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(54) FALL DETECTION SYSTEM

FALLDETEKTIONSSYSTEM

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 62/323,266, filed on April 15, 2016 entitled "Breathing Rate Detection System, Fall Detection System, and Ranging System for a Self-Contained Breathing Apparatus" and U.S. Utility Application No. 15/486,897, filed April 13, 2017 entitled "Fall Detection System"

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates generally to a fall detection system, and in particular, to a fall detection system configured for automatically detecting a fall event and issuing an alert that the fall event has occurred.

Description of the Related Art

[0003] There are many fields in which detecting and indicating whether an individual has fallen is highly desirable. Firefighting, for example, is a dangerous job with many known and unknown hazards that may cause the firefighter to fall down. Various personal alert safety system (PASS) devices have been developed to detect lack of motion of a firefighter. Typically, PASS devices are configured to monitor movement using a 3-axis accelerometer. If the PASS device does not detect user movement for a pre-determined length of time, such as 20 seconds, the PASS device goes into a pre-alarm state. If motion is detected during the pre-alarm state, the PASS device automatically resets and returns to a monitoring mode. However, if the PASS device does not detect motion for an additional pre-determined length of time (such as 10 seconds, or 30 seconds total), the PASS device goes into an alarm mode until it is manually reset.

[0004] While the existing PASS devices provide an important alert function in case a firefighter falls down, they are nonetheless associated with a number of disadvantages. If a fall event occurs (fall, building collapse, falling debris), and a firefighter is in danger, it may take 30 seconds for the conventional PASS device to go into full alarm mode to alert others that the firefighter has fallen. In a worst case scenario, this length of time may be a difference between life and death for the fallen firefighter. Furthermore, existing PASS devices may be activated into a pre-alarm state during routine firefighting operations, such as standing on a ladder or waiting to enter a fire scene. Activation of the PASS device in such situations is undesirable because it diverts the firefighter's attention from the task at hand. Additionally, existing PASS devices are not configured to detect a type of a fall event (e.g., falling down a set of stairs, falling through a floor or roof, or falling off a ladder), or an orientation of the firefighter relative to a reference plane (e.g., the ground) after the fall event. Thus, existing PASS devices cannot provide information about the type of distress that the firefighter may be experiencing after falling.

[0005] Similar fall detection devices have been developed for consumer use to issue an alert, such as by dialing an emergency number, when a user manually activates the device, such as by pressing a button. Other devices can automatically issue an alert after a fall is detected. However, such devices are configured to activate after detecting an acceleration or force that exceeds a pre-determined threshold. As a result, these devices may be activated in situations that do not involve a fall, such as jumping from an elevated position. In addition, these devices are not configured to detect an orientation of the user when a fall event is detected because they are typically worn loosely on the user's body.

[0006] Furthermore the document WO 2015/036245 A1 discloses a fall detection system and method. The fall detection system comprises a processing unit configured to determine context information about a user and/or the environment in which the user is located and to increase the sensitivity of a fall detection algorithm used to detect falls by the user in the event that the determined context information indicates that the user is or may be at an increased risk of falling.

[0007] The document US 2015/0090751 A1 discloses a carrying plate for a breathing apparatus. It includes a back plate defining a plurality of apertures therein that are arranged in two columns extending down opposing side edges of the back plate.

[0008] The documents US 2001/0032059 A1 discloses an attitude indicator and activity monitoring device. The device is mounted on the thigh of a patient and measurements are taken from an acceleration sensor within the device. The acceleration measurements are communicated to a receiver when the measurement deviate from acceptable threshold whereby the receiver indicates an alert condition.

[0009] Recently, mobile telephone applications have been developed which utilize the accelerometer of the mobile telephone to detect a fall event. These applications are similar to the PASS device in that they enter a pre-alarm mode for a pre-determined amount of time to allow the user an option to restore the application to a monitoring state. In addition, these devices are not configured to detect a type of a fall event, or an orientation of the user relative to a reference plane after the fall event.

[0010] While a variety of fall detection systems exist in the art, there is a continued need in the art for improved fall

detection systems. For example, there is a need for an improved fall detection system that eliminates a pre-determined pre-alarm period before the system goes into a full alarm mode. There is a further need in the art for an improved fall detection system that is configured to detect a type of a fall event and activate an alarm based on the type of the fall event. There is an additional need in the art for an improved fall detection system that is configured to detect an orientation of the user relative to a reference plane after the fall event.

SUMMARY OF THE INVENTION

[0011] Generally, provided is an improved fall detection system that eliminates a pre-determined pre-alarm period before the system goes into a full alarm mode. Preferably, provided is an improved fall detection system that is configured to detect a type of a fall event and activate an alarm based on the type of the fall event. Preferably, provided is an improved fall detection system that is configured to detect an orientation of the user relative to a reference plane after the fall event.

[0012] A fall detection system according to claim 1 is provided.

[0013] Claims 2 to 9 describe further advantageous embodiments of the fall detection system.

[0014] Also a self-contained breathing apparatus (SCBA) according to claim 10 is provided.

[0015] Claims 11 to 15 describe preferred embodiments of the SCBA.

[0016] These and other features and characteristics of the present disclosure, as well as the methods of operation and functions of the related elements of structures and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 is a schematic view of a fall detection system in accordance with one preferred and non-limiting embodiment or aspect of the present invention;

FIG. 2 is a perspective view of a self-contained breathing apparatus configured for use with the fall detection system of **FIG. 1;** and

FIG. 3 is a flow chart of steps for activating an alarm mode of the fall detection system of **FIG. 1.**

DETAILED DESCRIPTION OF THE PREFERRED EXAMPLES

[0018] For purposes of the description hereinafter, the terms "end", "upper", "lower", "right", "left", "vertical", "horizontal", "top", "bottom", "lateral", "longitudinal" and derivatives thereof shall relate to the invention as it is oriented in the drawing figures. However, it is to be understood that the invention may assume various alternative variations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification, are simply exemplary embodiments of the invention. Hence, specific dimensions and other physical characteristics related to the embodiments disclosed herein are not to be considered as limiting.

[0019] As used in the specification and the claims, the singular form of "a", "an", and "the" include plural referents unless the context clearly dictates otherwise. As used in the specification and the claims, all ranges or ratios disclosed herein are to be understood to encompass any and all subranges or sub-ratios subsumed therein. For aspect or embodiment, a stated range or ratio of "1 to 10" should be considered to include any and all subranges between (and inclusive of) the minimum value of 1 and the maximum value of 10; that is, all sub-ranges or sub-ratios beginning with a minimum value of 1 or more and ending with a maximum value of 10 or less, such as but not limited to, 1 to 6.1, 3.5 to 7.8, and 5.5 to 10.

