



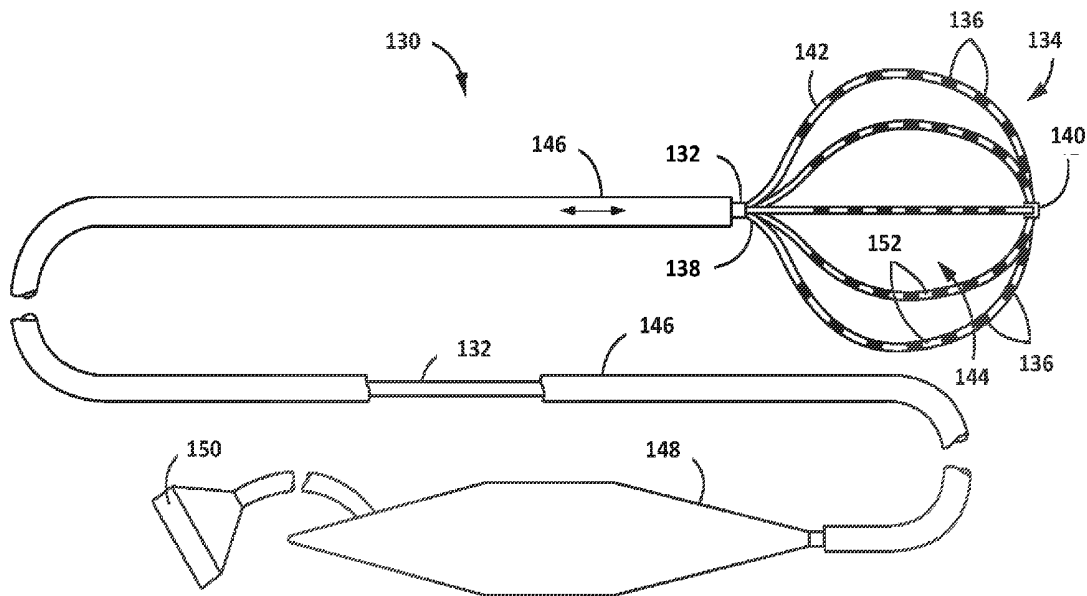
US 20170172508A1

(19) **United States**(12) **Patent Application Publication**
Hultz et al.(10) **Pub. No.: US 2017/0172508 A1**(43) **Pub. Date: Jun. 22, 2017**(54) **AUTOMATIC MAPPING USING VELOCITY
INFORMATION****Publication Classification**(51) **Int. Cl.***A61B 5/00* (2006.01)*A61B 6/00* (2006.01)*A61B 5/042* (2006.01)(52) **U.S. Cl.**CPC *A61B 5/6858* (2013.01); *A61B 5/6852*
(2013.01); *A61B 5/0422* (2013.01); *A61B*
6/503 (2013.01)(71) Applicant: **Boston Scientific Scimed Inc.**, Maple
Grove, MN (US)(72) Inventors: **Paul Hultz**, Brookline, NH (US);
Mordechai Perlman, Cambridge, MA
(US); **Nathan H. Bennett**, Cambridge,
MA (US); **Brian Stewart**, North
Reading, MA (US)(21) Appl. No.: **15/383,475**(22) Filed: **Dec. 19, 2016****Related U.S. Application Data**(60) Provisional application No. 62/270,030, filed on Dec.
20, 2015.

(57)

ABSTRACT

Systems for facilitating display of cardiac mapping information include a mapping probe configured to sense cardiac electrical signals. The systems also include a processing unit configured to receive the cardiac electrical signals; determine signal features; and determine conduction characteristics. The processing unit also is configured to generate, based on the signal features and the corresponding conduction characteristics, a cardiac map.



