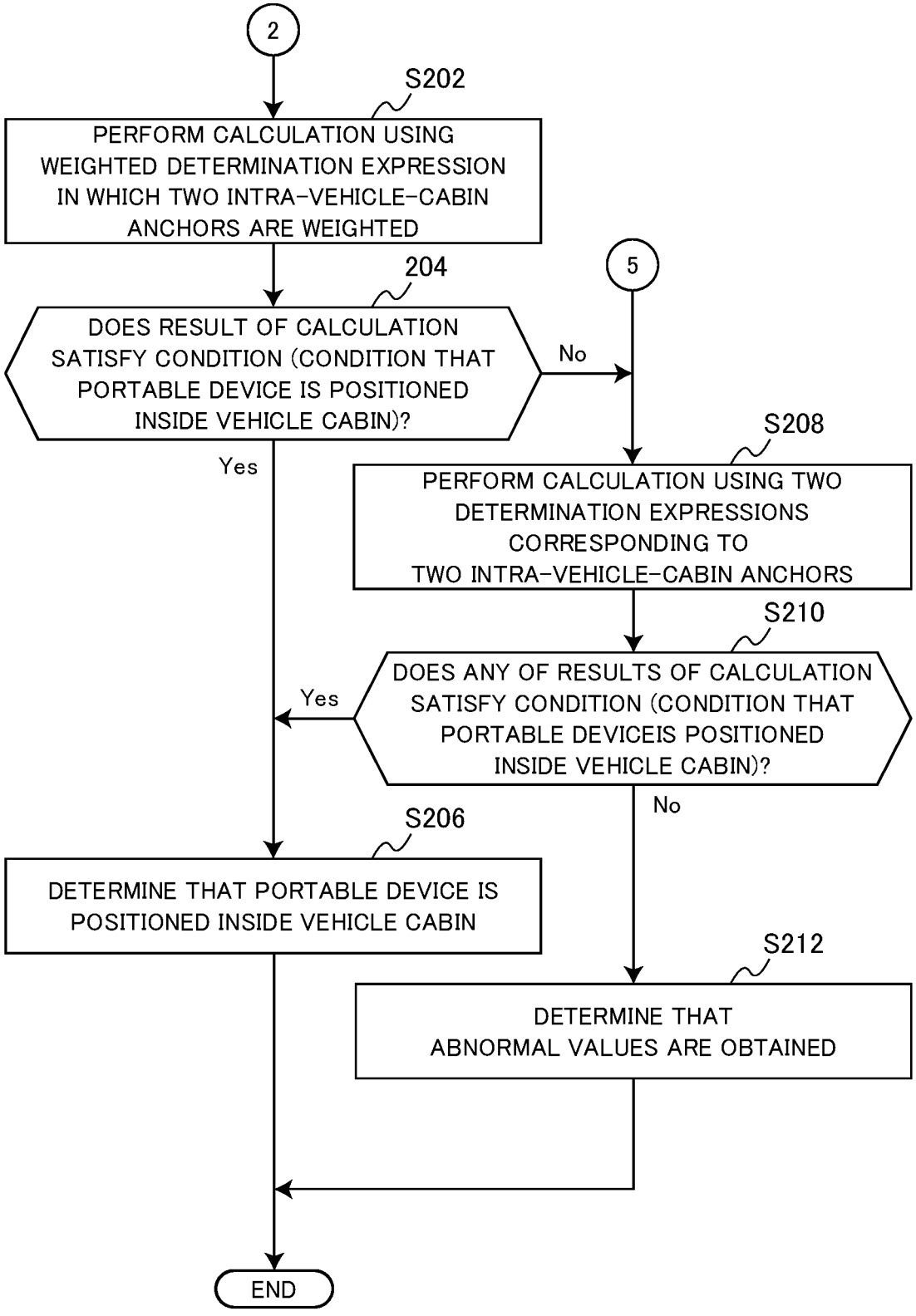

2
S202
PERFORM CALCULATION USING WEIGHTED DETERMINATION EXPRESSION IN WHICH TWO INTRA-VEHICLE-CABIN ANCHORS ARE WEIGHTED
204
DOES RESULT OF CALCULATION SATISFY CONDITION (CONDITION THAT PORTABLE DEVICE IS POSITIONED INSIDE VEHICLE CABIN)?
No
5
Yes
S208
PERFORM CALCULATION USING TWO DETERMINATION EXPRESSIONS CORRESPONDING TO TWO INTRA-VEHICLE-CABIN ANCHORS
S210
DOES ANY OF RESULTS OF CALCULATION SATISFY CONDITION (CONDITION THAT PORTABLE DEVICEIS POSITIONED INSIDE VEHICLE CABIN)?
Yes
No
S206
DETERMINE THAT PORTABLE DEVICE IS POSITIONED INSIDE VEHICLE CABIN
S212
DETERMINE THAT ABNORMAL VALUES ARE OBTAINED
END

