



US 20150088020A1

(19) **United States**
(12) **Patent Application Publication**
Dreisbach et al.

(10) **Pub. No.: US 2015/0088020 A1**
(43) **Pub. Date: Mar. 26, 2015**

(54) **SYSTEM AND METHOD FOR INTERACTIVE PROCESSING OF ECG DATA**

A61B 5/0432 (2006.01)
A61B 5/00 (2006.01)
A61B 5/046 (2006.01)
A61B 5/0464 (2006.01)
A61B 5/044 (2006.01)
A61B 5/0472 (2006.01)

(71) Applicant: **Bardy Diagnostics, Inc.**, Vashon, WA (US)

(72) Inventors: **Ezra M. Dreisbach**, Vashon, WA (US);
Jason Felix, Vashon Island, WA (US);
Gust H. Bardy, Carnation, WA (US)

(52) **U.S. Cl.**
CPC *A61B 5/04017* (2013.01); *A61B 5/044* (2013.01); *A61B 5/04087* (2013.01); *A61B 5/0472* (2013.01); *A61B 5/748* (2013.01); *A61B 5/7203* (2013.01); *A61B 5/6823* (2013.01); *A61B 5/046* (2013.01); *A61B 5/0432* (2013.01); *A61B 5/0006* (2013.01); *A61B 5/0022* (2013.01)

(21) Appl. No.: **14/341,698**

(22) Filed: **Jul. 25, 2014**

USPC **600/523**

Related U.S. Application Data

(63) Continuation-in-part of application No. 14/082,071, filed on Nov. 15, 2013, which is a continuation-in-part of application No. 14/080,717, filed on Nov. 14, 2013, said application No. 14/082,071 is a continuation-in-part of application No. 14/080,725, filed on Nov. 14, 2013.

(60) Provisional application No. 61/882,403, filed on Sep. 25, 2013, provisional application No. 61/882,403, filed on Sep. 25, 2013.

Publication Classification

(51) **Int. Cl.**
A61B 5/04 (2006.01)
A61B 5/0408 (2006.01)

(57) **ABSTRACT**

A system and method for interactive processing of ECG data are presented. An electrocardiogram is displayed. A user selection of a portion of the displayed ECG is received. Digitized signals corresponding to the selection are obtained. A list of digital filters for filtering the selection are displayed. A user selection of one or more sets of the digital filters is received, with each of the sets including one or more of the filters from the list. The selected sets are applied to the digitized signals for the selection. A filtered ECG for the selection is generated for each of the sets based on the signals filtered by that set. The filtered selection ECG for each of the sets are presented on the display.

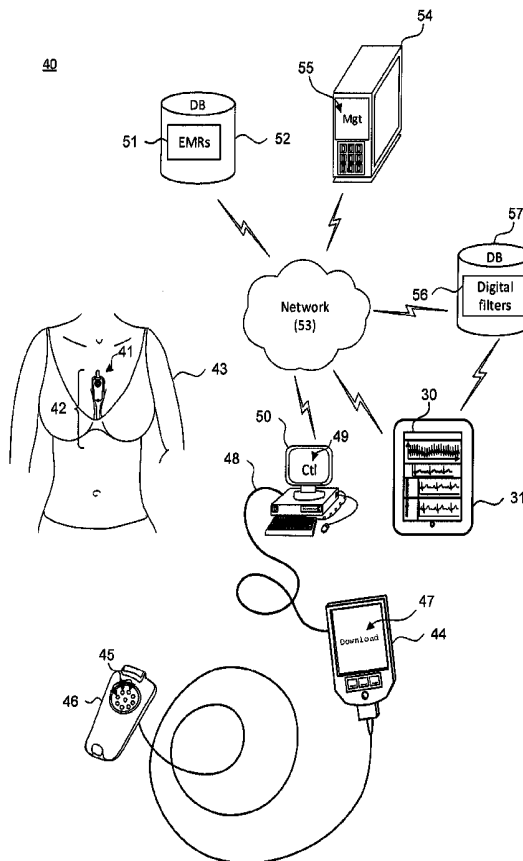


Fig. 1.

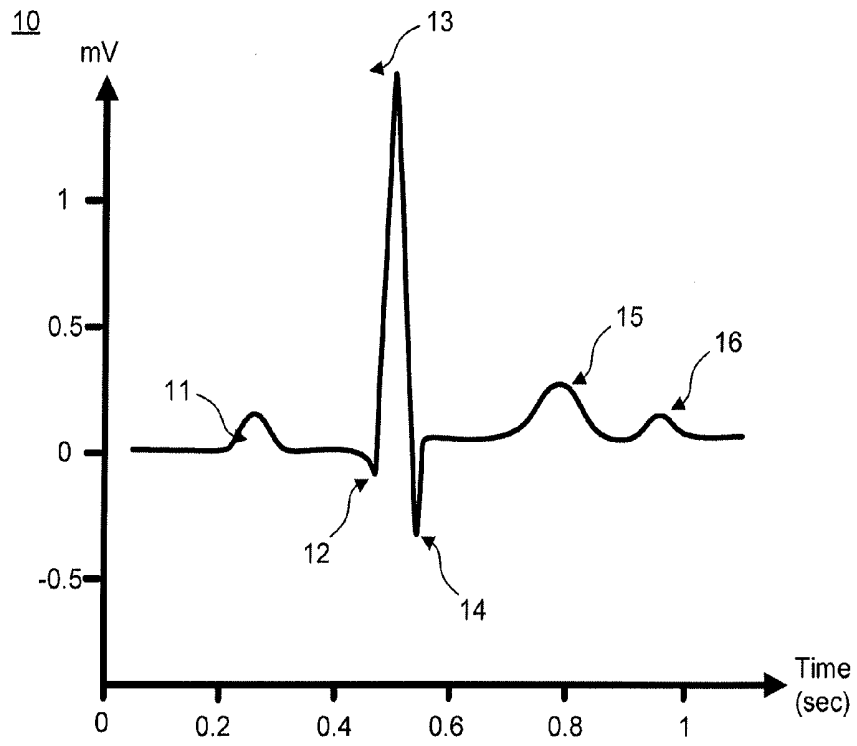


Fig. 2.

