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DESCRIPTION

[0001] A new hearing aid system is provided with improved automatic selection and adjustment of hearing aid signal processing parameters in response to sound environment, geographical position, and user feedback. In particular, the new hearing aid system features optimization of hearing aid signal processing parameters based on geographical position and Bayesian incremental preference elicitation.

[0002] Today's conventional hearing aids typically comprise a Digital Signal Processor (DSP) for processing of sound received by the hearing aid for compensation of the user's hearing loss. As is well known in the art, the processing of the DSP is controlled by signal processing algorithms having various parameters for adjustment of the actual signal processing performed, such as the gains in each of the frequency channels of a multi-channel hearing aid, corner frequencies or slopes of frequency-selective filter algorithms, parameters controlling knee-points and compression ratios of compressor algorithms, etc.

[0003] The flexibility of the DSP is often utilized to provide a plurality of different algorithms with various signal processing parameters. For example, various algorithms may be provided for noise suppression, i.e. attenuation of undesired signals and amplification of desired signals. Desired signals are usually speech or music, and undesired signals can be background speech, restaurant clatter, music (when speech is the desired signal), traffic noise, etc.

[0004] The different algorithms and parameters are typically included to provide comfortable and intelligible reproduced sound quality in different categories of sound environments, such as speech, babble speech, restaurant clatter, music, traffic noise, etc.

[0005] Audio signals obtained from different sound environments may possess very different characteristics, e.g. average and maximum sound pressure levels (SPLs) and/or frequency content. Therefore, in a hearing aid with a DSP, each category of sound environment may be associated with particular signal processing algorithms with particular settings of signal processing parameters that provide processed sound of optimum signal quality for the category of the sound environment in question.

[0006] Consequently, today's DSP based hearing aids are usually provided with a number of different signal processing algorithms, wherein each algorithm is tailored to a particular category of the sound environment and/or particular user preferences. Signal processing parameters are typically determined during an initial fitting session in a dispenser's office and programmed into the hearing aid by activating desired algorithms and setting algorithm parameters in a non-volatile memory area of the hearing aid and/or transmitting desired algorithms and algorithm parameter settings to the non-volatile memory area.

[0007] Some known hearing aids are capable of automatically classifying the user's sound environment into one of a number of categories of the sound environment, such as speech, babble speech, restaurant clatter, music, traffic noise, etc.

[0008] Obtained classification results may be utilised in the hearing aid to automatically select signal processing characteristics of the hearing aid, e.g. to automatically switch to the most suitable signal processing algorithm and parameters for the environment category in question. Such a hearing aid will be able to automatically maintain optimum sound quality and/or speech intelligibility for the individual hearing aid user in various categories of sound environments.

[0009] US 2007/0140512 A1 and WO 01/76321 disclose examples of classifier approaches.

[0010] US 2011/293123 A1 discloses systems and methods that provide an environment-based sound profiling system, which collects, analyses, and uses environmental sounds from various sources and from different locations to produce environment-based sound profiles. Such environment-based sound profiles can be used to produce sound filters that can be applied to a selected hearing aid profile or modulated output signals of the user's hearing aids, as well as to other hearing aids, allowing individual hearing aid users to benefit from the experiences of others. Thus, instead of selecting hearing correction parameters derived for one environment that can be applied to other, nominally similar, environments, the system can produce sound profiles specific to a location and produce corresponding sound filters for that location.

[0011] WO 2007/042043 A2 discloses a method for effective estimation of signal processing parameters in a hearing aid that is capable of incorporating user perception of sound quality. It is based on an interactive estimation process that incorporates, possibly inconsistent, user feedback based on Bayesian incremental preference elicitation.

[0012] WO 2012/066149 A1 discloses a personal device for compensating hearing impairment by implementing the functionality of a hearing aid and interacting with ear buds, bone anchored hearing aid or cochlear implant. The disclosed device comprises location sensors, such as GPS, and a user interface for controlling and changing parameters. WO 2012/066149 A1 further discloses that a module performs analysis of the microphone signal, resulting in a set of descriptors. Descriptors can include geo-location of the situation. Adjustments made by the user are stored and taken into account simultaneously with the listening situation, and WO 2012/066149 A1 further discloses automatic learning of user adjustments.

[0013] A new hearing aid system is provided with a hearing aid that includes the geographical position of the new hearing aid system and user feedback in its determination of the category of the sound environment.

[0014] The sound environment within a certain geographical area typically remains in the same category over time. Thus, incorporation of the geographical position in the determination of the category of the current sound environment will improve the determination of the category, i.e. the determination of the category may be made faster, and/or the determination of the category may be made with increased certainty.

[0015] A new hearing aid system is provided according to claim 1.

[0016] The provision of the first output to the first processor may be based on Bayesian incremental preference elicitation of the adjustment.

[0017] The hearing aid system has a library of signal processing algorithms $F(\Theta)$, where Θ is the algorithm parameter space, including parameters controlling selection of algorithms for execution, e.g. a noise suppression algorithm may be selected for execution in a noisy environment and may not be selected for execution in a quiet environment.

[0018] The location detector includes at least one of a GPS receiver, a calendar system, a WIFI network interface, a mobile phone network interface, for determining the geographical position of the hearing aid system and optionally the velocity of the hearing aid system.

[0019] The first sound environment detector may be configured for determining the category of the sound environment surrounding the hearing aid system based on the sound signal received by the hearing aid system, the determined geographical position of the hearing aid system, and at least one parameter selected from the group consisting of: A date, a time of day, a velocity of the hearing aid system, and a signal strength of a signal received by the GPS receiver.

[0020] The sound environment at a specific geographical position, such as a city square, may change in a repetitive way during the year in a similar way from one year to another and/or during a day in a similar way from one day to another, e.g. due to repeated variations in traffic, number of people, etc, and such variations may be taken into account by allowing the sound environment detector to include the date and/or the time of day in the determining the category of sound environment.

[0021] Signal strength of signals received by the GPS receiver decreases significantly when the hearing aid system is inside a building and thus, information on GPS signal strength may be used by the sound environment detector to determine whether the hearing aid system is inside a building.

[0022] Information on moving speed as for example determined by the GPS receiver may be used by the sound environment detector to determine that the hearing aid system is inside a transportation vehicle, such as in a car.

[0023] The hearing aid may be of any type configured to be head worn at, and shifting position and orientation together with, the head, such as a BTE, a RIE, an ITE, an ITC, a CIC, etc, hearing aid.

[0024] Throughout the present disclosure, the term GPS receiver is used to designate a receiver of satellite signals of any satellite navigation system that provides location and time information anywhere on or near the Earth, such as the satellite navigation system maintained by the United States government and freely accessible to anyone with a GPS receiver and typically designated "the GPS-system", the Russian GLObal NAvigation Satellite System (GLONASS), the European Union Galileo navigation system, the Chinese Compass navigation system, the Indian Regional Navigational 20 Satellite System, etc, and also including augmented GPS, such as StarFire, Omnistar, the Indian GPS Aided Geo Augmented Navigation (GAGAN), the European Geostationary Navigation Overlay Service (EGNOS), the Japanese Multifunctional Satellite Augmentation System (MSAS), etc. In augmented GPS, a network of ground-based reference stations measure small variations in the GPS satellites' signals, correction messages are sent to the GPS system satellites that broadcast the correction messages back to Earth, where augmented GPS-enabled receivers use the corrections while computing their positions to improve accuracy. The International Civil Aviation Organization (ICAO) calls this type of system a satellite-based augmentation system (SBAS).

[0025] The hearing aid may further comprise one or more orientation sensors, such as gyroscopes, e.g. MEMS gyros, tilt sensors, roll ball switches, etc, configured for outputting signals for determination of orientation of the head of a user wearing the hearing aid, e.g. one or more of head yaw, head pitch, head roll, or combinations hereof, e.g. inclination or tilt.

[0026] Throughout the present disclosure, a calendar system is a system that provides users with an electronic version of a calendar with data that can be accessed through a network, such as the Internet. Well-known calendar systems include, e.g., Mozilla Sunbird, Windows Live Calendar, Google Calendar, Microsoft Outlook with Exchange Server, etc.

[0027] Throughout the present disclosure, the word "tilt" denotes the angular deviation from the heads normal vertical position, when the user is standing up or sitting down. Thus, in a resting position of the head of a person standing up or sitting down, the tilt is 0°, and in a resting position of the head of a person lying down, the tilt is 90°.

[0028] The first sound environment detector may be configured for provision of the first output for selection of first values of the set of signal processing parameters Θ based on user head orientation as determined based on the output signals of the one or more orientation sensors. For example, if the user changes position from sitting up to lying down in order to take a nap, the environment detector may cause the first signal processor to switch signal processing algorithm(s) accordingly, e.g. the first hearing aid may be automatically muted.