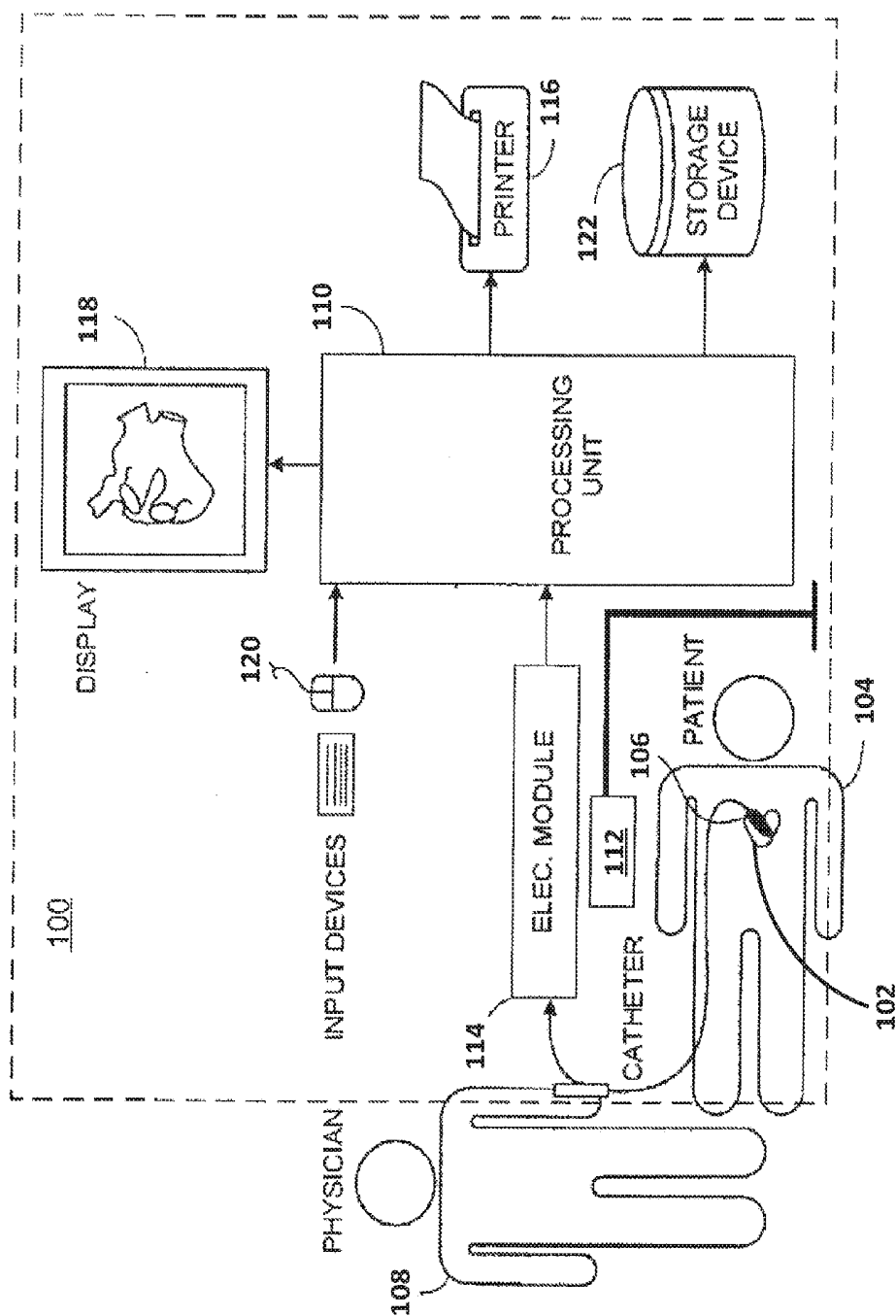


FIG. 1A

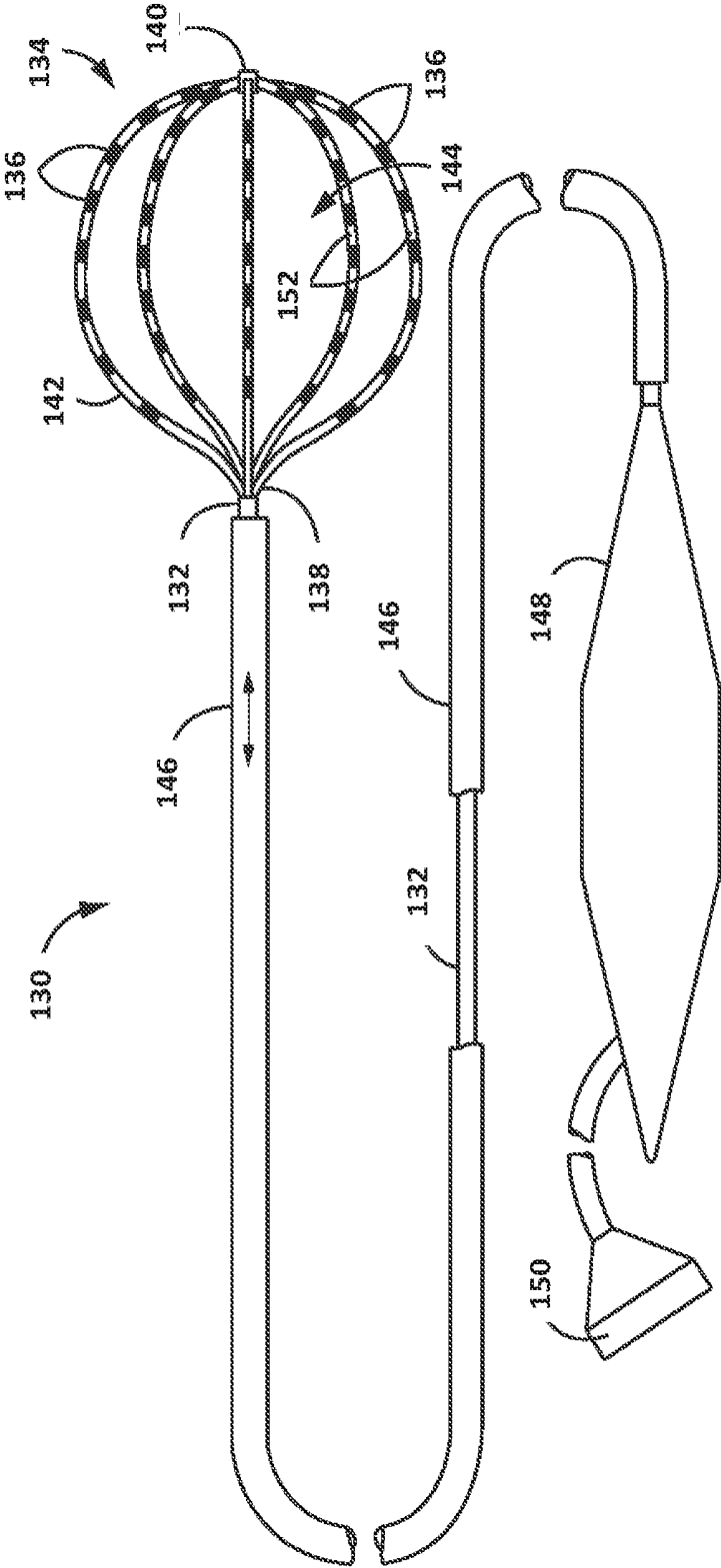


FIG. 1B

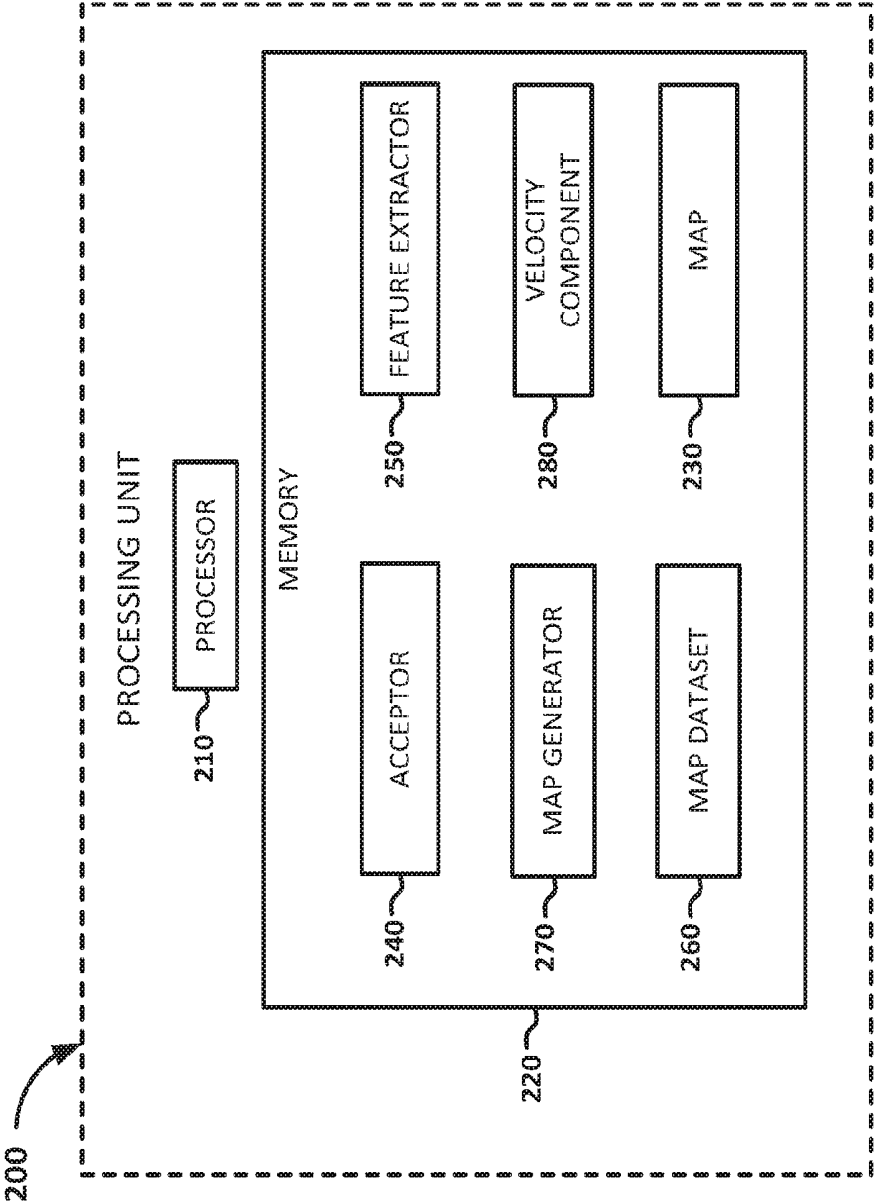


FIG. 2

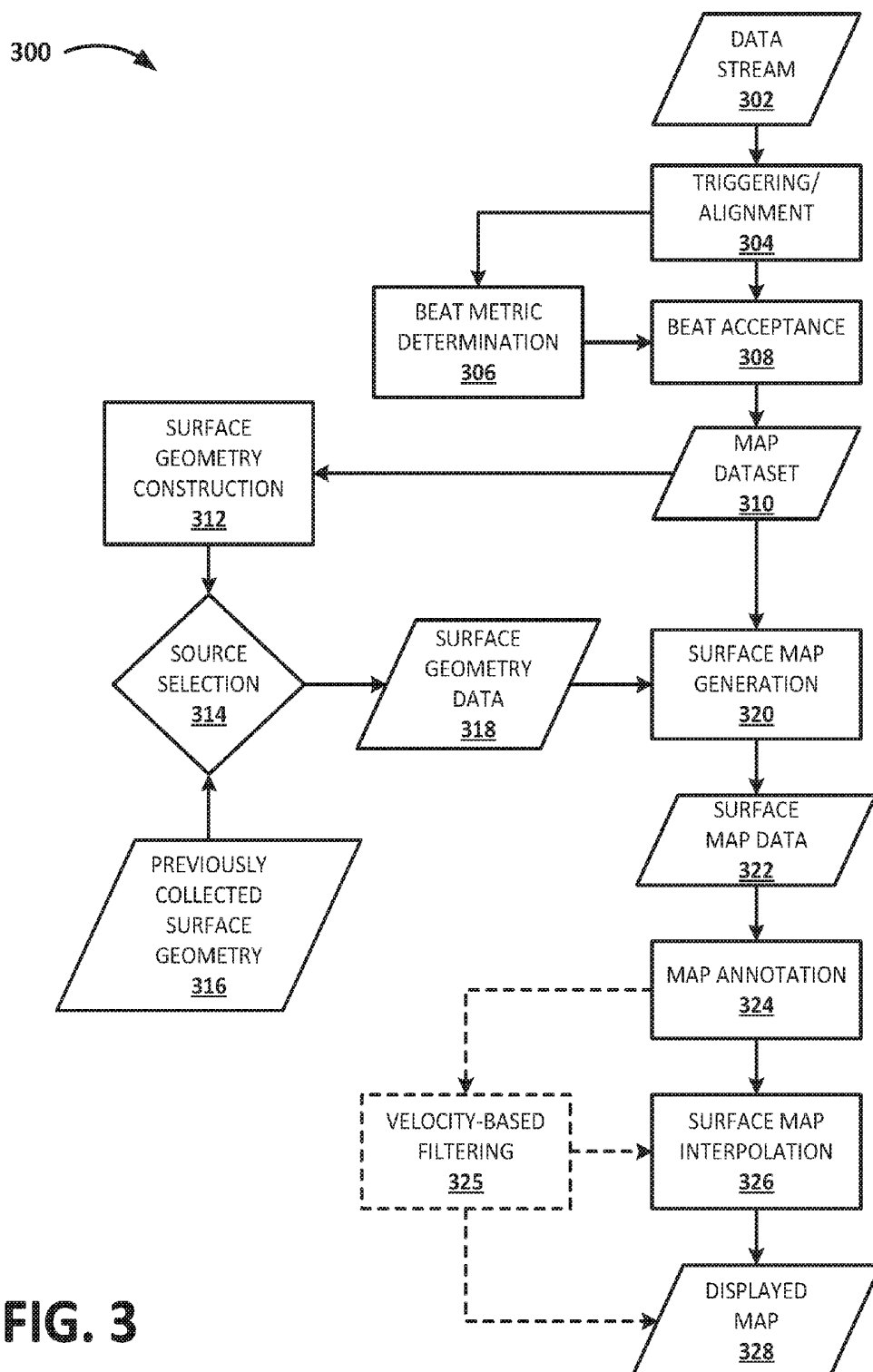
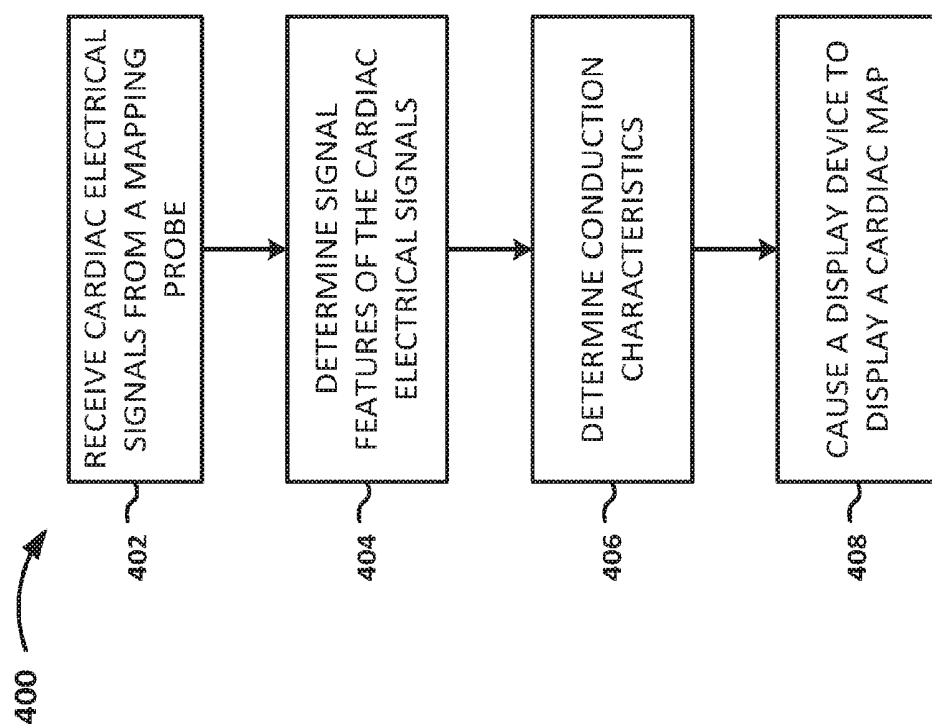


