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(54) DISPLACEMENT MEASUREMENT IN A FALL DETECTION SYSTEM

WEGMESSUNG IN EINEM FALLERKENNUNGSSYSTEM

MESURE DE DÉPLACEMENT DANS UN SYSTÈME DE DÉTECTION DE CHUTE

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Description

TECHNICAL FIELD OF THE INVENTION

5 **[0001]** The invention relates to the measurement of the displacement of an object, and in particular to a method and system for the measurement of the displacement of an object during a fall using an accelerometer.

BACKGROUND TO THE INVENTION

10 **[0002]** Three-dimensional accelerometers can be attached to objects, and can measure the acceleration of the object in three dimensions. As part of these measurements, the accelerometer measures accelerations on the object caused by gravity.

15 **[0003]** Generally, a personal fall detection system comprises a user worn sensor module that is arranged to wirelessly send out an alarm signal to the remaining part of the system in the event that an emergency situation is detected. Such a sensor module may comprise an alarm button that the user can press to have the module send out the alarm signal or a detector that detects if a user has fallen, whereby the sensor module automatically sends out an alarm signal.

20 **[0004]** Many existing automatic fall detection solutions are based on measuring acceleration of the daily activities and falls of the user with a fall detector attached to the body, usually at the waist. The basic principle of these fall detection solutions is to detect the large or significant impact caused by the body hitting the ground during a fall. Some solutions can also detect the change in orientation of the body caused by a fall, which improves the success rate in detecting falls.

25 **[0005]** MAARIT KANGAS ET AL: "Determination of simple thresholds for accelerometry-based parameters for fall detection", Eng. in Med and Bio. Soc., 2007. EMBS 2007. 29th Annual Int. Conf. of the IEEE, IEEE, Piscataway, NJ, USA, 1 August 2007, pages 1367-1370, and LINDEMANN U ET AL: "Evaluation to a fall detector based on accelerometers: a pilot study", Med. and Bio. Eng. and Comp., Springer, Heidelberg, vol. 43, no. 5, 1 September 2005, pages 548-551, both disclose a personal fall detection system based on accelerometers wherein the instants preceding the impact are monitored, in particular the sensors velocity.

[0006] However, the existing solutions still have an unacceptably high false alarm rate. This is because measuring the change in body orientation in conjunction with detecting the occurrence of a large impact is often not sufficient to distinguish all daily activities of a user from a fall.

30 **[0007]** The fall detection system can be provided with additional functionality to generate more information about the activities of the user, which can improve the performance. In particular, adding a displacement measurement sensor to the sensor module can improve the performance. This is because going from a standing position to falling onto

35 **[0008]** the ground results in the height of the sensor module decreasing by about the height from the waist to the ground, if the sensor module is attached to the waist. This displacement information is useful for distinguishing some daily activities from falls and improves the fall detection performance.

[0009] Integrating a barometer into an accelerometer-based fall detection system that allows absolute height to be measured from air pressure, fulfills the above requirement. However, including this type of additional component in the sensor module leads to increased energy consumption and size for the system. In addition, measurements by barometers can be adversely affected by changes in the environment, such as a change in the ambient pressure or temperature.

40 **[0010]** Therefore, there is a need for an alternative methodology for measuring the displacement of a sensor module that includes an accelerometer.

SUMMARY OF THE INVENTION

45 **[0011]** According to a first aspect of the invention, there is provided a personal fall detection system comprising the features of claim 1.

[0012] Preferably, the processor is adapted to determine that the sensor module has suffered an impact if the measured accelerations are characteristic of a collision with a solid object.

50 **[0013]** Preferably, the processor is adapted to determine that the sensor module has suffered an impact if a magnitude of the measured acceleration exceeds a predetermined threshold.

[0014] Alternatively, the processor is adapted to determine that the sensor module has suffered an impact if the magnitude of the acceleration measured in a specified direction exceeds a predetermined threshold.

[0015] Alternatively, the processor is adapted to determine that the sensor module has suffered an impact if a variance of the measurements from the accelerometer exceeds a predetermined threshold.

55 **[0016]** Preferably, the processor is further adapted to identify an impact time, the time at which the sensor module suffered the impact.

[0017] Preferably, the processor is adapted to identify the impact time by examining a time stamp of the measured accelerations.

[0018] Preferably, the processor is further adapted to identify an onset time, the time at which the sensor module started to move prior to the impact.

[0019] Preferably, the processor is adapted to identify the onset time by examining the measured accelerations before the impact to identify a stable period in which the measured accelerations vary by less than a predetermined threshold, and to identify the onset time as the time at which the stable period ends.

[0020] Alternatively, or in addition, the processor is adapted to identify the onset time by examining the measured accelerations before the impact to identify a variation in the direction of the measured acceleration that is above a predetermined threshold, and to identify the onset time as the time at which the variation in the direction first exceeded the threshold.

[0021] Preferably, the processor is adapted to estimate the vertical displacement of the sensor module by twice integrating the measurements from the accelerometer between the onset time and impact time.

[0022] Preferably, the processor is adapted to estimate the gravitational acceleration at the onset time by identifying the component of the measured acceleration at the onset time that acts in a vertical direction.

[0023] Preferably, the processor is adapted to subtract the estimated gravitational acceleration from the measurements that are used by the processor to estimate the vertical displacement of the sensor module.

[0024] Preferably, the means is further adapted to trigger an alarm if it is determined that a fall has taken place.

[0025] In some embodiments, the processor is part of the sensor module. However, in other embodiments, the processor is part of a base unit that is separate to the sensor module.

[0026] According to a second aspect of the invention, there is provided a method comprising the steps of claim 14.

