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SYSTEMS AND METHODS FOR DETECTING A POSITION OF A SUBJECT

Abstract

A system for detecting changes in the position of a subject is provided. An imaging device captures one or more images in a room where a subject may be located and provides the one or more images to an artificial neural network for processing. The ANN processes the images to determine a current state of a subject in the room. If the determined current state of the subject is associated with one or more alerts, the system delivers one or more alerts, which may be audible, visual, and/or haptic.

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Background/Summary

RELATED APPLICATION [0001] The present application claims priority to U.S. provisional patent application No. 63/368,317 filed Jul. 13, 2022, which is incorporated herein by reference in its entirety.

BACKGROUND
Field of the Invention
[0002] The present disclosure is generally directed toward machine learning and computer vision and more specifically related to systems and methods for monitoring a subject to detect changes in a position of the subject.
Related Art
[0003] Care facilities, other facilities, and private residences where individuals are housed have a need to monitor the well being of their occupants. In some circumstances, occupants of such facilities and homes may fall or find themselves in situations without anyone nearby being aware or able to assist. Existing technologies designed to address these issues generally require wearable devices with accelerometers and buttons. When the accelerometers activate or when the buttons are pressed, they trigger alert messages that are designed to elicit prompt responses. However, these solutions necessitate that the occupants consistently wear one or more devices and that an occupant has the capacity to engage with a device by pressing a button. This interactivity requirement for emergency alerting presents significant issues. Accordingly, what is needed is a system and method that overcomes these significant problems found in the conventional systems as described above.
SUMMARY
[0004] In one aspect, the field of view of a camera sensor is trained on a at least a portion of a room where a subject may be located. The camera is configured to periodically and automatically capture images of the field of view of the camera sensor within the room. The captured images may be color, infrared, black and white, or some other type of image corresponding to the ambient environment of the room and the capabilities of the camera sensor. The captured images are processed by a trained machine learning model, such as an artificial neural network (“ANN”), e.g., a convolutional neural network, to determine if a subject is present by being at least partially within the field of view of the sensor, and to determine a position of the subject when the subject is present. The input to the ANN can be multiple images taken over time or a single image and the ANN architecture is configured to receive and process such input.
[0005] The possible positions of the subject can include at least sitting, standing, in-bed, and fallen. Other positions may also be defined as desired to convey the orientation and safety of the subject. The possible positions of the subject are referred to herein as “states” and additional states may include, away (i.e., not present), with caregiver present, and with others present, just to name a few. For example, in one aspect, a valid state as determined by the ANN may be sitting with others present, or in-bed with caregiver present, or standing.
[0006] In one aspect, the input to the ANN is processed by the ANN. The output from the ANN is provided to a state machine application which analyzes the ANN output to determine the current state of the subject based on the ANN output, ANN output history, and previous state history. For example, a determined ANN output of “away” may update the state of the person and trigger an alert to family members or staff at a facility where the subject is located. Alternatively, a determined state of “fallen” may trigger an alert to a set of emergency contacts, such as a caregiver

or family member. The determined state can also be saved into a memory and subsequently used to contribute towards a set of collected activity data on a person. Advantageously, an alert may be in the form of an audible or visual notification, a digital notification, a pre-recorded phone call, a text message, a computer sound, or other physical or digital notification or communication to alert one or more desired individuals of the subject's current state and/or location and/or position. Additionally, the type of alert may convey whether assistance is needed by the subject.

[0007] In one aspect, the ANN is continuously trained by continuous monitoring of the image data collected by the camera sensor. Each room may have a separately trained ANN instance so as to tune the ANN instance specifically to the unique environment. Training the ANN may advantageously improve the operation of all cameras in all rooms, but more importantly such training specifically improves the operation of a particular camera in a particular room. Accordingly, captured images from a particular room are continuously analyzed by human data labelers and/or algorithmic processes to confirm the various states of a subject within the room. This process for continuously tuning the ANN may include applying machine learning methods, such as neural network back propagation, to increase the accuracy of the learning model with the specifically collected dataset.

[0008] In one aspect, the complete system, including the camera, the ANN and the audible and visual notification hardware, is located in the room that is being monitored. In an alternative aspect, certain portions of the system may be located elsewhere, such as audible and visual notification hardware, and the processors that execute the ANN application and the state machine application.

[0009] In one aspect, the system includes a mobile application that allows a live feed or delayed feed of the field of view of the camera and current state detected by the state machine application. The mobile application may also allow views of still images captured by the camera sensor. Advantageously, the mobile application may also allow a user to configure different types of alerts based on customized criteria established by the user. The mobile application may also be configured to access a plurality of cameras in a variety of different rooms of a facility or different rooms at different facilities. The mobile application may also be configured to provide information about one or more subjects being monitored, for example, the amount of time a subject spent in-bed, the number of times a subject stands, the number of times and/or times of day a subject gets out of bed, and other helpful information as determined by the ANN as a result of the ongoing image analysis.

[0010] Other features and advantages of the present invention will become more readily apparent to those of ordinary skill in the art after reviewing the following detailed description and accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The structure and operation of the present invention will be understood from a review of the following detailed description and the accompanying drawings in which like reference numerals refer to like parts and in which:

[0012] FIG. **1** illustrates an example infrastructure, in which one or more of the processes described herein may be implemented, according to an embodiment;

[0013] FIG. **2** illustrates an example processing system, by which one or more of the processes described herein may be executed, according to an embodiment;

[0014] FIG. **3** illustrates an example training process for an example artificial neural network, by which one or more of the processes described herein may be executed, according to an embodiment;

[0015] FIG. **4** illustrates an example operation of an example artificial neural network, by which

one or more of the processes described herein may be executed, according to an embodiment;
[0016] FIG. **5** is a flow diagram illustrating an example process for determining a state of a subject according to an embodiment of the invention;
[0017] FIG. **6** is a flow diagram illustrating an example process for providing a state of a subject to a remote use according to an embodiment of the invention; and
[0018] FIG. **7** is a flow diagram illustrating an example process for continuous improvement of an artificial neural network according to an embodiment of the invention.

DETAILED DESCRIPTION

[0019] Disclosed herein are systems, methods, and non-transitory computer-readable media for detecting changes in a position of a subject. For example, one method disclosed herein allows for one or more images of a room to be captured by a camera sensor and fed into an application including an ANN portion and a state machine portion for processing. The ANN portion of the application combined with the state machine portion of the application processes the image(s) to determine a current state of the subject. If the determined current state of the subject is associated with one or more alerts, the system delivers one or more alerts, which may be audible, visual, and/or haptic.
[0020] After reading this description it will become apparent to one skilled in the art how to implement the invention in various alternative embodiments and alternative applications. However, although various embodiments of the present invention will be described herein, it is understood that these embodiments are presented by way of example only, and not limitation. As such, this detailed description of various alternative embodiments should not be construed to limit the scope or breadth of the present invention as set forth in the appended claims.

