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(54) **HEARING SYSTEM AND METHOD FOR OPERATING A HEARING SYSTEM**

(57) The invention concerns a hearing system (200) including a hearing device (110), wherein the hearing system (200) comprises a plurality of notification channels which are configured for delivering a notification to a recipient. The hearing system (200) further comprises a memory (115, 135) storing instructions (116, 136), and a processor (114, 134) communicatively coupled to the memory (115, 135) and configured to execute instructions to monitor the hearing system (200) for a plurality of notification events; and, upon detection of one of the plurality of notification events, to provide a rule associated with the detected notification event; and to determine

by the associated rule and based on a current system state a subset of the plurality of notification channels (101) for delivering a notification associated with the detected notification event; and to initiate delivery of the associated notification via the determined subset of the plurality of notification channels (101, 201). The invention further concerns a method for operating a hearing system including a hearing device, and a non-transitory computer-readable medium storing instructions for executing a method for operating a hearing system including a hearing device.

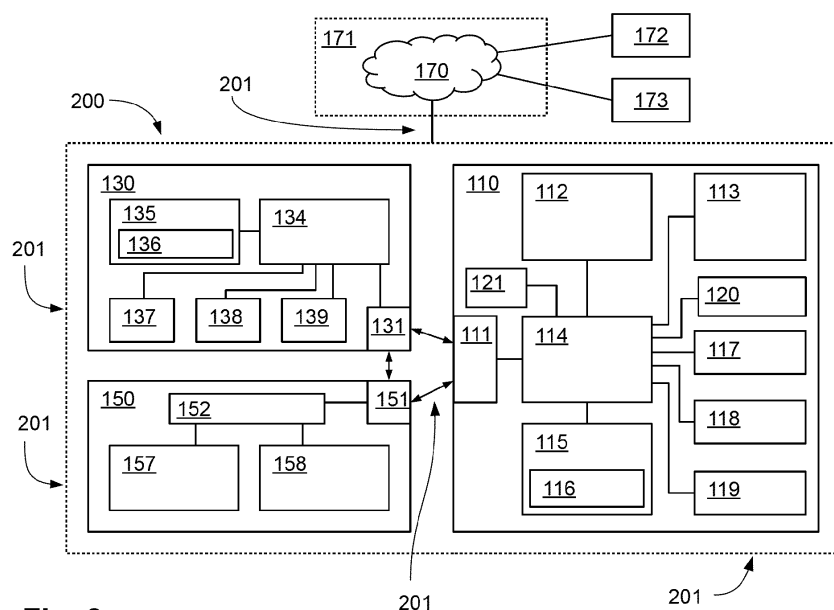


Fig. 2

Description

Technical Field

[0001] The present invention concerns a hearing system including a hearing device, wherein the hearing system comprises a plurality of notification channels that are configured for delivering a notification to a recipient. The invention further concerns a method for operating a hearing system including a hearing device, and a non-transitory computer-readable medium storing instructions for executing a method for operating a hearing system including a hearing device.

Background Art

[0002] Mobile devices as e.g. smartphones or wearables as e.g. smartwatches or hearing devices offer a plurality of possibilities to deliver a notification or message to a user. Hearing device hereby refers to hearing aids or hearing instruments providing assistance to hearing-impaired users, but also to other wearables as e.g. headphones, earbuds or similar devices that are typically worn in or at the ear of a user to deliver acoustic signals to the user.

[0003] Such mobile devices get more and more integrated in modern hearing systems, i.e. systems that include at least one hearing device and may comprise additional components as e.g. mobile or stationary devices. As a result, modern hearing systems offer a wealth of notification channels via which a notification or message generated or received by the hearing system can be delivered to the user or to third parties.

[0004] At the same time, the integration of more and more new components or devices into modern hearing other mobile devices as e.g. rechargeable batteries, active vents, physiological sensors, system sensors etc. yields an increasing amount of information that may or needs to be notified to the user of hearing systems or to third parties as e.g. caretakers, audiologists, service providers, manufacturers, emergency responders etc.

[0005] The large number of the potentially available notification channels and the large amount of information that may be or needs to be notified via these channels, however, can be overwhelming and handling of notifications may be challenging. In addition, the number and type of notification channels of a hearing system which are available at a given time can significantly vary depending on e.g. which of the components of the hearing system are currently connected and/or active. It may thus be difficult or confusing for a user to understand by which channels a given type of notifications will be delivered. Furthermore, as hearing systems are versatile and many different types of components can be integrated, the information channels can be redundant which may add to the confusion of the user. Delivering notifications or messages via too many channels may also be undesirable as there may be an information overflow resulting in the

notifications not being noticed by the recipient as intended. As the delivery of notifications also consumes electrical power which is generally limited in hearing devices and/or in mobile devices, it may also be relevant from an operational point of view which type of channels (e.g. high or low power consumption) and/or how many channels are used for delivering a notification.

[0006] It is therefore an object of the invention to overcome the disadvantages of hearing systems and methods to operate hearing systems according to the prior art. In particular, it is an object of the invention to provide a hearing system and a method for operating a hearing system that improve the delivery of notifications by a hearing system. It is a further object of the invention to provide a hearing system with a notification system and a method for operating a hearing system with a notification system that are simple to use and facilitate the management of notification delivery by the hearing system. It is a further object of the invention, to provide a hearing system with a notification system and a method for operating a hearing system with a notification system which are versatile and may be adapted by a user.

Summary of the Invention

[0007] The problems of the invention are solved by a hearing system according to claim 1. The hearing system includes a hearing device and comprises a plurality of notification channels which are configured for delivering a notification to a recipient. The hearing system further comprises a memory storing instructions, and a processor communicatively coupled to the memory and configured to execute instructions to monitor the hearing system for a plurality of notification events. The processor is further configured to execute instructions to, upon detection of one of the plurality of notification events, provide a rule associated with the detected notification event, and to determine by the associated rule and based on a current system state a subset of the plurality of notification channels for delivering a notification associated with the detected notification event. The processor is further configured to execute instructions to initiate delivery of the associated notification via the determined subset of the plurality of notification channels.

[0008] A hearing system in the present context refers to a system of components which includes at least one hearing device. A hearing device may be used to improve the hearing or communication capability of a user, for instance by compensating a hearing loss of a hearing-impaired user. In this case, the hearing device is commonly referred to as a hearing instrument such as a hearing aid or a hearing prosthesis. The hearing device may enable or enhance hearing by a user wearing the hearing device by providing processed audio content received by the hearing device to the user. For example, the hearing device may provide an amplified version of the audio content received by e.g. a microphone in the environment of the user to enhance the acoustic perception by the

user. The hearing device may additionally or alternatively provide audio content to the user based on an audio stream (e.g., an electrical audio signal) received by the hearing device from a streaming source (e.g. a table microphone or a streaming service).

[0009] The hearing device may also provide for a situational enhancement of an acoustic scene, e.g. beam-forming and/or active noise cancelling (ANC), with or without amplification of the reproduced sound. The hearing device may also be implemented as a hearing protection device, such as an earplug that is configured to protect the user's hearing.

[0010] Different types of hearing devices configured to be worn in or at an ear include earbuds, earphones, hearables, and hearing instruments such as receiver-in-the-canal (RIC) hearing aids, behind-the-ear (BTE) hearing aids, in-the-ear (ITE) hearing aids, invisible-in-the-canal (IIC) hearing aids, completely-in-the-canal (CIC) hearing aids, cochlear implant systems configured to provide electrical stimulation representative of audio content to a user, a bimodal hearing system configured to provide both amplification and electrical stimulation representative of audio content to a user, or any other suitable hearing prostheses.

[0011] In some cases, the hearing device may include one or more physiological sensors configured to perform measurements of a physiological condition of a user while the user is wearing the hearing device. The physiological sensor may e.g. be implemented by a photoplethysmography (PPG) sensor. Output data may be provided by the PPG sensor as a PPG waveform, which may be indicative of a blood property, such as a heart rate, a blood pressure, a heart rate variability, an oxygen saturation index (SpO_2), a maximum rate of oxygen consumption (VO_2^{max}), and/or a concentration of an analyte contained in the tissue, such as water and/or glucose. Other exemplary sensors that can be included in the hearing device and which can be representative of a physiological condition of the user, in particular while the user wears the hearing device, are motion sensors (e.g., an inertial measurement unit (IMU), an accelerometer, a gyroscope, etc.) configured to output motion data representative of motion of the hearing device, temperature sensors (e.g., a thermometer, a thermocouples, a resistance temperature detector, a thermistor, etc.) configured to output temperature data representative of a temperature and/or a change in temperature of the hearing device, and/or touch sensors (e.g., a capacitive touch sensor, a resistive touch sensor, etc.) configured to output touch data representative of a contact of the user with the hearing device.

[0012] The hearing system may comprise more than one hearing device, in particular two hearing devices which are configured to be worn at different ears of the user. In this case, such a system of two hearing devices is sometimes referred to as a binaural hearing device. The hearing system may comprise further devices as e.g. mobile devices like smartphones, tablet computers,

and/or wearables like a wearable microphone, smart glasses or a smartwatch. The hearing system may also include stationary devices as e.g. personal computers, table microphones, base or charging stations for the hearing device, and/or alarm clocks or hi-fi systems etc.

[0013] Typically, the components of the hearing system are communicatively coupled with each other in a way that data can be exchanged between the components. It is possible that different components are connected by different communication devices, means, and/or protocols. Suitable exemplary communication connections comprise wireless connections as e.g. Bluetooth, WLAN (also Wifi) and/or radio connections, but also wire-bound connections as e.g. serial bus connections, in particular Universal Serial Bus (USB) connections, or parallel bus connections.

