(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 December 2013 (05.12.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/179020 A1

(51) International Patent Classification:
A61B 5/00 (2006.01) *A61B 5/024* (2006.01)
A61B 5/02 (2006.01) *A61B 5/0452* (2006.01)

(21) International Application Number:
PCT/GB2013/051408

(22) International Filing Date:
28 May 2013 (28.05.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1209412.4 28 May 2012 (28.05.2012) GB

(71) Applicant: **OBS MEDICAL LIMITED** [GB/GB]; Brook House, 174 Brook Drive, Milton Park, Abingdon, Oxfordshire OX14 4SD (GB).

(72) Inventor: **STRACHAN, Iain Guy David**; OBS Medical Limited, Brook House, 174 Brook Drive, Milton Park, Abingdon, Oxfordshire OX14 4SD (GB).

(74) Agent: **TYSON, Robin Edward**; 14 South Square, Gray's Inn, London, Greater London WC1R 5JJ (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

WO 2013/179020 A1

(54) Title: NARROW BAND FEATURE EXTRACTION FROM CARDIAC SIGNALS

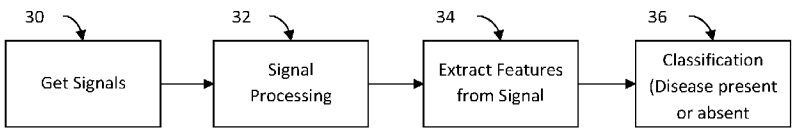

Figure 3 – System Overview

(57) Abstract: A PPG or other cardiac signal is analysed by calculating its amplitude in a narrow frequency range around the estimated heart rate or a harmonic of the heart rate. Cardiac signals from a patient in different states, e.g. exercise and non-exercise or limb lowered and limb raised can be analysed and the amplitude in the narrow range compared to determine various vascular conditions such as peripheral arterial disease.

NARROW BAND FEATURE EXTRACTION FROM CARDIAC SIGNALS

The present invention relates to a method of and apparatus for processing a cardiac signal from a human or animal subject to allow detection of some aspect of the condition of the subject. More particularly, the method involves analysing the features of a narrow frequency band of the cardiac signal as a way of improving the robustness of the result.

It is well known to obtain cardiac signals from human or animal subjects, for example electrocardiograms (ECG) or photoplethysmograms (PPG) and to examine or analyse these signals to determine some aspect of the condition of the subject. In common with many signals from human or animal subjects, however, the quality of the signals can vary greatly depending on accuracy and security of sensor positioning, and the signals are inherently noisy. There is a widespread need and interest, therefore, in processing such signals to allow greater accuracy and robustness in the conclusions to be drawn from them.

One example of analysis of cardiac signals is in the detection of Peripheral Arterial Disease (PAD) in which PPG signals are obtained from two pulse oximeter sensors, one mounted on the toe and one on the foot. Each sensor provides two separate PPG signals, one at infra red and one at red frequencies. Conventionally, two 30 second segments of data are collected from a supine subject, one with the leg lowered and one with the leg raised above the level of the heart. For healthy subjects, there is an increase in the amplitude of the PPG waveform when the leg is raised because the heart has to work harder to pump blood above the level of the heart. In a diseased patient, however, the heart is already working harder due to the occlusion in the arteries in the leg, and no amplitude increase (or sometimes an amplitude decrease) is observed. Typically, to classify the patient as diseased or not, the root mean square (RMS) amplitude over the 30 second period is calculated for each of the eight signals (IR and red signals for each of the toe and foot sensors in each of the lowered and raised position), and a weighted average is calculated of all of them with the weight coefficients being set to distinguish between diseased and normal patients by means of multiple linear regression of a set of

empirical training data. However, the waveforms collected are often corrupted by noise which may be due to movement artefact or poor sensor placement. This noise introduces errors into the calculation of the RMS amplitude.

Another example of cardiac signal analysis is in the analysis of ECG waveforms to obtain a respiration rate. It is known that respiration causes a periodic variation in the heart rate, but again it can be difficult to separate this signal given the amount of noise and possible movement artefact.

