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(71) Applicant *(for all designated States except US)*: **SHARP KABUSHIKI KAISHA** [JP/JP]; 22-22, Nagaike-cho, Abeno-ku, Osaka-shi, Osaka, 5458522 (JP).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **LAI, Yungkai Kyle**. **FU, Yongji**.

(74) Agent: **HARAKENZO WORLD PATENT & TRADEMARK**; Daiwa Minamimorimachi Building, 2-6, Tenjinbashi 2-chome Kita, Kita-ku, Osaka-shi, Osaka, 5300041 (JP).

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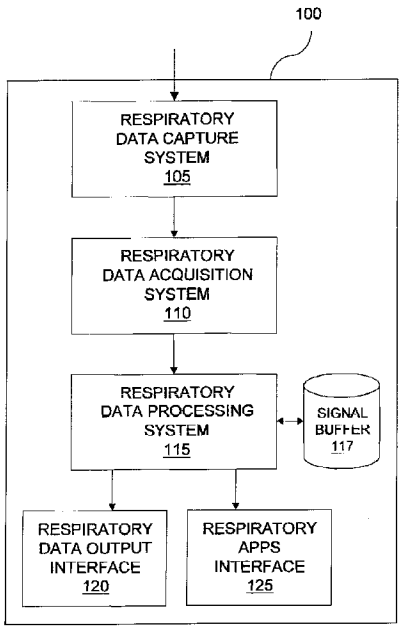
(54) **Title**: METHODS AND DEVICES FOR CONTINUAL RESPIRATORY MONITORING USING ADAPTIVE WINDOWING

FIG. 1



(57) **Abstract**: Methods and devices for continual respiratory monitoring of a human subject using adaptive windowing provide continual estimates of the respiration period of the subject by continually buffering and evaluating samples of a respiratory signal in which the subject's breath sounds are embodied, and dynamically adjust the sampling window length based at least in part on the respiration period. Through this adaptive windowing technique, a sampling window length is maintained that is tailored to the subject's breathing habits, does not unduly inhibit real-time respiratory monitoring, and does not place unnecessary burdens on memory and processing resources of the respiratory monitoring device.

WO 2011/115240 A1

DESCRIPTION

TITLE OF INVENTION: METHODS AND DEVICES FOR CONTINUAL RESPIRATORY MONITORING USING ADAPTIVE WINDOWING

TECHNICAL FIELD

The present invention relates to continual physiological state monitoring and, more particularly, to continual respiratory monitoring of a human subject.

BACKGROUND ART

Continual monitoring of the physiological state of people who suffer from chronic diseases is an important aspect of chronic disease management. By way of example, continual respiratory monitoring is in widespread use managing respiratory diseases such as asthma and sleep apnea.

One variable commonly monitored in respiratory monitoring applications is respiration period, which is a measured time of a breathing cycle from the start of inspiration to the end of expiration. In these applications, the respiration period may itself be an output, or may be an input used in determining other outputs, such as whether apnea is occurring. To estimate a respiration period, a respiratory monitoring device often buffers and evaluates

samples of a respiratory signal in which lung sounds of a person being monitored are embodied, wherein all samples are of a predetermined length, i.e. fixed sampling window length.

Selecting a fixed sampling window length for estimating a respiration period presents challenges. The window must be long enough to cover at least one full breathing cycle of the person being monitored. Moreover, it may be beneficial for the window to cover multiple breathing cycles to enable the estimate to overcome short-term signal anomalies, such as high noise and irregular breathing patterns. On the other hand, the longer the window is, the less frequently estimates can be made, which inhibits real-time monitoring. Moreover, the window length must comport with memory and processing constraints of the respiratory monitoring device, which can be severe, especially in ambulatory monitoring devices.

Further complicating the selection of a fixed sampling window length is the high degree of variability in human respiration periods. There is no "typical" human respiration period. For some people, an average respiration period may be as short as two seconds, whereas for others an average respiration period may be as long as 15 seconds. In conventional respiratory monitoring devices, this has routinely led to selection of a long window that can accommodate even the longest respiration period. Unfortunately, selecting the window length to accommodate

the abnormal case of the extreme "long breather" can unduly inhibit real-time monitoring and impose unnecessary burdens on memory and processing resources of the respiratory monitoring device.

