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(54) **METHOD AND APPARATUS FOR MONITORING THE RESPIRATION ACTIVITY OF A SUBJECT**

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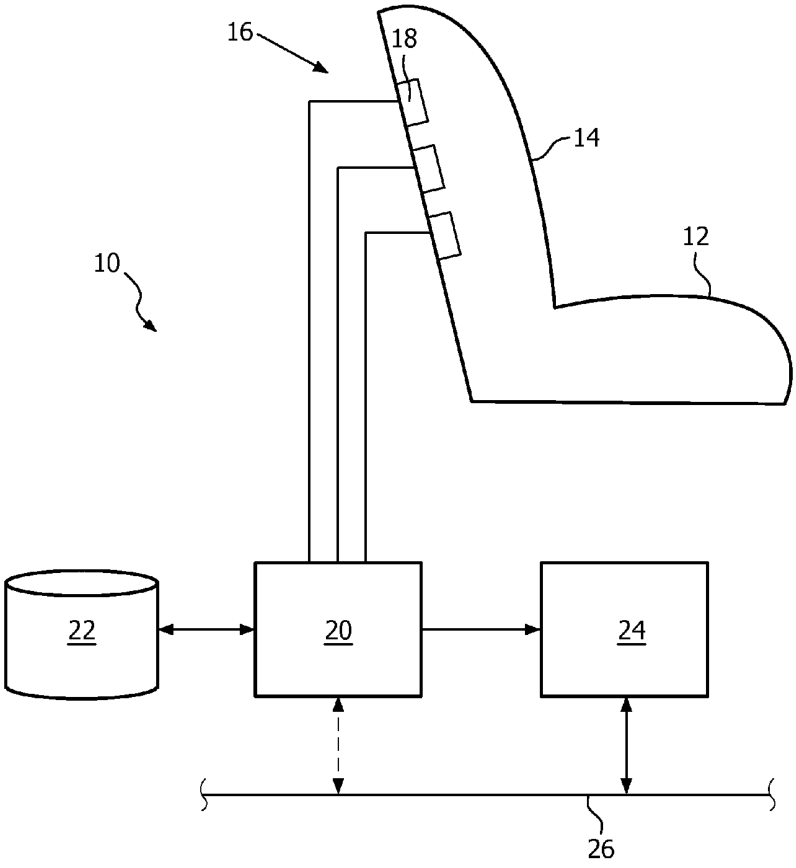
(57) **ABSTRACT**

The invention relates to a method for monitoring the respiration activity of a subject, comprising the acquisition of a sensor signal of at least one Doppler-Radar sensor representing the respiration activity of a subject, the transformation of the sensor signal into a transformation signal being a series according to Formula (I) where a_k is a set of predetermined constant coefficients specific for one individual subject, and processing the transformation signal S(t). The transformation signal can be analysed with basic signal processing techniques that are applied in the field of inductive plethysmography. The invention is further related to a corresponding monitoring system.



