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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 March 2012 (01.03.2012)

PCT

(10) International Publication Number
WO 2012/025815 A1

(51) **International Patent Classification:**
A61B 5/02 (2006.01) *A61B 7/00* (2006.01)

(21) **International Application Number:**
PCT/IB201 1/001938

(22) **International Filing Date:**
25 August 201 1 (25.08.201 1)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
2010/06120 25 August 2010 (25.08.2010) ZA

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(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, 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, KM, 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, PE, PG, PH, PL, PT, QA, RO, RS, RU, 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, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) **Title:** A SYSTEM AND METHOD FOR CLASSIFYING A HEART SOUND

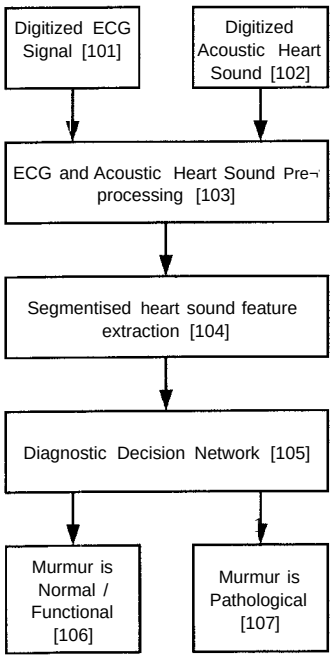

Figure 1

(57) **Abstract: A** method and system for electronically classifying a pre-processed heart sound signal of a patient as functional (normal) or pathological is provided. The pre-processed patient heart sound signal is segmentised and features are extracted therefrom (104) to build up a feature vector which is representative of the heart sound signal. The feature vector is then fed to a diagnostic decision support network (105) comprising a plurality of artificial neural networks, each relating to a known heart pathology, which is in turn used to conduct the classification.

WO 2012/025815 A1

Declarations under Rule 4.17 :

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *of inventorship (Rule 4.17(iv))*

Published:

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

A SYSTEM AND METHOD FOR CLASSIFYING A HEART SOUND

FIELD OF THE INVENTION

This invention relates to a system and method for classifying a heart sound, more particularly for classifying a digitised acoustic heart sound so as to provide a diagnosis and differentiation between functional and pathological heart sounds.

BACKGROUND TO THE INVENTION

Cardiac auscultation refers to the process of determining cardiac well-being or illness by listening to the heart through a stethoscope. The results obtained by means of these techniques can, however, be very subjective and depend to a large extent on the experience and acquired knowledge of the diagnosing health care worker.

The majority of cardiac abnormalities manifest themselves as cardiac murmurs. However, not all murmurs are pathological. Innocent heart murmurs are sounds made by blood circulating through heart chambers and valves or blood vessels near the heart. Innocent heart murmurs are more common in children and are considered to be harmless.

Echo-cardiography is a technique which is considered by many to be one of the, if not the, most accurate aids in the field. It utilises ultrasound technology to generate visual images of the beating heart, but requires advanced training, skill and experience to manipulate the ultrasound probe in order to obtain useful images. An echo-cardiography system will, however, require an investment of close to ZAR1 Million at the time of writing, excluding costs associated with, for example, the training of staff to operate the system and meaningfully analyse the images obtained. This high cost

means that echo-cardiography systems are not a feasible option for the majority of healthcare institutions in less affluent areas.

It is estimated that up to 90% of paediatric patients will exhibit some form of heart murmur on examination, although less than 1% will eventually turn out to have a congenital heart defect. Although most paediatric cardiologists can diagnose an innocent heart murmur with a very high degree of accuracy, sensitivity and specificity, even a routine paediatric cardiology evaluation is generally too costly for people from middle to low income groups.

This is particularly true in the context of a large number of developing countries, such as South Africa, where, in addition to the high cost of paediatric cardiology evaluations, patients often have to travel long distances from rural communities in order to visit one of the few paediatric cardiologists available for the population of approximately 48 million people. The referral of paediatric patients to paediatric cardiologists can therefore become extremely difficult and in most cases impractical from a logistical point of view.

When a serious congenital cardiac defect goes undetected, the physical, socio-economical and emotional damage to the patient and his or her caretakers can be enormous.

It is therefore of the utmost importance that private healthcare physicians and nurses who look after paediatric patients must be able to determine which patients will require additional evaluation as well as the urgency with which such evaluation should be conducted.

The only assistance presently available to healthcare workers to evaluate heart sounds is the common stethoscope, which can be either mechanical or electronic. Besides the rate and frequency (pitch) of the heart sounds,

morphological features, which might provide an important indication of a critical heart disorder, may be undetectable by the human ear.

A low cost, portable, digital system for analysing heart sounds and making preliminary diagnoses would therefore be a very useful instrument to healthcare workers operating in the field. In order to be useful in such an automated system, recorded heart sounds must, however, be digitised and pre-processed for optimal feature extraction. Only once such pre-processing has been done will the signals be useful in a decision making network. Naturally, the more accurately features can be extracted, the more accurate the resulting diagnoses may be.

PCT patent application PCT/IB201 0/001 923, which is incorporated in its entirety herein by reference, discloses a medical decision support system which provides a process for pre-processing recorded heart sound signals to render them useful in decision support system. The patent application does not, however, disclose a method or system for classifying the pre-processed recorded heart sound signals to provide a diagnosis or differentiation between functional and pathological heart sounds.

