US 20180325426A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2018/0325426 A1**

Shaw et al. (43) **Pub. Date: Nov. 15, 2018**

(54) **ACTIVITIES OF DAILY LIVING MONITORING AND REPORTING SYSTEM**

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(21) Appl. No.: **15/901,764**

(22) Filed: **Feb. 21, 2018**

Related U.S. Application Data

(60) Provisional application No. 62/590,140, filed on Nov. 22, 2017, provisional application No. 62/505,784, filed on May 12, 2017.

Publication Classification

(51) **Int. Cl.**

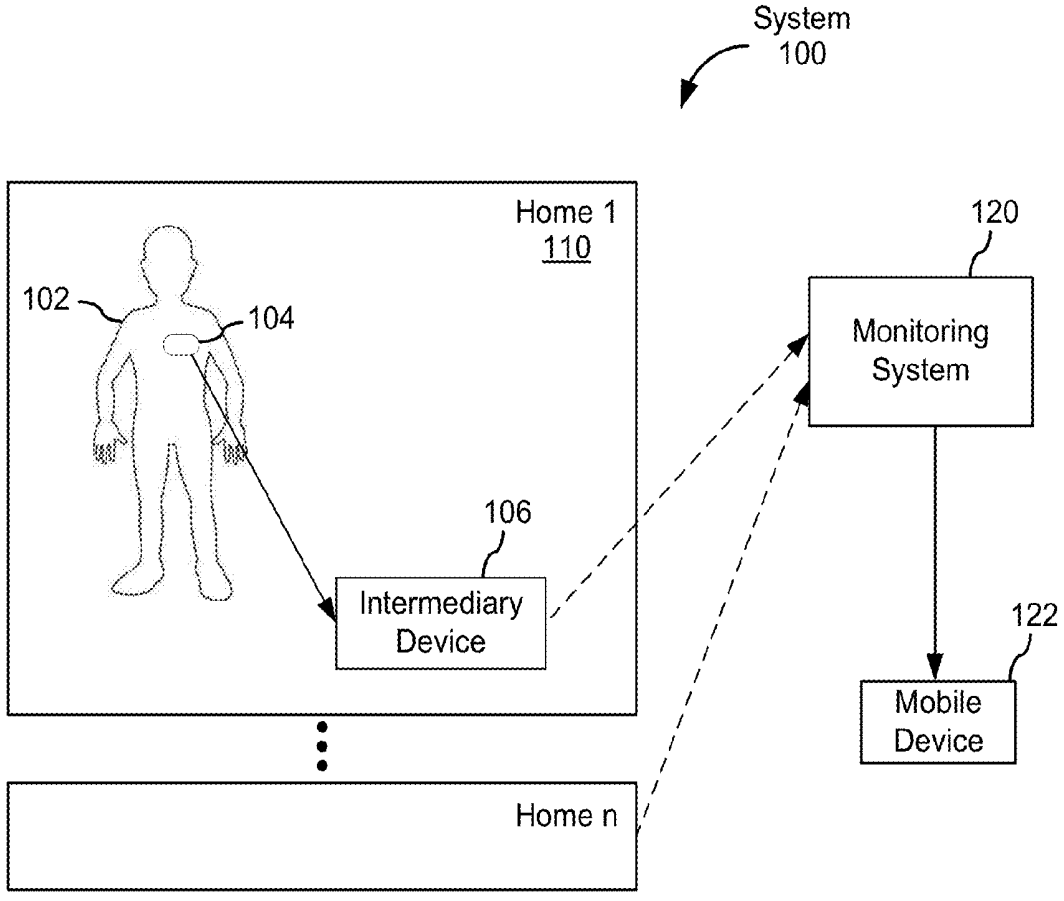
A61B 5/11	(2006.01)
G06F 11/34	(2006.01)
G06F 11/30	(2006.01)
G06N 3/08	(2006.01)
G01P 13/00	(2006.01)
A61B 5/00	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 5/1118*** (2013.01); ***G06F 11/3438*** (2013.01); ***G06F 11/3013*** (2013.01); *G01C 19/00* (2013.01); ***G01P 13/00*** (2013.01); ***A61B 5/6823*** (2013.01); ***A61B 5/6833*** (2013.01); ***G06N 3/08*** (2013.01)

(57) **ABSTRACT**

A user-wearable electronic device includes a housing configured to be worn on a user's torso, a plurality of sensors disposed in the housing, including a first sensor to sense motion of the user and produce raw activities of daily living (ADL) data, and a biometric sensor to sense one or more biometric characteristics of the user. One or more processors in the electronic device or an intermediary device generate, for a sequence of time periods, ADL identification information by processing the raw ADL data using one or more neural networks pre-trained to recognize a predefined set of ADLs. Each pre-trained neural network includes a plurality of neural network layers, including at least one layer that includes a recurrent neural network. Reports that include ADL information corresponding to the generated ADL identification information for time periods in the sequence of time periods are transmitted to a monitoring system.



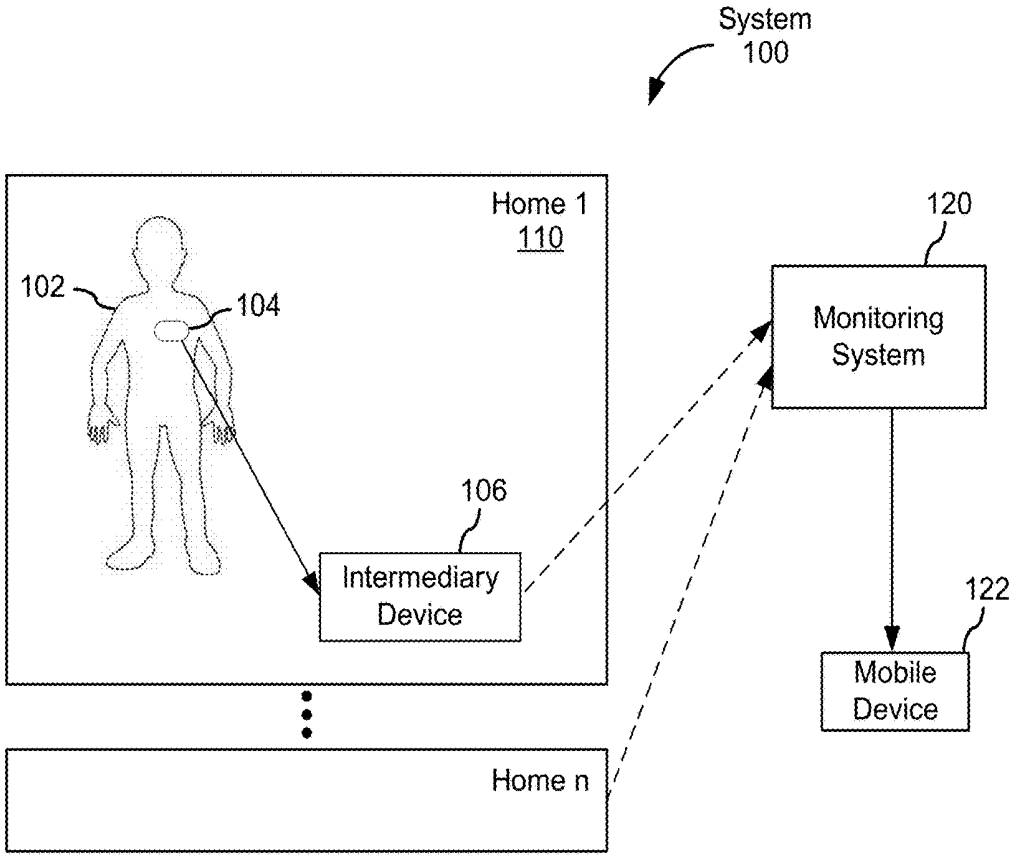


Figure 1A

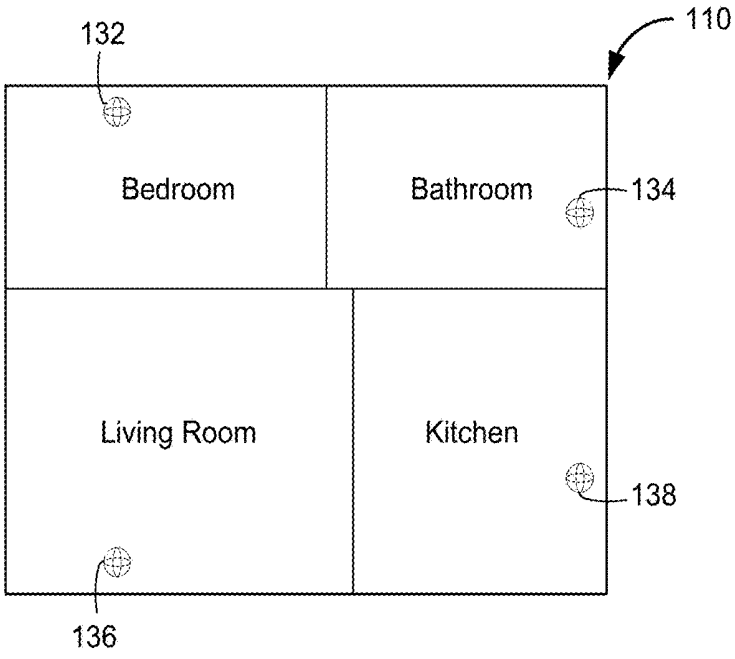


Figure 1B

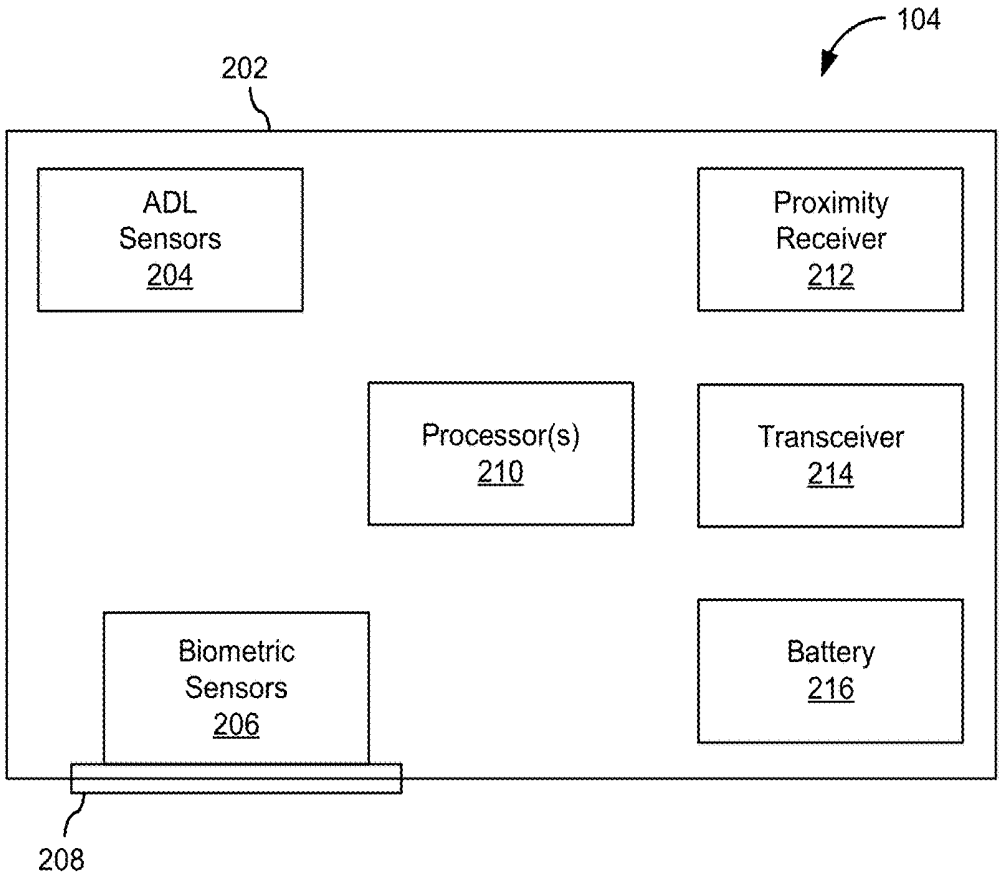

104
202
ADL
Sensors
204
Proximity
Receiver
212
Processor(s)
210
Transceiver
214
Biometric
Sensors
206
Battery
216
208