[0020] As used in the specification and the claims, the term "fall event" means an unintended change in position of a user from a first position to a second position, wherein the first position and the second position differ in orientation or elevation of the user relative to the ground.

[0021] As used in the specification and the claims, the term "acceleration event" means a deviation of acceleration of an object from pre-determined range, such as but not limited to, 1 G to 3 G.

[0022] As used in the specification and the claims, the term "substantially parallel" means a relative angle as between two objects (if extended to theoretical intersection), such as elongated objects and including reference lines, that is from 0° to 5°, or from 0° to 3°, or from 0° to 2°, or from 0° to 1°, or from 0° to 0.5°, or from 0° to 0.25°, or from 0° to 0.1°, inclusive of the recited values. As used in the specification and the claims, the term "substantially perpendicular" means a relative angle as between two objects (if extended to theoretical intersection), such as elongated objects and including reference lines, that

is from 85° to 95°, or from 87° to 93°, or from 89° to 91°, or from 89.5° to 90.5°, or from 89.9° to 90.1°, inclusive of the recited values.

[0023] In various preferred and non-limiting embodiments or aspects, and with reference to **FIGS. 1-3,** the present disclosure is directed to a fall detection system **100** configured for automatically detecting a fall event and issuing an alert that the fall event has occurred. As discussed herein, the fall detection system **100** may be configured to detect a type of a fall event and activate an alarm based on the type of the fall event. Additionally, the fall detection system **100** may be configured to detect an orientation of the user relative to a reference plane after the fall event. The fall detection system **100** is used with other equipment worn by the user, in form of a self-contained breathing apparatus (SCBA).

Fall Detector

[0024] With reference to **FIG. 1,** in one preferred and non-limiting embodiment or aspect, the fall detection system **100** has at least one sensor **102** (hereinafter referred to as "sensor **102")** configured for detecting orientation and acceleration of a host, such as a user or an object configured to be worn by the user, in a three-dimensional space. The sensor **102** is operatively connected to a controller **104** configured for receiving information detected by the sensor **102,** analyzing the information detected by the sensor **102** to determine whether the information is indicative of a fall event, and activate one or more indicator devices **106** (hereinafter referred to as "indicator device **106")** if a fall event is detected.

[0025] In some embodiments or aspects, the sensor **102,** controller **104,** and indicator device **106** may be received within a housing **108** to define an integrated fall detection system **100.** The housing **108** may be sealed to prevent water intrusion into an interior of the housing that receives the sensor **102,** controller **104,** and indicator device **106.** The housing **108** may be made from a material that is resistant to heat such that functionality of the fall detection system **100** can be maintained even with exposure of the housing **108** to high heat (500 °F). In other examples, the components of the fall detection system **100** may be provided as separate items configured for interacting together. The fall detection system **100** may have a power source **110** for powering various components of the fall detection system **100.** In some examples, the power source **110** may be integral with the housing **108** such that a single power source **110** provides power to the sensor **102,** the controller **104,** and the indicator device **106.** In other examples, a plurality of power sources **110** may be provided, with each power source **110** powering at least one of the sensor **102,** the controller **104,** and the indicator device **106.**

[0026] As discussed herein, the fall detection system **100** is configured to be worn by a user indirectly, such as by being connected to equipment that is carried by the user. Alternatively to the claimed subject matter, the fall detection system **100** may be in the form of a bracelet, necklace, belt, or other accessory that is worn by the user, such as by being attached to the user's wrist, waist, neck, or other body part. In other examples, as discussed herein, the fall detection system **100** may be connected to a backpack or other accessory that is carried by the user.

Sensor

[0027] In various embodiments or aspects, the sensor **102** of the fall detection system **100** is connected to the user in such manner as to be capable of sensing a change in position of the user's body over time, such as acceleration, orientation, and distance. The sensor **102** may be an electronic or electromechanical device that is configured to measure acceleration. In some embodiments or aspects, the sensor **102** may be configured to measure static acceleration, such as gravity, and/or dynamic acceleration, such as forces due to movement or vibration. For example, the sensor **102** may be an accelerometer configured for detecting acceleration in three reference axes (i.e., translation in X, Y, and Z axes). In other examples, the sensor **102** may be an accelerometer configured for detecting acceleration in three reference axes and rotation about each of the three axes (i.e., a 6-axis accelerometer). In further examples, the sensor **102** may be an omni-directional magnetometer. By measuring a magnitude of static acceleration due to gravity, the sensor **102** can be used to determine an angle at which the fall detection device **100** is tilted relative to the ground. Similarly, by sensing a magnitude of dynamic acceleration, the sensor **102** can be used to determine a direction in which the fall detection device **100** is moving. The sensor **102** may be operated continuously, or intermittently, such as in pre-determined active intervals separated by pre-determined inactive intervals. In each embodiment or aspect, the sensor **102** is configured for sensing for acceleration of the fall detection device **100** having pre-determined characteristics that are indicative of a fall event.

[0028] One of ordinary skill in the art will understand that the sensor **102** may be a single sensor, or an array of two or more sensors described hereinabove. For example, the sensor **102** may have a plurality of single- or dual-axis accelerometers combined together and configured for sensing acceleration due to translation and/or rotation in a three-dimensional space defined by, for example, a Cartesian coordinate system.

Controller

[0029] The data obtained by the sensor **102** is communicated to the controller **104,** such as by a wired or wireless connection, for analyzing and determining whether the data contains any of the pre-determined characteristics of a fall

event that the sensor **102** is configured to detect. For example, the pre-determined characteristics may include free fall, impact, and lack of motion. Based on the characteristics of this data (i.e., whether the data contains information regarding pre-determined characteristics of the fall event), the controller **104** can activate the indicator device **106** to provide an alert that a fall event has occurred.