[0029] Alternatively, the output signals of the one or more orientation sensors may be input to another part of the hearing aid system, e.g. the first processor, configured for selection of the first values of the set of signal processing parameters Θ based on the output signals of the one or more orientation sensors and the output of the first sound environment detector.

[0030] The signal processing algorithms may comprise a plurality of sub-algorithms or sub-routines that each performs a particular subtask in the signal processing algorithm. As an example, the signal processing algorithm may comprise different signal processing sub-routines such as frequency selective filtering, single or multi-channel compression, adaptive feedback cancellation, speech detection and noise reduction, etc.

[0031] Furthermore, several distinct selections of signal processing algorithms, sub-algorithms or sub-routines may be grouped together to form two, three, four, five or more different pre-set listening programs which the user may be able to select between in accordance with his/hers preferences.

[0032] The signal processing algorithms will have one or several related algorithm parameters. These algorithm parameters can usually be divided into a number of smaller parameters sets, where each such algorithm parameter set is related to a particular part of the signal processing algorithms or to particular sub-routines. These parameter sets control certain characteristics of their respective algorithms or subroutines such as corner-frequencies and slopes of filters, compression thresholds and ratios of compressor algorithms, adaptation rates and probe signal characteristics of adaptive feedback cancellation algorithms, etc.

[0033] Values of the algorithm parameters are preferably intermediately stored in a volatile data memory area of the processing means such as a data RAM area during execution of the respective signal processing algorithms or sub-routines. Initial values of the algorithm parameters are stored in a non-volatile memory area such as an EEPROM/Flash memory area or battery backed-up RAM memory area to allow these algorithm parameters to be retained during power supply interruptions, usually caused by the user's removal or replacement of the hearing aid's battery or manipulation of an ON/OFF switch.

[0034] The location detector, e.g. including a GPS receiver, may be included in the first hearing aid for determining the geographical position of the user, when the user wears the hearing aid in its intended operational position on the head, based on satellite signals in the well-known way. Hereby, the user's current position and possibly orientation can be provided, e.g. to the first sound environment detector, based on data from the first hearing aid.

[0035] The sound environment detector may be configured for storing hearing aid parameters together with GPS-data on a remote server, e.g. on a remote server accessed through the Internet, possibly together with a hearing profile of the user, e.g. for backup of hearing aid settings at various GPS-locations, and/or for sharing of hearing aid settings at various GPS-locations with other hearing aid users.

[0036] Thus, the sound environment detector may be configured for retrieving a hearing aid setting of another user made at the current GPS-location. The hearing aid settings may be grouped according to hearing profile similarities and/or age and/or race and/or ear size, etc, and the hearing aid setting of another user may be selected in accordance with the user's belonging to such groups.

[0037] The first sound environment detector may be included in the first hearing aid, whereby signal transmission between the sound environment detector and other circuitry of the hearing aid is facilitated.

[0038] Alternatively, the location detector, e.g. including the GPS receiver, may be included in a hand-held device that is interconnected with the hearing aid.

[0039] The hand-held device may be a GPS receiver, a smart phone, e.g. an Iphone, an Android phone, windows phone, etc, e.g. with a GPS receiver, and a calendar system, etc, interconnected with the hearing aid.

[0040] The first sound environment detector may be included in the hand-held device. The first sound environment detector may benefit from the larger computing resources and power supply typically available in a hand-held device as compared with the limited computing resources and power available in a hearing aid.

[0041] The hand-held device may accommodate a user interface configured for user control of the hearing aid system, e.g. including the first hearing aid.

[0042] The hand-held device may have an interface for connection with a Wide-Area-Network, such as the Internet.

[0043] The hand-held device may access the Wide-Area-Network through a mobile telephone network, such as GSM, IS-95, UMTS, CDMA-2000, etc.

[0044] Through the Wide-Area-Network, e.g. the Internet, the hand-held device may have access to electronic time management and communication tools used by the user for communication and for storage of time management and communication information relating to the user. The tools and the stored information typically reside on a remote server accessed through the Wide-Area-Network.

[0045] The hearing aid may comprise a data interface for transmission of control signals from the hand-held device to other parts of the hearing aid system, including the first hearing aid.

[0046] The hearing aid may comprise a data interface for transmission of the output of the one or more orientation sensors to the hand-held device.

[0047] The data interface may be a wired interface, e.g. a USB interface, or a wireless interface, such as a Bluetooth interface, e.g. a Bluetooth Low Energy interface.

[0048] The hearing aid may comprise an audio interface for reception of an audio signal from the hand-held device and possibly other audio signal sources.

[0049] The audio interface may be a wired interface or a wireless interface. The data interface and the audio interface may be combined into a single interface, e.g. a USB interface, a

Bluetooth interface, etc.

[0050] The hearing aid may for example have a Bluetooth Low Energy data interface for exchange of sensor and control signals between the hearing aid and the hand-held device, and a wired audio interface for exchange of audio signals between the hearing aid and the hand-held device.

[0051] The first sound environment detector may comprise a first feature extractor for determination of characteristic parameters of the first audio input signal.

[0052] The feature extractor may determine characteristic parameters of the audio input signal, such as average and maximum sound pressure levels (SPLs), signal power, spectral data and other well-known features. Spectral data may include Discrete Fourier Transform coefficients, Linear Predictive Coding parameters, cepstrum parameters or corresponding differential cepstrum parameters.

[0053] The feature extractor may output the characteristic parameters to a first environment classifier configured for determining the category of the sound environment based on the determined characteristic parameters and the geographical position.

[0054] The first environment classifier is configured for determining the category of sound environments into a number of sound environment classes or categories, such as speech, babble speech, restaurant clatter, music, traffic noise, etc. The classification process may utilise a simple nearest neighbour search, a neural network, a Hidden Markov Model system or another system capable of pattern recognition. The output of the environmental classification is a set of probabilities indicating the probabilities of the sound environment belonging to the respective categories.

[0055] The first environment classifier may output a determined category of the sound environment to a first parameter map configured for provision of the output for selection of the appropriate first signal processing algorithm(s) and parameters for execution by the first processor.

[0056] In this way, obtained classification results may be utilised in the hearing aid to automatically select signal processing characteristics of the hearing aid, e.g. to automatically switch to the most suitable algorithm for the sound environment in question. Such a hearing aid will be able to maintain optimum sound quality and/or speech intelligibility for the individual hearing aid user in various categories of sound environments.

[0057] As an example, it may be desirable to switch between an omni-directional and a directional microphone preset program in dependence of, not just the level of background noise, but also on further signal characteristics of this background noise. In situations where the user of the hearing aid communicates with another individual in the presence of the background noise, it would be beneficial to be able to identify and categorize the type of background noise. Omni-directional operation could be selected in the event that the noise being traffic noise to allow the user to clearly hear approaching traffic independent of its direction of arrival. If, on the other hand, the background noise was categorized as being babble-noise, the directional listening program could be selected to allow the user to hear a target speech signal with improved signal-to-noise ratio (SNR) during a conversation.

[0058] Applying Hidden Markov Models for analysis and classification of the microphone signal may for example obtain a detailed characterisation of e.g. a microphone signal. Hidden Markov Models are capable of modelling stochastic and non-stationary signals in terms of both short and long time temporal variations.

[0059] The sound environment detector is configured for recording the geographical position determined by the location detector together with the determined category of the sound environment at the geographical position. Recording may be performed at regular time intervals, and/or with a certain geographical distance between recordings, and/or triggered by certain events, e.g. a shift in category of the sound environment, a change in signal processing, such as a change in signal processing programme, a change in signal processing parameters, etc., etc.

[0060] When the hearing aid system is located within a threshold distance from a geographical position of a previous recording of a category of the sound environment and/or within an area of previously recorded geographical positions with identical recordings of the category of the sound environment, the sound environment detector is configured for increasing the probability that the current sound environment is of the same category as already recorded at or proximate the current geographical position, or, determining that the current sound environment is of the already recorded category of the sound environment.

[0061] The first sound environment detector may be configured for determining the category of the sound environment by considering a probability of occurrence for a previously recorded category of the sound environment that is within a distance threshold from the determined geographical position.

[0062] The threshold distance may be predetermined, e.g. reflecting the uncertainty of the determination of geographical position of the location detector, e.g. less than or equal to the uncertainty of the location detector, or less than or equal to an average distance between recordings of geographical position and category of the sound environment, or less than a characteristic size of significant features at the current geographical position such as a sports arena, a central station, a city hall, a theatre, etc. The threshold distance may also be adapted to the current environment, e.g. resulting in relatively small threshold distances in areas, e.g. urban areas, with short distances between recordings of different categories of the sound environment, and resulting in relatively large threshold distances in areas, e.g. open ranges, with large distances between recordings of different categories of the sound environment.

