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*[Continued on next page]*

(54) Title: NON INVASIVE ANALYSIS OF BODY SOUNDS

(57) Abstract: This method for analysing the sounds of body fluid flows comprises: - simultaneously acquiring (2) sounds from various locations of a body; - identifying (6) the points of maximum sound intensity (PMIs) of the acquired sounds for each acquisition instant; - determining (10) the source locations of the acquired sounds; and - determining (12, 14) the sound radiation patterns of the acquired sounds. The invention also relates to the corresponding device, system and program.

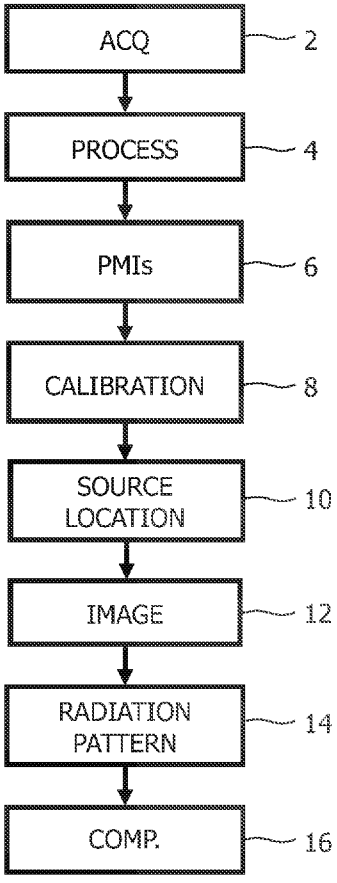


FIG. 1

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# NON INVASIVE ANALYSIS OF BODY SOUNDS

## FIELD OF THE INVENTION

The present invention concerns a method, a device and a system for analysing the sounds of body fluid flows.

In several organs of bodies, such as the human body, the fluid flows have distinctive sounds characteristics and the knowledge of those sounds characteristics provides important information to physicians for establishing diagnosis.

For example, heart murmurs or abnormal heart sounds are caused by turbulent blood flow through narrow or abnormally functioning valves.

## BACKGROUND OF THE INVENTION

Several existing techniques allow to acquire sounds from various locations of the body and to analyse them. This is the case for example in the patent document US 6,699,204-B1

However, the existing techniques focus on identifying the location of the origins of sound but fail to analyse other important distinctive characteristics.

More precisely, an important sound characteristic is the radiation of the sounds. To illustrate, a murmur of aortic stenosis would originate in the second interspace on the right of the sternum and may radiate to the carotid arteries. A murmur of mitral valve prolapse may radiate into the left axilla.

Today, the physicians must identify the sound radiation by manual auscultation using stethoscopes. Identifying the sound radiations is time consuming, leaves no medical record and depends essentially on the abilities and skills of the physician.

Accordingly, there is a need for a technique that would allow a better analysis of the sounds of the body fluid flows.

## SUMMARY OF THE INVENTION

To solve this problem, the invention relates to a method as recited in claim 1 for analysing the sounds of body fluid flows comprising simultaneously acquiring sounds from various locations of a body and determining characteristics of the fluid flows wherein determining characteristics comprises identifying the points of maximum sound intensity of the acquired sounds for each acquisition instant determining the source locations of the acquired sounds, and determining the sound radiation patterns of the acquired sounds.

The invention also relates to a device as recited in claim 8 for analysing the sound of body fluid flows comprising an input unit for receiving data corresponding to sounds simultaneously acquired from various locations of a body and an analysing unit for determining fluid flows characteristics wherein said analysing unit comprises means for identifying the points of maximum sound intensity for each acquisition instant, means for determining the source locations of the acquired sounds, and means for determining the sounds radiation patterns of the acquired sounds.

The invention also relates to a computer program performing said method and to a system including said device.

The invention provides a non invasive solution to analyse characteristics of the body fluid flows in more detail than the existing solutions and especially the sound radiation pattern.

## BRIEF DESCRIPTION OF THE DRAWINGS

Those and other features and advantages of the invention will become apparent upon reading the following description given only by the way of non limiting example, and offered with reference to the annexed figures. in which:

- Fig.1 represents a general flow chart of the process of the invention; and
- Fig.2 represents a schematic of the system of the invention.

## DETAILED DESCRIPTION OF THE INVENTION

The embodiment of the example relates to the acquisition of acoustic heart signals from the entire chest region of a human body, that is to say the analysis of the chest sounds.

The method of the invention will now described with reference to Fig.1.

The method starts by a simultaneous acquisition 2 of the sounds of body flows by an adapted array of sensors set on specific monitored areas of the body. For each acquisition instant, the sound level for each sensor is recorded.

