BED HAVING FEATURES FOR SENSING SLEEPER PRESSURE AND GENERATING ESTIMATES OF BRAIN ACTIVITY FOR USE IN DISEASE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 63/227,110, filed July 29, 2021. The disclosure of the prior application is considered part of (and is incorporated by reference in) the disclosure of this application.

STATE CLASSIFICATION

[0002] The present document relates to automation of a consumer device such as a bed with sensors and a computer controllers to operate on data from the sensors.

BACKGROUND

[0003] 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.

SUMMARY

[0004] A system of one or more computers can be configured to perform particular operations or actions by virtue of having software, firmware, hardware, or a combination of them installed on the system that in operation causes or cause the system to perform the actions. One or more computer programs can be configured to perform particular operations or actions by virtue of including instructions that, when executed by data processing apparatus, cause the apparatus to perform the actions. According to a first aspect of the present invention, there is provided a system comprising: a bed having a mattress; a sensor configured to: sense pressure of a sleeper on the mattress and transmit, to a controller, pressure data generated from the sensing of pressure of the sleeper on the mattress; a controller comprising a processor and a memory, the controller configured to receive the pressure data; identify, from the pressure data, one or more motion parameters; determine one or more cardiac measures of the sleeper from the motion parameters; determine, from the cardiac parameters, one or more neurologic measures in one or more bands ($\delta,\theta,\alpha,\beta$) of the sleeper; and determine, sleep-related

disease states for the sleeper. Other embodiments of this example include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

[0005] Implementations may include one or more of the following features. To determine the neurologic measures and to determine disease state, the controller is configured to provide, to a classifier, the cardiac measures of the sleeper; and receive, from the classifier, a classification of the sleeper into an insomnia-state or a non-insomnia state. The classifier is configured to use a linear model to generate the neurologic measures, the linear model having terms for at least one of the group consisting of the i) cardiac measures and ii) neurological measures. The terms include i) HR in non-rapid eye movement (NREM) sleep, ii) SDNN in NREM sleep, iii) inter-beat interval signal of a high-frequency band of cardiac activity variability (HF) in NREM sleep, iv) inter-beat interval signal of a low-frequency band of cardiac activity variability (LF) in NREM sleep, and v) a ratio of LF in NREM sleep to HF in NREM sleep. Each term is normalized with a normalization function and multiplied by a corresponding coefficient value. The classifier is configured to use a log-measure of a neurologic measure to select a disease state out of plurality of possible disease-states. The controller is further configured to determine the disease state of the sleeper using cardiac measures of a single sleep session while the sleeper is asleep in the single sleep session. The controller is further configured to cause the determination of the disease state to be displayed to the sleeper upon the end of the single sleep session. The disease state is REM behavior disorder (RBD). The disease state is periodic limb movement (PLM) disorder. The cardiac measures include at least one of the group consisting of heart rate (HR), heart rate variability (HRV), standard deviation of normal to normal intervals (SDNN), a PNN50 metric, and a R-R interval metric. The sensor is a load-cell.

[0006] A system of one or more computers can be configured to perform particular operations or actions by virtue of having software, firmware, hardware, or a combination of them installed on the system that in operation causes or cause the system to perform the actions. One or more computer programs can be configured to perform particular operations or actions by virtue of including instructions that, when executed by data processing apparatus, cause the apparatus to perform the actions. According to a second aspect of the present invention, there is provided a system comprising one or more processors; and computer-readable instructions that, when executed by the one or more processors, cause the processors to perform operations comprising determining cardiac

parameters of a user; identifying, from the cardiac parameters of the user, one or more neurologic measures in one or more bands (δ,θ,α,β) of the user; and identifying, from the neurologic measures in one or more bands (δ,θ,α,β) of the user and from the cardiac parameters of the user, sleep-related disease states for the user.

