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(71) Applicant: **Tunstall Integrated Health & Care Limited**
Doncaster, Yorkshire DN14 0HR (GB)

(72) Inventor: **PARKERPAYNE, Terry**
Doncaster, DN14 0HR (GB)

(74) Representative: **Appleyard Lees IP LLP**
15 Clare Road
Halifax HX1 2HY (GB)

(54) **TELEHEALTH CARE SYSTEM**

(57) A method of operating a telehealth care system is described. The method comprises analysing ultrasonic sound waves reflected from a client to identify, in real-time, a pattern in the reflected ultrasonic sound waves corresponding to chest movements of the client, and in response to determining a deviation in the real-time identified pattern from an expected pattern, predicting an alert event based on the deviation. If an alert even is predicted an alert signal is issued. Suitably a client may be monitored in a contactless, non-invasive, fashion and events warranting an alert to a remote alarm centre predicted at an early stage thereby facilitating quicker dispatch of aid to the client.

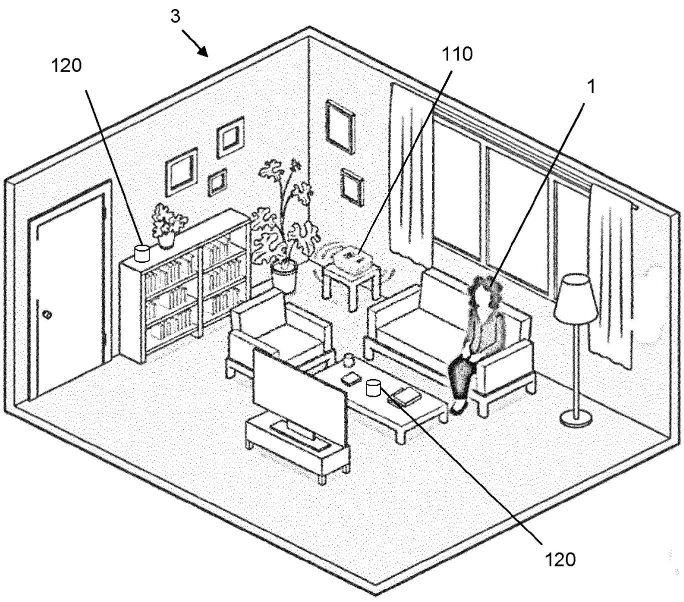

Fig. 7

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Description

Field of the Invention

[0001] The present disclosure relates to a telehealth care system and a method of operation thereof. In particular, the present disclosure relates to a telecare system which provides predictive care for a client via contactless sensing of the client's current condition.

Background

[0002] Telehealth care systems used in social care environments to socially monitor a client are well known. Typical systems include a range of wearable sensors - i.e. contact sensors - which collect data on the client and relay that data to a remote monitoring site, such as a call centre, via a hub unit installed in the client's dwelling. For example, one sensor might monitor a breathing rate of the client, while another sensor monitors hearth rate. In the event of an emergency situation, such as a heart attack occurring (which would likely trigger both a breathing and heart rate monitor), an alarm is raised with the call centre which dispatches aid to the client accordingly. Often a phone call is established between the call centre and the client's hub unit (which has suitable audio inputs/outputs) so that the client and call centre operator may converse; e.g. so that the operator may provide status updates and reassurance to the client.

[0003] The alarm is raised to the call centre upon the sensor detecting a signal which passes a certain predefined threshold that signifies that a sufficiently bad event has happened / is happening to the client. One limitation of these systems is that events that do not cause a sensor signal above the threshold are not reported, even if it is an event which may be causing the client discomfort and distress, requiring the client to manually request aid (typically the wearable device includes a manually operated alarm button).

[0004] Another limitation is that the sensors are only operable if the client chooses to wear them, which may not always be the case, and the client may even unintentionally forget to wear the sensor. It will be appreciated that an emergency situation is not detectable in such scenarios. Some systems monitor that the sensors are being worn, and notify the client if they are not, but there is still a period of inoperability in the intervening time.

[0005] It is therefore highly desirable to develop a telehealth care system that overcomes such limitations.

Summary

[0006] The example embodiments have been provided with a view to addressing at least some of the difficulties that are encountered with current telehealth care systems whether those difficulties have been specifically mentioned above or will otherwise be appreciated from the discussion herein.

[0007] In particular, it is an aim to enable predictive care that can be used to alert telehealth care professionals and the client to a change in current circumstances that potentially could be the precursor to more serious events, so as to capture a possible emergency in its infancy so that appropriate care can be sought ahead of said more serious events.

[0008] Moreover, it is an aim to remove the need for contact sensors for monitoring breathing and heartrate. Instead the example embodiments utilise a contactless sensing technique.

[0009] It is a further aim to leverage machine learning to monitor data from the sensors and to characterise and adapt over time the uniqueness of each user and hence sense any deviation from the norm so as to more rapidly enable the predictive care to alert as necessary the user and telehealth care professionals.

[0010] The present invention is defined according to the independent claims. Additional features will be appreciated from the dependent claims and the description herein.

[0011] In one aspect of the invention, there is provided a method of operating a telehealth care system. The method comprises analysing ultrasonic sound waves reflected from a client to identify, in real-time, a pattern in the reflected ultrasonic sound waves corresponding to chest movements of the client, and in response to determining a deviation in the real-time identified pattern from an expected pattern, predicting an alert event based on the deviation. If an alert even is predicted an alert signal is issued.

[0012] In this way the client may be monitored in a contactless, non-invasive, fashion, and may even be directly informed of a possible emergency via a suitable audible alert signal issued to them by e.g. speakers within the dwelling. Thus the client may conduct themselves within their dwelling without worrying about whether they are wearing a suitable sensor or whether the sensor may have sufficient battery power.

[0013] Moreover, issuing an alert at an early stage of a possible emergency may save valuable time in dispatching aid to the client. Suitably an alert signal issued to a remote alarm centre may include data relating to the alert event (e.g. pattern data, prediction data) so that an operator may make an informed decision on escalating the alert to e.g. dispatch aid (i.e. allowing the operator to make an informed, human, opinion on the automatic prediction).

[0014] The alert event may be any suitable event that may desirable for an operator of the telehealth care system - typically located at a remote monitoring centre - to know about. For example, the predicted alert event may be one of difficulty breathing, heart attack, arrythmia, and infection.

[0015] The pattern(s) which are identified (and accordingly the expected pattern(s) they are compared to) may correspond to one or both of a breathing rate of the client and heart rate of the client. In particular, the pattern may be a waveform which is determined by measuring received reflected ultrasonic sound waves at a suitable sampling frequency. The sampling frequency may be at least 100 Hz to measure breathing rate and at least 480 Hz to measure heart rate. The waveform may be suitably analysed using digital processing to extract the waveform from background noise using real-time recorded ambient noise from a plurality of audio input devices.

[0016] Predicting the alert event based on the pattern/waveform alone may give rise to false positives, and so further data may be captured concurrently with the ultrasonic sound waves upon which to base a prediction of an alert event. For example, predicting the alert event may further include capturing an audio recording and comparing the audio recording with the identified deviated pattern. Predicting the alert event may also be based on a determination of whether the client is moving, and therefore exerting themselves, based on an overall position, or locomotion, measurement of the client using the ultrasonic waves. It may also be desirable to exclude patterns which are known to arise from normal activities such as exercising - i.e. non-alert events - from the analysis, and so suitably predicting the alert event may including checking for such patterns.

[0017] In one aspect of the invention there is provided a computer program comprising instructions which, when executed by a computer, cause the computer to carry out at least some of the method as substantially described above.

