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(54) Title: SLEEP RESPONSE AND ANALYSIS SYSTEM

(57) Abstract: A sleep response and analysis system comprises: at least one integrated unit of a signal receiving unit (1), a processing unit (2), a response unit (3), a database (4), and a display unit (5) to detect and measure brainwave signals for analyzing and classifying sleep stages during sleep by processing data with artificial intelligence (AI). The signal receiving unit (1) comprises at least one integrated unit of a signal receiver (11), a signal converter (12), and an interface unit (13) at a position. The signal receiver (11) is installed around the ear, and/or earlobe, and/or ear canal, or a combination thereof. The classification of sleep stages with using brainwave signals, is performed by the mutual processing of at least two types of AI, on at least two positions, wherein the AI consists of Deep Learning AI (21), and Machine Learning AI (22). The response unit (3) is configured to generate frequencies or sounds arranged as Binaural beats.

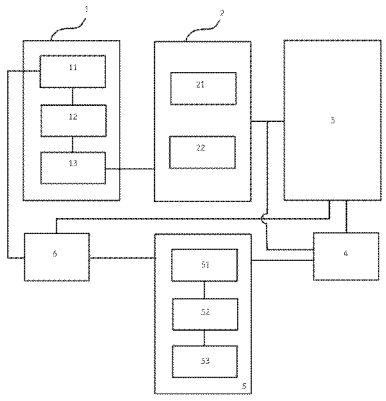

FIG. 1

WO 2024/049363 A1

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SLEEP RESPONSE AND ANALYSIS SYSTEM

Field of invention

The present invention relates to engineering, especially, to a sleep response and analysis system.

Background of the invention

Sleep is a natural state where the body experiences a reduction in self-awareness, perception of external stimuli, stimuli, or various movements, allowing the body's systems or organs, especially the brain, heart, and blood vessels, to rest or decrease activity. Additionally, sleep is a crucial element in facilitating the recovery of bodily functions, maintaining chemical balance, and normalizing neurotransmitters, thereby organizing cognitive processes, thoughts, or memories acquired during wakefulness stage.

For the above reasons, sleep is crucial in leading life of every individual. Importantly, a good sleep is not only just about getting enough sleep, but the qualitied sleep needs to achieve optimal stages or levels of sleep depth also. Therefore, evaluating sleep solely based on sleep duration is insufficient. It is imperative to measure and analyze sleep quality as well. Sleep involves more than just waking-up and falling asleep; there are numerous other phases that occur during sleep. In accordance with this invention, sleep stages can be classified into two phases: Non-Rapid Eye Movement Sleep (Non-REM Sleep) and Rapid Eye Movement Sleep (REM Sleep).

As for the ordinary sleeping phase or Non-REM Sleep, sleeping during this period can be divided into three stages of sleep as follows:

Stage 1 (N1) is characterized by a state of drowsiness, marking the initial transition into sleep, wherein, generally, this phase lasts for a short period of time. During this stage, brain activity begins to slow down, and eye movements might be slow. Furthermore, hypnic jerks, or a sudden sensation of falling or muscle twitching might, can also take place. Additionally, some individuals might encounter hypnagogic hallucinations in forms of auditory or visual sensations. However, the sleep during this stage does not significantly impact the body.

Stage 2 (N2) is the period of light sleep and is considered the transitional phase between the initial sleep state and deep sleep. During this stage, heart rate slows down, and the body temperature slightly decreases, wherein the sleep in this stage influences the body by enhancing short-term memory consolidation and promoting increased focus and attentiveness.

Stage 3 (N3), also known as the deep sleep stage, is characterized by a diminished responsiveness of the body to external stimuli. If awakened during the N3 stage, a strong sense of disorientation may be experienced, as the body is in a state of maximum relaxation, and the body's secretion of Growth Hormone is released during this stage.

Furthermore, another sleep stage is the Rapid Eye Movement Sleep (REM Sleep). During this phase, there is rapid movement of the eyes. The brain activity during this period closely is activated as that when awake, and it is characterized by heightened dreaming compared to other sleep stages. Sleep during this stage encourages memory consolidation, long-term learning, and imagination.