[0030] As used herein, the controller **104** includes, or is operable to execute appropriate custom-designed or conventional software to perform and implement the processing steps of the method and system of the present disclosure, thereby forming a specialized and particular computing system. The controller **104** may include a variety of discrete computer-readable media components for analyzing information sensed by the sensor **102** and for activating the indicator device **106** when the information contains pre-determined characteristics indicative of a fall event. For example, this computer-readable media may include any media that can be accessed by the controller **104,** such as volatile media, non-volatile media, removable media, non-removable media, transitory media, non-transitory media, etc. As a further example, this computer-readable media may include computer storage media, such as media implemented in any method or technology for storage of information, such as computer-readable instructions, data structures, program modules, or other data; random access memory (RAM), read only memory (ROM), electrically erasable programmable read only memory (EEPROM), flash memory, or other memory technology; CD-ROM, digital video disks (DVDs), or other optical disk storage; magnetic cassettes, magnetic tape, magnetic disk storage, or other magnetic storage devices; or any other medium which can be used to store the desired information and which can be accessed by the controller **104.** Further, this computer-readable media may include communications media, such as computer-readable instructions, data structures, program modules, or other data in a modulated data signal, such as a carrier wave or other transport mechanism and may include any information delivery media, wired media (such as a wired network and a direct-wired connection), and wireless media (such as acoustic signals, radio frequency signals, optical signals, infrared signals, biometric signals, bar code signals, etc.). Of course, combinations of any of the above should also be included within the scope of computer-readable media. The controller **104** further may include a system memory with computer storage media in the form of volatile and non-volatile memory, such as ROM and RAM. A basic input/output system (BIOS) with appropriate computer-based routines assists in transferring information between components within the controller **104** and is normally stored in ROM. The RAM portion of the system memory typically contains data and program modules that are immediately accessible to or presently being operated on by the processing unit, *e.g.,* an operating system, application programming interfaces, application programs, program modules, program data, and other instruction-based computer-readable codes.

Indicator

[0031] When the controller **104** determines that information sensed by the sensor **102** contains pre-determined characteristics of a fall event, the controller **104** may activate, by wired or wireless control, the indicator device **106.** In some preferred and non-limiting embodiments or aspects, the indicator device **106** may be a visual indicator device **106a,** an audible indicator device **106b,** a remote signaling indicator device **106c,** or any combination thereof. For example, the indicator device **106** may have one or more lights, such as one or more light-emitting diodes (LEDs), that are illuminated when the controller **104** activates the indicator device **106.** The one or more lights may be lit continuously when the indicator device **106** is activated. Alternatively, the one or more lights may be lit intermittently at a pre-determined interval or sequence. The visual indicator device **106a** may be provided on the housing **108** and/or on an external device in communication with the fall detection device **100.** For example, the visual indicator device **106a** may be provided on a helmet worn by the user or another component connected to or worn by the user. In some examples, the visual indicator device **106a** may have at least one infrared light source configured for being detected with a thermal imaging sensor.

[0032] In other preferred and non-limiting embodiments or aspects, the indicator device **106** may be an audio indicator device **106b** having at least one speaker and/or a piezo buzzer. The at least one speaker and/or a piezo buzzer may be integrated with the housing **108** of the fall detection device 100, and/or on an external device in communication with the fall detection device **100.** In further embodiments or aspects, the indicator device **106** may be a remote signaling indicator device **106c** configured to provide a remote signal to an external device. For example, the indicator device **106** can wirelessly send a signal to an external device to indicate that a fall event has occurred. The remote signal can be a long-range (900 MHz) or a short-range (2,400 MHz) signal. The short-range signal may be configured for transmission from the fall detection device **100** to another local device, such as another user. The long range signal may be configured for transmission from the fall detection device **100** to a remote device using a cellular telephone network, or base stations with mobile or main command centers. In some examples, the remote device may be an incident command center at a fire scene. The indicator device **106** may be configured to indicate a position of the fall detection device **100** after a fall event has been detected.

[0033] In some preferred and non-limiting embodiments or aspects, the indicator device **106** may be configured to activate different types of alarms based on different fall events. For example, the indicator device **106** may activate a first indicator type, such as the visual indicator device **106a,** if the fall event that is detected by the sensor **102** is indicative of falling down a set of stairs. The indicator device **106** may activate a second indicator type, such as the remote signaling

indicator device **106c,** if the fall event that is detected by the sensor **102** is indicative of a building collapse. One of ordinary skill in the art will appreciate that a plurality of indicator devices **106** can be activated simultaneously or sequentially depending on the type of fall event that is detected by the sensor **102.**

[0034] In some preferred and non-limiting embodiments or aspects, the indicator device **106** may be reset after it has been activated. For example, a reset mechanism **112,** such as a button, may be provided to turn off the indicator device **106** after activation. The reset mechanism **112** may be provided directly on the housing **108** of the fall detection system **100** to allow manual resetting of the indicator device **106** by the user. Alternatively, or in addition, the reset mechanism **112** may be provided on an external device in wireless communication with the fall detection system **100** to allow for remote resetting of the indicator device **106.**

SCBA system

[0035] The fall detection system **100** is integrated on equipment configured to be carried or worn by the user. In some embodiments or aspects, the fall detection system **100** may be used contrary to the claimed subject matter with a helmet worn on a user's head. In the claimed subject matter, the fall detection system **100** is configured for use with a self-contained breathing apparatus (SCBA). There exists a variety of SCBAs and similar systems, some of which are available through Mine Safety Appliances Company. Such SCBAs may be configured for use in a variety of applications, such as firefighting and industrial use. With reference to **FIG. 2,** an SCBA **200** has a tank **202,** a pressure regulator **204** connected to the tank **202,** and an air line **206** connecting the pressure regulator **204** to a mask **208.** The tank **202** is mounted and supported on a rigid frame **210** that is worn on a user's back. A pair of shoulder straps **212** and a belt strap **214** are connected to the frame **210.** The shoulder straps **212** and the belt strap **214** are configured to enable wearing of the SCBA **200** in a manner similar to a backpack, where the tank **202** and the frame **210** are positioned on the user's back.

[0036] The fall detection system **100** is integrated with the SCBA **200** At least a portion of the fall detection system **100** is connected to the frame **210** of the SCBA **200**. At least the sensor **102** of the fall detection system **100** is positioned on the frame **210** of the SCBA **200.** Positioning of at least a portion of the fall detection system **100** on the frame **210** provides several advantages. When worn by the user, the frame **210** is positioned close to the center of gravity of the user, regardless of the user's height and weight. In addition, the position of the frame **210** remains substantially unchanged relative to the user's body. In this manner, readings from the sensor **102** may be used to determine the orientation of the user based on the orientation of the frame **210.**

Fall Detection System Operation

[0037] The fall detection system **100** may be configured to detect changes in orientation of the sensor **102** (and, therefore, changes in orientation of the user), measure acceleration experienced by the sensor **102** (and, therefore, a force experienced by the user), and sense movement of the sensor **102** (and, therefore, movement of the user). This information can be used by the controller **104** as criteria for analyzing whether movement of the sensor **102** (and, therefore, movement of the user) in a three-dimensional space can be characterized as a fall event.

