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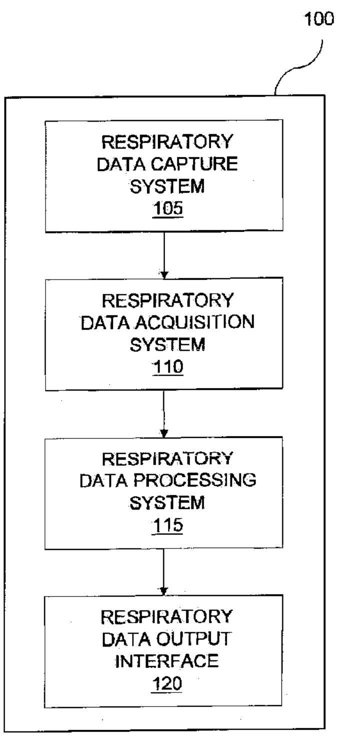
(54) Title: LIGHTWEIGHT WHEEZE DETECTION METHODS AND SYSTEMS

FIG. 1



(57) Abstract: Lightweight wheeze detection methods and systems for portable respiratory health monitoring devices conserve computing resources in portable respiratory health monitoring devices by employing lightweight algorithm that calculates a partial short-time Fourier transform (STFT) image of a respiratory signal that includes all data points necessary for wheeze detection but excludes many data points that are unnecessary for wheeze detection. The methods and systems provide substantial savings in computing resources while still ensuring every wheeze in a respiratory signal is detected.

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DESCRIPTION

TITLE OF INVENTION: LIGHTWEIGHT WHEEZE DETECTION METHODS AND SYSTEMS

TECHNICAL FIELD

The present invention relates to ambulatory health monitoring and, more particularly, to lightweight wheeze detection methods and systems designed to improve portable respiratory health monitoring devices.

BACKGROUND ART

Wheeze monitoring is an important aspect of chronic respiratory disease management, such as asthma management. Wheezes are adventitious lung sounds that are superimposed on normal breath sounds and indicate constricted breathing. A wheeze is generally characterized by a high pitch sound lasting a predetermined duration, and can be detected by evaluating time and frequency components of a respiratory signal.

In conventional wheeze monitoring, a complete short-time Fourier transform (STFT) image is calculated to detect wheezes in a respiratory signal. The complete STFT image provides a two-dimensional representation of the amplitude of the respiratory signal for all data points in a time and frequency domain according to the well-known formula:

$$\mathbf{STFT}\{x(t)\} \equiv X(\tau,\omega) = \int_{-\infty}^{\infty} x(t)w(t-\tau)e^{-j\omega t}\,dt$$

where w(t) is the window function, x(t) is the signal to be transformed and $X(\tau,\omega)$ is the Fourier transform of $x(t)w(t-\tau)$, a complex function representing the phase and magnitude of the signal over time and frequency. Wheezes can be detected from evaluation of selected data points in the complete STFT image.

Conventional wheeze monitoring is not well-suited for portable respiratory health monitoring devices that continually acquire and evaluate a respiratory signal as a person wearing the system goes about his or her daily life. Such devices have limited computing resources, and calculating a complete STFT image to detect wheezes often consumes an unacceptably large share of those scarce resources.

SUMMARY OF INVENTION

In one aspect of the invention, an ambulatory health monitoring device comprises a respiratory data capture system; a respiratory data acquisition system; a respiratory data processing system, a respiratory data output interface, wherein the respiratory data processing system further comprises: a receiving section for receiving a respiratory signal from the capture system via the acquisition system, a noncontiguous line calculating section for calculating noncontiguous lines of a short-time Fourier transform (STFT) image of the respiratory signal until a start line of the STFT image conforming to one or more wheeze peak criteria is identified, a contiguous line calculating section for calculating, once a start line conforming to the wheeze peak criteria is identified, contiguous lines of the STFT image preceding the start line and contiguous lines of the STFT image following the start line until both a preceding line and a following line not conforming to the wheeze peak criteria are identified, a determining section for determining, once both a preceding line and a following line not conforming to the wheeze peak criteria are identified, using a total count of calculated lines of the STFT image conforming to the wheeze peak criteria whether a duration of a peak conforms to one or more wheeze duration criteria, , a wheeze rate calculating section for calculating, upon determining that the duration conforms to the wheeze duration criteria, a wheeze rate and a transmitting section for transmitting information indicative of the wheeze rate to the output interface.

In another aspect of the invention, a lightweight wheeze detection method comprises the steps of receiving a respiratory signal; calculating noncontiguous lines of a short-time Fourier transform (STFT) image of the respiratory signal until a start line of the STFT image conforming to one or more wheeze peak criteria is identified; calculating, once a start line conforming to the wheeze peak criteria is identified, contiguous lines of the STFT image preceding the start line and contiguous lines of the STFT image following the start line until both a preceding line and a following line not conforming to the wheeze peak criteria are identified; and, determining, once both a preceding line and a following line not conforming to the wheeze peak criteria are identified, by the processing system using a total count of calculated lines of the STFT image conforming to the wheeze peak criteria whether a duration of a peak conforms to one or more wheeze duration criteria.

In yet another aspect of the invention, a lightweight wheeze detection method comprises the steps of receiving a respiratory signal; calculating a partial STFT image of the respiratory signal comprising selected data points of selected lines of a complete STFT image of the respiratory signal, wherein the lines and the data points are selected based at least in part on one or more wheeze peak criteria; and detecting a wheeze in the partial STFT image based at least in part on the wheeze peak criteria.

These and other aspects of the invention will be better understood by reference to the following detailed description taken in conjunction with the drawings that are briefly described below. Of course, the invention is defined by the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 shows an ambulatory health monitoring device in some embodiments of the invention.

FIG. 2 shows a wheeze detection method performed by a respiratory data processing system in some embodiments of the invention.

FIG. 3 shows a respiratory signal received by a respiratory data processing system.

FIG. 4 shows a line of a STFT image calculated by a respiratory data processing system.

FIG. 5 shows binary values of wheeze detection parameters calculated by a respiratory data processing system.

FIG. 6 is a map showing selected data points of a STFT image calculated by a respiratory data processing system.

FIG. 7 shows a complete STFT image.

FIG. 8 shows the sections of the respiratory data processing system.

DESCRIPTION OF EMBODIMENTS

The present invention provides lightweight wheeze detection methods and systems for portable respiratory health monitoring devices. The invention conserves computing resources in portable respiratory health monitoring devices by employing a lightweight algorithm that calculates a partial STFT image of a respiratory signal that includes all data points that are necessary for wheeze detection but excludes many data points that are unnecessary for wheeze detection. The methods and systems provide substantial savings in computing resources while still ensuring every wheeze in a respiratory signal is detected.

