

DESCRIPTION

TITLE OF INVENTION

POSITION ERROR PREDICTION DEVICE, MODEL CREATION DEVICE,
POSITION ERROR PREDICTION METHOD, MODEL CREATION METHOD,
AND PROGRAM

[Technical Field]

[0001]

The present invention relates to a position error prediction device, a model creation device, a position error prediction method, a model creation method, and a program.

[Background Art]

[0002]

Position information and information indicating the magnitude of the error in the position information (hereinafter, referred to as the magnitude of the position error) can be obtained using a satellite positioning system such as a GNSS. For example, in a case where the travel position of a vehicle traveling on a road A is positioned by a satellite positioning system, the vehicle may be regarded as traveling on a nearby road B depending on the degree of the error in the positioned position information. In a case where charging is performed

depending on the road of travel, misrecognition of the road on which the vehicle travels becomes a subject. A technique is provided for calculating the probability of making a mistake on the road on which a vehicle travels (hereinafter, referred to as a failure rate) and preparing for road misrecognition using position error information provided by a satellite positioning system.

[0003]

Regarding the error estimation, Patent Document 1 discloses a technique for estimating an error in an estimated altitude in estimating the altitude of a measurement position based on an atmospheric pressure value measured by an atmospheric pressure sensor.

[Citation List]

[Patent Document]

[0004]

[Patent Document 1] Japanese Unexamined Patent Publication No. 2017-9512

Summary of Invention

[Technical Subject]

[0005]

The magnitude of a position error provided by a satellite positioning system varies from time to time even at the same point, and the value thereof follows a probability distribution. Accordingly, for example, there

remains a subject in terms of reliability even if the failure rate is calculated from the magnitude of a position error obtained at a certain time. In order to improve the accuracy of information calculated using position error magnitude information (e.g. failure rate), it is necessary to predict the probability distribution of the magnitude of the position error. Patent Document 1 does not disclose a method for predicting the probability distribution of the magnitude of a position error.

[0006]

The present disclosure provides a position error prediction device, a model creation device, a position error prediction method, a model creation method, and a program capable of solving the above subjects.

[Subject to be solved]

[0007]

According to one aspect of the present invention, a position error prediction device is provided for predicting a probability distribution of a magnitude of an error in position information where a moving body is considered to be present. The position error prediction device includes a prediction unit predicting a probability distribution of a magnitude of the error at a prediction target point based on a prediction model indicating a relationship between terrain feature data indicating a

terrain feature at a certain point and a probability distribution of a magnitude of the error at the point and the terrain feature data at the prediction target point.

[0008]

According to one aspect of the present invention, a model creation device includes: a data acquisition unit acquiring terrain feature data indicating a terrain feature at a certain point and information indicating a magnitude of an error in position information positioned by a satellite positioning system and acquired a plurality of times from the satellite positioning system at the point; a learning data creation unit calculating a probability distribution of the magnitude of the error based on the information indicating the magnitude of the error acquired the plurality of times; and a prediction model creation unit creating a prediction model indicating a relationship between the terrain feature data and the probability distribution of the magnitude of the error based on the terrain feature data and the probability distribution of the magnitude of the error.

[0009]

According to one aspect of the present invention, a position error prediction method is provided for predicting a probability distribution of a magnitude of an error in position information where a moving body is

considered to be present. The position error prediction method includes predicting a probability distribution of a magnitude of the error at a prediction target point based on a prediction model indicating a relationship between terrain feature data indicating a terrain feature at a certain point and a probability distribution of a magnitude of the error at the point and the terrain feature data at the prediction target point.

[0010]

According to one aspect of the present invention, a model creation method includes: acquiring terrain feature data indicating a terrain feature at a certain point and information indicating a magnitude of an error in position information positioned by a satellite positioning system and acquired a plurality of times from the satellite positioning system at the point; calculating a probability distribution of the magnitude of the error based on the information indicating the magnitude of the error acquired the plurality of times; and creating a prediction model indicating a relationship between the terrain feature data and the probability distribution of the magnitude of the error based on the terrain feature data and the probability distribution of the magnitude of the error.

[0011]

According to one aspect of the present invention, a program is provided for causing a computer to execute a position error prediction process for predicting a probability distribution of a magnitude of an error in position information where a moving body is considered to be present, the process including predicting a probability distribution of a magnitude of the error at a prediction target point based on a prediction model indicating a relationship between terrain feature data indicating a terrain feature at a certain point and a probability distribution of a magnitude of the error at the point and the terrain feature data at the prediction target point.

[0012]

According to one aspect of the present invention, a program is provided for causing a computer to execute a process including: acquiring terrain feature data indicating a terrain feature at a certain point and information indicating a magnitude of an error in position information positioned by a satellite positioning system and acquired a plurality of times from the satellite positioning system at the point; calculating a probability distribution of the magnitude of the error based on the information indicating the magnitude of the error acquired the plurality of times; and creating a prediction model indicating a relationship between the terrain feature data

and the probability distribution of the magnitude of the error based on the terrain feature data and the probability distribution of the magnitude of the error.

[Advantageous Effects of Invention]

[0013]

According to the position error prediction device, the position error prediction method, and the program described above, it is possible to estimate the distribution of the magnitude of a position error in satellite positioning. According to the model creation device, the model creation method, and the program described above, it is possible to create a prediction model predicting the distribution of the magnitude of a position error in satellite positioning.