OBJECT OF THE INVENTION

It is an object of this invention to provide a system and method for classifying pre-processed recorded heart sound signals to provide a diagnosis or differentiation between functional and pathological heart sounds which alleviates at least some of the abovementioned problems.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided a method of classifying a pre-processed heart sound signal of a patient,

the method being characterised in that the pre-processed patient heart sound signal is electronically compared to a plurality of similarly pre-processed heart sounds corresponding to each of a plurality of pathologies and a diagnosis made by determining whether the patient heart sound corresponds to the heart sounds of any one or more of the pathologies.

Further features of the invention provide for the determination to include a confidence measure to indicate the confidence with which a diagnosis is made; and for an artificial neural network (ANN) to be provided for each pathology, each artificial neural network being trained with at least features extracted from the pre-processed heart sounds corresponding to the applicable pathology, and each artificial neural network to be used to determine whether the pre-processed patient heart sound corresponds to the pathology associated therewith.

Still further features of the invention provides for a diagnostic decision support network to be provided which comprises the artificial neural networks for each pathology, the diagnostic decision support network being used to determine if the pre-processed patient heart sound signal corresponds to the heart sounds of any one or more of the pathologies; and for the pre-processed heart sound signal to be segmentised and features are extracted therefrom, the features being compiled into a feature vector which serves as input to the diagnostic decision network.

Yet further features of the invention provide for the heart sound signal to be pre-processed by identifying or predicting locations of individual heart beats within the heart sound signal, predicting locations and durations for systole and diastole segments of the heart sound signal, compiling a peak array containing peak locations within the heart sound signal that correspond to possible locations of S1 and S2 heart sound pulses in the heart sound signal, calculating interval sizes between the peak locations in the peak array, selecting and isolating heart beats in the heart sound signal that were

detected with the highest level of confidence based on the predicted durations of the systole and diastole segments of the heart sound signal and the peak array, determining if segmentation of the heart sound signal is possible based on the selected and isolated heart beats, dividing inter-peak intervals that make up the heart sound signal into even and odd groups in the order in which they appear if segmentation of the heart sound signal was found to be possible, and calculating the variance and mean for both groups and taking the group with the largest ratio of variance over mean as corresponding to the diastole intervals and the other group as corresponding to the systole intervals.

The invention also provides a system for classifying a pre-processed heart sound signal of a patient, the system including a processor configured to compare the pre-processed patient heart sound to a plurality of similarly pre-processed heart sounds corresponding to each of a plurality of pathologies and to provide a diagnosis by determining whether the patient heart sound signal corresponds to the heart sounds of any one or more of the pathologies.

Further features of the invention provide for the processor to be further configured to calculate a confidence measure indicative of the confidence with which a diagnosis is made; for the system to include a diagnostic decision support network comprising an artificial neural network associated with each pathology, the artificial neural networks being trained with at least features extracted from the pre-processed heart sounds associated with its pathology and the processor being further configured to use the diagnostic decision support network to provide the diagnosis; and for the processor to be further configured to segmentise the heart sound signal and to extract features therefrom, and to compile the features into a feature vector which serves as input to the diagnostic decision network.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example only with reference to the accompanying representations in which:

Figure 1 is flow diagram for a system for classifying a heart sound signal of a patient;

Figure 2 is patient heart signal including (a) an ECG reference signal with R-T peaks start and end systole region, (b) a single cardiac cycle with S1 and S3 components segmented with an ASD murmur, and (c) an envelope of a beat used to find the S1 and S2 regions;

Figure 3 is (a) a Shannon envelope for a patient heart signal and time indexes used for features calculation and (b) STFT segments time division of a signal;

Figure 4 is a flow diagram of the classification process of a recorded heart sound;

Figure 5 is a classification model using artificial neural networks to identify specific murmur types;

Figure 6 is a tanh transfer function used in the classification system; and

Figure 7 is a flow diagram of diagnosis and confidence measure calculation.

DETAILED DESCRIPTION WITH REFERENCE TO THE DRAWINGS

To enable an automated system to distinguish between pathological and normal heart murmurs an acoustic heart sound signal (102) and its associated ECG (101) signal must be digitised and pre-processed (103) for optimal feature extraction (104) for input into a support decision network (105) as shown in Figure 1. It is with this feature extraction from the segmented heart sound recording (104) and decision support network (105) that the current invention is concerned.

The means for receiving the digitized acoustic heart sound at step (102) may include an electronic stethoscope placed on the chest of the subject, analogue circuitry including amplifiers, analogue filters and an analogue-to-digital converter.

Likewise, the means for receiving the digitised ECG signal at a step (101) may include three ECG leads with ECG electrodes connected to it, an analogue differential amplifier with a feedback line, analogue filters and an analogue-to-digital converter.

PCT patent application PCT/IB201 0/001 923 describes in detail the pre¬processing of heart sounds. In brief, however, the pre-processing of the digitized acoustic heart sound and digitised ECG signal at step (103) includes the steps of digitally filtering the respective signals, determining the presence of an acoustic heart sound and ECG signals, locating the positions of the S1 and S2 heart sounds within the respective heart beats that make up the heart sound signal, locating the QRS peak within the respective ECG periods and parsing the recorded digitized acoustic heart sound within its respective heart beat cycles as illustrated in Figure 2.

At step (104), the heart beat cycles are then segmented and specific features are extracted from them. As shown in more detail in Figure 3, the

segmentation includes the division of the heart beat cycles into a predetermined number of segments (a, b, c, d, e and f) for each of which a power spectrum is then calculated and features extracted from a Shannon envelope of the signal. The features are extracted from the Shannon envelope at predetermined time indexes so as to be representative of the beats making up the signal. From these specific feature points a feature vector is compiled and serves as input to a diagnostic decision support network shown at step (105).