FIG. 3

**FIG. 4**

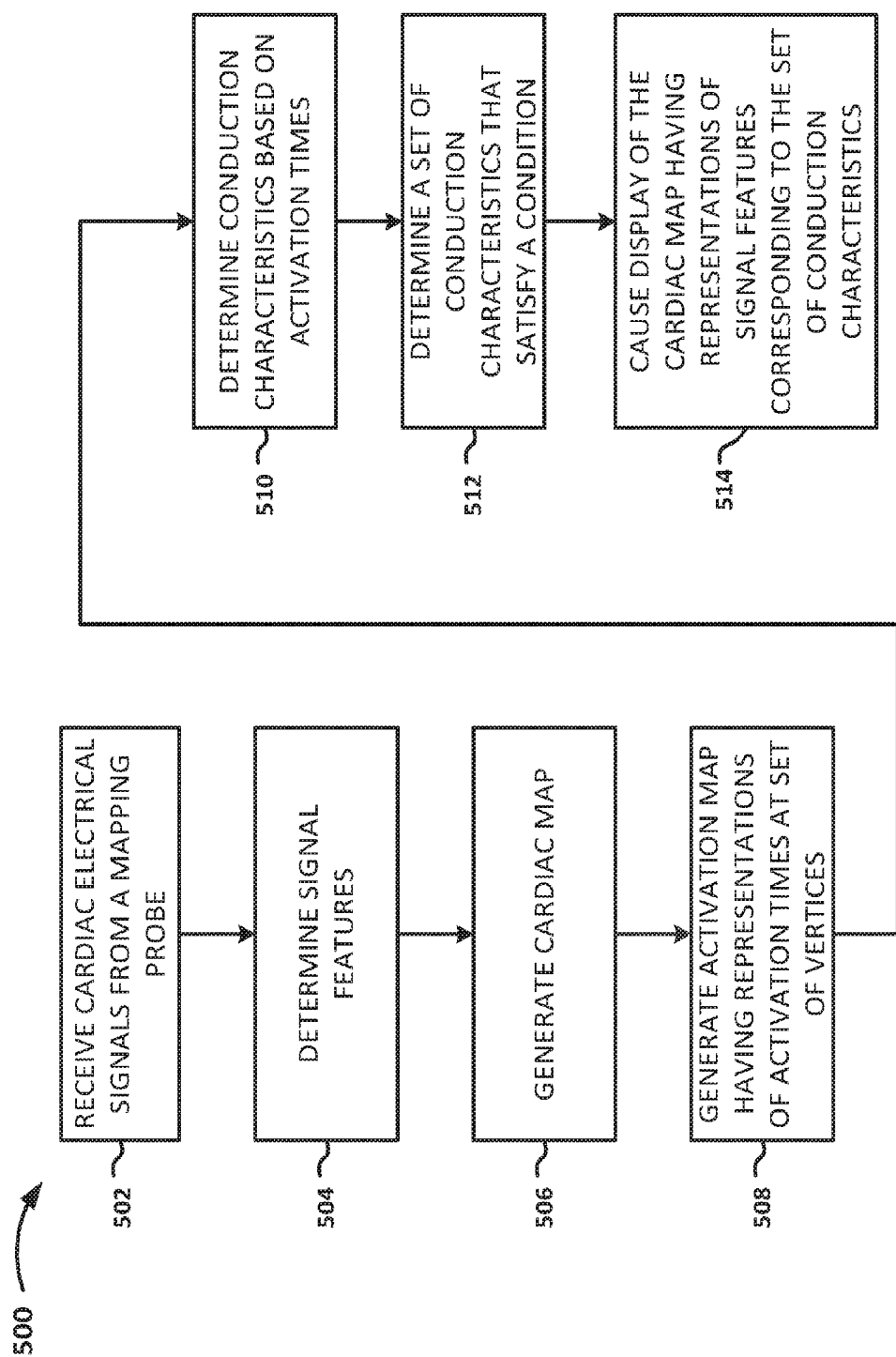


FIG. 5

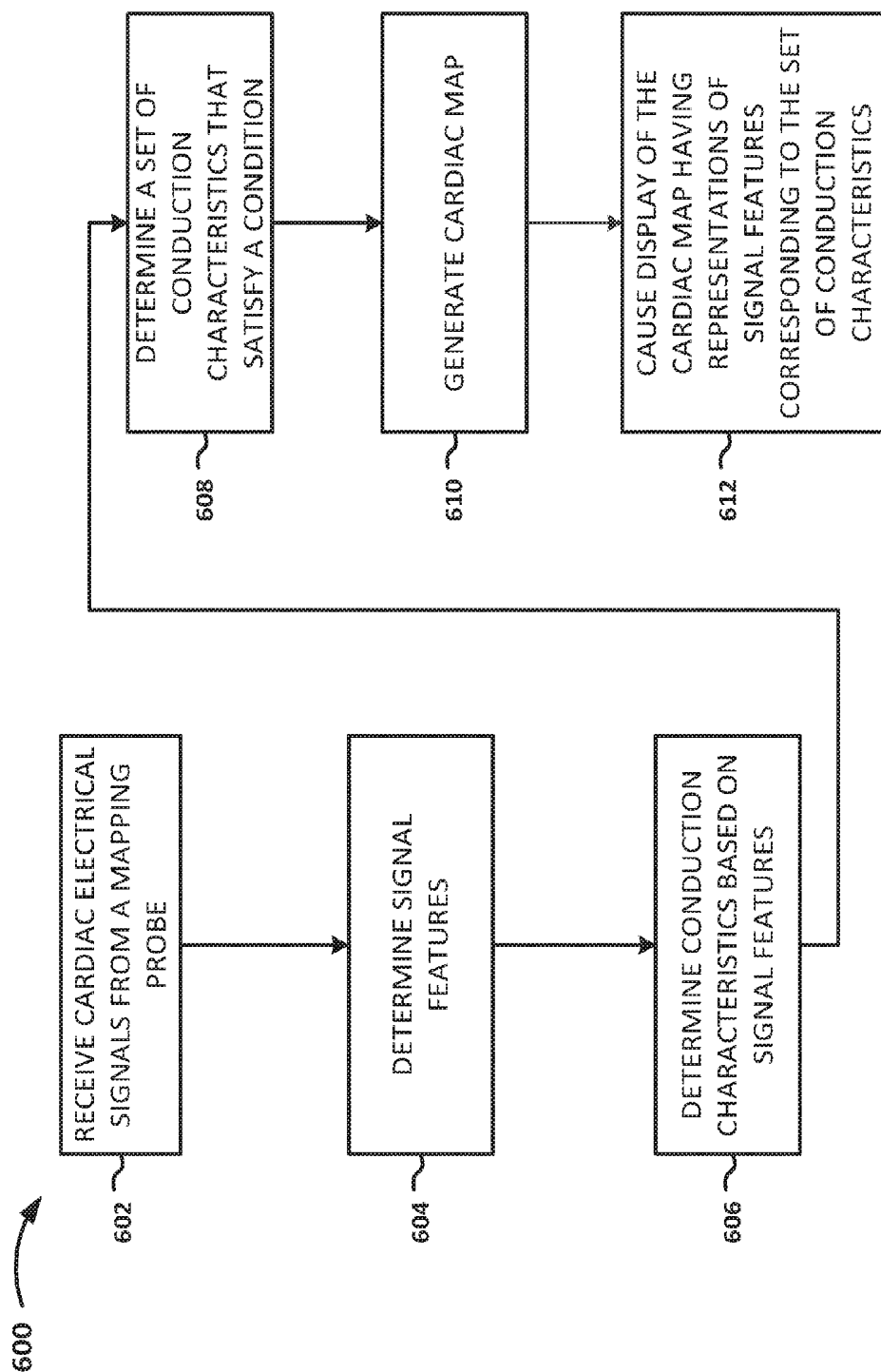


FIG. 6

AUTOMATIC MAPPING USING VELOCITY INFORMATION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Provisional Application No. 62/270,030, filed Dec. 20, 2015, which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments of this disclosure relate to systems and methods for providing information about a patient's heart and, in particular, to systems and methods for electro-anatomically mapping a patient's heart.

