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(71) Demandeur/Applicant:
SAAB AB, SE

(72) Inventeur/Inventor:
HAGSTEDT, ANDERS, SE

(74) Agent: ROBIC

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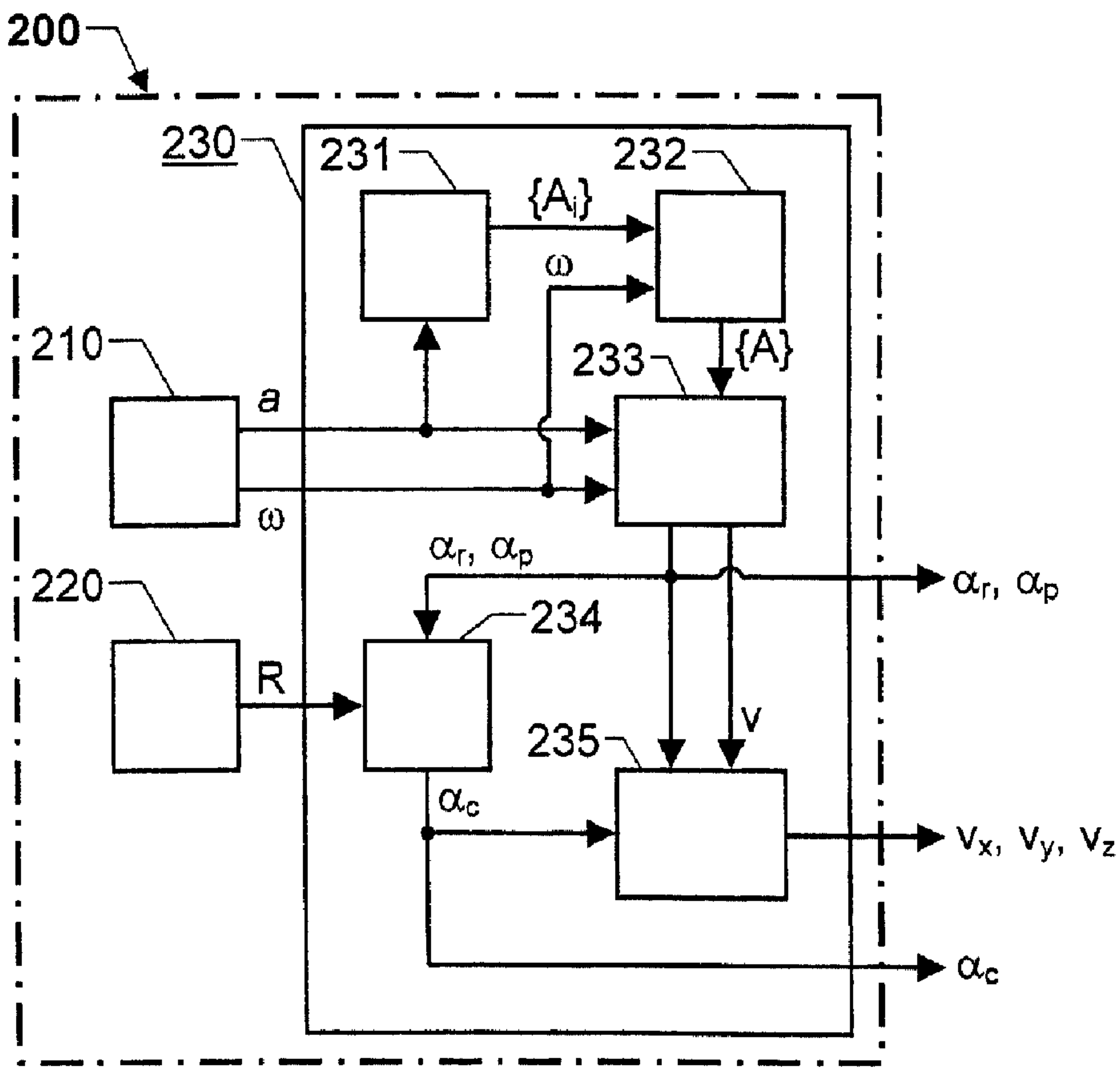
(54) Title: AUTONOMOUS VELOCITY ESTIMATION AND NAVIGATION



(57) Abrégé/Abstract:
The present invention relates to measurement of a spatial velocity vector (v_x, v_y, v_z), i.a. in order to make determination of a geographical position possible. A proposed spatial velocity meter (200) includes an inertial measurement unit (210), a direction-sensing module (220) and a velocity processor (230). The inertial measurement unit (210) registers acceleration parameters (a)

(57) **Abrégé(suite)/Abstract(continued):**
and angular velocity parameters (ω) in three dimensions. The direction-sensing module (220) registers a natural reference signal (R). The velocity processor (230) receives the acceleration parameters (a), the angular velocity parameters (ω) and the natural reference signal (R), and based thereon, generates the spatial velocity vector (v_x, v_y, v_z).

Abstract

The present invention relates to measurement of a spatial velocity vector (v_x, v_y, v_z), i.a. in order to make determination of a geographical position possible. A proposed spatial velocity meter (200) includes an inertial measurement unit (210), a direction-sensing module (220) and a velocity processor (230). The inertial measurement unit (210) registers acceleration parameters (*a*) and angular velocity parameters (ω) in three dimensions. The direction-sensing module (220) registers a natural reference signal (R). The velocity processor (230) receives the acceleration parameters (*a*), the angular velocity parameters (ω) and the natural reference signal (R), and based thereon, generates the spatial velocity vector (v_x, v_y, v_z).

Autonomous Velocity Estimation and Navigation

THE BACKGROUND OF THE INVENTION AND PRIOR ART

The present invention relates generally to navigation and velocity estimation in crafts and vehicles. More particularly the invention relates to a spatial velocity meter according to the preamble of claim 1, a navigation arrangement according to the preamble of claim 9, a method for spatial velocity estimation according to the preamble of claim 10 and a navigation method according the claim 19. The invention also relates to computer programs according to the claims 17 and 20 respective computer readable media according to the claims 18 and 21.

In the last decades, navigation systems have been developed which facilitate the determination of a position dramatically compared to the earlier known methods. These navigation systems determine positions on basis of accurate radio signals received from a plurality of satellites, and are commonly referred to as global navigation satellite systems (GNSS:s).

An alternative or complementary way to navigate and determine a craft's movement can be provided by an inertial measurement system (INS). The INS registers relative movements of the craft. Based on these movements, in turn, conclusions may be drawn as to the craft's speed and course. In case certain initial conditions are known, such as data defining a starting position and an initial speed, it is also possible to produce updated position information for the craft. The INS normally contains an inertial measurement unit (IMU), which in turn includes accelerometers and rate gyros. The accelerometers measure specific forces which are translated to a known coordinate frame with aid of angular measurements performed by the rate gyros. Newton's laws of motion are applied to generate velocity and attitude information.

