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(54) **BED WITH FOOT WARMING SYSTEM**

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A61B 5/00	(2006.01)

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

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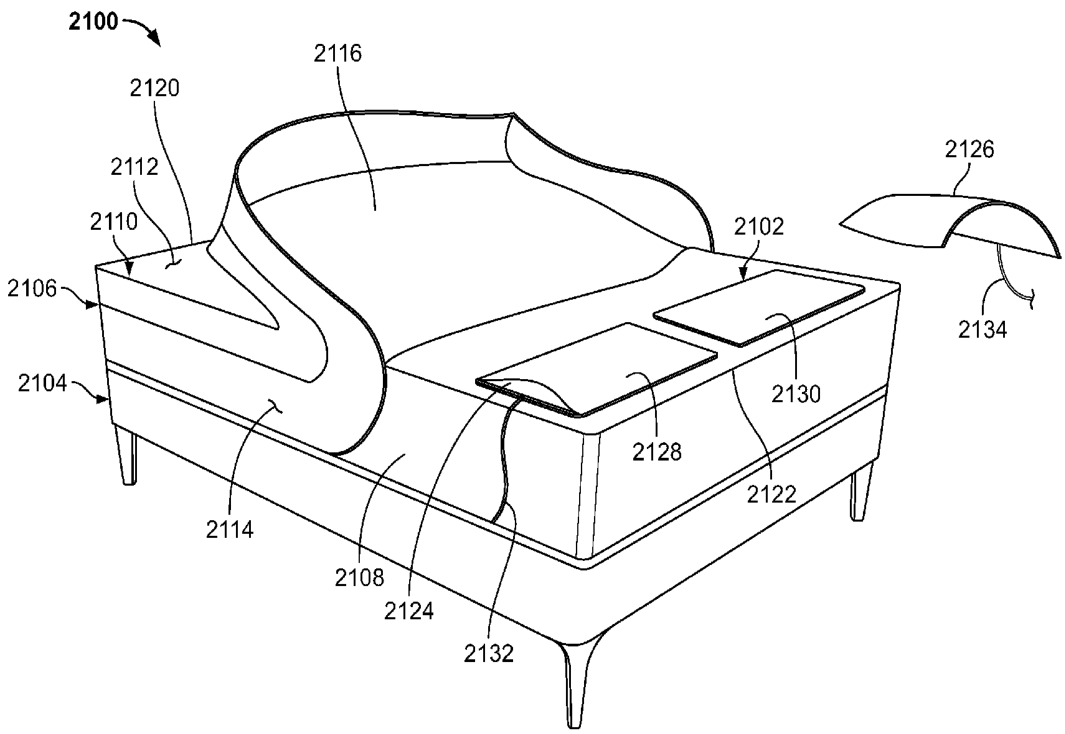
(57) **ABSTRACT**

A bed can include a mattress and a foot warming system. The mattress can include a mattress cover and a support structure that is positioned under and covered by the mattress cover. The foot warming system can include a heating unit an envelope, a power source, and an electrical connector electrically connecting the heating unit to the power source. The heating unit can be positioned inside the envelope between the envelope top and the envelope bottom. The heating unit and the envelope can be positioned at a foot of the bed under mattress cover between the support structure and the mattress cover.



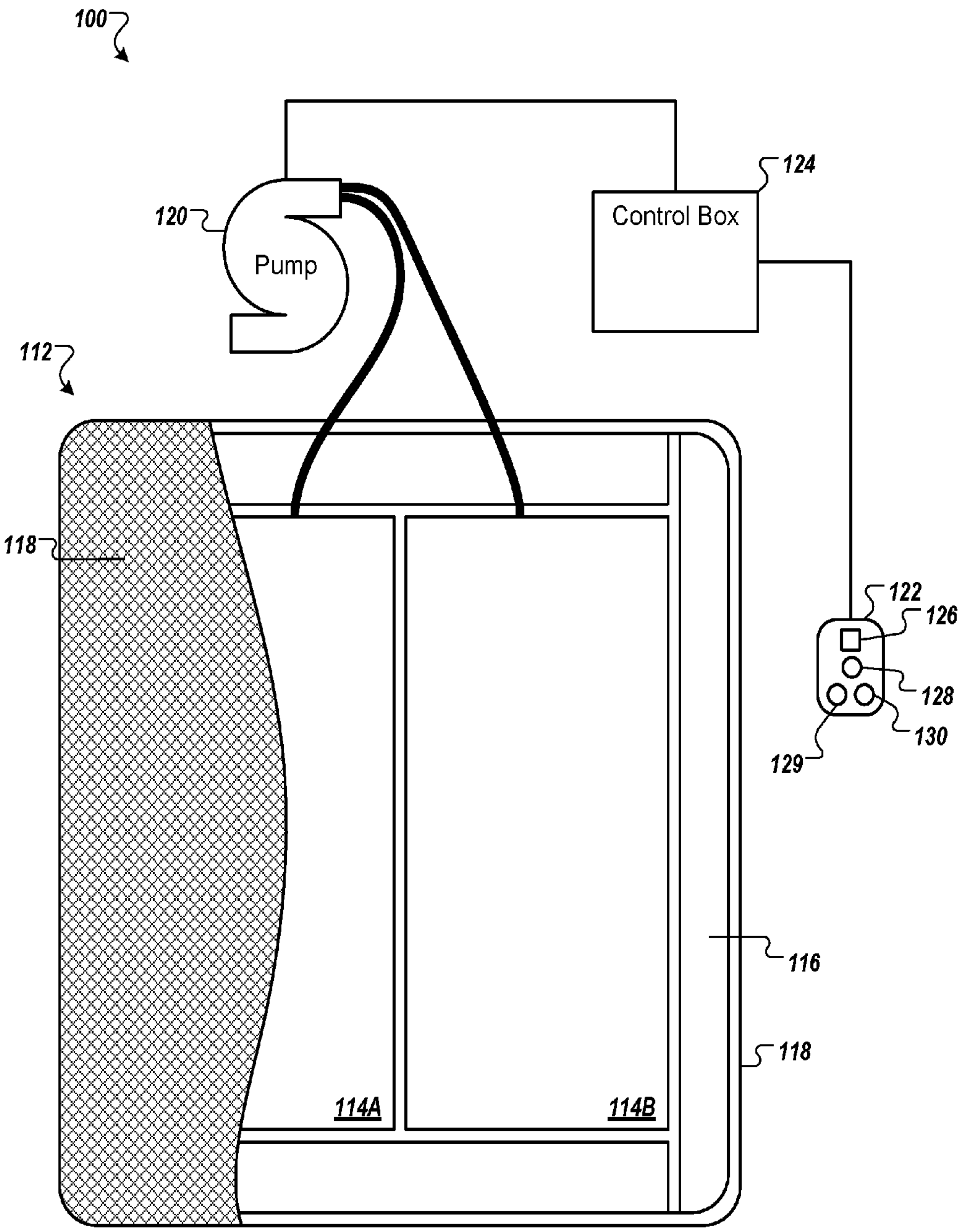

100
Pump
120
Control Box
124
112
118
122
126
128
129
130
116
118
114A
114B

FIG. 1

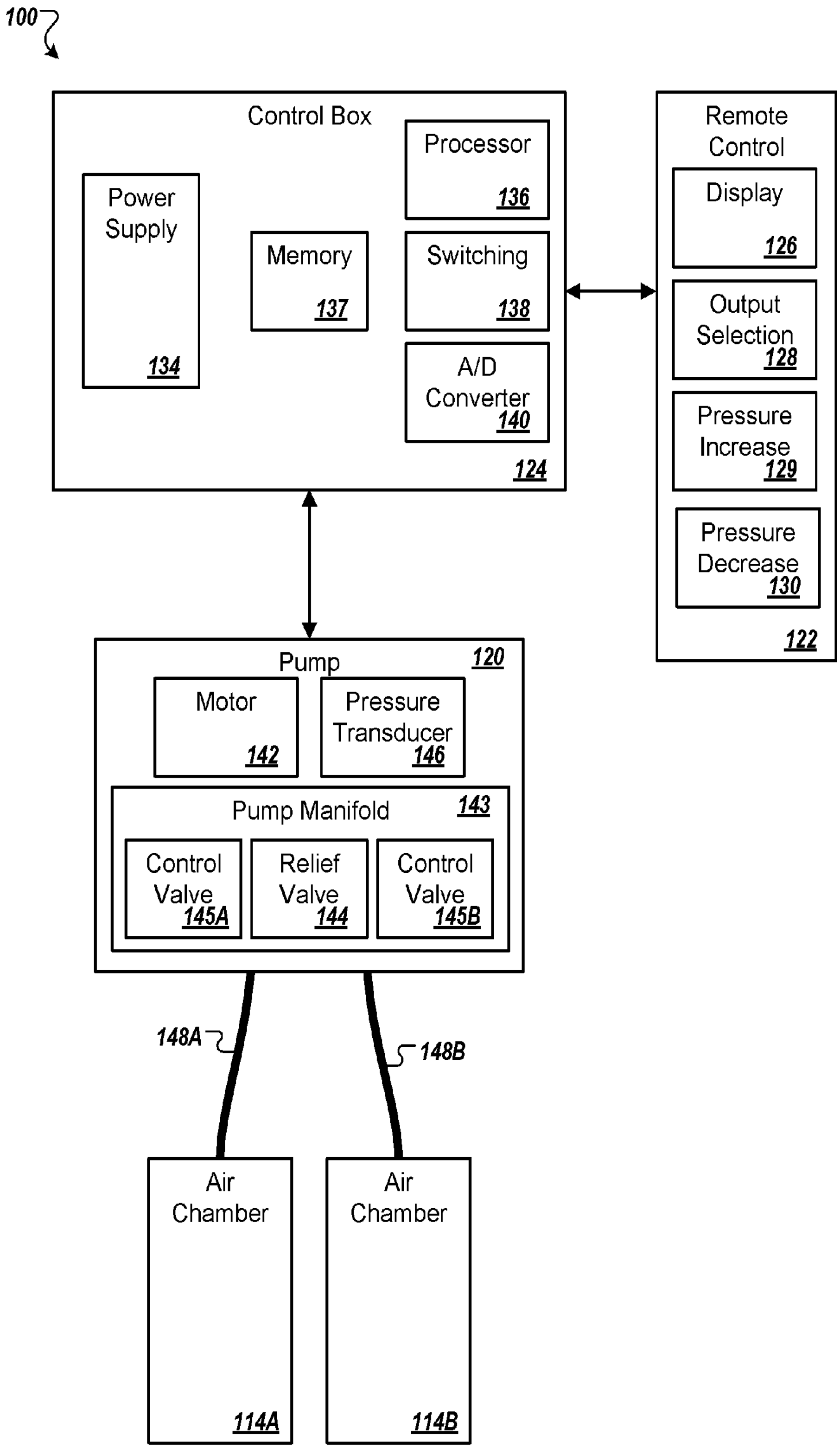

100
Control Box
Power Supply
134
Memory
137
Processor
136
Switching
138
A/D Converter
140
124
Remote Control
Display
126
Output Selection
128
Pressure Increase
129
Pressure Decrease
130
122
Pump
120
Motor
142
Pressure Transducer
146
Pump Manifold
143
Control Valve
145A
Relief Valve
144
Control Valve
145B
148A
148B
Air Chamber
114A
Air Chamber
114B

FIG. 2

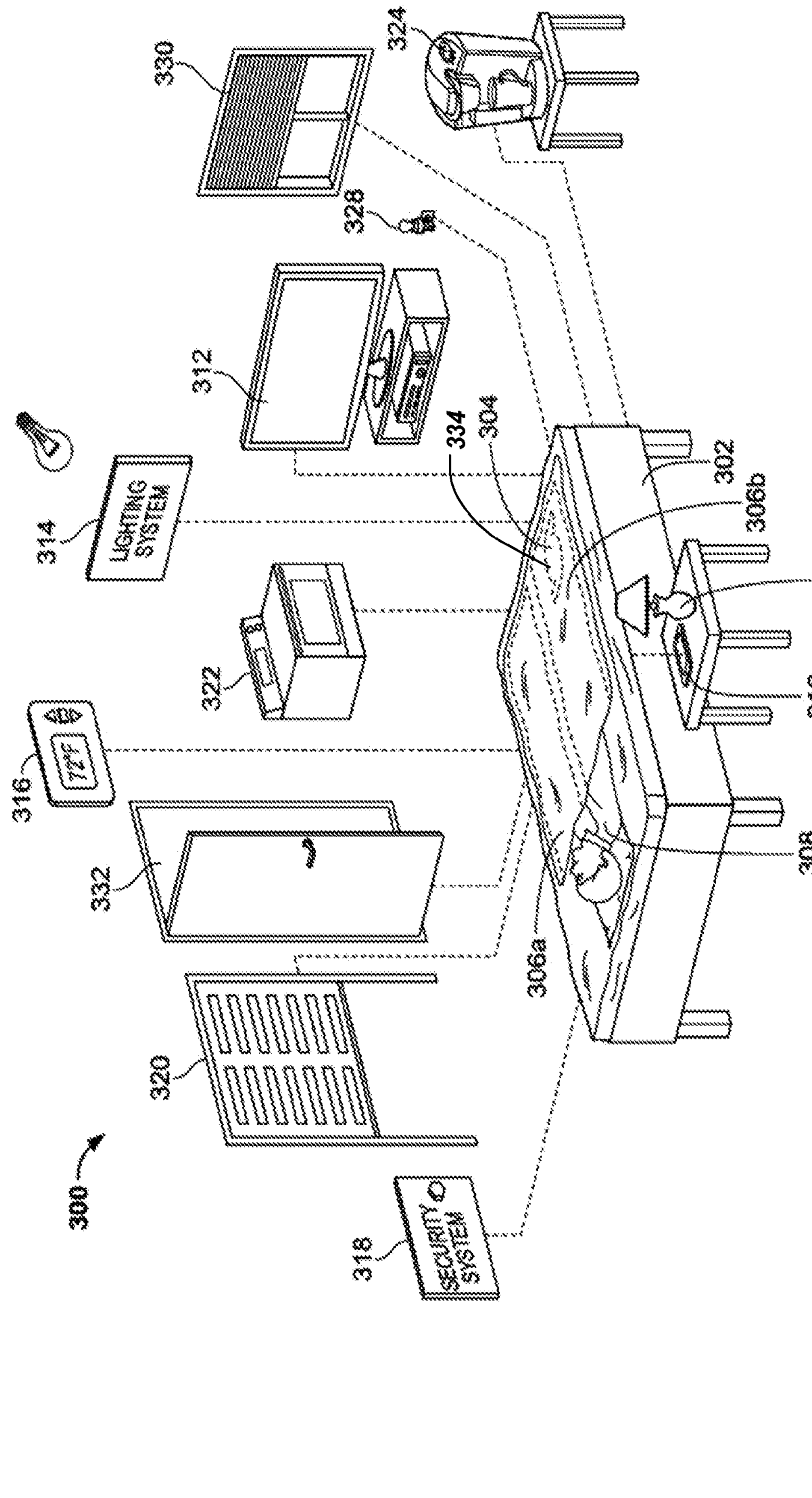

300
302
304
306a
306b
308
310
312
314
LIGHTING SYSTEM
316
72°F
318
SECURITY SYSTEM
320
322
324
326
328
330
332
334

FIG. 3

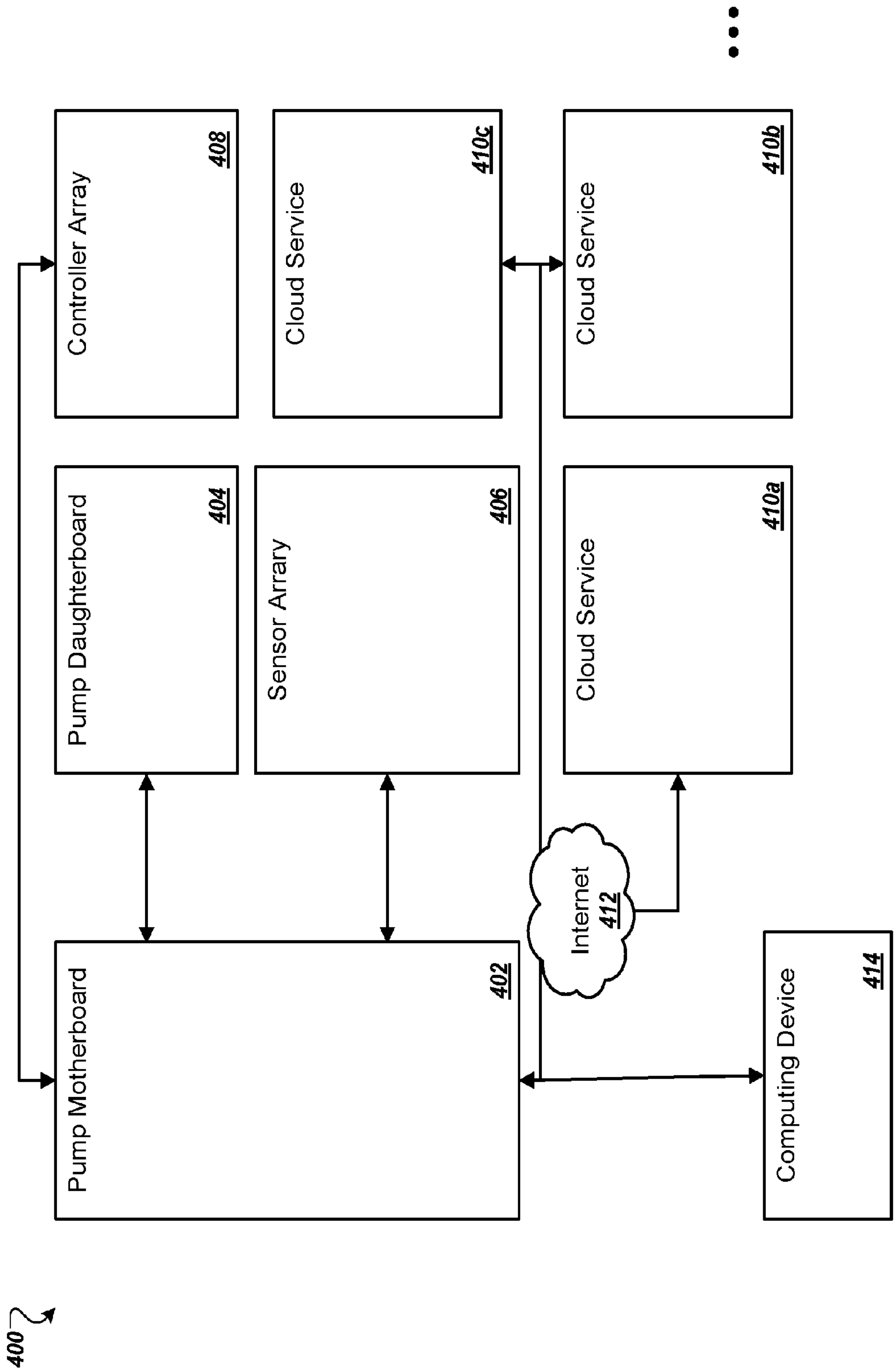

400
Pump Motherboard
402
Pump Daughterboard
404
Sensor Array
406
Controller Array
408
Cloud Service
410a
Cloud Service
410b
Cloud Service
410c
Internet
412
Computing Device
414

FIG. 4A

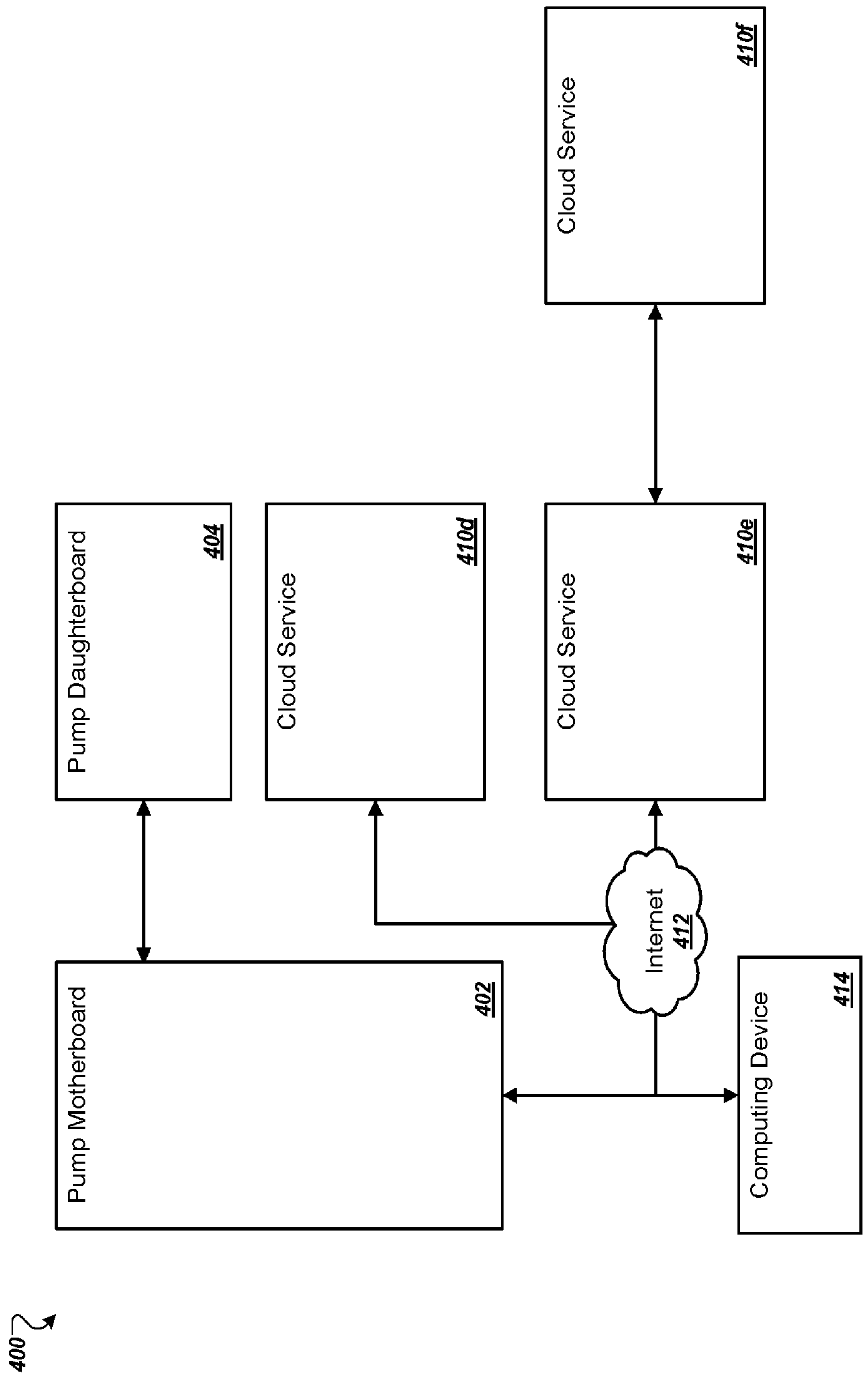

400
Pump Motherboard
402
Pump Daughterboard
404
Cloud Service
410d
Cloud Service
410e
Cloud Service
410f
Internet
412
Computing Device
414

FIG. 4B

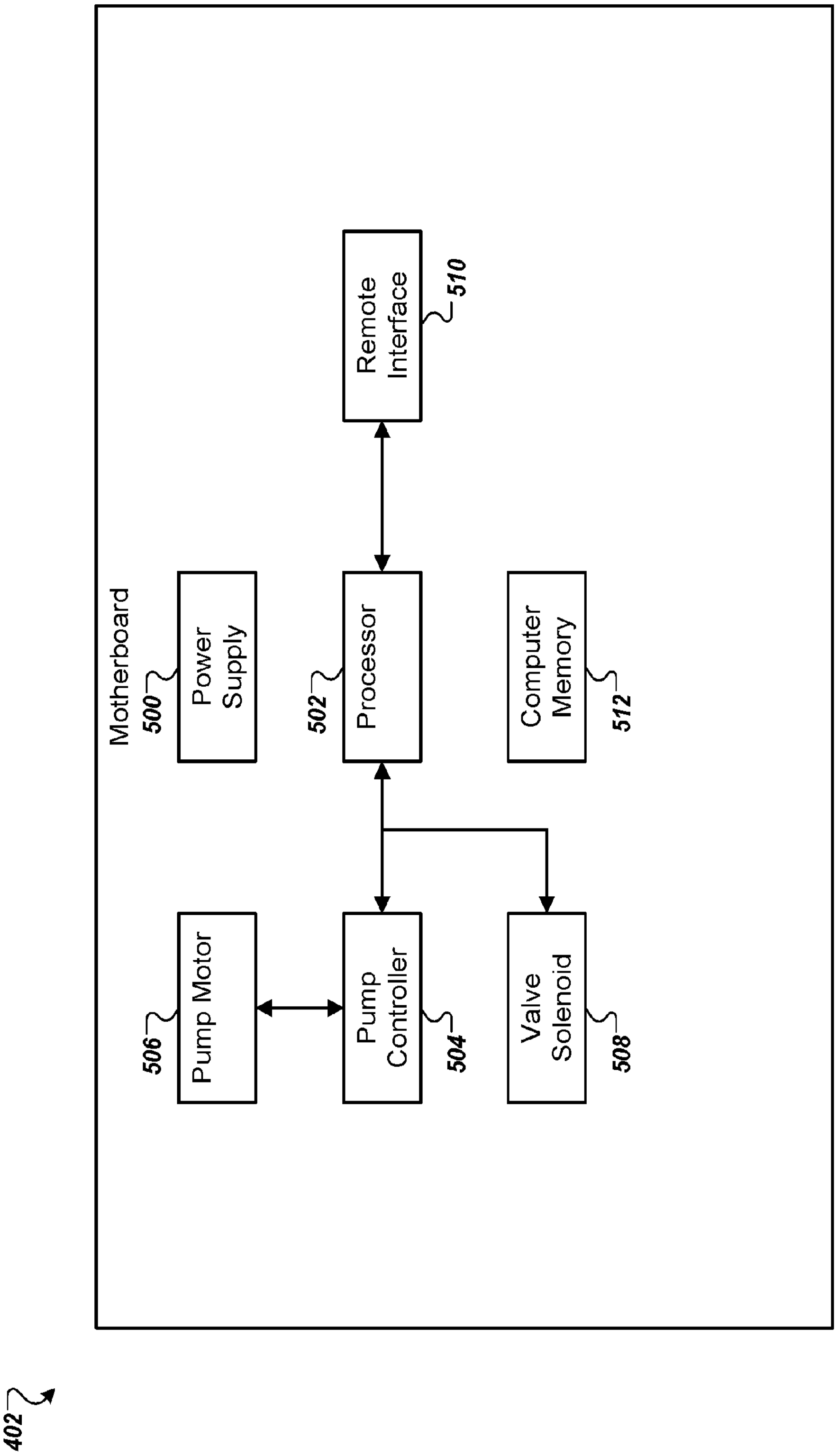

Motherboard
500
Power Supply
502
Processor
512
Computer Memory
Remote Interface
510
506
Pump Motor
Pump Controller
504
Valve Solenoid
508
402

FIG. 5

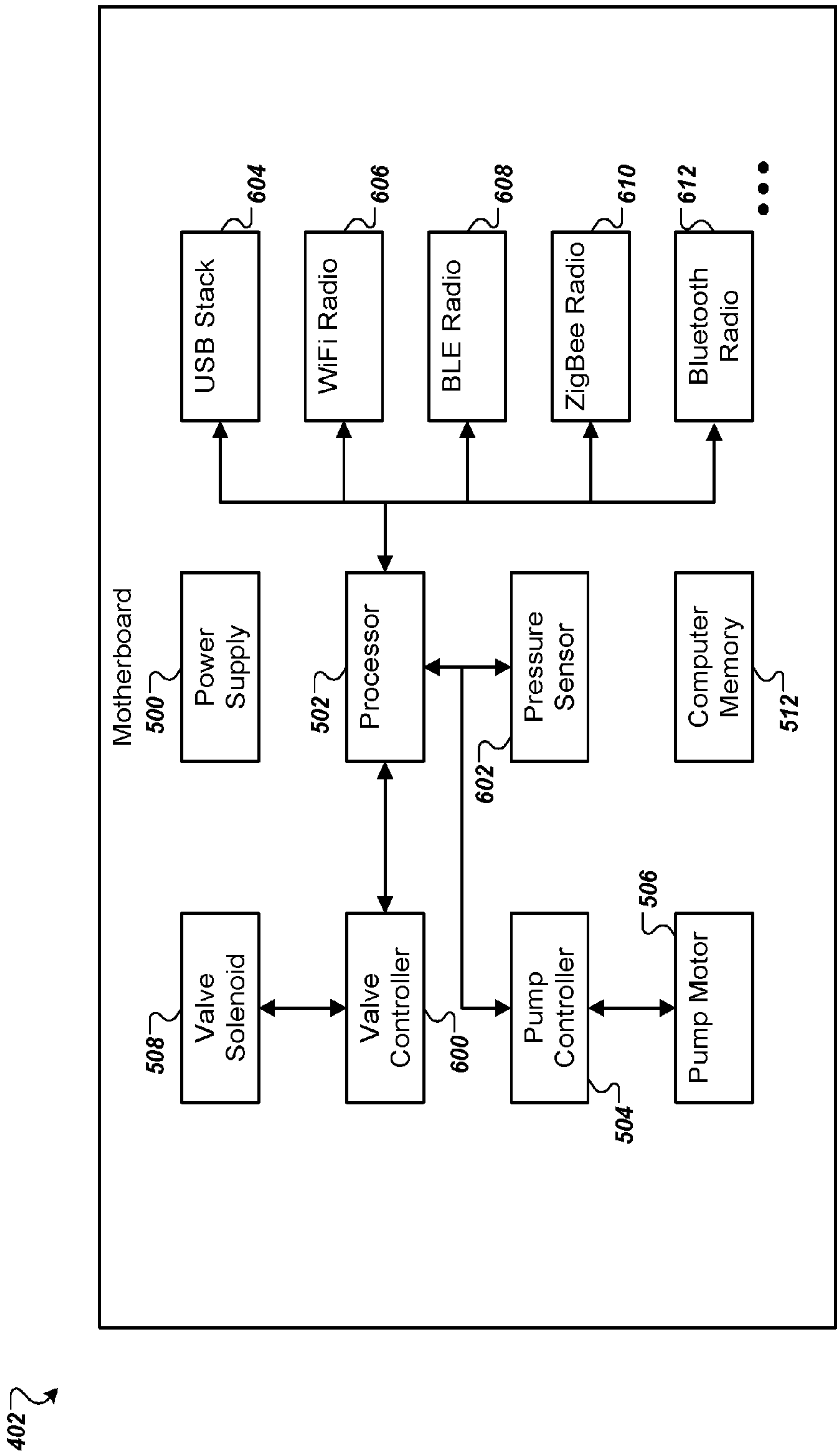

402
Motherboard
500
Power Supply
502
Processor
602
Pressure Sensor
512
Computer Memory
508
Valve Solenoid
600
Valve Controller
504
Pump Controller
506
Pump Motor
604
USB Stack
606
WiFi Radio
608
BLE Radio
610
ZigBee Radio
612
Bluetooth Radio