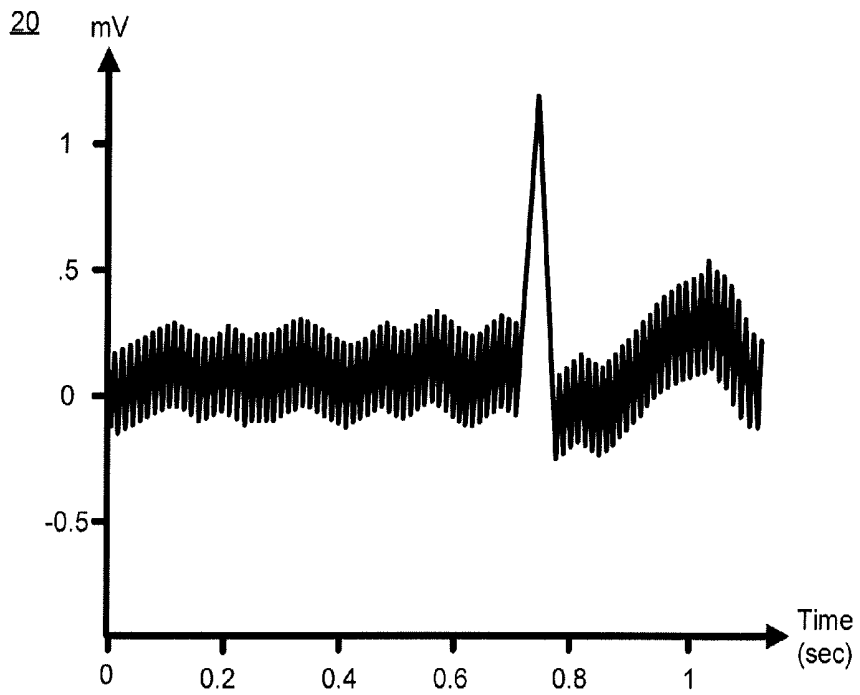


Fig. 3.

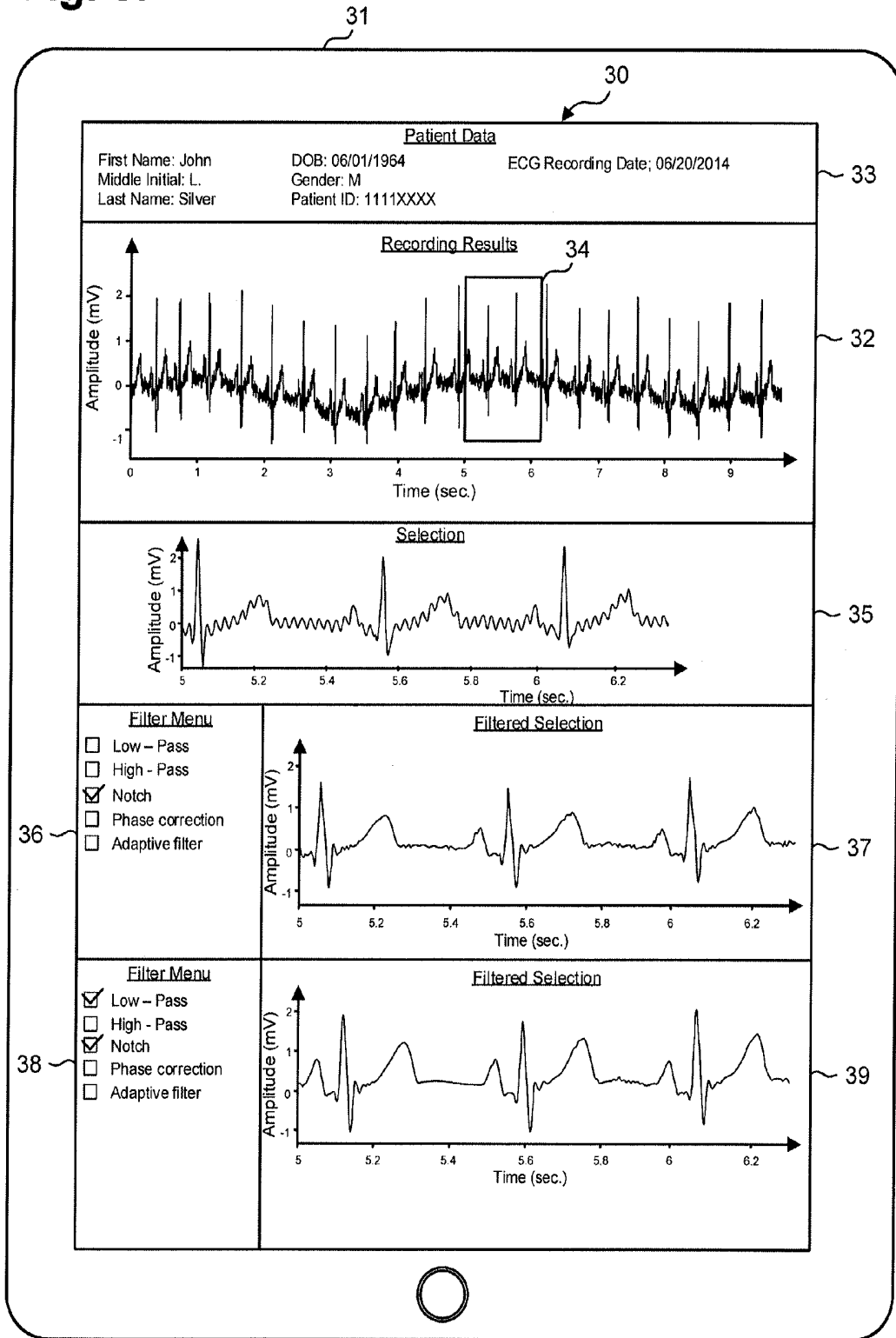


Fig. 4.

