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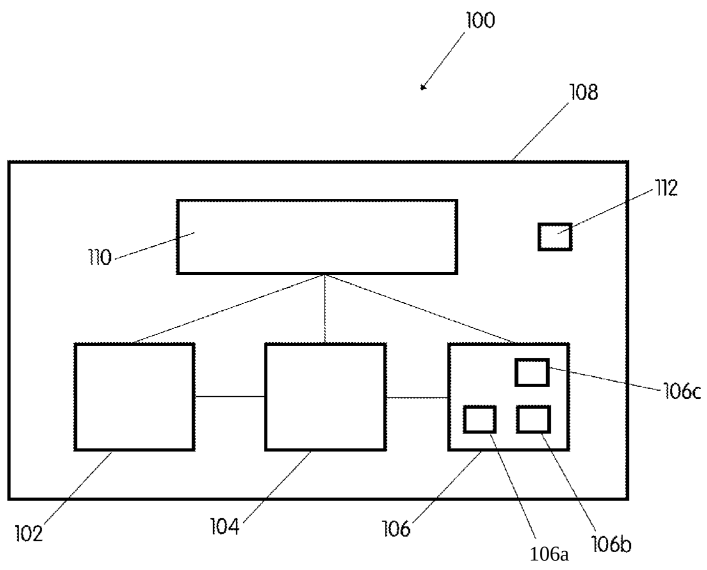

FIG. 1

(57) Abstract: A fall detection system includes at least one sensor configured to detect acceleration and orientation of a host, at least one indicator device having an alarm mode, and a controller operatively connected to the at least one sensor and the at least one indicator device. The controller is programmed to receive data generated by the at least one sensor, 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 the at least one indicator device to enter the alarm mode. The at least one specified parameter includes at least one of the following: an acceleration exceeding a predetermined threshold, a change between a starting and a final orientation of the host before and after an acceleration event, a lack of movement of the host for a predetermined time after the acceleration event, or any combination thereof.

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FALL DETECTION SYSTEM

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" the disclosures of which are incorporated by reference herein in their entireties.

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] 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.

[0007] 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

[0008] 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 tall 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.

(0009] In some preferred and non-limiting embodiments or aspects, provided is a fall detection system that may have at least one sensor configured to detect acceleration of a host, at least one indicator device having an alarm mode, and a controller operatively connected to the at least one sensor and the at least one indicator device, the controller programmed or configured to receive data generated by the at least one sensor, 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 to enter the alarm mode. The at least one specified parameter may include at least one of the following: an acceleration exceeding a predetermined threshold, a change between a starting orientation of the host before an acceleration event and a final orientation of the host after the acceleration event, a lack of movement of the host for a predetermined length of time after the acceleration event, or any combination thereof.

[0010] In other preferred and non-limiting embodiments or aspects, the predetermined threshold for the acceleration event may be at least about 3 G. The predetermined length of time after the acceleration event may be in the range of about 0 seconds to about 5 seconds. The at least one sensor may be configured to detect at least one of static acceleration and dynamic acceleration. The at least one sensor may be at least one of the following: a 3-axis accelerometer, a 6-axis accelerometer, an omni-directional magnetometer, or any combination thereof. The at least one indicator device may be a visual indicator device. The visual indicator device may be at least one of a light-emitting diode and an infrared emitter. The at least one indicator device may be an audible indicator device. The audible indicator device may be at least one of a speaker and a piezo buzzer. The at least one indicator device may be a remote signaling indicator device programmed or configured for wireless communication with at least one remote device. The remote signaling indicator device may be programmed or configured to send at least one of a wireless short-range signal and a wireless long-range signal to the at least one remote device. A reset mechanism may be provided for turning off the at least one indicator after activation. A power source may be provided for supplying power to at least one of the following: the controller, the at least one sensor, the at least one indicator device, or any combination thereof.