[0018] In one aspect of the invention there is provided a telehealth care system arranged to implement the above techniques. Such a system comprises a communication module, one or more audio outputs and inputs, and a computing unit. The communication module is arranged to communicate with a remote alarm centre. The audio outputs are arranged to output ultrasonic sound waves, and the audio inputs are arranged to receive the ultrasonic sound waves which are reflected from a client. The computing unit is arranged to, in real-time, identify a pattern in the reflected ultrasonic sound waves corresponding to chest movements of the client and, in response to determining that the real-time identified pattern deviates from an expected pattern, predict an alert event based on the deviation. The computing unit then may then control either an audio output (including the possibility of multiple audio outputs), or the communication module, or indeed both an audio output and communication module, to issue an alert signal.

[0019] It will be appreciated that such a system may be implemented by a single device incorporating each of the core elements, each of the elements may be part of separate devices, or any logical combination thereof. For example, preferably the audio inputs and outputs are configured as one type of device, while the communication module and computing unit are arranged together in a single device. In another example, the computing unit is provided as part of a server, and therefore may not even be housed within the client's dwelling.

Brief Description of the Drawings

[0020] For a better understanding of the present disclosure reference will now be made by way of example only to the accompanying drawings, in which:

Fig. 1 shows a general principle of using soundwaves to measure distance to an object;

Fig. 2 shows the application of Fig. 1 to measuring displacement of a client's chest;

Fig. 3 illustrates an example waveform arising from measuring chest movement;

Fig. 4 demonstrates digital processing of a received audio input to extract a waveform;

Fig. 5 shows examples of comparing a deviated waveform to an expected waveform;

Fig. 6 summarises a method of operation of a telehealth care system;

Fig. 7 shows a telehealth care system arranged in a client dwelling;

Fig. 8 shows an example hub unit of a telehealth care system;

Fig. 9 shows an example audio IO unit of a telehealth care system.

Detailed Description

Contactless monitoring of a client

[0021] One solution to the problem of clients not wearing a monitor assigned to them, or overcoming issues with clients not wearing or configuring the devices in a manner suitable for proper monitoring, is to move to a contactless system of client monitoring. Moreover, it is desirable that such a contactless system be operable with as little input or configuration from a client as possible. Consider that the typical clients of telehealth care systems are not technology savvy, and so it is desirable to reduce the need for client interaction with a monitoring (e.g. sensor) device.

[0022] The approach to contactless monitoring taken in the present disclosure is to use sound waves (more specifically ultrasonic waves) to measure, in real time, movements in a client's chest to determine at least one of a breathing rate and heart rate of the client.

[0023] Breathing rate and heart rate provide a useful indication of a current status of a client because changes in breathing and/or heart rate may be correlated with a number of different situations for which the client may require aid. For example: low breathing rate may correspond to difficulty breathing, and so to gasping motions; shallow breathing may correspond to an imminent heart attack; erratic heart rate may correspond to arrythmia and also indicate heart trouble; increased heart rate and pulse (particularly while the client is stationary) may indicate that the client has an infection or a potentially more serious condition; and of course it is extremely useful to know whether a client's breathing or heart rate has stopped entirely.

[0024] Figure 1 shows the general principle of using sound waves to measure the position of an object. Here sound waves 10 are emitted (at a predetermined frequency) from an emitter 12 and reflected from an object 14. When used in a telehealth care system, the object 14 would be the client in their dwelling, and more than one emitter and receiver may be provided. The reflected waves 16 are captured by a receiver 18 (usually embodied in the same device as the emitter 12 for simplicity, as shown) and a time of flight from emission of the emitted waves 10 and receipt of the reflected waves 16 may be used to determine a distance to the object 14.

[0025] Figure 2 demonstrates measuring chest motions of a client 1 (in a social care environment) based on measuring reflected sound waves; i.e. measuring displacement of the chest. Figure 2A shows the position of the client's chest 2 after inhaling. Figure 2B shows the position of the client's chest 2 after exhaling. Measuring the client's chest position as it transitions between the inhale and exhale positions yields a pattern from which the client's breathing rate may be determined (i.e. based on time between inhaling and exhaling). More specifically, the breathing rate may be measured as a function of time to look for changes in the breathing rate.

[0026] The fluctuation in position of the chest 2 - i.e. the rise and fall of the chest - can be measured provided it is sampled at a sufficient frequency; this is because the chest motion of a client is an inherently continuous motion however analysing the reflected sound waves must be done in a discrete fashion. The Nyquist-Shannon theorem establishes that in order to accurately resolve a periodic signal it must be sampled at twice the highest frequency component of the waveform of the signal in question.

[0027] Human resting breathing rates are typically in the range of 12-25 breaths per minute 'bpm', with breathing rates under duress not typically exceeding around 50 bpm. The Nyquist rate for sampling normal breathing is therefore around 50 Hertz 'Hz', and during duress around 100 Hz. Therefore, by sampling the sound waves reflected from the client's chest at a frequency of at least 100 Hz, a pattern corresponding to the breathing rate of the client may be established. It will however be appreciated that such sampling rates are minimums which correspond to idealised, repetitive, stable patterns. A client's breathing rate may not however be nicely repetitive and stable, and may fluctuate considerably, particularly when in distress, and so in general the higher the sampling rate the better.

[0028] Another consideration is that, in order to adequately resolve the rise and fall of the chest, the sound waves must have wavelengths of the same order (or shorter) than the rise and fall. For most adults, chest movements due to breathing are between 5 and 15 centimetres 'cm'. It will however be appreciated that those with lung conditions, or generally lower lung capacity, will have shallower breaths and correspondingly shorter chest movements; possibly in the range of around 1 to 2 centimetres. Thus the sound waves should preferably have a frequency of at least 7 kHz (corresponding to chest movements of 5 cm), and further preferably of at least 17 kHz to 34 kHz (corresponding to chest movements of 1 to 2 cm).

[0029] It will be appreciated however that the range of sound frequencies above reside in the human audible spectrum (approximately 20 Hz to 20,000 Hz). Client monitoring using sound waves within this spectrum is heavily discouraged due to the constant buzzing that would be heard by the client 1.

[0030] Instead, it is preferred that for continuous operation within a client dwelling, monitoring of a client's chest motion be conducted at ultrasonic frequencies (above 20 kHz), which is generally above a sound hearable by humans. To adequately ensure the sound will be above the range of human hearing, it is further preferred that monitoring should be conducted at 22 kHz or above. Suitably, ultrasonic frequencies are far in excess of the Nyquist rates for sampling breathing motion, and also allow for chest motions as small as 1.5 cm (22 kHz) to be measured. Advantageously such ultrasonic frequencies may be achieved using common audio technology such as paper cone/magnet loudspeakers, which also allows such speakers to be used for normal audible frequency output.

[0031] Similar to as described above, measuring the chest motion of the client 1 may yield information on the client's heart rate; again, provided that it is suitably sampled and resolved. That is, deflections in the client's chest position due their heartbeat will yield a pattern which may be analysed to determine the client's heart rate.

[0032] Human heart rates typically range from 40 to 150 beats per minute 'bpm' in adults and around 150 to 240 bpm in infants. The Nyquist rate for sampling an adult heart rate is therefore around 300 Hz, and for infants up to around 480 Hz.

[0033] The typical range of chest motion arising due to heartbeat is between 4 millimetres 'mm' and 12 mm. The corresponding sound frequency range to resolve such motion is 28.5 kHz to 86 kHz. That is, using sound waves of at least 86 kHz should be able to resolve chest motions due to heartbeats of as small as 4 mm. Frequencies above 28.5 kHz are already well above audible frequencies and so suitable for use in a client dwelling.