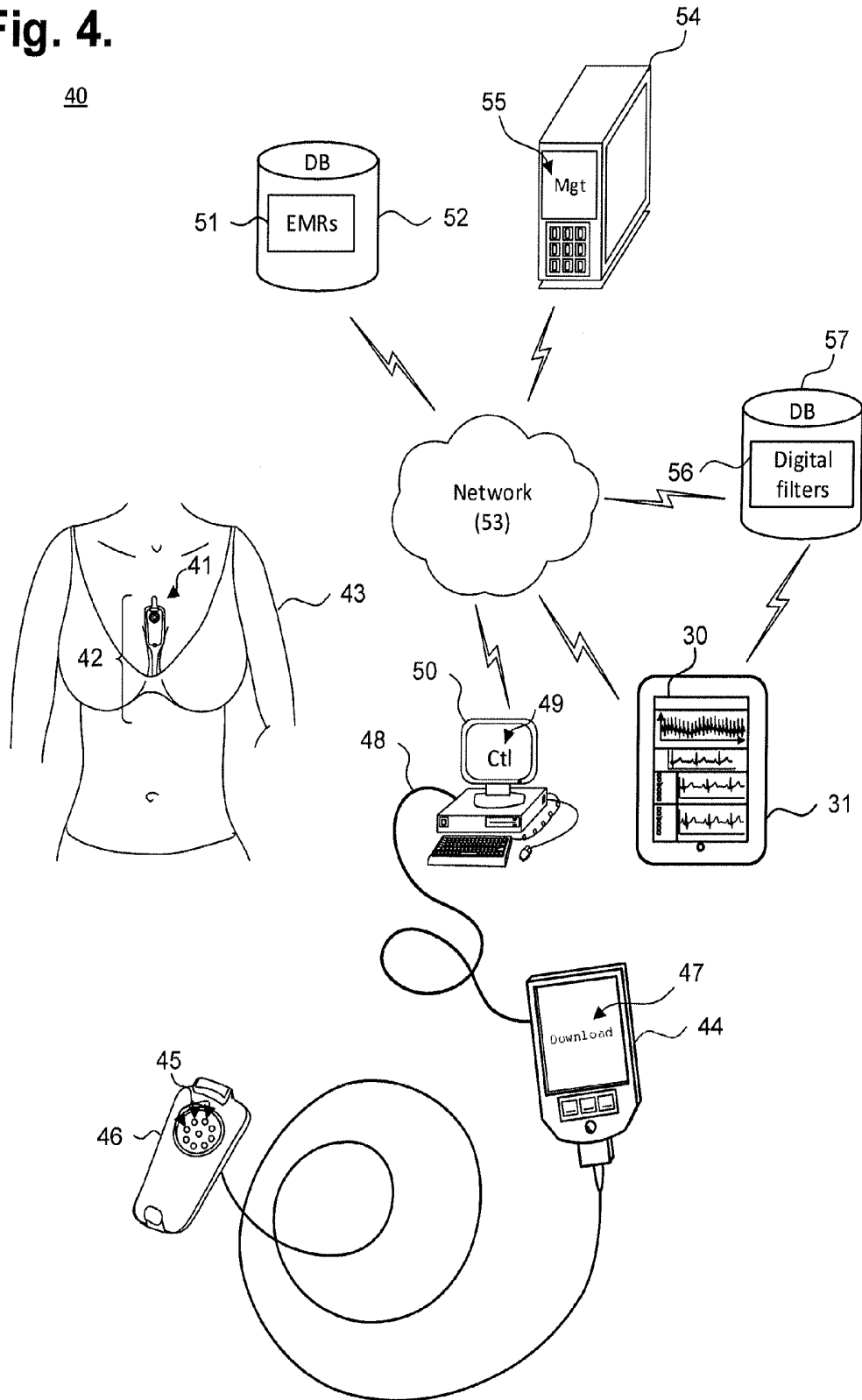


Fig. 5.

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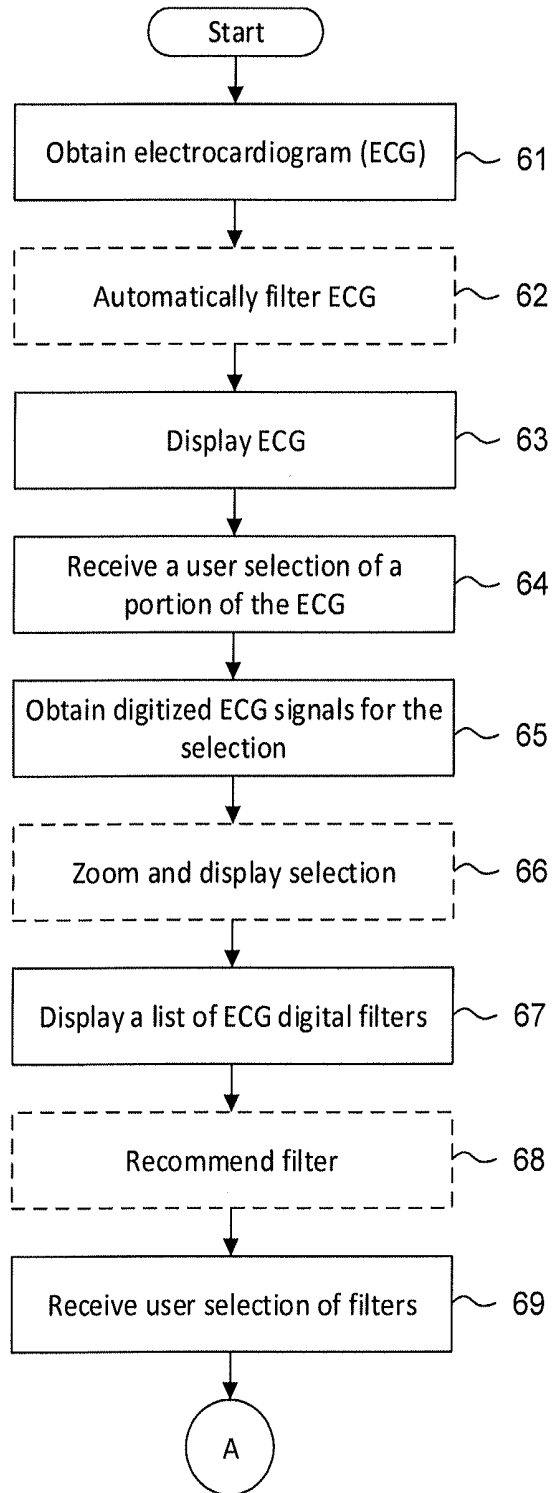


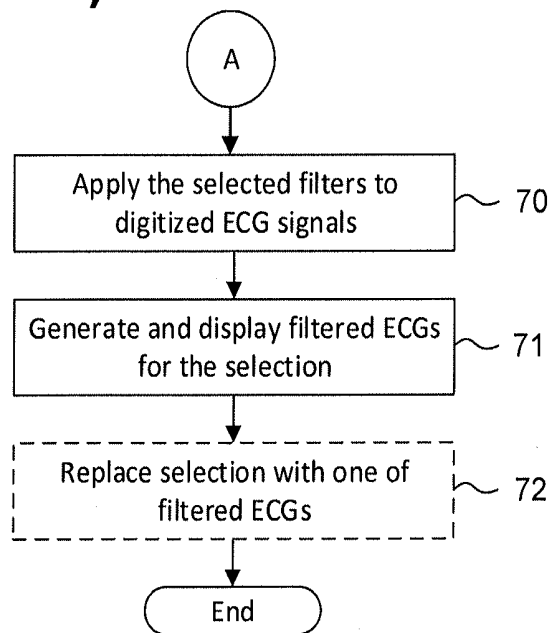
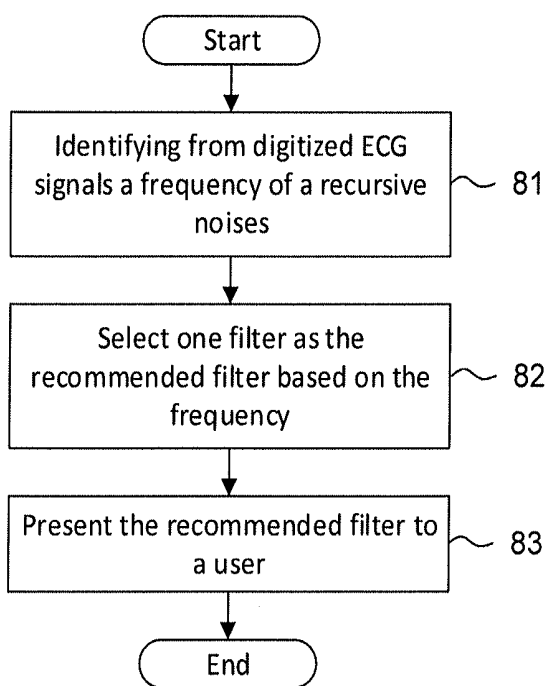
Fig. 5. (Con't)

Fig. 6.