1. System Overview

1.1. Infrastructure

[0021] FIG. **1** illustrates an example infrastructure in which one or more of the disclosed processes may be implemented, according to an embodiment. The infrastructure may comprise a platform **110** (e.g., one or more servers) which hosts and/or executes one or more of the various functions, processes, methods, and/or software modules described herein. Platform **110** may comprise dedicated servers, or may instead comprise cloud instances, which utilize shared resources of one or more servers. These servers or cloud instances may be collocated and/or geographically distributed. Platform **110** may also comprise or be communicatively connected to a server application **112** and/or one or more databases **114** and/or one or more sensors **116**. In addition, platform **110** may be communicatively connected to one or more user systems **130** (e.g., mobile devices, laptops, personal computers, etc.) via one or more networks **120**. Platform **110** may also be communicatively connected to one or more external systems **140** (e.g., other platforms, websites, camera systems, etc.) via one or more networks **120**.
[0022] Network(s) **120** may comprise the Internet, and platform **110** may communicate with user system(s) **130** through the Internet using standard transmission protocols, such as HyperText Transfer Protocol (HTTP), HTTP Secure (HTTPS), File Transfer Protocol (FTP), FTP Secure (FTPS), Secure Shell FTP (SFTP), and the like, as well as proprietary protocols. While platform **110** is illustrated as being connected to various systems through a single set of network(s) **120**, it should be understood that platform **110** may be connected to the various systems via different sets of one or more networks. For example, platform **110** may be connected to a subset of user systems **130** and/or external systems **140** via the Internet, but may be connected to one or more other user systems **130** and/or external systems **140** via an intranet. Furthermore, while only a few user systems **130** and external systems **140**, one server application **112**, and one set of database(s) **114** are illustrated, it should be understood that the infrastructure may comprise any number of user systems, external systems, server applications, and databases.
[0023] User system(s) **130** may comprise any type or types of computing devices capable of wired and/or wireless communication, including without limitation, desktop computers, laptop

computers, tablet computers, smart phones or other mobile phones, servers, game consoles, head mounted displays, televisions, set-top boxes, electronic kiosks, point-of-sale terminals, Automated Teller Machines, and/or the like. User system(s) **130** may include one or more application **132**, databases **134** (e.g., a memory **134**) and one or more sensors **136**.

[0024] External system **140** may comprise any type of imaging system such as a camera system. External system **140** may be located in a room occupied by a subject. In one aspect, external system **140** includes one or more sensors **146** that are configured to capture image data. For example, the sensor **146** may be trained on a high traffic portion of the room that is occupied by the subject such as the bed and/or other furniture. The image data that is captured may be black and white image data, color image data, infra-red image data, and the like. The external system **140** is configured to communicate with the platform **110** via the network **120** and is further configured to transmit the information captured by the sensor, along with related meta data, over the network **120** to platform **110**. In one aspect, the transmission of the image data and related meta data may occur via an application **142** that executes on the external system **140**. For example, application **142** may be a firmware application written to directly transmit image data and meta data to platform **110** via the network **120**. Additionally, external system **140** may capture and send image data and related meta data one image at a time or external system **140** may capture multiple images and related meta data and store the information in memory **144** and perform some level of computational preprocessing (e.g., resizing, down sampling, encryption, etc.) before transmitting the image data and related meta data to the platform **110**.

[0025] In one aspect, platform **110** and external system **140** may be integrated into a single device. Alternatively, platform **110** may be deployed in the cloud while external system **140** is deployed in the room occupied by the subject.

[0026] In one aspect, the application **112** of the platform **110** is configured to process the information (e.g., image data and related meta data) received from the external system **140** to determine a state of the subject who occupies the room in which the external system **140** is deployed. The application **112** is further configured to store one or more states of the subject that are determined over time and, in certain circumstances when predetermined criteria a met, the application **112** is further configured to transmit an alert to one or more recipients. For example, an alert may be an indication that the subject has fallen. Alternatively, an alert may be an indication that the subject is awake.

[0027] In one aspect, application **112** is implemented as an artificial neural network (ANN) and includes state machine logic that is used to determine the state of the subject in one or more images.

[0028] In one aspect, an image that is captured by external system **140** comprises three dimensions, namely a height dimension, a width dimension, and color channels. For example, the three dimensions of an image may be represented as 224×224×3. Advantageously, the application **112** and/or application **142** is configured to apply certain image preprocessing techniques to the one or more images captured by the sensor of the external system **140** to modify, if necessary, the dimensions of the image in order to comply with the expected dimensions of an image that is input to the application **112** when implemented as an ANN. Such image preprocessing techniques may include resizing, center cropping, and channel collapsing.

[0029] In one aspect, the application **112** when implemented as an ANN may accept as input one or more images and process the one or more images through one or more of a convolutional neural network, recurrent neural network, and/or attention network for the purpose of classifying one or more subjects in the one or more images into one of five states. The application **112** when implemented as an ANN is trained to determine a confidence of the image being classified as one of five states and provide a confidence output, between 0 and 1, for each state. In one aspect, this may be accomplished using, e.g., a softmax ANN output layer.

[0030] In one aspect, the five states include: sitting, standing, in-bed, fall, or empty room. The names of the five states may be used as labels to describe the action of the subject in the image. In one aspect, an output from the ANN is provided for each of the five states and a confidence score for each state is also provided. Accordingly, the state machine portion of the application **112** receives as input a confidence score for the subject being in each of the five states.

[0031] In one aspect, captured images from external system **140** may be stored in memory **114** by application **112** and later be provided to a user system **130** upon request. In response to such a request by a user system **130**, the application **112** is configured to transmit via network **120** one or more images stored in memory **114** to the requesting user system **130**. Such transmitted images may be static images or a series of images may be transmitted to a requesting user system **130** as a live feed of the room that is occupied by the subject.

[0032] The state machine portion of the application **112** receives the current state of the subject from the ANN portion of the application **112** and stores the current state in memory **114**. The current state of the subject is subsequently used by the application **112** to determine whether the subject has changed state. Advantageously, determining whether the subject has changed state allows the application **112** to store a time (or at least an approximate time) that a state change occurred. Additionally, a change in state may prompt the application **112** to trigger one or more alerts to one or more individuals such as a caregiver and/or a family member.

[0033] In one aspect, the state machine portion of application **112** may use the most confident output from the ANN (e.g., the highest confidence score) to determine which state the subject is in. Additionally, the state machine portion of application **112** is configured to initially determine whether the output of the ANN portion of application **112** is sufficiently confident to be considered. In one aspect, the state machine portion of application **112** applies a threshold to the confidence score such that, for example, if the highest confidence score is under 0.4, the confidence scores from the ANN portion of application **112** are not considered. In such a circumstance, the state machine portion of application **112** determines that the state of the subject remains unchanged. However, in such a circumstance, the application **112** may save the image received from external system **140** in memory **114** and subsequently be used for future ANN model training.

