DESCRIPTION

Title of Invention:

POSITIONING APPARATUS, POSITIONING METHOD, AND POSITIONING PROGRAM

Technical Field

[0001] The present disclosure relates to a positioning apparatus, a positioning method, and a positioning program.

Background Art

[0002] There is a technique that performs three-dimensional positioning of a terminal that is present in a space where multiple base stations are installed and that performs wireless communication with each of the multiple base stations, on the basis of a relative angle formed by each one of the multiple base stations and the terminal.

Citation List

Non-Patent Literature

[0003] Non-Patent Literature 1: Futa Watanabe, "Wireless Sensor Network Localization Using AoA Measurements with Two-Step Error Variance-Weighted Least Squares," IEEE ACCESS, DOI: 10.1109/ACCESS.2021.3050309

Summary of Invention

Technical Problem

[0004] Non-Patent Literature 1 discloses a technique to determine the position of a terminal based on information on the relative angle between the terminal and each base station. The technique disclosed by Non-Patent Literature 1 has a challenge that an error is large when the shape of an area where the terminal is present is not a perfect cube.

weighted mean parameter on a condition by condition basis.

[0019] Various types can be contemplated for possible configuration examples of a positioning system 90 including the positioning apparatus 100. A representative configuration example of the positioning system 90 is described below with reference to drawings. The positioning apparatus 100 is provided in any of the components shown in each example or by being distributed in at least any of the components as appropriate.

Fig. 2 shows a specific example of the positioning system 90. The positioning system 90 includes N (N being an integer equal to or greater than 2) base stations and a terminal.

In this example, the terminal first transmits information showing its terminal ID to each base station. Then, each base station receives the information showing the terminal ID from the terminal, performs an AOA (Angle-Of-Arrival) calculation based on the received information and observation data of each base station, and transmits information showing each of the result of the AOA calculation and its base station ID to the terminal. Next, the terminal performs a positioning calculation based on the information received from the respective base stations. Here, the positioning calculation is a calculation related to three-dimensional positioning of the terminal.

[0020] Fig. 3 shows a specific example of the positioning system 90. For the positioning system 90 of Fig. 3, differences from the positioning system 90 shown in Fig. 2 are primarily described. The positioning system 90 further includes a locator to execute a portion of positioning calculation. The locator is a dedicated device for performing positioning calculations.

In this example, the terminal transmits the information received from each base station to the locator in order to delegate the execution of a portion of positioning calculation to the locator. The locator executes the portion of positioning calculation

Embodiment 1 is that it includes a radio wave intensity acquisition unit 190.

[0080] The radio wave intensity acquisition unit 190 acquires information showing a radio wave intensity corresponding to each base station and sends the acquired information to the parameter changing unit 170.

[0081] The parameter changing unit 170 sets a parameter value using the information acquired by the radio wave intensity acquisition unit 190.

[0082] ***Description of operation***

Fig. 17 is a flowchart illustrating an example of the operation of the positioning apparatus 100. Referring to this drawing, differences from the operation of the positioning apparatus 100 according to Embodiment 1 are primarily described.

[0083] (Step S31)

The radio wave intensity acquisition unit 190 acquires information showing the radio wave intensity corresponding to each base station and sends the acquired information to the parameter changing unit 170.

[0084] (Step S16)

The parameter changing unit 170 defines an area that contains the temporary position of the terminal and base stations that correspond to radio wave intensities equal to or higher than an intensity reference value, and changes the value of a parameter in accordance with the lengths of the sides of the defined area. In the present embodiment, the target area is a space that contains the terminal and base stations with a radio wave intensity with respect to the terminal being equal to or higher than the intensity reference value among the multiple base stations. The intensity reference value may be defined in any manner.

[0085] *** Description of the effects of Embodiment 3***

Claims

[Claim 1] A positioning apparatus comprising:

a temporary position computation unit to, using a plurality of two-dimensional direction vectors and a plurality of three-dimensional direction vectors, determine a temporary position of a terminal communicating with each of a plurality of base stations in a three-dimensional space, wherein the plurality of two-dimensional direction vectors are vectors that are each computed using each of a plurality of observed angles which has been observed as an angle formed by a position of each of the plurality of base stations and the terminal, said vectors being based on an angle for a two-dimensional direction of the plurality of observed angles, and the plurality of three-dimensional direction vectors are vectors that are each computed using each of the plurality of observed angles and are based on an angle for a three-dimensional direction of the plurality of observed angles;

a two-dimensional position computation unit to determine a two-dimensional position of the terminal using a two-dimensional component of the position of each of the plurality of base stations, the plurality of two-dimensional direction vectors, and a plurality of two-dimensional weights, wherein the plurality of two-dimensional weights are each a weight corresponding to the two-dimensional component of the position of each of the plurality of base stations and determined based on the two-dimensional component of the position of each of the plurality of base stations and on a two-dimensional component of the temporary position;

a three-dimensional position computation unit to determine a three-dimensional position of the terminal using a three-dimensional component of the position of each of the plurality of base stations, the plurality of three-dimensional direction vectors, and a plurality of three-dimensional weights, wherein the plurality of

three-dimensional weights are each a weight corresponding to the three-dimensional component of the position of each of the plurality of base stations and determined based on the three-dimensional component of the position of each of the plurality of base stations and on a three-dimensional component of the temporary position; and

a position aggregation unit to determine a weighted mean of the two-dimensional position and a two-dimensional component of the three-dimensional position as a two-dimensional component of a position of the terminal, and to adopt a third-dimension component of the three-dimensional position as a third-dimension component of the position of the terminal.