[0063] A user interface of the hearing aid system may be configured to associate certain categories of the sound environment with respective geographical areas.

[0064] In absence of useful GPS signals, the location detector may determine the geographical position of the hearing aid system based on the postal address of a WIFI network the hearing aid system may be connected to, or by triangulation based on signals possibly received from various GSM-transmitters as is well-known in the art of mobile phones. Further, the location detector may be configured for accessing a calendar system of the user to obtain information on the expected whereabouts of the user, e.g. meeting room, office, canteen, restaurant, home, etc and to include this information in the determination of the geographical position. Thus, Information from the calendar system of the user may substitute or supplement information on the geographical position determined by otherwise, e.g. by a GPS receiver.

[0065] For example, the sound environment detector may automatically switch the hearing aid(s) of the hearing aid system to flight mode, i.e. radio(s) of the hearing aid(s) are turned off, when the location detector detects that the user is in an airplane.

[0066] Also, when the user is inside a building, e.g. a high rise building, GPS signals may be absent or so weak that the geographical position cannot be determined by a GPS receiver. Information from the calendar system on the whereabouts of the user may then be used to provide information on the geographical position, or information from the calendar system may supplement information on the geographical position, e.g. indication of a specific meeting room may provide information on which floor in a high rise building, the hearing aid system is located. Information on height is typically not available from a GPS receiver.

[0067] The location detector may automatically use information from the calendar system, when the geographical position cannot be determined otherwise, e.g. when the GPS-receiver is unable to provide the geographical position. In the event that no information on geographical position is available to the location detector, e.g. from the GPS receiver and the calendar system, the sound environment detector may categorize the sound environment in a conventional way based on the received sound signal; or, the hearing aid may be set to operate in a mode selected by the user, e.g. previously during a fitting session, or when the situation occurs.

[0068] The user may not be satisfied with the automatic selection of parameter values and may perform an adjustment of signal processing parameters using the user interface, e.g. the user may change the current selection of signal processing algorithm to another signal processing algorithm, e.g. the user may switch from a directional signal processing algorithm to an omni-directional signal processing algorithm.

[0069] The sound environment detector is configured for incorporation of user adjustments of signal processing parameter values over time.

[0070] The sound environment detector is configured for automatic adjustment of at least one signal processing parameter $\theta \in \Theta$ in the hearing aid system with the library of signal processing algorithms F(Θ), where Θ is the algorithm parameter space, including parameters controlling selection of algorithms for execution, e.g. a noise suppression algorithm is selected for execution in a noisy environment and is not selected for execution in a quiet environment.

[0071] The sound environment detector is configured for
recording an adjustment made by the user of the hearing aid system, and modifying the automatic adjustment of the at least one signal processing parameter $\theta \in \Theta$ in response to the recorded adjustment based on (Bayesian) incremental preference elicitation, so that the next time the same sound environment is detected, the modified automatic adjustment is performed.

[0072] Bayesian inference involves collecting evidence that is meant to be consistent or inconsistent with a given hypothesis. The degree of belief in a hypothesis changes as evidence accumulates. With enough evidence, it will often become very high or very low.

[0073] Bayesian inference uses a numerical estimate of the degree of belief in a hypothesis before evidence has been observed and calculates a numerical estimate of the degree of belief in the hypothesis after evidence has been observed.

[0074] Bayes' theorem adjusts probabilities given new evidence in the following way:

$$P(H_0|E) = \frac{P(E|H_0)\,P(H_0)}{P(E)}$$

where

H_0 represents a hypothesis, called a null hypothesis that was inferred before new evidence, E, became available,

$P(H_0)$ is called the *prior probability* of H_0,

$P(E|H_0)$ is called the *conditional probability* of seeing the evidence E given that the hypothesis H_0 is true. It is also called the *likelihood function* when it is expressed as a function of H_0 given E, and

$P(E)$ is called the *marginal probability* of E: the probability of witnessing the new evidence E under all mutually exclusive hypotheses.

It can be calculated as the sum of the product of all probabilities of mutually exclusive hypotheses and corresponding conditional probabilities: $\Sigma P(E|H_i)P(H_i)$.

$P(H_0 | E)$ is called the *posterior probability* of H_0 given E.

[0075] The factor $P(E|H_0) / P(E)$ represents the impact that the evidence has on the belief in the hypothesis. If it is likely that the evidence will be observed when the hypothesis under consideration is true, then this factor will be large. Multiplying the prior probability of the hypothesis by this factor would result in a large posterior probability of the hypothesis given the evidence. Under Bayesian inference, Bayes' theorem therefore measures how much new evidence should alter a belief in a hypothesis.

[0076] For more information on Bayes' theorem and Bayesian inference, c.f.: "Information Theory, Inference, and Learning Algorithms" by David J. C. Mackay, Cambridge University Press, 2003.

[0077] The Bayesian approach to probability theory is a consistent and coherent theory for reasoning under uncertainty. Since perceptual feedback from listeners is (partially) unknown and often inconsistent, such a statistic approach is needed to cope with these uncertainties. Below, the Bayesian approach and in particular the Bayesian Incremental Preference Elicitation approach, to hearing aid processing will be treated in more detail.

[0078] The sound environment detector of the new hearing aid system makes it possible to effectively learn a complex relationship between desired adjustments of signal processing parameters relating to the sound environment and corrective user adjustments that are a personal, time-varying, nonlinear, and stochastic. Thus, the sound environment detector may be considered a learning sound environment detector.

[0079] The sound environment detector may update at least one signal processing parameter $\theta \in \Theta$ each time a user makes an adjustment. Alternatively, the updating may be performed in accordance with certain criteria, for example that the user has made a predetermined number of adjustments so that only significant adjustments lead to an update.

[0080] Sometimes, during operation of the device, the user is not satisfied with the quality of the received signal, and therefore performs adjustment(s) of the hearing aid system with the user interface. The learning goal is to slowly absorb the regular patterns by the sound environment detector into model parameters θ. Ultimately, the process will lead to a reduced number of user manipulations.

[0081] A parameter update is performed only when knowledge about the user's preferences is available. While the user interface is not being manipulated during normal operation of the device, the user may be content with the delivered signal quality, but this is uncertain. After all, the user may not be wearing the device. However, when the user starts manipulating the user interface, it is assumed that the user is not content at that moment. The beginning of a user interface manipulation phase is denoted the **dissent moment.** While the user manipulates the user interface, the user is likely still searching for a better adjustment. A next learning moment occurs right after the user has stopped manipulating the user interface. At this time, it is assumed that the user has found a satisfying adjustment; and this is called the **consent moment.** Dissent and consent moments identify situations for collecting negative and positive teaching data, respectively.

[0082] Below, one exemplary method of adapting to user preferences is disclosed. The method is based on Bayesian Incremental Preference Elicitation, but other methods are possible. Assume that the adjustable signal processing parameters at the k^{th} dissent moment and consent moments were set to θ_{kd} and θ_{kc} respectively. Also assume that the output of the environmental sound classifier during the k^{th} user manipulation phase remained approximately constant at C_k.

[0083] Apparently, under environmental conditions C_k, the user prefers θ_{kc} over θ_{kd} (represented by (end user) decision $d_k = \theta_{kc} > \theta_{kd}$). The set of all user decisions up to the k^{th} decision is represented by $D_{k-1} = \{d_1, d_2, ..., d_{k-1}\}$. Then a Bayesian update scheme is used to absorb the k^{th} observation. Let the parameter map from classes onto hearing aid parameters be represented by a probabilistic function $p(\theta \mid C, \omega)$, where ω represent the parameters for the parameter map 40.

[0084] A Bayesian update for the parameter map based on the k^{th} user's manipulation is then given by

$$p(\omega \mid C, D_k) = p(d_k \mid C, \omega) \times p(\omega \mid C, D_{k-1}) / p(C)$$

[0085] In Chu and Gharamani (Preference Learning with Gaussian Processes, 22nd Int'l conf on Machine Learning, 2005), this Bayesian update equation has been worked out in detail for a Gaussian process based parameter map 40.

[0086] The new hearing aid system may be a binaural hearing aid system with two hearing aids, one for the right ear and one for the left ear of the user.

[0087] Thus, the new hearing aid system may comprise a second hearing aid with a second microphone for provision of a second audio input signal in response to sound signals received at the second microphone,
a second processor that is configured to process the second audio input signal in accordance with a second signal processing algorithms $F(\Theta)$ to generate a second hearing loss compensated audio signal, and
a second output transducer for providing a second acoustic output signal based on the second hearing loss compensated audio signal.