In each night's sleep, individuals enter various stages of sleep and sleep cycles that change progressively. Examining and measuring sleep stages can be accomplished through a range of methods and variables. One such variable capable of identifying sleep stages is Electroencephalography, obtained from an Electroencephalogram device (EEG). EEG involves in detecting electrical currencies from the scalp, brain's surface, or deep brain regions, wherein EEG is able to detect and see changes in electrical waves during sleep. Moreover, sleep-related disorders can be diagnosed with EEG operation due to the fact that different brain regions are responsible for regulating the functions of various organs and systems within the body.

Generally, reading the values of electroencephalography signals involves in assessment and analysis by experts to process the data or signals indicating the level of sleep stage accurately. However, this is accompanied by the significant costs of the specialist's expertise. Currently, therefore, inventions have been developed to devise devices or systems for examining EEG signals using automated systems or processing units or computers for analysis, as shown below.

The US application published as US20190328996A1 under the title "Method and system for inducing sleep", the international patent application No. PCT/US2017/045517 under the invention title "In-ear sensing systems and methods for biological signal monitoring", and Thai patent application No. 1903002441 under the title "Hearing aid device" all disclose devices or systems used to examine brainwave signals, particularly those obtained through electroencephalography, followed by an analysis to obtain values corresponding to sleep stages or other parameters that may elicit responses from users through sound or a certain rhythm.

Thai patent application No. 1601000904, filed under the title "Laboratory Unit for Receiving, Modifying Signals, along with Signal Analysis and Processing of Brain Waves to Output Results in a Certain Format", disclose the invention pertains to a laboratory unit for receiving, modifying, along with signal analysis and processing of brainwave signals to output results in a certain format. The laboratory unit is an independent unit that operates without analysis and processing from a computer or a portable computer device, resulting in facilitating ease of handling, portability, and usage due to its size, quantity, and components used in accordance with the invention. With electronic devices providing any results combined or with chips and/or generally a small-sized Microcontroller Unit (MCU), or wireless MCU, which obtain brainwave signals detectable in a certain output format, capable of being applied to other things. The invention comprises four main parts: "a brainwave signal reception part", which one possible embodiment of this part is an electrode for receiving brainwave signals into "a signal modification part" for analysis and processing. The signal modification part, as the second part, is arranged to filter out low-frequency signals, then amplify the signals, followed by converting the analog signal into digital signal. Afterward, it is arranged to filter out high-frequency signals and then enters "an analysis and processing part" using a set of commands, consequently leading to outputting results in a certain output format, which is "an output part" to be applied to various possible operations, not limited to any specific operation, contingent upon the command set within, indicating analysis and processing conditions, and one of these operations may occur in real-time, with data transmission from one place to another. One possible embodiment is wirelessly through a medium, such as radio waves, possibly in the form of Bluetooth.

Thai patent application No. 1101003254, filed under the title "Automated Brain Signal-Based Sleep Level Monitoring Device", disclose invention pertaining to an automated brain signal-based sleep level monitoring device that aims to measure preliminary sleep levels and initiate awakening when entering stage 2 of sleep, which is the phase that provides the highest level of refreshment. The device is invented to detect general sleep abnormalities by solely using brainwave signals, for sleep level analysis. It is compact in size and suitable for general individuals of all genders and ages seeking highly efficient relaxation. Users simply attach electrodes to record electrical signals from specified positions of groups of brain cells. Subsequently, the processing program measures sleep duration and triggers a wake-up sound when transitioning into stage 2 of sleep for a specific duration. The automated brain signal-based sleep level monitoring device comprises electrodes, amplifiers, analog-to-digital converters, wire connections via USB ports, portable computers, and a control system comprising microcontrollers, speakers, and microphones.

Additionally, the UK patent application No. GB2014020565, filed under the title "headphone", discloses invention related to a specific type of headphone comprising an EEG sensor that detects the sleep level of the headphone wearer in the vicinity around the ear.