[0034] In one aspect, if the highest confidence score from the ANN portion of application **112** exceeds the threshold, the state machine portion of application **112** obtains previous outputs of the ANN portion of application **112** that have been stored in memory **114** and analyzes the previous outputs to determine whether a sufficient amount of time has elapsed to allow for a state change. The elapsed time can be measured literally or as a function of the number of ANN outputs that are analyzed. For example, if the external system **140** is capturing images at a rate of one per minute and the state machine portion of application **112** analyzes five prior outputs from the ANN portion of application **112** (e.g., five images were captured since the most recent state change), the literal passing of five minutes may be considered sufficient for the subject to have changed state. Alternatively, if the external system is capturing live feed video at a frame rate of 30 frames per second and the state machine portion of application **112** analyzes three hundred prior outputs from the ANN portion of application **112**, the three hundred prior outputs may not be considered sufficient for the subject to have changed state.

[0035] Advantageously, the analysis performed by the state machine portion of application **112** functions as a small time buffer and applies a short delay before the application **112** changes the state of the subject. This allows the application **112** to determine that when the subject is in a new state compared to the current state for a sufficient period of time, the state of the subject is determined to have changed and the current state of the subject is updated in memory **114** to reflect the newly determined state of the subject.

[0036] In one aspect, when a change in the state of the subject has been determined by the state machine portion of application **112**, the time of the state change and the current state are stored in memory **114**. This allows the current state to always be available for sending to one or more user systems **130** upon request. Additionally, upon any state change, the current state is evaluated to identify any predetermine alerts that may correspond to the current state. Such alerts may then be sent by the application **112** via the network **120**. Such alerts may be sent, e.g., to one or more user systems **130** and one or more external systems **140**. For example, sending an alert to a user system **130** may notifying a subscribed user that the subject in the room has changed states.

[0037] In one aspect, time period may be allowed to elapse after a state of the subject has changed and before any alert is sent. This time period advantageously ensures that the subject has been in the new current state for a defined duration, such as one minute, before triggering an alert. The time period that is allowed to elapse may be unique to each state. For example, a fall alert may be sent immediately while a standing alert may be delayed for one minute before sending to determine if the standing state was a transitional state between, e.g., an in-bed state and a sitting state. In one aspect, the state machine portion of application **112** maintains a timer that tracks how long the subject is out of bed, meaning when they are in the standing, sitting, empty room, or fall state. Advantageously, this timer allows the application **112** to alert one or more individuals when the subject has been out of bed for a predetermined duration of time. Such an alert can facilitate assistance to a subject when the subject has not safely returned to bed in a normal period of time.

[0038] In one aspect, the application **112** may send one or more alerts to one or more user systems **130**. Such alerts may be in the form of text messages, push notifications, application pop ups, and pre-recorded phone calls. In one aspect, the alert may trigger the user system **130** to deliver haptic feedback to a user of the user system **130**. Advantageously, certain types of alerts, for example, alerts corresponding to the fall state and/or corresponding to the subject being out of bed for too long may trigger a pre-recorded phone call to the user system **130**. Other alerts triggered by other state changes and/or other timers may trigger less intrusive push notifications and text messages.

[0039] In one aspect, the user system **130** is configured to receive alerts and notify the user of the user system **130**. This may be accomplished via the application **132**. Additionally, the application **132** may be configured to communicate with the application **112** on the platform **110** to obtain the current state of a subject and present the current state of the subject on a user interface of the user system **130**. The application **132** of the user system **130** may also cooperate with the application **112** of the platform **110** to provide a live feed of the room where the subject is located such that images captured from the external system **140** in the room where the subject is located can be presented on a user interface of the user system **130**. The application **132** may also cooperate with the application **112** to obtain and provide to a user of user system **130** certain historical state information about the subject and to select and configure certain alerts to be sent to the user system **130**. For example, the application **132** may cooperate with the application **112** to allow a user of the user system **130** to configure one or more alerts to be sent to the user system **130** for certain state changes, certain elapsed timers, and to provide information about historical alerts, and to view certain analytics about the subject based on historical data such as image data and meta data and state data corresponding to the subject.

[0040] In one aspect, the application **132** allows the user of the user system **130** to opt into certain alerts such as state changes to sitting, standing, in-bed, fall, empty room, and elapsed timers for when the subject has been out of bed for an amount of time that exceeds a predetermined threshold, which may be customized for the particular subject.

[0041] In one aspect, if an external system **140** fails to communicate with the platform **110** for a certain period of time, an elapsed timer corresponding to that certain period of time may trigger an alert. Such an alert may advantageously include analytics of any image data and or meta data received from the external system **140** prior to the gap in communication.

[0042] In one aspect, the application **132** allows a user of the user system **130** to configure a blackout period during which alerts are not presented to the user of the user system **130**, notwithstanding the fact that an alert was triggered and sent by the platform **110** to the user system **130**. For example, the user may configure an alerting blackout period from 9am to 7pm. Advantageously, certain types of alerts, such as a fall alert, can be configured for immediate delivery, even during a blackout period that has been set by a user of the user system **130**.

[0043] In one aspect, each external system **140** may be associated with one or more user accounts that are designated as an administrator for the external system **140**. The administrator account allows an appropriate user to determine what other users and or users systems **130** may access information about the subject via platform **110**.

[0044] In one aspect, multiple users who are not an administrator may be given access to view information about a subject. These additional users may be set up as caregiver users and associated with the external system **140** and allowed access to the data and information provided to the platform **110** by the external system **140**.

[0045] In one aspect, the administrative user has additional privileges corresponding to a particular subject with respect to external system **140** that is in the room occupied by the particular subject. For example, the administrative user may be allowed to blur or disable the live feed from external system **140** or may be allowed to limit access to the live feed from external system **140** to certain users such as caregiver users or other users. This may advantageously preserve the privacy of the subject.

[0046] In one aspect, the application **132** on the user system **130** cooperates with the application **112** on the platform **110** to provide analytics about a subject that are based on the subject's state history. These analytics may include durations that a subject spent in each state during a certain time window and may include the number of times the subject was in each state during a certain time window. For example, such analytics may include the amount of time the subject spent in-bed and the number of times the subject transitioned from a different state to the in-bed state.

[0047] In one aspect, certain metrics about a subject may be presented by the application **132** on a user interface of the user system **130** as historical trend data and may also include comparative analytics that compare the subject against a larger population of subjects who are monitored by the platform **110** via separate external systems **140**. In this fashion, caregivers and users of user systems **130** and even subjects can compare a particular subject against a larger population of subjects.