[Brief Description of Drawings]

[0014]

Fig. 1A is a diagram illustrating an example of a position error prediction device according to a first embodiment of the present disclosure.

Fig. 1B is a diagram illustrating an example of a position error prediction system according to the first embodiment of the present disclosure.

Fig. 2A is a first diagram illustrating a map data processing method in the present disclosure.

Fig. 2B is a second diagram illustrating the map data processing method in the present disclosure.

Fig. 2C is a third diagram illustrating the map data processing method in the present disclosure.

Fig. 2D is a fourth diagram illustrating the map data processing method in the present disclosure.

Fig. 3A is a first diagram illustrating terrain feature data of the present disclosure.

Fig. 3B is a second diagram illustrating the terrain feature data of the present disclosure.

Fig. 3C is a third diagram illustrating the terrain feature data of the present disclosure.

Fig. 4 is a diagram illustrating the probability distribution of error information of the present disclosure.

Fig. 5 is a diagram illustrating a prediction model of the present disclosure.

Fig. 6 is a flowchart illustrating an example of learning processing in the first embodiment of the present disclosure.

Fig. 7 is a flowchart illustrating an example of prediction processing in the first embodiment of the present disclosure.

Fig. 8A is a diagram illustrating an example of a position error prediction device according to a second embodiment of the present disclosure.

Fig. 8B is a diagram illustrating an example of a position error prediction system according to the second embodiment of the present disclosure.

Fig. 9 is a diagram illustrating learning data selection processing in the second embodiment of the present disclosure.

Fig. 10 is a flowchart illustrating an example of learning processing in the second embodiment of the present disclosure.

Fig. 11 is a diagram illustrating an example of the hardware configurations of the position error prediction device and a model creation device according to each embodiment of the present invention.

[Description of Embodiments]

[0015]

<First Embodiment>

Hereinafter, a method for predicting the probability distribution of the magnitude of a position error according to a first embodiment of the present invention will be described with reference to Figs. 1A to 7.

(Configuration)

Fig. 1A is a diagram illustrating an example of a position error prediction device according to the first embodiment of the present invention. When terrain feature data at a certain point is input, a position error prediction device 10 predicts the probability distribution of the magnitude of a position error provided by a satellite positioning system at that point. As illustrated in Fig. 1, the position error prediction device 10 includes a terrain feature data acquisition unit 11, a prediction unit 12, a storage unit 13, an output unit 14, and a learning unit 15.

[0016]

The terrain feature data acquisition unit 11 acquires terrain feature data indicating a terrain feature at a certain point, which is necessary for predicting the probability distribution of the magnitude of a position error at that point.

The prediction unit 12 predicts the probability distribution of the magnitude of the position error based on the terrain feature data acquired by the terrain feature data acquisition unit 11 and a prediction model M.

The storage unit 13 stores the prediction model M and various data.

The output unit 14 outputs the result of the prediction performed by the prediction unit 12.

When terrain feature data at a certain point is input, the learning unit 15 creates the prediction model M outputting the probability distribution of the magnitude of a position error at that point. The learning unit 15 includes a data acquisition unit 151, a learning data creation unit 152, and a model creation unit 153. The data acquisition unit 151 acquires terrain feature data for learning, position information provided by a satellite positioning system, and a position error magnitude. The learning data creation unit 152 calculates a path shape (described later) from the position information and calculates the probability distribution of the position error magnitude from the position error magnitude. The model creation unit 153 creates the prediction model M predicting the probability distribution of the position error magnitude.

[0017]

The learning unit 15 may be configured as a device independent of the position error prediction device 10. An example is illustrated in Fig. 1B. Fig. 1B is a diagram illustrating an example of a position error prediction system in the first embodiment of the present disclosure.

A position error prediction system 1 includes a position error prediction device 10' and a model creation

device 150. The position error prediction device 10' and the model creation device 150 may be communicably connected to each other. The position error prediction device 10' includes the terrain feature data acquisition unit 11, the prediction unit 12, the storage unit 13, and the output unit 14. The model creation device 150 includes the data acquisition unit 151, the learning data creation unit 152, and the model creation unit 153. The functions of the functional units are as described with reference to Fig. 1A. The model creation device 150 creates the prediction model M predicting the probability distribution of the magnitude of an error in position information provided by a satellite positioning system. The position error prediction device 10' acquires the prediction model M created by the model creation device 150 and stores the prediction model M in the storage unit 13. Although the position error prediction device 10 exemplified in Fig. 1A will be described below as an example, it is possible to create the prediction model M and predict the probability distribution of the magnitude of a position error at any point by the same processing even when the position error prediction system 1 is used.

[0018]

The magnitude of position information and a position error provided by a satellite positioning system such as a

GNSS is affected by the terrain at that point. The terrain is, for example, the presence or absence of a building or a tree and its height at that point. For example, when a high-rise building is built, it is difficult to receive a satellite signal and the position error tends to be large. In addition, in a case where position information on a vehicle is a target, the magnitude of the position error is affected by the positional relationship between the direction and speed of travel of the vehicle and a building at that point as well as a static feature such as the presence or absence a building and its height. From this point of view, the terrain feature data also includes the road shape and the orientation at that point.

[0019]

(Processing of Three-dimensional Map Data)

Next, a method for calculating terrain feature data from three-dimensional map data will be described with reference to Figs. 2A to 2D. Figs. 2A to 2D are first to fourth diagrams illustrating the map data processing method in the present disclosure, respectively.