FIG. 8

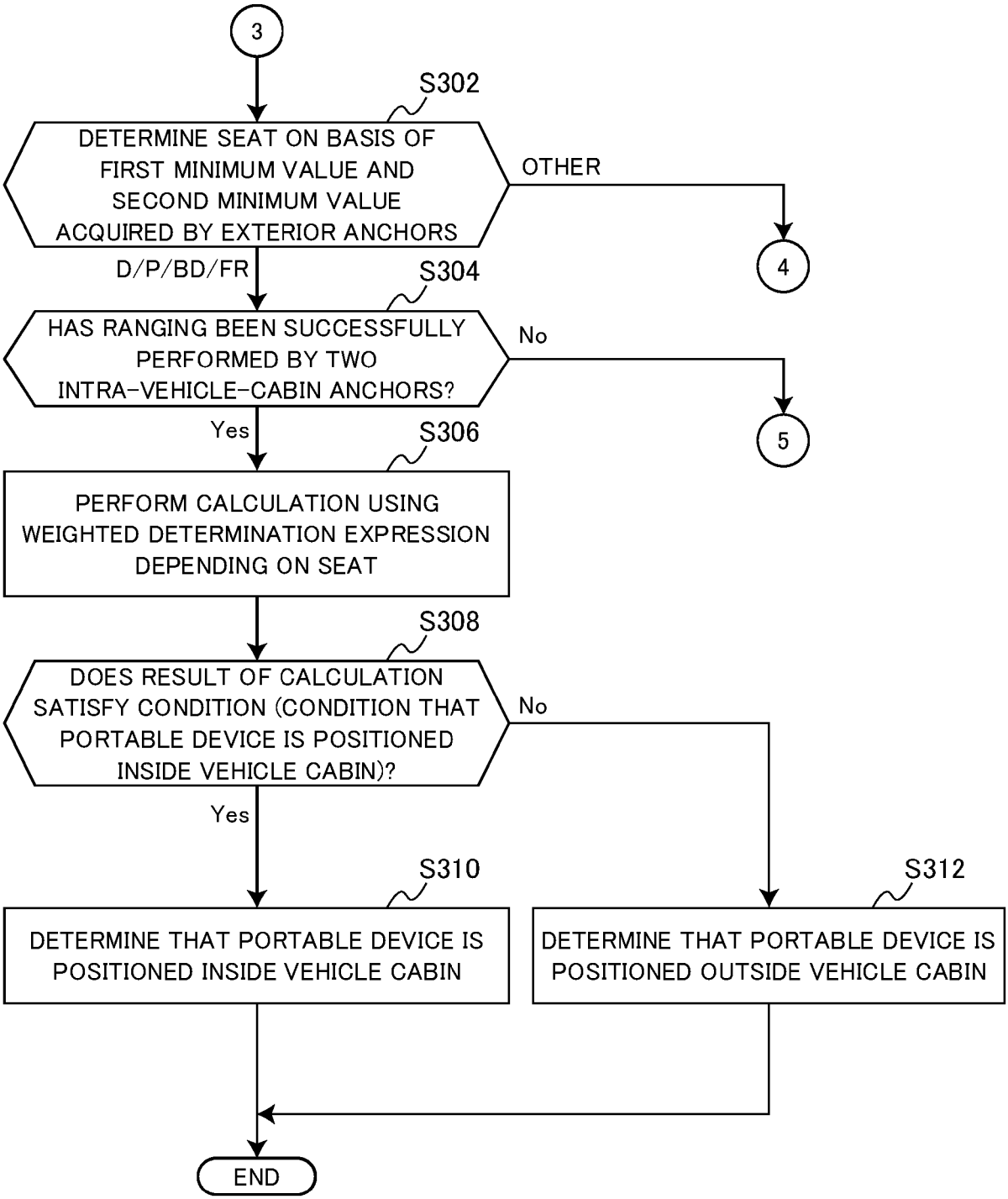
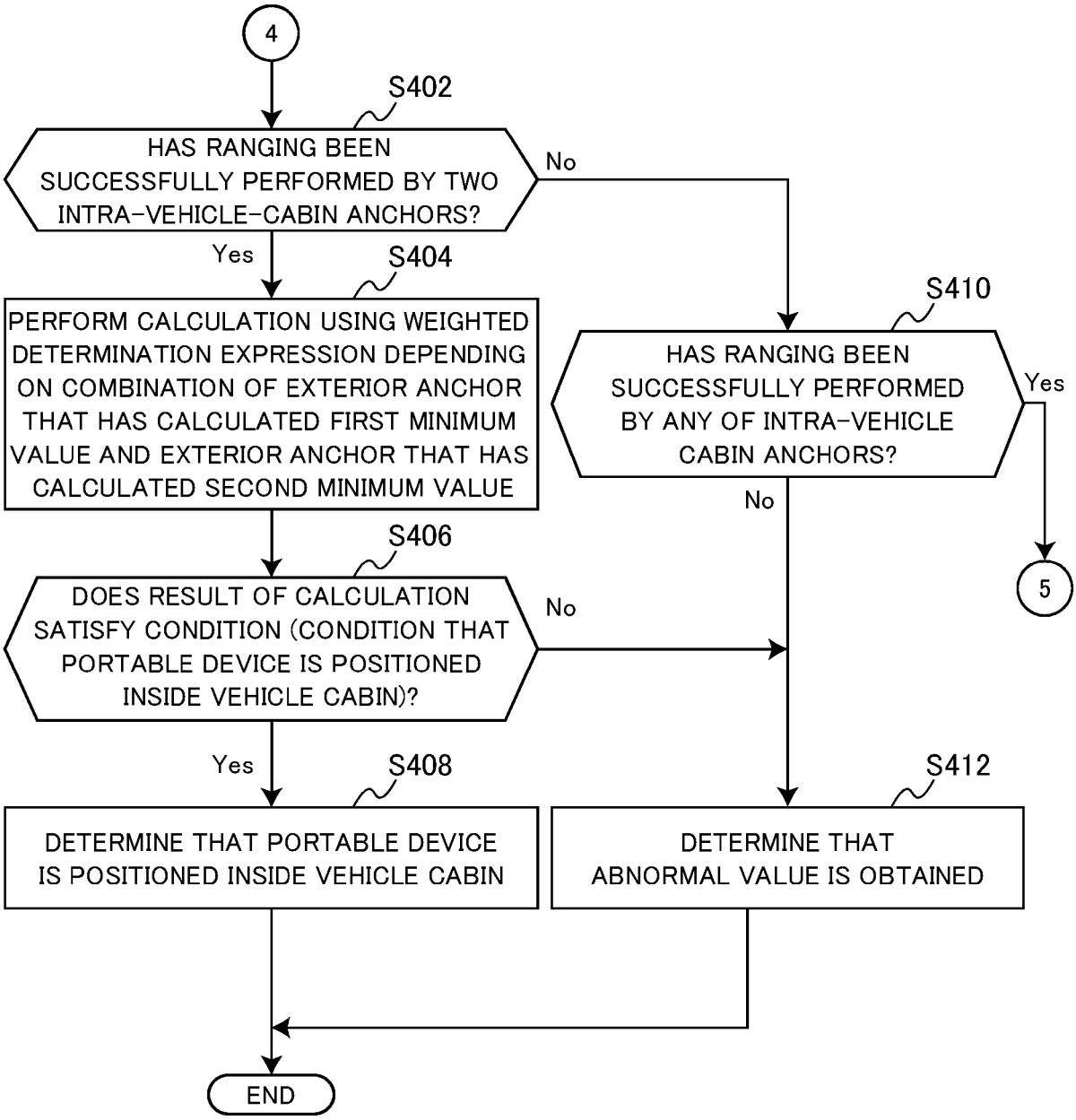

3
S302
DETERMINE SEAT ON BASIS OF FIRST MINIMUM VALUE AND SECOND MINIMUM VALUE ACQUIRED BY EXTERIOR ANCHORS
OTHER
4
D/P/BD/FR
S304
HAS RANGING BEEN SUCCESSFULLY PERFORMED BY TWO INTRA-VEHICLE-CABIN ANCHORS?
No
5
Yes
S306
PERFORM CALCULATION USING WEIGHTED DETERMINATION EXPRESSION DEPENDING ON SEAT
S308
DOES RESULT OF CALCULATION SATISFY CONDITION (CONDITION THAT PORTABLE DEVICE IS POSITIONED INSIDE VEHICLE CABIN)?
No
Yes
S310
DETERMINE THAT PORTABLE DEVICE IS POSITIONED INSIDE VEHICLE CABIN
S312
DETERMINE THAT PORTABLE DEVICE IS POSITIONED OUTSIDE VEHICLE CABIN
END

FIG. 9


4
S402
HAS RANGING BEEN SUCCESSFULLY PERFORMED BY TWO INTRA-VEHICLE-CABIN ANCHORS?
No
Yes
S404
PERFORM CALCULATION USING WEIGHTED DETERMINATION EXPRESSION DEPENDING ON COMBINATION OF EXTERIOR ANCHOR THAT HAS CALCULATED FIRST MINIMUM VALUE AND EXTERIOR ANCHOR THAT HAS CALCULATED SECOND MINIMUM VALUE
S406
DOES RESULT OF CALCULATION SATISFY CONDITION (CONDITION THAT PORTABLE DEVICE IS POSITIONED INSIDE VEHICLE CABIN)?
No
Yes
S408
DETERMINE THAT PORTABLE DEVICE IS POSITIONED INSIDE VEHICLE CABIN
S410
HAS RANGING BEEN SUCCESSFULLY PERFORMED BY ANY OF INTRA-VEHICLE CABIN ANCHORS?
Yes
No
5
S412
DETERMINE THAT ABNORMAL VALUE IS OBTAINED
END

DETERMINATION DEVICE, DETERMINATION METHOD, AND DETERMINATION SYSTEM

CROSS REFERENCE TO RELATED APPLICATION(S)

[0001] This application is based upon and claims benefit of priority from Japanese Patent Application No. 2022-046585, filed on Mar. 23, 2022, and Japanese Patent Application No. 2022-104515, filed on Jun. 29, 2022, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] The present invention relates to a determination device, a determination method, and a determination system.

[0003] In recent years, technologies of estimating a position of a target device through wireless communication have been developed. For example, JP 2021-099289A discloses a technology of performing wireless communication between a wireless communication device installed in a portable device and a plurality of wireless communication devices installed in a vehicle, and estimating the position of the portable device on the basis of intersections of directions of arrival of radio waves from the portable device. The intersections are estimated on the basis of the wireless communication.

SUMMARY

[0004] However, when using the technology disclosed in JP 2021-099289A, there are the plurality of intersections of directions of arrival of radio waves in a vertical direction, and this may deteriorate the position estimation accuracy. In addition, the position estimation accuracy deteriorates drastically in the case where a calculated ranging value acquired by a wireless communication device is longer than an actual length due to an effect of an obstacle and the like.

[0005] Accordingly, the present invention is made in view of the aforementioned issues, and an object of the present invention is to determine a position of a target device with higher accuracy.