[0088] The circuitry of the second hearing aid is preferably identical to the circuitry of the first hearing aid apart from the fact that the second hearing aid, typically, is adjusted to compensate a hearing loss that is different from the hearing loss compensated by the first hearing aid, since; typically, binaural hearing loss differs for the two ears.

[0089] The first sound environment detector may be configured for determining the category of the sound environment surrounding the user of the hearing aid system based on the first and second audio input signals and the geographical position of the hearing aid system.

[0090] The first sound environment detector may be configured for provision of a second output to the second processor for selection of the second signal processing algorithm and parameters F(Θ) for execution by the second processor to generate the second hearing loss compensated audio signal.

[0091] Alternatively, the second hearing aid may comprise a second sound environment detector similar to the first sound environment detector and configured for determining the category of the sound environment based on the first and second audio input signals and the geographical position of the hearing aid system, and for provision of a second output to the second processor for selection of second values of the set of signal processing parameters Θ based on the category determined by the second sound environment detector.

[0092] In binaural hearing aid systems, it is important that the signal processing algorithms of the first and second signal processors are selected in a coordinated way. Since sound environment characteristics may differ significantly at the two ears of a user, it will often occur that independent determination of category of the sound environment at the two ears of a user differs, and this may lead to undesired different signal processing of sounds in the hearing aids. Thus, preferably the signal processing algorithms of the first and second processors are selected based on the same signals, such as sound signals received at the hand-held device, or both sound signals received at the left ear and sound signals received at the right ear, or a combination of sound signals received at the hand-held device and sound signals received at the left ear and sound signals received at the right ear, etc.

[0093] Like the first sound environment detector, the second sound environment detector may comprise a second feature extractor for determination of characteristic parameters of the second audio input signal.

[0094] The second feature extractor may output the characteristic parameters to a second environment classifier for determining the category of the sound environment based on the determined characteristic parameters and the geographical position.

[0095] The second environment classifier may output a category of the sound environment to a second parameter map configured for provision of the output for selection of the second signal processing algorithm of the second processor.

[0096] As already mentioned, methods in the new hearing aid system have the capability of absorbing user preferences changing over time and/or changes in typical sound environments experienced by the user. The personalization of the hearing aid may be performed during normal use of the hearing aid. These advantages are obtained by absorbing user adjustments of the hearing aid in the parameters of the hearing aid processing. Over time, this approach leads to fewer user manipulations during periods of unchanging user preferences. Further, the methods are robust to inconsistent user behaviour.

[0097] User preferences for signal processing parameters are elicited during normal use in a way that is consistent and coherent and in accordance with theory for reasoning under uncertainty.

[0098] The new hearing aid system is capable of learning a complex relationship between desired adjustments of signal processing parameters and corrective user adjustments that are a personal, time-varying, nonlinear, and/or stochastic.

[0099] The new hearing aid system is capable of distinguishing different user preferences caused by different sound environments. Hereby, signal processing parameters may automatically be adjusted in accordance with the user's perception of the best possible parameter setting for the actual sound environment.

[0100] Signal processing in the new hearing aid system may be performed by dedicated hardware or may be performed in a signal processor, or performed in a combination of dedicated hardware and one or more signal processors.

[0101] As used herein, the terms "processor", "signal processor", "controller", "system", etc., are intended to refer to CPU-related entities, either hardware, a combination of hardware and software, software, or software in execution.

[0102] For example, a "processor", "signal processor", "controller", "system", etc., may be, but is not limited to being, a process running on a processor, a processor, an object, an executable file, a thread of execution, and/or a program.

[0103] By way of illustration, the terms "processor", "signal processor", "controller", "system", etc., designate both an application running on a processor and a hardware processor. One or more "processors", "signal processors", "controllers", "systems" and the like, or any combination hereof, may reside within a process and/or thread of execution, and one or more "processors", "signal processors", "controllers", "systems", etc., or any combination hereof, may be localized on one hardware processor, possibly in combination with other hardware circuitry, and/or distributed between two or more hardware processors, possibly in combination with other hardware circuitry.

[0104] Also, a processor (or similar terms) may be any component or any combination of components that is capable of performing signal processing. For examples, the signal processor may be an ASIC processor, a FPGA processor, a general purpose processor, a microprocessor, a circuit component, or an integrated circuit.

[0105] The drawings illustrate the design and utility of embodiments, in which similar elements are referred to by common reference numerals. These drawings are not necessarily drawn to scale. In order to better appreciate how the above-recited and other advantages and objects are obtained, a more particular description of the embodiments will be rendered, which are illustrated in the accompanying drawings. These drawings depict only typical embodiments and are not therefore to be considered limiting of its scope.

Fig. 1

shows a new hearing aid system with a single hearing aid with an orientation sensor and a hand-held device with a GPS receiver, a sound environment detector, and a user interface,

Fig. 2

shows a new hearing aid system with a single hearing aid with an orientation sensor, a sound environment detector, and a hand-held device with a GPS receiver, and a user interface,

Fig. 3

shows a new hearing aid system with two hearing aids with orientation sensors, sound environment detectors, and a hand-held device with a GPS receiver, and a user interface, and

Fig. 4

shows a new hearing aid system with two hearing aids with orientation sensors and a hand-held device with a sound environment detector, a GPS receiver, and a user interface.

[0106] Various exemplary embodiments are described hereinafter with reference to the figures. It should be noted that the figures are not drawn to scale and that elements of similar structures or functions are represented by like reference numerals throughout the figures. It should also be noted that the figures are only intended to facilitate the description of the embodiments. They are not intended as an exhaustive description of the claimed invention or as a limitation on the scope of the claimed invention. In addition, an illustrated embodiment needs not have all the aspects or advantages shown. An aspect or an advantage described in conjunction with a particular embodiment is not necessarily limited to that embodiment and can be practiced in any other embodiments even if not so illustrated, or not so explicitly described.

[0107] The new hearing aid system will now be described more fully hereinafter with reference to the accompanying drawings, in which various types of the new hearing aid system are shown. The new hearing aid system may be embodied in different forms not shown in the accompanying drawings and should not be construed as limited to the embodiments and examples set forth herein.

[0108] Similar reference numerals refer to similar elements in the drawings.

[0109] Fig. 1 schematically illustrates a new hearing aid system 10 with a single first hearing aid 12 with an orientation sensor 44, and a hand-held device 30 with a GPS receiver 48, a sound environment detector 14 and a user interface 45.

[0110] The first hearing aid 12 may be of any type configured to be head worn at the head, such as a BTE, a RIE, an ITE, an ITC, a CIC, etc, hearing aid.

[0111] The first hearing aid 12 comprises a first front microphone 16 and first rear microphone 18 connected to respective A/D converters (not shown) for provision of respective digital input signals 20, 22 in response to sound signals received at the microphones 16, 18 in a sound environment surrounding the user of the hearing aid system 10. The digital input signals 20, 22 are input to a hearing loss processor 24 that is configured to process the digital input signals 20, 22 in accordance with signal processing algorithms $F(\Theta)$ to generate a hearing loss compensated output signal 26. The hearing loss compensated output signal 26 is routed to a D/A converter (not shown) and an output transducer 28 for conversion of the hearing loss compensated output signal 26 to an acoustic output signal.

[0112] The new hearing aid system 10 further comprises a hand-held device 30, e.g. a smart phone, accommodating the sound environment detector 14 for determining the category of the sound environment surrounding the user of the hearing aid system 10. The determining the category is based on a sound signal picked up by a microphone 32 in the hand-held device. Based on the determination of the category, the sound environment detector 14 provides an output 34 to the hearing aid processor 24 for selection of the signal processing algorithm(s) and parameter(s) appropriate for the categorized sound environment.

[0113] Thus, the hearing aid processor 24 is automatically switched to the most suitable one or more algorithm(s) for the categorized sound environment whereby optimum sound quality and/or speech intelligibility is maintained in various sound environments. The signal processing algorithms of the processor 24 may perform various forms of noise reduction and dynamic range compression as well as a range of other signal processing tasks.

[0114] The first sound environment detector 14 benefits from the computing resources and power supply typically available in the hand-held device 30 that are larger than the resources and power supply available in the first hearing aid 12.

[0115] The sound environment detector 14 comprises a feature extractor 36 for determination of characteristic parameters of the received sound signals from the microphone 32. The parameters may relate to signal power, spectral data and other well-known features.

[0116] The sound environment detector 14 further comprises an environment classifier 38 for determining the category of the sound environment based on the determined characteristic parameters output by the feature extractor 36. The environment classifier 38 categorizes the sounds into a number of environmental categories, such as speech, babble speech, restaurant clatter, music, traffic noise, etc. The classification process may utilise a simple nearest neighbour search, a neural network, a Hidden Markov Model system or another system capable of pattern recognition. The output of the environmental classifier 38 is a set of probabilities indicating the probabilities of the sound environment belonging to the respective categories.