Accordingly, one aspect of the present invention provides a method of processing a cardiac signal from a human or animal subject to detect an indication of a vascular condition, comprising the steps of:

obtaining a cardiac signal for each of two different states of the subject;

estimating the heart rate in each cardiac signal;

determining, for each cardiac signal, a value representative of the amplitude of the cardiac signal over a predetermined limited range of frequencies around the frequency corresponding to the estimated heart rate or to a harmonic of the estimated heart rate; and

comparing the determined values to detect said indication of a vascular condition.

Another aspect of the present invention provides a computer program comprising computer-executable code that when executed on a computer system causes the computer system to perform a method according to any one of the preceding claims. A further aspect of the invention provides a computer-readable medium storing a computer program according to the preceding aspect of the invention.

A yet further aspect of the invention provides an apparatus for processing a cardiac signal from a human or animal subject to detect an indication of a vascular condition, comprising:

an input section configured to receive a cardiac signal for a plurality of different states of the subject;

an estimation section configured to estimate the heart rate in each cardiac signal;

a determination section configured to determine, for each cardiac signal, a value representative of the amplitude of the cardiac signal over a predetermined limited range

of frequencies around the frequency corresponding to the estimated heart rate or to a harmonic of the estimated heart rate; and

a comparison section configured to compare the determined values to detect said indication of a vascular condition

Thus, with the present invention the amplitude feature of the cardiac signal is limited to a predetermined narrow range around the estimated heart rate or a harmonic (i.e. a multiple) of the estimated heart rate. This can remove noise and artefact and thus result in a more accurate amplitude measurement in contrast with the prior art broadband approach of computing the RMS power in the whole signal. The fundamental (i.e. frequency corresponding to the heart rate) may be used, or the first or second harmonic (double or triple the frequency corresponding to the heart rate).

Preferably, the values representative of the amplitude of the cardiac signal are obtained by measuring the power in the cardiac signals over the predetermined limited range of frequencies. This can be done by computing the area under the curve of a frequency domain representation of each cardiac signal over the predetermined limited range of frequencies.

Alternatively, the cardiac signals can be transformed into the frequency domain, for example by a Fast Fourier Transform, spectral components outside the predetermined limited range of frequencies can then be easily removed, the signals converted back into the time domain and the amplitude (for example the RMS amplitude) measured.

Another alternative way of obtaining the values representative of the amplitude of the cardiac signals is to bandpass filter the cardiac signals to remove frequencies outside the predetermined limited range. Again, the predetermined limited range can be around the frequency corresponding to the heart rate, or around a harmonic of that frequency.

An advantage of determining the value representative of the amplitude over a predetermined limited range around a harmonic of the heart rate is that this can be at a frequency which is far removed from any noise or movement artefact.

The method is applicable to PPG signals, for example in the red and infra red region for detecting PAD as mentioned above, or two ECG signals.

The different states of the subject could correspond to the subject's body position being changed, or to the subject during exercise and relaxation.

In the case of detection of PAD, the two signals also come from two different parts of the subject's body, for example the foot and toe.

It should be appreciated therefore that the invention can be applied to two or more signals, from the same or different sensors.

The comparison of the two values representative of amplitude can comprise calculating the difference between them or calculating a weighted sum of the values. The result can be compared with a threshold. The values, or the result of the difference or weighted sum calculation can be compared with corresponding values from a training set which can include values from normal and abnormal subjects (e.g. diseased and not diseased).

The heart rate can be estimated by a variety of known methods, for example the detection of peaks in the cardiac signals. Preferably, a value for the confidence of the estimate of heart rate is also obtained, for example by comparing the heart rate estimate to the nearest maximum in the power spectrum of the cardiac signal. Further measures of confidence can be obtained by comparing the nearest maximum in the power spectrum with a harmonic of the estimated heart rate and also by checking the heart rate estimate against the normal heart rate range for that type of subject.