BACKGROUND

[0003] Use of minimally invasive procedures, such as catheter ablation, to treat a variety of heart conditions, such as supraventricular and ventricular arrhythmias, is becoming increasingly prevalent. Often, these procedures involve the mapping of electrical activity in the heart at various locations on the endocardial or epicardial surface, referred to as cardiac mapping, to identify the mechanism of the arrhythmia followed by a targeted ablation of the site. To perform the cardiac mapping, a catheter with one or more electrodes can be inserted into the patient's heart.

[0004] Cardiac mapping techniques include contact mapping, near contact mapping, and non-contact mapping. In contact mapping, one or more catheters are advanced into the heart and physiological signals resulting from the electrical activity of the heart are acquired with one or more electrodes located at the catheter distal tip after determining that the tip is in stable and steady contact with the endocardial surface of a heart chamber. The location and electrical activity can be measured on a point-by-point basis at, for example, about 50 to 200 points on the internal surface of the heart to construct an electro-anatomical depiction of the heart.

[0005] In near-contact mapping, a movable catheter having multiple spatially distributed electrodes is placed in a heart chamber of interest and moved to one or more locations within the chamber of interest, where the electrodes are on or near, such as within millimeters of, the endocardial surface of the heart chamber. Measurements are taken automatically at each of the locations of the catheter, without determining whether the electrodes are in contact with the surface of the heart. These measurements are analyzed to detect the endocardial surface of the heart chamber in the vicinity of the catheter. The location of the catheter, e.g., a location provided by a tracking system, and the measurements from the electrodes are used to reconstruct the chamber anatomy, where, for example, 20,000 measurements may be made to construct an electro-anatomical depiction of the heart. As the tracked catheter is moved inside the chamber, a partial or complete representation of the chamber anatomy can be constructed.

[0006] In non-contact mapping, a multiple electrode catheter is placed in the heart chamber of interest and the catheter is deployed to assume a three-dimensional shape. Using the signals detected by the non-contact electrodes and information on chamber anatomy and relative electrode location, the system calculates and provides physiological information regarding the endocardial surface of the heart

chamber. In any of these cardiac mapping techniques, the generated map may then serve as the basis for deciding on a therapeutic course of action, such as tissue ablation, to alter the propagation of the heart's electrical activity and to restore normal heart rhythm.

SUMMARY

[0007] As stated above, before treating an arrhythmia the arrhythmia needs to be identified, which typically involves the mapping of electrical activity in the heart at various locations on the endocardial or epicardial surface. Many arrhythmias are caused by reentry of an activation signal, in which the activation signal propagates repeatedly around a fixed circuit. Reentry of an activation signal can occur when an activation signal includes a pathway where the activation signal propagates slower than usual. Due to the slow propagation of the activation signal, the cardiac tissue may have sufficient time to recover between cycles. Oftentimes, a pathway where the activation signal propagates slower than normal passes through a narrow strip of myocardium. As such, limited ablation along the pathway will often terminate a reentrant arrhythmia and, therefore, can be used as an effective treatment strategy. Throughout this disclosure, the term "slow pathway" may be used, interchangeably, to refer to a pathway where an activation signal propagates slower than the typical propagation speed for the particular patient under a particular set of circumstances (e.g., when the patient is at rest or in motion, when the patient is stressed or relaxed, when other physiological parameters have certain levels or characteristics, and/or the like).

[0008] Since reentries are oftentimes caused by slow pathways, it may be advantageous for a mapping system to facilitate the display of these slow pathways, in order to focus a user's attention. Accordingly, embodiments disclosed herein provide systems and methods for facilitating the display of slow pathways. Exemplary embodiments include the following.

[0009] In Example 1, a system for facilitating display of cardiac mapping information comprises a mapping probe configured to sense a plurality of cardiac electrical signals; and a processing unit configured to: receive the plurality of cardiac electrical signals; determine a plurality of signal features, each of the plurality of signal features comprising a feature of one of the plurality of cardiac electrical signals; determine a plurality of conduction characteristics, each of the plurality of conduction characteristics based on one or more of the plurality of signal features; and generate, based on the plurality of signal features and the corresponding plurality of conduction characteristics, a cardiac map, the cardiac map comprising an anatomical shell and a set of annotations representing at least a portion of the plurality of signal features.

[0010] In Example 2, the system of Example 1, wherein the processing unit is further configured to determine a set of conduction characteristics, of the plurality of conduction characteristics, that satisfy a condition, wherein the set of annotations comprises a representation of each of the plurality of signal features that corresponds to one of the set of conduction characteristics that satisfy the condition.

[0011] In Example 3, a system for facilitating display of cardiac mapping information comprises a mapping probe configured to sense a plurality of cardiac electrical signals; and a processing unit configured to: receive the plurality of cardiac electrical signals; determine a plurality of signal

features, each of the plurality of signal features comprising a feature of one of the plurality of cardiac electrical signals; determine a plurality of conduction characteristics, each of the plurality of conduction characteristics based on one or more of the plurality of signal features; determine a set of conduction characteristics, of the plurality of conduction characteristics, that satisfy a condition; and provide, for presentation on a display device, a cardiac map, the cardiac map comprising an anatomical shell and a representation of each of the plurality of signal features that corresponds to one of the set of conduction characteristics that satisfy the condition.

[0012] In Example 4, the system of Example 3, wherein the cardiac map does not include a representation of a signal feature that does not correspond to one of the set of conduction characteristics that satisfy the condition.

[0013] In Example 5, the system of any of Examples 3 and 4, wherein a conduction characteristic satisfies the condition when the conduction characteristic is within a particular range.

[0014] In Example 6, the system of any of Examples 3 and 4, wherein the conduction characteristics are conduction velocities and wherein a conduction characteristic satisfies the condition when the conduction characteristic is no greater than a threshold.

[0015] In Example 7, the system of any of Examples 3 and 4, wherein the conduction characteristics are activation gradients and wherein an activation gradient satisfies the condition when the activation gradient is no less than a threshold.

[0016] In Example 8, the system of any of Examples 3-7, wherein each of the plurality of signal features comprises at least one of an activation time, a minimum voltage value, a maximum voltage value, a maximum negative time-derivative of voltage, an instantaneous potential, a voltage amplitude, a dominant frequency, a mean cycle length, and a peak-to-peak voltage.

[0017] In Example 9, the system of Example 8, each of the plurality of signal features comprising an activation time, and wherein the processing unit is configured to determine the plurality of conduction characteristics by: determining a gradient associated with each of the plurality of activation times; and determining the inverse of the gradient associated with each of the plurality of activation times.

[0018] In Example 10, the system of Example 9, wherein each of the plurality of signal features comprises an activation time associated with a single beat.

[0019] In Example 11, the system of Example 8, wherein the processing unit is configured to determine the plurality of conduction characteristics by performing a least-squares computation using at least three electrode activation times, wherein each of the at least three electrode activation times is associated with one of at least three non-collinear electrode locations.

[0020] In Example 12, a method for facilitating display of cardiac mapping information comprises receiving, from a mapping probe, a plurality of cardiac electrical signals; determining a plurality of signal features, each of the plurality of signal features comprising a feature of one of the plurality of cardiac electrical signals; determining a plurality of conduction characteristics, each of the plurality of conduction characteristics based on one or more of the plurality of signal features; and causing a display device to display, based on the plurality of conduction characteristics, a car-

diac map, the displayed cardiac map comprising an anatomical shell and a representation of at least one of the plurality of signal features.

[0021] In Example 13, the method of Example 12, further comprising: generating an activation map, the activation map comprising the anatomical shell, a plurality of vertices and a representation of each of a plurality of activation times at a vertex of the plurality of vertices; determining activation time differences for each vertex, wherein each of the plurality of conduction characteristics is determined based on one or more of the activation time differences; determining a set of conduction characteristics, of the plurality of conduction characteristics, that satisfy a condition, wherein a conduction characteristic satisfies the condition when the conduction characteristic is within a particular range; and wherein the displayed cardiac map does not include a representation of a signal feature that does not correspond to one of the set of conduction characteristics that satisfy the condition.

