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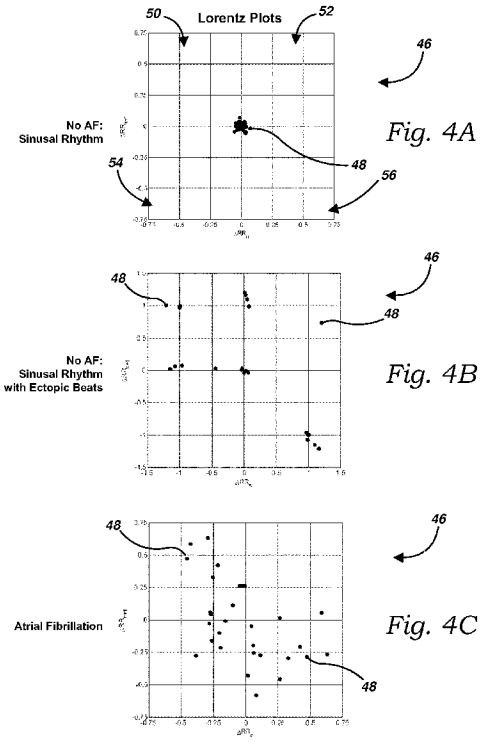

Fig. 4A

Fig. 4B

Fig. 4C

(57) Abstract: An atrial fibrillation detection system for analyzing and identifying atrial fibrillation signs of a user includes an at least one computing device configured for receiving and processing an at least one biosignal associated with heart activity of the user as captured by an at least one beat detector, and subsequently transmitting said processed at least one biosignal, as a plurality of sequence segments, making up an at least one interbeat interval sequence of the biosignal, to an at least one classifier configured for determining a probability of the at least one interbeat interval sequence of the biosignal being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm. A normalized histogram based on a two-dimensional Lorenz-plot is transmitted to the at least one classifier, e.g. to an artificial neural network.

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ATRIAL FIBRILLATION DETECTION SYSTEM AND METHODS OF USE

RELATED APPLICATIONS

[0001] This application claims priority and is entitled to the filing date of ES application number P201531775 – filed on December 7, 2015. The contents of the aforementioned application is incorporated by reference herein.

BACKGROUND

[0002] The subject of this patent application relates generally to atrial fibrillation, and more particularly to an atrial fibrillation detection system and associated methods of use configured for analyzing and identifying atrial fibrillation signs.

[0003] Applicant(s) hereby incorporate herein by reference any and all patents and published patent applications cited or referred to in this application.

[0004] By way of background, atrial fibrillation ("AF") is an abnormal heart rhythm characterized by rapid and irregular beating, often starting as brief periods of abnormal beating and becoming longer and possibly constant over time. AF is associated with an increased risk of heart failure, dementia, and stroke. It is one of the most, if not the most, commonly sustained forms of arrhythmia, increasing in prevalence with the age of patients; from 0.5% at 40–50 years of age, to 5–15% at 80 years of age. Men are more often affected than women. The lifetime risk of developing AF is roughly 25% in those who have reached the age of 40.

[0005] AF usually progresses from short, rare episodes, to longer and more frequent attacks. Clinically, different types of AF are distinguished, based on the presentation and duration of the arrhythmia. Paroxysmal AF consists of self-terminating episodes, usually shorter than 48 hours. Persistent AF is present when an AF episode either lasts longer than 7 days or requires termination by cardioversion (either pharmacological or electrical). Long-standing persistent AF is considered so when it has lasted for more than 1 year. Permanent AF is said to exist when the presence of the arrhythmia is accepted both by the patient and the physician. In general terms, a patient is usually diagnosed from paroxysmal AF and as time goes on it will evolve to sustained forms of AF. The distribution of paroxysmal AF recurrences is not random, but clustered, and AF burden (the time ratio with and without AF) can vary markedly over months or even years in individual patients. Asymptomatic AF (silent AF) is common even in

symptomatic patients, irrespective of whether the initial presentation was persistent or paroxysmal.

[0006] Rapid and irregular heart rates may be perceived as palpitations or exercise intolerance and occasionally may produce anginal chest pain (if the high heart rate causes ischemia). Other possible symptoms include congestive symptoms such as shortness of breath or swelling. The arrhythmia is sometimes only identified with the onset of a stroke or a transient ischemic attack ("TIA"). Additionally, AF episodes can self-terminate and the triggering situations of a new episode are not easily predictable. As such, it is not uncommon for a patient to first become aware of AF from a routine physical examination or ECG, as it often does not cause symptoms. It has been estimated that 7-day continuous ECG monitoring may document the arrhythmia in approximately 70% of AF patients. To process these long-term ECG signals, either real-time or offline, AF detection algorithms are needed. Thus, there is a need for systems and methods capable of detecting AF signs (i.e., able to distinguish between AF and non-AF rhythms) as early and accurately as possible, so that such patients may be promptly diagnosed and treated in order to effectively control the disease.

[0007] Aspects of the present invention fulfill these needs and provide further related advantages as described in the following summary.

SUMMARY

[0008] Aspects of the present invention teach certain benefits in construction and use which give rise to the exemplary advantages described below.

[0009] The present invention solves the problems described above by providing an atrial fibrillation detection system and associated methods of use are disclosed for analyzing and identifying atrial fibrillation signs of a user. In at least one embodiment, the system includes an at least one computing device configured for receiving and processing an at least one biosignal associated with heart activity of the user as captured by an at least one beat detector, and subsequently transmitting said processed at least one biosignal, as a plurality of sequence segments, making up an at least one interbeat interval sequence of the biosignal, to an at least one classifier configured for determining a probability of the at least one interbeat interval sequence of the biosignal being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm. Upon receiving the at least one biosignal from the at least one beat detector, the at least one computing device is further configured for representing each of an at least one beat of the biosignal with an univocal and repeatable point. An interbeat interval between each of the at least one beat and an immediately preceding beat of the biosignal is calculated. An at least one interbeat interval sequence is generated consisting of consecutive interbeat intervals of the

biosignal. The interbeat interval sequence is divided into a plurality of finite sequence segments of a pre-defined temporal length consisting of consecutive interbeat intervals of the interbeat interval sequence. For each sequence segment, said sequence segment is encoded by generating a scatter plot that represents the dispersion of data associated with the interbeat interval sequence. The scatter plot is encoded by generating a histogram that represents an amount of plot points plotted in each particular region of the scatter plot. The histogram is normalized by dividing a bin count of each bin by the total sum of plot points in the scatter plot. The normalized histogram is transmitted to an at least one classifier in selective communication with the at least one computing device, where a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm is determined.

[0010] Other features and advantages of aspects of the present invention will become apparent from the following more detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of aspects of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying drawings illustrate aspects of the present invention. In such drawings:

[0012] Figure 1 is a simplified schematic view of an exemplary atrial fibrillation detection system, in accordance with at least one embodiment;

[0013] Figure 2 is a flow diagram of an exemplary method for analyzing and identifying atrial fibrillation signs, in accordance with at least one embodiment;

[0014] Figure 3A is a schematic of an exemplary biosignal captured by an at least one beat detector of the exemplary atrial fibrillation detection system, in accordance with at least one embodiment;

[0015] Figure 3B is an illustration of an exemplary interbeat interval sequence, in accordance with at least one embodiment;

[0016] Figures 4A-4C are illustrations of exemplary Lorentz plots of sequence segments of exemplary interbeat interval sequences, plotted on a two-dimensional graph, in accordance with at least one embodiment;

[0017] Figures 5A-5C are illustrations of exemplary histograms of the sequence segments of Figs. 4A-4C, respectively, plotted on a three-dimensional graph, in accordance with at least one embodiment; and

[0018] Figures 6A-6C are illustrations of exemplary matrix views of the normalized histograms of Figs. 5A-5C, respectively, in accordance with at least one embodiment.

[0019] The above described drawing figures illustrate aspects of the invention in at least one of its exemplary embodiments, which are further defined in detail in the following description. Features, elements, and aspects of the invention that are referenced by the same numerals in different figures represent the same, equivalent, or similar features, elements, or aspects, in accordance with one or more embodiments.

DETAILED DESCRIPTION

[0020] Turning now to Fig. 1, there is shown a simplified schematic view of an exemplary atrial fibrillation detection system **20**. The system **20** provides, in at least one embodiment, an at least one computing device **22** configured for receiving and processing select data obtained by an at least one beat detector **24** – such as an electrocardiogram ("ECG") device, for example (though any other type of device, sensor or combination thereof, now known or later developed, capable of substantially carrying out the functionality described herein may be substituted) – positioned and configured for obtaining biosignal data related to a user's heart activity (i.e., electrical activity of the user's heart). Accordingly, in at least one embodiment, the computing device **22** is in selective communication with the beat detector **24**. In at least one embodiment, the computing device **22** and the beat detector **24** are one and the same – as such, it is intended that those terms as used herein are to be interchangeable with one another. Additionally, in at least one embodiment, an at least one classifier **26** – such as an artificial neural network ("ANN"), for example (though any other type of device, system or combination thereof, now known or later developed, capable of substantially carrying out the functionality described herein may be substituted) – is in selective communication with the computing device **22** and configured for analyzing said data obtained by the at least one beat detector **24** and processed by the computing device **22**, as discussed in detail below. In at least one embodiment, the computing device **22** and the classifier **26** are also one and the same – as such, it is intended that those terms as used herein are to be interchangeable with one another. Additionally, in at least one embodiment, an at least one data storage device **28** is in selective communication with the computing device **22** and configured for storing said data obtained by the beat detector **24**, processed by the computing device **22**, and analyzed by the classifier **26**, along with certain other data as discussed further below. In at least one embodiment, the

computing device **22** and data storage device **28** are also one and the same – as such, it is intended that those terms as used herein are to be interchangeable with one another.