SUMMARY OF INVENTION

In one aspect of the invention, a respiratory monitoring device comprises a receiving section for receiving a respiratory signal, an extracting section for extracting a sample of the respiratory signal having a length equal to a sampling window length from the respiratory signal received by the receiving section, an estimating section for estimating a respiration period based at least in part on the sample, an adjusting section for adjusting the sampling window length based at least in part on the respiration period.

In another aspect of the invention, a method for respiratory monitoring of a human subject using adaptive windowing comprises receiving a respiratory signal; storing in a signal buffer a sample of the respiratory signal, wherein the sample has a length equal to a sampling window length; estimating a respiration period based at least in part on the sample; and adjusting the sampling window length based at least in part on the respiration period.

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 a respiratory monitoring device in some embodiments of the invention.

FIG. 2 shows a method for respiratory monitoring of a human subject using adaptive windowing by the respiratory monitoring device of FIG. 1 in some embodiments of the invention.

FIG. 3 shows the sections of the respiratory data processing system in some embodiments of the invention.

DESCRIPTION OF EMBODIMENTS

The present invention provides methods and devices for continual respiratory monitoring of a human subject using adaptive windowing. The present methods and devices provide continual estimates of the respiration period of the subject by continually buffering and evaluating samples of a respiratory signal in which the subject's breath sounds are embodied, and dynamically adjust the sampling window length based at least in part on the respiration period. Through this adaptive windowing technique, a sampling window length is maintained that is tailored to the subject's

breathing habits, does not unduly inhibit real-time respiratory monitoring, and does not place unnecessary burdens on memory and processing resources of the respiratory monitoring device.

FIG. 1 shows a respiratory 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. Processing system 115 is also communicatively coupled with a signal buffer 117, and may be communicatively coupled to a respiratory applications interface 125.

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, processes the respiratory signal to continually estimate the respiration period of the subject being monitored. To continually estimate the respiration period, processing system 115 continually buffers in signal buffer 117 and evaluates samples of the respiratory signal, wherein the length of each sample is equal to a sampling window length. Processing system 115 under control of the processor transmits information generated based at least in part on the respiratory period to output interface 120. This information may include the respiration period or a respiration rate generated from the respiration period, for example. In addition, processing system 115 may transmit the sampling window length to applications interface 125 for use in other respiratory monitoring applications, such as an apnea monitoring or an airway patency monitoring application.

FIG. 3 shows the sections that are contained in the respiratory data processing system 115. The processing system 115 includes a receiving section 305 for receiving a respiratory signal from the capture system via the acquisition system. The processing system 115 further includes an

extracting section 306 for extracting a sample of the respiratory signal having a length equal to a sampling window length from the respiratory signal received by the receiving section. The extracting section 306 then send the extracted sample of the respiratory signal to the signal buffer 117.The processing system 115 further includes an estimating section 310 for estimating a respiration period based at least in part on the sample that is stored in the signal buffer 117. The processing system 115 further includes an adjusting section 315 for adjusting the sampling window based at least in part on the respiration period. The processing system 115 further includes a transmitting section 320 for transmitting information generated based at least in part on the respiration period to the output interface whereon the information is displayed.

In some embodiments, the sampling window is a rectangular window. In these embodiments, data within the window are given equal weight, whereas data outside the window are given no weight, although outside data may be given weight as part of a different sample. Moreover, in some embodiments, the sampling window is non-overlapping, whereas in other embodiments the sampling window is an overlapping, rolling window. Regardless, processing system 115 dynamically adjusts the length of the sampling window based on the respiration period, as will be explained

hereinafter in greater detail.

Output interface 120 includes a user interface for displaying information received from processing system 115 generated based at least in part on the respiration period, such as respiration period or respiration rate information. Output interface 120 may also have a data management interface to an internal or external data management system that stores the information and/or a network interface that transmits the information to a remote monitoring device, such as a monitoring device at a clinician facility.

Applications interface 125 is an optional interface that interfaces with one or more respiratory monitoring applications, such as an apnea or airway patency monitoring application, that use sampling window length information received from processing system 115 to facilitate respiratory monitoring.

In some embodiments, capture system 105, acquisition system 110, processing system 115, output interface 120 and applications interface 125 (where present) are part of a portable 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, output interface 120 and/or applications interface 125 may be part of separate devices that are remotely coupled via

wired or wireless links.