[0014] A notification channel herein refers to any means configured to allow for local or remote delivery of a notification. Such means may include one or more devices, units, modules, (sub)systems, circuitry and may be hardware and/or software implemented. A notification channel for local delivery to a user of the hearing system may for instance include a speaker for delivering an acoustic notification, also called "receiver" in the context of hearing aids, a display or an indicator light for delivering a visual notification, and/or a vibrating device for delivering a haptic, in particular vibrotactile notification. The notification channel may be configured for local and/or remote delivery of notifications to third parties as e.g. hearing care professionals (HCP), emergency medical services (EMS), and/or to other registered or predefined contact persons as e.g. a care taker or selected relatives of the user. A notification channel may include an interface for delivering a notification remotely via e.g. a data connection to a remote network, and/or an interface to e.g. a messenger, an e-mail or an phone service. Such interfaces may for example be provided by a messaging and/or e-mail application or a corresponding client executed on the hearing system. A notification channel in the present sense may also include an interface to a data pipeline which allows for delivering a notification to a data file as e.g. to a log file for data logging.

[0015] The plurality of notification channels refers to an essentially arbitrary number of notification channels larger than one. A subset of the plurality of notification channels herein refers to a set of one or more of the notification channels selected from the plurality of notification channels. The subset can be equal to the plurality of notification channels, i.e. the subset may comprise all notification channels of the plurality of notification channels.

[0016] A notification herein refers to an act, process, action, instance that is suited to give notice of an information to a recipient. A recipient, in the present context, may be a person, a device, or an entity that is defined in the hearing system as the intended target for the notification to be delivered. In particular, the recipient may e.g. be a person, for example a user of the hearing system

or a third part as e.g. an HCP, or it may be an electronic device or service, and/or a data file. The intended recipient may be defined by the notification event. The information about the recipient or a reference to the recipient may be carried by the notification event, and/or the information about the intended recipient may be defined in the rule associated with the notification event, and/or the intended recipient for a given notification can be provided by the hearing system, for instance by the processor based on data and/or information stored in the memory. The intended recipient for a given notification may be changeable e.g. upon corresponding input by a user or an HCP. A given notification may be associated with one or more recipients, usually depending on the nature of the notification, e.g. the content.

[0017] Notification herein includes visual notifications as e.g. continuous, colored and/or blinking indicator lights, or alert or pop-up windows related to text messages, e-mails etc. which can be displayed on a graphical display. Some notifications may require a user response as e.g. an input with a confirmation or acknowledgement. Notifications herein also include acoustic notifications as e.g. playing a sound, for instance an alarm sound or an easily recognizable melody, or a spoken text messages which can be prerecorded or synthesized. A particular type of acoustic notification which may be triggered by receipt of an e-mail or text message may include reading out a text of the e-mail or the message to the reader via an acoustic notification channel and/or displaying the content on a display screen. The content conveyed by a notification thus may be dynamic (i.e. content of an e-mail or text message) whereas the type or form of the notification as well as the associated notification event (e.g. the fact that an e-mail or text message was received) may be static. Notification herein further also includes datasets or messages that are intended to be delivered to and stored in e.g. a data file e.g. for later access.

[0018] The delivery of notifications by the hearing system is generally triggered by notification events. Notification events are typically predefined in the hearing system, i.e. the hearing system comprises a known plurality of possible notification events that can be issued by the hearing system. Each notification event of the plurality of notification events is associated with a corresponding notification. The information conveyed by the notification may be static, i.e. each time the notification is delivered the information conveyed by the notification is the same as e.g. a red light is turned on, and/or the information can be adaptive, i.e. the information conveyed by the notification can depend on circumstances as e.g. the notification conveys the content of a text message.

[0019] Typically, the hearing system may include an event handler, which is e.g. executed by the processor, which initiates delivery of an associated notification upon detection of a notification event that has been issued. The issuance of notification events can be monitored by e.g. polling the system, i.e. the processor continuously querying the relevant components of the hearing system

for notification events, or by interrupts i.e. the relevant components of the hearing system notify e.g. the processor about the issuance of a notification event. Notification events can essentially be issued by all components of the hearing system, as far as they are relevant for the notification system of the hearing system.

[0020] The processor may be implemented by one or more computer processing devices, including general purpose processors (e.g., central processing units (CPUs), graphics processing units (GPUs), microprocessors, etc.), special purpose processors (e.g., application specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), etc.), image signal processors, digital signal processors, deep neural network (DNN) acceleration processors, or the like. The processor may be selectively and communicatively coupled to the memory. The memory and the processor may each include or be implemented by computer hardware that is configured to store and/or process computer software. In some embodiments, the memory and/or the processor may be distributed between multiple devices and/or multiple locations and may serve a particular implementation. For example, various computer processing devices, which may be included in processor, may also be distributed between the hearing device and another component of the hearing system as e.g. a computing device (e.g., a mobile device, personal computer, and/or other computing device) which is communicatively coupled (e.g., by way of a wired and/or wireless connection) to the hearing device.

[0021] The memory may store and/or otherwise maintain executable data used by processor to perform any of the functionality described herein. For example, the memory may store the instructions that may be executed by the processor. The memory may be implemented by one or more memory or storage devices, including any memory or storage devices described herein, that are configured to store data in a transitory or non-transitory manner. The instructions may be executed by the processor to cause the processor to perform any of the functionality described herein. The instructions may be implemented by any suitable application, software, code, and/or other executable data instance. Additionally, the memory may also maintain any other data accessed, managed, used, and/or transmitted by the processor in a particular implementation.

[0022] According to the invention, each notification event has, besides an associated notification, an associated rule for determining the subset of the plurality of notification channels for delivering the associated notification based on a current system state. The hearing system therefore provides for a plurality of such rules, each one of which is associated with one of the plurality of notification events. The plurality of rules may be provided as a predefined plurality of rules. The predefined plurality of rules may form part of e.g. a user profile of a user of the hearing system and may form part of the settings of the hearing device. The plurality of rules may be stored

in the memory of the hearing system. According to the invention, the processor of the hearing system is configured to, upon detection of one of the notification events, provide a rule associated with the detected notification event. Providing the associated rule may comprise reading out the memory of the hearing system where the plurality of associated rules may be stored as a set of predefined rules. Some of the rules may be mandatory or static, e.g. the respective rule cannot be changed by a user. Other rules may be dynamic and may be changed according to preferences.

[0023] The "current system state" hereby refers to a "current state of the hearing system" and is defined by parameter values of a plurality of system parameters of the hearing system. The system parameters of the hearing system are typically based on data obtained through system monitoring of the hearing system, in particular by monitoring the hearing device or e.g. a mobile device which can belong to the hearing system. The monitoring can be achieved through polling, i.e. the processing unit continuously or at regular intervals querying components of the hearing system for status and e.g. detection values e.g. of sensors. Alternatively or additionally, the monitoring can be achieved by interrupts, i.e. by the components of the hearing system notifying the processing unit of e.g. a change of status or detection values.

[0024] Exemplary system parameters comprise internal status parameters of the hearing system as e.g. memory usage, processor load, system temperature, battery charging level, operational status of a sensor (i.e. sensor health) as e.g. operational status of a microphone, in particular a clogging status, but also operational status of other components as e.g. a receiver or a vent opening. Furthermore, the system parameters can include a signal strength and/or connection quality of a wireless communication network as e.g. a Bluetooth or wireless LAN (often termed WLAN or Wifi) connection or similar.

[0025] The system parameters herein, however, may also include derived parameters that are determined based on other system parameters and are indicative e.g. of a physiological status of the user. For example, a motion status of the hearing device as determined e.g. by accelerometers of the hearing device and/or other components of the hearing system can be used to determine a motion status of the user which motion status of the user can form a system parameter. Similarly, a temperature detected by a temperature sensor of the hearing device and/or another component of the hearing system may be used to determine a body temperature of the user which may also be regarded as system parameter in the present sense.

[0026] The rule associated with a notification event uses a given current system state, i.e. the parameter values of the plurality of system parameters, as an input and yields as an output a subset of the plurality of notification channels for delivering the associated notification. As such, the rule can be regarded as a mapping from the set of system parameter values to the set of notification

channels. By providing such a rule for each notification event, the invention allows to select the most appropriate notification channels dependent on a current status of the hearing system.

[0027] It is one of the advantages of the invention that it provides for a hearing system which allows for systematic and easy handling of large numbers of notification channels and notification events. Preferred embodiments of the hearing system therefore include a plurality of at least three, preferably at least five, or ten or more notification channels. For the same reason, preferred embodiments of hearing system comprise a plurality of at least three, preferably at least five, or ten or more notification events.

[0028] The plurality of rules associated with the plurality of notification events can comprise rules that are completely or partially hardcoded in the sense that the mapping from the current system status to certain notification channels cannot be changed. Such rules may be referred to as static rules. This may be preferred for notification events that e.g. relate to alert notifications, e.g. in the case of a medical emergency detected by the hearing system which always needs to result in e.g. delivering a notification to an EMS. Other rules, in contrast, can be softcoded in the sense that the rule can be changed and adapted to particular needs or preferences. Such rules may be referred to as dynamic rules.

[0029] Dynamic rules may be changed for example by user input, by settings provided by an HCP, and/or by machine learning algorithms which determine preferred or suitable notification channels for the delivery of associated notifications based, for instance, on behavioral patterns of the user or frequency of occurrence of certain notification events in a particular hearing system. Such rules may e.g. include weights that can be adjusted in order to adapt the mapping by the rule according to e.g. safety requirements, recommendations of an HCP, and/or needs or preferences of the user. In particular, the hearing system may also provide for a user interface which allows the user to adjust the settings or weights for such a rule. The user interface can e.g. include a device or means for receiving user gestures for input as e.g. tapping on the hearing device or it can make use of an interactive display as e.g. a touchscreen of a further component of the hearing system as e.g. a smartphone.

[0030] Whether or not, and if so, to which amount the rule for determining the subset of notification channels for a given notification event can be changed or adjusted preferably depends on the nature of the associated notification, i.e. for example whether the associated notification concerns an emergency, a health relevant setting of the hearing system, or a user preference or setting.