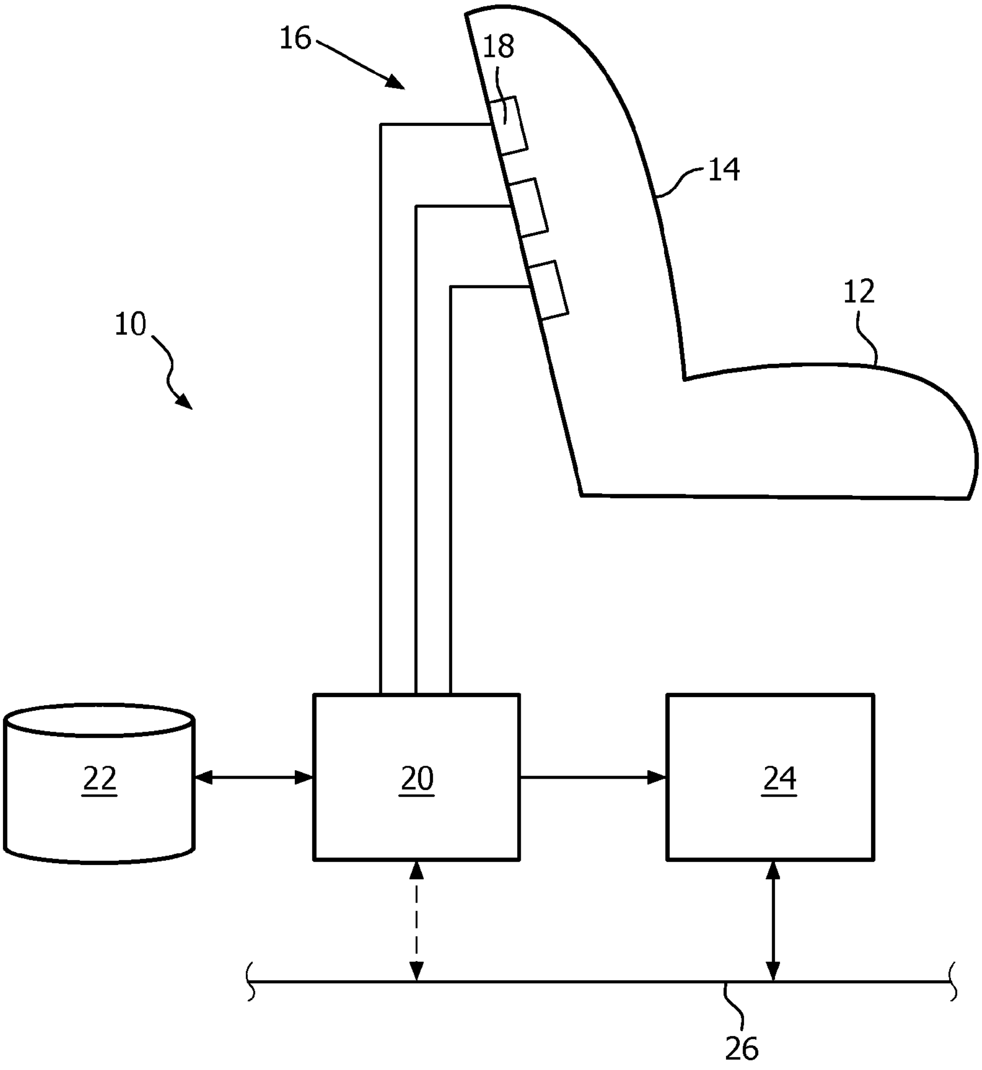


FIG. 1

6. The method according to claim **1**, characterized in that D(t) is the sum of the sensor signals $D_i(t)$, i=1 to n from n sensors.

7. The method according to claim **1**, characterized in that a plurality of sensor signals $D_i(t)$, i=1 to n is acquired from a plurality of n sensors,

and one set of coefficients a_k is determined for each one of these n sensors.

8. The method according to claim **7**, characterized in that one transformation signal $S_i(t)$ is derived for each sensor i according to

$$S_i(t) = \sum_{k=0}^{m} a_{ki} D_i(t)^k,$$

and a summarized transformation signal $\hat{S}(t)$ is calculated as the sum

$$\hat{S}(t) = \sum_{i=1}^{n} S_i(t)$$

of the transformation signals $S_i(t)$ of the sensors.

9. System (**10**; **30**) for monitoring the respiration activity of a subject (**32**), comprising:

at least one Doppler-Radar sensor (**18**) provided to acquire a sensor signal D(t) representing the respiration activity of a subject (**32**), characterized by a signal transformation unit (**20**) provided for transforming the sensor signal D(t) into a transformation signal S(t), S(t) being a series according to

$$S(t) = \sum_{k=0}^{m} a_k D(t)^k,$$

where a_k is a set of predetermined constant coefficients,

a storage unit (**22**) for storing sets a_k of predetermined constant coefficients,

and a processing unit (**24**) for processing the transformation signal S(t).

10. System according to claim **9**, characterized by a plurality of Doppler-Radar sensors (**18**) disposed at different positions within a measurement range.

11. System according to claim **10**, characterized in that said sensor transformation unit (**20**) is provided for transforming a sensor signal $D_i(t)$ of each sensor i into a transformation signal $S_i(t)$ and to summarize the resulting transformation signals $S_i(t)$ to a summarized transformation signal $\hat{S}(t)$.

12. System according to claim **10**, characterized in that said sensor transformation unit (**20**) is provided for summarizing sensor signals $D_i(t)$ of the sensors to a sum D(t) and to transforming the summarized signal D(t) into a transformation signal S(t).