According to the invention, the diagnostic decision support network shown at step (105) is implemented by means of a neural network which indicates that the input heart sound is either normal, at step (106), or contains a murmur associated with a predefined pathology, at step (107). From the neural network's output, signal quality and segmentation steps a confidence factor is also calculated to indicate the confidence with which the final decision was made.

The steps of segmenting the pre-processed heart sound and conducting the feature extraction (104) are exemplified in more detail by the flow diagram shown in Figure 4. The Shannon envelope is calculated at step (602) from the heart beat periods with S1 and S2 identified (during pre-processing of the heart sound signal) at (601). Eight Shannon envelope components (features) are then extracted from the Shannon envelope at (603). These components are illustrated in Figure 3 as time indexes. These time indexes, shown as x2 to x9 are positioned at times 0.1, 0.15, 0.35, 0.5, 0.65, 0.85 in the systole region of the heat beat and at times 0 and 0.5 in the S2 region. The envelope's mean values in these regions are then calculated and normalized by scaling the resulting 8 feature points to have a maximum value of 1, at step (604).

From the said heart beat periods (601) the identified S1 and S2 sounds, as well as the systole region, are segmented into bins (a to f) at (605), as shown

in more detail in signal (b) of Figure 3. The Short-Time Fourier Transform ("STFT") is calculated for the overlapping bins a, b, c, d, e and f at (606). The STFT is split into low frequencies (LF), 20-150Hz and high frequencies (HF) 150-420Hz. 12 values, 4 LF and 8 HF values are then extracted from the 6 bin segments spanning the entire S1, systole and S2 region at (607). The HF values are scaled to the same magnitude as the LF values to enable the detection of soft murmurs. The feature set is normalized limiting the range to [-1;1] at (608). The high frequency components of segments a and b are removed as well as 2 LF components of segment b, reducing the feature vector to 54 values. The number of values in the feature vector is therefore calculated as follows:

6 regions * (8HF +4LF) = 72

72 - (8HF + 8LF) = 56

56 - (2bLF) = 54

The 62 point feature vector thus calculated at (609), consisting of the Shannon and STFT features, is then fed into a network of artificial neural networks (ANNs) at (610). The network is shown in more detail in Figure 5. Each ANN (shown as "ANN 1" to "ANN n") in the network represents a specific pathology. An ANN is created for each pathology and is trained with features extracted from heart sounds representative of that specific pathology, as well as with features from normal heart sounds. A tanh transfer function is used on each of the network outputs limiting the range to [-1;1], as shown in Figure 6. Each output of the above-mentioned ANNs is used to determine if the analysed heart beats of a recorded heart sound contains a pathological murmur. The confidence with which this decision is made is also calculated at (611).

Figure 7 illustrates the process used to analyse each **ANN**'s outputs to determine if a heart sound contains a pathological murmur as well as to determine the confidence with which this decision is made. For each heart

beat analysed, each **ANN**'s output (701) within the ensemble of ANNs is used to calculate the percentage of beats classified as normal and the percentage classified as pathological in a recorded signal. A single beat is classified as normal if all ANN outputs specify the beat as normal and pathological if one or more of the ANN outputs classify it as pathological at (702). For a complete heart sound recording to be classified as normal all ANNs within the ensemble of ANNs must classify at least 60% of the beats making up the signal as normal (60% of the beats were below the ANN output threshold). If at least one ANN within the ensemble of ANNs classifies more than 40% of the beats making up the recorded signal as pathological, the heart sound as a whole is classified as pathological (in other words 40% or more of the beats where above the threshold) (703).

Each ANN in the network classifies all selected beats from a recording. Their outputs are limited in the range [-1 , 1] corresponding to [normal; pathological]. Values in between are considered uncertain or badly correlated with the training set. The confidence measurement is a weighted sum of the ANN's outputs, where the weight is calculated as the percentage of beats matching the signal classification.

If a signal is classified as normal only those beats that contributed to a normal classification are considered. To calculate the confidence measure for a normal acoustic heart recording the average output for the selected beats at the input that was detected as normal is determined for each ANN output (704). The average ANN output for each ANN is then multiplied with the percentage of normal heart beats detected by the specific ANN (705) and these values are then used to calculate the average confidence for all the ANN outputs (706).

To calculate a confidence measure for a pathological acoustic heart recording, a quality vector is determined based on the statistical results obtained from the accuracy testing of each network, therefore assigning a

quality value to each ANN calculated according to the ANN's accuracy (707). If more than one ANN in the ensemble of ANNs detects a pathology, the quality value used is increased accordingly. For each ANN that detects a pathology, the average output for the selected beats at the input that were detected as pathological is calculated (708). If a single ANN determined the recorded acoustic heart sound as normal, the confidence with which it is done is determined, the same method as specified in the steps above (704, 705, 706) is used. To determine the final confidence value with which a pathological acoustic heart sound recording was identified, the average of the ANN outputs is added to the quality number (determined from the quality vector) and the confidence value of the ANNs that detected the heart sound as normal is subtracted (709).

It will be appreciated that many other methods of classifying a heart sound signal of a patient exist which fall within the scope of the invention, particularly in the manner in which the heart sound signal is pre-processed and compared to similarly pre-processed heart sound signals associated with pathologies.

Similarly, the system for classifying a heart sound signal of a patient can have any suitable configuration and need not rely on ANNs. It will further be appreciated that the processor used to implement the system can be a single device, such as a computer, or multiple devices in a cooperative arrangement. Where ANNs are used they can have any suitable configuration.

CLAIMS:

1. A method of classifying a pre-processed heart sound signal of a patient, the method being characterised in that the pre-processed patient heart sound signal is electronically compared to a plurality of similarly pre-processed heart sounds corresponding to each of a plurality of pathologies and a diagnosis made by determining whether the patient heart sound corresponds to the heart sounds of any one or more of the pathologies.