[0117] The sound environment detector 14 further comprises a parameter map 40 for the provision of the output 34 for selection of the signal processing algorithm(s) and parameter(s) from the available library of signal processing algorithms and parameters F(Θ). The parameter map 40 maps the output of the environment classifier 38 to a set of parameters $\theta \in \Theta$ for the hearing aid sound processor 20. Examples of such parameters are: Amount of noise reduction, amount of gain and amount of HF gain, algorithm control parameters controlling whether corresponding signal algorithms are selected for execution or not, corner-frequencies and slopes of filters, compression thresholds and ratios of compressor algorithms, adaptation rates and probe signal characteristics of adaptive feedback cancellation algorithms, etc. Other parameters may be included.

[0118] The hand-held device 30 includes a location detector 41 with a GPS receiver 42 configured for determining the geographical position of the hearing aid system 10. The illustrated hand-held device 30 is a smart phone also having mobile interface 48 comprising a GSM-interface for interconnection with a mobile phone network and a WIFI interface 48 as is well-known in the art of mobile phones. In absence of useful GPS signals, the position of the illustrated hearing aid system 10 may be determined as the address of the WIFI network or by triangulation based on signals received from various GSM-transmitters as is well-known in the art of mobile phones.

[0119] The illustrated sound environment detector 14 is configured for recording the determined geographical positions together with the determined categories of the sound environment at the respective geographical positions. Recording may be performed at regular time intervals, and/or with a certain geographical distance between recordings, and/or triggered by certain events, e.g. a shift in category of the sound environment, a change in signal processing, such as a change in signal processing programme, a change in signal processing parameters, etc., etc.

[0120] When the hearing aid system 10 is located within an area of geographical positions with recordings of a specific category of the sound environment, the sound environment detector is configured for increasing the probability that the current sound environment is of the respective previously recorded category of the sound environment.

[0121] A user interface 45 of the hearing aid system 10 may be configured to allocate certain categories of the sound environment to certain geographical areas.

[0122] The illustrated sound environment detector 14 is also configured for accessing a calendar system of the user, e.g. through the mobile interface 48, to obtain information on the whereabouts of the user, e.g. meeting room, office, canteen, restaurant, home, etc, and to include this information in the determining of the category of the sound environment. Information from the calendar system of the user may substitute or supplement information on the geographical position determined by the GPS receiver.

[0123] For example, the sound environment detector 14 may automatically switch the hearing aid(s) of the hearing aid system 10 to flight mode, i.e. radio(s) of the hearing aid(s) are turned off, when the user is in an airplane as indicated in the calendar system of the user.

[0124] Also, when the user is inside a building, e.g. a high rise building, GPS signals may be absent or so weak that the geographical position cannot be determined by the GPS receiver. Information from the calendar system on the whereabouts of the user may then be used to provide information on the geographical position, or information from the calendar system may supplement information on the geographical position, e.g. indication of a specific meeting room may provide information on the floor in a high rise building. Information on height is typically not available from a GPS receiver.

[0125] The sound environment detector 14 may automatically use information from the calendar system, when the GPS-receiver is unable to provide the geographical position. In the event that no information on geographical position is available from the GPS receiver and calendar system, the sound environment detector may categorize the sound environment in a conventional way based on the received sound signal; or, the hearing aid may be set to operate in a mode selected by the user, e.g. previously during a fitting session, or when the situation occurs.

[0126] The hearing aid 12 comprises one or more orientation sensors 44, such as gyroscopes, e.g. MEMS gyros, tilt sensors, roll ball switches, etc, configured for outputting signals for determination of orientation of the head of a user wearing the hearing aid, e.g. one or more of head yaw, head pitch, head roll, or combinations hereof, e.g. tilt, i.e. the angular deviation from the heads normal vertical position, when the user is standing up or sitting down. E.g. in a resting position, the tilt of the head of a person standing up or sitting down is 0°, and in a resting position, the tilt of the head of a person lying down is 90°.

[0127] The first processor 24 is configured for selection of the first signal processing algorithm of the processor 24 based on user head orientation as determined based on the output signals 46 of the one or more orientation sensors 44 and the output control signal 34 of the first sound environment detector 14. For example, if the user changes position from sitting up to lying down in order to take a nap, the sound environment detector 14 may cause the signal processor 24 to switch program accordingly, e.g. the first hearing aid 12 may be automatically muted.

[0128] The environment classifier 38 maps statistics from the audio signal (such as SNR, RMS) plus location data (from GPS) onto environmental classes such as babble, in-a-car, at-a-cocktail-party, in-a-church. The user may not be satisfied with the automatic selection of parameter values and may perform an adjustment of signal processing parameters using the user interface, e.g. the user may change the current selection of signal processing algorithm to another signal processing algorithm, e.g. the user may switch from a directional signal processing algorithm to an omni-directional signal processing algorithm.

[0129] The sound environment detector is configured for incorporation of user adjustments of signal processing parameter values over time.

[0130] The sound environment detector is configured for automatic adjustment of at least one signal processing parameter $\theta \in \Theta$ in the hearing aid system 10 with the library of signal processing algorithms $F(\Theta)$, where Θ is the algorithm parameter space, including parameters controlling selection of algorithms for execution, e.g. a noise suppression algorithm is selected for execution in a noisy environment and is not selected for execution in a quiet environment.

[0131] The learning environment sound detector 14 is configured for
recording an adjustment made by the user of the hearing aid system with the user interface 45, and
modifying the automatic adjustment of the at least one signal processing parameter $\theta \in \Theta$ in response to the recorded adjustment based on Bayesian incremental preference elicitation, so that the next time the same sound environment is detected, the modified automatic adjustment is performed.

[0132] Bayesian inference involves collecting evidence that is meant to be consistent or inconsistent with a given hypothesis. The degree of belief in a hypothesis changes as evidence accumulates. With enough evidence, it will often become very high or very low.

[0133] The illustrated hearing aid system includes a sound environment detector that operates to adjust the signal processing parameters $\theta \in \Theta$ in response to the sound environment surrounding the hearing aid system 10.

[0134] The environment classifier 38 takes as input U, which is a vector of relevant features with respect to the sound environment, e.g., including short-term RMS and SNR estimates of x_t. U will also include GPS location. Outputs of the environmental classifier are represented by the discrete class variable C. Example classes include speech, noise, speech-in-noise, in-the-car, -in-a-church, at-a-cocktail-party, etc. The environmental classes map onto the hearing aid parameters θ through the parameter map 40.

[0135] As mentioned above, sometimes, during operation of the device, the user is not satisfied with the quality of the received signal y_t, and therefore performs adjustment(s) of the hearing aid system with the user interface 45. The learning goal is to slowly absorb the regular patterns by the sound environment detector into model parameters θ. Ultimately, the process will lead to a reduced number of user manipulations.

[0136] A parameter update is performed only when knowledge about the user's preferences is available. While the user interface 45 is not being manipulated during normal operation of the device, the user may be content with the delivered signal quality, but this is uncertain. After all, the user may not be wearing the device. However, when the user starts manipulating the user interface, it is assumed that the user is not content at that moment. The beginning of a user interface manipulation phase is denoted the **dissent moment.** While the user manipulates the user interface, the user is likely still searching for a better adjustment. A next learning moment occurs right after the user has stopped manipulating the user interface 45. At this time, it is assumed that the user has found a satisfying adjustment; and this is called the **consent**

moment. Dissent and consent moments identify situations for collecting negative and positive teaching data, respectively.

[0137] A method of adapting to user preferences is in the hearing aid system 10 that is based on Bayesian Incremental Preference Elicitation, but other methods are possible. Assume that the adjustable signal processing parameters at the k^{th} dissent moment and consent moments were set to θ_{kd} and θ_{kc} respectively. Also assume that the output of the environmental sound classifier during the k^{th} user manipulation phase remained approximately constant at C_k.

[0138] Apparently, under environmental conditions C_k, the user prefers θ_{kc} over θ_{kd} (represented by (end user) decision $d_k = \theta_{kc} > \theta_{kd}$). The set of all user decisions up to the k^{th} decision is represented by $D_{k-1} = \{d_1, d_2, ..., d_{k-1}\}$. A Bayesian update scheme is used to absorb the k^{th} observation. Let the parameter map 40 from classes onto hearing aid parameters be represented by a probabilistic function $p(\theta \mid C, \omega)$, where ω represent the parameters for the parameter map 40.

[0139] A Bayesian update for the parameter map based on the k^{th} user's manipulation is then given by

$$p(\omega \mid C, D_k) = p(d_k \mid C, \omega) \times p(\omega \mid C, D_{k-1}) / \ p(C)$$

[0140] In Chu and Gharamani (Preference Learning with Gaussian Processes, 22nd Int'l conf on Machine Learning, 2005), this Bayesian update equation has been worked out in detail for a Gaussian process based parameter map 40.