The acquisition is followed by a processing step 4 during which the acquired signals are transformed in order to provide digital signals corresponding to the acquired sounds. In the described example, the output of the processing step is a table referencing the characteristics of the acquired sound for each sensor and for each acquisition instant.

Acquisition and processing of acoustic signals for body fluid flows is a well documented technique and will not be described in details.

The method then comprises identifying 6 the locations of the maximum sound intensity for each acquisition instant. Accordingly, through the array of sensors, a mapping of the locations of the points of maximal intensity (PMIs) is obtained for each acquisition instant.

Advantageously, the method comprises a calibration 8 during which radiation flows cycles and body regions are defined.

More precisely, in certain cases, such as for blood flows, body fluid flows present cyclic patterns. This is detected during the calibration by analysing several acquisition instants and identifying said cycles.

Similarly, body regions can be defined by the analysis of several acquisition instants by considering the repartition of the PMIs. In the described example of heart sounds monitoring, four primary regions of acquisition are defined, namely the aortic area, the pulmonic area, the mitral area and the tricuspid area.

The method then comprises determining 10 the locations of the sound sources. This sources locations determination is performed by processing several acquisition instants and the location of the maximum of several PMIs is determined as a source location.

Advantageously, a source location is determined for each body region.

From a practical point of view, in the embodiment described, the calibration and the determination of the source locations are performed simultaneously by use of a loop classification algorithm applied to the PMIs and converging over several acquisition instants.

The process then comprises creating 12 an instantaneous sound record with the source locations and the points of maximal intensity.

In the embodiment described, this record is formed as a digital image, also called snapshot or frame, graphically representing the source locations of the sounds and the points of maximal intensity. Advantageously other sound characteristics such as frequency, amplitude, duration or the like are also part of this image.

The method then comprises determining 14 the radiation pattern for the acquired sounds. In the embodiment described, this is performed by applying a tracking algorithm between consecutive images. Each image containing a distribution of the intensity of sounds, the processor computes how and where the sounds of each source radiate using image tracking algorithms applied to the PMIs associated with that source.

Advantageously, the heuristic that the acoustic signals usually radiate in particular patterns is used to refine and guide the tracking system to determine the radiation pattern of the acquired sounds. Reference radiation patterns are used to improve the determination.

At that stage, the process of the invention is able to provide both an instantaneous view of the source locations and points of maximum sound intensity as well as radiation patterns tracked over several consecutive images. In the embodiment described those elements are graphically provided to a physician through a display screen.

In the embodiment described, the method of the invention also comprises comparing 16 the acquired sounds and determined radiation patterns to references in an attempt to match the acquired sounds and radiation patterns to existing conditions. For example, the output of the comparison system is a correlation percentage identifying the match between the characteristics of the acquired sounds and the references.

The comparison allows a categorization of the etiology of the radiation by comparing its location, timing, duration and other characteristics to existing references.

This comparison provides a physician with a helpful insight on the diagnosis and assists the physician or the operator in the decision process. Furthermore, the information obtained does not depend upon the skills or abilities of the operator or of the physician and can be recorded for later use.

Accordingly, the invention describes a non invasive method for analysing the radiation patterns of body fluid flows and providing help for the diagnosis of medical conditions.

With reference to Fig.2, a system according to an embodiment of the invention is now described.

The system first comprises a sensor assembly 18 comprising an array of sound sensors which are, in the example, set on an inflatable wearable vest. The inflatable vest also comprises pressure means which are not represented. Those pressure means are used to apply, through the inflatable vest, a similar pressure to each sensor and to press the sensors towards the chest of the human body.

For example, the sensors are microphones or piezo-electric sensors. The distribution of the sensors is arranged so that the entire chest region is optimally covered.

The sensor assembly 18 performs the simultaneous acquisition 2 of sounds from the body fluid flows as described previously with reference to Fig.1. The sensor assembly 18 is connected to an analysing apparatus 20 which, in the example, is a dedicated device. In another embodiment, this analysing apparatus can be implemented as a mix of software and hardware in another electronic apparatus, such as for example a computer.

The analysing apparatus 20 first comprises an input stage 22 with appropriate amplifiers, band-pass filters, and analog to digital converters. Of course, the input stage 22 is

adapted to the actual sensors used in the sensor assembly 18. The input stage 22 performs the processing step 4 as described with reference to Fig.1.

The digital signals corresponding to the acquired sounds are then analysed by a processor 24.

The processor 24 first comprises a unit 26 for determining the points of maximum sound intensity or PMIs, as described with reference to step 6 of Fig.1. The processor 24 also comprises a unit 28 for determining the locations of the sources of the acquired sounds. As indicated with reference to Fig.1, in the embodiment described, the calibration 8 is performed through a converging determination 10 of the source locations. Accordingly, unit 28 performs both steps 8 and 10 as described with reference to Fig.1.