2. A method as claimed in claim 1 in which the determination includes a confidence measure to indicate the confidence with which a diagnosis is made.

3. A method as claimed in claim 1 or claim 2 in which an artificial neural network (ANN) is provided for each pathology, each artificial neural network being trained with at least features extracted from the pre-processed heart sounds corresponding to the applicable pathology, and wherein each artificial neural network is used to determine whether the pre-processed patient heart sound corresponds to the pathology associated therewith.

4. A method as claimed in any one of the preceding claims in which a diagnostic decision support network is provided which comprises the artificial neural networks for each pathology, the diagnostic decision support network being used to determine if the pre-processed patient heart sound signal corresponds to the heart sounds of any one or more of the pathologies.

5. A method as claimed in claim 3 or claim 4 in which the pre-processed heart sound signal is segmentised and features are extracted

therefrom, the features being compiled into a feature vector which serves as input to the diagnostic decision network.

6. A method as claimed in any one of the preceding claims in which for the heart sound signal is pre-processed by identifying or predicting locations of individual heart beats within the heart sound signal, predicting locations and durations for systole and diastole segments of the heart sound signal, compiling a peak array containing peak locations within the heart sound signal that correspond to possible locations of S1 and S2 heart sound pulses in the heart sound signal, calculating interval sizes between the peak locations in the peak array, selecting and isolating heart beats in the heart sound signal that were detected with the highest level of confidence based on the predicted durations of the systole and diastole segments of the heart sound signal and the peak array, determining if segmentation of the heart sound signal is possible based on the selected and isolated heart beats, dividing inter-peak intervals that make up the heart sound signal into even and odd groups in the order in which they appear if segmentation of the heart sound signal was found to be possible, and calculating the variance and mean for both groups and taking the group with the largest ratio of variance over mean as corresponding to the diastole intervals and the other group as corresponding to the systole intervals.

7. A system for classifying a pre-processed heart sound signal (103) of a patient, the system including a processor configured to compare the pre-processed patient heart sound to a plurality of similarly pre-processed heart sounds corresponding to each of a plurality of pathologies and to provide a diagnosis by determining whether the patient heart sound signal corresponds to the heart sounds of any one or more of the pathologies.

8. A system as claimed in claim 7 in which the processor is further configured to calculate a confidence measure (709) indicative of the confidence with which a diagnosis is made.

9. A system as claimed in claim 7 or claim 8 which includes a diagnostic decision support network (105) comprising an artificial neural network (ANN) associated with each pathology, the artificial neural networks being trained with at least features extracted from the pre-processed heart sounds associated with its pathology and the processor being further configured to use the diagnostic decision support network to provide the diagnosis.

10. A system as claimed in any one of claims 7 to 9 in which the processor is configured to segmentise the heart sound signal and to extract features therefrom (104), and to compile the features into a feature vector (609) which serves as input to the diagnostic decision support network (105).

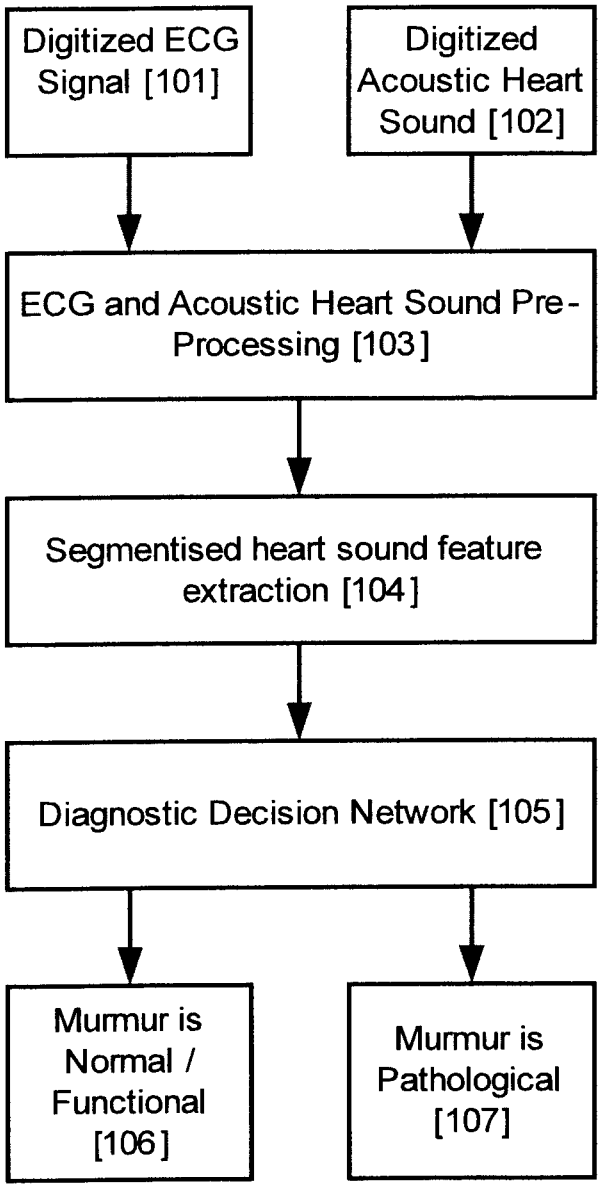
Digitized ECG Signal [101]
Digitized Acoustic Heart Sound [102]
ECG and Acoustic Heart Sound Pre-Processing [103]
Segmentised heart sound feature extraction [104]
Diagnostic Decision Network [105]
Murmur is Normal / Functional [106]
Murmur is Pathological [107]