Fig. 2A illustrates an example of a target point P and the surrounding terrain. The target point P is, for example, the current position of a vehicle. With the target point P at the center and, for example, the north

direction set as a reference, a building and so on in that direction are detected for each azimuth angle α . In Fig. 2A, the heights of the building and so on are indicated by shading and a higher building or the like is at a whiter part. For example, a high-rise building BH and a low-rise building LH2 are at the azimuth angle α position indicated by the arrow A and a low-rise building LH is in the south direction.

[0020]

As illustrated in Fig. 2B, an elevation angle β between the line connecting the apex of the building or the like and the target point P and the ground is calculated for each range of the predetermined azimuth angle α . In a case where the high-rise building BH is in front and a low-rise building BL2 is behind the high-rise building BH as illustrated in Fig. 2B, the elevation angle β formed by the horizon and the line connecting the target point P and the apex of the high-rise building BH is calculated. Then, for each predetermined range of the azimuth angle α (e.g. for each 45-degree range), the elevation angle β is calculated in relation to the tallest building or the like in that range.

[0021]

Fig. 2C illustrates the relationship between the azimuth angle α and the elevation angle β . In the graph

of Fig. 2C, the vertical axis indicates the elevation angle and the horizontal axis indicates the azimuth angle. L1 indicates a boundary elevation angle. The lower part of the boundary elevation angle L1 indicates a space where a satellite signal is blocked by a building or the like, and the upper part of the boundary elevation angle L1 indicates a space without blockage.

[0022]

In the graph illustrated in Fig. 2D, a blockage-free angle is illustrated for each elevation angle β . The blockage-free angle indicates the total range of no blockage by a building or the like in the 360-degree azimuth angle range. Lines 301, 302, and 303 in Fig. 2D indicate the blockage-free range at an elevation angle of 30 degrees, that is, a range at the upper part of the boundary elevation angle L1. 190 indicates that the total blockage-free range (lines 301, 302, and 303) is 190 degrees. In other words, at the target point P in Fig. 2A, a building or the like being at the position where the elevation angle is 30 degrees is in the range of 170 degrees (360 - 190) out of 360 degrees. In the present disclosure, the blockage-free range at an elevation angle of 30 degrees being 190 degrees is described as the blockage-free angle at an elevation angle of 30 degrees being 190 degrees. The blockage-free angle at an

elevation angle of 45 degrees (total azimuth angle range corresponding to lines 451 and 452) is 280 degrees, and the blockage-free angle at an elevation angle of 60 degrees (total azimuth angle range corresponding to lines 601 and 602) is 280 degrees. In addition, at an elevation angle of 75 degrees, the blockage-free angle (total azimuth angle range corresponding to line 751) is 360 degrees. This means that there are no buildings and so on in any direction at the height where the elevation angle is 75 degrees when viewed from the target point P.

[0023]

The blockage-free angle is related to the ease of satellite signal reception and the magnitude of a position error. For example, at a larger blockage-free angle, a satellite signal is easier to receive and the position error tends to be smaller. In the present disclosure, this blockage-free angle is used in predicting the probability distribution of the magnitude of a position error. The processing of blockage-free angle calculation from the three-dimensional map data described above may be performed by a user. Alternatively, the position error prediction device 10 may have a function of executing the processing.

Next, parameters (terrain feature data) used in predicting the probability distribution of the magnitude

of a position error will be described with reference to Figs. 3A to 3C.

[0024]

(Terrain Feature Data)

Figs. 3A to 3C are first to third diagrams illustrating the terrain feature data of the present disclosure, respectively.

In the graph illustrated in Fig. 3A, a boundary count is illustrated for each elevation angle β . The boundary count indicates the boundary between a blockage portion and a non-blockage portion. Arrows 30A to 30D indicate boundaries at an elevation angle of 30 degrees. The boundary count is four at an elevation angle of 30 degrees. Arrows 45A to 45B indicate boundaries at an elevation angle of 45 degrees, and arrows 60A to 60B indicate boundaries at an elevation angle of 60 degrees. The boundary count is two at an elevation angle of 45 degrees, and the boundary count is two at an elevation angle of 60 degrees. The boundary count is related to the number of buildings or the like at each elevation angle. The number of buildings or the like at that elevation angle is different, even at the same blockage-free angle, on condition that the boundary count is different. For example, the ease of satellite signal reception may differ even at the same blockage-free angle in a case where one

large building is built in the north direction and a case where one small building is built in each of the north, south, east, and west. Accordingly, in the present disclosure, the boundary count is used as a parameter affecting the status of satellite signal reception, that is, the magnitude of a position error.

[0025]

The graph illustrated in Fig. 3B illustrates the blockage-free angle. The blockage-free angle has been described above with reference to Fig. 2D. In the case of use as an input parameter, for example, the blockage-free angles at the respective elevation angles may be further divided into eight equal parts for each azimuth angle range and may be divided into the blockage-free angles in the azimuth angle ranges of 0 degrees to 90 degrees, 45 degrees to 135 degrees, 90 degrees to 180 degrees, 135 degrees to 225 degrees, 180 degrees to 270 degrees, 225 degrees to 315 degrees, 270 degrees to 0 degrees, and 315 degrees to 15 degrees. For example, in the case of Fig. 3B, the blockage-free angle in the azimuth angle range of 0 degrees to 90 degrees at an elevation angle of 30 degrees is 90 degrees and the blockage-free angle in the azimuth angle range of 270 degrees to 360 degrees at an elevation angle of 30 degrees is 30 degrees. In the present disclosure, the blockage-free angle for each

elevation angle and each predetermined azimuth angle range is used as a parameter affecting the magnitude of a position error. Alternatively, the sum of the blockage-free angles at the elevation angles described with reference to Fig. 2D may be used as a parameter affecting the magnitude of a position error.