FIG. 2 shows a method for respiratory monitoring of a human subject using adaptive windowing in some embodiments of the invention. In these embodiments, the method is performed by processing system 115 under control of a processor that executes software instructions.

At Step 205, processing system 115 sets the sampling window length to an initial length. In some embodiments, the initial length is selected to ensure that at least one complete respiration period will be captured for a long breather.

At Step 210, processing system 115 stores in signal buffer 117 a sample of the respiratory signal received from capture system 105 via acquisition system 120. The length of the sample is equal to the sampling window length, which at first is the initial length.

At Step 215, processing system 115 estimates the respiration period by evaluating the sample of the respiratory signal stored in signal buffer 117. The respiration period is a measured time of a breathing cycle from the start of inspiration to the end of expiration. In some embodiments, if the sample includes multiple breathing cycles, an average respiration period taken across all cycles is adopted as the estimate. In other embodiments, if the sample includes multiple breathing cycles, the respiration period of the most recent cycle is adopted as the estimate. Moreover, breathing

cycles that exhibit poor signal quality or large variance from the norm may be excluded from the estimate.

At Step 220, processing system 115 transmits information generated based on the respiration period estimate to output interface 120, which displays the information on a user screen. By way of example, the transmitted and displayed information may be the respiration period itself, a respiration rate calculated from the respiration period, or a moving average of the respiration period or of the respiration rate calculated from the current respiration period and earlier respiration periods.

At Step 225, processing system 115 compares the current respiration period estimate with the immediately preceding respiration period estimate, if any exists. If there is an immediately preceding estimate (i.e. if the current estimate is not the initial estimate) and the difference between the current and immediately preceding estimates is below a predetermined threshold, the respiratory period is considered stable enough to bypass dynamic adjustment of the sampling window length and the flow returns immediately to Step 210, whereupon a new sample is buffered at the current window length. On the other hand, if the current estimate is the initial estimate, or if the difference between the current and the immediately preceding estimates is above the threshold, the respiratory period is not considered stable

enough to bypass dynamic adjustment of the sampling window length and the flow instead advances to Step 230, before returning to Step 210.

At Step 230, processing system 115 adjusts the sampling window length using the current respiration period estimate and a multiplier. By way of example, the multiplier may be statically or dynamically determined based on a physical condition of the person being monitored (e.g. whether the person is a known asthmatic), the quality of the respiratory signal (signal quality), the length of the current respiration period, and/or the stability of the respiration period. For example, if current signal quality is poor or the respiration period is unstable, the multiplier may be set to a large number such that the sampling window will capture a large number of complete breathing cycles, which can help improve the reliability of the respiration period estimate by taking an average over several cycles. On the other hand, if current signal quality is good and the respiration period is stable, the multiplier may be set to a low number such that sampling window captures a small number of complete breathing cycles, which increases the frequency of respiratory period estimation and reduces burdens on the memory and processing resources of the respiratory monitoring device. Accordingly, the current respiration period estimate and a judiciously selected multiplier result in dynamic tuning of the sampling window to

a length that strikes a desired balance between the competing goals of reliable respiration period estimation, on the one hand, and real-time monitoring and memory/processing resource conservation, on the other.

At Step 235, processing system 115 optionally exports the adjusted sampling window length information to applications interface 125, which may use the information in one or more respiratory monitoring applications, such as an apnea or airway patency monitoring application.

Some embodiments of the present invention disclose devices which comprise repeating the storing and estimating steps at the adjusted sampling window length.

Some embodiments of the present invention disclose devices in which the adjusting step is conditioned on an outcome of a comparison of the respiration period with a preceding respiration period estimate.

Some embodiments of the present invention disclose devices in which the adjusting step comprises multiplying the respiration period by a multiplier.

Some embodiments of the present invention disclose devices in which the multiplier is determined based at least in part on a physical condition of a human subject being monitored.

Some embodiments of the present invention disclose devices in which the multiplier is determined based at least in

part on signal quality.

Some embodiments of the present invention disclose devices in which the multiplier is determined based at least in part on the respiration period.

Some embodiments of the present invention disclose devices that comprise transmitting by the processing system to an applications interface the sampling window length.