FIG. 6

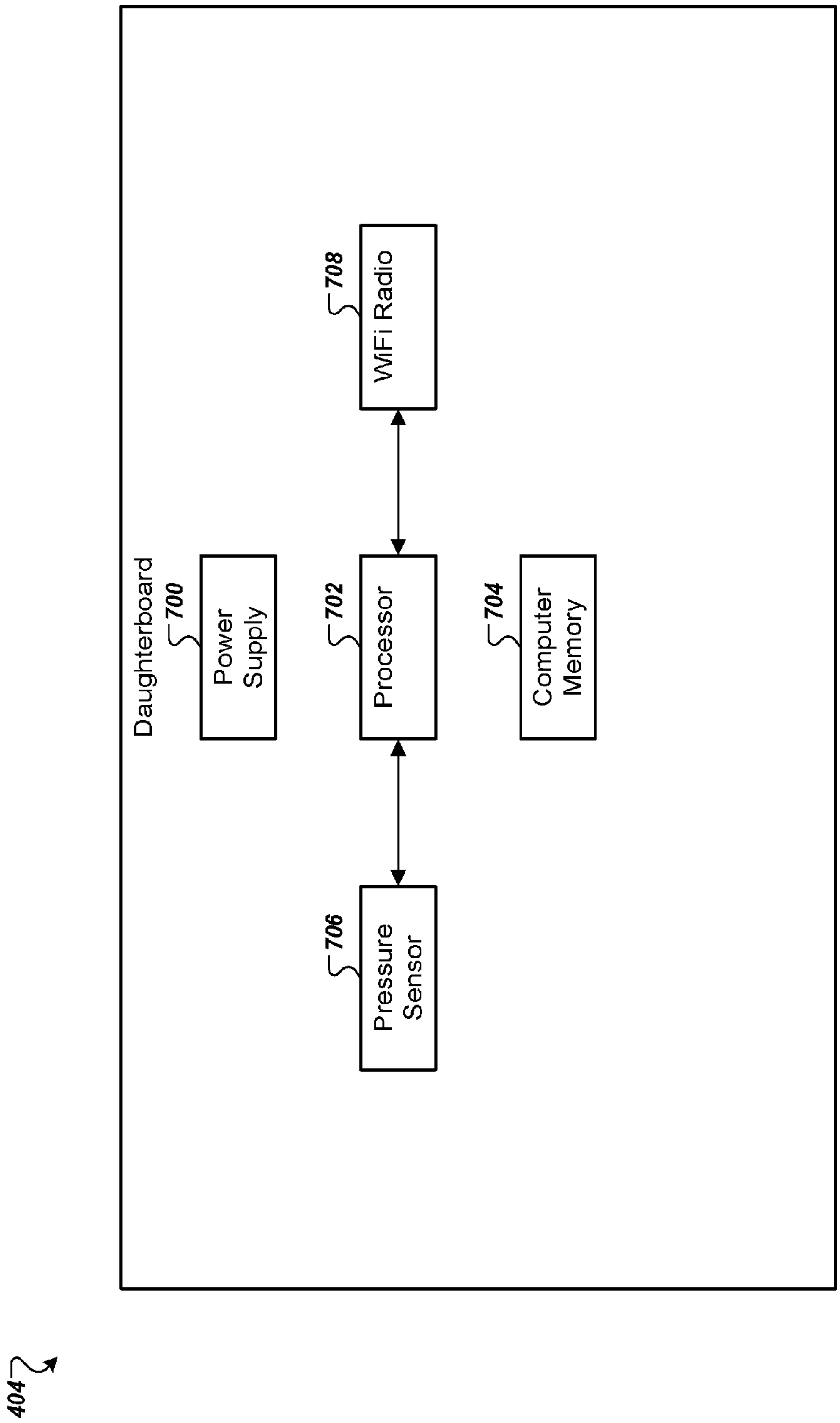

Daughterboard
700
Power Supply
702
Processor
704
Computer Memory
706
Pressure Sensor
708
WiFi Radio
404

FIG. 7

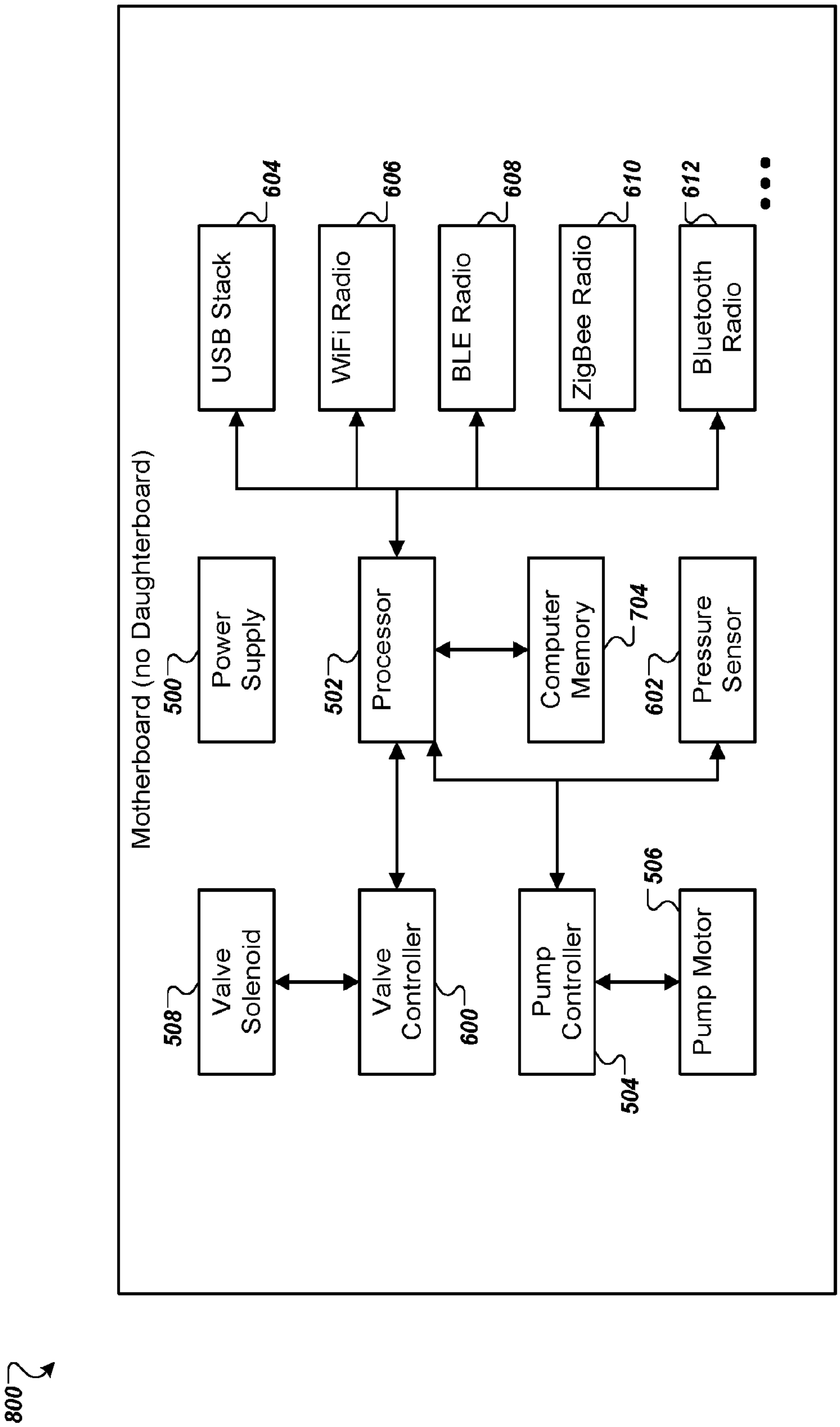

Motherboard (no Daughterboard)
500
Power Supply
502
Processor
Computer Memory
704
602
Pressure Sensor
508
Valve Solenoid
Valve Controller
600
Pump Controller
504
506
Pump Motor
USB Stack
604
WiFi Radio
606
BLE Radio
608
ZigBee Radio
610
Bluetooth Radio
612
800

FIG. 8

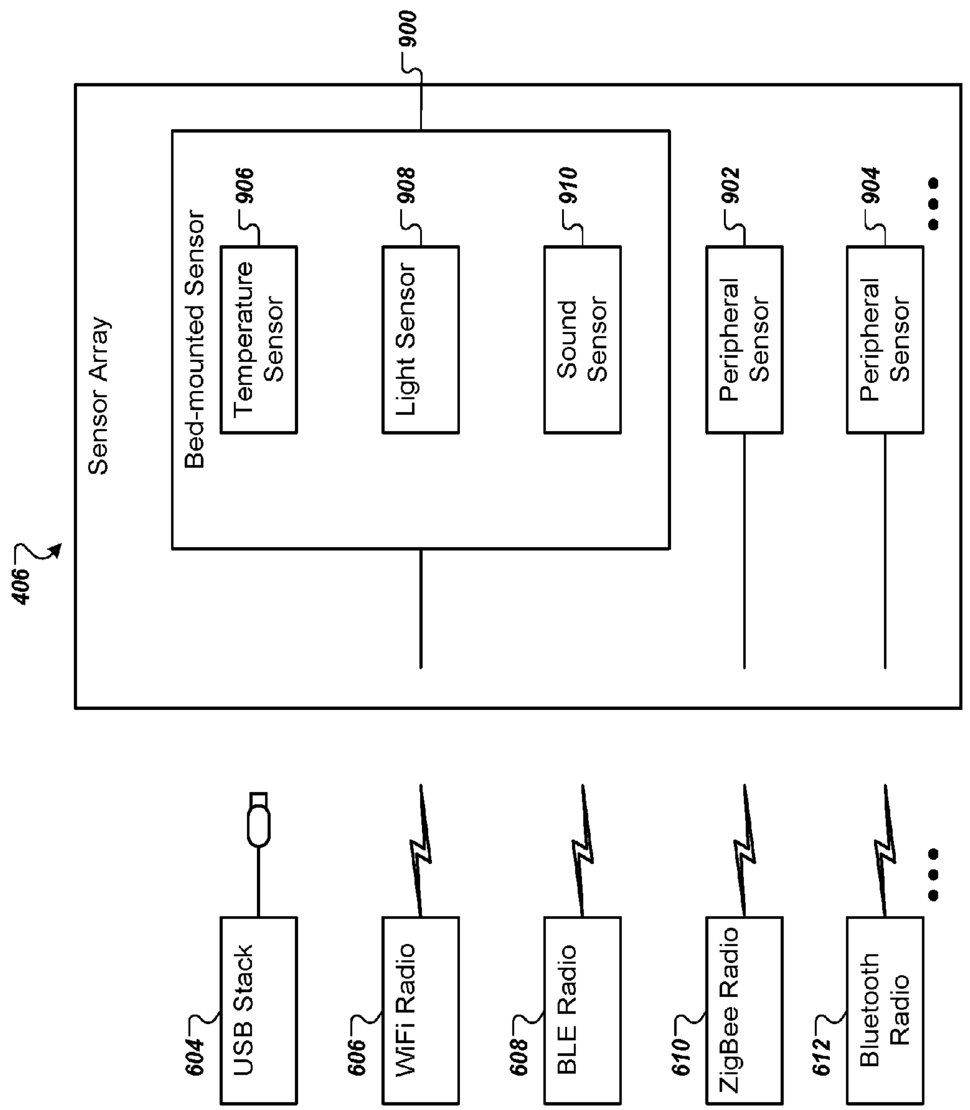

406
Sensor Array
900
Bed-mounted Sensor
Temperature Sensor
906
Light Sensor
908
Sound Sensor
910
Peripheral Sensor
902
Peripheral Sensor
904
USB Stack
604
WiFi Radio
606
BLE Radio
608
ZigBee Radio
610
Bluetooth Radio
612

FIG. 9

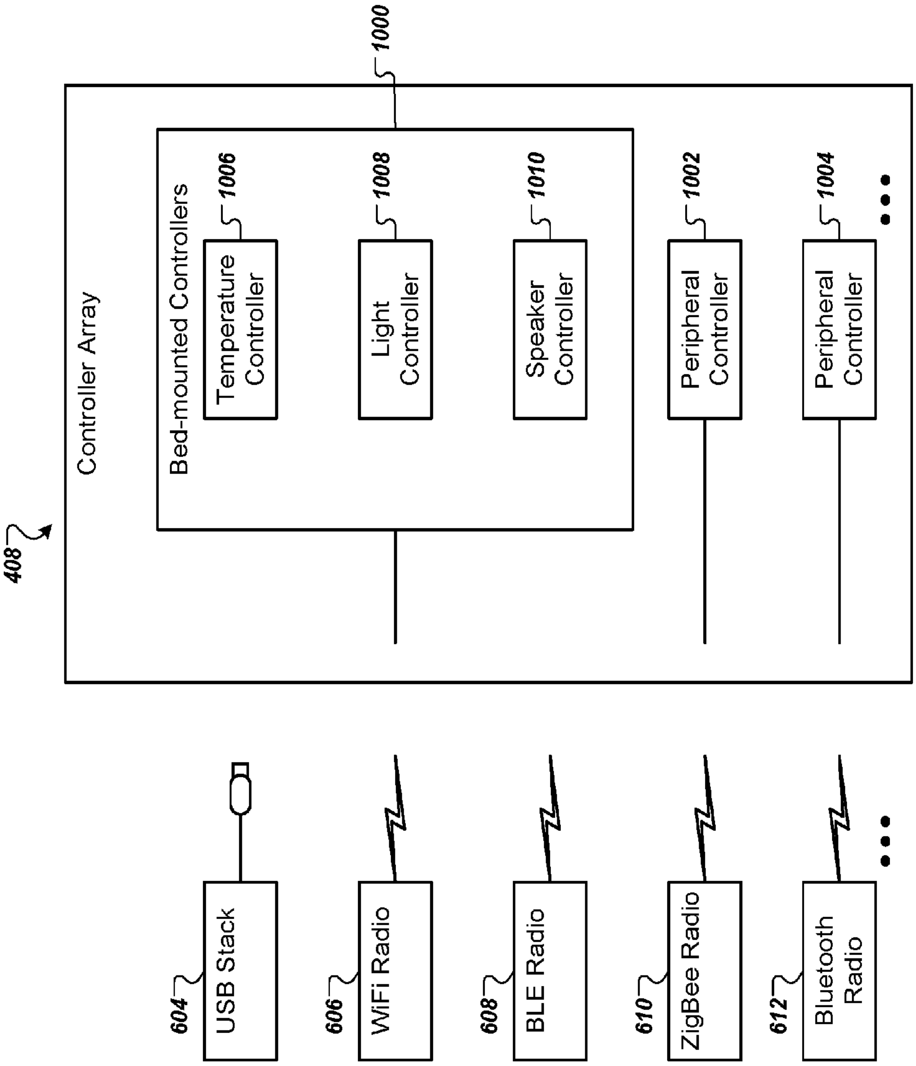

408
Controller Array
1000
Bed-mounted Controllers
Temperature Controller
1006
Light Controller
1008
Speaker Controller
1010
Peripheral Controller
1002
Peripheral Controller
1004
604
USB Stack
606
WiFi Radio
608
BLE Radio
610
ZigBee Radio
612
Bluetooth Radio

FIG. 10

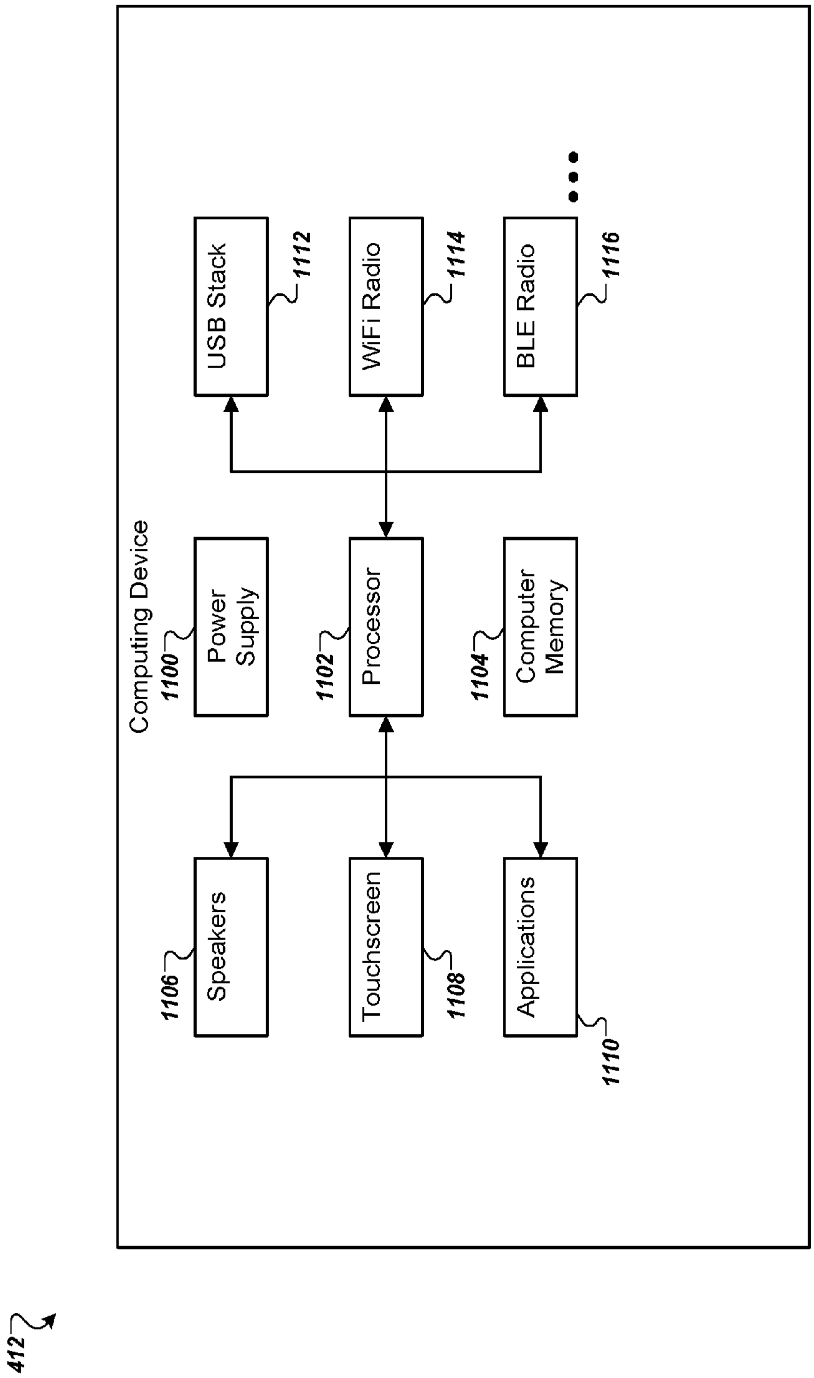

412
Computing Device
1100
Power Supply
1102
Processor
1104
Computer Memory
1106
Speakers
1108
Touchscreen
1110
Applications
1112
USB Stack
1114
WiFi Radio
1116
BLE Radio

FIG. 11

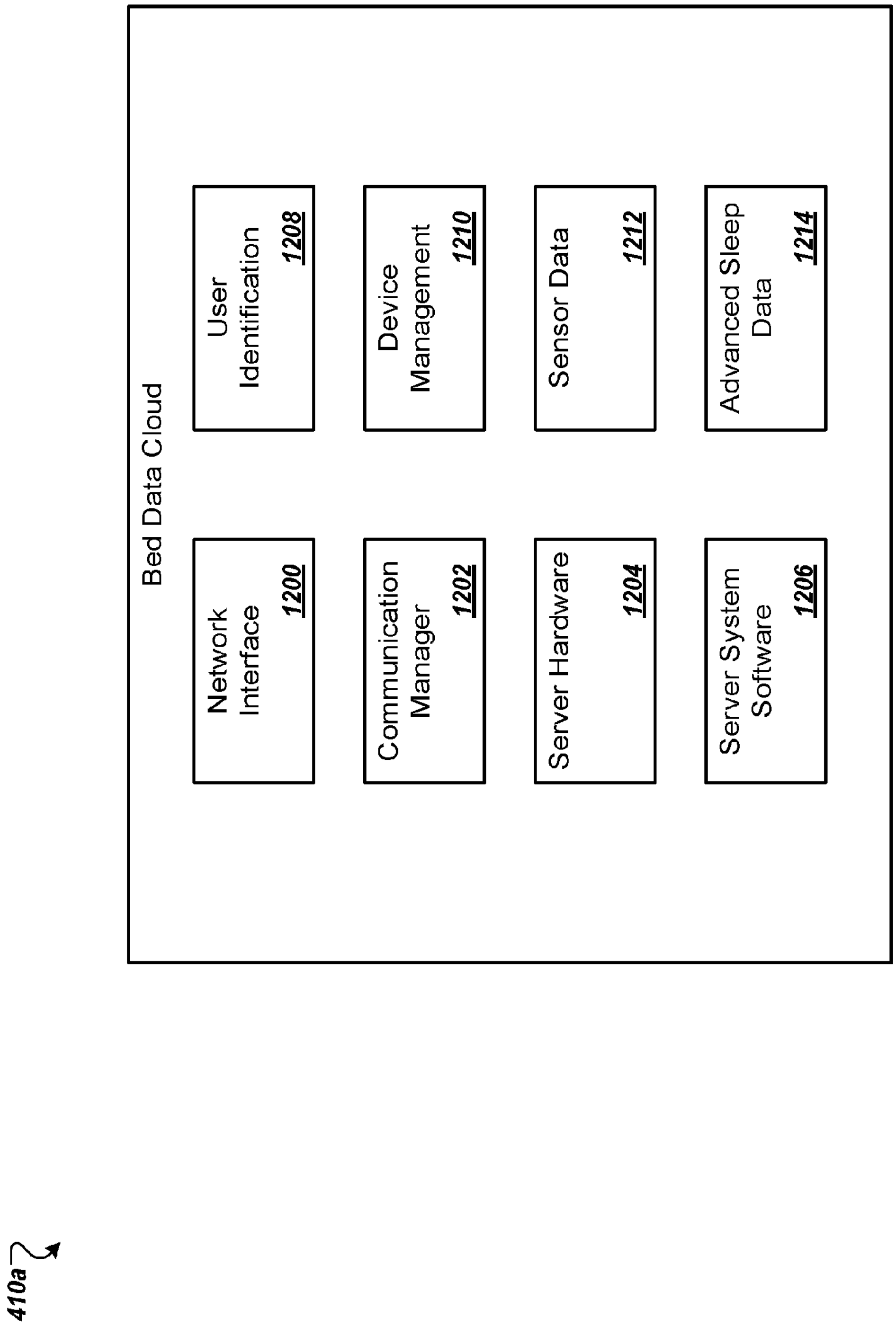

410a
Bed Data Cloud
Network Interface 1200
Communication Manager 1202
Server Hardware 1204
Server System Software 1206
User Identification 1208
Device Management 1210
Sensor Data 1212
Advanced Sleep Data 1214

FIG. 12

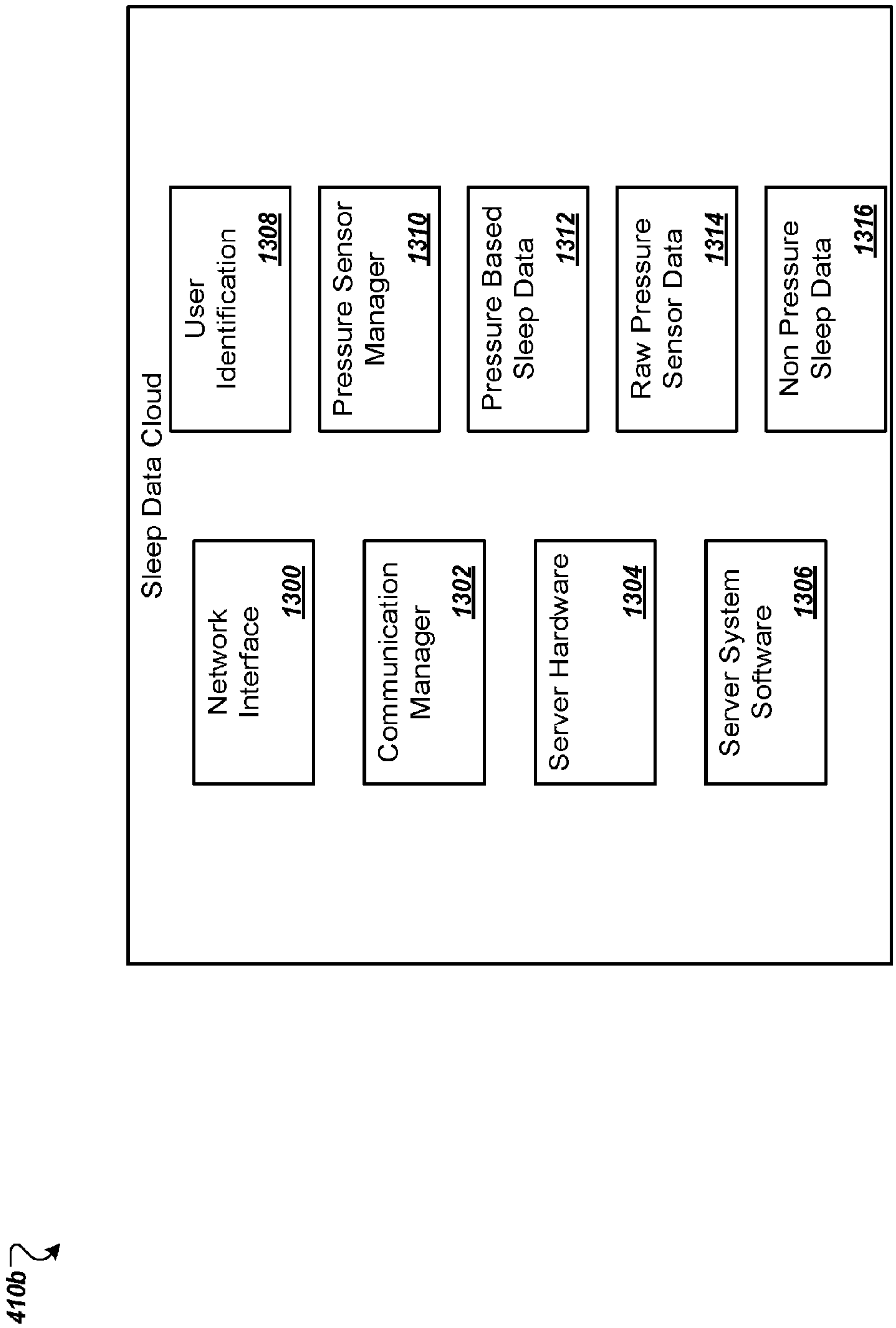

410b
Sleep Data Cloud
Network Interface 1300
Communication Manager 1302
Server Hardware 1304
Server System Software 1306
User Identification 1308
Pressure Sensor Manager 1310
Pressure Based Sleep Data 1312
Raw Pressure Sensor Data 1314
Non Pressure Sleep Data 1316

FIG. 13

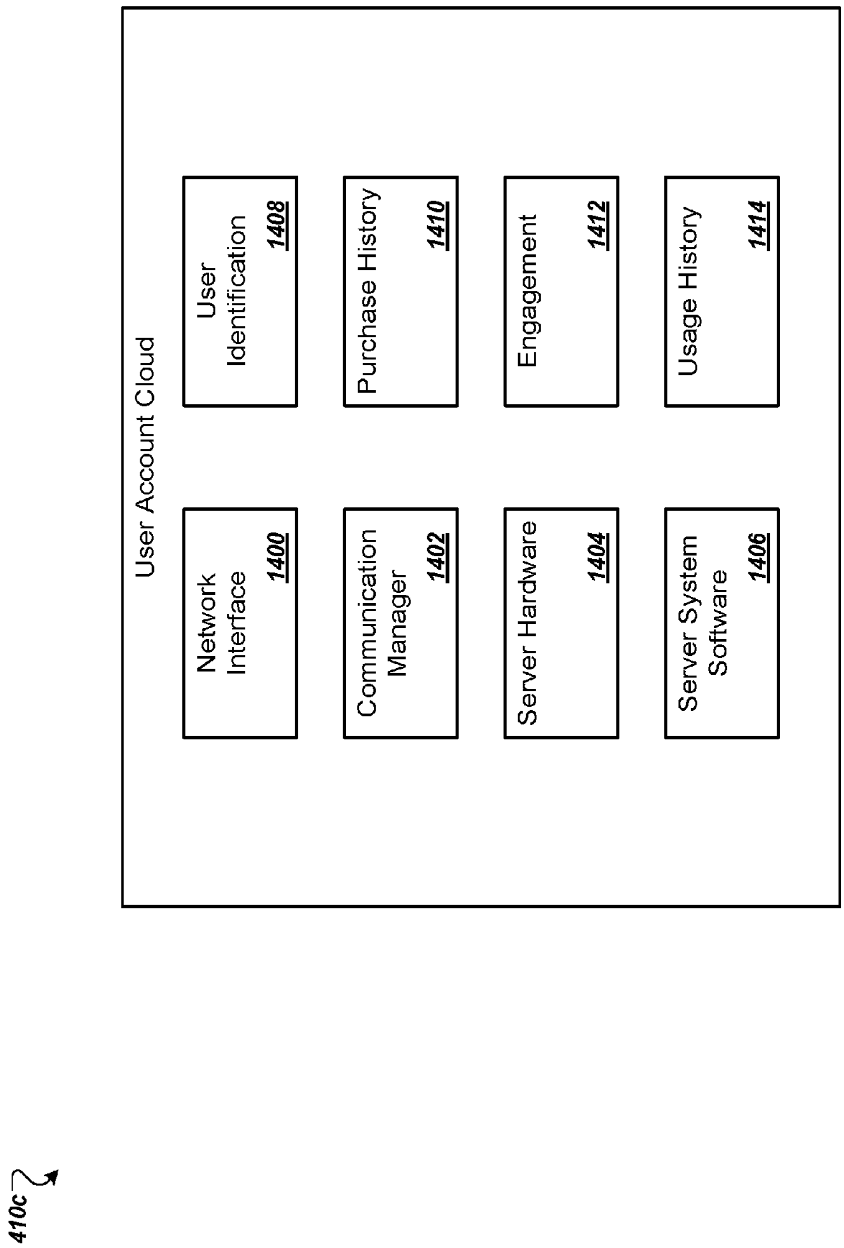

410c
User Account Cloud
Network Interface 1400
Communication Manager 1402
Server Hardware 1404
Server System Software 1406
User Identification 1408
Purchase History 1410
Engagement 1412
Usage History 1414