[0034] It will therefore be appreciated that monitoring a client using ultrasonic sound waves allows for both breathing rate and heart rate to be measuring simultaneously. Preferably such monitoring should be conducted using sound waves of at least 28.5 kHz, and further preferably of substantially at least 86 kHz. Frequencies closer to the lower end of the range (i.e. around 28.5 kHz) may advantageously be achievable using common audio equipment which may also output audible frequency sound - e.g. paper cone/magnet loudspeakers. Frequencies at the upper end of the range (i.e. around 86 kHz) may require dedicated hardware - e.g. a piezo electric transducer-though such an approach is correspondingly more costly.

[0035] Figure 3 is an idealised illustrative example of a pattern that might arise from suitably sampling a client's chest motion using ultrasonic waves. More specifically, Figure 3 illustrates a waveform 20 that might be expected to arise from plotting the position (x) of the client's chest as a function of time t based on measurements of the time of flight of ultrasonic waves. It will be appreciated that an offset of the waveform on the x axis (i.e. distance from 0) may be used to approximate a general position of the client 1 from the emitter/receiver 12/18. It will also be appreciated that other methods of analysing patterns in the reflected wave measurements may also be employed without visualising and analysing them specifically as a waveform.

[0036] The waveform 20 is a superposition of a first waveform 22 corresponding to the breathing motion of the chest and a second waveform 24 corresponding to the heartbeat motion. By suitably analysing the superimposed waveform 20, details relating to the constituent first & second waveforms 22 & 24 may be extracted, and the breathing rates and heart rates determined accordingly. For example, in the first waveform 22 (corresponding to the larger sine wave in waveform 20), the peak to peak separation corresponds to one full exhale followed by one full inhale. Similarly, in the second waveform 24 (corresponding to the smaller sinewave following the larger one in waveform 20), the peak to peak separation corresponds to the time between heartbeats.

[0037] It will be appreciated that in real world usage the superimposed waveform 20, corresponding to the chest deflections measured from the reflected ultrasonic waves 16, will be mixed in with ambient noise from the environment; for example, noise from a television, mobile phone, and/or cooker, to name but a few possible sources. Thus, the waveform 20 corresponding to the chest motion will typically need to be extracted from this background noise (at least in all but the quietest environments). This may be achieved by recording ambient noise levels using multiple audio inputs (e.g. an array of microphones) and digitally processing the to remove the unwanted noise or otherwise extract the first and second waveforms 22, 24. The array of audio inputs could be the same as, or separate to, the audio inputs used to receive the reflected ultrasonic waves 16. Moreover, the array of audio inputs may be formed as part of a single device unit (provided there was some spatial separation of the audio inputs within the device), or could be positioned throughout the dwelling as part of separate devices in communication with each other.

[0038] Figure 4 shows an example of digital processing for noise cancellation. A first signal 26 is a signal received by an audio input acting as a receiver 18 for ultrasonic sound waves. The first signal 26 comprises noise 28 and a waveform 30 corresponding to chest motions of the client 1 hidden within the noise 28. A second (noise) signal 32 is formed based on audio recorded by one or more additional audio inputs which is inverted; that is, the second signal represents a signal inversion of ambient noise. The two signals 28 and 32 are superimposed which results in the third signal 34, where it can be seen that the waveform 30 can now be resolved from on top of a low level white noise signal 36.

Predicting an alert event

[0039] Obtaining current (i.e. real time) breathing and heart rate information from a client does not in itself provide information which is useful to predicting an alert event; that is; a situation relating to the client which would be cause for raising an alarm with an alarm / call centre.

[0040] The aim of the predictive care is to trigger an alert signal before the alert event becomes a reality; e.g. to alert an alarm centre before a heart attack has occurred, rather than during or after (although the present techniques would certainly indicate such events too). In this way, valuable seconds may be saved in dispatching aid to a client (if necessary), thereby potentially saving lives.

[0041] To determine whether an alert event might occur, the real-time chest motion data is compared with an expected normal chest motion for the client. Put another way, the current chest motion data derived from reflected ultrasonic waves corresponding to the client's chest movement, is compared in real-time with expected chest motion data for the client. Deviations in the real-time data compared to the expected data are then used to predict whether an alert event is likely to occur.

[0042] Figure 5 shows examples of a deviation in a currently measured pattern from an expected pattern. More specifically, Figure 5 shows a comparison of current to expected waveforms for a client. The various signals are measured over 1 minute (x axis) with amplitude corresponding to the measured range of chest motion. The large amplitude signals correspond to chest motions due to breathing. Barely visibly are small amplitude signals following the large amplitude wave which correspond to chest motions due to heart rate. The signals are separated on the y axis with respect to an average number of heart beats per minute determined from the small amplitude signals.

[0043] A baseline waveform 38 represents an expected "normal" pattern for the client 1. By way of example, this waveform corresponds to approximately 7.5 breaths per minute and an average heart rate of 83 bpm. Analysis of the deviation of other signals from this baseline may be used to predict the onset of an alert event.

[0044] A first waveform 40 corresponds to a first example state of the client 1. Here the client 1 is measured as having only 5 breaths per minute and an average heart rate of 77 bpm. As the client's breathing rate has decreased, this indicates that the client might be having difficulty breathing, and is taking large gulps of air to compensate (corresponding to large amplitude chest measurements). In such a case it may also be appropriate to augment the analysis with audio recording (e.g. via the ultrasonic audio input, or another audio input such as might be used for noise cancellation) in order to establish whether the client is indeed gulping for air (and possible choking).

[0045] A second waveform 42 corresponds to a second example state of the client 1. Here the client 1 is measured as having 15 breaths per minute and an average heart rate of 86 bpm. As the client's breathing rate and heart rate has increased moderately, this might indicate that the client 1 is fighting an infection.

[0046] In such cases it may also be appropriate to combine the pattern analysis with real-time absolute measurements of the client's position relative to the ultrasonic receiver, so as to check whether the client is exerting themselves by moving or is stationary. Put another way, locomotion of the client may be analysed. In this way false positives may be prevented. Measuring absolute position of the client may also be useful in other situations, not only predicting infection.

[0047] A third waveform 44 corresponds to a third example state of the client 1. Here the client 1 is measured as having 30 breaths per minute and an average heart rate of 92 bpm. The client's very shallow breathing by comparison to the baseline 38 (indicated by the small amplitude signal), in addition to the high breathing rate and heart rate, may indicate a precursor to a heart attack.

[0048] It will be appreciated that these are merely illustrative examples only of the present technique, and not limiting. Other average breathing and heart rates may be determined to indicate these sorts of alert events (i.e. client situations). Moreover, other situations may be determined from the pattern analysis. For example, an erratic heart rate waveform (such that it might not even be possible to accurately determine an average heart rate) might indicate that the client 1 is suffering arrhythmia. In another example, a lack of measurable heart rate may indicate that the client's heart has stopped.

[0049] To determine what is normal for a client 1 - e.g. what is the baseline waveform 38 for a particular client - some form of calibration is useful. Preferably, the baseline pattern is updated regularly; i.e. continuous rebaselining is performed. This is because what is considered 'normal' for a client 1 will change over time due to age, illness, fitness, etc.