[0027] According to a third aspect of the invention, there is provided a computer program product for performing the method described above when executed on a computer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The invention will now be described, by way of example only, with reference to the following drawings, in which:

Fig. 1 shows a fall detection system in accordance with the invention;

Fig. 2 is a block diagram showing the sensor module of the fall detection system in more detail;

Fig. 3 is a flow chart illustrating a method in accordance with the invention;

Fig. 4 is an illustration of a sensor module and user falling; and

Fig. 5 is a graph showing some exemplary measurements from an accelerometer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] Figure 1 shows a fall detection system in use by a user 2. The fall detection system comprises a sensor module 4 that is worn by the user 2 and a base unit 6. The sensor module 4 can be worn on any part of the user's body, but it is preferred that it is worn around the user's waist or chest in order to improve the detection of any falls.

[0030] The sensor module 4 comprises at least an accelerometer for measuring the acceleration experienced by the sensor module 4 and some means for communicating with the base unit 6. If the sensor module 4 detects a fall or other alarm condition, the sensor module 4 communicates with the base unit 6, and the base unit 6 can issue or trigger an alarm.

[0031] In alternative embodiments, the functionality of the sensor module 4 and base unit 6 can be combined into a single device.

[0032] Figure 2 shows the sensor module 4 in more detail. In this embodiment, the sensor module 4 comprises an accelerometer 8 that measures the acceleration experienced by the sensor module 4 in three dimensions, and a processor 10 for determining whether a fall has taken place from the accelerometer 8 measurements. The accelerometer 8 can measure the acceleration continuously or at discrete intervals and can time-stamp each measurement (although it is possible for the processor 10 to time-stamp the measurements as they are written into the memory 18). The sensor module 4 also comprises an antenna 12 and associated transceiver circuitry 14 for communicating with the base unit 6, an alarm unit 16 for issuing an alarm signal or tone in the event that an alarm condition is detected and a memory 18 for storing a set of measurements from the accelerometer 8.

[0033] In a preferred embodiment, the memory 18 is a circular buffer or similar type of device that continuously or periodically stores the measurements covering a particular time period from the accelerometer 8 for subsequent retrieval by the processor 10. Thus, when the memory 18 is full, further measurements will overwrite the oldest measurements stored in the memory 18 so that the memory 18 contains the n most recent accelerometer measurements covering a specific time interval T preceding the present. Clearly, the memory 18 must have sufficient capacity to store accelerometer measurements covering at least the time taken for a fall. For example, a memory 18 that can store accelerometer measurements covering a period of five seconds should be sufficient for implementing the invention.

[0034] In accordance with the invention, the displacement of the sensor module 4 is estimated by twice integrating

the measurements from the accelerometer 8. By making this displacement estimation available to a fall detection algorithm executing in the processor 10, the performance of the false alarm rate of the fall detection system can be improved.

[0035] Figure 3 illustrates a method of estimating the displacement of the sensor module 4 in accordance with an embodiment of the invention. The method starts at step 101 when an impact occurs. An "impact" is defined as a measurement or set of measurements from the accelerometer 8 that are characteristic of a collision with a solid object, such as the ground. In particular, an impact can be a measurement whose magnitude exceeds a predetermined threshold or a measurement along a particular axis or in a particular direction whose magnitude exceeds a predetermined threshold. Alternatively, as an impact will result in a large variance in the output from the accelerometer 8, an impact can be identified by comparing the variance in the measurements to a predetermined threshold. The processor 10 can identify the impact by examining the measurements from the accelerometer 8 as they are stored in the memory 18.

[0036] As described above, the accelerometer 8 continuously or periodically provides measurements of the acceleration to the memory 18 for storage. Therefore, at the point that the processor 10 determines that an impact has occurred (which may be shortly after the impact has occurred due to processing delays or through confirming the fall by examining subsequent accelerometer measurements), the memory 18 will contain measurements of the acceleration covering a time interval T.

[0037] In step 103, the processor 10 determines the time that the impact occurred. To do this, the processor 10 examines the accelerometer measurements stored in the memory 18 to identify the highest or peak acceleration measurement that is associated with the impact. If the accelerometer 8 provides separate measurements of the acceleration along each of the three-dimensional axes, the processor 10 can examine the magnitude of the acceleration vector to determine the highest or peak acceleration.

[0038] Once the peak measurement is found, the time of the measurement is determined from the associated timestamp, and this time is recorded as t_{impact} .

[0039] Once the impact time has been determined, the method identifies the time at which the fall started t_{onset} (step 105).

[0040] Preferably, the method determines t_{onset} from the accelerometer measurements stored in the memory 18. To do this, the processor examines the accelerometer measurements in the memory 18 preceding the measurement at time t_{impact} to identify if the measurements exhibit a stable period where the magnitude and/or direction of the acceleration measured by the accelerometer 8 do not significantly vary.

[0041] In particular, it has been noted that measurements by an accelerometer 8 before a fall starts are generally stable, in that the variance of the measurements is below a predetermined threshold. Therefore, the processor 10 can examine the measurements stored in the memory 18 for a stable period preceding the impact at t_{impact} , and the time that the fall started can be determined as the time associated with the accelerometer measurement at the end of this stable period.

[0042] In addition or alternatively to the above, the direction of the acceleration measured by the accelerometer 8 can start to change at the onset of a fall, so the processor 10 can examine the stored measurements to identify a period before the impact time t_{impact} in which the direction starts to change at a rate that is higher than a predetermined threshold. The fall onset time t_{onset} can be determined as the time associated with the accelerometer measurement at the start of this period of direction change.

[0043] If the processor 10 identifies an onset time using both of these methods, the processor 10 can take an average of the times to use as t_{onset} .