[0031] The hearing system of the invention is configured to initiate delivery of the notification associated with a detected notification event to the recipient via the determined subset of the plurality of notification channels which was determined based on the current system state and the rule associated with the notification event. The

hearing system itself can deliver the notification to the intended recipient via e.g. an acoustic channel as a loud-speaker or via a visual channel as e.g. a display screen of the hearing system. The notifications may be delivered as push notifications, notifying the user even when the corresponding notification channel is not actively used by the user at the time of delivery. Alternatively, the hearing system can be configured to only initiate the delivery of a given notification whereas the actual delivery to the recipient or recipients may be achieved by an external device or service as e.g. a messaging or e-mail service running on a remote server. In such cases, the hearing system can initiate the delivery via a messaging or e-mail application or client running on the hearing system which in turn connects to the remote server for delivering the notification. Both direct delivery and only initiating delivery of a notification can be implemented on the same hearing system for different notifications.

[0032] Not all notifications need to be notified to the recipient immediately or require an immediate response by the recipient, e.g. the user. In some embodiments of the invention, certain notifications may therefore be delivered as subliminal notifications. Subliminal notifications herein refer to notifications that are presented to the user below a threshold of conscious awareness. Such subliminal notifications may be used e.g. to delivery encouraging or motivating notifications to the user in case a low state of mind or mood is detected based on e.g. behavioral patterns of the user. The notifications can also be used as a reminder for the intake of e.g. non-mandatory medication as e.g. supplemental nutrition products, or for other, particularly non-mandatory, tasks or matters.

[0033] User consent for the delivery of subliminal notifications is mandatory. The hearing system therefore needs to be configured to ensure that the subliminal notifications are only delivered to the user after explicit consent has been given. To this end, the hearing system may include a hardware or software implemented consent module which ensures that such notifications cannot be delivered without the proper permission of the user. The user consent may be selective and may concern only certain types of subliminal notifications whereas consent may be denied for other subliminal notifications.

[0034] Subliminal notifications may include e.g. adapting the color of visual notifications by changing the color of a notification light, or changing a theme of notifications on a graphical display. Preferably, however, delivering such subliminal notifications in the hearing system include a notification channel for acoustic delivery of a notification. In order to acoustically deliver a subliminal notification to a user of the hearing system, a hearing loss, the notification context and/or e.g. an activity context of the wearer may need to be considered. In order to effectively deliver such subliminal notifications, the perception threshold may also need to be determined by e.g. referring to an audiogram of the intended recipient. To this end, the hearing system may have the audiogram stored in its memory for reference.

[0035] In case the consent has been given by the user, delivery of the subliminal notification may be initiated by the hearing system. In order to deliver the notification, a presentation mode may need to be defined wherein the presentation mode may include parameters as e.g. presenting below an acoustical perception threshold, define a number of repetitions of the notification, and/or identify or define acoustic sceneries which allow acoustical masking of the notification. Masking may e.g. be achieved by masking by noise, embedding into music or the notification can be embedded in the acoustic scenery of the surrounding sound. A sound classifier may be implemented in the system to classify the scenery.

[0036] The delivery of the notification may utilize a well-known biological effect typically referred to as stochastic resonance. Stochastic resonance uses the natural low level noise in the human sensory system as e.g. the auditory system to provide an effective stimulation while being almost or fully imperceptible to the user. Human sensory systems have a lower detection level threshold below which an external stimuli is not detectable and thus not perceivable. Utilizing naturally present noise, i.e. a stochastic signal present in all sensory systems, the stochastic signal of the noise may add up with the external acoustic stimuli which by itself is too small to generate a sensory response. The noise together in resonance with the peaks of the external stimuli, however, may generate a signal which exceeds neural activation thresholds and thus causes a perceivable event.

[0037] The delivery of the subliminal notifications that were presented to the user can be logged for later reference. This can be achieved e.g. by including a notification channel for delivering the notification to a log file to the subset of the plurality of notification channels. Alternatively, only the number of repetitions of a notification can be logged separately. If the user has previously consented to sharing usage data, the a notification channel for remote delivery can also be included in order to inform e.g. an HCP or another third party of the delivery of the notifications. Such data may be used for testing the effectiveness of the subliminal messaging system. The content and/or type of the subliminal notification can be provided by the hearing system itself or can be provided to the hearing system by e.g. third parties via a remote data connection, e.g. via a mobile device of the hearing system.

[0038] In an embodiment of the hearing system, the plurality of notification channels comprises at least one of the following: a channel for optical delivery of a notification; a channel for acoustic delivery of a notification; a channel for haptic delivery of a notification; a channel for delivery of a notification representative of audio content via direct electrical stimulation of the nervous system of a user; a channel for delivery of a notification to a data log file; and/or a channel for delivery of a notification to a local and/or remote data network.

[0039] The channel for optical delivery may include any suitable device or means allowing for delivery of an op-

tical signal to the recipient. The optical signal may be e.g. visually perceivable by the recipient in case the recipient is a person or it can be optically detectable by e.g. an optical sensor in case the recipient is another device. The channel for optical delivery thus may include a channel for visual delivery in some embodiments. The suitable device or means for optical delivery may include e.g. an indicator light or a display screen of a component of the hearing system, as e.g. a display screen of a personal computer, a tablet, a mobile phone, a smartwatch, or another wearable.

[0040] The channel for acoustic delivery may include any suitable device or means allowing for delivery of an acoustic signal to the recipient. In particular, the suitable device or means for delivery of an acoustic signal comprise an electroacoustic transducer of the hearing system, for example a loudspeaker of a component of the hearing system, e.g. a receiver of the hearing device, or a loudspeaker of a mobile phone, a smartwatch or another wearable of the hearing system. The suitable device or means can also include a buzzer and/or an indicator light of an alarm clock which may form part of the hearing system. The channel for haptic delivery may include any suitable device or means to deliver a haptic signal which pertains to the sense of touch of a recipient. In particular, the suitable means for delivery of a haptic signal may include a vibrating device of a component of the hearing system, in particular a vibrating device of a mobile phone included in the hearing system. The channel for haptic delivery thus in particular also refers to a channel for vibrotactile delivery in some embodiments, wherein vibrotactile refers to pertaining to the sense of touch which perceives it as vibration.

[0041] The channel for delivery via direct electrical stimulation of the nervous system of a user may include any suitable device or means for delivering an electric signal which is capable of stimulating parts of the nervous system of the recipient, typically the user. The suitable means may include a surface electrode which is in contact with the skin of the recipient or the suitable means may comprise an electrode which may be implanted for direct stimulation of nerve cells of the recipient. In this case, the channel may in particular also include an electronic interface connecting e.g. a component of the hearing device worn by the user outside of the body, e.g. behind the ear, to a component of the hearing device which is implanted.

[0042] The channel for delivery to a data log file may include any suitable device or means for adding data to a data file and may, in particular, include e.g. a software or hardware implemented data pipeline which allows the hearing system to write data to a data file stored in a memory, e.g. a memory of the hearing system or a remote memory.

[0043] The channel for delivery to a local or remote data network may include any suitable device or means for connecting the hearing system to a local or remote data network in a communicative manner. In particular,

the suitable device or means may comprise a connection interface for a connection to a local or a remote communication network as e.g. a wireless communication port or a wire-bound connection port.

[0044] The hearing system may utilize components of the hearing system that are already present as notification channels. In one particular embodiment of the hearing system, a notification channel for acoustic delivery may comprise an audio output unit of the hearing device, in particular an electroacoustic transducer of the hearing device for outputting an acoustic signal directly into the auditory canal of a user. By using the electroacoustic transducer of the hearing device as one of the notification channels, a notification can be easily and directly delivered to the user without the need for additional constructive elements. In alternative embodiments, the acoustic output channel can be provided by a separate device as e.g. by a buzzer of an alarm clock which may be included in the hearing system, or a loudspeaker of a smartwatch or smartphone.

[0045] In an embodiment of the hearing system, the system parameters comprise one or more of the following: an operational status of a component of the hearing system, in particular of the hearing device; a detection value of a sensor of the hearing system, in particular of a sensor of the hearing device; an operational status of a service to which the hearing system is connected or which is executed on the hearing system; and/or a status of a user of the hearing system as determined by the hearing system.

[0046] An operational status of a component of the hearing system or the hearing device may refer to a metric which is indicative of the component's operation. The hearing system may have self-tests implemented in order to assess the operational status of one or more of its components. The operational status may include an activation status, i.e. whether the component is activated or not. The operational status may also indicate a health of the component's operation, i.e. whether or not the component is working as intended. The operational status may include an indication of a maintenance status of a component which may e.g. be based on a self-test or which may be set based on a maintenance timer indicating a maintenance period.

[0047] The component herein may refer to a component of the hearing system as e.g. the hearing device, or it may refer to a part of a component as e.g. a battery, a processor, and/or a storage unit. The component may also refer to a sensor included in the hearing system, in particular in the hearing device, for providing detection values which are indicative of a system state or a physiological state of a user. A detection value of a sensor herein refers to a value representative of a measurement taken by the respective sensor. The detection value of the sensor can also be indicative of the operational status of a component of the hearing system.

[0048] The operational status of a service to which the hearing system is connected or which is executed on the

hearing system may refer to a metric relating to a status of a connection to a communication network as e.g. a remote network or a local network to which the hearing system is connected. The status may also refer to status of a connection to a communication network within the hearing system and by which the components of the hearing system are connected with each other. The connection may be both wireless or wire-bound. The service may also refer to a software service being executed on one or more components of the hearing system as e.g. a client/server service.

[0049] The status of a user may include detection values of e.g. physiological sensors which are directly indicative of a physiological state of the user and may include blood pressure blood oxygen saturation, temperature etc. The status of a user may also include derived detection values which are indicative of a status of the user as e.g. a motion status based on the motion status of the hearing device when it is worn by the user etc.

[0050] In an embodiment of the hearing system, the plurality of system parameters comprises one or more of the following: an operational status of a microphone of the hearing device, in particular a clogging status; an operational status of a receiver of the hearing device, preferably a clogging status of the receiver; an operational status of a vent opening of the hearing device, in particular a clogging status; an operational status of a battery of the hearing system, in particular of the hearing device, preferably a charging status of the battery; an operational status of a sensor of the hearing system, in particular of the hearing device; an operational status of the processing unit of the hearing system, in particular of the hearing device; an operational status of the memory of the hearing system, in particular of the hearing device; and/or an operational status of a network connection of the hearing system, in particular of the hearing device.