Figure 2

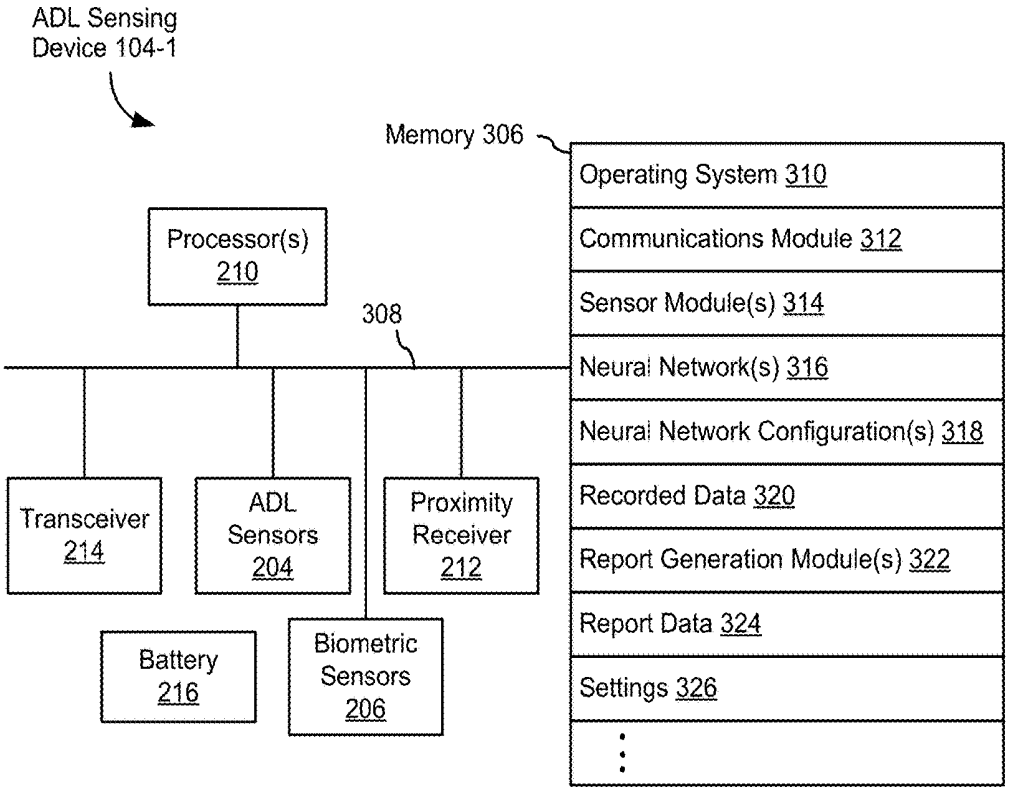


Figure 3A

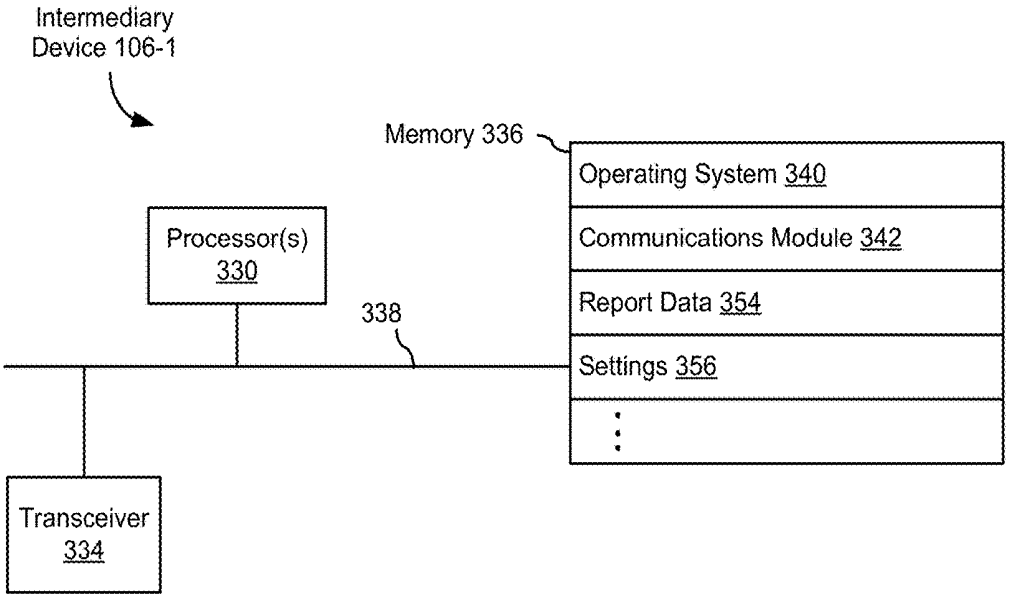


Figure 3B

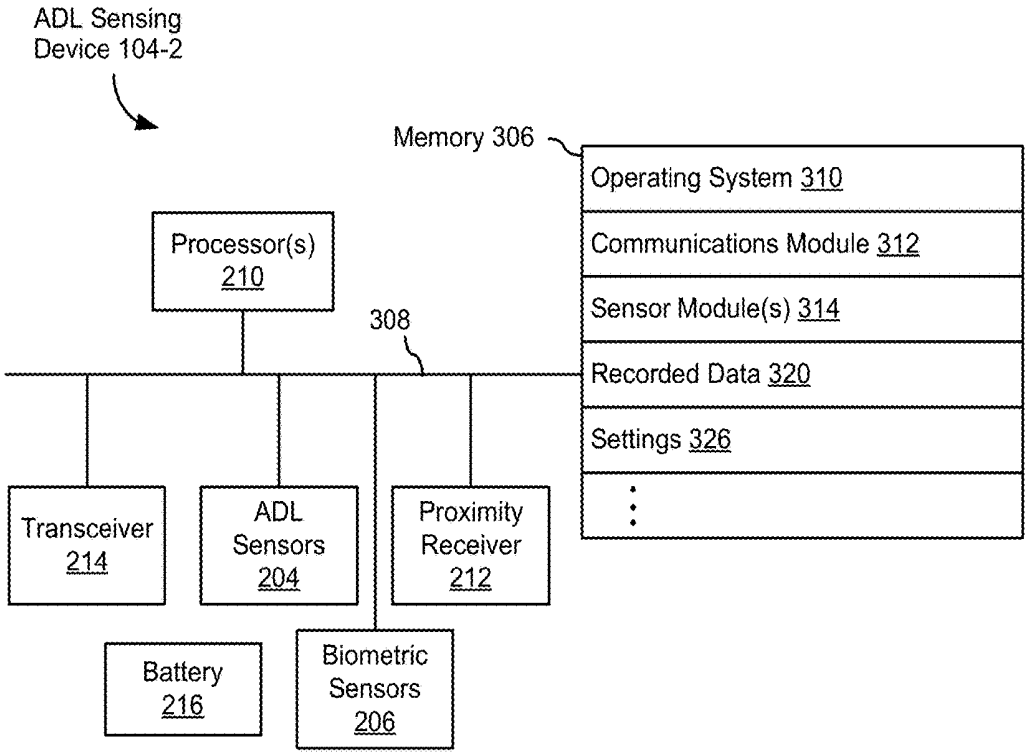


Figure 3C

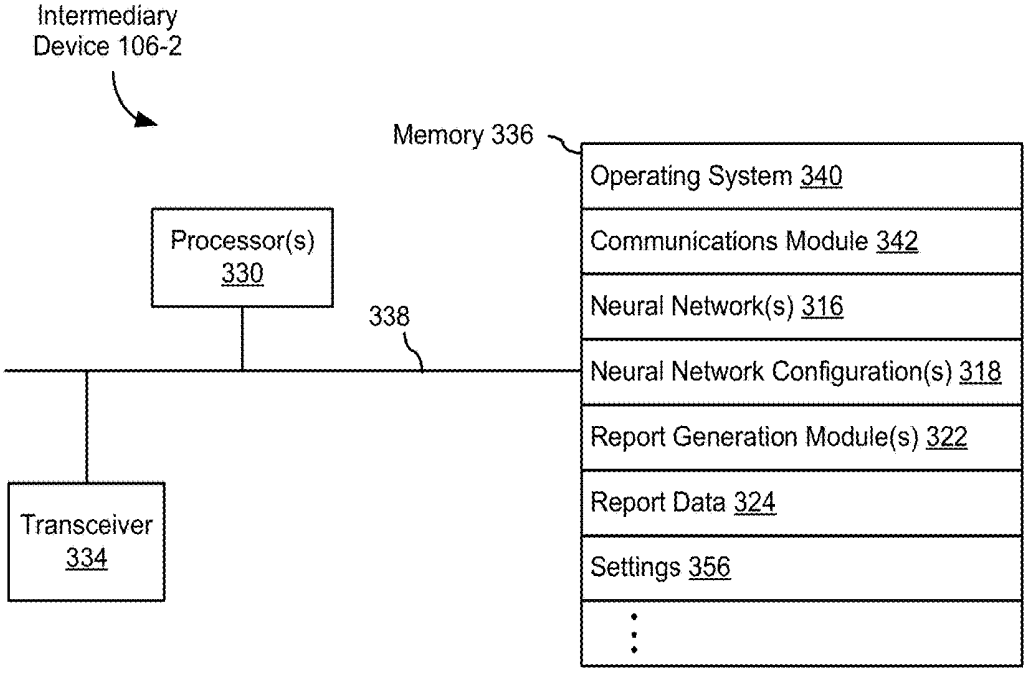


Figure 3D

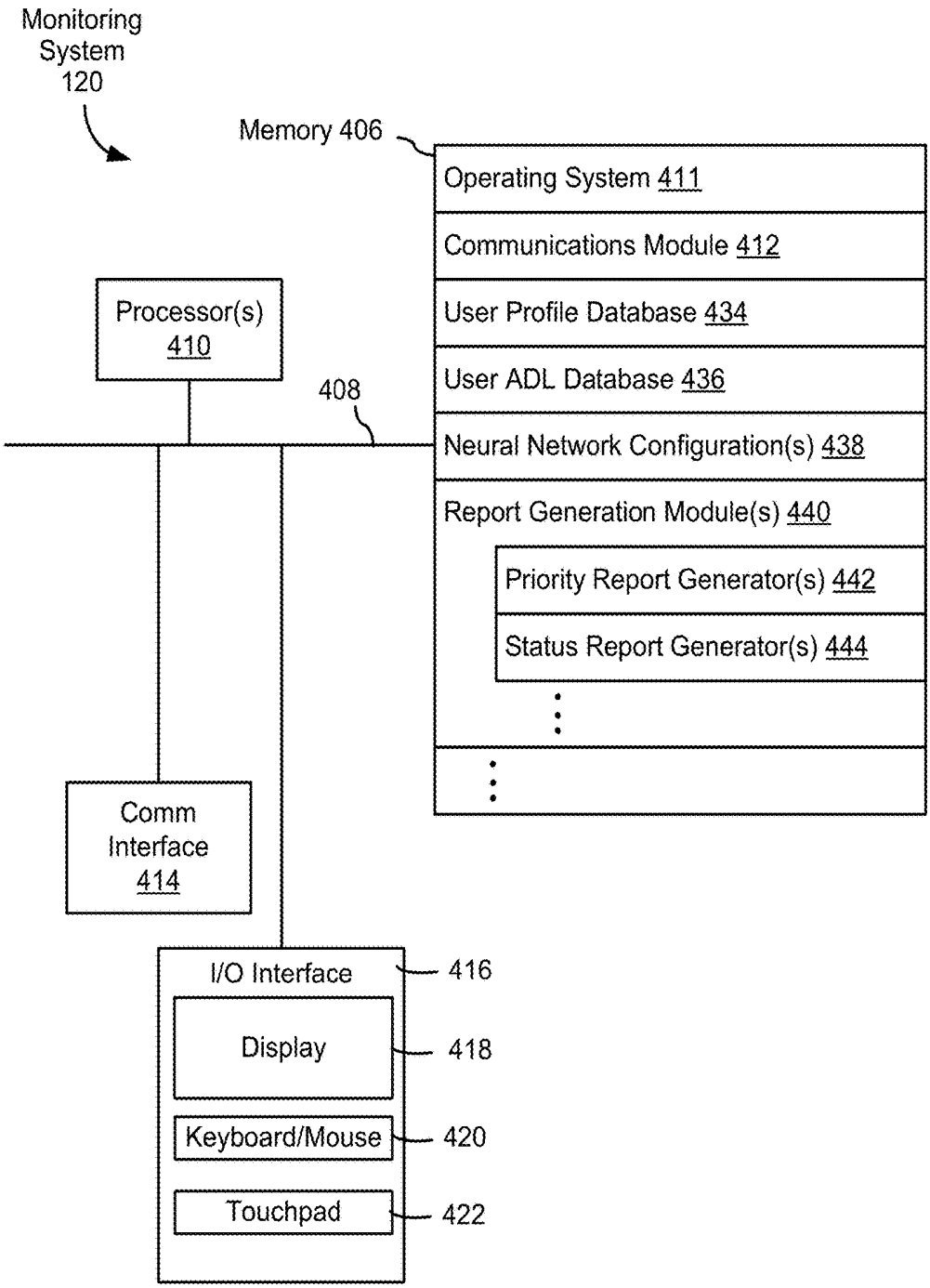

Monitoring System 120
Memory 406
Operating System 411
Communications Module 412
User Profile Database 434
User ADL Database 436
Neural Network Configuration(s) 438
Report Generation Module(s) 440
Priority Report Generator(s) 442
Status Report Generator(s) 444
Processor(s) 410
408
Comm Interface 414
I/O Interface
416
Display
418
Keyboard/Mouse
420
Touchpad
422

Figure 4

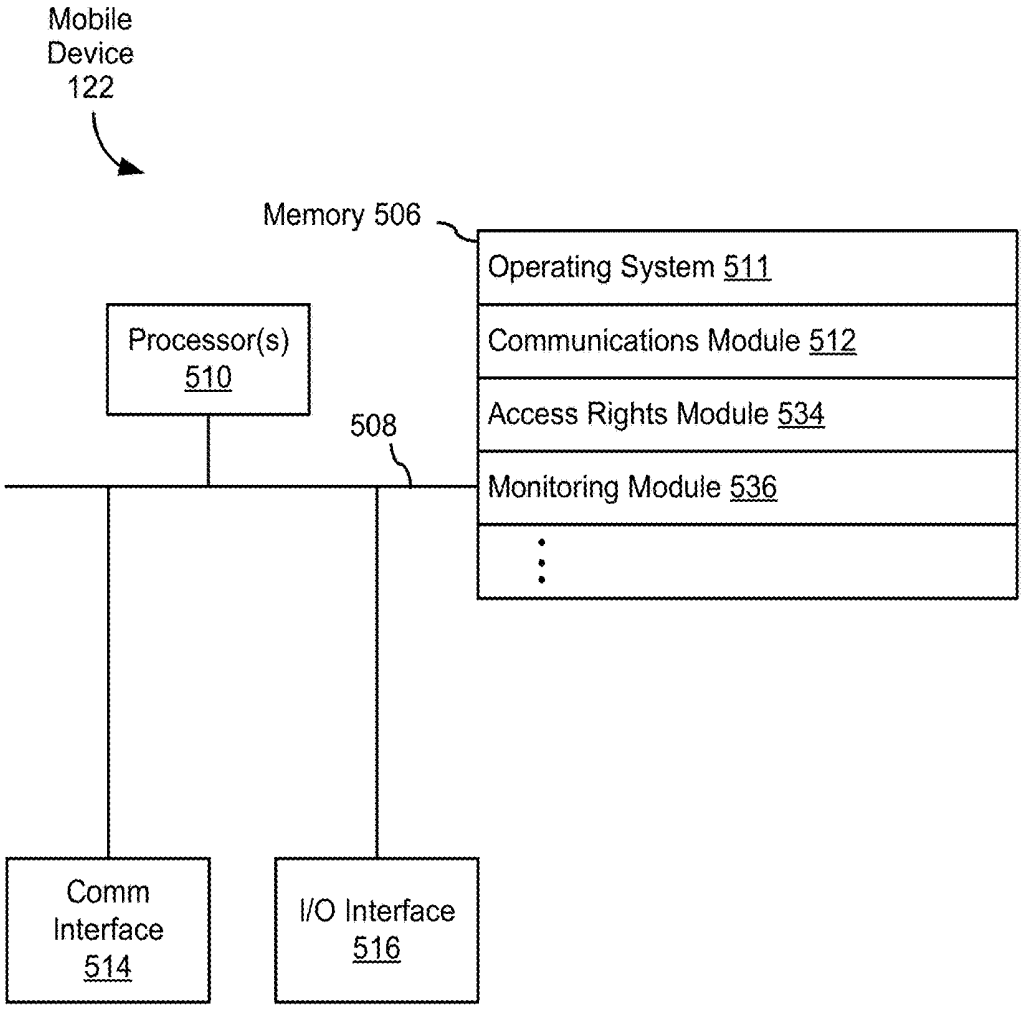

Mobile Device 122
Memory 506
Operating System 511
Communications Module 512
Access Rights Module 534
Monitoring Module 536
Processor(s) 510
508
Comm Interface 514
I/O Interface 516