Embodiments of the invention will be further described by way of example with reference to the accompanying drawings in which:

Figures 1(a) to (e) show example PPG signals obtained from a subject's foot and toe in the red and infra red regions, together with the corresponding power spectrum (frequency domain representation) of the four signals;

Figures 2(a) to (e) show example poor quality PPG signals obtained from the foot and toe of a subject in the red and infra red regions, together with the corresponding power spectrum (frequency domain representation);

Figure 3 schematically illustrates the process of one embodiment of the invention;

Figure 4 schematically illustrates one embodiment of the extraction of features from a PPG signal; and

Figure 5 schematically illustrates PPG measurements to detect Peripheral Arterial Disease in a human subject.

As illustrated in Figure 5, one embodiment of the present invention may be used in the analysis of PPG signals used to detect Peripheral Arterial Disease. Figure 5 schematically illustrates the way such signals are obtained, as mentioned above PPG signals in both the red and infra red region are obtained from both the foot and toe of a subject with the leg first lowered and then raised. The signals from the foot and toe sensors (50, 51) are collected by a PPG controller (52) and then output to a data processor (54) which analyses the signals as explained below and outputs the results.

Figure 1 illustrates in Figures 1(a) to (d), four good quality PPG signals obtained in the infra red and red regions for the foot and the toe. All of the signals are relatively clean, apart from the foot red sensor which shows a small artefact at around 200 samples. Figure 1(e) shows the power spectra (frequency domain representations) of the four sensors, with a narrow band highlighted around the "fundamental" frequency, which corresponds to the heart rate. The present invention, as explained below, analyses the amplitude within that narrow band, or within a similar narrow band around one of the harmonics which are visible at frequency (x-axis) values of about 75 and 105. It is necessary to use a small band around the heart rate or fundamental thereof because the heart rate varies slightly from beat to beat with the respiratory cycle (known as *Respiratory Sinus Arrhythmia*).

By way of comparison, Figure 2 illustrates that poor quality signals for foot and toe PPG in the infra red and red regions with three of the four sensors showing a large spike-like artefact just after 500 samples. This appears in the power spectrum of Figure 2(e) as a secondary peak at a lower frequency in all four power spectra. This peak influences the height of the curves at the fundamental frequency. In this case, although the illustrated narrow band around the "fundamental" frequency excludes the noise, it can be seen that using one of the harmonic peaks would result in significantly less pollution by the artefact.

Figure 3 schematically illustrates the overview of the processing of the signals. In step 30 the signals are obtained by means of PPG sensors and controller (50, 51 and 52) and then steps 32, 34 and 36 the signals are processed, the amplitude features in the

frequency band under consideration extracted, and the subject classified by means of the processor 54.

In more detail, the PPG signals are collected for 30 seconds with the leg lowered and also then with the leg raised as shown in steps 41 and 42 of Figure 4. The heart rate is then robustly determined for the 30 second interval (that is to say a heart rate is estimated with the leg lowered and another heart rate estimated with the leg raised). This can be done by any known technique, but in this embodiment the most stable of the four wave forms is selected (either by a heuristic such as measuring the noise level, or simply choosing the most consistent channel, e.g. the toe IR, from prior observation), and performing a simple peak detection algorithm on it to locate the maxima of the signal. A typical public domain peak detection algorithm involves searching for a maximum by detecting whether the signal has fallen a fixed amount below the current "maximum", and if so marking it as a peak. This peak detection algorithm therefore gives a number of "instantaneous heart rate" estimates in terms of the peak-to-peak times. An estimate of heart rate for the 30 second interval can be determined based on the median peak-to-peak time, excluding those whose peak-to-peak distance would correspond to an unrealistic heart rate (e.g. outside the normal range of 45 to 150 beats per minute).

A further check on the integrity of the estimate may be made by comparing the power spectrum of the cardiac signal in the region of the estimated heart rate. If the nearest maximum in the power spectrum is not within a specified tolerance of the estimated heart rate, then the data is deemed unmeasurable.

A similar check may also be applied to the maxima in the power spectrum at multiples (harmonics) of the estimated heart rate.

