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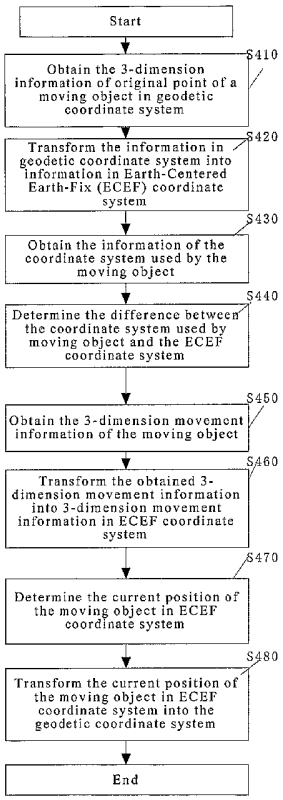
(54) Title: METHOD AND SYSTEM FOR MOBILE LOCATION



(57) Abstract: The present invention provides a method and system for mobile location. Firstly, the method and system determines 3-demension information of a original point of a moving object, which is based on a distinguishable coordinate system with the distinguishable coordinate system being the Earth coordinate system; next, detect s a 3 -demension movement of the mov ing object and produces corresponding 3-demension movement information; and finally, transforms the 3demension movement information to the information conforming to the distinguishable coordinate system. This invention can position an object in connection with the GPS accurately, or can position an object accurately in the situation that the GPS can not be used, such as in the area where GPS signal can not be received, especially in the high buildings or in the forest.

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METHOD AND SYSTEM FOR MOBILE LOCATION

Background Art

The present invention relates to a positioning system, and particularly, to a mobile positioning method and system.

Global Positioning System (GPS) is widely used in navigating and positioning. Generally, the positioning location of GPS is based on a geodetic coordinate system.

Figure 1 is a schematic diagram of the geodetic coordinate system. The geodetic coordinate system is a coordinate system taking reference ellipsoid surface as datum. In the geodetic coordinate system, the position of point P is usually indicated by geodetic longitude ϕ, geodetic latitude λ and geodetic altitude h, but the position of point P could be indicated by geodetic longitude ϕ and geodetic latitude λ only when point P is just on the ellipsoid surface, wherein the geodetic longitude ϕ of point P is the angle between the prime meridian plane and the geodetic meridian plane passing through point P, the geodetic latitude λ is the angle between the equator and the normal passing through point P, and the geodetic altitude h is the distance from point P to reference ellipsoid surface along the normal.

Besides geodetic coordinate system, there are many other coordinate systems, which take different references as datum, e.g. Earth-Centered Earth-Fix (ECEF) coordinate system and etc.

Figure 2 is a schematic diagram of ECEF coordinate system. The origin (0,0,0) of ECEF coordinate system is located at the centroid of the Earth, where Z-axis is directed towards the Conventional Terrestrial Pole defined in BIH1984.0, X-axis is directed to the intersection of the equator and the prime meridian plane of BIH1984.0, and Y-axis completes a right-handed system together with X-axis and Z-axis. The position of point P (X, Y, Z) is indicated by the distance from point P to X-axis, Y-axis and Z-axis respectively.

Although GPS is widely used in positioning, GPS receiver can't accurately receive signal in certain areas, especially in closed urban area like in a high building, or in the forest, even when the signal is transmitted from a satellite, because GPS signal is often shielded by landform and objects on the ground.

In addition to GPS, there are multiple techniques aiming for precise positioning, e.g. using mobile network for supplementing GPS to position or asking a person to carry a step counter for calculating the walking distance when the area is small. However, defects of different degrees exist in the techniques above. For example, using a mobile network for supplementing GPS to position is limited by the mobile network. No precise positioning can be carried out in a region with no mobile network or a region in mobile network where the signal does not receive well. Similarly, using a step counter for positioning is limited by the step counter's self-set walking distance.

In all positioning systems, to precisely position a positioning object, the 3-dimension movement information of the positioning object shall be obtained. Therefore, obtaining the 3-dimension movement information of the positioning object is a key problem in the positioning system.