[0141] The new hearing system 10 shown in Fig. 2 is similar to the new hearing aid system of Fig. 1 and operates in the same way, except for the fact that the sound environment detector 14 has been moved from the hand-held device 30 in Fig. 1 to the first hearing aid 12 of Fig. 2. In this way, the microphone output signals 20, 22 can be connected directly to the sound environment detector 14 so that the sound environment can be categorized based on signals received by the microphones in the hearing aid without increasing data transmission requirements.

[0142] The new hearing aid system 10 shown in Fig. 3 is a binaural hearing aid system with two hearing aids, a first hearing aid 12A for the right ear and a second hearing aid 12B for the left ear of the user, and a hand-held device 30 comprising the GPS receiver 42 and the mobile interface 48.

[0143] Each of the illustrated first hearing aid 12A and second hearing aid 12B is similar to the hearing aid shown in Fig. 2 and operates in a similar way, except for the fact that the respective sound environment detectors 14A, 14B co-operate to provide co-ordinated selection of signal processing algorithms in the two hearing aids 12A, 12B as further explained below.

[0144] Each of the first and second hearing aids 12A, 12B' of the binaural hearing aid system 10 comprises a binaural sound environment detector 14A, 14B for determining the category of the sound environment surrounding a user of the binaural hearing aid system 10. The determination of the category is based on the output signals of the microphones 20A, 22A, 20B, 22B. Based on the determination of the category, the binaural sound environment detector 14A, 14B provides outputs 34A, 34B to the respective hearing aid processors 24A, 24B for selection of the signal processing algorithm appropriate for the category of the sound environment. Thus, the binaural sound environment detectors 14A, 14B determine the category of the sound environment based on signals from both hearing aids, i.e. binaurally, whereby hearing aid processors 24A, 24B are automatically switched in co-ordination to the most suitable algorithm for the category of the sound environment whereby optimum sound quality and/or speech intelligibility are maintained in various sound environments by the binaural hearing aid system 10.

[0145] The binaural sound environment detectors 14A, 14B illustrated in Fig. 3 are both similar to the sound environment detector 14 shown in Fig. 2 apart from the fact that the first sound environment detector 14 only receives inputs from one hearing aid 12 while each of the binaural sound environment detectors 14A, 14B receives inputs from both hearing aids 12A, 12B. Thus, in Fig. 3, signals are transmitted between the hearing aids 12A, 12B so that the algorithms executed by the signal processors 24A, 24B are selected in coordination.

[0146] In Fig. 3, the output of the environment classifier 14A of the first hearing aid 12A is transmitted to the second hearing aid 12B, and the output of the environment classifier 14B of the second hearing aid 12B is transmitted to the first hearing aid 12A. The parameter maps 40A, 40B of the first and second hearing aids 12A, 12B then operate based on the same two inputs to produce the control signals 34A, 34B for selection of the processor algorithms, and since the parameter mapping units 34A, 34B receive identical inputs, algorithm selections in the two hearing aids 12A, 12B are co-ordinated.

[0147] The transmission data rate is low, since only a set of probabilities or logic values for the categories of the sound environment has to be transmitted between the hearing aids 12A, 12B. Rather high latency can be accepted. By applying time constants to the variables that will change according to the output of the parameter mapping, it is possible to smooth out differences that may be caused by latency. As already mentioned, it is important that signal processing in the two hearing aids is coordinated. However if transition periods of a few seconds are allowed the hearing aid system can operate with only 3-4 transmissions per second. Hereby, power consumption is kept low.

[0148] The sound environment detectors 14A, 14B incorporate determined positions provided by the hand-held unit 30 of the new hearing aid system 10 in the same way as disclosed above with reference to Figs. 1 and 2.

[0149] In the new binaural hearing aid system 10 shown in Fig. 4, co-ordinated signal processing in the two hearing aids 12A, 12B is obtained by provision of a single sound environment detector 14 similar to the sound environment detector shown in Fig. 1 and operating in a similar way apart from the fact that the sound environment detector 14 provides two control outputs 34A, 34B, one of which 34A is connected to the first hearing aid 12A, and the other of which 34B is connected to the second hearing aid 12B. The illustrated sound environment detector 14 is accommodated in the hand-held device 30.

[0150] Each of the hearing aids 12A, 12B is similar to the hearing aid 12 shown in Fig. 1 and operates in the same way.

REFERENCES CITED IN THE DESCRIPTION

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- WO0176321A [0009]
- US2011293123A1 [0010]
- WO2007042043A2 [0011]
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- **DAVID J. C. MACKAY**Information Theory, Inference, and Learning AlgorithmsCambridge University Press20030000 [0076]
- **CHUGHARAMANI**Preference Learning with Gaussian Processes22nd Int'l conf on Machine Learning, 2005, [0085] [0140]

PATENTKRAV

1. Et høreapparatsystem (10), der omfatter

et første høreapparat (12) med

en første mikrofon (16, 18) til at tilvejebringe et første audioindgangssignal som funktion af lydsignaler, der modtages ved den første mikrofon i et lydmiljø,

en første processor (24), der er indrettet til at behandle det første audioindgangssignal med en signalbehandlingsalgoritme F(Θ), hvor Θ er et sæt signalbehandlingsparametre, for at generere et første høretabskompenseret audiosignal, og

en første udgangstransducer (28) til at tilvejebringe et første akustisk udgangssignal baseret på det første høretabskompenserede audiosignal,

en positionsdetektor (41), der er indrettet til at bestemme høreapparatsystemets geografiske position,

en første lydmiljødetektor (14), der er indrettet til at

bestemme en kategori for det lydmiljø, der omgiver høreapparatsystemet, ved at bestemme et første sæt sandsynligheder, der angiver sandsynlighederne for at lydmiljøet tilhører de respektive kategorier, baseret på det første audiosignal og høreapparatsystemets geografiske position, og

tilvejebringe et første udgangssignal til den første processor til at selektere første værdier for sættet af signalbehandlingsparametre Θ baseret på det første sæt sandsynligheder, der er bestemt af den første lydmiljødetektor,

en brugerflade (45), der gør det muligt for brugeren af høreapparatsystemet at foretage justering af mindst én signalbehandlingsparameter θ ϵ Θ, og hvor

den første lydmiljødetektor (14) yderligere er indrettet til at

registrere justeringen af signalbehandlingsparametrene θ ϵ Θ, hvoraf der er mindst én, hvilken justering er foretaget af brugeren af høreapparatsystemet,

tilvejebringe et første udgangssignal til den første processor baseret på justeringen,

registrere den geografiske position sammen med kategorien for lydmiljøet ved den geografiske position, og bestemme kategorien for lydmiljøet ved at øge sandsynligheden for, at lydmiljøet er af samme kategori, som det lydmiljø, der tidligere blev registreret inden for en tærskelafstand fra den samme geografiske position.

2. Høreapparatsystemet ifølge krav 1, hvor tilvejebringelse af det første udgangssignal til den første processor er baseret på Bayesian incremental preference elicitation af justeringen.

3. Høreapparatsystemet ifølge krav 1 eller 2, hvor positionsdetektoren indbefatter en GPS-modtager.

4. Høreapparatsystemet ifølge krav 3, hvor den første lydmiljødetektor yderligere er indrettet til at bestemme kategorien for det lydmiljø, der omgiver høreapparatsystemet, baseret på mindst én parameter, der er selekteret fra den gruppe, der består af: En dato, et tidspunkt på dagen, en hastighed for høreapparatsystemet, og en signalstyrke for et signal, der modtages af GPS-modtageren.

5. Høreapparatsystemet ifølge et hvilket som helst af de foregående krav, hvor brugerfladen yderligere er indrettet til at knytte visse kategorier for lydmiljøet til respektive geografiske områder.

6. Høreapparatsystemet ifølge et hvilket som helst af de foregående krav, hvor positionsdetektoren er indrettet til automatisk at tilgå et kalendersystem for brugeren for at få information om brugerens position og at bestemme høreapparatsystemets geografiske position baseret på informationen om brugerens position, når positionsdetektoren ikke er i stand til at bestemme høreapparatsystemets geografiske position på anden måde.

7. Høreapparatsystemet ifølge et hvilket som helst af de foregående krav, hvor den første lydmiljødetektor er indrettet til automatisk at skifte høreapparatsystemets første høreapparat til flytilstand, når positionsdetektoren detekterer, at brugeren er i et fly.

8. Høreapparatsystemet ifølge et hvilket som helst af de foregående krav, hvor det første høreapparat omfatter mindst én orienteringssensor (44), der er indrettet til at tilvejebringe information om brugerens hoveds orientering, når brugeren bærer det første høreapparat i dets tiltænkte anvendelsesposition, og hvor det første høreapparat er indrettet til at selektere de første værdier baseret på informationen vedrørende brugerens hoveds orientering.