FIG. 1 shows an ambulatory health monitoring device 100 in some embodiments of the invention. Monitoring device 100 includes a respiratory data capture system 105, a respiratory data acquisition system 110, a respiratory data processing system 115 and a respiratory data output interface 120 communicatively coupled in series.

Capture system 105 detects lung sounds at a detection point, such as a trachea, chest or back of a person being monitored and transmits a respiratory signal to acquisition system 110 in the form of an electrical signal generated from detected lung sounds. Capture system 105 may include, for example, a sound transducer positioned on the body of a human subject.

Acquisition system 110 amplifies, filters, performs analog/digital (A/D) conversion and automatic gain control

(AGC) on the respiratory signal received from capture system 105, and transmits the respiratory signal to processing system 115. Amplification, filtering, A/D conversion and AGC may be performed by serially arranged pre-amplifier, band-pass filter, final amplifier, A/D conversion and AGC stages, for example.

Processing system 115, under control of a processor executing software instructions, performs time and frequency domain processing, including calculation of partial STFT images, on the respiratory signal to detect wheezes and calculate wheeze rate. Processing system 115 under control of the processor outputs the wheeze rate to data output interface 120.

FIG. 8 shows the sections that are contained in the respiratory processing system 115. The processing system 115 includes a receiving section 805 for receiving a respiratory signal from the capture system via the acquisition system 110.

The processing system 115 further includes a noncontiguous line calculating section 810 for calculating noncontiguous lines of a STFT image of the respiratory signal until a start line of the STFT image conforming to one or more wheeze peak criteria is identified.

The processing system 115 further includes a contiguous line calculating section 815 for calculating, once a start line conforming to the wheeze peak criteria is identified, contiguous lines of the STFT image preceding the start lie and contiguous lines of the STFT image following the start line until both a preceding line and a following not conforming to the wheeze peak criteria are identified.

The processing system 115 further includes a determining section 820 for determining, once both a preceding line and a following line not conforming to the wheeze peak criteria are identified, using a total count of calculated lines of the STFT image conforming to the wheeze peak criteria whether a duration of a peak conforms to one or more wheeze duration criteria.

The processing system 115 further includes a wheeze rate calculating section 825 for calculating, upon determining that the duration conforms to the wheeze duration criteria, a wheeze rate. The processing system 115 further includes a transmitting section 830 for transmitting information indicative of the wheeze rate to the output interface.

Data output interface 120 includes one or more of a user interface, a local analysis module, a data management element and a network interface for displaying, processing, storing and/or transmitting information received from processing system 115, such as wheeze rate.

While in the illustrated embodiment capture system 105, acquisition system 110, processing system 115 and data output interface 120 are part of a portable (e.g. wearable) ambulatory health monitoring device that monitors a person's physiological well-being in real-time as the person performs daily activities, in other embodiments capture system 105, acquisition system 110, processing system 115 and/or data output interface 120 may be part of separate devices that are remotely coupled via wired or wireless links.

FIG. 2 shows a wheeze detection method performed by processing system 115 in some embodiments of the invention under control of a processor that executes software instructions. The method will be described in conjunction with FIGS. 3-7.

Initially, processing system 115 receives a time domain respiratory signal from acquisition system 110 (S205). FIG. 3 shows an exemplary time domain respiratory signal received by a processing system 115. The x-axis of the respiratory signal is time in seconds and the y-axis of the respiratory signal is sound amplitude in arbitrary units. The respiratory signal exhibits periodicity corresponding to a respiratory cycle (i.e. inhale/exhale). Wheezes are not readily detectable in the time domain respiratory signal.

Next, processing system 115 calculates noncontiguous lines of an STFT image of the respiratory signal until a start line conforming to wheeze peak criteria is identified. In this regard, processing system 115 compares the frequency, height and width of the highest amplitude peak of a candidate start line of an STFT image with predetermined frequency, height and width thresholds, respectively (S215). This amplitude peak can be seen as, for example, a minimum peak frequency, a minimum peak height and a minimum peak width of the start line of the STFT image. If the frequency, height and width of the highest amplitude peak of the candidate start line are all above threshold, the candidate start line is chosen as the start line and the flow moves to Step S225. On the other hand, if one or more of the frequency, height or width of the highest amplitude peak of the candidate start line is below threshold, processing system 115 advances N lines (S220) from the candidate start line and re-performs Step S215 at the new candidate start line. Steps S215 and S220 are repeated in a loop until a start line is chosen or all candidate start lines have been calculated and found wanting.

To better illustrate, FIG. 4 shows a line of an STFT image calculated by processing system 115. The line is a slice of a complete STFT image taken over a short time window of size W. The x-axis of the line is frequency in hertz and the y-axis of the line is amplitude in arbitrary units. The highest amplitude peak in the line is centered at about 190 Hz. In Step S215, the frequency, height and width of the peak are compared with frequency, height and width thresholds, respectively, to determine whether the line is chosen as the start line. By way of example, a frequency threshold may be set at 150 Hz to conform to a minimum frequency required for a peak to be properly classified as a wheeze. Since the frequency of the peak shown in FIG. 4 is greater than 150 Hz, the frequency threshold would be surpassed in this example. Similar comparisons would be made between the height of the peak (indicated by the circle in FIG. 4) and the width of the peak (indicated in FIG.4) and minimum height and width thresholds characteristic of a wheeze to determine whether the line is chosen as the start line.

The value of N used in Step S220 is judiciously selected to correspond to a minimum duration required for a peak to be properly classified as a wheeze. By selecting a value for N that conforms to a wheeze of minimum duration, the total number of lines calculated by processing system 115 is reduced by up to a factor of N as compared with wheeze detection methods that calculate a complete STFT image. Moreover, this reduction in calculations is realized without risking failure to detect any wheeze expressed in the respiratory signal. More particularly, the value of N may be determined according to the formula:

$$N = D/[W(1-X)]$$

where D is the minimum wheeze duration, W is the window size of each STFT line and X is the percentage of overlap between adjacent STFT lines. By way of example, D may be configured as 250 ms, W may be configured as 80 ms and X may be configured as 0.50, such that the formula yields N = 6, after rounding.

Once the start line has been chosen, processing system 115 calculates contiguous lines preceding the start line until a preceding line not conforming to the wheeze peak criteria is identified. In this regard, processing system 115 first checks whether the current line, which is initially the start line, is the earliest available line of the STFT image (S225). If the current line is the earliest available line, calculation of preceding lines is not possible and the flow moves to Step S245. On the other hand, if the current line is not the earliest available line, calculation of preceding lines is possible and processing system 115 moves back one line (S230) and compares the frequency, height and width of the highest amplitude peak of the new current line with predetermined frequency, height and width thresholds, respectively (S235). If one of the frequency, height and width of the highest amplitude peak of the current line is below threshold, the flow moves to Step S240. On the other hand, if all of the frequency, height or width of the highest amplitude peak of the current line are above threshold, processing system 115 returns to Step S225. Steps S225- S235 are repeated in loop until a line preceding the start line is found to not conform to the wheeze peak criteria or all available lines preceding the start line have been calculated and found to conform.