[0021] At the outset, it should be noted that communication between each of the at least one computing device **22**, at least one beat detector **24**, at least one classifier **26**, and at least one data storage device **28** may be achieved using any wired- or wireless-based communication protocol (or combination of protocols) now known or later developed. As such, the present invention should not be read as being limited to any one particular type of communication protocol, even though certain exemplary protocols may be mentioned herein for illustrative purposes. It should also be noted that the term "computing device" is intended to include any type of computing or electronic device, now known or later developed, capable of substantially carrying out the functionality described herein – such as desktop computers, mobile phones, smartphones, laptop computers, tablet computers, personal data assistants, gaming devices, wearable devices, etc. As such, the system **20** should not be read as being limited to use with any one particular type of computing or electronic device, even though certain exemplary devices may be mentioned or shown herein for illustrative purposes.

[0022] With continued reference to Fig. 1, in at least one embodiment, the at least one beat detector **24** is positioned on a wearable device, such as garment or other accessory being worn by the user, such as described in at least U.S. Patent Application Publication No. 2013/0338472, the contents of which are hereby incorporated herein by reference. In still further embodiments, the at least one beat detector **24** may be appropriately positioned in contact with (or proximal to) the user using any other means now known or later developed. Again, in further embodiments, the at least one beat detector **24** may be any other type of device, sensor or combination thereof, now known or later developed, capable of substantially carrying out the functionality described herein. In at least one embodiment, the computing device **22** is also removably engagable with the user – either directly with the user's body or with a wearable device, such as a garment or other accessory being worn by the user. In at least one such embodiment, the beat detector **24** is positioned within the computing device **22**. In an alternate embodiment, the computing device **22** is positioned elsewhere – either still local to the user or remotely, or even divided, with some of the functional units implemented in a computing device **22** local to the user and other units implemented in remote computer work stations.

[0023] In at least one embodiment, the computing device **22** contains the hardware and software necessary to carry out the exemplary methods for analyzing and identifying atrial fibrillation signs, as described herein. Furthermore, in at least one embodiment, the computing device **22** comprises a plurality of computing devices selectively working in concert with one

another to carry out the exemplary methods analyzing and identifying atrial fibrillation signs, as described herein. In at least one embodiment, the computing device **22** provides a user application **30** residing locally in memory **32** on the computing device **22**, the user application **30** being configured for selectively communicating with each of the at least one beat detector **24** and classifier **26**, as discussed further below. It should be noted that the term "memory" is intended to include any type of electronic storage medium (or combination of storage mediums) now known or later developed, such as local hard drives, RAM, flash memory, secure digital ("SD") cards, external storage devices, network or cloud storage devices, integrated circuits, etc. In at least one embodiment, the computing device **22** provides an at least one display screen **34** configured for displaying the atrial fibrillation data, as discussed in detail below. In at least one such embodiment, the display screen **34** is a touchscreen.

[0024] In use, in at least one embodiment, the system **20** is capable of analyzing and identifying atrial fibrillation signs in users/patients – particularly, distinguishing between AF and non-AF rhythms – using information contained in a biosignal **36** associated with heart activity of the user (such as an ECG sequence, for example). In at least one embodiment, as illustrated in the flow diagram of Fig. 2, and as further illustrated in the exemplary schematic of Fig. 3A, a biosignal **36** associated with heart activity of the user is captured by the at least one beat detector **24** (**202**) and transmitted to the user application **30** of the computing device **22** (**204**). In at least one such embodiment, where the beat detector **24** is an ECG sensor or the like, the beat detector **24** senses and transmits raw ECG data, as the biosignal **36**, to the computing device **22**. In at least one embodiment, the user application **30** represents each of an at least one beat **38** of the biosignal **36** with an univocal and repeatable point **40** (**206**). In at least one such embodiment, the user application **30** selects the point **40** having a maximum absolute derivative value among the biosignal **36**. In at least one further embodiment, other repeatable points **40** could be selected by the user application **30**, such as an R-peak value or a maximum negative/positive derivative value for example.

[0025] With continued referenced to Figs. 2 and 3A, in at least one embodiment, the user application **30** calculates an interbeat interval **42** ("RR_n") between each of the at least one beat **38** ("t_n") and an immediately preceding beat **38** ("t_{n-1}") of the biosignal **36** (**208**). In at least one such embodiment, the user application **30** uses the following formula: $RR_n = t_n - t_{n-1}$, where t_n represents a timestamp of a current beat **38** n. In at least one embodiment, no processing is performed to smooth the biosignal **36** or remove any ectopic activity.

[0026] With continued reference to Figs. 2 and 3A, and as further illustrated in Fig. 3B, in at least one embodiment, the user application **30** generates an at least one interbeat interval sequence **43** consisting of consecutive interbeat intervals **42** of the biosignal **36** (**210**). In at

least one embodiment, the user application **30** divides the interbeat interval sequence **43** into a plurality of finite sequence segments **44** of a pre-defined temporal length **L**, consisting of consecutive interbeat intervals **42** of the interbeat interval sequence **43** and, in turn, the biosignal **36** (**212**). For example, in the exemplary embodiment, each sequence segment **44** has a length **L** of thirty (30) seconds. However, in further embodiments, any other length **L** deemed appropriate under the circumstances may be substituted without departing from the spirit or scope of the present invention. The user application **30** then encodes each sequence segment **44** by generating a two-dimensional scatter plot **46** that represents the dispersion of data associated with the interbeat interval sequence **43**.

[0027] In a bit more detail and with continued reference to Fig. 2, in at least one embodiment, the user application **30** calculates an interbeat interval difference ("ΔRR_n") between each of the at least one interbeat interval **42** ("RR_{n+1}") and an immediately preceding interbeat interval **42** ("RR_n") of the sequence segment **44** (**214**). In at least one such embodiment, the user application **30** uses the following formula: $\Delta RR_n = RR_{n+1} - RR_n$. In at least one embodiment, the user application **30** then encodes an uncorrelated nature of three consecutive interbeat interval differences as a plot point **48** on the scatter plot **46** (**216**), being a point defined as by the pair (ΔRR_n, ΔRR_{n+1}). In at least one such embodiment, as illustrated in Figs. 4A-4C, the scatter plot **46** is a Lorentz plot. For example, if three consecutive interbeat interval differences are very similar, the corresponding plot point **48** will be near *(0,0)* on the scatter plot **46**; for a short-medium-iong sequence of three consecutive interbeat interval differences, the plot point **48** will be in a first quadrant **50** of the scatter plot **46**; for a long-short-long sequence of three consecutive interbeat interval differences, the plot point **48** will be in a second quadrant **52** of the scatter plot **46**; for a long-medium-short sequence of three consecutive interbeat interval differences, the plot point **48** will be in a third quadrant **54** of the scatter plot **46**; and for a short-long-short sequence of three consecutive interbeat interval differences, the plot point **48** will be in a fourth quadrant **56** of the scatter plot **46**. For illustrative purposes, Fig. 4A depicts an exemplary scatter plot **46** representing a sequence segment **44** having a length **L** of approximately thirty (30) seconds and containing a non-AF sinusal rhythm, Fig. 4B depicts a further exemplary scatter plot **46** representing a sequence segment **44** having a length **L** of approximately thirty (30) seconds and containing a non-AF sinusal rhythm with ectopic beats, and Fig. 4C depicts a still further exemplary scatter plot representing a sequence segment **44** having a length **L** of approximately thirty (30) seconds and containing an atrial fibrillation rhythm. It should be noted that in further embodiments, any other method of generating a dispersion or scatter plot **46** of the sequence segment **44**, now known or later developed, may be substituted so long as such methods are capable of substantially carrying out the functionality described herein.

[0028] With continued reference to Fig. 2, in at least one embodiment, the user application **30** next encodes each scatter plot **46** by generating a histogram **58** (either two-dimensional or three-dimensional) that represents an amount of plot points **48** plotted in each particular region of the scatter plot **46** (**218**). In at least one embodiment, the histogram **58** contains a pre-defined number of bins **60**, with the bins **60** each having a pre-defined bin width **W**. In at least one such embodiment, the histogram **58** contains forty-nine (49) bins **60**, with each bin **60** having a bin width **W** of 150 milliseconds ("ms"). Additionally, in at least one such embodiment, the bins **60** are arranged in a matrix – such as a 7x7 matrix where the histogram **58** contains forty-nine (49) bins **60** – as illustrated in Figs. 5A-5C, which respectively continue the illustratives of Figs. 4A-4C. In an alternate embodiment, the bins **60** are arranged in an array – such as an array of forty-nine (49) integers where the histogram **58** contains forty-nine (49) bins **60**. In further embodiments, any other number of bins **60** and/or bin widths **W** deemed appropriate under the circumstances may be substituted without departing from the spirit or scope of the present invention.