Once the heart rate has been robustly estimated (the heart rate will be the same for all four sensors), in steps 43 and 44 the power spectrum in the vicinity of the fundamental or a harmonic of the heart rate is computed over a narrow band of frequencies. The narrow band is defined in this embodiment as +/- 10 bins of the 1024 point FFT which corresponds to a frequency range of about 0.5Hz. This is based on the variability of the heart rate and determined empirically during the training process, and would typically be in the range 0.2 to 0.5Hz. Having calculated the power spectrum, for example resulting in a plot as illustrated in Figure 1(e) or Figure 2(e), an amplitude-like

feature can be computed in steps 45 and 46 by calculating the area under the curve of the plot over the narrow band. The power spectrum and amplitude calculation can be done in a variety of ways:

(a) by a Fast Fourier Transform whose length is the next power of two greater than the number of samples (in this case there are 750 samples for a 30 second interval so the length of the FFT will be 1024). The power spectrum is then computed from the absolute value of the complex-valued FFT spectrum.

(b) by the "All Poles" method. In this method the linear prediction coefficients of the waveform are computed via the Yule-Walker equations. The linear prediction coefficients obtained represent the denominator of a polynomial function in the complex domain which can be evaluated at a sequence of points on the unit circle in the complex domain. Poles corresponding to significant spectral content in the signal can be identified and their distance from the origin in the complex domain represents the amplitude. (This is a well-known technique based on the original papers: G. Udny Yule "On a Method of Investigating Periodicities in Disturbed Series, with Special Reference to Wolfer's Sunspot Numbers" Philosophical Transactions of the Royal Society of London, Ser. A, Vol. 226, (1927) 267—298; and Gilbert Walker "On Periodicity in Series of Related Terms," Proceedings of the Royal Society of London, Ser. A, Vol. 131, (1931) 518--532. More modern explanations can be found on the web.)

The amplitude-like feature in the narrow band is computed for all eight signals (infra red and red for foot and toe with the leg raised and lowered).

The eight values thus calculated are then used in step 48 to compute an index I by applying a weighted sum according to the formula:

$$I = a + \sum_{i=1}^{i=8} b_i x_i$$

Where the constant offset a and weighting coefficients b_i are determined by multiple linear regression from a training set of previously-acquired PPG readings, together with an assessment of the disease/non-disease state determined by alternative

diagnostic methods. The subject is classified as disease positive if the index is below a predetermined threshold, or as clear if the index is above the threshold.

An alternative way of measuring the amplitude, rather than computing the area under the curve of the power spectrum in the narrow frequency band is to calculate the root mean square (RMS) value of the cardiac signals in the time domain after having removed undesired spectral content. This can be achieved in one of two ways.

(A) The first way is to transform the cardiac signals into the frequency domain, for example by computing the 1024 point complex-valued FFT. Then all entries in the FFT outside the desired frequency window around the fundamental or selected harmonic are set to 0. The FFT is symmetric so this involves leaving non-zero data in either half of the spectrum. The signal is then converted back into the time domain by computing the inverse FFT, and the RMS value of the resultant signal for the 30 seconds can be computed. Because the resultant signal has had its spectral content limited to the narrow region around the fundamental or a harmonic, it becomes an approximate sinusoid at the heart rate or one of its multiples.

(B) Another alternative approach is to digitally bandpass filter the cardiac signals using a bandpass filter set to pass only the narrow desired range of frequencies around the fundamental or selected harmonic, and then to calculate the RMS value for 30 seconds as mentioned above.

Although the invention has been described above with reference to methods embodying the invention, the invention can also be embodied as apparatus. For example, an apparatus for processing a cardiac signal from a human or animal subject to detect an indication of a vascular condition, comprising:

an input section configured to receive a cardiac signal for a plurality of different states of the subject;

an estimation section configured to estimate the heart rate in each cardiac signal;

a determination section configured to determine, for each cardiac signal, a value representative of the amplitude of the cardiac signal over a predetermined limited range of frequencies around the frequency corresponding to the estimated heart rate or to a harmonic of the estimated heart rate; and

a comparison section configured to compare the determined values to detect said indication of a vascular condition.

Furthermore, any of the detailed method features described above with reference to the method embodiments can be embodied as apparatus sections.

It is possible to implement the apparatus sections as dedicated hard-wired electronic circuits; however the various sections do not have to be separate from each other, and could all be integrated onto a single electronic chip. Furthermore, the sections can be embodied as a combination of hardware and software, and the software can be executed by any suitable general-purpose microprocessor, such that in one embodiment the apparatus can be a conventional personal computer (PC), such as a standard desktop or laptop computer, or can be a dedicated device.