* * * * *

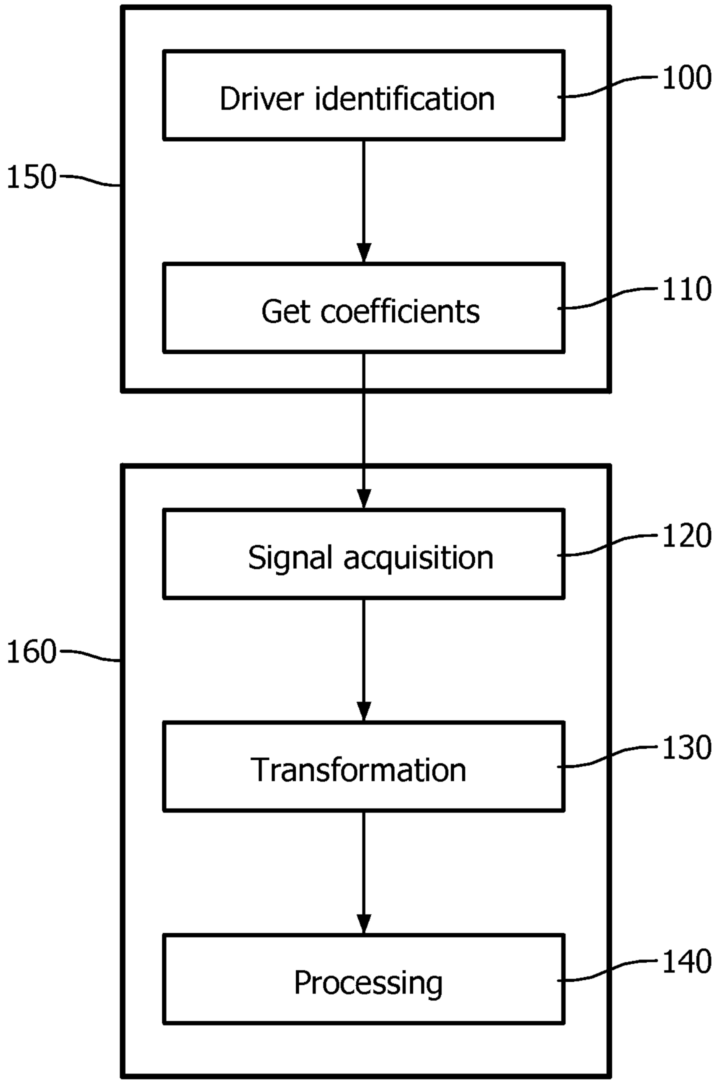

Driver identification
100
150
Get coefficients
110
Signal acquisition
120
160
Transformation
130
Processing
140

FIG. 2

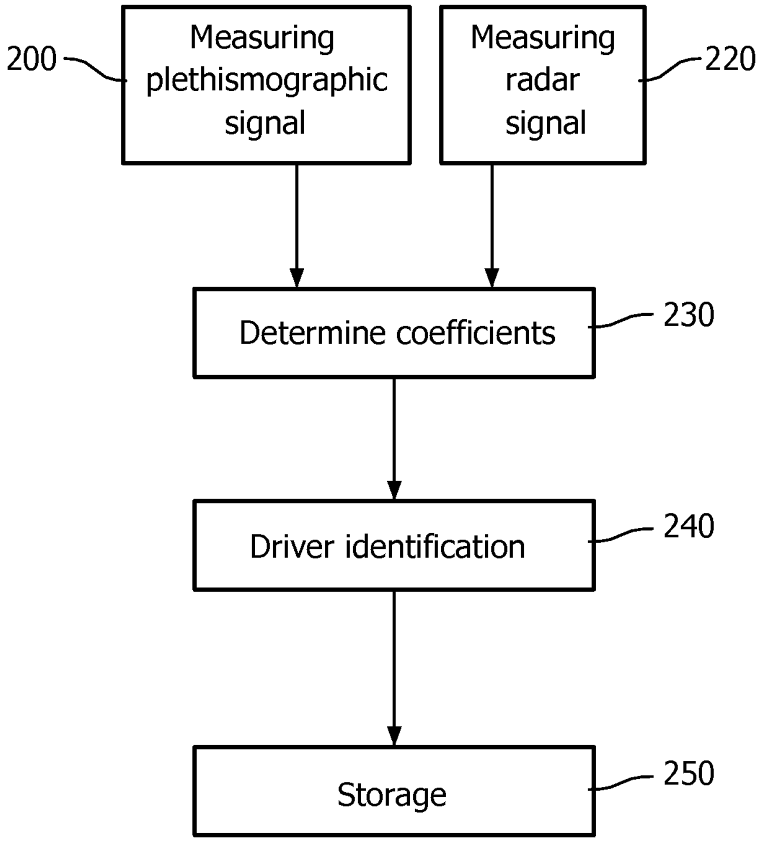

200
Measuring plethismographic signal
Measuring radar signal
220
Determine coefficients
230
Driver identification
240
Storage
250

FIG. 3

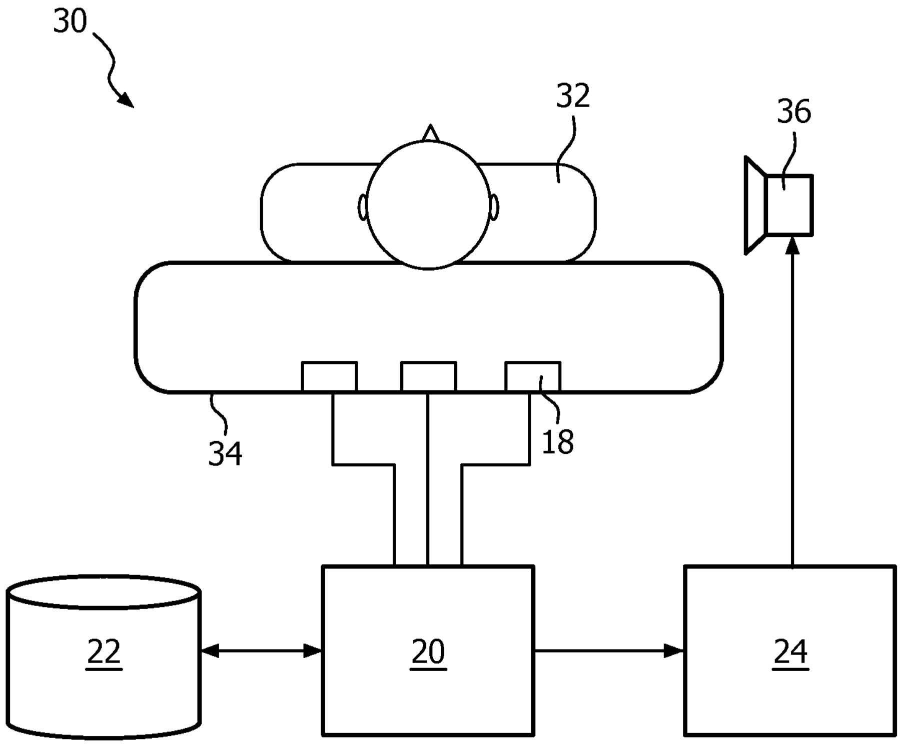


FIG. 4

METHOD AND APPARATUS FOR MONITORING THE RESPIRATION ACTIVITY OF A SUBJECT

FIELD OF THE INVENTION

[0001] The invention relates to the field of monitoring the respiration activity of a subject, for example, in clinical applications, systems for monitoring the physiological state of a driver or passenger in a vehicle, a biofeedback system for controlling the subject's relaxation, or the like.