Figure 1

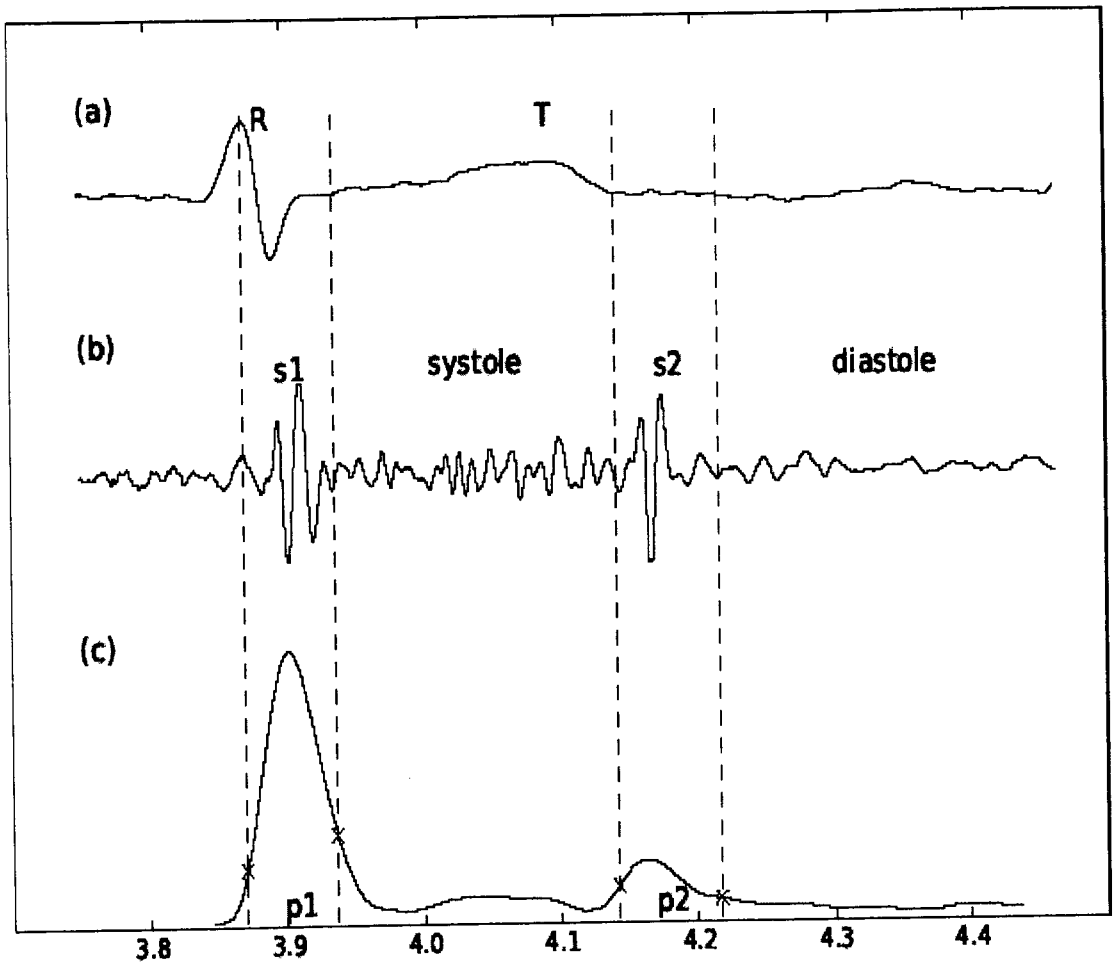

Figure 2

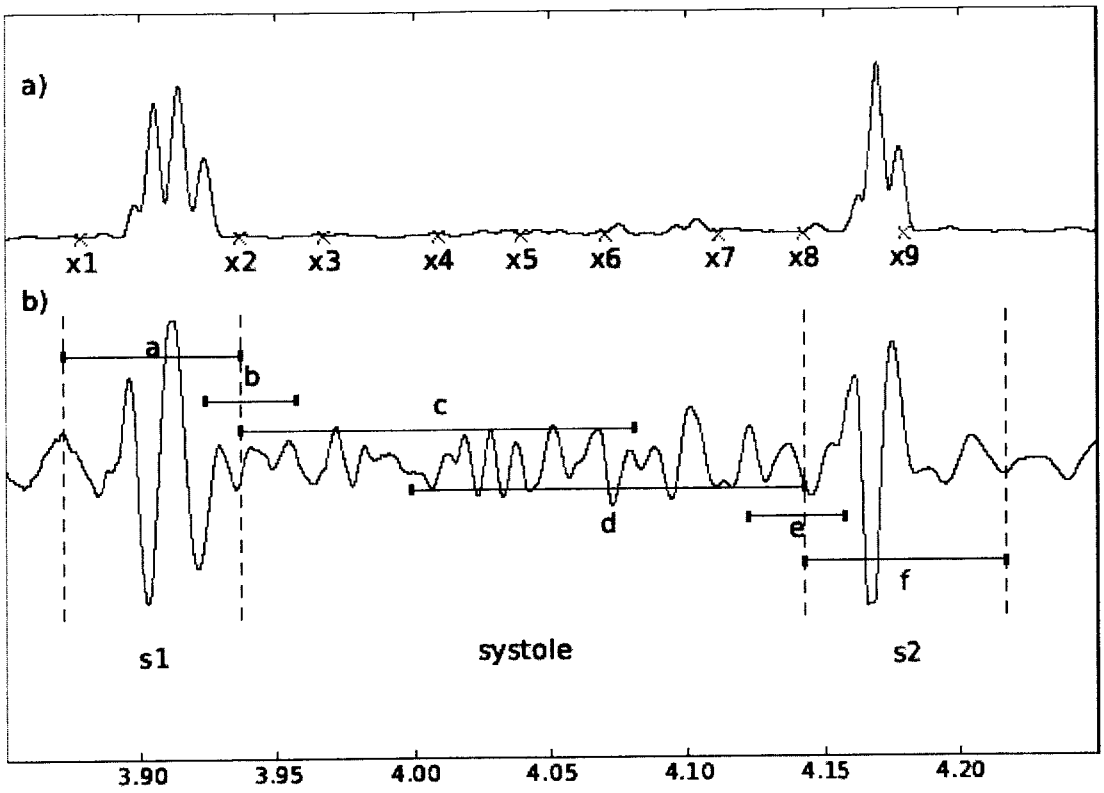
a)
x1
x2
x3
x4
x5
x6
x7
x8
x9
b)
a
b
c
d
e
f
s1
systole
s2
3.90
3.95
4.00
4.05
4.10
4.15
4.20