9. Høreapparatsystemet ifølge et hvilket som helst af de foregående krav, hvor positionsdetektoren er en del af det første høreapparat.

10. Høreapparatsystemet ifølge krav 1 – 8, og som yderligere omfatter et håndholdt apparat (30), der er forbundet i kommunikation med det første høreapparat, idet det håndholdte apparat rummer positionsdetektoren.

11. Høreapparatsystemet ifølge krav 10, hvor det håndholdte apparat også rummer den første lydmiljødetektor.

12. Høreapparatsystemet ifølge krav 10 eller 11, hvor det håndholdte apparat omfatter brugerfladen.

13. Høreapparatsystemet ifølge kravs 1 – 10, hvor det første høreapparat rummer den første lydmiljødetektor.

14. Høreapparatsystemet ifølge et hvilket som helst af de foregående krav, og som yderligere omfatter

et andet høreapparat med

en anden mikrofon til at tilvejebringe et andet audioindgangssignal som funktion af de lydsignaler, der modtages ved den anden mikrofon,

en anden processor, der er indrettet til at behandle det andet audioindgangssignal med en signalbehandlingsalgoritme F(Θ) for at generere et andet høretabskompenseret audiosignal, og

en anden udgangstransducer til at tilvejebringe et andet akustisk signal baseret på det andet høretabskompenserede audiosignal,

hvor den første lydmiljødetektor er indrettet til at bestemme kategorien for lydmiljøet baseret på det første og det andet audioindgangssignal og høreapparatsystemets geografiske position.

15. Høreapparatsystemet ifølge krav 14, hvor den første lydmiljødetektor er indrettet til at tilvejebringe et andet udgangssignal til selektering af andre værdier for sættet af signalbehandlingsparametre Θ baseret på det sæt sandsynligheder, der er bestemt af den første lydmiljødetektor.

16. Høreapparatsystemet ifølge krav 14, hvor det andet høreapparat omfatter:

En anden lydmiljødetektor, der er indrettet til at

bestemme en kategori for det lydmiljø, der omgiver høreapparatet, ved at bestemme et andet sæt sandsynligheder, der angiver sandsynlighederne for, at lydmiljøet tilhører de respektive kategorier, baseret på det første og det andet audioindgangssignal og høreapparatsystemets geografiske position, og

tilvejebringelse af et andet udgangssignal til den anden processor til selektering af andre værdier for sættet af signalbehandlingsparametre Θ baseret på det andet sæt sandsynligheder, der er bestemt af den anden lydmiljødetektor.