[0051] Whereas the system parameters are not restricted to particular parameters, the afore mentioned list represents a selection of parameters that have been proven to be advantageous to be included when assessing the status of the hearing system, in particular the hearing device.

[0052] In another embodiment of the hearing system, the plurality of system parameters comprises one or more of the following: a physiological status of a user as determined by the hearing system, in particular by the hearing device; a motion status of a user as determined by the hearing system, in particular by the hearing device; a wearing status of the hearing device as determined by the hearing system.

[0053] As miniaturization of physiological sensors progresses and it becomes increasingly common to include such sensors in hearing systems, in particular in hearing devices, it has proven to be particularly advantageous to include one or more select parameters which are indicative of a status of the user as system parameters. As such, some aspects of the user's condition are

integrated into the hearing system and the user - hearing system cooperation and interaction may be greatly facilitated and/or improved. Modern hearing systems typically allow for the integration of or connection to communication services. Such communication services may comprise a mobile phone network as well as e-mail or other messenger services. As it may be beneficial for the user to receive notifications relating to such type of services, the plurality of system parameters advantageously comprises one or more of the following: a status of a telephone application or service executed at least in part on the hearing system, in particular a call status; and/or a status of a messaging application or service executed at least in part on the hearing system, in particular an inbox status; and/or a status of a calendar and/or task manager application or service executed at least in part on the hearing system, in particular a reminder status. Whereas the status of a variety of other applications or services executed on the hearing system or to which the hearing system is connected may be included to the plurality of system parameters, it has proven to be particularly advantageous to at least include the afore mentioned status'.

[0054] A status of a calendar or task manager application or service as a system parameter may include parameters values being indicative on whether a calendar entry or a task needs to be reminded of. Such parameter values may for example specifically include whether a reminder is due and/or to which degree, e.g. urgent or optional etc. A status of a telephone application or service may include parameter values being indicative for the status of a phone connection and/or may include historical information. Such parameter values may for example indicate an incoming call, hanging up after a call and/or whether a call has been received in absence. Similarly, a status of a messenger service applications or service as e.g. e-mail or a mobile messenger may include parameter values that indicate receipt and/or a sent status of an e-mail or text message.

[0055] Including the mentioned status as system parameters of the hearing system allows for better integration of such services into the hearing system and, in particular, to be used to issue notification events and deliver notifications via notification channels as described herein.

[0056] In an embodiment of the hearing system, determining the subset of the plurality of notification channels includes determining the current system state by obtaining data from one or more components of the hearing system, preferably from one or more components of the hearing device, in particular from one or more sensors, wherein the data obtained is indicative of the parameter value of at least one of the plurality of system parameters.

[0057] Obtaining data from the one or more components may be achieved e.g. by polling or by interrupts, i.e. by the processor requesting the one or more components to provide data (i.e. by polling) or by the one or more components providing the data to the processor

upon request by the one or more components (i.e. by interrupts). Components herein may refer to different components of a single device of the hearing system as well as to a device which is a part of the hearing system.

[0058] In some embodiments, the issuance of one, several or all of the plurality of the notification events may be related to a transition of the hearing system into a predefined system state associated with the respective notification event(s). In one particular embodiment of the invention, the issuance of each notification event may be related to a transition of the hearing system into or out of an associated predefined system state, wherein each predefined system state is defined by predefined conditions for each of the plurality of system parameters.

[0059] The associated predefined system state herein refers to a system state defined by a predefined set of conditions for the plurality of system parameters. Predefined hereby refers to the conditions being available prior to the issuance of the respective notification events. Predefined particularly does not preclude the conditions from being adaptable by a user or by a HCP in order to e.g. adjust or set the trigger threshold(s) for issuance of one or more notification events according to requirements or preferences.

[0060] The hearing system is in the predefined system state when the plurality of system parameters satisfy the predefined set of conditions. In case the predefined system state is associated with a notification event, a transition into, or stay in this predefined system state may result in the issuance of the corresponding notification event. The issuance of a notification event referred to as "being related to" a transition of the hearing system into a predefined system state means e.g. "being caused by", "being triggered by" and/or "being initiated by" the transition of the current system state into the associated predefined system state.

[0061] Different predefined conditions can apply to the same system parameters for different predefined system states. Dependent on the system parameter, the predefined condition e.g. may comprise a threshold value and a logical expression as e.g. a relational operator defining a relation of the parameter value with respect to the threshold value as e.g. "larger or equal than", "smaller than" etc. In other examples, the condition may be of Boolean type, i.e. true or false, or the system parameter may comprise a set of strings as parameter values and the corresponding predefined condition can include one or more of these strings. The skilled artisan immediately understands what kind of conditions may apply dependent on the type of system parameters.

[0062] An exemplary system parameter is e.g. a charging status of a battery of the hearing device. The corresponding parameter value may be a proportion of a total capacity of the battery as e.g. 70%. A predefined condition associated with one or more of the predefined system states may e.g. be given by a threshold value of 30 %. Should the corresponding parameter value fall below this threshold, the hearing system may transition into a pre-

defined system state which can cause the issuance of a notification event for an associated notification containing the information "Battery low". In contrast, as long as the value is above this threshold, the corresponding predefined system state maybe indicate "Battery high" and no notification event may be issued as no notification is necessary. The same system parameter can also have two or more associated conditions which can be defined by e.g. two thresholds, for example 30% and 70% battery charging level. The upper threshold of 70% may differentiate between two predefined system states which may be termed as "Battery high" and "Battery normal", whereas the lower threshold may differentiate between "Battery normal" and "Battery low". Depending on e.g. the hearing system or the settings, transitioning between each of these predefined system states may cause the issuance of a notification event.

[0063] In an embodiment, each rule comprises a preference value for each one of the plurality of notification channels for each predefined condition associated with one of the plurality of system parameters. Each preference value may be represented by a number indicating the preference for the use of the respective notification channel if the corresponding condition is met by the associated system parameter. The plurality of preference values for each rule may therefore be represented in a two-dimensional array, e.g. in a matrix representation, wherein e.g. each column representing a condition associated with one of the system parameters whereas each row represents one of the plurality of notification channels. The preference values may be integers, fractions, or real numbers, but may also include other types of variables as strings or characters. In some embodiments, the preference values can be Boolean values which may be represented e.g. by 1 and 0 or by strings corresponding to "true" and "false". In other embodiments, the associated rule according to the hearing system may implement a different type of logic as e.g. fuzzy logic. In this case, the preference values may represent, for instance, truth values of a many-valued logic as e.g. well-known Fuzzy logic in which the truth value of variables may be any real number between 0 and 1. As such, the preference values may be chosen for example as a fraction or real number in the interval from 0 to 1, or as an integer on a grading scale from e.g. 0 to 10, wherein 0 may indicate least preferred and 1 or 10, respectively, may indicate most preferred. Possible values can also range from -1 to +1 where 0 is neutral and positive numbers represent "desirable" (or "good") whereas negative numbers indicate "undesirable" (or "bad").

[0064] The hearing system may also provide for mandatory preference values which may be defined for certain notification channels and conditions. Mandatory preference values herein indicate that, if the select condition is satisfied, the respective notification channel is to be used in any case for the delivery of the respective notification (or, vice versa, is never to be used), independent on the values of the remaining system param-

eters. Mandatory preference values may be used for notifications to ERS in case of emergencies or to an HCP in case there has been a crucial system failure etc.

[0065] The mandatory preference values may be represented by e.g. particular numbers that are not used for regular preference values and/or by upper and lower limits of an interval from which the preference values are chosen, e.g. in an interval from 0 to 10, wherein 0 may be used to indicate that the respective notification channel shall never be determined to belong to the subset if the corresponding condition is met and 10 may indicate that the respective notification channel shall always be determined to belong to the subset if the corresponding condition is met.

[0066] In an embodiment of the hearing system, determining the subset of the plurality of notification channels includes determining, for each of the notification channels, whether the respective notification channel belongs to the subset based on the preference values for the respective notification channel, wherein only predefined conditions are considered that are satisfied by the current system state.

[0067] When determining the subset by the associated rule and based on the current system state, an output value of the rule may be determined, e.g. calculated or computed, for a given notification channel based on the preference values corresponding to this respective notification channel, wherein the output value is indicative of whether or not the notification channel is to be included in the subset. The output values may have any suitable form that can be interpreted by hearing system to determine the subset of the plurality of notification channels. The output value for a given notification channel may be determined based on only the preference values of the conditions that are satisfied by the current system status.

[0068] When applying the rule associated with a given notification event, it may first be determined for each one of the plurality of notification channels whether one of the conditions that are satisfied by the current system state include an mandatory preference value (in cases where the hearing system provides for such mandatory preference values). If this is the case, it may immediately be determined that the corresponding notification channel always belongs (or, as the case may be, never belongs) to the subset of notification channels for delivering the associated notification. If there are no mandatory preference values, the output value for the respective channel needs to be determined based on the preference values, in particular of the satisfied predefined conditions, for the corresponding notification channel.

[0069] The output value may be a Boolean value, e.g. represented by 0 and 1, for each of the plurality of notification channels. The output of the rule may thus be a Boolean array having one Boolean entry for each one of the plurality of notification channels of the hearing system. The entries in the Boolean array may indicate whether or not the respective notification channel belongs to the subset for delivering the associated notification. The

associated rule in this case may be regarded as a mapping from the plurality of system parameter to a Boolean array having a length corresponding to the number of notification channels in the plurality of notification channels. As already mentioned in the above, other embodiments of the hearing system may implement a multi-valued logic as e.g. Fuzzy logic in which the output values for a given notification channels may contain fractions between 0 and 1.