[0044] If the processor 10 is unable to identify a stable period in the stored measurements or a period in which the direction of the acceleration starts to change (or if the processor 10 wants to verify the reliability of either or both of these measurements), the processor 10 can estimate the onset time using the following:

[0045] From

$$H = \frac{1}{2}gt_{\text{fall_duration}}^2 \tag{1}$$

where H is the height displacement, g is acceleration due to gravity, and $t_{\text{fall-duration}}$ is the duration of the fall, we obtain:

$$t_{\text{fall_duration}} = \sqrt{\frac{2H}{g}} \tag{2}$$

[0046] Therefore, if the height displacement is assumed to be around 0.8 to 1 meter (based on the sensor module being worn around a user's waist, the time at which the fall started can be determined from:

$$t_{\text{onset}} = t_{\text{impact}} - t_{\text{fall_duration}} \quad (3)$$

[0047] It will be appreciated that this value for t_{onset} is only strictly suitable for an object or person in free fall, but it is used here as an approximate value for normal (non-free) falls.

[0048] In step 107, the processor 10 estimates the gravitational acceleration on the accelerometer 8 when the fall started (i.e. at time t_{onset}). This is done by identifying the component of the accelerometer 8 measurement at t_{onset} (or just before t_{onset}) that corresponds to gravity. If it is assumed that the y-axis of the accelerometer 8 is perpendicular to the ground (see Figure 4), the processor 10 can estimate the gravitational acceleration on the accelerometer 8 at t_{onset} by taking the y-component of the t_{onset} measurement.

[0049] In step 109, the processor 10 calculates the displacement that has taken place during the fall.

[0050] As shown in Figure 4, it is assumed that the sensor module 4 is attached to the user's waist and that the y-axis of the accelerometer 8 in the sensor module 4 is pointing downwards, in the direction that gravity will act when the sensor module 4 is in its normal orientation.

[0051] The acceleration represented by the measurements from the accelerometer 8 is a superposition of gravity and accelerations caused by external forces. As the external forces on the sensor module 4 at the fall onset time t_{onset} are unknown, the displacement calculated in this step is an approximate value.

[0052] It will be appreciated that it is only necessary to calculate the displacement in the gravity direction. Therefore, the acceleration in the x, y and z axes must be mapped to the gravity direction according to the orientation of the sensor module 4. However, it can be seen in Figure 4 that the orientation of the sensor module 4 changes during a fall, because the sensor module 4 follows an arc to the floor instead of a straight line downwards.

[0053] In the approximation, it is assumed that the initial force acting in the gravity (y-axis) direction is zero. Therefore, equation (3) can be used to estimate the fall onset time t_{onset} .

[0054] In most cases of a forward/backward (i.e. along the z-axis) or left/right side (i.e. along the x-axis) fall, one axis will always be perpendicular to the direction in which gravity acts and can be omitted from the calculation, since gravity will not have a component along that axis during the fall. For example, in the forward fall illustrated in Figure 1, the x-axis does not need to be considered.

[0055] In forward/backward falls, the accelerations along the y-axis and z-axis contribute to the vertical displacement via the angle Φ (it is assumed that the x-axis is perpendicular to the direction in which gravity acts at all times during the fall). The angle Φ can be estimated by

$$\Phi = \arccos(y/r) \quad (4)$$

where

$$r = \sqrt{x^2 + y^2 + z^2} \quad (5)$$

[0056] Since the measurements from the accelerometer 8 will consist of two parts, gravity and the other accelerations on the sensor module 4, gravity is compensated for by subtracting the initial y-axis measurement y_{initial} obtained in step 107.

[0057] The displacement of the sensor module 4 during the fall can then be obtained from the y- and z-axis components of the measurements over the period $t_{\text{fall_duration}}$ by evaluating equation (6) below.

$$\begin{aligned}
 H &= \iint_{t_{fall_duration}} (y \cos \Phi + z \sin \Phi - y_{init}) dt dt \\
 H &= \iint_{t_{fall_duration}} \left(\frac{-y^2}{\sqrt{x^2 + y^2 + z^2}} + z \sqrt{\frac{x^2 + z^2}{x^2 + y^2 + z^2}} - y_{init} \right) dt dt \\
 H &= \iint_{t_{fall_duration}} \left(\frac{y^2 + z \sqrt{x^2 + z^2}}{\sqrt{x^2 + y^2 + z^2}} - y_{init} \right) dt dt \tag{6}
 \end{aligned}$$

[0058] Figure 5 shows an exemplary graph illustrating a displacement calculation in accordance with the invention. The three lines represent the x-, y- and z-axis measurements from the accelerometer 8 for the time interval T for a forward fall. The displacement calculation twice integrates the acceleration measurements between the fall onset point and the "hitting ground" point, and results in a vertical displacement of 105.54 centimeters.

[0059] It will be appreciated that the above algorithm calculates the displacement when the fall is a forward fall or a backward fall. Based on same principle, if the fall is a left or right side fall, the x-axis and y-axis readings will be used in the calculation.

[0060] In a more general case, all components of acceleration will be used in the displacement calculation. In this case, the displacement is calculated by evaluating

$$\begin{aligned}
 H &= \iint_{t_{fall_duration}} (y \cos \Phi + x \sin \Phi_x + z \sin \Phi_z - \Omega \cos \Phi) dt dt \\
 H &= \iint_{t_{fall_duration}} \left(\frac{-y(y - \Omega)}{\sqrt{x^2 + y^2 + z^2}} - \frac{x^2}{\sqrt{x^2 + y^2}} + \frac{z^2}{\sqrt{y^2 + z^2}} \right) dt dt \tag{7}
 \end{aligned}$$

where Φ_x and Φ_z are the components of Φ in the X-Y and Y-Z planes respectively, and Ω is the acceleration due to gravity (9.8ms^{-2}).

[0061] The displacement estimation algorithm presented above can be integrated into a fall detection system that also includes orientation and impact detection. When the sensor module detects an orientation change and a big impact, it will ascertain the time of impact t_{impact} and calculate the displacement. If the displacement value is reasonable (say 0.5 to 1.5 meters), then the processor 10 can classify the impact as a fall, otherwise, the processor 10 can ignore the impact.