[0006] To solve the above described problem, according to an aspect of the present invention, there is provided a determination device comprising a determination section configured to determine an area where a portable device is positioned, on a basis of wireless communication between a plurality of first wireless communication devices installed at different portions of a mobile object and a second wireless communication device installed in a portable device, in conformity with a designated communication standard, wherein the determination section determines the area where the portable device is positioned, by using different determination expressions depending on the respective first wireless communication devices, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device through wireless communication compliant with the designated communication standard and a determination target area.

[0007] To solve the above described problem, according to another aspect of the present invention, there is provided a determination method comprising causing a processor to determine an area where a portable device is positioned, on a basis of wireless communication between a plurality of first wireless communication devices installed at different portions of a mobile object and a second wireless communication device installed in a portable device, in conformity with a designated communication standard, wherein the determination further includes determining the area where the portable device is positioned, by using different determination expressions depending on the respective first wireless communication devices, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device through wireless communication compliant with the designated communication standard and a determination target area.

[0008] To solve the above described problem, according to another aspect of the present invention, there is provided determination system comprising: a plurality of first wireless communication devices installed at different portions of a mobile object; a second wireless communication device installed in a portable device; and a determination section configured to determine an area where the portable device is positioned, on a basis of wireless communication between the respective first wireless communication devices and the second wireless communication device in conformity with a designated communication standard, wherein the determination device determines the area where the portable device is positioned, by using different determination expressions depending on the respective first wireless communication devices, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device through wireless communication compliant with the designated communication standard and a determination target area.

[0009] As described above, according to the present invention, it is possible to determine a position of a target device with higher accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** is a block diagram illustrating a configuration example of a determination system **1** according to an embodiment of the present invention.

[0011] FIG. **2** is a diagram illustrating an example of disposing first wireless communication devices **110** according to the embodiment.

[0012] FIG. **3** is a diagram for describing a situation where a difference between ranging values according to the embodiment is very small.

[0013] FIG. **4** is a diagram for describing an effect of area determination based on RSSIs according to the embodiment.

[0014] FIG. **5** is a flowchart illustrating an example of a flow of area determination of a portable device **20** by the determination system **1** according to the embodiment.

[0015] FIG. **6** is a flowchart illustrating an example of a flow of area determination of the portable device **20** by a determination section **125** according to the embodiment.

[0016] FIG. **7** is a flowchart illustrating the example of the flow of area determination of the portable device **20** by the determination section **125** according to the embodiment.

[0017] FIG. **8** is a flowchart illustrating the example of the flow of area determination of the portable device **20** by the determination section **125** according to the embodiment.

[0018] FIG. **9** is a flowchart illustrating the example of the flow of area determination of the portable device **20** by the determination section **125** according to the embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENT(S)

[0019] Hereinafter, referring to the appended drawings, preferred embodiments of the present invention will be described in detail. It should be noted that, in this specification and the appended drawings, structural elements that have substantially the same function and structure are denoted with the same reference numerals, and repeated explanation thereof is omitted.

1. Embodiment

1.1.1. System Configuration Example

[0020] First, a configuration example of a determination system **1** according to an embodiment of the present invention will be described. FIG. **1** is a block diagram illustrating the configuration example of the determination system **1** according to the embodiment of the present invention.

[0021] As illustrated in FIG. **1**, the determination system **1** according to the present embodiment includes a mobile object **10** and a portable device **20**.

Mobile Object **10**

[0022] The mobile object **10** according to the present embodiment may be a means of transportation having a space for passengers (for example, a vehicle cabin in a case of a vehicle) such as a vehicle, an airplane, a ship, or the like, for example.

[0023] As illustrated in FIG. **1**, the mobile object **10** according to the present embodiment may include a plurality of first wireless communication devices **110**, a determination device **120**, and a control target device **130**.

First Wireless Communication Device **110**

[0024] The respective first wireless communication devices **110** are installed at different portions of the mobile object **10** according to the present embodiment.

[0025] In the case of the example illustrated in FIG. **1**, the mobile object **10** includes seven first wireless communication devices **110**A to **110**G. However, the number of first wireless communication devices **110** installed in/on the mobile object **10** is not limited to the above-described example.

[0026] Each of the first wireless communication devices **110** according to the present embodiment performs wireless communication with a second wireless communication device **210** installed in the portable device **20** in conformity with a designated communication standard.

[0027] For example, each of the first wireless communication devices **110** according to the present embodiment calculates an RSSI of a signal received from the second wireless communication device through wireless communication compliant with the designated communication standard.

[0028] In addition, for example, each of the first wireless communication devices **110** according to the present embodiment performs ranging (a process of estimating a distance between the first wireless communication device **110** and the second wireless communication device **210**) based on wireless communication with the second wireless communication device **210** in conformity with a designated communication standard.

[0029] Each of the first wireless communication devices **110** according to the present embodiment outputs a calculated RSSI and a ranging value calculated through the ranging (an estimated value of the distance between the first wireless communication device **110** and the second wireless communication device **210**) to the determination device **120**.

[0030] Examples of the designated communication standard according to the present embodiment include ultra-wideband (UWB) wireless communication.

[0031] Each of the first wireless communication devices **110** according to the present embodiment may calculate the ranging value through the technology disclosed in JP 2021-099289A or the like, for example.

[0032] Note that, the designated communication standard according to the present embodiment is not limited to the ultra-wideband wireless communication. Any standards capable of estimating a distance between the first wireless communication devices **110** and the second wireless communication device **210** may be adopted as the designated communication standard according to the present embodiment.

Determination Device **120**

[0033] The determination device **120** according to the present embodiment includes a determination section **125** configured to determine an area where the portable device **20** is positioned, on the basis of wireless communication between the respective first wireless communication devices and the second wireless communication device in conformity with the designated communication standard.

[0034] In addition, one of features of the determination section **125** according to the present embodiment is to determine the area where the portable device **20** is positioned, by using different determination expressions depending on the respective first wireless communication devices **110**, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device **210** through the wireless communication compliant with the designated communication standard and a determination target area.

[0035] Note that, details of the area determination performed by the determination section **125** according to the present embodiment will be described later.

[0036] In addition, the determination section **125** according to the present embodiment may control behavior of the control target device **130** on the basis of a result of the area determination.

[0037] For example, the determination section **125** may permit an engine (an example of the control target device **130**) of the mobile object **10** to start in the case where it is determined that the portable device **20** is positioned in the vehicle cabin of the mobile object **10**.

[0038] Alternatively, for example, in the case where it is determined that the portable device **20** is positioned in a trunk of the mobile object **10**, the determination section **125** may cause a sound output device (an example of the control target device **130**) of the mobile object **10** to output

a message indicating that the portable device **20** is positioned in the trunk.

[0039] Alternatively, for example, in the case where it is determined that the portable device **20** is positioned near an outside of the mobile object **10**, the determination section **125** may instruct a lock device (an example of the control target device **130**) to be opened. The lock device is installed in a door of the mobile object **10**.

[0040] The functions of the determination section **125** according to the present embodiment are implemented by various kinds of processors.

Control Target Device **130**

[0041] The control target device **130** according to the present embodiment may be various kinds of devices that perform designated behavior under control based on a result of determination made by the determination device **120**.

[0042] For example, the control target device **130** according to the present embodiment may be the engine, the lock device of the door, the sound output device, a display device, lighting equipment or the like.

Portable Device **20**

[0043] The portable device **20** according to the present embodiment is carried by a user of the mobile object **10** (such as an owner of the mobile object **10** or a person who has permission from the owner to use the mobile object **10**).

[0044] As illustrated in FIG. **1**, the portable device **20** according to the present embodiment includes at least the second wireless communication device **210**.

Second Wireless Communication Device **210**

[0045] The second wireless communication device **210** according to the present embodiment performs wireless communication with the respective first wireless communication devices **110** installed in the mobile object **10** in conformity with the designated communication standard. In addition, the second wireless communication device **210** according to the present embodiment performs ranging in cooperation with the respective first wireless communication devices **100** installed in the mobile object **10**.

[0046] The configuration example of the determination system **1** according to the present embodiment has been described above. Note that, the configuration described above with reference to FIG. **1** is a mere example. The configuration of the determination system **1** according to the present embodiment is not limited thereto.