[0070] In order to determine the output Boolean value, a sum may be formed based on the preference values of the relevant conditions wherein the result of the sum is used to determine whether or not the respective channel is to be used for the delivery of the associated notification or not. In case of Boolean preference values which are represented by 0 for "false" and 1 for "true", the output Boolean value for a given notification channel can simply be determined based on the sum, e.g. if the sum equals 0, none of the relevant preference values is set to 1 and the respective notification channel is determined not to belong to the subset for delivery of the associated notification. Similarly, the notification channel is determined to belong to the subset if the sum is non-zero which indicates that at least one of the preference values is 1. If the sum is normalized to one, the output Boolean value (in terms of ones and zeros) is directly given by the sum.

[0071] The sum may also be a weighted sum where the preference values may form the weights. The sum may be normalized. Determining whether or not the respective channel is to be used for the delivery of the associated notification may for instance be determined by the (optionally normalized) sum satisfying a given condition, e.g. the sum being larger or small than a threshold, resulting in the output Boolean value. Many other ways can be envisaged as to how the subset of notification channels may be determined based on the preference values.

[0072] In an embodiment, the hearing system is configured to provide a user interface enabling a user to adjust one or more of the rules associated with the plurality of notification events by user input. In a particular embodiment, the user interface may be configured to enable a user to adjust one or more of the preference values. The user interface may be a graphical user interface of the hearing system as e.g. a display screen of a mobile device. The user interface may also be an acoustic user interface and can e.g. use speech recognition for obtaining spoken user commands as an input. The user interface may also be configured to receive and/or recognize gestures of the user as e.g. tapping on the hearing device or sliding along a touch sensitive area of the hearing device.

[0073] The user interface may be configured to regularly query the user for valuation of the quality of service regarding the notification delivery, e.g. after delivery of a notification and/or at regular time intervals. Such queries may be limited to a certain number of times in order not to annoy the user. The user may provide his valuation

via the interface presented to him. The interface, for instance, may be configured to offer the possibility to input a satisfaction value regarding the choice of a specific notification channel that was used for the delivery of a notification by the hearing system for a given system state. The interface, however, may also be configured to provide the plurality of preference values for a given notification channel for valuation, or the plurality of preference values for a given condition for all notification channels.

[0074] The satisfaction value may be binary (e.g. "satisfied" or "not satisfied", "+" or "-", or displayed by positive or negative emojis) or it can include valuation on a scale ranging from a minimum to a maximum value, in which case a graphical user interface may include a slider for inputting the valuation. The satisfaction value may be used to increase, i.e. to values corresponding to more desirable, or decrease the corresponding preference value, i.e. to values corresponding to less desirable, for the respective notification channel. The user interface may be configured to stop querying the user for a given notification channel after a predefined number of queries or if e.g. a mandatory preference value or a very low preference value is reached based on previous valuation(s). "Very low", here, refers to a value that qualifies as very undesirable and based on repeated user valuation.

[0075] Alternatively or additionally, the interface may be configured to allow the user to enter a dialogue for adjusting the preference values associated with the notification channels of the hearing system on his own volition. The interface may be configured to present the preference values for adjustment one at a time, a subset at a time, or all at once. In particular, the interface may be configured to present the preference values or a subset thereof to the user for adjustment in an array-like manner, in particular in a tabular or grid arrangement. The preference values may be presented for instance in a two-dimensional array representation, e.g. as a matrix, wherein the columns indicate conditions associated with system parameters and the rows correspond to a notification channel each. In other embodiments, the interface may be configured to present the preference values for one select notification channel in a manner of a one-dimensional array, e.g. as a vector. The user may set individual preference values by directly accessing the corresponding entries. The interface may be configured to allow valuation of a subset of preference values, e.g. all preference values for a given notification channel or a given condition, at a time with a single input, or may provide for adjustment of each preference value individually. The interface may, as a security measure, prevent the user from altering certain preference values which are relevant for safety and/or required by regulations.

[0076] The present invention also includes and extends to a method for operating a hearing system as disclosed in the context with the hearing system. In particular, the present invention further concerns a method for operating a hearing system including a hearing device,

comprising: monitoring the hearing system for a plurality of notification events; and, upon detection of one of the plurality of notification events, providing a rule associated with the detected notification event; and determining by the associated rule and based on a current system state a subset of the plurality of notification channels for delivering a notification associated with the detected notification event; and initiating delivery of the associated notification via the determined subset of the plurality of notification channels.

[0077] The invention also concerns a non-transitory computer-readable medium storing instructions to execute a method for operating a hearing system including a hearing device, the method comprising: monitoring the hearing system for plurality of notification events; and, upon detection of one of the plurality of notification events, providing a rule associated with the detected notification event; and determining by the associated rule and based on a current system state a subset of the plurality of notification channels for delivering a notification associated with the detected notification event; and initiating delivery of the associated notification via the determined subset of the plurality of notification channels. The non-transitory computer-readable medium of the invention particularly stores instructions to execute the method to operate a hearing system as disclosed herein, in particular on a hearing system as disclosed herein.

[0078] The non-transitory computer-readable medium (also referred to as a processor-readable medium) includes any non-transitory medium that participates in providing data (e.g. instructions) that may be read by a computer (e.g. by a processor of a computer). Such a medium may take many forms, including, but not limited to, non-volatile media, and/or volatile media. Non-volatile media may include, for example, optical or magnetic disks and other persistent memory. Volatile media may include, for example, dynamic random access memory ("DRAM"), which typically constitutes a main memory. Common forms of computer-readable media include, for example, a disk, hard disk, magnetic tape, any other magnetic medium, a compact disc read-only memory ("CD-ROM"), a digital video disc ("DVD"), any other optical medium, random access memory ("RAM"), programmable read-only memory ("PROM"), electrically erasable programmable read-only memory ("EPROM"), FLASH-EEPROM, any other memory chip or cartridge, or any other tangible medium from which a computer can read.

Brief Description of the Drawings

[0079] The invention is further illustrated by way of exemplary implementations which are described in detail below and which are shown in the accompanying figures. The figures show schematically:

Fig. 1 an embodiment of a hearing system according to the invention formed by a hearing device;

- Fig. 2 a further embodiment of a hearing system according to the invention including a hearing device and a mobile device and a stationary device;
- Fig. 3 a diagram of a method according to the invention;
- Fig. 4 a possible representation of a rule for determining a subset of notification channels of a hearing system according to the invention based on a current system state which is associated with one of the plurality of predefined notification events.

[0080] The figures are generally not drawn to scale and depict various viewpoints and perspectives. Some components or operations shown in the figures may be separated into different blocks or combined into a single block for the purposes of discussion. Corresponding parts or components are generally referred to by the same reference numerals. The invention shall not be limited to the particular implementations and is intended to cover modifications, equivalents, and alternatives falling within the scope of the disclosed technology as defined by the appended claims.

Detailed Description

[0081] FIG. 1 shows an illustrative embodiment of a hearing system 100 according to the invention. The hearing system 100 is formed by a hearing device 110 which includes a processor 114 that is communicatively coupled to several components of the hearing device 110.

[0082] The processor 114 may be implemented by one or more computer processing devices, including general purpose processors (e.g. central processing units (CPUs), microprocessors, etc.), special purpose processors (e.g. application specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), etc.), image signal processors, or the like. The processor 114 is communicatively coupled to a memory 115. The memory 115 may store and/or otherwise maintain executable data used by processor 114 to perform any of the functionality described herein. For example, memory 115 may store instructions 116 that may be executed by processor 114. The memory 115 may be implemented by one or more memory or storage devices, including any memory or storage devices that are configured to store data in a transitory or non-transitory manner. The instructions 116 may be executed by the processor 114 to cause hearing device 110 to perform the functionality described herein. The instructions 116 may be implemented by any suitable application, software, code, and/or other executable data instance. Additionally, memory 115 may also maintain any other data accessed, managed, used, and/or transmitted by processor 114 in a particular implementation. The hearing device 110 further includes an audio input

unit 112 which is communicatively coupled with the processor 114. The audio input unit 112 is configured to receive an input signal and obtain an electrical audio input signal from the received input signal. The audio input signal is provide by the audio input unit 112 to the processor 114. The audio input unit 112 may be formed by or comprise one or more electroacoustic transducers, e.g. one or more microphones. The received input signal can be an audio signal, e.g. in the form of an audio stream, in which case the audio input unit 112 is configured to provide the input audio signal based on the received audio stream. The received audio stream may be provided for instance from another hearing device, a peripheral device and/or a remote device, e.g., a table microphone device, or any other remote device constituting a streaming source or a device connected to a streaming source, including but not limited to a mobile phone, laptop, or television.

[0083] The hearing device 110 further includes an audio output unit 113 which is communicatively coupled with the processor unit 114. The audio output unit 113 is configured to output an electrical audio output signal received from the processor 114 as an output signal to the user. Outputting the audio output signal may comprise providing, in particular generating, an output signal based on the audio output signal. For example, the audio output unit 113 may transfer or stream the audio output signal to another device, e.g. a peripheral device and/or a remote device. The output signal may also be an acoustic signal based on the audio output signal. In this case, the audio output unit 113 may be formed by or comprise one or more electroacoustic output transducers, in particular one or more speakers and/or so-called receivers. The audio output unit 113 may also be configured to output the output audio signal as an output signal for output electrodes of an implant as e.g. a cochlear implant of a user.

[0084] Furthermore, the hearing device 110 comprises several output units 117, 118, 119 for delivering information to a user of the hearing device 110. The output units 117, 118, 119 thus form at least part of a plurality of notification channels 101 for delivering a notification to the user. The output devices 117, 118, 119 are communicatively coupled to the processor 114. The output units 117, 118, 119 may comprise an indicator light 117, a buzzer 118 for playing a simple sound as e.g. a beep, and/or a shaker or vibrator device 119 that is configured to provide a haptic feedback to a user wearing or holding the hearing device 110. The audio output unit 113 also forms part of a further notification channel in the present sense for the delivery of e.g. acoustic notifications as e.g. a melody or a text message can be played or read out loud, respectively, to the user. It is to be understood that the hearing device 110 may also comprise only some of these output units 117, 118, 119 and/or additional output units which may form part of further notification channels in the present sense.