[0022] In Example 14, the method of Example 13, wherein determining an activation time difference of a vertex includes performing a least-squares computation using at least three activation times associated with the vertex and at least two other map vertices of the activation map.

[0023] In Example 15, the method of Example 12, wherein determining the plurality of conduction characteristics includes: performing a least-squares computation using at least three electrode activation times, wherein each of the at least three electrode activation times is associated with one of at least three non-collinear electrode locations of the mapping probe.

[0024] In Example 16, a system for facilitating display of cardiac mapping information comprises a mapping probe configured to sense a plurality of cardiac electrical signals; and a processing unit configured to: receive the plurality of cardiac electrical signals; determine a plurality of signal features, each of the plurality of signal features comprising a feature of one of the plurality of cardiac electrical signals; determine a plurality of conduction characteristics, each of the plurality of conduction characteristics based on one or more of the plurality of signal features; and generate, based on the plurality of signal features and the corresponding plurality of conduction characteristics, a cardiac map, the cardiac map comprising an anatomical shell and a set of annotations representing at least a portion of the plurality of signal features.

[0025] In Example 17, the system of Example 16, wherein a first annotation of the set of annotations is associated with a first map point lying on the anatomical shell, and wherein the processing unit is configured to generate the first annotation by performing an interpolation based on a set of vectors, wherein each of the set of vectors is associated with an additional map point and comprises one of the plurality of electrical signal features and a corresponding one of the plurality of conduction characteristics.

[0026] In Example 18, the system of Example 16, wherein the processing unit is further configured to determine a set of conduction characteristics, of the plurality of conduction characteristics, that satisfy a condition, wherein the set of annotations comprises a representation of each of the plurality of signal features that corresponds to one of the set of conduction characteristics that satisfy the condition and wherein the cardiac map does not include a representation of

a signal feature that does not correspond to one of the set of conduction characteristics that satisfy the condition.

[0027] In Example 19, the system of Example 18, wherein a conduction characteristic satisfies the condition when the conduction characteristic is within a particular range.

[0028] In Example 20, the system of Example 18, wherein the conduction characteristics are conduction velocities and wherein a conduction characteristic satisfies the condition when the conduction characteristic is no greater than a threshold.

[0029] In Example 21, the system of Example 18, wherein the conduction characteristics are activation gradients and wherein an activation gradient satisfies the condition when the activation gradient is no less than a threshold.

[0030] In Example 22, the system of Example 16, wherein each of the plurality of signal features comprises at least one of an activation time, a minimum voltage value, a maximum voltage value, a maximum negative time-derivative of voltage, an instantaneous potential, a voltage amplitude, a dominant frequency, a mean cycle length, and a peak-to-peak voltage.

[0031] In Example 23, a system for facilitating display of cardiac mapping information comprises a mapping probe configured to sense a plurality of cardiac electrical signals; and a processing unit configured to: receive the plurality of cardiac electrical signals; determine a plurality of signal features, each of the plurality of signal features comprising a feature of one of the plurality of cardiac electrical signals; determine a plurality of conduction characteristics, each of the plurality of conduction characteristics based on one or more of the plurality of signal features; determine a set of conduction characteristics, of the plurality of conduction characteristics, that satisfy a condition; and provide, for presentation on a display device, a cardiac map, the cardiac map comprising an anatomical shell and a representation of each of the plurality of signal features that corresponds to one of the set of conduction characteristics that satisfy the condition.

[0032] In Example 24, the system of Example 23, wherein the cardiac map does not include a representation of a signal feature that does not correspond to one of the set of conduction characteristics that satisfy the condition.

[0033] In Example 25, the system of Example 23, wherein a conduction characteristic satisfies the condition when the conduction characteristic is within a particular range.

[0034] In Example 26, the system of Example 23, wherein the conduction characteristics are conduction velocities and wherein a conduction characteristic satisfies the condition when the conduction characteristic is no greater than a threshold.

[0035] In Example 27, the system of Example 23, wherein the conduction characteristics are activation gradients and wherein an activation gradient satisfies the condition when the activation gradient is no less than a threshold.

[0036] In Example 28, the system of Example 23, wherein each of the plurality of signal features comprises at least one of an activation time, a minimum voltage value, a maximum voltage value, a maximum negative time-derivative of voltage, an instantaneous potential, a voltage amplitude, a dominant frequency, a mean cycle length, and a peak-to-peak voltage.

[0037] In Example 29, the system of Example 28, each of the plurality of signal features comprising an activation time, and wherein the processing unit is configured to

determine the plurality of conduction characteristics by: determining a gradient associated with each of the plurality of activation times; and determining the inverse of the gradient associated with each of the plurality of activation times.

[0038] In Example 30, the system of Example 29, wherein each of the plurality of signal features comprises an activation time associated with a single beat.

[0039] In Example 31, the system of Example 28, wherein the processing unit is configured to determine the plurality of conduction characteristics by performing a least-squares computation using at least three electrode activation times, wherein each of the at least three electrode activation times is associated with one of at least three non-collinear electrode locations.

[0040] In Example 32, a method for facilitating display of cardiac mapping information comprises receiving, from a mapping probe, a plurality of cardiac electrical signals; determining a plurality of signal features, each of the plurality of signal features comprising a feature of one of the plurality of cardiac electrical signals; determining a plurality of conduction characteristics, each of the plurality of conduction characteristics based on one or more of the plurality of signal features; and causing a display device to display, based on the plurality of conduction characteristics, a cardiac map, the displayed cardiac map comprising an anatomical shell and a representation of at least one of the plurality of signal features.

[0041] In Example 33, the method of Example 32, further comprising: generating an activation map, the activation map comprising the anatomical shell, a plurality of vertices and a representation of each of a plurality of activation times at a vertices of the plurality of vertices; determining activation time differences for each vertex, wherein each of the plurality of conduction characteristics is determined based on one or more of the activation time differences; determining a set of conduction characteristics, of the plurality of conduction characteristics, that satisfy a condition, wherein a conduction characteristic satisfies the condition when the conduction characteristic is within a particular range; and wherein the displayed cardiac map does not include a representation of a signal feature that does not correspond to one of the set of conduction characteristics that satisfy the condition.

[0042] In Example 34, the method of Example 32, wherein determining an activation time difference of a vertex includes performing a least-squares computation using at least three activation times associated with the vertex and at least two other map vertices of the activation map.

[0043] In Example 35, the method of Example 32, wherein determining the plurality of conduction characteristics includes: performing a least-squares computation using at least three electrode activation times, wherein each of the at least three electrode activation times is associated with one of at least three non-collinear electrode locations of the mapping probe.

[0044] While multiple embodiments are disclosed, still other embodiments of the disclosed subject matter will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the disclosure. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] FIG. 1A is a diagram illustrating an electro-anatomical mapping system, in accordance with embodiments of the present disclosure.

[0046] FIG. 1B is a schematic view of a mapping probe for use in association with embodiments of the system of FIG. 1A, in accordance with embodiments of the present disclosure.

[0047] FIG. 2 is a block diagram depicting an illustrative processing unit for use with a mapping system, in accordance with embodiments of the present disclosure.

[0048] FIG. 3 is a flow diagram depicting an illustrative process for generating a cardiac map, in accordance with embodiments of the present disclosure.

[0049] FIG. 4 is a flow diagram depicting an illustrative method for facilitating display of cardiac mapping information, in accordance with embodiments of the present disclosure.

[0050] FIG. 5 is a flow diagram depicting another illustrative method for facilitating display of cardiac mapping information, in accordance with embodiments of the present disclosure.

[0051] FIG. 6 is a flow diagram depicting another illustrative method for facilitating display of cardiac mapping information, in accordance with embodiments of the present disclosure.

[0052] While the disclosed subject matter is amenable to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and are described in detail below. The intention, however, is not to limit the disclosure to the particular embodiments described. On the contrary, the disclosure is intended to cover all modifications, equivalents, and alternatives falling within the scope of the disclosure as defined by the appended claims.

[0053] As the terms are used herein with respect to ranges of measurements (such as those disclosed immediately above), “about” and “approximately” may be used, interchangeably, to refer to a measurement that includes the stated measurement and that also includes any measurements that are reasonably close to the stated measurement, but that may differ by a reasonably small amount such as will be understood, and readily ascertained, by individuals having ordinary skill in the relevant arts to be attributable to measurement error, differences in measurement and/or manufacturing equipment calibration, human error in reading and/or setting measurements, adjustments made to optimize performance and/or structural parameters in view of differences in measurements associated with other components, particular implementation scenarios, imprecise adjustment and/or manipulation of objects by a person or machine, and/or the like.

[0054] Although the term “block” may be used herein to connote different elements illustratively employed, the term should not be interpreted as implying any requirement of, or particular order among or between, various steps disclosed herein unless and except when explicitly referring to the order of individual steps.