A 3 -dimension handwriting recognition method and system, which is a new 3-dimension information obtaining method and system, is disclosed successively in the patent application under Chinese application No. 02144248.7 (application date: September 28, 2002; inventors: Du Yonggang, Tu Jiawen, Feng Lei, Shao Xiaoling) and the patent application under Chinese application No. 02159784.7 (application date: December 26, 2002; inventors: Shao Xiaoling, Tu Jiawen, Feng Lei) (contents of the above two patent applications are incorporated herein by reference). The system tracks the user's handwriting input in 3-dimension space, produces corresponding 3-dimension movement data, and constitutes 3-dimension movement tracks, which are projected then on a 2-dimension plane to produce a corresponding 2-dimension image for handwriting recognition. The system can further transmit the tracked 3-dimension movement data or 3-dimension movement tracks to terminals such as PDA, Laptop, mobile phone and etc. via wireless transmission, e.g. Bluetooth, or wired connection.

Therefore, a new mobile positioning method and system is needed due to the drawbacks existing in the above positioning systems.

Contents of the Invention

An object of the present invention is to provide a mobile positioning method and system, being a new application according to the above mentioned invention. The method and system can perform precise positioning by supplementing GPS, or in areas where the conventional GPS receiver can't receive and measure the signal from a GPS satellite.

The present invention provides a method for positioning a moving object. The method comprise: firstly, determining 3-dimension information of an original point of a moving object, which 3-dimension information is based on a distinguishable coordinate system; secondly, detecting a 3-dimension movement of the moving object and producing corresponding 3-dimension movement information; finally, transforming the 3-dimension movement information to information conforming to the distinguishable coordinate system.

The distinguishable coordinate system is a geodetic coordinate system, and the 3-dimension movement information is based on another coordinate system, so it is necessary to detect the difference between the distinguishable coordinate system and another coordinate system. The difference can be determined by detecting the direction angle between the distinguishable coordinate system and another coordinate system.

The present invention can precisely position a moving object by setting an original point and using 3-dimension tracking technique. The present invention can perform precise position in connect with GPS, or perform precise position in case the GPS cannot be used, e.g. in regions where the GPS signal can't be received, especially in high buildings or in the forests.

The objects and attainments together with a fuller understanding of the present invention will become apparent and appreciated by referring to the following description and appended claims taken in conjunction with the accompanying drawings.

Description Of Figures

The invention is explained in further detail, and by way of example, with reference to the accompanying drawings wherein:

Figure 1 is a schematic diagram of the geodetic coordinate system;

Figure 2 is the schematic diagram of the Earth-Centered Earth-Fix (ECEF) coordinate system;

Figure 3 is a structural diagram of the mobile positioning system according to an embodiment of the present invention;

Figure 4 is a flowchart of the mobile positioning method according to an embodiment of the present invention; and

Figure 5 is a flowchart illustrating the producing of 3-dimension movement information of a moving object according to an embodiment of the present invention.

Mode of Carrying out the Invention

The present invention is further illustrated with reference to the accompanying drawings and embodiments thereof.

Figure 3 is a structural diagram of the mobile positioning system according to an embodiment of the present invention. System 300 comprises an original point determining device 310, a 3-dimension movement tracking device 320 and a data processing device 330.

The original point determining device 310 determines the 3-dimension information of the original point of a moving object, which 3-dimension information is based on an distinguishable coordinate system, e.g. the geodetic coordinate system used by GPS. The original point determining device 310 can be a GPS receiver, and can also be an input device. When the original point determining device 310 is a GPS receiver, the GPS receiver is used for measuring the 3-dimension information of the original point of a moving object, and the obtained 3-dimension information is based on the geodetic coordinate system; when the original point determining device 310 is an input device, the input device is used for manually inputting the 3-dimension information of original point of the moving object recorded on blueprint which is obtained through pre-measuring, and the 3-dimension information is based on an distinguishable coordinate system, which could be geodetic coordinate system or Earth-Centered Earth-Fix (ECEF) coordinate system.

The 3-dimension movement tracking device 320 comprises a 3-dimension movement detecting device 322 for detecting the 3-dimension movement of a moving object and producing the corresponding original

information of the 3-dimension movement, which is based on a coordinate system. The coordinate system is a coordinate system possessed by the 3-dimension movement detecting device 322 per se. The 3-dimension movement detecting device 322 can be a 3-dimension movement detecting sensor, in which the produced 3-dimension movement information is based on the coordinate system of the sensor. The 3-dimension movement detecting device 322 can further be other devices with the same or similar functions, in which the produced 3-dimension movement information is based on coordinate systems of other types. The producing procedure of the 3-dimension movement information is illustrated in detail in the following Figure 5.