The output of units 28 and 26 are provided to an image determination unit 30. As described with reference to step 12, this image determination unit 30 provides digital images featuring the source locations of the sounds and the points of maximum sound intensity to a radiation pattern determination unit 32. The radiation pattern determination unit 32 performs the determination step 14 by tracking the points of maximum sound intensity for each source location over several frames.

Advantageously, the processor 24 also comprises a pattern comparing unit 34 for performing the comparison step 16 as described with reference to Fig.1.

Finally, in the described example, the processor 24 also comprises a display interface 36 for controlling a display screen 40 and displaying the frames, the radiation patterns and the results of the comparing unit to a physician or an operator.

Generally speaking the processor 24 is also connected to a memory unit 42 for storing the acquired sounds, the image data, the radiation patterns and any other final or intermediate result.

Of course many other embodiments of this system can be realized and the sensors, input stage, processing units, memory and display can be spread over several apparatus or combined.

In one embodiment, the sensors are digital wireless sensors connected to a wireless computer running a software program and using the computer screen and memory unit.

In such an embodiment, the method described above is performed by a computer program comprising instructions which are executed by a processor of a computer. This program is formed on a computer software medium.

In another embodiment, the sensors transmit their data to the processor through a telecommunication network such as the Internet to allow remote monitoring.

Of course, the invention can be used for other bodies than the human body and other fluid flows than the blood flows.

# CLAIMS

1. Method for analysing the sounds of body fluid flows comprising simultaneously acquiring (2) sounds from various locations of a body and determining characteristics of the fluid flows wherein determining characteristics comprises:

- identifying (6) the points of maximum sound intensity (PMIs) of the acquired sounds for each acquisition instant;
- determining (10) the source locations of the acquired sounds; and
- determining (12, 14) the sound radiation patterns of the acquired sounds.

2. Method according to claim 1, wherein determining (6) the source locations of the acquired sounds comprises analysing several acquisition instants and determining the maximum of several points of maximum sound intensity as a source location.

3. Method according to claim 2, further comprising defining (8) sound acquisition cycles and/or regions based on the periodicity and repartition of the points of maximum sound intensity.

4. Method according to anyone of claims 1 to 3, wherein determining the radiation patterns comprises:

- creating (12) a digital image for each acquisition instant of the points of maximum sound intensity; and
- tracking (14) the points of maximum sound intensity over several consecutive images to obtain said radiation patterns.

5. Method according to claim 4, wherein tracking the points of maximum sound intensity further comprises refining the radiation patterns by use of reference radiation patterns.

6. Method according to anyone of claims 1 to 5, further comprises comparing (16) the determined fluid flow characteristics with existing references and providing a match likelihood of the characteristics of the acquired sounds with said existing references.

7. Method according to anyone of claims 1 to 6, wherein said body fluid flows are human heart blood flows.

8. Device for analysing the sound of body fluid flows comprising an input unit for receiving data corresponding to sounds simultaneously acquired from various locations of a body and an analysing unit (24) for determining fluid flows characteristics wherein said analysing unit comprises:

- means (26) for identifying the points of maximum sound intensity (PMIs) for each acquisition instant;
- means (28) for determining the source locations of the acquired sounds; and
- means (30, 32) for determining the sounds radiation patterns of the acquired sounds.

9. System for analysing sounds of body fluid flows comprising a device according to claim 8 and a sensor assembly (18) adapted to simultaneously acquire sounds at various location of a body.

10. System according to claim 9, wherein said sensor assembly comprises sounds sensors mounted on an inflatable wearable vest for a human body, said sensors being connected to pressure regulation means adapted to apply the same pressure to each sensor.

11. Computer program product comprising a set of instructions which, when loaded in a memory of a device for analysing the sounds of body fluid flows, makes said device execute the steps of the method as claimed in any one of claims 1 to 7.