DETAILED DESCRIPTION

[0055] FIG. 1A shows a schematic diagram of an exemplary embodiment of an electro-anatomical mapping system 100, in accordance with embodiments of the disclosure. The

mapping system 100 may be used for mapping cardiac structures 102 of a patient 104, and may be operated by one or more users 106, such as a physician and/or a technician. Throughout this disclosure, the term “cardiac structure” can mean any portion of a subject’s heart and/or adjacent features such as, for example, an endocardium, an epicardium, an entire heart, a heart chamber, a portion of a heart chamber, a valve, a coronary sinus and/or its tributaries, a portion of a coronary sinus and/or a portion of its tributaries, a pulmonary artery, other surrounding vasculature and/or the like. As such, while the embodiments discussed herein are primarily discussed in relation to endocardium mapping, the embodiments may also be used in epicardium mapping, as well. While this disclosure discusses using the mapping system to map cardiac structures 102, embodiments of the mapping system 100 can also, or alternatively, be used to map other organs and biological tissue including, but not limited to, kidneys, lungs, brains, gall bladders, livers, spleens and intestines.

[0056] As shown in FIG. 1A, the mapping system 100 includes one or more catheters 106, each having one or more electrodes situated at or toward the distal end of the catheter 106 and/or along a body of the catheter 106. The one or more catheters 106 may be situated in or near a cardiac structure 102 of the patient 104. The system 100 may be configured to obtain intracardiac electrogram (EGM) signals from the one or more electrodes on one or more of the catheters 106. In embodiments, the one or more catheters 106 include one or more reference catheters, where each of the reference catheters includes one or more electrodes and may be secured in place in a stable position in or near the cardiac structure 102 or other structure being mapped. In embodiments, the one or more catheters 106 may include up to five reference catheters, each having one or more electrodes and being secured in place in a stable position in or near the structure being mapped. In some embodiments, the one or more reference catheters include at least one coronary sinus catheter.

[0057] In embodiments, the catheters 106 may include one or more mapping probes having one or more electrodes. For example, a mapping probe may include multiple spatially distributed electrodes disposed at a distal end of a flexible catheter body. During a cardiac mapping procedure, a mapping probe is displaced to multiple locations within the heart chamber into which the mapping probe is inserted. In embodiments, the distal end of the mapping probe is fitted with multiple electrodes spread somewhat uniformly over a distal end of the catheter. For example, the electrodes may be mounted on the mapping probe following a 3D olive shape, a basket shape, and/or the like. The electrodes are mounted on a device capable of deploying the electrodes into the desired shape while inside the heart, and retracting the electrodes when the catheter is removed from the heart. To allow deployment into a 3D shape in the heart, electrodes may be mounted on a balloon, shape memory material such as Nitinol, actuable hinged structure, and/or the like.

[0058] At each of the locations to which the mapping probe is moved, the multiple electrodes acquire cardiac electrical signals. The cardiac electrical signals may be sensed, for example, on the endocardial surface of the heart and/or in a heart chamber at a point away from the surface. As used herein, a mapped representation of a cardiac electrical signal feature that is sensed at a point inside a heart chamber is referred to as being below the endocardial

surface. That is, for example, because the cardiac map includes an anatomical shell that represents an endocardial surface and, from the perspective of the viewer, a point that is located inside the chamber, and not on the endocardial surface, would appear to be “below” the mapped surface.

[0059] As the term is used herein, a sensed cardiac electrical signal may refer to one or more sensed signals. Each cardiac electrical signal may include a number of intracardiac electrograms (EGMs) sensed within a patient’s heart, and may include any number of features that may be ascertained by aspects of the system **100**. Examples of cardiac electrical signal features include, but are not limited to, activation times, minimum voltage values, maximum voltage values, maximum negative time-derivatives of voltages, instantaneous potentials, voltage amplitudes, dominant frequencies, peak-to-peak voltages, and/or the like. A cardiac electrical signal feature may refer to one or more features extracted from one or more cardiac electrical signals, derived from one or more features that are extracted from one or more cardiac electrical signals, and/or the like. Additionally, a representation, on a cardiac and/or a surface map, of a cardiac electrical signal feature may represent one or more cardiac electrical signal features, an interpolation of a number of cardiac electrical signal features, and/or the like.

[0060] Each cardiac signal also may be associated with a set of respective position coordinates that corresponds to the location at which the cardiac electrical signal was sensed. Each of the respective position coordinates for the sensed cardiac signals may include three-dimensional Cartesian coordinates, polar coordinates, and/or the like. In embodiments, other coordinate systems can be used. In embodiments, an arbitrary origin is used and the respective position coordinates refer to positions in space relative to the arbitrary origin. Since, in embodiments, the cardiac signals may be sensed on the endocardial surface, in the chamber enclosed by the endocardial surface and outside the endocardial surface, the respective position coordinates may be on the endocardial surface of the patient’s heart, below the endocardial surface and/or on the epicardial surface.

[0061] Consequently, reconstructing and presenting to a user **108** (such as a physician and/or technician) physiological data pertaining to cardiac electrical activity may be based on information acquired at multiple locations, thereby providing a more accurate and faithful reconstruction of physiological behavior of the endocardium surface. In embodiments that include one or more mapping probes, at least one of the mapping probes may be displaced to multiple locations within the heart, where the acquisition of cardiac electrical signals at multiple probe locations in the heart chamber enables the one or more mapping probes to effectively act as a “mega-catheter” whose effective number of electrodes and electrode span is proportional to the product of the number of locations in which signal acquisition is performed and the number of electrodes on the one or more mapping probes. In embodiments, the one or more mapping probes may be configured for contact mapping, near-contact mapping, and/or non-contact mapping.

[0062] To enhance the quality of the reconstructed physiological information at the endocardium surface, in some embodiments a mapping probe may be moved to more than three locations (for example, more than 5, 10, or even 50 locations) within the heart chamber. Further, the spatial range over which the mapping probe is moved may be larger

than one third ($\frac{1}{3}$) of the diameter of the heart cavity (for example, larger than 35%, 40%, 50% or even 60% of the diameter of the heart cavity). Additionally, in some embodiments the reconstructed physiological information is computed based on signals measured over several heart beats, either at a single location within the heart chamber or over several locations. In circumstances where the reconstructed physiological information is based on multiple measurements over several heart beats, the measurements may be synchronized with one another so that the measurement are performed at approximately the same phase of the heart cycle. The signal measurements over multiple beats may be synchronized based on features detected from physiological data such as surface ECG and/or intracardiac EGMs.

[0063] The mapping system **100** further includes a processing unit **110** which performs several of the operations pertaining to the mapping procedure, including the reconstruction procedure to determine the physiological information at the endocardium surface (e.g., as described above) and/or within a heart chamber. The processing unit **110** also may perform a catheter registration procedure. The processing unit **110** may be, include, or be included in, an electrical processor, a software processor, a general purpose microprocessor and/or a special purpose microprocessor, and may include a sole processor or multiple processors or cores.

[0064] The location of a catheter **106** inserted into the heart chamber can be determined using a sensing and tracking system **112** that provides the 3D spatial coordinates of the catheter **106** and/or its multiple electrodes with respect to the catheter’s **106** coordinate system as established by the sensing and tracking system **112**. Embodiments of the system **100** use a hybrid location technology that combines impedance location with magnetic location technology. This combination may enable the system **100** to accurately track mapping probes and/or other catheters **106** that are connected to the system **100**. Magnetic location technology uses magnetic fields generated by a localization generator positioned under the patient table to track catheters with magnetic sensors. Impedance location technology may be used to track catheters that may not be equipped with a magnetic location sensor, and may utilize surface ECG patches.

[0065] In embodiments, to perform a mapping procedure and reconstruct physiological information on the endocardium surface, the processing unit **110** may align the coordinate system of a mapping probe (e.g., catheter **106**) with the endocardium surface’s coordinate system. The processing unit **110** (or some other processing component of the system **100**) may determine a coordinate system transformation function that transforms the 3D spatial coordinates of the catheter’s **106** locations into coordinates expressed in terms of the endocardium surface’s coordinate system, and/or vice-versa. In embodiments, such a transformation may not be necessary. The processing unit **110** also may perform post-processing operations on the physiological information to extract and display useful features of the information to the user **108** of the system **100** and/or other persons (e.g., a physician).

[0066] According to embodiments, the signals acquired by the multiple electrodes of a catheter **106** (e.g., a mapping probe) are passed to the processing unit **110** via an electrical module **114**, which may include, for example, a signal conditioning component. The electrical module **114** may be configured to receive the signals communicated from the

catheter 106 and perform signal enhancement operations on the signals before they are forwarded to the processing unit 110. The electrical module 114 may include signal conditioning hardware, software, and/or firmware that may be used to amplify, filter and/or sample intracardiac potential measured by one or more electrodes. In embodiments, the electrical module 114 may also be configured to receive signals from any number of other catheters, provide signals to catheters, and/or the like.

[0067] The cardiac electrical signals typically have a maximum amplitude of 60 mV, with a mean of a few millivolts. In embodiments, the signals are bandpass filtered in a frequency range (e.g., 0.5-500 Hz) and sampled with analog to digital converters (e.g., with 15-bit resolution at 1 kHz). To avoid interference with electrical equipment in the room, the signals may be filtered to remove the frequency corresponding to the power supply (e.g., 60 Hz). Other types of signal processing operations such as spectral equalization, automatic gain control, etc. may also take place. For example, in embodiments, the cardiac electrical signals may be unipolar signals, measured relative to a reference (which may be a virtual reference) such as, for example, a coronary sinus catheter or Wilson's Central Terminal (WCT), from which the signal processing operations may compute differences to generate bipolar signals. The signals may be otherwise processed (e.g., filtered, sampled, etc.) before and/or after generating the bipolar signals. The resultant processed signals are forwarded by the electrical module 114 to the processing unit 110 for further processing.