[0050] In one example, data from a measurement window sometime in the past (a trailing calibration window) may be used to determine the baseline pattern. An example measurement window is a couple of days centred one week in the past; though it will be appreciated other values could also be chosen. Such a trailing calibration window provides a profile for the client 1, on the assumption that such a window corresponds to what is normal for the client. In this way re-baselining is performed automatically, without any specific client involvement. Accordingly, data corresponding to alert events may be flagged such that said data may be easily recognised and ignored if it later falls within the trailing calibration window.

[0051] In another example, calibration is performed by measuring the client's chest motion during a specific time and/or while performing a specific task. Such an approach is not generally preferred, however, as requiring a client to "do" something for the calibration to take effect is unlikely to be performed regularly, even if done properly.

[0052] Preferably, analysis of the real-time chest motion pattern in comparison to an expected pattern is conducted using a suitable Machine Learning 'ML' algorithm implemented on a suitable computer (or network of computing devices). Compared with normal software algorithms, ML provides significant advantages for quickly classifying certain waveforms as being related to a certain condition. More specifically, a classification type ML algorithm may be employed to classify a particular waveform (which is a deviation from the baseline waveform) as being produced by a particular condition effecting the client (i.e. which would give rise to an alert event).

[0053] In a similar vein, an ML algorithm may be able to more readily identify certain patterns as being related to a certain activity that does not correspond to an alert event. That is, in addition to classifying waveforms for predicting alert events, the ML algorithm may classify waveforms that do not correspond to an alert event. Consider that the client's breathing and heart rate are likely to increase by measurable degrees when doing certain 'normal' tasks like exercising, standing up and sitting down, and moving around the dwelling. Moreover, events which are classified as non-alert events may be flagged and excluded from calibration if they should fall within the calibration window, and so what is considered 'normal' chest motion for a client may be better established (i.e. by excluding anomalous data corresponding to activity).

[0054] It will of course be appreciated that normal (non-ML) software algorithms, implemented on suitable computing architecture, could also be employed.

[0055] In response to determining that there is a deviation of the real-time chest motion pattern, and correlation of that deviated pattern to an alert event (i.e. predicting a deteriorating condition of the client 1), an alert signal is issued. The alert signal may be issued to the client 1, an alarm centre (to be received by an operator there), and/or both.

[0056] In one example, an alert signal issued to the client may take the form of a voice communication, for example using a suitable audio output device provided within the client's dwelling (which may even be the ultrasonic emitter operating at audible frequency ranges). This could be specific information on the type of event being detected, or a more general instruction to contact the alarm/call centre. In another example, the client alert may be a signal transmitted to a wearable social care device (such as an alarm trigger) which causes a light to turn on, or periodically flash, etc, so as to inform the client that an abnormal breathing or heartrate has been detected; the client may be trained accordingly to recognise that the light means an abnormal status has been detected and to contact the alarm/call centre.

[0057] In one example, an alert signal issued to the alarm centre may be an alarm notification which includes information on the client and the alert event which is being predicted, by which an operator is made aware that a potentially deteriorating condition of the client 1 has been detected. In addition to the alarm notification, the alert signal may comprise data relating to the predicted alert event; for example, the alert signal may include data on the measured waveform giving rise to the prediction, a sound recording captured by audio inputs in the client dwelling, and/or video data captured from a camera device within the client dwelling. In this way an operator at the alarm centre may be provided with additional information upon which to base an appropriate course of action.

[0058] For example, in response to receiving the alert signal, an operator at the alarm centre may contact the client so as to ascertain whether the client is e.g. in pain, distress, feeling unwell, or otherwise impaired. The operator may also dispatch aid to the client such as onsite careers, first aiders, paramedics, etc, either before or after contacting the client (or even forgoing contacting the client at all). Dispatching aid immediately may be appropriate in situations where a serious alert event is being predicted, and so it is vital for aid to get to the client without delay.

[0059] It will be appreciated that notification of the alert signal may be handled using appropriate software and computing and communication modules.

[0060] Figure 6 summarises a method of operation of a telehealth care system consistent with the above disclosed techniques. At step 601, ultrasonic waves are emitted from a suitable output unit within a client's dwelling. At step 602, the ultrasonic waves which have been reflected from a client and received by a suitable input unit, are analysed in real-time to identify a pattern corresponding to chest movements of the client. At step 603, a deviation of the real-time identified pattern from an expected pattern is determined. At step 604, an alert event is predicted based on the deviated pattern. At step 605, a suitable alert signal is issued.

Example telehealth care system

[0061] Figure 7 demonstrates an example telehealth care installation (or system) 100 as arranged within a client's dwelling 1. Figure 8 illustrates an example hub unit 110 compatible with the system 100. Figure 9 illustrates an example audio input/output 'IO' unit 120 compatible with the system 100.

[0062] The system 100 comprises a communication module 112 arranged to communicate with a remote alarm centre (not shown). The communication module 112 is configured to establish communication with the alarm centre using an appropriate communication network; for example, and without limitation, a public switched telephone network 'PSTN', Voice over Internet Protocol 'VoIP', and/or a cellular telecommunications network.

[0063] Here the communication module 112 is configured as part of the hub unit 110. The hub unit 110 may be configured to receive an alarm signal from a social alarm trigger device wearable by a client 2. As will be familiar to those in the art, the social alarm trigger device may transmit a radio frequency signal to the hub unit 110 in response to an event such as a client falling over, and in turn the hub unit 110 may raise an alarm with the alarm centre.

[0064] The system 100 also comprises one or more audio inputs 122 (i.e. ultrasonic receivers 18) and one or more audio outputs 124 (i.e. ultrasonic emitters 12); e.g. one or more speakers (outputs) and one or more microphones (inputs). Here the audio inputs 122 and outputs 124 are configured as part of one or more audio IO devices 120 (two such devices are shown in Figure 7). The audio IO devices 120 are preferably distributed throughout the dwelling 1 - i.e. they are remote from the hub unit 110 - in order to provide audio coverage throughout the dwelling, particularly when the dwelling has separate distinct rooms (as is usually the case). Suitably the audio IO devices 120 are arranged to electronically communicate with the hub unit 110 (either wired or wirelessly) to facilitate transfer of data between the devices.

[0065] In another example, audio input(s) 122 and output(s) 124 may be provided as part of the hub unit 110, either in addition to or instead of the audio IO devices 120. In yet another example audio inputs and outputs may be implemented as separate devices; such an arrangement may be beneficial if it is desired to move bulky speaker equipment onto shelving at edges of the dwelling 1, but it is desirable to have microphones more centrally within the dwelling 1 (e.g. on a coffee table).

[0066] The audio output(s) 124 are configured to output ultrasonic sound waves while the audio inputs 122 are configured to receive ultrasonic sound waves. More specifically, the audio inputs 122 are arranged to receive ultrasonic sound 16 reflected from the client 2; i.e. receive and measure ultrasonic sound at frequencies emitted by the output(s) 124. In this example, the audio outputs may output sound in a frequency range between 22 kHz and 28.5 kHz. That is, a frequency range which is suitably above audible hearing frequencies but possible to produce using common paper cone/magnet speakers, and which may be suitable for resolving both breathing rate and heart rate of the client 1.

[0067] The system 100 comprises a computing unit 114 arranged to identify a pattern in the reflected ultrasonic sound waves corresponding to the chest movements of the client of the client 2. Preferably the pattern is identified in substantially real time (i.e. with as small a delay as possible between receiving the reflected ultrasonic waves and analysing the corresponding data to identify a pattern).

[0068] The computing unit 114 is configured to determine whether the real-time identified pattern deviates from an expected chest movement pattern of the client. If so, the computing unit 114 is arranged to predict an alert event based on the detected deviation and control the communication module 112 to issue an alert signal.