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SYSTEM AND METHOD FOR INTERACTIVE PROCESSING OF ECG DATA

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This non-provisional patent application is a continuation-in-part of U.S. patent application Ser. No. 14/082,071, filed Nov. 15, 2013, pending; which is a continuation-in-part of U.S. patent application Ser. No. 14/080,717, filed Nov. 14, 2013, pending, and a continuation-in-part of U.S. patent application Ser. No. 14/080,725, filed Nov. 14, 2013, pending; and which further claims priority under 35 U.S.C. §119 (e) to U.S. Provisional Patent application Ser. No. 61/882,403, filed Sep. 25, 2013, the disclosures of which are incorporated by reference.

FIELD

[0002] This application relates in general to electrocardiography and, in particular, to a system and method for interactive processing of electrocardiogram (ECG) data.

BACKGROUND

[0003] An ECG procedure measures cardiac electrical potentials that can be graphed to visually depict the electrical activity of the heart over time. Conventionally, a standardized set format 12-lead configuration is used by an ECG machine to record cardiac electrical signals from well-established traditional chest locations. Sensed cardiac electrical activity is represented by PQRSTU waveforms that can be interpreted post-ECG recodation to derive heart rate and physiology and for use in medical diagnosis and treatment.

[0004] Within an ECG waveform, the P-wave represents atrial electrical activity. The QRSTU components represent ventricular electrical activity. Some cardiac conditions have frequency-specific content. The QRS complex in ventricular tachyarrhythmia, for instance, has a maximum amplitude at 4 Hz, while the frequencies associated with ventricular fibrillation are concentrated in the 4-7 Hz range. Cardiac vagal activity and respiratory sinus arrhythmias are seen in the 0.15-0.50 Hz range. Other frequencies may reflect other cardiac conditions.

[0005] Noise in recorded signals or other artifacts that do not reflect cardiac activity can contribute to an incorrect diagnosis of a patient. The main sources of noise in an ECG machine are common mode noise, such as 60 Hz power line noise, baseline wander, muscle noise, and radio frequency noise from equipment including pacemakers or other implanted medical devices. Such noise can contribute to an incorrect diagnosis of the patient. For example, electrical or mechanical artifacts, such as produced by poor electrode contact or tremors, can simulate life-threatening arrhythmias. Similarly, baseline wander produced by excessive body motion during an ECG procedure may simulate an ST segment shift ordinarily seen in myocardial ischemia or injury.

[0006] Current ECG over-reading software generally does not allow a user to apply an arbitrary noise filter of choice to an ECG trace; users are generally limited to a set of proprietary filters. In addition, conventional over-reading software generally fails to provide users with a way to compare the results of combinations of arbitrary noise filters, thus preventing the user from finding the most appropriate filter. This is especially relevant when trying to record the P-wave or cardiac atrial signal.

[0007] Therefore, a need remains for a way to facilitate real-time, interactive processing of an ECG.

SUMMARY

[0008] An ECG is displayed to a user, and a user selection of a desired portion of the ECG is received. A list of filters is provided to the user, and the user can try applying different filters to the selection by selecting of one or more sets of the filters in the list. For each of the sets, the filters are applied to digitized signals corresponding to the selection, a filtered ECG for the selection is generated based on the signals filtered by each of the sets, and the filtered selection ECG traces are displayed to the user. The filtered selections can be displayed side-by-side, allowing the user to compare the ECG traces of the selection filtered using the different sets of filters, and to decide whether application of certain filters resulted in an easily-interpretable ECG, or whether different filters need to be applied. As the result, the user can select the most appropriate filters for the selection, which facilitates removal of noise and enhancement of ECG features that were corrupted by noise or were made difficult to see due to the amplitude of the noise. In addition, by applying the filters to only a particular selection, the user is permitted to filter the selection without degrading the quality of other portions of the ECG.

[0009] One embodiment provides a computer-implemented system and method for interactive processing of ECG data. An electrocardiogram is displayed. A user selection of a portion of the displayed ECG is received. Digitized signals corresponding to the selection are obtained. A list of digital filters for filtering the selection are displayed. A user selection of one or more sets of the digital filters is received, with each of the sets including one or more of the filters from the list. The selected sets are applied to the digitized signals for the selection. A filtered ECG for the selection is generated for each of the sets based on the signals filtered by that set. The filtered selection ECG for each of the sets are presented on the display.

[0010] Providing a real-time, interactive ECG processing apparatus and method for a user, such as a cardiologist or a trained technician, to select and apply ECG noise filters to a desired portion of an ECG trace, particularly but not exclusively the P-wave, simplifies ECG result processing and improves ECG interpretation accuracy.

[0011] Still other embodiments of the present invention will become readily apparent to those skilled in the art from the following detailed description, wherein are described embodiments by way of illustrating the best mode contemplated for carrying out the invention. As will be realized, the invention is capable of other and different embodiments and its several details are capable of modifications in various obvious respects, all without departing from the spirit and the scope of the present invention. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a graph showing, by way of example, a normal ECG waveform for a single cardiac cycle.

[0013] FIG. 2 is a graph showing, by way of example, an ECG waveform of a patient with atrial flutter for a single cardiac cycle, where the ECG waveform has been corrupted by power line noise.

[0014] FIG. 3 is a diagram showing a screen shot generated by an application for interactive processing of ECG data in accordance with one embodiment.

[0015] FIG. 4 is a functional block diagram showing a system for interactive processing of ECG data in accordance with one embodiment.

[0016] FIG. 5 is a flow diagram showing a method for interactive processing of ECG data in accordance with one embodiment.

[0017] FIG. 6 is a flow diagram showing a routine for recommending an ECG filter for use in the method of FIG. 5 in accordance with one embodiment.

DETAILED DESCRIPTION

[0018] An ECG includes multiple waveforms reflecting multiple contractions of a patient's heart. FIG. 1 is a graph showing, by way of example, a normal ECG waveform **10** for a single cardiac cycle. The x-axis represents time in approximate units of tenths of a second. The y-axis represents cutaneous electrical signal strength in approximate units of millivolts. The P-wave **11**, when recorded from the anterior thorax, normally has a smooth, initially upward slope, (i.e., a positive vector) that indicates atrial depolarization from right to left atrium. The QRS complex usually begins with the downward deflection of a Q wave **12**, followed by a larger upward deflection of an R-wave **13**, and terminated with a downward waveform of the S wave **14**, collectively representative of ventricular depolarization. The T wave **15** is normally a modest upward waveform, representative of ventricular repolarization, while the U wave **16**, often not directly observable, indicates repolarization of the Purkinje conduction fibers.