Next, processing system 115 calculates contiguous lines following the start line until a following line not conforming to the wheeze peak criteria is identified. In this regard, processing system 115 advances to the first line after the start line (S240, S245) and compares the frequency, height and width of the highest amplitude peak of the current line with the frequency, height and width thresholds, respectively (S250). If one of the frequency, height and width of the highest amplitude peak of the current line is below threshold, the flow moves to Step S255. On the other hand, if all of the frequency, height or width of the highest amplitude peak of the current line are above threshold, processing system 115 returns to Step S245. Steps S245 and S250 are repeated in a loop until a line following the start line is found to not conform to the wheeze peak criteria.

Naturally, the order in which processing system 115 calculates contiguous lines preceding and following the start line is reversible. That is, processing system 115 may first calculate contiguous lines following the start line and thereafter calculate contiguous lines preceding the start line.

Importantly, calculation of the contiguous lines preceding and following the start line is limited to a region of each contiguous line within a predetermined range of a central frequency of the highest amplitude peak of the start line. For example, if the line of FIG. 4 is chosen as the start line, processing system 115 limits calculation of each contiguous line preceding and following the start line to data points bounded by the dotted lines shown in FIG. 4. This limitation provides additional significant reduction in the number of data points of the STFT image calculated by processing system 115 as compared to methods that calculate the complete STFT image.

Once both a preceding line and a following line not conforming to the wheeze peak criteria are identified, processing system 115 determines using the total count of calculated lines conforming to the wheeze peak criteria whether the duration of the highest amplitude peak conforms to a wheeze duration criterion. In this regard, processing system 115 compares the total number of above-threshold lines calculated attendant to performing Steps S215, S235 and S250 with a wheeze duration threshold (S255). In some embodiments, the total count is compared directly with a wheeze duration threshold that is expressed as a number of lines (e.g. N = 6). In other embodiments, the total count is converted to a duration in units of time and the duration is compared with a wheeze duration threshold that is expressed in units of time. In either event, if the comparison is below the threshold, the duration of the peak conforming to the wheeze peak criteria is insufficient to classify the peak as a wheeze, and the flow returns to Step S220. On the other hand, if the comparison is above the threshold, the duration of the peak is sufficient to classify the peak as a wheeze, and processing system 115 processes the wheeze (S260). Wheeze processing may include, for example, calculating a wheeze rate according to the formula:

$$R = t_w / t_{tot}$$

where R is the wheeze rate, t_w is the duration of the wheeze, and t_{tot} is the duration of a respiratory cycle.

FIG. 5 shows exemplary binary values of wheeze detection parameters determined by processing system 115 attendant to performing the method of FIG. 2. Values of "1" indicate conformance with a given criterion and values of "0" indicate nonconformance with a given criterion. FIG. 5 shows values for the following criteria: peak height 510, peak width 520, peak contiguity 530 (i.e. whether the peak height and peak width criteria are satisfied for both the preceding line and the current line) and wheeze detection 540 (i.e. whether peak contiguity persists over a minimum wheeze duration).

FIG. 6 is a map (fast wheeze algorithm) showing selected data points of a STFT image of the respiratory signal calculated by processing system 115 attendant to performing the method of FIG. 2. Dark areas of the map indicate data points that were calculated. Light areas of the map indicate data points that were not calculated, and reflect calculation savings relative to methods wherein the complete SFTF image is calculated.

FIG. 7 is a complete STFT image (shown here in black and white) showing the amplitude of different frequencies (shown as white areas against the black background) expressed in the respiratory signal at different times. Juxtaposition of FIG. 6 and FIG. 7 makes clear that the number of data points calculated by processing system 115 attendant to performing the method of FIG. 2 is significantly lower than the number of data points in the complete STFT image, as nonessential lines of the STFT image are skipped as a result of Steps S215 and S220, and other lines of the STFT image are only calculated in a limited frequency range as a result of frequency-bounding the lines calculated in Steps S235 and S250.

Some embodiments of the present invention disclose devices in which the wheeze peak criteria comprise minimum peak frequency, minimum peak height and minimum peak width of the start line of the STFT image.

Some embodiments of the present invention disclose devices in which conformance of a calculated line of the STFT image to the wheeze peak criteria is identified upon detecting that frequency, height and width of a highest amplitude peak in the calculated line exceed a predetermined frequency, height and width threshold, respectively.

Some embodiments of the present invention disclose devices in which nonconformance of a calculated line of the STFT image with the wheeze peak criteria is identified upon detecting that one or more of frequency, height or width of a highest amplitude peak in the calculated line is below a predetermined frequency, height or width threshold, respectively.

Some embodiments of the present invention disclose devices in which the wheeze duration criteria comprise a minimum wheeze duration.

Some embodiments of the present invention disclose devices in which conformance of the duration to the wheeze duration criteria is determined based at least in part on a comparison of the total count with a predetermined wheeze duration threshold.

Some embodiments of the present invention disclose devices in which each consecutive pair of the noncontiguous lines is separated by a predetermined number of lines of the STFT image determined in accordance with a minimum wheeze duration.

Some embodiments of the present invention disclose devices in which the processing system limits calculation of the contiguous lines preceding the start line and the contiguous lines following the start line to a region of each contiguous line that is within a predetermined range of a frequency of a highest amplitude peak of the start line.

Some embodiments of the present invention disclose methods, which comprise, upon determining that the duration conforms to the wheeze duration criteria, the step of calculating by the processing system a wheeze rate.

Some embodiments of the present invention disclose methods, which comprise, upon determining that the duration does not conform to the wheeze duration criteria, the steps of skipping by the processing system a predetermined number of lines of the STFT image determined in accordance with a minimum wheeze duration and re-performing the first calculating step.

Some embodiments of the present invention disclose an ambulatory health monitoring device in which the wheeze peak criteria comprise minimum peak frequency, minimum peak height and minimum peak width.

Some embodiments of the present invention disclose an ambulatory health monitoring device in which conformance of a calculated line of the STFT image to the wheeze peak criteria is identified upon detecting that frequency, height and width of a highest amplitude peak in the calculated line exceed predetermined frequency, height and width thresholds, respectively.

Some embodiments of the present invention discloses an ambulatory health monitoring device in which nonconformance of a calculated line of the STFT image with the wheeze peak criteria is identified upon detecting that one or more of frequency, height or width of a highest amplitude peak in the calculated line is below a predetermined frequency, height or width threshold, respectively.

Some embodiments of the present invention discloses an ambulatory health monitoring device in which the wheeze duration criteria comprise a minimum wheeze duration.