[0062] For example, the user may suddenly rotate the sensor module 90 degrees in their hands and generate a big impact, but the calculated displacement will be near to zero, so the processor 10 will decide that a fall has not taken place.

[0063] The displacement calculation according to the invention provides the advantages that the false alarm rate of detecting falls can be improved, no height sensor is needed, which may increase the energy consumption and volume of the sensor module 4 and that as the complexity of the quadratic integration calculation is low, it can be easily exploited in a sensor module for a fall detection system.

[0064] Although the invention has been described as implemented completely in the sensor module, it will be appreciated that part of the method can be implemented by a processor in the base unit 6 of the personal fall detection system. For example, the sensor module 4 can transmit all accelerometer measurements to the base unit 6 for analysis by a processor in that unit 6.

[0065] In addition, although the invention provides a method and apparatus for approximately determining a change in height of a sensor module resulting from a fall, based only on measurements made by an accelerometer, it will be appreciated that the invention can be used to determine displacement during other events that have characteristic start and end points represented in the accelerometer measurements, and in which the orientation of the accelerometer may change.

[0066] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments.

[0067] Variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word

"comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope. A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems.

Claims

1. A personal fall detection system (4) comprising:

a sensor module (4) that is suitable for attachment to a user (2), the sensor module (4) comprising an accelerometer (8) for measuring accelerations acting on the sensor module (4), a processor (10) for analysing the measured accelerations to determine if the sensor module (4) has suffered an impact, and for estimating a vertical displacement of the sensor module (4) during a time period immediately before the impact; wherein the processor (10) estimates the vertical displacement of the sensor module (4) by twice integrating the measurements from the accelerometer (8); and means for determining if a fall has taken place using the estimated vertical displacement of the sensor module.

2. A personal fall detection system as claimed in claim 1, wherein the processor is adapted to determine that the sensor module has suffered an impact if:

the measured accelerations are characteristic of a collision with a solid object;
a measured acceleration exceeds a predetermined threshold;
an acceleration measured in a specified direction exceeds a predetermined threshold; or
a variance of the measurements from the accelerometer exceeds a predetermined threshold.

3. A personal fall detection system as claimed in any preceding claim, wherein the processor is further adapted to identify an impact time, the time at which the sensor module suffered the impact.

4. A personal fall detection system as claimed in claim 3, wherein the processor is adapted to identify the impact time by examining a time stamp of the measured accelerations.

5. A personal fall detection system as claimed in any preceding claim, wherein the processor is further adapted to identify an onset time, the time at which the sensor module started to move prior to the impact.

6. A personal fall detection system as claimed in claim 5, wherein the processor is adapted to identify the onset time by examining the measured accelerations before the impact to identify a stable period in which the measured accelerations vary by less than a predetermined threshold, and to identify the onset time as the time at which the stable period ends.

7. A personal fall detection system as claimed in claim 5 or 6, wherein the processor is adapted to identify the onset time by examining the measured accelerations before the impact to identify a variation in the direction of the measured acceleration that is above a predetermined threshold, and to identify the onset time as the time at which the variation in the direction first exceeded the threshold.

8. A personal fall detection system as claimed in claim 5, 6 or 7, when dependent on claim 3 or 4, wherein the processor is adapted to estimate the vertical displacement of the sensor module by twice integrating the measurements from the accelerometer between the onset time and impact time.

9. A personal fall detection system as claimed in any of claims 5, 6, 7 or 8, wherein the processor is adapted to estimate the gravitational acceleration at the onset time by identifying the component of the measured acceleration at the onset time that acts in a vertical direction.

10. A personal fall detection system as claimed in claim 9, wherein the processor is adapted to subtract the estimated gravitational acceleration from the measurements that are used by the processor to estimate the vertical displacement

of the sensor module.

11. A personal fall detection system as claimed in claim 1, wherein the means is further adapted to trigger an alarm if it is determined that a fall has taken place.

12. A personal fall detection system as claimed in any preceding claim, wherein the processor is part of the sensor module.

13. A personal fall detection system as claimed in any of claims 1 to 11, further comprising a base unit (6) separate to the sensor module, the processor (10) being part of the base unit.

14. A method for use in a personal fall detection system comprising a sensor module that is suitable for attachment to a user, the method comprising:

measuring accelerations acting on the sensor module;

analysing the measured accelerations to determine if the sensor module has suffered an impact;

estimating a vertical displacement of the sensor module during a time period immediately before the impact by twice integrating the measurements from the accelerometer; and

determining if a fall has taken place using the estimated vertical displacement of the sensor module.

15. A computer program product comprising computer code embodied therein, the computer code, when executed on a computer, performing the method as claimed in claim 14.

Patentansprüche

1. Persönliches Sturzerkennungssystem (4) mit:

einem Sensormodul (4), das sich zur Befestigung an einem Benutzer (2) eignet, wobei das Sensormodul (4) einen Beschleunigungsmesser (8) umfasst, um auf das Sensormodul (4) einwirkende Beschleunigungen zu messen;

einem Prozessor (10) zum Analysieren der gemessenen Beschleunigungen, um zu ermitteln, ob das Sensormodul (4) einen Aufprall erlitten hat, und um eine vertikale Verschiebung des Sensormoduls (4) während eines Zeitraumes unmittelbar vor dem Aufprall zu berechnen, wobei der Prozessor (10) die vertikale Verschiebung des Sensormoduls (4) durch zweimaliges Integrieren der Messungen von dem Beschleunigungssensor (8) berechnet; sowie

Mitteln, um unter Verwendung der berechneten vertikalen Verschiebung des Sensormoduls zu ermitteln, ob ein Sturz stattgefunden hat.