[0029] With continued reference to Fig. 2, in at least one embodiment, the user application **30** next normalizes the histogram **58** by dividing a bin count of each bin **60** by the total sum of plot points **48** in the scatter plot **46** (**220**) – as illustrated in Figs. 6A-6C, which respectively continue the illustratives of Figs. 4A-4C and 5A-5C. The normalized histogram **62** represents the sequence of interbeat interval differences of the consecutive interbeat intervals **42** that make up the sequence segment **44** of the interbeat interval sequence **43**. In at least one embodiment, the user application **30** transmits the normalized histogram **62** to the at least one classifier **26** (**222**) which, in turn, analyzes the normalized histogram **62** to determine a probability of the sequence segment **44** of the interbeat interval sequence **43** (and, in turn, the associated portion of the biosignal **36**) being an atrial fibrillation rhythm or non-AF rhythm (**224**). In at least one embodiment, if the classifier **26** determines that the probability of the sequence segment **44** being an atrial fibrillation rhythm is relatively greater than the probability of the sequence segment **44** being a non-AF rhythm, the user application **30** concludes that sequence segment **44** is an atrial fibrillation rhythm (**226**). Similarly, if the classifier **26** determines that the probability of the sequence segment **44** being a non-AF rhythm is relatively greater than the probability of the sequence segment **44** being an atrial fibrillation rhythm, the user application **30** concludes that the sequence segment **44** is a non-AF rhythm (**228**).

[0030] In at least one embodiment, as mentioned above, the classifier **26** is an artificial neural network ("ANN"). Additionally, the classifier **26** must be trained prior to performing the above-described method. In at least one such embodiment, the classifier **26** contains, or

otherwise has access to, a database of a sufficient number of labeled instances of interbeat interval sequences **43** substantially representing an entire universe of possible rhythms – such as the MIT-BIH Atrial Fibrillation Database ("AFDB") and/or MIT-BIH Arrhythmia Database ("MITDB") for example – which allows the classifier **26** to automatically learn the inner rules that govern decisions. In at least one embodiment, the ANN uses rectified linear unit ("ReLU") hidden networks, softmax activation function for output neurons, and dropout and max-norm regularization in order to optimize the performance of the classifier **26**. However, in further embodiments, any other type of ANN and/or ANN modifications, now known or later developed, may be substituted. In still further embodiments, rather than being an ANN, the classifier **26** may comprise any other type of device, system or combination thereof, now known or later developed, capable of substantially carrying out the functionality described herein.

[0031] Thus, in at least one embodiment, the classifier **26** is able to distinguish between AF and non-AF rhythms using the information contained in a thirty (30) second sequence segment **44** of the interbeat interval sequence **43** of a biosignal **36**. As a result, in at least one such embodiment, every detected beat should be considered and no morphology assessment should be needed in order to eliminate ectopic beats that can potentially be confused with an AF rhythm. In this way, the system **20** is capable of being integrated in any beat analysis system (including ECG analysis systems) that performs beat detection, such as implantable or external cardiac monitors or offline analysis platforms such as Holter analysis software.

[0032] Aspects of the present specification may also be described as follows:

[0033] 1. A method for analyzing and identifying atrial fibrillation signs of a user, the method comprising the steps of: transmitting to an at least one computing device an at least one biosignal associated with heart activity of the user as captured by an at least one beat detector; representing each of an at least one beat of the biosignal with an univocal and repeatable point; calculating an interbeat interval between each of the at least one beat and an immediately preceding beat of the biosignal; generating an at least one interbeat interval sequence consisting of consecutive interbeat intervals of the biosignal; dividing the interbeat interval sequence into a plurality of finite sequence segments of a pre-defined temporal length consisting of consecutive interbeat intervals of the interbeat interval sequence; and for each sequence segment: encoding said sequence segment by generating a scatter plot that represents the dispersion of data associated with the interbeat interval sequence; encoding the scatter plot by generating a histogram that represents an amount of plot points plotted in each particular region of the scatter plot; normalizing the histogram by dividing a bin count of each bin by the total sum of plot points in the scatter plot; transmitting the normalized histogram to an at least one classifier in selective communication with the at least one computing device;

and determining, via the classifier, a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm.

[0034] 2. The method according to embodiment 1, wherein the step of representing each of the at least one beat of the biosignal with an univocal and repeatable point, further comprises the step of selecting a one of the points having a maximum absolute derivative value among the biosignal.

[0035] 3. The method according to embodiments 1-2, wherein the step of dividing the interbeat interval sequence into a plurality of finite sequence segments of a pre-defined temporal length, further comprises the step of dividing the interbeat interval sequence into a plurality of finite sequence segments each having a length of thirty seconds.

[0036] 4. The method according to embodiments 1-3, wherein the step of encoding said sequence segment by generating a scatter plot, further comprises the step of encoding said sequence segment by generating a two-dimensional scatter plot.

[0037] 5. The method according to embodiments 1-4, wherein the step of encoding said sequence segment by generating a two-dimensional scatter plot, further comprises the steps of: calculating an interbeat interval difference between each of the at least one interbeat interval and an immediately preceding interbeat interval of said sequence segment; and encoding an uncorrelated nature of three consecutive interbeat interval differences as a plot point on the scatter plot.

[0038] 6. The method according to embodiments 1-5, wherein the step of encoding said sequence segment by generating a two-dimensional scatter plot, further comprises the step of encoding said sequence segment by generating a two-dimensional Lorentz plot.

[0039] 7. The method according to embodiments 1-6, wherein the step of encoding the scatter plot by generating a histogram, further comprises the step of generating a two-dimensional histogram that represents an amount of plot points plotted in each particular region of the scatter plot.

[0040] 8. The method according to embodiments 1-7, wherein the step of encoding the scatter plot by generating a histogram, further comprises the step of generating a three-dimensional histogram that represents an amount of plot points plotted in each particular region of the scatter plot.

[0041] 9. The method according to embodiments 1-8, wherein the step of generating a histogram further comprises the step of generating a histogram containing a pre-defined number of bins, with the bins each having a pre-defined bin width.

[0042] 10. The method according to embodiments 1-9, further comprising the step of generating a histogram containing forty-nine bins, with each bin having a bin width of 150 milliseconds.

[0043] 11. The method according to embodiments 1-10, further comprising the step of arranging the bins in a matrix.

[0044] 12. The method according to embodiments 1-11, further comprising the step of arranging the bins in an array.

[0045] 13. The method according to embodiments 1-12, wherein the step of transmitting the normalized histogram to an at least one classifier, further comprises the step of transmitting the normalized histogram to an at least one artificial neural network trained for analyzing the normalized histogram.

[0046] 14. The method according to embodiments 1-13, wherein the step of determining, via the classifier, a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm, further comprises the steps of: upon the classifier determining that the probability of said sequence segment being an atrial fibrillation rhythm is relatively greater than the probability of said sequence segment being a non-atrial fibrillation rhythm, concluding that said sequence segment is an atrial fibrillation rhythm; and upon the classifier determining that the probability of said sequence segment being a non-atrial fibrillation rhythm is relatively greater than the probability of said sequence segment being an atrial fibrillation rhythm, concluding that said sequence segment is a non-atrial fibrillation rhythm.

[0047] 15. The method according to embodiments 1-14, further comprising the step of implementing an at least one data storage device in selective communication with the at least one computing device and configured for storing data captured by the at least one beat detector, processed by the at least one computing device, and analyzed by the at least one classifier.

[0048] 16. The method according to embodiments 1-15, further comprising the step of positioning the at least one beat detector on a wearable device worn by the user.

[0049] 17. The method according to embodiments 1-16, wherein the step of positioning the at least one beat detector further comprises the step of positioning an at least one electrocardiogram device on the wearable device worn by the user.

[0050] 18. A method for analyzing and identifying atrial fibrillation signs of a user, the method comprising the steps of: transmitting to an at least one computing device an at least one biosignal associated with heart activity of the user as captured by an at least one beat detector; representing each of an at least one beat of the biosignal with an univocal and repeatable point; calculating an interbeat interval between each of the at least one beat and an immediately preceding beat of the biosignal; generating an at least one interbeat interval sequence consisting of consecutive interbeat intervals of the biosignal; dividing the interbeat interval sequence into a plurality of finite sequence segments of a pre-defined temporal length consisting of consecutive interbeat intervals of the interbeat interval sequence; and for each sequence segment: calculating an interbeat interval difference between each of the at least one interbeat interval and an immediately preceding interbeat interval of said sequence segment; encoding an uncorrelated nature of three consecutive interbeat interval differences as a plot point on a scatter plot; encoding the scatter plot by generating a histogram that represents an amount of plot points plotted in each particular region of the scatter plot, the histogram containing a pre-defined number of bins, with each bin having a pre-defined bin width; normalizing the histogram by dividing a bin count of each bin by the total sum of plot points in the scatter plot; transmitting the normalized histogram to an at least one classifier in selective communication with the at least one computing device; and determining, via the classifier, a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm.