[0069] In other words, the computing unit 114 is arranged to perform the contactless client monitoring techniques described above.

[0070] In a preferred example the computing unit 114 is configured as part of the hub unit 110. In this way connection to the communication module 112 is more readily achieved, and indeed could be configured to be controlled by the same processor. Beneficially a single device may both analyse the ultrasonic data and raise an alert signal with the remote alarm centre, which reduces the possible fail points in the system (thereby providing robustness) and beneficially ensures that client data does not have to be transferred out of the device (except when optionally included as part of an alarm signal). The audio IO devices 120 may forward data corresponding to the received ultrasonic sound waves via a suitable inbuilt communication module 126 to the hub unit 110 via its communication module 112.

[0071] In another example each of the audio IO devices 120 may be provided with a suitably configured computing unit 128 (i.e. processor) to analyse ultrasonic waves specifically received by an audio input 122 associated with that particular audio IO device 120 (and also to control the ultrasonic output through output 124). The audio IO devices may then communicate the processed data to the hub unit 110, or send a notification to the hub unit 110 indicating that it should issue an alert.

[0072] In yet another example, the computing unit 114 may be provided as part of a remote server which is configured to receive and process the ultrasonic wave measurements from the system audio inputs 122. The server may receive data direct from the audio inputs if the IO devices 120 have been provided with a suitable network (e.g. internet) connection, or may receive data from the hub unit 110 (e.g. via the communication module 112) if the audio input data is transferred to the hub unit 110 from the IO devices 120 first.

[0073] The alert signal may take a variety of forms. In one example, the alert signal may be an audio alert output via the same audio outputs 124 which are acting as ultrasonic emitters. For example, the alert signal may be a recorded voice warning output through the IO devices 120 and intended to make the client 2 aware of a possible medical situation. In another example, the alert signal may be an alarm notification issued to an operator of the remote alarm centre via the communication module 112.

[0074] In summary, exemplary embodiments of an improved telehealth care system which contactlessly monitors a client's wellbeing has been described. In particular, the exemplary embodiments monitor heart rate and breathing rate to identify events warranting an alert to a remote alarm centre - sometimes termed emergency events, such as a heart attack - at an early stage of the event, i.e. before existing techniques for monitoring a client would register a problem and raise an alarm. Suitably, valuable seconds or even minutes may be saved when raising an alarm and getting aid dispatched to a client.

[0075] The system and its components may be manufactured industrially. An industrial application of the example embodiments will be clear from the discussion herein.

[0076] As will be appreciated by one skilled in the art, the present techniques may be embodied as a system, method or computer program product. Accordingly, aspects of the techniques described herein may take the form of an entirely hardware embodiment, an entirely software embodiment, or an embodiment combining software and hardware aspects.

[0077] Furthermore, the present techniques may take the form of a computer program product embodied in a computer readable medium having computer readable program code embodied thereon. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable medium may be, for example, but is not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing.

[0078] Computer program code for carrying out operations of the present techniques may be written in any combination of one or more programming languages, including object-oriented programming languages and conventional procedural programming languages. Code components may be embodied as procedures, methods or the like, and may comprise subcomponents which may take the form of instructions or sequences of instructions at any of the levels of abstraction, from the direct machine instructions of a native instruction set to high-level compiled or interpreted language constructs.

[0079] Embodiments of the present techniques also provide a non-transitory data carrier carrying code which, when implemented on a processor, causes the processor to carry out any of the methods described herein.

[0080] The techniques further provide processor control code to implement the above-described methods, for example on a general purpose computer system or on a digital signal processor (DSP). The techniques also provide a carrier carrying processor control code to, when running, implement any of the above methods, in particular on a non-transitory data carrier. The code may be provided on a carrier such as a disk, a microprocessor, CD- or DVD-ROM, programmed memory such as non-volatile memory (e.g. Flash) or read-only memory (firmware), or on a data carrier such as an optical or electrical signal carrier. Code (and/or data) to implement embodiments of the techniques described herein may comprise source, object or executable code in a conventional programming language (interpreted or compiled) such as Python, C, or assembly code, code for setting up or controlling an ASIC (Application Specific Integrated Circuit) or FPGA (Field Programmable Gate Array), or code for a hardware description language such as Verilog (RTM) or VHDL (Very high speed integrated circuit Hardware Description Language). As the skilled person will appreciate, such code and/or data may be distributed between a plurality of coupled components in communication with one another. The techniques may comprise a controller which includes a microprocessor, working memory and program memory coupled to one or more of the components of the system.

[0081] It will also be clear to one of skill in the art that all or part of a logical method according to embodiments of the present techniques may suitably be embodied in a logic apparatus comprising logic elements to perform the steps of the above-described methods, and that such logic elements may comprise components such as logic gates in, for example a programmable logic array or application-specific integrated circuit. Such a logic arrangement may further be embodied in enabling elements for temporarily or permanently establishing logic structures in such an array or circuit using, for example, a virtual hardware descriptor language, which may be stored and transmitted using fixed or transmittable carrier media.

[0082] In an embodiment, the present techniques may be realised in the form of a data carrier having functional data thereon, said functional data comprising functional computer data structures to, when loaded into a computer system or network and operated upon thereby, enable said computer system to perform all the steps of the methods described herein.

[0083] The methods described herein may be wholly or partly performed on an apparatus, i.e. an electronic device, using a machine learning or artificial intelligence model. A function associated with AI may be performed through the non-volatile memory, the volatile memory, and the processor. The AI model may be processed by an artificial intelligence-dedicated processor designed in a hardware structure specified for artificial intelligence model processing. The processor may include one or a plurality of processors. At this time, one or a plurality of processors may be a general purpose processor, such as a central processing unit (CPU), an application processor (AP), or the like, a graphics-only processing unit such as a graphics processing unit (GPU), a visual processing unit (VPU), and/or an AI-dedicated processor such as a neural processing unit (NPU). The one or a plurality of processors control the processing of the input data in accordance with a predefined operating rule or artificial intelligence (AI) model stored in the non-volatile memory and the volatile memory.

[0084] The predefined operating rule or artificial intelligence model is provided through training or learning. Here, being provided through learning means that, by applying a learning algorithm to a plurality of learning data, a predefined operating rule or AI model of a desired characteristic is made. The learning may be performed in a device itself in which AI according to an embodiment is performed, and/o may be implemented through a separate server/system. The learning algorithm is a method for training a predetermined target device (for example, a robot) using a plurality of learning data to cause, allow, or control the target device to make a determination or prediction. Examples of learning algorithms include, but are not limited to, supervised learning, unsupervised learning, semi-supervised learning, or reinforcement learning.

[0085] The artificial intelligence model may include a plurality of neural network layers. Each of the plurality of neural network layers includes a plurality of weight values and performs neural network computation by computation between a result of computation by a previous layer and the plurality of weight values. Examples of neural networks include, but are not limited to, convolutional neural network (CNN), deep neural network (DNN), recurrent neural network (RNN), restricted Boltzmann Machine (RBM), deep belief network (DBN), bidirectional recurrent deep neural network (BRDNN), generative adversarial networks (GAN), and deep Q-networks

[0086] Although preferred embodiment(s) of the present invention have been shown and described, it will be appreciated by those skilled in the art that changes may be made without departing from the scope of the invention as defined in the claims.

Claims

1. A method of operating a telehealth care system, comprising:

analysing ultrasonic sound waves reflected from a client to identify, in real-time, a pattern in the reflected ultrasonic sound waves corresponding to chest movements of the client, and
in response to determining a deviation in the real-time identified pattern from an expected pattern, predicting an alert event based on the deviation, and issuing an alert signal.