BACKGROUND OF THE INVENTION

[0002] Monitoring systems for measuring the respiration activity of a subject are known for various applications. For example, in clinical intensive care situations, such applications are used to monitor the respiration activity of a patient. Another application is a biofeedback system based on guided breathing exercises to assist a subject to fall asleep. Moreover, a further application for a method and a device for monitoring the respiration activity is the early detection of the drowsiness of a driver of a vehicle. In all these applications sensors are used to acquire a sensor signal representing the respiration activity of the subject of interest, and this signal is further processed and interpreted by the system.

[0003] A measuring principle to monitor the respiration effort is thorax inductive plethysmography, where a band is placed around the subject's thorax and monitors the change of the cross sectional area of the thorax due to breathing. Although such a so-called respiband is commonly used in medical applications, however, it is not acceptable in consumer product applications, like the above mentioned biofeedback systems or driver monitoring systems, since the attachment of the band is inconvenient, cumbersome and not acceptable for the common user. For this reason contactless methods are preferred. Sensor based monitoring systems exist that comprise an array of contactless sensors such as radar sensors based on the Doppler-Radar principle. Each of these sensors is able to detect a change of a distance during a time period of an object from the sensor. Due to their operational principle Doppler-Radar sensors can be used for detecting a breathing related thorax motion. They can readily be integrated into furniture parts or in car equipment such as a car seat or the steering wheel. For example, for the above mentioned application of early detection of a driver's drowsiness, an array of Doppler-Radar sensors can be integrated into the backrest of the drivers seat. By such an array a contactless reliable monitoring of the breathing activity is possible.

[0004] In the use of the well-known method of inductive plethysmography, as mentioned above, the signal processing can be performed on the basis of a vast experience, however, the method of contactless monitoring the respiration activity with the help of Doppler-Radar sensors is more difficult because of a lack of such experience. An important problem in this context is that the algorithms developed for respiband measurements cannot be readily transferred to Doppler-Radar sensor measurements and still have to be developed to provide processing results with the same reliability. Generally there is a desire to apply the experiences with well-known measurement techniques, like inductive or resistive measuring, to the field of Doppler-Radar measurements.

SUMMARY OF THE INVENTION

[0005] It is therefore an object of the present invention to provide a method for monitoring the respiration activity of a subject with the help von Doppler-Radar sensors wherein basic signal processing techniques can be used that have already been tested in the field of inductive plethysmography, to simplify the development of a respective contactless monitoring system and to provide processing results with higher reliability.

[0006] Another object of the present invention is to provide a respective apparatus for monitoring the respiration activity of a subject that operates according to the above mentioned principles.

[0007] This objects are achieved by a method for monitoring the respiration activity of the subject according to claim **1**, as well as by an apparatus according to claim **9**.

[0008] According to the method according to the present invention, a sensor signal D(t) of at least one Doppler-Radar sensor is acquired that represents the respiration activity of a subject. According to the well-known Doppler principle electro magnetic waves are reflected at the chest wall and undergo a Doppler frequency shift if the chest wall is moving due to the respiration of the subject. Therefore the received signal contains information of the thorax motion.

[0009] This sensor signal D(t) is transformed into a so-called transformation signal S(t), S(t) being a series according to

$$S(t) = \sum_{k=0}^{m} a_k D(t)^k \tag{1}$$

that is, the transformation signal S(t) represents the sum of terms each representing powers of the original sensor signal D(t), multiplied by a constant coefficient a_k. One set of a_k, k=0 to m can be determined for a suitably chosen number m. The resulting transformation signal S(t) can then be further processed.

[0010] By the above mentioned equation (1), the original sensor signal D(t) is transformed into a transformation signal S(t) that represents an estimation of a corresponding inductive plethysmographic signal measured at the same subject under the same conditions. However, the transformation signal S(t) provides the advantage that it can be treated with well-known signal processing methods, especially with the same algorithms as in measuring an inductive plethysmographic signal originally by a respiband, without the use of Doppler-Radar sensors.

[0011] The mathematical relation between the Doppler-Radar signal D(t) and the an estimated plethysmographic signal S(t) according to equation (1) is based on the following derivation.

[0012] The human thorax can be described by an artificial torso model, where the radius of the thorax, which is assumed to be cylindrical, changes due to breathing homogeneously for all directions. The signal S(t) of an associated respiband that extends around the circumference of the thorax can than be expressed by

$$S(t) = \alpha L(R_0 + \Delta R(t))^2 = \alpha L(R_0^2 + 2R_0\Delta R(t) + \Delta R(t)^2) \tag{2}$$

[0013] In this equation (2) R(t) is the radius of the thorax, that is separated in a reference radius R_0 and a time varying term ΔR(t). Here, the length L is assumed to be constant.