The U.S. patent No. 6,449,559 describes a fully coupled positioning solution, wherein INS data is integrated with GPS data by means of a Kalman filter. Thereby, a positioning accuracy may be achieved, which is better than what would be possible to attain with a GPS receiver only.

The U.S. patent No. 6,170,344 discloses a purely IMU-based system for monitoring distortions in a pipeline. A so-called pipeline pig is here used to register parameters relating to accelerations and angular velocities. Based on these data, and a set of initial conditions in the form of an initial attitude matrix and an initial velocity vector, a Kalman filter is used to provide i.a. a velocity vector.

Hence, the prior art includes various solutions for positioning and determination of a craft's velocity based on IMU data. However, there is yet no example of a solution through which an accurate velocity vector may be determined without the input of artificially generated external information. Namely, either reception of GPS signals (or equivalent GNSS signals) is required, or an initial velocity vector must be supplied. This renders the known solutions comparatively vulnerable and sensitive to disturbances and spoofing.

SUMMARY OF THE INVENTION

The object of the present invention is therefore to provide an autonomous solution, which alleviates the problem above and thus provides a velocity vector without any artificially generated external information being required.

It is also an object of the invention to provide an autonomous navigation solution, which renders it possible to determine updated positions in the absence of information pertaining to an initial speed.

According to one aspect of the invention these objects are achieved by the initially described spatial velocity meter, which is characterized in that it comprises a direction-sensing module which is adapted to register a natural reference signal. Moreover, the velocity processor is adapted to receive the natural reference signal and determine the velocity vector on further basis of this signal. Thus, by means of the natural reference signal, attitude, velocity and acceleration of a craft may repeatedly be determined, and one or more velocity vectors may be expressed in relation to the earth.

Obviously, an important advantage attained thereby is that the velocity meter becomes robust and reliable, since it is independent from any artificially generated external input.

According to a preferred embodiment of this aspect of the invention, the direction-sensing module includes a magnetic measurement unit, which is adapted to register a field vector of the terrestrial magnetic field to represent the natural reference signal. Consequently, the velocity processor is adapted to receive the field vector and determine the velocity vector on further basis of this vector.

According to another preferred embodiment of this aspect of the invention, the velocity meter is adapted to be mounted in a craft in order to register the craft's spatial velocity along a longitudinal body axis of the craft. The velocity processor is adapted to implement an estimation procedure, for instance by means of a Kalman filter, which in turn is adapted to derive the at least one velocity vector based on a relationship between three dimensional forces and three dimensional angular velocities in respect of an axis being parallel to the longitudinal body axis of the craft. A velocity meter of this type is advantageous because thereby relevant velocity vectors and attitude angles, e.g. expressing roll and pitch, may be efficiently generated.

According to a preferred embodiment of this aspect of the invention, the velocity meter contains a plumb-bob module which is adapted to receive the acceleration parameters. In response to these parameters, the plumb-bob module produces a set of initial attitude parameters. Preferably, the velocity meter also contains an attitude-updating module, which is adapted to receive the set of initial attitude parameters and the angular velocity parameters. Based on these parameters, the attitude-updating module produces a set of updated attitude parameters.

According to a preferred embodiment of this aspect of the invention, the spatial velocity meter includes an error estimation module, which is adapted to receive the set of updated attitude parameters, the acceleration parameters and the angular velocity parameters. Based on these parameters, the error estimation module produces a craft velocity and at least one adjusted attitude angle. The proposed error estimation module is advantageous because thereby it possible to determine the amounts and signs of any measurement errors, and perform relevant adjustments.

According to a preferred embodiment of this aspect of the invention, the spatial velocity meter contains a course calculation module, which is adapted to receive the natural reference signal and the at least one adjusted attitude angle. Based thereon, the course calculation module produces a course angle, i.e. an angle expressing a course in relation to an absolute geographical reference. Naturally, this angle constitutes desirable information in most navigation applications.

According to a preferred embodiment of this aspect of the invention, the spatial velocity meter contains a velocity transform module, which is adapted to receive the craft velocity, the at least one adjusted attitude angle and the course angle. Based thereon, the velocity transform module produces the velocity vector, for example according to the so-called North/ East/Down coordinate frame. This is desirable because it renders it possible to express a craft's velocity in absolute terms with respect to a well-known reference.

According to another aspect of the invention these objects are achieved by the initially described navigation arrangement, which is characterized in that it includes the above proposed spatial velocity meter, which is adapted to produce the spatial velocity vector.

According to yet another aspect of the invention these objects are achieved by the initially described velocity estimation method, which is characterized by the steps of: registering a natural reference signal (e.g. by registering a field vector of the terrestrial magnetic field, or by other means receiving an initial heading input); and determining a velocity vector on basis of the acceleration parameters, the angular velocity parameters and the natural reference signal.

The advantages of this method are apparent from the discussion hereinabove with reference to the proposed velocity meter.

According to a further aspect of the invention these objects are achieved by a computer program directly loadable into the internal memory of a computer, comprising software for controlling the above proposed velocity estimation method when said program is run on a computer.

According to another aspect of the invention these objects are achieved by a computer readable medium, having a program recorded thereon, where the program is to make a computer control the above proposed velocity estimation method.

According to yet another aspect of the invention these objects are achieved by the initially described navigation method, which is characterized by estimating the spatial velocity according to the above proposed procedure.

According to a further aspect of the invention these objects are achieved by a computer program directly loadable into the internal memory of a computer, comprising software for controlling the above proposed navigation method when said program is run on a computer.

According to another aspect of the invention these objects are achieved by a computer readable medium, having a program recorded thereon, where the program is to make a computer control the above proposed navigation method.

Thereby, the invention offers a speed measurement and navigation tool for critical applications wherein a high accuracy and a high reliability is desired, and at the same time, independence from artificially generated external inputs is required.

Further advantages, advantageous features and applications of the present invention will be apparent from the following description and the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is now to be explained more closely by means of preferred embodiments, which are disclosed as examples, and with reference to the attached drawings.