[0019] ECG signals include low amplitude voltages in the presence of high offsets and noise, which requires the signals to be amplified and filtered prior to being displayed for interpretation. In an unfiltered ECG, some of the features may not be apparent, particularly if their shapes have been corrupted by noise. For example, the P-wave morphology, presence or absence, timing, and size can be indicative of a variety of cardiac conditions. An abnormally large P-wave can be indicative of atrial hypertrophy, an abnormally wide P-wave can be indicative of an intra-atrial block, and atrial flutter may cause the P-waves to adopt a "saw-tooth" or negative shape. Absent or not-easily discernible P-waves can be indicative of atrial fibrillation, while discrete P-waves that vary from beat-to-beat with at least three different morphologies, can be indicative of multifocal atrial tachycardia. A dissociation between the timing of the P-wave and the QRS complex can indicate ventricular tachycardia. Other associations between the P-wave and cardiac conditions exist. Identifying presence, timing and morphology of the P-wave is critical to arrhythmia diagnosis.

[0020] Noise in an ECG or inadequate signal clarity is a major problematic for cardiologists when caring for patients with possible cardiac arrhythmias. FIG. 2 is a graph showing, by way of example, an ECG waveform **20** of a patient with atrial flutter for a single cardiac cycle, where the ECG waveform **20** has been corrupted by power line noise. In the United States, power line noise has a frequency of 60 Hz with a high amplitude. The wall outlets in an examination room invariably surround a patient and create an electrical field that causes power line noise to be coupled into the ECG. Here the patient's ECG lacks a clearly defined P-wave, with the signal

noise obscuring the "saw-tooth" P-wave shape seen in the underlying atrial flutter. As a result, the diagnosis is missed.

[0021] Classical ways to reduce power line noise are to make physical changes to the circuit design of ECG equipment. For instance, power line noise can be reduced by isolating front-end ground electronics from the digital components of the machine, and using shielded cables to acquire ECG signals driven with a common voltage to reduce noise from being coupled from proximal power lines. However, some degree of power line noise will always be present due to the power draw of the ECG machine itself. Power line noise is more predictable and more readily lends itself to classical noise-reduction techniques, as described above.

[0022] Other types of noise, such as those associated with muscle activity, often the main source of ECG noise, including baseline wander, is best diminished with a more patient-specific and dynamic method of noise reduction involving the appropriate application of digital noise filters.

[0023] Digital filters are inherently flexible. Changing the characteristics of a digital filter merely involves changing the program code or filter coefficients. They also do not require physical reconstruction of the ECG system, and thus tend to be low cost and highly compatible with existing ECG equipment. Noise present in an ECG of one patient can be different from noise present in an ECG of another patient, and the flexibility provided by the digital filters helps to clarify each individual ECG and provide for patient-specific ECG signal processing. In addition, digital filters are immune to the effects of wear and degradation that all hardware experiences.

[0024] ECG noise can be effectively reduced by allowing a user to pick particular portions of an ECG for application of a filter and allowing the user to compare results of applications of different filters to the selected portions. This is critical when seeking to record the more difficult-to-see P-wave compared to the high voltage high frequency content of the QRS wave. FIG. 3 is a diagram showing a screen shot generated by an application **30** for interactive processing of ECG data in accordance with one embodiment. The application **30** can be a downloadable application executed on a user device **31**. While the user device **31** is shown as a tablet computer with reference to FIG. 1, other kinds of user devices **31**, such as mobile phones, desktop computer, laptop computers, portable media players are possible; still other types of user devices **31** are possible. The user device **31** can include components conventionally found in general purpose programmable computing devices, such as a central processing unit, memory, input/output ports, network interfaces, and non-volatile storage, although other components are possible. The central processing unit can implement computer-executable code, including digital ECG filters, which can be implemented as modules. The modules can be implemented as a computer program or procedure written as source code in a conventional programming language and presented for execution by the central processing unit as object or byte code. Alternatively, the modules could also be implemented in hardware, either as integrated circuitry or burned into read-only memory components. The various implementations of the source code and object and byte codes can be held on a computer-readable storage medium, such as a floppy disk, hard drive, digital video disk (DVD), random access memory (RAM), read-only memory (ROM) and similar storage mediums. Other types of modules and module functions are possible, as well as other physical hardware components.

[0025] The application **30** receives results of an ECG monitoring, which can include an ECG **32**, including in a printed form. The ECG **32** can be received at once, such as upon completion of monitoring, or in portions, as the monitoring progresses. In addition to the ECG **32**, the application **30** can display information about the patient **33** such as the patient's name, date of birth, gender, and patient ID; other clinical or physiological information associated with the patient can also be displayed.

[0026] A user may select a portion **34** of the displayed ECG **32** for application of one or more digital filters, such as by clicking on the portion or highlighting the portion with a mouse. The selected portion **34** can be zoomed and displayed in a separate area **35** of the application screen. By looking at the selection in the area **35**, the user can decide what filters to apply to the selection **34**.

[0027] Application of filters to an ECG can result in a loss of clinical information present in the ECG waves. Only a limited number of filters can be applied before such clinical information is lost due to the filters introducing distortions into some part of the ECG signals. For example, a high-pass filter, a filter whose purpose is to remove low-frequency noise, introduces distortions to the ST segment of ECG. The distortion arises from the combination of the frequencies of some of the noise overlapping with the spectra of useful ECG waves, with the noise generally being stochastic; thus any attempt of removing the noises after signal acquisition is typically accompanied by some degree of signal degradation. An excessive number or an incorrect set of applied filters can remove useful diagnostic features from the ECG waveform, leading to false diagnostic statements. By selecting a portion **34** of the ECG and, applying filters only to that portion, the rest of the ECG **32** is maintained intact and unfiltered.

[0028] The user may filter the selection **34** using a list of ECG digital noise filters provided by application in filter selection menus **36**, **38**. By selecting the filters in different menus **36**, **38**, the user can select different sets of filters for filtering the ECG **32**. Each of the digital filters is a mathematical algorithm that is applied to digital ECG signals to output a set of filtered signals that differs from the set of the ECG signals to which that filter is initially applied. The filters can be stored in the memory of the user device **31**. Such filters can include a low-pass filter, which attenuates noise with a frequency higher than a cut-off frequency; a high-pass filter, which attenuates signals with frequencies lower than the cut-off frequency; a notch filter, which passes all frequencies except those in a stop-band centered on a center frequency; a phase correction filter, which corrects a phase of an ECG wave following earlier digital processing; and an adaptive filter, which obtains the frequency of the noise present, such as based on patient input or by calculating the noise, and minimizes the identified noise. Other types of filters are possible.