[0048] In one aspect, a safety/wellness score for an individual subject is generated by the application **112**. For example, the safety/wellness score can be a numerical score between 0 and 100 that is a measure of how much time the subject spent in-bed. The score may be weighted such that riskier behaviors such as leaving the room have a more negative impact on the score versus less risky behaviors such as standing, which in turn has a larger negative impact on the score than sitting.

[0049] In one aspect, a user of a user system **130** can view via the application **132** a comparison of the amount of time a subject has spent in-bed, sitting, and out of bed. The application **132** is also configured to provide to a user of the user system **130** those certain hours within a twenty four hour period that have the highest frequency for the subject to be out of bed. Additionally, the application **132** is configured to provide a user of the user system **130** the number of falls that have been detected for a subject and the number of times the subject has been out of bed during a selected time period.

[0050] In one aspect, the application **132** is configured to provide the user of the user system **130** a daily update that summarizes the state changes and corresponding analytics from the previous night (or some other predetermined time period). The daily update may, for example, include information such as the safety/wellness score, the during of time the subject spent in-bed, the number of times the subject left the bed, and other desirable information that can be customized by the user of the user system **130**.

[0051] Platform **110** may comprise web servers which host one or more websites and/or web services. In embodiments in which a website is provided, the website may comprise a graphical user interface, including, for example, one or more screens (e.g., webpages) generated in HyperText Markup Language (HTML) or other language. Platform **110** transmits or serves one or more screens of the graphical user interface in response to requests from user system(s) **130**. In some embodiments, these screens may be served in the form of a wizard, in which case two or more screens may be served in a sequential manner, and one or more of the sequential screens may depend on an interaction of the user or user system **130** with one or more preceding screens. The requests to platform **110** and the responses from platform **110**, including the screens of the graphical user interface, may both be communicated through network(s) **120**, which may include the Internet, using standard communication protocols (e.g., HTTP, HTTPS, etc.). These screens (e.g., webpages) may comprise a combination of content and elements, such as text, images, videos, animations, references (e.g., hyperlinks), frames, inputs (e.g., textboxes, text areas, checkboxes, radio buttons, drop-down menus, buttons, forms, etc.), scripts (e.g., JavaScript), and the like, including elements comprising or derived from data stored in one or more databases (e.g., database(s) **114**) that are locally and/or remotely accessible to platform **110**. Platform **110** may also respond to other requests from user system(s) **130**.

[0052] Platform **110** may further comprise, be communicatively coupled with, or otherwise have access to one or more database(s) **114**. For example, platform **110** may comprise one or more database servers which manage one or more databases **114**. A user system **130** or server application **112** executing on platform **110** may submit data (e.g., user data, form data, etc.) to be stored in database(s) **114**, and/or request access to data stored in database(s) **114**. Any suitable database may be utilized, including without limitation MySQL™, Oracle™, IBM™, Microsoft SQL™ Access™, PostgreSQL™, and the like, including cloud-based databases and proprietary databases. Data may be sent to platform **110**, for instance, using the well-known POST request supported by HTTP, via FTP, and/or the like. This data, as well as other requests, may be handled, for example, by server-side web technology, such as a servlet or other software module (e.g., comprised in server application **112**), executed by platform **110**.

[0053] In embodiments in which a web service is provided, platform **110** may receive requests from user system(s) **130** and/or external system(s) **140**, and provide responses in extensible Markup Language (XML), JavaScript Object Notation (JSON), and/or any other suitable or desired format. In such embodiments, platform **110** may provide an application programming interface (API) which defines the manner in which user system(s) **130** and/or external system(s) **140** may interact with the web service. Thus, user system(s) **130** and/or external system(s) **140** (which may themselves be servers), can define their own user interfaces, and rely on the web service to implement or otherwise provide the backend processes, methods, functionality, storage, and/or the like, described herein. For example, in such an embodiment, a client application **132** executing on one or more user system(s) **130** may interact with a server application **112** executing on platform **110** to execute one or more or a portion of one or more of the various functions, processes, methods, and/or software modules described herein. Client application **132** may be “thin,” in which case processing is primarily carried out server-side by server application **112** on platform **110**. A basic example of a thin client application **132** is a browser application, which simply requests, receives, and renders webpages at user system(s) **130**, while server application **112** on platform **110** is responsible for generating the webpages and managing database functions. Alternatively, the client application may be “thick,” in which case processing is primarily carried out client-side by user system(s) **130**. It should be understood that client application **132** may perform an amount of processing, relative to server application **112** on platform **110**, at any point along this spectrum between “thin” and “thick,” depending on the design goals of the particular implementation. In any case, the application described herein, which may wholly reside on either platform **110** (e.g., in which case server application **112** performs all processing) or user system(s) **130** (e.g., in which case client application **132** performs all processing) or be distributed between platform **110** and user system(s) **130** (e.g., in which case server application **112** and client application **132** both perform processing), can comprise one or more executable software modules that implement one or more of the processes, methods, or functions of the application described herein.

1.2. Example Processing Device

[0054] FIG. **2** is a block diagram illustrating an example wired or wireless system **200** that may be used in connection with various embodiments described herein. For example, system **200** may be used as or in conjunction with one or more of the functions, processes, or methods (e.g., to store and/or execute the application or one or more software modules of the application) described herein, and may represent components of platform **110**, user system(s) **130**, external system(s) **140**, and/or other processing devices described herein. System **200** can be a server or any conventional personal computer, or any other processor-enabled device that is capable of wired or wireless data communication. In one aspect, system **200** can be a camera system having the field of view of an imaging sensor trained on at least a portion of a room. Other computer systems and/or architectures may be also used, as will be clear to those skilled in the art.

[0055] System **200** preferably includes one or more processors, such as processor **210**. Additional processors may be provided, such as an auxiliary processor to manage input/output, an auxiliary processor to perform floating-point mathematical operations, a special-purpose microprocessor having an architecture suitable for fast execution of signal-processing algorithms (e.g., digital-signal processor), a slave processor subordinate to the main processing system (e.g., back-end processor), an additional microprocessor or controller for dual or multiple processor systems, and/or a coprocessor. Such auxiliary processors may be discrete processors or may be integrated with processor **210**. Examples of processors which may be used with system **200** include, without limitation, the Pentium® processor, Core i7® processor, and Xeon® processor, all of which are available from Intel Corporation of Santa Clara, California.

[0056] Processor **210** is preferably connected to a communication bus **205**. Communication bus **205** may include a data channel for facilitating information transfer between storage and other peripheral components of system **200**. Furthermore, communication bus **205** may provide a set of signals used for communication with processor **210**, including a data bus, address bus, and/or control bus (not shown). Communication bus **205** may comprise any standard or non-standard bus architecture such as, for example, bus architectures compliant with industry standard architecture (ISA), extended industry standard architecture (EISA), Micro Channel Architecture (MCA), peripheral component interconnect (PCI) local bus, standards promulgated by the Institute of Electrical and Electronics Engineers (IEEE) including IEEE 488 general-purpose interface bus (GPIB), IEEE 696/S-100, and/or the like.