Figure 1 shows a craft in relation to a coordinate system and a set of vectors being representative for the solution according to the invention,

Figure 2 shows a block diagram over a spatial velocity meter according to an embodiment of the invention,

Figure 3 illustrates, by means of a flow diagram, a general method of estimating a spatial velocity according to the invention,

Figure 4 shows a block diagram over a navigation arrangement according to an embodiment of the invention, and

Figure 5 illustrates, by means of a flow diagram, a general method of navigating according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Figure 1 shows a craft 110 in relation to a coordinate system x, y and z. A set of vectors is illustrated, which describes the movement of the craft's 110 body. This set of vectors includes a gravitation vector g^b, a velocity vector v^b, an acceleration vector $\dot{v}^b$ and an angular velocity vector ω^b. An IMU in the craft 110 is presumed to measure a specific force vector $f_s^{\,b}$ (e.g. force per unit mass), which may be expressed:

$$f_s^{\,b} = -g^b + \dot{v}^b + \omega^b \times v^b.$$

In so-called body-fixed coordinates, i.e. coordinates described in relation to the body of the craft 110, the gravitation vector g^b is given by:

$$g^b = c_n^b \cdot g^n = c_{n'}^b \cdot c_n^{n'} \cdot g^n = c_{n'}^b \cdot \begin{bmatrix} -\sin(d\theta) \\ \sin(d\phi)\cos(d\theta) \\ \cos(d\phi)\cos(d\theta) \end{bmatrix} \cdot g,$$

where c_n^b denotes a transformation matrix from an actual local system *n* to an actual body fixed system *b*,

$c_{n'}^b$ is a body attitude transformation matrix calculated by the proposed velocity processor,

$c_n^{n'}$ is a transformation matrix from the actual local system *n* to a calculated local level system *n'* represented by the calculated transformation to the actual body fixed system *b*, and

$d\phi$ and $d\theta$ constitute attitude errors as defined by rotations from the actual local system *n* to the calculated local level system *n'* about x- and y-axes in a horizontal plane in relation to the body.

Thus, provided that the force vector f_s^b is expressed as three linear sub vectors f_x, f_y and f_z, this gives:

$$\begin{bmatrix} f_x \\ f_y \\ f_z \end{bmatrix} = -\begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \cdot \begin{bmatrix} -\sin(d\theta) \\ \sin(d\phi)\cos(d\theta) \\ \cos(d\phi)\cos(d\theta) \end{bmatrix} \cdot g + \begin{bmatrix} \dot{v}_x \\ \dot{v}_y \\ \dot{v}_z \end{bmatrix} + \begin{bmatrix} 0 & -\omega_z & \omega_y \\ \omega_z & 0 & -\omega_x \\ -\omega_y & \omega_x & 0 \end{bmatrix} \cdot \begin{bmatrix} v_x \\ v_y \\ v_z \end{bmatrix}$$

where $\begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix}$ is the transform matrix $c_{n'}^b$,

$\dot{v}_x$, $\dot{v}_y$ and $\dot{v}_z$ are three linearly independent sub vectors of the acceleration vector $\dot{v}^b$,

$\begin{bmatrix} 0 & -\omega_z & \omega_y \\ \omega_z & 0 & -\omega_x \\ -\omega_y & \omega_x & 0 \end{bmatrix}$ is a matrix which represents the angular velocity vector ω^b, and

v_x, v_y and v_x are three linearly independent sub vectors of the velocity vector v^b,

By assuming that the main velocity component v is aligned with the body axis x, and that $d\phi$ and $d\theta$ are relatively small, the following expression is obtained:

$$\begin{bmatrix} f_x \\ f_y \\ f_z \end{bmatrix} = -\begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \cdot \begin{bmatrix} -d\theta \\ d\phi \\ 1 \end{bmatrix} \cdot g + \begin{bmatrix} \dot{v} \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 & -\omega_z & \omega_y \\ \omega_z & 0 & -\omega_x \\ -\omega_y & \omega_x & 0 \end{bmatrix} \cdot \begin{bmatrix} v \\ 0 \\ 0 \end{bmatrix} \qquad (1)$$

which may also be expressed as:

$$\begin{bmatrix} f_x \\ f_y \\ f_z \end{bmatrix} + \begin{bmatrix} g \cdot c_{13} \\ g \cdot c_{23} \\ g \cdot c_{33} \end{bmatrix} = \begin{bmatrix} g \cdot c_{11} & -g \cdot c_{12} & 0 & 1 \\ g \cdot c_{21} & -g \cdot c_{22} & \omega_z & 0 \\ g \cdot c_{31} & -g \cdot c_{32} & -\omega_y & 0 \end{bmatrix} \cdot \begin{bmatrix} d\theta \\ d\phi \\ v \\ \dot{v} \end{bmatrix} \qquad (2)$$

where c_{11}, c_{12}, c_{13}, c_{21}, c_{22}, c_{23}, c_{31}, c_{32}, and c_{33} represent the components of the body attitude transformation matrix $c_{n'}^{b}$ calculated by the proposed velocity processor,

g is regarded as known, or is a measured parameter representing the gravitation vector,

$d\phi$ and $d\theta$ are sought data in the form of errors in the calculated body attitude transformation matrix $c_{n'}^{b}$,

f_x, f_y and f_z represent data from the IMU in the form of forces in three dimensions,

ω_z and ω_y represent data from the IMU in the form angular rates about the body axes, and

v and $\dot{v}$ represent the desired output data in the form of velocity and acceleration respectively.

According to a preferred embodiment of the invention, the attitude transformation errors $d\phi$ and $d\theta$, the velocity data v and the acceleration data $\dot{v}$ in (2) (or (1)) are calculated repeatedly by means of an estimation function, which may be implemented as a Kalman filter. By registering a course angle in relation to an external reference which exists naturally (e.g. by registering a field vector of the terrestrial magnetic field, or by other means receiving initial heading data), the velocity and acceleration parameters v and $\dot{v}$ can be related to an external reference, such that a calculated velocity vector may be expressed in relation to the earth. This will be further explained below with reference to the figure 2 and 3.

Figure 2 shows a block diagram over a spatial velocity meter 200 according to an embodiment of the invention, which includes an inertial measurement unit 210, a direction-sensing module 220 and a velocity processor 230.

The inertial measurement unit 210 is adapted to register acceleration specific parameters *a* and angular velocity parameters ω in three dimensions x, y and z. The direction-sensing module

220 is adapted to register a natural reference signal R upon which a course angle α_c may be determined. Thus, the direction-sensing module 220 may include a magnetic measurement unit 220 which registers a field vector of the terrestrial magnetic field, and delivers this parameter to the velocity processor 230. Alternatively, the direction-sensing module 220 may receive a natural reference signal R in the form of an initial heading input, for instance via a manual entry, and forward this information to the velocity processor 230.

Besides the natural reference signal R, the velocity processor 230 receives the acceleration parameters *a* and the angular velocity parameters ω. Based on these parameters *a*, ω and R, the velocity processor 230 generates attitude angles of the craft 110 and a velocity vector v_x, v_y, v_z, which expresses a velocity in relation to the earth, for instance by means of the above-mentioned estimation function.

The velocity processor 230, in turn, may include a plumb-bob module 231 which is adapted to receive the acceleration parameters *a*. In response to these parameters *a*, the plumb-bob module 231 produces a set of initial attitude parameters $\{A_i\}$ representing an initial attitude of the craft in which the velocity meter 200 is mounted. An attitude-updating module 232 in the velocity processor 230 receives the set of initial attitude parameters $\{A_i\}$ and the angular velocity parameters ω. On basis thereof, the attitude updating module 232 produces a set of updated attitude parameters $\{A\}$, which represent a current orientation of the craft.