Some embodiments of the present invention disclose devices in which the respiratory monitoring application comprises one of an apnea monitoring or airway patency monitoring application.

Some embodiments of the present invention disclose methods in which the comprise transmitting by the processing system to a respiratory data output interface information generated based at least in part on the respiration period, and displaying on the output interface the information.

Some embodiments of the present invention disclose methods that comprise repeating the storing and estimating steps at the adjusted sampling window length.

Some embodiments of the present invention disclose methods in which the adjusting step is conditioned on an outcome of a comparison of the respiration period with a preceding respiration period estimate.

Some embodiments of the present invention disclose methods in which the adjusting step comprises multiplying

the respiration period by a multiplier.

Some embodiments of the present invention disclose methods in which the multiplier is determined based at least in part on a physical condition of a human subject being monitored.

Some embodiments of the present invention disclose methods in which the multiplier is determined based at least in part on signal quality.

Some embodiments of the present invention disclose methods in which the multiplier is determined based at least in part on the respiration period.

Some embodiments of the present invention disclose methods that comprise transmitting to an applications interface the sampling window length, whereupon the sampling window length is used in a respiratory monitoring application.

Some embodiments of the present invention disclose methods in which the respiratory monitoring application comprises one of an apnea monitoring or airway patency monitoring application.

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. A respiratory monitoring device, comprising:

a receiving section for receiving a respiratory signal;

an extracting section for extracting a sample of the respiratory signal having a length equal to a sampling window length from the respiratory signal received by the receiving section;

an estimating section for estimating a respiration period based at least in part on the sample;

an adjusting section for adjusting the sampling window length based at least in part on the respiration period.

2. The device of claim 1, wherein the adjusting section repeats at the adjusted sampling window length.

3. The device of claim 1, wherein the adjusting section conditions the adjustment of the sampling window length on an outcome of a comparison of the respiration period with a preceding respiration period estimate.

4. The device of claim 1, wherein the adjusting section adjusts the sampling window length by multiplying the respiration period by a multiplier.

5. The device of claim 4, wherein the multiplier is determined based at least in part on a physical condition of a human subject being monitored.

6. The device of claim 4, wherein the multiplier is determined based at least in part on signal quality.

7. The device of claim 4, wherein the multiplier is determined based at least in part on the respiration period.

8. The device of claim 4, further comprising a transmitting section for transmitting to an applications interface the sampling window length, whereupon the sampling window length is used in a respiratory monitoring application.

9. The device of claim 8, wherein the respiratory monitoring application comprises one of an apnea monitoring or airway patency monitoring application.

10. A method for respiratory monitoring of a human subject using adaptive windowing, comprising:

receiving a respiratory signal;

storing in a signal buffer a sample of the respiratory signal, wherein the sample has a length equal to a sampling

window length;

estimating a respiration period based at least in part on the sample; and

adjusting the sampling window length based at least in part on the respiration period.

11. The method of claim 10, further comprising transmitting to a respiratory data output interface information generated based at least in part on the respiration period; and displaying on the output interface the information.