Considering the details of the disclosed inventions in terms of components, operational functions, and the accuracy, which need to be improved, therefore, from the above problem, this invention has been made to invent a sleep response and analysis system to solve the mentioned problems. The present invention, when comparing this invention to prior disclosed inventions, has notable differences significantly existed. These differences include the system according to this invention has component for analyzing brainwave signals corresponding to sleep stages, which has been enhanced in accuracy and precision through the collaboration of a processing unit and Artificial Intelligence (AI) capabilities. Importantly, this innovation achieves an accuracy rate of up to 86 percent, the details will be explained in the next section on the detailed description of the invention disclosure.

Summary of the invention

This invention is involved in a sleep response and analysis system comprising: at least one integrated unit of a signal receiving unit, a processing unit, and a response unit, at

a position. The system may further comprise a database and a display unit. The system is designed to detect and measure brainwave signals for analyzing and classifying sleep stages during sleep, wherein the system processes data with artificial intelligence (AI).

The purpose of the invention is to invent a sleep response and analysis system configured to provide a responsive and accurate real-time measurement and classification of user's sleep stages based on electroencephalogram (EEG) signals. Furthermore, the system is also compact in size, non-intrusive to the user's sleep, and can provide feedback to the user through certain stimuli.

Brief description of the drawing

The invention is herein described, by way of example only, with reference to the accompanying drawings.

FIG. 1 illustrates an example of a sleep response and analysis system according to this invention.

Detailed description of the invention

The invention to be disclosed herein are described in details with reference to the illustrations. However, this invention may be provided in different aspects and ought not to be limited to the disclosed figure. The figure has been made so that this disclosure is absolutely clear that those who are skilled in the art can fully understand in the figure. However, thickness and scale of the figure may be exaggerated for clarity.

This invention is related to a sleep response and analysis system comprising: at least one integrated unit of a signal receiving unit 1; a processing unit 2; a response unit 3; a database 4; and a display unit 5 to detect and measure brainwave signals for analyzing and classifying sleep stages during sleep by processing data with artificial intelligence (AI).

The signal receiving unit 1 is configured to receive data, measure values, inspect, or detect electroencephalography (EEG) brainwave signals of user 6 in order to transmit received data or signals to the processing unit 2 for analysis and sleep stage classification,

wherein the signal receiving unit 1 comprising: at least one integrated unit of a signal receiver 11, a signal converter 12, and an interface unit 13 at a position, wherein the signal

receiver 11 is installed around the ear, and/or earlobe, and/or ear canal, or a combination thereof,

wherein the signal receiver 11 preferably is configured, as an electrode or an electrical terminal for detecting brainwave signals of the user 6 during sleep, and

wherein, in accordance with this invention, the signal receiving unit 11 is configured to detect brainwave signals by being installed in the vicinity of the ear (Ear EEG), and/or on the auricle the earlobe, and/or the ear canal, or a combination thereof. Preferably, the electrodes are provided to have at least eight signal channels, installed on both ears, four signal channels on each side.

The signal converter unit 12 functions to read the values of brainwave signals from the signal receiving unit 11, wherein the signal converting unit 12 comprises signal amplification and signal conversion devices, with at least one mutual integrated configuration, to perform signal amplification (as the Amplifier) and to convert the signals received from the signal receiving unit 11, which are in analog form, into digital signals representing in one form of data processing, wherein the signal converter (12) is from ADS1294, and/or ADS1299, and/or ADS1115, and/or an analog-to-digital signal converter, or a combination thereof.

Furthermore, the conversion of the signal converter unit 12 above is not limited the rights, the most suitable development or enhancement of signal conversion devices for data reception or transmission to be provided. Preferably, the signal converting unit 12 is selected from ADS1294, wherein the data received from the signal receiving unit 11 is transmitted through analog data to the signal converter unit 12, where the data is converted into digital format and then forwarded to the interface unit 13.

The interface unit 13 is configured to control the operation of the signal converter 12, record and organize data into packages for transmitting the data to the processing unit 2,

wherein the data transmission of the system according this invention, configuring to transmit and receive data in both wired and wireless forms, and

wherein the wireless data transmission is selected from Bluetooth, Wi-Fi, Cellular, 3G, 4G, 5G, Google Nest, Google Thread, or LoRa (Long Range), or a combination thereof.