Preferably, the velocity processor 230 includes an error estimation module 233, which is adapted to receive the set of updated attitude parameters $\{A\}$, the acceleration parameters *a* and the angular velocity parameters ω. Based on these parameters $\{A\}$, *a* and ω, the error estimation module 233 produces a craft velocity v plus adjusted attitude angles α_r and α_p. The adjusted attitude angles α_r and α_p express appropriate correction angles with respect to the orientation of the craft, for example in terms of a roll angle α_r and a pitch angle α_p.

Moreover, it is preferable if the velocity processor 230 includes a course calculation module 234 and a velocity transform module 235. The course calculation module 234 receives the natural reference signal R plus the adjusted attitude angles α_r and α_p, and based thereon, produces a course angle α_c. The velocity transform module 235 receives the course angle α_c, the craft velocity v and the adjusted attitude angles α_r, and α_p. Based thereon, the velocity transform module 235, in turn, produces the at least one velocity v_x, v_y, and v_z in relation to the earth, which may be further used to generate positioning information. The details regarding this will be discussed below with reference to the figures 4 and 5.

A method of estimating a spatial velocity performed by the velocity meter described above is illustrated in figure 3 by means of a flow diagram. A first step 310 registers acceleration parameters and angular velocity parameters in three dimensions. Subsequently, or in parallel, a step 320 registers a natural reference signal. Finally, a step 330 determines a velocity vector on basis of the acceleration parameters, the angular velocity parameters and the natural reference signal. The velocity vector is generated by applying the equation (2) (or (1)) above in an estimation process which also may take into account any additional knowledge about the dynamics of the application. The procedure then loops back to the step 310.

According to a preferred embodiment of the invention, in a first run-through of the sequence, the step 330 involves the sub-step of producing a set of initial attitude parameters in response to the acceleration parameters. In each subsequent run-through of the sequence, however, a set of updated attitude parameters is produced on basis of a set of current angular velocity parameters received via the step 310.

It is also preferable if the step 330 involves the further sub-steps of producing a craft velocity and at least one adjusted attitude angle on basis of the updated attitude parameters, the acceleration parameters and the angular velocity parameters. Namely, based on the natural reference signal and the at least one adjusted attitude angle, yet a sub-step may calculate a course angle describing a course in relation to an absolute geographical reference. Moreover, the step 330 preferably involves a sub-step of producing the velocity vector on basis of the craft velocity, the at least one adjusted attitude angle and the course angle.

Figure 4 shows a block diagram over a navigation arrangement 400 according to an embodiment of the invention. The navigation arrangement 400 includes the proposed spatial velocity meter 200 for producing a velocity vector v_x, v_y and v_z, and an integrator module 436, which on one hand, receives the velocity vector v_x, v_y and v_z, and on the other hand, receives an initial position coordinate P_i indicating a geographic starting point for a craft. The integrator module 436 repeatedly generates an updated position coordinate P based on the initial position coordinate P_i and updated values of the velocity vector v_x, v_y and v_z.

Figure 5 illustrates, by means of a flow diagram, a general method of navigating according to the invention.

A first step 510 receives an initial position coordinate. Then, a step 520 determines a spatial velocity based on registered acceleration parameters and registered angular velocity parameters according to the proposed procedure, i.e. as described above with reference to the figure 3. After that, a step 530 integrates the spatial velocity vector with respect to a previous position (which primary is equal to the initial position coordinate received in the step 510). Subsequently, a step 540 determines an updated position coordinate based on the integration, where after the procedure loops back to the step 520.

All of the process steps, as well as any sub-sequence of steps, described with reference to the figures 3 and 5 above may be controlled by means of a programmed computer apparatus, preferably located in the proposed navigation arrangement. Moreover, although the embodiments of the invention described above with reference to the drawings comprise computer apparatus and processes performed in computer apparatus, the invention thus also extends to computer programs, particularly computer programs on or in a carrier, adapted for putting the invention into practice. The program may be in the form of source code, object code, a code intermediate source and object code such as in partially compiled form, or in any other form suitable for use in the implementation of the process according to the invention. The carrier may be any entity or device capable of carrying the program. For example, the carrier may comprise a storage medium, such as a ROM (Read Only Memory), for example a CD (Compact Disc) or a semiconductor ROM, or a magnetic recording medium, for example a floppy disc or hard disc. Further, the carrier may be a transmissible carrier such as an electrical or optical signal which may be conveyed via electrical or optical cable or by radio or by other means. When the program is embodied in a signal which may be conveyed directly by a cable or other device or means, the carrier may be constituted by such cable or device or means. Alternatively, the carrier may be an integrated circuit in which the program is embedded, the integrated circuit being adapted for performing, or for use in the performance of, the relevant processes.

The term “comprises/comprising” when used in this specification is taken to specify the presence of stated features, integers, steps or components. However, the term does not preclude the presence or addition of one or more additional features, integers, steps or components or groups thereof.

The invention is not restricted to the described embodiments in the figures, but may be varied freely within the scope of the claims.

Claims

1. A spatial velocity meter (200) comprising:

an inertial measurement unit (210) adapted to register acceleration parameters (a) and angular velocity parameters (ω) in three dimensions (x, y, z); and

a velocity processor (230) adapted to receive the acceleration parameters (a), receive the angular velocity parameters (ω), and based on at least these parameters, generate a velocity vector (v_x, v_y, v_z) expressing a velocity in relation to the earth, **characterized in that**

the velocity meter (200) comprises a direction-sensing module (220) which is adapted to register a natural reference signal (R), and

the velocity processor (230) is adapted to receive the natural reference signal (R) and determine the velocity vector (v_x, v_y, v_z) on further basis of the natural reference signal (R).

2. A spatial velocity meter (200) according to claim 1, **characterized in that** the direction-sensing module (220) comprises a magnetic measurement unit which is adapted to register a field vector (B) of the terrestrial magnetic field to represent the natural reference signal (R), and the velocity processor (230) is adapted to receive the field vector (B) and determine the velocity vector (v_x, v_y, v_z) on further basis of the field vector (B).

3. A spatial velocity meter (200) according to any one of the claims 1 or 2, **characterized in that** it is adapted to be mounted in a craft (110) to register the craft's (110) spatial velocity, and the velocity processor (230) is adapted to implement an estimation procedure, which in turn is adapted to derive the velocity vector (v_x, v_y, v_z) based on a relationship between three dimensional forces and three dimensional angular velocities in respect of an axis (x) being parallel to a longitudinal body axis of the craft (110).

4. A spatial velocity meter (200) according to any one of the preceding claims, **characterized in that** it comprises a plumb-bob module (231) adapted to receive the acceleration parameters (*a*) and in response thereto produce a set of initial attitude parameters ($\{A_i\}$).

5. A spatial velocity meter (200) according to claim 4, **characterized in that** it comprises an attitude updating module (232) adapted to receive the set of initial attitude parameters ($\{A_i\}$), receive the angular velocity parameters (ω) and based thereon produce a set of updated attitude parameters ($\{A\}$).