2. Persönliches Sturzerkennungssystem nach Anspruch 1, wobei der Prozessor so eingerichtet ist, dass er feststellt, dass das Sensormodul einen Aufprall erlitten hat, wenn:

die gemessenen Beschleunigungen Kennzeichen eines Zusammenstoßes mit einem Festkörper sind;

eine gemessene Beschleunigung einen zuvor festgelegten Schwellwert überschreitet;

eine in einer spezifizierten Richtung gemessene Beschleunigung einen zuvor festgelegten Schwellwert überschreitet; oder

eine Abweichung der Messungen von dem Beschleunigungsmesser einen zuvor festgelegten Schwellwert überschreitet.

3. Persönliches Sturzerkennungssystem nach einem der vorangegangenen Ansprüche, wobei der Prozessor weiterhin so eingerichtet ist, dass er einen Aufprallzeitpunkt, d.h. den Zeitpunkt, zu dem das Sensormodul den Aufprall erlitten hat, identifiziert.

4. Persönliches Sturzerkennungssystem nach Anspruch 3, wobei der Prozessor so eingerichtet ist, dass er den Aufprallzeitpunkt durch Prüfen eines Zeitstempels der gemessenen Beschleunigungen identifiziert.

5. Persönliches Sturzerkennungssystem nach einem der vorangegangenen Ansprüche, wobei der Prozessor weiterhin so eingerichtet ist, dass er eine Onset-Zeit, d.h. den Zeitpunkt, zu dem sich das Sensormodul vor dem Aufprall zu bewegen begann, identifiziert.

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6. Persönliches Sturzerkennungssystem nach Anspruch 5, wobei der Prozessor so eingerichtet ist, dass er die Onset-Zeit durch Prüfen der gemessenen Beschleunigungen vor dem Aufprall identifiziert, um einen stabilen Zeitraum zu identifizieren, in dem die gemessenen Beschleunigungen um weniger als einen zuvor festgelegten Schwellwert variieren, und um die Onset-Zeit als den Zeitpunkt zu identifizieren, zu dem der stabile Zeitraum endet.
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7. Persönliches Sturzerkennungssystem nach Anspruch 5 oder 6, wobei der Prozessor so eingerichtet ist, dass er die Onset-Zeit durch Prüfen der gemessenen Beschleunigungen vor dem Aufprall identifiziert, um eine Abweichung in der Richtung der gemessenen Beschleunigung zu identifizieren, die oberhalb eines zuvor festgelegten Schwellwertes liegt, und um die Onset-Zeit als den Zeitpunkt zu identifizieren, zu dem die Abweichung in der Richtung zuerst den Schwellwert überschritten hat.
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8. Persönliches Sturzerkennungssystem nach Anspruch 5, 6 oder 7 bei Abhängigkeit von Anspruch 3 oder 4, wobei der Prozessor so eingerichtet ist, dass er die vertikale Verschiebung des Sensormoduls durch zweimaliges Integrieren der Messungen von dem Beschleunigungsmesser zwischen der Onset-Zeit und dem Aufprallzeitpunkt berechnet.
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9. Persönliches Sturzerkennungssystem nach einem der Ansprüche 5, 6, 7 oder 8, wobei der Prozessor so eingerichtet ist, dass er die Fallbeschleunigung zu der Onset-Zeit berechnet, indem er die Komponente der gemessenen Beschleunigung zu der Onset-Zeit identifiziert, die in einer vertikalen Richtung wirkt.
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10. Persönliches Sturzerkennungssystem nach Anspruch 9, wobei der Prozessor so eingerichtet ist, dass er die berechnete Fallbeschleunigung von den Messungen abzieht, die von dem Prozessor zur Berechnung der vertikalen Verschiebung des Sensormoduls verwendet werden.
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11. Persönliches Sturzerkennungssystem nach Anspruch 1, wobei die Mittel weiterhin so eingerichtet sind, dass sie einen Alarm auslösen, wenn ermittelt wird, dass ein Sturz stattgefunden hat.
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12. Persönliches Sturzerkennungssystem nach einem der vorangegangenen Ansprüche, wobei der Prozessor einen Teil des Sensormoduls darstellt.
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13. Persönliches Sturzerkennungssystem nach einem der Ansprüche 1 bis 11, das weiterhin eine von dem Sensormodul getrennte Basiseinheit (6) umfasst, wobei der Prozessor (10) einen Teil der Basiseinheit darstellt.
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14. Verfahren zur Anwendung in einem persönlichen Sturzerkennungssystem mit einem Sensormodul, das sich zur Befestigung an einem Benutzer eignet, wobei das Verfahren die folgenden Schritte umfasst, wonach:
- auf das Sensormodul einwirkende Beschleunigungen gemessen werden;
die gemessenen Beschleunigungen analysiert werden, um zu ermitteln, ob das Sensormodul einen Aufprall erlitten hat;
eine vertikale Verschiebung des Sensormoduls während eines Zeitraumes unmittelbar vor dem Aufprall durch zweimaliges Integrieren der Messungen von dem Beschleunigungssensor berechnet wird; und
unter Verwendung der berechneten vertikalen Verschiebung des Sensormoduls ermittelt wird, ob ein Sturz stattgefunden hat.
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15. Computerprogrammprodukt mit darin verkörpertem Computercode, wobei der Computercode bei Ausführung auf einem Computer, das Verfahren nach Anspruch 14 durchführt.

Revendications

- 50
1. Système personnel de détection de chute (4), comprenant :
- un module capteur (4) qui est approprié pour être attaché à un utilisateur (2), le module capteur (4) comprenant un accéléromètre (8) pour mesurer des accélérations agissant sur le module capteur (4) ;
- 55 un processeur (10) pour analyser les accélérations mesurées pour déterminer si le module capteur (4) a subi un impact, et pour estimer un déplacement vertical du module capteur (4) au cours d'une période immédiatement avant l'impact ; dans lequel le processeur (10) estime le déplacement vertical du module capteur (4) en intégrant deux fois les mesures à partir de l'accéléromètre (8) ; et

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des moyens pour déterminer si une chute a eu lieu en utilisant le déplacement vertical estimé du module capteur.

