[0121]

At Step S356, a current position (X_v, Y_v) is recalculated by using the corrected travel distance $L^{t(i)}_{co}$ calculated at Step S354, an estimated orientation $\theta^{t(i)}_e$ estimated at Step S32, the expression 17, and the expression 18. Here, a value on the z coordinate is regarded as unchanged.

[0122]

<Technical effects of embodiment>

In the present embodiment, when a Doppler velocity is calculated (S22), the Doppler velocity is used as a velocity initial value V^0 (S24) and, when the velocity of a vehicle is 0 km/h (S14), the velocity is used as a velocity initial value V^0 (S16). Further, when the expression (12), which is a tight coupling type estimation expression, can be solved, a velocity at the initial time obtained from the expression (12) is used as a velocity initial value V^0 (S28). A velocity initial value V^0 determined by any one of such methods has a good accuracy.

[0123]

Then an estimated velocity V_e is estimated by using the velocity initial value V^0 determined in this way and an acceleration integrated value ΔV_G (S30). After the velocity initial value V^0 is renewed therefore, the accuracy of an estimated velocity V_e that has deteriorated due to the cumulative error of the acceleration integrated value ΔV_G improves.

[0124]

In the present embodiment in addition, when a velocity initial value V^0 is determined, a corrected past velocity $V^{t(i)}_{co}$ is obtained by correcting a pre-correction past estimated velocity $V^{t(i)}_e$ which is an estimated velocity V_e after a time point t(N) when a velocity initial value V^0 is renewed previous time until a time point t(0) when a velocity initial value V^0 is renewed this time, so

CLAIMS

1. A travel distance estimation device comprising:

a traveling direction acceleration determination unit that successively determines a traveling direction acceleration, which is a traveling direction component of a detection value of an acceleration sensor moving together with a movable object;

an integration processing unit that successively calculates an acceleration integrated value by integrating the traveling direction accelerations determined by the traveling direction acceleration determination unit;

an initial setting value determination unit that determines, as a velocity initial value of the movable object, a velocity of the movable object calculated based on a Doppler shift amount from a satellite of a satellite positioning system or a velocity of the movable object at a time of stoppage of the movable object;

an estimated velocity determination unit that successively estimates an estimated velocity of the movable object based on the acceleration integrated value calculated by the integration processing unit and the velocity initial value determined by the initial setting value determination unit;

a travel distance calculation unit that successively calculates an estimated travel distance of the movable object based on the estimated velocity determined by the estimated velocity determination unit and a time;

a past velocity correction unit that, upon determining the velocity initial value by the initial setting value determination unit, determines corrected past velocities by correcting pre-correction past estimated velocities so that the corrected past velocities are continuous with the velocity initial value determined this time, wherein the pre-corrected past estimated

velocities are the estimated velocities that were successively determined by the estimated velocity determination unit during a time period from when the velocity initial value was determined by the initial setting value determination unit the previous time until the velocity initial value is determined by the initial setting value determination unit this time; and

a travel distance correction unit that, upon determining the corrected past velocities by the past velocity correction unit, recalculates based on the corrected past velocities and the time period an estimated travel distance during the time period from when the velocity initial value was determined by the initial setting value determination unit the previous time until the velocity initial value is determined by the initial setting value determination unit this time,

wherein

the integration processing unit successively calculates the acceleration integrated value and successively calculates a relative azimuth relative to the traveling direction at a base point of time by integrating a yaw rate detected by a yaw rate sensor, the yaw rate sensor detecting the yaw rate of the movable object;

the travel distance estimation device further comprising:

a satellite signal acquisition unit that acquires a satellite signal from the satellite of the satellite positioning system;

a satellite direction velocity calculation unit that calculates a satellite direction velocity based on the Doppler shift amount of a radio wave from the satellite, the satellite direction velocity being a component of a velocity of the movable object in the direction to the satellite; and

a line-of-sight vector calculation unit that calculates a line-of-sight vector from the movable object to the satellite based on the satellite signal,

wherein

the initial setting value determination unit determines, as the velocity initial value, the velocity of the movable object calculated based on the Doppler shift amount of the radio wave from the satellite of the satellite positioning system,

the initial setting value determination unit determines the velocity initial value based on:

a velocity estimation expression showing a relationship among the satellite direction velocity, the line-of-sight vector, the velocity of the mobile object, and a traveling orientation of the mobile object;

the satellite direction velocity calculated by the satellite direction velocity calculation unit;

the line-of-sight vector calculated by the line-of-sight vector calculation unit; and

the relative azimuth calculated by the integration processing unit, and

in an expression showing the relationship among the satellite direction velocity, the line-of-sight vector, and a velocity vector of the mobile object in the velocity estimation expression, a magnitude of the velocity vector is constrained by the velocity of the mobile object and a time variation of a direction of the velocity vector is constrained by a time variation of the azimuth of the mobile object in the traveling direction.