[0014] On the other hand, a Doppler-Radar signal acquired by a Doppler-Radar sensor is proportional to the distance $\Delta R(t)$ between the sensor and the subject only, according to the following equation (3):

$$D(t)=\beta\Delta R(t) \tag{3}$$

[0015] In order to transform the radar based measured signal D(t) to S(t), D(t) according to the above equation (3) is inserted into equation (2), which gives:

$$S(t) = \alpha LR_0 + \frac{2\alpha LR_0}{\beta}D(t) + \frac{\alpha L}{\beta^2}D(t)^2 \tag{4}$$

[0016] This expression can be written as a sum of three terms:

$$S(t)=a_0+a_1D(t)+a_3D(t)^2 \tag{5}$$

[0017] Since a human torso has usually not a cylindrical shape, the above expression (5) can be generalized as follows:

$$S(t) = \sum_{k=0}^{m} a_k D(t)^k \tag{1}$$

[0018] That is, above equation (1) represents a generalization of the simplified torso model that has been assumed in the above considerations.

[0019] a_k is a set of predetermined constant coefficients that may be specific for a individual subject. Such a set of a_k can be acquired in a calibration procedure in which a plethysmographic signal and a Doppler-Radar sensor signal are measured at the same time, and a set of a_k is derived from this measurement. The number m can be chosen arbitrarily.

[0020] Once a set of a_k is determined for a subject to be monitored, an estimated transformation signal S(t) can be determined by being transformed from the Doppler-Radar sensor signal D(t) and further processed according to the signal processing methods applicable to inductive plethysmographic signals. With other words, the estimated transformation signal S(t) is treated like an original respiration signal acquired with a respiband.

[0021] According to a preferred embodiment of the present invention, the set of coefficient a_k is taken from a look-up table.

[0022] In this case the set of coefficient a_k is present when the measurement begins and can be taken, for example, from a suitable storage unit to transform the measured sensor signal D(t) to the transformation signal S(t), that can be further processed.

[0023] According to another preferred embodiment, this look-up table contains a plurality of different sets of coefficients a_k.

[0024] To use a set a_k that is specific for an individual subject, each set of a_k has to be selected from a plurality of sets a_k to choose the one that matches the present subject to be monitored.

[0025] Preferably this subject is identified, and a corresponding sets of coefficients a_k is chosen from the plurality of sets of coefficients a_k according to the result of the identification. This identification can take place automatically by the monitoring system, or the user is requested to input an identification information into the system. According to this information, a set of a_k is selected from the look-up table. Alternatively a default set of a_k can be chosen for the further processing in case the result of the identification is negative, that is, if no matching set of a_k can be found.

[0026] According to another preferred embodiment of the invention, a set of coefficients a_k for an individual subject is acquired in a calibration step, comprising measuring a plethysmographic signal S'(t) related to the subject's breathing over a period of time; measuring a sensor signal D(t) related to the subject's thorax motion over the same period of time; and determine a set of coefficients a_k from S'(t) and D(t) according to the relation

$$S'(t) = \sum_{k=0}^{m} a_k D(t)^k. \tag{6}$$

[0027] This calibration process can be done, for example, in a garage or at the site of the car seller. The determination of the coefficients a_k can be done via standard signal processing schemes of data from simultaneous measurements with a respiband and the radar set up.

[0028] According to a preferred embodiment of the present invention, D(t) is the sum of the sensor signals $D_i(t)$, i=1 to n, from n sensors.

[0029] In the presence of more than one Doppler-Radar sensor, all sensor signals $D_i(t)$ are summarized to a common sensor signal D(t) that is further processed according equation (1), that is, it is further transformed into the transformation signal S(t). In this case one set of constant coefficients a_k is necessary for an individual subject.

[0030] Forming the sum D(t) of all Doppler-Radar sensors provides the advantage that possible irregularities in the respiration of the subject can be perceived by the monitoring system easier than in the case of using only one Doppler-Radar sensor. Typically a plurality of sensors is distributed in a measurement range that represents an area covering the moving part of the thorax during the breathing activity. In a simplified example, the chest movement and the abdominal movements are measured by different sensors. While a irregularity like, for example, yawning is measured only by one sensor, this irregularity may be missed by the other sensor. If, however, both sensor signals are summed up, the irregularity will still show in the sum signal. With a help of a pattern detection algorithm, irregularities in the breathing process can be found in the sum signal.

[0031] According to another preferred embodiment of the present invention, a plurality of sensor signals $D_i(t)$, i=1 to n is acquired from a plurality of n sensors, and one set of coefficients a_k is determined for each one of these sensors.

[0032] In this case the transformation signal can be determined individually for each sensor signal $D_i(t)$ with the help of a respective set of coefficients a_{ki}, so that an estimated transformation signal $S_i(t)$ will exist corresponding to each sensor signal $D_i(t)$. The set of coefficients a_{ki} for each sensor must be determined individually in the calibration procedure as described above.

