

PERSONAL INERTIAL NAVIGATION SYSTEM

TECHNICAL FIELD

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The present invention relates to a personal navigation system and in particular, to a personal inertial navigation system (PINS) using satellite networks and technology.

SUMMARY OF THE INVENTION

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Embodiments of the present invention provides a Personal Inertial Navigation System (PINS) that is capable of being deployed fast, independent of infrastructure setup such as Wi-Fi access points or Psudolite, without solely relying on navigation satellites and not affected by electromagnetic interference. Embodiments of the present invention provides a personal navigation system that integrates an inertial sensor suit which includes a gyroscope and an accelerometer. A satellite signal receiver and a Digital Signal Processor (DSP) are used to compute a target user's position based on the data from the inertial sensor suit and/or the received satellite signal. In the event of satellite signals outage, the target user's position can be solely calculated by the DSP with built-in algorithms, e.g. an Adaptive Kalman Filter Algorithm, based on the data obtained from the inertial sensor suit. When satellite signals become available and the Dilution of Precision (DOP) is good, more accurate position data of the target user can be determined by comparing the computed position data with the position data obtained based on the received satellite signals, by using a Kalman Filter Algorithm. The inertial sensor suit in the present invention does not include a magnetometer for measuring the heading of a target user, therefore the personal navigation system of the present invention is not affected by electromagnetic interference from surrounding environments.

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According to one embodiment of the present invention, the satellite signals can be obtained from both GPS and GLONASS networks, through a GPS+GLONASS receiver. With GPS and GLONASS networks combining, the number of satellites in view is increased and the positioning and navigation accuracy of the personal navigation system is

greatly improved, especially when the number of visible satellites drops due to dense forested terrain or surrounding buildings and structures.

Other aspects and advantages of the present invention will become apparent from the following detailed description, illustrating by way of example the inventive concept of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the present invention will be described in detail with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram showing a personal inertial navigation system according to one embodiment of the present invention;

Fig. 2 is a block diagram showing a personal inertial navigation system according to another embodiment of the present invention;

Fig. 3 shows the way for fitting the personal inertial navigation system according to embodiments of the present invention on a person.

Fig. 4 shows the process for calculating position of a target user by using the personal navigation system according to one embodiment of the present invention.

Fig. 5A-5C respectively shows the detailed steps of process 1-3 shown in Fig. 4 according to one embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Embodiments of the present invention use satellite signals together with signals from an inertial sensor suit in a personal navigation system for the positioning and navigation of a target user, or solely use signals from an inertial sensor suit for the

positioning and navigation of a target user when the satellite signals are not available or the DOP is not good enough.

As shown in Fig. 1, a personal navigation system 100 according to one
5 embodiment of the present invention includes a digital signal processor (DSP) 110, an inertial sensor suit 120 and a GPS receiver 130 coupled to DSP 110. The sensor suite includes a 3-axis accelerometer 122, a 3-axis Gyroscope 124 and a barometer 126, to enable measurements of position-related and/or motion-related data of the target user. In the event of complete visible satellite outage, DSP 110 reads the output from 3-axis
10 accelerometer 122, 3-axis Gyroscope 124 and barometer 126, and computes in real time the target user's Latitude, Longitude, and Altitude data using a non-magnetometer based algorithm. An Adaptive Kalman filter Algorithm 111 is provided in a movement profile and distance computation unit 112 to perform the computation. It should be noted that the barometer 126 is an optional element of the system 100. In some other personal
15 navigation systems, the barometer 126 may not be included if there is no interest in determining the Altitude of the target user. Additionally, the Adaptive Kalman filter 111 may be replaced with other types of algorithms, e.g. a Kalman filter, when the data readings from 3-axis accelerometer 122 and barometer 126 are processed.

20 The movement direction of the target user in real time is calculated by the DSP 110 with the built-in Adaptive Kalman filter algorithm 111, based on the 3D angular velocity data from the Gyroscope 124 and the initial heading data of the target user obtained from manual input or a digital compass. The 3D acceleration data from the accelerometer 122 is used to calculate by the DSP 110 the distance travelled in real time of the target user,
25 with the built-in Adaptive Kalman filter algorithm 111 in movement profile and distance computation unit 112. The Latitude and Longitude information of the target user therefore can be computed based on the movement direction and the distance travelled by the target user. When necessary, the Altitude of the target user is calculated by DSP 110, based on the data readings from the barometer 126, and processed with the built-in Adaptive
30 Kalman filter algorithm 111. It should be noted that a different algorithm may be used for calculating different position data, e.g. the Adaptive Kalman filter algorithm 111 is for

calculating the movement direction of the target user, while another algorithm maybe used for the calculation of other position data.