[0057] System **200** preferably includes a main memory **215** and may also include a secondary memory **220**. Main memory **215** provides storage of instructions and data for programs executing on processor **210**, such as one or more of the functions and/or modules discussed herein. It should be understood that programs stored in the memory and executed by processor **210** may be written and/or compiled according to any suitable language, including without limitation C/C++, Java, JavaScript, Perl, Visual Basic, .NET, and the like. Main memory **215** is typically semiconductor-based memory such as dynamic random access memory (DRAM) and/or static random access memory (SRAM). Other semiconductor-based memory types include, for example, synchronous dynamic random access memory (SDRAM), Rambus dynamic random access memory (RDRAM), ferroelectric random access memory (FRAM), and the like, including read only memory (ROM).

[0058] Secondary memory **220** may optionally include an internal medium **225** and/or a removable medium **230**. Removable medium **230** is read from and/or written to in any well-known manner. Removable storage medium **230** may be, for example, a magnetic tape drive, a compact disc (CD) drive, a digital versatile disc (DVD) drive, other optical drive, a flash memory drive, and/or the like.

[0059] Secondary memory **220** is a non-transitory computer-readable medium having computer-executable code (e.g., disclosed software modules) and/or other data stored thereon. The computer software or data stored on secondary memory **220** is read into main memory **215** for execution by processor **210**.

[0060] In alternative embodiments, secondary memory **220** may include other similar means for allowing computer programs or other data or instructions to be loaded into system **200**. Such means may include, for example, a communication interface **245**, which allows software and data to be transferred from external storage medium **250** to system **200**. Examples of external storage medium **250** may include an external hard disk drive, an external optical drive, an external magneto-optical drive, and/or the like. Other examples of secondary memory **220** may include semiconductor-based memory, such as programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable read-only memory (EEPROM), and flash memory (block-oriented memory similar to EEPROM).

[0061] As mentioned above, system **200** may include a communication interface **245**. Communication interface **245** allows software and data to be transferred between system **200** and external devices (e.g. printers), networks, or other information sources or information recipients. For example, computer software or executable code may be transferred to system **200** from a network server (e.g., platform **110**) via communication interface **245** and digital information such as digital image files and digital video content may be transferred from system **200** to a network server (e.g., platform **110**) via communication interface **245**. Examples of communication interface **245** include a built-in network adapter, network interface card (NIC), Personal Computer Memory Card International Association (PCMCIA) network card, card bus network adapter, wireless network adapter, Universal Serial Bus (USB) network adapter, modem, a wireless data card, a communications port, an infrared interface, an IEEE 1394 fire-wire, and any other device capable of interfacing system **200** with a network (e.g., network(s) **120**) or another computing device. Communication interface **245** preferably implements industry-promulgated protocol standards, such as Ethernet IEEE 802 standards, Fiber Channel, digital subscriber line (DSL), asynchronous digital subscriber line (ADSL), frame relay, asynchronous transfer mode (ATM), integrated digital services network (ISDN), personal communications services (PCS), transmission control protocol/Internet protocol (TCP/IP), serial line Internet protocol/point to point protocol (SLIP/PPP), and so on, but may also implement customized or non-standard interface protocols as well.

[0062] Software and data transferred via communication interface **245** are generally in the form of electrical communication signals **260**. These signals **260** may be provided to communication interface **245** via a communication channel **255**. In an embodiment, communication channel **255** may be a wired or wireless network (e.g., network(s) **120**), or any variety of other communication links. Communication channel **255** carries signals **260** and can be implemented using a variety of wired or wireless communication means including wire or cable, fiber optics, conventional phone line, cellular phone link, wireless data communication link, radio frequency ("RF") link, or infrared link, just to name a few.

[0063] Computer-executable code (e.g., computer programs, such as the disclosed application, or software modules) is stored in main memory **215** and/or secondary memory **220**. Computer programs can also be received via communication interface **245** and stored in main memory **215** and/or secondary memory **220**. Such computer programs, when executed, enable system **200** to perform the various functions of the disclosed embodiments as described elsewhere herein.

[0064] In this description, the term "computer-readable medium" is used to refer to any non-transitory computer-readable storage media used to provide computer-executable code and/or other data to or within system **200**. Examples of such media include main memory **215**, secondary memory **220** (including internal memory **225**, removable medium **230**, and external storage medium **250**), and any peripheral device communicatively coupled with communication interface **245** (including a network information server or other network device). These non-transitory computer-readable media are means for providing executable code, programming instructions, software, and/or other data to system **200**.

[0065] In an embodiment that is implemented using software, the software may be stored on a computer-readable medium and loaded into system **200** by way of removable medium **230**, I/O interface **235**, or communication interface **245**. In such an embodiment, the software is loaded into system **200** in the form of electrical communication signals **260**. The software, when executed by processor **210**, preferably causes processor **210** to perform one or more of the processes and functions described elsewhere herein.

[0066] In an embodiment, I/O interface **235** provides an interface between one or more components of system **200** and one or more input and/or output devices **240**. Example input devices include, without limitation, sensors, such as a camera or other imaging sensor, keyboards, touch screens or other touch-sensitive devices, biometric sensing devices, computer mice, trackballs, pen-based pointing devices, and/or the like. Examples of output devices include, without limitation, other processing devices, cathode ray tubes (CRTs), plasma displays, light-emitting diode (LED) displays, liquid crystal displays (LCDs), printers, vacuum fluorescent displays (VFDs), surface-conduction electron-emitter displays (SEDs), field emission displays (FEDs), head mounted displays (HMDs), and/or the like. In some cases, an input and output device **240** may be combined, such as in the case of a touch panel display (e.g., in a smartphone, tablet, or other mobile device).

[0067] In an embodiment, the I/O device **240** may be any type of external or integrated display and may include one or more discrete displays that in aggregate form the I/O device **240**. The I/O device **240** may be capable of 2D or 3D presentation of visual information to a user of the system **200**. In one embodiment, the I/O device **240** may be a virtual reality or augmented reality device in the form of HMD by the user so the user may visualize the presentation of information in 3D.

[0068] System **200** may also include optional wireless communication components that facilitate wireless communication over a voice network and/or a data network (e.g., in the case of user system **130**). The wireless communication components comprise an antenna system **275**, a radio system **270**, and a baseband system **265**. In system **200**, radio frequency (RF) signals are transmitted and received over the air by antenna system **275** under the management of radio system **270**.

[0069] In an embodiment, antenna system **275** may comprise one or more antennae and one or more multiplexors (not shown) that perform a switching function to provide antenna system **275** with transmit and receive signal paths. In the receive path, received RF signals can be coupled from a multiplexor to a low noise amplifier (not shown) that amplifies the received RF signal and sends the amplified signal to radio system **270**.