[0068] As further shown in FIG. 1A, the cardiac mapping system 100 also may include peripheral devices such as a printer 116, a display device 118 and/or input devices 120, all of which may be interconnected to the processing unit 110. Additionally, the mapping system 100 includes storage device 122 that may be used to store data acquired by the various interconnected modules, including the volumetric images, raw data measured by electrodes and/or the resultant endocardium representation computed therefrom, the partially computed transformations used to expedite the mapping procedures, the reconstructed physiological information corresponding to the endocardium surface, and/or the like. According to embodiments, the storage device may also, or alternatively, be used to store computer-executable instructions for facilitating aspects of embodiments of procedures described herein.

[0069] The illustrative mapping system 100 shown in FIG. 1A is not intended to suggest any limitation as to the scope of use or functionality of embodiments of the present disclosure. Neither should the illustrative mapping system 100 be interpreted as having any dependency or requirement related to any single component or combination of components illustrated therein. Additionally, various components depicted in FIG. 1A may be, in embodiments, integrated with various ones of the other components depicted therein (and/or components not illustrated), all of which are considered to be within the ambit of the present disclosure. For example, the electrical module 114 may be integrated with the processing unit 110 and/or the storage device 120 may be integrated with the processing unit 110.

[0070] FIG. 1B is a schematic view of a mapping probe 130, which may, for example, be used in association with embodiments of the system 100 of FIG. 1A, in accordance with embodiments of the disclosure. The mapping probe 130 has a flexible catheter body 132, the distal end of which

carries the three-dimensional basket structure 134 that includes the mapping electrodes 136. As stated above, the mapping electrodes 136 sense cardiac electrical signals; and the sensed signals are sent to a processing unit 110, via a wired and/or wireless connection. The processing unit 110 processes the sensed signals and a cardiac map is created. The types of cardiac maps created can include, but are not limited to, the following: a voltage map, an activation map, a fractionation map, a velocity map, and/or the like.

[0071] The basket structure 134 comprises a base member 138 and an end cap 140 between which flexible splines 142 generally extend in a circumferentially spaced relationship. In embodiments, the basket structure 134 takes the form of a basket defining an open interior space 144. In embodiments, the splines 142 are made of a resilient inert material, such as Nitinol metal or silicone rubber, and are connected between the base member 138 and the end cap 140 in a resilient, pre-tensed condition, to bend and conform to the tissue surface they contact. In other embodiments, such as the catheters described in U.S. Pat. Nos. 8,103,327, 8,447,377, and 8,755,861, which are entitled "CARDIAC MAPPING CATHETER" and are hereby incorporated herein by reference in their entireties, the splines of the catheter may not bend and conform to the tissue surface they contact. In the illustrated embodiments, eight splines 142 form the three-dimensional structure 134. Additional or fewer splines 142 could be used in other embodiments, and the three-dimensional structure 134 may be configured according to any number of different shapes such as, for example, generally spherical shapes, generally elliptical shapes, generally tear-drop shapes, and/or the like. As illustrated, each spline 142 carries eight mapping electrodes 136. Additional or fewer mapping electrodes 136 could be disposed on each spline 142 in other embodiments of the three-dimensional structure 134. In the illustrated embodiments, the three-dimensional structure 134 is relatively small (e.g., 40 mm or less in diameter). In embodiments, the three-dimensional structure 134 is larger (e.g., 40 mm in diameter or greater).

[0072] In embodiments, a slidable sheath 146 is movable along the major axis of the catheter body 132. Moving the sheath 146 forward (i.e., toward the distal end) causes the sheath 146 to move over the three-dimensional structure 134, thereby collapsing the structure 134 into a compact, low profile condition suitable for introduction into an interior space, such as, for example, into the heart. In contrast, moving the sheath 146 rearward (i.e., toward the proximal end) exposes the three-dimensional structure 134, allowing the structure 134 to elastically expand and assume the pre-tensed position illustrated in FIG. 1B. Further details of embodiments of the three-dimensional structure 134 are disclosed, for example, in U.S. Pat. No. 5,647,870, entitled "MULTIPLE ELECTRODE SUPPORT STRUCTURES," which is hereby incorporated by reference in its entirety.

[0073] Additionally, further details of mapping catheters that may be used in association with embodiments of the system 100 of FIG. 1A, in accordance with embodiments of the disclosure, are disclosed, for example, in U.S. Pat. Nos. 8,103,327, 8,447,377 and 8,755,861 and were incorporated herein by reference in their entireties above.

[0074] In embodiments where the mapping probe 130 uses a wired connection, a signal wire (not shown) may be electrically coupled to each mapping electrode 136. The wires may extend through the body 132 of the mapping catheter 130 into a handle 148, in which they may be

coupled to an external connector **150**, which may be, for example, a multiple pin connector. The connector **150** electrically couples the mapping electrodes **136** to the processing system **110**. Further details on mapping systems and methods for processing signals generated by mapping catheters are discussed, for example, in U.S. Pat. No. 6,070,094, entitled "SYSTEMS AND METHODS FOR GUIDING MOVABLE ELECTRODE ELEMENTS WITHIN MULTIPLE-ELECTRODE STRUCTURE;" U.S. Pat. No. 6,233,491, entitled "CARDIAC MAPPING AND ABLATION SYSTEMS;" and U.S. Pat. No. 6,735,465, entitled "SYSTEMS AND PROCESSES FOR REFINING A REGISTERED MAP OF A BODY CAVITY;" the disclosures of which are incorporated herein by reference in their entireties.

[0075] Additionally, further details of mapping systems and methods for processing signals generated by mapping catheters are discussed, for example, in U.S. Pat. No. 8,103,338, entitled "Impedance Based Anatomy Generation;" U.S. Pat. No. 8,615,287, entitled "Catheter Tracking and Endocardium Representation Generation;" and U.S. Pat. No. 9,107,599, entitled "Electroanatomical Mapping;" the disclosures of which are incorporated herein by reference.

[0076] It is noted that other electrode structures could be deployed on the distal end of a mapping probe **130**. It is further noted that the multiple mapping electrodes **136** may be disposed on more than one structure, rather than, for example, the single mapping probe **130** illustrated in FIG. 1B. For example, if mapping within the left atrium with multiple mapping structures, an arrangement comprising a coronary sinus catheter carrying multiple mapping electrodes and a basket catheter carrying multiple mapping electrodes positioned in the left atrium may be used. As another example, if mapping within the right atrium with multiple mapping structures, an arrangement comprising a decapolar catheter carrying multiple mapping electrodes for positioning in the coronary sinus, and a loop catheter carrying multiple mapping electrodes for positioning around the tricuspid annulus may be used. Additionally, in embodiments, the mapping electrodes **136** may be separated from one another by insulated gaps **152**.

[0077] Although the mapping electrodes **136** have been described as being carried by dedicated mapping probes, such as the mapping probe **130**, the mapping electrodes **136** may be carried on non-mapping dedicated probes or multi-function probes. For example, an ablation catheter can be configured to include one or more mapping electrodes.

[0078] FIG. 2 is a block diagram of an illustrative processing unit **200**, in accordance with embodiments of the disclosure. The processing unit **200** may be, be similar to, include, or be included in the processing unit **110** depicted in FIG. 1A. As shown in FIG. 2, the processing unit **200** may be implemented on a computing device that includes a processor **210** and a memory **220**. Although the processing unit **200** is referred to herein in the singular, the processing unit **200** may be implemented in multiple instances (e.g., as a server cluster), distributed across multiple computing devices, instantiated within multiple virtual machines, and/or the like. One or more components for facilitating cardiac mapping may be stored in the memory **220**. In embodiments, the processor **210** may be configured to instantiate the one or more components to generate a cardiac map **230**, which may be stored in the memory **220**.

[0079] As is further depicted in FIG. 2, the processing unit **200** may include an acceptor **240** configured to receive cardiac electrical signals from a mapping probe (e.g., the catheter **106** depicted in FIG. 1A, and/or the mapping probe **130** depicted in FIG. 1B). The sensed cardiac electrical signals may include a number of intracardiac electrograms (EGMs) sensed within a patient's heart. The acceptor **240** may also receive an indication of a measurement location corresponding to each of the electrical signals. In embodiments, the acceptor **240** may be configured to determine whether to accept the cardiac electrical signals that have been received. The acceptor **240** may utilize any number of different components and/or techniques to determine which electrical signals or beats to accept, such as filtering, beat matching, morphology analysis, positional information (e.g., catheter motion), respiration gating, and/or the like. In embodiments, for example, the acceptor **240** may accept and reject cardiac electrical signals (e.g., EGMS), signal features, beats, and/or the like, based on velocity information, as described in further detail below.