Some embodiments of the present invention discloses an ambulatory health monitoring device in which conformance of the duration to the wheeze duration criteria is determined based at least in part on a comparison of the total count with a predetermined wheeze duration threshold.

Some embodiments of the present invention discloses an ambulatory health monitoring device in which each consecutive pair of the noncontiguous lines is separated by a predetermined number of lines of the STFT image determined in accordance with a minimum wheeze duration.

Some embodiments of the present invention discloses an ambulatory health monitoring device in which the processing system limits calculation of the contiguous lines preceding the start line and the contiguous lines following the start line to a region of each contiguous line that is within a predetermined range of a frequency of a highest amplitude peak of the start line.

Some embodiments of the present invention disclose methods in which the lines are selected and the wheeze is detected by the processing system based at least in part on one or more wheeze duration criteria.

Some embodiments of the present invention disclose methods in which the wheeze peak criteria comprise minimum peak frequency, minimum peak height and minimum peak width.

Some embodiments of the present invention disclose methods in which conformance of a calculated line of the STFT image to the wheeze peak criteria is identified upon detecting that frequency, height and width of a highest amplitude peak in the calculated line exceed predetermined frequency, height and width thresholds, respectively.

Some embodiments of the present invention disclose methods in which nonconformance of a calculated line of the STFT image with the wheeze peak criteria is identified upon detecting that one or more of frequency, height or width of a highest amplitude peak in the calculated line is below a predetermined frequency, height or width threshold, respectively.

Some embodiments of the present invention disclose methods in which the wheeze duration criteria comprise a minimum wheeze duration.

Some embodiments of the present invention disclose methods in which conformance to the wheeze duration criteria is determined based at least in part on a comparison of the total count with a predetermined wheeze duration threshold.

Some embodiments of the present invention disclose methods in which each consecutive pair of the noncontiguous lines is separated by a predetermined number of lines of the STFT image determined in accordance with a minimum wheeze duration.

Some embodiments of the present invention disclose methods in which the second calculating step comprises limiting by the processing system calculation of the contiguous lines preceding the start line and the contiguous lines following the start line to a region of each contiguous line that is within a predetermined range of a frequency of a highest amplitude peak of the start line.

It will be appreciated by those of ordinary skill in the art that the invention can be embodied in other specific forms without departing from the spirit or essential character hereof. The present description is therefore considered in all respects to be illustrative and not restrictive. The scope of the invention is indicated by the appended claims, and all changes that come with in the meaning and range of equivalents thereof are intended to be embraced therein.

CLAIMS

1. An ambulatory health monitoring device, comprising:

a respiratory data capture system;

a respiratory data acquisition system;

a respiratory data processing system; and

a respiratory data output interface,

wherein the respiratory data processing system further comprises:

a receiving section for receiving a respiratory signal from the capture system via the acquisition system,

a noncontiguous line calculating section for calculating noncontiguous lines of a short-time Fourier transform (STFT) image of the respiratory signal until a start line of the STFT image conforming to one or more wheeze peak criteria is identified,

a contiguous line calculating section for calculating, once a start line conforming to the wheeze peak criteria is identified, contiguous lines of the STFT image preceding the start line and contiguous lines of the STFT image following the start line until both a preceding line and a following line not conforming to the wheeze peak criteria are identified,

a determining section for determining, once both a preceding line and a following line not conforming to the wheeze peak criteria are identified, using a total count of calculated lines of the STFT image conforming to the wheeze peak criteria whether a duration of a peak conforms to one or more wheeze duration criteria,

a wheeze rate calculating section for calculating, upon determining that the duration conforms to the wheeze duration criteria, a wheeze rate and

a transmitting section for transmitting information indicative of the wheeze rate to the output interface.

2. The device of claim 1, wherein the wheeze peak criteria comprises a minimum peak frequency, minimum peak height and minimum peak width of the start line of the STFT image.

3. The device of claim 1, wherein conformance of a calculated line of the STFT image to the wheeze peak criteria is identified upon detecting that frequency, height and width of a highest amplitude peak in the calculated line exceed a predetermined frequency, height and width threshold, respectively.

4. The device of claim 1, wherein nonconformance of a calculated line of the STFT image with the wheeze peak criteria is identified upon detecting that one or more of frequency, height or width of a highest amplitude peak in the

calculated line is below a predetermined frequency, height or width threshold, respectively.

5. The device of claim 1, wherein the wheeze duration criteria comprise a minimum wheeze duration.

6. The device of claim 1, wherein conformance of the duration to the wheeze duration criteria is determined based at least in part on a comparison of the total count with a predetermined wheeze duration threshold.

7. The device of claim 1, wherein each consecutive pair of the noncontiguous lines is separated by a predetermined number of lines of the STFT image determined in accordance with a minimum wheeze duration.

8. The device of claim 1, wherein the processing system limits calculation of the contiguous lines preceding the start line and the contiguous lines following the start line to a region of each contiguous line that is within a predetermined range of a frequency of a highest amplitude peak of the start line.

9. The device of claim 1, wherein the respiratory data acquisition system is communicatively coupled with the

respiratory data capture system, the respiratory data processing system is communicatively coupled with the respiratory data acquisition system, and the respiratory data output interface is communicatively coupled with the processing system.

10. A lightweight wheeze detection method, comprising the steps of:

receiving a respiratory signal;

calculating noncontiguous lines of a short-time Fourier transform (STFT) image of the respiratory signal until a start line of the STFT image conforming to one or more wheeze peak criteria is identified;

calculating, once a start line conforming to the wheeze peak criteria is identified, contiguous lines of the STFT image preceding the start line and contiguous lines of the STFT image following the start line until both a preceding line and a following line not conforming to the wheeze peak criteria are identified; and,

determining, once both a preceding line and a following line not conforming to the wheeze peak criteria are identified, using a total count of calculated lines of the STFT image conforming to the wheeze peak criteria whether a duration of a peak conforms to one or more wheeze duration criteria.

11. The method of claim 10, further comprising, upon determining that the duration conforms to the wheeze duration criteria, the step of calculating by the processing system a wheeze rate.

12. The method of claim 10, further comprising, upon determining that the duration does not conform to the wheeze duration criteria, performing the steps of:

skipping a predetermined number of lines of the STFT image determined in accordance with a minimum wheeze duration; and

re-performing the first calculating step.

13. A lightweight wheeze detection method, comprising the steps of:

receiving a respiratory signal;

calculating a partial short-time Fourier transform (STFT) image of the respiratory signal comprising selected data points of selected lines of a complete STFT image of the respiratory signal, wherein the lines and the data points are selected based at least in part on one or more wheeze peak criteria; and

detecting a wheeze in the partial STFT image based at least in part on the wheeze peak criteria.

14. The method of claim 13, wherein the lines are selected and the wheeze is detected by the processing system based at least in part on one or more wheeze duration criteria.