2. The method of claim 1, wherein the real-time identified pattern and expected pattern correspond to chest movements arising from a breathing rate of the client.

3. The method of claim 1 or 2, wherein the real-time identified pattern and expected pattern correspond to chest movements arising from a heart rate of the client.

4. The method of any preceding claim, wherein the pattern is a waveform.

5. The method of claim 4, wherein analysing the ultrasonic sound waves includes digital processing to extract the waveform from background noise using real-time recorded ambient noise from a plurality of audio input devices.

6. The method of any preceding claim, wherein the predicting of the alert event is further based on audio recorded substantially concurrently with the ultrasonic sound waves being analysed.

7. The method of any preceding claim, wherein the predicting of an alert event is further based on measuring a locomotion of the client.

8. The method of any preceding claim, wherein the expected pattern is determined from historic data of ultrasonic sound waves reflected from the client.

9. The method of any preceding claim, wherein the predicting an alert event based on the deviation includes checking whether the deviation corresponds to a non-alert event such as a normal activity performed by the client.

10. The method of any preceding claim, wherein the predicted alert event includes at least one of difficulty breathing, heart attack, arrythmia, and infection.

11. The method of any preceding claim, wherein issuing the alert signal includes outputting an audible warning to the client.

12. The method of any preceding claim, wherein issuing the alert signal includes transmitting an alarm notification to an alarm centre along with data corresponding to the identified pattern upon which the predicted alert event is based.

13. The method of claim 12 further comprising, in response to receiving the alarm notification by the alarm centre, dispatching aid to the client.

14. A computer program comprising instructions which, when executed by a computer, cause the computer to carry out the method of any of claims 1 to 12.

15. A telehealth care system, comprising:

    a communication module arranged to communicate with a remote alarm centre,
    one or more audio outputs arranged to output ultrasonic sound waves, and one or more audio inputs arranged to receive ultrasonic sound waves reflected from a client, and
    a computing unit arranged to, in real-time, identify a pattern in the reflected ultrasonic sound waves corresponding to chest movements of the client and, in response to determining that the real-time identified pattern deviates from an expected pattern, predict an alert event based on the deviation, and control at least one of an audio output and the communication module to issue an alert signal.