[0047] For example, each of the mobile object **10** and the portable device **20** may further include a structural element for performing wireless communication compliant with another communication standard that is different from the designated communication standard described above. In this case, the determination section **125** may authenticate the portable device **20** on the basis of the wireless communication compliant with the other communication standard and may control behavior of the control target device **130** further on the basis of a result of the authentication.

[0048] The configuration of the determination system **1** according to the present embodiment may be flexibly modified in accordance with specifications, operations, and the like.

1.2. Example of Disposing First Wireless Communication Devices 110

[0049] Next, an example of disposing the first wireless communication devices **110** according to the present embodiment will be described. FIG. **2** is a diagram illustrating the example of disposing the first wireless communication devices **110** according to the present embodiment.

[0050] In the case of the example illustrated in FIG. **2**, the seven first wireless communication devices **110**A to **110**G are disposed at different portions of the mobile object **10**.

[0051] More specifically, the first wireless communication device **110**A is disposed on a right side of a front bumper of the mobile object **10**. The first wireless communication device **110**B is disposed on a right side of a rear bumper of the mobile object **10**. The first wireless communication device **110**C is disposed on a left side of the rear bumper of the mobile object **10**. The first wireless communication device **110**D is disposed on a left side of the front bumper of the mobile object **10**.

[0052] In addition, the first wireless communication device **110**E is disposed near a front middle portion (for example, between a driver's seat **140**D and a front passenger seat **140**P) in the vehicle cabin of the mobile object **10**. The first wireless communication device **110**F is disposed near a rear middle portion (for example, in the middle of a rear seat **140**R) in the vehicle cabin.

[0053] In addition, the first wireless communication device **110**G is disposed in a specific space in the mobile object **10**. Here, the specific space according to the present embodiment may be a space in the mobile object **10**, and may be a space for which the area determination is performed separately from the vehicle cabin.

[0054] Examples of the specific space according to the present embodiment include the trunk (luggage compartment). Note that, in the case where the specific space is the trunk, the trunk may be a (closed) space that is clearly separated from the vehicle cabin, or may be an (open) space that is connected with the vehicle cabin.

[0055] Hereinafter, a case where the specific space according to the present embodiment is the trunk will be described as a major example. In other words, the first wireless communication device **110**G is disposed in the trunk of the mobile object **10**.

[0056] However, the specific space according to the present embodiment is not limited to the trunk. For example, the specific space may be a partial space or the like in the vehicle cabin such as a glove compartment in the vehicle cabin.

[0057] At least one or more first wireless communication devices **110** according to the present embodiment may be disposed in the vehicle cabin in the mobile object **10**, in the specific space in the mobile object **10**, and on an exterior of the mobile object **10**.

[0058] The determination section **125** of the determination device **120** according to the present embodiment determines whether the portable device **20** is positioned in the vehicle cabin, in the specific space, or on the exterior of the mobile object **10** on the basis of wireless communication between the second wireless communication device **210** and the respective first wireless communication devices **110** disposed as described above, in conformity with the designated communication standard.

1.3. Determination Example

[0059] Next, a detailed example of the area determination performed by the determination section **125** according to the present embodiment will be described.

[0060] One of features of the determination section **125** according to the present embodiment is to determine the area where the portable device **20** is positioned, by using different determination expressions depending on the respective first wireless communication devices **110**, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device **210** through the wireless communication compliant with the designated communication standard and a determination target area.

[0061] In this case, the determination section **125** determines the area where the portable device **20** is positioned, by using a weighted determination expression in which different weights are given to the respective first wireless communication devices **110**, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device **210** through wireless communication compliant with the designated communication standard and a determination target area.

[0062] Next, a detailed example of determination will be described with reference to the layout of the first wireless communication devices **110** illustrated in FIG. **2**.

[0063] For example, the determination section **125** determines whether the portable device **20** is positioned inside or outside the trunk (an example of the specific space) on the basis of respective RSSIs calculated by four first wireless communication devices **110** disposed near the trunk.

[0064] The four first wireless communication devices **110** may include the first wireless communication devices **110**B and **110**C that are disposed on the rear bumper of the mobile object **10**, the first wireless communication device **110**F that is disposed near the rear middle portion in the vehicle cabin of the mobile object **10**, and the first wireless communication device **110**G that is disposed in the trunk of the mobile object **10**.

[0065] More specifically, the determination section **125** may determine whether the portable device **20** is positioned inside or outside the trunk by using a determination expression (1) listed below.

$$y = b + wrB * RB + wrC * RC + wrF * RF + wrG * RG \quad (1)$$

[0066] In the determination expression (1), b represents a constant, wrB to wrG represent respective weights given to RSSIs calculated by the respective first wireless communication devices **110**B to **110**G, and RB to RG represent the respective RSSIs calculated by the first wireless communication devices **110**B to **110**G.

[0067] In this case, the determination section **125** may determine that the portable device **20** is positioned inside the trunk if $y > 0$, and the determination section **125** may determine that the portable device **20** is positioned outside the trunk if $y \leq 0$. On the other hand, the determination section **125** may determine that the portable device **20** is positioned inside the trunk if $y \leq 0$, and the determination section **125** may determine that the portable device **20** is positioned outside the trunk if $y > 0$. The constant b is appropriately set in such a manner that each of the above-described conditions is satisfied.

[0068] Note that, for example, it is possible to improve the determination accuracy of the determination expression (1) listed above, when increasing the weight wrG given to an RSSI calculated by the first wireless communication device **110**G that is the nearest to the trunk.

[0069] Alternatively, for example, the determination section **125** determines whether the portable device **20** is positioned inside the vehicle cabin or on an outer right side of the vehicle cabin on the basis of respective RSSIs calculated by four first wireless communication devices **110** closer to the right side of the mobile object **10**.

[0070] The four first wireless communication devices **110** may include the first wireless communication device **110**A that is disposed on the right side of the front bumper of the mobile object **10**, the first wireless communication device **110**B that is disposed on the right side of the rear bumper of the mobile object **10**, and the first wireless communication devices **110**E and **110**F that are disposed inside the vehicle cabin of the mobile object **10**.

[0071] More specifically, the determination section **125** may determine whether the portable device **20** is positioned inside or outside the vehicle cabin by using a determination expression (2) listed below.

$$y = b + wrA * RA + wrB * RB + wrE * RE + wrF * RF \quad (2)$$

[0072] In the determination expression (2), b represents a constant, wrA to wrF represent respective weights given to RSSIs calculated by the respective first wireless communication devices **110**A to **110**F, and RA to RF represent the respective RSSIs calculated by the first wireless communication devices **110**A to **110**F.

[0073] In this case, the determination section **125** may determine that the portable device **20** is positioned on the outer right side of the vehicle cabin (of the mobile object **10**) if $y > 0$, and the determination section **125** may determine that the portable device **20** is positioned inside the vehicle cabin if $y \leq 0$. On the other hand, the determination section **125** may determine that the portable device **20** is positioned on the outer right side of the vehicle cabin (of the mobile object **10**) if $y \leq 0$, and the determination section **125** may determine that the portable device **20** is positioned inside the vehicle cabin if $y > 0$. The constant b is appropriately set in such a manner that each of the above-described conditions is satisfied.

[0074] Note that, it is also possible to improve the determination accuracy of the determination expression (2) listed above when weights wrA and wrB are negative numbers and weights wrE and wrF are positive numbers. The weights wrA and wrB are given to respective RSSIs calculated by the first wireless communication devices **110**A and **110**B disposed on right portions of the exterior of the mobile object **10**. The weights wrE and wrF are given to respective RSSIs calculated by the first wireless communication devices **110**E and **110**F disposed inside the vehicle cabin of the mobile object **10**.

[0075] The detailed example of the area determination using the determination expression in which weights are given to the RSSIs according to the present embodiment has been described above.

[0076] However, the weighted determination expression according to the present embodiment is not limited thereto. In the weighted determination expression according to the

present embodiment, different weights may be given to respective ranging values acquired by the first wireless communication devices **110**.