[0026]

Fig. 3C illustrates the orientation of a vehicle and travel position information P1 to P5. The position information P1, P2, P3, P4, and P5 are, for example, vehicle position information acquired from map data in this order during the travel of the vehicle. Alternatively, the position information P1 to P5 are position information on a planned travel or an actual travel path acquired from map data with reference to the map data before or after travel. For example, even in the case of positioning at the same target position P, the magnitude of the position information provided by the satellite positioning system is different in the case of travel from the lower side of the page through P1 to P5 and in the case of travel in the opposite direction from the right side of the page. Accordingly, in the present disclosure, $\cos\theta$ calculated with regard to an angle θ formed by a vehicle orientation-indicating vector L31 formed by connecting the position information P5 observed

one ahead of the target point P and the position information positioned at the target point P and a vehicle orientation-indicating vector L32 formed by connecting the position information positioned at the target point P and the position information P1 observed a predetermined number ahead (or position information P1 observed ahead of the target point P by a predetermined distance based on the distance of travel calculated based on the speed of the vehicle) and the orientation of the vehicle during passage through the target point P (arrow direction of line L31) are used as parameters affecting the magnitude of a position error. The line L31 represents the latest orientation of the vehicle, and the line L32 represents the average orientation of the vehicle in the latest predetermined period. $\cos\theta$ and the vehicle orientation (direction of line L31) are referred to as a path shape. The vehicle orientation may be specified by, for example, the azimuth angle described with reference to Fig. 2A.

[0027]

In the present embodiment, the boundary count, the blockage-free angle, and the path shape are used as terrain feature data indicating the terrain features at the target point P, these are used as input parameters, the probability distribution of the magnitude of the position error at the target point P is used as an output,

and the relationship between the two is learned. When the terrain feature data at any point is input subsequently, the prediction model M predicting the probability distribution of the magnitude of the position error at that point is created. The boundary count and the blockage-free angle can be obtained by three-dimensional map data analysis. The path shape at the target point P can be obtained by analyzing the position information obtained from the satellite positioning system when the vehicle actually travels at the target point P. The data acquisition unit 151 of the learning unit 15 acquires the position information measured at the target point P, and the learning data creation unit 152 calculates the path shape.

[0028]

Fig. 4 is a diagram illustrating the probability distribution of error information of the present disclosure.

When the vehicle actually travels, the position information P1, P2, P3, P4, P5, and P positioned during the travel and position error range information Q1, Q2, Q3, Q4, Q5, and Q indicating the magnitudes of the errors in the position information can be obtained as exemplified in Fig. 4a. The position error range information Q1 and the like are indicated by broken-line circles. When the

travel of the vehicle is repeated many times, the position error range information Q_1 , Q_2 , Q_3 , Q_4 , Q_5 , and Q respectively corresponding in time to the position information P_1 , P_2 , P_3 , P_4 , P_5 , and P can be obtained. For example, N travels and position error measurements are performed with regard to the target point P and N position error magnitudes are recorded. The probability distribution of the magnitude of the position error at the target point P can be calculated from this information. For example, when N is 10 and a position error magnitude x_1 is measured 3 times, x_2 is measured twice, and x_3 is measured 5 times as position error information, a probability distribution is obtained in which the probability that the magnitude of the position error is x_1 is 30%, the probability that the magnitude of the position error is x_2 is 20%, and the probability that the magnitude of the position error is x_3 is 50%. A graph 100a illustrates an example of the probability distribution of the magnitude of the position error at the target point P . The vertical axis of the graph 100a indicates the probability, and the horizontal axis indicates the magnitude of the position error. The data acquisition unit 151 of the learning unit 15 acquires the magnitude of the position error measured a predetermined number of times (e.g. 50 times) at the target point P . The learning

data creation unit 152 calculates the probability distribution of the magnitude of the position error based on the acquired position error magnitude.

[0029]

Fig. 5 is a diagram illustrating the prediction model of the present disclosure.

When the input parameters (terrain feature data) described in Figs. 3A to 3C are input, the learning unit 15 creates the prediction model M, which outputs a probability distribution 100b of the magnitude of the position error based on the measured value calculated by the method described with reference to Fig. 4, using a regression method capable of multiple outputs (e.g. neural network).

[0030]

Next, the processing of creating the prediction model M will be described.

Fig. 6 is a flowchart illustrating an example of the learning processing according to the first embodiment of the present disclosure.

First, the data acquisition unit 151 acquires terrain feature data at a plurality of points (Step S11). The terrain feature data is the boundary count described in Fig. 3A and the blockage-free angle described in Fig. 2D or Fig. 3B. It is preferable to have as much learning

data as possible in order to create the prediction model M with high accuracy, and thus the terrain feature data at each target point is acquired by using points that have various terrain features as target points. The data acquisition unit 151 may acquire three-dimensional map data including information at a plurality of points, and the learning unit 15 may calculate the boundary count and the blockage-free angle at each point from the map data. The data acquisition unit 151 records the respective target points, boundary counts, and blockage-free angles in association in the storage unit 13 with regard to every target point.