FIG. 1

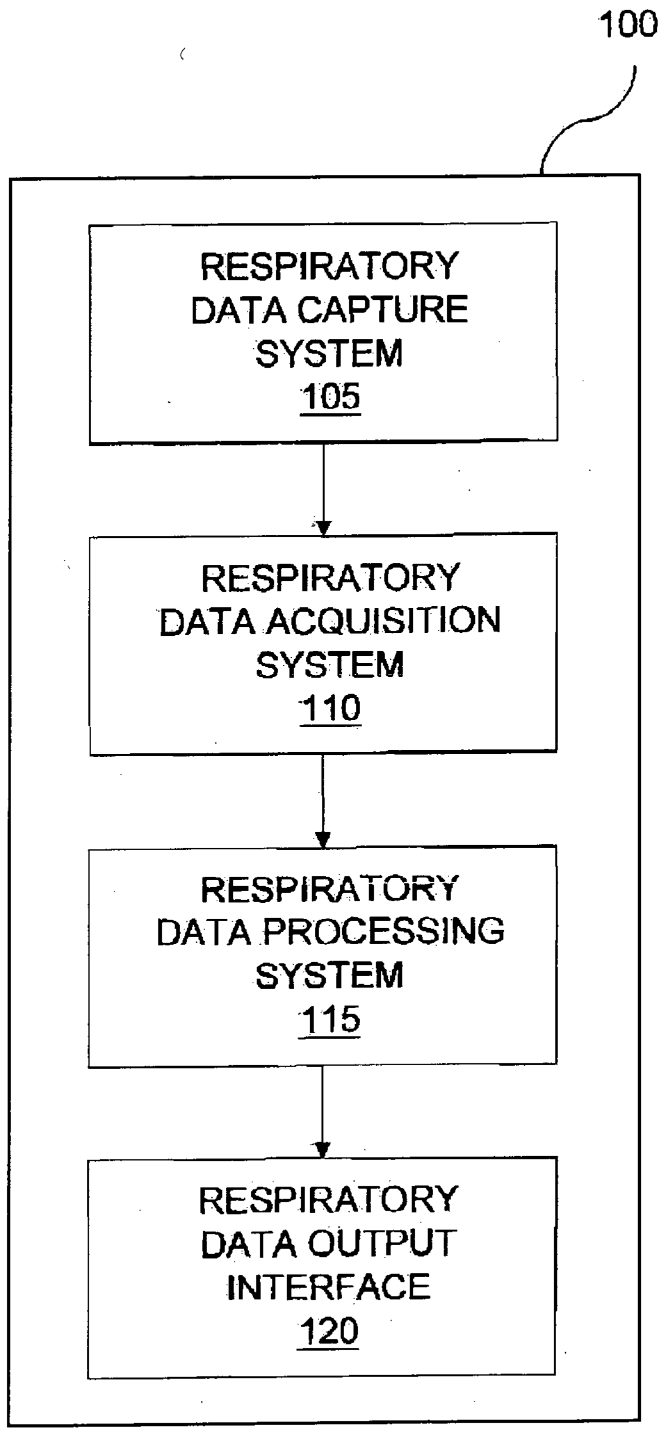
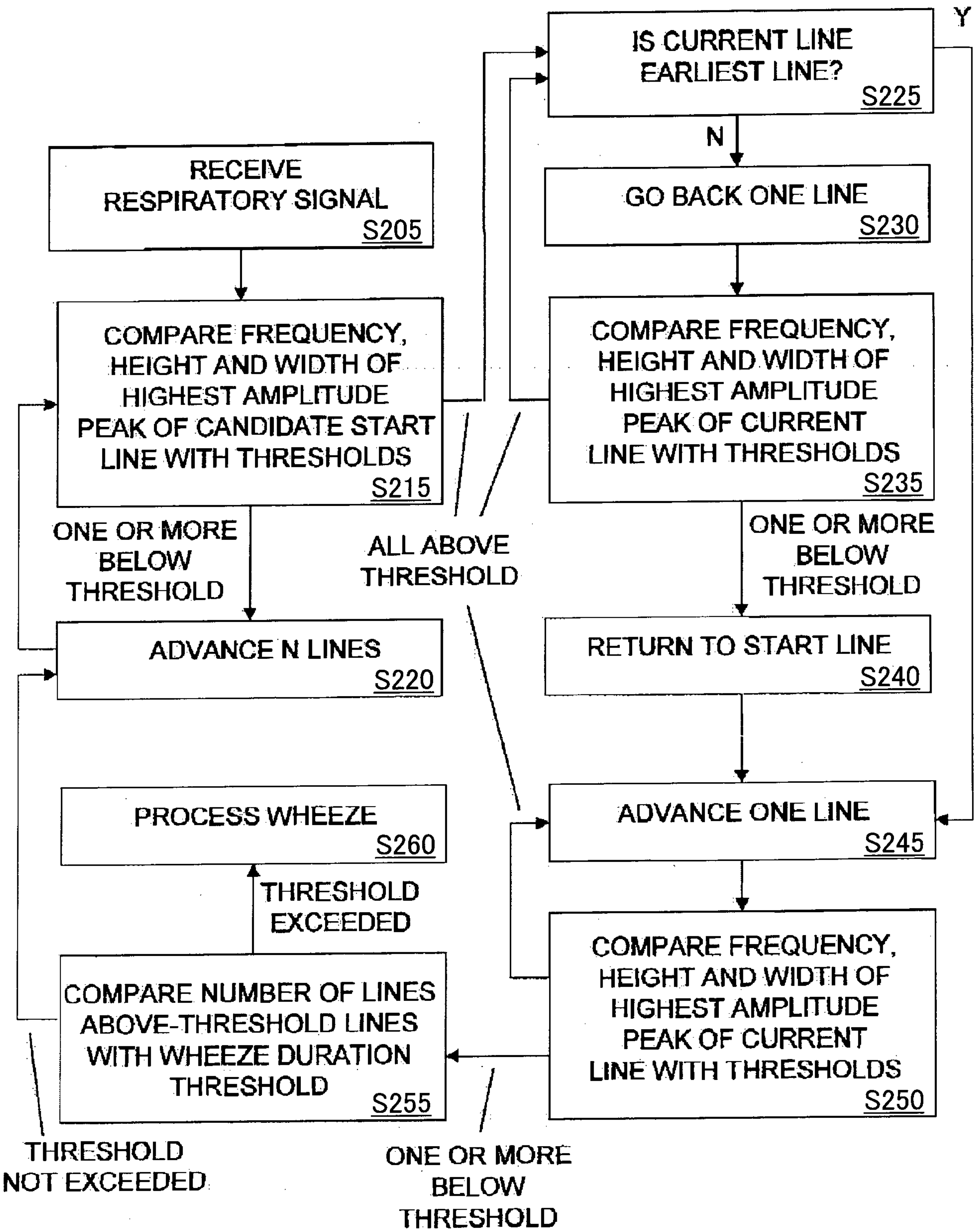
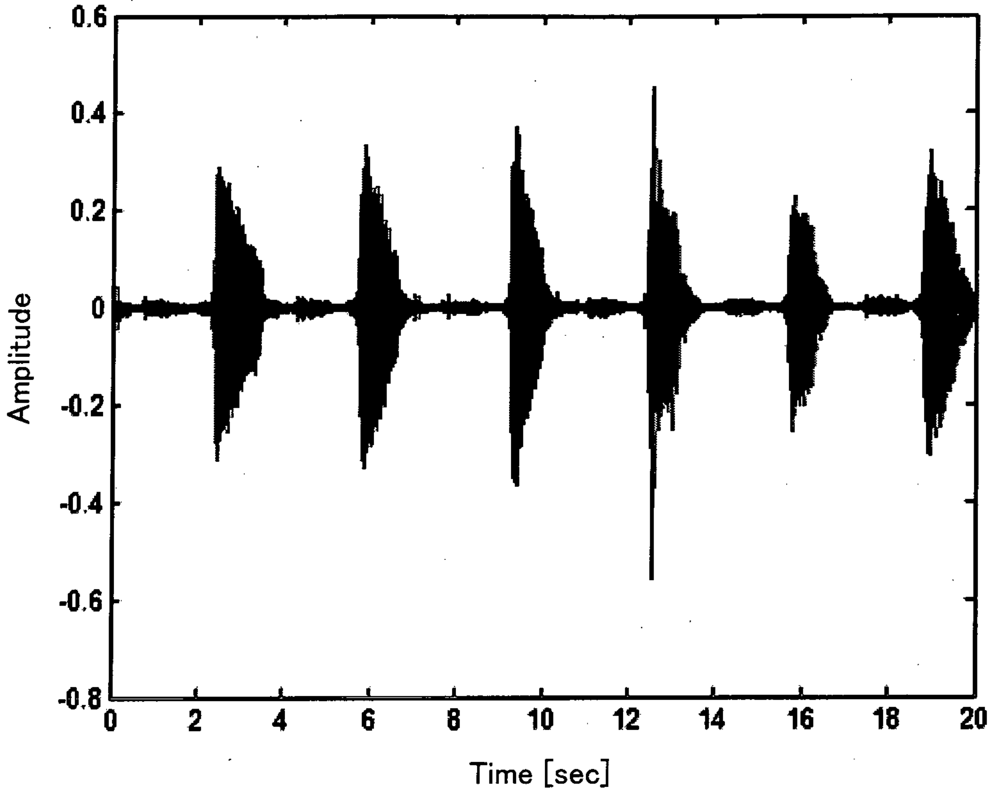