[Claim 2] The positioning apparatus according to claim 1, wherein

each of the plurality of two-dimensional weights is a value that is dependent on an inverse of a distance formed between the two-dimensional component of the position of each of the plurality of base stations and the two-dimensional component of the temporary position, and

each of the plurality of three-dimensional weights is a value that is dependent on an inverse of a distance formed between the three-dimensional component of the position of each of the plurality of base stations and the three-dimensional component of the temporary position.

[Claim 3] The positioning apparatus according to claim 1 or 2, further comprising:

a parameter changing unit to change a value of a weighted mean parameter to a value that is dependent on a shape of a target area, the weighted mean parameter being a parameter used with the weighted mean.

[Claim 4] The positioning apparatus according to claim 3, wherein

the parameter changing unit changes the value of the weighted mean parameter

in accordance with a ratio of a length of the target area in a shorter direction to a length of the target area in a longer direction and a ratio between a diagonal length of the target area in two dimensions and a height of the target area.

[Claim 5] The positioning apparatus according to claim 3 or 4, wherein

the parameter changing unit changes the value of the weighted mean parameter with reference to a lookup table that shows values of the weighted mean parameter on a condition by condition basis.

[Claim 6] The positioning apparatus according to any one of claims 3 to 5, wherein

the target area is an area defined based on the temporary position.

[Claim 7] The positioning apparatus according to any one of claims 3 to 5, further comprising:

an area information input unit to receive information showing each of a length of the target area in a longer direction, a length of the target area in a shorter direction, and a height of the target area.

[Claim 8] The positioning apparatus according to any one of claims 3 to 5, wherein

the target area is a space that contains the terminal and base stations with a radio wave intensity with respect to the terminal being equal to or higher than an intensity reference value among the plurality of base stations.

[Claim 9] A positioning method comprising:

by using a plurality of two-dimensional direction vectors and a plurality of three-dimensional direction vectors, determining, by a computer, a temporary position of a terminal communicating with each of a plurality of base stations in a three-dimensional space, wherein the plurality of two-dimensional direction vectors are

vectors that are each computed using each of a plurality of observed angles which has been observed as an angle formed by a position of each of the plurality of base stations and the terminal, said vectors being based on an angle for a two-dimensional direction of the plurality of observed angles, and the plurality of three-dimensional direction vectors are vectors that are each computed using each of the plurality of observed angles and are based on an angle for a three-dimensional direction of the plurality of observed angles;

determining, by the computer, a two-dimensional position of the terminal using a two-dimensional component of the position of each of the plurality of base stations, the plurality of two-dimensional direction vectors, and a plurality of two-dimensional weights, wherein the plurality of two-dimensional weights are each a weight corresponding to the two-dimensional component of the position of each of the plurality of base stations and determined based on the two-dimensional component of the position of each of the plurality of base stations and on a two-dimensional component of the temporary position;

determining, by the computer, a three-dimensional position of the terminal using a three-dimensional component of the position of each of the plurality of base stations, the plurality of three-dimensional direction vectors, and a plurality of three-dimensional weights, wherein the plurality of three-dimensional weights are each a weight corresponding to the three-dimensional component of the position of each of the plurality of base stations and determined based on the three-dimensional component of the position of each of the plurality of base stations and on a three-dimensional component of the temporary position; and

determining, by the computer, a weighted mean of the two-dimensional position and a two-dimensional component of the three-dimensional position as a two-

dimensional component of a position of the terminal, and adopting a third-dimension component of the three-dimensional position as a third-dimension component of the position of the terminal.

[Claim 10] A positioning program that causes a positioning apparatus as a computer to execute:

a temporary position computation process to, using a plurality of two-dimensional direction vectors and a plurality of three-dimensional direction vectors, determine a temporary position of a terminal communicating with each of a plurality of base stations in a three-dimensional space, wherein the plurality of two-dimensional direction vectors are vectors that are each computed using each of a plurality of observed angles which has been observed as an angle formed by a position of each of the plurality of base stations and the terminal, said vectors being based on an angle for a two-dimensional direction of the plurality of observed angles, and the plurality of three-dimensional direction vectors are vectors that are each computed using each of the plurality of observed angles and are based on an angle for a three-dimensional direction of the plurality of observed angles;

a two-dimensional position computation process to determine a two-dimensional position of the terminal using a two-dimensional component of the position of each of the plurality of base stations, the plurality of two-dimensional direction vectors, and a plurality of two-dimensional weights, wherein the plurality of two-dimensional weights are each a weight corresponding to the two-dimensional component of the position of each of the plurality of base stations and determined based on the two-dimensional component of the position of each of the plurality of base stations and on a two-dimensional component of the temporary position;

a three-dimensional position computation process to determine a three-

dimensional position of the terminal using a three-dimensional component of the position of each of the plurality of base stations, the plurality of three-dimensional direction vectors, and a plurality of three-dimensional weights, wherein the plurality of three-dimensional weights are each a weight corresponding to the three-dimensional component of the position of each of the plurality of base stations and determined based on the three-dimensional component of the position of each of the plurality of base stations and on a three-dimensional component of the temporary position; and

a position aggregation process to determine a weighted mean of the two-dimensional position and a two-dimensional component of the three-dimensional position as a two-dimensional component of a position of the terminal, and to adopt a third-dimension component of the three-dimensional position as a third-dimension component of the position of the terminal.