[0070] In an alternative embodiment, radio system **270** may comprise one or more radios that are configured to communicate over various frequencies. In an embodiment, radio system **270** may combine a demodulator (not shown) and modulator (not shown) in one integrated circuit (IC). The demodulator and modulator can also be separate components. In the incoming path, the demodulator strips away the RF carrier signal leaving a baseband receive audio signal, which is sent from radio system **270** to baseband system **265**.

[0071] If the received signal contains audio information, then baseband system **265** decodes the signal and converts it to an analog signal. Then the signal is amplified and sent to a speaker. Baseband system **265** also receives analog audio signals from a microphone. These analog audio signals are converted to digital signals and encoded by baseband system **265**. Baseband system **265** also encodes the digital signals for transmission and generates a baseband transmit audio signal that is routed to the modulator portion of radio system **270**. The modulator mixes the baseband transmit audio signal with an RF carrier signal, generating an RF transmit signal that is routed to antenna system **275** and may pass through a power amplifier (not shown). The power amplifier amplifies the RF transmit signal and routes it to antenna system **275**, where the signal is switched to the antenna port for transmission.

[0072] Baseband system **265** is also communicatively coupled with processor **210**, which may be a central processing unit (CPU). Processor **210** has access to data storage areas **215** and **220**. Processor **210** is preferably configured to execute instructions (i.e., computer programs, such as the disclosed application, or software modules) that can be stored in main memory **215** or secondary memory **220**. Computer programs can also be received from baseband processor **260** and stored in main memory **210** or in secondary memory **220**, or executed upon receipt. Such computer programs, when executed, enable system **200** to perform the various functions of the disclosed embodiments.

[0073] FIG. **3** illustrates an example training process for an example artificial neural network (ANN) **300**, by which one or more of the processes described herein may be executed, according to an embodiment. In the illustrated embodiment, the ANN **300** receives input data **310** (e.g., an image captured by external system **140**) at the input layer **320**. The input layer **320** processes the input data to generate one or more outputs that are provided to the intermediate layer **330**. As the input layer **320** processes the input data **310**, the input layer **320** may use one or more parameters **390** (e.g., parameter **390-1**, parameter **390-2**, . . . , parameter **390-*n***) in the processing.

[0074] The intermediate layer **330** may comprise a plurality of hidden layers **340** (e.g., layer **340-1**, . . . , layer **340-*n***). Each hidden layer **340** of the intermediate layer **330** receives one or more inputs from the input layer **320** or another hidden layer **340** and processes the one or more inputs to generate one or more outputs that are provided to another hidden layer **340** or to the output layer **350**. As each hidden layer **340** performs its processing, the respective hidden layer **340** may use one or more parameters **390** (e.g., parameter **390-1**, parameter **390-2**, . . . , parameter **390-*n***) in the processing. The output layer **350** processes all of the inputs it receives from the various hidden layers **340** of the intermediate layer **330** and generates output data **360** comprising a confidence score associated with each of the five states that the subject in the one or more images processed by the ANN may be in. The output data **360** is compared to validated input data **370** (e.g., the known state of the subject in the input image data) and the results of the comparison **380** are used to adjust one or more parameters **390**. Advantageously, the adjusted parameters **390** operate to improve the subsequent processing of input data **310** by the ANN **300** to generate more accurate output data **360**.

[0075] In one aspect, the system **100** employs an Artificial Neural Network (ANN), for example embodied in application **112**, to analyze sensor data. The sensor data is primarily one or more images captured by one or more cameras embedded in one or more external systems **140**. The input to the ANN is typically a preprocessed image, structured to align with the ANN's requirements with respect to the dimensions of an image.

[0076] In one aspect, image preprocessing includes a series of operations applied to a captured image, which is intrinsically three-dimensional, having a height dimension, a width dimension, and color channels (e.g., 224×224×3). The series of operations may include image resizing, center cropping, and channel collapsing, and these operations are aimed at tailoring each image captured by an external system **140** to match the ANN's input specifications.

[0077] In one aspect, the ANN may be implemented using architectures such as a Convolutional Neural Network (CNN), a Recurrent Neural Network (RNN), or a Transformer Neural Network (TNN). The ANN is configured to process an image or a sequence of images to determine the state of a subject in the room where the external system **140** is located. The potential states into which the subject may be classified include sitting, standing, in-bed, fall, or empty room. The output of the ANN is a 1×5 dimensional vector the comprises the five states into which the subject may be classified and a confidence score (e.g., ranging from 0 to 1) associated with each state.

[0078] To improve accuracy of the ANN over time, the ANN undergoes an initial training phase using a large dataset of images, such as ImageNet with known states for each image. Subsequent to the initial training, the ANN is further trained by using images collected of a specific room during installation of the external system **140**. In one aspect, this additional training comprises collecting approximately 500 to 1000 images per state of a sample subject in the particular room where the external system **140** is located.

[0079] Post-installation, when the system is deployed and operational, the system continuously collects image data from the particular room where the external system **140** is located and at least a portion of such images are processed to confirm the state corresponding to each image and the processed images and their known states are provided to the ANN for additional training. A portion of the software **112** on the platform **110** determines the conditions for subsequent data collection, for example when singular or average confidence levels determined by the ANN fall below a certain threshold.

[0080] Advantageously, in one aspect, human annotators may be employed to review the additional image data to confirm the state of an image to be used for additional training of the system. For example, human annotators may be used to review images with a confidence level below a certain threshold or images that are determined algorithmically or determine by a human annotator to be unique compared to existing images in the training set. Images that have been reviewed by a human annotator may be stored in memory **114** in association with their confirmed state until such time as a sufficiently large number of images and confirmed states has been accumulated. At that time, the ANN can be trained using the additional images and confirmed states. This iterative process of additional image collection, confirming of the corresponding state for each image, and additional training of the ANN may advantageously continue as long as there is more data to be collected and confirmed.

[0081] In one aspect, each installed external system **140** has a unique set of ANN parameters/weights, specifically trained on data gathered from its specific room. Alternatively, or in combination, a global ANN model may exist with all external systems **140** sharing the same ANN parameters/weights for the processing of images by the application **112**. In this fashion, additional images that are collected and associated with confirmed states across all external systems **140** may be used for subsequent training of the global ANN model.

[0082] In one aspect, to account for the potential that conditions in a particular room may change over time, such as a change in the occupant and the presence of a new subject or a significant decrease in model confidence, a specialized ANN that was trained on the specific room can undergo additional training using new data, for example image data captured after the new occupant has arrived. The flexibility provided by the potential to retrain a specialized ANN previously trained on a specific room ensures the sustained accuracy of the ANN despite changes in the room or the subject who occupies the room.