100
RESPIRATORY DATA CAPTURE SYSTEM 105
RESPIRATORY DATA ACQUISITION SYSTEM 110
RESPIRATORY DATA PROCESSING SYSTEM 115
RESPIRATORY DATA OUTPUT INTERFACE 120

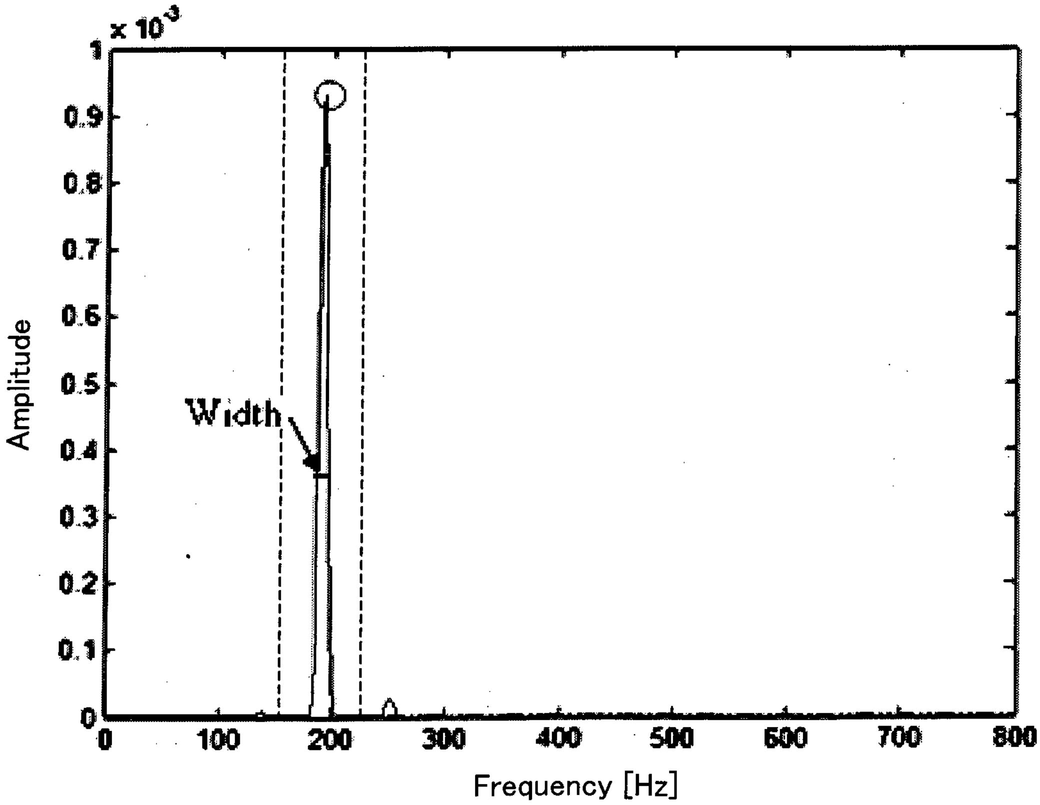
FIG. 2


RECEIVE RESPIRATORY SIGNAL
S205
COMPARE FREQUENCY, HEIGHT AND WIDTH OF HIGHEST AMPLITUDE PEAK OF CANDIDATE START LINE WITH THRESHOLDS
S215
ONE OR MORE BELOW THRESHOLD
ADVANCE N LINES
S220
ALL ABOVE THRESHOLD
IS CURRENT LINE EARLIEST LINE?
S225
Y
N
GO BACK ONE LINE
S230
COMPARE FREQUENCY, HEIGHT AND WIDTH OF HIGHEST AMPLITUDE PEAK OF CURRENT LINE WITH THRESHOLDS
S235
ONE OR MORE BELOW THRESHOLD
RETURN TO START LINE
S240
ADVANCE ONE LINE
S245
COMPARE FREQUENCY, HEIGHT AND WIDTH OF HIGHEST AMPLITUDE PEAK OF CURRENT LINE WITH THRESHOLDS
S250
ONE OR MORE BELOW THRESHOLD
COMPARE NUMBER OF LINES ABOVE-THRESHOLD LINES WITH WHEEZE DURATION THRESHOLD
S255
THRESHOLD EXCEEDED
PROCESS WHEEZE
S260
THRESHOLD NOT EXCEEDED