[0038] In the firefighting field, users wearing an SCBA **200** at a fire scene will primarily be in the upright position, wherein the SCBA **200** and the frame **210** are oriented in a substantially vertical orientation relative to the ground, or in a crawling position, wherein the SCBA **200** and the frame **210** are oriented in a substantially horizontal position that is parallel and offset relative to the ground. The sensor **102** can be used to detect the orientation of the frame **210,** and therefore the orientation of the user. Information detected by the sensor **102** can be used by the controller **104** to determine whether the orientation of the frame **210,** and therefore the orientation of the user, falls within an expected orientation. For example, an expected orientation of the sensor **102** may be a vertical orientation (i.e., substantially perpendicular to the ground) at a height of approximately 36 inches from the ground, or a horizontal orientation (i.e., substantially parallel to the ground) and vertically offset relative to the ground at approximately 24 inches. Orientations of the sensor **102** that are not within these expected orientations (or within a pre-determined range from these expected orientations) may indicate that the user has fallen and may need assistance. For example, non-typical orientations of the user include, without limitation, if the user is upside-down or lying on his/her back. As discussed herein, data from the sensor **102** regarding the orientation of the sensor **102** may be used by the controller **104** as criteria for deciding whether an alarm mode should be initiated by activating the indicator device **106.** For example, the controller **104** may use non-typical orientation of the sensor **102** (and, therefore, the user) as a trigger condition for initiating the alarm mode.

[0039] In addition to using the orientation of the sensor **102**/frame **210** to determine the orientation of the user, the fall detection system **100** may use information regarding acceleration that is detected by the sensor **102** and correlate this information to a force experienced by the user. In some examples, the fall detection system **100** may use information regarding a magnitude and duration of acceleration during the acceleration event that is detected by the sensor **102,** and correlate this information to a force experienced by the user. Depending on the magnitude of acceleration detected by the sensor **102** (and, optionally, duration of acceleration), the controller **104** can initiate an alarm mode by activating the

indicator device **106** if the acceleration magnitude (and, optionally, acceleration duration) exceeds a pre-determined threshold (3 G). For example, a zero acceleration measurement in the vertical axis is indicative of a free fall condition. This zero acceleration measurement may be followed by a large positive acceleration, such as when the user hits the ground after free falling. If the positive measurement in acceleration after a zero measurement exceeds a pre-determined threshold (3 G), the controller **104** may initiate the alarm mode by activating the indicator device **106.** Some acceleration events are typical (i.e. jumping off of a truck), while others (falling off of a roof, getting hit by a brick) can cause injury to the user. In this manner, acceleration events that are below the pre-determined threshold can be ignored, while acceleration events that are above the pre-determined threshold will result in activation of the indicator device **106** to provide an alert that the user has fallen.

[0040] In addition to using the orientation of the sensor **102**/frame **210** to determine the orientation of the user and an acceleration experienced by the user, the fall detection system **100** may use information regarding motion of the sensor **102** (and, therefore, the user) after experiencing an acceleration event. In some preferred and non-limiting embodiments or aspects, the controller **104** may be configured to detect whether the user is stationary or moving after experiencing an acceleration event. For example, if a user is not moving within a pre-determined period of time, such as 0 to 5 seconds, after experiencing an acceleration event, this information may be indicative that the user has fallen and is unable to move. The controller **104** can activate the indicator device **106** to indicate that the user has fallen and that assistance is needed.

[0041] With reference to **Table I** below, various types of fall events are shown, such as falling from an elevated position, falling down a set of stairs, falling due building collapse, and falling due to being hit by an object. While not an exhaustive list, the fall events listed in **Table I** are the most typical fall events experienced by firefighters at a fire scene. For each fall event, the controller **104** analyzes data from the sensor **102** relating to the orientation of the user before an acceleration event, acceleration magnitude during the fall, acceleration magnitude during impact, final orientation of the user, and movement after the fall to determine whether an alarm should be activated.

Table I

Type of Fall Event	Starting Orientation	Acceleration during fall event	Impact	Final orientation	Movement after fall event	Trigger Condition Sequence	Alarm
Fall from elevated position	Vertical (typical)	0	Large (60 G)	Non-vertical	No	Acceleration, Impact, Lack of Movement	Yes
Fall from elevated position	Vertical (typical)	0	Large (60 G)	Non-vertical	Yes	Acceleration, Impact, Movement	No
Fall down stairs	Standing or crawling	High (60 G)	Medium (30 G)	Non-vertical	No	Acceleration, Impact, Lack of Movement	Yes
Fall down stairs	Standing or crawling	High (60 G)	Medium (30 G)	Non-vertical	Yes	Acceleration, Impact, Movement	No
Building collapse	Standing or crawling	Small (10 G)	Large (60 G)	Non-vertical	No	Impact, Lack of Movement, Orientation	Yes
Building collapse	Standing or crawling	Small (10 G)	Large (60 G)	Non-vertical	Yes	Impact, Lack of Movement, Orientation	No
Flying object	Standing or crawling	Small (10 G)	Medium (30 G)	Non-vertical	No	Impact, Lack of Movement, Orientation	Yes
Flying object	Standing or crawling	Small (10 G)	Medium (30 G)	Non-vertical	Yes	Impact, Movement, Orientation	No

[0042] For example, in a fall from an elevated position, such as when falling from a roof, the user may be initially in an upright position and end in a non-vertical position after falling. In addition, the user will experience zero acceleration during free falling, and a large acceleration upon impact. The controller **104** can automatically activate the indicator device **106** depending on whether the user is able to move within a pre-determined period of time (0 to 5 seconds) after falling.

[0043] After the controller **104** analyzes orientation, acceleration, and motion information from the sensor **102,** the controller **104** can determine whether this information is indicative of a fall event, such as one of the fall events listed in **Table I** above, and automatically activate the indicator device **106.** In some examples, the controller **104** may activate the indicator device **106** to communicate, via short-range signals, to other users in the vicinity of the fallen user. In this manner, other users can provide assistance to the fallen user. In other examples, the indicator device **106** may provide a visual or audible indication to the user that a fall event has occurred and ask the user to acknowledge whether assistance is needed. For example, the user can turn off the indicator device **106** via the reset mechanism **112** if the user is able to safely move after experiencing the fall event.

[0044] Having described the structure of the fall detection system **100** and the SCBA **200,** a method of using the fall detection system **100** will now be described with reference to **FIG. 3.** Initially, the sensor **102** is configured to detect an initial position of the user (block **300)** (e.g., standing or crawling), and use this value as a reference position. The controller **104** may continuously update the reference position to account for changes in the position of the user during use of the fall detection system **100.** The sensor **102** is configured to detect all movement of the user in a three-dimensional space and correlate such movement to an acceleration measurement (block **302).** Using the sensor data, the controller **104** determines whether the acceleration measured by the sensor **102** exceeds a pre-determined threshold value (block **304).** If the acceleration measurement does not exceed the pre-determined threshold, the controller **104** continues to monitor the sensor data for any acceleration value that may exceed the acceleration threshold. If the controller **104** detects that the acceleration data from the sensor **102** exceeds the pre-determined threshold, the controller **104** analyzes sensor data regarding the position of the user after the acceleration event (block **306).** The controller **104** also analyzes sensor

data regarding movement of the user after the acceleration event (block **308).** If movement of the user is detected within a predetermined length of time after the acceleration event, the controller **104** will not activate an alarm mode (block **310).** However, if no movement of the user is detected within the predetermined length of time after the acceleration event, the controller **104** activates the alarm mode, wherein the indicator device **106** is activated to indicate that the user has fallen.