6. A spatial velocity meter (200) according to claim 5, **characterized in that** it comprises an error estimation module (233) adapted to receive the set of updated attitude parameters ($\{A\}$), receive the acceleration parameters (*a*), receive the angular velocity parameters (ω), and based thereon produce a craft velocity (v) and at least one adjusted attitude angle (α_r, α_p).

7. A spatial velocity meter (200) according to claim 6, **characterized in that** it comprises a course calculation module (234) adapted to receive the natural reference signal (R), receive the at least one adjusted attitude angle (α_r, α_p), and based thereon produce a course angle (α_c).

8. A spatial velocity meter (200) according to claim 7, **characterized in that** it comprises a velocity transform module (235) adapted to receive the craft velocity (v), receive the at least one adjusted attitude angle (α_r, α_p), receive the course angle (α_c), and based thereon produce the velocity vector (v_x, v_y, v_z).

9. A navigation arrangement (400) for determining a geographical position of a craft (110), comprising:

an integrator module (436) adapted to receive an initial position coordinate (P_i), receive a velocity vector (v_x, v_y, v_z), and based thereon, generate an updated position coordinate (P),

characterized in that the navigation arrangement comprises a spatial velocity meter (200) according to any of the claims 1 - 8, and the spatial velocity meter (200) being adapted to produce the velocity vector (v_x, v_y, v_z).

10. A method for spatial velocity estimation comprising registering acceleration parameters (*a*) and angular velocity parameters (ω) in three dimensions, **characterized by** the steps of:

registering a natural reference signal (R); and

determining a velocity vector (v_x, v_y, v_z) on basis of the acceleration parameters (*a*), the angular velocity parameters (ω) and the natural reference signal (R).

11. A method according to claim 10, **characterized by** the registration of the natural reference signal (R) involving registering a field vector (B) of the terrestrial magnetic field; and the determination of the velocity vector (v_x, v_y, v_z) being based on the field vector (B).

12. A method according to any one of the claims 10 or 11, **characterized by** producing a set of initial attitude parameters ($\{A_i\}$) in response to the acceleration parameters (*a*).

13. A method according to claim 12, **characterized by** producing a set of updated attitude parameters ($\{A\}$) on basis of the set of initial attitude parameters ($\{A_i\}$) and the angular velocity parameters (ω).

14. A method according to claim 13, **characterized by** producing a craft velocity (v) and at least one adjusted attitude angle (α_r, α_p) on basis of the updated attitude parameters ($\{A\}$), the acceleration parameters (*a*), and the angular velocity parameters (ω).

15. A method according to claim 14, **characterized by** calculating a course angle (α_c) on basis of the natural reference signal (R) and the at least one adjusted attitude angle (α_r, α_p).

16. A method according to claim 15, **characterized by** producing the velocity vector (v_x, v_y, v_z) on further basis of the craft velocity (v), the at least one adjusted attitude angle (α_r, α_p), and the course angle (α_c).

17. A computer program directly loadable into the internal memory of a computer, comprising software for controlling the steps of any of the claims 10 – 16 when said program is run on the computer.

18. A computer readable medium, having a program recorded thereon, where the program is to make a computer control the steps of any of the claims 10 – 16.

19. A navigation method comprising the steps of:

receiving an initial position coordinate (P_i);

registering acceleration parameters (*a*) and angular velocity parameters (ω) in three dimensions;

estimating a spatial velocity in relation to the earth based on at least the acceleration and the angular velocity parameters (a, ω); and

determining an updated position coordinate (P) based on the initial position coordinate (P_i) and an integration of the velocity vector (v_x, v_y, v_z), **characterized by** estimating the spatial velocity according to any of the claims 10 – 16.

20. A computer program directly loadable into the internal memory of a computer, comprising software for controlling the method of the claim 19 when said program is run on the computer.

21. A computer readable medium, having a program recorded thereon, where the program is to make a computer control the method of the claim 19.