[0033] Preferably a transformation signal $S_i(t)$ is derived for each sensor i according to

$$S_i(t) = \sum_{k=0}^{m} a_{ki} D_i(t)^k \tag{7}$$

and a summarized transformation signal $\hat{S}(t)$ is calculated as the sum

$$\hat{S}(t) = \sum_{i=1}^{n} S_i(t) \tag{8}$$

of the transformation signals $S_i(t)$ of the sensors.

[0034] This means that the sum of the transformation signals is formed from the individual transformation signals $S_i(t)$ derived from each original Doppler-Radar sensor signal $D_i(t)$.

[0035] A corresponding system for monitoring the respiration activity of a subject according to the present invention comprises at least one Doppler-Radar sensor provided to acquire a sensor signal D(t) representing the respiration activity of a subject, a sensor transformation unit provided for transforming the sensor signal D(t) into a transformation signal S(t), S(t) being a series according to

$$S(t) = \sum_{k=0}^{m} a_k D(t)^k \tag{1}$$

where a_k is a set of predetermined constant coefficients, a storage unit for storing sets of a_k of predetermined constant coefficients, and a processing unit for processing the transformation signal S(t).

[0036] Preferably this system further comprises a plurality of Doppler-Radar sensors disposed at different positions within a measurement range.

[0037] This measurement range typically corresponds to an area of the thorax moving during the breathing motion. For example, one sensor can be provided in the chest region, while the other sensor is disposed in the abdominal region so that each sensor measures different movements during the breathing motion. This increases the chance to measure a breathing irregularity that may only concern the movement in one thorax region, while another region shows a normal breathing activity.

[0038] According to another preferred embodiment of this system, the sensor transformation unit is provided for transforming a sensor signal $D_i(t)$ of each sensor i into a transformation signal $S_i(t)$ and to summarize the resulting transformation signals $S_i(t)$ to a summarized transformation signal $\hat{S}(t)$.

[0039] According to another preferred embodiment, the sensor transformation unit is provided for summarizing sensor signals $D_i(t)$ of the sensors to a sum D(t) and to transform the summarized signal D(t) into a transformation signal S(t). This transformation can be performed according to the rules according to the present invention as already described, i.e. to transform the summarized signal D(t) into a power series according to equation (1) so that the sum of these terms is represent by the transformation signal S(t).

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter. In the drawings:

[0041] FIG. **1** is a schematic view of a sensor based monitoring system according to a first embodiment of the present invention;

[0042] FIG. **2** is a flow diagram showing an embodiment of the method according to the present invention;

[0043] FIG. **3** is another flow diagram demonstrating a calibrating step according to the method of the present invention; and

[0044] FIG. **4** is a schematic view of another sensor based monitoring system according to a second embodiment of the present invention

DETAILED DESCRIPTION OF EMBODIMENTS

[0045] FIG. **1** shows a system **10** for monitoring the respiration activity of a subject, for instance a driver located on a driver's seat **12** of a vehicle. Alternatively the seat or chair is part of a biofeedback system for monitoring or controlling the relaxation of the person using the seat. Instead of a seat or chair the system may comprise a mattress. Such an embodiment is described more in detail below in connection with FIG. **4**. At the rear side of the back rest **14** of the seat **12**, an array **16** of sensors **18** is integrated into the seat **12**. These sensors are Doppler-Radar sensors to monitor the breathing activity of the subject. Each sensor **18** has a defined measuring range corresponding to a determined area of the subject's thorax. For example, an upper sensor **18** of the array **16** can be provided to monitor the chest area of the subject, while a lower sensor **18** is provided to monitor the abdominal movements of the thorax. According to the Doppler principle, electromagnetic waves emitted by the sensors **18** are reflected at the chest wall and undergo Doppler frequency shift if the chest wall is moving due to the respiration of the subject. Therefore the signals received by the sensors **18** contain information about the thorax motion.

[0046] The system **10** further comprises a sensor transformation unit **20** to receive sensor signals acquired by the Doppler-Radar sensors **18**. This unit **20** may further comprise control functions for controlling the sensors **18**, for example, to activate only a limited subset of sensors **18** within the array **16**. That is, the transformation unit **20** is not only provided for signal transformation tasks, as will be laid out in the following, but may comprise further functions.

[0047] Once the signal transformation unit **20** has received a sensor signal D(t) of the sensors **18**, this sensor signal D(t) is transformed into a transformation signal S(t), as will be further explained below. The transformation is such that the resulting transformation signal S(t) can be handled like a signal resulting from an inductive plethysmography, i.e. a respiband measurement that measures the change of the circumference of the thorax during the breathing motion. Existing signal processing methods can be applied readily to such a transformated signal S(t), which is treated as an estimated plethysmographic signal.

[0048] Sets of coefficients a_k necessary for this transformation are stored in a storage unit **22** that communicates with the signal transformation unit **20**. Each set of predetermined constant coefficients a_k may be specific for an individual subject. For different subjects a plurality of sets of coefficients a_k is stored in the storage unit **22**.