Claims

1. A fall detection system (100) comprising:

at least one sensor (102) configured to detect acceleration and orientation of a user;
at least one indicator device (106) having an alarm mode; and
a controller (104) operatively connected to the at least one sensor (102) and the at least one indicator device (106), the controller (104) programmed or configured to:

receive data generated by the at least one sensor (102);
compare at least a portion of the received data with at least one specified parameter indicative of a fall event; and
based on the comparison, activating or causing the activation of the at least one indicator device (106) to enter the alarm mode,

wherein the at least one specified parameter comprises at least one of the following: an acceleration exceeding a predetermined threshold, a change between a starting orientation of the user before an acceleration event and a final orientation of the user after the acceleration event, a lack of movement of the user for a predetermined length of time after the acceleration event, or any combination thereof, **characterized in that**,
the fall detection system (100) is integrated in a self-contained breathing apparatus, SCBA, (200) **in that** at least a portion of the fall detection system (100) is connected to a rigid frame (210) of the SCBA (200), the frame (210) is positioned proximate to a center of gravity of the user to determine the orientation of the user based on an orientation of the at least one sensor (102).

2. The fall detection system of claim 1, wherein the predetermined threshold for the acceleration event is at least about 3 G.

3. The fall detection system of claim 1 or 2, wherein the predetermined length of time after the acceleration event is in the range of 0 to about 5 seconds.

4. The fall detection system of one of the preceding claims, wherein the at least one sensor (102) is configured to detect at least one of static acceleration and dynamic acceleration.

5. The fall detection system of one of the preceding claims, wherein the at least one sensor (102) is at least one of the following: a 3-axis accelerometer, a 6-axis accelerometer, an omni-directional magnetometer, or any combination thereof.

6. The fall detection system of claim 1, wherein the at least one indicator device (106) is a visual indicator device (106a), in particular at least one of a light-emitting diode and an infrared emitter.

7. The fall detection system of claim 1, wherein the at least one indicator device (106) is an audible indicator device (106b), in particular at least one of a speaker and a piezo buzzer.

8. The fall detection system of claim 1, wherein the at least one indicator device (106) is a remote signaling indicator device (106c) programmed or configured for wireless communication with at least one remote device, in particular to send at least one of a wireless short-range signal and a wireless long-range signal to the at least one remote device.

9. The fall detection system of one of the preceding claims, further comprising a reset mechanism for turning off the at least one indicator device after activation.

10. A self-contained breathing apparatus, SCBA, (200) comprising:

a tank mounted on a rigid frame (210) configured for mounting on a user's back using one or more straps (212, 214); and
a fall detection system (100) according to one of the preceding claims wherein:
the user is wearing the rigid frame (210).

11. The SCBA of claim 10, wherein the predetermined threshold for the acceleration event is at least about 3 G and the predetermined length of time after the acceleration event is the range of about 0 seconds to about 5 seconds.

12. The SCBA of claim 10 or 11, wherein the at least one sensor (102) is configured to detect at least one of static acceleration and dynamic acceleration.

13. The SCBA of one of the claims 10 to 12, wherein the at least one sensor (102) is at least one of the following: a 3-axis accelerometer, a 6-axis accelerometer, an omni-directional magnetometer, or any combination thereof.

14. The SCBA of one of the claims 10 to 13, wherein the at least one indicator device (106) is at least one of a visual indicator device (106a), an audible indicator device (106b), and a remote-signaling indicator device (106c).

15. The SCBA of one of the claims 10 to 14, further comprising a reset mechanism (112) for turning off the at least one indicator device (106) after activation.

Patentansprüche

1. Sturzerkennungssystem (100), umfassend:

zumindest einen Sensor (102), der zum Erkennen von Beschleunigung und Ausrichtung eines Benutzers ausgelegt ist;
zumindest eine Anzeigevorrichtung (106) mit einem Alarmmodus; und
eine Steuerung (104), die mit dem zumindest einen Sensor (102) und der zumindest einen Anzeigevorrichtung (106) wirkverbunden ist, wobei die Steuerung (104) programmiert oder ausgelegt ist zum:

Empfangen von Daten, die durch den zumindest einen Sensor (102) erzeugt werden;
Vergleichen zumindest eines Teils der empfangenen Daten mit zumindest einem spezifizierten Parameter, der auf ein Sturzereignis hinweist; und
basierend auf dem Vergleich, Aktivieren oder Veranlassen der Aktivierung der zumindest einen Anzeigevorrichtung (106) zum Eintritt in den Alarmmodus,
wobei der zumindest eine spezifizierte Parameter zumindest eines der folgenden umfasst: eine Beschleunigung, die einen vorbestimmten Schwellenwert überschreitet, eine Änderung zwischen einer Anfangsausrichtung des Benutzers vor einem Beschleunigungsereignis und einer Endausrichtung des Benutzers nach dem Beschleunigungsereignis, eine fehlende Bewegung des Benutzers für eine vorbestimmte Zeitspanne nach dem Beschleunigungsereignis oder eine Kombination davon, **dadurch gekennzeichnet, dass**,
das Sturzerkennungssystem (100) in ein unabhängiges Atemschutzgerät, SCBA, (200) integriert ist, indem zumindest ein Teil des Sturzerkennungssystems (100) mit einem starren Rahmen (210) des SCBA (200) verbunden ist, wobei der Rahmen (210) in der Nähe eines Schwerpunkts des Benutzers positioniert ist, um die Ausrichtung des Benutzers basierend auf einer Ausrichtung des zumindest einen Sensors (102) zu bestimmen.

2. Sturzerkennungssystem nach Anspruch 1, wobei der vorbestimmte Schwellenwert für das Beschleunigungsereignis zumindest etwa 3 G beträgt.

3. Sturzerkennungssystem nach Anspruch 1 oder 2, wobei die vorbestimmte Zeitspanne nach dem Beschleunigungsereignis in dem Bereich von 0 bis etwa 5 Sekunden liegt.

4. Sturzerkennungssystem nach einem der vorhergehenden Ansprüche, wobei der zumindest eine Sensor (102) zum Erkennen von zumindest entweder statischer Beschleunigung oder dynamischer Beschleunigung ausgelegt ist.