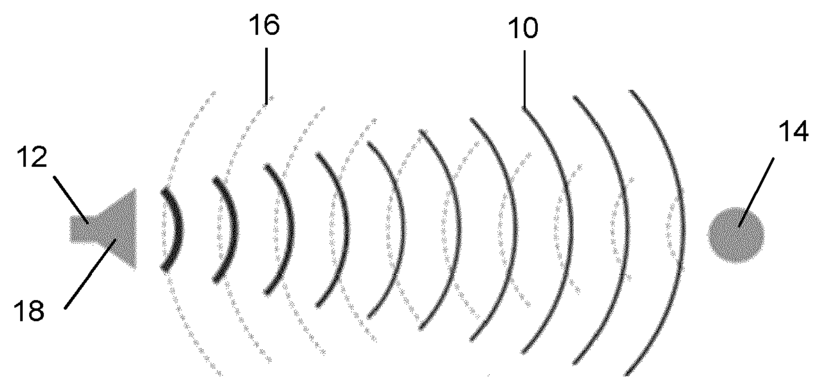

Fig. 1

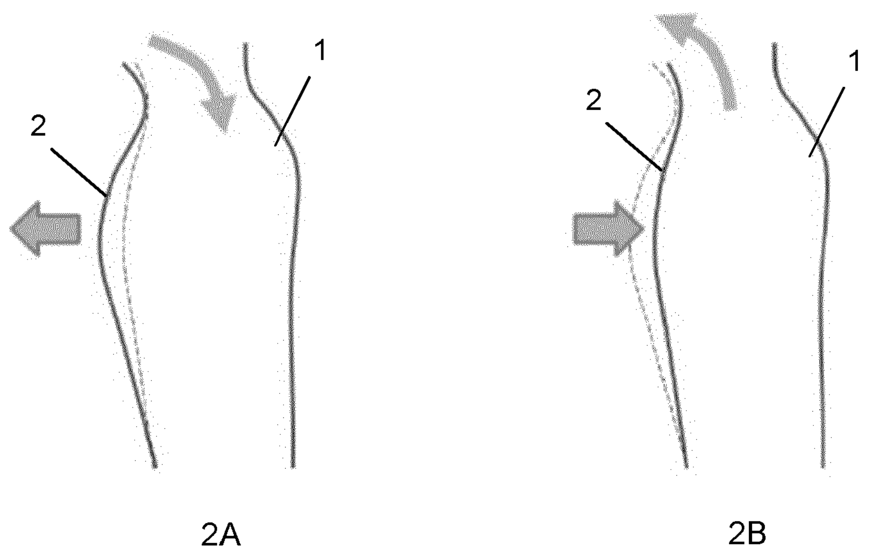

Fig. 2

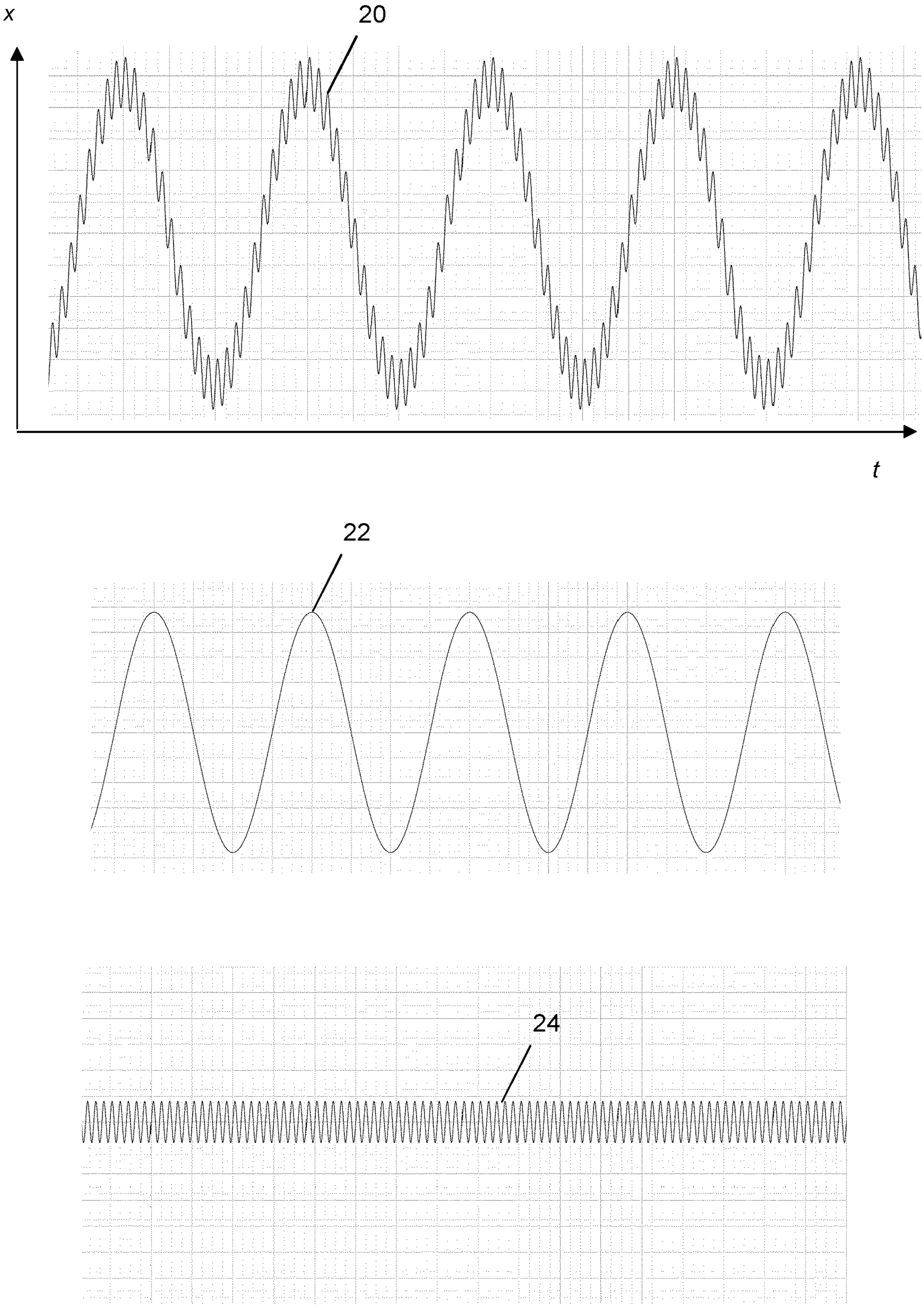

Fig. 3

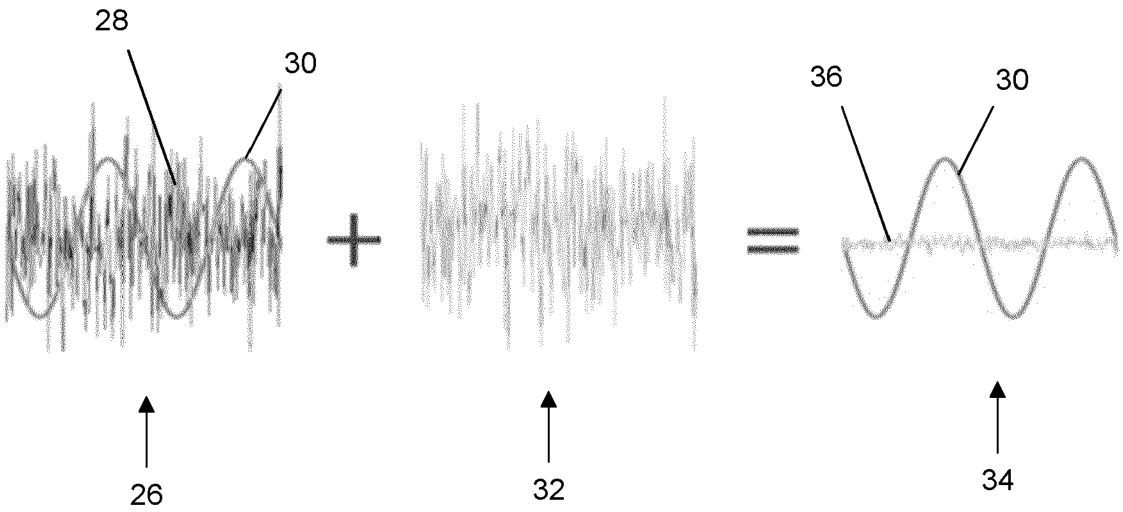

Fig. 4

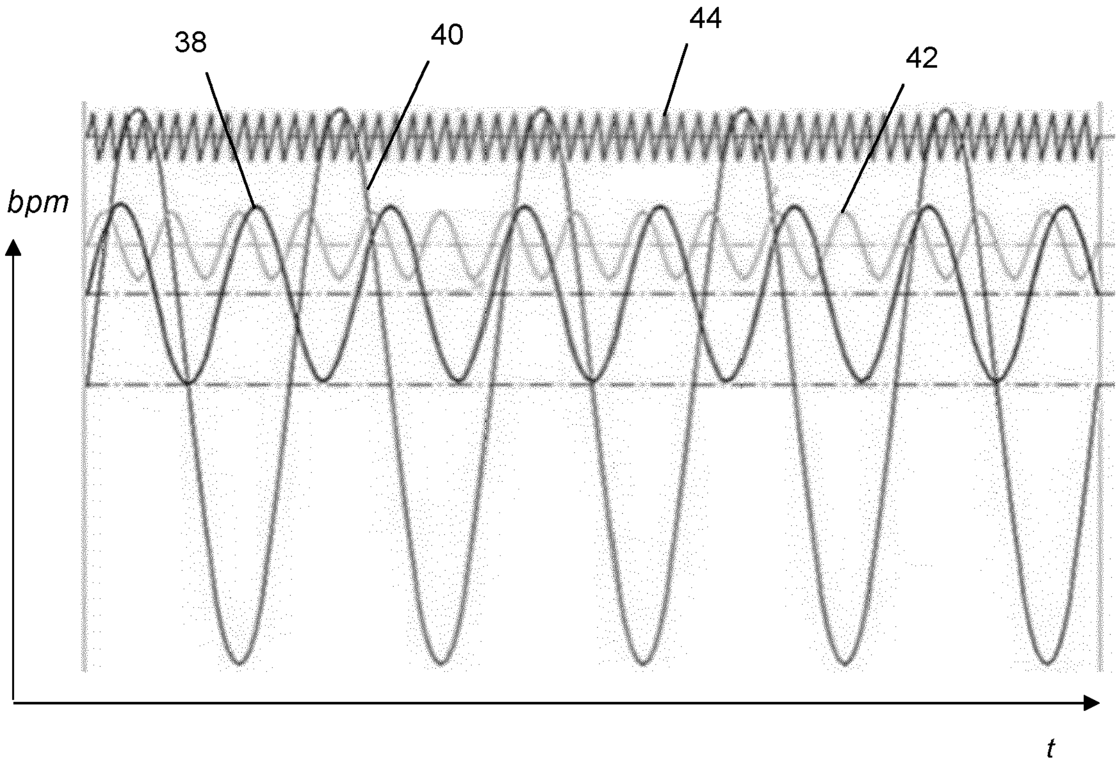

Fig. 5

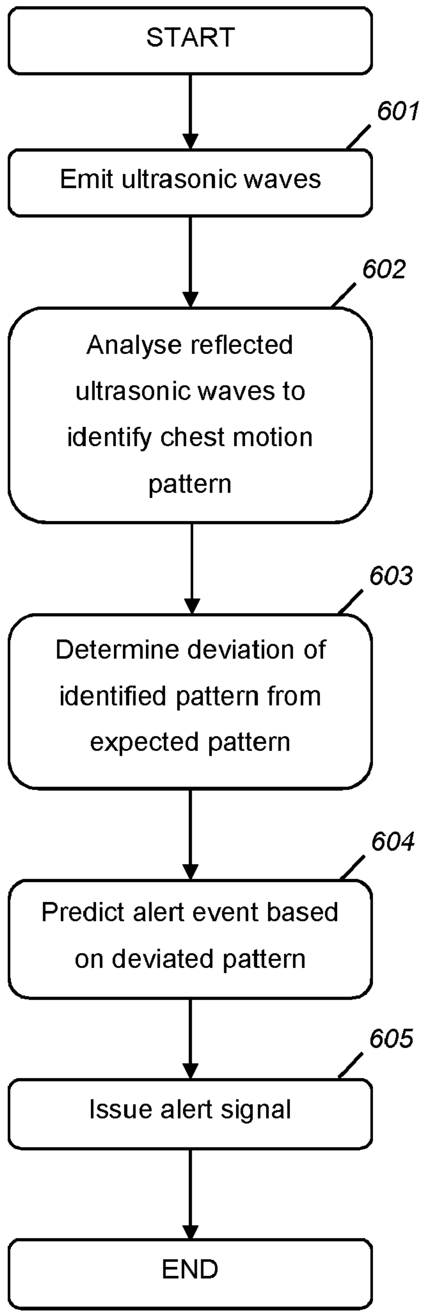
START
601
Emit ultrasonic waves
602
Analyse reflected ultrasonic waves to identify chest motion pattern
603
Determine deviation of identified pattern from expected pattern
604
Predict alert event based on deviated pattern
605
Issue alert signal
END