[0029] The user can customize the filter selection menus **36**, **38**. For instance, the user can change the order in which the filters are displayed in the selection menus **36**, **38**, such as by dragging and dropping the filters with a mouse. Thus, if the user uses particular filters more often than other filters, the more used filters can be brought to the top of the menus **36**, **38**. Further, the order of the filters in the filter selection menu **36** can be different from the order in the menu **38**.

[0030] Also, the user can select the displayed filters, such as by clicking on a name of one of the filters, and change one or more parameters of the selected filter. For example, if the

selected filter is a high-pass filter, the user can enter a cut-off frequency used for the filter. Other parameters can also be changed. The desired parameters can be changed in a separate window of the application **32** that appears upon the filter being selected, though other ways for the user to change the parameters are possible. Still other ways to customize the filter selection menus are possible.

[0031] The user may apply different filters or combinations of filters to the selection **34**, and see the results of applications of different filters side-by-side in the areas **37** and **39**. For example, the user may select a notch filter to be applied to the selection **34**, and see the results of the application of the filter, a filtered ECG of the selection, in the area **37**. While the application of the notch filter results in a clearer shape of the selection **34**, including that of the P-wave, if the user is still not satisfied with the result, the user can choose in the filter selection menu **38** to choose to apply a different set of filters, choosing the notch filter in combination with the low-pass filter to further remove the noise from the selection **34**, with the results of the application of the filters being displayed in the area **39**. The user can compare the application of different selected filters side-by-side and decide whether any of the applied filters or combinations of filters produce a satisfactory result or whether applications of other filters are necessary. The results of application of different filters to the selection **34** are displayed to the user immediately upon becoming available, allowing the user to explore different filter set possibilities in real-time and reducing the time necessary to find the most appropriate filter set.

[0032] If the user is satisfied with a filtered ECG of the selection in the area **37** or **39**, the user can replace the selection **34** of the ECG **32** with the filtered ECG of the selection in area **37** or **39**, such as by dragging the selection in the area **37**, **39** to the displayed ECG **32** or pressing a button on the screen of the application **31** (not shown).

[0033] While two sets of filter selection menus **36**, **38** and areas with the results of filter application **38**, **39** are shown in the screen of the application, in a further embodiment, other numbers of filter menus and areas showing results of the filtering using the selected filters are possible.

[0034] As further described with reference to FIGS. **5** and **6**, the application **30** can make a recommendation (not shown) of one or more filters to be applied to the selection **34**. The recommendation is created by identifying a frequency of a noise recurring in the selection **34** ("recursive noise"), such as presence of 60 Hz power line noise, based on one or more of user input or mathematical estimation of the noise frequency, and recommending the frequency based on the noise. For example, if the recursive noise includes power line noise, a notch filter or a low-pass filter can be recommended to remove the noise. The recommendation can be presented in different ways, such as presenting the recommendation in a separate field on the screen of the application **30** or by highlighting the filters presented in the menus **36**, **38**.

[0035] In a further embodiment, in addition to providing a filtering recommendation, the application **30** can automatically apply one or more filters to an ECG prior to presenting the ECG to the user, saving the user the labor of filtering noise that can be automatically identified and removed. The application **30** can identify the presence of noise in an ECG received from an ECG monitor or from another source, automatically apply a filter or a combination of filters to digitized signals for portions of the ECG with the noise, and generate the ECG **32** that is displayed to the user based on digitized

signals that have been filtered and any digitized signals that did not include the noise. For example, if the application 30 identifies baseline wander corrupting a received ECG, which can be identified using techniques such as measuring deviation of signals from the baseline in a random fashion within set frequency domains, the application 30 can automatically apply a filter or a set of filters to digitized signals for portions of the ECG with the baseline wander, and generate the ECG 32 displayed to the user based on digitized signals that have been filtered and signals that have not been corrupted by the baseline wander. The filters to be applied can be determined via testing, such by as applying different filters, such as various high-pass filters, or combinations of filters to the digitized signals and identifying the filters or combinations of filters that result in the greatest reduction of the baseline wander. In a further embodiment, a preset filter or combination of filters can be used to automatically reduce or remove the baseline wander. In a still further embodiment, the application 30 can also test effect of changing parameters of the filters on the removal of the noise, and choose the most appropriate parameters for the filters used. Other kinds of automated application of filters are possible.

[0036] The application can obtain results of an ECG recording from a variety of sources. FIG. 4 is a functional block diagram showing a system 40 for interactive processing of ECG data in accordance with one embodiment. As seen in FIG. 2, the application 30 can receive the results from a long-term ECG monitor, a monitor that continuously monitors patient information over a number of days.

[0037] In one embodiment, the long-term electrocardiography ECG monitor can be the extended wear ambulatory physiological sensor monitor 41 described in detail in a commonly-assigned U.S. Patent application, entitled "Extended Wear Ambulatory Electrocardiography and Physiological Sensor Monitor," Ser. No. 14/080,725, filed Nov. 14, 2013, pending, the disclosure of which is incorporated by reference. The placement of the wearable monitor 41 in a location at the sternal midline 42 (or immediately to either side of the sternum) of the patient 43 significantly improves the ability of the wearable monitor 41 to cutaneously sense cardiac electric signals, particularly the P-wave (or atrial activity) and, to a lesser extent, the QRS interval signals in the ECG waveforms that indicate ventricular activity, while simultaneously facilitating comfortable long-term wear for many weeks. As further described in detail in commonly-assigned U.S. Patent application, entitled "Remote Interfacing of Extended Wear Electrocardiography and Physiological Sensor Monitor," Ser. No. 14/082,071, filed on Nov. 15, 2013, pending, the disclosure of which is incorporated by reference, upon completion of the monitoring period, the monitor 41 can be connected to a download station 44, which could be a programmer or other device that permits the retrieval of stored ECG monitoring data, execution of diagnostics on or programming of the monitor recorder 41, or performance of other functions. The monitor 41 has a set of electrical contacts (not shown) that enable the monitor recorder 41 to physically interface to a set of terminals 45 on a paired receptacle 46 of the download station 44. In turn, the download station 44 can execute a communications or offload program 47 ("Offload") or similar program that interacts with the monitor recorder 41 via the physical interface to retrieve the stored ECG monitoring data. The download station 44 could be the user device 31 or another server, personal computer, tablet or handheld computer, smart mobile device, or purpose-built programmer

designed specific to the task of interfacing with a monitor 41. Still other forms of download station 44 are possible.