FIG. 1

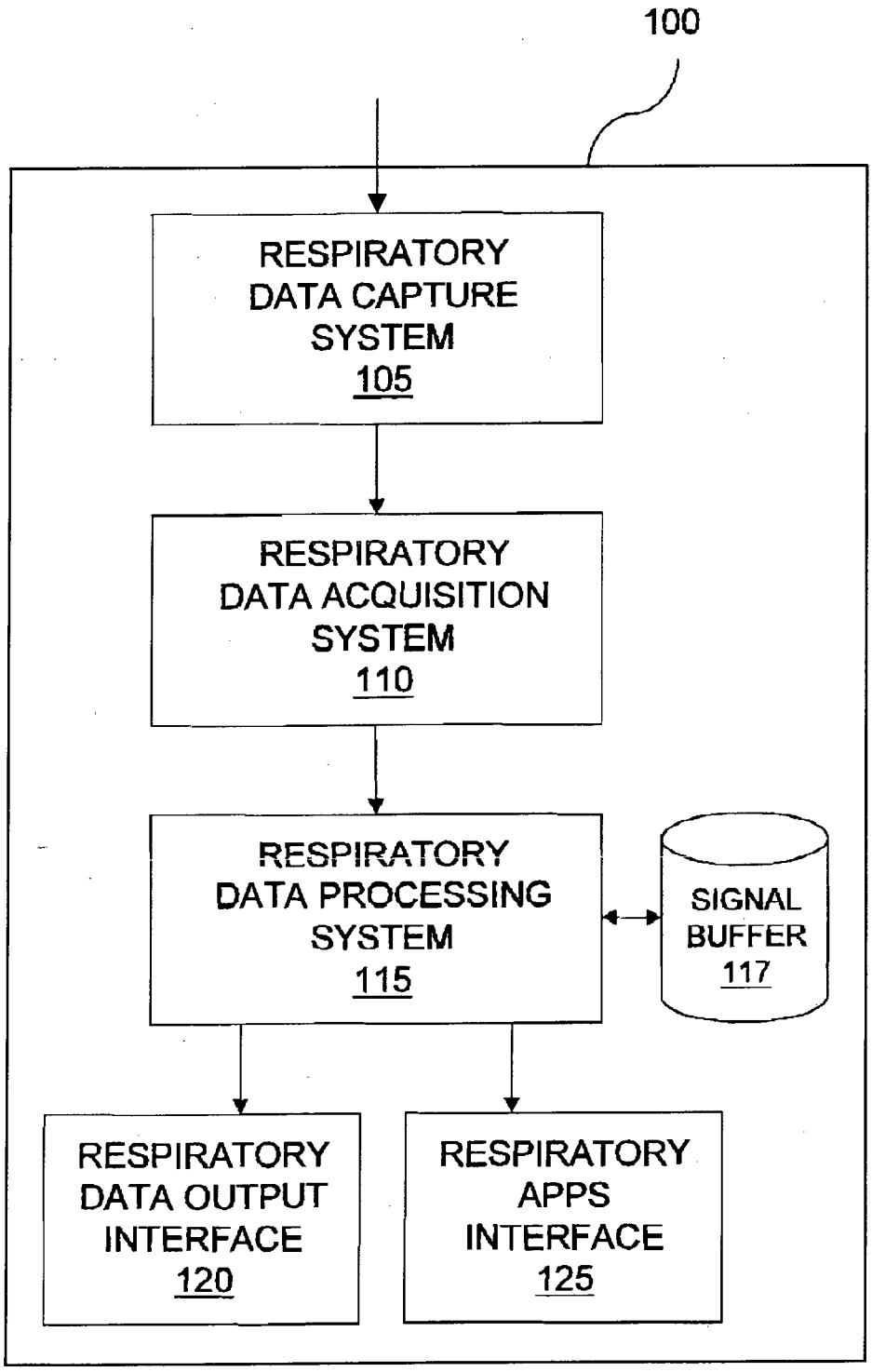

100
RESPIRATORY DATA CAPTURE SYSTEM 105
RESPIRATORY DATA ACQUISITION SYSTEM 110
RESPIRATORY DATA PROCESSING SYSTEM 115
SIGNAL BUFFER 117
RESPIRATORY DATA OUTPUT INTERFACE 120
RESPIRATORY APPS INTERFACE 125