The 3-dimension movement tracking device 320 further comprises a coordinate system difference detecting device 324 for detecting the difference between a distinguishable coordinate system and a coordinate system on which the original information is based. The difference can be determined by detecting the direction angle between the distinguishable coordinate system and the coordinate system on which the original information is based. The coordinate system difference detecting device 324 can be an direction sensor.

The data processing device 330 is used for transforming the 3-dimension movement information into information conforming to the distinguishable coordinate system. The transforming procedure is illustrated in the following Figure 4.

The mobile positioning system 300 further comprises a storage 340, which is connected respectively to the original point determining device 310, 3-dimension

movement tracking device 320 and data processing device 330 for storing information.

Figure 4 is the flowchart of the mobile positioning method according to an embodiment of the present invention.

Firstly, the 3-dimension information of the original point of the moving object in geodetic coordinate system is obtained (step S410).

The 3-dimension information is the 3-dimension position of the original point in a distinguishable coordinate system, e.g. geodetic coordinate system, namely, the geodetic longitude ϕ, geodetic latitude λ and geodetic altitude h of the original point. The 3-dimension position of the original point can be determined by the pre-measured data recorded on blueprint, or by the data obtained through GPS receiver measuring.

Secondly, the information in the geodetic coordinate is transformed into information in the Earth-Centered Earth-Fix (ECEF) coordinate (step S420). The information transformation between the two coordinates can be implemented through the following coordinate transformation equation (1):

$$\begin{aligned} X &= (N+h)\cos\phi\cos\lambda \\ Y &= (N+h)\cos\phi\sin\lambda \\ Z &= [N(1-e^2)+h]\sin\phi \end{aligned} \qquad (1)$$

Wherein, ϕ, λ, h represent the longitude, latitude and altitude in geodetic coordinate system; X, Y, Z represent the coordinates in the Earth-Centered Earth-Fix (ECEF) coordinate system; $N = a/\sqrt{1-e^2\sin^2\phi}$ is the prime vertical radius of

curvature in geodetic coordinate system; $e^2 = 2f - f^2$ is the eccentricity square; $f = \frac{a-b}{a}$ is the ellipsoid flattening; a is the ellipsoid equatorial radius in the geodetic coordinate system (semi-major earth axis); b is the ellipsoid polar radius in the geodetic coordinate system (semi-minor earth axis).

Thirdly, the information of the coordinate system used by the moving object is obtained (step S430).

The coordinate system used by a moving object is based on the coordinate system possessed by the 3-dimension movement detecting sensor itself, i.e. sensor coordinate system (the so-called right-handed Descartes coordinate system) because the mobile positioning system 300 detects the 3-dimension movement of the moving object by means of 3-dimension movement detecting sensor and produces information corresponding to the 3-dimension movement. During the movement of the moving object, the sensor coordinate system is always changing relative to the coordinate system used by the original point of the moving object, therefore the coordinate system used by the moving object at the original point can be employed as its coordinate system throughout the whole movement, and the 3-dimension movement information produced thereby is based on the coordinate system.

Next, the difference between the coordinate system used by the moving object and the Earth-Centered Earth-Fix (ECEF) coordinate system is determined (step S440).

The difference can be determined by detecting the direction angle between the Earth-Centered Earth-Fix (ECEF) coordinate system and the coordinate system used by the moving object, i.e. the coordinate system used by the sensor when the moving object is at the original point. A direction sensor is used for measuring the direction, i.e., roll, inclination and azimuth angles, of the platform to which the direction sensor is attached in order to obtain the direction angle.

The direction sensor measures the direction angle between ECEF coordinate system and the sensor coordinate system by using a magnetic field strength meter, and the north of the direction sensor in the geodetic coordinate system is that the magnetic north is stronger than the true north. Therefore, the difference between the true north and the magnetic north caused by the earth magnetic field must be compensated. The difference can be obtained from existing chart listed with regional differences.

Then, the 3-dimension movement of the moving object is detected, and the corresponding 3-dimension movement information produced thereby is obtained (step S450).

The 3-dimension movement of the moving object can be detected by the 3-dimension movement detecting sensor, and information corresponding to the 3-dimension movement can be produced as well. The 3-dimension movement information can be the 3-dimension movement tracks of the moving object. Since the 3-dimension acceleration information of the moving object is obtained by

detecting of the 3-dimension movement detecting sensor, the movement tracks of the moving object can be obtained through the following Equation (2):

$$d = v_0 t + \frac{1}{2} * at^2 \qquad (2)$$

Wherein, a represents acceleration, t is the time interval, d represents the movement tracks of the moving object, v_0 is the initial velocity.