[0077] In this case, the determination section **125** may determine the area where the portable device **20** is positioned, by using a weighted determination expression in which different weights are given to the respective first wireless communication devices **110** on the basis of first wireless communication devices **110** that have successfully performed ranging with regard to the second wireless communication device **210** and a determination target area.

[0078] For example, the determination section **125** may use a determination expression (3) listed below when determining whether the portable device **20** is positioned inside or outside the trunk on the basis of respective ranging values acquired by the first wireless communication devices **110**B, **110**C, **110**F, and **110**G.

$$y = b + w1B * LB + w1C * LC + w1F * LF + w1G * LG \quad (3)$$

[0079] In the determination expression (3), b represents a constant, w1B to w1G represent respective weights given to ranging values acquired by the respective first wireless communication devices **110**B to **110**G, and LB to LG represent the respective ranging values acquired by the first wireless communication devices **110**B to **110**G.

[0080] In this case, the determination section **125** may determine that the portable device **20** is positioned inside the trunk if $y > 0$, and the determination section **125** may determine that the portable device **20** is positioned outside the trunk if $y \leq 0$. On the other hand, the determination section **125** may determine that the portable device **20** is positioned inside the trunk if $y \leq 0$, and the determination section **125** may determine that the portable device **20** is positioned outside the trunk if $y > 0$. The constant b is appropriately set in such a manner that each of the above-described conditions is satisfied.

[0081] Note that, for example, it is possible to improve the determination accuracy of the determination expression (3) listed above, when increasing the weight w1G given to a ranging value acquired by the first wireless communication device **110**G that is the nearest to the trunk.

[0082] Alternatively, the determination section **125** may use a determination expression (4) listed below when determining whether the portable device **20** is positioned inside the vehicle cabin or on an outer right side of the vehicle cabin on the basis of respective ranging values acquired by the first wireless communication devices **110**A, **110**B, **110**E, and **110**F.

$$y = b + w1A * LA + w1B * LB + w1E * LE + w1F * LF \quad (4)$$

[0083] In the determination expression (4), b represents a constant, w1A to w1F represent respective weights given to ranging values acquired by the respective first wireless communication devices **110**A to **110**F, and LA to LF represent the respective ranging values acquired by the first wireless communication devices **110**A to **110**F.

[0084] In this case, the determination section **125** may determine that the portable device **20** is positioned on the outer right side of the vehicle cabin (of the mobile object **10**) if $y > 0$, and the determination section **125** may determine that the portable device **20** is positioned inside the vehicle cabin if $y \leq 0$. On the other hand, the determination section **125** may determine that the portable device **20** is positioned on the outer right side of the vehicle cabin (of the mobile object **10**) if $y \leq 0$, and the determination section **125** may determine that the portable device **20** is positioned inside the vehicle cabin if $y > 0$. The constant b is appropriately set in such a manner that each of the above-described conditions is satisfied.

[0085] Note that, for example, it is also possible to improve the determination accuracy of the determination expression (4) listed above when weights w1A and w1B are negative numbers and weights w1E and w1F are positive numbers. The weights w1A and w1B are given to respective ranging values acquired by the first wireless communication devices **110**A and **110**B disposed on right portions of the exterior of the mobile object **10**. The weights w1E and w1F are given to respective ranging values acquired by the first wireless communication devices **110**E and **110**F disposed inside the vehicle cabin of the mobile object **10**.

[0086] The detailed example of the area determination using the weighted determination expression in which weights are given to the ranging values according to the present embodiment has been described above.

[0087] Next, a detailed example of area determination using a weighted determination expression in which weights are given to RSSIs and ranging values according to the present embodiment has been described above.

[0088] For example, the determination section **125** may use a determination expression (5) listed below when determining whether the portable device **20** is positioned inside or outside the trunk on the basis of ranging values and RSSIs acquired by the respective first wireless communication devices **110**B, **110**C, **110**F, and **110**G.

$$y = b + w1B * LB + w1C * LC + w1F * LF + w1G * LG + wrB * RB + wrC * RC + wrF * RF + wrG * RG \quad (5)$$

[0089] In the determination expression (5), b represents a constant, wrB to wrG represent respective weights given to RSSIs calculated by the respective first wireless communication devices **110**B to **110**G, and RB to RG represent the respective RSSIs calculated by the first wireless communication devices **110**B to **110**G. In addition, in the determination expression (5), w1B to w1G represent respective weights given to ranging values acquired by the respective first wireless communication devices **110**B to **110**G, and LB to LG represent the respective ranging values acquired by the first wireless communication devices **110**B to **110**G.

[0090] In this case, the determination section **125** may determine that the portable device **20** is positioned inside the trunk if $y > 0$, and the determination section **125** may determine that the portable device **20** is positioned outside the trunk if $y \leq 0$. On the other hand, the determination section **125** may determine that the portable device **20** is positioned inside the trunk if $y \leq 0$, and the determination section **125** may determine that the portable device **20** is positioned outside the trunk if $y > 0$. The constant b is appropriately set in such a manner that each of the above-described conditions is satisfied.

[0091] Note that, for example, it is possible to improve the determination accuracy of the determination expression (**5**) listed above, when increasing the weights wrG and w1G

related to the first wireless communication device **110**G that is the nearest to the trunk.

[0092] Note that, the weights wrB to wrG given to the RSSIs may be different from the weights w1B to w1G given to the ranging values.

[0093] For example, the weights wrB to wrG given to the RSSIs may be heavier than the weights w1B to w1G given to the ranging values.

[0094] By setting the weights as described above, it is expected to obtain an effect of further improving the determination accuracy at a boundary between spaces as will be described later.

[0095] Alternatively, the determination section **125** may use a determination expression (6) listed below when determining whether the portable device **20** is positioned inside the vehicle cabin or on an outer right side of the vehicle cabin on the basis of ranging values and RSSIs acquired by the respective first wireless communication devices **110**A, **110**B, **110**E, and **110**F.

$$y = b + wlA * LA + wlB * LB + wlE * LE + wlF * LF + wrA * RA + wrB * RB + wrE * RE + wrF * RF \quad (6)$$

[0096] In the determination expression (6), b represents a constant, wrA to wrF represent respective weights given to RSSIs calculated by the respective first wireless communication devices **110**A to **110**F, and RA to RF represent the respective RSSIs calculated by the first wireless communication devices **110**A to **110**F. In addition, in the determination expression (**6**) listed above, wlA to w1F represent respective weights given to ranging values acquired by the respective first wireless communication devices **110**A to **110**F, and LA to LF represent the respective ranging values acquired by the first wireless communication devices **110**A to **110**F.

[0097] In this case, the determination section **125** may determine that the portable device **20** is positioned on the outer right side of the vehicle cabin (of the mobile object **10**) if $y > 0$, and the determination section **125** may determine that the portable device **20** is positioned inside the vehicle cabin if $y \leq 0$. On the other hand, the determination section **125** may determine that the portable device **20** is positioned on the outer right side of the vehicle cabin (of the mobile object **10**) if $y \leq 0$, and the determination section **125** may determine that the portable device **20** is positioned inside the vehicle cabin if $y > 0$. The constant b is appropriately set in such a manner that each of the above-described conditions is satisfied.

[0098] Note that, for example, it is also possible to improve the determination accuracy of the determination expression (6) listed above when weights wrA, wrB, wlA, and wlB are negative numbers and weights wrE, wrF, wlE, and w1F are positive numbers. The weights wrA, wrB, wlA, and w1B are related to the first wireless communication devices **110**A and **110**B disposed on the right portions of the exterior of the mobile object **10**. The weights wrE, wrF, wlE, and w1F are related to the first wireless communication devices **110**E and **110**F disposed inside the vehicle cabin of the mobile object **10**.

[0099] Note that, the weights wrA to wrF given to the RSSIs may be different from the weights w1A to w1F given to the ranging values.

[0100] For example, the weights wrA to wrF given to the RSSIs may be heavier than the weights w1A to w1F given to the ranging values.

[0101] By setting the weights as described above, it is expected to obtain an effect of further improving the determination accuracy at the boundary between the spaces as will be described later.

[0102] The detailed examples of the weighted determination expressions according to the present embodiment have been described above.