Figure 3

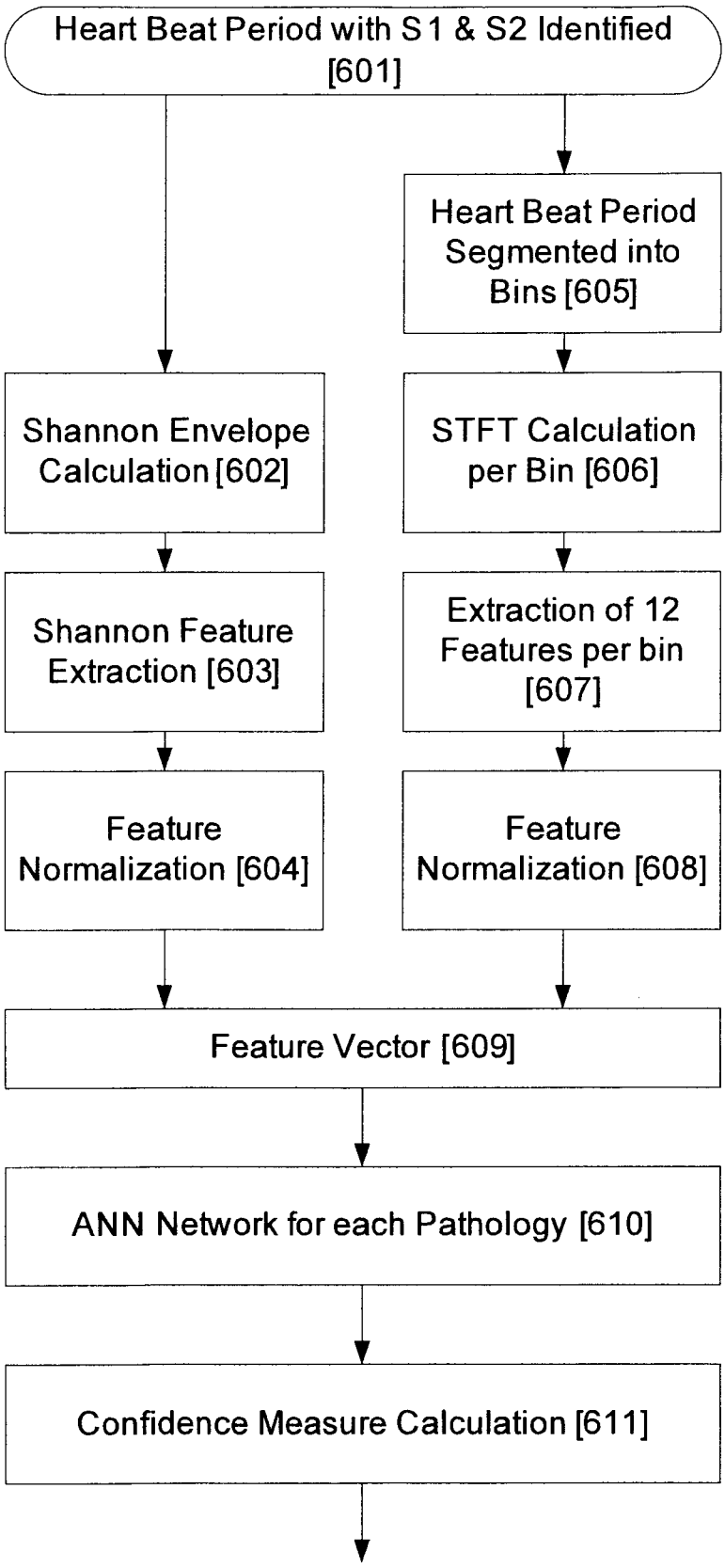
Heart Beat Period with S1 & S2 Identified [601]
Heart Beat Period Segmented into Bins [605]
Shannon Envelope Calculation [602]
STFT Calculation per Bin [606]
Shannon Feature Extraction [603]
Extraction of 12 Features per bin [607]
Feature Normalization [604]
Feature Normalization [608]
Feature Vector [609]
ANN Network for each Pathology [610]
Confidence Measure Calculation [611]