Thus, the position of the moving object at any measurement point in the sensor coordinate system can be obtained through the following Equations (3):

$$X_i = \sum_{n=0}^{i} \left(v_n t_n + \frac{1}{2} * a_n {t_n}^2 \right)$$
$$Y_i = \sum_{n=0}^{i} \left(v_n t_n + \frac{1}{2} * a_n {t_n}^2 \right)$$
$$Z_i = \sum_{n=0}^{i} \left(v_n t_n + \frac{1}{2} * a_n {t_n}^2 \right) \qquad (3)$$

Wherein, Xi, Yi, Zi represent the 3-dimension movement distance of the moving object in the sensor coordinate system, tn represents the sampling interval, a_n is the 3-dimension acceleration information between sampling times (t_{n-1}, t_n), $v_n = v_{n-1} + a_n t$ represents the velocity at sampling instant t_n.

Thereafter, the obtained 3-dimension movement information is transformed into the 3-dimension movement information in ECEF coordinate system (step S460).

Since the obtained 3-dimension movement information is based on sensor coordinate system, so it needs to be transformed into the ECEF coordinate system. The information transformation between the two coordinates can be performed through the following coordinate transforming Equation (4):

$$X_{Ei} = l_1 X_i + l_2 Y_i + l_3 Z_i$$
$$Y_{Ei} = m_1 X_i + m_2 Y_i + m_3 Z_i$$
$$Z_{Ei} = n_1 X_i + n_2 Y_i + n_3 Z_i \qquad (4)$$

Wherein, XEi, YEi, ZEi are the 3-dimension movement tracks of the moving object in the ECEF coordinate system, and

$$l_1 = \cos\theta_Y \cos\theta_Z - \cos\theta_X \sin\theta_Y \sin\theta_Z$$
$$l_2 = -\cos\theta_Y \sin\theta_Z - \cos\theta_X \sin\theta_Y \cos\theta_Z$$
$$l_3 = \sin\theta_Y \sin\theta_Z$$

$$m_1 = \cos\theta_Y \sin\theta_Z + \cos\theta_X \cos\theta_Y \sin\theta_Z$$
$$m_2 = -\sin\theta_Y \sin\theta_Z + \cos\theta_X \cos\theta_Y \cos\theta_Z$$
$$m_3 = -\sin\theta_X \cos\theta_Y$$

$$n_1 = \sin\theta_X \sin\theta_Z$$
$$n_2 = \sin\theta_X \cos\theta_Z$$
$$n_3 = \cos\theta_X$$

In which, θX, θY, θZ represent the direction angle between the ECEF coordinate system and the sensor coordinate system.

Next, the current position of the moving object in ECEF coordinate system is determined (step S470).

The current 3-dimension position of the moving object in the ECEF coordinate system can be obtained through the following Equation (5):

$$X_E = X_0 + X_{Ei}$$
$$Y_E = Y_0 + Y_{Ei}$$
$$Z_E = Z_0 + Z_{Ei} \qquad (5)$$

Wherein, XE, YE, ZE represent the current 3-dimension positions of the moving object in ECEF coordinate system, X0, Y0, Z0 represent the 3-dimension positions of the original point of the moving object in ECEF coordinate system, XEi, YEi, ZEi represent the 3-dimension movement tracks of the moving object in ECEF coordinate system.

In the end, the current position of the moving object in ECEF coordinate system is transformed into the geodetic coordinate system (step S480). The transformation between the two coordinate systems is illustrated through the following Equation (6):

$$\phi = a\tan\left(\frac{Z + e'^2 b\sin^3\theta}{p - e^2 a\cos^3\theta}\right)$$
$$\lambda = a\tan 2(Y, X)$$
$$h = \frac{p}{\cos(\phi)} - N(\phi) \qquad (6)$$

Wherein, ϕ, λ, h represent the longitude, latitude and altitude in the geodetic coordinate system; X, Y, Z represent the ECEF coordinate, while the intermediate variable $p = \sqrt{X^2 + Y^2}$ and the intermediate variable $e'^2 = \frac{a^2 - b^2}{a^2}$;

$N(\phi)=a/\sqrt{1-e^2\sin^2\phi}$ represents the prime vertical radius of curvature in the geodetic coordinate system; $e^2=2f-f^2$ is the eccentricity square; $f=\frac{a-b}{a}$ is ellipsoid flattening; a is the ellipsoid equatorial radius of the geodetic coordinate system (semi-major earth axis); b is the ellipsoid polar radius of the geodetic coordinate system (semi-minor earth axis).