[0103] Note that, the constant b and the respective weights in the above-listed determination expressions (1) to (6) may be found through a machine learning method such as a support vector machine (SVM). For example, when using the SVM, it is possible to derive the constant b and the weights wA to wG by finding a split straight line that optimizes determination of whether the portable device **20** is positioned inside or outside the trunk or the like.

[0104] In addition, as described above, the RSSIs or the ranging values may be set as targets of weighting, or both the RSSIs and the ranging values may be set as targets of weighting in the weighted determination expressions according to the present embodiment.

[0105] For example, in the case where the ranging values are used as the targets of weighting, it is possible to assure the determination accuracy by performing determination while using a ranging value that is normally acquired by another first wireless communication device **110** even if some of the first wireless communication devices **110** have failed to acquire ranging values or have acquired abnormal values due to effects of obstacles (human bodies, metal, or the like), a surrounding environment, and the like.

[0106] Note that, sometimes a difference between the acquired ranging values may be very small in a situation where the portable device **20** is positioned in a region that is very close to the boundary between the spaces such as a region near a window or the like serving as a portion of the door of the mobile object **10** like a region **90** illustrated in FIG. **3**.

[0107] For example, in the case of the example illustrated in FIG. **3**, a difference between two ranging values becomes very small. One of the two ranging values is calculated by each of the first wireless communication devices **110**A, **110**B, **110**E, and **110**F in a situation where the portable device **20** is positioned in the vehicle cabin and in the region **90** while the portable device **20** is very close to the window. The other of the two ranging values is calculated by each of the first wireless communication devices **110**A, **110**B, **110**E, and **110**F in a situation where the portable device **20** is positioned outside the vehicle cabin but in the region **90** while the portable device **20** is very close to the window. In this case, this may deteriorate the accuracy of determining whether the portable device **20** is positioned inside the vehicle cabin or on an outer right side of the vehicle cabin.

[0108] On the other hand, the RSSIs drastically decay due to transmission or diffraction even when an object interposed between devices that exchange signals is a transparent object such as a window. Therefore, it is possible to maintain high determination accuracy by performing determination using the RSSIs even in a situation where the portable device **20** is positioned in a region that is very close to the boundary between the spaces.

[0109] FIG. **4** is a diagram for describing an effect of area determination based on RSSIs according to the present embodiment.

[0110] Note that, sometimes the first wireless communication devices **110** may be referred to as anchors in the following description and in FIG. **4** to FIG. **9**.

[0111] FIG. **4** illustrates determination success rates of determining whether the portable device **20** is positioned inside the vehicle cabin or on an outer right side of the vehicle cabin in the case where the portable device **20** is disposed at a plurality of spots in the region **90** under four conditions listed below.

[0112] Condition 1: Determine whether the portable device **20** is positioned inside the vehicle cabin or on an outer right side of the vehicle cabin by using the weighted determination expression using ranging values acquired by four anchors including the first wireless communication devices **110**A, **110**B, **110**E, and **110**F.

[0113] Condition 2: Determine whether the portable device **20** is positioned inside the vehicle cabin or on an outer right side of the vehicle cabin by using the weighted determination expression using RSSIs and ranging values acquired by the four anchors including the first wireless communication devices **110**A, **110**B, **110**E, and **110**F.

[0114] Condition 3: Determine whether the portable device **20** is positioned inside the vehicle cabin or on an outer right side of the vehicle cabin by using the weighted determination expression using ranging values acquired by two anchors including the first wireless communication devices **110**E and **110**F.

[0115] Condition 4: Determine whether the portable device **20** is positioned inside the vehicle cabin or on an outer right side of the vehicle cabin by using the weighted determination expression using RSSIs and ranging values acquired by the two anchors including the first wireless communication devices **110**E and **110**F.

[0116] With reference to FIG. **4**, when the four anchors are used, the determination success rate obtained by using the weighted determination expression in which only the ranging values are weighted is almost equal to the determination success rate obtained by using the weighted determination expression in which both the ranging values and the RSSIs are weighted.

[0117] In addition, with reference to FIG. **4**, when two anchors are used, the determination success rate obtained by using the weighted determination expression in which both the ranging values and the RSSIs are weighted is drastically higher than the determination success rate obtained by using the weighted determination expression in which only the ranging values are weighted.

[0118] In addition, the determination success rate obtained by using the weighted determination expression in which the ranging values and RSSIs acquired by the two anchors are weighted is almost equal to the determination success rate obtained by using the weighted determination expression in which the ranging values and RSSIs acquired by the two anchors are weighted.

[0119] Therefore, it is possible to maintain the high determination accuracy by performing determination using the RSSIs even in a situation where the portable device **20** is positioned in a region that is very close to the boundary between the spaces.

[0120] In addition, by performing determination using the RSSIs, it is possible to reduce the number of anchors to be used for the determination, and it is expected to obtain an effect of reducing cost.

1.4. Flow of Determination

[0121] Next, a flow of the area determination of the portable device **20** by the determination system **1** according to the present embodiment will be described.

[0122] FIG. **5** is a flowchart illustrating an example of a flow of area determination of the portable device **20** by the determination system **1** according to the present embodiment.

[0123] In the case of the example illustrated in FIG. **5**, the plurality of first wireless communication devices **110** first calculate respective ranging values by performing ranging based on wireless communication with the second wireless communication device **210** in conformity with the designated communication standard (Step S**11**).

[0124] Next, the plurality of first wireless communication devices **110** calculates respective RSSIs of signals received from the second wireless communication device **210** through wireless communication with the second wireless communication device **210** in conformity with the designated communication standard (Step S**12**).

[0125] Note that, for example, the signals from which the first wireless communication devices **110** calculate the RSSIs may be signals received from the second wireless communication device **210** during ranging.

[0126] Next, the determination device **120** determines an area (Step S**13**) by using the weighted determination expressions listed above, on the basis of the ranging values calculated in Step S**11** and the RSSIs calculated in Step S**12**.

[0127] In addition, the determination device **120** controls behavior of the control target device **130** (Step S**14**) on the basis of a result of the area determination performed in Step S**13**.

[0128] The example of the flow of the area determination of the portable device **20** by the determination system **1** according to the present embodiment has been described above.

[0129] Next, a detailed example of the flow of the area determination according to the present embodiment will be described.

[0130] FIG. **6** to FIG. **9** is a flowchart illustrating an example of the flow of area determination of the portable device **20** by the determination section **125** according to the present embodiment.

[0131] Note that, FIG. **6** to FIG. **9** and the following description uses the same layout as the layout of the first wireless communication devices **110** illustrated in FIG. **2**.

[0132] In addition, the weighted determination expressions used in processes illustrated in FIG. **6** to FIG. **9** may be determination expressions in which both ranging values and RSSIs are used.

[0133] In addition, sometimes the four first wireless communication devices **110**A, **110**B, **110**C, and **110**D may also be referred to as exterior anchors in the following description and in FIG. **6** to FIG. **9**. Sometimes the first wireless communication devices **110**E and **110**F may also be referred to as intra-vehicle-cabin anchors. Sometimes the first wireless communication device **110**G may also be referred to as an intra-trunk anchor.

[0134] First, description will be given with reference to FIG. **6**. In the case of the example illustrated in FIG. **6**, the determination section **125** first determines whether the intra-

trunk anchor has successfully performed ranging between the intra-trunk anchor and the second wireless communication device **210** (Step S**102**).

[0135] Note that, the determination section **125** may determine that the ranging has been successfully performed in the case where the ranging values are calculated.

[0136] In the case where it is determined that the intra-trunk anchor has successfully performed ranging (Yes in Step S**102**), the determination section **125** performs a calculation using a weighted determination expression depending on another anchor that also has successfully performed ranging (Step S**104**).

[0137] For example, the determination section **125** may perform a calculation using the above-listed determination expression (5) in the case where ranging has been successfully performed by three first wireless communication devices **110**B, **110**C, and **110**F. The first wireless communication devices **110**B and **110**C are disposed on the rear bumper of the mobile object **10**. The first wireless communication device **110**F is disposed near the rear middle portion in the vehicle cabin of the mobile object **10**.