FIG. 14

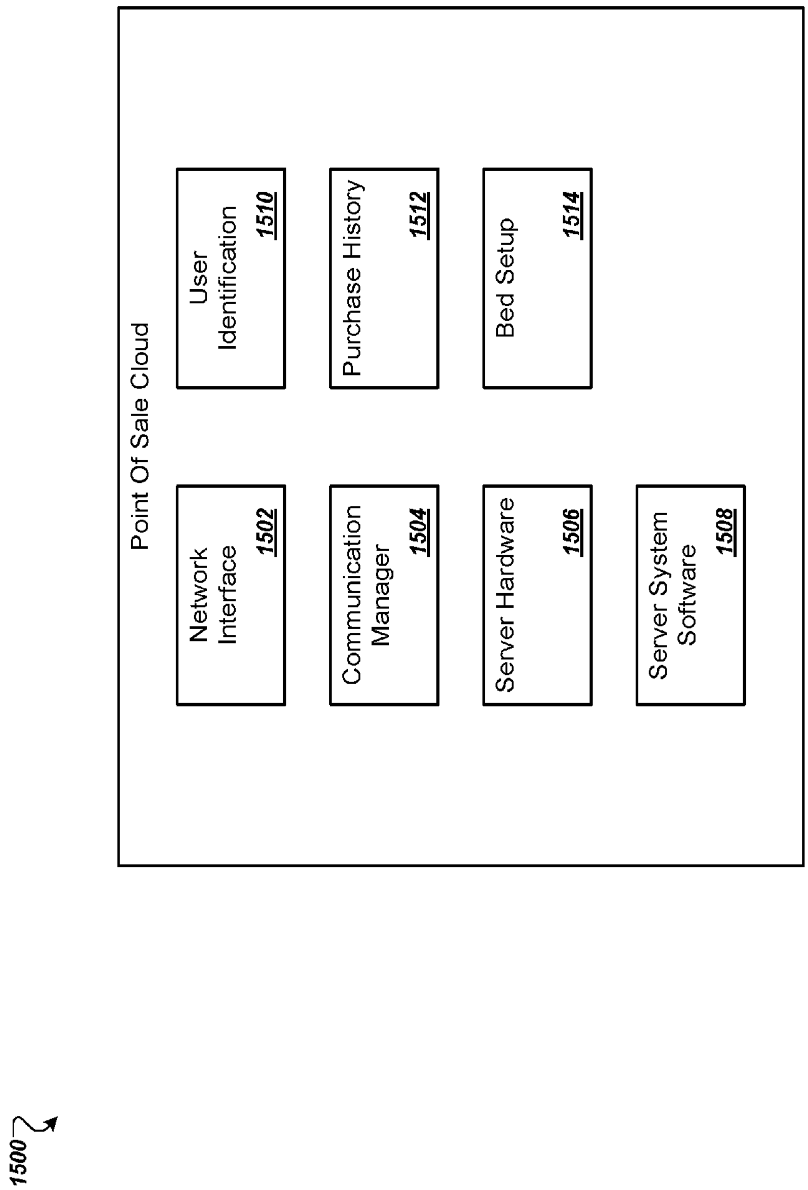

Point Of Sale Cloud
Network Interface 1502
Communication Manager 1504
Server Hardware 1506
Server System Software 1508
User Identification 1510
Purchase History 1512
Bed Setup 1514
1500

FIG. 15

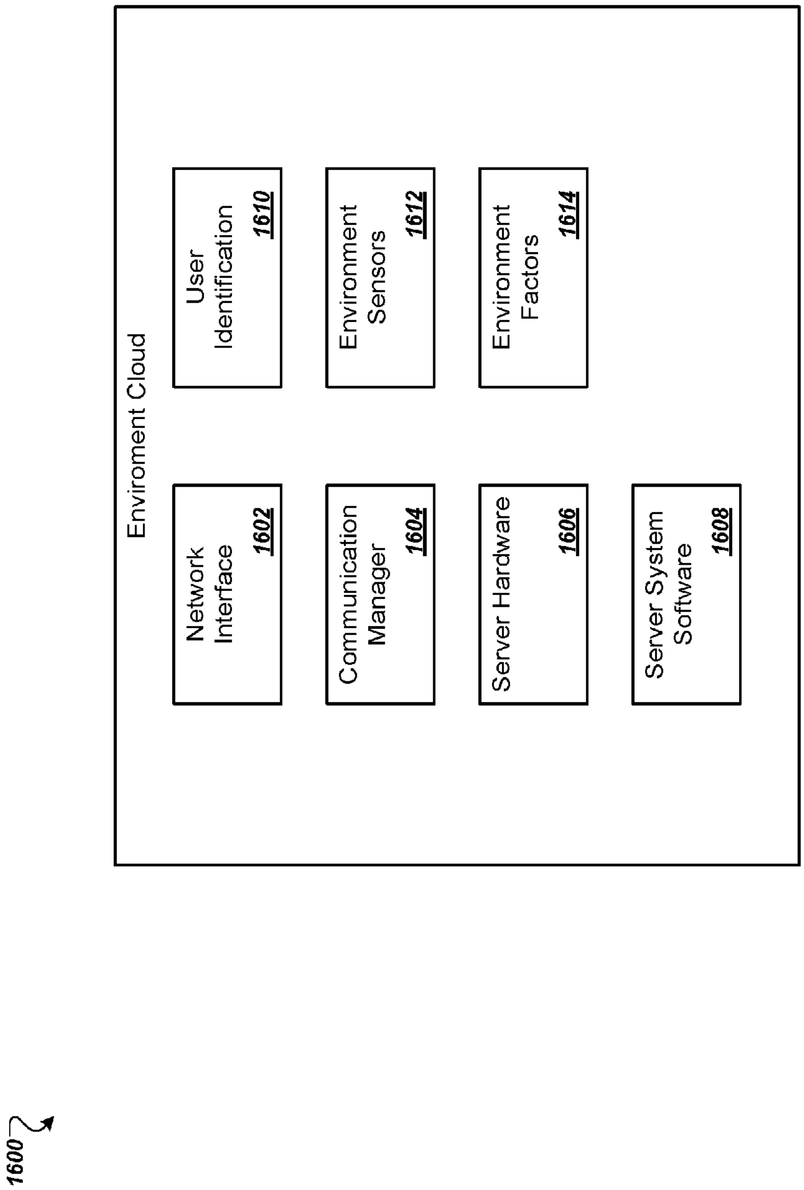

Enviroment Cloud
Network Interface 1602
Communication Manager 1604
Server Hardware 1606
Server System Software 1608
User Identification 1610
Environment Sensors 1612
Environment Factors 1614
1600

FIG. 16

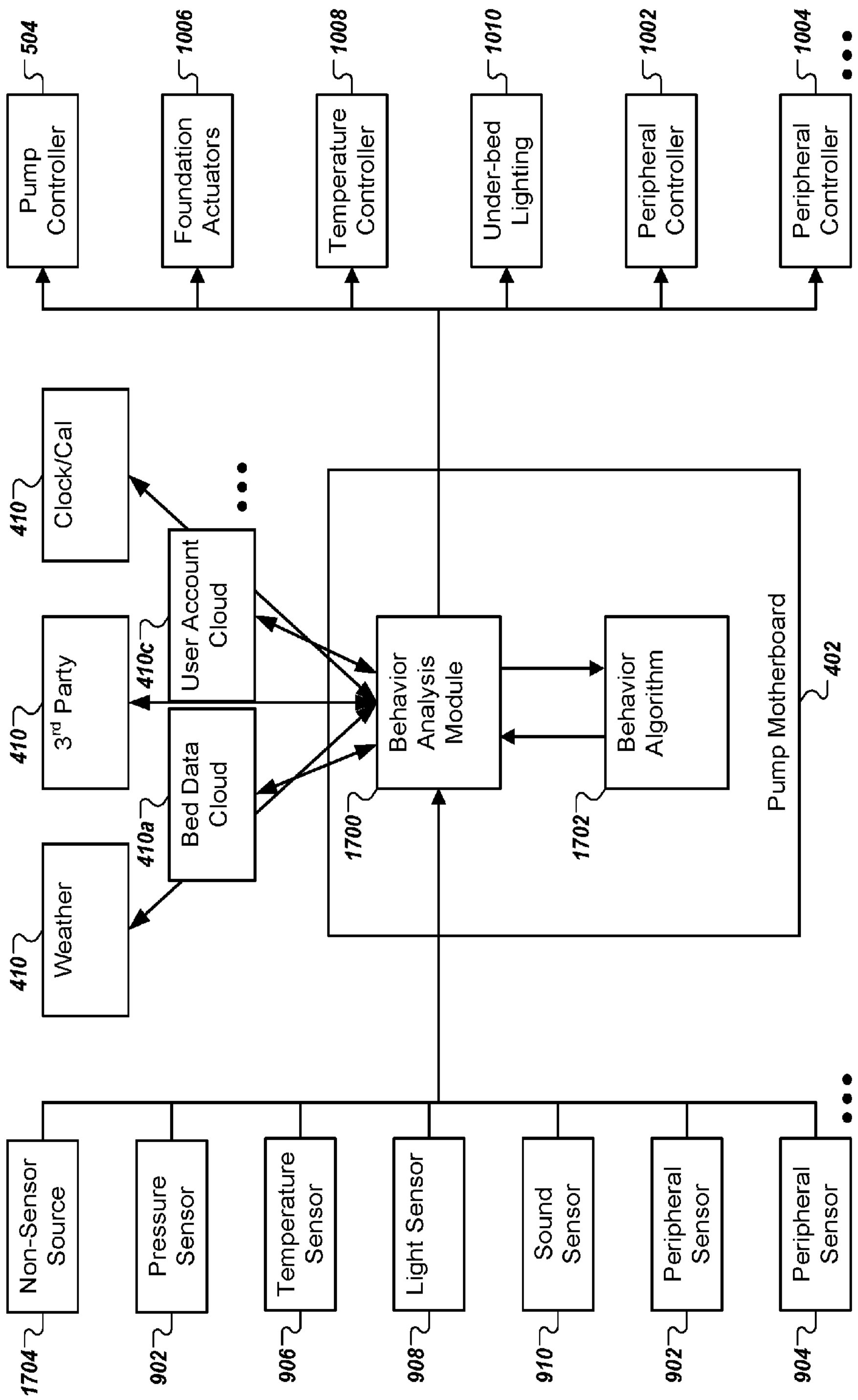

Pump Controller
504
Foundation Actuators
1006
Temperature Controller
1008
Under-bed Lighting
1010
Peripheral Controller
1002
Peripheral Controller
1004
Clock/Cal
410
3rd Party
410
Weather
410
User Account Cloud
410c
Bed Data Cloud
410a
Behavior Analysis Module
1700
Behavior Algorithm
1702
Pump Motherboard
402
Non-Sensor Source
1704
Pressure Sensor
902
Temperature Sensor
906
Light Sensor
908
Sound Sensor
910
Peripheral Sensor
902
Peripheral Sensor
904

FIG. 17

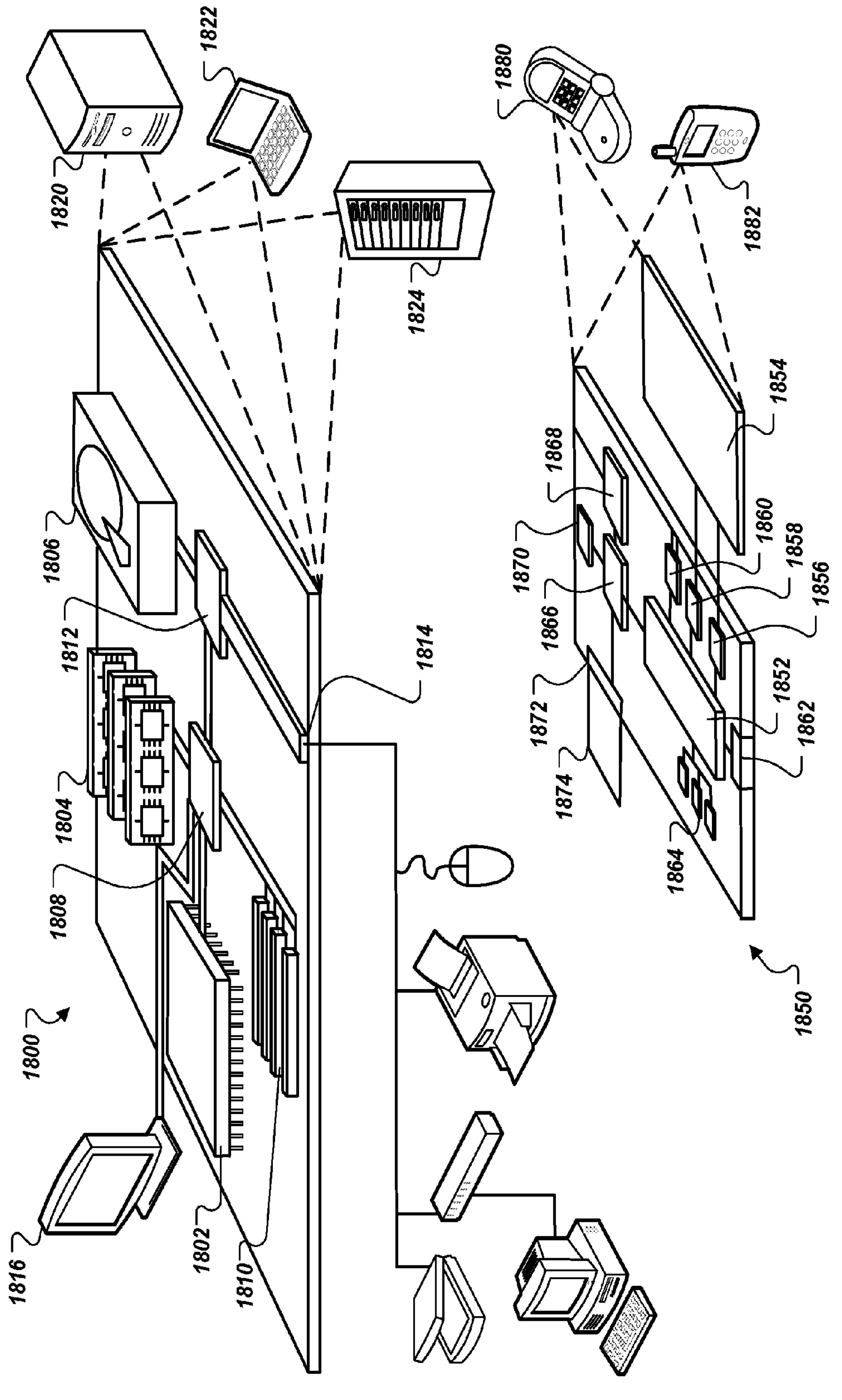

1800
1802
1804
1806
1808
1810
1812
1814
1816
1820
1822
1824
1850
1852
1854
1856
1858
1860
1862
1864
1866
1868
1870
1872
1874
1880
1882

FIG. 18

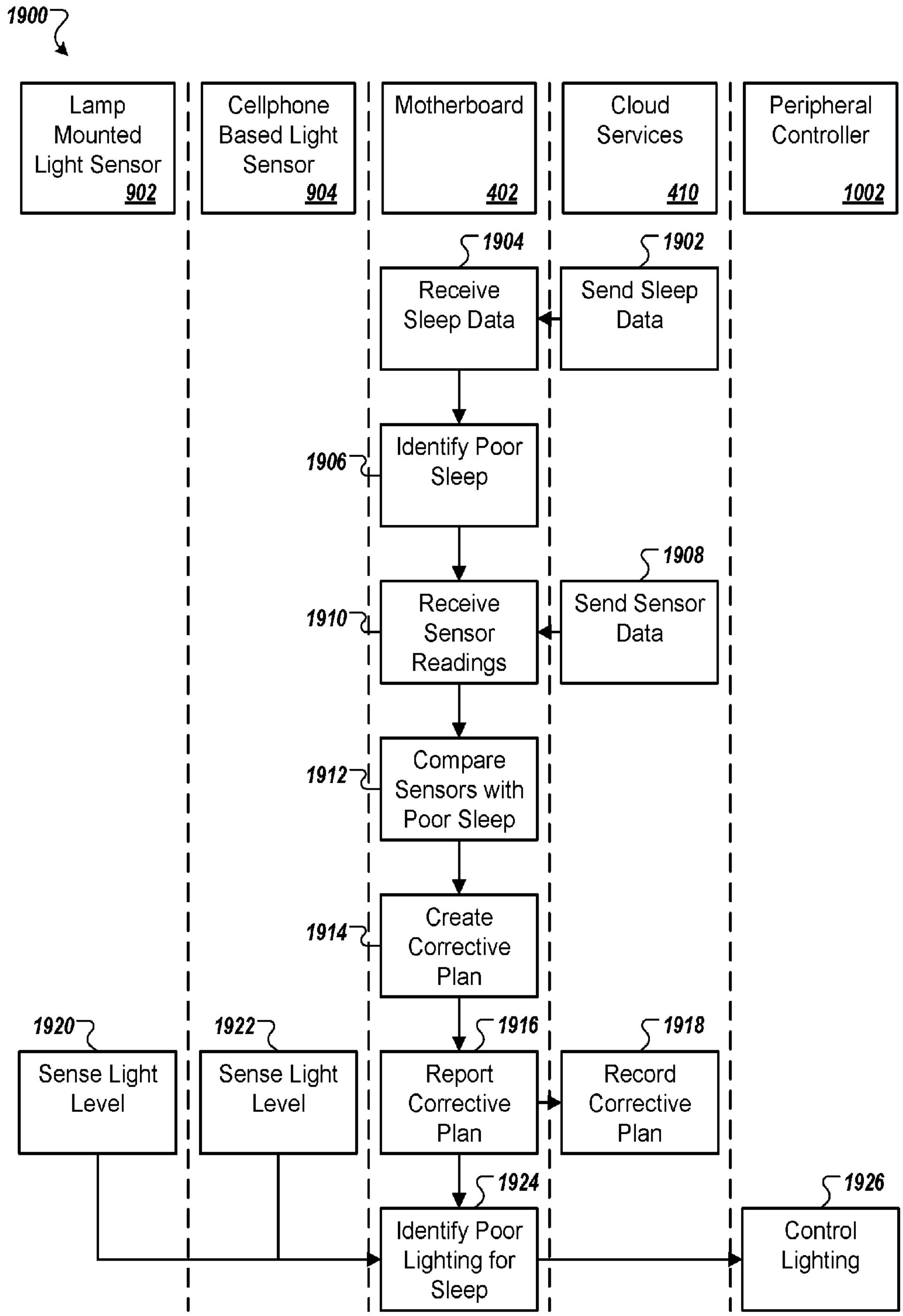

1900
Lamp Mounted Light Sensor 902
Cellphone Based Light Sensor 904
Motherboard 402
Cloud Services 410
Peripheral Controller 1002
1904
Receive Sleep Data
1902
Send Sleep Data
1906
Identify Poor Sleep
1908
Send Sensor Data
1910
Receive Sensor Readings
1912
Compare Sensors with Poor Sleep
1914
Create Corrective Plan
1920
Sense Light Level
1922
Sense Light Level
1916
Report Corrective Plan
1918
Record Corrective Plan
1924
Identify Poor Lighting for Sleep
1926
Control Lighting

FIG. 19

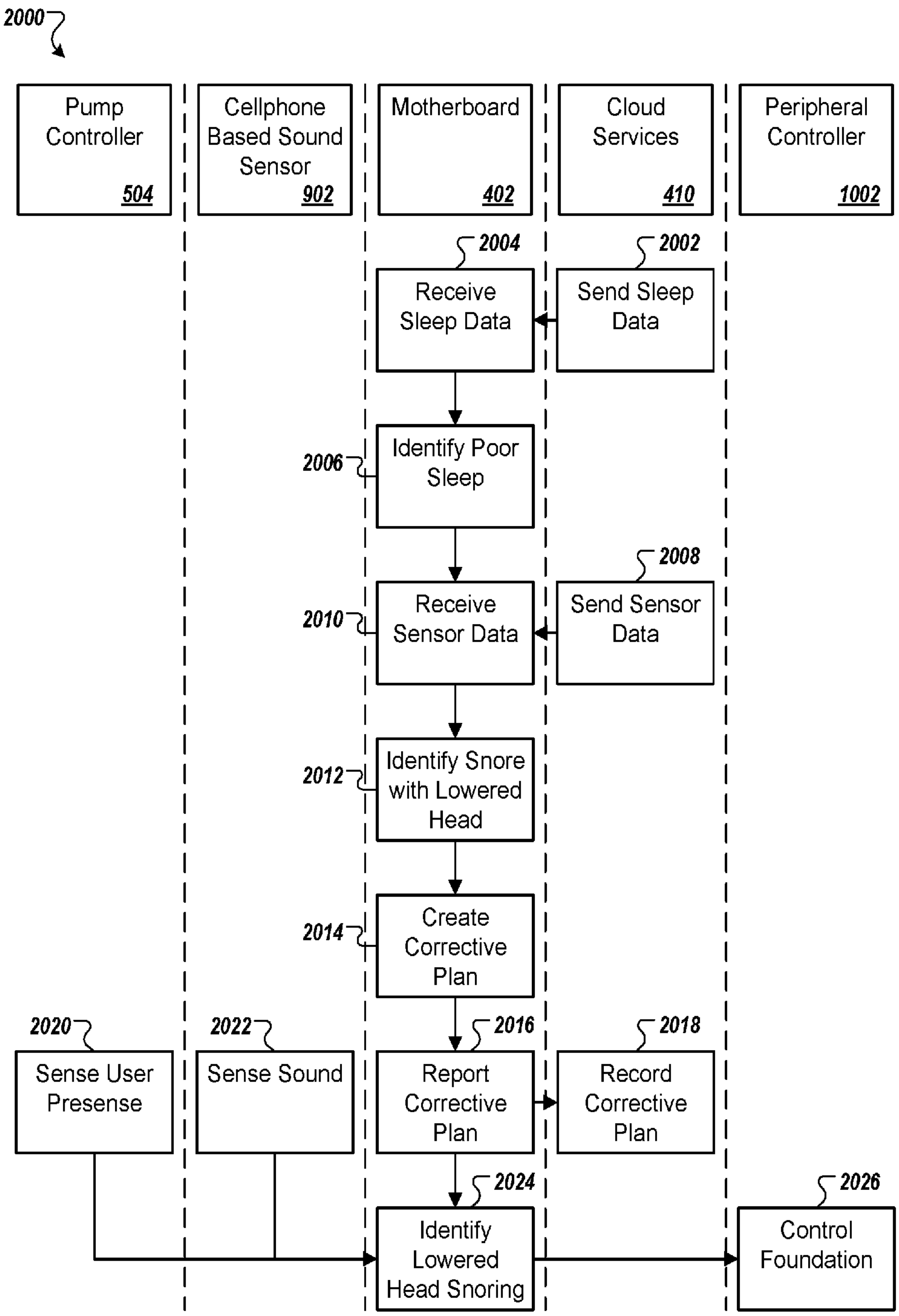

2000
Pump Controller 504
Cellphone Based Sound Sensor 902
Motherboard 402
Cloud Services 410
Peripheral Controller 1002
2004
Receive Sleep Data
2002
Send Sleep Data
2006
Identify Poor Sleep
2008
Send Sensor Data
2010
Receive Sensor Data
2012
Identify Snore with Lowered Head
2014
Create Corrective Plan
2020
Sense User Presense
2022
Sense Sound
2016
Report Corrective Plan
2018
Record Corrective Plan
2024
Identify Lowered Head Snoring
2026
Control Foundation

FIG. 20

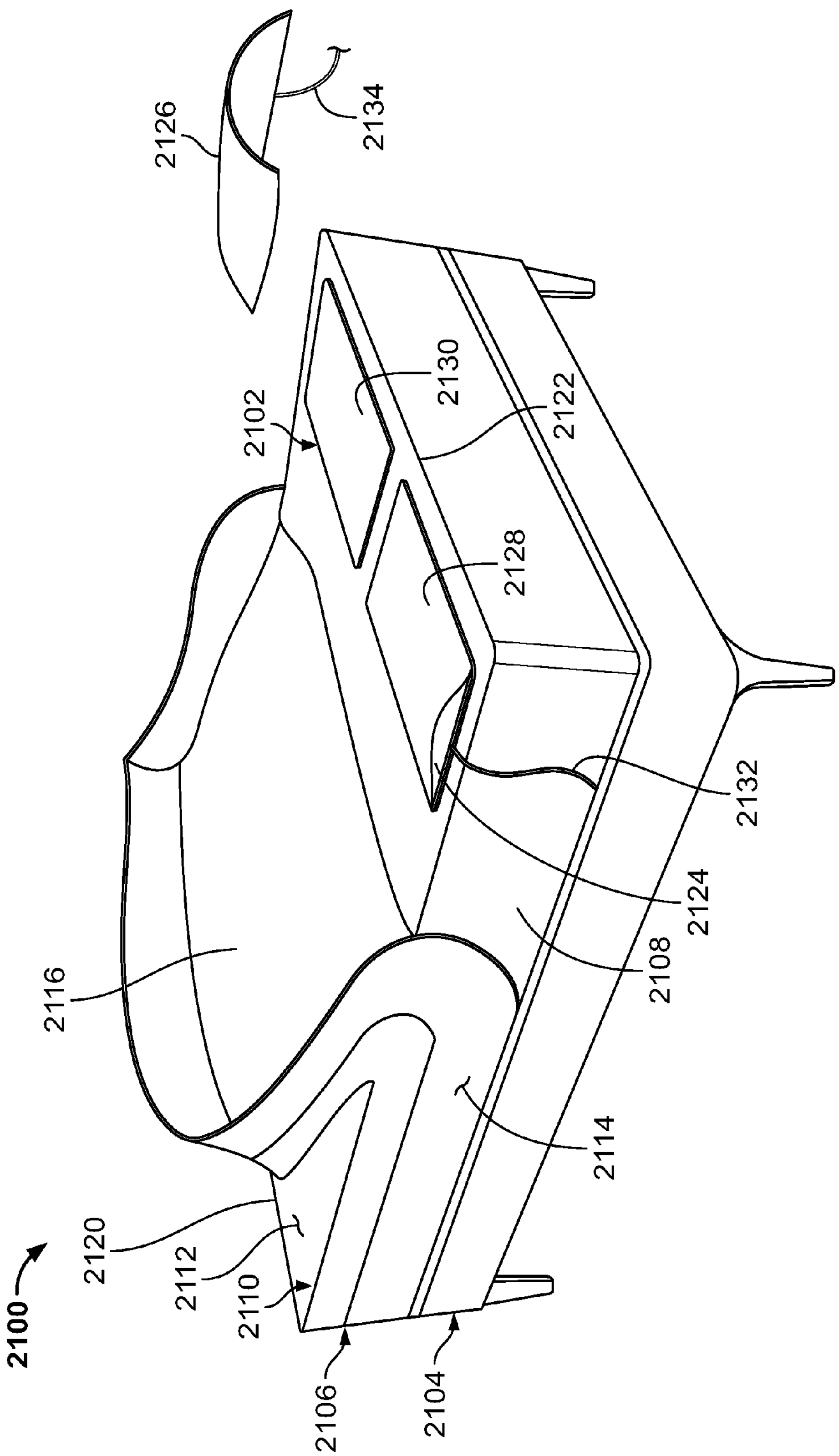

2100
2102
2104
2106
2108
2110
2112
2114
2116
2120
2122
2124
2126
2128
2130
2132
2134

FIG. 21

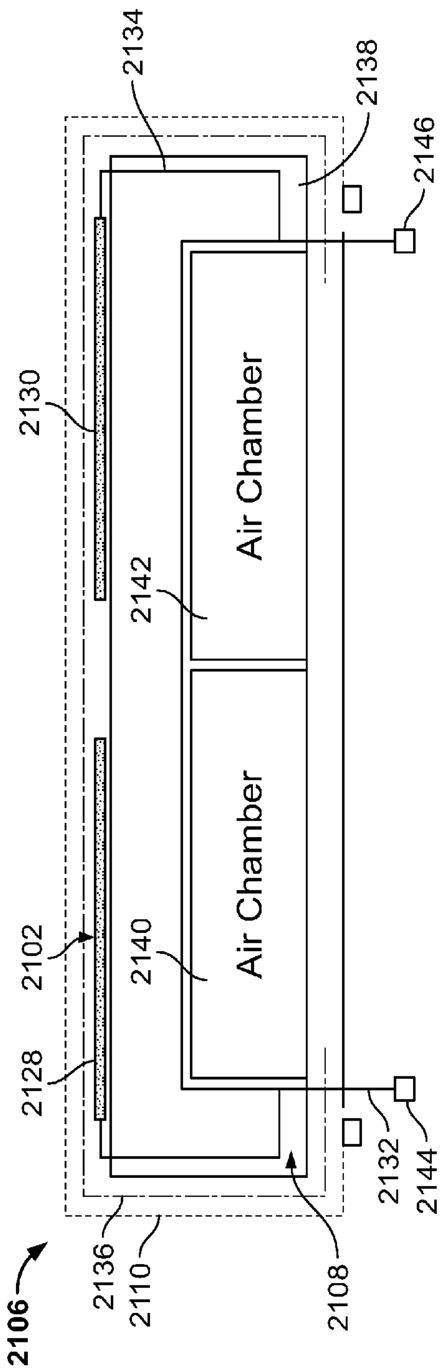

2106
2136
2110
2108
2128
2102
2140
Air Chamber
2142
Air Chamber
2130
2134
2138
2146
2132
2144