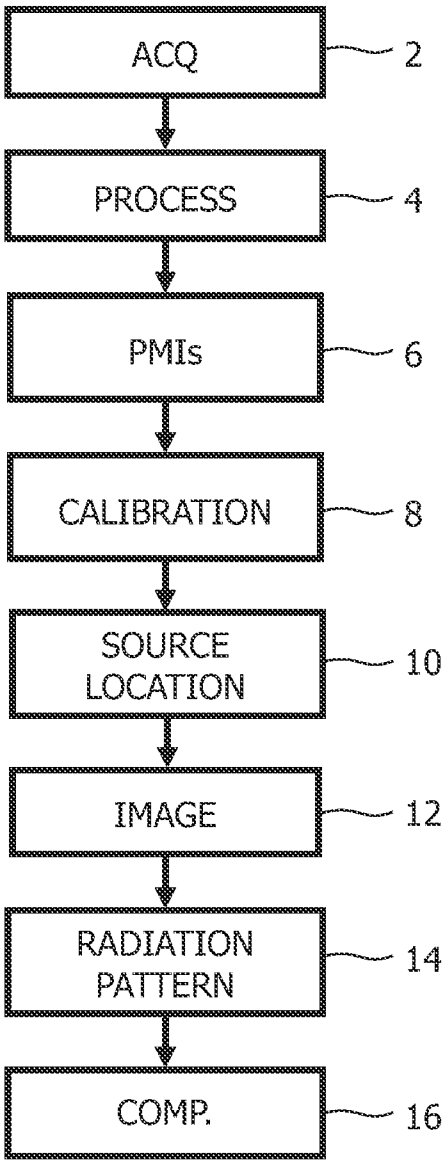
ACQ
2
PROCESS
4
PMIs
6
CALIBRATION
8
SOURCE LOCATION
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IMAGE
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RADIATION PATTERN
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COMP.
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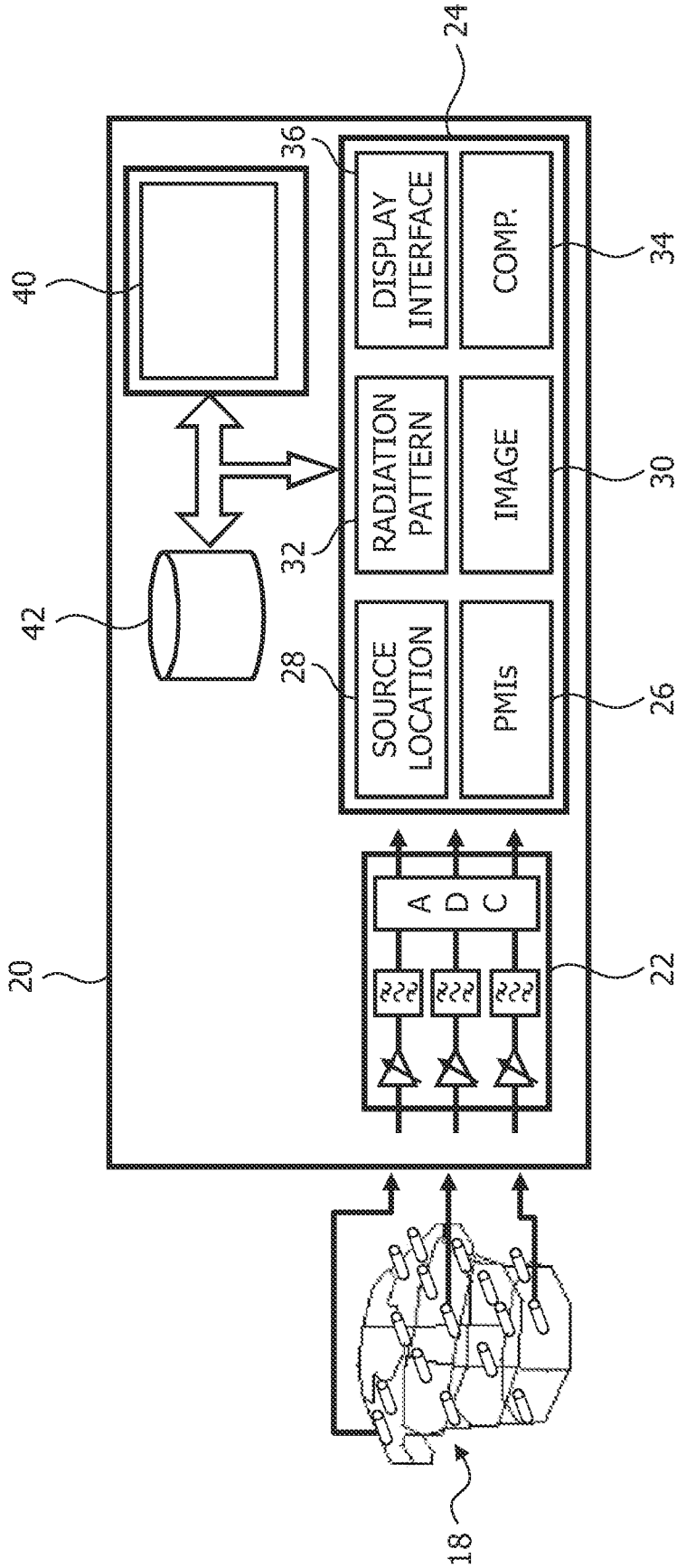
FIG. 1


24
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DISPLAY INTERFACE
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RADIATION PATTERN
IMAGE
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SOURCE LOCATION
PMIs
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FIG. 2

# INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/050860

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B7/02 A61B7/04

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 practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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

[X] See patent family annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 12 June 2009 | 23/06/2009 |

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

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International application No
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