The invention can also be embodied as a computer program stored on any suitable computer-readable storage medium, such as a solid-state computer memory, a hard drive, or a removable disc-shaped medium in which information is stored magnetically, optically or magneto-optically. The computer program comprises computer-executable code that when executed on a computer system causes the computer system to perform a method embodying the invention.

CLAIMS

1. A method of processing a cardiac signal from a human or animal subject to detect an indication of a vascular condition, comprising the steps of:

obtaining a cardiac signal for a plurality of different states of the subject;

estimating the heart rate in each cardiac signal;

determining, for each cardiac signal, a value representative of the amplitude of the cardiac signal over a predetermined limited range of frequencies around the frequency corresponding to the estimated heart rate or to a harmonic of the estimated heart rate; and

comparing the determined values to detect said indication of a vascular condition.

2. A method according to claim 1 wherein the values representative of the amplitude of the cardiac signals are obtained by measuring the power in a frequency domain representation of the cardiac signals over the predetermined limited range of frequencies.

3. A method according to claim 2 wherein the power in the frequency domain representation of the cardiac signals over the predetermined limited range of frequencies is measured by computing the area under the curve of a frequency domain representation of each signal over the predetermined limited range of frequencies.

4. A method according to claim 1 wherein the values representative of the amplitude of the cardiac signals are obtained by conversion of the cardiac signals to the frequency domain, removing spectral components outside the predetermined limited range of frequencies, converting the signals back to the time domain and measuring their amplitude.

5. A method according to claim 1 wherein the values representative of the amplitude of the cardiac signals are obtained by bandpass filtering the cardiac

signals to remove frequencies outside the predetermined limited range of frequencies and measuring the amplitude of the bandpass filtered cardiac signals.

6. A method according to any one of the preceding claims wherein the cardiac signals are photoplethysmograms.

7. A method according to claim 6 wherein red and infra red photoplethysmogram signals are obtained for each of two states of the subject.

8. A method according to any one of the preceding claims wherein the photoplethysmograms are obtained from different parts of body of the subject.

9. A method according to any one of the preceding claims wherein the step of comparing the states comprises calculating the relationship between them.

10. A method according to any one of the preceding claims wherein the step of comparing the states comprises the step of calculating a weighted sum of them.

11. A method according to any one of the preceding claims wherein the step of comparing the states comprises a step of comparison with a threshold.

12. A method according to any one of the preceding claims wherein the step of comparing the states comprises the step of comparison with values in, or obtained from, a training set of values.

13. A method according to any one of the preceding claims wherein the step of estimating the heart rate comprises detection of peaks in the cardiac signals.

14. A method according to any one of the preceding claims further comprising calculating a measure of confidence in the heart rate estimate by comparing the heart rate estimate to the nearest maximum in the power spectrum of the cardiac signals in the physiological range of heart rates.

15. A computer program comprising computer-executable code that when executed on a computer system causes the computer system to perform a method according to any one of the preceding claims.

16. A computer-readable medium storing a computer program according to claim 15.

17. An apparatus for processing a cardiac signal from a human or animal subject to detect an indication of a vascular condition, comprising:

an input section configured to receive a cardiac signal for a plurality of different states of the subject;

an estimation section configured to estimate the heart rate in each cardiac signal;

a determination section configured to determine, for each cardiac signal, a value representative of the amplitude of the cardiac signal over a predetermined limited range of frequencies around the frequency corresponding to the estimated heart rate or to a harmonic of the estimated heart rate; and

a comparison section configured to compare the determined values to detect said indication of a vascular condition.

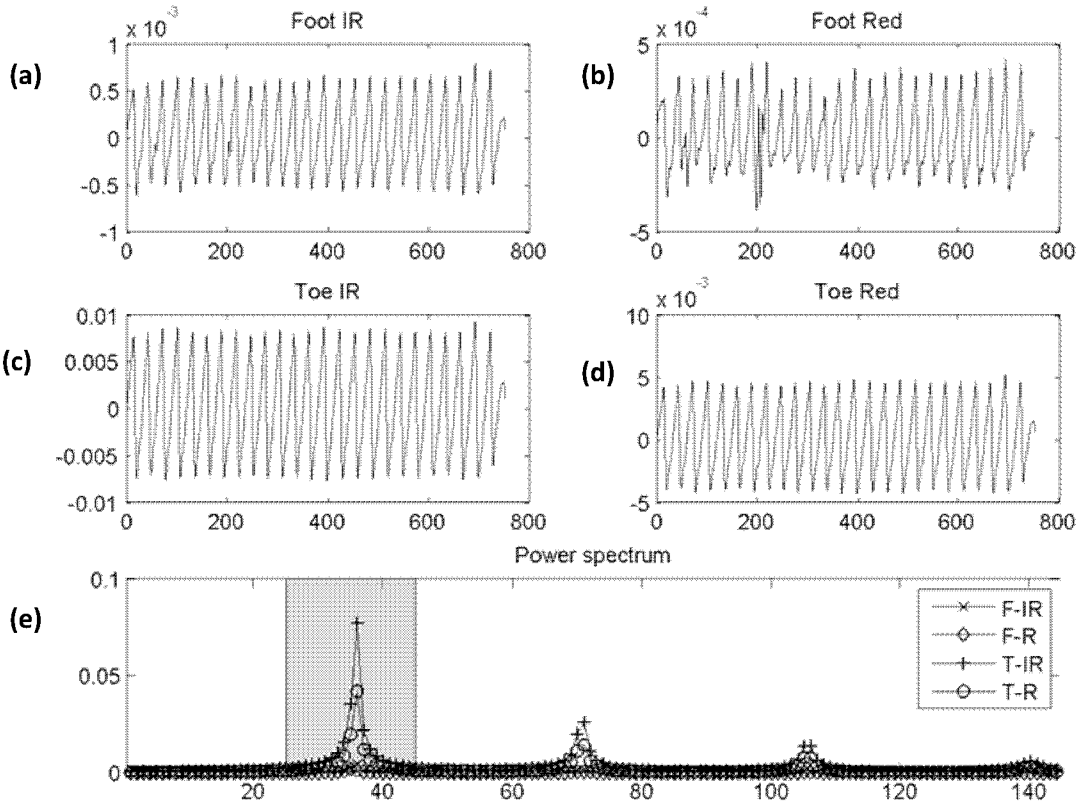

Figure 1 – Clean signal for one leg position, and the power spectrum

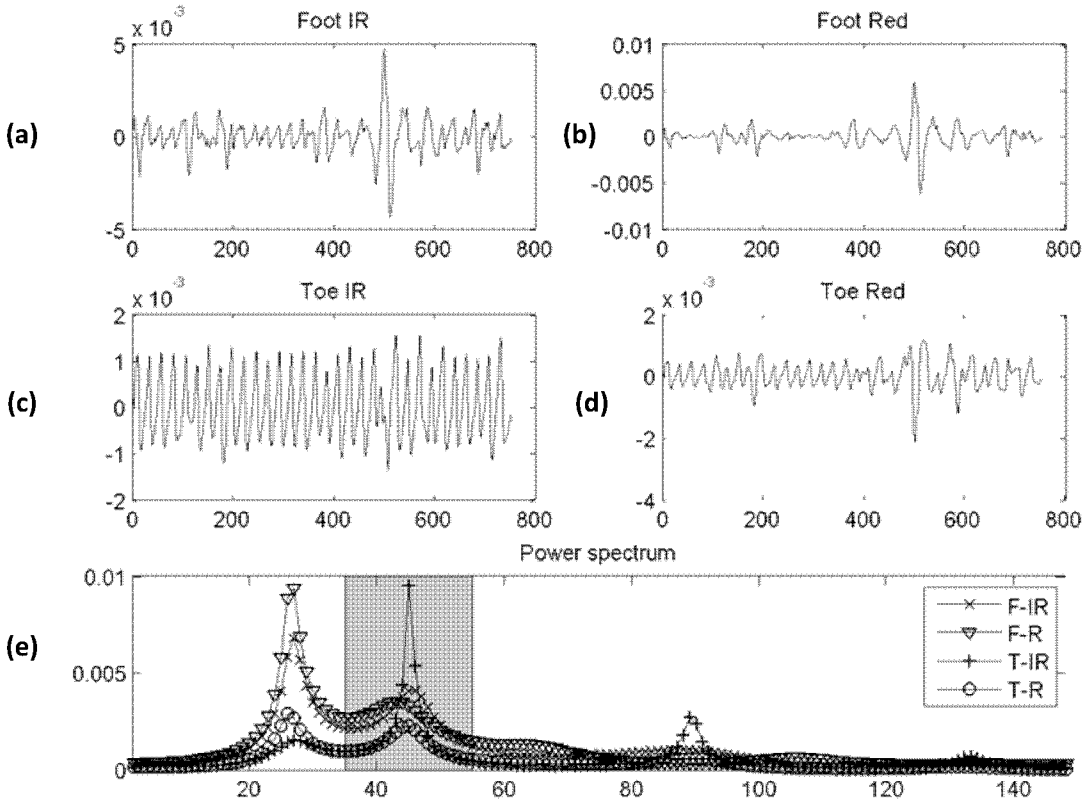

Figure 2 – Poor quality signal for one leg position, and the power spectrum

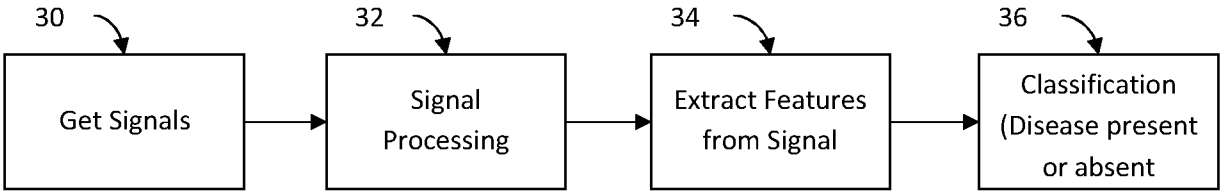

Figure 3 – System Overview

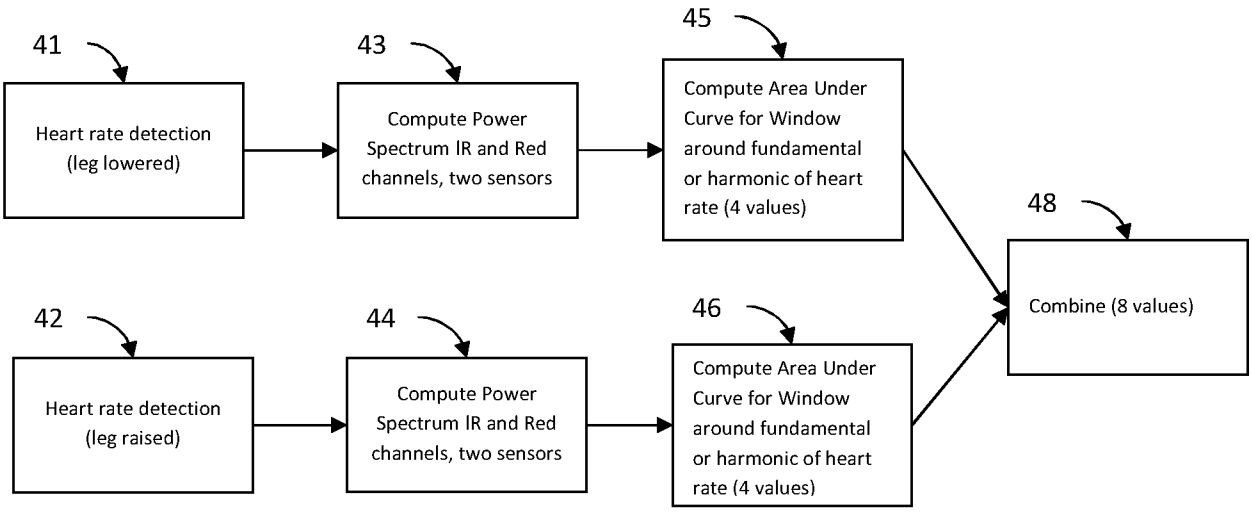

Figure 4 – Details of feature extraction algorithm

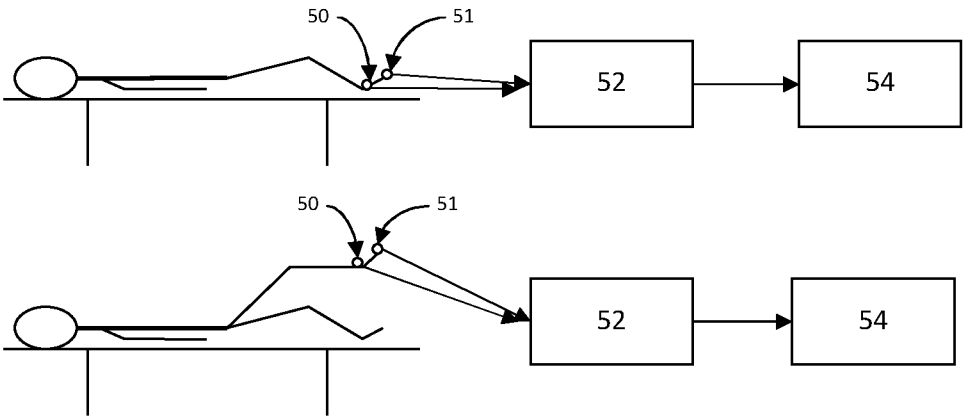

Figure 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2013/051408

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/00 A61B5/02 A61B5/024 A61B5/0452
ADD.

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)
A61B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/228136 A1 (KEEL ALLEN J [US] ET AL) 9 September 2010 (2010-09-09) paragraph [0009] paragraph [0016] - paragraph [0019] paragraph [0088] -----	17