As shown in Fig. 1, system 100 may include a temperature sensor 140 coupled to DSP 110. Temperature sensor 140 provides the data for DSP 110 to compensate the temperature drift in 3-axis Gyroscope 124. In addition, the NMEA 0183(National Marine Electronics Association) output of the system 100 may be transmitted to external devices, e.g. a central controller (now shown), through a serial port 113, e.g. an RS422 or a Can bus interface.

When satellite signals are available, the position data of the target user, e.g. the user's Latitude, Longitude and Altitude data, can be obtained based on the satellite signals received through GPS receiver 130. These data can be compared with the position data of the target user computed based on the readings from the inertial sensor suit 120 to acquire more accurate position data using a Kalman Filter Algorithm. In the event of GPS satellite signals outage, the position data of the target user can be calculated solely based on the data related to the position of the target user from the inertial sensor suit 120.

In another embodiment as shown in Fig. 2, a personal navigation system 200 includes a 3-axis accelerometer 222, a 3-axis Gyroscope 224, and a barometer 226 coupled to a DSP 210. Personal navigation system 200 may further include a temperature sensor 240 coupled to DSP 210. The configurations, functions and working procedures of the above elements in system 200 are similar to those in the previous embodiment. In the present embodiment, system 200 further includes a GPS+GLONASS receiver 230. GLONASS is a satellite network established by Russian government with 24 satellites round the globe which provides signals which are accessible in Singapore geographical area. In situations where there are satellite signals blockage due to dense forested terrain or buildings and structures, the number of visible satellites in the GPS network may be reduced drastically. In such instances, a personal navigation system according to the present embodiment has the ability to enhance personal tracking using GPS + GLONASS network, as a supplement to the GPS-only satellite network. The GPS + GLONASS network can provide a total 36 to 42 satellites in operation. With GPS and GLONASS

network combining, the number of satellites in view is increased and the positioning and navigation accuracy is greatly improved..

A personal navigation system according to the embodiments of the present invention may be worn on the waist belt or sewed to the vest of a target user, as shown in Fig. 3. The personal navigation system according to the embodiments of the present invention may further comprise a wireless interface such as Bluetooth, WiFi or the like, to transmit its computed position data of a target user to a portable or handheld terminal. Graphical software may be utilized in a remote monitoring site such as a Command Post, showing 3D illustrations of the computed positions of a target user.

According to one embodiment of the present invention, a method for calculating position of a target user by using the personal inertial navigation system includes the following three major processes, as shown in Fig. 4.

Process 1: calculating the direction of the target user based on the readings from the 3-axis gyroscope and the readings from the 3-axis accelerometer.

Process 2: calculating the distance travelled of the target user based on the readings from the 3-axis accelerometer. Then the latitude and longitude data of the target user can be determined according to the direction obtained in Process 1 and the Distance travelled obtained in Process 2.

Process 3: calculating the Altitude of the target user based on the readings from the barometer.

Through the processes illustrated above, the Latitude, Longitude and Altitude information of the target user in real time can be obtained based on the readings from the sensor suit when satellite signals are not available, or the dilution of precision (DOP) is not good enough. If the satellite signals are available and the DOP is good enough, the computed position of the target user, e.g. Latitude, Longitude, Altitude of the target user, based on the readings from the sensor suit, can be compared with the position data of the

target user obtained based on the satellite signals received through GPS-only receiver or GPS+GLONASS receiver to determine more accurate position data, i.e. Latitude, Longitude and Altitude of the target user, by a predetermined estimation model, e.g. Kalman Filter Algorithm.

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The details of each process will be explained below.

Fig. 5A (1) shows the detailed steps of process 1 for calculating the direction of the target user according to one embodiment of the present invention, which includes the following steps.