[0038] Upon retrieving stored ECG monitoring data from the monitor 41, middleware (not shown) first operates on the retrieved data to adjust the ECG capture quality, as necessary, and to convert the retrieved data into a format suitable for use by third party post-monitoring processing software, such as the application 30. If the download station 44 is not the user device 31, the formatted data can then be retrieved from the download station 44 over a hard link 48 using a control program 49 ("Ctl") or analogous application executing on a personal computer 50 or other connectable computing device, via a communications link (not shown), whether wired or wireless, or by physical transfer of storage media (not shown). The personal computer 50 or other connectable device may also execute middleware that converts ECG data and other information into a format suitable for use by a third-party post-monitoring processing program, such the application 30. Note that formatted data stored on the personal computer 50 would have to be maintained and safeguarded in the same manner as electronic medical records (EMRs) 51 in a secure database 52, as further discussed infra. In a further embodiment, the download station 44 is able to directly interface with other devices over a computer communications network 53, which could be some combination of a local area network and a wide area network, including the Internet, over a wired or wireless connection. Still other forms of download station 44 are possible. In addition, the wearable monitor 41 can interoperate with other devices, as further described in detail in commonly-assigned U.S. Patent application, entitled "Remote Interfacing of Extended Wear Electrocardiography and Physiological Sensor Monitor," Ser. No. 14/082,071, filed on Nov. 15, 2013, pending, the disclosure of which is incorporated by reference. In addition, the wearable monitor 41 is capable of interoperating wirelessly with mobile devices, including so-called "smartphones," such as described in in commonly-assigned U.S. Patent application, entitled "Computer-Implemented System And Method for Providing A Personal Mobile Device-Triggered Medical Intervention," filed on Mar. 17, 2014, the disclosure of which is incorporated by reference.

[0039] Other kinds of long-term monitors, such as Holter monitors (not shown), can be used to obtain the data processed by the application 30. In addition, the application 30 can receive the results from other kinds of ECG monitors, such as a standard 12-lead ECG monitor (not shown) that records a patient's ECG during a visit to a doctor's office, which can provide the results to the application 30 through the download station 44 or in other ways described above. Still other kinds of ECG and physiological monitors, from which data can be received, are possible. Further, in one embodiment, the results can be obtained by the application 30 upon the completion of the monitoring. In a further embodiment, the results can be provided to the application 30 running on the user device 31 as they are obtained.

[0040] While as mentioned above the user device 31 can be the download station 44 and receive ECG recording data from an ECG monitor directly, the application 30 running on the user device 31 can also receive results of monitoring from other sources, such as from a server 54 storing results of completed recordings or "monitorings". A client-server model could be used to employ a server 54 to remotely interface with the download station 44 over the network 53 and retrieve the formatted data or other information. The server 54

executes a patient management program 55 (“Mgt”) or similar application that stores the retrieved formatted data and other information in the secure database 52 cataloged in that patient’s EMRs 51. The application 30 can receive the results of the monitoring from the server 54. In addition, the patient management program 55 could manage a subscription service that authorizes a monitor recorder 41 to operate for a set period of time or under pre-defined operational parameters.

[0041] The patient management program 55, or other trusted application, also maintains and safeguards the secure database 52 to limit access to patient EMRs 51 to only authorized parties for appropriate medical or other uses, such as mandated by state or federal law, such as under the Health Insurance Portability and Accountability Act (HIPAA) or per the European Union’s Data Protection Directive. For example, a physician may seek to review and evaluate his patient’s ECG monitoring data, as securely stored in the secure database 52.

[0042] Still other sources from which the application 30 can receive the results of the ECG monitoring are possible.

[0043] As mentioned above, the application 30 applies one or more of ECG digital filters to a user selection of a displayed ECG trace 32. The application 30 can obtain the filters 56 from a database 57, with which the application 30 can interact via the network 53. The database 57 can be updated with more filters 56, allowing the application 30 and present them to the user as the filters 56 become available.

[0044] Allowing a user to choose and selectively apply filters to selected portions of an ECG facilitates obtaining an ECG that includes discernible diagnostic information and can be used for patient diagnosis. FIG. 5 is a flow diagram showing a method 60 for interactive processing of ECG data in accordance with one embodiment. Initially, an ECG 32 that is a result of electrocardiographic monitoring of a patient is obtained by the application 30 executed on the user device 31 (step 61). The ECG 32 can be obtained from an ECG monitor or from other sources, as described above, and can be obtained upon a completion of the monitoring, or continuously received in real-time as monitoring progresses. In a still further embodiment, both the ECG 32 and the digitized ECG signals corresponding to the ECG 32 can be obtained.

[0045] Optionally, if the application 30 identifies presence of noise, such as baseline wander, in the ECG received from a monitor or another source, the application 30 can automatically apply one or more filters to digitized signals corresponding to portions of the obtained ECG that has the noise, with the ECG 32 that is subsequently displayed to the user being generated based on the filtered digitized signals and signals for portions of the ECG that did not include the baseline wander, as further described above with reference to FIG. 3 (step 62).

[0046] The ECG 32, after having been optionally automatically filtered, is displayed on a display screen of the user device 31 (step 63). If the ECG 32 is received over a period of time, such as when the ECG is a result of an ongoing electrocardiographic monitoring, portions of the ECG can be updated in real-time as they are being received, with the displayed ECG being updated as more results of the monitoring become available. If the ECG 32 is a result of an already completed monitoring, all portions of the ECG can be displayed at the same time.

[0047] A user selection 34 of a portion of the ECG is received, such as via the user touching the portion on the touch-screen display of the user device 31, entering the selec-

tion from a keyboard, or using a mouse (step 64). Digitized ECG signals corresponding to the selected portion 34 of the ECG are obtained by the application 30 (step 65). If the digitized signals for the ECG 32 were received with the ECG 32, the signals corresponding to the selection 34 can be identified among the received signals. If no digitized ECG signals have been received, the application 30 can reconstruct the digitized signals from the selection 34. Other ways to obtain the digitized signals are possible.

[0048] Optionally, the selection is zoomed and the zoomed selection 35 is displayed to the user by the application (step 66). A list, such as in the selection menus 36, 38, of a plurality of digital ECG filters for filtering the selection is displayed to the user, with the user being able to select one or more sets of the filters for filtering the selection (step 67). Optionally, a filter recommended for processing the selection 34 is determined and displayed to the user, as further described with reference to FIG. 6 (step 68). A user selection of one or more sets of the filters is received by the application 30, with each of the filter sets including at least one of the filters displayed (step 69). The application 30 applies each of the sets of the selected filters to the digitized ECG signals for the selection (step 70), generates filtered ECG for the selection based on the digital signals filtered by each of the sets, and displays the filtered ECG for the selection on portions 37, 39 of the display screen of the user device 31 (step 71). The filtered ECGs can be displayed visually proximate to each other, allowing comparison of results of filtering side-by-side, and thus enabling the user to decide which of the results is more useful, whether one of the results satisfies the user’s needs, or whether a still different set of filters needs to be applied. Optionally, upon receiving a user selection of one of the filtered ECGs for the selection, the application 30 can replace the selected portion 34 of the ECG 32 with the selected filtered ECG (step 72), ending the method 60.