[0138] On the other hand, in the case where the ranging has not been successfully performed by at least one of the three anchors, the determination section **125** performs a calculation using different weighted determination expressions depending on the anchor(s) that have failed to perform ranging.

[0139] Next, the determination section **125** determines whether or not a condition (condition that the portable device **20** is positioned inside the trunk) is satisfied by a result of the calculation using the weighted determination expression (for example, $y > 0$ in the case of the determination expression (**5**) listed above) (Step S**106**).

[0140] Here, in the case where the result of the calculation satisfies the condition (condition that the portable device **20** is positioned inside the trunk), the determination section **125** determines that the portable device **20** is positioned inside the trunk (Step S **108**), and the determination process ends.

[0141] On the other hand, the determination section **125** proceeds to a process of determining whether the portable device **20** is positioned inside or outside the vehicle cabin in the case where it is determined that the intra-trunk anchor has failed to perform ranging in Step S**102** (No is Step S**102**) or in the case where the result of calculation does not satisfy the condition (condition that the portable device **20** is positioned inside the trunk) in Step S**106** (No in Step S**106**).

[0142] As described above, the determination section **125** according to the present embodiment may determine whether or not the portable device **20** is positioned in the specific space, and then if it is determined that the portable device **20** is not positioned in the specific space, the determination device may determine whether the portable device **20** is positioned in the vehicle cabin or outside the mobile object **10**.

[0143] The above-described process flow makes it possible to efficiently and accurately determine whether the portable device **20** is positioned inside or outside the vehicle cabin on the premise that the portable device **20** is not positioned in the specific space such as the trunk.

[0144] When determining whether the portable device **20** is positioned inside or outside the vehicle cabin, the determination section **125** first determines whether or not ranging has been successfully performed by at least two exterior anchors (Step S**110**).

[0145] The determination section **125** proceeds to Step S**302** illustrated in FIG. **8** in the case where it is determined that the ranging has been successfully performed by the at least two exterior anchors (Yes in Step S**110**).

[0146] On the other hand, the determination section **125** determines whether or not ranging has been successfully performed by at least one intra-vehicle-cabin anchor (Step S**112**) in the case where it has not been determined that the ranging has been successfully performed by the at least two exterior anchors (No in Step S**110**), that is, in the case where the ranging has not been successfully performed by three or more exterior anchors.

[0147] The determination section **125** proceeds to Step S**202** illustrated in FIG. **7** in the case where it is determined that the ranging has been successfully performed by at least one intra-vehicle-cabin anchor (Yes in Step S**112**).

[0148] On the other hand, the determination section **125** determines that abnormal values are obtained (Step S**114**) and ends the determination process because many anchors disposed in the trunk, in the vehicle cabin, and on the exterior have failed to perform ranging in the case where it has not been determined that the ranging has been successfully performed by the at least one intra-vehicle-cabin anchor (No in Step S**112**), that is, in the case where both of the two intra-vehicle-cabin anchors have failed to perform ranging.

[0149] Next, description will continue with reference to FIG. **7**. The determination section **125** performs a calculation using a weighted determination expression in which the two intra-vehicle-cabin anchors are weighted (Step S**202**) in the case where it is determined that the ranging has been successfully performed by at least one intra-vehicle-cabin anchor in Step S**112** illustrated in FIG. **6** (Yes in Step S**112**).

[0150] The weighted determination expression in which the two intra-vehicle-cabin anchors are weighted may be a mathematical expression including a constant, respective ranging values calculated by the two intra-vehicle-cabin anchors, and weights given to the ranging values.

[0151] Next, the determination section **125** determines whether or not a result of the calculation obtained in Step S**202** satisfies a condition (condition that the portable device **20** is positioned inside the vehicle cabin) (Step S**204**).

[0152] In the case where the result of the calculation satisfies the condition (condition that the portable device **20** is positioned inside the vehicle cabin) (Yes in Step S**204**), the determination section **125** determines that the portable device **20** is positioned inside the vehicle cabin (Step S**206**), and ends the determination process.

[0153] On the other hand, in the case where the result of the calculation does not satisfy the condition (condition that the portable device **20** is positioned inside the vehicle cabin) (No in Step S**204**), the determination section **125** performs a calculation using two determination expressions corresponding to the two intra-vehicle-cabin anchors (Step S**208**).

[0154] Each of the two determination expressions may be an expression that simply determines whether a ranging value calculated by one of the intra-vehicle-cabin anchors is large or small.

[0155] In the case where any of results of the calculation obtained in Step S**208** satisfies the condition (condition that the portable device **20** is positioned inside the vehicle cabin), the determination section **125** determines that the portable device **20** is positioned inside the vehicle cabin (Step S**206**), and ends the determination process.

[0156] On the other hand, the determination section **125** determines that abnormal values are obtained (Step S**212**) and ends the determination process in the case where neither of the results of the calculation obtained in Step S**208** satisfies the condition (condition that the portable device **20** is positioned inside the vehicle cabin).

[0157] Next, description will continue with reference to FIG. **8**. In the case where it is determined that the ranging has been successfully performed by the at least two exterior anchors in Step S**110** illustrated in FIG. **6**, (Yes in Step S**110**), the determination section **125** according to the present embodiment determines positional relations between the portable device **20** and seats installed in the vehicle cabin, on the basis of ranging values calculated by the plurality of first wireless communication devices **110** disposed on the exterior of the mobile object **10**.

[0158] More specifically, the determination section **125** determines a seat closer to the portable device **20** (Step S**302**) on the basis of a first minimum value (smallest ranging value among acquired ranging values) and a second minimum value (second-smallest ranging value among the acquired ranging values) among the ranging values acquired by the exterior anchors.

[0159] For example, the determination section **125** may determine that the seat closer to the portable device **20** is a driver's seat (D) in the case where a ranging value calculated by the first wireless communication device **110**A is the first minimum value and a ranging value calculated by the first wireless communication device **110**B is the second minimum value.

[0160] In addition, for example, the determination section **125** may determine that the seat closer to the portable device **20** is a front passenger seat (P) in the case where a ranging value calculated by the first wireless communication device **110**C is the first minimum value and a ranging value calculated by the first wireless communication device **110**D is the second minimum value.

[0161] In addition, for example, the determination section **125** may determine that the seat closer to the portable device **20** is a rear seat (BD) in the case where a ranging value calculated by the first wireless communication device **110**B is the first minimum value and a ranging value calculated by the first wireless communication device **110**C is the second minimum value.

[0162] In addition, for example, the determination section **125** may determine that the seat closer to the portable device **20** is the front seats (FR) in the case where a ranging value calculated by the first wireless communication device **110**A is the first minimum value and a ranging value calculated by the first wireless communication device **110**D is the second minimum value.

[0163] In addition, for example, the determination section **125** may set a result of determination to "other" in the case where ranging values calculated by the first wireless communication devices **110**A and **110**C are the first minimum value and ranging values calculated by the first wireless communication devices **110**B and **110**D are the second minimum value.

[0164] The determination section **125** proceeds to Step S**402** illustrated in FIG. **9** in the case where a determination result obtained in Step S**302** indicates "other" ("other" in Step S**302**).

[0165] On the other hand, the determination section **125** determines whether or not ranging has been successfully performed by the both intra-vehicle-cabin anchors (Step S**304**) in the case where the determination result obtained in Step S**302** indicates "D", "P", "BD", or "FR" (D/P/BD/FR in Step Section **302**).

[0166] The determination section **125** proceeds to Step S**208** illustrated in FIG. **7** in the case where it has not been determined that the ranging has been successfully performed by the both intra-vehicle-cabin anchors (No in Step S**304**), that is, in the case where any of the intra-vehicle-cabin anchors has failed to perform ranging.

[0167] On the other hand, in the case where it is determined that the ranging has been successfully performed by the both intra-vehicle-cabin anchors (Yes in Step S**304**), the determination section **125** performs a calculation (Step S**306**) using a weighted determination expression depending on the seat determined in Step S **302**.

[0168] In other words, the determination section **125** selects one of the four different weighted determination expressions depending on the seat (D/P/BD/FR) determined in Step S**306**.