Figure 5

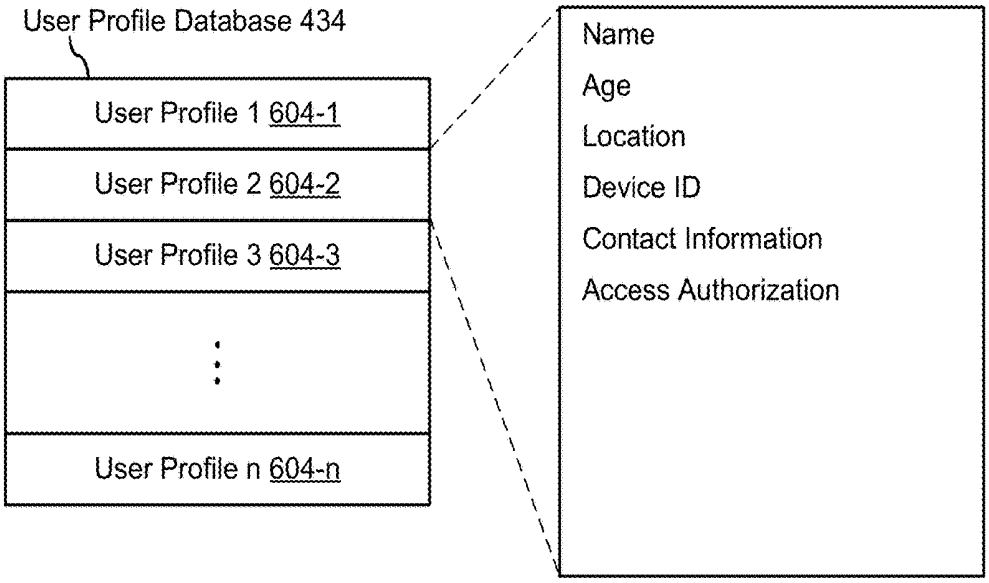


Figure 6A

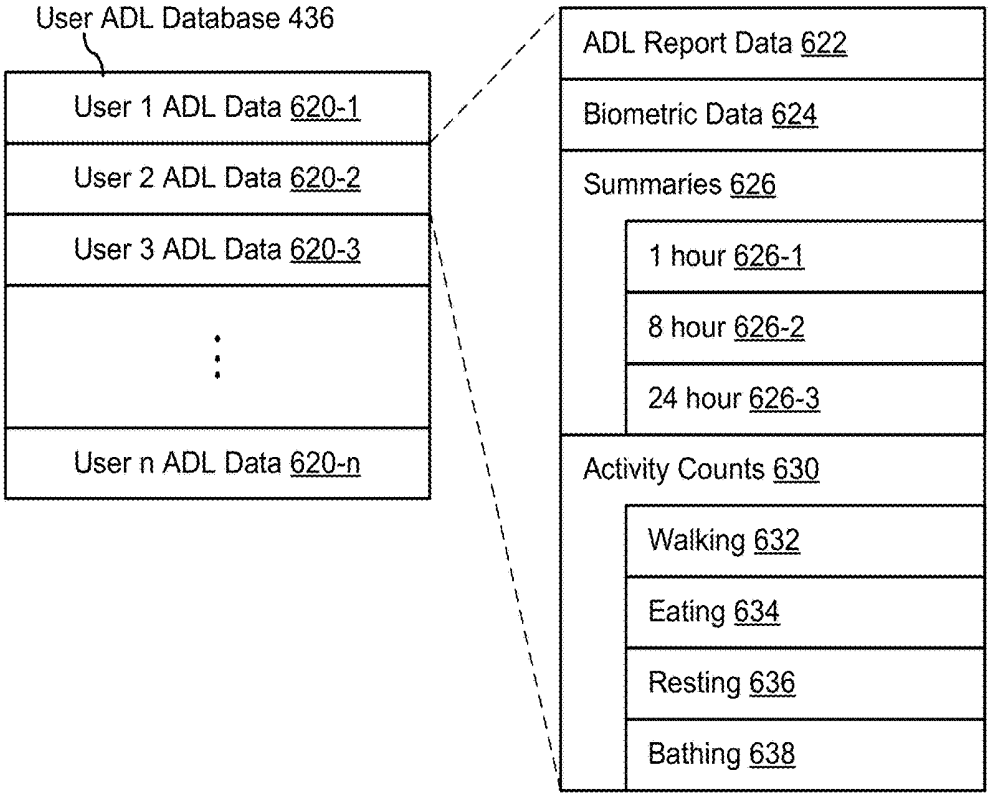


Figure 6B

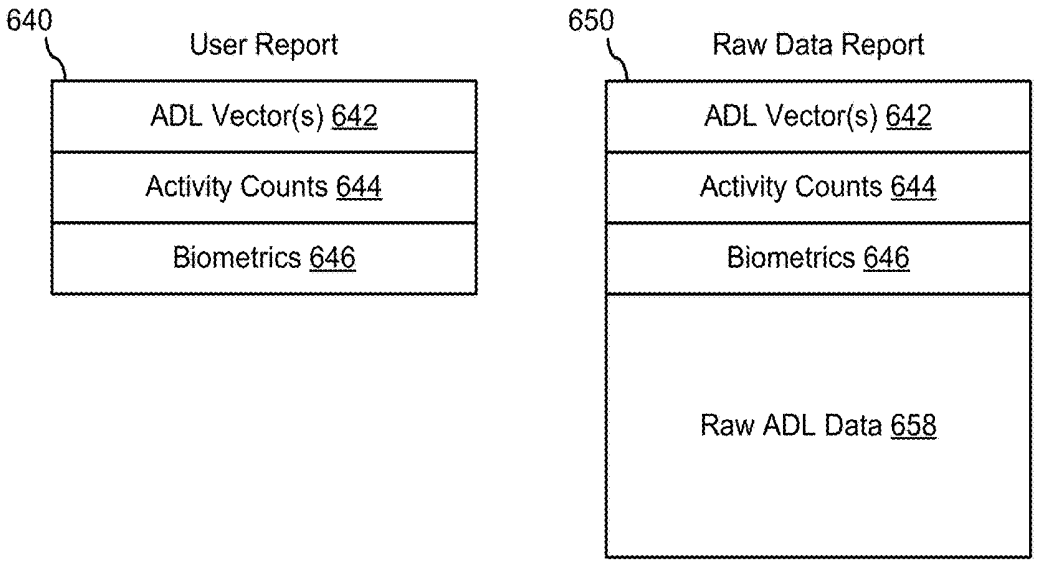


Figure 6C

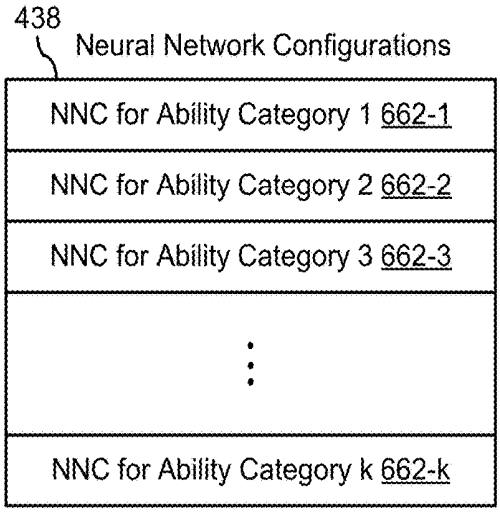


Figure 6D

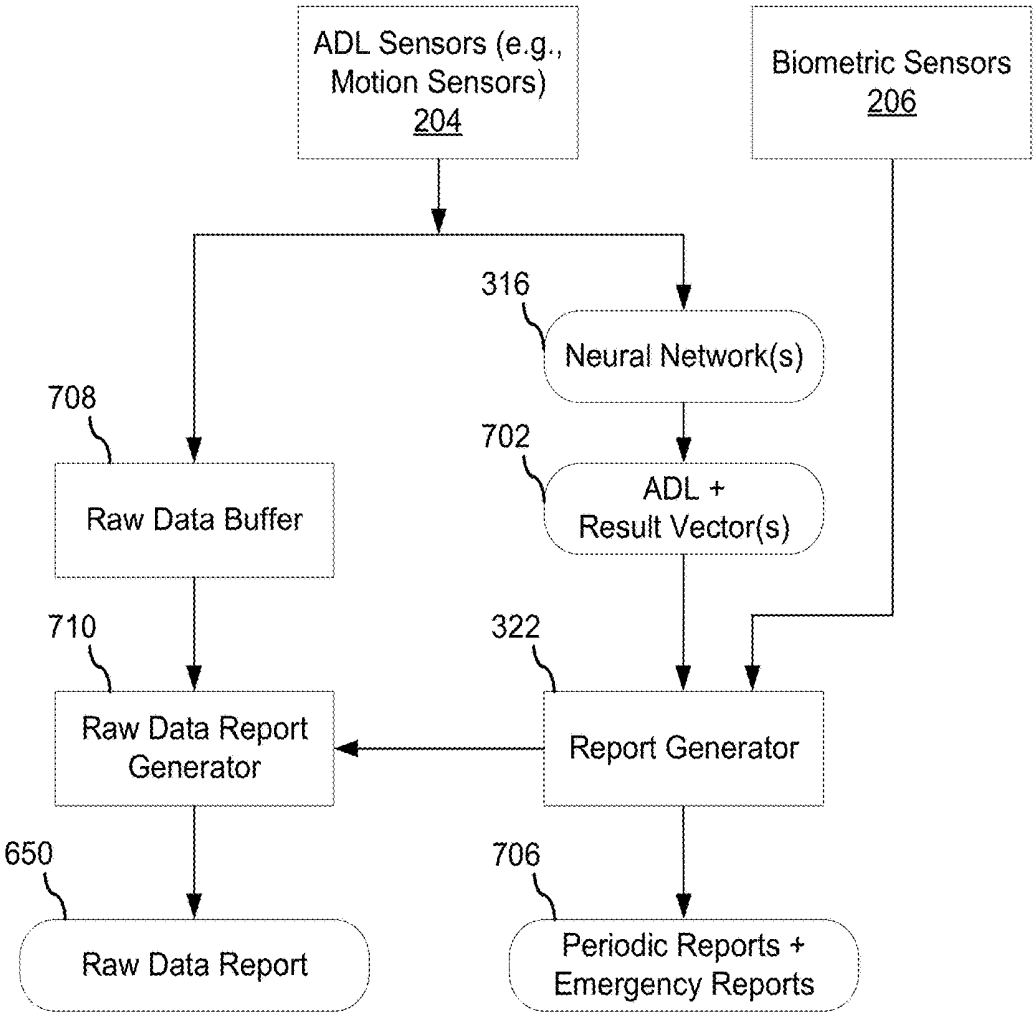

ADL Sensors (e.g., Motion Sensors) 204
Biometric Sensors 206
316
Neural Network(s)
708
Raw Data Buffer
702
ADL + Result Vector(s)
710
Raw Data Report Generator
322
Report Generator
650
Raw Data Report
706
Periodic Reports + Emergency Reports