[0049] Recommending an ECG filter to the user can save the user time and simplify ECG interpretation for the user. FIG. 6 is a flow diagram showing a routine 80 for recommending an ECG filter to a user for use in the method 60 of FIG. 5 in accordance with one embodiment. First, a frequency of a recursive noise present in the ECG selection is identified (step 81). Second, one or more digital filters are selected based on the noise frequency (step 82). For example, if the selection includes high-frequency recursive noise, a low-pass filter can be chosen for the recommendation. Lastly, the selected filter is recommended to a user, terminating the routine 80 (step 83).

[0050] While the invention has been particularly shown and described as referenced to the embodiments thereof, those skilled in the art will understand that the foregoing and other changes in form and detail may be made therein without departing from the spirit and scope.

What is claimed is:

1. A system for interactive processing of ECG data, comprising:
 - a display module configured to display an electrocardiogram (ECG);
 - a receipt module configured to receive a user selection of a portion of the displayed ECG;
 - a signal module configured to obtain digitized signals corresponding to the selection;
 - a list module configured to display a list of digital filters for filtering the selection;

- a selection module configured to receive a user selection of one or more sets of the digital filters, each of the sets comprising one or more of the filters from the list;
 an application module configured to apply the selected sets to the digitized signals for the selection;
 a generation module configured to generate for each of the sets a filtered ECG of the selection based on the signals filtered by that set; and
 a set module configured to display the filtered selection ECG for each of the sets.
2. A system according to claim 1, wherein the ECG is based on electrocardiographic monitoring of a patient performed by a long-term electrocardiographic monitor.
3. A system according to claim 2, wherein the monitor is located along the patient's sternum when performing the monitoring.
4. A system according to claim 3, wherein the selection comprises a P-Wave comprised in the ECG.
5. A system according to claim 1, further comprising a recommendation module configured to recommend one of the filters in the list to a user, comprising:
 an identification module configured to identify from the digitized signals a frequency of recursive noise in the selection;
 selecting one of the filters as the recommended filter based on the frequency; and
 presenting the selected filter as the recommended filter.
6. A system according to claim 5, wherein the filters on the list comprise one or more of a low-pass filter, high-pass filter, notch filter, phase correction filter, and an adaptive filter.
7. A system according to claim 1, wherein the user selection of the filters comprises at least two of the sets of the filters and the filtered ECG for the at least two sets are displayed visually proximate to each other.
8. A system according to claim 1, further comprising:
 a filtered selection module configured to receive a user selection of the filtered selection ECG for one of the sets; and
 a replacement module configured to replace the selection in the displayed ECG with the filtered selection ECG.
9. A system according to claim 1, further comprising one or more of:
 a signal receipt module configured to receive digitized signals for the ECG comprising the digitized signals for the selection; and
 an identification module configured to identify the digitized ECG signals for the selection among the received digitized signals for the ECG.
10. A system according to claim 1, further comprising:
 a noise module configured to obtain an ECG corrupted by an ECG noise;
 a portion module configured to identify one or more portions of the corrupted ECG comprising the noise;
 an automation module configured to automatically apply one or more of the filters to digitized signals for the portions of the corrupted ECG; and
 an ECG generation module configured to generate the ECG based on the automatically filtered digitized signals.
11. A method for interactive processing of ECG data, comprising the steps of:
 displaying an electrocardiogram (ECG);
 receiving a user selection of a portion of the displayed ECG;
 obtaining digitized signals corresponding to the selection;
 displaying a list of digital filters for filtering the selection;
 receiving a user selection of one or more sets of the digital filters, each of the sets comprising one or more of the filters from the list;
 applying the selected sets to the digitized signals for the selection;
 generating for each of the sets a filtered ECG of the selection based on the signals filtered by that set; and
 displaying the filtered selection ECG for each of the sets.
12. A method according to claim 11, wherein the ECG is based on electrocardiographic monitoring of a patient performed by a long-term electrocardiographic monitor.
13. A method according to claim 12, wherein the monitor is located along the patient's sternum when performing the monitoring.
14. A method according to claim 13, wherein the selection comprises a P-Wave comprised in the ECG.
15. A method according to claim 11, further comprising recommending one of the filters in the list to a user, comprising the steps of:
 identifying a frequency of recursive noise in the selection;
 selecting one of the filters as the recommended filter based on the frequency; and
 presenting the selected filter as the recommended filter.
16. A method according to claim 15, wherein the filters on the list comprise one or more of a low-pass filter, high-pass filter, notch filter, phase correction filter, and an adaptive filter.
17. A method according to claim 11, wherein the user selection of the filters comprises at least two of the sets of the filters and the filtered ECGs for the at least two sets are displayed visually proximate to each other.
18. A method according to claim 11, further comprising the steps of:
 receiving a user selection of the filtered selection ECG for one of the sets; and
 replacing the selection in the displayed ECG with the filtered selection ECG.
19. A method according to claim 11, further comprising the steps of:
 receiving digitized signals for the ECG comprising the digitized signals for the selection; and
 identifying the digitized ECG signals for the selection among the received digitized signals for the ECG.
20. A method according to claim 11, further comprising the steps of:
 obtaining an ECG corrupted by an ECG noise;
 identifying one or more portions of the corrupted ECG comprising the noise;
 automatically applying one or more of the filters to digitized signals for the portions of the corrupted ECG; and
 generating the ECG based on the automatically filtered digitized signals.

专利名称(译)	用于ECG数据交互处理的系统和方法		
公开(公告)号	US20150088020A1	公开(公告)日	2015-03-26
申请号	US14/341698	申请日	2014-07-25
[标]申请(专利权)人(译)	BARDY诊断		
申请(专利权)人(译)	BARDY诊断, INC.		
当前申请(专利权)人(译)	BARDY诊断, INC.		
[标]发明人	DREISBACH EZRA M FELIX JASON BARDY GUST H		
发明人	DREISBACH, EZRA M. FELIX, JASON BARDY, GUST H.		
IPC分类号	A61B5/04 A61B5/0408 A61B5/0432 A61B5/00 A61B5/046 A61B5/0464 A61B5/044 A61B5/0472		
CPC分类号	A61B5/04017 A61B5/044 A61B5/04087 A61B5/0472 A61B5/748 A61B5/0022 A61B5/6823 A61B5/046 A61B5/0464 A61B5/0432 A61B5/0006 A61B5/7203 A61B5/0402 A61B5/0452 G16H40/63		
优先权	61/882403 2013-09-25 US		
外部链接	Espacenet USPTO		

摘要(译)

提出了一种用于ECG数据的交互处理的系统和方法。显示心电图。接收用户对所显示的ECG的一部分的选择。获得对应于选择的数字化信号。显示用于过滤选择的数字滤波器列表。接收用户对一组或多组数字滤波器的选择，其中每组包括来自列表的一个或多个滤波器。所选择的组应用于数字化信号以供选择。基于由该组过滤的信号，为每个组生成用于选择的滤波ECG。每组的滤波选择ECG显示在显示器上。