2. A travel distance estimation device comprising:

a traveling direction acceleration determination unit that successively determines a traveling direction acceleration, which is a traveling direction component of a detection value of an acceleration sensor moving together with a movable object;

an integration processing unit that successively calculates an acceleration integrated value by integrating the traveling direction

accelerations determined by the traveling direction acceleration determination unit;

an initial setting value determination unit that determines, as a velocity initial value of the movable object, a velocity of the movable object calculated based on a Doppler shift amount from a satellite of a satellite positioning system or a velocity of the movable object at a time of stoppage of the movable object;

an estimated velocity determination unit that successively estimates an estimated velocity of the movable object based on the acceleration integrated value calculated by the integration processing unit and the velocity initial value determined by the initial setting value determination unit;

a travel distance calculation unit that successively calculates an estimated travel distance of the movable object based on the estimated velocity determined by the estimated velocity determination unit and a time;

a past velocity correction unit that, upon determining the velocity initial value by the initial setting value determination unit, determines corrected past velocities by correcting pre-correction past estimated velocities so that the corrected past velocities are continuous with the velocity initial value determined this time, wherein the pre-corrected past estimated velocities are the estimated velocities that were successively determined by the estimated velocity determination unit during a time period from when the velocity initial value was determined by the initial setting value determination unit the previous time until the velocity initial value is determined by the initial setting value determination unit this time; and

a travel distance correction unit that, upon determining the corrected past velocities by the past velocity correction unit, recalculates based on the corrected past velocities and the time period an estimated travel distance during the time period from when the velocity initial value was determined by

the initial setting value determination unit the previous time until the velocity initial value is determined by the initial setting value determination unit this time,

the travel distance estimation device further comprising:

a satellite signal acquisition unit that acquires a satellite signal from the satellite of the satellite positioning system;

a satellite direction velocity calculation unit that calculates a satellite direction velocity based on the Doppler shift amount of a radio wave from the satellite, the satellite direction velocity being a component of a velocity of the movable object in the direction to the satellite; and

a line-of-sight vector calculation unit that calculates a line-of-sight vector from the movable object to the satellite based on the satellite signal,

wherein

the initial setting value determination unit determines, as the velocity initial value, the velocity of the movable object calculated based on the Doppler shift amount of the radio wave from the satellite of the satellite positioning system,

the initial setting value determination unit determines the velocity initial value of the movable object based on:

a velocity estimation expression showing a relationship among the satellite direction velocity, the line-of-sight vector, the velocity of the mobile object, a traveling orientation of the mobile object, and a clock drift;

the satellite direction velocity calculated by the satellite direction velocity calculation unit; and

the line-of-sight vector calculated by the line-of-sight vector calculation unit, and

in an expression showing the relationship among the satellite direction velocity, the line-of-sight vector, a velocity vector of the mobile object, and the clock drift in the velocity estimation expression, a magnitude of the velocity

vector is constrained by the velocity of the mobile object and the clock drift is constrained by a constraint condition that a time variation of the clock drift is linear.

3. The travel distance estimation device according to claim 1 or 2, further comprising:

an estimated orientation determination unit that successively determines a traveling orientation of the movable object; and

a position determination unit that, based on the estimated travel distance calculated by the travel distance calculation unit and the traveling orientation determined by the estimated orientation determination unit, successively determines a relative position of the movable object relative to a position determined the previous time,

wherein

upon recalculating by the travel distance correction unit the estimated travel distance, the position determination unit recalculates, based on the recalculated estimated travel distance and the traveling orientation determined by the estimated orientation determination unit, a relative position of the movable object after the velocity initial value was determined by the initial setting value determination unit the previous time until the velocity initial value is determined by the initial setting value determination unit this time.

4. The travel distance estimation device according to any one of claims 1 to 3, wherein

assuming a liner increase in errors of the pre-correction past estimated velocities, the past velocity correction unit determines the corrected past velocity this time by correcting each of the pre-correction past estimated

velocities with a correction amount obtained by multiplying the difference between the velocity initial value determined by the initial setting value determination unit and a latest pre-correction past estimated velocity by a coefficient corresponding to the time period after the time when the initial setting value determination unit determines the velocity initial value the previous time until the time when each of the pre-correction past estimated velocities is estimated.

5. The travel distance estimation device according to claim 1, wherein the velocity estimation expression includes a clock drift in addition to the satellite direction velocity, the line-of-sight vector, the velocity of the movable object, and the traveling orientation of the movable object.

6. The travel distance estimation device according to claim 5, wherein the velocity estimation expression is further constrained by a condition that a time variation of the clock drift is linear.

7. The travel distance estimation device according to any one of claims 1 to 6, wherein:

the velocity estimation expression includes a term of the initial velocity value and a term of the acceleration integrated value as a term of the velocity of the mobile object; and

when determining the velocity initial value by using the velocity estimation expression, the initial setting value determination unit determines the velocity initial value based on the acceleration integrated value calculated by the integration processing unit in addition to the velocity estimation expression, the satellite direction velocity calculated by the satellite direction velocity calculation unit, and the a line-of-sight vector calculated by the

line-of-sight vector calculation unit.