[0007] Implementations may include one or more of the following features. The system further comprising a bed having one or more sensors for sensing the user for the determining of the cardiac parameters of the user. The one or more sensors include load-cells. The one or more sensors include pressure sensors. The system further comprising a wearable device for sensing the user for the determining of the cardiac parameters of the user.

[0008] There is disclosed a method of operating a bed system includes: sensing, via one or more sensors of the bed system, cardiac parameters of a user; identifying, from the cardiac parameters of the user, one or more neurologic measures of the user; identifying, from the neurologic measures of the user and from the cardiac parameters of the user, insomnia of the user; and outputting a signal in response to identifying insomnia from the neurologic measures of the user and the cardiac parameters of the user.

[0009] Implementations may include one or more of the following features. Identifying the neurologic measures and identifying insomnia of the user comprises: providing, to a classifier, the cardiac parameters of the user; and receiving, from the classifier, a classification of the user into an insomnia-state or a non-insomnia state. The classifier is configured to use a linear model to generate the neurologic measures, the linear model having terms for at least one of the group consisting of the i) cardiac parameters and ii) neurological measures.

[0010] There is disclosed a method includes: receiving, from a sensor of a bed system, pressure data; identifying, from the pressure data, one or more motion parameters; determining, from the motion parameters, one or more cardiac measures of a sleeper of the bed system; determining, from the cardiac parameters, one or more neurologic measures of the sleeper; and determining, a disease state for the sleeper.

[0011] Implementations may include one or more of the following features. The cardiac measures include at least one of the group consisting of heart rate (HR), heart rate variability (HRV), standard deviation of normal to normal intervals (SDNN), a PNN50 metric, and a R-R interval metric. Determining the neurologic measures and determining the disease state comprises: providing, to a classifier, the cardiac measures of the sleeper; and receiving, from the classifier, a classification of the

sleeper into an insomnia-state or a non-insomnia state. The classifier is configured to use a linear model to generate the neurologic measures, the linear model having terms for at least one of the group consisting of the i) cardiac measures and ii) neurological measures. The terms include i) HR in non-rapid eye movement (NREM) sleep, ii) SDNN in NREM sleep, iii) inter-beat interval signal of a high-frequency band of cardiac activity (HF) in NREM sleep, iv) inter-beat interval signal of a low-frequency band of cardiac activity (LF) in NREM sleep, and v) a ratio of LF in NREM sleep to HF in NREM sleep. Each term is normalized with a normalization function and multiplied by a corresponding coefficient value. The classifier is configured to use a log-measure of a neurologic measure to select a disease state out of plurality of possible disease-states. The method further includes determining the disease state of the sleeper using cardiac measures of a single sleep session while the sleeper is asleep in the single sleep session. The method further includes causing the determination of the disease state to be displayed to the sleeper upon the end of the single sleep session. The disease state is REM behavior disorder (RBD). The disease state is periodic limb movement (PLM) disorder. The sensor is a load-cell.

[0012] According to a third aspect of the present invention, there is provided a non-transient computer readable medium containing program instructions for causing a computer to perform operations comprising: sensing cardiac parameters of a user; identifying, from the cardiac parameters of the user, one or more neurologic measures in one or more bands (δ,θ,α,β) of the user; and identifying, from the neurologic measures in one or more bands (δ,θ,α,β) of the user and from the cardiac parameters of the user, sleep-related disease states for the user.

[0013] Implementations may include one or more of the abovementioned features.

[0014] According to a fourth aspect of the present invention, there is provided a non-transient computer readable medium storing instructions that, when executed by one or more processors, cause the processors to perform operations comprising: sensing, via one or more sensors of a bed system, cardiac parameters of a user; identifying, from the cardiac parameters of the user, one or more neurologic measures in one or more bands (δ,θ,α,β) of the user; identifying, from the neurologic measures in one or more bands (δ,θ,α,β) of the user and from the cardiac parameters of the user, insomnia

of the user; and outputting a signal in response to identifying insomnia from the neurologic measures in one or more bands (δ,θ,α,β) of the user and the cardiac parameters of the user.