DRAWINGS

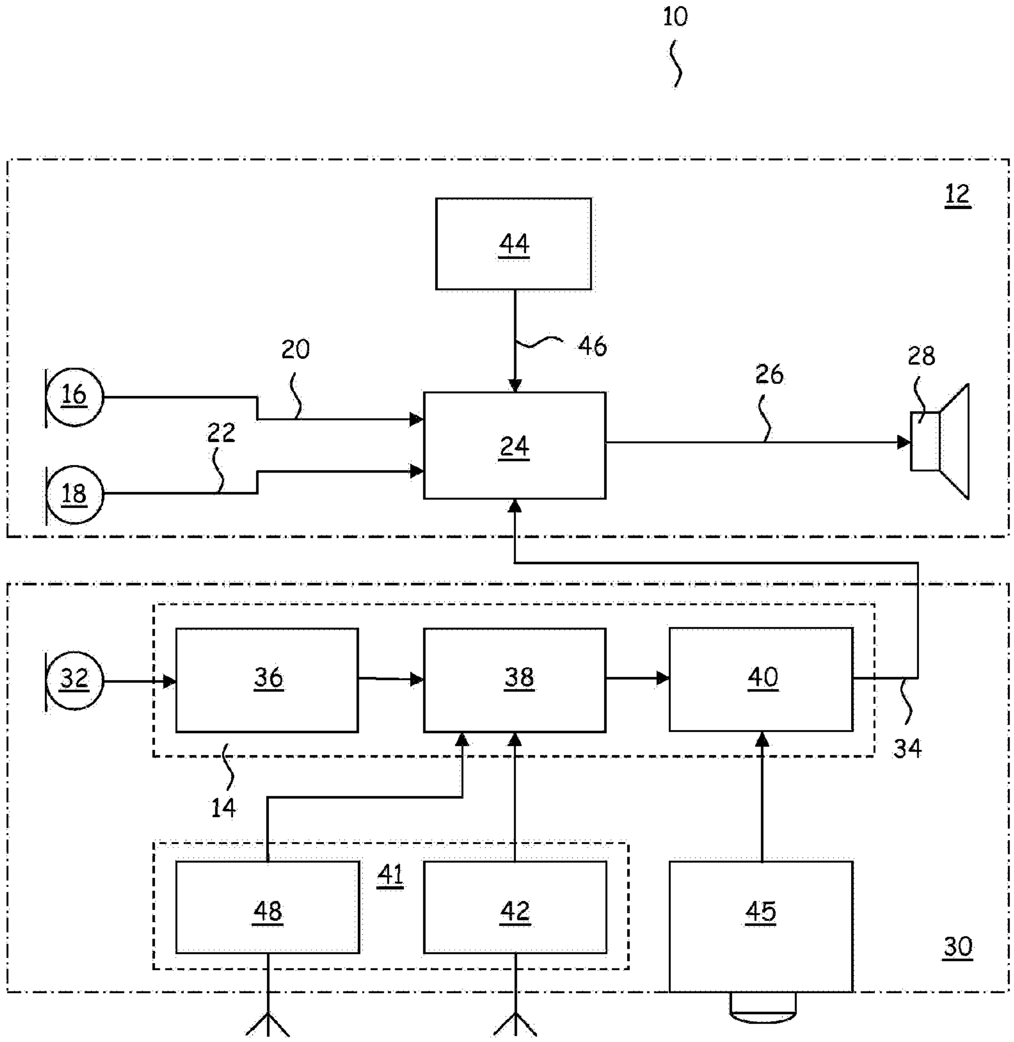


Fig. 1

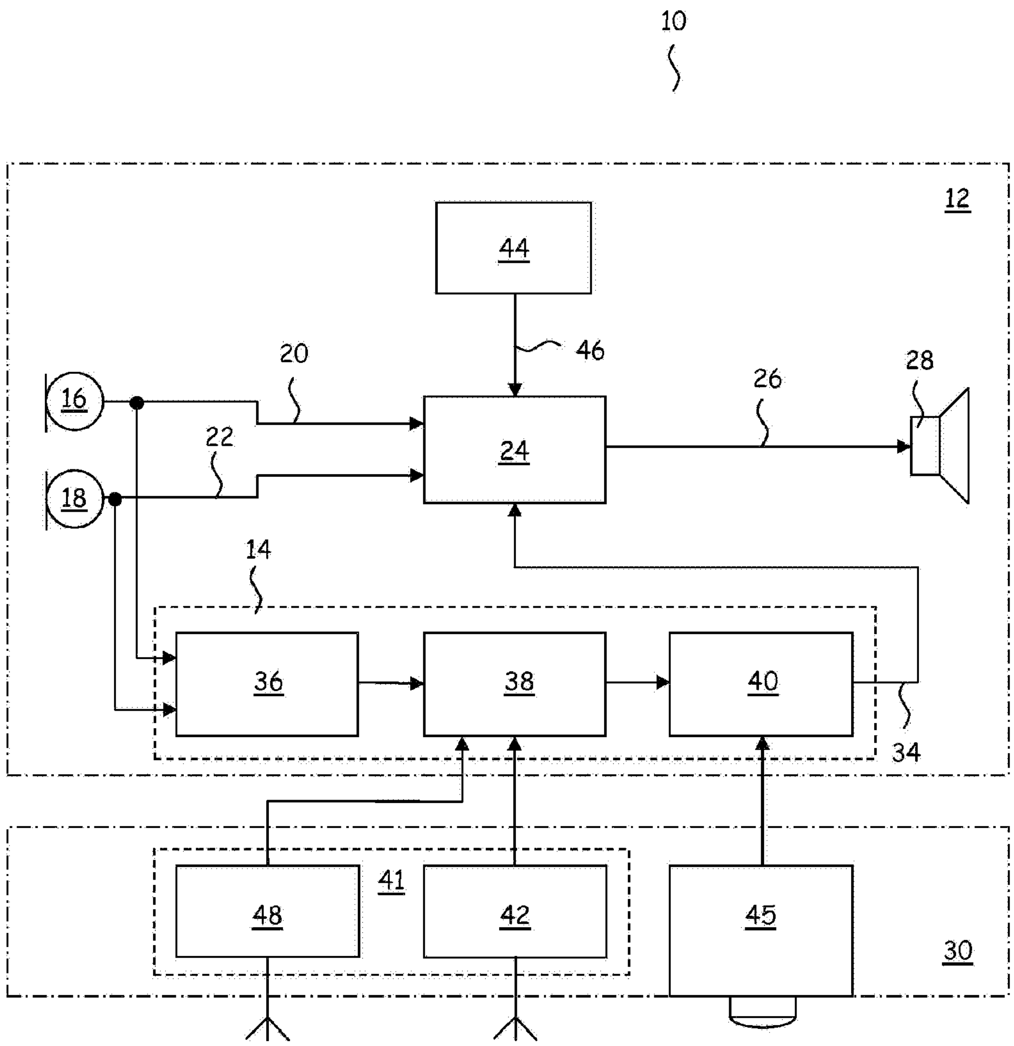
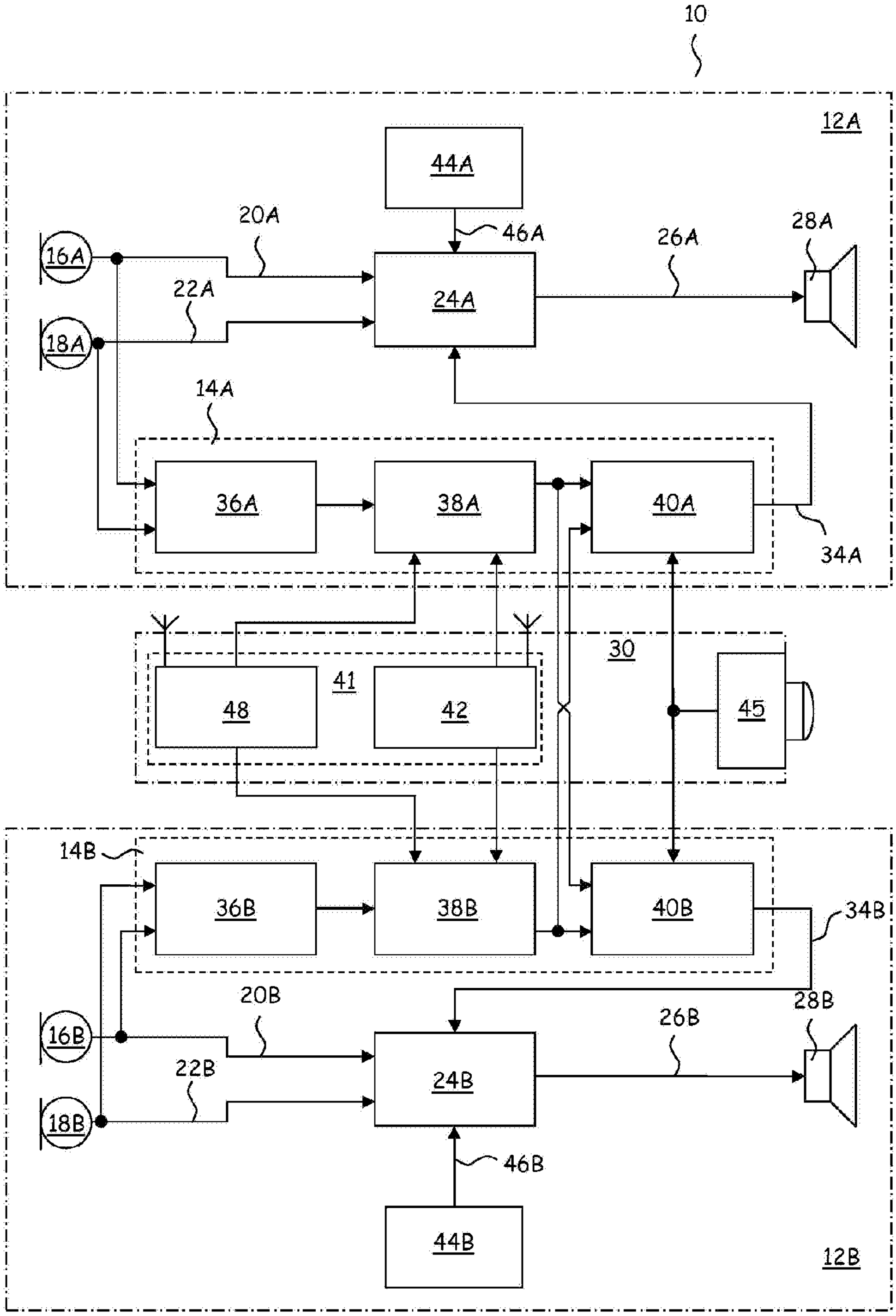


Fig. 2


10
12A
44A
46A
20A
26A
28A
16A
24A
22A
18A
14A
36A
38A
40A
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41
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45
14B
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44B
12B

Fig. 3

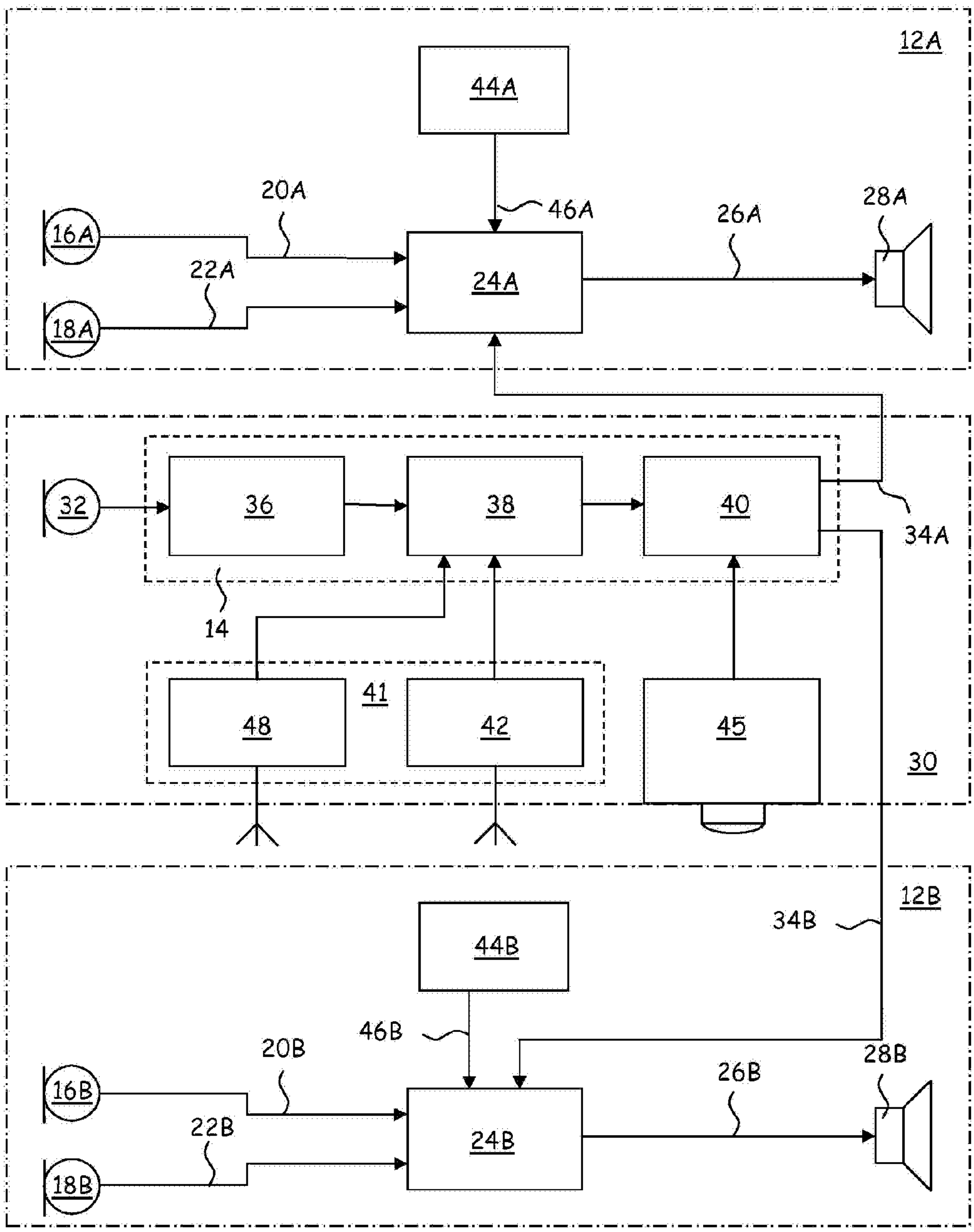
12A
44A
20A
46A
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Fig. 4