Figure 5 is a flowchart illustrating the producing of 3-dimension movement information of the moving object according to an embodiment of the present invention. The 3-dimension movement information is the 3-dimension movement tracks of the moving object. Firstly, the 3-dimension acceleration information of the moving object is obtained (step S510); secondly, 3-dimension coordinates of each point are calculated based on the 3-dimension acceleration information of the moving object (step S520); and thirdly, the 3-dimension movement tracks of the moving object are plotted based on the 3-dimension coordinates of each point (step S530).

While the present invention is described in conjunction with specific embodiments, many alternatives, modifications and variations will be apparent to those ordinarily skilled in the art in light of the foregoing description. It is intended to embrace all such alternatives, modifications and variations as fall within the spirit and scope of the appended claims.

What is claimed is:

1. A method for positioning a moving object, comprising the steps:

a. determining 3 -dimension information of an original point of the moving object, which is based on a distinguishable coordinate system;

b. detecting a 3-dimension movement of the mov ing object and producing corresponding 3-dimension movement information;

c. transforming said 3-dimension movement information to information conforming to the distinguishable coordinate system.

2. The method according to claim 1 , wherein said distinguish able coordinate system is an Earth coordinate system.

3. The method according to claim 1 , wherein said 3 -dimension movement information is based on another coordinate system, the method further comprising the step:

detecting difference between said distinguis hable coordinate system and said another coordinate system.

4. The method according to claim 3, wherein said difference can be determined by detecting the direction angle between said distinguishable coordinate system and said another coordinate system.

5. The method according to claim 4, further comprising the step:

compensating the deviation of the Earth magnetic field between the direction of real north produced by the direction angle detection and the magnetic north pole of the Earth.

6. A system for mobile location, comprising:

an original point determining device for determining 3-dimension information of an original point of a moving object, which is based on a distinguishable coordinate system;

a 3 -dimension movement tracking device for detect ing a 3-dimension movement of said mov ing object and producing corresponding 3 -dimension movement information;

a data processing device for transform ing said 3 -dimension movement information to information conforming to said distinguishable coordinate system.

7. The system according to claim 6 , wherein said distinguish able coordinate system is an Earth coordinate system.

8. The system according to claim 6 , wherein said original point determining device is a GPS receiver for detecting the 3-dimension information of the original point of said mov ing obje ct, which is based on an Earth coordinate system.

9. The system according to claim 6, further comprising a storage for storing information.

10. The system according to claim 6 , wherein said 3 -dimension movement information is based on another coordinate system , and said 3 -dimension movement tracking device is used to detect difference between said distinguishable coordinate system and said another coordinate system.

11. The system according to claim 10, wherein said difference can be determined by detecting the direction angle between said distinguishable coordinate system and said another coordinate system.

12. A 3-dimension movement tracking device, comprising:

a 3 -dimension movement detecting device for detect ing a 3-dimension movement of a moving object and producing corresponding original information of the 3-dimension movement, which is based on a coordinate system;

a coordinate system difference detecting device for detecting difference between a distinguishable coordinate system and said a coordinate system;

wherein the original information and the difference being used to provide a position of the moving object in the distinguishable coordinate system.

13. The device according to claim 12 , wherein said distinguish able coordinate system is an Earth coordinate system.

14. The device according to claim 12 , wherein said 3 -dimension movement detecting device comprises a 3-dimension movement detecting sensor.

15. The device according to claim 12, wherein said coordinate system difference detecting device comprises a direction sensor for detecting the direction angle between said distinguish able coordinate system and said a coordinate system.