[0049] Once the transformation signal S(t) has been determined, it can be further processed in a processing unit **24** to analyze the transformation signal in view of irregularities. Such an irregularity could be yawning of the subject, which explicitly shows in a pattern of at least one sensor signal of one of the sensors **18**. If such an irregularity is identified, this is taken as an indication of relaxation of the person in the seat. In case the seat is the seat of a driver of a vehicle the yawning may be considered as an indication of a critical state of the driver concerned, and a feedback signal could be given to him. Similarly in case the seat is a part of a biofeedback system intended for assisting the user to relax a feedback signal can be given to the use. In case of the seat is a driver's seat, The signal indicating a certain irregularity (assumed to represent respective certain physiological state of the subject) could be output by the processing unit **24** and transmitted via a bus system. In case the of a vehicle this could be for instance the CAN bus **26** of the car. In other applications the seat or chair may be connected to a local area network (wired or wireless). Via the bus-system or network the processing unit would be connected to other hardware units, that may arranged to produce a feedback signal to the user. This signal could for in stance be an audio and/or video signal.

[0050] It is noted that the example of the monitoring system **10** in FIG. **1** is only one application of monitoring the respiration activity of a subject. Moreover, the schematic architecture of the system **10** comprising a signal transformation unit **20** and a processing unit **24** is only to be understood as an example. The transformation function and the further processing functions could also be performed by one single hardware unit, and so the division of these tasks into two operational units **20** and **24** has only been made for explanatory reasons. Just to mention one further example, the different units **22**, **24** and **26** could be connected via the bus system or network **26** itself.

[0051] An embodiment of a method for monitoring the respiration activity of a subject with the help of the monitoring system **10** in FIG. **1** will be explained in the following with regard to the flow diagram of FIG. **2**.

[0052] First, in step **100**, the user is identified as the subject to be monitored. This identification can be performed automatically by the system by detecting certain characteristics of the subject, or by input of a user ID into the system **10**. Once the driver (subject) is identified, one set of coefficients a_k is polled from the storage unit **22** according to result of the identification (step **110**). Usually a plurality of sets of constants a_k is stored within a look-up table inside the storage unit **22**, and one of these sets a_k is selected according to the identification result.

[0053] If no identification of the subject is possible, i.e. the result of the identification step **100** is negative and no set of individual a_k matching the subject is present in the look-up table, a default (standard) set of a_k can polled from the look-up table and the further processing can be carried out on this basis.

[0054] The further meaning of this set of coefficients a_k necessary for a single transformation will be explained below.

[0055] In a further step **120**, sensor signals D(t) are acquired from the sensors **18** representing the respiration activity of the subject. The sensor signal D(t) of a Doppler-Radar sensor is proportional to the distance between the sensor and the subject (i.e. the thorax wall at which the electromagnetic waves are reflected back to the sensor). To simplify the further processing of the sensor signals, the original sensor signal is transformed into a transformation signal S(t) in a transformation step **130** according to the following equation:

$$S(t) = \sum_{k=0}^{m} a_k D(t)^k \tag{1}$$

[0056] This means that the transformation signal S(t) is formed by a sum of terms, each term being a power of the original sensor signal D(t) multiplied with a coefficients a_k. The number m can be chosen as desired. a_k, k=0 to m represent the coefficients that are taken from the look-up table in the foregoing step **110**.

[0057] This transformation signal S(t) represents an estimated plethysmographic signal that can be treated as a signal acquired from a respiband or the like. Signal processing methods applicable to such respiband signals can be used for further processing the transformation signal S(t) in a processing step **140**. It is, however, noted that the transformation signal S(t) can also be treated with signal processing methods applicable to resistive measurements, since the signals acquired by these methods can also be developed mathematically to a power series.

[0058] While the user identification step **100** and the subsequent step **110** of polling the coefficients from the look-up table represent an initialization procedure **150** of the whole process, it is understood that the following steps **120**, **130** and **140** will be carried out (and repeated) continuously in a permanent monitoring routine **160**. That is to say, during monitoring the subject, there will be a permanent process of signal acquisition, immediate transformation of the acquired signals and eventually further processing of the transformation signal.

[0059] In the case of a plurality of sensors **18** as shown in FIG. **1**, there are different possibilities to handle the original sensor signals D(t). One possibility is to sum up the sensor signals $D_i(t)$, i=1 to n from n sensors and to further process the sum D(t) in the way as described above. This means that the sum of all sensor signals $D_i(t)$ is treated like one common sensor signal D(t). For the further transformation into the transformation signal S(t) only one set of coefficients a_k is necessary for one subject.

[0060] Using a plurality of sensors **18** provides the advantage that each of these sensors **18** can be disposed at a different position within the array **16**. For example, an irregularity in the breathing rhythm can be detected by one sensor **18** while another sensor **18** does not detect any irregularities. However, in the sum D(t) of both of these sensor signals $D_i(t)$, the irregularity will be present. One typical example for an irregularity is a yawning pattern that may show in the sensor signals of one sensor but is not detectable in the sensor signals of another sensor.

[0061] Another possibility to handle the sensor signals $D_i(t)$, i=1 to n of n sensors is to transform each sensor signal $D_i(t)$ into a corresponding transformation signal $S_i(t)$, i=1 to N, so that N transformation signals $S_i(t)$ will be present. Each of these transformation signals $S_i(t)$ is calculated according to

$$S_i(t) = \sum_{k=0}^{m} a_{ki} D_i(t)^k. \tag{7}$$

[0062] It is clear that one set of coefficients a_k, is necessary in this case for each sensor.