2. Système personnel de détection de chute selon la revendication 1, dans lequel le processeur est adapté pour déterminer que le module capteur a subi un impact si :

les accélérations mesurées sont caractéristiques d'une collision avec un objet solide ;
une accélération mesurée dépasse un seuil prédéterminé ;
une accélération mesurée dans une direction spécifiée dépasse un seuil prédéterminé ; ou
une variance des mesures à partir de l'accéléromètre dépasse un seuil prédéterminé.

3. Système personnel de détection de chute selon une quelconque revendication précédente, dans lequel le processeur est en outre adapté pour identifier un temps d'impact, le temps auquel le module capteur a subi l'impact.

4. Système personnel de détection de chute selon la revendication 3, dans lequel le processeur est adapté pour identifier le temps d'impact en examinant une estampille temporelle des accélérations mesurées.

5. Système personnel de détection de chute selon une quelconque revendication précédente, dans lequel le processeur est en outre adapté pour identifier un temps de début, le temps auquel le module capteur a commencé de se déplacer avant l'impact.

6. Système personnel de détection de chute selon la revendication 5, dans lequel le processeur est adapté pour identifier le temps de début en examinant les accélérations mesurées avant l'impact pour identifier une période stable dans laquelle les accélérations mesurées varient de moins d'un seuil prédéterminé, et pour identifier le temps de début en tant que temps auquel la période stable se termine.

7. Système personnel de détection de chute selon la revendication 5 ou 6, dans lequel le processeur est adapté pour identifier le temps de début en examinant les accélérations mesurées avant l'impact pour identifier une variation de la direction de l'accélération mesurée qui est supérieure à un seuil prédéterminé, et pour identifier le temps de début en tant que temps auquel la variation de la direction a dépassé le seuil pour la première fois.

8. Système personnel de détection de chute selon la revendication 5, 6 ou 7, lorsqu'elle dépend de la revendication 3 ou 4, dans lequel le processeur est adapté pour estimer le déplacement vertical du module capteur en intégrant deux fois les mesures à partir de l'accéléromètre entre le temps de début et le temps d'impact.

9. Système personnel de détection de chute selon une quelconque des revendications 5, 6, 7 ou 8, dans lequel le processeur est adapté pour estimer l'accélération gravitationnelle au temps de début en identifiant la composante de l'accélération mesurée au temps de début qui agit dans une direction verticale.

10. Système personnel de détection de chute selon la revendication 9, dans lequel le processeur est adapté pour soustraire l'accélération gravitationnelle estimée des mesures qui sont utilisées par le processeur pour estimer le déplacement vertical du module capteur.

11. Système personnel de détection de chute selon la revendication 1, dans lequel les moyens sont en outre adaptés pour déclencher une alarme s'il est déterminé qu'une chute a eu lieu.

12. Système personnel de détection de chute selon une quelconque revendication précédente, dans lequel le processeur fait partie du module capteur.

13. Système personnel de détection de chute selon une quelconque des revendications 1 à 11, en outre comprenant une unité de base (6) séparée du module capteur, le processeur (10) faisant partie de l'unité de base.

14. Procédé destiné à être utilisé dans un système personnel de détection de chute comprenant un module capteur qui est approprié pour être attachée à un utilisateur, le procédé comprenant :

la mesure d'accélérations agissant sur le module capteur ;
l'analyse des accélérations mesurées pour déterminer si le module capteur a subi un impact ;
l'estimation d'un déplacement vertical du module capteur au cours d'une période immédiatement avant l'impact en intégrant deux fois les mesures à partir de l'accéléromètre ; et

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la détermination d'un cas de chute en utilisant le déplacement vertical estimé du module capteur.

15. Produit programme d'ordinateur comprenant un code informatique incorporé dans celui-ci, le code informatique, lorsqu'il est exécuté sur un ordinateur, réalisant le procédé selon la revendication 14.

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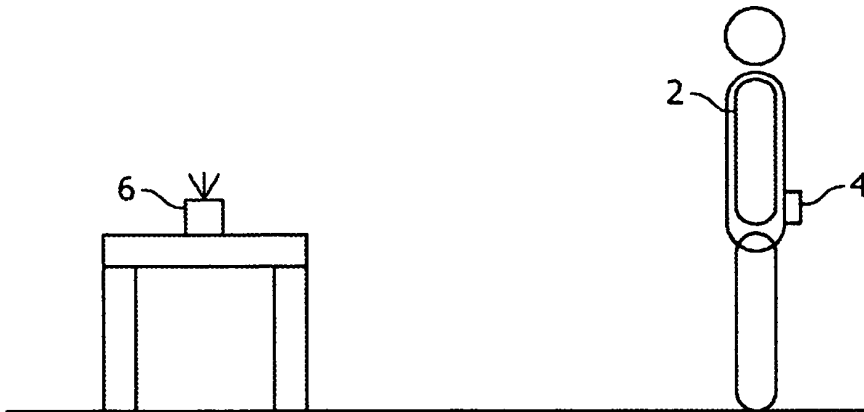