FIG. 2

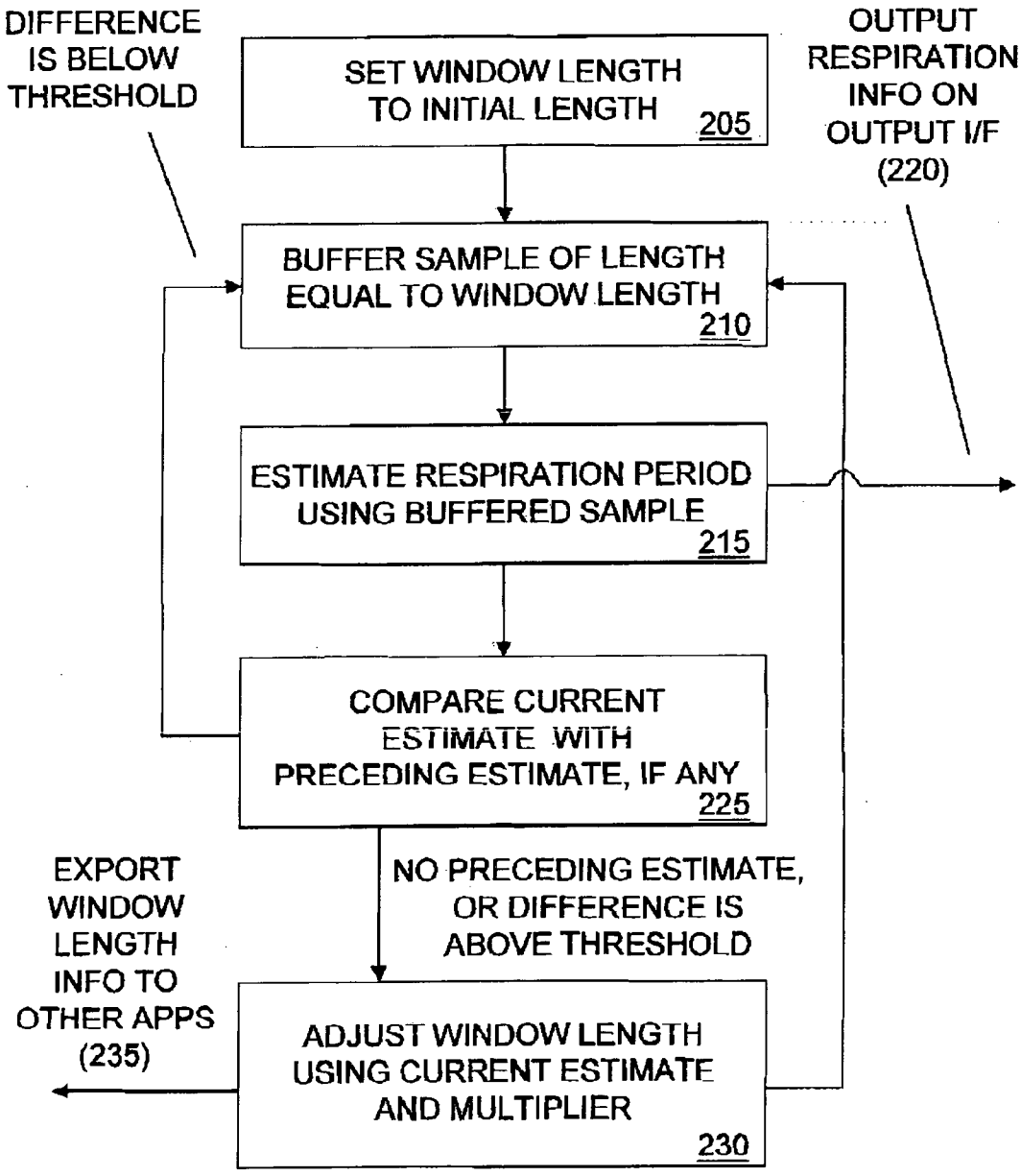
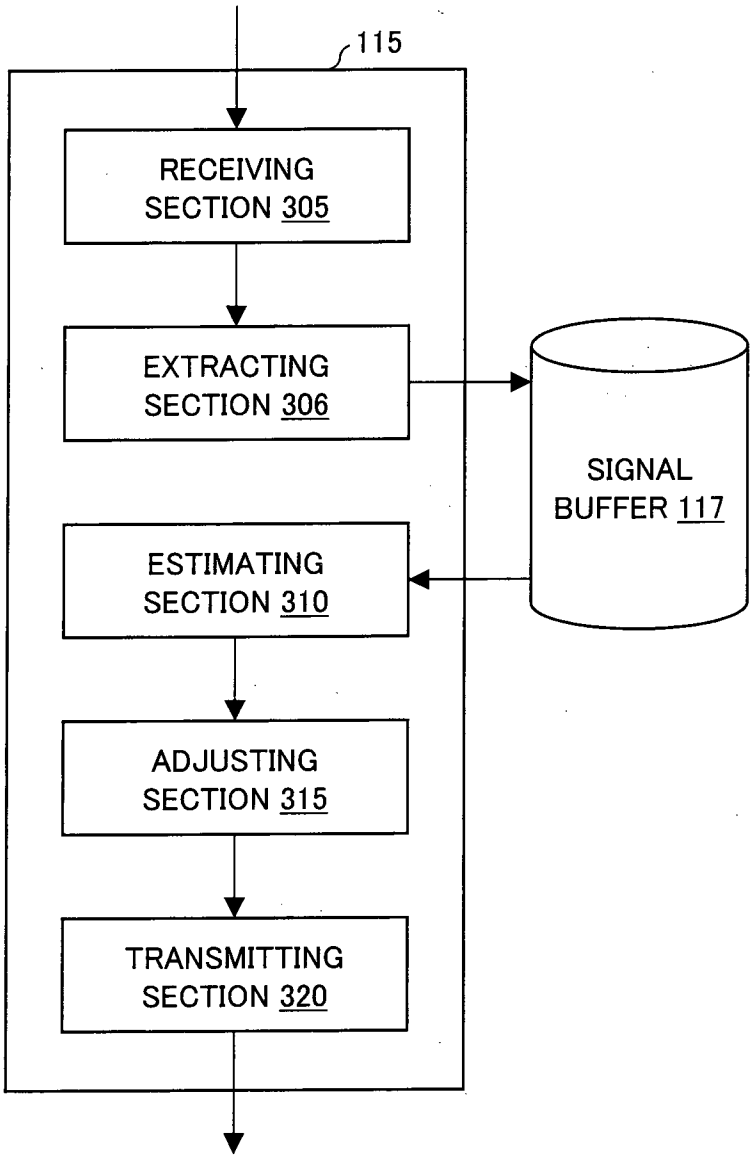