FIG. 22

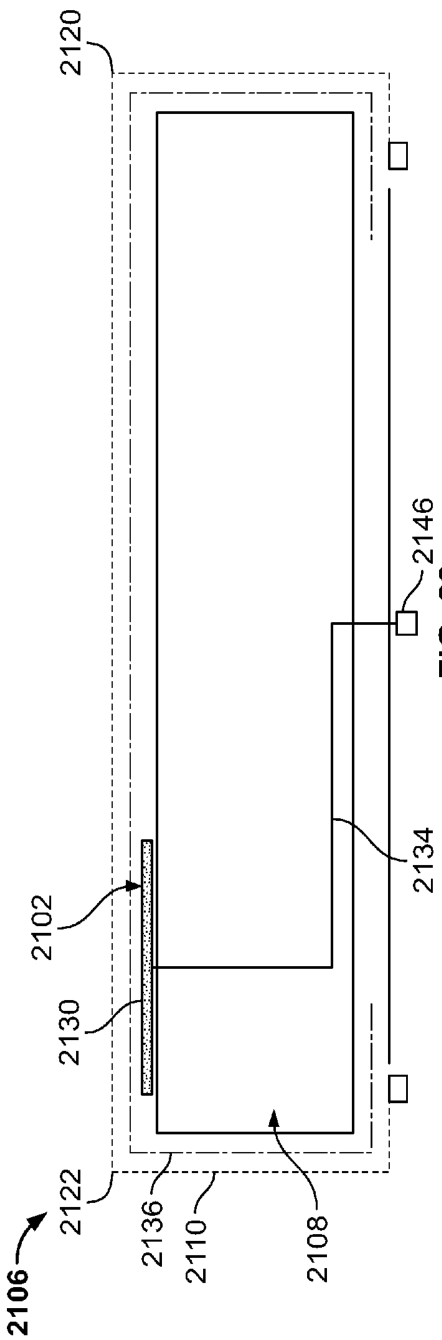

2106
2122
2136
2110
2108
2130
2102
2134
2146
2120

FIG. 23

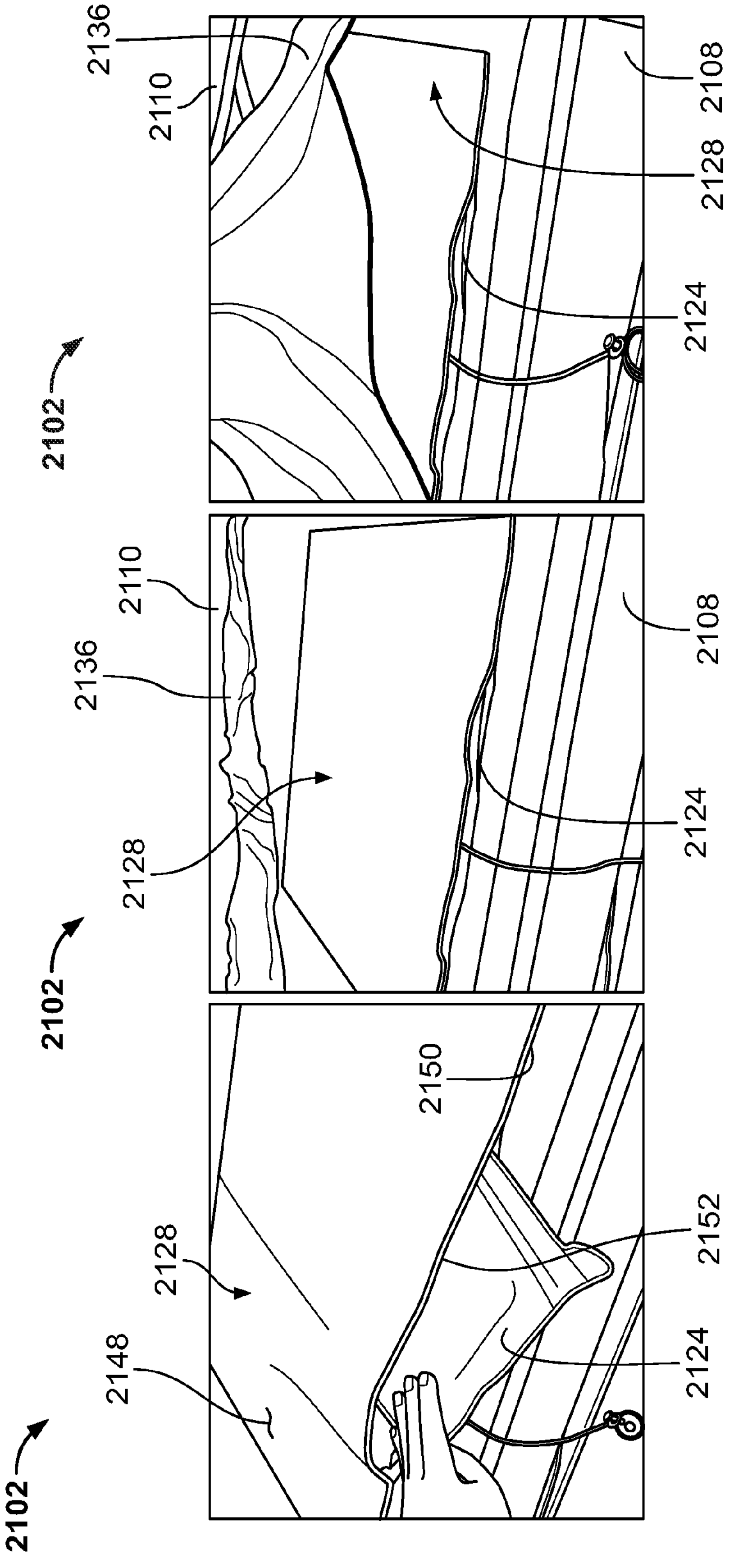


FIG. 24A

FIG. 24B

FIG. 24C

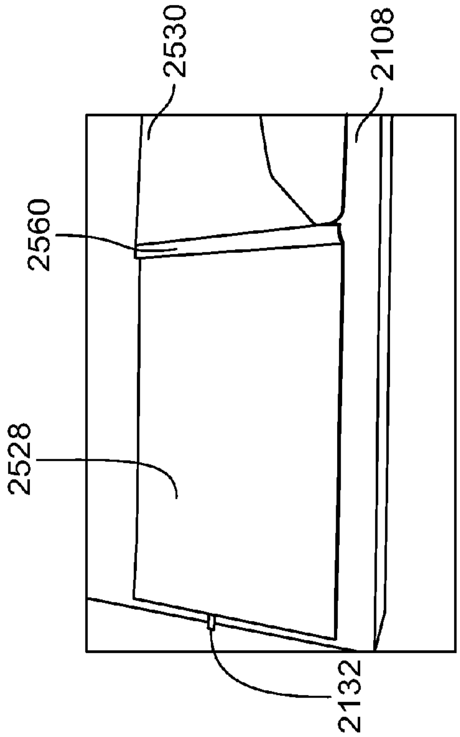


FIG. 25B

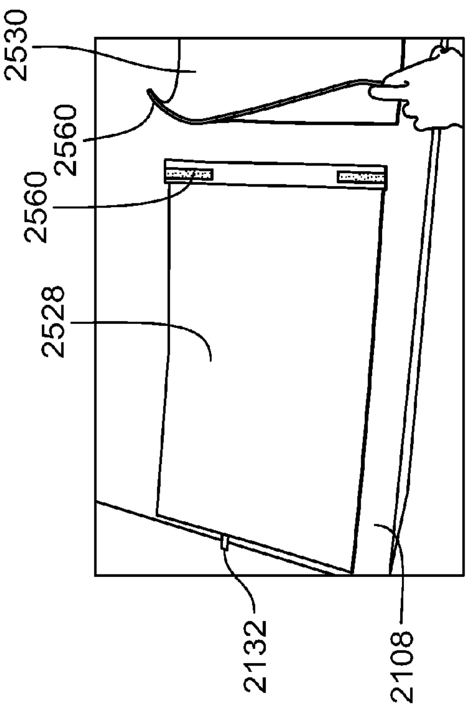


FIG. 25A

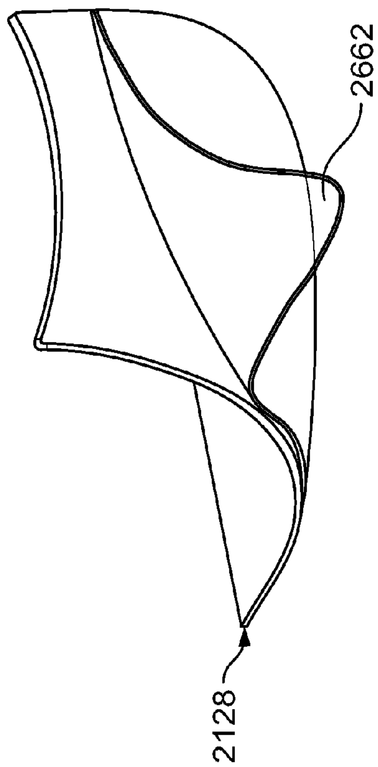
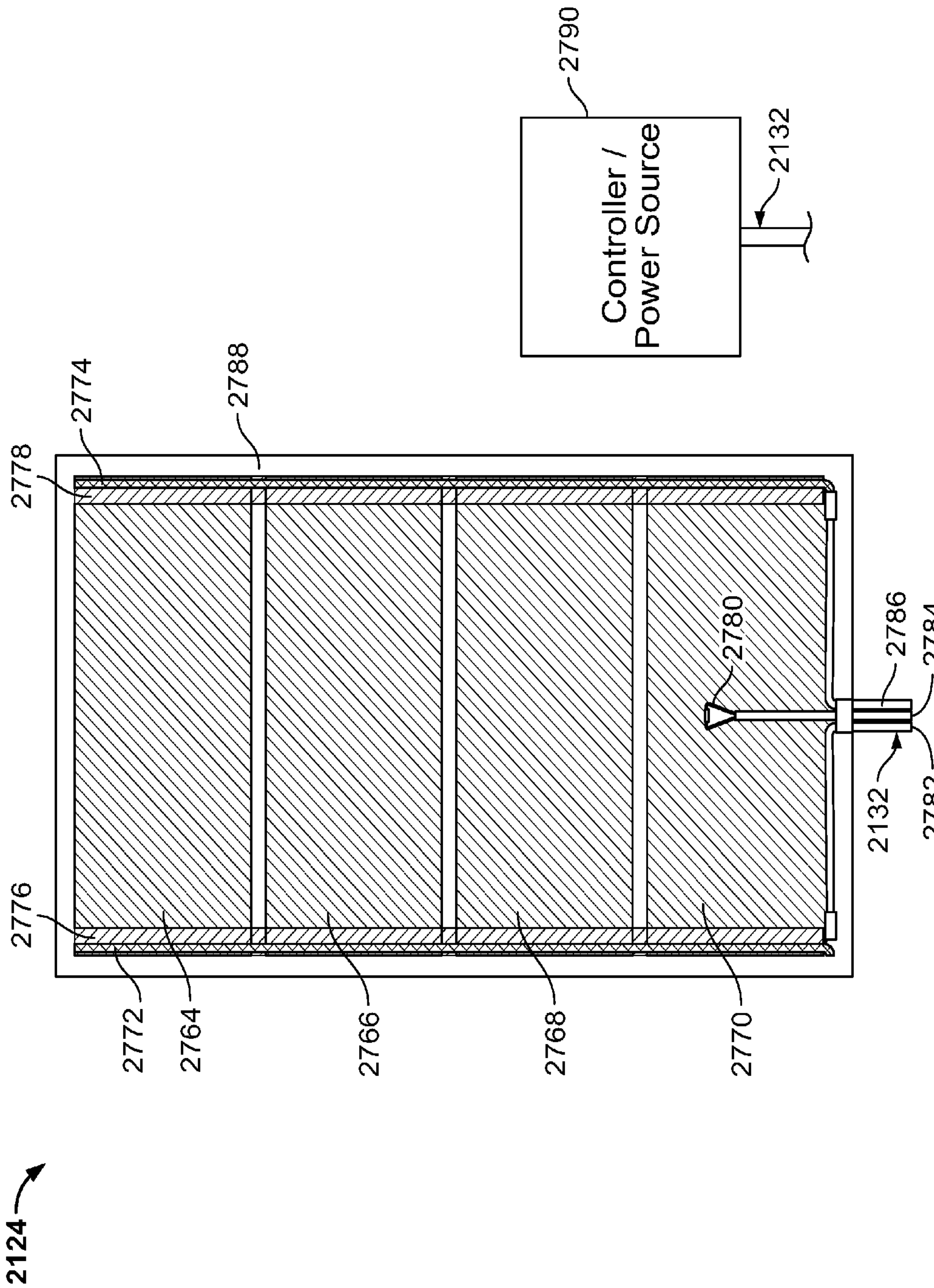


FIG. 26



2124
2790
Controller / Power Source
2132
2774
2788
2778
2776
2772
2764
2766
2768
2770
2780
2786
2784
2782

FIG. 27

BED WITH FOOT WARMING SYSTEM

[0001] The present invention relates to beds, and more particularly to bed warming.

BACKGROUND

[0002] In general, a bed is a piece of furniture used as a location to sleep or relax. Many modern beds include a soft mattress on a bed frame. The mattress may include springs, foam material, and/or an air chamber to support the weight of one or more occupants. In some cases, users can have relatively poor sleep quality using beds that appear comfortable and otherwise suitable.

SUMMARY

[0003] Some embodiments of a mattress and related assemblies can include one or more of the features and functions disclosed herein. Some embodiments can include a warming system positioned in the mattress at a foot of a mattress. The warming system can include a heating unit such as an electrically conductive fabric that is relatively thin and flexible for warming the foot of the mattress. The warming system can be configured to warm the feet of the user so as to induce rapid onset of sleep. The warming system can be automatically controlled to achieve desired comfort and sleep quality. Various embodiments can be configured with particular functions and features.

[0004] In one aspect, A bed can include a mattress and a foot warming system. The mattress can include a mattress cover and a support structure that is positioned under and covered by the mattress cover. The foot warming system can include a heating unit, a power source, and an electrical connector electrically connecting the heating unit to the power source. The heating unit can be positioned inside the envelope between the envelope top and the envelope bottom. The heating unit and the envelope can be positioned at a foot of the bed under mattress cover between the support structure and the mattress cover.

[0005] Implementations can include any, all, or none of the following features. The support structure can include at least one foam layer. The envelope bottom is attached to the foam layer. The envelope includes a fire resistant material. The bed further includes a fire resistant cap covering the support structure, the envelope, and the heating unit. The envelope top includes a breathable mesh and the envelope bottom comprises a fire resistant material. The heating unit includes a flexible layer of electrically conductive fabric, such as carbon encased in a flexible polymer material. The power source includes a controller configured to selectively power the heating unit to generate heat.

[0006] Implementations can also include any, all, or none of the following features. The controller is configured to access historical sleep metrics that represent a sleep quality of a user while the user was sleeping in the bed, access historical sensor data that represent sensor readings that measure environmental conditions affecting the user while the user was sleeping in the bed, identify, in the historical sleep metrics, incidences of low quality sleep experienced by the user, generate a corrective plan that specifies a change to the foot warming system to improve sleep quality, and drive the foot warming system according to the generated corrective plan. The controller is configured to determine an expected bed time for a user of the bed and drive the foot warming system to heat the foot of the bed via the heating unit to reach a target temperature prior to the expected bed time. The controller drives the foot warming system via pulse wave modulation to maintain temperature at the target temperature once the target temperature has been reached. The bed further includes a sensor configured to detect the user entering the bed, wherein the sensor is in communication with the controller and wherein the controller is further configured to reduce power to the heating unit upon the sensor detecting the user entering the bed. The controller stops powering the heating unit as soon as the user is detected entering the bed. The controller reduces power to the heating unit at a predetermined amount of time after the user is detected entering the bed. The foot warming system includes a temperature sensor in communication with the controller and the controller is configured to drive the heating unit as a function of a difference between sensed temperature and target temperature such that the controller supplies more power to the heating unit in response to determining a relatively large difference between the sensed temperature and target temperature and the controller supplies less power to the heating unit in response to determining a relatively small difference between the sensed temperature and target temperature. The controller is configured to determine whether the user is asleep as a function of sensed data and drive the foot warming system as a function of whether the user is determined to be asleep. The controller is further configured to monitor a sleeping routine of the user over multiple days via one or more sensors to determine a learned sleep schedule and drive the foot warming system to heat the foot of the bed via the heating unit as a function of the learned sleep schedule. The support structure of the mattress comprises a first air chamber sized for supporting a first user, a second air chamber sized for supporting a second user, and a foam layer positioned above the first and second chambers, wherein the heating unit comprises a first heating unit connected to the foam layer above the first air chamber and a second heating unit connected to the foam layer above the second air chamber. The first heating unit is attached to the foam layer via the envelope having a first envelope opening and the second heating unit is attached to the foam layer via a second envelope having a second envelope opening, wherein the first and second heating units are removable through the first and second envelope openings, respectively. The heating unit is a relatively thin layer with a width of between 21 inches and 31 inches and a depth of between 10 inches and 20 inches. The heating unit includes a first tinned copper bus bar, a second tinned copper bus bar extending substantially parallel to the first tinned copper bus bar, multiple strips of carbon-based electrically conductive material extending from the first to the second tinned copper bus bar, a temperature sensor, and a plurality of wires electrically connecting the power source to each of the first tinned copper bus bar, the second tinned copper bus bar, and the temperature sensor.

[0007] In another aspect, a bed including a mattress and a foot warming system. The mattress includes a mattress cover and a support structure that is positioned under and covered by the mattress cover. The foot warming system includes a heating unit positioned under the mattress cover and comprising a plurality of flexible flat heating elements spaced with gaps between each of the flexible flat heating elements, a power source, and an electrical connector electrically connecting the heating units to the power source.

[0008] Implementations can also include any, all, or none of the following features. The support structure includes an air chamber and a foam that defines a pathway through which the electrical connector extends between the heating unit and the power source. The heating unit includes a first tinned copper bus bar, a second tinned copper bus bar extending substantially parallel to the first tinned copper bus bar, a temperature sensor, and a plurality of wires electrically connecting the power source to each of the first tinned copper bus bar, the second tinned copper bus bar, and the temperature sensor, and wherein the flexible flat heating elements are connected in parallel between the first and second tinned copper bus bars.

[0009] Other features, aspects and potential advantages will be apparent from the accompanying description and figures.

DESCRIPTION OF DRAWINGS

[0010] FIG. **1** shows an example air bed system.

[0011] FIG. **2** is a block diagram of an example of various components of an air bed system.

[0012] FIG. **3** shows an example environment including a bed in communication with devices located in and around a home.

[0013] FIGS. **4**A and **4**B are block diagrams of example data processing systems that can be associated with a bed.

[0014] FIGS. **5** and **6** are block diagrams of examples of motherboards that can be used in a data processing system that can be associated with a bed.

[0015] FIG. **7** is a block diagram of an example of a daughterboard that can be used in a data processing system that can be associated with a bed.

[0016] FIG. **8** is a block diagram of an example of a motherboard with no daughterboard that can be used in a data processing system that can be associated with a bed.

[0017] FIG. **9** is a block diagram of an example of a sensory array that can be used in a data processing system that can be associated with a bed.

[0018] FIG. **10** is a block diagram of an example of a control array that can be used in a data processing system that can be associated with a bed

[0019] FIG. **11** is a block diagram of an example of a computing device that can be used in a data processing system that can be associated with a bed.

[0020] FIGS. **12-16** are block diagrams of example cloud services that can be used in a data processing system that can be associated with a bed.

[0021] FIG. **17** is a block diagram of an example of using a data processing system that can be associated with a bed to automate peripherals around the bed.

[0022] FIG. **18** is a schematic diagram that shows an example of a computing device and a mobile computing device.

[0023] FIG. **19** is a swimlane diagram of an example process for determining a single phenomenon from sensors of the same type.

[0024] FIG. **20** is a swimlane diagram of an example process for determining a single phenomenon from sensors of different types.

[0025] FIG. **21** is a perspective view of an example bed having a foot warming system.

[0026] FIG. **22** is a schematic end view of a mattress having a foot warming system.

[0027] FIG. **23** is a schematic side view of the mattress of FIG. **22**.

[0028] FIGS. **24**A-**24**C are top perspective views of a foot warming system for use in the beds of FIGS. **21-23**.

[0029] FIGS. **25**A and **25**B are top perspective views of envelopes of a foot warming system being attached.

[0030] FIG. **26** is a perspective view of a bottom of an envelope of a foot warming system.

[0031] FIG. **27** is a top view of components of a foot warming system.

[0032] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0033] A bed having a foot warming system can improve sleep quality by warming a user's feet to induce rapid onset of sleep for the user and extend sleep duration. Such a system can include an heating unit placed at a foot of a mattress and within the mattress so as to suitable warm a user's feet without being intrusive for the rest of the sleeping experience. Such a system can be configured such that a user hardly feels or otherwise notices the foot warming system positioned in the mattress except for the warming effect that it generates. Such a system can be driven automatically to improve sleep quality, alone or in conjunction with other features described herein.

[0034] Example Airbed Hardware

[0035] FIG. **1** shows an example air bed system **100** that includes a bed **112**. The bed **112** includes at least one air chamber **114** surrounded by a resilient border **116** and encapsulated by bed ticking **118**. The resilient border **116** can comprise any suitable material, such as foam.

[0036] As illustrated in FIG. **1**, the bed **112** can be a two chamber design having first and second fluid chambers, such as a first air chamber **114**A and a second air chamber **114**B. In alternative embodiments, the bed **112** can include chambers for use with fluids other than air that are suitable for the application. In some embodiments, such as single beds or kids' beds, the bed **112** can include a single air chamber **114**A or **114**B or multiple air chambers **114**A and **114**B. First and second air chambers **114**A and **114**B can be in fluid communication with a pump **120**. The pump **120** can be in electrical communication with a remote control **122** via control box **124**. The control box **124** can include a wired or wireless communications interface for communicating with one or more devices, including the remote control **122**. The control box **124** can be configured to operate the pump **120** to cause increases and decreases in the fluid pressure of the first and second air chambers **114**A and **114**B based upon commands input by a user using the remote control **122**. In some implementations, the control box **124** is integrated into a housing of the pump **120**.

[0037] The remote control **122** can include a display **126**, an output selecting mechanism **128**, a pressure increase button **129**, and a pressure decrease button **130**. The output selecting mechanism **128** can allow the user to switch air flow generated by the pump **120** between the first and second air chambers **114**A and **114**B, thus enabling control of multiple air chambers with a single remote control **122** and a single pump **120**. For example, the output selecting mechanism **128** can by a physical control (e.g., switch or button) or an input control displayed on display **126**. Alternatively, separate remote control units can be provided for each air chamber and can each include the ability to control multiple air chambers. Pressure increase and decrease buttons **129** and **130** can allow a user to increase or decrease the pressure, respectively, in the air chamber selected with the output selecting mechanism **128**. Adjusting the pressure within the selected air chamber can cause a corresponding adjustment to the firmness of the respective air chamber. In some embodiments, the remote control **122** can be omitted or modified as appropriate for an application. For example, in some embodiments the bed **112** can be controlled by a computer, tablet, smart phone, or other device in wired or wireless communication with the bed **112**.

[0038] FIG. **2** is a block diagram of an example of various components of an air bed system. For example, these components can be used in the example air bed system **100**. As shown in FIG. **2**, the control box **124** can include a power supply **134**, a processor **136**, a memory **137**, a switching mechanism **138**, and an analog to digital (A/D) converter **140**. The switching mechanism **138** can be, for example, a relay or a solid state switch. In some implementations, the switching mechanism **138** can be located in the pump **120** rather than the control box **124**.

[0039] The pump **120** and the remote control **122** are in two-way communication with the control box **124**. The pump **120** includes a motor **142**, a pump manifold **143**, a relief valve **144**, a first control valve **145**A, a second control valve **145**B, and a pressure transducer **146**. The pump **120** is fluidly connected with the first air chamber **114**A and the second air chamber **114**B via a first tube **148**A and a second tube **148**B, respectively. The first and second control valves **145**A and **145**B can be controlled by switching mechanism **138**, and are operable to regulate the flow of fluid between the pump **120** and first and second air chambers **114**A and **114**B, respectively.

[0040] In some implementations, the pump **120** and the control box **124** can be provided and packaged as a single unit. In some alternative implementations, the pump **120** and the control box **124** can be provided as physically separate units. In some implementations, the control box **124**, the pump **120**, or both are integrated within or otherwise contained within a bed frame or bed support structure that supports the bed **112**. In some implementations, the control box **124**, the pump **120**, or both are located outside of a bed frame or bed support structure (as shown in the example in FIG. **1**).

[0041] The example air bed system **100** depicted in FIG. **2** includes the two air chambers **114**A and **114**B and the single pump **120**. However, other implementations can include an air bed system having two or more air chambers and one or more pumps incorporated into the air bed system to control the air chambers. For example, a separate pump can be associated with each air chamber of the air bed system or a pump can be associated with multiple chambers of the air bed system. Separate pumps can allow each air chamber to be inflated or deflated independently and simultaneously. Furthermore, additional pressure transducers can also be incorporated into the air bed system such that, for example, a separate pressure transducer can be associated with each air chamber.

[0042] In use, the processor **136** can, for example, send a decrease pressure command to one of air chambers **114**A or **114**B, and the switching mechanism **138** can be used to convert the low voltage command signals sent by the processor **136** to higher operating voltages sufficient to operate the relief valve **144** of the pump **120** and open the control valve **145**A or **145**B. Opening the relief valve **144** can allow air to escape from the air chamber **114**A or **114**B through the respective air tube **148**A or **148**B. During deflation, the pressure transducer **146** can send pressure readings to the processor **136** via the A/D converter **140**. The A/D converter **140** can receive analog information from pressure transducer **146** and can convert the analog information to digital information useable by the processor **136**. The processor **136** can send the digital signal to the remote control **122** to update the display **126** in order to convey the pressure information to the user.

[0043] As another example, the processor **136** can send an increase pressure command. The pump motor **142** can be energized in response to the increase pressure command and send air to the designated one of the air chambers **114**A or **114**B through the air tube **148**A or **148**B via electronically operating the corresponding valve **145**A or **145**B. While air is being delivered to the designated air chamber **114**A or **114**B in order to increase the firmness of the chamber, the pressure transducer **146** can sense pressure within the pump manifold **143**. Again, the pressure transducer **146** can send pressure readings to the processor **136** via the A/D converter **140**. The processor **136** can use the information received from the A/D converter **140** to determine the difference between the actual pressure in air chamber **114**A or **114**B and the desired pressure. The processor **136** can send the digital signal to the remote control **122** to update display **126** in order to convey the pressure information to the user.

[0044] Generally speaking, during an inflation or deflation process, the pressure sensed within the pump manifold **143** can provide an approximation of the pressure within the respective air chamber that is in fluid communication with the pump manifold **143**. An example method of obtaining a pump manifold pressure reading that is substantially equivalent to the actual pressure within an air chamber includes turning off pump **120**, allowing the pressure within the air chamber **114**A or **114**B and the pump manifold **143** to equalize, and then sensing the pressure within the pump manifold **143** with the pressure transducer **146**. Thus, providing a sufficient amount of time to allow the pressures within the pump manifold **143** and chamber **114**A or **114**B to equalize can result in pressure readings that are accurate approximations of the actual pressure within air chamber **114**A or **114**B. In some implementations, the pressure of the air chambers **114**A and/or **114**B can be continuously monitored using multiple pressure sensors (not shown).

[0045] In some implementations, information collected by the pressure transducer **146** can be analyzed to determine various states of a person lying on the bed **112**. For example, the processor **136** can use information collected by the pressure transducer **146** to determine a heart rate or a respiration rate for a person lying in the bed **112**. For example, a user can be lying on a side of the bed **112** that includes the chamber **114**A. The pressure transducer **146** can monitor fluctuations in pressure of the chamber **114**A and this information can be used to determine the user's heart rate and/or respiration rate. As another example, additional processing can be performed using the collected data to determine a sleep state of the person (e.g., awake, light sleep, deep sleep). For example, the processor **136** can determine when a person falls asleep and, while asleep, the various sleep states of the person.

[0046] Additional information associated with a user of the air bed system **100** that can be determined using information collected by the pressure transducer **146** includes motion of the user, presence of the user on a surface of the bed **112**, weight of the user, heart arrhythmia of the user, and apnea. Taking user presence detection for example, the pressure transducer **146** can be used to detect the user's presence on the bed **112**, e.g., via a gross pressure change determination and/or via one or more of a respiration rate signal, heart rate signal, and/or other biometric signals. For example, a simple pressure detection process can identify an increase in pressure as an indication that the user is present on the bed **112**. As another example, the processor **136** can determine that the user is present on the bed **112** if the detected pressure increases above a specified threshold (so as to indicate that a person or other object above a certain weight is positioned on the bed **112**). As yet another example, the processor **136** can identify an increase in pressure in combination with detected slight, rhythmic fluctuations in pressure as corresponding to the user being present on the bed **112**. The presence of rhythmic fluctuations can be identified as being caused by respiration or heart rhythm (or both) of the user. The detection of respiration or a heartbeat can distinguish between the user being present on the bed and another object (e.g., a suit case) being placed upon the bed.

[0047] In some implementations, fluctuations in pressure can be measured at the pump **120**. For example, one or more pressure sensors can be located within one or more internal cavities of the pump **120** to detect fluctuations in pressure within the pump **120**. The fluctuations in pressure detected at the pump **120** can indicate fluctuations in pressure in one or both of the chambers **114**A and **114**B. One or more sensors located at the pump **120** can be in fluid communication with the one or both of the chambers **114**A and **114**B, and the sensors can be operative to determine pressure within the chambers **114**A and **114**B. The control box **124** can be configured to determine at least one vital sign (e.g., heart rate, respiratory rate) based on the pressure within the chamber **114**A or the chamber **114**B.

[0048] In some implementations, the control box **124** can analyze a pressure signal detected by one or more pressure sensors to determine a heart rate, respiration rate, and/or other vital signs of a user lying or sitting on the chamber **114**A or the chamber **114**B. More specifically, when a user lies on the bed **112** positioned over the chamber **114**A, each of the user's heart beats, breaths, and other movements can create a force on the bed **112** that is transmitted to the chamber **114**A. As a result of the force input to the chamber **114**A from the user's movement, a wave can propagate through the chamber **114**A and into the pump **120**. A pressure sensor located at the pump **120** can detect the wave, and thus the pressure signal output by the sensor can indicate a heart rate, respiratory rate, or other information regarding the user.

[0049] With regard to sleep state, air bed system **100** can determine a user's sleep state by using various biometric signals such as heart rate, respiration, and/or movement of the user. While the user is sleeping, the processor **136** can receive one or more of the user's biometric signals (e.g., heart rate, respiration, and motion) and determine the user's present sleep state based on the received biometric signals. In some implementations, signals indicating fluctuations in pressure in one or both of the chambers **114**A and **114**B can be amplified and/or filtered to allow for more precise detection of heart rate and respiratory rate.

[0050] The control box **124** can perform a pattern recognition algorithm or other calculation based on the amplified and filtered pressure signal to determine the user's heart rate and respiratory rate. For example, the algorithm or calculation can be based on assumptions that a heart rate portion of the signal has a frequency in the range of 0.5-4.0 Hz and that a respiration rate portion of the signal a has a frequency in the range of less than 1 Hz. The control box **124** can also be configured to determine other characteristics of a user based on the received pressure signal, such as blood pressure, tossing and turning movements, rolling movements, limb movements, weight, the presence or lack of presence of a user, and/or the identity of the user. Techniques for monitoring a user's sleep using heart rate information, respiration rate information, and other user information are disclosed in U.S. Patent Application Publication No. 20100170043 to Steven J. Young et al., titled "APPARATUS FOR MONITORING VITAL SIGNS," the entire contents of which is incorporated herein by reference.