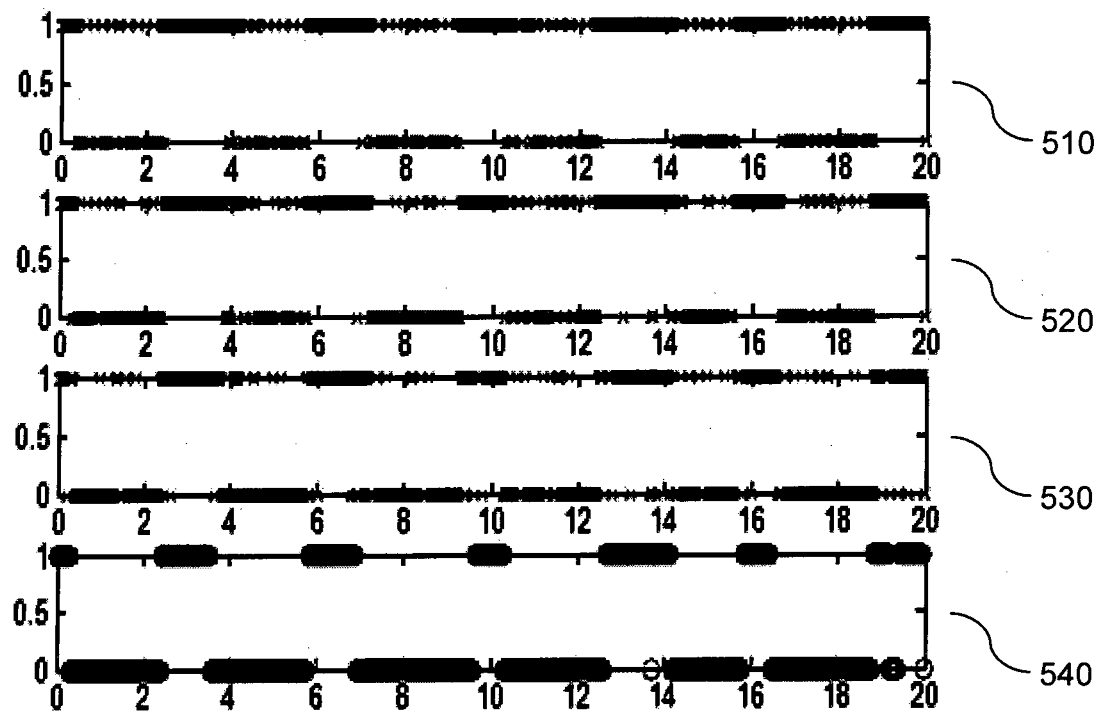
F I G. 3


0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Amplitude
0
2
4
6
8
10
12
14
16
18
20
Time [sec]

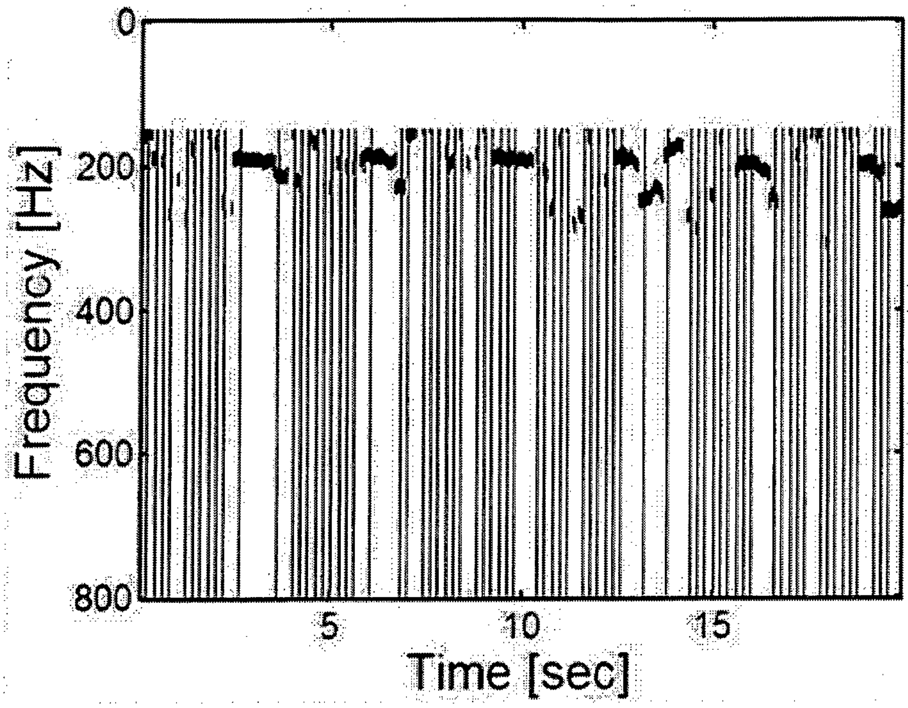
F I G. 4


x 10^-3
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Amplitude
Width
0
100
200
300
400
500
600
700
800
Frequency [Hz]