5. Sturzerkennungssystem nach einem der vorhergehenden Ansprüche, wobei der zumindest eine Sensor (102)

zumindest einer der folgenden ist: ein 3-Achsen-Beschleunigungsmesser, ein 6-Achsen-Beschleunigungsmesser, ein omnidirektionaler Magnetometer oder eine Kombination davon.

6. Sturzerkennungssystem nach Anspruch 1, wobei die zumindest eine Anzeigevorrichtung (106) eine optische Anzeigevorrichtung (106a) ist, insbesondere mindestens eines von einer Leuchtdiode und einem Infrarotstrahler.

7. Sturzerkennungssystem nach Anspruch 1, wobei die zumindest eine Anzeigevorrichtung (106) eine akustische Anzeigevorrichtung (106b), insbesondere zumindest ein Lautsprecher oder ein Piezo-Summer ist.

8. Sturzerkennungssystem nach Anspruch 1, wobei die zumindest eine Anzeigevorrichtung (106) eine Fernsignalanzeigevorrichtung (106c) ist, die für eine drahtlose Kommunikation mit zumindest einer entfernten Vorrichtung programmiert oder ausgelegt ist, insbesondere um zumindest eines von einem drahtlosen Kurzstreckensignal und einem drahtlosen Langstreckensignal an die zumindest eine entfernte Vorrichtung zu senden.

9. Sturzerkennungssystem nach einem der vorhergehenden Ansprüche, ferner umfassend einen Rücksetzmechanismus zum Ausschalten der zumindest einen Anzeigevorrichtung nach der Aktivierung.

10. Unabhängiges Atemschutzgerät, SCBA, (200), umfassend:

einen an einem starren Rahmen (210) montierten Tank, der zur Befestigung auf dem Rücken eines Benutzers unter Verwendung eines oder mehrerer Gurte (212, 214) ausgelegt ist; und
ein Sturzerkennungssystem (100) nach einem der vorhergehenden Ansprüche, wobei:
der Benutzer den starren Rahmen (210) trägt.

11. SCBA nach Anspruch 10, wobei der vorbestimmte Schwellenwert für das Beschleunigungsereignis zumindest etwa 3 G beträgt und die vorbestimmte Zeitspanne nach dem Beschleunigungsereignis in dem Bereich von etwa 0 Sekunden bis etwa 5 Sekunden liegt.

12. SCBA nach Anspruch 10 oder 11, wobei der zumindest eine Sensor (102) zum Erkennen von zumindest einer von statischer Beschleunigung und dynamischer Beschleunigung ausgelegt ist.

13. SCBA nach einem der Ansprüche 10 bis 12, wobei der zumindest eine Sensor (102) zumindest einer der folgenden ist: ein 3-Achsen-Beschleunigungsmesser, ein 6-Achsen-Beschleunigungsmesser, ein omnidirektionaler Magnetometer oder eine Kombination davon.

14. SCBA nach einem der Ansprüche 10 bis 13, wobei die zumindest eine Anzeigevorrichtung (106) zumindest eine von einer optischen Anzeigevorrichtung (106a), einer akustischen Anzeigevorrichtung (106b) oder einer Fernsignalanzeigevorrichtung (106c) ist.

15. SCBA nach einem der Ansprüche 10 bis 14, ferner umfassend einen Rücksetzmechanismus (112) zum Abschalten der zumindest einen Anzeigevorrichtung (106) nach der Aktivierung.

Revendications

1. Système de détection de chute (100) comprenant :

l'au moins un capteur (102) configuré pour détecter l'accélération et l'orientation d'un utilisateur ;
l'au moins un dispositif indicateur (106) ayant un mode d'alarme ; et
un dispositif de commande (104) connecté de manière fonctionnelle à l'au moins un capteur (102) et à l'au moins un dispositif indicateur (106), le dispositif de commande (104) étant programmé ou configuré pour :

recevoir des données générées par l'au moins un capteur (102) ;
comparer l'au moins une portion des données reçues avec l'au moins un paramètre spécifié indicatif d'un événement de chute ; et
sur la base de la comparaison, activer ou amener l'activation de l'au moins un dispositif indicateur (106) pour qu'il entre dans le mode d'alarme,
dans lequel l'au moins un paramètre spécifié comprend au moins l'un parmi les suivants : une accélération

dépassant un seuil prédéterminé, un changement entre une orientation de départ de l'utilisateur avant un événement d'accélération et une orientation finale de l'utilisateur après l'événement d'accélération, un manque de mouvement de l'utilisateur pendant une durée prédéterminée après l'événement d'accélération, ou toute combinaison de ceux-ci, **caractérisé en ce que**,
le système de détection de chute (100) est intégré dans un appareil respiratoire isolant, SCBA, (200) **en ce qu'**au moins une portion du système de détection de chute (100) est connectée à un cadre (210) rigide du SCBA (200), le cadre (210) étant positionné à proximité d'un centre de gravité de l'utilisateur pour déterminer l'orientation de l'utilisateur sur la base d'une orientation de l'au moins un capteur (102).

2. Système de détection de chute selon la revendication 1, dans lequel le seuil prédéterminé pour l'événement d'accélération est d'au moins environ 3 G.

3. Système de détection de chute selon la revendication 1 ou 2, dans lequel la durée prédéterminée après l'événement d'accélération est dans la plage de 0 à environ 5 secondes.

4. Système de détection de chute selon l'une quelconque des revendications précédentes, dans lequel l'au moins un capteur (102) est configuré pour détecter au moins l'une parmi une accélération statique et une accélération dynamique.

5. Système de détection de chute selon l'une des revendications précédentes, dans lequel l'au moins un capteur (102) est au moins l'un parmi les suivants : un accéléromètre à trois axes, un accéléromètre à six axes, un magnétomètre omnidirectionnel, ou une combinaison quelconque de ceux-ci.

6. Système de détection de chute selon la revendication 1, dans lequel l'au moins un dispositif indicateur (106) est un dispositif indicateur visuel (106a), en particulier au moins l'un parmi une diode électroluminescente et un émetteur infrarouge.

7. Système de détection de chute selon la revendication 1, dans lequel l'au moins un dispositif indicateur (106) est un dispositif indicateur audible (106b), en particulier au moins l'un parmi un haut-parleur et un vibreur piézo-électrique.

8. Système de détection de chute selon la revendication 1, dans lequel l'au moins un dispositif indicateur (106) est un dispositif indicateur de signalisation à distance (106c) programmé ou configuré pour une communication sans fil avec l'au moins un dispositif distant, en particulier pour envoyer au moins l'un parmi un signal à courte portée sans fil et un signal à longue portée sans fil à l'au moins un dispositif distant.