[0031]

Next, the vehicle is caused to travel a predetermined number of times or more at each of the plurality of target points and the vehicle position information and the position error magnitude are measured at predetermined time intervals, on the vehicle travel path including the target point, and using a satellite positioning system. The data acquisition unit 151 acquires the position error magnitude and the position information measured a predetermined number of times or more at each of the plurality of points (Step S12). The data acquisition unit 151 records the respective target points, position information, and position error

magnitudes in association in the storage unit 13 with regard to every target point.

[0032]

Next, the learning data creation unit 152 calculates the path shape at each point (Step S13). As described with reference to Fig. 3C, the learning data creation unit 152 calculates the path shape ($\cos\theta$ and orientation in Fig. 3C) based on the latest and average vehicle orientations with regard to each target point. The learning data creation unit 152 records the respective target points and path shapes in association in the storage unit 13 with regard to every target point.

[0033]

Next, the learning data creation unit 152 calculates the probability distribution of the magnitude of the position error at each point (Step S14). As described with reference to Fig. 4, the learning data creation unit 152 calculates the probability distribution of the magnitude of the position error for each target point based on the magnitude of the position error measured a predetermined number of times or more at each target point. The learning data creation unit 152 records the respective target points and probability distributions of the magnitudes of the position errors in association in the storage unit 13 with regard to every target point.

[0034]

Next, the model creation unit 153 generates the prediction model M (Step S15). The model creation unit 153 reads the target point-specific boundary count, blockage-free angle, path shape, and probability distribution of the magnitude of the position error recorded in the storage unit 13 for each target point. For example, in a case where 100 target points (1 to 100) are set, the model creation unit 153 selects some of the target points 1 to 100 and gives these to the prediction model M in the process of learning. Then, in a case where the boundary count, blockage-free angle, and path shape at the target point 1 are input with the target point 1 included in the selections, for example, the prediction model M is trained so as to output the probability distribution of the magnitude of the position error calculated with regard to the target point 1. The same applies to the rest of the selected target points. The model creation unit 153 repeats the processing of selecting some of the target points 1 to 100 to learn the prediction model M using these as learning data a predetermined number of times. As a result, it is possible to create the prediction model M outputting the probability distribution of the magnitude of the position error obtained at the point P by inputting the terrain

feature data at the point P such as the boundary count, the blockage-free angle, and the path shape.

[0035]

Next, the processing of predicting position error distribution information obtained from a satellite positioning system at any point based on the prediction model M created as a result of the processing of Fig. 6 will be described.

Fig. 7 is a flowchart illustrating an example of the prediction processing according to the first embodiment of the present disclosure.

First, the terrain feature data acquisition unit 11 acquires terrain feature data at a new point (Step S21). The new point is where the probability distribution of the magnitude of a position error is unknown. The terrain feature data acquisition unit 11 acquires the boundary count, blockage-free angle, and path shape at the prediction target point. For example, a user calculates the boundary count and the blockage-free angle by the method described with reference to Figs. 2A to 2D and Figs. 3A to 3B based on three-dimensional map data including the prediction target point and inputs these to the position error prediction device 10. In addition, the user calculates the path shape ($\cos\theta$ and orientation) based on the assumed vehicle orientation and speed values at the

prediction target point and the shape of the road at the prediction target point on the map data and inputs this value to the position error prediction device 10. The terrain feature data acquisition unit 11 acquires the terrain feature data input to the position error prediction device 10 (boundary count, blockage-free angle, and path shape) and passes these to the prediction unit 12.

[0036]

The prediction unit 12 predicts the distribution of the magnitude of the position error at the new point (Step S22). The prediction unit 12 inputs the boundary count, blockage-free angle, and path shape to the learning-completed prediction model M. The prediction model M predicts the probability distribution of the magnitude of the position error. Next, the output unit 14 outputs the result of the prediction performed by the prediction model M (Step S23). For example, the output unit 14 outputs a probability distribution graph (e.g. graph 100a in Fig. 4 and graph 100b in Fig. 5) on a display or the like.

[0037]

According to the present embodiment, it is possible to obtain the probability distribution of the magnitude of a position error provided by a satellite positioning system at any point. Accordingly, even in a case where a failure rate is calculated based on the magnitude of the

position error, for example, the accuracy of the failure rate can be grasped. In addition, on condition that terrain feature data at a target point is known, the probability distribution of the magnitude of the position error at that point can be obtained, and thus the probability distribution of the magnitude of a position error can be predicted in advance regarding a road of first travel as well.

[0038]

<Second Embodiment>

Next, the processing of predicting the probability distribution of the magnitude of a position error in a second embodiment will be described with reference to Figs. 8A to 10.

Fig. 8A is a diagram illustrating an example of a position error prediction device according to the second embodiment of the present disclosure. A position error prediction device 10A includes the terrain feature data acquisition unit 11, the prediction unit 12, the storage unit 13, the output unit 14, and a learning unit 15A. The configuration identical to those of the first embodiment will not be described below.