[0011] In other preferred and non-limiting embodiments or aspects, provided is a self-contained breathing apparatus that may have a tank mounted on a rigid frame configured for mounting on a user's back using one or more straps and a fall detection system. The fall detection system may have at least one sensor connected to the rigid frame to detect acceleration of the user wearing the rigid frame, at least one indicator device having an alarm mode, and a controller operatively connected to the at least one sensor and the at least one indicator device, the controller programmed or configured to receive data generated by the at least one sensor, 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, activate or cause the activation of the at least one indicator device to enter the alarm mode. The at least one specified parameter may include at least one of the following: an acceleration exceeding a predetermined threshold, a change between a starting orientation of the host before an acceleration event and a final orientation of the host after the acceleration event, a lack of movement of the host for a predetermined length of time after the acceleration event, or any combination thereof.

[0012] In some preferred and non-limiting embodiments or aspects, the predetermined threshold for the acceleration event may be at least about 3 G. The predetermined length of time after the acceleration event may be in the range of about 0 seconds to about 5 seconds. The at least one sensor may be configured to detect at least one of static acceleration and dynamic acceleration. The at least one sensor may be at least one of the following: a 3-axis accelerometer, a 6-axis accelerometer, an omni-directional magnetometer, or any combination thereof. The at least one indicator device may be at least one of a visual indicator device, an audible indicator device, and a remote-signaling indicator device. A reset mechanism may be for turning off the at least one indicator after activation.

[0013] Further preferred and non-limiting embodiments or aspects will now be set forth in the following numbered clauses.

[0014] Clause 1: A fall detection system comprising:

at least one sensor configured to detect acceleration and orientation of a host;

at least one indicator device having an alarm mode; and

a controller operatively connected to the at least one sensor and the at least one indicator device, the controller programmed or configured to:

receive data generated by the at least one sensor;

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 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 host before an acceleration event and a final orientation of the host after the acceleration event, a lack of movement of the host for a predetermined length of time after the acceleration event, or any combination thereof.

[0015] Clause 2: The fall detection system of clause 1, wherein the predetermined threshold for the acceleration event is at least about 3 G.

[0016] Clause 3: The fall detection system of clause 1 or 2, wherein the predetermined length of time after the acceleration event is in the range of about 0 seconds to about 5 seconds.

[0017] Clause 4: The fall detection system of any of clauses 1-3, wherein the at least one sensor is configured to detect at least one of static acceleration and dynamic acceleration.

[0018] Clause 5: The fall detection system of any of clauses 1-4, wherein the at least one sensor is at least one of the following: a 3-axis accelerometer, a 6-axis accelerometer, an omni-directional magnetometer, or any combination thereof.

[0019] Clause 6: The fall detection system of any of clauses 1-5, wherein the at least one indicator device is a visual indicator device.

[0020] Clause 7: The fall detection system of any of clauses 1-6, wherein the visual indicator device is at least one of a light-emitting diode and an infrared emitter.

[0021] Clause 8: The fall detection system of any of clauses 1-7, wherein the at least one indicator device is an audible indicator device.

[0022J Clause 9: The fall detection system of any of clauses 1-8, wherein the audible indicator device is at least one of a speaker and a piezo buzzer.

[0023] Clause 10: The fall detection system of any of clauses 1-9, wherein the at least one indicator device is a remote signaling indicator device programmed or configured for wireless communication with at least one remote device.

[0024] Clause 11: The fall detection system of any of clauses 1-10, wherein the remote signaling indicator is programmed or configured to send at least one of a wireless short-range signal and a wireless long-range signal to the at least one remote device.

[0025] Clause 12: The fall detection system of any of clauses 1-11, further comprising a reset mechanism for turning off the at least one indicator after activation.

[0026] Clause 13: The fall detection system of any of clauses 1-12, further comprising a power source for supplying power to at least one of the following: the controller, the at least one sensor, the at least one indicator device, or any combination thereof.