[0015] Implementations may include one or more of the following features. Identifying the neurologic measures and identifying insomnia of the user comprises: providing, to a classifier, the cardiac

parameters of the user; and receiving, from the classifier, a classification of the user into an insomnia-state or a non-insomnia state.

[0016] According to a fifth aspect of the present invention, there is provided a non-transient computer readable medium storing instructions that, when executed by one or more processors, cause the processors to perform operations comprising: receiving, from a sensor of a bed system, pressure data; identifying, from the pressure data, one or more motion parameters; determining, from the motion parameters, one or more cardiac measures of a sleeper of the bed system; determining, from the cardiac parameters, one or more neurologic measures in one or more bands (δ,θ,α,β) of the sleeper; and determining, sleep-related disease states for the sleeper.

[0017] Implementations may include one or more of the following features. The cardiac measures include at least one of the group consisting of heart rate (HR), heart rate variability (HRV), standard deviation of normal to normal intervals (SDNN), a PNN50 metric, and a R-R interval metric. Determining the neurologic measures and determining the disease state comprises: providing, to a classifier, the cardiac measures of the sleeper; and receiving, from the classifier, a classification of the sleeper into an insomnia-state or a non-insomnia state. The classifier is configured to use a linear model to generate the neurologic measures, the linear model having terms for at least one of the group consisting of the i) cardiac measures and ii) neurological measures.

[0018] Other features, examples and potential advantages will be apparent from the accompanying description and figures.

DESCRIPTION OF DRAWINGS

[0019] FIG. 1 shows an example air bed system.

[0020] FIG. 2 is a block diagram of an example of various components of an air bed system.

[0021] FIG. 3 shows an example environment including a bed in communication with devices located in and around a home.

[0022] FIGs. 4A and 4B are block diagrams of example data processing systems that can be associated with a bed.

[0023] 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.

WHAT IS CLAIMED IS:

1. A system comprising:

a bed having a mattress;

a sensor configured to:

sense pressure of a sleeper on the mattress; and

transmit, to a controller, pressure data generated from the sensing of pressure of the sleeper on the mattress;

a controller comprising a processor and a memory, the controller configured to:

receive the pressure data;

identify, from the pressure data, one or more motion parameters;

determine one or more cardiac measures of the sleeper from the motion parameters;

determine, from the cardiac parameters, one or more neurologic measures in one or more bands (δ,θ,α,β) of the sleeper; and

determine, sleep-related disease states for the sleeper.

2. The system of claim 1, wherein the cardiac measures include heart rate variability (HRV).

3. The system as in any of the preceding claims, wherein to determine the neurologic measures in one or more bands (δ,θ,α,β) and to determine the sleep-related disease states, the controller is configured to:

provide, to a classifier, the cardiac measures of the sleeper; and

receive, from the classifier, a classification of the sleeper into an insomnia-state or a non-insomnia state.

4. The system as in any of the preceding claims, wherein the classifier is configured to use a linear model to generate the neurologic measures, the linear model having terms for at least one of the group consisting of the i) cardiac measures and ii) neurological measures.

5. The system as in any of the preceding claims, wherein the terms include i) HR in non-rapid eye movement (NREM) sleep, ii) SDNN in NREM sleep, iii) inter-beat interval signal of a high-frequency band of cardiac activity (HF) in NREM sleep, iv) inter-beat interval signal of a low-frequency band of cardiac activity (LF) in NREM sleep, and v) a ratio of LF in NREM sleep to HF in NREM sleep.

6. The system as in any of the preceding claims, wherein each term is normalized with a normalization function and multiplied by a corresponding coefficient value.

7. The system as in any of the preceding claims, wherein the classifier is configured to use a log-measure of a neurologic measure to select a sleep-related disease state out of plurality of possible sleep-related disease-states.