[0051] For example, the pressure transducer **146** can be used to monitor the air pressure in the chambers **114**A and **114**B of the bed **112**. If the user on the bed **112** is not moving, the air pressure changes in the air chamber **114**A or **114**B can be relatively minimal, and can be attributable to respiration and/or heartbeat. When the user on the bed **112** is moving, however, the air pressure in the mattress can fluctuate by a much larger amount. Thus, the pressure signals generated by the pressure transducer **146** and received by the processor **136** can be filtered and indicated as corresponding to motion, heartbeat, or respiration.

[0052] In some implementations, rather than performing the data analysis in the control box **124** with the processor **136**, a digital signal processor (DSP) can be provided to analyze the data collected by the pressure transducer **146**. Alternatively, the data collected by the pressure transducer **146** could be sent to a cloud-based computing system for remote analysis.

[0053] In some implementations, the example air bed system **100** further includes a temperature controller configured to increase, decrease, or maintain the temperature of a bed, for example for the comfort of the user. For example, a pad can be placed on top of or be part of the bed **112**, or can be placed on top of or be part of one or both of the chambers **114**A and **114**B. Air can be pushed through the pad and vented to cool off a user of the bed. Conversely, the pad can include a heating element that can be used to keep the user warm. In some implementations, the temperature controller can receive temperature readings from the pad. In some implementations, separate pads are used for the different sides of the bed **112** (e.g., corresponding to the locations of the chambers **114**A and **114**B) to provide for differing temperature control for the different sides of the bed.

[0054] In some implementations, the user of the air bed system **100** can use an input device, such as the remote control **122**, to input a desired temperature for the surface of the bed **112** (or for a portion of the surface of the bed **112**). The desired temperature can be encapsulated in a command data structure that includes the desired temperature as well as identifies the temperature controller as the desired component to be controlled. The command data structure can then be transmitted via Bluetooth or another suitable communication protocol to the processor **136**. In various examples, the command data structure is encrypted before being transmitted. The temperature controller can then configure its elements to increase or decrease the temperature of the pad depending on the temperature input into remote control **122** by the user.

[0055] In some implementations, data can be transmitted from a component back to the processor **136** or to one or more display devices, such as the display **126**. For example, the current temperature as determined by a sensor element of temperature controller, the pressure of the bed, the current position of the foundation or other information can be transmitted to control box **124**. The control box **124** can then transmit the received information to remote control **122** where it can be displayed to the user (e.g., on the display **126**).

[0056] In some implementations, the example air bed system **100** further includes an adjustable foundation and an articulation controller configured to adjust the position of a bed (e.g., the bed **112**) by adjusting the adjustable foundation that supports the bed. For example, the articulation controller can adjust the bed **112** from a flat position to a position in which a head portion of a mattress of the bed is inclined upward (e.g., to facilitate a user sitting up in bed and/or watching television). In some implementations, the bed **112** includes multiple separately articulable sections. For example, portions of the bed corresponding to the locations of the chambers **114**A and **114**B can be articulated independently from each other, to allow one person positioned on the bed **112** surface to rest in a first position (e.g., a flat position) while a second person rests in a second position (e.g., an reclining position with the head raised at an angle from the waist). In some implementations, separate positions can be set for two different beds (e.g., two twin beds placed next to each other). The foundation of the bed **112** can include more than one zone that can be independently adjusted. The articulation controller can also be configured to provide different levels of massage to one or more users on the bed **112**.

[0057] Example of a Bed in a Bedroom Environment

[0058] FIG. **3** shows an example environment **300** including a bed **302** in communication with devices located in and around a home. In the example shown, the bed **302** includes pump **304** for controlling air pressure within two air chambers **306***a* and **306***b* (as described above with respect to the air chambers **114**A-**114**B). The pump **304** additionally includes circuitry for controlling inflation and deflation functionality performed by the pump **304**. The circuitry is further programmed to detect fluctuations in air pressure of the air chambers **306***a-b* and used the detected fluctuations in air pressure to identify bed presence of a user **308**, sleep state of the user **308**, movement of the user **308**, and biometric signals of the user **308** such as heart rate and respiration rate. In the example shown, the pump **304** is located within a support structure of the bed **302** and the control circuitry **334** for controlling the pump **304** is integrated with the pump **304**. In some implementations, the control circuitry **334** is physically separate from the pump **304** and is in wireless or wired communication with the pump **304**. In some implementations, the pump **304** and/or control circuitry **334** are located outside of the bed **302**. In some implementations, various control functions can be performed by systems located in different physical locations. For example, circuitry for controlling actions of the pump **304** can be located within a pump casing of the pump **304** while control circuitry **334** for performing other functions associated with the bed **302** can be located in another portion of the bed **302**, or external to the bed **302**. As another example, control circuitry **334** located within the pump **304** can communicate with control circuitry **334** at a remote location through a LAN or WAN (e.g., the internet). As yet another example, the control circuitry **334** can be included in the control box **124** of FIGS. **1** and **2**.

[0059] In some implementations, one or more devices other than, or in addition to, the pump **304** and control circuitry **334** can be utilized to identify user bed presence, sleep state, movement, and biometric signals. For example, the bed **302** can include a second pump in addition to the pump **304**, with each of the two pumps connected to a respective one of the air chambers **306***a-b*. For example, the pump **304** can be in fluid communication with the air chamber **306***b* to control inflation and deflation of the air chamber **306***b* as well as detect user signals for a user located over the air chamber **306***b* such as bed presence, sleep state, movement, and biometric signals while the second pump is in fluid communication with the air chamber **306***a* to control inflation and deflation of the air chamber **306***a* as well as detect user signals for a user located over the air chamber **306***a*.

[0060] As another example, the bed **302** can include one or more pressure sensitive pads or surface portions that are operable to detect movement, including user presence, user motion, respiration, and heart rate. For example, a first pressure sensitive pad can be incorporated into a surface of the bed **302** over a left portion of the bed **302**, where a first user would normally be located during sleep, and a second pressure sensitive pad can be incorporated into the surface of the bed **302** over a right portion of the bed **302**, where a second user would normally be located during sleep. The movement detected by the one or more pressure sensitive pads or surface portions can be used by control circuitry **334** to identify user sleep state, bed presence, or biometric signals.

[0061] In some implementations, information detected by the bed (e.g., motion information) is processed by control circuitry **334** (e.g., control circuitry **334** integrated with the pump **304**) and provided to one or more user devices such as a user device **310** for presentation to the user **308** or to other users. In the example depicted in FIG. **3**, the user device **310** is a tablet device; however, in some implementations, the user device **310** can be a personal computer, a smart phone, a smart television (e.g., a television **312**), or other user device capable of wired or wireless communication with the control circuitry **334**. The user device **310** can be in communication with control circuitry **334** of the bed **302** through a network or through direct point-to-point communication. For example, the control circuitry **334** can be connected to a LAN (e.g., through a Wi-Fi router) and communicate with the user device **310** through the LAN. As another example, the control circuitry **334** and the user device **310** can both connect to the Internet and communicate through the Internet. For example, the control circuitry **334** can connect to the Internet through a WiFi router and the user device **310** can connect to the Internet through communication with a cellular communication system. As another example, the control circuitry **334** can communicate directly with the user device **310** through a wireless communication protocol such as Bluetooth. As yet another example, the control circuitry **334** can communicate with the user device **310** through a wireless communication protocol such as ZigBee, Z-Wave, or another wireless communication protocol suitable for the application. As another example, the control circuitry **334** can communicate with the user device **310** through a wired connection such as, for example, a USB connector or another wired connection suitable for the application.

[0062] The user device **310** can display a variety of information and statistics related to sleep, or user **308**'s interaction with the bed **302**. For example, a user interface displayed by the user device **310** can present information including amount of sleep for the user **308** over a period of time (e.g., a single evening, a week, a month, etc.) amount of deep sleep, ratio of deep sleep to restless sleep, time lapse between the user **308** getting into bed and the user **308** falling asleep, total amount of time spent in the bed **302** for a given period of time, heart rate for the user **308** over a period of time, respiration rate for the user **308** over a period of time, or other information related to user interaction with the bed **302** by the user **308** or one or more other users of the bed **302**. In some implementations, information for multiple users can be presented on the user device **310**, for example information for a first user positioned over the air chamber **306***a* can be presented along with information for a second user positioned over the air chamber **306***b*. In some implementations, the information presented on the user device **310** can vary according to the age of the user **308**. For example, the information presented on the user device **310** can evolve with the age of the user **308** such that different information is presented on the user device **310** as the user **308** ages as a child or an adult.

[0063] The user device **310** can also be used as an interface for the control circuitry **334** of the bed **302** to allow the user **308** to enter information. The information entered by the user **308** can be used by the control circuitry **334** to provide better information to the user or to various control signals for controlling functions of the bed **302** or other devices. For example, the user can enter information such as weight, height, and age and the control circuitry **334** can use this information to provide the user **308** with a comparison of the user's tracked sleep information to sleep information of other people having similar weights, heights, and/or ages as the user **308**. As another example, the user **308** can use the user device **310** as an interface for controlling air pressure of the air chambers **306***a* and **306***b*, for controlling various recline or incline positions of the bed **302**, for controlling temperature of one or more surface temperature control devices of the bed **302**, or for allowing the control circuitry **334** to generate control signals for other devices (as described in greater detail below).

[0064] In some implementations, control circuitry **334** of the bed **302** (e.g., control circuitry **334** integrated into the pump **304**) can communicate with other devices or systems in addition to or instead of the user device **310**. For example, the control circuitry **334** can communicate with the television **312**, a lighting system **314**, a thermostat **316**, a security system **318**, or other house hold devices such as an oven **322**, a coffee maker **324**, a lamp **326**, and a nightlight **328**. Other examples of devices and/or systems that the control circuitry **334** can communicate with include a system for controlling window blinds **330**, one or more devices for detecting or controlling the states of one or more doors **332** (such as detecting if a door is open, detecting if a door is locked, or automatically locking a door), and a system for controlling a garage door **320** (e.g., control circuitry **334** integrated with a garage door opener for identifying an open or closed state of the garage door **320** and for causing the garage door opener to open or close the garage door **320**). Communications between the control circuitry **334** of the bed **302** and other devices can occur through a network (e.g., a LAN or the Internet) or as point-to-point communication (e.g., using Bluetooth, radio communication, or a wired connection). In some implementations, control circuitry **334** of different beds **302** can communicate with different sets of devices. For example, a kid bed may not communicate with and/or control the same devices as an adult bed. In some embodiments, the bed **302** can evolve with the age of the user such that the control circuitry **334** of the bed **302** communicates with different devices as a function of age of the user.

[0065] The control circuitry **334** can receive information and inputs from other devices/systems and use the received information and inputs to control actions of the bed **302** or other devices. For example, the control circuitry **334** can receive information from the thermostat **316** indicating a current environmental temperature for a house or room in which the bed **302** is located. The control circuitry **334** can use the received information (along with other information) to determine if a temperature of all or a portion of the surface of the bed **302** should be raised or lowered. The control circuitry **334** can then cause a heating or cooling mechanism of the bed **302** to raise or lower the temperature of the surface of the bed **302**. For example, the user **308** can indicate a desired sleeping temperature of 74 degrees while a second user of the bed **302** indicates a desired sleeping temperature of 72 degrees. The thermostat **316** can indicate to the control circuitry **334** that the current temperature of the bedroom is 72 degrees. The control circuitry **334** can identify that the user **308** has indicated a desired sleeping temperature of 74 degrees, and send control signals to a heating pad located on the user **308**'s side of the bed to raise the temperature of the portion of the surface of the bed **302** where the user **308** is located to raise the temperature of the user **308**'s sleeping surface to the desired temperature.

[0066] The control circuitry **334** can also generate control signals controlling other devices and propagate the control signals to the other devices. In some implementations, the control signals are generated based on information collected by the control circuitry **334**, including information related to user interaction with the bed **302** by the user **308** and/or one or more other users. In some implementations, information collected from one or more other devices other than the bed **302** are used when generating the control signals. For example, information relating to environmental occurrences (e.g., environmental temperature, environmental noise level, and environmental light level), time of day, time of year, day of the week, or other information can be used when generating control signals for various devices in communication with the control circuitry **334** of the bed **302**. For example, information on the time of day can be combined with information relating to movement and bed presence of the user **308** to generate control signals for the lighting system **314**. In some implementations, rather than or in addition to providing control signals for one or more other devices, the control circuitry **334** can provide collected information (e.g., information related to user movement, bed presence, sleep state, or biometric signals for the user **308**) to one or more other devices to allow the one or more other devices to utilize the collected information when generating control signals. For example, control circuitry **334** of the bed **302** can provide information relating to user interactions with the bed **302** by the user **308** to a central controller (not shown) that can use the provided information to generate control signals for various devices, including the bed **302**.

[0067] Still referring to FIG. **3**, the control circuitry **334** of the bed **302** can generate control signals for controlling actions of other devices, and transmit the control signals to the other devices in response to information collected by the control circuitry **334**, including bed presence of the user **308**, sleep state of the user **308**, and other factors. For example, control circuitry **334** integrated with the pump **304** can detect a feature of a mattress of the bed **302**, such as an increase in pressure in the air chamber **306***b*, and use this detected increase in air pressure to determine that the user **308** is present on the bed **302**. In some implementations, the control circuitry **334** can identify a heart rate or respiratory rate for the user **308** to identify that the increase in pressure is due to a person sitting, laying, or otherwise resting on the bed **302** rather than an inanimate object (such as a suitcase) having been placed on the bed **302**. In some implementations, the information indicating user bed presence is combined with other information to identify a current or future likely state for the user **308**. For example, a detected user bed presence at 11:00 am can indicate that the user is sitting on the bed (e.g., to tie her shoes, or to read a book) and does not intend to go to sleep, while a detected user bed presence at 10:00 pm can indicate that the user **308** is in bed for the evening and is intending to fall asleep soon. As another example, if the control circuitry **334** detects that the user **308** has left the bed **302** at 6:30 am (e.g., indicating that the user **308** has woken up for the day), and then later detects user bed presence of the user **308** at 7:30 am, the control circuitry **334** can use this information that the newly detected user bed presence is likely temporary (e.g., while the user **308** ties her shoes before heading to work) rather than an indication that the user **308** is intending to stay on the bed **302** for an extended period.

[0068] In some implementations, the control circuitry **334** is able to use collected information (including information related to user interaction with the bed **302** by the user **308**, as well as environmental information, time information, and input received from the user) to identify use patterns for the user **308**. For example, the control circuitry **334** can use information indicating bed presence and sleep states for the user **308** collected over a period of time to identify a sleep pattern for the user. For example, the control circuitry **334** can identify that the user **308** generally goes to bed between 9:30 pm and 10:00 pm, generally falls asleep between 10:00 pm and 11:00 pm, and generally wakes up between 6:30 am and 6:45 am based on information indicating user presence and biometrics for the user **308** collected over a week. The control circuitry **334** can use identified patterns for a user to better process and identify user interactions with the bed **302** by the user **308**.

[0069] For example, given the above example user bed presence, sleep, and wake patterns for the user **308**, if the user **308** is detected as being on the bed at 3:00 pm, the control circuitry **334** can determine that the user's presence on the bed is only temporary, and use this determination to generate different control signals than would be generated if the control circuitry **334** determined that the user **308** was in bed for the evening. As another example, if the control circuitry **334** detects that the user **308** has gotten out of bed at 3:00 am, the control circuitry **334** can use identified patterns for the user **308** to determine that the user has only gotten up temporarily (for example, to use the rest room, or get a glass of water) and is not up for the day. By contrast, if the control circuitry **334** identifies that the user **308** has gotten out of the bed **302** at 6:40 am, the control circuitry **334** can determine that the user is up for the day and generate a different set of control signals than those that would be generated if it were determined that the user **308** were only getting out of bed temporarily (as would be the case when the user **308** gets out of the bed **302** at 3:00 am). For other users **308**, getting out of the bed **302** at 3:00 am can be the normal wake-up time, which the control circuitry **334** can learn and respond to accordingly.

[0070] As described above, the control circuitry **334** for the bed **302** can generate control signals for control functions of various other devices. The control signals can be generated, at least in part, based on detected interactions by the user **308** with the bed **302**, as well as other information including time, date, temperature, etc. For example, the control circuitry **334** can communicate with the television **312**, receive information from the television **312**, and generate control signals for controlling functions of the television **312**. For example, the control circuitry **334** can receive an indication from the television **312** that the television **312** is currently on. If the television **312** is located in a different room from the bed **302**, the control circuitry **334** can generate a control signal to turn the television **312** off upon making a determination that the user **308** has gone to bed for the evening. For example, if bed presence of the user **308** on the bed **302** is detected during a particular time range (e.g., between 8:00 pm and 7:00 am) and persists for longer than a threshold period of time (e.g., 10 minutes) the control circuitry **334** can use this information to determine that the user **308** is in bed for the evening. If the television **312** is on (as indicated by communications received by the control circuitry **334** of the bed **302** from the television **312**) the control circuitry **334** can generate a control signal to turn the television **312** off. The control signals can then be transmitted to the television (e.g., through a directed communication link between the television **312** and the control circuitry **334** or through a network). As another example, rather than turning off the television **312** in response to detection of user bed presence, the control circuitry **334** can generate a control signal that causes the volume of the television **312** to be lowered by a pre-specified amount.

[0071] As another example, upon detecting that the user **308** has left the bed **302** during a specified time range (e.g., between 6:00 am and 8:00 am) the control circuitry **334** can generate control signals to cause the television **312** to turn on and tune to a pre-specified channel (e.g., the user **308** has indicated a preference for watching the morning news upon getting out of bed in the morning). The control circuitry **334** can generate the control signal and transmit the signal to the television **312** to cause the television **312** to turn on and tune to the desired station (which could be stored at the control circuitry **334**, the television **312**, or another location). As another example, upon detecting that the user **308** has gotten up for the day, the control circuitry **334** can generate and transmit control signals to cause the television **312** to turn on and begin playing a previously recorded program from a digital video recorder (DVR) in communication with the television **312**.

[0072] As another example, if the television **312** is in the same room as the bed **302**, the control circuitry **334** does not cause the television **312** to turn off in response to detection of user bed presence. Rather, the control circuitry **334** can generate and transmit control signals to cause the television **312** to turn off in response to determining that the user **308** is asleep. For example, the control circuitry **334** can monitor biometric signals of the user **308** (e.g., motion, heart rate, respiration rate) to determine that the user **308** has fallen asleep. Upon detecting that the user **308** is sleeping, the control circuitry **334** generates and transmits a control signal to turn the television **312** off. As another example, the control circuitry **334** can generate the control signal to turn off the television **312** after a threshold period of time after the user **308** has fallen asleep (e.g., 10 minutes after the user has fallen asleep). As another example, the control circuitry **334** generates control signals to lower the volume of the television **312** after determining that the user **308** is asleep. As yet another example, the control circuitry **334** generates and transmits a control signal to cause the television to gradually lower in volume over a period of time and then turn off in response to determining that the user **308** is asleep.

[0073] In some implementations, the control circuitry **334** can similarly interact with other media devices, such as computers, tablets, smart phones, stereo systems, etc. For example, upon detecting that the user **308** is asleep, the control circuitry **334** can generate and transmit a control signal to the user device **310** to cause the user device **310** to turn off, or turn down the volume on a video or audio file being played by the user device **310**.

[0074] The control circuitry **334** can additionally communicate with the lighting system **314**, receive information from the lighting system **314**, and generate control signals for controlling functions of the lighting system **314**. For example, upon detecting user bed presence on the bed **302** during a certain time frame (e.g., between 8:00 pm and 7:00 am) that lasts for longer than a threshold period of time (e.g., 10 minutes) the control circuitry **334** of the bed **302** can determine that the user **308** is in bed for the evening. In response to this determination, the control circuitry **334** can generate control signals to cause lights in one or more rooms other than the room in which the bed **302** is located to switch off. The control signals can then be transmitted to the lighting system **314** and executed by the lighting system **314** to cause the lights in the indicated rooms to shut off. For example, the control circuitry **334** can generate and transmit control signals to turn off lights in all common rooms, but not in other bedrooms. As another example, the control signals generated by the control circuitry **334** can indicate that lights in all rooms other than the room in which the bed **302** is located are to be turned off, while one or more lights located outside of the house containing the bed **302** are to be turned on, in response to determining that the user **308** is in bed for the evening. Additionally, the control circuitry **334** can generate and transmit control signals to cause the nightlight **328** to turn on in response to determining user **308** bed presence or whether the user **308** is asleep. As another example, the control circuitry **334** can generate first control signals for turning off a first set of lights (e.g., lights in common rooms) in response to detecting user bed presence, and second control signals for turning off a second set of lights (e.g., lights in the room in which the bed **302** is located) in response to detecting that the user **308** is asleep.

[0075] In some implementations, in response to determining that the user **308** is in bed for the evening, the control circuitry **334** of the bed **302** can generate control signals to cause the lighting system **314** to implement a sunset lighting scheme in the room in which the bed **302** is located. A sunset lighting scheme can include, for example, dimming the lights (either gradually over time, or all at once) in combination with changing the color of the light in the bedroom environment, such as adding an amber hue to the lighting in the bedroom. The sunset lighting scheme can help to put the user **308** to sleep when the control circuitry **334** has determined that the user **308** is in bed for the evening.

[0076] The control circuitry **334** can also be configured to implement a sunrise lighting scheme when the user **308** wakes up in the morning. The control circuitry **334** can determine that the user **308** is awake for the day, for example, by detecting that the user **308** has gotten off of the bed **302** (i.e., is no longer present on the bed **302**) during a specified time frame (e.g., between 6:00 am and 8:00 am). As another example, the control circuitry **334** can monitor movement, heart rate, respiratory rate, or other biometric signals of the user **308** to determine that the user **308** is awake even though the user **308** has not gotten out of bed. If the control circuitry **334** detects that the user is awake during a specified time frame, the control circuitry **334** can determine that the user **308** is awake for the day. The specified time frame can be, for example, based on previously recorded user bed presence information collected over a period of time (e.g., two weeks) that indicates that the user **308** usually wakes up for the day between 6:30 am and 7:30 am. In response to the control circuitry **334** determining that the user **308** is awake, the control circuitry **334** can generate control signals to cause the lighting system **314** to implement the sunrise lighting scheme in the bedroom in which the bed **302** is located. The sunrise lighting scheme can include, for example, turning on lights (e.g., the lamp **326**, or other lights in the bedroom). The sunrise lighting scheme can further include gradually increasing the level of light in the room where the bed **302** is located (or in one or more other rooms). The sunrise lighting scheme can also include only turning on lights of specified colors. For example, the sunrise lighting scheme can include lighting the bedroom with blue light to gently assist the user **308** in waking up and becoming active.

[0077] In some implementations, the control circuitry **334** can generate different control signals for controlling actions of one or more components, such as the lighting system **314**, depending on a time of day that user interactions with the bed **302** are detected. For example, the control circuitry **334** can use historical user interaction information for interactions between the user **308** and the bed **302** to determine that the user **308** usually falls asleep between 10:00 pm and 11:00 pm and usually wakes up between 6:30 am and 7:30 am on weekdays. The control circuitry **334** can use this information to generate a first set of control signals for controlling the lighting system **314** if the user **308** is detected as getting out of bed at 3:00 am and to generate a second set of control signals for controlling the lighting system **314** if the user **308** is detected as getting out of bed after 6:30 am. For example, if the user **308** gets out of bed prior to 6:30 am, the control circuitry **334** can turn on lights that guide the user **308**'s route to a restroom. As another example, if the user **308** gets out of bed prior to 6:30 am, the control circuitry **334** can turn on lights that guide the user **308**'s route to the kitchen (which can include, for example, turning on the nightlight **328**, turning on under bed lighting, or turning on the lamp **326**).

[0078] As another example, if the user **308** gets out of bed after 6:30 am, the control circuitry **334** can generate control signals to cause the lighting system **314** to initiate a sunrise lighting scheme, or to turn on one or more lights in the bedroom and/or other rooms. In some implementations, if the user **308** is detected as getting out of bed prior to a specified morning rise time for the user **308**, the control circuitry **334** causes the lighting system **314** to turn on lights that are dimmer than lights that are turned on by the lighting system **314** if the user **308** is detected as getting out of bed after the specified morning rise time. Causing the lighting system **314** to only turn on dim lights when the user **308** gets out of bed during the night (i.e., prior to normal rise time for the user **308**) can prevent other occupants of the house from being woken by the lights while still allowing the user **308** to see in order to reach the restroom, kitchen, or another destination within the house.

[0079] The historical user interaction information for interactions between the user **308** and the bed **302** can be used to identify user sleep and awake time frames. For example, user bed presence times and sleep times can be determined for a set period of time (e.g., two weeks, a month, etc.). The control circuitry **334** can then identify a typical time range or time frame in which the user **308** goes to bed, a typical time frame for when the user **308** falls asleep, and a typical time frame for when the user **308** wakes up (and in some cases, different time frames for when the user **308** wakes up and when the user **308** actually gets out of bed). In some implementations, buffer time can be added to these time frames. For example, if the user is identified as typically going to bed between 10:00 pm and 10:30 pm, a buffer of a half hour in each direction can be added to the time frame such that any detection of the user getting onto the bed between 9:30 pm and 11:00 pm is interpreted as the user **308** going to bed for the evening. As another example, detection of bed presence of the user **308** starting from a half hour before the earliest typical time that the user **308** goes to bed extending until the typical wake up time (e.g., 6:30 am) for the user can be interpreted as the user going to bed for the evening. For example, if the user typically goes to bed between 10:00 pm and 10:30 pm, if the user's bed presence is sensed at 12:30 am one night, that can be interpreted as the user getting into bed for the evening even though this is outside of the user's typical time frame for going to bed because it has occurred prior to the user's normal wake up time. In some implementations, different time frames are identified for different times of the year (e.g., earlier bed time during winter vs. summer) or at different times of the week (e.g., user wakes up earlier on weekdays than on weekends).

[0080] The control circuitry **334** can distinguish between the user **308** going to bed for an extended period (such as for the night) as opposed to being present on the bed **302** for a shorter period (such as for a nap) by sensing duration of presence of the user **308**. In some examples, the control circuitry **334** can distinguish between the user **308** going to bed for an extended period (such as for the night) as opposed to going to bed for a shorter period (such as for a nap) by sensing duration of sleep of the user **308**. For example, the control circuitry **334** can set a time threshold whereby if the user **308** is sensed on the bed **302** for longer than the threshold, the user **308** is considered to have gone to bed for the night. In some examples, the threshold can be about 2 hours, whereby if the user **308** is sensed on the bed **302** for greater than 2 hours, the control circuitry **334** registers that as an extended sleep event. In other examples, the threshold can be greater than or less than two hours.

[0081] The control circuitry **334** can detect repeated extended sleep events to determine a typical bed time range of the user **308** automatically, without requiring the user **308** to enter a bed time range. This can allow the control circuitry **334** to accurately estimate when the user **308** is likely to go to bed for an extended sleep event, regardless of whether the user **308** typically goes to bed using a traditional sleep schedule or a non-traditional sleep schedule. The control circuitry **334** can then use knowledge of the bed time range of the user **308** to control one or more components (including components of the bed **302** and/or non-bed peripherals) differently based on sensing bed presence during the bed time range or outside of the bed time range.

[0082] In some examples, the control circuitry **334** can automatically determine the bed time range of the user **308** without requiring user inputs. In some examples, the control circuitry **334** can determine the bed time range of the user **308** automatically and in combination with user inputs. In some examples, the control circuitry **334** can set the bed time range directly according to user inputs. In some examples, the control circuitry **334** can associate different bed times with different days of the week. In each of these examples, the control circuitry **334** can control one or more components (such as the lighting system **314**, the thermostat **316**, the security system **318**, the oven **322**, the coffee maker **324**, the lamp **326**, and the nightlight **328**), as a function of sensed bed presence and the bed time range.

[0083] The control circuitry **334** can additionally communicate with the thermostat **316**, receive information from the thermostat **316**, and generate control signals for controlling functions of the thermostat **316**. For example, the user **308** can indicate user preferences for different temperatures at different times, depending on the sleep state or bed presence of the user **308**. For example, the user **308** may prefer an environmental temperature of 72 degrees when out of bed, 70 degrees when in bed but awake, and 68 degrees when sleeping. The control circuitry **334** of the bed **302** can detect bed presence of the user **308** in the evening and determine that the user **308** is in bed for the night. In response to this determination, the control circuitry **334** can generate control signals to cause the thermostat to change the temperature to 70 degrees. The control circuitry **334** can then transmit the control signals to the thermostat **316**. Upon detecting that the user **308** is in bed during the bed time range or asleep, the control circuitry **334** can generate and transmit control signals to cause the thermostat **316** to change the temperature to 68. The next morning, upon determining that the user is awake for the day (e.g., the user **308** gets out of bed after 6:30 am) the control circuitry **334** can generate and transmit control circuitry **334** to cause the thermostat to change the temperature to 72 degrees.

[0084] In some implementations, the control circuitry **334** can similarly generate control signals to cause one or more heating or cooling elements on the surface of the bed **302** to change temperature at various times, either in response to user interaction with the bed **302** or at various pre-programmed times. For example, the control circuitry **334** can activate a heating element to raise the temperature of one side of the surface of the bed **302** to 73 degrees when it is detected that the user **308** has fallen asleep. As another example, upon determining that the user **308** is up for the day, the control circuitry **334** can turn off a heating or cooling element. As yet another example, the user **308** can pre-program various times at which the temperature at the surface of the bed should be raised or lowered. For example, the user can program the bed **302** to raise the surface temperature to 76 degrees at 10:00 pm, and lower the surface temperature to 68 degrees at 11:30 pm.

[0085] In some implementations, in response to detecting user bed presence of the user **308** and/or that the user **308** is asleep, the control circuitry **334** can cause the thermostat **316** to change the temperature in different rooms to different values. For example, in response to determining that the user **308** is in bed for the evening, the control circuitry **334** can generate and transmit control signals to cause the thermostat **316** to set the temperature in one or more bedrooms of the house to 72 degrees and set the temperature in other rooms to 67 degrees.

[0086] The control circuitry **334** can also receive temperature information from the thermostat **316** and use this temperature information to control functions of the bed **302** or other devices. For example, as discussed above, the control circuitry **334** can adjust temperatures of heating elements included in the bed **302** in response to temperature information received from the thermostat **316**.

[0087] In some implementations, the control circuitry **334** can generate and transmit control signals for controlling other temperature control systems. For example, in response to determining that the user **308** is awake for the day, the control circuitry **334** can generate and transmit control signals for causing floor heating elements to activate. For example, the control circuitry **334** can cause a floor heating system for a master bedroom to turn on in response to determining that the user **308** is awake for the day.