DIFFERENCE IS BELOW THRESHOLD
SET WINDOW LENGTH TO INITIAL LENGTH 205
OUTPUT RESPIRATION INFO ON OUTPUT I/F (220)
BUFFER SAMPLE OF LENGTH EQUAL TO WINDOW LENGTH 210
ESTIMATE RESPIRATION PERIOD USING BUFFERED SAMPLE 215
COMPARE CURRENT ESTIMATE WITH PRECEDING ESTIMATE, IF ANY 225
EXPORT WINDOW LENGTH INFO TO OTHER APPS (235)
NO PRECEDING ESTIMATE, OR DIFFERENCE IS ABOVE THRESHOLD
ADJUST WINDOW LENGTH USING CURRENT ESTIMATE AND MULTIPLIER 230

FIG. 3


115
RECEIVING SECTION 305
EXTRACTING SECTION 306
SIGNAL BUFFER 117
ESTIMATING SECTION 310
ADJUSTING SECTION 315
TRANSMITTING SECTION 320

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/056516

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.
X/Y	JP 2005-66045 A (Konica Minolta Medical & Graphic, Inc) 2005.03.17, (No Family)	1-7,10/8,9,11
Y	WO 2006/008745 A2 (INTERCURE LTD.) 2006.01.26, & JP 2008-507316 A & US 2008/0319333 A1 & US 2009/0118631 A1 & EP 1804649 A & CA 2574642 A & KR 10-2007-0048201 A & CN 101128150 A & IL 180866 D	8,9,11
Y	JP 8-131421 A (Matsushita Electric Industrial Co., Ltd.) 1996.05.28, (No Family)	8,9,11

☐ 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
20.04.2011	10.05.2011

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	MIYAZAWA Hiroshi 2Q 9407 Telephone No. +81-3-3581-1101 Ext. 3292

专利名称(译)	使用自适应窗口进行连续呼吸监测的方法和装置		
公开(公告)号	EP2547257A4	公开(公告)日	2014-12-03
申请号	EP2011756423	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	LAI YUNGKAI KYLE FU YONGJI		
发明人	LAI, YUNGKAI KYLE FU, YONGJI		
IPC分类号	A61B5/08 A61B5/00 A61B7/00		
CPC分类号	A61B5/0816 A61B5/4818 A61B7/003		
优先权	12/661521 2010-03-18 US		
其他公开文献	EP2547257A1		
外部链接	Espacenet		

摘要(译)

使用自适应窗口对人类受试者进行连续呼吸监测的方法和装置通过持续缓冲和评估其中体现受试者呼吸音的呼吸信号样本来提供对受试者呼吸周期的连续估计，并动态调整采样窗口长度至少部分地基于呼吸期。通过这种自适应加窗技术，保持采样窗口长度，该采样窗口长度适合于受试者的呼吸习惯，不会过度抑制实时呼吸监测，并且不会对呼吸监测设备的存储器和处理资源造成不必要的负担。