Importantly, the data transmission above is not limited the rights, the development or improvement of other forms of long-range wireless signal transmission for data and command reception or transmission to be performed,

wherein the interface unit 13 is preferably selected from an internet of things (IoT) device, and/or ESPino32, and/or ESP32, or a combination thereof, most preferably ESP32.

Furthermore, the signal converter 12 and the interface unit 13 may be integrated as a single device.

The data received from the signal receiving unit 1 is transmitted to the processing unit 2, where the processing unit 2 is responsible for analyzing, calculating, assessing, categorizing, or classifying the received brainwave signals to classify various levels of sleep stages,

wherein the classification of sleep stages is preferably classified into five levels, namely:

a first level, the waking state, representing as the symbol "W";

a second level, the ordinary sleeping state 1 (non-REM sleep 1), representing as the symbol "N1";

a third level, the ordinary sleeping state 2 (non-REM sleep 2), representing as the symbol "N2";

a fourth level, the ordinary sleeping state 3 (Non-REM Sleep 3), representing as the symbol "N3"; and

a fifth level, the Rapid Eye Movement (REM) sleep stage, representing as the symbol "REM".

The processing unit 2 is selected from a microcontroller, and/or a personal computer (PC), and/or a small-sized portable computer, and/or a laptop, and/or a cloud computing unit, or a combination thereof, wherein the processing unit 2 is equipped with at least one instance of a program set and/or Artificial Intelligence (AI), configured to process the data received from the interface unit 13, in order to classify the levels of sleep stages of the user 6 in real-time, preferably to classify at intervals of at least every thirty seconds.

Furthermore, the signal receiving unit 1 is configured to continuously monitor the user's 6 brainwaves and transmit these data to the processing unit 2 every thirty seconds for classifying the levels of sleep stages, which one above process is designated as one epoch,

Preferably, the classification of sleep stages with using brainwave signals, is performed by the mutual processing of at least two types of AI, on at least two positions, wherein the AI consists of Deep Learning AI 21, and Machine Learning AI 22.

The classification of sleep stages of the system according to this invention, wherein the processing of AI is performed by utilizing at least two positions of the Deep Learning AI 21 to classify levels of sleep stages from brain electroencephalography signals received from the signal receiving unit 1,

wherein the classification of a single epoch preferably comprises ninety positions of the Deep Learning AI 21, which each position is configured to be trained from disparate data and targets, achieved by arranging sleep level data into datasets or models. For instance, pairing the sleep level W with the sleep level N1 to create Model 1, pairing sleep levels W with sleep level N1 and the sleep level N2 to create Model 2. This arrangement of the datasets or models of all possible combinations is generated from five sleep levels: W, N1, N2, N3, and REM, wherein the arrangement, according to this invention, results in at least ninety positions of the Deep Learning AI 21.

Subsequently, utilizing the arrangement of the datasets or models obtained from the Deep Learning AI 21, according to this invention, to perform the classification of sleep stages for a single epoch with the Machine Learning AI 22 to enable the classification of sleep stages (W, N1, N2, N3, or REM) of the user 6 selected as one of the sleep stages,

wherein the Machine Learning AI 22 is preferably selected from K-Nearest Neighbors (k-NN) Machine Learning.

AS a result, the classification of sleep stages by the processing unit 2, according to this invention, creates the accuracy of the sleep stage classification when compared to various databases and processing methods. The experimental table below demonstrates the accuracy in sleep stage classification as shown in the following table.