Figure 7

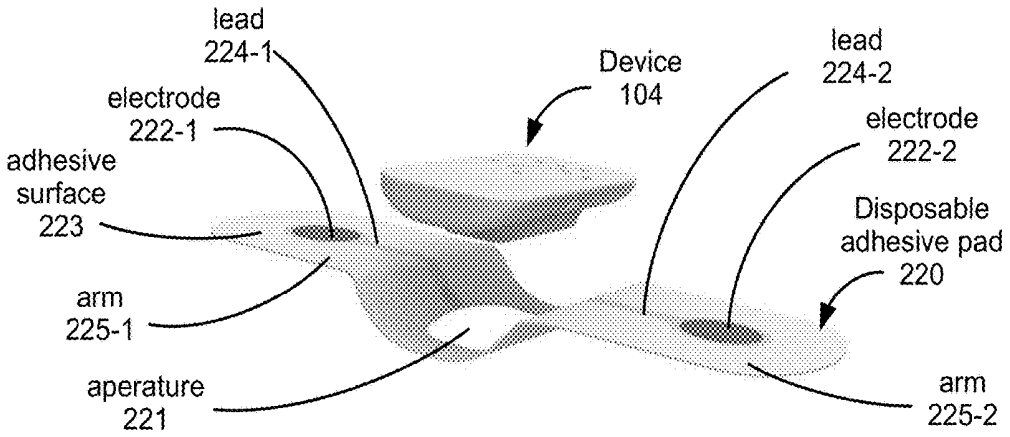


Figure 8A

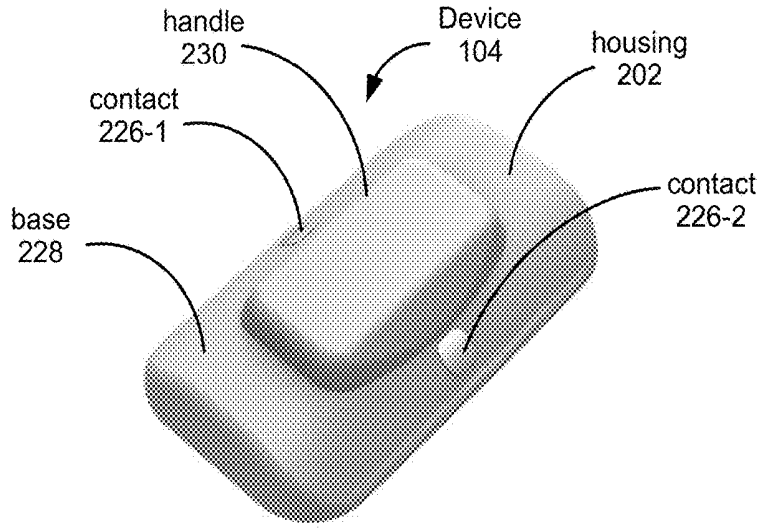


Figure 8B

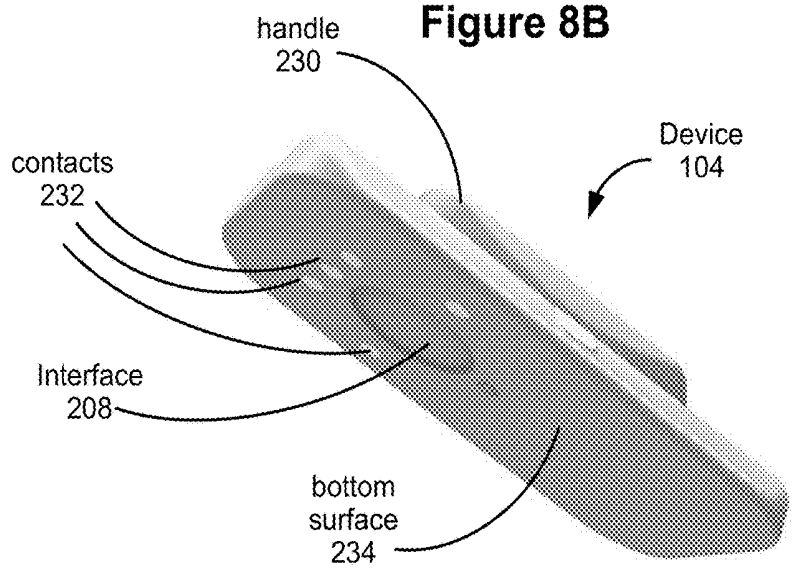


Figure 8C

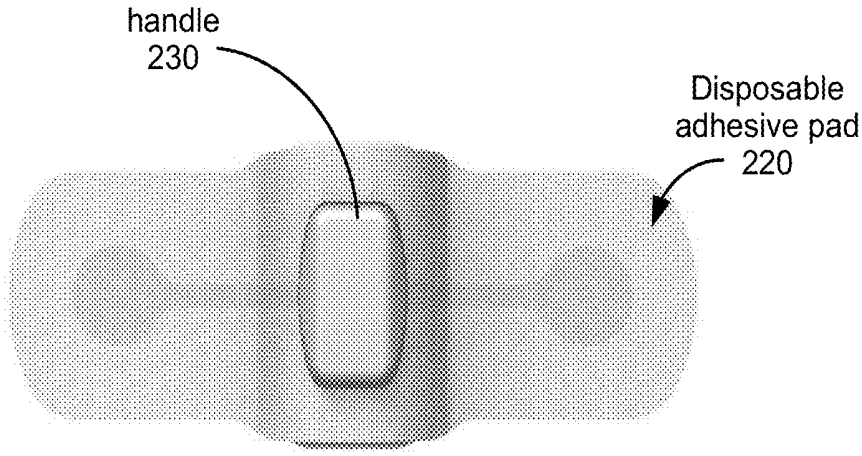


Figure 8D

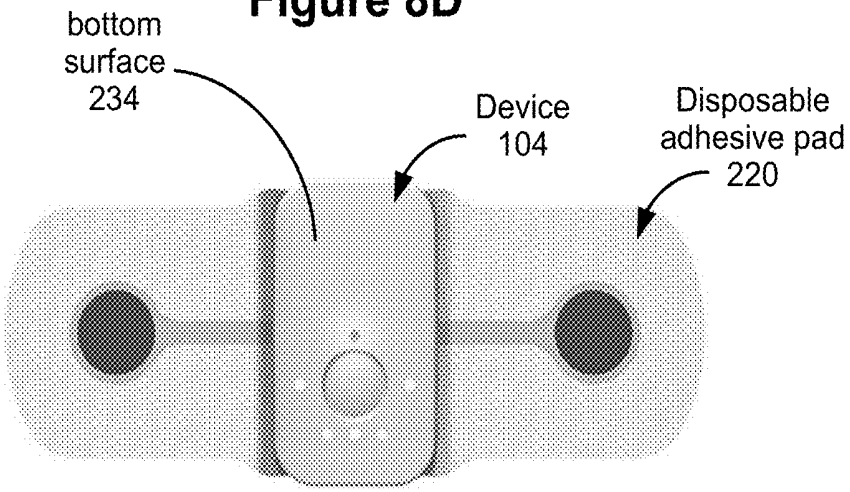


Figure 8E

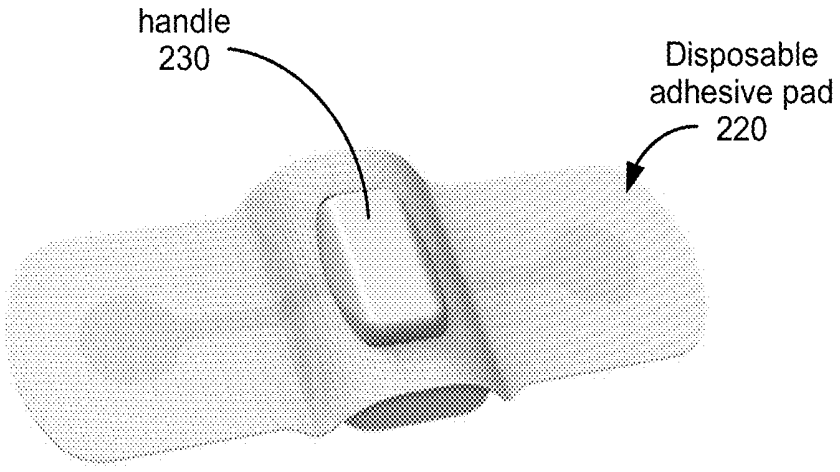
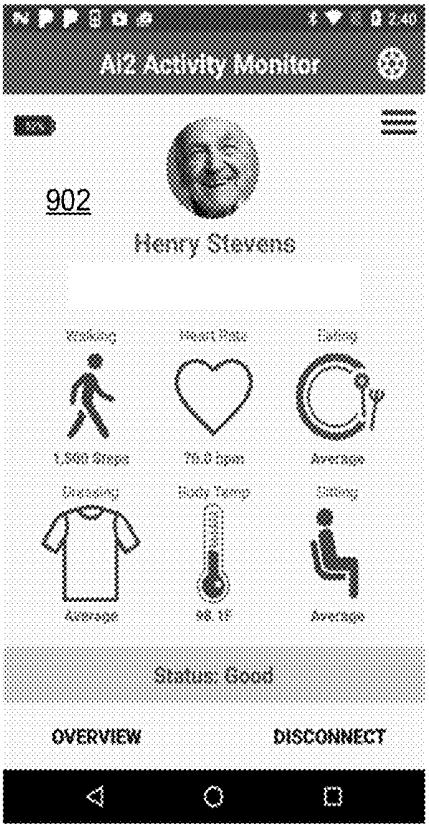
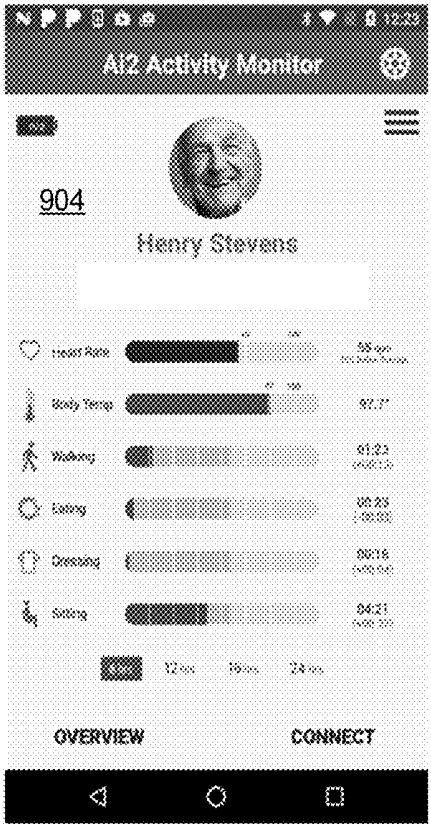
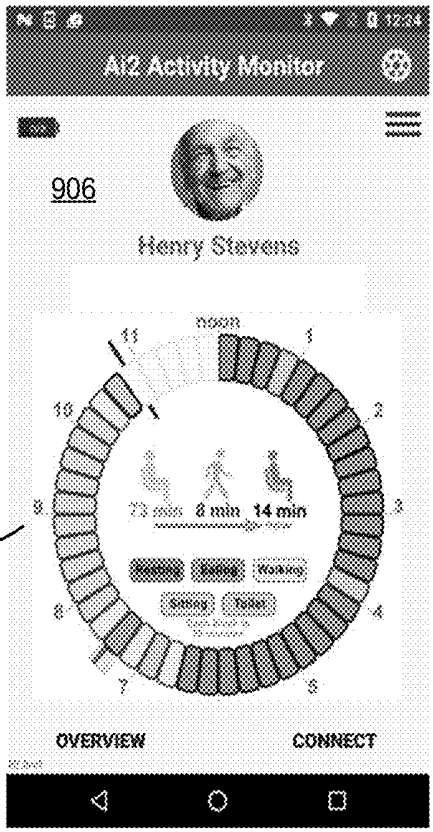


Figure 8F







dominant activity summary 910

Figure 9A

Local time: Tuesday, Oct 3, 12:31pm PST 908

Client Name	Status	Update	Most recent ADL	Heart Rt [bpm]	Sk.Temp [F]	Resp [bpm]	Lyg On [hrs]	Steps [steps]	Gait	Eating	Dressing	Toilet	Battery	On Body [hours]	Patch ID
Henry Stevens	Good	< 1m ago	Walking, 24m	73 bpm	97.5 F	21 bpm	7h34m	1,523	Good	24m ago	5h ago	2h ago	94%	2hrs	D8:F1:D0:68:37:E8
Jane Smith	Good	< 1m ago	Sitting, 2h21m	78 bpm	96.8 F	20 bpm	6h09m	230	Good	2h ago	3h ago	5h ago	72%	8 hrs	AB:1F:67:B8:61:E8
Abe Townsend	High temp	< 1m ago	In bed, 12h33m	85 bpm	100.5 F	27 bpm	12h33m	12	--	--	--	1h ago	45%	27 hrs	98:2F:D0:73:37:92
Josh Goodwin	Good	< 1m ago	Eating, 17m	73 bpm	94.5 F	21 bpm	7h34m	1,523	Good	Now	6h ago	5h ago	17%	47 hrs	23:F1:98:88:37:E8
Leonora Banks	Off Body	5h ago	Off Body, 5hrs	--	--	--	--	--	--	12h ago	17h ago	13 ago	--	--	AB:F1:D0:AB:37:82
Henry Stevens	Stumbles = 3	< 1m ago	Sitting, 1h45m	73 bpm	95.9 F	21 bpm	7h34m	434	Stumble	1h ago	6h ago	2h ago	86%	6 hrs	84:F1:88:78:37:E8
Vena Gaskill	FALL! 2m ago	< 1m ago	Lying down, 2m	121 bpm	97.2 F	29 bpm	1h04m	345	FALL!	4h ago	3h ago	3h ago	55%	24 hrs	9A:F1:D0:88:37:86
John Sanders	No food	< 1m ago	Walking, 2m	73 bpm	94.5 F	21 bpm	7h34m	873	Good	none	6h ago	4h ago	97%	1 hrs	AB:F1:87:88:37:E8

Figure 9B

ACTIVITIES OF DAILY LIVING MONITORING AND REPORTING SYSTEM

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application 62/590,140, filed Nov. 22, 2017, and to Provisional Patent Application 62/505,784, filed May 12, 2017, each of which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] This relates generally to health monitoring devices, including but not limited to wearable electronic wellness tracking devices that monitor and report activities of daily living.

BACKGROUND

[0003] Activities of daily living (ADL) are routine activities that people tend to do every day, and a person's ability to perform them is important in determining the person's ability to live independently. The level of assistance a person may need with regard to day-to-day living can be determined by monitoring the ADLs the person performs over a given period of time.

[0004] Healthcare professionals have an interest in monitoring ADLs in order to evaluate their patients, but conventional ADL monitoring systems can be burdensome and expensive, requiring multiple monitoring devices. Further, conventional ADL monitoring systems can be inaccurate due to wide ranges of motions associated with each ADL, which vary from person to person. Additionally, conventional ADL monitoring systems can lack the flexibility and mobility required for tracking a person in multiple locations around a house, due to rigid vision systems that are limited in terms of lighting and field of view. Camera-based ADL monitoring systems are also associated with privacy issues, as people dislike the idea of being on camera while performing certain personal activities like bathing and toileting.

SUMMARY

[0005] Accordingly, there is a need for ADL monitoring and reporting systems with improved monitoring methods and more portable and self-contained devices. Such methods and devices optionally complement or replace conventional methods and devices for monitoring and reporting ADLs. Such methods provide more accurate ADL classifications by using pre-trained neural networks to interpret raw data, and such devices eliminate the need to install multiple sensing components by being self-contained in a wearable form factor, thereby creating more accurate results with less burdensome hardware. The aforementioned deficiencies and other problems associated with ADL monitoring systems are reduced or eliminated by the disclosed ADL monitoring and reporting systems.

[0006] In accordance with some embodiments, a user-wearable electronic device includes a housing configured to be worn on a user's torso, the housing including an interface configured to be in direct contact with the user's skin; a plurality of sensors disposed in the housing, including a first sensor to produce raw ADL data, and a biometric sensor coupled to the interface and configured to sense one or more biometric characteristics of the user and generate corresponding biometric data. The device further includes one or more processors, disposed in the housing and coupled to the one or more sensors, and configured to generate, for each time period in a sequence of successive time periods, ADL identification information for the time period by processing the raw ADL data produced by the first sensor using one or more neural networks pre-trained to recognize a predefined set of ADLs. In some embodiments, at least one of the pre-trained neural networks includes a plurality of neural network layers, at least one layer of the plurality of neural network layers comprising a recurrent neural network, wherein an output of the one or more neural networks for each time period corresponds to the generated ADL identification information for the time period. In some embodiments, each pre-trained neural network includes a plurality of neural network layers, at least one layer of the plurality of neural network layers comprising a recurrent neural network.

[0007] The device also includes a transmitter, disposed in the housing and coupled to at least one processor of the one or more processors, to transmit one or more reports corresponding to the user, wherein a respective report for the user includes ADL information corresponding to the generated ADL identification information for one or more time periods in the sequence of time periods.

[0008] In some other embodiments, obtaining raw ADL data corresponding to a user and processing the raw ADL data to produce ADL identification information for one or more time periods in a sequence of successive time period is distributed over two or more devices, at least one of which processes the raw ADL data, or related ADL information, using one or more neural networks pre-trained to recognize a predefined set of ADLs. For example, in some embodiments, a user-wearable electronic device includes a housing configured to be worn by or embedded in a device worn by a user; one or more sensors disposed in the housing, including a first sensor to sense motion of the user and produce raw ADL data corresponding to the user. The device also includes a transmitter, optionally disposed in the housing, to transmit the ADL data or ADL information generated from the ADL data, to a monitoring system or to an intermediate device at which the ADL data or ADL information is further processed to generate, for each time period in a sequence of successive time periods, ADL identification information for the time period by processing the raw ADL data produced by the first sensor or ADL information generated from the ADL data, using one or more neural networks pre-trained to recognize a predefined set of ADLs. In some of these embodiments, at least one of the pre-trained neural networks includes a plurality of neural network layers, at least one layer of the plurality of neural network layers comprising a recurrent neural network, wherein an output of the one or more neural networks for each time period corresponds to the generated ADL identification information for the time period. In some of these embodiments, each of the pre-trained neural networks includes a plurality of neural network layers, at least one layer of the plurality of neural network layers comprising a recurrent neural network.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a better understanding of the various described embodiments, reference should be made to the Description of Embodiments below, in conjunction with the following drawings in which like reference numerals refer to corresponding parts throughout the figures.

[0010] FIG. **1**A is a context diagram illustrating a user-wearable electronic device, configured to perform ADL monitoring and reporting, in accordance with some embodiments.

[0011] FIG. **1**B is a context diagram illustrating an example layout of a living environment including beacons in accordance with some embodiments.

[0012] FIG. **2** is a block diagram illustrating components of a user-wearable electronic device in accordance with some embodiments.

[0013] FIGS. **3**A-**3**B are block diagrams illustrating a user-wearable electronic device and an intermediary device in accordance with a first set of embodiments.

[0014] FIGS. **3**C-**3**D are block diagrams illustrating a user-wearable electronic device and an intermediary device in accordance with a second set of embodiments.

[0015] FIG. **4** is a block diagram illustrating an implementation of a monitoring system in accordance with some embodiments.

[0016] FIG. **5** is a block diagram illustrating an implementation of a mobile device in accordance with some embodiments.

[0017] FIG. **6**A is a block diagram illustrating an implementation of a user profile database in accordance with some embodiments.

[0018] FIG. **6**B is a block diagram illustrating an implementation of a user ADL database in accordance with some embodiments.

[0019] FIG. **6**C is a block diagram illustrating information included in a user report and information included in a raw data report, in accordance with some embodiments

[0020] FIG. **6**D is a block diagram illustrating neural network configurations for particular ability categories in accordance with some embodiments.

[0021] FIG. **7** is a flow chart illustrating data flow in a user-wearable electronic device, configured to perform ADL monitoring and reporting, in accordance with some embodiments.

[0022] FIGS. **8**A-**8**F illustrate an embodiment of a user-wearable electronic device from multiple perspectives.

[0023] FIGS. **9**A-**9**B illustrate a set of reports displayed in user interfaces of an ADL monitoring system in accordance with some embodiments.

DESCRIPTION OF EMBODIMENTS

[0024] Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the various described embodiments. However, it will be apparent to one of ordinary skill in the art that the various described embodiments may be practiced without these specific details. In other instances, well-known methods, procedures, components, circuits, and networks have not been described in detail so as not to unnecessarily obscure aspects of the embodiments.

[0025] It will also be understood that, although the terms first, second, etc. are, in some instances, used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first contact could be termed a second contact, and, similarly, a second contact could be termed a first contact, without departing from the scope of the various described embodiments. The first contact and the second contact are both contacts, but they are not the same contact, unless the context clearly indicates otherwise.