[0027] Clause 14: A self-contained breathing apparatus (SCBA) comprising:

a tank mounted on a rigid frame configured for mounting on a user's back using one or more straps; and

a fall detection system comprising:

at least one sensor connected to the rigid frame and configured for detecting acceleration and orientation of the user wearing the rigid frame;

at least one indicator having an alarm mode; and

a controller operatively connected to the at least one sensor for receiving data detected by the at least one sensor, analyzing the data detected by the at least one sensor for predetermined characteristics indicative of a fall event, and activating the at least one indicator to the alarm mode upon detecting data with the predetermined characteristics indicative of the fall event,

wherein the predetermined characteristics of the fall event comprise an acceleration event exceeding a predetermined threshold, a change between a starting orientation of the user before the acceleration event and a final orientation of the user after the acceleration event, and a lack of movement of the user after the acceleration event.

[0028] Clause 15: The SCBA of clause 14, wherein the predetermined threshold for the acceleration event is at least 3 G.

[0029] Clause 16: The SCBA of clause 14 or 15, wherein the predetermined length of time after the acceleration event is 0 to 5 seconds.

[0030] Clause 17: The SCBA of any of clauses 14-16, wherein the at least one sensor is configured for detecting static acceleration and dynamic acceleration.

[0031] Clause 18: The SCBA of any of clauses 14-17, wherein the at least one sensor is one of a 3-axis accelerometer, a 6-axis accelerometer, and an omni-directional magnetometer.

[0032] Clause 19: The SCBA of any of clauses 14-18, wherein the at least one indicator device is at least one of a visual indicator device, an audible indicator device, and a remote-signaling indicator device.

[0033] Clause 20: The SCBA of any of clauses 14-19, further comprising a reset mechanism for turning off the at least one indicator after activation.

[0034] 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

[0035] **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;

[0036] **FIG. 2** is a perspective view of a self-contained breathing apparatus configured for use with the fall detection system of **FIG. 1**; and

[0037J **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

[0038] For puiposes 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.

[0039] 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.

[0040] 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.

[0041] 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.

[0042] 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.

[0043] 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. In various examples, the fall detection system **100** may be used with other equipment worn by the user, such as a harness, belt, or a frame for supporting equipment, such as a self-contained breathing apparatus (SCBA).

Fall Detector

[0044] 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.

[0045] 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.**

[0046] As discussed herein, the fall detection system **100** is configured to be worn by a user, either directly, such as by being connected to the body and/or clothing of the user, or indirectly, such as by being connected to equipment that is carried by the user. For example, 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

[0047] 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 elecromechanical 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.

[0048] 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

[0049] 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 predetermined characteristics of the fall event), the controller **104** can activate the indicator device **106** to provide an alert that a fall event has occurred.

(0050] 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

[0051] 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.

[0052] 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.

[0053] 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.**

[0054] 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

[0055] The fall detection system **100** may be integrated on equipment configured to be carried or worn by the user. In some preferred and non-limiting embodiments or aspects, the fall detection system **100** may be used with a helmet worn on a user's head. In other preferred and non-limiting embodiments or aspects, the fall detection system **100** may be 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.

[0056] The fall detection system **100** may be integrated with the SCBA **200.** In some preferred and non-limiting embodiments or aspects, at least a portion of the fall detection system **100** may be connected to the frame **210** of the SCBA **200.** For example, at least the sensor **102** of the fall detection system **100** may be 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

(0057] 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.

[0058] 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.

(0059] 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.

[0060] 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.

[0061] 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-verticai	II	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	Staildtr g or cravvim*	High (60 G)	Medium (3(! b)	Non-vertical	II	Acceleration. Impact, Lack of Movement	Yes
Fall down stairs	Standing or crawling	High (60 G)	Medium (3C) 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 ✗✗ crawling	Smi l (10 G)	Medium (30 G)	Non-vertical	II	Impact, Lack of Movement, Orientation	Yes
Flying object	Standing or crawling	Small (10 G)	Medium (30 G)	Non-vertical	Yes	Impact, Movement, Orientation	No

[0062] 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.

|0063] 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.

[0064] 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.