Method	channel	Sleep stages					Accuracy
		W	N1	N2	N3	REM	
According to this invention	Fpz-Cz	90.32	53.29	89.56	89.46	86.83	86.96
According to this invention	Pz-Oz	89.25	40.83	87.79	83.61	86.78	84.69
SleepEEGNet 2019	Fpz-Cz	89.19	52.19	86.77	85.13	85.02	84.26
DeepSleepNet 2017	Fpz-Cz	84.70	46.60	85.90	84.80	82.40	82.00
Tsinalis et al. 2016	Fpz-Cz	71.60	47.70	84.60	84.00	81.40	78.90
Tsinalis et al. 2016	Fpz-Cz	65.40	43.70	80.60	84.90	74.50	74.80
SleepEEGNet 2019	Pz-Oz	90.27	44.64	85.74	81.55	82.88	82.83
DeepSleepNet 2017	Pz-Oz	88.10	37.00	82.70	77.30	80.30	79.80

From the table indicating the accuracy in sleep stage classification above, it has been found that the processing method with the AIs of the sleep response and analysis system, as described in this invention, achieves a higher accuracy of 86.96% and 84.69% respectively, compared to previously disclosed predictions or research.

The data, signals, and brain electroencephalography waves received from the signal receiving unit 1, the processing unit 2, and the response unit 3 are configured to be recorded and stored in the database 4,

wherein the database 4 is selected from memory units, and/or hard disks, and/or SSD storage units, and/or servers, and/or cloud databases, or a combination thereof, and

wherein the wireless data transmission is selected from Bluetooth, Wi-Fi, Cellular, 3G, 4G, 5G, Google Nest, Google Thread, or LoRa (Long Range), or a combination thereof, but it is not limited the rights of the development or improvement of other forms of long-range wireless signal transmission for data reception or transmission to be performed.

The database 4 is configured to store and record raw data and/or personal data of the user 6, and/or sleep stage classification data, or significant data of the sleep response and analysis system according to this invention.

The sleep response and analysis system, according to this invention, preferably comprises the display unit 5 comprising at least one mutual integrated configuration of a computer 51, and/or a web application 52, and/or a mobile application 53 which are collectively composed,

wherein this display unit 5 is designed, for the user 6 or the system developer of the sleep response and analysis system, according to this invention, to read the results of analysis or data obtained from the database 4 in order to present the data and/or manage enhancements to the system.

Furthermore, the sleep response and analysis system of this invention comprises the response unit 3, wherein the response unit 3 is configured to transmit a signal, frequency waveform, or a sound to the user 6 in order to create a perception or stimuli to the user 6 in a manner enhancing the quality of sleep to be more efficient.

The response unit 3 is configured as either headphones or speakers, in order to generate frequencies or sounds arranged as Binaural beats, wherein the user 6 is perceivable through airborne sound transmission, and/or bone conduction sound transmission, individually, or a combination thereof.

Any change made to this invention may be vividly understood and can be done by a person skilled in the field. The change may be within the scope and intent of this invention as shown in the claim attached.

Claims

1. A sleep response and analysis system comprising: at least one integrated unit of a signal receiving unit (1); a processing unit (2); a response unit (3); a database (4); and a display unit (5) to detect and measure brainwave signals for analyzing and classifying sleep stages during sleep by processing data with artificial intelligence (AI), **characterized in that**,

The signal receiving unit (1) comprising: at least one integrated unit of a signal receiver (11), a signal converter (12), and an interface unit (13) at a position, wherein the signal receiver (11) is installed around the ear, and/or earlobe, and/or ear canal, or a combination thereof,

preferably, the classification of sleep stages with using brainwave signals, is performed by the mutual processing of at least two types of AI, on at least two positions, wherein the AI consists of Deep Learning AI (21), and Machine Learning AI (22), and

the response unit (3) is configured to generate frequencies or sounds arranged as Binaural beats.

2. The system according to claim 1, wherein the signal receiver (11) preferably is configured, as an electrode or an electrical terminal for detecting brainwave signals of the user (6) during sleep.

3. The system according to claim 1, wherein the signal converter (12) is from ADS1294, ADS1299, ADS1115, an analog-to-digital signal converter, or a combination thereof.

4. The system according to claim 1, wherein the interface unit (13) is configured to control the operation of the signal converter (12), record and organize data into packages for transmitting the data to the processing unit (2).

5. The system according to any one of claims 1 to 4, wherein the interface unit (13) is preferably selected from an internet of things (IoT) device, and/or ESPino32, and/or ESP32, or a combination thereof.