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Step 5001, computing the angular velocity 3D vector and the acceleration 3D vector based on the readings from the 3-axis gyroscope and the 3-axis accelerometer.

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Step 5002, estimating heading of the target user according to the computed vectors by using an Adaptive Kalman Filter, to obtain the best possible heading. In this step, as shown in Fig. 5 A(2), the computed angular velocity 3D vector is fed to an adder together with a Angular velocity error determined by the Adaptive Kalman filter, based on the pre-calibrated data (known state) of the gyroscope's and accelerometer's gain and bias error, to determine a fixed Angular velocity. Then the fixed Angular velocity and the computed acceleration 3D vector are used to determine the best possible heading of the target user by the Adaptive Kalman filter.

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Step 5003, determining the Direction of the target user based on the estimated heading and the initial heading from manual input or a digital compass. In this step, both the estimated heading and the initial heading are fed to an adder to calculate the direction of the target user.

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Fig. 5B shows the detailed steps of process 2 for calculating the Distance Travelled of the target user according to one embodiment of the present invention, which includes the following steps.

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Step 5011, computing the acceleration 3D vector based on the readings from the 3-axis accelerometer.

5 Step 5012, estimating the stride distance and frequency based on the computed vector obtained from Step 5011 by using a Kalman filter.

Step 5013, computing the Distance Travelled by time integration.

10 Step 5014, categorizing movement profile of the target user into a predetermined model, according to the estimated stride distance and frequency. The movement profile may include the forward, backward, side movement, crawling or climbing movements of the target user.

15 In Step 5015, the stride distance for each of the predetermined movement profiles can be calibrated according to the Distance Travelled obtained based on the satellite signals from GPS-only or GPS+GLONASS receiver and the categorization in Step 5014 and the movement profile determined by the 3-axis gyroscope, such as forward, backward, side movement, crawling, and climbing. The calibrated stride distance and the corresponding movement profile may be stored in an EEPROM device.

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In Step 5016, when satellite signals are available and the dilution of precision (DOP) is good enough, comparing the computed Distance Travelled in Step 5013 with the Distance Travelled obtained based on the satellite signals from GPS-only or GPS+GLONASS receiver to determine more accurate Distance Travelled of the target user by using a Kalman filter.

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30 According to one embodiment of the present invention, the stride distance for each of the predetermined movement profiles can also be calibrated according to the accurate Distance Travelled obtained in Step 5015 and the movement profile determined by the 3-axis gyroscope, such as forward, backward, side movement, crawling, and climbing. The calibrated stride distance and the corresponding movement profile are stored in an EEPROM.

Fig. 5C shows the detailed steps of process 3 for calculating the Altitude of the target user according to one embodiment of the present invention, which includes the following steps.

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Step 5021, obtaining the Altitude of the target user according to the reading from the barometer by using a Kalman filter.

Step 5022, when satellite signals are available and the dilution of precision (DOP) is good enough, comparing the barometer altitude with the altitude of the target user obtained based on the satellite signals from GPS-only or GPS+GLONASS receiver to determine a more accurate altitude of the target user using a Kalman filter.

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Step 5023, if needed, calibrating the barometer according to the comparison result in Step 5022.

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With integrating GPS+GLONASS receiver to a non-compass/magnetometer assisted inertial personal navigation system for personal tracking, the error of distance travelled in any direction of any movement profile, e.g. walk, jog, back track and stationary, is less than 2%; the error of heading direction in any direction of any movement profile is less than 2°; the error of altitude is less than 1.5 m with 0.28 m resolution.

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Although embodiments of the present invention have been illustrated in conjunction with the accompanying drawings and described in the foregoing detailed description, it should be appreciated that the present invention is not limited to the embodiments disclosed. Therefore, the present invention should be understood to be capable of numerous rearrangements, modifications, alternatives and substitutions without departing from the spirit of the invention as set forth and recited by the following claims.

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CLAIMS

1. A personal navigation system comprising:
 - a digital signal processor;
 - 5 a satellite signal receiver coupled to the digital processor to receive satellite signals;
 - an inertial sensor suit coupled to the digital signal processor which includes an accelerometer and a gyroscope;
 - 10 wherein the digital signal processor estimates a user's direction based on the data from the accelerometer and the gyroscope, computing the user's distance travelled based on the data from the accelerometer.