[0085] The hearing device 110 may further comprise

at least one physiological sensor 120 which is configured to detect a sensor value which is indicative of a physiological condition of a user of the hearing device 110. In some examples, the physiological sensor 120 may be implemented by a photoplethysmography (PPG) sensor. Output data may be provided by the PPG sensor as a PPG waveform, which may be indicative of a blood property, such as a heart rate, a blood pressure, a heart rate variability, an oxygen saturation index (SpO₂), a maximum rate of oxygen consumption (VO₂^{max}), and/or a concentration of an analyte contained in the tissue, such as water and/or glucose. The physiological sensor 120, however, may also be a thermoelectric sensor for determining a temperature of the wearer.

[0086] The physiological sensor 120 may in certain embodiments also form a notification channel or a part thereof. For example, in embodiments in which the sensor 120 includes an active optical sensor comprising a visible light source, the light source may be used as notification channel for delivering a notification to the user by e.g. repeated activation in a blinking pattern.

[0087] The hearing device 110 may further comprise one or more system sensors exemplarily indicated in FIG. 1 by sensor 121 that are indicative of one or more system parameters. The system parameters may contribute to define a system state of the hearing device 110. The sensor may be e.g. a liquid sensor for detecting the ingress of liquid or an accelerometer detecting motion of the hearing device 110. The detected values obtained from sensor 121 may be, by extension, indicative of a state of the user, for instance the detected motion status of the hearing device 110 may be used to determine a motion status of the user wearing the hearing device 110. Whether or not the hearing device 110 is worn by the user may be derived from the motion and/or be determined based on other sensors as e.g. a temperature sensor.

[0088] In order to communicate with other components that may be included in the hearing system 100, the hearing device 110 may include a communication interface 111 which may particularly configured to connect to a wireless service via e.g. a Bluetooth protocol, WLAN (often also referred to as Wifi), or other suitable wireless communication networks and/or protocols. In some embodiments, the communication interface 111 may also include connectors for a wire-bound connection. The communication interface 111 may also be configured for communication by a proprietary protocol, in particular for communication with a second hearing device of a binaural system.

[0089] The plurality of notification channels 101 of the hearing system 100 may thus comprise audio output unit 113, output units 117-119, physiological sensor 120 as well as communication interface 111, the latter one for delivering a notification to a communication network and ultimately to e.g. remote third parties.

[0090] FIG. 2 shows a further embodiment of a hearing system 200 according to the invention. The hearing sys-

tem 200 includes the hearing device 110 and, as further components, comprises a mobile device 130 and stationary device 150.

[0091] The mobile device may be a mobile phone or a smartwatch and may include a processor 134 which is communicatively coupled with a memory 135. Similar to memory 115 of the hearing device 119, the memory 135 of the mobile device 130 may store and/or otherwise maintain executable data used by processor 134 to perform any of the functionality described herein. For example, memory 135 may store instructions 136 that may be executed by processor 134. The instructions 136 may be implemented by any suitable application, software, code, and/or other executable data instance. Additionally, memory 135 may also maintain any other data accessed, managed, used, and/or transmitted by processor 134 in a particular implementation. In particular, processor 134 and memory 135 may cooperate with processor 114 and memory 115 of the hearing device 110 in order to provide for the functionality described herein.

[0092] The mobile device 130 is communicatively coupled to the hearing device 110 via a communication interface 131 of the mobile device 130 (indicated in FIG. 2 by a bi-directional arrow). Similar to the communication device 111 of the hearing device 110, the communication interface 131 may be configured to connect to a wireless communication network via e.g. a Bluetooth protocol, WLAN (often also referred to as Wifi), or other suitable wireless communication protocols. In some embodiments, the communication interface 131 may also include connectors for a wire-bound connection. The communication interface 131 is communicatively coupled to the processor 134.

[0093] The mobile device 130 may include several output units 137, 138, and 139. The output units 137, 138 and 139 may in particular comprise a display screen 137, a loudspeaker 138, and/or a shaker or vibrator device 139 that is configured to provide a haptic feedback to a user of the hearing system 200. The output units 137, 138, and 139 together with the output units 117, 118, and 119 of the hearing device form at least a part of a plurality of notification channels 201 of the hearing system 200 for delivering a notification to the user.

[0094] The hearing system 200 may further include a stationary device 150 which is communicatively coupled to the hearing device 110 and/or the mobile device 130 (indicated in Fig. 2 by bi-directional arrows) via a communication interface 151. The communication interfaces 111, 131, and 151 may be configured to provide for the same or for different communication protocols between the various components of the hearing system 200. In particular, the communication network and/or protocol used for the communication between the mobile device 130 and the stationary device 150 may be different from the communication network and/or protocol used between the mobile device 130 or the stationary device 150, respectively, and the hearing device 110.

[0095] The stationary device 150 may be e.g. a per-

sonal computer, a household appliance, or, as in the present case, an alarm clock 150. The stationary device 150 comprises a processing unit 152, which may include a processor and a memory (not shown), and may further comprise output units 157 and 158. The output unit 157 may be implemented as a signal light whereas the output unit 158 may be implemented as a buzzer. The output units 157 and 158 may also form part of notifications channels 201 of the hearing system 200.

[0096] The hearing system 200 may be connected to e.g. a cloud 170 which, for instance, belongs to a remote communication network 171. The connection to the remote communication network 171 may be achieved by only one, by several, or by all of the components of the hearing system 200 individually. Typically, however, the hearing device 110 itself connects via another component of the hearing system 200 to the remote communication network 171 due to constraints regarding e.g. available electrical power and/or processing capacity in the hearing device 110.

[0097] Third parties 172 and 173 may connect directly or via the cloud 170 to the hearing system 200. The third parties 172 and 173 may include Hearing Care Professionals (HCP) 172, an Emergency First Responders (EFR) 173, and/or another predefined contact as e.g. a close relative of the user of the hearing system 200. The connection to the remote communication network 171, e.g. via the interfaces 111, 131, and/or 151, may also form a notification channel for delivering a notification remotely.

[0098] The plurality of notification channels 201 of the hearing system 200 may thus comprise audio output unit 113, output units 117-119, the physiological sensor 120, output units 137-139, and/or 157-158, as well as communication interfaces 111, 131, 151 which allow for initiating delivery of a notification for instance locally via any one of the components 110, 130, 150 or remotely via the communication network 171.

[0099] FIG. 3 shows an illustrative method 300 that may be performed by a hearing system, e.g. the hearing system 100 or 200, according to the principles described herein. While FIG. 3 illustrates exemplary operations according to one embodiment, other embodiments may omit, add to, reorder, and/or modify any of the operations shown in FIG. 3. Moreover, each of the operations depicted in FIG. 3 may be performed in any of the ways described herein.

[0100] As shown, the hearing system 100, 200 monitors itself for issuance of a notification event as indicated by operation 310 in FIG. 3. Typically, the monitoring is governed by a processing entity of the hearing system 100, 200 as e.g. the processor 114, 134 and/or the processing unit 152. As pointed out in the above, notification events in the present sense are typically predefined events in the hearing system 100, 200 which is configured to issue and detect several notification events to form a plurality of possible notification events.

[0101] Typically, the hearing system 100, 200 may in-

clude an event handler, which is e.g. executed by the processor 114, 134 and/or by the processing unit 154. The event handler may detect events issued in the hearing system 100, 200 and discriminate between notification events belonging to the plurality of notification events and other events. The event handler typically also governs the handling of a notification event and may e.g. initiate delivery of a notification associated with the notification event that has been issued.

[0102] The detection step is depicted in operation 320 in FIG. 3. In case the hearing system 100, 200 determines in operation 320 that a detected event does not belong to the predefined plurality of notification events, the hearing system 100, 200 continues with monitoring and returns to operation 310 as indicated by arrow 320.2.

[0103] In case one of the plurality of the notification events is detected as indicated by arrow 320.1, the hearing system 100, 200 provides a rule associated with the detected notification event in operation 330. The associated rule may be carried as supplemental information by the notification event itself. The associated rule may also be obtained by the processor 114, 134 or the processing unit 154 from a memory of the hearing system 100, 200 as e.g. the memory 115, 135 and may form part of the set of instructions 116, 136 stored therein. In other implementations, the associated rule can also be generated procedurally by the processor 114, 134 or the processing unit 154, e.g. at runtime.

[0104] In operation 340, the hearing system 100, 200 determines by the associated rule, based on a current system state 350, a subset of the plurality of notification channels 101, 201. The subset of the plurality of notification channels 101, 201 is intended to be used for the delivery of a notification associated with the notification event detected in operation 320.

[0105] The current system state 350 is reflected by the current parameters values of a plurality of system parameters. Exemplary system parameters include battery charging status of one of the components of the hearing system 100, 200, a clogging status of a receiver or microphone of the hearing device 110 or of one of the further components 130 or 150 etc. Relevant system parameters may further include a detected or derived physiological status of the user of the hearing system 100, 200 based on data obtained by e.g. the exemplary physiological sensor 120 or the system sensor 121 of the hearing device 110. Further examples of such system parameters and how the associated rule may determine the subset of the plurality of notification channels 101, 201 are given in the description of FIG. 4.

[0106] After the subset of the plurality of notification channels 101, 201 has been determined in operation 340, the hearing system 100, 200 initiates the delivery of the associated notification. Initiating the delivery may include the processor 114, 134 and/or the processing unit 154 to take the necessary steps as e.g. sending instructions to other components of the hearing system to deliver the notification. In particular, initiating the delivery

may include providing the actual notification (e.g. from memory 115, 135 or generating it procedurally at runtime) associated with the notification event and providing it to the notification channel of the determined subset of the plurality of notification channels 101, 201. In some embodiments, initiating the delivery of the associated notification may include delivering instructions for dispatching the notification to the intended recipient or delivering the notification itself via the communication interface 111, 131, 151 to the remote communication network 171.