[0039]

The learning unit 15A includes the data acquisition unit 151, the learning data creation unit 152, the model

creation unit 153, and a learning data selection unit 154. As described with reference to Fig. 6, the model creation unit 153 repeats the processing of selecting some of a plurality of target points and learning the prediction model M a predetermined number of times to enhance the accuracy of the prediction model M. The learning data selection unit 154 classifies the probability distribution of the magnitude of the position error into groups similar in distribution during the learning of the prediction model M. Then, in the processing of target point selection, the learning data selection unit 154 selects a target point such that the ratio of the number of learning data selected from each group is substantially equal. The model creation unit 153 creates the prediction model M using a set of the selected probability distribution of the position error magnitude and input data corresponding thereto.

[0040]

The learning unit 15A may be configured as a device independent of the position error prediction device 10. An example is illustrated in Fig. 8B. Fig. 8B is a diagram illustrating an example of a position error prediction system in the second embodiment of the present disclosure. A position error prediction system 1A includes the position error prediction device 10' and a

model creation device 150A. The model creation device 150A includes the data acquisition unit 151, the learning data creation unit 152, the model creation unit 153, and the learning data selection unit 154. The functions thereof are as described with reference to Fig. 8A. The position error prediction device 10' is as described with reference to Fig. 1B. Hereinafter, the position error prediction device 10A exemplified in Fig. 8A will be described as an example.

[0041]

Fig. 9 is a diagram illustrating learning data selection processing according to the second embodiment of the present disclosure.

The distribution of the magnitude of the position error may be the same or close at different points. For example, as a result of measuring the magnitude of the position error a predetermined number of times at a plurality of points with different terrain features, 1000 probability distributions similar to a graph 9a, 10 probability distributions similar to a graph 9b, and 8 probability distributions similar to a graph 9c can be obtained. (a result such as the graph 9a with a high probability of position error magnitude = 0 can be obtained relatively frequently at many points) When the processing of selecting any learning data from these data

and learning the prediction model M is repeated, the selected learning data is biased toward data similar to the graph 9a and the prediction model M that predicts a probability distribution similar to the graph 9a is created irrespective of what terrain feature data is given. In order to prevent such a situation, in the second embodiment, the number of data is adjusted, as illustrated in Fig. 9, such that the pattern of probability distribution is not biased. For example, the learning data selection unit 154 selects 10 out of 1000 probability distributions similar to the graph 9a and selects, as learning data, terrain feature data respectively corresponding to 10 probability distributions similar to the graph 9b and 8 probability distributions similar to the graph 9c. The model creation unit 153 learns the prediction model M using the selected learning data. As a result, the prediction model M is created using unbiased learning data and a prediction error (bias) is prevented.

[0042]

Next, the processing of creating the prediction model M in the second embodiment will be described.

Fig. 10 is a flowchart illustrating an example of the learning processing according to the second embodiment of the present disclosure. The processing identical to that of the first embodiment will be briefly described.

First, the data acquisition unit 151 acquires terrain feature data at a plurality of points (Step S11). Next, the data acquisition unit 151 acquires the position error magnitude and the position information measured a predetermined number of times or more at each of the plurality of points (Step S12). Next, the learning data creation unit 152 calculates the path shape at each point (Step S13). Next, the learning data creation unit 152 calculates the probability distribution of the magnitude of the position error at each point (Step S14).

[0043]

Next, the learning data selection unit 154 classifies the probability distribution of the magnitude of the position error (Step S151). The learning data selection unit 154 classifies, for example, those similar in position error probability peak into the same group.

[0044]

Next, the model creation unit 153 generates the prediction model M (Step S152). At this time, the learning data selection unit 154 performs unbiased learning data selection from the classified group. For example, in the case of classification into group A and group B, the learning data selection unit 154 selects 10 probability distributions each such that the ratio of the number of probability distributions selected from group A

and group B is equal and reads the terrain feature data corresponding to the selected probability distribution from the storage unit 13. The model creation unit 153 gives the selected terrain feature data and probability distribution of the magnitude of the position error to the prediction model M and performs learning. The learning data selection unit 154 performs unbiased learning data selection, and the model creation unit 153 repeats the processing of training the prediction model M using the selected learning data to create the prediction model M.

[0045]

According to the present embodiment, the effect of prediction accuracy improvement can be obtained in addition to the effect of the first embodiment.

[0046]

Fig. 11 is a diagram illustrating an example of the hardware configurations of the position error prediction device and the model creation device in each embodiment of the present disclosure.

A computer 900 is, for example, a server terminal device or a personal computer (PC) including a CPU 901, a main storage device 902, an auxiliary storage device 903, an input-output interface 904, and a communication interface 905. The computer 900 is equipped with the position error prediction devices 10 and 10A and the model

creation devices 150 and 150A. The operation of each of the processing units described above is stored in the auxiliary storage device 903 in the form of a program. The CPU 901 reads the program from the auxiliary storage device 903, loads it into the main storage device 902, and executes the above processing in accordance with the program. The CPU 901 ensures a storage area corresponding to the storage unit 13 in the main storage device 902 in accordance with the program. The CPU 901 ensures a storage area storing data in processing in the auxiliary storage device 903 in accordance with the program.

[0047]

In at least one embodiment, the auxiliary storage device 903 is an example of a non-temporary tangible medium. Other non-temporary tangible medium examples include a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, and a semiconductor memory connected via the input-output interface 904. In a case where this program is distributed to the computer 900 by a communication line, the distributed computer 900 may load the program into the main storage device 902 and execute the above processing. The program may be for realizing a part of the above functions. Further, the program may be a so-called difference file (difference program) that realizes the

above function in combination with another program pre-stored in the auxiliary storage device 903.

[0048]

It is possible to replace components in the above embodiments with known components as appropriate without departing from the spirit of the present invention. The technical scope of the present invention is not limited to the above embodiments, and various modifications can be made without departing from the spirit of the present invention.

For example, although the three of boundary count, blockage-free angle, and path shape are used as input parameters regarding the prediction model M in the embodiments, only one or two of these may be used instead.

[0049]

<Additional Notes>

The position error prediction devices 10 and 10A, the position error prediction method, and the program according to the embodiments are grasped as follows as an example.

[0050]

(1) A position error prediction device 10, 10A according to a first aspect is a position error prediction device for predicting a probability distribution of a magnitude of an error in position information where a

moving body is considered to be present, the position error prediction device including a prediction unit 12 predicting a probability distribution of a magnitude of the error at a prediction target point based on a prediction model M indicating a relationship between terrain feature data indicating a terrain feature at a certain point and a probability distribution of a magnitude of the error at the point and the terrain feature data at the prediction target point.

As a result, it is possible to obtain the probability distribution of the magnitude of an error in position information obtained from a satellite positioning system at any point.

[0051]

(2) The position error prediction device 10, 10A according to a second aspect is the position error prediction device 10, 10A according to (1), in which the terrain feature data is a value indicating a magnitude of a space where there is no blockage in relation to a satellite of a satellite positioning system for each elevation angle from a ground at the point over the point.

[0052]

(3) The position error prediction device 10, 10A according to a third aspect is the position error prediction device 10, 10A according to (1) to (2), in

which the terrain feature data is a value indicating the number of boundaries between a space where there is no blockage and a space where there is blockage in relation to a satellite of a satellite positioning system for each elevation angle from a ground at the point over the point.

[0053]

(4) The position error prediction device 10, 10A according to a fourth aspect is the position error prediction device 10, 10A according to (1) to (3), in which the terrain feature data is a predetermined feature quantity based on a shape of a travel path of a moving body passing through the point and an orientation of the moving body.

[0054]

(5) The position error prediction device 10, 10A according to a fifth aspect is the position error prediction device 10, 10A according to (1) to (4), further including a learning unit 15 creating the prediction model by learning a relationship between the terrain feature data and the probability distribution calculated based on the magnitudes of a plurality of the errors measured at a point having the terrain feature data.

[0055]

(6) The position error prediction device 10A according to a sixth aspect is the position error

prediction device 10A according to (5), in which the learning unit 15 classifies the probability distribution into groups of similarities, selects the probability distribution from each of the groups such that a ratio of the number of the probability distributions selected from the respective groups is a ratio in a predetermined range that can be regarded as equal (e.g. range of 1:1.5 to 1.5:1 with reference to 1:1 in the case of 2 groups), and creates the prediction model based on the selected probability distribution and the terrain feature data corresponding to the probability distribution.

As a result, it is possible to prevent a decline in prediction accuracy attributable to a bias in learning data.

[0056]

(7) A model creation device 150, 150A according to a seventh aspect includes: a data acquisition unit 151 acquiring terrain feature data indicating a terrain feature at a certain point and a plurality of pieces of information indicating a magnitude of an error in position information positioned by a satellite positioning system and acquired from the satellite positioning system at the point; a learning data creation unit 152 calculating a probability distribution of the magnitude of the error based on the plurality of pieces of information indicating

the magnitude of the error; and a prediction model creation unit 153 creating a prediction model indicating a relationship between the terrain feature data and the probability distribution of the magnitude of the error based on the terrain feature data and the probability distribution of the magnitude of the error.

As a result, when terrain feature data at any point is input, it is possible to create a prediction model outputting the probability distribution of the magnitude of an error in position information obtained from a satellite positioning system at that point.

[0057]

(8) A position error prediction method according to an eighth aspect is a position error prediction method for predicting a probability distribution of a magnitude of an error in position information where a moving body is considered to be present, the position error prediction method including predicting a probability distribution of a magnitude of the error at a prediction target point based on a prediction model indicating a relationship between terrain feature data indicating a terrain feature at a certain point and a probability distribution of a magnitude of the error at the point and the terrain feature data at the prediction target point.

[0058]

(9) A model creation method according to a ninth aspect includes: acquiring terrain feature data indicating a terrain feature at a certain point and a plurality of pieces of information indicating a magnitude of an error in position information positioned by a satellite positioning system and acquired from the satellite positioning system at the point; calculating a probability distribution of the magnitude of the error based on the plurality of pieces of information indicating the magnitude of the error; and creating a prediction model indicating a relationship between the terrain feature data and the probability distribution of the magnitude of the error based on the terrain feature data and the probability distribution of the magnitude of the error.

[0059]

(10) A program according to a tenth aspect is a program for causing a computer to execute a position error prediction process for predicting a probability distribution of a magnitude of an error in position information where a moving body is considered to be present, of the process comprising predicting a probability distribution of a magnitude of the error at a prediction target point based on a prediction model indicating a relationship between terrain feature data indicating a terrain feature at a certain point and a

probability distribution of a magnitude of the error at the point and the terrain feature data at the prediction target point.

[0060]

(11) A program according to an eleventh aspect is a program for causing a computer to execute a process comprising: acquiring terrain feature data indicating a terrain feature at a certain point and a plurality of pieces of information indicating a magnitude of an error in position information positioned by a satellite positioning system and acquired from the satellite positioning system at the point; calculating a probability distribution of the magnitude of the error based on the plurality of pieces of information indicating the magnitude of the error; and creating a prediction model indicating a relationship between the terrain feature data and the probability distribution of the magnitude of the error based on the terrain feature data and the probability distribution of the magnitude of the error.

[Industrial Applicability]

[0061]

According to the position error prediction device, the error prediction method, and the program described above, it is possible to estimate the distribution of the magnitude of a positioned position error in satellite

positioning. According to the model creation device, the model creation method, and the program described above, it is possible to create a prediction model predicting the distribution of the magnitude of a position error in satellite positioning.

[Reference Signs List]

[0062]

- 1 position error prediction system
- 10 position error prediction device
- 11 terrain feature data acquisition unit
- 12 prediction unit
- 13 storage unit
- 14 output unit
- 15 learning unit
- 150, 150A model creation device
- 151 data acquisition unit
- 152 learning data creation unit
- 153 model creation unit
- 900 computer
- 901 CPU
- 902 main storage device
- 903 auxiliary storage device
- 904 input-output interface
- 905 communication interface

Claims

[Claim 1]

A position error prediction device for predicting a probability distribution of a magnitude of an error in position information where a moving body is considered to be present, the position error prediction device comprising a prediction unit predicting a probability distribution of a magnitude of the error at a prediction target point based on a prediction model indicating a relationship between terrain feature data indicating a terrain feature at a certain point and a probability distribution of a magnitude of the error at the point and the terrain feature data at the prediction target point.

[Claim 2]

The position error prediction device according to claim 1,
wherein the terrain feature data is a value indicating a magnitude of a space where there is no blockage in relation to a satellite of a satellite positioning system for each elevation angle from a ground at the point over the point.

[Claim 3]

The position error prediction device according to claim 1 or 2,

wherein the terrain feature data is a value indicating the number of boundaries between a space where there is no blockage and a space where there is blockage in relation to a satellite of a satellite positioning system for each elevation angle from a ground at the point over the point.

[Claim 4]

The position error prediction device according to any one of claims 1 to 3,

wherein the terrain feature data is a predetermined feature quantity based on a shape of a travel path of a moving body passing through the point and an orientation of the moving body.

[Claim 5]

The position error prediction device according to any one of claims 1 to 4, further comprising a learning unit creating the prediction model by learning a relationship between the terrain feature data and the probability distribution calculated based on the magnitudes of a plurality of the errors measured at a point having the terrain feature data.

[Claim 6]

The position error prediction device according to claim 5,

wherein the learning unit classifies the probability distribution into groups of similarities, selects the probability distribution from each of the groups such that a ratio of the number of the probability distributions selected from the respective groups is a ratio in a predetermined range that can be regarded as equal, and creates the prediction model based on the selected probability distribution and the terrain feature data corresponding to the probability distribution.

[Claim 7]

A model creation device comprising:

a data acquisition unit acquiring terrain feature data indicating a terrain feature at a certain point and a plurality of pieces of information indicating a magnitude of an error in position information positioned by a satellite positioning system and acquired from the satellite positioning system at the point;

a learning data creation unit calculating a probability distribution of the magnitude of the error based on the plurality of pieces of information indicating the magnitude of the error; and

a prediction model creation unit creating a prediction model indicating a relationship between the terrain feature data and the probability distribution of the magnitude of the error based on the terrain feature data and the probability distribution of the magnitude of the error.

[Claim 8]

A position error prediction method for predicting a probability distribution of a magnitude of an error in position information where a moving body is considered to be present, the position error prediction method comprising:

predicting a probability distribution of a magnitude of the error at a prediction target point based on a prediction model indicating a relationship between terrain feature data indicating a terrain feature at a certain point and a probability distribution of a magnitude of the error at the point and the terrain feature data at the prediction target point.

[Claim 9]

A model creation method comprising:
acquiring terrain feature data indicating a terrain feature at a certain point and a plurality of pieces of

information indicating a magnitude of an error in position information positioned by a satellite positioning system and acquired from the satellite positioning system at the point;

calculating a probability distribution of the magnitude of the error based on the plurality of pieces of information indicating the magnitude of the error; and

creating a prediction model indicating a relationship between the terrain feature data and the probability distribution of the magnitude of the error based on the terrain feature data and the probability distribution of the magnitude of the error.

[Claim 10]

A program for causing a computer to execute a position error prediction process for predicting a probability distribution of a magnitude of an error in position information where a moving body is considered to be present, the process comprising predicting a probability distribution of a magnitude of the error at a prediction target point based on a prediction model indicating a relationship between terrain feature data indicating a terrain feature at a certain point and a probability distribution of a magnitude of the error at

the point and the terrain feature data at the prediction target point.

[Claim 11]

A program for causing a computer to execute a process comprising:

acquiring terrain feature data indicating a terrain feature at a certain point and a plurality of pieces of information indicating a magnitude of an error in position information positioned by a satellite positioning system and acquired from the satellite positioning system at the point;

calculating a probability distribution of the magnitude of the error based on the plurality of pieces of information indicating the magnitude of the error; and

creating a prediction model indicating a relationship between the terrain feature data and the probability distribution of the magnitude of the error based on the terrain feature data and the probability distribution of the magnitude of the error.