9. Système de détection de chute selon l'une des revendications précédentes, comprenant en outre un mécanisme de réinitialisation pour mettre hors tension l'au moins un dispositif indicateur après activation.

10. Appareil respiratoire isolant, SCBA, (200) comprenant :

un réservoir monté sur un cadre (210) rigide configuré pour être monté sur le dos d'un utilisateur en utilisant une ou plusieurs sangles (212, 214) ; et
un système de détection de chute (100) selon l'une des revendications précédentes dans lequel : l'utilisateur porte le cadre rigide (210).

11. SCBA selon la revendication 10, dans lequel le seuil prédéterminé pour l'événement d'accélération est d'au moins environ 3 G et la durée prédéterminée après l'événement d'accélération est la plage d'environ 0 seconde à environ 5 secondes.

12. SCBA selon la revendication 10 ou 11, dans lequel l'au moins un capteur (102) est configuré pour détecter au moins l'une parmi une accélération statique et une accélération dynamique.

13. SCBA selon l'une des revendications 10 à 12, dans lequel l'au moins un capteur (102) est au moins l'un parmi les suivants : un accéléromètre à trois axes, un accéléromètre à six axes, un magnétomètre omnidirectionnel, ou une combinaison quelconque de ceux-ci.

14. SCBA selon l'une des revendications 10 à 13, dans lequel l'au moins un dispositif indicateur (106) est au moins l'un parmi un dispositif indicateur visuel (106a), un dispositif indicateur audible (106b) et un dispositif indicateur de

signalisation à distance (106c).

15. SCBA selon l'une des revendications 10 à 14, comprenant en outre un mécanisme de réinitialisation (112) pour éteindre au moins un dispositif indicateur (106) après l'activation.