[0107] In some implementations, the hearing system 100, 200 itself delivers the notification to the user which is the case when the determined subset of the plurality of notification channels 101, 201 includes e.g. output units 117-119 and/or 137-139 or audio output unit 113 via which the associated notification is locally delivered to the user. The delivery of the associated notification not the intended recipient is indicated in FIG. 3 by operation 370.

[0108] FIG. 4 depicts a possible representation of a rule which is associated with one of the plurality of predefined notification events of the hearing system 100, 200. The representation of FIG. 4 includes a two-dimensional array 400. The columns 410 of the two-dimensional array 400 each correspond to a condition $C_1 \dots C_m$ for system parameters $SP_1 \dots SP_k$. The index l of the system parameters SP_l runs from $1 \dots k$ and indicates that the plurality of system parameters includes k system parameters $SP_1 \dots SP_k$ which are considered for defining a system state in this specific implementation of the hearing system 100, 200.

[0109] The conditions $C_1 \dots C_j \dots C_m$ represent conditions for the system parameters $SP_1 \dots SP_k$. There may be more conditions than system parameters, i.e. $m > k$, as there may be system parameters associated with two conditions as e.g. SP_2 associated with C_4 and C_5 , or three conditions as e.g. SP_1 associated with C_1 , C_2 , and C_3 . Other system parameters have only one condition associated with them as e.g. SP_3 and C_6 . Several conditions for a single system parameter as e.g. C_1 , C_2 , C_3 for SP_1 allow for differentiating between several states of the hearing system 100, 200 which are defined by e.g. different regimes of one single system parameter. An example is a battery charging status (SP_1) of a battery in the hearing system 100, 200. By having three conditions C_1 , C_2 , C_3 , three different charging levels as e.g. "low", "medium", "full" may be differentiated by the hearing system 100, 200. The condition C_1 may be satisfied if the charging status falls below a lower predefined threshold. The condition C_2 may be satisfied when the battery charging status lies between the lower and a predefined upper threshold, and the condition C_3 may be satisfied if the battery charging status lies above the upper threshold.

[0110] The rows 420 of the two-dimensional array 400 of FIG. 4 each represent one notification channel NC_i of the plurality of notification channels 101, 201. The index i is running from $1 \dots n$ where n indicates the number of

notification channels NC_i contained in the plurality of notification channels 101, 201.

[0111] The rows and columns of the two-dimensional array 400 contain preference values $PV_{11} \dots PV_{nm}$. As such, each pairing of a notification channel NC_i (i.e. one row) with a condition C_j (i.e. one column) has an associated preference value PV_{ij} . The two-dimensional array 400 thus contains $n \times m$ preference values PV_{ij} which defined the rule associated with the detected notification event for determining a subset of the plurality of notification channels 101, 201 for the delivery of the notification associated with the respective notification event.

[0112] It has to be noted that the first two rows and the first column in the representation of FIG. 4 are shown for indicating the meaning of the respective rows and channels. A corresponding representation as shown in FIG. 4 with all cells filled with the actual values rather than variables could be used to provide an interface for a user on a display screen included in the hearing system 101, 201 for adjusting the preference values $PV_{11} \dots PV_{nm}$ according to preferences.

[0113] Whereas various methods can be envisaged as to how it is determined whether or not a given notification channel shall belong to the subset of notification channels for the delivery of the associated notification for a given system state, a specific example is described in the following.

[0114] In a specific implementation of the hearing system 100, 200, the preference values $PV_{11} \dots PV_{nm}$ may be Boolean values which can be represented by 0 and 1 in the two-dimensional array 400. In other implementations, the preference values may of course include other integers and/or also fractions. In order to determine whether a given notification channel NC_i shall belong to the subset or not, it is first determined which conditions are satisfied by the current system state. The current system state as determined e.g. in operation 350 of the method 300 depicted in FIG. 3, may be defined only by conditions C_2 of system parameter SP_1 and condition C_j of system parameter SP_j being satisfied. All other conditions are not satisfied by the parameter values of the system parameters $SP_1 \dots SP_k$ for the exemplary current system state.

[0115] Evaluating the rule represented by the two-dimensional array 400 for determining the subset of the plurality of notification channels 101, 201 may, in this implementation, include simply forming a sum of all preference values of the conditions that are satisfied, i.e. $PV_{i2} + PV_{ij}$, in the respective row of NC_i (indicated by hatching in FIG. 4). Based on whether the sum is equal to zero or non-zero, it may be decided whether the respective notification channel NC_i belongs to the subset of the plurality of notification channels 101, 201 or not.

[0116] In some embodiments, the evaluation of the associated rule may thus yield a Boolean one-dimensional array of length n assigning to each of the notification channels NC_i whether it belongs to the subset (e.g. represented by "true" or 1) or not (e.g. represented by "false"

or 0). The Boolean value for one notification channel NC_i may e.g. be determined based on forming a (normalized) sum of the preference values of satisfied conditions in the row associated with the respective notification channel NC_i and comparing it for instance with a threshold value. The sum may also e.g. be divided by the number of summands, i.e. the number of satisfied conditions, and may thus form the arithmetic mean of the relevant preference values for the given notification channel.

[0117] It becomes immediately obvious that the representation of the rule associated with one of the plurality of notification events by a two-dimensional array 400 offers a simple way for determining the subset of the plurality of notification channels (101, 201) as well as an intuitive representation that may be presented to the user by an interface of the hearing system 100, 200 for adjusting the personal preference settings.

Claims

1. Hearing system (100, 200) including a hearing device (110), the hearing system (100, 200) comprising:

a plurality of notification channels (101, 201) which are configured for delivering a notification to a recipient, and
 a memory (115, 135) storing instructions (116, 136), and
 a processor (114, 134) communicatively coupled to the memory (115, 135) and configured to execute the instructions to:

- monitor the hearing system (100, 200) for a plurality of notification events; and,
- upon detection of one of the plurality of notification events, provide a rule associated with the detected notification event; and
- determine by the associated rule and based on a current system state a subset of the plurality of notification channels (101, 201) for delivering a notification associated with the detected notification event; and
- initiate delivery of the associated notification via the determined subset of the plurality of notification channels (101, 201).

2. Hearing system (100, 200) according to claim 1, wherein the plurality of notification channels (101, 201) comprises at least one of the following:

- a channel for optical delivery of a notification;
- a channel for acoustic delivery of a notification;
- a channel for haptic delivery of a notification;
- a channel for delivery of a notification representative of audio content via direct electrical stimulation of the nervous system of a user;

- a channel for delivery of a notification to a data log file;
- a channel for delivery of a notification to a local and/or remote data network.

3. Hearing system (100, 200) according to claim 2, wherein the plurality of notification channels (101, 201) includes a channel for acoustic delivery of a notification, wherein the channel for acoustic delivery comprises an audio output unit of the hearing device, in particular an electroacoustic transducer of the hearing device for outputting a notification as acoustic signal directly into the auditory canal of a user.

4. Hearing system (100, 200) according to any one of claims 1 to 3, wherein the current system state is defined by parameter values of a plurality of system parameters of the hearing system, wherein the system parameters comprise one or more of the following:

- an operational status of a component of the hearing system, in particular of the hearing device;
- a detection value of a sensor of the hearing system, in particular of a sensor of the hearing device;
- a status of a service to which the hearing system is connected or which is executed on the hearing system;
- a status of a user of the hearing system as determined by the hearing system.

5. Hearing system (100, 200) according to claim 4, wherein the plurality of system parameters comprises one or more of the following:

- an operational status of a microphone of the hearing device, in particular a clogging status;
- an operational status of a receiver of the hearing device, preferably a clogging status of the receiver;
- an operational status of a vent opening of the hearing device, in particular a clogging status;
- an operational status of a battery of the hearing system, in particular of the hearing device, preferably a charging status of the battery;
- an operational status of a sensor of the hearing system, in particular of the hearing device;
- an operational status of the processing unit of the hearing system, in particular of the hearing device;
- an operational status of the memory of the hearing system, in particular of the hearing device;
- an operational status of a network connection of the hearing system, in particular of the hearing

device.

6. Hearing system (100, 200) according to claim 4 or 5, wherein the plurality of system parameters comprises one or more of the following:

- a physiological status of a user as determined by the hearing system, in particular by the hearing device;
- a motion status of a user as determined by the hearing system, in particular by the hearing device;
- a wearing status of the hearing device as determined by the hearing system.

7. Hearing system (100, 200) according to any one of claims 4 to 6, wherein the plurality of system parameters comprises one or more of the following:

- a status of a telephone application or client executed at least in part on the hearing system;
- a status of a messaging application or client executed at least in part on the hearing system;
- a status of a calendar and/or task manager application or service executed at least in part on the hearing system.

8. Hearing system (100, 200) according to claim 4 to 7, wherein determining the subset of the plurality of notification channels (101, 201) includes determining the current system state by obtaining data from one or more components of the hearing system, preferably from one or more components of the hearing device, in particular from one or more sensors, wherein the data obtained is indicative of the parameter value of at least one of the plurality of system parameters.

9. Hearing system (100, 200) according to any one of claims 4 to 8, wherein the issuance of each notification event is related to a transition of the hearing system (100, 200) into a predefined system state associated with the notification event, wherein each predefined system states is defined by predefined conditions for each of the plurality of system parameters.

10. Hearing system (100, 200) according to claim 9, wherein each rule comprises a preference value for each one of the plurality of notification channels (101, 201) for each predefined condition associated with one of the plurality of system parameters.

11. Hearing system (100, 200) according to claim 10, wherein determining the subset of the plurality of notification channels (101, 201) includes determining for each of the notification channels whether the respective notification channel belongs to the subset

based on the preference values for the respective notification channel of all predefined conditions that are satisfied by the current system state.

12. Hearing system (100, 200) according to claim 1 to 11, wherein the hearing system (100, 200) is configured to provide a user interface enabling a user to adjust one or more of the rules associated with the plurality notification events by user input.

13. Hearing system (100, 200) according to any one of claims 10 or 11 in combination with claim 12, wherein the user interface is configured to enable a user to adjust one or more of the preference values by user input.