6. The system according to any one of claims 1, or 3 to 5, wherein the signal converter (12) and the interface unit (13) may be integrated as a single device.

7. The system according to claim 1, wherein the processing unit (2) is selected from a microcontroller, and/or a personal computer (PC), and/or a small-sized portable computer, and/or a laptop, and/or a cloud computing unit, or a combination thereof.

8. The system according to any one of claims 1 to 7, wherein the classification of sleep stages is preferably classified into five levels, namely:

a first level, the waking state, representing as the symbol "W";

a second level, the ordinary sleeping state 1 (non-REM sleep 1), representing as the symbol "N1";

a third level, the ordinary sleeping state 2 (non-REM sleep 2), representing as the symbol "N2";

a fourth level, the ordinary sleeping state 3 (Non-REM Sleep 3), representing as the symbol "N3"; and

a fifth level, the rapid eye movement (REM) sleep stage, representing as the symbol "REM".

9. The system according to claim 1, 7, or 8, wherein the processing unit (2) is configured to classified the levels of sleep stages of the user (6) in real-time, preferably to classify at intervals of at least every thirty seconds.

10. The system according to claim 1, wherein the processing of AI is performed by utilizing at least two positions of the Deep Learning AI (21) to classify levels of sleep stages from brain electroencephalography signals received from the signal receiving unit (1).

11. The system according to any one of claims 1 to 10, wherein the classification of a single epoch preferably comprises ninety positions of the Deep Learning AI (21).

12. The system according to claim 1, wherein the Machine Learning AI (22) is preferably selected from K-Nearest Neighbors (k-NN) Machine Learning.

13. The system according to claim 1, wherein data, signals, and brain electroencephalography waves received from the signal receiving unit (1), the processing unit (2), and the response unit (3) are configured to be recorded and stored in the database (4).

14. The system according to any one of claims 1 to 13, wherein the database (4) is selected from memory units, and/or hard disks, and/or SSD storage units, and/or servers, and/or cloud databases, or a combination thereof.

15. The system according to claim 1, wherein the response unit (3) is configured as either headphones or speakers, in order to generate frequencies or sounds arranged as Binaural beats.

16. The system according to any one of claims 1 to 15, wherein the response unit (3) generates frequencies or sounds arranged as Binaural beats, wherein the user (6) is perceivable through airborne sound transmission, and/or bone conduction sound transmission, individually, or a combination thereof.

17. The system according to claim 1, configuring to transmit and receive data in both wired and wireless forms.

18. The system according to any one of claims 1 to 17, wherein the wireless data transmission is selected from Bluetooth, and/or Wi-Fi, and/or Cellular, and/or 3G, and/or 4G, and/or 5G, and/or Google Nest, and/or Google Thread, and/or LoRa (Long Range), or a combination thereof.