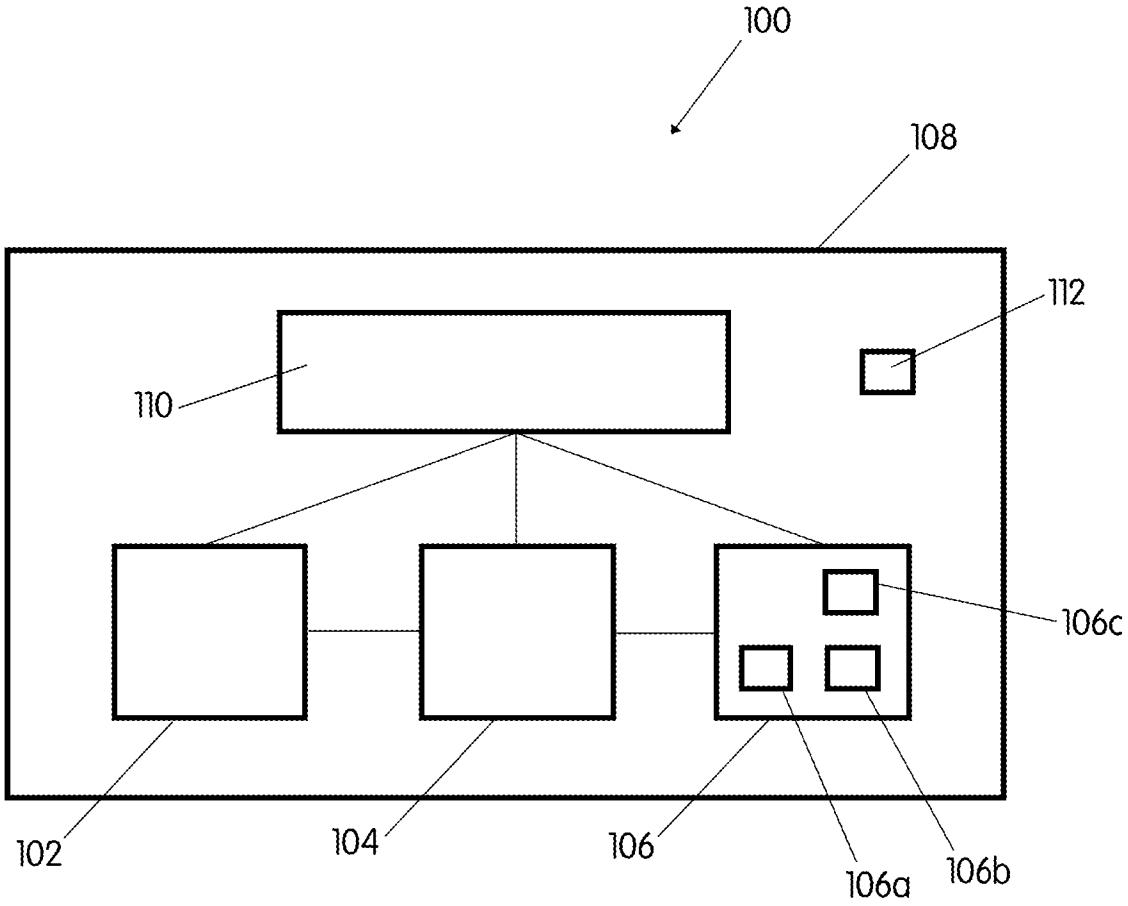

FIG. 1

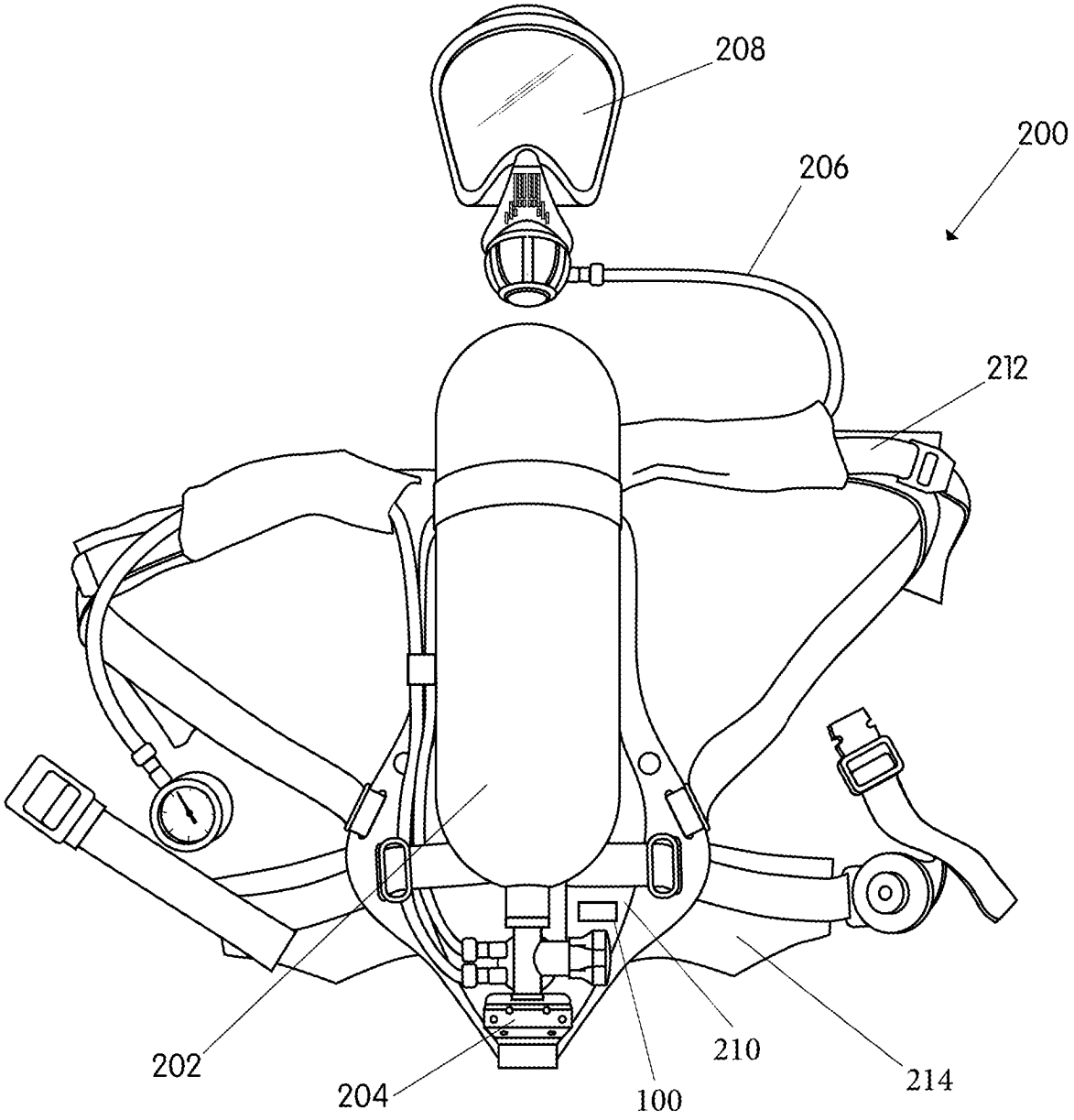

FIG. 2

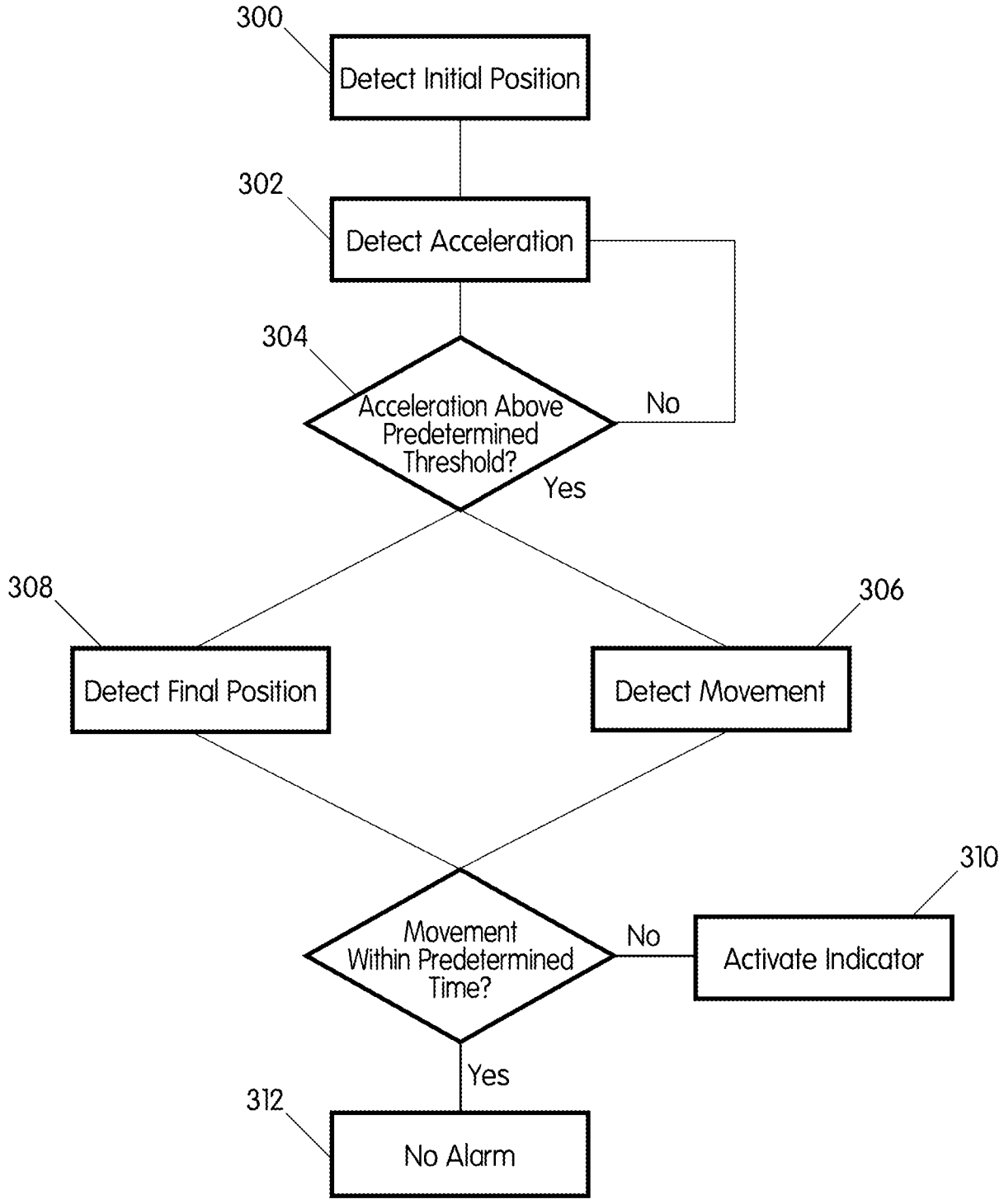
300
Detect Initial Position
302
Detect Acceleration
304
Acceleration Above Predetermined Threshold?
No
Yes
308
Detect Final Position
306
Detect Movement
Movement Within Predetermined Time?
No
310
Activate Indicator
Yes
312
No Alarm

FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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- US 48689717 **[0001]**
- WO 2015036245 A1 **[0006]**
- US 20150090751 A1 **[0007]**
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