[0088] The control circuitry **334** can additionally communicate with the security system **318**, receive information from the security system **318**, and generate control signals for controlling functions of the security system **318**. For example, in response to detecting that the user **308** in is bed for the evening, the control circuitry **334** can generate control signals to cause the security system to engage or disengage security functions. The control circuitry **334** can then transmit the control signals to the security system **318** to cause the security system **318** to engage. As another example, the control circuitry **334** can generate and transmit control signals to cause the security system **318** to disable in response to determining that the user **308** is awake for the day (e.g., user **308** is no longer present on the bed **302** after 6:00 am). In some implementations, the control circuitry **334** can generate and transmit a first set of control signals to cause the security system **318** to engage a first set of security features in response to detecting user bed presence of the user **308**, and can generate and transmit a second set of control signals to cause the security system **318** to engage a second set of security features in response to detecting that the user **308** has fallen asleep.

[0089] In some implementations, the control circuitry **334** can receive alerts from the security system **318** and indicate the alert to the user **308**. For example, the control circuitry **334** can detect that the user **308** is in bed for the evening and in response, generate and transmit control signals to cause the security system **318** to engage or disengage. The security system can then detect a security breach (e.g., someone has opened the door **332** without entering the security code, or someone has opened a window when the security system **318** is engaged). The security system **318** can communicate the security breach to the control circuitry **334** of the bed **302**. In response to receiving the communication from the security system **318**, the control circuitry **334** can generate control signals to alert the user **308** to the security breach. For example, the control circuitry **334** can cause the bed **302** to vibrate. As another example, the control circuitry **334** can cause portions of the bed **302** to articulate (e.g., cause the head section to raise or lower) in order to wake the user **308** and alert the user to the security breach. As another example, the control circuitry **334** can generate and transmit control signals to cause the lamp **326** to flash on and off at regular intervals to alert the user **308** to the security breach. As another example, the control circuitry **334** can alert the user **308** of one bed **302** regarding a security breach in a bedroom of another bed, such as an open window in a kid's bedroom. As another example, the control circuitry **334** can send an alert to a garage door controller (e.g., to close and lock the door). As another example, the control circuitry **334** can send an alert for the security to be disengaged.

[0090] The control circuitry **334** can additionally generate and transmit control signals for controlling the garage door **320** and receive information indicating a state of the garage door **320** (i.e., open or closed). For example, in response to determining that the user **308** is in bed for the evening, the control circuitry **334** can generate and transmit a request to a garage door opener or another device capable of sensing if the garage door **320** is open. The control circuitry **334** can request information on the current state of the garage door **320**. If the control circuitry **334** receives a response (e.g., from the garage door opener) indicating that the garage door **320** is open, the control circuitry **334** can either notify the user **308** that the garage door is open, or generate a control signal to cause the garage door opener to close the garage door **320**. For example, the control circuitry **334** can send a message to the user device **310** indicating that the garage door is open. As another example, the control circuitry **334** can cause the bed **302** to vibrate. As yet another example, the control circuitry **334** can generate and transmit a control signal to cause the lighting system **314** to cause one or more lights in the bedroom to flash to alert the user **308** to check the user device **310** for an alert (in this example, an alert regarding the garage door **320** being open). Alternatively, or additionally, the control circuitry **334** can generate and transmit control signals to cause the garage door opener to close the garage door **320** in response to identifying that the user **308** is in bed for the evening and that the garage door **320** is open. In some implementations, control signals can vary depend on the age of the user **308**.

[0091] The control circuitry **334** can similarly send and receive communications for controlling or receiving state information associated with the door **332** or the oven **322**. For example, upon detecting that the user **308** is in bed for the evening, the control circuitry **334** can generate and transmit a request to a device or system for detecting a state of the door **332**. Information returned in response to the request can indicate various states for the door **332** such as open, closed but unlocked, or closed and locked. If the door **332** is open or closed but unlocked, the control circuitry **334** can alert the user **308** to the state of the door, such as in a manner described above with reference to the garage door

320. Alternatively, or in addition to alerting the user 308, the control circuitry 334 can generate and transmit control signals to cause the door 332 to lock, or to close and lock. If the door 332 is closed and locked, the control circuitry 334 can determine that no further action is needed.

[0092] Similarly, upon detecting that the user 308 is in bed for the evening, the control circuitry 334 can generate and transmit a request to the oven 322 to request a state of the oven 322 (e.g., on or off). If the oven 322 is on, the control circuitry 334 can alert the user 308 and/or generate and transmit control signals to cause the oven 322 to turn off. If the oven is already off, the control circuitry 334 can determine that no further action is necessary. In some implementations, different alerts can be generated for different events. For example, the control circuitry 334 can cause the lamp 326 (or one or more other lights, via the lighting system 314) to flash in a first pattern if the security system 318 has detected a breach, flash in a second pattern if garage door 320 is on, flash in a third pattern if the door 332 is open, flash in a fourth pattern if the oven 322 is on, and flash in a fifth pattern if another bed has detected that a user of that bed has gotten up (e.g., that a child of the user 308 has gotten out of bed in the middle of the night as sensed by a sensor in the bed 302 of the child). Other examples of alerts that can be processed by the control circuitry 334 of the bed 302 and communicated to the user include a smoke detector detecting smoke (and communicating this detection of smoke to the control circuitry 334), a carbon monoxide tester detecting carbon monoxide, a heater malfunctioning, or an alert from any other device capable of communicating with the control circuitry 334 and detecting an occurrence that should be brought to the user 308's attention.

[0093] The control circuitry 334 can also communicate with a system or device for controlling a state of the window blinds 330. For example, in response to determining that the user 308 is in bed for the evening, the control circuitry 334 can generate and transmit control signals to cause the window blinds 330 to close. As another example, in response to determining that the user 308 is up for the day (e.g., user has gotten out of bed after 6:30 am) the control circuitry 334 can generate and transmit control signals to cause the window blinds 330 to open. By contrast, if the user 308 gets out of bed prior to a normal rise time for the user 308, the control circuitry 334 can determine that the user 308 is not awake for the day and does not generate control signals for causing the window blinds 330 to open. As yet another example, the control circuitry 334 can generate and transmit control signals that cause a first set of blinds to close in response to detecting user bed presence of the user 308 and a second set of blinds to close in response to detecting that the user 308 is asleep.

[0094] The control circuitry 334 can generate and transmit control signals for controlling functions of other household devices in response to detecting user interactions with the bed 302. For example, in response to determining that the user 308 is awake for the day, the control circuitry 334 can generate and transmit control signals to the coffee maker 324 to cause the coffee maker 324 to begin brewing coffee. As another example, the control circuitry 334 can generate and transmit control signals to the oven 322 to cause the oven to begin preheating (for users that like fresh baked bread in the morning). As another example, the control circuitry 334 can use information indicating that the user 308 is awake for the day along with information indicating that the time of year is currently winter and/or that the outside temperature is below a threshold value to generate and transmit control signals to cause a car engine block heater to turn on.

[0095] As another example, the control circuitry 334 can generate and transmit control signals to cause one or more devices to enter a sleep mode in response to detecting user bed presence of the user 308, or in response to detecting that the user 308 is asleep. For example, the control circuitry 334 can generate control signals to cause a mobile phone of the user 308 to switch into sleep mode. The control circuitry 334 can then transmit the control signals to the mobile phone. Later, upon determining that the user 308 is up for the day, the control circuitry 334 can generate and transmit control signals to cause the mobile phone to switch out of sleep mode.

[0096] In some implementations, the control circuitry 334 can communicate with one or more noise control devices. For example, upon determining that the user 308 is in bed for the evening, or that the user 308 is asleep, the control circuitry 334 can generate and transmit control signals to cause one or more noise cancellation devices to activate. The noise cancellation devices can, for example, be included as part of the bed 302 or located in the bedroom with the bed 302. As another example, upon determining that the user 308 is in bed for the evening or that the user 308 is asleep, the control circuitry 334 can generate and transmit control signals to turn the volume on, off, up, or down, for one or more sound generating devices, such as a stereo system radio, computer, tablet, etc.

[0097] Additionally, functions of the bed 302 are controlled by the control circuitry 334 in response to user interactions with the bed 302. For example, the bed 302 can include an adjustable foundation and an articulation controller configured to adjust the position of one or more portions of the bed 302 by adjusting the adjustable foundation that supports the bed. For example, the articulation controller can adjust the bed 302 from a flat position to a position in which a head portion of a mattress of the bed 302 is inclined upward (e.g., to facilitate a user sitting up in bed and/or watching television). In some implementations, the bed 302 includes multiple separately articulable sections. For example, portions of the bed corresponding to the locations of the air chambers 306*a* and 306*b* can be articulated independently from each other, to allow one person positioned on the bed 302 surface to rest in a first position (e.g., a flat position) while a second person rests in a second position (e.g., a reclining position with the head raised at an angle from the waist). In some implementations, separate positions can be set for two different beds (e.g., two twin beds placed next to each other). The foundation of the bed 302 can include more than one zone that can be independently adjusted. The articulation controller can also be configured to provide different levels of massage to one or more users on the bed 302 or to cause the bed to vibrate to communicate alerts to the user 308 as described above.

[0098] The control circuitry 334 can adjust positions (e.g., incline and decline positions for the user 308 and/or an additional user of the bed 302) in response to user interactions with the bed 302. For example, the control circuitry 334 can cause the articulation controller to adjust the bed 302 to a first recline position for the user 308 in response to sensing user bed presence for the user 308. The control circuitry 334 can cause the articulation controller to adjust the bed 302 to a second recline position (e.g., a less reclined, or flat position) in response to determining that the user **308** is asleep. As another example, the control circuitry **334** can receive a communication from the television **312** indicating that the user **308** has turned off the television **312**, and in response the control circuitry **334** can cause the articulation controller to adjust the position of the bed **302** to a preferred user sleeping position (e.g., due to the user turning off the television **312** while the user **308** is in bed indicating that the user **308** wishes to go to sleep).

[0099] In some implementations, the control circuitry **334** can control the articulation controller so as to wake up one user of the bed **302** without waking another user of the bed **302**. For example, the user **308** and a second user of the bed **302** can each set distinct wakeup times (e.g., 6:30 am and 7:15 am respectively). When the wakeup time for the user **308** is reached, the control circuitry **334** can cause the articulation controller to vibrate or change the position of only a side of the bed on which the user **308** is located to wake the user **308** without disturbing the second user. When the wakeup time for the second user is reached, the control circuitry **334** can cause the articulation controller to vibrate or change the position of only the side of the bed on which the second user is located. Alternatively, when the second wakeup time occurs, the control circuitry **334** can utilize other methods (such as audio alarms, or turning on the lights) to wake the second user since the user **308** is already awake and therefore will not be disturbed when the control circuitry **334** attempts to wake the second user.

[0100] Still referring to FIG. **3**, the control circuitry **334** for the bed **302** can utilize information for interactions with the bed **302** by multiple users to generate control signals for controlling functions of various other devices. For example, the control circuitry **334** can wait to generate control signals for, for example, engaging the security system **318**, or instructing the lighting system **314** to turn off lights in various rooms until both the user **308** and a second user are detected as being present on the bed **302**. As another example, the control circuitry **334** can generate a first set of control signals to cause the lighting system **314** to turn off a first set of lights upon detecting bed presence of the user **308** and generate a second set of control signals for turning off a second set of lights in response to detecting bed presence of a second user. As another example, the control circuitry **334** can wait until it has been determined that both the user **308** and a second user are awake for the day before generating control signals to open the window blinds **330**. As yet another example, in response to determining that the user **308** has left the bed and is awake for the day, but that a second user is still sleeping, the control circuitry **334** can generate and transmit a first set of control signals to cause the coffee maker **324** to begin brewing coffee, to cause the security system **318** to deactivate, to turn on the lamp **326**, to turn off the nightlight **328**, to cause the thermostat **316** to raise the temperature in one or more rooms to 72 degrees, and to open blinds (e.g., the window blinds **330**) in rooms other than the bedroom in which the bed **302** is located. Later, in response to detecting that the second user is no longer present on the bed (or that the second user is awake) the control circuitry **334** can generate and transmit a second set of control signals to, for example, cause the lighting system **314** to turn on one or more lights in the bedroom, to cause window blinds in the bedroom to open, and to turn on the television **312** to a pre-specified channel.

[0101] Examples of Data Processing Systems Associated with a Bed

[0102] Described here are examples of systems and components that can be used for data processing tasks that are, for example, associated with a bed. In some cases, multiple examples of a particular component or group of components are presented. Some of these examples are redundant and/or mutually exclusive alternatives. Connections between components are shown as examples to illustrate possible network configurations for allowing communication between components. Different formats of connections can be used as technically needed or desired. The connections generally indicate a logical connection that can be created with any technologically feasible format. For example, a network on a motherboard can be created with a printed circuit board, wireless data connections, and/or other types of network connections. Some logical connections are not shown for clarity. For example, connections with power supplies and/or computer readable memory may not be shown for clarities sake, as many or all elements of a particular component may need to be connected to the power supplies and/or computer readable memory.

[0103] FIG. **4A** is a block diagram of an example of a data processing system **400** that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. This system **400** includes a pump motherboard **402** and a pump daughterboard **404**. The system **400** includes a sensor array **406** that can include one or more sensors configured to sense physical phenomenon of the environment and/or bed, and to report such sensing back to the pump motherboard **402** for, for example, analysis. The system **400** also includes a controller array **408** that can include one or more controllers configured to control logic-controlled devices of the bed and/or environment. The pump motherboard **400** can be in communication with one or more computing devices **414** and one or more cloud services **410** over local networks, the Internet **412**, or otherwise as is technically appropriate. Each of these components will be described in more detail, some with multiple example configurations, below.

[0104] In this example, a pump motherboard **402** and a pump daughterboard **404** are communicably coupled. They can be conceptually described as a center or hub of the system **400**, with the other components conceptually described as spokes of the system **400**. In some configurations, this can mean that each of the spoke components communicates primarily or exclusively with the pump motherboard **402**. For example, a sensor of the sensor array may not be configured to, or may not be able to, communicate directly with a corresponding controller. Instead, each spoke component can communicate with the motherboard **402**. The sensor of the sensor array **406** can report a sensor reading to the motherboard **402**, and the motherboard **402** can determine that, in response, a controller of the controller array **408** should adjust some parameters of a logic controlled device or otherwise modify a state of one or more peripheral devices. In one case, if the temperature of the bed is determined to be too hot, the pump motherboard **402** can determine that a temperature controller should cool the bed.

[0105] One advantage of a hub-and-spoke network configuration, sometimes also referred to as a star-shaped network, is a reduction in network traffic compared to, for example, a mesh network with dynamic routing. If a particular sensor generates a large, continuous stream of traffic, that traffic may only be transmitted over one spoke of the network to the motherboard **402**. The motherboard **402** can, for example, marshal that data and condense it to a smaller data format for retransmission for storage in a cloud service **410**. Additionally or alternatively, the motherboard **402** can generate a single, small, command message to be sent down a different spoke of the network in response to the large stream. For example, if the large stream of data is a pressure reading that is transmitted from the sensor array **406** a few times a second, the motherboard **402** can respond with a single command message to the controller array to increase the pressure in an air chamber. In this case, the single command message can be orders of magnitude smaller than the stream of pressure readings.

[0106] As another advantage, a hub-and-spoke network configuration can allow for an extensible network that can accommodate components being added, removed, failing, etc. This can allow, for example, more, fewer, or different sensors in the sensor array **406**, controllers in the controller array **408**, computing devices **414**, and/or cloud services **410**. For example, if a particular sensor fails or is deprecated by a newer version of the sensor, the system **400** can be configured such that only the motherboard **402** needs to be updated about the replacement sensor. This can allow, for example, product differentiation where the same motherboard **402** can support an entry level product with fewer sensors and controllers, a higher value product with more sensors and controllers, and customer personalization where a customer can add their own selected components to the system **400**.

[0107] Additionally, a line of air bed products can use the system **400** with different components. In an application in which every air bed in the product line includes both a central logic unit and a pump, the motherboard **402** (and optionally the daughterboard **404**) can be designed to fit within a single, universal housing. Then, for each upgrade of the product in the product line, additional sensors, controllers, cloud services, etc., can be added. Design, manufacturing, and testing time can be reduced by designing all products in a product line from this base, compared to a product line in which each product has a bespoke logic control system.

[0108] Each of the components discussed above can be realized in a wide variety of technologies and configurations. Below, some examples of each component will be further discussed. In some alternatives, two or more of the components of the system **400** can be realized in a single alternative component; some components can be realized in multiple, separate components; and/or some functionality can be provided by different components.

[0109] FIG. 4B is a block diagram showing some communication paths of the data processing system **400**. As previously described, the motherboard **402** and the pump daughterboard **404** may act as a hub for peripheral devices and cloud services of the system **400**. In cases in which the pump daughterboard **404** communicates with cloud services or other components, communications from the pump daughterboard **404** may be routed through the pump motherboard **402**. This may allow, for example, the bed to have only a single connection with the internet **412**. The computing device **414** may also have a connection to the internet **412**, possibly through the same gateway used by the bed and/or possibly through a different gateway (e.g., a cell service provider).

[0110] Previously, a number of cloud services **410** were described. As shown in FIG. **4**B, some cloud services, such as cloud services **410***d* and **410***e*, may be configured such that the pump motherboard **402** can communicate with the cloud service directly—that is the motherboard **402** may communicate with a cloud service **410** without having to use another cloud service **410** as an intermediary. Additionally or alternatively, some cloud services **410**, for example cloud service **410***f*, may only be reachable by the pump motherboard **402** through an intermediary cloud service, for example cloud service **410***e*. While not shown here, some cloud services **410** may be reachable either directly or indirectly by the pump motherboard **402**.

[0111] Additionally, some or all of the cloud services **410** may be configured to communicate with other cloud services. This communication may include the transfer of data and/or remote function calls according to any technologically appropriate format. For example, one cloud service **410** may request a copy for another cloud service's **410** data, for example, for purposes of backup, coordination, migration, or for performance of calculations or data mining. In another example, many cloud services **410** may contain data that is indexed according to specific users tracked by the user account cloud **410***c* and/or the bed data cloud **410***a*. These cloud services **410** may communicate with the user account cloud **410***c* and/or the bed data cloud **410***a* when accessing data specific to a particular user or bed.

[0112] FIG. **5** is a block diagram of an example of a motherboard **402** that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In this example, compared to other examples described below, this motherboard **402** consists of relatively fewer parts and can be limited to provide a relatively limited feature set.

[0113] The motherboard includes a power supply **500**, a processor **502**, and computer memory **512**. In general, the power supply includes hardware used to receive electrical power from an outside source and supply it to components of the motherboard **402**. The power supply can include, for example, a battery pack and/or wall outlet adapter, an AC to DC converter, a DC to AC converter, a power conditioner, a capacitor bank, and/or one or more interfaces for providing power in the current type, voltage, etc., needed by other components of the motherboard **402**.

[0114] The processor **502** is generally a device for receiving input, performing logical determinations, and providing output. The processor **502** can be a central processing unit, a microprocessor, general purpose logic circuitry, application-specific integrated circuitry, a combination of these, and/or other hardware for performing the functionality needed.

[0115] The memory **512** is generally one or more devices for storing data. The memory **512** can include long term stable data storage (e.g., on a hard disk), short term unstable (e.g., on Random Access Memory) or any other technologically appropriate configuration.

[0116] The motherboard **402** includes a pump controller **504** and a pump motor **506**. The pump controller **504** can receive commands from the processor **502** and, in response, control the function of the pump motor **506**. For example, the pump controller **504** can receive, from the processor **502**, a command to increase the pressure of an air chamber by 0.3 pounds per square inch (PSI). The pump controller **504**, in response, engages a valve so that the pump motor **506** is configured to pump air into the selected air chamber, and can engage the pump motor **506** for a length of time that corresponds to 0.3 PSI or until a sensor indicates that pressure has been increased by 0.3 PSI. In an alternative configuration, the message can specify that the chamber should be inflated to a target PSI, and the pump controller **504** can engage the pump motor **506** until the target PSI is reached.

[0117] A valve solenoid **508** can control which air chamber a pump is connected to. In some cases, the solenoid **508** can be controlled by the processor **502** directly. In some cases, the solenoid **508** can be controlled by the pump controller **504**.

[0118] A remote interface **510** of the motherboard **402** can allow the motherboard **402** to communicate with other components of a data processing system. For example, the motherboard **402** can be able to communicate with one or more daughterboards, with peripheral sensors, and/or with peripheral controllers through the remote interface **510**. The remote interface **510** can provide any technologically appropriate communication interface, including but not limited to multiple communication interfaces such as WiFi, Bluetooth, and copper wired networks.

[0119] FIG. **6** is a block diagram of an example of a motherboard **402** that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. Compared to the motherboard **402** described with reference to FIG. **5**, the motherboard in FIG. **6** can contain more components and provide more functionality in some applications.

[0120] In addition to the power supply **500**, processor **502**, pump controller **504**, pump motor **506**, and valve solenoid **508**, this motherboard **402** is shown with a valve controller **600**, a pressure sensor **602**, a universal serial bus (USB) stack **604**, a WiFi radio **606**, a Bluetooth Low Energy (BLE) radio **608**, a ZigBee radio **610**, a Bluetooth radio **612** and a computer memory **512**.

[0121] Similar to the way that the pump controller **504** converts commands from the processor **502** into control signals for the pump motor **506**, the valve controller **600** can convert commands from the processor **502** into control signals for the valve solenoid **508**. In one example, the processor **502** can issue a command to the valve controller **600** to connect the pump to a particular air chamber out of the group of air chambers in an air bed. The valve controller **600** can control the position of the valve solenoid **508** so that the pump is connected to the indicated air chamber.

[0122] The pressure sensor **602** can read pressure readings from one or more air chambers of the air bed. The pressure sensor **602** can also preform digital sensor conditioning.

[0123] The motherboard **402** can include a suite of network interfaces, including but not limited to those shown here. These network interfaces can allow the motherboard to communicate over a wired or wireless network with any number of devices, including but not limited to peripheral sensors, peripheral controllers, computing devices, and devices and services connected to the Internet **412**.

[0124] FIG. **7** is a block diagram of an example of a daughterboard **404** that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In some configurations, one or more daughterboards **404** can be connected to the motherboard **402**. Some daughterboards **404** can be designed to offload particular and/or compartmentalized tasks from the motherboard **402**. This can be advantageous, for example, if the particular tasks are computationally intensive, proprietary, or subject to future revisions. For example, the daughterboard **404** can be used to calculate a particular sleep data metric. This metric can be computationally intensive, and calculating the sleep metric on the daughterboard **404** can free up the resources of the motherboard **402** while the metric is being calculated. Additionally and/or alternatively, the sleep metric can be subject to future revisions. To update the system **400** with the new sleep metric, it is possible that only the daughterboard **404** that calculates that metric need be replaced. In this case, the same motherboard **402** and other components can be used, saving the need to perform unit testing of additional components instead of just the daughterboard **404**.

[0125] The daughterboard **404** is shown with a power supply **700**, a processor **702**, computer readable memory **704**, a pressure sensor **706**, and a WiFi radio **708**. The processor can use the pressure sensor **706** to gather information about the pressure of the air chamber or chambers of an air bed. From this data, the processor **702** can perform an algorithm to calculate a sleep metric. In some examples, the sleep metric can be calculated from only the pressure of air chambers. In other examples, the sleep metric can be calculated from one or more other sensors. In an example in which different data is needed, the processor **702** can receive that data from an appropriate sensor or sensors. These sensors can be internal to the daughterboard **404**, accessible via the WiFi radio **708**, or otherwise in communication with the processor **702**. Once the sleep metric is calculated, the processor **702** can report that sleep metric to, for example, the motherboard **402**.

[0126] FIG. **8** is a block diagram of an example of a motherboard **800** with no daughterboard that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In this example, the motherboard **800** can perform most, all, or more of the features described with reference to the motherboard **402** in FIG. **6** and the daughterboard **404** in FIG. **7**.

[0127] FIG. **9** is a block diagram of an example of a sensory array **406** that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In general, the sensor array **406** is a conceptual grouping of some or all the peripheral sensors that communicate with the motherboard **402** but are not native to the motherboard **402**.

[0128] The peripheral sensors of the sensor array **406** can communicate with the motherboard **402** through one or more of the network interfaces of the motherboard, including but not limited to the USB stack **604**, a WiFi radio **606**, a Bluetooth Low Energy (BLE) radio **608**, a ZigBee radio **610**, and a Bluetooth radio **612**, as is appropriate for the configuration of the particular sensor. For example, a sensor that outputs a reading over a USB cable can communicate through the USB stack **604**.

[0129] Some of the peripheral sensors **900** of the sensor array **406** can be bed mounted **900**. These sensors can be, for example, embedded into the structure of a bed and sold with the bed, or later affixed to the structure of the bed. Other peripheral sensors **902** and **904** can be in communication with the motherboard **402**, but optionally not mounted to the bed. In some cases, some or all of the bed mounted sensors **900** and/or peripheral sensors **902** and **904** can share networking hardware, including a conduit that contains wires from each sensor, a multi-wire cable or plug that, when affixed to the motherboard **402**, connect all of the associated sensors with the motherboard **402**. In some embodiments, one, some, or all of sensors **902**, **904**, **906**, **908**, and **910** can sense one or more features of a mattress, such as pressure, temperature, light, sound, and/or one or more other features of the mattress. In some embodiments, one, some, or all of sensors **902**, **904**, **906**, **908**, and **910** can sense one or more features external to the mattress. In some embodiments, pressure sensor **902** can sense pressure of the mattress while some or all of sensors **902**, **904**, **906**, **908**, and **910** can sense one or more features of the mattress and/or external to the mattress.

[0130] FIG. **10** is a block diagram of an example of a controller array **408** that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In general, the controller array **408** is a conceptual grouping of some or all peripheral controllers that communicate with the motherboard **402** but are not native to the motherboard **402**.

[0131] The peripheral controllers of the controller array **408** can communicate with the motherboard **402** through one or more of the network interfaces of the motherboard, including but not limited to the USB stack **604**, a WiFi radio **606**, a Bluetooth Low Energy (BLE) radio **608**, a ZigBee radio **610**, and a Bluetooth radio **612**, as is appropriate for the configuration of the particular sensor. For example, a controller that receives a command over a USB cable can communicate through the USB stack **604**.

[0132] Some of the controllers of the controller array **408** can be bed mounted **1000**. These controllers can be, for example, embedded into the structure of a bed and sold with the bed, or later affixed to the structure of the bed. Other peripheral controllers **1002** and **1004** can be in communication with the motherboard **402**, but optionally not mounted to the bed. In some cases, some or all of the bed mounted controllers **1000** and/or peripheral controllers **1002** and **1004** can share networking hardware, including a conduit that contains wires for each controller, a multi-wire cable or plug that, when affixed to the motherboard **402**, connects all of the associated controllers with the motherboard **402**.

[0133] FIG. **11** is a block diagram of an example of a computing device **412** that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. The computing device **412** can include, for example, computing devices used by a user of a bed. Example computing devices **412** include, but are not limited to, mobile computing devices (e.g., mobile phones, tablet computers, laptops) and desktop computers.

[0134] The computing device **412** includes a power supply **1100**, a processor **1102**, and computer readable memory **1104**. User input and output can be transmitted by, for example, speakers **1106**, a touchscreen **1108**, or other not shown components such as a pointing device or keyboard. The computing device **412** can run one or more applications **1110**. These applications can include, for example, application to allow the user to interact with the system **400**. These applications can allow a user to view information about the bed (e.g., sensor readings, sleep metrics), or configure the behavior of the system **400** (e.g., set a desired firmness to the bed, set desired behavior for peripheral devices). In some cases, the computing device **412** can be used in addition to, or to replace, the remote control **122** described previously.

[0135] FIG. **12** is a block diagram of an example bed data cloud service **410***a* that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In this example, the bed data cloud service **410***a* is configured to collect sensor data and sleep data from a particular bed, and to match the sensor and sleep data with one or more users that use the bed when the sensor and sleep data was generated.

[0136] The bed data cloud service **410***a* is shown with a network interface **1200**, a communication manager **1202**, server hardware **1204**, and server system software **1206**. In addition, the bed data cloud service **410***a* is shown with a user identification module **1208**, a device management **1210** module, a sensor data module **1210**, and an advanced sleep data module **1214**.

[0137] The network interface **1200** generally includes hardware and low level software used to allow one or more hardware devices to communicate over networks. For example the network interface **1200** can include network cards, routers, modems, and other hardware needed to allow the components of the bed data cloud service **410***a* to communicate with each other and other destinations over, for example, the Internet **412**. The communication manger **1202** generally comprises hardware and software that operate above the network interface **1200**. This includes software to initiate, maintain, and tear down network communications used by the bed data cloud service **410***a*. This includes, for example, TCP/IP, SSL or TLS, Torrent, and other communication sessions over local or wide area networks. The communication manger **1202** can also provide load balancing and other services to other elements of the bed data cloud service **410***a*.

[0138] The server hardware **1204** generally includes the physical processing devices used to instantiate and maintain bed data cloud service **410***a*. This hardware includes, but is not limited to processors (e.g., central processing units, ASICs, graphical processers), and computer readable memory (e.g., random access memory, stable hard disks, tape backup). One or more servers can be configured into clusters, multi-computer, or datacenters that can be geographically separate or connected.

[0139] The server system software **1206** generally includes software that runs on the server hardware **1204** to provide operating environments to applications and services. The server system software **1206** can include operating systems running on real servers, virtual machines instantiated on real servers to create many virtual servers, server level operations such as data migration, redundancy, and backup.

[0140] The user identification **1208** can include, or reference, data related to users of beds with associated data processing systems. For example, the users can include customers, owners, or other users registered with the bed data cloud service **410***a* or another service. Each user can have, for example, a unique identifier, user credentials, contact information, billing information, demographic information, or any other technologically appropriate information.

[0141] The device manager **1210** can include, or reference, data related to beds or other products associated with data processing systems. For example, the beds can include products sold or registered with a system associated with the bed data cloud service **410***a*. Each bed can have, for example, a unique identifier, model and/or serial number, sales information, geographic information, delivery information, a listing of associated sensors and control peripherals, etc. Additionally, an index or indexes stored by the bed data cloud service **410***a* can identify users that are associated with beds. For example, this index can record sales of a bed to a user, users that sleep in a bed, etc.

[0142] The sensor data **1212** can record raw or condensed sensor data recorded by beds with associated data processing systems. For example, a bed's data processing system can have a temperature sensor, pressure sensor, and light sensor. Readings from these sensors, either in raw form or in a format generated from the raw data (e.g. sleep metrics) of the sensors, can be communicated by the bed's data processing system to the bed data cloud service **410***a* for storage in the sensor data **1212**. Additionally, an index or indexes stored by the bed data cloud service **410***a* can identify users and/or beds that are associated with the sensor data **1212**.

[0143] The bed data cloud service **410***a* can use any of its available data to generate advanced sleep data **1214**. In general, the advanced sleep data **1214** includes sleep metrics and other data generated from sensor readings. Some of these calculations can be performed in the bed data cloud service **410***a* instead of locally on the bed's data processing system, for example, because the calculations are computationally complex or require a large amount of memory space or processor power that is not available on the bed's data processing system. This can help allow a bed system to operate with a relatively simple controller and still be part of a system that performs relatively complex tasks and computations.