(0065] Although the invention has been described in detail for the purpose of illustration based on what is currently considered to be the most practical and preferred embodiments, it is to be understood that such detail is solely for that purpose and that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover modifications and equivalent arrangements that are within the spirit and scope of the appended claims. For example, it is to be understood that the present invention contemplates that, to the extent possible, one or more features of any embodiment can be combined with one or more features of any other embodiment.

What is claimed is:

1. A tall detection system comprising:

at least one sensor configured to detect acceleration and orientation of a host;

at least one indicator device having an alarm mode; and

a controller operatively connected to the at least one sensor and the at least one indicator device, the controller programmed or configured to:

receive data generated by the at least one sensor;

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 to enter the alarm mode,

wherein the at least one specified parameter comprises at least one of the following: an acceleration exceeding a predetennined threshold, a change between a starting orientation of the host before an acceleration event and a final orientation of the host after the acceleration event, a lack of movement of the host for a predetermined length of time after the acceleration event, or any combination thereof.

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

3. The fall detection system of claim 1, 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 claim 1, wherein the at least one sensor is configured to detect at least one of static acceleration and dynamic acceleration.

5. The fall detection system of claim 1, wherein the at least one sensor 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 is a visual indicator device.

7. The fall detection system of claim 6, wherein the visual indicator device is at least one of a light-emitting diode and an infrared emitter.

8. The fall detection system of claim 1, wherein the at least one indicator device is an audible indicator device.

9. The fall detection system of claim 8, wherein the audible indicator device is at least one of a speaker and a piezo buzzer.

10. The fall detection system of claim 1, wherein the at least one indicator device is a remote signaling indicator device programmed or configured for wireless communication with at least one remote device.

11. The fall detection system of claim 10, wherein the remote signaling indicator device is programmed or configured to send at least one of a wireless short-range signal and a wireless long-range signal to the at least one remote device.

12. The fall detection system of claim 1, further comprising a reset mechanism for turning off the at least one indicator device after activation.

13. The fall detection system of claim 1, further comprising a power source for supplying power to at least one of the following: the controller, the at least one sensor, the at least one indicator device, or any combination thereof.

14. A self-contained breathing apparatus (SCBA) comprising:

a tank mounted on a rigid frame configured for mounting on a user's back using one or more straps; and

a fall detection system comprising:

at least one sensor connected to the rigid frame to detect acceleration and orientation of the user wearing the rigid frame;

at least one indicator device having an alarm mode; and

a controller operatively connected to the at least one sensor and the at least one indicator device, the controller programmed or configured to receive data generated by the at least one sensor, 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, activate or cause the activation of the at least one indicator device 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 host before an acceleration event and a final orientation of the host after the acceleration event, a lack of movement of the host for a predetermined length of time after the acceleration event, or any combination thereof.

15. The SCBA of claim 14, wherein the predetermined threshold for the acceleration event is at least about 3 G.

16. The SCBA of claim 14, wherein the predetermined length of time after the acceleration event is the range of about 0 seconds to about 5 seconds.

17. The SCBA of claim 14, wherein the at least one sensor is configured to detect at least one of static acceleration and dynamic acceleration.

18. The SCBA of claim 14, wherein the at least one sensor is at least one of the following: a 3-axis accelerometer, a 6-axis accelerometer, an omni-directional magnetometer, or any combination thereof.

19. The SCBA of claim 14, wherein the at least one indicator device is at least one of a visual indicator device, an audible indicator device, and a remote-signaling indicator device.

20. The SCBA of claim 14, further comprising a reset mechanism for turning off the at least one indicator device after activation.