[0051] 19. An atrial fibrillation detection system for analyzing and identifying atrial fibrillation signs of a user, the system comprising: an at least one computing device configured for receiving and processing an at least one biosignal associated with heart activity of the user as captured by an at least one beat detector, and subsequently transmitting said processed at least one biosignal to an at least one classifier configured for determining a probability of the biosignal being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm; wherein, upon receiving the at least one biosignal from the at least one beat detector, the at least one computing device is further configured for: representing each of an at least one beat of the biosignal with an univocal and repeatable point; calculating an interbeat interval between each of the at least one beat and an immediately preceding beat of the biosignal; generating an at least one interbeat interval sequence consisting of consecutive interbeat intervals of the biosignal; dividing the interbeat interval sequence into a plurality of finite sequence segments of a pre-defined temporal length consisting of consecutive interbeat intervals of the interbeat interval sequence; and for each sequence segment: encoding said sequence segment by generating a scatter plot that represents the dispersion of data associated with the interbeat interval sequence; encoding the scatter plot by generating a histogram that represents an

amount of plot points plotted in each particular region of the scatter plot; normalizing the histogram by dividing a bin count of each bin by the total sum of plot points in the scatter plot; transmitting the normalized histogram to an at least one classifier in selective communication with the at least one computing device; and determining, via the classifier, a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm.

[0052] 20. The atrial fibrillation detection system according to embodiment 19, wherein while representing each of the at least one beat of the biosignal with an univocal and repeatable point, the computing device is further configured for selecting a one of the points having a maximum absolute derivative value among the biosignal.

[0053] 21. The atrial fibrillation detection system according to embodiments 19-20, wherein each of the sequence segments has a length of thirty seconds.

[0054] 22. The atrial fibrillation detection system according to embodiments 19-21, wherein the scatter plot is a two-dimensional scatter plot.

[0055] 23. The atrial fibrillation detection system according to embodiments 19-22, wherein the computing device is further configured for: calculating an interbeat interval difference between each of the at least one interbeat interval and an immediately preceding interbeat interval of said sequence segment ; and encoding an uncorrelated nature of three consecutive interbeat interval differences as a plot point on the scatter plot.

[0056] 24. The atrial fibrillation detection system according to embodiments 19-23, wherein the two-dimensional scatter plot is a Lorentz plot.

[0057] 25. The atrial fibrillation detection system according to embodiments 19-24, wherein the histogram is a two-dimensional histogram.

[0058] 26. The atrial fibrillation detection system according to embodiments 19-25, wherein the histogram is a three-dimensional histogram.

[0059] 27. The atrial fibrillation detection system according to embodiments 19-26, wherein the histogram contains a pre-defined number of bins, with the bins each having a pre-defined bin width.

[0060] 28. The atrial fibrillation detection system according to embodiments 19-27, wherein the histogram contains forty-nine bins, with each bin having a bin width of 150 milliseconds.

[0061] 29. The atrial fibrillation detection system according to embodiments 19-28, wherein the bins of the histogram are arranged in a matrix.

[0062] 30. The atrial fibrillation detection system according to embodiments 19-29, wherein the bins of the histogram are arranged in an array.

[0063] 31. The atrial fibrillation detection system according to embodiments 19-30, wherein the at least one classifier is an artificial neural network trained for analyzing the normalized histogram.

[0064] 32. The atrial fibrillation detection system according to embodiments 19-31, wherein the artificial neural network uses rectified linear unit hidden networks, softmax activation function for output neurons, and dropout and max-norm regularization in order to optimize the performance of the classifier.

[0065] 33. The atrial fibrillation detection system according to embodiments 19-32, wherein while determining, via the classifier, a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm, the computing device is further configured for: upon the classifier determining that the probability of said sequence segment being an atrial fibrillation rhythm is relatively greater than the probability of said sequence segment being a non-atrial fibrillation rhythm, concluding that said sequence segment is an atrial fibrillation rhythm; and upon the classifier determining that the probability of said sequence segment being a non-atrial fibrillation rhythm is relatively greater than the probability of said sequence segment being an atrial fibrillation rhythm, concluding that said sequence segment is a non-atrial fibrillation rhythm.

[0066] 34. The atrial fibrillation detection system according to embodiments 19-33, further comprising an at least one data storage device in selective communication with the at least one computing device and configured for storing data captured by the at least one beat detector, processed by the at least one computing device, and analyzed by the at least one classifier.

[0067] 35. The atrial fibrillation detection system according to embodiments 19-34, wherein the at least one beat detector is an electrocardiogram device.

[0068] 36. The atrial fibrillation detection system according to embodiments 19-35, wherein the at least one beat detector is positionable on a wearable device worn by the user.

[0069] In closing, regarding the exemplary embodiments of the present invention as shown and described herein, it will be appreciated that an atrial fibrillation detection system and associated methods of use are disclosed and configured for analyzing and identifying atrial fibrillation signs. Because the principles of the invention may be practiced in a number of configurations beyond those shown and described, it is to be understood that the invention is

not in any way limited by the exemplary embodiments, but is generally directed to an atrial fibrillation detection system and is able to take numerous forms to do so without departing from the spirit and scope of the invention. It will also be appreciated by those skilled in the art that the present invention is not limited to the particular geometries and materials of construction disclosed, but may instead entail other functionally comparable structures or materials, now known or later developed, without departing from the spirit and scope of the invention.

[0070] Certain embodiments of the present invention are described herein, including the best mode known to the inventor(s) for carrying out the invention. Of course, variations on these described embodiments will become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventor(s) expect skilled artisans to employ such variations as appropriate, and the inventor(s) intend for the present invention to be practiced otherwise than specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described embodiments in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

[0071] Groupings of alternative embodiments, elements, or steps of the present invention are not to be construed as limitations. Each group member may be referred to and claimed individually or in any combination with other group members disclosed herein. It is anticipated that one or more members of a group may be included in, or deleted from, a group for reasons of convenience and/or patentability. When any such inclusion or deletion occurs, the specification is deemed to contain the group as modified thus fulfilling the written description of all Markush groups used in the appended claims.

[0072] Unless otherwise indicated, all numbers expressing a characteristic, item, quantity, parameter, property, term, and so forth used in the present specification and claims are to be understood as being modified in all instances by the term "about." As used herein, the term "about" means that the characteristic, item, quantity, parameter, property, or term so qualified encompasses a range of plus or minus ten percent above and below the value of the stated characteristic, item, quantity, parameter, property, or term. Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and attached claims are approximations that may vary. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical indication should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and values setting forth the broad scope of the invention are approximations, the numerical ranges and values set forth in

the specific examples are reported as precisely as possible. Any numerical range or value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. Recitation of numerical ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate numerical value falling within the range. Unless otherwise indicated herein, each individual value of a numerical range is incorporated into the present specification as if it were individually recited herein.

[0073] Use of the terms "may" or "can" in reference to an embodiment or aspect of an embodiment also carries with it the alternative meaning of "may not" or "cannot." As such, if the present specification discloses that an embodiment or an aspect of an embodiment may be or can be included as part of the inventive subject matter, then the negative limitation or exclusionary proviso is also explicitly meant, meaning that an embodiment or an aspect of an embodiment may not be or cannot be included as part of the inventive subject matter. In a similar manner, use of the term "optionally" in reference to an embodiment or aspect of an embodiment means that such embodiment or aspect of the embodiment may be included as part of the inventive subject matter or may not be included as part of the inventive subject matter. Whether such a negative limitation or exclusionary proviso applies will be based on whether the negative limitation or exclusionary proviso is recited in the claimed subject matter.

[0074] The terms "a," "an," "the" and similar references used in the context of describing the present invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Further, ordinal indicators – such as "first," "second," "third," etc. – for identified elements are used to distinguish between the elements, and do not indicate or imply a required or limited number of such elements, and do not indicate a particular position or order of such elements unless otherwise specifically stated. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., "such as") provided herein is intended merely to better illuminate the present invention and does not pose a limitation on the scope of the invention otherwise claimed. No language in the present specification should be construed as indicating any non-claimed element essential to the practice of the invention.

[0075] When used in the claims, whether as filed or added per amendment, the open-ended transitional term "comprising" (along with equivalent open-ended transitional phrases thereof such as "including," "containing" and "having") encompasses all the expressly recited elements, limitations, steps and/or features alone or in combination with un-recited subject matter; the named elements, limitations and/or features are essential, but other unnamed elements,

limitations and/or features may be added and still form a construct within the scope of the claim. Specific embodiments disclosed herein may be further limited in the claims using the closed-ended transitional phrases "consisting of" or "consisting essentially of" in lieu of or as an amendment for "comprising." When used in the claims, whether as filed or added per amendment, the closed-ended transitional phrase "consisting of" excludes any element, limitation, step, or feature not expressly recited in the claims. The closed-ended transitional phrase "consisting essentially of" limits the scope of a claim to the expressly recited elements, limitations, steps and/or features and any other elements, limitations, steps and/or features that do not materially affect the basic and novel characteristic(s) of the claimed subject matter. Thus, the meaning of the open-ended transitional phrase "comprising" is being defined as encompassing all the specifically recited elements, limitations, steps and/or features as well as any optional, additional unspecified ones. The meaning of the closed-ended transitional phrase "consisting of" is being defined as only including those elements, limitations, steps and/or features specifically recited in the claim, whereas the meaning of the closed-ended transitional phrase "consisting essentially of" is being defined as only including those elements, limitations, steps and/or features specifically recited in the claim and those elements, limitations, steps and/or features that do not materially affect the basic and novel characteristic(s) of the claimed subject matter. Therefore, the open-ended transitional phrase "comprising" (along with equivalent open-ended transitional phrases thereof) includes within its meaning, as a limiting case, claimed subject matter specified by the closed-ended transitional phrases "consisting of" or "consisting essentially of." As such, embodiments described herein or so claimed with the phrase "comprising" are expressly or inherently unambiguously described, enabled and supported herein for the phrases "consisting essentially of" and "consisting of."