[0144] FIG. **13** is a block diagram of an example sleep data cloud service **410***b* that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In this example, the sleep data cloud service **410***b* is configured to record data related to users' sleep experience.

[0145] The sleep data cloud service **410***b* is shown with a network interface **1300**, a communication manager **1302**, server hardware **1304**, and server system software **1306**. In addition, the sleep data cloud service **410***b* is shown with a user identification module **1308**, a pressure sensor manager **1310**, a pressure based sleep data module **1312**, a raw pressure sensor data module **1314**, and a non-pressure sleep data module **1316**.

[0146] The pressure sensor manager **1310** can include, or reference, data related to the configuration and operation of pressure sensors in beds. For example, this data can include an identifier of the types of sensors in a particular bed, their settings and calibration data, etc.

[0147] The pressure based sleep data **1312** can use raw pressure sensor data **1314** to calculate sleep metrics specifically tied to pressure sensor data. For example, user presence, movements, weight change, heart rate, and breathing rate can all be determined from raw pressure sensor data **1314**. Additionally, an index or indexes stored by the sleep data cloud service **410***b* can identify users that are associated with pressure sensors, raw pressure sensor data, and/or pressure based sleep data.

[0148] The non-pressure sleep data **1316** can use other sources of data to calculate sleep metrics. For example, user entered preferences, light sensor readings, and sound sensor readings can all be used to track sleep data. Additionally, an index or indexes stored by the sleep data cloud service **410***b* can identify users that are associated with other sensors and/or non-pressure sleep data **1316**.

[0149] FIG. **14** is a block diagram of an example user account cloud service **410***c* that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In this example, the user account cloud service **410***c* is configured to record a list of users and to identify other data related to those users.

[0150] The user account cloud service **410***c* is shown with a network interface **1400**, a communication manager **1402**, server hardware **1404**, and server system software **1406**. In addition, the user account cloud service **410***c* is shown with a user identification module **1408**, a purchase history module **1410**, an engagement module **1412**, and an application usage history module **1414**.

[0151] The user identification module **1408** can include, or reference, data related to users of beds with associated data processing systems. For example, the users can include customers, owners, or other users registered with the user account cloud service **410***a* or another service. Each user can have, for example, a unique identifier, and user credentials, demographic information, or any other technologically appropriate information.

[0152] The purchase history module **1410** can include, or reference, data related to purchases by users. For example, the purchase data can include a sale's contact information, billing information, and salesperson information. Additionally, an index or indexes stored by the user account cloud service **410***c* can identify users that are associated with a purchase.

[0153] The engagement **1412** can track user interactions with the manufacturer, vendor, and/or manager of the bed and or cloud services. This engagement data can include communications (e.g., emails, service calls), data from sales (e.g., sales receipts, configuration logs), and social network interactions.

[0154] The usage history module **1414** can contain data about user interactions with one or more applications and/or remote controls of a bed. For example, a monitoring and configuration application can be distributed to run on, for example, computing devices **412**. This application can log and report user interactions for storage in the application usage history module **1414**. Additionally, an index or indexes stored by the user account cloud service **410***c* can identify users that are associated with each log entry.

[0155] FIG. **15** is a block diagram of an example point of sale cloud service **1500** that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In this example, the point of sale cloud service **1500** is configured to record data related to users' purchases.

[0156] The point of sale cloud service **1500** is shown with a network interface **1502**, a communication manager **1504**, server hardware **1506**, and server system software **1508**. In addition, the point of sale cloud service **1500** is shown with a user identification module **1510**, a purchase history module **1512**, and a setup module **1514**.

[0157] The purchase history module **1512** can include, or reference, data related to purchases made by users identified in the user identification module **1510**. The purchase information can include, for example, data of a sale, price, and location of sale, delivery address, and configuration options selected by the users at the time of sale. These configuration options can include selections made by the user about how they wish their newly purchased beds to be setup and can include, for example, expected sleep schedule, a listing of peripheral sensors and controllers that they have or will install, etc.

[0158] The bed setup module **1514** can include, or reference, data related to installations of beds that users' purchase. The bed setup data can include, for example, the date and address to which a bed is delivered, the person that accepts delivery, the configuration that is applied to the bed upon delivery, the name or names of the person or people who will sleep on the bed, which side of the bed each person will use, etc.

[0159] Data recorded in the point of sale cloud service **1500** can be referenced by a user's bed system at later dates to control functionality of the bed system and/or to send control signals to peripheral components according to data recorded in the point of sale cloud service **1500**. This can allow a salesperson to collect information from the user at the point of sale that later facilitates automation of the bed system. In some examples, some or all aspects of the bed system can be automated with little or no user-entered data required after the point of sale. In other examples, data recorded in the point of sale cloud service **1500** can be used in connection with a variety of additional data gathered from user-entered data.

[0160] FIG. **16** is a block diagram of an example environment cloud service **1600** that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. **1-3**. In this example, the environment cloud service **1600** is configured to record data related to users' home environment.

[0161] The environment cloud service **1600** is shown with a network interface **1602**, a communication manager **1604**, server hardware **1606**, and server system software **1608**. In addition, the environment cloud service **1600** is shown with a user identification module **1610**, an environmental sensor module **1612**, and an environmental factors module **1614**.

[0162] The environmental sensors module **1612** can include a listing of sensors that users' in the user identification module **1610** have installed in their bed. These sensors include any sensors that can detect environmental variables—light sensors, noise sensors, vibration sensors, thermostats, etc. Additionally, the environmental sensors module **1612** can store historical readings or reports from those sensors.

[0163] The environmental factors module **1614** can include reports generated based on data in the environmental sensors module **1612**. For example, for a user with a light sensor with data in the environment sensors module **1612**, the environmental factors module **1614** can hold a report indicating the frequency and duration of instances of increased lighting when the user is asleep.

[0164] In the examples discussed here, each cloud service **410** is shown with some of the same components. In various configurations, these same components can be partially or wholly shared between services, or they can be separate. In some configurations, each service can have separate copies of some or all of the components that are the same or different in some ways. Additionally, these components are only supplied as illustrative examples. In other examples each cloud service can have different number, types, and styles of components that are technically possible.

[0165] FIG. **17** is a block diagram of an example of using a data processing system that can be associated with a bed (such as a bed of the bed systems described herein) to automate peripherals around the bed. Shown here is a behavior analysis module **1700** that runs on the pump motherboard **402**. For example, the behavior analysis module **1700** can be one or more software components stored on the computer memory **512** and executed by the processor **502**. In general, the behavior analysis module **1700** can collect data from a wide variety of sources (e.g., sensors, non-sensor local sources, cloud data services) and use a behavioral algorithm **1702** to generate one or more actions to be taken (e.g., commands to send to peripheral controllers, data to send to cloud services). This can be useful, for example, in tracking user behavior and automating devices in communication with the user's bed.

[0166] The behavior analysis module **1700** can collect data from any technologically appropriate source, for example, to gather data about features of a bed, the bed's environment, and/or the bed's users. Some such sources include any of the sensors of the sensor array **406**. For example, this data can provide the behavior analysis module **1700** with information about the current state of the environment around the bed. For example, the behavior analysis module **1700** can access readings from the pressure sensor **902** to determine the pressure of an air chamber in the bed. From this reading, and potentially other data, user presence in the bed can be determined. In another example, the behavior analysis module can access a light sensor **908** to detect the amount of light in the bed's environment.

[0167] Similarly, the behavior analysis module **1700** can access data from cloud services. For example, the behavior analysis module **1700** can access the bed cloud service **410*a*** to access historical sensor data **1212** and/or advanced sleep data **1214**. Other cloud services **410**, including those not previously described can be accessed by the behavior analysis module **1700**. For example, the behavior analysis module **1700** can access a weather reporting service, a 3^{rd} party data provider (e.g., traffic and news data, emergency broadcast data, user travel data), and/or a clock and calendar service.

[0168] Similarly, the behavior analysis module **1700** can access data from non-sensor sources **1704**. For example, the behavior analysis module **1700** can access a local clock and calendar service (e.g., a component of the motherboard **402** or of the processor **502**).

[0169] The behavior analysis module **1700** can aggregate and prepare this data for use by one or more behavioral algorithms **1702**. The behavioral algorithms **1702** can be used to learn a user's behavior and/or to perform some action based on the state of the accessed data and/or the predicted user behavior. For example, the behavior algorithm **1702** can use available data (e.g., pressure sensor, non-sensor data, clock and calendar data) to create a model of when a user goes to bed every night. Later, the same or a different behavioral algorithm **1702** can be used to determine if an increase in air chamber pressure is likely to indicate a user going to bed and, if so, send some data to a third-party cloud service **410** and/or engage a peripheral controller **1002**.

[0170] In the example shown, the behavioral analysis module **1700** and the behavioral algorithm **1702** are shown as components of the motherboard **402**. However, other configurations are possible. For example, the same or a similar behavioral analysis module and/or behavior algorithm can be run in one or more cloud services, and the resulting output can be sent to the motherboard **402**, a controller in the controller array **408**, or to any other technologically appropriate recipient.

[0171] FIG. **18** shows an example of a computing device **1800** and an example of a mobile computing device that can be used to implement the techniques described here. The computing device **1800** is intended to represent various forms of digital computers, such as laptops, desktops, workstations, personal digital assistants, servers, blade servers, mainframes, and other appropriate computers. The mobile computing device is intended to represent various forms of mobile devices, such as personal digital assistants, cellular telephones, smart-phones, and other similar computing devices. The components shown here, their connections and relationships, and their functions, are meant to be exemplary only, and are not meant to limit implementations of the inventions described and/or claimed in this document.

[0172] The computing device **1800** includes a processor **1802**, a memory **1804**, a storage device **1806**, a high-speed interface **1808** connecting to the memory **1804** and multiple high-speed expansion ports **1810**, and a low-speed interface **1812** connecting to a low-speed expansion port **1814** and the storage device **1806**. Each of the processor **1802**, the memory **1804**, the storage device **1806**, the high-speed interface **1808**, the high-speed expansion ports **1810**, and the low-speed interface **1812**, are interconnected using various busses, and can be mounted on a common motherboard or in other manners as appropriate. The processor **1802** can process instructions for execution within the computing device **1800**, including instructions stored in the memory **1804** or on the storage device **1806** to display graphical information for a GUI on an external input/output device, such as a display **1816** coupled to the high-speed interface **1808**. In other implementations, multiple processors and/or multiple buses can be used, as appropriate, along with multiple memories and types of memory. Also, multiple computing devices can be connected, with each device providing portions of the necessary operations (e.g., as a server bank, a group of blade servers, or a multi-processor system).

[0173] The memory **1804** stores information within the computing device **1800**. In some implementations, the memory **1804** is a volatile memory unit or units. In some implementations, the memory **1804** is a non-volatile memory unit or units. The memory **1804** can also be another form of computer-readable medium, such as a magnetic or optical disk.

[0174] The storage device **1806** is capable of providing mass storage for the computing device **1800**. In some implementations, the storage device **1806** can be or contain a computer-readable medium, such as a floppy disk device, a hard disk device, an optical disk device, or a tape device, a flash memory or other similar solid state memory device, or an array of devices, including devices in a storage area network or other configurations. A computer program product can be tangibly embodied in an information carrier. The computer program product can also contain instructions that, when executed, perform one or more methods, such as those described above. The computer program product can also be tangibly embodied in a computer- or machine-readable medium, such as the memory **1804**, the storage device **1806**, or memory on the processor **1802**.

[0175] The high-speed interface **1808** manages bandwidth-intensive operations for the computing device **1800**, while the low-speed interface **1812** manages lower bandwidth-intensive operations. Such allocation of functions is exemplary only. In some implementations, the high-speed interface **1808** is coupled to the memory **1804**, the display **1816** (e.g., through a graphics processor or accelerator), and to the high-speed expansion ports **1810**, which can accept various expansion cards (not shown). In the implementation, the low-speed interface **1812** is coupled to the storage device **1806** and the low-speed expansion port **1814**. The low-speed expansion port **1814**, which can include various communication ports (e.g., USB, Bluetooth, Ethernet, wireless Ethernet) can be coupled to one or more input/output devices, such as a keyboard, a pointing device, a scanner, or a networking device such as a switch or router, e.g., through a network adapter.

[0176] The computing device **1800** can be implemented in a number of different forms, as shown in the figure. For example, it can be implemented as a standard server **1820**, or multiple times in a group of such servers. In addition, it can be implemented in a personal computer such as a laptop computer **1822**. It can also be implemented as part of a rack server system **1824**. Alternatively, components from the computing device **1800** can be combined with other components in a mobile device (not shown), such as a mobile computing device **1850**. Each of such devices can contain one or more of the computing device **1800** and the mobile computing device **1850**, and an entire system can be made up of multiple computing devices communicating with each other.

[0177] The mobile computing device **1850** includes a processor **1852**, a memory **1864**, an input/output device such as a display **1854**, a communication interface **1866**, and a transceiver **1868**, among other components. The mobile computing device **1850** can also be provided with a storage device, such as a micro-drive or other device, to provide additional storage. Each of the processor **1852**, the memory **1864**, the display **1854**, the communication interface **1866**, and the transceiver **1868**, are interconnected using various buses, and several of the components can be mounted on a common motherboard or in other manners as appropriate.

[0178] The processor **1852** can execute instructions within the mobile computing device **1850**, including instructions stored in the memory **1864**. The processor **1852** can be implemented as a chipset of chips that include separate and multiple analog and digital processors. The processor **1852** can provide, for example, for coordination of the other components of the mobile computing device **1850**, such as control of user interfaces, applications run by the mobile computing device **1850**, and wireless communication by the mobile computing device **1850**.

[0179] The processor **1852** can communicate with a user through a control interface **1858** and a display interface **1856** coupled to the display **1854**. The display **1854** can be, for example, a TFT (Thin-Film-Transistor Liquid Crystal Display) display or an OLED (Organic Light Emitting Diode) display, or other appropriate display technology. The display interface **1856** can comprise appropriate circuitry for driving the display **1854** to present graphical and other information to a user. The control interface **1858** can receive commands from a user and convert them for submission to the processor

1852. In addition, an external interface **1862** can provide communication with the processor **1852**, so as to enable near area communication of the mobile computing device **1850** with other devices. The external interface **1862** can provide, for example, for wired communication in some implementations, or for wireless communication in other implementations, and multiple interfaces can also be used.

[0180] The memory **1864** stores information within the mobile computing device **1850**. The memory **1864** can be implemented as one or more of a computer-readable medium or media, a volatile memory unit or units, or a non-volatile memory unit or units. An expansion memory **1874** can also be provided and connected to the mobile computing device **1850** through an expansion interface **1872**, which can include, for example, a SIMM (Single In Line Memory Module) card interface. The expansion memory **1874** can provide extra storage space for the mobile computing device **1850**, or can also store applications or other information for the mobile computing device **1850**. Specifically, the expansion memory **1874** can include instructions to carry out or supplement the processes described above, and can include secure information also. Thus, for example, the expansion memory **1874** can be provide as a security module for the mobile computing device **1850**, and can be programmed with instructions that permit secure use of the mobile computing device **1850**. In addition, secure applications can be provided via the SIMM cards, along with additional information, such as placing identifying information on the SIMM card in a non-hackable manner.

[0181] The memory can include, for example, flash memory and/or NVRAM memory (non-volatile random access memory), as discussed below. In some implementations, a computer program product is tangibly embodied in an information carrier. The computer program product contains instructions that, when executed, perform one or more methods, such as those described above. The computer program product can be a computer- or machine-readable medium, such as the memory **1864**, the expansion memory **1874**, or memory on the processor **1852**. In some implementations, the computer program product can be received in a propagated signal, for example, over the transceiver **1868** or the external interface **1862**.

[0182] The mobile computing device **1850** can communicate wirelessly through the communication interface **1866**, which can include digital signal processing circuitry where necessary. The communication interface **1866** can provide for communications under various modes or protocols, such as GSM voice calls (Global System for Mobile communications), SMS (Short Message Service), EMS (Enhanced Messaging Service), or MMS messaging (Multimedia Messaging Service), CDMA (code division multiple access), TDMA (time division multiple access), PDC (Personal Digital Cellular), WCDMA (Wideband Code Division Multiple Access), CDMA2000, or GPRS (General Packet Radio Service), among others. Such communication can occur, for example, through the transceiver **1868** using a radio-frequency. In addition, short-range communication can occur, such as using a Bluetooth, WiFi, or other such transceiver (not shown). In addition, a GPS (Global Positioning System) receiver module **1870** can provide additional navigation- and location-related wireless data to the mobile computing device **1850**, which can be used as appropriate by applications running on the mobile computing device **1850**.

[0183] The mobile computing device **1850** can also communicate audibly using an audio codec **1860**, which can receive spoken information from a user and convert it to usable digital information. The audio codec **1860** can likewise generate audible sound for a user, such as through a speaker, e.g., in a handset of the mobile computing device **1850**. Such sound can include sound from voice telephone calls, can include recorded sound (e.g., voice messages, music files, etc.) and can also include sound generated by applications operating on the mobile computing device **1850**.

[0184] The mobile computing device **1850** can be implemented in a number of different forms, as shown in the figure. For example, it can be implemented as a cellular telephone **1880**. It can also be implemented as part of a smart-phone **1882**, personal digital assistant, or other similar mobile device.

[0185] Various implementations of the systems and techniques described here can be realized in digital electronic circuitry, integrated circuitry, specially designed ASICs (application specific integrated circuits), computer hardware, firmware, software, and/or combinations thereof. These various implementations can include implementation in one or more computer programs that are executable and/or interpretable on a programmable system including at least one programmable processor, which can be special or general purpose, coupled to receive data and instructions from, and to transmit data and instructions to, a storage system, at least one input device, and at least one output device.

[0186] These computer programs (also known as programs, software, software applications or code) include machine instructions for a programmable processor, and can be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the terms machine-readable medium and computer-readable medium refer to any computer program product, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal. The term machine-readable signal refers to any signal used to provide machine instructions and/or data to a programmable processor.

[0187] To provide for interaction with a user, the systems and techniques described here can be implemented on a computer having a display device (e.g., a CRT (cathode ray tube) or LCD (liquid crystal display) monitor) for displaying information to the user and a keyboard and a pointing device (e.g., a mouse or a trackball) by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback (e.g., visual feedback, auditory feedback, or tactile feedback); and input from the user can be received in any form, including acoustic, speech, or tactile input.

[0188] The systems and techniques described here can be implemented in a computing system that includes a back end component (e.g., as a data server), or that includes a middleware component (e.g., an application server), or that includes a front end component (e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the systems and techniques described here), or any combination of such back end, middleware, or front end components. The components of the system can be interconnected by any form or medium of digital data communication (e.g., a communication network). Examples of communication networks include a local area network (LAN), a wide area network (WAN), and the Internet.

[0189] The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

[0190] FIG. **19** is a swimlane diagram of an example process **1900** for responding to low quality sleep of a user. For clarity, the process **1900** is being described with reference to components of the data processing system **400**. However, other system or systems can be used to perform the same or a similar process.

[0191] In the process **1900**, a user is sleeping a bed equipped with a data processing system such as those described in this document. The user's bed is in the user's bedroom, which is equipped with a number of sensors and automated devices. These include a lamp with a light sensor connected to the data processing system and window blinds that can be opened and closed by the data processing system. Further, the user's cellular phone is in communication with the data processing system. Unbeknownst to the user in the process **1900**, lights outside the user's window occasionally come on. These lights partially illuminate the user's bedroom and disturb the user's sleep without waking the user fully awake. To correct for this, the user's bed is able to identify these periods of restlessness, identify the problem with the illumination, and take a corrective action that will result in better sleep for the user.

[0192] The process **1900** can begin, for example, when cloud services **410** send **1902** sleep data to a receiving **1904** motherboard **402**. For example, cloud services **410** such as the user account cloud **410***c* and/or sleep data cloud **410***b* can track the user's sleep data reported by the motherboard **402**. Once enough data is collected, or on a different schedule (e.g., once a week or when computing resources are not otherwise assigned), the motherboard **402** can retrieve this sleep data that contains historical sleep metrics that represent a sleep quality of a user while the user was sleeping in a bed. For example, the sleep data may include biological readings (e.g., heartrate, breathing, and movement), aggregate readings (e.g., sleep quality on a numeric scale) or other appropriate metrics.

[0193] The motherboard **402** can identify **1906** periods of poor sleep quality. For example, the metrics may include a sleep quality values along with associated timestamps, and the motherboard **402** can identify incidences of low sleep quality values and their associated time stamps. Examples of user behavior that can be indicative low sleep quality include, but are not limited to, excessive motion, increased heart rate, and an increase in respiration rate.

[0194] The cloud services **410** can send **1908** sensor data to the motherboard **402** and the motherboard **402** can receive **1910** the sensor data. For example, in order to identify environmental factors that might be causing the periods of low sleep quality, the motherboard **402** can request historical sensor data that describes the environment the user is sleeping in during these periods. This historical sensor data may be stored in, and served by, the bed data cloud **410***a*, the sleep data cloud **410***b*, the environment cloud **1600**, and/or other cloud services.

[0195] With this data, the motherboard **402** can compare **1912** the sensor data during periods of poor sleep against periods of better sleep. As has been previously described, the user's sleep is being disturbed by a light outside the window. This environmental phenomenon may be embodied in the sensor data received from, for example, a light sensor **902** on the user's lamp and a light sensor on the user's cellular phone **904**. As such, the motherboard **402** may determine that in periods of poor sleep, the light sensor **902** may be reporting greater levels of illumination and the cellular phone **904** may be reporting a change in the color of illumination.

[0196] This determination may be made by the motherboard **402** without any specific user input and/or without the user's knowledge. For example, the motherboard **402** may routinely perform these kinds of comparisons to identify opportunities for improved user sleep. If no such opportunities are found, the motherboard **402** need not report anything to the user. As will be shown below, when this opportunity is found, the result may or may not be reported to the user and/or the system may make adjustments without needing user input.

[0197] The motherboard **402** can create **1914** a corrective plan to improve the user's sleep quality. In this example, the motherboard **402** may determine that a cause of the user's sleep quality problems is the illumination in the user's environment. The motherboard **402** may examine, for example, historical records of the illumination devices controlled by the motherboard **402** to determine if these devices are the cause of the problematic illumination. For example, the motherboard **402** can access these historical records from local memory (e.g., computer memory **512**) and/or from cloud services (e.g., bed data cloud **410***a*).

[0198] In this case, the motherboard **402** does not determine that the devices are causing the problematic illumination. However, the motherboard **402** may determine that the user's window blinds are open at night, allowing light to enter the user's environment. As such, the motherboard can create a corrective plan that includes computer-operable instructions to 1) close the blinds when the user falls asleep, 2) close the blinds when sensed illumination increases above a threshold value, 3) closes the blinds when the user's sleep quality falls below a threshold, and/or 4) closes the blinds at times of the day when the lights have historically illuminated the user's environment. For example, the corrective plan can include a file (e.g., an XML, file or other structured file format) containing computer-readable data (e.g., binary, ASCII characters) with instructions to perform one or all of the described remedies.

[0199] Additionally or alternatively, the corrective plan can include human-readable text generated to describe to the user 1) that they are experiencing low-quality sleep, 2) the identified cause of the low quality sleep (i.e., the illumination), 3) steps the user can take to improve their sleep (e.g., closing the blinds themselves, moving their bed away from the window), and/or 4) a description of the computer-readable instructions that will be used by the motherboard **402** to automate the user's devices to improve the user's sleep.

[0200] This report can be communicated to the user through any technologically appropriate scheme. For example, an application or web-browser on the users cellular phone may show the report, the report may be emailed to the user's email address, or the report can be added to a daily report given to the user upon waking (e.g., such a report may also include the day's weather prediction, traffic warnings, and/or calendar agenda).

[0201] The motherboard **402** can report **1916** the corrective plan to a receiving **1918** cloud service **410**. For example, the motherboard **402** may transmit the report, or elements (e.g., just the computer-readable elements) to a cloud service **410** such as the bed data cloud **410***a* and/or the sleep data cloud **410***b*. This report may then be analyzed and/or made available for further analysis. For example, if the user shares the bed with another user, or if there is another user in a different room of the same house, the sleep data cloud **410***b* can analyze the other user's sleep history to determine if the other user has experienced low quality sleep at the same time and if the other user is likely to benefit from corrective plan. Additionally, the corrective plan may be made available by the cloud services **410** if, for example, the user replaces their current bed with a new bed having a new data processing system.

[0202] Going forward, the motherboard **402** may operate with the corrective plan in place. For example, if the corrective plan calls for closing the blinds at a particular time or in response to a detection that the user is asleep, the motherboard **402** may close the blinds at the designated time. Described here is a case in which the user prefers to fall asleep with soft under-bed lighting lit and the blinds open.

[0203] The lamp-mounted light sensor and the cellular phone based light sensor **904** can sense light levels **1920** and **1922**, and report these light levels to the motherboard. For example, the lamp mounted light sensor **902** may be in generally constant communication with the motherboard, and the cellular phone may report light readings when the cellular phone is connected to the same WiFi network as the motherboard **402**. When the user goes to sleep, having the blinds open and the under-bed lighting lit, the light levels reported by the light sensors **902** and **904** to the motherboard **402** may be below the threshold at which the corrective plan indicates poor sleep by the user.

[0204] Later, the light outside of the user's window may come on, and the sensors **902** and **904** may report the increased illumination and change in illumination color to the motherboard **402**. The motherboard **402** may then identify **1924** that the lighting threshold value has been crossed. In order to control **1926** the lighting in the room, the motherboard **1926** may take one or more corrective actions. In this example, the motherboard **402** may issue a command to an environmental control system, such as the peripheral controller **1002** to close the blinds, and another command to the same or a different environmental control system, such as a lighting controller (not shown) to turn off or turn down the under-bed lighting. In general environmental control systems may include one or more of the peripheral controllers **1000-1006** and/or any other technologically appropriate device that can receive commands to affect the environment in which a user is sleeping.

[0205] While a particular number, type, and order of operations have been shown, it will be understood that different numbers, types, and orders of operations may be used. For example, after the system has been configured to use the corrective plan, the user may add or remove one or more peripheral controller or sensor to the system. In the case of a new light sensor being added, this new light sensor may be included in the identification **1924** of illumination levels that can cause low quality sleep. In another case of a new automated lighting system being added, the corrective plan can be updated include instructions to, or responded to by the motherboard **402**, by turning off the new lighting system.

[0206] In some cases, more or less data may be communicated to the cloud services **410**. For example, the sleep data **1902** and sensor data **1908** may be stored by the motherboard **402** and/or the corrective plan **1918** may never need be reported to the cloud services **410**. In some cases, this may support the use of beds that are completely separated from the Internet and not able to access any cloud services.

[0207] FIG. **20** is a swimlane diagram of an example process **2000** for responding to low quality sleep of a user. For clarity, the process **2000** is being described with reference to components of the data processing system **400**. However, other system or systems can be used to perform the same or a similar process.

[0208] In the process **2000**, the user of a bed is experiencing reduced sleep quality due to snoring. For some users, snoring may be reduced or eliminated by elevating the user's head. Additionally, many users are not aware of the duration and intensity of their snoring, as it occurs when they are sleep. The process **2000** includes both a response by the automated bed to elevate the users head, as well as a report to the user informing the user of their snoring issue. The user may then respond to this notification as appropriate, including but not limited to changing their sleeping habits and/or seeking medical advice related to their snoring.

[0209] The process **2000** can begin, for example, when cloud services **410** send **2002** sleep data to a receiving **2004** motherboard **402**. For example, cloud services **410** such as the user account cloud **410***c* and/or sleep data cloud **410***b* can track the user's sleep data reported by the motherboard **402**. Once enough data is collected, or on a different schedule (e.g., once a week or when computing resources are not otherwise assigned), the motherboard **402** can retrieve this sleep data that contains historical sleep metrics that represent a sleep quality of a user while the user was sleeping in a bed. For example, the sleep data may include biological readings (e.g., heartrate, breathing, and movement), aggregate readings (e.g., sleep quality on a numeric scale) or other appropriate metrics.

[0210] The motherboard **402** can identify **2006** periods of poor sleep quality. For example, the metrics may include a sleep quality values along with associated timestamps, and the motherboard **402** can identify incidences of low sleep quality values and their associated time stamps.

[0211] The cloud services **410** can send **2008** sensor data to the motherboard **402** and the motherboard **402** can receive **2010** the sensor data. For example, in order to identify environmental factors that might be causing the periods of low sleep quality, the motherboard **402** can request historical sensor data that describes the environment the user is sleeping in during these periods. This historical sensor data may be stored in, and served by, the bed data cloud **410***a*, the sleep data cloud **410***b*, the environment cloud **1600**, and/or other cloud services.

[0212] With this data, the motherboard **402** can compare **2012** the sensor data during periods of poor sleep against periods of better sleep. As has been previously described, the user's sleep is being disturbed by a periods of heavy snoring. This phenomenon may be embodied in the sensor data received from, for example, sound sensor **902** on the user's cellular phone. As such, the motherboard **402** may determine that in periods of poor sleep, the sound sensor **902** may be reporting sound data that is consistent with the sound of the user snoring. For example, if the motherboard **402** detects low frequency sound of frequency of approximately 500 hz, the motherboard **402** can identify that sound as user snoring.

[0213] This determination may be made by the motherboard **402** without any specific user input and/or without the user's knowledge. For example, the motherboard **402** may routinely perform these kinds of comparisons to identify opportunities for improved user sleep. If no such opportunities are found, the motherboard **402** need not report anything to the user. As will be shown below, when this opportunity is found, the result may or may not be reported to the user and/or the system may make adjustments without needing user input.

[0214] The motherboard **402** can create **2014** a corrective plan to improve the user's sleep quality. In this example, the motherboard **402** may determine that a cause of the user's sleep quality problems is the user's snoring. The motherboard **402** may examine, for example, historical records of the pump controller **504** and the sound sensor **902** to identify that when the user is present in bed—based on pressure readings from the pump controller **504**—and when the sound of snoring is detected—based on input from the sound sensor **902**—the user is experiencing reduced sleep quality.

[0215] As such, the motherboard **402** can create a corrective plan that includes computer-operable instructions to elevate the head portion of the bed's foundation when the user is detected in bed and sleep. In one alternative, the motherboard **402** can create a corrective plan that includes computer-operable instructions to elevate the head portion when the user is detect in bed, asleep, and generating sounds constant with snoring. For example, the corrective plan can include a file (e.g., an XML, file or other structured file format) containing computer-readable data (e.g., binary, ASCII characters) with instructions to perform one or all of the described remedies.