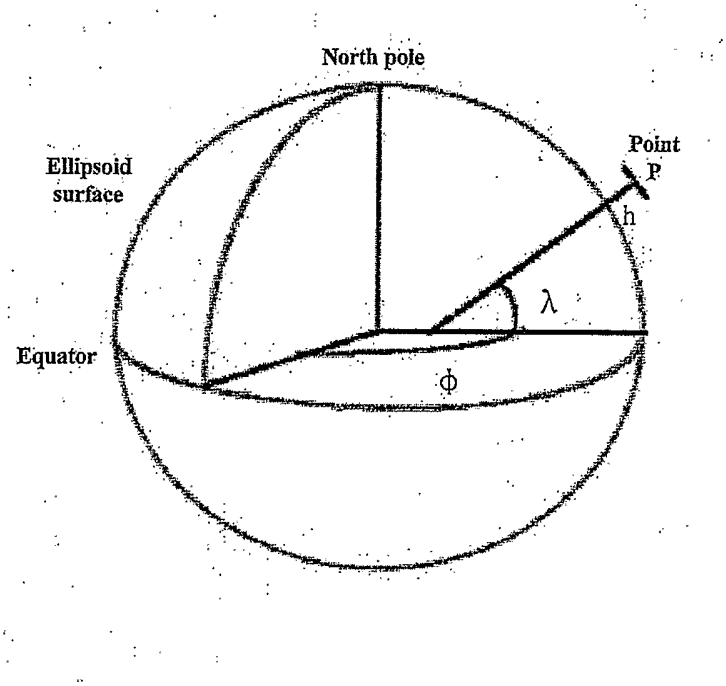

Fig. 1

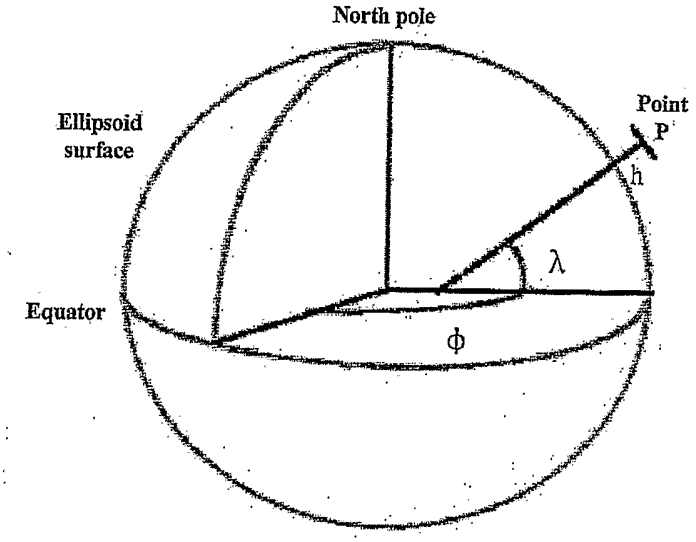

Fig. 2

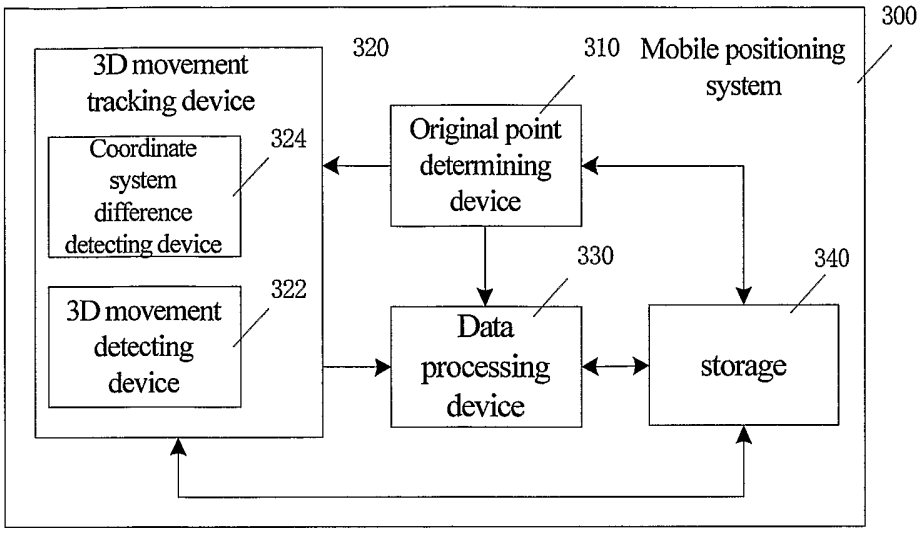
300
320
310
Mobile positioning system
3D movement tracking device
Original point determining device
324
Coordinate system difference detecting device
330
340
322
3D movement detecting device
Data processing device
storage