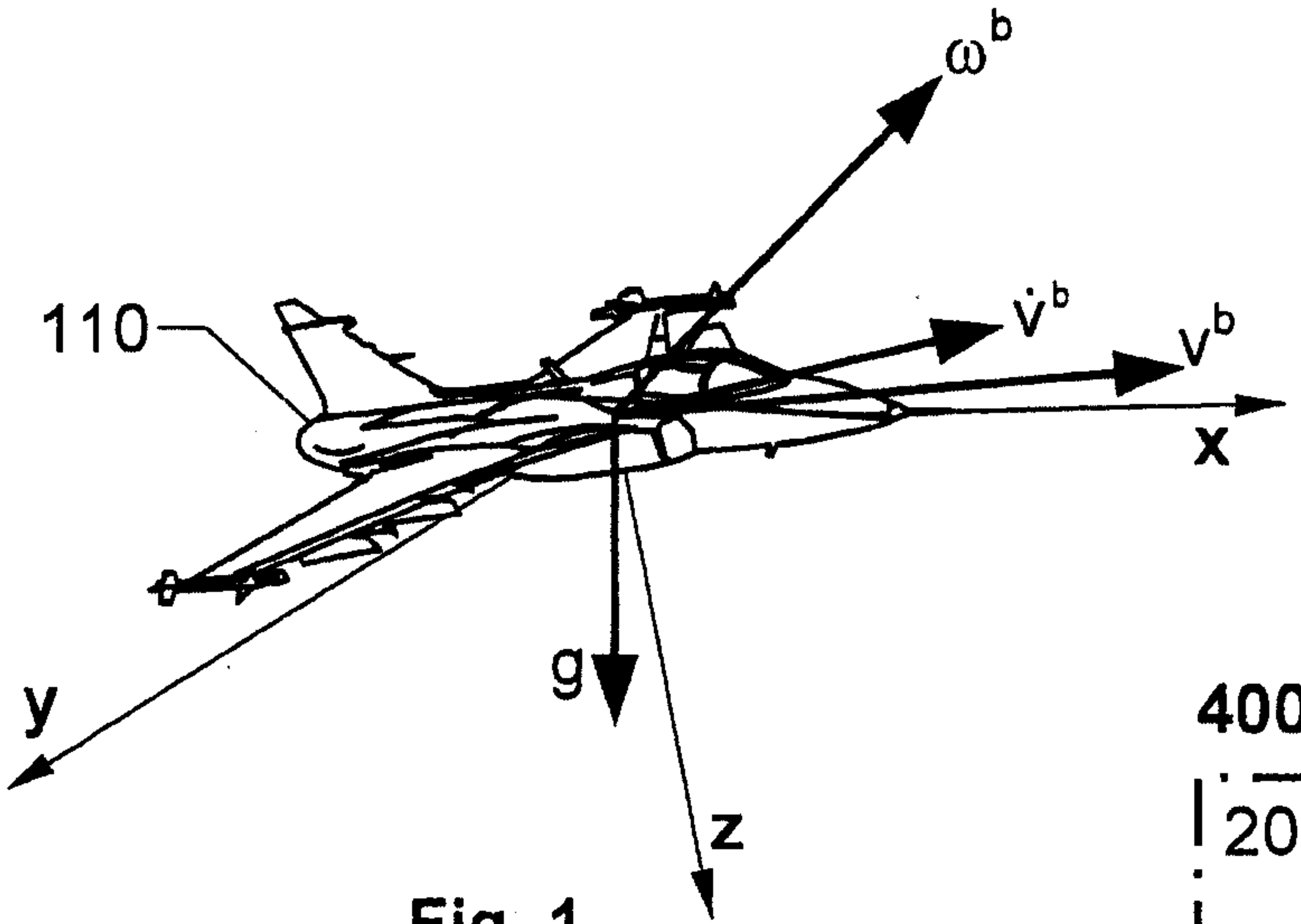


Fig. 1

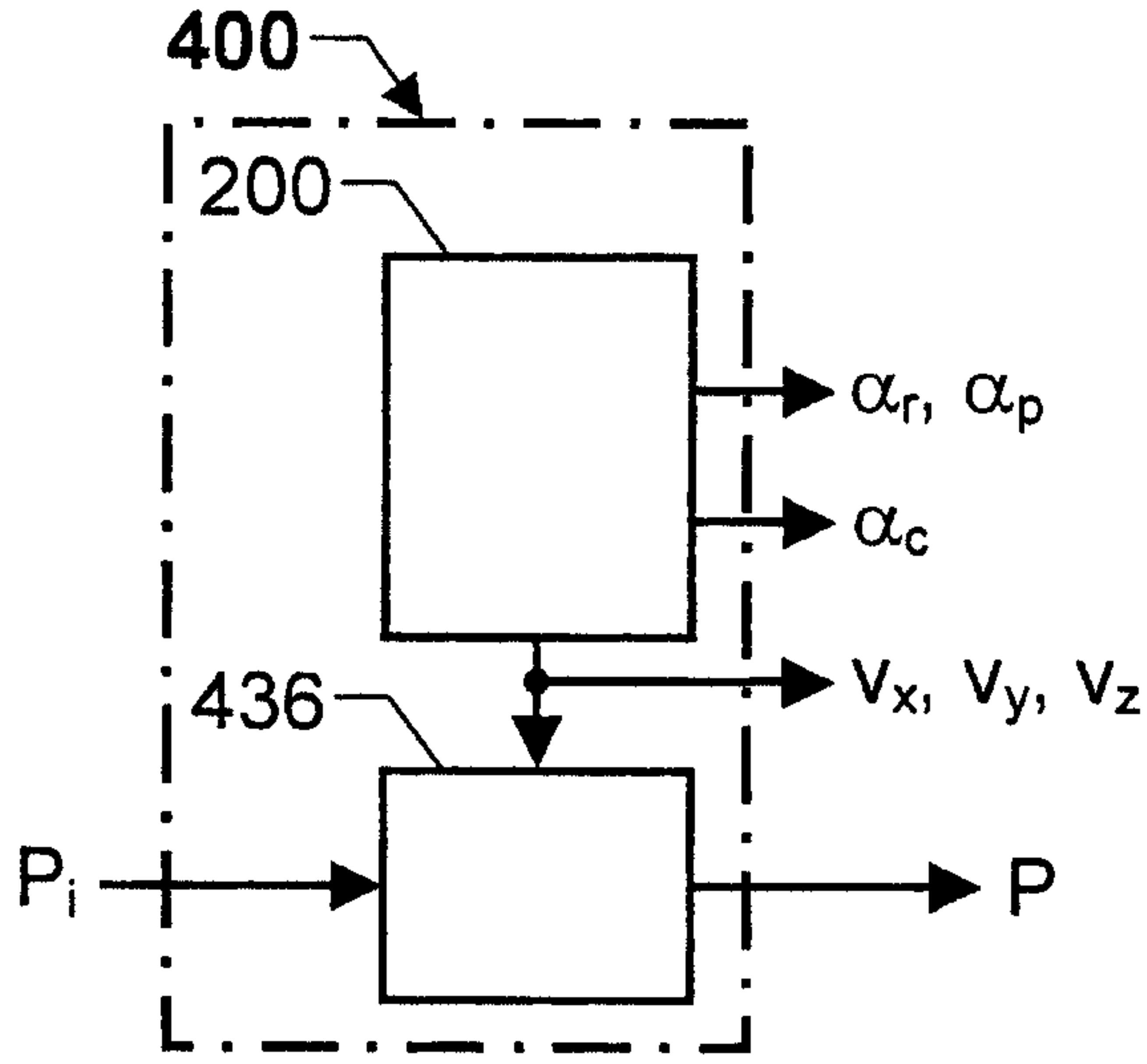


Fig. 4

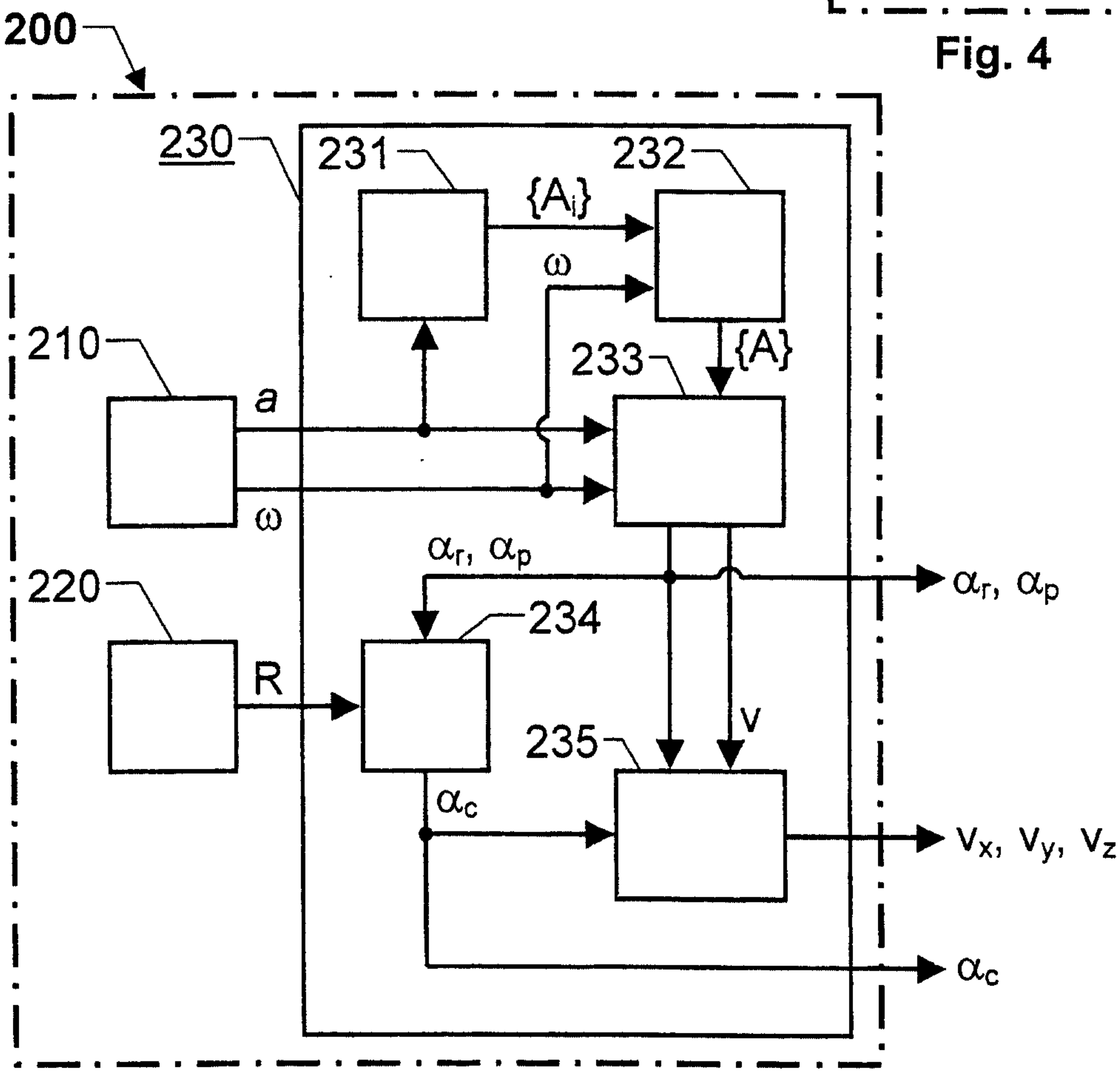


Fig. 2