[0026] The terminology used in the description of the various described embodiments herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used in the description of the various described embodiments and the appended claims, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will also be understood that the term "and/or" as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items. It will be further understood that the terms "includes," "including," "comprises," and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0027] As used herein, the term "if" is, optionally, construed to mean "when" or "upon" or "in response to determining" or "in response to detecting," depending on the context. Similarly, the phrase "if it is determined" or "if [a stated condition or event] is detected" is, optionally, construed to mean "upon determining" or "in response to determining" or "upon detecting [the stated condition or event]" or "in response to detecting [the stated condition or event]," depending on the context.

[0028] Attention is now directed toward embodiments of activities of daily living (ADL) monitoring and reporting systems in accordance with some embodiments. FIG. **1**A is a block diagram illustrating a sample embodiment of an ADL monitoring and reporting system **100**. Person **102**, sometimes herein called a user, is monitored by user-wearable ADL monitoring device **104**. In some embodiments, ADL monitoring device **104** is affixed directly to the person's skin. Optionally, ADL monitoring device **104** is physically coupled to person **102** by way of clothing or any other object that is attached to the person. In some embodiments, ADL monitoring device **104** reports ADL data, or ADL identification information generated from the ADL data, to intermediary device **106**, which receives the ADL data or ADL identification information and transmits a subset of the data, all of the data, or a representation of the data to monitoring system **120**, sometimes herein called a monitoring station. In some embodiments, intermediate device **106** processes ADL data received from ADL monitoring device **104**, for example using one or more neural networks, as discussed in more detail below, to produce ADL identification information, and transmits the ADL identification information to a monitoring system, from which authorized users can access the ADL identification information. In some other embodiments, ADL monitoring device **104** directly transmits ADL data or ADL identification information to monitoring system **120**.

[0029] In some embodiments, person **102**, ADL monitoring device **104**, and intermediary device **106** are located in a home **110**. It is understood that home **110** is any living arrangement in which a healthcare professional or anyone in a caregiver role may wish to monitor ADLs of one or more persons, including, for example, a house, an apartment, an assisted care facility, or a hospital. In some embodiments, home **110** is one of a plurality of homes, such as n homes

where n is an integer greater than 1, or greater than 2. Each home **110** typically houses one or more people and one or more ADL monitoring devices, all of which report ADL data (e.g., ADL identification information) to monitoring system **120**, either directly or through one or more intermediary devices **106**. In other embodiments, home **110** is the only home from which ADL data is reported to monitoring system **120**.

[0030] In some embodiments, mobile device **122** is communicatively coupled to monitoring system **120**, and provides access to ADL reports for healthcare professionals (or those otherwise fulfilling a caregiver role) wishing to monitor ADL data from one or more persons **102**. In embodiments in which the ADLs of multiple people are being monitored, mobile device **122** optionally provides access to a desired subset of the people whose ADL's are being monitored. For example, a caregiver is optionally given access, via mobile device **122**, to the ADL information for a particular subset of persons whose ADL information is being reported to monitoring system **120**. Access rights are optionally assigned according to security levels, relevance levels, legal constraints, and/or on a need-to-know basis. For example, a first person's caregiver may be given access to ADL for the first person, while a second person's caregiver may be given access to ADL reports for the second person. As another example, for embodiments in which monitoring system **120** receives ADL reports from a plurality of different homes or rooms in a nursing home, caregivers may only have access to ADL reports for users assigned to each respective caregiver. In yet another example, different caregivers are given access to ADL information at different levels of granularity. For example, relatives of a monitored person may be given access only to summary reports for the monitored person, for example daily summary reports, without access to more detailed ADL information, while healthcare professionals assigned to monitor the person have access all ADL information or more detailed ADL information. Optionally or alternatively, for embodiments in which there is no mobile device **122**, monitoring system **120** provides access to ADL reports.

[0031] FIG. **1**B illustrates an example layout of a home **110**, which includes four rooms in this example. In some embodiments, each room of a plurality of rooms of a home include a location or proximity beacon **132-138**. In some embodiments, only a subset of the rooms in a home include a location or proximity sensor **132-138**. The illustrated placement of beacons **132-138** in FIG. **1**B is merely an example, and it is understood that placement of each beacon **132-138** in each respective room may depend on factors such as room dimensions, contents, activity types, safety constraints, and the like. Operation of location or proximity beacons **132-138** is discussed below with reference to FIG. **2**.

[0032] FIG. **2** is a block diagram illustrating components of the user-wearable electronic device **104** (see FIG. **1**A), in accordance with some embodiments. User-wearable electronic device **104** includes housing **202**, one or more ADL sensors **204**, one or more biometric sensors **206**, interface **208** for coupling the one or more biometric sensors **206** to a user's skin, configured to be in direct contact with a user's skin, one or more processors **210**, proximity receiver **212** (sometimes called a location or proximity sensor), transceiver **214**, and battery **216**. Transceiver **214** typically includes a transmitter and receiver, with the transmitter being used to transmit user reports that include ADL information regarding the user wearing the device, and the receiver being used to receive software and configuration updates, and optionally commands and other information. Battery **216** is typically a rechargeable battery, implemented using any appropriate battery technology. In some embodiments, device **104** optionally includes only a subset of the aforementioned components. For example, in some embodiments, user-wearable electronic device **104** may include an ADL sensor **204** but no biometric sensor **206** and interface **208**. In some embodiments, user-wearable electronic device **104** does not include proximity receiver **212**.

[0033] In some embodiments, housing **202** is configured to be worn on or near a user's torso. In some embodiments, housing **202** is configured to be in direct contact with the user's skin, or affixed to an object, such as an adhesive layer, that is in direct contact with the user's skin. In some embodiments, housing **202** is placed on or near any portion of the user's torso that moves with the user, such as the chest, stomach, back, shoulder, or side of the body. In some embodiments, housing **202** has a compact form factor that allows device **104** to be worn on the user's body without causing a nuisance to the user. For example, housing **202** may have a length no greater than 10 centimeters (cm), a width no greater than 6.5 cm, and a thickness no greater than 0.5 cm. A typical size is 5 to 8.5 cm in length, 2.5 to 5 cm in width, and 0.1 to 0.25 cm in thickness. Other dimensions are possible as well, with a person of ordinary skill in the art recognizing that the bigger the housing, the more of a nuisance its presence may be on the user's body. However, since a bigger housing can fit more components and/or a larger battery **216**, and different dimensions can be optimized to fit various sizes of internal components, the exact dimensions of housing **202** are not meant to be limiting to any of the disclosed embodiments. In some embodiments, the form factor of housing **202** is configured to allow device **104** to fit within underclothing, such as a band of an article of underclothing, which helps to ensure the device is maintained in contact with the user's skin. Optionally, housing **202** is configured to allow user-wearable electronic device **104** to be integrated into an article of clothing that conforms to the skin. Additionally, housing **202** includes a waterproof or water-resistant seal so that user-wearable electronic device **104** is washable with a machine washer and can withstand activities involving water (e.g., bathing) and environments having high humidity. In order to further minimize any discomfort that may be caused by the presence of housing **202** on the user's body, in some embodiments, housing **202** and all components within the housing may be configured to have a total weight no greater than 60 grams. In other embodiments, the total weight may be no greater than 25 grams, 20 grams, 15 grams, or 10 grams.

[0034] In some embodiments, ADL sensors **204** include an accelerometer, an orientation sensor, a motion sensor, a gyroscopic sensor, or a combination thereof. In some embodiments, ADL sensors **204** include only one of the aforementioned sensors. ADL sensors **204** generate acceleration data, orientation data, motion data, gyroscopic data, or a combination thereof in response to movements associated with ADLs. In some embodiments, a predefined set of basic ADLs monitored by user-wearable electronic device **104** includes dressing, eating, transferring/ambulation, continence/toileting, bathing/hygiene, sitting, and sleeping/napping. Optionally, a predefined set of instrumental ADLs

monitored by user-wearable electronic device **104** includes housekeeping, meal preparation, transportation, talking/socialization/communication, managing personal finances/accounting, and managing medications, or any subset of those activities. In various embodiments, user-wearable electronic device **104** is configured to monitor a subset of p basic ADLs, where p is 3, 4 or 5, or more generally p is an integer greater than 2, greater than 3, or greater than 4.

[0035] In some embodiments, biometric sensors **206** include a temperature sensor for sensing temperature of the user, an electrocardiography (EKG) sensor for detecting electrical activity associated with the user's heart, a heart rate sensor for measuring the user's heart rate, a blood pressure sensor for measuring at least one parameter of the user's blood pressure, a bioimpedance sensor for measuring at least one parameter of the user's body composition, a total water content sensor, a photoplethysmograph (PPG) sensor for measuring the user's heart rate, or any subset or combination thereof. In some embodiments, biometric sensor **206** includes only one of the aforementioned sensors (e.g., a heart rate sensor), or only two of the aforementioned sensors (e.g., a temperature sensor and heart rate sensor). In some embodiments, biometric sensor **206** is coupled to interface **208** of housing **202** to allow biometric sensor **206** close access to the user's skin. In some embodiments, interface **208** is an opening in housing **202**, which allows for direct physical contact of biometric sensor **206** with the user's skin. In other embodiments, interface **208** is a region of housing **202** in which a cross section of housing material is smaller (i.e., thinner) when compared to a region outside of interface **208**, which is useful for establishing electrical contact with the user's skin. By enabling direct or close access to the user's skin, interface **208** allows biometric sensor **206** to accurately sense biometric characteristics of the user.

[0036] FIGS. **8**A-**8**F illustrate an embodiment of a user-wearable electronic device **104** from multiple perspectives. FIG. **8**A shows an exploded, bottom perspective view of device **104** in conjunction with a disposable adhesive pad **220**, while FIG. **8**B shows a top perspective view of device **104** and FIG. **8**C shows a different bottom perspective view of device **104** than FIG. **8**A. Referring to FIGS. **8**A, **8**B, and **8**C, in some embodiments, a handle portion **230** (see FIG. **8**B) of device **104**'s housing **202** is configured to mate with or protrude through an aperture **221** in disposable adhesive pad **220**. In some embodiments, disposable adhesive pad **220** includes electrodes **222-1** and **222-2** that are connected to a biometric sensor **206** inside housing **202** via leads **224-1** and **224-2** on a surface of disposable adhesive pad **220**, and contacts **226-1** and **226-2** on the exterior of housing **202** (see FIG. **8**B). In some embodiments, housing **202** of device **140** includes a base **228** and a handle **230**, which protrudes from base **228** and is configured to mate with or protrude through aperture **221** of disposable adhesive pad **220**. In some embodiments, disposable adhesive pad **220** includes arms **225-1**, **225-2** that extended away from device **104** when device **104** is mated with disposable adhesive pad **220**, and each arm **225** includes an adhesive surface **223** for holding electrodes **222** and a bottom surface **234** of device **104** against the skin of a user.

[0037] In some embodiments, bottom surface **234** of device **234** includes a plurality of contacts **232** for making electrical and mechanical contact with a user's skin, and providing electrical signals to one or more biometric sensors **206** inside housing **202**. In some embodiments, bottom surface **234** of device **234** includes interface **208** through which one or more biometric sensors **206** make contact with or are coupled to the skin of the user.

[0038] FIG. **8**D shows a top view of device **104** inserted into disposable adhesive pad **220**, while FIG. **8**E shows a bottom view of device **104** inserted into disposable adhesive pad **220** and FIG. **8**F shows a top perspective view of device **104** inserted into disposable adhesive pad **220**.

[0039] FIG. **3**A is a block diagram illustrating a user-wearable electronic device **104-1** in accordance with some embodiments. In some embodiments, device **104-1** includes one or more processors **210**, sometimes called CPUs, or hardware processors, or microcontrollers; transceiver **214**; one or more biometric sensors **206**; ADL sensors **204**; memory **306**; and one or more communication buses **308** for interconnecting these components. Device **104-1** optionally includes proximity receiver **212**. For example, if the system **100** determines a user's ADLs in part based on the proximity of the user to one or more beacons, then device **104-1** includes a proximity receiver **212**. Communication buses **308** optionally include circuitry (sometimes called a chipset) that interconnects and controls communications between system components.

[0040] As explained above with reference to FIG. **2**, device **104-1** includes a battery **216**. The inclusion of battery **216** in device **104-1** enables operation of device **104-1** as a mobile device, without connection to an external power source (i.e., external to device **104-1**). In some embodiments, battery **216** is sized, or has sufficient capacity, to enable operation of device **104-1** for at least one day, or at least two days, or three days, or a week, before the battery requires recharging.

[0041] Memory **306** includes high-speed random access memory, such as DRAM, SRAM, DDR RAM or other random access solid state memory devices, and may include non-volatile memory, such as flash memory devices, or other non-volatile solid state storage devices. Memory **306**, or alternately the non-volatile memory device(s) within memory **306**, comprises a non-transitory computer readable storage medium. In some embodiments, memory **306**, or the computer readable storage medium of memory **306** stores the following programs, modules, and data structures, or a subset or superset thereof:

- **[0042]** operating system **310**, for handling basic computer functions of device **104-1**;
- **[0043]** communications module **312** used for transmitting ADL data and/or reports via transceiver **214** to monitoring system **120**, or an intermediary device **106**, or other system; and optionally for receiving updates, instructions and/or other information from one or more external sources, such as monitoring system **120**, via transceiver **214**;
- **[0044]** sensor module(s) **314**, sometimes implemented as device drivers, for controlling and/or receiving data from ADL sensors **204**, biometric sensors **206**, and proximity receiver **212**;
- **[0045]** one or more neural networks **316**, described in more detail elsewhere in this document, for processing raw data from at least one of the ADL sensors **204** so as to determine which activities of daily living the user of the device has been engaged in during each of a sequence of time periods;

[0046] neural network configuration(s) **318**, which are used to configure the one or more neural networks; the neural network configuration(s) **318** are generated by one or more other systems configured to training one or more similar neural networks using training data, and then included in device **104-1**, or transmitted to device **104-1**; when the one or more neural networks **316** are configured using neural network configuration(s) **318**, the one or more neural networks **316** are pre-trained neural networks;

[0047] recorded data **320**, which includes recorded raw ADL data from the ADL sensors **204**, and/or biometric sensors **206**, and optionally proximity information associated with the information received from proximity receiver **212**;

[0048] one or more report generation modules **322**, which generate reports, described in more detail below, for transmission to an intermediary device, a monitoring system, or other system from which ADL information regarding the user is retrieved;

[0049] report data **324**, which are the aforementioned reports, or data included in those reports; and

[0050] settings **326**, typically including a device identifier, optionally including an identifier of the user of the device **104-1**, and optionally including settings that enable and disable various features of device **104-1**.

[0051] Each of the above identified elements may be stored in one or more of the previously mentioned memory devices that together form memory **306**. Each of the above mentioned modules or programs, including the aforementioned modules and operating system, corresponds to a set of instructions and data for performing a function described above. The above identified modules or programs (i.e., sets of instructions) need not be implemented as separate software programs, procedures or modules, and thus various subsets of these modules may be combined or otherwise re-arranged in various embodiments. In some embodiments, memory **306** may store a subset of the modules and data structures identified above. Furthermore, memory **306** may store additional modules and data structures not described above. In some embodiments, the programs, modules, and data structures stored in memory **306**, or the computer readable storage medium of memory **306**, provide instructions for implementing respective operations of the methods described herein.

[0052] Although FIG. **3**A shows an electronic device **104-1**, FIG. **3**A is intended more as a functional description of the various features which may be present in a user-wearable electronic device, than as a structural schematic of the embodiments described herein. In practice, and as recognized by those of ordinary skill in the art, items shown separately could be combined and some items could be separated.