Figure 4

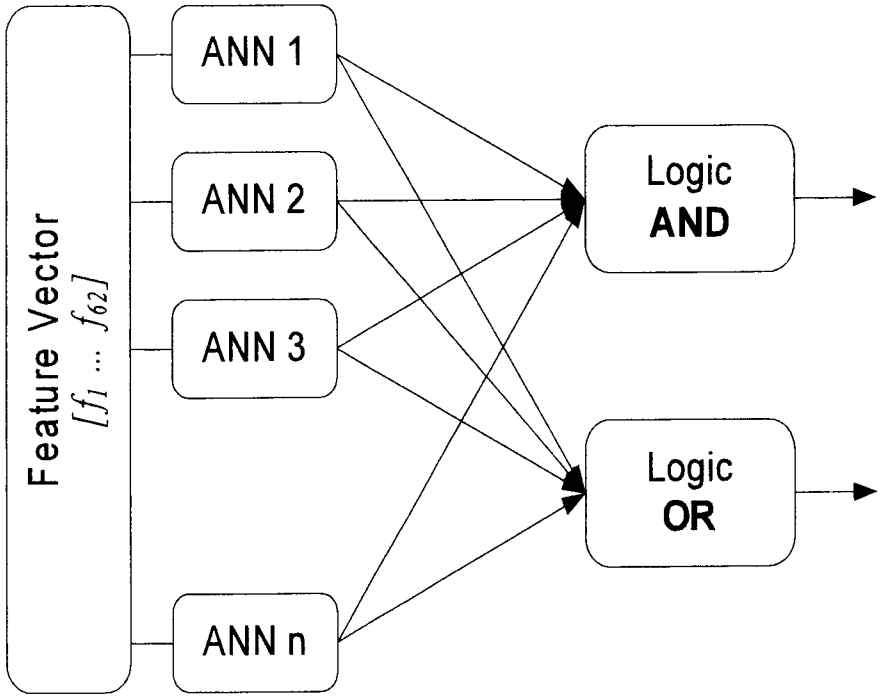

Figure 5

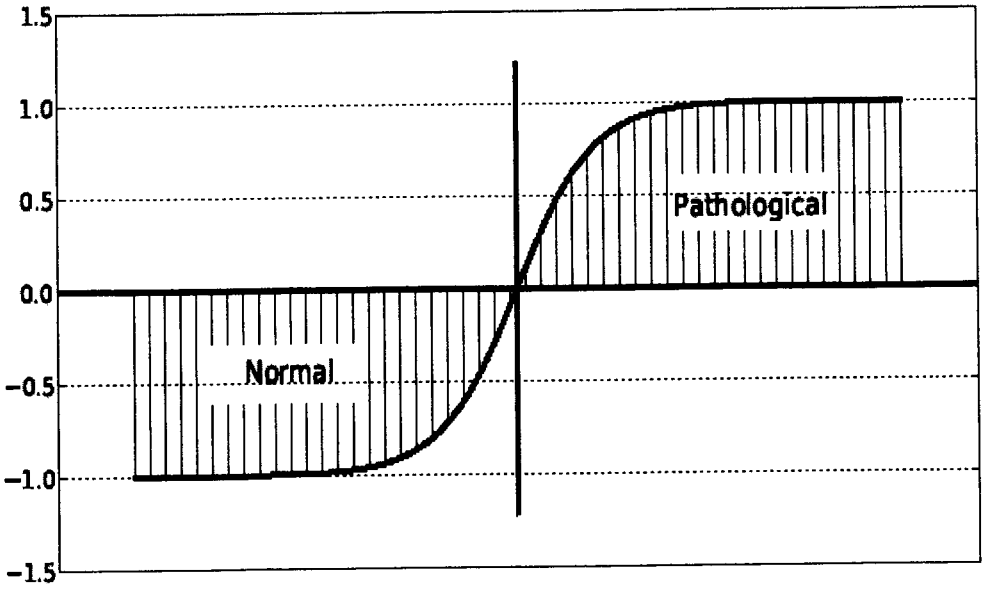

Figure 6

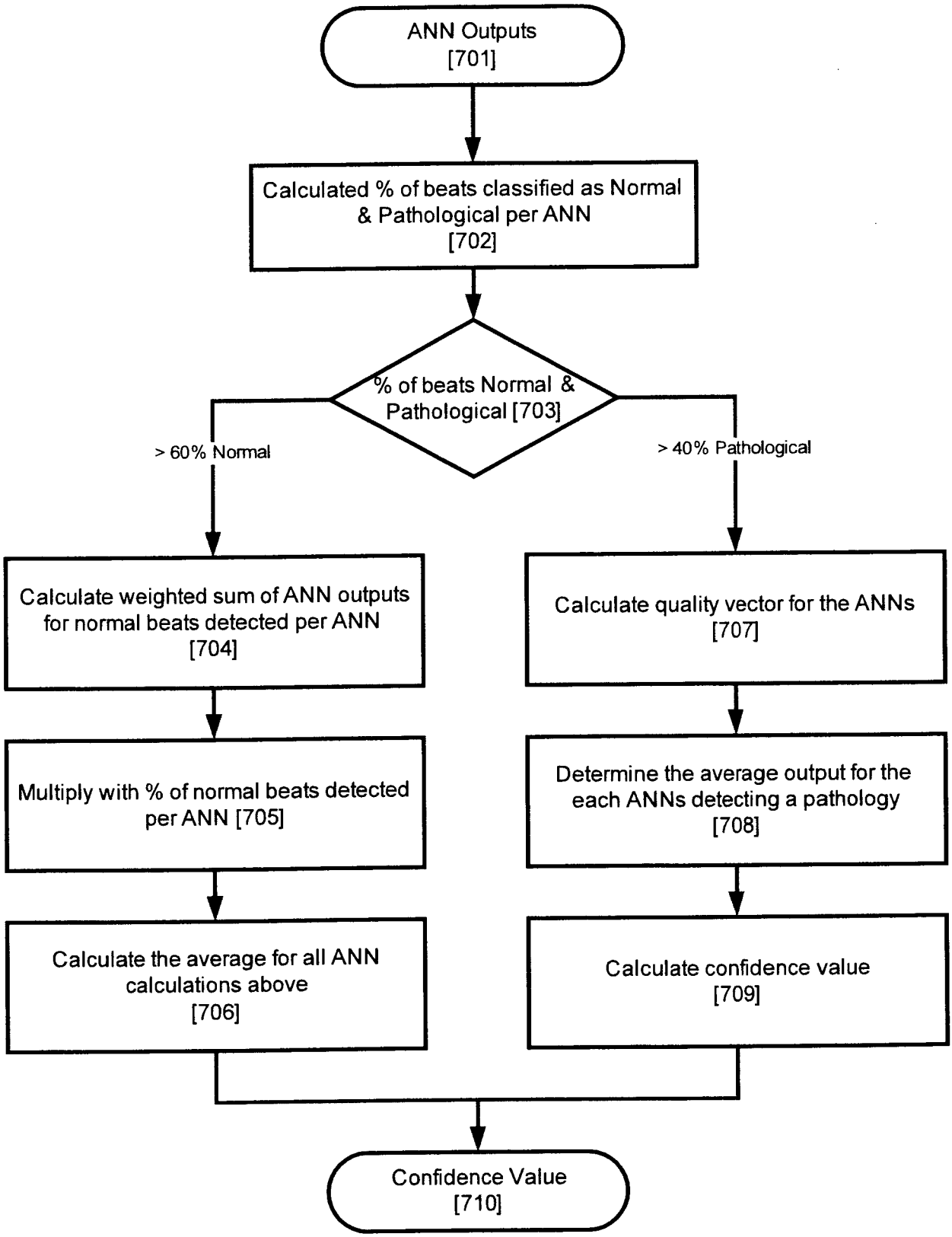
ANN Outputs
[701]
Calculated % of beats classified as Normal & Pathological per ANN
[702]
% of beats Normal & Pathological [703]
> 60% Normal
> 40% Pathological
Calculate weighted sum of ANN outputs for normal beats detected per ANN
[704]
Multiply with % of normal beats detected per ANN [705]
Calculate the average for all ANN calculations above
[706]
Calculate quality vector for the ANNs
[707]
Determine the average output for the each ANNs detecting a pathology
[708]
Calculate confidence value
[709]
Confidence Value
[710]

Figure 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB20 11/00 1938

A. CLASSIFICATION OF SUBJECT MATTER

Int. CI.

A61B 5/02 (2006.01) ***A61B 7/00*** (2006.01)

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)

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)

EPODOC, WPI: IPC and EC: A61B5, A61B7, G06N3/02, G06N5/00, G06N7/00 and Keywords: Heart, cardiac, cardio, auscultation sound, artificial neural network, expert system, back propagation, RBF, Gaussian, Bayesian, diagnostic decision network, knowledge based model, fuzzy logic, comparison, correlation, match, signature, bank, collection, database, pathological, abnormal, disease, stenosis, regurgitation, murmur, congenital, divergence, confidence, manhattan, variance, segment, feature extraction, filter; and like terms.

GOOGLE PATENTS, GOOGLE SCHOLAR Keywords: Heart sound, cardiac, auscultation, artificial neural network, expert system^ signature, database, pathological, disease, murmur, segmentation, dispersion, variance, diastolic, systolic; and like terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	**US7733224 B2** (TRAN) **8 June 2010** **column 62, line 6 1-64; column 73, line 9-10; column 73, line 18-26; column 73, line 29-3 1; column 73, line 39-45; column 73, line 48-53; column 74, line 45-50; column 74, line 53-57; column 79, line 24-33; column 79, line 39-40; column 79, line 42-45; column 79, line 43-45; column 96, line 49-53**	**1-5, 7-10**