X	US 2007/004977 A1 (NORRIS MARK A [US]) 4 January 2007 (2007-01-04) paragraph [0001] - paragraph [0013] paragraph [0043] - paragraph [0047] figures 1,7 -----	17
X	US 5 609 158 A (CHAN ERIC K Y [US]) 11 March 1997 (1997-03-11) column 15, line 57 - column 16, line 27 -----	17

☐ 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
8 August 2013	14/08/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kowalczyk, Szczepan

5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2013/051408

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 1-16
because they relate to subject matter not required to be searched by this Authority, namely:

Claims 1-16 are directed to diagnostic methods practised on the human or animal body, which are covered by the provision of Rule 39(1)(iv) PCT and are not required to be searched by the International Search Authority.

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2013/051408

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010228136 A1	09-09-2010	NONE	
US 2007004977 A1	04-01-2007	NONE	
US 5609158 A	11-03-1997	US 5609158 A	11-03-1997
		WO 9741773 A1	13-11-1997

专利名称(译)	从心脏信号中提取窄带特征		
公开(公告)号	EP2854620A1	公开(公告)日	2015-04-08
申请号	EP2013727961	申请日	2013-05-28
[标]申请(专利权)人(译)	OBS医疗		
申请(专利权)人(译)	OBS医药有限		
当前申请(专利权)人(译)	OBS医药有限		
[标]发明人	STRACHAN IAIN GUY DAVID		
发明人	STRACHAN, IAIN GUY DAVID		
IPC分类号	A61B5/00 A61B5/02 A61B5/024 A61B5/0452		
CPC分类号	A61B5/04012 A61B5/02007 A61B5/02416 A61B5/0245 A61B5/0452 A61B5/0456 A61B5/1455 A61B5/7203		
代理机构(译)	尼科尔斯迈克尔·约翰·		
优先权	2012009412 2012-05-28 GB		
外部链接	Espacenet		

摘要(译)

通过在估计的心率或心率的谐波附近的窄频率范围内计算其幅度来分析PPG或其他心脏信号。来自不同状态的患者的心脏信号，例如可以分析运动和非运动或肢体下降和肢体抬高，并在较窄范围内的振幅进行比较，以确定各种血管状况，如外周动脉疾病。