Fig. 3

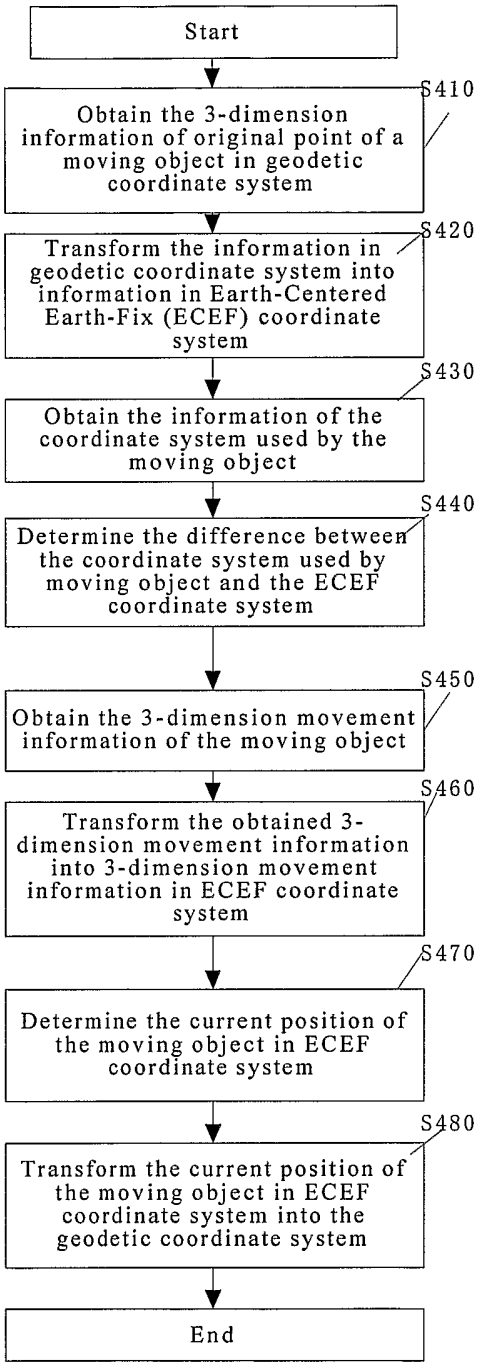
Start
S410
Obtain the 3-dimension information of original point of a moving object in geodetic coordinate system
S420
Transform the information in geodetic coordinate system into information in Earth-Centered Earth-Fix (ECEF) coordinate system
S430
Obtain the information of the coordinate system used by the moving object
S440
Determine the difference between the coordinate system used by moving object and the ECEF coordinate system
S450
Obtain the 3-dimension movement information of the moving object
S460
Transform the obtained 3-dimension movement information into 3-dimension movement information in ECEF coordinate system
S470
Determine the current position of the moving object in ECEF coordinate system
S480
Transform the current position of the moving object in ECEF coordinate system into the geodetic coordinate system
End

Fig. 4

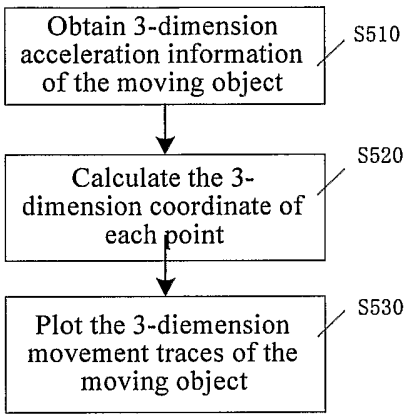
Obtain 3-dimension acceleration information of the moving object
S510
Calculate the 3-dimension coordinate of each point
S520
Plot the 3-diemension movement traces of the moving object
S530

Fig. 5

INTERNATIONAL SEARCH REPORT

IB2004/052765

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01S7/295 G01S5/14 G06F3/033

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01S G06F G05D B25J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 981 884 A (SATO ET AL) 9 November 1999 (1999-11-09) column 8, line 55 - column 13, line 24; figures 2,3,34,35	1-4,6,7, 9-15 8
X Y	US 5 587 558 A (MATSUSHIMA ET AL) 24 December 1996 (1996-12-24) column 8, line 8 - column 9, line 46; figure 1	1-4,6,7, 9-15 8
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[X] Further documents are listed in the continuation of box C.

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21 March 2005	01/04/2005

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