[0083] FIG. **4** illustrates an example operation of an example artificial neural network **400**, by which one or more of the processes described herein may be executed, according to an embodiment. In the illustrated embodiment, the ANN **400** receives input data **410** (e.g., an image from external system **140**) at the input layer **420**. The input layer **420** processes the input data to generate one or more outputs that are provided to the intermediate layer **430**. As the input layer **420** processes the input data **410**, the input layer **420** may use one or more parameters **490** (e.g., parameter **490-1**, parameter **490-2**, . . . , parameter **490**-*n*) in the processing.

[0084] The intermediate layer **430** may comprise a plurality of hidden layers **440** (layer **440-1**, . . . , layer **440**-*n*). Each hidden layer **440** of the intermediate layer **430** receives one or more inputs from the input layer **420** or another hidden layer **440** and processes the one or more inputs to generate one or more outputs that are provided to another hidden layer **440** or to the output layer **450**. As each hidden layer **440** performs its processing, the respective hidden layer **440** may use one or more parameters **490** (parameter **490-1**, parameter **490-2**, . . . , parameter **490**-*n*) in the processing. The output layer **450** processes all of the inputs it receives from the various hidden layers **440** of the intermediate layer **430** and generates output data **460** comprising a confidence score associated with each of the five states that the subject in the one or more images processed by the ANN may be in.

[0085] FIG. **5** is a flow diagram illustrating an example process **500** for determining a state of a subject according to an embodiment of the invention. In one aspect, the process of FIG. **5** may be carried out by the system described with respect to FIG. **1** in combination with one of more processing devices described with respect to FIG. **2** that may be executing artificial neural networks that are trained and operated as described in FIGS. **3** and **4**.

[0086] Initially, at **510** the system captures one or more images. The image capture is done by a camera device that is positioned in a room. The imaging sensor of the camera device is advantageously trained on a desired portion of the room, for example, a portion that includes the bed and perhaps other furniture that may be commonly occupied by the subject who is the occupant of the room.

[0087] The images that are captured at **510** may be single still images or may be a series of images at a sufficiently high frame rate (e.g., 30 frames per second) to be considered digital video. The images may be color, black and white, infrared, or some other type of image that the sensor of the camera device is capable of capturing.

[0088] Next, at **515** the image (or images) are provided as an input to the artificial neural network. In one aspect, images are captured by the camera device and sent via a network to a server (e.g., platform **110**) where the images are provided as input to the ANN (e.g., application **112**).

[0089] Next, at **520**, the ANN processes the images to determine a current state of the subject. In one aspect, there are 5 states that a subject may be in at any given time. Those states include: (1) in-bed; (2) sitting; (3) standing; (4) away; and (5) fall. For example, when an image or series of images includes a single individual and that individual is on the bed (covered by blankets or otherwise), the (1) in-bed state is determined. Alternatively, when an image or series of images includes a single individual and that individual is sitting on furniture or on the floor, the (2) sitting state is determined. Alternatively, when an image or series of images includes a single individual and that individual is standing in the room or walking around the room, the (3) standing state is determined. Alternatively, when an image or series of images does not include any individual, the (4) away state is determined. Finally, when an image or series of images includes a single individual and that individual has their torso or hand on the floor, the (5) fall state is determined.

[0090] In one aspect, an image or series of images may include more than one individual. When there is more than one individual in an image or series of images, if one individual has their torso or hand on the floor, the (5) fall state is determined, regardless of the other potential states that other individuals in the image(s) may be in. Alternatively, if no individual is in the (5) fall state but an individual is in-bed, the (1) in-bed state is determined, regardless of the other potential states that other individuals in the image(s) may be in. Alternatively, if there is no individual in the (5) fall state and there is no individual in-bed, but there is a person sitting, the (2) sitting state is determined, regardless of the other potential states that other individuals in the image(s) may be in. Alternatively, if all individuals in the image(s) are standing, the (3) standing state is determined.

[0091] Next, at **525**, the current state of the subject as determined by the combination of the ANN portion of the application **112** and the state machine portion of the application **112** based on the analysis of the image or series of images, the system saves the determined state of the subject in association with a timestamp to generate a record of the state of the subject at a particular date and time.

[0092] Next, at **530**, the system analyzes the determined current state of the subject to determine if there are one or more alerts associated with the determined current state of the subject. For example, a user of the system who is a family member of the subject, may create a custom alert to notify the user when the subject is standing or sitting so that the user is aware when the subject is likely awake and alert and ready for a visitor.

[0093] Finally, at **535**, the system generates and sends one or more alerts that may be associated with the determined current state of the subject based on the analysis of the one or more images performed by the ANN.

[0094] FIG. **6** is a flow diagram illustrating an example process **600** for providing a state of a subject to a remote use according to an embodiment of the invention. In one aspect, the process of FIG. **6** may be carried out by the system described with respect to FIG. **1** in combination with one of more processing devices described with respect to FIG. **2** that may be executing artificial neural networks that are trained and operated as described in FIGS. **3** and **4**. Initially, at **610**, the system establishes a connection with a remote user. The remote user may be using a user device **130** and the application **112** may establish a connection via a network **120** with the application **132** on the user device **130**.

[0095] Next, at **615**, the system optionally provides via the network **120** a live feed of the subject (or the subject's room), if such content was requested by the user system **130**.

[0096] Next, at **620**, the system optionally provides via the network **120** a recorded video of the subject (or the subject's room), if such content was requested by the user system **130**.

[0097] Next, at **625**, the system optionally provides via the network **120** a still image of the subject (or the subject's room), if such content was requested by the user system **130**.

[0098] Next at **630**, the system receives from the application **132** a configuration defining when an alert is requested. For example, the application **132** may submit criteria for when an alert is requested, such as when the subject has transitioned to a fall state or when the subject has transitioned from the in-bed state to a different state. An alert configuration may also be based on a timer or some other collected or analytic data, for example, if the subject has not been in the in-bed state for a predetermined length of time.

[0099] Next, at **635**, in response to receiving the alert configuration, the system stores the alert configuration in association with the subject and the requesting user.

[0100] FIG. **7** is a flow diagram illustrating an example process **700** for continuous improvement of an artificial neural network according to an embodiment of the invention. In one aspect, the process of FIG. **7** may be carried out by the system described with respect to FIG. **1** in combination with one of more processing devices described with respect to FIG. **2** that may be executing artificial neural networks that are trained and operated as described in FIGS. **3** and **4**.

[0101] Initially, at **710**, the external system **140** captures one or more images and those images are validated to confirm the state of the subject in each of the one or more images. The validation may be done by a human annotator or by a separately trained ANN. Advantageously, the additional images captured by the external system **140** are specific to a particular room and therefore the images may be captured at different times of day to account for different ambient lighting conditions during daytime and nighttime hours.

[0102] Next, at **715**, the one or more images are input into the ANN assigned to the particular room. Alternatively, in the case of a global ANN model, the one or more images are input into the global ANN.