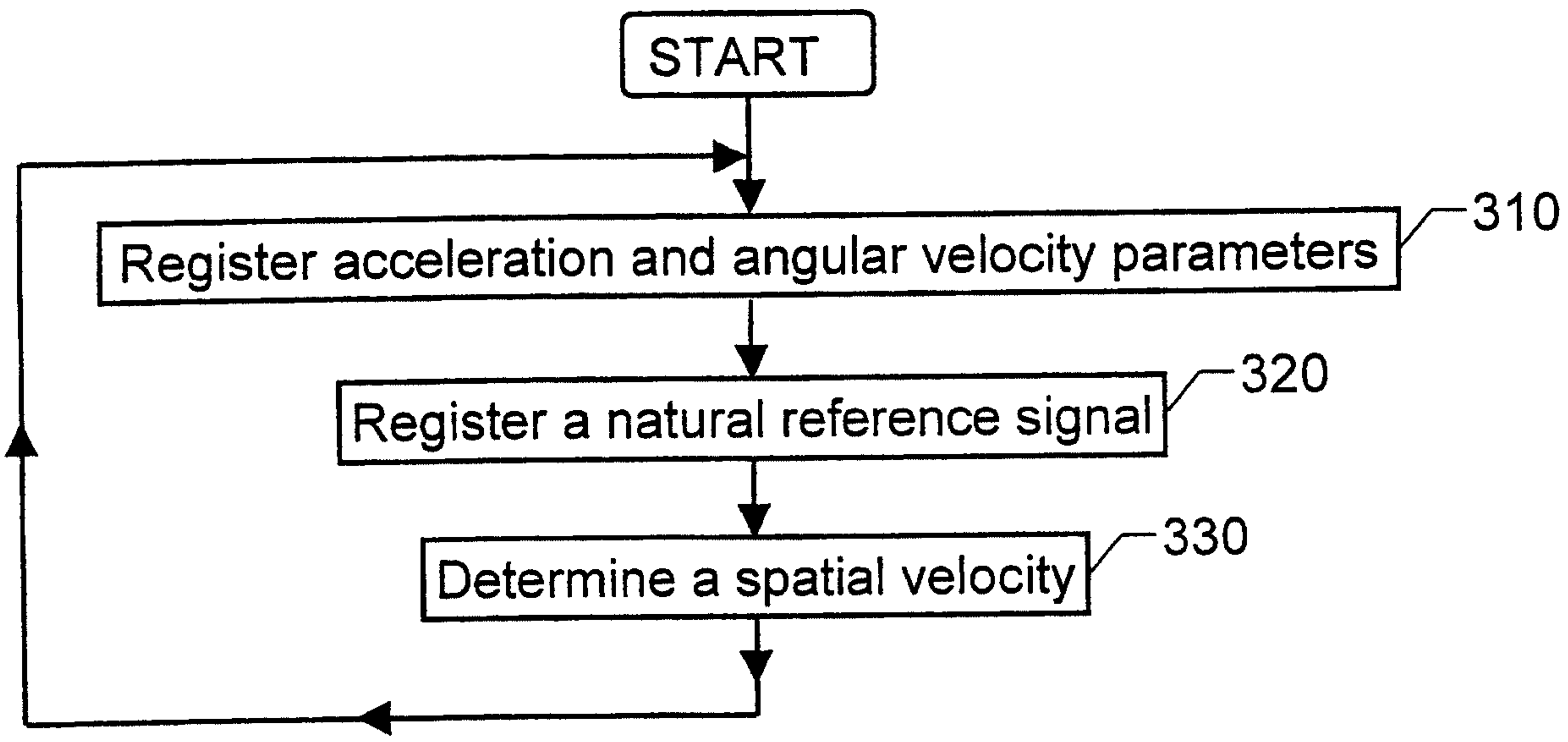

START
Register acceleration and angular velocity parameters
310
Register a natural reference signal
320
Determine a spatial velocity
330