[0076] All patents, patent publications, and other publications referenced and identified in the present specification are individually and expressly incorporated herein by reference in their entirety for the purpose of describing and disclosing, for example, the compositions and methodologies described in such publications that might be used in connection with the present invention. These publications are provided solely for their disclosure prior to the filing date of the present application. Nothing in this regard should be construed as an admission that the inventors are not entitled to antedate such disclosure by virtue of prior invention or for any other reason. All statements as to the date or representation as to the contents of these documents is based on the information available to the applicants and does not constitute any admission as to the correctness of the dates or contents of these documents.

[0077] It should be understood that the logic code, programs, modules, processes, methods, and the order in which the respective elements of each method are performed are purely exemplary. Depending on the implementation, they may be performed in any order or in

parallel, unless indicated otherwise in the present disclosure. Further, the logic code is not related, or limited to any particular programming language, and may comprise one or more modules that execute on one or more processors in a distributed, non-distributed, or multiprocessing environment.

[0078] The methods as described above may be used in the fabrication of integrated circuit chips. The resulting integrated circuit chips can be distributed by the fabricator in raw wafer form (that is, as a single wafer that has multiple unpackaged chips), as a bare die, or in a packaged form. In the latter case, the chip is mounted in a single chip package (such as a plastic carrier, with leads that are affixed to a motherboard or other higher level carrier) or in a multi-chip package (such as a ceramic carrier that has either or both surface interconnections or buried interconnections). In any case, the chip is then integrated with other chips, discrete circuit elements, and/or other signal processing devices as part of either (a) an intermediate product, such as a motherboard, or (b) an end product. The end product can be any product that includes integrated circuit chips, ranging from toys and other low-end applications to advanced computer products having a display, a keyboard or other input device, and a central processor.

[0079] While aspects of the invention have been described with reference to at least one exemplary embodiment, it is to be clearly understood by those skilled in the art that the invention is not limited thereto. Rather, the scope of the invention is to be interpreted only in conjunction with the appended claims and it is made clear, here, that the inventor(s) believe that the claimed subject matter is the invention.

CLAIMS

What is claimed is:

1. A method for analyzing and identifying atrial fibrillation signs of a user, the method comprising the steps of:
   transmitting to an at least one computing device an at least one biosignal associated with heart activity of the user as captured by an at least one beat detector;
   representing each of an at least one beat of the biosignal with an univocal and repeatable point;
   calculating an interbeat interval between each of the at least one beat and an immediately preceding beat of the biosignal;
   generating an at least one interbeat interval sequence consisting of consecutive interbeat intervals of the biosignal;
   dividing the interbeat interval sequence into a plurality of finite sequence segments of a pre-defined temporal length consisting of consecutive interbeat intervals of the interbeat interval sequence; and
   for each sequence segment:
      encoding said sequence segment by generating a scatter plot that represents the dispersion of data associated with the interbeat interval sequence;
      encoding the scatter plot by generating a histogram that represents an amount of plot points plotted in each particular region of the scatter plot;
      normalizing the histogram by dividing a bin count of each bin by the total sum of plot points in the scatter plot;
      transmitting the normalized histogram to an at least one classifier in selective communication with the at least one computing device; and
      determining, via the classifier, a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm.

2. The method of claim 1, wherein the step of representing each of the at least one beat of the biosignal with an univocal and repeatable point, further comprises the step of selecting a one of the points having a maximum absolute derivative value among the biosignal.

3. The method of claim 1, wherein the step of dividing the interbeat interval sequence into a plurality of finite sequence segments of a pre-defined temporal length, further comprises the step of dividing the interbeat interval sequence into a plurality of finite sequence segments each having a length of thirty seconds.

4. The method of claim 1, wherein the step of encoding said sequence segment by generating a scatter plot, further comprises the step of encoding said sequence segment by generating a two-dimensional scatter plot.

5. The method of claim 4, wherein the step of encoding said sequence segment by generating a two-dimensional scatter plot, further comprises the steps of:

calculating an interbeat interval difference between each of the at least one interbeat interval and an immediately preceding interbeat interval of said sequence segment; and

encoding an uncorrelated nature of three consecutive interbeat interval differences as a plot point on the scatter plot.

6. The method of claim 5, wherein the step of encoding said sequence segment by generating a two-dimensional scatter plot, further comprises the step of encoding said sequence segment by generating a two-dimensional Lorentz plot.

7. The method of claim 1, wherein the step of generating a histogram further comprises the step of generating a histogram containing a pre-defined number of bins, with the bins each having a pre-defined bin width.

8. The method of claim 7, further comprising the step of generating a histogram containing forty-nine bins, with each bin having a bin width of 150 milliseconds.

9. The method of claim 1, wherein the step of transmitting the normalized histogram to an at least one classifier, further comprises the step of transmitting the normalized histogram to an at least one artificial neural network trained for analyzing the normalized histogram.

10. The method of claim 1, wherein the step of determining, via the classifier, a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm, further comprises the steps of:

upon the classifier determining that the probability of said sequence segment being an atrial fibrillation rhythm is relatively greater than the probability of said sequence segment being a non-atrial fibrillation rhythm, concluding that said sequence segment is an atrial fibrillation rhythm; and

upon the classifier determining that the probability of said sequence segment being a non-atrial fibrillation rhythm is relatively greater than the probability of said sequence segment being an atrial fibrillation rhythm, concluding that said sequence segment is a non-atrial fibrillation rhythm.

11. A method for analyzing and identifying atrial fibrillation signs of a user, the method comprising the steps of:

transmitting to an at least one computing device an at least one biosignal associated with heart activity of the user as captured by an at least one beat detector;

representing each of an at least one beat of the biosignal with an univocal and repeatable point;

calculating an interbeat interval between each of the at least one beat and an immediately preceding beat of the biosignal;

generating an at least one interbeat interval sequence consisting of consecutive interbeat intervals of the biosignal;

dividing the interbeat interval sequence into a plurality of finite sequence segments of a pre-defined temporal length consisting of consecutive interbeat intervals of the interbeat interval sequence; and

for each sequence segment:

calculating an interbeat interval difference between each of the at least one interbeat interval and an immediately preceding interbeat interval of said sequence segment;

encoding an uncorrelated nature of three consecutive interbeat interval differences as a plot point on a scatter plot;

encoding the scatter plot by generating a histogram that represents an amount of plot points plotted in each particular region of the scatter plot, the histogram containing a pre-defined number of bins, with each bin having a pre-defined bin width;

normalizing the histogram by dividing a bin count of each bin by the total sum of plot points in the scatter plot;

transmitting the normalized histogram to an at least one classifier in selective communication with the at least one computing device; and

determining, via the classifier, a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm.

12. An atrial fibrillation detection system for analyzing and identifying atrial fibrillation signs of a user, the system comprising:

an at least one computing device configured for receiving and processing an at least one biosignal associated with heart activity of the user as captured by an at least one beat detector, and subsequently transmitting said processed at least one biosignal to an at least one classifier configured for determining a probability of the biosignal being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm;

wherein, upon receiving the at least one biosignal from the at least one beat detector, the at least one computing device is further configured for:

representing each of an at least one beat of the biosignal with an univocal and repeatable point;

calculating an interbeat interval between each of the at least one beat and an immediately preceding beat of the biosignal;

generating an at least one interbeat interval sequence consisting of consecutive interbeat intervals of the biosignal;

dividing the interbeat interval sequence into a plurality of finite sequence segments of a pre-defined temporal length consisting of consecutive interbeat intervals of the interbeat interval sequence; and

for each sequence segment:

encoding said sequence segment by generating a scatter plot that represents the dispersion of data associated with the interbeat interval sequence;

encoding the scatter plot by generating a histogram that represents an amount of plot points plotted in each particular region of the scatter plot;

normalizing the histogram by dividing a bin count of each bin by the total sum of plot points in the scatter plot;

transmitting the normalized histogram to an at least one classifier in selective communication with the at least one computing device; and

determining, via the classifier, a probability of said sequence segment being an atrial fibrillation rhythm or a non-atrial fibrillation rhythm.

13. The atrial fibrillation detection system of claim 12, wherein while representing each of the at least one beat of the biosignal with an univocal and repeatable point, the computing device is further configured for selecting a one of the points having a maximum absolute derivative value among the biosignal.

14. The atrial fibrillation detection system of claim 12, wherein each of the sequence segments has a length of thirty seconds.

15. The atrial fibrillation detection system of claim 12, wherein, for each sequence segment, the computing device is further configured for:

calculating an interbeat interval difference between each of the at least one interbeat interval and an immediately preceding interbeat interval of said sequence segment; and

encoding an uncorrelated nature of three consecutive interbeat interval differences as a plot point on the scatter plot.

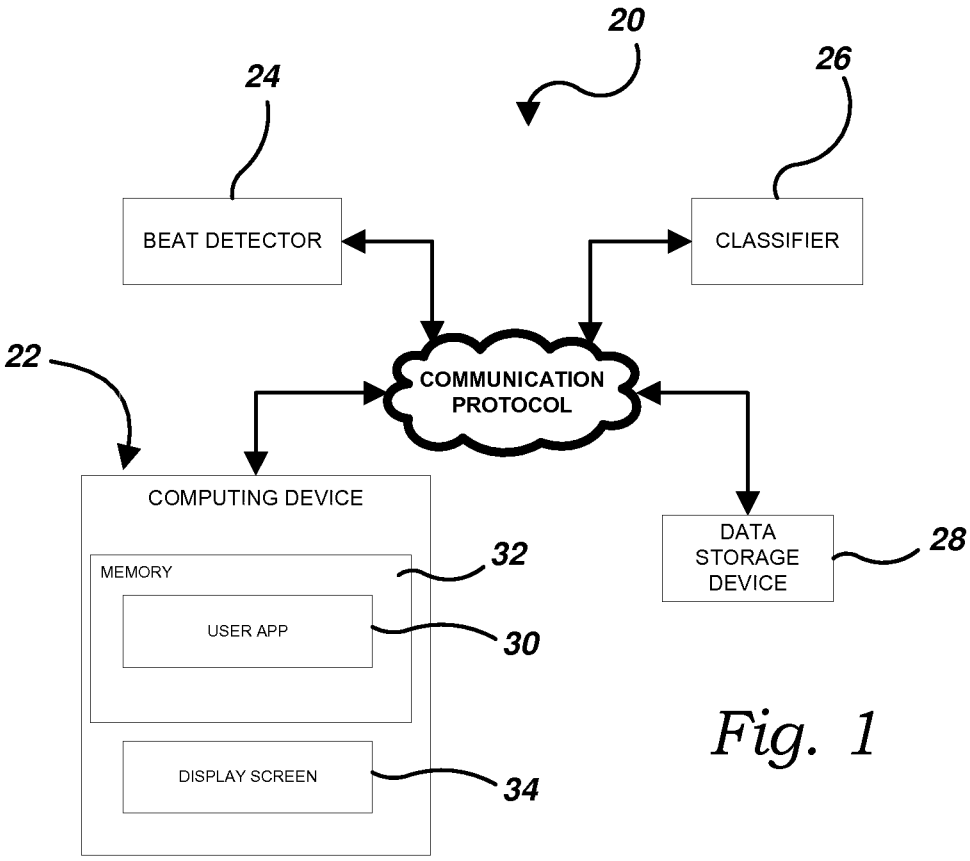
16. The atrial fibrillation detection system of claim 12, wherein the histogram is a three-dimensional histogram containing a pre-defined number of bins, with the bins each having a pre-defined bin width.

17. The atrial fibrillation detection system of claim 16, wherein the histogram contains forty-nine bins, with each bin having a bin width of 150 milliseconds.

18. The atrial fibrillation detection system of claim 12, wherein the at least one classifier is an artificial neural network trained for analyzing the normalized histogram.

19. The atrial fibrillation detection system of claim 18, wherein the artificial neural network uses rectified linear unit hidden networks, softmax activation function for output neurons, and dropout and max-norm regularization in order to optimize the performance of the classifier.

20. The atrial fibrillation detection system of claim 12, wherein the at least one beat detector is an electrocardiogram device.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24
26
BEAT DETECTOR
CLASSIFIER
22
COMMUNICATION PROTOCOL
COMPUTING DEVICE
MEMORY
32
USER APP
30
DISPLAY SCREEN
34
DATA STORAGE DEVICE
28

Fig. 1

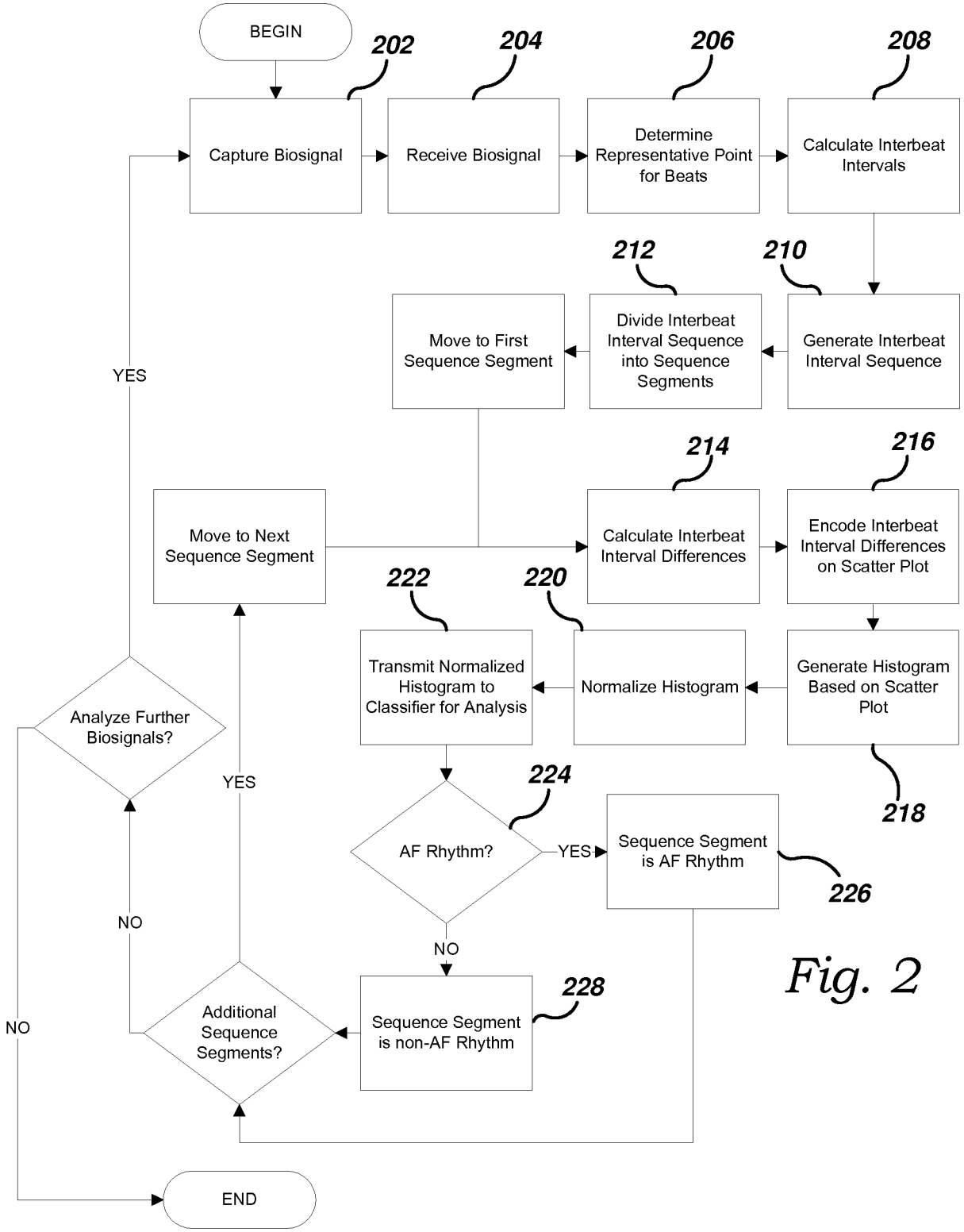
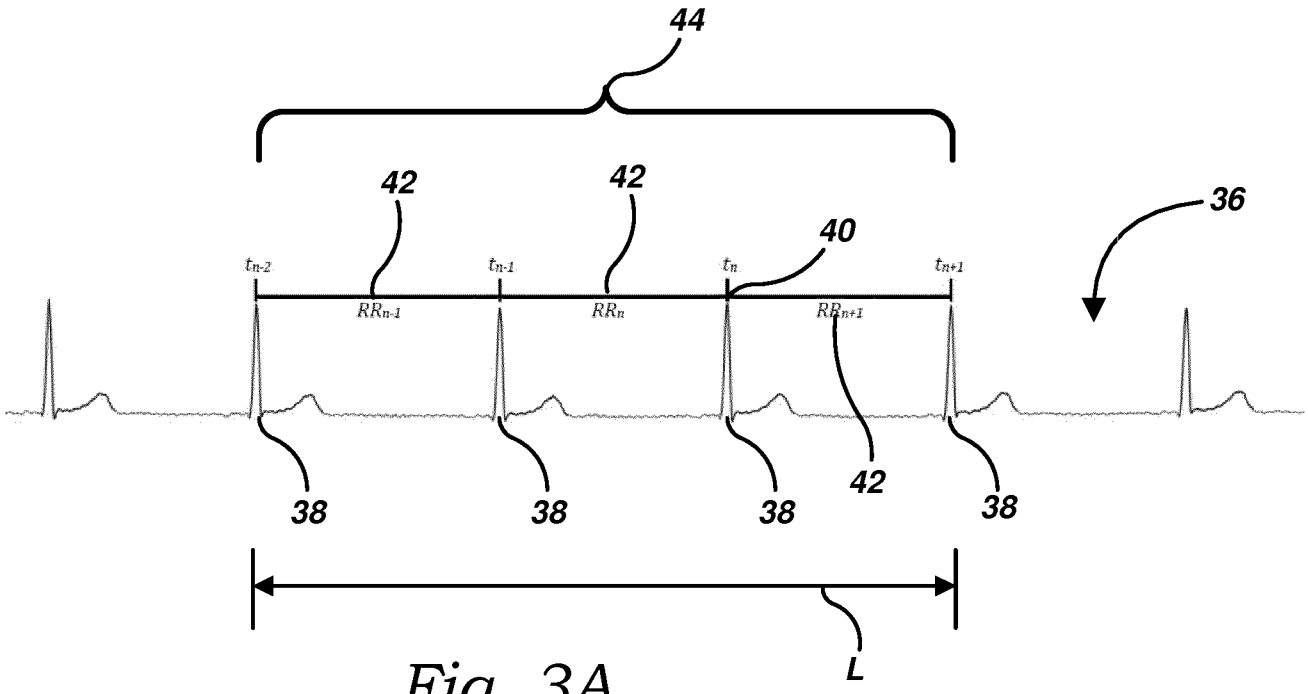

BEGIN
202
204
206
208
Capture Biosignal
Receive Biosignal
Determine Representative Point for Beats
Calculate Interbeat Intervals
212
210
Move to First Sequence Segment
Divide Interbeat Interval Sequence into Sequence Segments
Generate Interbeat Interval Sequence
YES
214
216
Move to Next Sequence Segment
Calculate Interbeat Interval Differences
Encode Interbeat Interval Differences on Scatter Plot
222
220
Transmit Normalized Histogram to Classifier for Analysis
Normalize Histogram
Generate Histogram Based on Scatter Plot
Analyze Further Biosignals?
YES
224
218
AF Rhythm?
YES
Sequence Segment is AF Rhythm
226
NO
NO
228
Additional Sequence Segments?
Sequence Segment is non-AF Rhythm
NO
END

Fig. 2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42
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36
40
t_{n-2}
t_{n-1}
t_n
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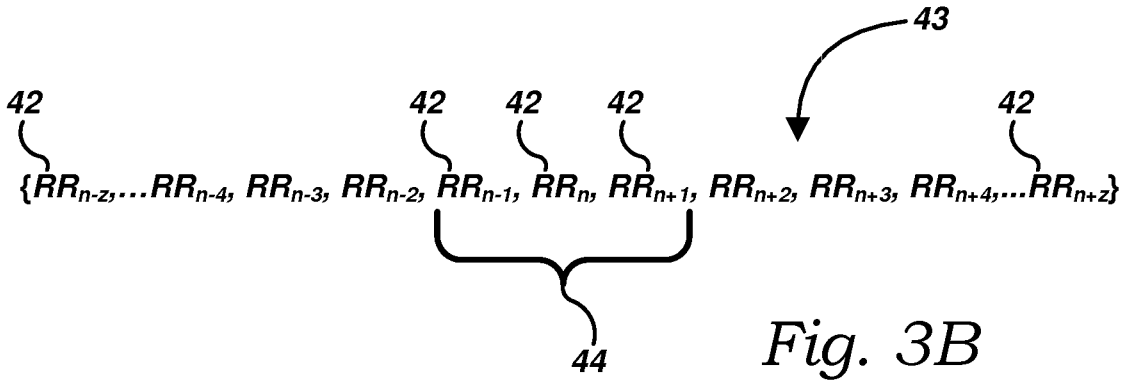
RR_{n-1}
RR_n
RR_{n+1}
38
38
38
42
38
L

Fig. 3A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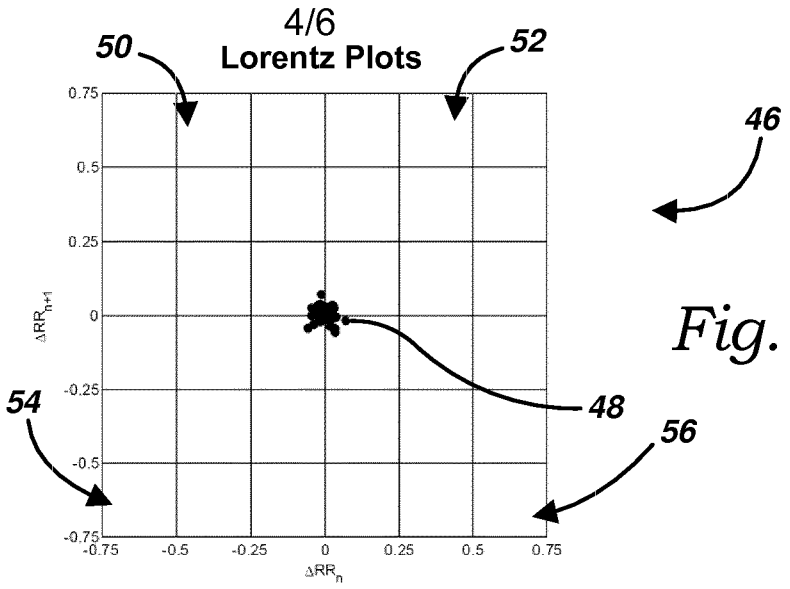
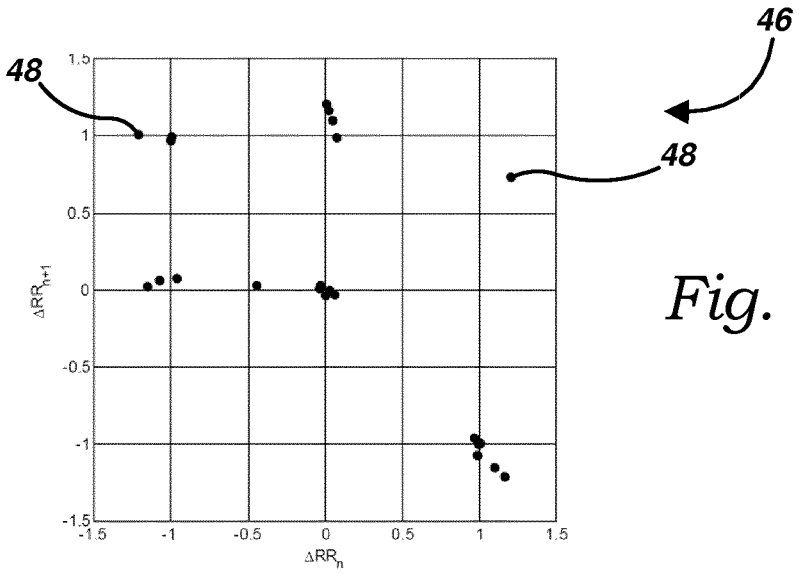
44

Fig. 3B



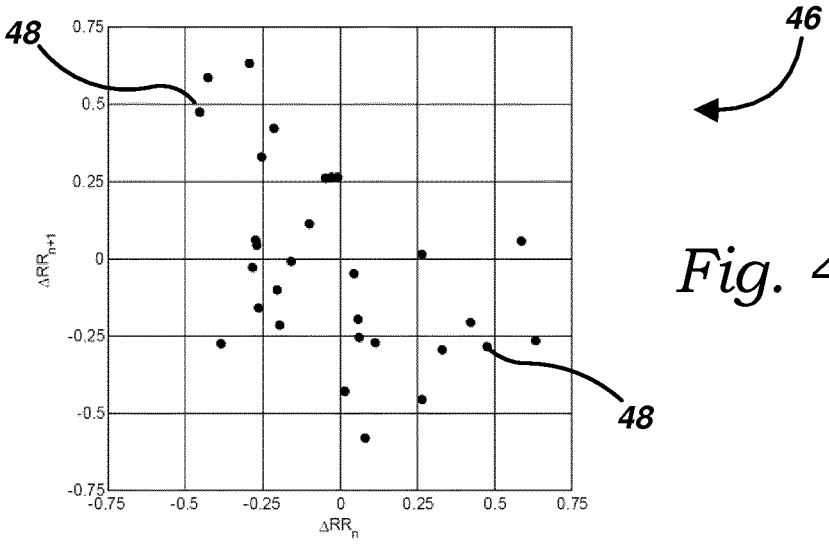
No AF:
Sinusal Rhythm

Fig. 4A



No AF:
Sinusal Rhythm
with Ectopic Beats

Fig. 4B



Atrial Fibrillation

Fig. 4C

Histograms

No AF: Sinusal Rhythm

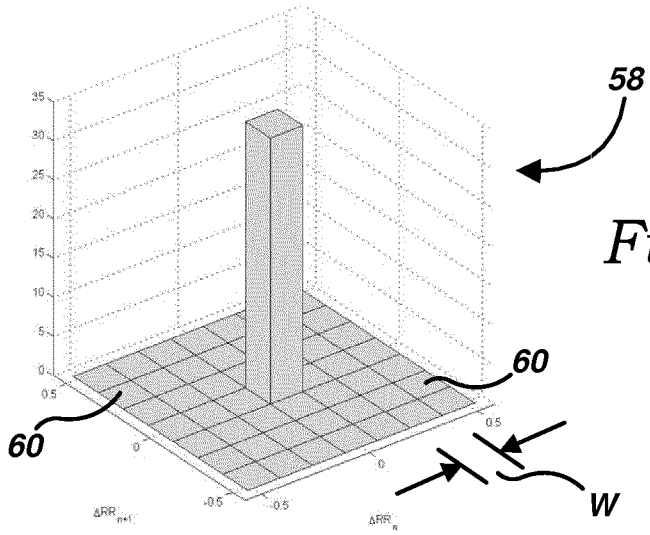


Fig. 5A

No AF: Sinusal Rhythm with Ectopic Beats

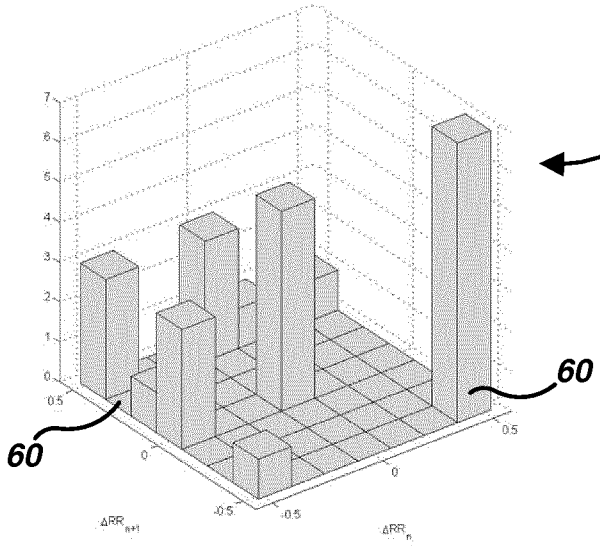


Fig. 5B

Atrial Fibrillation

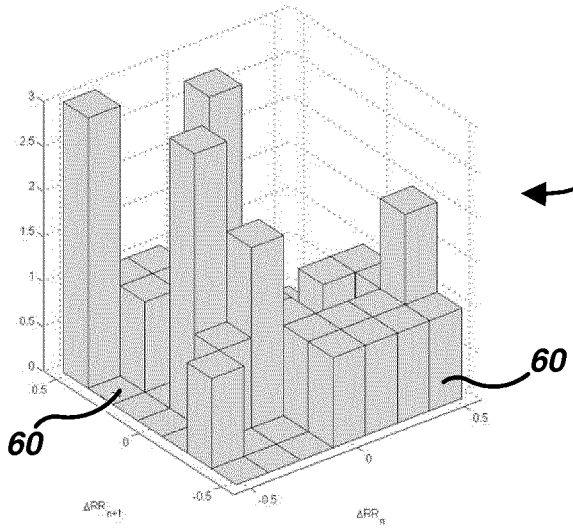


Fig. 5C

Matrix Views of Normalized Histograms

No AF: Sinusal Rhythm

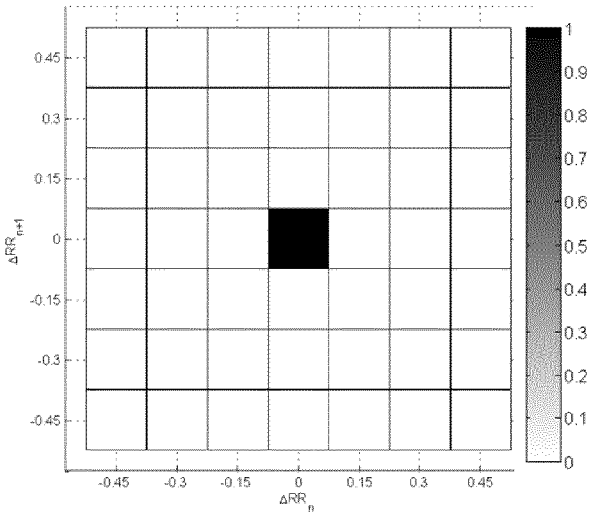


Fig. 6A

No AF: Sinusal Rhythm with Ectopic Beats

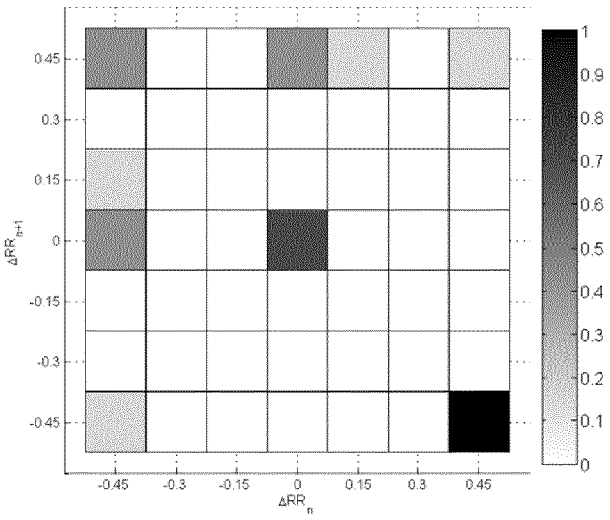


Fig. 6B

Atrial Fibrillation

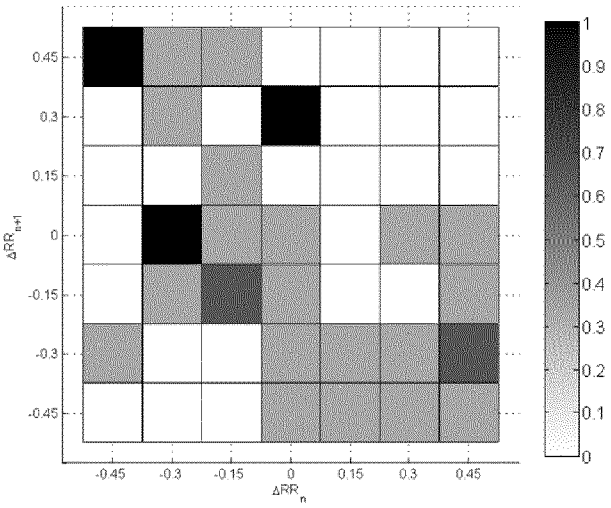


Fig. 6C

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/080146

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/024 A61B5/0245 A61B5/046
ADD. A61B5/00

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/161703 A1 (HOUBEN RICHARD P M [BE] ET AL) 3 July 2008 (2008-07-03) 2D/3D-historgram from Lorenzplot, no neural network; figures 1,2,4,5 paragraphs [0015] - [0017], [0019], [0024] - [0042], [0050]	12-20

-/--

[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

"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
14 February 2017	24/02/2017

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	Albrecht, Ronald

3

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SARKAR S ET AL: "A Detector for a Chronic Implantable Atrial Tachyarrhythmia Monitor", IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, IEEE SERVICE CENTER, PISCATAWAY, NJ, USA, vol. 55, no. 3, 1 March 2008 (2008-03-01), pages 1219-1224, XP011342629, ISSN: 0018-9294, DOI: 10.1109/TBME.2007.903707 abstract section I section II.A	12-20
X	LIJUAN ZHANG ET AL: "Automatic recognition of cardiac arrhythmias based on the geometric patterns of Poincar?", PHYSIOLOGICAL MEASUREMENT, INSTITUTE OF PHYSICS PUBLISHING, BRISTOL, GB, vol. 36, no. 2, 13 January 2015 (2015-01-13), pages 283-301, XP020278208, ISSN: 0967-3334, DOI: 10.1088/0967-3334/36/2/283 [retrieved on 2015-01-13] abstract figures 1-4 sections 2.1, 2.2, 2.3.1,2.4	12-20
A	US 6 377 844 B1 (GRAEN DAVE [US]) 23 April 2002 (2002-04-23) column 5, lines 34-60 figure 1	13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2016/080146

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.: 1-11
because they relate to subject matter not required to be searched by this Authority, namely:

Rule 39.1(iv) PCT - Diagnostic method practised on the human or animal body

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/EP2016/080146

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008161703 A1	03-07-2008	NONE	
US 6377844 B1	23-04-2002	NONE	

专利名称(译)	心房颤动检测系统及使用方法		
公开(公告)号	EP3386381A1	公开(公告)日	2018-10-17
申请号	EP2016808630	申请日	2016-12-07
[标]申请(专利权)人(译)	智能解决方案技术公司		
申请(专利权)人(译)	SMART解决方案技术，S.L.		
当前申请(专利权)人(译)	SMART解决方案技术，S.L.		
[标]发明人	IBANEZ CATALA XAVIER		
发明人	IBANEZ CATALA, XAVIER		
IPC分类号	A61B5/024 A61B5/0245 A61B5/046 A61B5/00		
CPC分类号	A61B5/02405 A61B5/0245 A61B5/046 A61B5/7267 A61B5/0006 A61B5/04012 A61B5/044 A61B5/04525		
代理机构(译)	Grund的，MARTIN		
优先权	2015031775 2015-12-07 ES		
外部链接	Espacenet		

摘要(译)

一种用于分析和识别用户的心房颤动征兆的心房颤动检测系统，包括：至少一个计算装置，被配置为接收和处理与由至少一个节拍检测器捕获的用户的心脏活动相关联的至少一个生物信号，以及随后将所述经处理的至少一个生物信号作为多个序列段发送到至少一个分类器，所述多个序列段构成生物信号的至少一个间隔间隔序列，所述至少一个分类器被配置用于确定所述至少一个间隔间隔序列的概率。生物信号是心房颤动的节律或非心房颤动的节律。基于二维洛伦兹图的归一化直方图被发送到至少一个分类器，例如，到人工神经网络。