[0216] Additionally or alternatively, the corrective plan can include human-readable text generated to describe to the user 1) that they are experiencing low-quality sleep, 2) the identified cause of the low quality sleep (i.e., snoring), 3) steps the user can take to improve their sleep (e.g., sleeping with an elevated head, seeking medical advice), and/or 4) a description of the computer-readable instructions that will be used by the motherboard **402** to automate the user's devices to improve the user's sleep.

[0217] This report can be communicated to the user through any technologically appropriate scheme. For example, an application or web-browser on the users cellular phone may show the report, the report may be emailed to the user's email address, or the report can be added to a daily report given to the user upon waking (e.g., such a report may also include the day's weather prediction, traffic warnings, and/or calendar agenda).

[0218] The motherboard **402** can report **2016** the corrective plan to a receiving **2018** cloud service **410**. For example, the motherboard **402** may transmit the report, or elements (e.g., just the computer-readable elements) to a cloud service **410** such as the bed data cloud **410*a*** and/or the sleep data cloud **410*b***. This report may then be analyzed and/or made available for further analysis. For example, if the user shares the bed with another user the sleep data cloud **410*b*** can analyze the other user's sleep history to determine if the other user has experienced low quality sleep when the first user is snoring. Additionally, the corrective plan may be made available by the cloud services **410** if, for example, the user replaces their current bed with a new bed having a new data processing system.

[0219] Going forward, the motherboard **402** may operate with the corrective plan in place. For example, if the corrective plan calls for elevating the head portion of the bed's foundation when the user is in the bed and asleep, the motherboard **402** may elevate the head portion of the foundation when these conditions are met.

[0220] The pump controller **504** can sense user presence **2020** and report to the motherboard **402**. For example, the pump controller **504** may have one or more pressure sensors that read when pressure in the bed increased, for example from a user laying in the bed. The pump controller **504** can then report these presence events to the motherboard **402**. Additionally or alternatively, the pump controller **504** can report the pressure readings to the motherboard **402**, and the motherboard **402** can determine if those readings indicate the user is present in the bed. In addition to presence, other phenomena may be sensed by the pump controller **504**. For example, the pump controller **504** may sense pressure changes due to user breathing and/or heartbeat. These readings may be used to, for example, determine if the user is asleep, and determine the sleep state or quality of sleep that the user is experiencing.

[0221] Similarly, the sound sensor **902** can sense **2022** sound in the user's environment and report that reading to the motherboard **402**. Using this reading, the motherboard **402** (or other technologically appropriate element) can examine the sound reading to detect user snoring.

[0222] If the motherboard **402** identifies **2024** that the user is in the bed, asleep, and if snoring sounds are detected when the bed's foundation is flat, the motherboard may react according to the corrective plan. In this case, the motherboard **402** can engage the peripheral controller **1002** that controls the bed's foundation to control **2026** the foundation and elevate the bed's head component. By doing so, the motherboard **402** may thus elevate the user's head, reducing or eliminating the user's snoring or the effects of the snoring.

[0223] While a particular number, type, and order of operations have been shown, it will be understood that different numbers, types, and orders of operations may be used. For example, in a bed without an articulated foundation, other peripheral controllers or other output devices may be engaged in an attempt to alleviate the user's snoring. For example, the firmness of the mattress may be changed to encourage the user to roll and/or a humidifier may be engaged to increase the humidity in the user's environment, and/or the foundation may move through a series of positions and elevations in an attempt to find a position that stops the snoring.

[0224] In some cases, more or less data may be communicated to the cloud services **410**. For example, the sleep data **2002** and sensor data **2008** may be stored by the motherboard **402** and/or the corrective plan **2018** may never need be reported to the cloud services **410**. In some cases, this may support the use of beds that are completely separated from the Internet and not able to access any cloud services.

[0225] In some cases, two users may share a bed and only one of the two users may snore. In such a case, the motherboard **402** can detect which of the two users is snoring and apply the corrective plan only to that user. In one configuration, each of the two users has a cellar phone that they plug in to charge on a nightstand on each of their respective sides of the bed. This configuration creates a system in which there are two sound sensors, each closer to one user and farther from the other. To determine which user is the one that is snoring, the motherboard may compare the magnitude of the sound readings from the two cellular phones to determine which is greater. Then, the motherboard **402** may determine the user with the cellular phone reporting louder snoring is the user that is snoring. Additionally or alternatively, the motherboard **402** may compare the sound input to the pressure readings from the pump controller **504**. As snoring is caused by user breathing, the motherboard **402** can examine the pressure readings and the sound readings to identify snoring sounds and breathing-based pressure changes that are occur with the same frequency. The motherboard **402** may then determine that the user whose breathing matches the snoring is the user that is snoring. In such as case, the motherboard **402** may apply the corrective action only to the user that is snoring and not to the other user.

[0226] Example Foot Warming System

[0227] FIG. **21** is a perspective view of an example bed **2100** having a foot warming system **2102**. The bed **2100** can have a foundation **2104** and a mattress **2106** supported by the foundation **2104**. In some embodiments, the bed **2100** can be an air bed system such as the air bed system **100** shown in FIG. **1** and having one, more than one, or all of the features described above with respect to FIGS. **1-20**. In other embodiments, the bed **2100** can be another type of bed suitable for the application, such as a bed having foam and/or springs without inflatable air chambers. In some embodiments, the foundation **2104** can be an articulable foundation. In other embodiments, the foundation **2104** need not be articulable. In some embodiments, the bed **2100** need not include any foundation at all.

[0228] In the embodiment shown in FIG. **21**, the mattress **2106** includes a support structure **2108** and a cover **2110** configured to cover the support structure **2108**. The cover **2110** has a top portion **2112** positioned on a top of the support structure **2108**, side portions **2114** extending around the outside of the support structure **2108**, and a bottom portion (not shown) so as to substantially enclose the support structure **2108**. The support structure **2108** is configured to support a user sleeping or otherwise resting on the mattress **2106**, and can include foam, springs, inflatable air chambers, and/or one or more other suitable mattress components. The cover **2110** can also include an additional padding layer **2116** at the top portion **2112**, such as a pillow top layer, a ticking layer, and/or other material suitable for the application.

[0229] The mattress **2106** can include a head **2120** and a foot **2122**. The foot warming system **2102** can be positioned at or near the foot **2122** of the mattress **2106** in a location configured for warming feet of a user laying on the mattress **2106**. As shown in FIG. **21**, the foot warming system **2102** can include one or more heating units **2124** and **2126**, envelopes **2128** and **2130**, electrical connectors **2132** and **2134** (such as one or more cables or wires), and one or more power sources (shown in FIG. **27**). In some embodiments, the power source can be a pump controller (such as control box **124** shown in FIGS. **1** and **2**) or an articulation controller (such as for controlling articulation of an adjustable base). In other embodiments, the power source can be another controller or power source suitable for the application.

[0230] The heating units **2124** and **2126** can be positioned inside the mattress **2106**. In some embodiments, the heating units **2124** and **2126** can comprise an electrically conductive fabric, such as a carbon-filled polymer material, for generating heat. In other embodiments, the heating units **2124** and **2126** can comprise another electrical assembly suitable for the application, such as resistance wiring and fabrics. The heating units **2124** and **2126** can be positioned inside the mattress cover **2110** and on top of the support structure **2108** so as to be between the support structure **2108** and the mattress cover **2110**. The electrically conductive fabric can be relatively flexible and can heat relatively evenly, to provide a positive foot warming experience for the user with little to no adverse impact on the softness and overall comfort of the mattress **2106**.

[0231] In some embodiments, the heating units **2124** and **2126** can be attached to the support structure **2108**. For example, FIG. **21** shows the heating unit **2124** attached to the support structure **2108** via the envelope **2128**. The heating unit **2124** can be positioned inside the envelope **2128**, which can be affixed to a top of the support structure **2108** via adhesive, thread, or another mechanism suitable for the application.

[0232] In the illustrated example, the heating unit **2124** is removably attached to the support structure because it is removably inserted into the envelope **2128**. For example, the heating unit **2126** is shown removed from its corresponding envelope **2130**. Accordingly, the envelopes **2128** and **2130** allow for the heating units **2124** and **2126** to be held in place with respect to the mattress **2106** while also being removable for repair or replacement.

[0233] In some embodiments, the envelopes **2128** and **2130** can be omitted. For example, in some embodiments the heating units **2124** and **2126** can be affixed to the support structure **2108** without the envelopes **2128** and **2130**. In other embodiments, the heating units **2124** and **2126** can be attached to the cover **2110**, the fire resistant cap **2136**, or other layer inside the mattress **2106**. Such attachments can be via adhesive, stitching, or other fastening mechanism suitable for the application.

[0234] While FIG. **21** shows the mattress **2106** with the cover **2110** partially removed to show internal components, the cover **2110** would be closed during normal operation of the mattress **2106**, substantially concealing the foot warming system **2102**.

[0235] The power source can be electrically connected to the heating units **2124** and **2126** so as to selectively drive (or power) the heating units **2124** and **2126** to heat the mattress **2106** at or near the foot **2122** of the mattress **2106**. This can warm the mattress **2106** at a user's feet, for example, to improve comfort and/or help induce sleep more rapidly.

[0236] FIG. **22** is a schematic end view of the mattress **2106** and the foot warming system **2102**. FIG. **23** is a schematic side view of the mattress **2106** and the foot warming system **2102**. As shown in FIGS. **22** and **23**, the mattress **2106** can include a fire resistant cap **2136** positioned inside the cover **2110**. The fire resistant cap **2136** can cover internal components of the mattress, including the support structure **2108** and components of the foot warming system **2102** (including the envelopes **2128** and **2130** and the heating units **2124** positioned therein.). In some embodiments, the fire resistant cap **2136** can include a 4 ounce jersey knit material. In other embodiments, the fire resistant cap **2136** can include one or more other materials suitable for the application. In still other embodiments, the fire resistant cap **2136** can be omitted.

[0237] FIG. **22** also shows an embodiment with the support structure **2108** including foam **2138** and air chambers **2140** and **2142**. In the embodiment shown, the foam **2138** is an upside-down foam tub covering the air chambers **2140** and **2142**. The air chambers **2140** and **2142** are adjustably inflatable air chambers each sized for supporting first and second users respectively, and can be the same as or similar to the air chambers **114**A and **114**B described above. The envelopes **2128** and **2130** can be adhered or otherwise attached to the foam **2138**, with the heating units **2124** and **2126** positioned inside.

[0238] FIGS. **22** and **23** also show an example embodiment of positioning of the electrical connectors **2132** and **2134**. As shown in FIG. **22**, the electrical connectors **2132** and **2134** include wires extending along the sides of the mattress **2106**, partially through the foam **2138**. The foam **2138** can define pathways allowing the electrical connectors **2132** to be routed through. In one embodiment, the electrical connector **2132** can be routed through a slit in cut in the foam **2138**. In another embodiment, the electrical connector **2132** can be routed through a hole bored through the foam **2138**. The electrical connectors **2132** and **2134** can terminate at connector ends **2144** and **2146**, which can connect to one or more power sources (not shown in FIGS. **22** and **23**) for powering the heating units **2124** and **2126**.

[0239] FIG. **23** shows the connector **2134** from a side view, extending from the envelope **2130** (with the heating unit **2126** positioned inside) near the foot **2122** of the mattress **2106** to the connector end **2146** positioned near a longitudinal center of the mattress **2106**. By positioning the connector end **2146** near the longitudinal center of the mattress **2106**, the mattress **2106** can be used with adjustable foundations to raise and lower the head **2120** and foot **2122** of the mattress **2106** while allowing the connector end **2146** to remain relatively stationary during articulation. This can allow the heating units **2124** and **2126** to be raised and lowered with the mattress **2106** while being connected to and powered by a power source that is relatively stationary during articulation.

[0240] FIGS. **24**A-**24**C are top perspective views of a portion of the foot warming system **2102**, including the heating unit **2124** and the envelope **2128**. In some embodiments, the envelope **2128** can include an envelope top **2148** and an envelope bottom **2150**. The envelope top **2148** can be attached to the envelope bottom **2150** around substantially all of their perimeters except for a portion to define an opening **2152**. The opening **2152** can allow for insertion and removal of the heating unit **2124**. In some embodiments, the opening **2152** can be sized smaller than the heating unit **2124**. The heating unit **2124** can comprise an electrically conductive fabric that is flexible so as to allow the heating unit **2124** to be compressed to fit through the opening **2152** and then expanded to lay flat within the envelope **2128**. In some embodiments, the opening **2152** can remain open while in other embodiments the opening **2152** can be closed. For example, the envelope **2128** can include a closure mechanism, such as a zipper, hook-and-loop fasteners (commonly called "VELCRO" after the VELCRO brand fasteners), or other suitable mechanism, to partially or totally close the opening **2152** such that the heating unit **2124** can be encapsulated inside. In other embodiments, the opening **2152** can be omitted and the heating unit **2124** can instead be sealed inside the envelope **2128** substantially permanently.

[0241] FIG. **24**A shows the heating unit **2124** being inserted through the opening **2152**. FIG. **24**B shows the heating unit **2124** positioned inside the envelope **2128** and laying substantially flat. FIG. **24**C shows the fire resistant cap **2136** in the process of being draped over the envelope **2128** and the heating unit **2124**.

[0242] In some embodiments, both the fire resistant cap **2136** and the envelope **2128** can include fire resistant material. For example, in some embodiments both the envelope top **2148** and the envelope bottom **2150** can include fire resistant material. In such embodiments, the envelope **2128** can provide fire protection from both the top and the bottom. In other embodiments, the envelope bottom **2150** can include fire resistant material while the envelope top **2148** can omit fire resistant material. For example, the envelope top **2148** can be a breathable mesh with little or no fire resistance. In such embodiments, the fire resistant cap **2136** can be relied on to provide fire protection from the top and the envelope bottom **2150** can be relied on to provide fire protection from the bottom. In some embodiments, the envelope **2128** can include fire resistant material and the fire resistant cap **2136** can be omitted.

[0243] FIGS. **25**A and **25**B are top perspective views of envelopes **2528** and **2530**. In the embodiment shown, the envelopes **2528** and **2530** are similar to the envelopes **2128** and **2130** shown in FIGS. **21**-**24**C, except that the envelopes **2528** and **2530** include attachment mechanism **2560**. The attachment mechanism **2560** can connect the envelope **2528** to the envelop **2530** along respective edges thereof. In such embodiments, the attachment mechanism **2560** can help hold each of the envelopes **2528** and **2530** in place, by allowing each to support the other. In some of such embodiments, the electrical connectors **2132** and **2134** can be positioned to provide further support for holding the envelopes **2528** and **2530** in place in conjunction with the attachment mechanism **2560**. In some of such embodiments, the envelopes **2528** and **2530** can be held in place without attaching the envelopes **2528** and **2530** directly to the support structure **2108**.

[0244] In some embodiments, the attachment mechanism **2560** can include hook-and-loop fasteners (commonly called "VELCRO" after the VELCRO brand fasteners). In other embodiments, the attachment mechanism can be another mechanism suitable for the application.

[0245] FIG. **26** is a perspective view of a bottom of the envelope **2128**, showing an adhesive backing **2662**. The adhesive backing **2662** can adhere the envelope **2128** to the support structure **2108** or cover **2110** of the mattress **2106**. In some embodiments, the adhesive backing **2662** can cover all or substantially all of one side of the envelope **2128**. In other embodiments, the adhesive backing **2662** can cover less than all of one side of the envelope **2128**. For example, in one embodiment the adhesive backing **2662** can be positioned in four corners of the envelope **2128**, with space in-between. In such embodiments, the envelope **2128** can be adhered, for example, to the support structure **2108** of the mattress **2106** only at corners of the envelope **2128**.

[0246] FIG. **27** is a top view of components of the foot warming system **2102**. In the embodiment shown in FIG. **27**, the heating unit **2124** includes electrically conductive fabric heating elements (heating elements **2764**, **2766**, **2768**, and **2770**), bus bars **2772** and **2774**, reinforcing tape **2776** and **2778**, temperature sensor **2780**, wires **2782**, **2784**, and **2786**, and bonding film **2788**. The connector **2132** can be a wire harness that includes the wires **2782**, **2784**, and **2786**. The wire **2782** electrically connects the bus bar **2772** to a controller (power source) **2790** and the wire **2786** electrically connects the bus bar **2774** to the controller **2790**. The wire **2784** electrically connects the temperature sensor **2780** to the controller **2790**, which can receive temperature signals from the temperature sensor **2780** and power the heating unit **2124** as a function of the received temperature signals. While only one wire **2784** is shown connecting to the temperature sensor **2780**, multiple wires can be used. In some embodiments, the controller **2790** can be a pump controller (such as control box **124** shown in FIGS. **1** and **2**) or an articulation controller (such as for controlling articulation of an adjustable base). In some of such embodiments, the controller **2790** can perform none, some, or all of the functions described above with respect to those controllers. In other embodiments, the controller **2790** can be another controller or power source suitable for the application. For example, the controller **2790** can be a controller dedicated to operating the foot warming system **2102** alone, or operating the foot warming system **2102** in conjunction with one or more other systems.

[0247] In some embodiments, multiple electrically conductive fabric heating elements can extend from bus bar **2772** to bus bar **2774**. In the illustrated embodiment, four separate fabric heating elements (the heating elements **2764**, **2766**, **2768**, and **2770**) are included. Gaps are shown spacing adjacent ones of the heating elements **2764**, **2766**, **2768**, and **2770**. In some embodiments, gaps between adjacent ones of the heating elements **2764**, **2766**, **2768**, and **2770** can be about 0.5 inch. In some embodiments, gaps between adjacent ones of the heating elements **2764**, **2766**, **2768**, and **2770** can be between 0.2 inch and 0.8 inch. In other embodiment, more or fewer heating elements can be used.

[0248] In some embodiments, the heating elements **2764**, **2766**, **2768**, and **2770** can comprise carbon-based electrically conductive fabric, which can conduct electricity between the bus bars **2772** and **2774** and which has a suitable resistance to generate heat. The heating elements **2764**, **2766**, **2768**, and **2770** can operate at relatively low power and heat relatively uniformly, thus warming a mattress with reduced risk of fire. For example, in some embodiments the power for the heating unit **2124** can be about 0.085-0.095 W/inch^2.

[0249] In some embodiments, the bus bars **2772** and **2774** can be tinned copper bus wires having a relatively thin diameter so as to allow for repeated bending when the mattress is in use. In some of such embodiments, the bus bars **2772** and **2774** can comprise wire braids. In other embodiments, the bus bars **2772** and **2774** can comprise conductive ink. In other embodiments, the bus bars **2772** and **2774** can have a different configuration as suitable for the application.

[0250] The temperature sensor **2780** can sense temperature at and around the heating unit **2124**, to provide feedback to the controller **2790** for powering the heating unit **2124**. In some embodiments, the temperature sensor **2780** can be placed proximate the heating element **2770**. In some of such embodiments, the temperature sensor **2780** can be proximate to but slightly spaced from the heating element **2770** via a layer of material, such as a layer of polyimide film. In various embodiments, the temperature sensor **2780** can be a thermistor, a thermocouple, or another suitable temperature sensor.

[0251] The reinforcing tape **2776** and **2778** can be placed along edges of the heating elements **2764**, **2766**, **2768**, and **2770** and the bus bars **2772** and **2774** to reinforce the heating unit **2124**. The bonding film **2788** can include top and bottom layers of film that enclose the heating elements **2764**, **2766**, **2768**, and **2770**, the bus bars **2772** and **2774**, the reinforcing tape **2776** and **2778**, the temperature sensor **2780**, and part of the wires **2782**, **2784**, and **2786**. The bonding film **2788** can protect components contained therein from moisture and tampering. In some examples, the bonding film **2788** can be polyurethane or another polymer material suitable to encase the flexible heating elements **2764**, **2766**, **2768**, and **2770**.

[0252] The heating unit **2124** can be a relatively thin layer sized and configured for being positioned inside a mattress for warming feet of a user of the mattress. In some embodiments, the heating unit **2124** can be sized and positioned for heating only a limited portion of the mattress including the feet of the user but not the head and torso of the user. In some embodiments, the heating unit **2124** can have a width of between 21 inches and 31 inches and a depth of between 10 inches and 20 inches. In some embodiments, the heating unit **2124** can have a width of between 25 inches and 28 inches and a depth of between 14 inches and 18 inches. In other embodiments, the size and position of the heating unit **2124** can be varied as suitable for the application.

[0253] In operation, the controller **2790** can selectively power the heating unit **2124** (and/or the heating unit **2126**) to generate heat and warm the mattress **2106**. The foot warming system **2102** can be controlled automatically, via inputs from a user interface (such as a mobile device or other remote control), or both. Automatic control can be performed as a function of a number of sensed events, such as the user entering or leaving the bed and/or the user falling asleep or waking.

[0254] The controller **2790** can have intelligence to allow for benefits such as pre-heating, timed shut off, temperature regulation via the temperature sensor **2780**, or other features that may enhance the user experience.

[0255] For example, the foot warming system **2102** can be controlled as a function of when the user goes to sleep. In one example, the user can identify an earliest time that they go to sleep. The controller **2790** can then drive the heating unit **2124** to warm for a predetermined time prior to this sleep time (e.g., 30 minutes) so that the mattress **2106** is warm when the user enters the mattress **2106**.

[0256] In another example, the foot warming system **2102** may be turned on via an instruction from the user through a user interface indicating the intent of user going to bed. Upon the user entering the mattress **2106**, the foot warming system **2102** can shut off automatically based on sensing the user entered in the mattress **2106**, or can continue to run for a given amount of time. In another example, the foot warming system **2102** can run until the user falls asleep as determined by one or more sensors.

[0257] During this operation, the warming system **2102** can maintain a constant temp level or adjust to a preset level in response to one or more timed or sensed events. The foot warming system **2102** can operate at different power levels as appropriate for the situation. For example, the foot warming system **2102** can operate a high power level in order to initially heat the mattress **2106** quickly, and then to operate at a lower power to maintain a target temperature, such as operating via pulse wave modulation.

[0258] In another example, the controller **2790** can determine an expected bed time for a user of the bed. This determination can be made as a function of user inputs regarding bed time. Alternatively, this determination can be made automatically by the controller **2790** as a function of a learned sleep schedule that is based on sensed data of the user historically entering bed night after night. Based on this information, the controller **2790** can drive the foot warming system **2102** to heat the foot of the mattress **2106** to reach a target temperature prior to the expected bed time.

[0259] In some of such applications, the controller **2790** can reduce power upon a sensor detecting the user enters the mattress **2106**. For example, the controller **2790** can cut power immediately such that the foot warming system **2102** only warms before the user enters the bed. Alternatively, the controller **2790** could slowly reduce power or reduce power after a given time period after the user enters the mattress **2106**.

[0260] In another example, the controller **2790** can determine whether the user is asleep as a function of sensed data and then drive the foot warming system **2102** as a function of whether the user is determined to be asleep. For example, the foot warming system **2102** can be driven until the user falls asleep and shut off in response to determining that the user is asleep based on sensed data.

[0261] In another example, the controller **2790** can drive the foot warming system **2102** automatically in order to improve sleep quality. For example, the controller **2790** can access historical sleep metrics that represent sleep quality of a user while the user was sleeping in the bed and/or access historical sensor data that represent sensor readings that measure environmental conditions affecting the user while the user was sleeping in the bed, such as sensed temperature. The controller **2790** can identify in the historical sleep metrics incidences of low quality sleep experienced by the user and incidences of high quality sleep by the user and then generate a corrective plan that specifies a change to the foot warming system to improve sleep quality based on historical sleep metric incidences associated with high quality sleep. The controller **2790** can then drive the foot warming system **2102** according to the generated corrective plan. The corrective plan can be based on the user's own sleep data and/or aggregate sleep data from other individuals.

[0262] In another example the controller **2790** can achieve a desired temperature as a function of sensed temperature, as sensed by the temperature sensor **2780**. The controller **2790** can drive the heating unit **2124** as a function of a difference between the sensed temperature and a target temperature such that the controller **2790** supplies more power to the electrically conductive fabric in response to determining a relatively large difference between the sensed temperature and the target temperature and the controller **2790** supplies less power to the heating unit **2124** in response to determining a relatively small difference between the sensed temperature and the target temperature.

[0263] In various embodiments, the foot warming system **2102** can be operated to improve user comfort and/or to induce rapid sleep onset. By warming the users feet upon entering the bed, some users have been shown to fall asleep more quickly, thus improving sleep quality. The foot warming system **2102** can be integrated into a mattress at a location suitable for a particular user with little or no negative impact on the comfort of the mattress. The foot warming system **2102** can actively monitor microclimate to maintain appropriate temperature. The foot warming system **2102** can be automatically controlled via sensed data, reducing or removing the need for user inputs. Various embodiments described herein can achieve one or more of these benefits, among others.

[0264] A number of embodiments of the invention have been described. Neverthe-less, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. For example, the heating units **2124** and **2126** can have different shapes, orientations, and construction than that illustrated and described. Moreover, one, more than one, or all of the features of the various systems described above can be combined as suitable for a given application. Similarly, one or more features present on one or more of the various embodiments can be considered optional, and need not necessarily be included in all embodiments. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A bed comprising:
- a mattress comprising:
  - a mattress cover; and
  - a support structure that is positioned under and covered by the mattress cover; and
- a foot warming system, wherein the foot warming system comprises:
  - a heating unit;
  - an envelope having an envelope top and an envelope bottom, wherein the heating unit is positioned inside the envelope between the envelope top and the envelope bottom, and wherein the heating unit and the envelope are positioned at a foot of the mattress under the mattress cover between the support structure and the mattress cover;
  - a power source; and
  - an electrical connector electrically connecting the heating unit to the power source.

2. The bed of claim **1**, wherein the support structure comprises at least one foam layer and the envelope bottom is attached to the foam layer.

3. The bed of claim **1**, wherein the envelope comprises a fire resistant material.

4. The bed of claim **3**, and further comprising:
- a fire resistant cap covering the support structure, the envelope, and the heating unit.

5. The bed of claim **1**, wherein the envelope top comprises a breathable mesh and the envelope bottom comprises a fire resistant material.

6. The bed of claim **1**, wherein the heating unit comprises a flexible layer of electrically conductive fabric.

7. The bed of claim 1, wherein the power source comprises a controller configured to selectively power the heating unit to generate heat.

8. The bed of claim 7, wherein the controller is configured to:

access historical sleep metrics that represent sleep quality of a user while the user was sleeping on the mattress;

access historical sensor data that represent sensor readings that measure environmental conditions affecting the user while the user was sleeping on the mattress;

identify, in the historical sleep metrics, incidences of low quality sleep experienced by the user and incidences of high quality sleep by the user;

generate a corrective plan that specifies a change to the foot warming system to improve sleep quality based on historical sleep metrics associated with the incidences of high quality sleep; and

drive the foot warming system according to the generated corrective plan.

9. The bed of claim 7, wherein the controller is configured to:

determine an expected bed time for a user of the bed; and

drive the foot warming system to heat the foot of the mattress via the heating unit to reach a target temperature prior to the expected bed time.

10. The bed of claim 9, wherein the controller drives the foot warming system via pulse wave modulation to maintain temperature at the target temperature once the target temperature has been reached.

11. The bed of claim 9, wherein the bed further comprises:

a sensor configured to detect the user laying on the mattress, wherein the sensor is in communication with the controller and wherein the controller is further configured to reduce power to the heating unit upon the sensor detecting the user laying on the mattress.

12. The bed of claim 11, wherein the controller stops powering the heating unit as soon as the user is detected laying on the mattress.

13. The bed of claim 11, wherein the controller reduces power to the heating unit at a predetermined amount of time after the user is detected laying on the mattress.

14. The bed of claim 7, wherein the foot warming system further comprises a temperature sensor in communication with the controller and wherein the controller is configured to drive the heating unit as a function of a difference between sensed temperature and target temperature such that the controller supplies more power to the heating unit in response to determining a relatively large difference between the sensed temperature and target temperature and the controller supplies less power to the heating unit in response to determining a relatively small difference between the sensed temperature and target temperature.

15. The bed of claim 7, wherein the controller is configured to:

determine whether the user is asleep as a function of sensed data; and

drive the foot warming system as a function of whether the user is determined to be asleep.

16. The bed of claim 7, wherein the controller is further configured to:

monitor a sleeping routine of the user over multiple days via one or more sensors to determine a learned sleep schedule; and

drive the foot warming system to heat the foot of the mattress via the heating unit as a function of the learned sleep schedule.

17. The bed of claim 1, wherein the support structure of the mattress comprises a first air chamber sized for supporting a first user, a second air chamber sized for supporting a second user, and a foam layer positioned above the first and second chambers, wherein the heating unit comprises a first heating unit connected to the foam layer above the first air chamber and a second heating unit connected to the foam layer above the second air chamber.

18. The bed of claim 17, wherein the first heating unit is attached to the foam layer via the envelope having a first envelope opening and the second heating unit is attached to the foam layer via a second envelope having a second envelope opening, wherein the first and second heating units are removable through the first and second envelope openings, respectively.

19. The bed of claim 1, wherein the heating unit is a relatively thin layer with a width of between 21 inches and 31 inches and a depth of between 10 inches and 20 inches.

20. A bed comprising:

a mattress comprising:

a mattress cover; and

a support structure that is positioned under and covered by the mattress cover; and

a foot warming system, wherein the foot warming system comprises:

a heating unit positioned under the mattress cover and comprising a plurality of flexible flat heating elements spaced with gaps between each of the flexible flat heating elements;

a power source; and

an electrical connector electrically connecting the heating units to the power source.

21. The bed of claim 20, wherein the support structure comprises an air chamber and a foam, wherein the foam defines a pathway through which the electrical connector extends between the heating unit and the power source.

22. The bed of claim 20, wherein the heating unit comprises a first tinned copper bus bar, a second tinned copper bus bar extending substantially parallel to the first tinned copper bus bar, a temperature sensor, and a plurality of wires electrically connecting the power source to each of the first tinned copper bus bar, the second tinned copper bus bar, and the temperature sensor, and wherein the flexible flat heating elements are connected in parallel between the first and second tinned copper bus bars.

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专利名称(译)	床有足部加温系统		
公开(公告)号	US20180116415A1	公开(公告)日	2018-05-03
申请号	US15/337034	申请日	2016-10-28
[标]申请(专利权)人(译)	Select Comfort的		
申请(专利权)人(译)	Select Comfort的CORPORATION		
当前申请(专利权)人(译)	Select Comfort的CORPORATION		
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外部链接	Espacenet USPTO		

摘要(译)

床可以包括床垫和足部加热系统。床垫可包括床垫罩和支撑结构，支撑结构位于床垫罩下方并由床垫罩覆盖。足部加温系统可包括加热单元，外壳，电源和将加热单元电连接到电源的电连接器。加热单元可以定位在信封顶部和信封底部之间的外壳内。加热单元和封套可以定位在床的脚下，位于支撑结构和床垫罩之间的床垫罩下方。