14. A method for operating a hearing system (100, 200) including a hearing device (110), in particular a hearing system (100, 200) according to any one of the preceding claims, comprising:

- monitoring (310) the hearing system (100, 200) for a plurality of notification events; and
- upon detection (320) of one of the plurality of notification events, providing (330) a rule associated with the detected notification event; and
- determining (340) by the associated rule and based on a current system state (350) a subset of a plurality of notification channels (101, 201) for delivering a notification associated with the detected notification event; and
- initiating (360) delivery of the associated notification via the determined subset of the plurality of notification channels (101, 201).

15. A non-transitory computer-readable medium storing instructions to execute a method for operating a hearing system (100, 200) including a hearing device (110), in particular to execute the method according to claim 14, comprising:

- monitoring (310) a hearing system (100, 200) for a plurality of notification events; and
- upon detection (320) of one of the plurality of notification events, providing (330) a rule associated with the detected notification event; and
- determining (340) by the associated rule and based on a current system state (350) a subset of a plurality of notification channels (101, 201) of the hearing system (100, 200) for delivering a notification associated with the detected notification event; and
- initiating (360) delivery of the associated notification via the determined subset of the plurality of notification channels (101, 201).

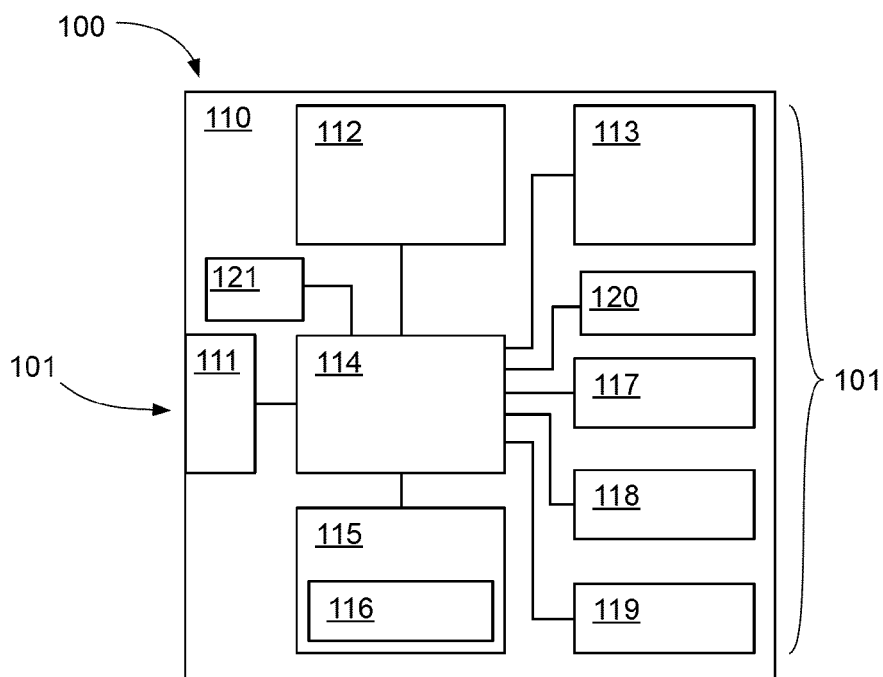


Fig. 1

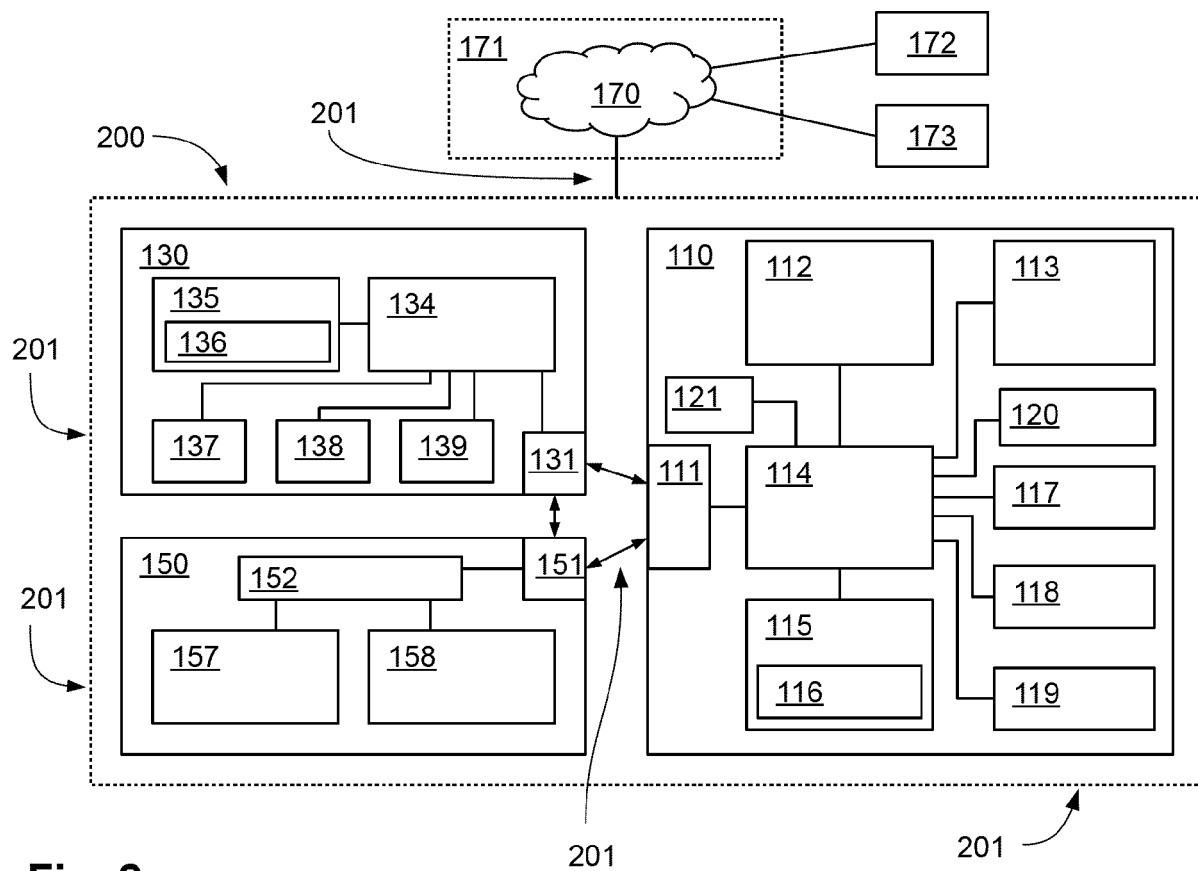


Fig. 2

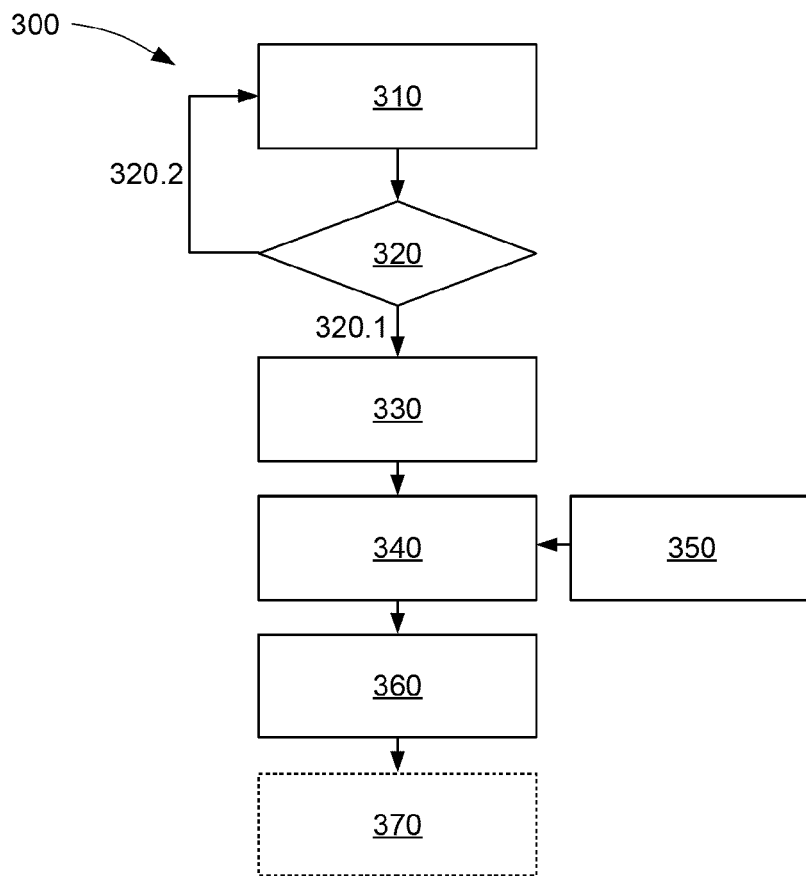


Fig. 3

		SP ₁			SP ₂		SP ₃	...	S _i	...	SP _k
		C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	...	C _j	...	C _m
420	NC ₁	PV ₁₁	PV ₁₂	PV ₁₃	...	...	...	...	...	...	PV _{1m}
	NC ₂	PV ₂₁	PV ₂₂	PV ₂₃	...	...	...	...	...	...	PV _{2m}
	NC ₃	PV ₃₁	PV ₃₂	PV ₃₃	...	...	...	...	...	...	PV _{3m}
	...	...	...	...	...	...	...	...	...	...	...
	NC _i	PV _{i1}	PV _{i2}	PV _{i3}	...	...	...	...	PV _{ij}	...	PV _{im}
	...	...	...	...	...	...	...	...	...	...	...
	NC _n	PV _{n1}	PV _{n2}	PV _{n3}	...	...	...	...	...	...	PV _{nm}

Fig. 4

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			H04R
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 7 September 2022	Examiner Bücker, Martin
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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The members are as contained in the European Patent Office EDP file on
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