[0053] FIG. **3**B is a block diagram illustrating an intermediary device **106-1** in accordance with some embodiments. In some embodiments, device **106-1** includes one or more processors **330**, sometimes called CPUs, or hardware processors, or microcontrollers; transceiver **334**; memory **336**; and one or more communication buses **338** for interconnecting these components. Communication buses **338** optionally include circuitry (sometimes called a chipset) that interconnects and controls communications between system components.

[0054] Memory **336** includes high-speed random access memory, such as DRAM, SRAM, DDR RAM or other random access solid state memory devices, and may include non-volatile memory, such as flash memory devices, or other non-volatile solid state storage devices. Memory **336**, or alternately the non-volatile memory device(s) within memory **336**, comprises a non-transitory computer readable storage medium. In some embodiments, memory **336**, or the computer readable storage medium of memory **336** stores the following programs, modules, and data structures, or a subset or superset thereof:

[0055] operating system **340**, for handling basic computer functions of device **106-1**;

[0056] communications module **342** used for receiving reports from device **104-1** via transceiver **334**; for receiving updates, instructions and optionally other information from monitoring system **120** or other system (i.e., other than intermediary device **106-1** and ADL sensing device **104-1**) via transceiver **334**; and for forwarding or sending reports or data to monitoring system **120** via transceiver **334**;

[0057] report data **354**, which are reports received from device **104-1**, or data included in those reports, which are stored for transmission to a monitoring system (such as system **120**, FIG. **4**), or other system (such as system **122**, FIG. **5**) from which ADL information regarding the user is retrieved by a caregiver; and

[0058] settings **356**, typically including a device identifier, and optionally including settings that enable and disable various features of device **106-1**.

[0059] Each of the above identified elements may be stored in one or more of the previously mentioned memory devices that together form memory **336**. Each of the above mentioned modules or programs, including the aforementioned modules and operating system, corresponds to a set of instructions and data for performing a function described above. The above identified modules or programs (i.e., sets of instructions) need not be implemented as separate software programs, procedures or modules, and thus various subsets of these modules may be combined or otherwise re-arranged in various embodiments. In some embodiments, memory **336** may store a subset of the modules and data structures identified above. Furthermore, memory **336** may store additional modules and data structures not described above. In some embodiments, the programs, modules, and data structures stored in memory **336**, or the computer readable storage medium of memory **336**, provide instructions for implementing respective operations of the methods described herein.

[0060] Although FIG. **3**B shows an electronic device **106-1**, FIG. **3**B is intended more as a functional description of the various features which may be present in an intermediary electronic device, than as a structural schematic of the embodiments described herein. In practice, and as recognized by those of ordinary skill in the art, items shown separately could be combined and some items could be separated.

[0061] In embodiments represented by FIGS. **3**A and **3**B, ADL sensing device **104-1** processes raw ADL data **320**, obtained from one or more ADL sensors **204**, using one or more neural networks **316** configured by neural network configuration(s) **318**, and generates reports **324** using report generation module(s) **322** for transmission to an intermediary device (e.g., intermediary device **106-1**), a monitoring

system (e.g., monitoring system **120**), or other system from which ADL information regarding the user is retrieved by a caregiver.

[0062] FIGS. **3**C and **3**D show another ADL sensing device **104-2** and intermediary device **106-2** in accordance with some embodiments. Features shared with FIGS. **3**A and **3**B are similarly numbered, and some are not further discussed for purposes of brevity. In these embodiments, the neural network processing modules (**316**, **318**) and report generation module(s) **322** are located (e.g., in memory **336**) in intermediary device **106-2**. In these embodiments, ADL sensing device **104-2** transmits raw ADL data (e.g., recorded data **320**), or data that has been initially or slightly processed to intermediary device **106-2**, and intermediary device **106-2** processes the raw ADL data (or slightly processed data) received from ADL sensing device **104-2**, using neural networks **316**, configured using neural network configuration(s) **318** as described above, and generates reports or report data **324** for monitoring system **120**, or other system from which ADL information regarding the user is retrieved by a caregiver, using one or more report generation modules **322** as described above.

[0063] Each of the above identified elements may be stored in one or more of the previously mentioned memory devices that together form memory **306** (of ADL sensing device **104-2**) and/or memory **336** (of intermediary device **106-2**). Each of the above mentioned modules or programs, including the aforementioned modules and operating system, corresponds to a set of instructions and data for performing a function described above. The above identified modules or programs (i.e., sets of instructions) need not be implemented as separate software programs, procedures or modules, and thus various subsets of these modules may be combined or otherwise re-arranged in various embodiments. In some embodiments, memory **306** and/or memory **336** may store a subset of the modules and data structures identified above. Furthermore, memory **306** and/or memory **336** may store additional modules and data structures not described above. In some embodiments, the programs, modules, and data structures stored in memory **306** and/or memory **336**, or the computer readable storage medium of memory **306** and/or memory **336**, provide instructions for implementing respective operations of the methods described herein.

[0064] As recognized by those of ordinary skill in the art, embodiments corresponding to FIGS. **3**A-**3**B and embodiments corresponding to FIGS. **3**C-**3**D are merely two non-limiting examples of distributed processing embodiments suitable for generating and processing raw ADL data so as to produce reports or report data having ADL identification information for a respective user. Stated another way, at least a portion of the neural network processing, at least a portion of the report generation processing, and/or other processing functions described herein are performed solely by processor(s) **210** of the ADL sensing device **104** in some embodiments, performed solely by processor(s) **330** of the intermediary device **106** in some embodiments, or performed by a combination of processors **210** and **330** in some embodiments.

[0065] In some embodiments, ADL sensing device **104** carries out all of the processing and transmits reports directly to a monitoring system, or other system from which ADL information regarding the user is retrieved by a caregiver, rendering an intermediary device unnecessary. In some embodiments, ADL sensing device **104** carries out all of the neural network processing and computations in real time, but only periodically sends ADL reports (e.g., once an hour, once every four hours, or once every eight hours), or only sends ADL reports when the sensing device **104** is plugged in to a power charger, thereby conserving battery power. In some embodiments, ADL sensing device **104** carries out all of the neural network processing and computations in real time, sends ADL reports periodically, but sends emergency reports in real time. In some embodiments, ADL sensing device **104** carries out all of the neural network processing and computations in real time, and sends the ADL reports in real time (e.g., as soon as a report is ready, such as every minute, every five minutes, every twenty minutes, or every hour). In some embodiments, ADL sensing device **104** carries out neural network processing and computations in real time, and sends ADL reports in real time if the sensing device **104** is in communicative range of an intermediary system **106**, a monitoring system **120**, or other system from which ADL information regarding the user is retrieved. Otherwise, if the sensing device **104** is outside of a communication range (e.g., the user leaves the house and the user's ADL sensing device **104** can no longer wirelessly communicate with the intermediary device **106** or the monitoring system **120**), the ADL sensing device **104** continues to sense ADL information and carry out neural network processing, storing ADL reports in local memory (e.g., memory **306**) until the sensing device **104** is once again in communication range of an intermediary device **106**, monitoring system **120**, or other system from which ADL information regarding the user can be retrieved (e.g., the user returns to the house and the user's ADL sensing device **104** sends ADL reports stored in memory **306** to the intermediary device **106** or the monitoring system **120**).

[0066] Although FIGS. **3**C-**3**D show electronic devices **104-2** and **106-2**, FIGS. **3**C-**3**D are intended more as a functional description of the various features which may be present in a user-wearable electronic device and an intermediary device, than as structural schematics of the embodiments described herein. In practice, and as recognized by those of ordinary skill in the art, items shown separately could be combined and some items could be separated.

[0067] FIG. **4** is a block diagram illustrating an implementation of a monitoring system **120** (see FIG. **1**A) in accordance with some embodiments. In some embodiments, monitoring system **120** includes one or more processors **410**, sometimes called CPUs, or hardware processors, or microcontrollers; memory **406**; one or more communication interfaces **414** (e.g., a transceiver, and/or a network interface); input/output (I/O) interface **416**; and one or more communication buses **408** for interconnecting these components. I/O interface **416** typically includes display **418**, which is optionally a touch-screen display. I/O interface **416** optionally includes a keyboard and/or mouse (or other pointing device) **420**, and optionally includes a touch-sensitive touchpad **422**. In some embodiments, monitoring system **120** is implemented as a server that does not include input/output interface **416**, and instead client systems such as mobile device **122** (FIGS. **1**A and **5**) are used by caregivers and other people to access reports and information stored in monitoring system **120** and to convey commands to monitoring system **120**.

[0068] Memory **406** includes high-speed random access memory, such as DRAM, SRAM, DDR RAM or other

random access solid state memory devices, and may include non-volatile memory, such as flash memory devices, or other non-volatile solid state storage devices. Memory **406**, or alternately the non-volatile memory device(s) within memory **406**, comprises a non-transitory computer readable storage medium. In some embodiments, memory **406**, or the computer readable storage medium of memory **306** stores the following programs, modules, and data structures, or a subset or superset thereof:

[0069] operating system **411**, for handling basic computer functions of monitoring system **120**;

[0070] communications module **412** used for receiving reports and exchanging information with other devices and systems via the one or more communications interfaces **414**;

[0071] a database or table or other collection of user profiles **434** of users for whom monitoring system **120** monitors activities of daily living and optionally other health or welfare information; user profiles are optionally implemented as or stored in a user profile database, as shown in FIG. **6**A;

[0072] user ADL database **436**, which includes ADL information, and optionally other health and welfare information, received by monitoring system **120** from one or more user-wearable electronic devices **104** (see FIGS. **1**A and **2**);

[0073] neural network configuration(s) **438**, which are used to configure the one or more neural networks in ADL monitoring device **104**, in intermediary device **106**, or in monitoring system **120** itself; the neural network configuration(s) **438** are generated by one or more other systems configured to train one or more similar neural networks using training data, and then stored in memory **406** of monitoring system **120**; in embodiments in which neural network processing of raw ADL data is performed by ADL monitoring device **104** or intermediary device **106**, respective neural network configurations **438** are transmitted to such systems;

[0074] one or more report generation modules **440**, which generate reports, described in more detail below, such as status reports regarding the monitored users, and priority reports (e.g., to report emergency situations); in some embodiments report generation module (s) **440** include a priority report generator **442**, a system report generator **444**, and optionally additional report generators.

[0075] In some embodiments, memory **406**, or the computer readable storage medium of memory **406** also stores one or more neural networks (e.g., similar to neural networks **316**, FIG. **3**A or **3**D, but not shown in FIG. **4**), described in more detail elsewhere in this document, for processing raw ADL data from at least one of the ADL sensors **204** so as to determine which activities of daily living the user wearing the device has been engaged in during each of a sequence of time periods. In such embodiments, raw ADL data from one or more user-wearable ADL sensing devices **104** is transmitted directly or indirectly from such devices **104** to monitoring system **120**, and monitoring system **120** processes the raw ADL data from each such user-wearable ADL sensing device **104** using one or more neural networks configured to recognize ADLs corresponding to the user of the user-wearable ADL sensing device **104**.

[0076] FIGS. **9**A and **9**B illustrate examples of reports or user interfaces generated by report generation module(s) **440** of monitoring system **120**, in accordance with some embodiments. FIG. **9**A shows three user interfaces, **902**, **904**, and **906**, for viewing ADL information, and other health and welfare information of a respective monitored user. Interface **906** includes a segmented, clock-shaped dominant activity summary **910**, having a sequence of time ordered segments, each representing or providing information identifying a dominant activity of a respective monitored user during a corresponding time period. In this example of interface **906**, each segment represents a fifteen minute period, although periods of other durations, such as 5 minutes, 10 minutes, 20 minutes, 30 minutes or 60 minutes, may be used in other embodiments. The physical position of each segment of summary **910** in user interface **906** corresponds to the time period for which that segment provides dominant activity information, for example in accordance with the hour hand position of the segment in a circularly arranged set of positions. In some embodiments, the color of each segment indicates the dominant detected activity of the monitored user during the corresponding time period. In some embodiments, selection of a respective segment, for example by moving a cursor (e.g., using a mouse) or focus selector (e.g., using a touch input on a touch-sensitive display or track pad) over the segment, causes the monitoring system to display additional ADL information for the corresponding time period, for example by showing the dominant activity during each of a sequence of shorter time periods (e.g., 3 minute time periods) within the time period (e.g., a 15 minute time period) corresponding to the selected segment.

[0077] FIG. **9**B illustrates a dashboard interface **908**, providing ADL and optionally other health and welfare information for each of a plurality of monitored users. In some embodiments, dashboard interface **908** highlights information indicative of potential health problems or emergency situations with respect to particular users, and/or provides information to the operator of dashboard interface **908** identifying monitored users for whom additional information meeting predefined criteria (e.g., emergency or potential health problem criteria) is available.

[0078] Each of the above identified elements may be stored in one or more of the previously mentioned memory devices that together form memory **406**. Each of the above mentioned modules or programs, including the aforementioned modules and operating system, corresponds to a set of instructions and data for performing a function described above. The above identified modules or programs (i.e., sets of instructions) need not be implemented as separate software programs, procedures or modules, and thus various subsets of these modules may be combined or otherwise re-arranged in various embodiments. In some embodiments, memory **406** may store a subset of the modules and data structures identified above. Furthermore, memory **406** may store additional modules and data structures not described above. In some embodiments, the programs, modules, and data structures stored in memory **406**, or the computer readable storage medium of memory **406**, provide instructions for implementing respective operations of the methods described herein.

[0079] Although FIG. **4** shows an electronic monitoring system **120**, FIG. **4** is intended more as a functional description of the various features which may be present in a monitoring system, than as a structural schematic of the

embodiments described herein. In practice, and as recognized by those of ordinary skill in the art, items shown separately could be combined and some items could be separated.

[0080] FIG. **5** is a block diagram illustrating an implementation of a mobile device **122** (see FIG. **1**A) in accordance with some embodiments. In some embodiments, mobile device **122** includes one or more processors **510**, sometimes called CPUs, or hardware processors, or microcontrollers; memory **506**; one or more communication interfaces **514** (e.g., a transceiver, and/or a network interface); input/output (I/O) interface **516**; and one or more communication buses **508** for interconnecting these components. I/O interface **516** typically includes a display, which is optionally a touch-screen display. For embodiments in which monitoring system **120** (see FIG. **4**) is implemented as a server that does not include input/output interface **416**, mobile device **122** functions as a client system and is used by caregivers to access reports and information stored in monitoring system **120** and to convey commands to monitoring system **120**. For embodiments in which monitoring system **120** (see FIG. **4**) does include input/output interface **416**, mobile device **122** functions as an optional, and more mobile, client system that can be used by caregivers in addition, or in the alternative, to monitoring system **120** to access reports and information stored in monitoring system **120** and to convey commands to monitoring system **120**.

[0081] Memory **506** includes high-speed random access memory, such as DRAM, SRAM, DDR RAM or other random access solid state memory devices, and may include non-volatile memory, such as flash memory devices, or other non-volatile solid state storage devices. Memory **506**, or alternately the non-volatile memory device(s) within memory **506**, comprises a non-transitory computer readable storage medium. In some embodiments, memory **506**, or the computer readable storage medium of memory **506** stores the following programs, modules, and data structures, or a subset or superset thereof:

- **[0082]** operating system **511**, for handling basic computer functions of mobile device **122**;
- **[0083]** communications module **512** used for receiving reports and exchanging information with other devices and systems (e.g., monitoring system **120**) via the one or more communications interfaces **514**;
- **[0084]** access rights module **534** used for determining access rights associated with the caregiver designated to use the particular mobile device **122**; and
- **[0085]** monitoring module **536**, which facilitates monitoring and review of ADL information by presenting or configuring for presentation (e.g., on a display included in communications interface **514**) ADL information and/or reports received from monitoring system **120**, corresponding to one or more user-wearable electronic devices **104** (see FIGS. **1**A and **2**).