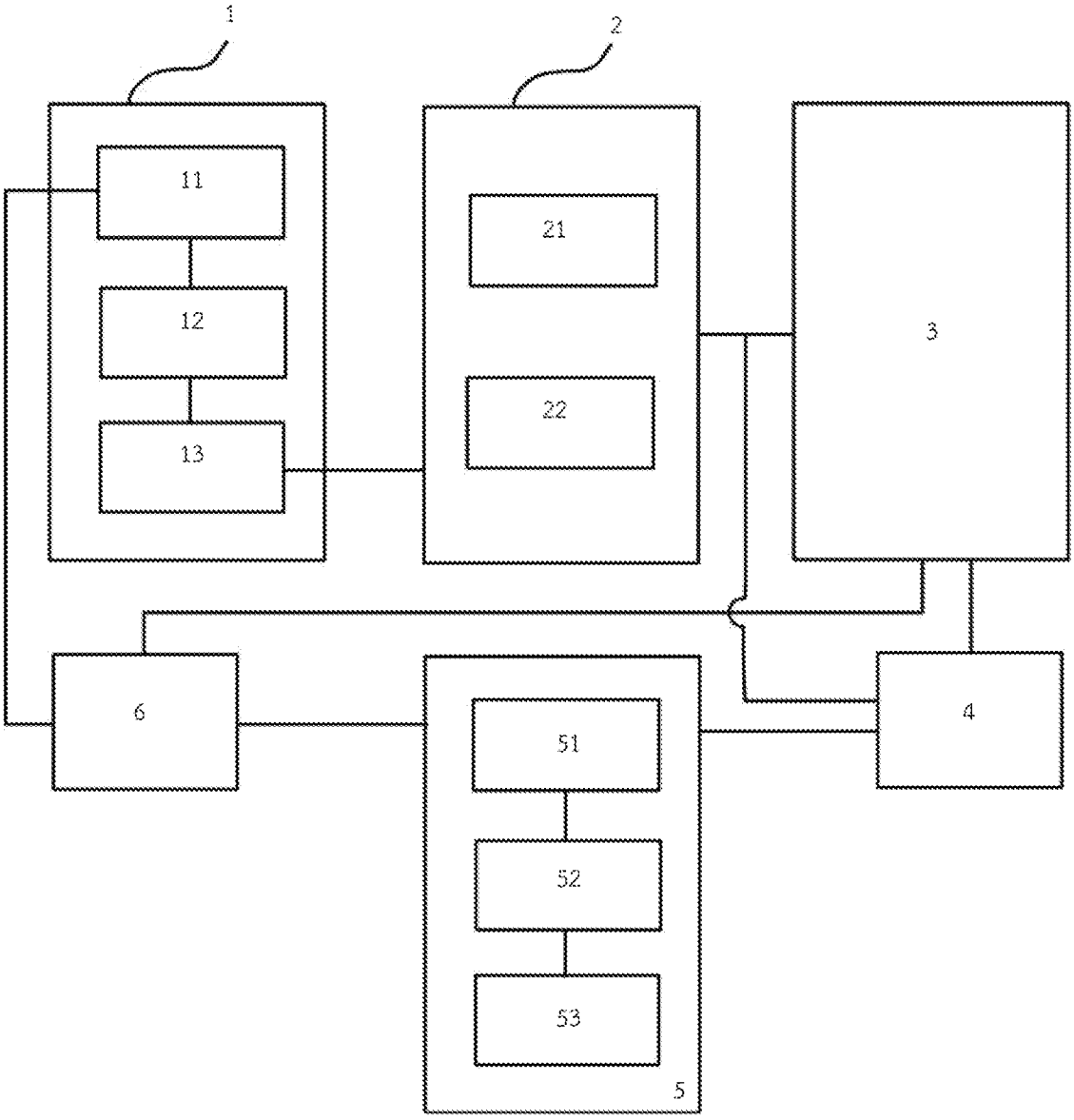

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/TH2023/050023

A. CLASSIFICATION OF SUBJECT MATTER

A61B5/369(2021.01)i; A61M21/02(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: A61B5, A61M21

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

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

CNTXT,ENTXT,DWPI,CJFD sleep stage?, EEG, classify+, sound?, AI, artificial intelligengce, Binaural beat?

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019328996 A1 (UNIV KOREA RES & BUS FOUND) 31 October 2019 (2019-10-31) specification paragraphs [0031]-[0122], and figures 1-11	1-18
X	CN 109731204 A (DEEPBLUE TECHNOLOGY SHANGHAI CO LTD) 10 May 2019 (2019-05-10) specification paragraphs [0035]-[0085], and figures 1-5	1-18
X	CN 109999314 A (UNIV JIANGNAN) 12 July 2019 (2019-07-12) specification paragraphs [0052]-[0107], and figures 1-9	1-18
X	CN 114366983 A (FAN J) 19 April 2022 (2022-04-19) specification paragraphs [0061]-[0202], and figures 1-8	1-18
X	CN 114939217 A (SHANGHAI SHUYAO INFORMATION TECHNOLOGY) 26 August 2022 (2022-08-26) specification paragraphs [0026]-[0130], and figures 1-5	1-18

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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Date of the actual completion of the international search	Date of mailing of the international search report
04 January 2024	**10 January 2024**

Name and mailing address of the ISA/CN	Authorized officer
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Information on patent family members

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