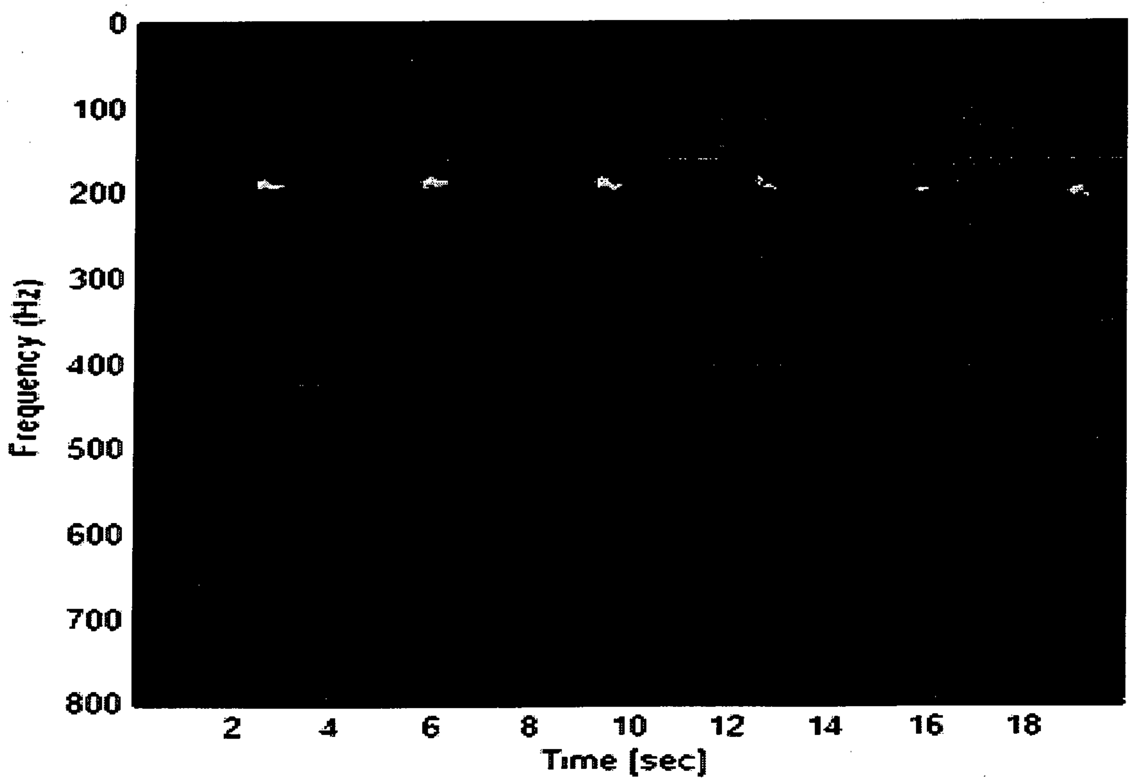
F I G. 5



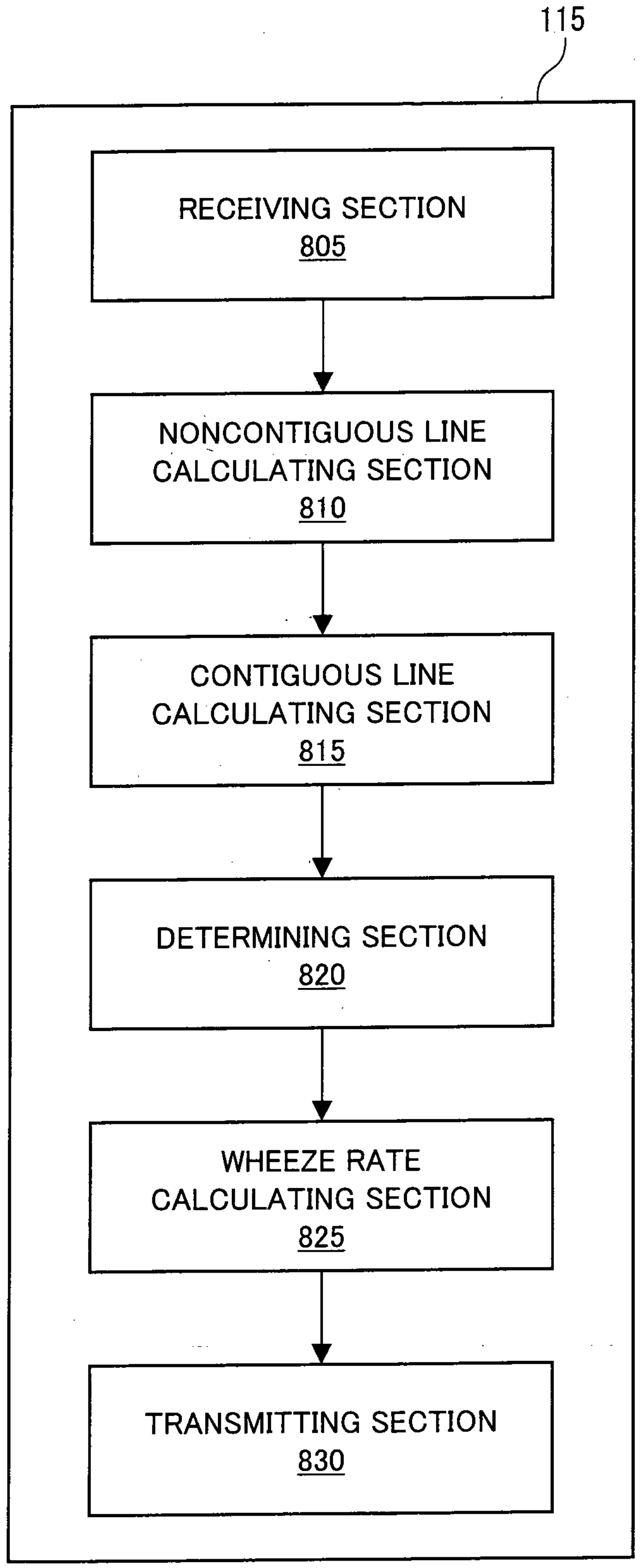
F I G. 6


0
200
400
600
800
Frequency [Hz]
5
10
15
Time [sec]

F I G. 7


0
100
200
300
400
500
600
700
800
Frequency (Hz)
2
4
6
8
10
12
14
16
18
Time [sec]

F I G. 8


115
RECEIVING SECTION
805
NONCONTIGUOUS LINE
CALCULATING SECTION
810
CONTIGUOUS LINE
CALCULATING SECTION
815
DETERMINING SECTION
820
WHEEZE RATE
CALCULATING SECTION
825
TRANSMITTING SECTION
830

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2011/056515

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. A61B5/08(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. A61B5/08

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2011
Registered utility model specifications of Japan 1996-2011
Published registered utility model applications of Japan 1994-2011

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2007/146687 A2 (VIVOMETRICS, INC.) 2007.12.21, & JP 2009-539499 A & US 2007/0287896 A1 & EP 2023804 A & CA 2655303 A	1-14
A	US 2007/0010722 A1 (KABUSHIKI KAISHA TOSHIBA) 2007.01.11, & JP 2007-14501 A	1-14
A	JP 2006-167427 A (AISIN SEIKI CO., LTD.) 2006.06.29, (No Family)	1-14

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22.04.2011	10.05.2011

Name and mailing address of the ISA/JP
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patsnap

专利名称(译)	轻量级喘息检测方法和系统		
公开(公告)号	[EP2547256A4](EP2547256A4)	公开(公告)日	2015-09-02
申请号	EP2011756422	申请日	2011-03-14
[标]申请(专利权)人(译)	夏普株式会社		
申请(专利权)人(译)	夏普株式会社		
当前申请(专利权)人(译)	夏普株式会社		
[标]发明人	FU YONGJI		
发明人	FU, YONGJI		
IPC分类号	A61B5/08 A61B5/00		
CPC分类号	A61B7/003		
优先权	12/661477 2010-03-18 US		
其他公开文献	EP2547256A1		
外部链接	Espacenet		

摘要(译)

用于便携式呼吸健康监测装置的轻量级喘息检测方法和系统通过采用轻量级算法来节省便携式呼吸健康监测装置中的计算资源，该算法计算呼吸信号的部分STFT图像，其包括喘息检测所需的所有数据点但排除许多数据点。对于喘息检测是不必要的。该方法和系统大大节省了计算资源，同时仍然确保检测到呼吸信号中的每个喘息。