FIG. 1

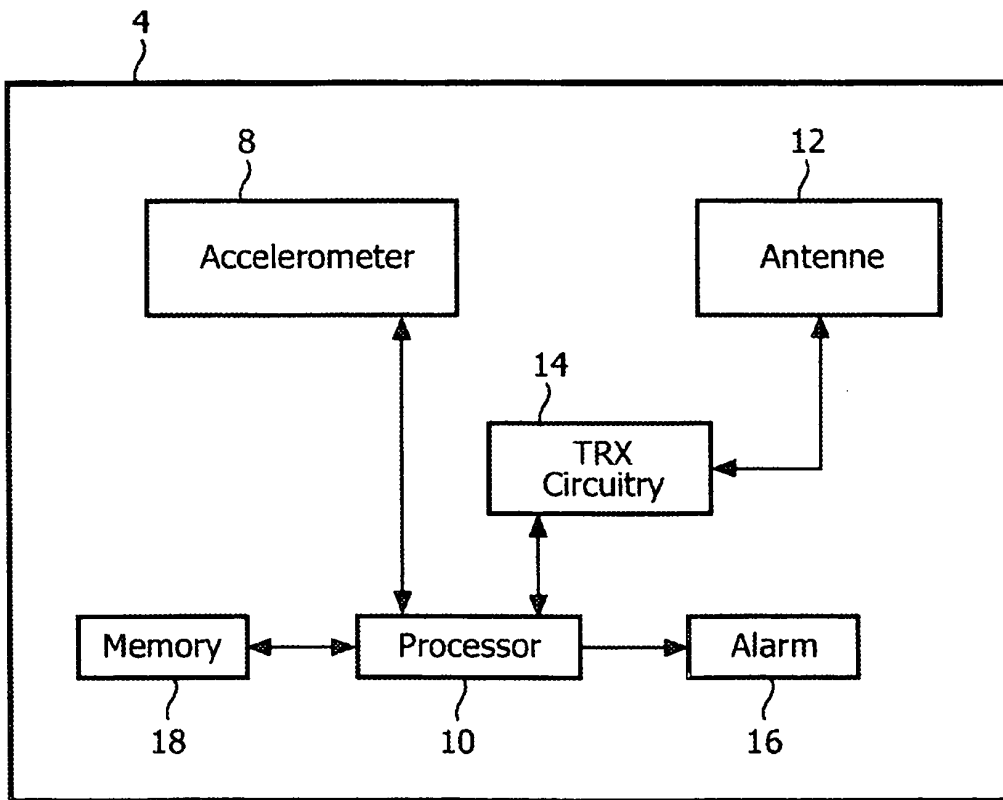


FIG. 2

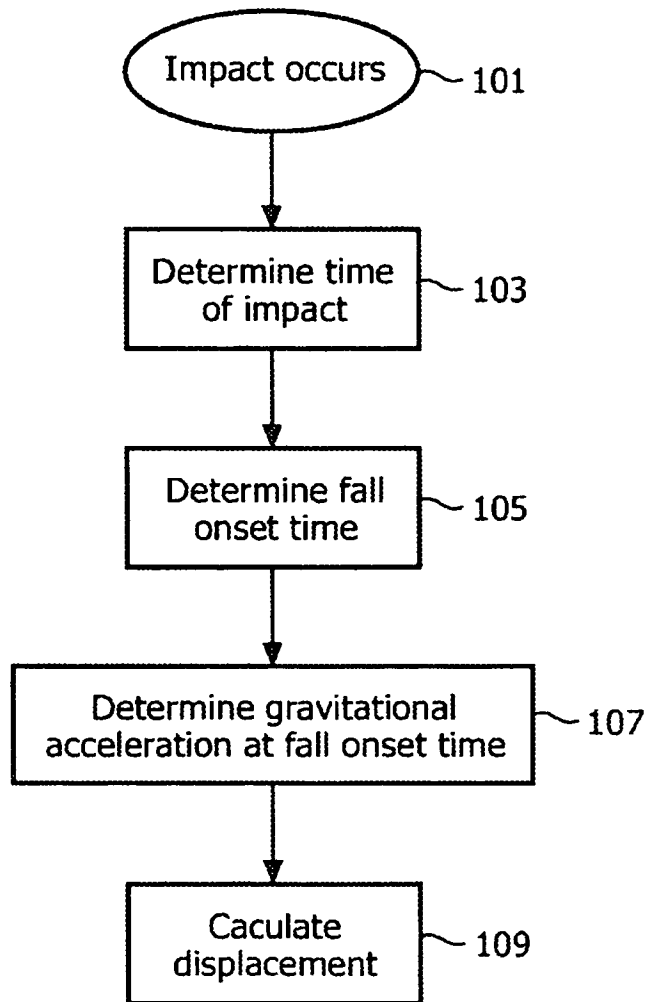


FIG. 3

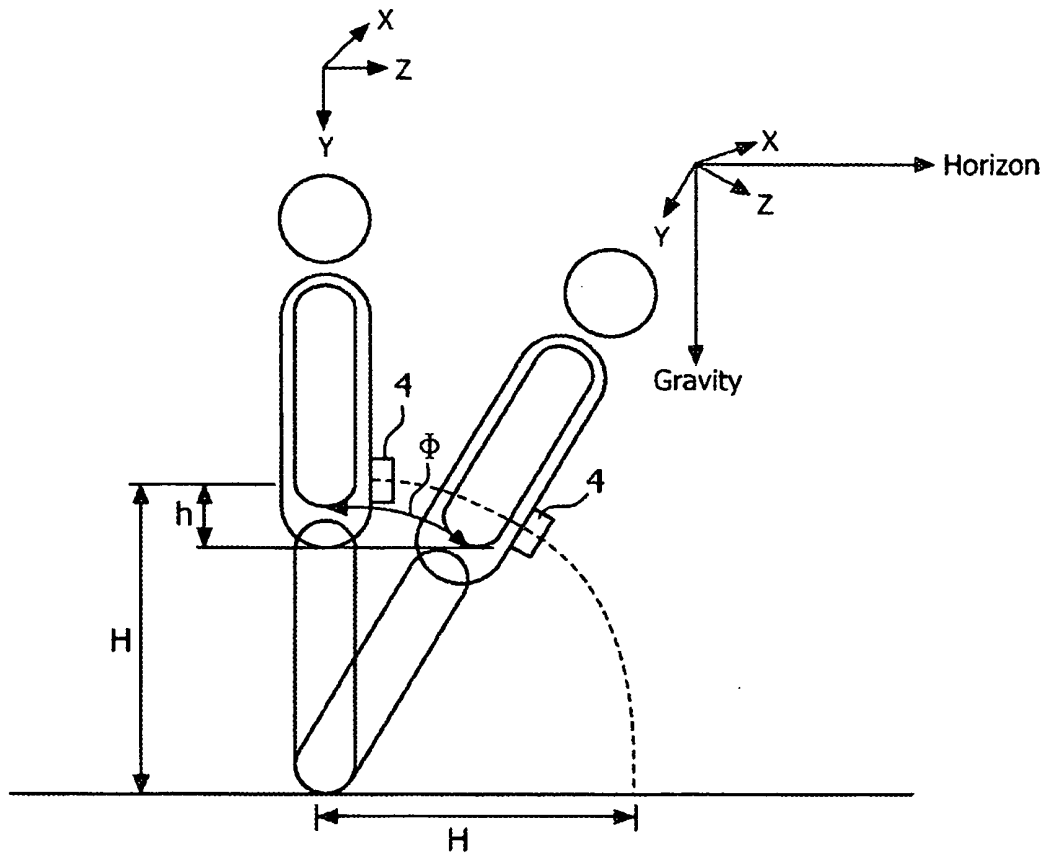


FIG. 4

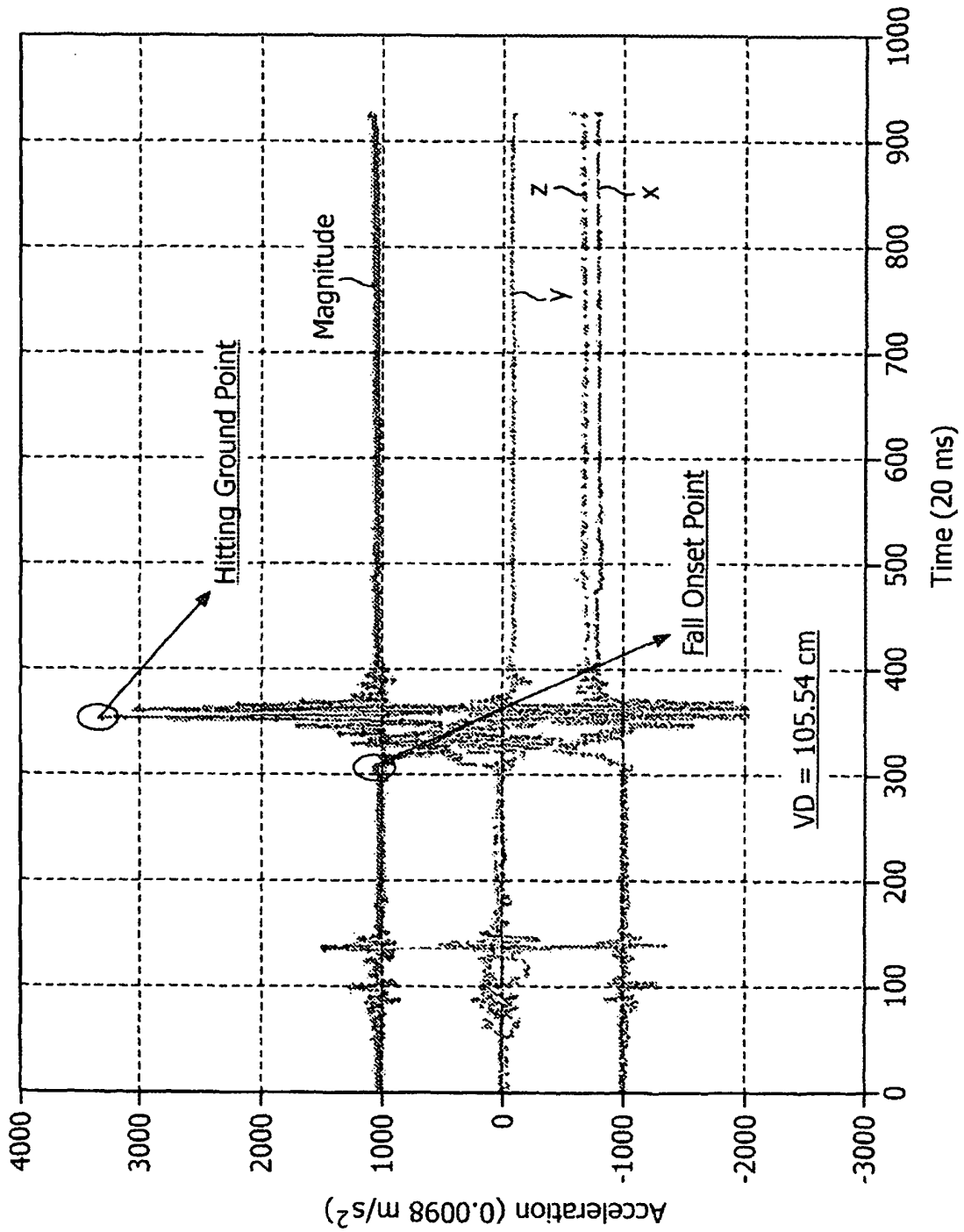


FIG. 5

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **MAARIT KANGAS et al.** Determination of simple thresholds for accelerometry-based parameters for fall detection. *Eng. in Med and Bio. Soc., 2007. EMBS 2007. 29th Annual Int. Conf. of the IEEE*, 01 August 2007, 1367-1370 [0005]
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专利名称(译)	跌倒检测系统中的位移测量		
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其他公开文献	EP2274734A1		
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摘要(译)

提供一种个人跌倒检测系统，包括适于附接到用户的传感器模块，该传感器模块包括用于测量作用在传感器模块上的加速度的加速度计；以及处理器，用于分析所测量的加速度以确定传感器模块是否已经受到冲击，并且用于在紧接冲击之前的时间段内估计传感器模块的垂直位移；其中，处理器通过对来自加速度计的测量值进行两次积分来估计传感器模块的垂直位移。