[0086] Each of the above identified elements may be stored in one or more of the previously mentioned memory devices that together form memory **506**. Each of the above mentioned modules or programs, including the aforementioned operating system, corresponds to a set of instructions and data for performing a function described above. The above identified modules or programs (i.e., sets of instructions) need not be implemented as separate software programs, procedures or modules, and thus various subsets of these modules may be combined or otherwise re-arranged in various embodiments. In some embodiments, memory **506** may store a subset of the modules and data structures identified above. Furthermore, memory **506** may store additional modules and data structures not described above. In some embodiments, the programs, modules, and data structures stored in memory **506**, or the computer readable storage medium of memory **506**, provide instructions for implementing respective operations of the methods described herein.

[0087] Although FIG. **5** shows an electronic mobile device **122**, FIG. **5** is intended more as a functional description of the various features which may be present in a mobile device, than as a structural schematic of the embodiments described herein. In practice, and as recognized by those of ordinary skill in the art, items shown separately could be combined and some items could be separated.

[0088] FIG. **6**A is a block diagram illustrating an implementation of a user profile database **434** in accordance with some embodiments. User profile database **434** includes a set of user profiles **604**, for example user profiles **604-1** to **604-*n*** for users **1** to n. In some embodiments, each user profile **604** includes the following information, or a subset or superset thereof: the user's name, age or birthdate, location (e.g., home address or other information identifying the location at which the user lives), an identifier of the user-wearable electronic device **104** used by the user; contact information for the user; and information identifying which people or groups of people are authorized to access the user's ADL information (or more generally ADL, health and welfare information). In some embodiments, a respective user profile includes additional information not listed here. For example, in some embodiments a user may use two user-wearable electronic devices, for example in rotation, with one being worn while the other is recharging, and in such embodiments, the user profile of the user includes device identifiers for both user-wearable electronic devices used by that user. In some embodiments, a respective user profile does not include some of the information items listed here.

[0089] FIG. **6**B is a block diagram illustrating an implementation of a user ADL database **436** in accordance with some embodiments. User ADL database **436** includes ADL data **620** (e.g., data **620-1** for user **1**, through data **620-*n*** for user n), which optionally includes other health and welfare information, for each of a plurality of users. In some embodiments, the ADL data **620** for each respective user includes the following information, or a subset or superset thereof:

- **[0090]** ADL report data **622**, which includes ADL information included in reports received from the electronic device **104** monitoring the user's ADLs;
- **[0091]** biometric data **624**, which includes biometric data or information included in reports received from the electronic device **104** monitoring the user's ADLs;
- **[0092]** summaries **626**, which are summaries or digests of the user's ADL information for various periods of time, such as one hour (e.g., a summary **626-1** of the user's ADL information for a period of one hour, typically the hour immediately preceding the current time), eight hours (e.g., a summary **626-2** of the user's ADL information for a period of eight hours, typically the eight hours immediately preceding the current time), and twenty-four hours (e.g., a summary **626-3** of the user's ADL information for a period of twenty-four hours, typically the twenty-four hours immediately

preceding the current time), and/or any period of time corresponding to a caregiver-specific shift (e.g., a summary of the user's ADL information over the course of the caregiver's entire shift); and

[0093] activity counts **630**, such as a number of times a user performed a first activity **632** (e.g., walking), a second activity **634** (e.g., eating), a third activity **636** (e.g., resting), a fourth activity **638** (e.g., bathing), any subset of activities, and/or any additional activities.

[0094] Examples of activity counts **630** include a walking activity count **632**, which is or includes, for example, a count of steps by the user, or a count of minutes in which the user was walking, during one or more predefined periods of times, such as fifteen minutes, one hour, eight hours, and/or twenty-four hours; an eating activity count **634**, which is or includes a count of minutes in which the user was eating, during one or more predefined period of times, such as fifteen minutes, one hour, eight hours, and/or twenty-four hours; a resting activity count **636**, which is or includes, for example, a count of minutes in which the user was resting (remaining stationary, or napping, or sleeping), during one or more predefined period of times, such as fifteen minutes, one hour, eight hours, and/or twenty-four hours; and/or a bathing activity count **638**, which is or includes, for example, a count of minutes in which the user was bathing or engaged in hygiene activities, during one or more predefined period of times, such as fifteen minutes, one hour, eight hours, and/or twenty-four hours. Another example of an activity count that is optionally determined by device **104** for each of one or more respective time periods, and included in activity counts **630**, is a count of the number of times the user has tripped or stumbled. In the aforementioned examples, each count of the number of instances of an ADL being performed may be considered with a corresponding count of time during which the instances were being performed in order to calculate a health-related value. For example, a user who walks for S minutes during a given period of time will have a higher level of health, welfare, fitness, and/or activity than a user who walks for T minutes during the given period of time, where T is less than S (sometimes represented as T<S).

[0095] FIG. **6**C is a block diagram illustrating information included in a user report **640** and information included in a raw data report **650**, in accordance with some embodiments. User reports **640** and raw data reports **650** are reports generated by a respective user-wearable electronic device **104** and sent to monitoring system **120**. In some embodiments, user reports **640** are generated by device **104** at evenly spaced reporting intervals, such as fifteen minutes, and include information for a corresponding report period. In some embodiments, a respective user report **640** includes ADL vectors **642** (described in more detail below) for the report period, activity counts **644** (e.g., activity counts for activities such as walking, eating, hygiene and resting) for the report period, and biometrics **646** (e.g., temperature and heart rate) for the report period.

[0096] In some embodiments, user-wearable electronic device **104** generates raw data reports **650** so as to provide monitoring system **120**, or one or more other systems, with raw ADL data **658** to enable the generation of improved, or personalized, neural network configurations. In some embodiments, a respective raw data report **650** includes ADL vectors **642** (described in more detail below) for a report period, activity counts **644** (e.g., activity counts for activities such as walking, eating, hygiene and resting) for the report period, biometrics **646** (e.g., temperature and heart rate) for the report period, and raw ADL data **658** for the report period.

[0097] FIG. **6**D is a block diagram illustrating neural network configurations **438** in accordance with some embodiments. In some embodiments, user-device **104** is configured to detect ability-specific activities which differ according to particular ability categories. Accordingly, memory **406** includes neural network configurations (NNCs) **662** programmed for detecting ADLs specific to different ability levels (e.g., **662-1** for NNC for ability category **1** through **662-*k*** for NNC for ability category k). In some embodiments, an ability category includes a predefined set of ADLs that includes one or more, two or more, or three or more ADLs specific to the ability category, and optionally includes one or more generic ADLs common to multiple ability categories.

[0098] Exemplary ability categories in accordance with some embodiments include, but are not limited to: ambulation-impaired activities (e.g., for users who use a cane, walker, or wheelchair for ambulation), and motor function-impaired activities (e.g., for users who have difficulty moving their hands, arms, hips, and the like). ADLs in different ability categories are detected using category-specific NNCs. For example, wheelchair-based ambulation is associated with different torso movements than walking-based ambulation, and accordingly, a first NNC is used for detecting ambulation based on movements associated with operating a wheelchair, and a second (different from the first) NNC is used for detecting ambulation based on movements associated with walking. As a further example, a motor function-impaired person may bathe by sitting in a bath, while a non-impaired person may bathe by standing in a shower. Accordingly, a first NNC is used for detecting bathing based on movements associated with taking a bath, and a second (different from the first) NNC is used for detecting bathing based on movements associated with taking a shower.

[0099] In some embodiments, memory **406** initially includes a generic ability category NNC, which enables device **104** to be used without a preprogrammed ability-specific NNC. In some embodiments, the generic NNC is subsequently updated or replaced with an updated neural network configuration according to a received update or based on subsequent training, resulting in processor(s) **210** reconfiguring or replacing the generic NNC with the updated configuration, thereby enabling ability-specific ADL identification information for time periods subsequent to the reconfiguring of the ADL sensing device **104** with an ability-specific NNC.

[0100] FIG. **7** is a flow chart illustrating data flow in an implementation of a user-wearable electronic device **104**, in accordance with some embodiments. As shown, information from one or more ADL sensors **204**, for example a motion sensor (e.g., an accelerometer), is provided to one or more pre-trained neural networks **316**, which produce one or more result vectors **702** for each report period. For example, in some embodiments, pre-trained neural networks **316** generate a set of result vectors every six seconds, and the result vectors for a report period, such as fifteen minutes are combined or collected by report generation module(s) **322**, which then produces a digest or other report **706** for each time period, sometimes called a periodic report (e.g., peri-

odic user reports **640**, FIG. **6**C) for transmission to monitoring system **120**. In some embodiments, reports **706** are transmitted at a predefined time of day or night, at a predefined time relative to a start or end time of a caregiver's shift, in response to an emergency (e.g., a detected fall), and/or on demand (e.g., upon request by a caregiver operating mobile device **122** or monitoring system **120**). In some embodiments, the result vectors include information useable to produce activity counts, such as the activity counts discussed elsewhere in this document. In some embodiments, report generation module(s) **322** also produces emergency reports **706** when the result vectors it receives from neural networks **316**, and/or the biometric information it receives from biometric sensors **206**, satisfy emergency report generation criteria. Examples of emergency report generation criteria are discussed below.

[0101] In some embodiments, raw ADL sensor data is temporarily stored in a raw data buffer **708** in user-wearable electronic device **104**, which, along with the report data included in the aforementioned periodic reports is provided to a raw data report generator **710**, which produces a raw data report (e.g., raw data report **650**, FIG. **6**C) for transmission to monitoring system **120**.

[0102] Through the use of one or more trained neural networks **316** in user-wearable electronic device **104**, ADLs are associated with certain characteristic motions and/or orientations. As a nonlimiting example, eating is typically associated with a forward-leaning motion or similar torso motion as the user inserts a utensil with food into the user's mouth. Similarly, other ADLs are associated with other patterns of movement and/or orientation. One or more neural networks in user-wearable electronic device **104** are trained to recognize motion and/or orientation patterns consistent with eating, and each of the other ADLs that device **104** is configured to monitor.

[0103] In some embodiments, as shown in FIGS. **2** and **3**, at least one processor **210** is coupled to the aforementioned sensors, and receives raw sensor data from ADL sensor **204** (hereinafter "raw ADL data") and raw sensor data from biometric sensor **206** (hereinafter "raw biometric data"). In some embodiments, processor **210** receives the raw ADL data and/or the raw biometric data at a rate of no less than 10 samples per second, in accordance with a sampling period.

[0104] For each time period in a sequence of successive time periods, processor **210** generates ADL identification information for the time period by processing the raw ADL data produced by ADL sensor **204** using one or more neural networks pre-trained to recognize a predefined set of ADLs. In some embodiments, the successive time periods each have a duration of no more than 30 seconds (for example, 6 seconds). In some embodiments, processor **210** processes at least 10 samples of raw ADL data for each time period of the successive time periods. Further, in some embodiments, a ratio of the time period (at which processor **210** generates ADL identification information) to the sampling period (at which processor **210** samples raw data) is no less than 100, and is typically between 100 and 5,000. In some embodiments, each pre-trained neural network includes a plurality of neural network layers, and at least one layer of the plurality of neural network layers is, or includes, a recurrent neural network. An output of the neural network for each time period corresponds to the generated ADL identification information for the respective time period.

[0105] In some embodiments, processor **210** generates the ADL identification information for a respective time period in the sequence of time periods by generating a set of scores, including one or more scores for each ADL in the predefined set of ADLs. In accordance with the generated set of scores, processor **210** determines a dominant activity for the respective time period, wherein the dominant activity is one of the ADLs in the predefined set of ADLs. In accordance with a determination that the one or more scores for the dominant activity for the respective time period meets predefined criteria, processor **210** includes in the generated ADL identification information for the respective time period information identifying the dominant activity for the respective time period. However, in accordance with a determination that the one or more scores for the dominant activity for the respective time period do not meet the predefined criteria, processor **210** includes in the generated ADL identification information for the respective time period information indicating that the user's activity during the respective time period has not been classified as any of the ADLs in the predefined set of ADLs. In some embodiments, the predefined set of ADLs includes N distinct ADLs, where N is an integer greater than 2, and the ADL identification information generated by the one or more processors for the time period includes a vector of having at least N+1 elements, only one of which is set to a non-null value. In other embodiments, the predefined set of ADLs includes N distinct ADLs, where N is an integer greater than 2, and the ADL identification information generated by the one or more processors for the time period includes a vector of having at least N elements, only one of which is set to a non-null value.

[0106] In some embodiments, proximity receiver **212** is disposed in or on housing **202**. Proximity receiver **212** obtains location or proximity information (hereinafter, "raw proximity information") corresponding to a range or proximity to one or more beacons **132-138** (see FIG. **1**B) at known locations in an environment occupied by the user, and communicates the raw proximity information to processor **210**, which determines location information of the user based on the raw proximity information. In some embodiments, location information includes a room in which the user is located (e.g., bedroom, bathroom, kitchen, or any other living room). In some embodiments, processor **210** uses the location information to supplement the raw ADL data in order to more accurately generate ADL identification information. For example, by taking advantage of certain location-based ADL assumptions (e.g., a person does not bathe in the kitchen, and likewise, does not eat in the bathroom), the one or more neural networks narrow down a subset of possible ADL identification information for a given set of raw ADL data.

[0107] In some embodiments, transceiver **214** is disposed in housing **202** and coupled to processor **210**. Transceiver **214** obtains ADL identification information for a sequence of time periods from processor **210**, and transmits reports for the user. In some embodiments, transceiver **214** transmits the reports at predefined times at intervals of no less than 5 minutes (for example, fifteen minutes). In other embodiments, transceiver **214** transmits the reports only when device **104** is connected to an external power source or otherwise receiving power from an external power source, for example so as to charge the internal battery **216** of the device. Further, in some embodiments, transceiver **214**

transmits the reports in response to a manual transmission command (e.g., by pressing a "transmit" button on device **104**, or by a caregiver requesting the reports while using monitoring system **120** or mobile device **122**). In some embodiments, reports are transmitted at a predetermined transmission rate (e.g., every fifteen minutes, every hour, every four hours, every eight hours, and/or once a day), but with aggregated ADL identification information from a plurality of time periods (e.g., ADL counts for five-minute or fifteen-minute windows of time). It is understood that the aforementioned reporting times and aggregation periods are exemplary, and a person of ordinary skill in the art may configure them to be set in accordance with caregiver-determined requirements and/or user-specific needs. In some embodiments, a respective report includes ADL information (e.g., a list of ADLs detected during given time periods) corresponding to the generated ADL identification information for one or more time periods in the sequence of time periods. In some embodiments, in addition to including ADL information, a respective report also includes biometric information corresponding to the raw biometric data generated by the biometric sensor for a time period corresponding to the respective report.