[0063] The different transformation signals $S_i(t)$ (gained in the transformation step **130**) are summarized in the following to calculate a sum

$$\hat{S}(t) = \sum_{i=1}^{n} S_i(t) \tag{8}$$

of the transformation signals $S_i(t)$ of the sensors. This summarized transformation signal $\hat{S}(t)$ can then be further processed (step **140**) and treated as an estimated plethysmographic signal with the according signal processing algorithms.

[0064] To acquire sets of predetermined constant coefficients a_k, a calibration step can be performed that is shown in the flow diagram of FIG. **3**.

[0065] In this calibration step, a plethysmographic signal S'(t) is measured over certain period of time. Such a signal S'(t) can be taken by a respiband measurement and is related to the subject's thorax volume (step **200**). At the same time, a Doppler-Radar sensor signal D(t) related to the subject's thorax motion is measured (step **220**). From both measurements, coefficients a_k are calculated according to the relation

$$S'(t) = \sum_{k=0}^{m} a_k D(t)^k. \tag{6}$$

in a following step **230** based on state-of-the-art statistical methods.

[0066] The user may be requested to input a user ID (step **240**), and the set of coefficients a_k is stored within the look-up table together with user identification data (step **250**).

[0067] According to the chosen set up, the coefficients a_k can be determined for each sensor **18** so that in the calibration step, coefficients a_k are determined for the whole set of sensors and stored together with the user ID. In case of use in a vehicle this could be stored in the car management system. In case the system is used for instance in a home as a relaxation system, as described below more in detail in connection with FIG. **4**, it could be stored locally or at another module or computer connected to a home network. It is possible to communicate all data, including the sets of coefficients a_k and user identification data, via the bus or network **26**, as shown in FIG. **1**.

[0068] Although the invention has been described above to create a transformation signal that corresponds to an estimation of a signal gained by inductive plethysmography with the help of a respiband, it is, however, possible to interpret the transformation signal as an estimated signal acquired by other methods. For example, resistive measuring of the circumference of the subject's thorax can also be estimated by the transformation signal, since a resistive measurement signal can also be simulated by a series of terms that include the Doppler radar signal information. In this respect other measurement techniques can possibly be acknowledged.

[0069] FIG. **4** shows another embodiment of a system **30** for monitoring the respiration activity of a subject **32** according to the present invention. This system **30** comprises a mattress wherein the array of sensors **18** is integrated to monitor a subject **32** lying on the top surface of the mattress **34**. The system **30** further comprises a signal transformation unit **20** and a processing unit **24**, as well as a storage unit **22**. The operation principle of the sensors **18**, the signal transformation unit **20**, the processing unit **24** and the storage unit **22** is basically the same as explained with respect to FIG. **1**, so that further explanations are omitted here for the sake of brevity. In the embodiment of FIG. **4**, the processing unit **24** communicates with an output unit **36** to generate an audio and/or video feedback signal perceivable by the subject **32** in case a respective command is received from the processing unit **24**. Such a feedback system can assist the subject **32** to relax by pacing the respiration rhythm, i.e. to give a perceivable feedback on the respiration as presently measured. Moreover, a similar system **30** comprising sensors **18** integrated in a mattress **34** can be used in clinical care for monitoring a patient.

[0070] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

1. A method for monitoring the respiration activity of a subject, comprising:

acquiring a sensor signal D(t) of at least one Doppler-Radar sensor representing the respiration activity of a subject,

characterized by

transforming the sensor signal D(t) into a transformation signal S(t), S(t) being a series according to

$$S(t) = \sum_{k=0}^{m} a_k D(t)^k,$$

where a_k is a set of predetermined constant coefficients, and processing the transformation signal S(t).

2. The method according to claim **1**, characterized in that the set of coefficients a_k is taken from a look-up table.

3. The method according to claim **2**, characterized in that the look-up table contains a plurality of different sets of coefficients a_k.

4. The method according to claim **3**, characterized in that the subject is identified, and one corresponding set of coefficients a_k is chosen from the plurality of sets of coefficients a_k according to the result of the identification.

5. The method according to claim **1**, characterized in that a set of coefficients a_k for one individual subject is acquired in a calibration step, comprising:

measuring a signal S'(t) related to the subject's thorax volume of the subject over a period of time;

measuring a sensor signal D(t) related to the subject's thorax motion over the same period of time;

determine a set of coefficients a_k from S'(t) and D(t) according to the relation

$$S'(t) = \sum_{k=0}^{m} a_k D(t)^k.$$

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摘要(译)

本发明涉及一种用于监测对象的呼吸活动的方法，包括获取表示对象的呼吸活动的至少一个多普勒 - 雷达传感器的传感器信号，将传感器信号转换为转换信号为根据公式（I）的系列，其中ak是一组特定于一个个体的预定常数系数，并处理变换信号S（t）。可以利用在感应体积描记术领域中应用的基本信号处理技术来分析变换信号。本发明还涉及相应的监控系统。