Fig. 6

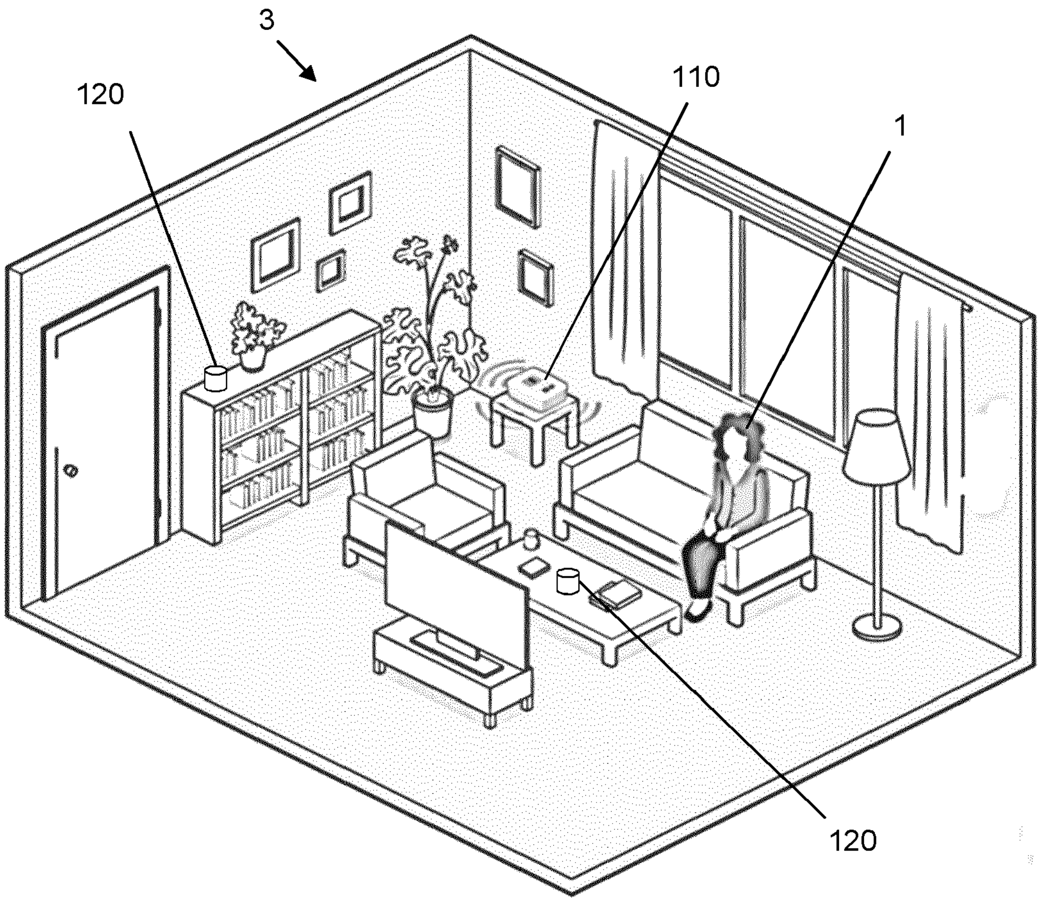

Fig. 7

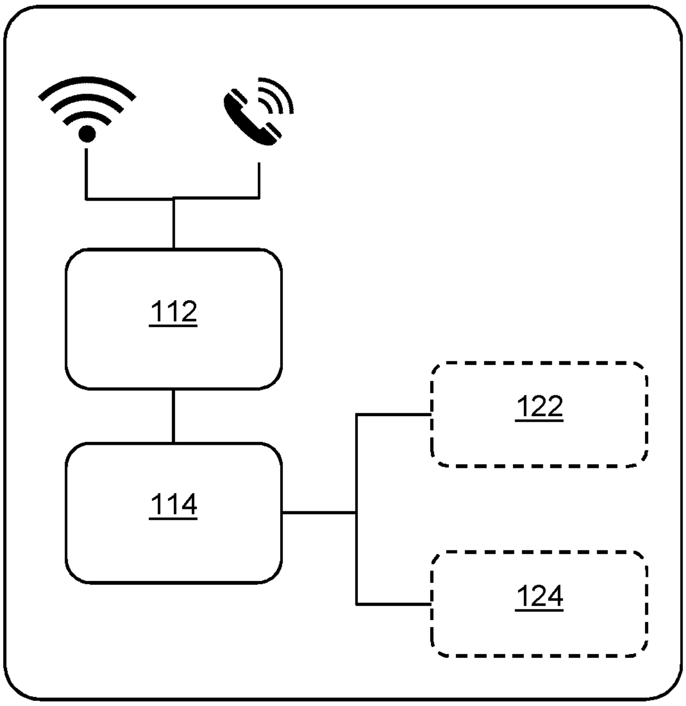

Fig. 8

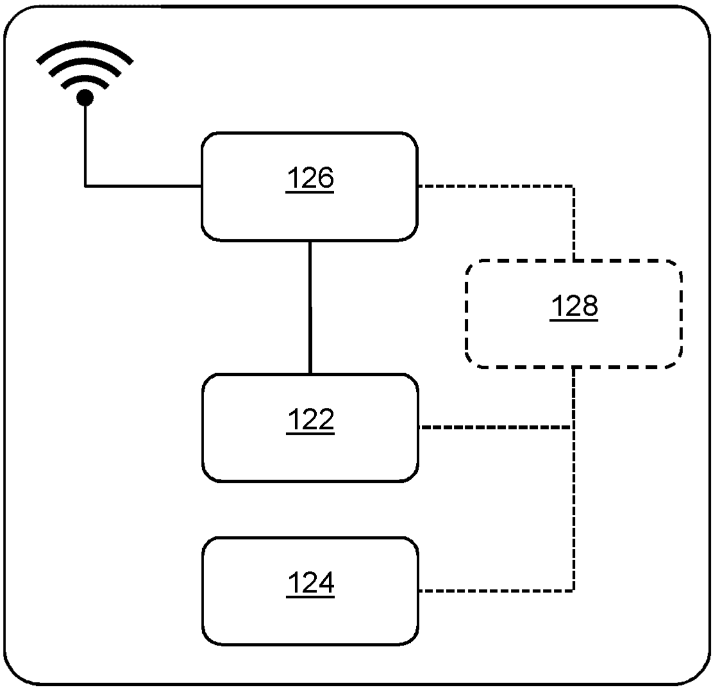

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 21 18 7266

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2021/169375 A1 (SLEPIAN MARVIN J [US]) 10 June 2021 (2021-06-10) * figures 1a,8,9 * * paragraphs [0029], [0045], [0048] *	1-4,8,9, 14,15 5-7, 10-13	INV. G08B21/04 A61B5/00
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1 The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	23 December 2021	Coffa, Andrew

CATEGORY OF CITED DOCUMENTS

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