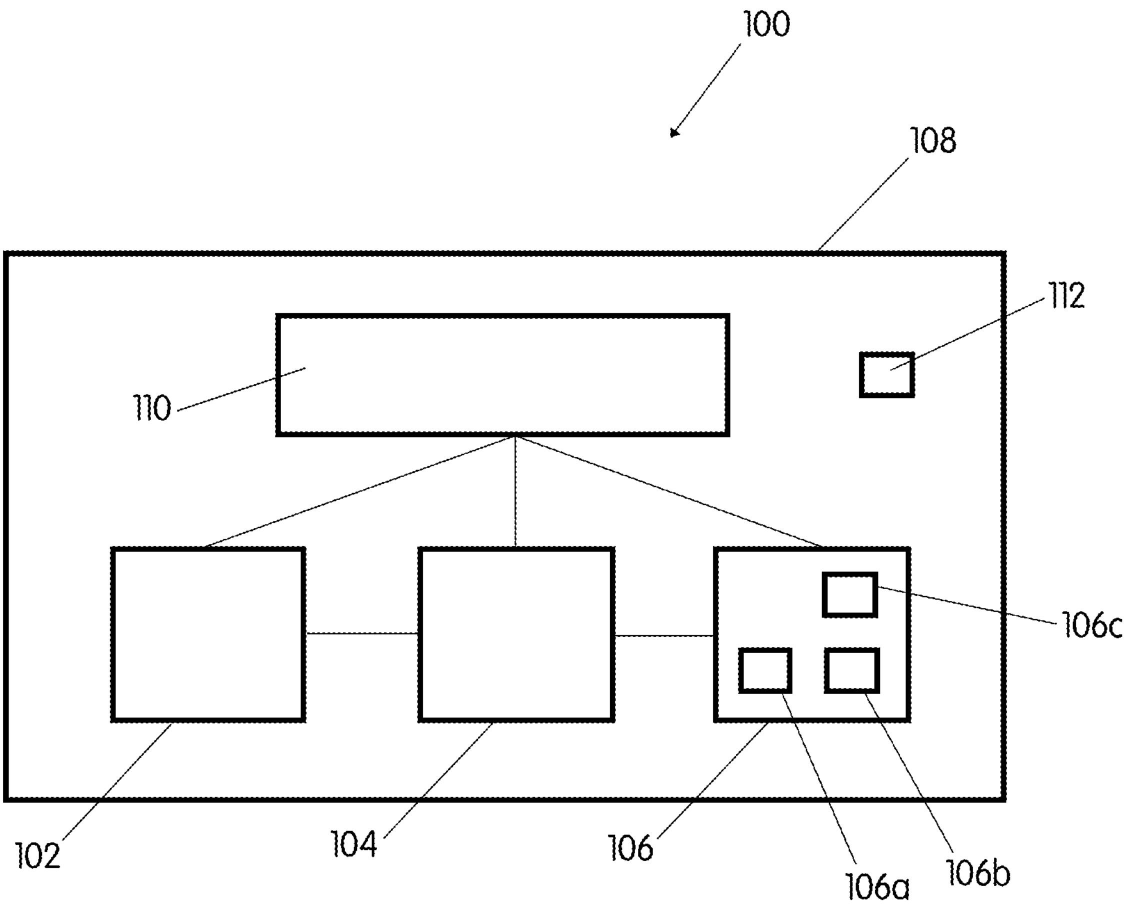

FIG. 1

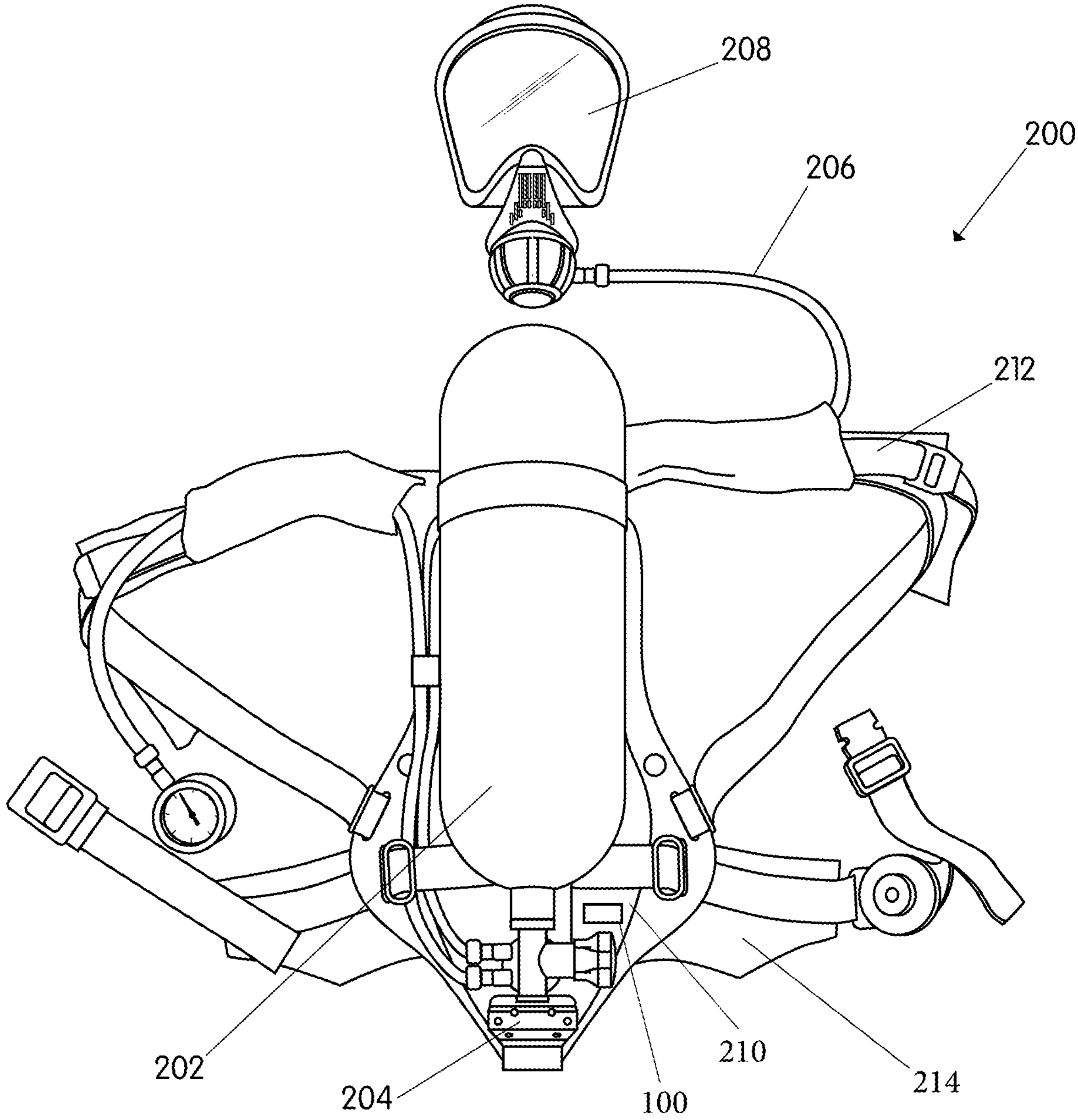

FIG. 2

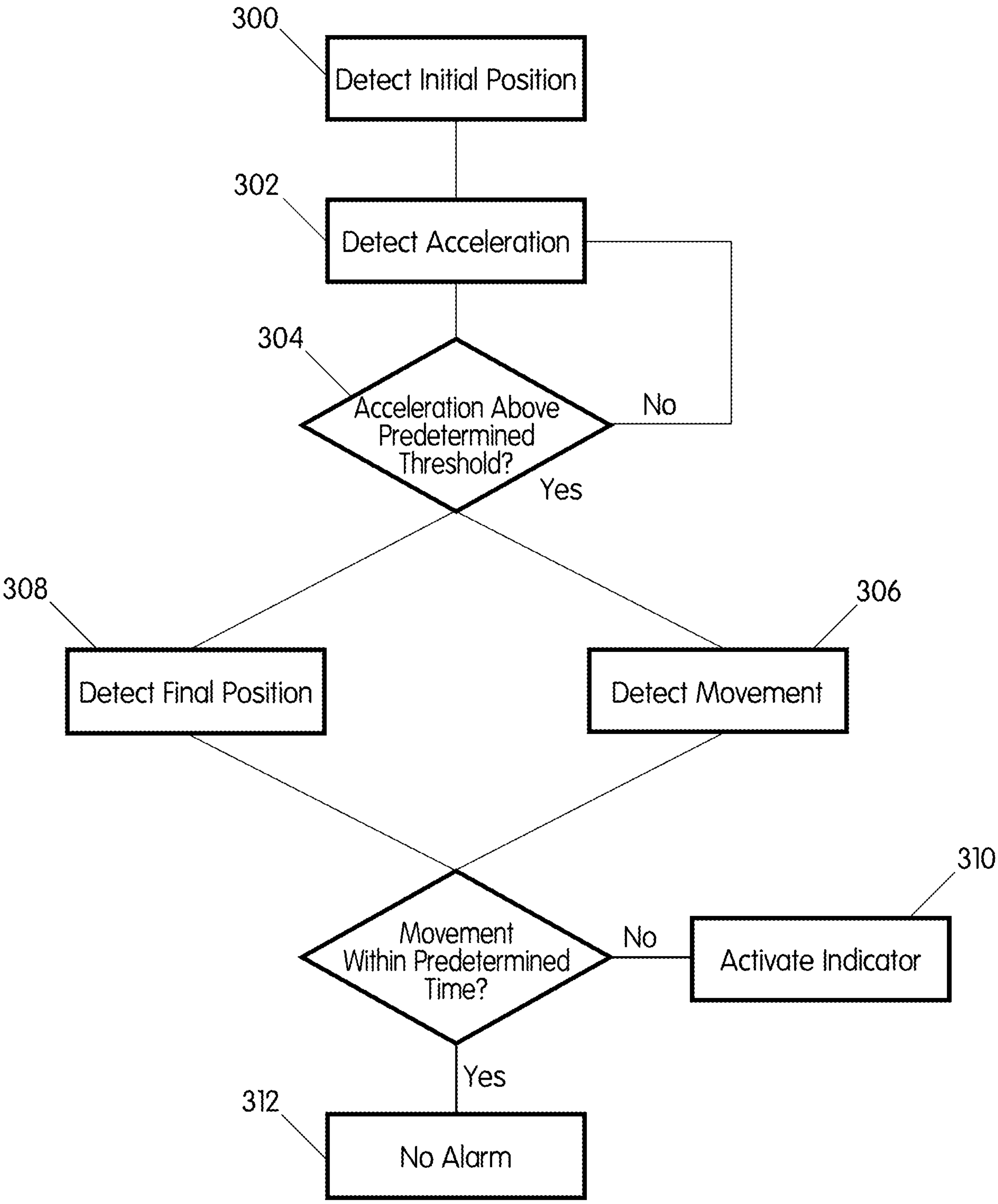
300
Detect Initial Position
302
Detect Acceleration
304
Acceleration Above Predetermined Threshold?
No
Yes
308
Detect Final Position
306
Detect Movement
310
Movement Within Predetermined Time?
No
Activate Indicator
Yes
312
No Alarm

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/027586

A. CLASSIFICATION OF SUBJECT MATTER
INV. G08B21/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G08B A61B A45F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2015/036245 A1 (KONINKL PHILIPS NV [NL]) 19 March 2015 (2015-03-19) figures 3,7 page 13, lines 19-34 page 14, lines 20-22 -----	1 2-20
Y	US 2015/090751 A1 (LANGFORD GRAHAM [GB] ET AL) 2 April 2015 (2015-04-02) figure 1 abstract -----	14-20
Y	US 2001/032059 A1 (KELLY PAUL B [US] ET AL) 18 October 2001 (2001-10-18) figure 5 paragraphs [0025], [0026], [0036], [0056], [0095], [0097], [0128] -----	2-13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 July 2017	18/07/2017

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/027586

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015036245 A1	19-03-2015	CN 105530865 A	27-04-2016
		EP 3043709 A1	20-07-2016
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