Fig. 3

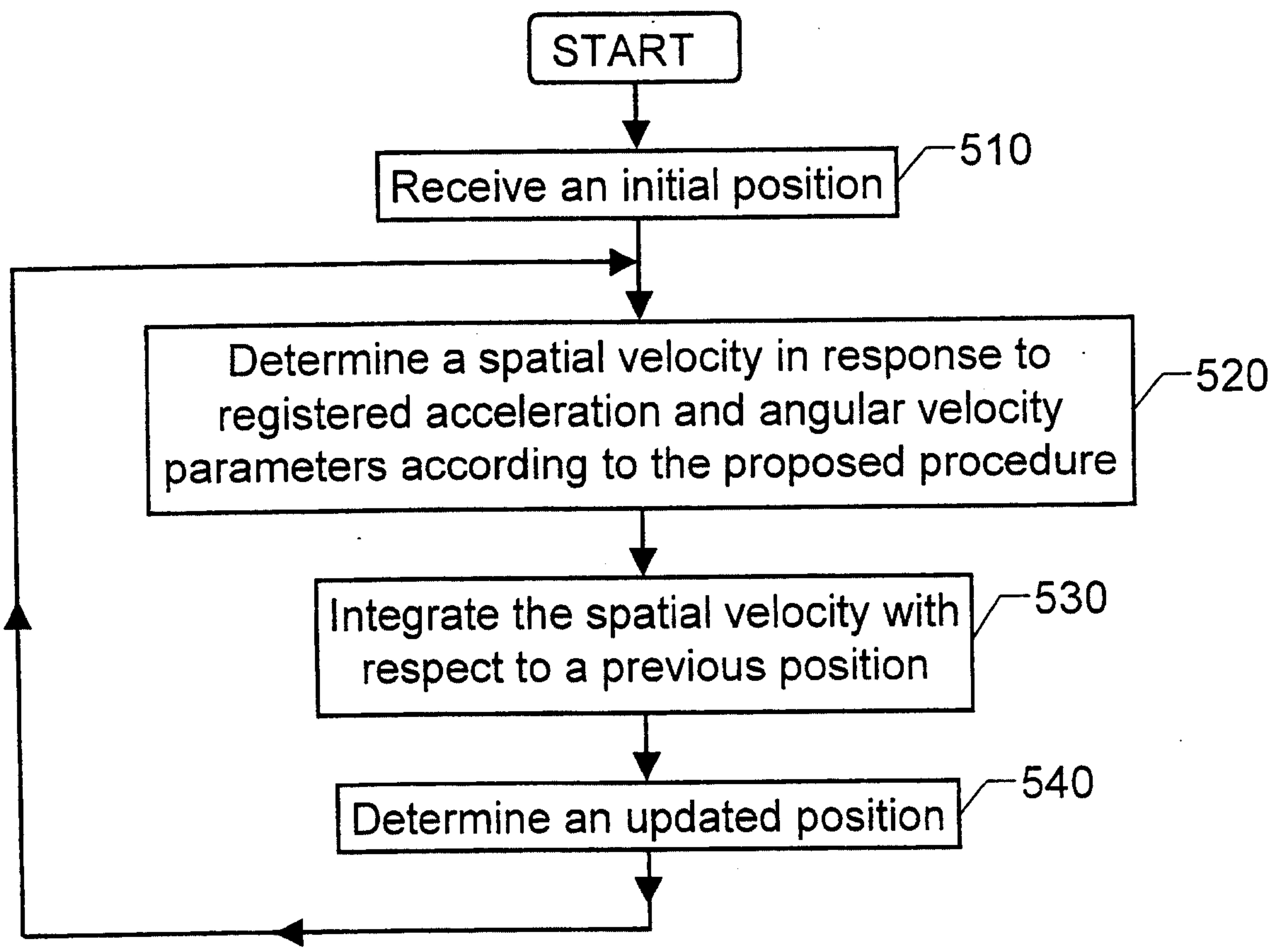
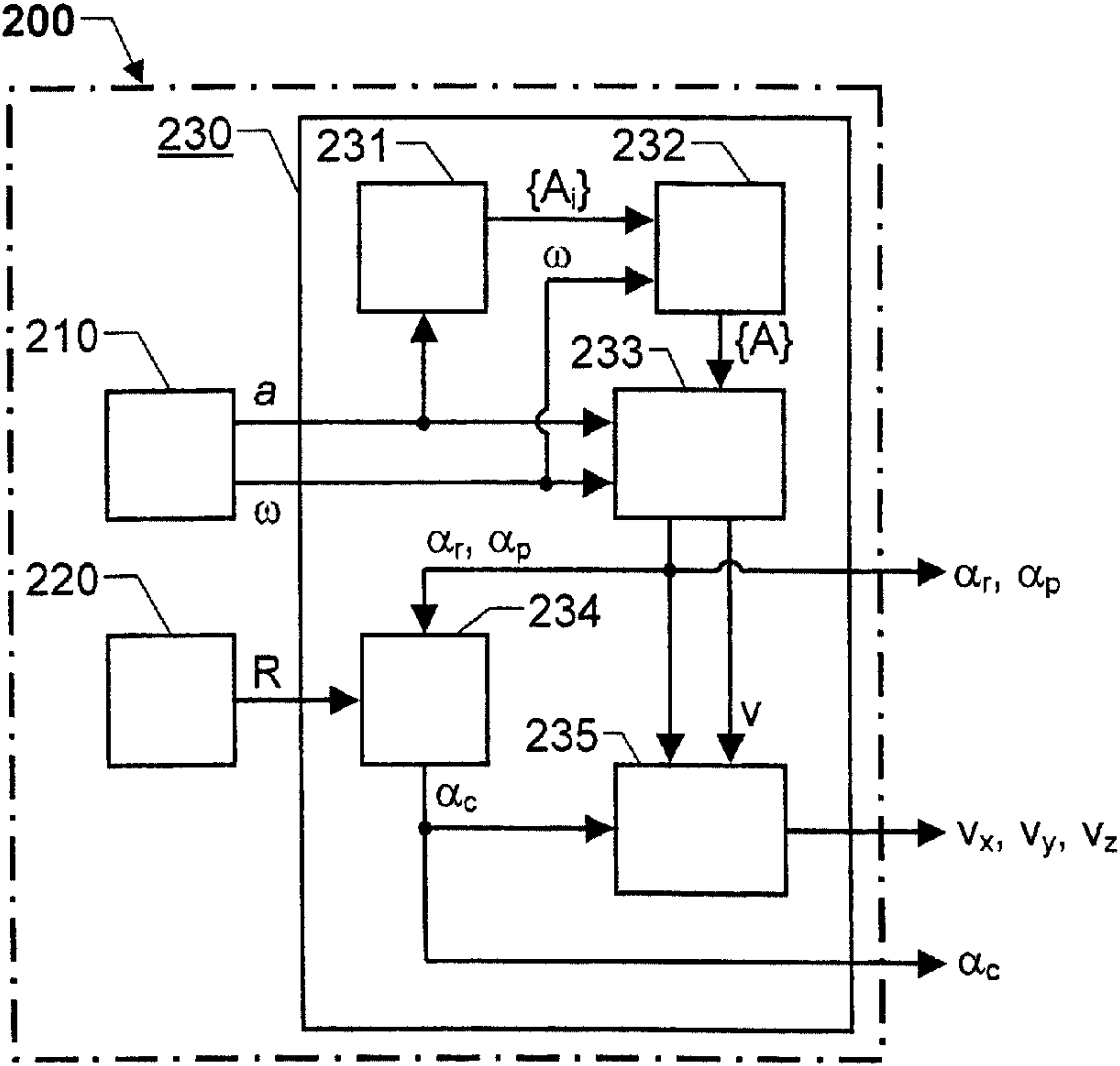

START
Receive an initial position
510
Determine a spatial velocity in response to registered acceleration and angular velocity parameters according to the proposed procedure
520
Integrate the spatial velocity with respect to a previous position
530
Determine an updated position
540

Fig. 5


200
230
231
232
{Ai}
ω
210
{A}
233
a
ω
αr, αp
220
234
αr, αp
R
V
235
αc
Vx, Vy, Vz
αc