[0108] Further, in some embodiments, in addition to or as an alternative to including ADL identification information, a respective report (e.g., raw data report **650**, FIG. **6**C) includes raw ADL data that has been stored by processor **210**. While processor **210** temporarily stores raw ADL data for one or more time periods, in some embodiments, the raw ADL data is not transmitted to a target system until device **104** is connected to an external power source (e.g., plugged into a power charger), in order to save battery power. Raw ADL data may be transmitted for use in the development of new or improved neural network configurations in order to, for example, identify additional classifications of activity, or improve the classification of raw ADL data into the predefined set of ADLs or other predefined categories (e.g., tripping, stumbling, exercise, etc.). In some embodiments, raw ADL data transmissions for the aforementioned purposes may be prompted by the determination that the one or more scores for the dominant activity for the respective time period do not meet the predefined criteria, as disclosed above. In other words, if raw ADL data cannot be classified as a particular ADL, or the classification has a low confidence score or other indicia of not meeting predefined reliability criteria, processor **210** stores the raw ADL data and transmits it for further analysis. In some embodiments, other data is transmitted along with the raw ADL data (e.g., the ADL identification vector(s), the biometric data, and/or the scores generated using the raw ADL data for the respective time periods).

[0109] In some embodiments, processor **210** automatically detects an emergency, based on the raw ADL data and/or biometric data, in accordance with predefined emergency detection criteria. In response to the automatic detection of an emergency, processor **210** initiates transmission of an emergency report to the target system using transceiver **214**. In some embodiments, the criteria for identifying an emergency include one or more of: heart rate high or low (e.g., above a first heart rate threshold or below a second heart rate threshold); body temperature high or low (e.g., above a first temperature threshold or below a second temperature threshold); breathing rate high or low (e.g., above a first breathing rate threshold or below a second breathing rate threshold); falling or stumbling; not sleeping during a time period of at least a predefined minimum duration; not eating or drinking during a time period of at least a predefined minimum duration; coughing in excess of a predefined threshold; choking; a crossed threshold of time during which an activity has been performed (e.g., sleeping or remaining in one position for too long); a crossed threshold of time between particular activities (e.g., too much time between meals); a crossed threshold of activity counts (e.g., too many or too little ADL events compared to a predefined goal or standard); or a combination of such factors.

[0110] In some embodiments, and with reference to FIG. **1**A, transceiver **214** wirelessly transmits the reports for the user to an intermediary device **106**, which forwards the reports for the user to a target system (e.g., monitoring system **120** or mobile device **122**). In some embodiments, intermediary device **106** is a power charger for device **104**, while in other embodiments, intermediary device **106** is a second instance of device **104** located in the same environment as the user (e.g. in the same building as, or otherwise co-located with, the user-wearable electronic device **104**). In some embodiments, intermediary device **106** is a docking station which serves as a repository for a user to return his or her device **104**, where the device **104** recharges and transmits data that may not have been otherwise transmitted while being worn by the user. In such embodiments, while the device **104** is being recharged (e.g., in a docking station), a replacement, backup, or alternative device **104** may be worn by the user so that the user's ADLs are always being monitored.

[0111] In some embodiments, transceiver **214** receives an updated configuration for the one or more neural networks, and sends the updated configuration to processor **210**, which reconfigures the one or more neural networks with the updated configuration. As a result, processor **210** thereafter generates ADL identification information for subsequent time periods using the one or more neural networks with the updated configuration. In some embodiments, all of the one or more neural networks are updated with new configurations at the same time. In some embodiments, or in some circumstances, just one of the neural networks is updated with a new configuration, or a subset of the neural networks are updated with new configurations when one or more updated configurations are received by device **104**. In some embodiments, the updated configuration allows for more accurate user-specific ADL identification schemes, based on analysis of previously received raw ADL data. For example, the updated configuration allows for personally targeted ADL identification schemes based on the user's personal habits (e.g., washing hair in the sink versus in the shower) or the user's historical activities (e.g., dancing, petting animals, etc.). In some embodiments, the updated configuration is customized in accordance with the geographic region of the user or cultural or other classifications associated with the user, or a combination thereof. In some embodiments, transceiver **214** is a wireless transceiver, while in other embodiments, transceiver **214** is a wired transceiver.

[0112] In some embodiments, rechargeable battery **216** is disposed within the housing, and processor **210** performs a predefined set of tasks while device **104** is determined to be connected to an external power source for recharging the battery. In some embodiments, the predefined set of tasks includes transmitting (e.g., through transceiver **214**)

recorded information that was not transmitted while the system was not connected to the external power source. Further, in some embodiments, the predefined set of tasks includes receiving (e.g., through transceiver **214**) update information for reconfiguring at least one aspect of device **104** (e.g., an updated configuration for the one or more neural networks as disclosed above).

[0113] The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A user-wearable electronic device, for monitoring user activities of daily living (ADL), comprising:

a housing configured to be worn on a user's torso;

a plurality of sensors disposed in the housing, including a first sensor to produce raw ADL data, and a biometric sensor configured to sense one or more biometric characteristics of the user and generate corresponding biometric data;

one or more processors, disposed in the housing and coupled to the one or more sensors, configured to:

for each time period in a sequence of successive time periods,

generate ADL identification information for the time period by processing the raw ADL data produced by the first sensor using one or more neural networks pre-trained to recognize a predefined set of ADLs, the pre-trained one or more neural networks each including a plurality of neural network layers, at least one layer of the plurality of neural network layers comprising a recurrent neural network, wherein an output of the one or more neural networks for each time period corresponds to the generated ADL identification information for the time period; and

a transmitter, disposed in the housing and coupled to at least one of the one or more processors, to transmit, at predefined times, reports for the user, wherein a respective report for the user includes ADL information corresponding to the generated ADL identification information for one or more time periods in the sequence of time periods.

2. The user-wearable device of claim **1**, wherein the biometric sensor and housing are configured to operatively couple the biometric sensor to the user's skin.

3. The user-wearable device of claim **1**, wherein the housing includes an interface configured to be in direct contact with the user's skin, and the biometric sensor is coupled to the interface.

4. The user-wearable device of claim **1**, wherein the respective report for the user further includes biometric information corresponding to the biometric data generated by the biometric sensor for a time period corresponding to the respective report.

5. The user-wearable device of claim **1**, wherein the biometric sensor includes at least one of: a temperature sensor for sensing temperature of the user, an EKG sensor for detecting electrical activity associated with the user's heart, a heart rate sensor for measuring the user's heart rate, and a blood pressure sensor for measuring at least one parameter of the user's blood pressure.

6. The user-wearable device of claim **1**, wherein the transmitter is configured to transmit the reports to a remotely located monitoring system that monitors ADL information for a plurality of users.

7. The user-wearable device of claim **1**, wherein the predefined set of ADLs includes three or more activities selected from the group consisting of dressing, eating, transferring/ambulation, continence/toileting, bathing/hygiene, sitting, and sleeping/napping.

8. The user-wearable device of claim **7**, wherein the predefined set of ADLs further includes one or more activities selected from the group consisting of shopping, housekeeping, meal preparation, transportation, and talking/socializing/communication.

9. The user-wearable device of claim **1**, wherein the first sensor comprises an accelerometer, an orientation sensor, motion sensor, or gyroscopic sensor.

10. The user-wearable device of claim **1**, further comprising a location or proximity sensor disposed in or on the housing;

wherein the one or more processors are further configured to:

determine location information for the user based on data from the location or proximity sensor; and

generate at least a portion of the ADL identification information for the time period by processing the raw ADL data produced by the first sensor and the location information for the user using at least one of the one or more neural networks.

11. The user-wearable device of claim **10**, wherein the location or proximity sensor is configured to obtain or generate range or proximity information corresponding to a range or proximity to one or more beacons at known locations in an environment occupied by the user; and wherein at least one processor of the one or more processors is configured to determine the location information for the user based on the range or proximity information.

12. The user-wearable device of claim **1**, wherein the transmitter is configured to wirelessly transmit the reports for the user to an intermediary device co-located with the user-wearable device that forwards the reports for the user to a target system.

13. The user-wearable device of claim **1**, wherein the one or more processors is configured to generate the ADL identification information for a respective time period in the sequence of time periods by:

generating a set of scores, including one or more scores for each ADL in the predefined set of ADLs;

in accordance with the generated set of scores, determining a dominant activity for the respective time period, wherein the dominant activity is one of the ADLs in the predefined set of ADLs;

in accordance with a determination that the one or more scores for the dominant activity for the respective time period meets predefined criteria, including in the generated ADL identification information for the respective time period information identifying the dominant activity for the respective time period.

14. The user-wearable device of claim **13**, wherein the one or more processors are further configured to generate the ADL identification information for a respective time period in the sequence of time periods by:

in accordance with a determination that the one or more scores for the dominant activity for the respective time period do not meet the predefined criteria, including in the generated ADL identification information for the respective time period information indicating that the user's activity during the respective time period has not been classified as any of the ADLs in the predefined set of ADLs.

15. The user-wearable device of claim **1**, wherein the predefined set of ADLs includes N distinct ADLs, where N is an integer greater than 2, and the ADL identification information generated by the one or more processors for the time period includes a vector of having at least N+1 elements, only one of which is set to a non-null value.

16. The user-wearable device of claim **1**, wherein the predefined set of ADLs includes N distinct ADLs, where N is an integer greater than 2, and the ADL identification information generated by the one or more processors for the time period includes a vector of having at least N elements, only one of which is set to a non-null value.

17. The user-wearable device of claim **1**, wherein

the pre-trained one or more neural networks include a first neural network having a first configuration;

the user-wearable device includes a receiver, disposed in the housing and coupled to at least one processor of the one or more processors, to receive an updated configuration for the first neural network; and

the one or more processors are further configured to reconfigure the first neural network with the updated configuration, and to thereafter generate ADL identification information for time periods subsequent to the reconfiguring of the first neural network, using the first neural network configured using the updated configuration.

18. The user-wearable device of claim **17**, wherein the transmitter and the receiver comprise a wireless transceiver.

19. The user-wearable device of claim **1**, wherein the housing has a length no greater than 10 cm, a width no greater than 6.5 cm and a thickness no greater than 0.5 cm.

20. The user-wearable device of claim **1**, wherein the housing and all components within the housing have a total weight no greater than 60 grams.

21. The user-wearable device of claim **1**, wherein the successive time periods each have a duration of no more than 30 seconds, and the predefined times at which the transmitter transmits reports for the user occur at intervals of no less than 5 minutes.

22. The user-wearable device of claim **1**, wherein the one or more processors are configured to receive raw ADL data from the first sensor at a rate of no less than 10 samples per second, in accordance with a sampling period, and a ratio of the time period to the sampling period is no less than 100.

23. The user-wearable device of claim **1**, wherein the one or more processors are configured to store the raw ADL data for one or more of the time periods in the sequence of time period, and to initiate transmission of the stored raw ADL data to the target system using the transmitter.

24. The user-wearable device of claim **1**, wherein the one or more processors are further configured to: automatically detect an emergency, based on the raw ADL data and/or biometric data, in accordance with predefined emergency detection criteria, and in response to the automatic detection of the emergency, to initiate transmission of an emergency report to the target system using the transmitter.

25. The user-wearable device of claim **1**, further comprising a rechargeable battery disposed within the housing, wherein the one or more processors are further configured to:

perform a predefined set of tasks while the user-wearable device is determined to be connected to a power source for recharging the user-wearable device's battery, the predefined set of tasks including transmitting recorded information not transmitted when the user-wearable device is connected to a power source for recharging the user-wearable device's battery, and receiving update information for reconfiguring at least one aspect of the user-wearable device.

26. A server system, comprising:

memory storing a plurality of neural network configurations, each neural network configurations corresponding to a distinct classification or a distinct group of classifications;

one or more processors for executing one or more programs; and

a communication interface, coupled to at least one of the one or more processors to provide each of the neural network configurations to corresponding user-wearable electronic devices or intermediary devices, each user-wearable electronic device or intermediary device for identifying user activities of daily living (ADL) of a respective user assigned to a classification or group of classifications corresponding to the neural network configuration provided to the user-wearable electronic device or intermediary device.

27. The server system of claim **26**, wherein a respective user-wearable electronic device of the corresponding user-wearable electronic devices or a respective intermediary device of the intermediary devices includes:

one or more neural networks configured with the neural network configuration provided by the server system to generate, for each time period in a sequence of successive time periods, ADL identification information for the time period by processing raw ADL data produced by a first sensor using one or more neural networks pre-trained to recognize a predefined set of ADLs, the one or more neural networks each including a plurality of neural network layers, at least one layer of the plurality of neural network layers comprising a recurrent neural network, wherein an output of the one or more neural networks for each time period corresponds to the generated ADL identification information for the time period.

28. An activities of daily living (ADL) monitoring system, comprising:

one or more processors, configured to:

collect raw ADL data produced by a first sensor;

for each time period in a sequence of successive time periods, generate ADL identification information for the time period by processing the raw ADL data produced by the first sensor using one or more neural networks pre-trained to recognize a predefined set of ADLs, the pre-trained one or more neural networks each including a plurality of neural network layers, at least one layer of the plurality of neural network

layers comprising a recurrent neural network, wherein an output of the one or more neural networks for each time period corresponds to the generated ADL identification information for the time period; and

transmit one or more reports corresponding to the user, wherein a respective report corresponding to the user includes ADL information corresponding to the generated ADL identification information for one or more time periods in the sequence of time periods.

29. The ADL monitoring system of claim **28**, wherein

the system includes a user-wearable electronic device and an intermediary device configured to receive raw ADL from the user-wearable electronic device;

the first sensor is disposed in a housing, located in the user-wearable electronic device, the housing configured to be worn by or affixed to a device worn by a user; and

the ADL identification information is generated by one or more processors in the intermediary device using the one or more neural networks pre-trained to recognize a predefined set of ADLs.

30. The ADL monitoring system of claim **28**, wherein the predefined set of ADLs includes three or more activities selected from the group consisting of dressing, eating, transferring/ambulation, continence/toileting, bathing/hygiene, sitting, and sleeping/napping.

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专利名称(译)	日常生活监测和报告系统的活动		
公开(公告)号	US20180325426A1	公开(公告)日	2018-11-15
申请号	US15/901764	申请日	2018-02-21
[标]发明人	SHAW KEVIN A		
发明人	SHAW, KEVIN A. BROWN, DAN W.		
IPC分类号	A61B5/11 G06F11/34 G06F11/30 G06N3/08 G01P13/00 A61B5/00		
CPC分类号	A61B5/1118 G06F11/3438 G06F11/3013 G06N3/08 G01P13/00 A61B5/6823 A61B5/6833 G01C19/00 G01P15/00 A61B2505/07 A61B5/0024 G01P15/18 G06N3/0445 G06N3/0454 G16H40/63 G16H40/67 G16H50/20 G16H50/70		
优先权	62/590140 2017-11-22 US 62/505784 2017-05-12 US		
外部链接	Espacenet USPTO		

摘要(译)

一种用户可穿戴电子设备，包括：壳体，被配置为佩戴在用户的躯干上；多个传感器，设置在壳体中，包括用于感测用户的运动并产生日常生活活动（ADL）数据的第一传感器，以及生物识别传感器，用于感测用户的一个或多个生物特征。电子设备或中间设备中的一个或多个处理器针对一系列时间段通过使用预训练的一个或多个神经网络处理原始ADL数据来生成ADL识别信息，以识别预定义的一组ADL。每个预训练的神经网络包括多个神经网络层，包括至少一个包括递归神经网络的层。包括与所生成的ADL标识信息相对应的ADL信息的报告在时间序列的时间段中被发送到监视系统。