[0103] Next, at **720**, the known state (confirmed state) for each of the one or more images are also input into the ANN assigned to the particular room. Alternatively, in the case of a global ANN model, the known state (confirmed state) for each of the one or more images are input into the global ANN.

[0104] Next at **725**, the ANN estimates the state for the one or more images that were input at **715**.

[0105] Next, at **730** the estimated state for each of the one or more images as determined at **725** is validated against the known state for each of the one or more images to determine the accuracy of the ANN estimate. In certain circumstances, one or more parameters or weights used by the ANN in generating the estimates may be revised to improve the accuracy of the ANN when processing future images and generating estimates of the state of the subject in those future images.

[0106] Next, at **735**, any revised parameters or weights are updated in the ANN to improve the accuracy and improve the confidence scores of future image processing by the ANN.

[0107] The above description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles described herein can be applied to other embodiments without departing from the spirit or scope of the invention. Thus, it is to be understood that the description and drawings presented herein represent a presently preferred embodiment of the invention and are therefore representative of the subject matter which is broadly contemplated by the present invention. It is further understood that the scope of the present invention fully encompasses other embodiments that may become obvious to those skilled in the art and that the scope of the present invention is accordingly not limited.

Claims

1. A system for detecting a position of a subject, comprising: a camera system having a camera sensor trained on a portion of a room occupied by a subject; an image preprocessing system configured to receive one or more images captured by the camera system and preprocess the one or more images to meet predetermined image characteristics; an artificial neural network (ANN) system configured to receive the one or more preprocessed images and estimate a confidence score corresponding to each of five states of the subject in the one or more images, wherein five states of the subject include: an empty room state; an in-bed state; a sitting state; a standing state; and a fall state; a state machine system configured to receive the estimated confidence scores for each of the five states from the ANN and analyze the estimated confidence scores in combination with one or more previously determined states of the subject and a current state of the subject to determine a new current state of the subject; and an alert system configured to receive the new current state of the subject and identify one or more alerts corresponding to the new current state of the subject and send the one or more alerts to one or more recipients via a data communication network.
2. The system of claim 1, wherein the one or more captured images comprise a series of still images captured at regular time intervals.
3. The system of claim 1, wherein the preprocessing system is further configured to: crop a length of the one or more images; crop a height of the one or more images; and adjust a color of the one or more images.
4. The system of claim 1, wherein the alert system is further configured to send at least one of a digital notification, a visual notification, an audible notification, and a haptic notification.
5. The system of claim 1, wherein the alert system is further configured to send one of: a text message, an email, a push notification, and an application pop up.
6. The system of claim 1, wherein the alert system is further configured to send one of: a computer sound and a prerecorded phone call.
7. The system of claim 1, wherein the alert system is further configured to send a haptic vibration.
8. The system of claim 1, wherein a first of the one or more images includes two or more individuals, and wherein the state machine system is further configured to: determine the new current state of the subject to be the fall state when one individual has their torso or hand on a floor; if the fall state is not determined, determine the new current state of the subject to be the in-bed state when an individual is in-bed; if one of the fall state and the in-bed state is not determined, determine the new current state of the subject to be the sitting state when an individual is sitting; and if one of the fall state, the in-bed state, and the sitting state is not determined, determine the new current state of the subject to be the standing state when all individuals are standing.
9. The system of claim 1, wherein the alert system is further configured to alert one or more individuals when the state of the subject has not been in-bed for a predetermined duration of time.
10. The system of claim 1, wherein the ANN is further configured to receive a plurality of images captured of the room over a period of time and a validated state corresponding to each image and process the plurality of images and their corresponding validated states to retrain the ANN.
11. A method for detecting a position of a subject, comprising: capturing one or more images by a camera system having a camera sensor trained on a portion of a room occupied by a subject; preprocessing the one or more images captured by the camera system to meet predetermined image characteristics; processing the one or more preprocessed images to estimate a confidence score corresponding to each of five states of the subject in the one or more images, wherein the five

states of the subject include: an empty room state; an in-bed state; a sitting state; a standing state; and a fall state; analyzing the estimated confidence scores for each of the five states in combination with one or more previously determined states of the subject and a current state of the subject to determine a new current state of the subject; identifying one or more alerts corresponding to the new current state of the subject; and sending the one or more alerts to one or more recipients via a data communication network.

12. The method of claim 11, wherein the one or more captured images provide a video feed of the room occupied by the subject.

13. The method of claim 11, wherein the one or more captured images comprise a series of still images captured at regular time intervals.

14. The method of claim 11, wherein preprocessing further comprises: cropping a length of the one or more images; cropping a height of the one or more images; and adjusting a color of the one or more images.

15. The method of claim 11, wherein sending one or more alerts to one or more recipients includes sending at least one of a digital notification, a visual notification, an audible notification, and a haptic notification.

16. The method of claim 15, wherein sending one or more digital notifications comprises sending one of: a text message, an email, a push notification, and an application pop up, wherein sending one or more audible notifications comprises sending one of: a computer sound and a pre-recorded phone call, and wherein sending one or more haptic notifications comprises sending a vibration.

17.-**18**. (canceled)

19. The method of claim 11, wherein a first of the one or more images includes two or more individuals, further comprising: determining the new current state of the subject to be the fall state when one individual has their torso or hand on a floor; if the fall state is not determined, determining the new current state of the subject to be the in-bed state when an individual is in-bed; if one of the fall state and the in-bed state is not determined, determining the new current state of the subject to be the sitting state when an individual is sitting; and if one of the fall state, the in-bed state, and the sitting state is not determined, determining the new current state of the subject to be the standing state when all individuals are standing.

20. The method of claim 11, further comprising alerting one or more individuals when the state of the subject has not been in-bed for a predetermined duration of time.

21. The method of claim 11, further comprising receiving a plurality of images captured of the room over a period of time and a validated state corresponding to each image and processing the plurality of images and their corresponding validated states to retrain an artificial neural network configured to process the one or more preprocessed images to estimate confidence scores corresponding to a state of the subject.

22.-**32**. (canceled)

33. A non-transitory computer readable medium having stored thereon one or more sequences of instructions for causing one or more processors to perform steps for detecting a position of a subject, the steps comprising: capturing one or more images by a camera system having a camera sensor trained on a portion of a room occupied by a subject; preprocessing the one or more images captured by the camera system to meet predetermined image characteristics; processing the one or more preprocessed images to estimate a confidence score corresponding to each of five states of the subject in the one or more images, wherein five states of the subject include: an empty room state; an in-bed state; a sitting state; a standing state; and a fall state; analyzing the estimated confidence scores for each of the five states in combination with one or more previously determined states of the subject and a current state of the subject to determine a new current state of the subject; identifying one or more alerts corresponding to the new current state of the subject; and sending the one or more alerts to one or more recipients via a data communication network.

34.-**43**. (canceled)