Y	**column 73, line 14-17; column 73, line 29-3 1; column 73, line 39-62; column 74, line 18-32; column 74, line 45-50; column 74, line 53-57; column 74, line 62 - column 75, line 3; column 74, line 66 - column 75, line 1; column 79, line 18-33; column 79, line 42-45**	6

[X] **Further documents are listed in the continuation of Box C** [X] **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**

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"&" **document member of the same patent family**

Date of the actual completion of the international search	Date of mailing of the international search report
23 November 201 1	06. 12.201 1
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **ASHOK KRISHNAN** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2190

INTERNATIONAL SEARCH REPORT

International application No.
PO7IB20 11/001938

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6572560 B1 (WATROUS et al.) 3 June 2003 column 5, line 36-40; column 5, line 44-45; column 5, line 46-54; column 5, line 51-54; column 5, line 60-64; column 6, line 22-33; column 8, line 24-26; column 8, line 33-37; column 8, line 45-57	1-5, 7-10
X	US 7351207 B2 (PRIEMER) 1 April 2008 Abstract; column 6, line 58 - column 7, line 7; column 8, line 4-12; column 10, line 30-37; column 10, line 40-47	1, 3-5, 7, 9, 10
Y	REGUEIRO-GOMEZ, A. et al., 'A new method for automated blood pressure measurement', Physiological Measurement. 1998, vol 19, pages 205-212 Abstract; figure 3; Section 2, page 207, para 2 - page 208, end of section 2; Section 31	6

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IB2011/001938

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	7733224	US	2008001735	us	201 1115624	US	201 1181422
us	6572560	AR	031675	AU	78458/00	AU	78459/00
		US	2002038089	US	6544189	US	2002052559
		US	6629937	US	68781 17	US	2003093003
		us	6953436	WO	0122883	WO	0122884
us	7351207	us	2005043643	US	20051 13708	US	7435224
		us	2009036789	WO	2005074794	WO	2005076148

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX