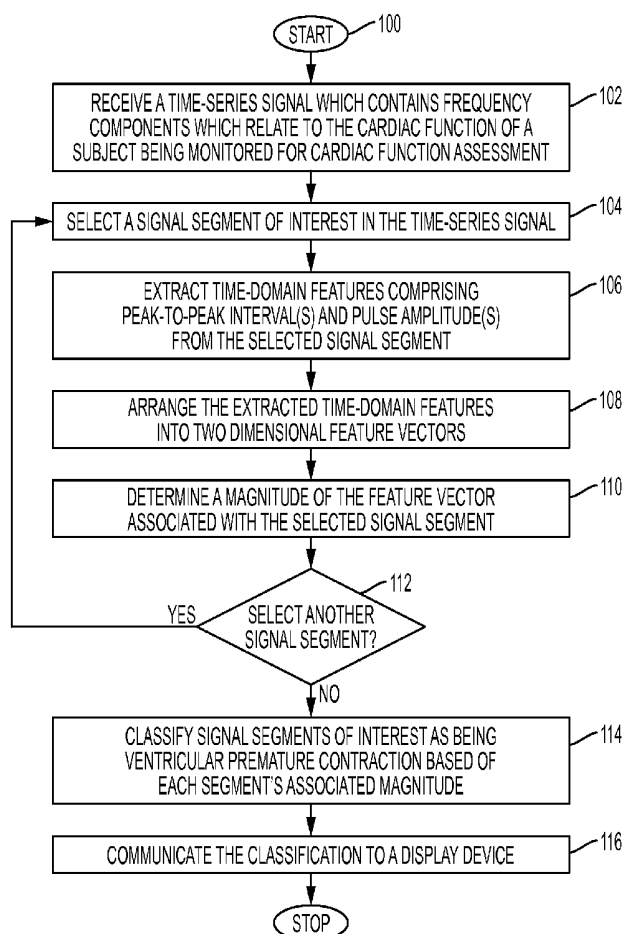




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(19) **United States**(12) **Patent Application Publication**
POLANIA-CABRERA et al.(10) **Pub. No.: US 2016/0287183 A1**(43) **Pub. Date: Oct. 6, 2016**(54) **CLASSIFYING A TIME-SERIES SIGNAL AS VENTRICULAR PREMATURE CONTRACTION**(52) **U.S. Cl.**
CPC *A61B 5/7264* (2013.01); *A61B 5/02028* (2013.01); *A61B 5/02416* (2013.01); *A61B 5/746* (2013.01); *A61B 5/7282* (2013.01)(71) Applicant: **XEROX CORPORATION**, Norwalk, CT (US)(72) Inventors: **Luisa Fernanda POLANIA-CABRERA**, Webster, NY (US); **Lalit Keshav MESTHA**, Fairport, NY (US)(21) Appl. No.: **14/674,736**(22) Filed: **Mar. 31, 2015****Publication Classification**(51) **Int. Cl.**
A61B 5/00 (2006.01)
A61B 5/024 (2006.01)
A61B 5/02 (2006.01)(57) **ABSTRACT**

What is disclosed is a system and method for classifying a time-series signal as ventricular premature contraction in a subject being monitored for cardiac function assessment. One embodiment hereof involves first, receive a time-series signal which contains frequency components that relate to the function of the subject's heart. Signal segments of interest are identified in the time-series signal. Time-domain features comprising the peak-to-peak interval between cardiac pulses and pulse amplitudes are extracted for each signal segment of interest. The time-domain features are arranged into a two dimensional feature vector. Each feature vector is associated with a respective signal segment. A magnitude of each signal segment's respective feature vector is determined. Signal segments are classified as being ventricular premature contraction based on each segment's associated magnitude. In one embodiment, signal segments with associated feature vectors having a smallest magnitude are classified as being ventricular premature contraction.



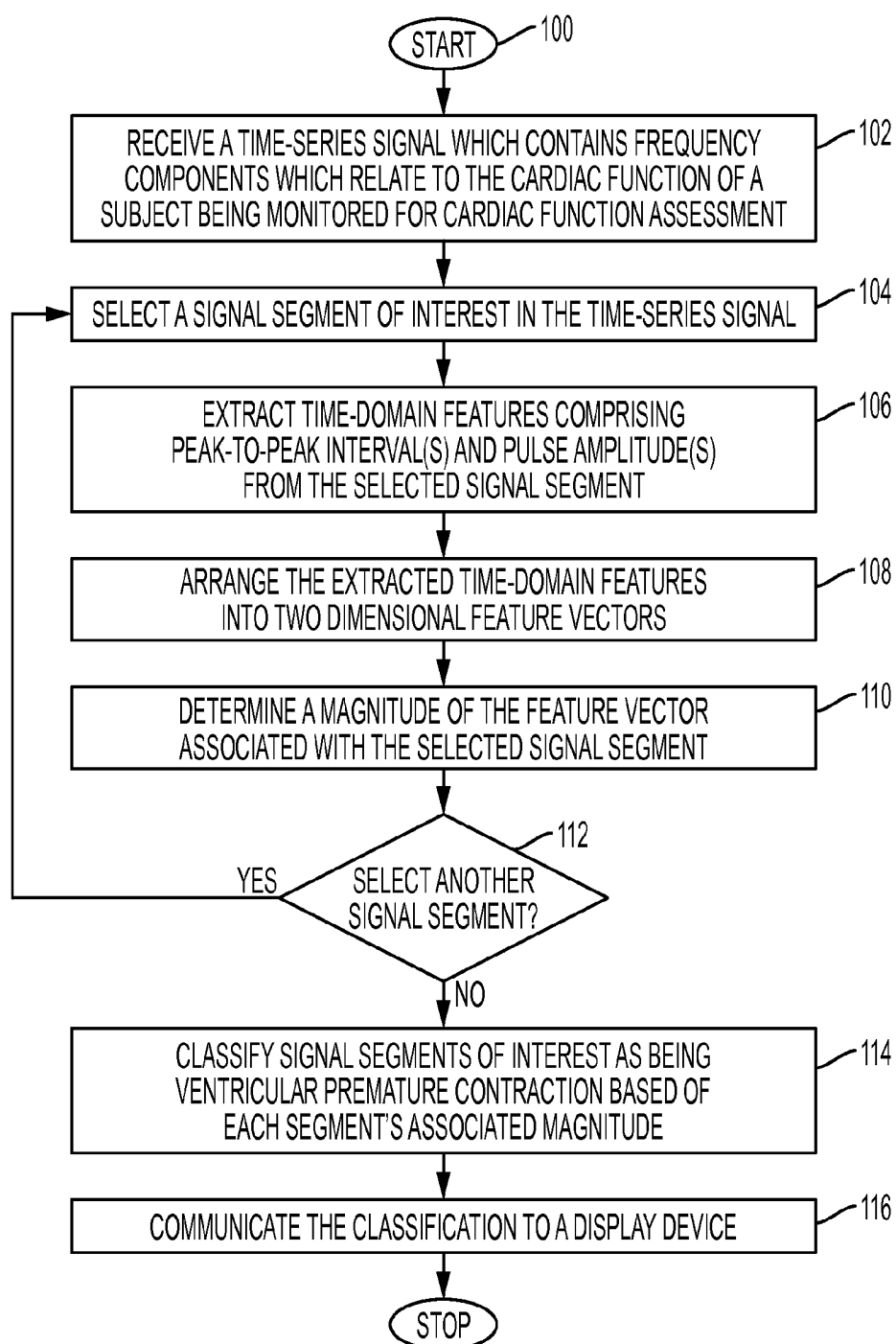


FIG. 1

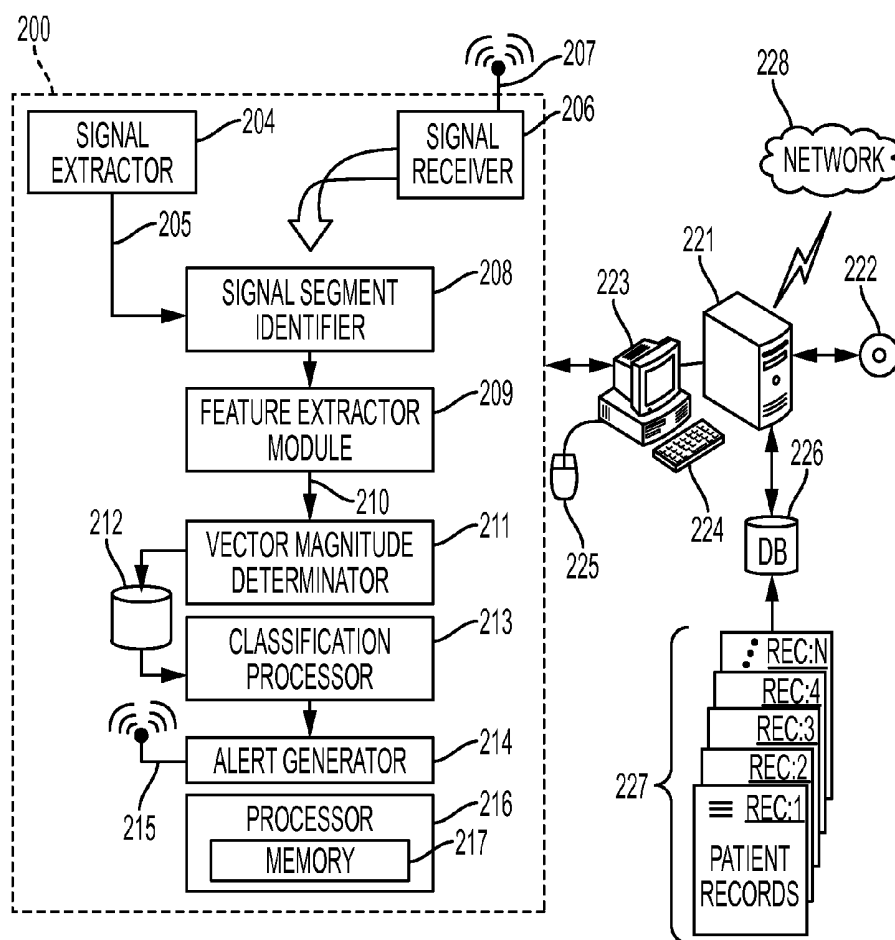


FIG. 2

CLASSIFYING A TIME-SERIES SIGNAL AS VENTRICULAR PREMATURE CONTRACTION

TECHNICAL FIELD

[0001] The present invention is directed to systems and methods for classifying a time-series signal as ventricular premature contraction in a subject being monitored for cardiac function assessment.

BACKGROUND

[0002] Among different types of arrhythmia, ventricular premature contraction (VPC) deserves special attention as it may lead to life-threatening cardiac conditions. Ventricular premature contractions are independent of the pace set by the sinoatrial node as they are caused by ectopic foci in the ventricular area of the heart. Previous studies have shown that VPC events after myocardial infarction are associated with an increased mortality rate. The increase in the frequency of VPC events may lead to ventricular tachycardia which, in turn, frequently evolves into ventricular fibrillation and sudden cardiac death. Methods for accurate and early detection of VPC events can be essential for patients with heart disease.

[0003] Accordingly, what is needed in this art are sophisticated systems and methods for classifying a time-series signal as ventricular premature contraction.

Incorporated References

[0004] The following U.S. Patents, U.S. Patent Applications, and Publications are incorporated herein in their entirety by reference.

[0005] “Classifying A Time-Series Signal As Ventricular Premature Contraction And Ventricular Tachycardia”, U.S. patent application Ser. No. 14/XXX,XXX, by Polanía-Cabrera et al., (Attorney Docket: 20150063US01 (420-P0240)).

[0006] “Method For Assessing Patient Risk For Ventricular Tachycardia”, U.S. Patent Application Ser. No. 14/xxx, xxx, by Mestha et al. (Attorney Docket: 20141576US01 (420-P0241)).

[0007] “Identifying A Type Of Cardiac Event From A Cardiac Signal Segment”, U.S. patent application Ser. No. 14/492,948, by Xu et al.

[0008] “System And Method For Detecting An Arrhythmic Cardiac Event From A Cardiac Signal”, U.S. patent application Ser. No. 14/519,607, by Kyal et al.

[0009] “Determining Cardiac Arrhythmia From A Video Of A Subject Being Monitored For Cardiac Function”, U.S. patent application Ser. No. 14/245,405, by Mestha et al.

[0010] “Method And Apparatus For Monitoring A Subject For Atrial Fibrillation”, U.S. patent application Ser. No. 13/937,740, by Mestha et al.

[0011] “Continuous Cardiac Signal Generation From A Video Of A Subject Being Monitored For Cardiac Function”, U.S. patent application Ser. No. 13/871,766, by Kyal et al.

[0012] “Continuous Cardiac Pulse Rate Estimation From Multi-Channel Source Video Data With Mid-Point Stitching”, U.S. patent application Ser. No. 13/871,728, by Kyal et al.

[0013] “Determining Cardiac Arrhythmia From A Video Of A Subject Being Monitored For Cardiac Function”, U.S. patent application Ser. No. 13/532,128, by Mestha et al.

[0014] “Continuous Cardiac Pulse Rate Estimation From Multi-Channel Source Video Data”, U.S. patent application Ser. No. 13/528,307, by Kyal et al.

[0015] “Estimating Cardiac Pulse Recovery From Multi-Channel Source Data Via Constrained Source Separation”, U.S. patent application Ser. No. 13/247,683, by Mestha et al.

BRIEF SUMMARY

[0016] What is disclosed is a system and method for classifying a time-series signal as ventricular premature contraction in a subject being monitored for cardiac function assessment. One embodiment hereof involves the following. A time-series signal is received which contains frequency components that relate to the function of the subject's heart. Signal segments of interest are identified in the time-series signal. Time-domain features comprising the peak-to-peak interval between cardiac pulses and pulse amplitudes are extracted for each signal segment of interest. The time-domain features are arranged into a two dimensional feature vector. Each feature vector is associated with a respective signal segment. A magnitude of each signal segment's respective feature vector is determined. Signal segments are classified as being ventricular premature contraction based on each segment's associated magnitude. In one embodiment, signal segments with associated feature vectors having a smallest magnitude are classified as being ventricular premature contraction.

[0017] Signal segments with a feature vector having a smallest magnitude are classified as being ventricular premature contraction.

[0018] Features and advantages of the above-described method will become readily apparent from the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The foregoing and other features and advantages of the subject matter disclosed herein will be made apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0020] FIG. 1 is a flow diagram which illustrates one example embodiment of the present method for classifying a time-series signal as ventricular premature contraction in accordance with the methods disclosed herein; and

[0021] FIG. 2 is a block diagram of one example signal processing system for classifying a time-series signal as ventricular premature contraction as described with respect to the flow diagram of FIG. 1.

DETAILED DESCRIPTION

[0022] What is disclosed is a system and method for classifying a time-series signal as ventricular premature contraction in a subject being monitored for cardiac function assessment.

Non-Limiting Definitions

[0023] “Plethysmography” is the study of relative blood volume changes in blood vessels which reside beneath the surface of skin tissue.

[0024] A “photoplethysmographic (PPG) signal” is a signal obtained using an optical instrument which captures the blood volume pulse over time.

[0025] A “videoplethysmographic (VPG) signal” is a signal extracted from processing batches of image frames of a video of the skin surface.

[0026] A “subject” refers to a living being. Although the term “person” or “patient” may be used throughout this disclosure, it should be appreciated that the subject may be something other than a human such as, for example, a primate. Therefore, the use of such terms is not to be viewed as limiting the scope of the appended claims strictly to humans.

[0027] “Cardiac function” refers to the function of the heart and, to a larger extent, to the cardio-vascular system. Cardiac function can be impacted by a variety of factors including age, stress, disease, overall health, and by environmental conditions such as altitude and pressure.

[0028] A “time-series signal” is a signal which contains frequency components which relate to cardiac function. The time-series signal can be a photoplethysmographic (PPG) signal or a videoplethysmographic (VPG) signal. Methods for obtaining time-series signals are disclosed in several of the incorporated references by Kyal et al and Mestha et al. One or more signal segments of interest are identified in the time-series signal.

[0029] A “signal segment of interest” refers to a portion of a time-series signal which has been identified as being of interest. Methods for obtaining a segment of a signal are well established in the signal processing arts. One method for classifying signal segments based on a clustering method is disclosed in the incorporated reference entitled: “Identifying A Type Of Cardiac Event From A Cardiac Signal Segment”, by Xu et al. Signal segments have a fixed length. A length of a signal segment can comprise of any of: a single cardiac cycle, a normalized cardiac cycle, multiple cardiac cycles, and multiple normalized cardiac cycles. Time-domain features are extracted from the signal segments of interest.

[0030] “Time-domain features” refers to the peak-to-peak interval between cardiac pulses in the signal segment and the cardiac pulse amplitude. Time-domain features are arranged into feature vectors. Methods for generating vectors are well established in the mathematical arts.

[0031] “Receiving a time-series signal” is intended to be widely construed and includes: retrieving, capturing, acquiring, or otherwise obtaining time-series signals for processing in accordance with the teachings hereof. Time-series signals can also be retrieved from a memory or storage device of the device used to capture those signals, or from a media such as a CDROM or DVD, retrieved from a remote device over a network, or downloaded from a web-based system or application which makes such signals available for processing.

[0032] It should be appreciated that the steps of “determining”, “analyzing”, “identifying”, “receiving”, “processing”, “classifying”, “extracting”, “selecting”, “performing”, “detrending”, “filtering”, “smoothing”, and the like, as used herein, include the application of any of a variety of signal processing techniques as well as mathematical operations according to any specific context or for any specific purpose. It should be appreciated that such steps may be facilitated or otherwise effectuated by a microprocessor executing

machine readable program instructions such that an intended functionality can be effectively performed.

Example Flow Diagram

[0033] Reference is now being made to the flow diagram of FIG. 1 which illustrates one example embodiment of the present method for classifying a time-domain signal as ventricular premature contraction. Flow processing begins at step 100 and immediately proceeds to step 102.

[0034] At step 102, receive a time-series signal containing frequency components which relate to a cardiac function of a subject being monitored for cardiac function assessment.

[0035] At step 104, select a signal segment of interest in the time-series signal. Signal segments have a fixed length. Such a selection may be effectuated by a user or technician using, for example, the workstation 221 of FIG. 2.

[0036] At step 106, extract time-domain features comprising peak-to-peak intervals between cardiac pulses and cardiac pulse amplitudes from the selected signal segment.

[0037] At step 108, arrange the extracted time-domain features into a two dimensional feature vector.

[0038] At step 110, determine a magnitude of the feature vector associated with the selected signal segment.

[0039] At step 112, a determination is made whether more signal segments are to be selected. If so then processing repeats with respect to step 104 wherein a next signal segment is identified or is otherwise selected for processing. Processing repeats in a similar manner until no more signal segments remain to be processed.

[0040] At step 114, classify signal segments as being ventricular premature contraction based on each segment’s associated magnitude. Remaining signal segments are unclassified or are classified as normal sinus rhythm. In one embodiment, signal segments with a smallest magnitude are classified as being ventricular premature contraction.

[0041] At step 116, communicate the classification to a display device. One example display device is shown at 223 of FIG. 2. In this embodiment, further processing stops. In other embodiments, the classification is communicated to a memory, a storage device, a handheld wireless device, a handheld cellular device, and/or a remote device over a network. An alert signal may be initiated in response to the classification, and a signal may be sent to a medical professional as is appropriate. Such an alert may take the form of a message displayed on a display device or a sound activated at, for example, a nurse’s station or a display of a device. The alert may take the form of a colored or blinking light which provides a visible indication that an alert condition exists. The alert can be a text, audio, and/or video message. The alert signal may be communicated to one or more remote devices over a wired or wireless network. The alert may be sent directly to a handheld wireless cellular device of a medical professional. Thereafter, additional actions would be taken in response to the alert.

[0042] It should be appreciated that the flow diagrams depicted herein are illustrative. One or more of the operations in the flow diagrams may be performed in a differing order. Other operations may be added, modified, enhanced, or consolidated. Variations thereof are intended to fall within the scope of the appended claims.

Block Diagram of Signal Processing System

[0043] Reference is now being made to FIG. 2 which illustrates a block diagram of one example signal processing system 200 for classifying a time-series signal as ventricular premature contraction, as described with respect to the flow diagram of FIG. 1.

[0044] Signal Extractor 204 outputs a time-series signal 205. Signal Receiver 206, in the alternative, wirelessly receives a time-series signals via antenna 207. Signal Segment Identifier 208 receives the time-series signal from one or both of Signal Extractor 204 and Signal Receiver 206 and divides the time-series signal in signal segments of interest. The subject's cardiac specialist may facilitate such an identification using the workstation 221. Once signal segments of interest have been identified or otherwise selected, Feature Extractor 209 extracts, from each of the signal segments, time-domain features and outputs the extracted features in the form of a two-dimensional feature vector 210. Each feature vector is associated with a respective signal segment of interest. The feature vectors 210 are received by Magnitude Determinator 211 which determines a magnitude of each of the feature vectors. The results thereof are stored to storage device 212. Classification Processor 213 retrieves the magnitudes from the storage device and classifies signal segments of interest as ventricular premature contraction based on the determined magnitudes. Alert Generator 214 initiates an alert signal via antenna 215 in response to one or more signal segments being classified as ventricular premature contraction. Central Processing Unit (CPU) 216 retrieves machine readable program instructions from Memory 217 and is provided to facilitate the functionality of any of the modules of the system 200. CPU 216, operating alone or in conjunction with other processors, may be configured to assist or otherwise perform the functionality of any of the modules or processing units of the system 200, as well as facilitating communication between the system 200 and the workstation 221.

[0045] Workstation 221 has a computer case which houses various components such as a motherboard with a processor and memory, a network card, a video card, a hard drive capable of reading/writing to machine readable media 222 such as a floppy disk, optical disk, CD-ROM, DVD, magnetic tape, and the like, and other software and hardware as is needed to perform the functionality of a computer workstation. The workstation includes a display device 223, such as a CRT, LCD, or touchscreen display, for displaying information, magnitudes, feature vectors, computed values, medical information, test results, and the like, which are produced or are otherwise generated by any of the modules or processing units of the system 200. A user can view any such information and make a selection from various menu options displayed thereon. Keyboard 224 and mouse 225 effectuate a user input or selection.

[0046] It should be appreciated that the workstation 221 has an operating system and other specialized software configured to display alphanumeric values, menus, scroll bars, dials, slideable bars, pull-down options, selectable buttons, and the like, for entering, selecting, modifying, and accepting information needed for performing various aspects of the methods disclosed herein. A user may use the workstation to identify signal segments of interest, set various parameters, and facilitate the functionality of any of the modules or processing units of the system 200. A user or technician may utilize the workstation to further modify the

determined magnitudes of the feature vectors as is deemed appropriate. The user may adjust various parameters being utilized or dynamically adjust, in real-time, system or settings of any device used to capture the time-series signals. User inputs and selections may be stored/retrieved in any of the storage devices 212, 222 and 226. Default settings and initial parameters can be retrieved from any of the storage devices. The alert signal initiated by Alert Generator 214 may be received and viewed on the display device 223 of the workstation and/or communicated to one or more remote devices over network 228, which may utilize a wired, wireless, or cellular communication protocol.

[0047] The workstation implements a database in storage device 226 wherein patient records are stored, manipulated, and retrieved in response to a query. Such records, in various embodiments, take the form of patient medical history stored in association with information identifying the patient (collectively at 227). It should be appreciated that database 226 may be the same as storage device 212 or, if separate devices, may contain some or all of the information contained in either storage device. Although the database is shown as an external device, the database may be internal to the workstation mounted, for example, on a hard disk therein.

[0048] Although shown as a desktop computer, it should be appreciated that the workstation can be a laptop, mainframe, tablet, notebook, smartphone, or a special purpose computer such as an ASIC, or the like. The embodiment of the workstation is illustrative and may include other functionality known in the arts. Any of the components of the workstation may be placed in communication with any of the modules of system 200 or any devices placed in communication therewith. Moreover, any of the modules of system 200 can be placed in communication with storage device 226 and/or computer readable media 222 and may store/retrieve therefrom data, variables, records, parameters, functions, and/or machine readable/executable program instructions, as needed to perform their intended functionality. Further, any of the modules or processing units of the system 200 may be placed in communication with one or more remote devices over network 228. It should be appreciated that some or all of the functionality performed by any of the modules or processing units of system 200 can be performed, in whole or in part, by the workstation. The embodiment shown is illustrative and should not be viewed as limiting the scope of the appended claims strictly to that configuration. Various modules may designate one or more components which may, in turn, comprise software and/or hardware designed to perform the intended function.

[0049] The teachings hereof can be implemented in hardware or software using any known or later developed systems, structures, devices, and/or software by those skilled in the applicable arts without undue experimentation from the functional description provided herein with a general knowledge of the relevant arts. One or more aspects of the methods described herein are intended to be incorporated in an article of manufacture. The article of manufacture may be shipped, sold, leased, or otherwise provided separately either alone or as part of a product suite or a service. The above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into other different systems or applications. Presently unforeseen or unanticipated alternatives, modifications, variations, or improvements may become apparent and/or subsequently

made by those skilled in this art which are also intended to be encompassed by the following claims. The teachings of any publications referenced herein are hereby incorporated by reference in their entirety.

What is claimed is:

1. A method for classifying a time-series signal as ventricular premature contraction for cardiac function assessment, the method comprising:

receiving a time-series signal containing frequency components which relate to a cardiac function of a subject being monitored for cardiac function assessment;

identifying at least one signal segment of interest in said time-series signal, said signal segments having a fixed length;

extracting time-domain features from each of said identified signal segments of interest, said features comprising peak-to-peak interval between cardiac pulses and pulse amplitude, said extracted features being represented by at least one two dimensional feature vector, each of said feature vectors being associated with a respective signal segment;

determining a magnitude of each of said two dimensional feature vectors; and

classifying signal segments of interest as being ventricular premature contraction based on a magnitude of said segment's respective associated feature vectors.

2. The method of claim 1, wherein said time-series signal is any of: a photoplethysmographic (PPG) signal, and a videoplethysmographic (VPG) signal.

3. The method of claim 1, wherein signal segments with a smallest magnitude are classified as being ventricular premature contraction.

4. The method of claim 1, wherein signal segments are classified using an unsupervised clustering method.

5. The method of claim 1, wherein, in advance of extracting said time-domain features, pre-processing said time-series signal to improve signal-to-noise ratio.

6. The method of claim 1, wherein, in advance of extracting said time-domain features, further comprising any of: detrending said time-series signal to remove non-stationary components;

filtering said time-series signal to remove unwanted frequencies; and

smoothing said time-series signal to remove unwanted artifacts.

7. The method of claim 1, wherein, in advance of extracting said time-domain features, further comprising any of: performing automatic peak detection on said signal segment to identify cardiac pulse peaks; and

filtering said signal segment to remove cardiac pulse peaks having more than at least a 20% change in consecutive peak-to-peak intervals.

8. The method of claim 1, wherein said signal segment is normalized to a frequency of a normalized heartbeat.

9. The method of claim 1, wherein a length of said signal segment comprises of any of: a single cardiac cycle, a normalized cardiac cycle, multiple cardiac cycles, and multiple normalized cardiac cycles.

10. The method of claim 1, further comprising any of: initiating an alert, and signaling a medical professional.

11. The method of claim 1, further comprising communicating said classification to any of: a memory, a storage

device, a display device, a handheld wireless device, a handheld cellular device, and a remote device over a network.

12. A system for classifying a time-series signal as ventricular premature contraction for cardiac function assessment, the system comprising:

a memory; and

a processor in communication with said memory, said processor executing machine readable program instructions for performing:

receiving a time-series signal containing frequency components which relate to a cardiac function of a subject being monitored for cardiac function assessment;

identifying at least one signal segment of interest in said time-series signal, said signal segments having a fixed length;

extracting time-domain features from each of said identified signal segments of interest, said features comprising peak-to-peak interval between cardiac pulses and pulse amplitude, said extracted features being represented by at least one two dimensional feature vector, each of said feature vectors being associated with a respective signal segment;

determining a magnitude of each of said two dimensional feature vectors; and

classifying signal segments of interest as being ventricular premature contraction based on a magnitude of said segment's respective associated feature vectors.

13. The system of claim 12, wherein said time-series signal is any of: a photoplethysmographic (PPG) signal, and a videoplethysmographic (VPG) signal.

14. The system of claim 12, wherein signal segments with a smallest magnitude are classified as being ventricular premature contraction.

15. The system of claim 12, wherein signal segments are classified using an unsupervised clustering method.

16. The system of claim 12, wherein, in advance of extracting said time-domain features, pre-processing said time-series signal to improve signal-to-noise ratio.

17. The system of claim 12, wherein, in advance of extracting said time-domain features, further comprising any of:

detrending said time-series signal to remove non-stationary components;

filtering said time-series signal to remove unwanted frequencies; and

smoothing said time-series signal to remove unwanted artifacts.

18. The system of claim 12, wherein, in advance of extracting said time-domain features, further comprising any of:

performing automatic peak detection on said signal segment to identify cardiac pulse peaks; and

filtering said signal segment to remove cardiac pulse peaks having more than at least a 20% change in consecutive peak-to-peak intervals.

19. The system of claim 12, wherein said signal segment is normalized to a frequency of a normalized heartbeat.

20. The system of claim 12, wherein a length of said signal segment comprises of any of: a single cardiac cycle, a normalized cardiac cycle, multiple cardiac cycles, and multiple normalized cardiac cycles.

21. The system of claim **12**, further comprising any of: initiating an alert, and signaling a medical professional.

22. The system of claim **12**, further comprising communicating said classification to any of: a memory, a storage device, a display device, a handheld wireless device, a handheld cellular device, and a remote device over a network.

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当前申请(专利权)人(译)	施乐公司		
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摘要(译)

什么是公开的是用于心功能评估被监控的受试者的时间序列信号作为室性早搏进行分类的系统和方法。一个实施本法第一个涉及，收到包含，涉及到受试者的心脏功能频率分量时间序列信号。感兴趣的信号段在时间序列信号进行识别。包括心脏脉冲和脉冲振幅之间的峰 - 峰值的时间间隔的时域特征被提取为每个感兴趣的信号段。时域特征被布置成一个二维特征向量。每个特征向量与各自的信号段相关联。每个信号段的各个特征向量的大小被确定。信号段被归类为根据每个段相关的幅度室性早搏。在一个实施方案中，与具有最小幅值相关联的特征矢量信号段被分类为室性早搏。