8. The system as in any of the preceding claims, wherein the controller is further configured to determine the sleep-related disease states of the sleeper using cardiac measures of a single sleep session while the sleeper is asleep in the single sleep session.

9. The system as in any of the preceding claims, wherein the controller is further configured to cause the determination of the sleep-related disease states to be displayed to the sleeper upon the end of the single sleep session.

10. The system as in any of the preceding claims, wherein the sleep-related disease states is REM behavior disorder (RBD).

11. The system as in any of the preceding claims, wherein the sleep-related disease states is periodic limb movement (PLM) disorder.

12. The system as in any of the preceding claim, wherein the sensor is a load-cell.

13. A system comprising:

one or more processors; and

computer-readable instructions that, when executed by the one or more processors, cause the processors to perform operations comprising:

determining cardiac parameters of a user;

identifying, from the cardiac parameters of the user, one or more neurologic measures in one or more bands (δ,θ,α,β) of the user; and

identifying, from the neurologic measures in one or more bands (δ,θ,α,β) of the user and from the cardiac parameters of the user, sleep-related disease states for the user.

14. The system of claim 13, the system further comprising a bed having one or more sensors for sensing the user for the determining of the cardiac parameters of the user.

15. The system as in one of claims 13-14, wherein the one or more sensors include load-cells.

16. The system as in one of claims 13-15, wherein the one or more sensors include pressure sensors.

17. The system as in one of claims 13-16, the system further comprising a wearable device for sensing the user for the determining of the cardiac parameters of the user.

18. A non-transient computer readable medium containing program instructions for causing a computer to perform operations comprising:

sensing cardiac parameters of a user;

identifying, from the cardiac parameters of the user, one or more neurologic measures in one or more bands (δ,θ,α,β) of the user; and

identifying, from the neurologic measures in one or more bands (δ,θ,α,β) of the user and from the cardiac parameters of the user, sleep-related disease states for the user.

19. A non-transient computer readable medium storing instructions that, when executed by one or more processors, cause the processors to perform operations comprising:

sensing, via one or more sensors of a bed system, cardiac parameters of a user;

identifying, from the cardiac parameters of the user, one or more neurologic measures in one or more bands (δ,θ,α,β) of the user;

identifying, from the neurologic measures in one or more bands (δ,θ,α,β) of the user and from the cardiac parameters of the user, insomnia of the user; and

outputting a signal in response to identifying insomnia from the neurologic measures in one or more bands (δ,θ,α,β) of the user and the cardiac parameters of the user.

20. The non-transient computer readable medium of claim 19, wherein identifying the neurologic measures and identifying insomnia of the user comprises:

providing, to a classifier, the cardiac parameters of the user; and

receiving, from the classifier, a classification of the user into an insomnia-state or a non-insomnia state.

21. A non-transient computer readable medium storing instructions that, when executed by one or more processors, cause the processors to perform operations comprising:

receiving, from a sensor of a bed system, pressure data;

identifying, from the pressure data, one or more motion parameters;

determining, from the motion parameters, one or more cardiac measures of a sleeper of the bed system;

determining, from the cardiac measures, one or more neurologic measures in one or more bands (δ,θ,α,β) of the sleeper; and

determining, sleep-related disease states for the sleeper.

22. The non-transient computer readable medium of claim 21, wherein the cardiac measures include heart rate variability (HRV).

23. The non-transient computer readable medium as in one of claims 21-22, wherein determining the neurologic measures in one or more bands (δ,θ,α,β) and determining the sleep-related disease states comprises:

providing, to a classifier, the cardiac measures of the sleeper; and

receiving, from the classifier, a classification of the sleeper into an insomnia-state or a non-insomnia state.

24. The non-transient computer readable medium as in one of claims 21-23, wherein the classifier is configured to use a linear model to generate the neurologic measures, the linear model having terms for at least one of the group consisting of the i) cardiac measures and ii) neurological measures.