[0169] Next, the determination section **125** determines whether or not a result of the calculation obtained in Step S**306** satisfies a condition (condition that the portable device **20** is positioned inside the vehicle cabin) (Step S**308**).

[0170] In the case where the result of the calculation satisfies the condition (condition that the portable device **20** is positioned inside the vehicle cabin) (Yes in Step S**308**), the determination section **125** determines that the portable device **20** is positioned inside the vehicle cabin (Step S**310**), and ends the determination process.

[0171] On the other hand, in the case where the result of the calculation does not satisfy the condition (condition that the portable device **20** is positioned inside the vehicle cabin) (No in Step S**308**), the determination section **125** determines that the portable device **20** is positioned outside the vehicle cabin (Step S**312**), and ends the determination process.

[0172] Note that, in Step S**312**, the determination section **125** may determine in which direction the portable device **20** is positioned in outside the portable device **10** on the basis of the seat determined in Step S**302**.

[0173] Next, description will continue with reference to FIG. **9**. The determination section **125** determines whether or not ranging has been successfully performed by the both intra-vehicle-cabin anchors (Step S**402**) in the case where the determination result obtained in Step S**302** illustrated in FIG. **8** indicates "other" ("other" in Step Section **302**).

[0174] In the case where it is determined that the ranging has been successfully performed by the both intra-vehicle-cabin anchors (Yes in Step S**402**), the determination section **125** performs a calculation using a weighted determination expression depending on a combination of an exterior anchor that has calculated the first minimum value and an exterior anchor that has calculated the second minimum value (Step S**404**).

[0175] In other words, in Step S**404**, the determination section **125** performs a calculation using a weighted determination expression depending on a combination of the first wireless communication devices **110**A and **110**C or a combination of the first wireless communication devices **110**B and **110**D.

[0176] Next, the determination section **125** determines whether or not a result of the calculation obtained in Step S**404** satisfies a condition (condition that the portable device **20** is positioned inside the vehicle cabin) (Step S**406**).

[0177] In the case where the result of the calculation obtained in Step S**404** satisfies the condition (condition that the portable device **20** is positioned inside the vehicle cabin) (Yes in Step S**406**), the determination section **125** determines that the portable device **20** is positioned inside the vehicle cabin (Step S**408**), and ends the determination process.

[0178] On the other hand, the determination section **125** determines that an abnormal value is obtained (Step S**412**) and ends the determination process in the case where the result of the calculation obtained in Step S**404** does not satisfy the condition (condition that the portable device **20** is positioned inside the vehicle cabin).

[0179] Alternatively, the determination section **125** determines whether or not the ranging has been successfully performed by any of the intra-vehicle-cabin anchors (Step S**410**) in the case where it has not been determined that the ranging has been successfully performed by the both intra-vehicle-cabin anchors in Step S**402** (No in Step S**402**).

[0180] The determination section **125** proceeds to Step S**208** illustrated in FIG. **7** in the case where it is determined that the ranging has been successfully performed by any of the intra-vehicle-cabin anchors (Yes in Step S**410**).

[0181] On the other hand, the determination section **125** determines that an abnormal value is obtained (Step S**412**) and ends the determination process in the case where it has not been determined that the ranging has been successfully performed by any of the intra-vehicle-cabin anchors (No in Step S**410**), that is, in the case where the both intra-vehicle-cabin anchors have failed to perform ranging.

[0182] The example of the flow of the area determination of the portable device **20** by the determination system **125** according to the present embodiment has been described above. As described above, the above-described determination method makes it possible to determine the position of the portable device **20** with higher accuracy.

[0183] Note that, the flow of the area determination according to the present embodiment may be flexibly modified depending on the number of first wireless communication devices **110**, the layout of the first wireless communication devices **110**, the position of the specific space, and the like.

[0184] In addition, the determination expressions used by the determination section **125** may be flexibly modified under the control using results of determination.

2. Supplement

[0185] Heretofore, preferred embodiments of the present invention have been described in detail with reference to the appended drawings, but the present invention is not limited thereto. It should be understood by those skilled in the art that various changes and alterations may be made without departing from the spirit and scope of the appended claims.

[0186] In addition, the series of processes performed by each of the devices described herein may be achieved by a program stored in a non-transitory computer readable storage medium. For example, each program is loaded into RAM, and executed by a processor such as a CPU when a computer executes each of the program. The storage medium may be a magnetic disk, an optical disc, a magneto-optical disc, flash memory, or the like, for example. Alternatively, the above-described programs may be distributed via a network without using the storage medium, for example.

What is claimed is:

1. A determination device comprising

a determination section configured to determine an area where a portable device is positioned, on a basis of wireless communication between a plurality of first wireless communication devices installed at different portions of a mobile object and a second wireless communication device installed in a portable device, in conformity with a designated communication standard,

wherein the determination section determines the area where the portable device is positioned, by using different determination expressions depending on the respective first wireless communication devices, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device through wireless communication compliant with the designated communication standard and a determination target area.

2. The determination device according to claim **1**,

wherein the determination section determines the area where the portable device is positioned, by using a weighted determination expression in which different weights are given to the respective first wireless communication devices, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device through wireless communication compliant with the designated communication standard and a determination target area.

3. The determination device according to claim **2**,

wherein the determination section determines the area where the portable device is positioned, by using a weighted determination expression in which different weights are given to the respective first wireless communication devices, each of which has successfully performed ranging through wireless communication with the second wireless communication device in conformity with the designated communication standard.

4. The determination device according to claim **3**,

wherein the determination section determines the area where the portable device is positioned, by using a weighted determination expression in which different weights are given to a ranging value and an RSSI that are calculated by a single first wireless communication device.

5. The determination device according to claim **4**,

wherein the determination section determines the area where the portable device is positioned, by using a weighted determination expression in which a higher weight is given to an RSSI among a ranging value and the RSSI that are calculated by a single first wireless communication device.

6. The determination device according to claim **3**, wherein

at least one or more first wireless communication devices are disposed in a vehicle cabin in the mobile object, in a specific space in the mobile object, and on an exterior of the mobile object, and

the determination section determines whether the portable device is positioned in the vehicle cabin, in the specific space, or outside the mobile object.

7. The determination device according to claim **6**,

wherein the determination section determines whether or not the portable device is positioned in the specific space, and then if it is determined that the portable device is not positioned in the specific space, the determination device determines whether the portable device is positioned in the vehicle cabin or outside the mobile object.

8. The determination device according to claim **6**,

wherein the specific space includes a trunk of the mobile object.

9. The determination device according to claim **6**,

wherein the determination section determines a positional relation between the portable device and a seat installed in the vehicle cabin, on a basis of ranging values calculated by the plurality of first wireless communication devices disposed on the exterior of the mobile object.

10. The determination device according to claim **9**,

wherein the determination section determines the area where the portable device is positioned, by using a weighted determination expression in which different weights are given to the respective first wireless communication devices on the basis of the positional relation between the portable device and the seat installed in the vehicle cabin.

11. The determination device according to claim **1**,

wherein the designated communication standard includes ultra-wideband wireless communication.

12. A determination method comprising

causing a processor to determine an area where a portable device is positioned, on a basis of wireless communication between a plurality of first wireless communication devices installed at different portions of a mobile object and a second wireless communication device installed in a portable device, in conformity with a designated communication standard,

wherein the determination further includes determining the area where the portable device is positioned, by using different determination expressions depending on the respective first wireless communication devices, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device through wireless communication compliant with the designated communication standard and a determination target area.

13. A determination system comprising:

a plurality of first wireless communication devices installed at different portions of a mobile object;

a second wireless communication device installed in a portable device; and

a determination section configured to determine an area where the portable device is positioned, on a basis of wireless communication between the respective first wireless communication devices and the second wireless communication device in conformity with a designated communication standard,

wherein the determination device determines the area where the portable device is positioned, by using different determination expressions depending on the respective first wireless communication devices, each of which has successfully calculated an RSSI with regard to a signal received from the second wireless communication device through wireless communication compliant with the designated communication standard and a determination target area.

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