[0080] The accepted cardiac electrical signals are received by a feature extractor **250** that is configured to extract one or more features from each of the cardiac electrical signals. According to embodiments, the features may include, for example, features, extracted from the cardiac electrical signals and/or derived from other features, such as, for example, activation times, minimum voltage values, maximum voltage values, maximum negative time-derivatives of voltages, instantaneous potentials, voltage amplitudes, dominant frequencies, peak-to-peak voltages, and/or the like. The acceptor **240** and/or feature extractor **250** may generate, from the acquired cardiac electrical signals, a map dataset **260**.

[0081] As shown in FIG. 2, the processing unit **200** includes a map generator **270** that is configured to generate, and facilitate presentation of, a map **230** corresponding to a cardiac structure based on the map dataset **260**. For example, the map generator **270** may be configured to facilitate presentation of the map **230** corresponding to the cardiac structure by performing interpolation, extrapolation and/or fitting based on cardiac signal features, velocity information, and/or the like. In embodiments, the map **230** may include a voltage map, an activation map, a fractionation map, a velocity map, a confidence map, and/or the like.

[0082] As is further shown in FIG. 2, the processing unit **200** includes a velocity component **280** that may be configured to determine one or more conduction velocities associated with an activation propagation. For example, in embodiments, the velocity component **280** may be configured to determine a number of conduction velocities corresponding to signal features extracted by the feature extractor **250**. In this manner, the map generator **270** may be configured to generate the cardiac map **230** based on extracted signal features and conduction velocities determined by the velocity component **280**. In other embodiments, the determined conduction velocities may correspond to map features generated by the map generator **270** rather than individual signal features extracted by the feature extractor **250**. In embodiments, the map **230** may include an anatomical shell and a set of annotations representing at least a portion of the extracted signal features.

[0083] In embodiments, for example, the processing unit **100** (e.g., using the velocity component **280** and/or the map generator **270**) may be configured to determine a set of

conduction velocities, of a plurality of conduction velocities, that satisfy a condition, where the set of annotations in the map **230** includes a representation of the signal features that correspond to one of the set of conduction velocities that satisfy the condition.

[0084] In embodiments, the velocity component **280** may be configured to determine a conduction velocity based on a “pre-filter” method or a “post-filter” method.

[0085] In embodiments, pre-filtering conduction velocities may include determining a propagation velocity using electrograms from a single cycle (or “beat”). Specifically, the relative activation times of nearby electrodes of a mapping catheter, in combination with their relative locations of the electrodes, can be used to estimate a local conduction velocity. In embodiments, the set of annotations in the map **230** can include a representation of the signal features that corresponds to the pre-filtered conduction velocities that satisfy a condition. Pre-filtering may be useful for rejecting electrograms (or entire beats) from the map based on the estimated local conduction velocities.

[0086] In embodiments, post-filtering conduction velocities may include building an activation map and estimating the velocity at each map vertex by determining a gradient at a map vertex using the activation values of nearby vertices. In embodiments, the set of annotations in the map **230** can include a representation of the signal features at map locations for which the post-filtered conduction velocities satisfy a condition.

[0087] Post-filtering and pre-filtering are explained in more detail below in FIGS. **5** and **6**, respectively.

[0088] The illustrative processing unit **200** shown in FIG. **2** is not intended to suggest any limitation as to the scope of use or functionality of embodiments of the present disclosure. Neither should the illustrative processing unit **200** be interpreted as having any dependency or requirement related to any single component or combination of components illustrated therein. Additionally, any one or more of the components depicted in FIG. **2** may be, in embodiments, integrated with various ones of the other components depicted therein (and/or components not illustrated), all of which are considered to be within the ambit of the present disclosure. For example, the acceptor **240** may be integrated with the feature extractor **250**. Additionally, the processing unit **200** may (alone and/or in combination with other components of the system **100** depicted in FIG. **1**, and/or other components not illustrated) perform any number of different functions and/or processes associated with cardiac mapping (e.g., triggering, blanking, field mapping, etc.) such as, for example, those described in U.S. Pat. No. 8,428,700, entitled “ELECTROANATOMICAL MAPPING;” U.S. Pat. No. 8,948,837, entitled “ELECTROANATOMICAL MAPPING;” U.S. Pat. No. 8,615,287, entitled “CATHETER TRACKING AND ENDOCARDIUM REPRESENTATION GENERATION;” U.S. Patent Publication 2015/0065836, entitled “ESTIMATING THE PREVALENCE OF ACTIVATION PATTERNS IN DATA SEGMENTS DURING ELECTROPHYSIOLOGY MAPPING;” U.S. Pat. No. 6,070,094, entitled “SYSTEMS AND METHODS FOR GUIDING MOVABLE ELECTRODE ELEMENTS WITHIN MULTIPLE-ELECTRODE STRUCTURE;” U.S. Pat. No. 6,233,491, entitled “CARDIAC MAPPING AND ABLATION SYSTEMS;” and U.S. Pat. No. 6,735,465, entitled “SYSTEMS AND PROCESSES FOR REFINING

A REGISTERED MAP OF A BODY CAVITY;” the disclosures of which are hereby expressly incorporated herein by reference.

[0089] According to embodiments, various components of the mapping system **100**, illustrated in FIGS. **1A** and **1B**, and/or the processing unit **200**, illustrated in FIG. **2**, may be implemented on one or more computing devices. A computing device may include any type of computing device suitable for implementing embodiments of the disclosure. Examples of computing devices include specialized computing devices or general-purpose computing devices such “workstations,” “servers,” “laptops,” “desktops,” “tablet computers,” “hand-held devices,” “general-purpose graphics processing units (GPUs),” and the like, all of which are contemplated within the scope of FIGS. **1A** and **2** with reference to various components of the system **100** and/or processing unit **200**.

[0090] In embodiments, a computing device includes a bus that, directly and/or indirectly, couples the following devices: a processor, a memory, an input/output (I/O) port, an I/O component, and a power supply. Any number of additional components, different components, and/or combinations of components may also be included in the computing device. The bus represents what may be one or more busses (such as, for example, an address bus, data bus, or combination thereof). Similarly, in embodiments, the computing device may include a number of processors, a number of memory components, a number of I/O ports, a number of I/O components, and/or a number of power supplies. Additionally any number of these components, or combinations thereof, may be distributed and/or duplicated across a number of computing devices.

[0091] In embodiments, memory (e.g., the storage device **120** depicted in FIG. **1A**, and/or the memory **220** depicted in FIG. **2**) includes computer-readable media in the form of volatile and/or nonvolatile memory and may be removable, nonremovable, or a combination thereof. Media examples include Random Access Memory (RAM); Read Only Memory (ROM); Electronically Erasable Programmable Read Only Memory (EEPROM); flash memory; optical or holographic media; magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices; data transmissions; and/or any other medium that can be used to store information and can be accessed by a computing device such as, for example, quantum state memory, and/or the like. In embodiments, the memory **120** and/or **220** stores computer-executable instructions for causing a processor (e.g., the processing unit **110** depicted in FIG. **1** and/or the processor **210** depicted in FIG. **2**) to implement aspects of embodiments of system components discussed herein and/or to perform aspects of embodiments of methods and procedures discussed herein.

[0092] Computer-executable instructions may include, for example, computer code, machine-useable instructions, and the like such as, for example, program components capable of being executed by one or more processors associated with a computing device. Examples of such program components include the map **230**, the acceptor **240**, the feature extractor **250**, the map dataset **260**, the map generator **270**, and the velocity component **280**. Program components may be programmed using any number of different programming environments, including various languages, development kits, frameworks, and/or the like. Some or all of the functionality

contemplated herein may also, or alternatively, be implemented in hardware and/or firmware.

[0093] FIG. 3 is a flow diagram of an illustrative process 300 for automated electro-anatomical mapping, in accordance with embodiments of the disclosure. Aspects of embodiments of the method 300 may be performed, for example, by a processing unit (e.g., the processing unit 110 depicted in FIG. 1A, and/or the processing unit 200 depicted in FIG. 2). A data stream 302 containing multiple signals is first input into the system (e.g., the mapping system 100 depicted in FIG. 1). During the automated electro-anatomical mapping process, a data stream 302 provides a collection of physiological and non-physiological signals that serve as inputs to the mapping process. The signals may be collected directly by the mapping system, and/or obtained from another system using an analog or digital interface. The data stream 302 may include cardiac electrical signals such as unipolar and/or bipolar intracardiac electrograms (EGMs), surface electrocardiograms (ECGs), electrode location information originating from one or more of a variety of methodologies (magnetic, impedance, ultrasound, real time MRI, etc.), tissue proximity information, catheter force and/or contact information obtained from one or more of a variety of methodologies (force spring sensing, piezo-electric sensing, optical sensing etc.), catheter tip and/or tissue temperature, acoustic information, catheter electrical coupling information, catheter deployment shape information, electrode properties, respiration phase, blood pressure, other physiological information, and/or the like.

[0094] For the generation of specific types of maps, one or more signals may be used as one or more references, during a triggering/alignment process 304, to trigger and align the data stream 302 relative to the cardiac, other biological cycle and/or an asynchronous system clock resulting in beat datasets. Additionally, for each incoming beat dataset, a number of beat metrics are computed during a beat metric determination process 306. Beat metrics may be computed using information from a single signal, spanning multiple signals within the same beat and/or from signals spanning multiple beats. The beat metrics provide multiple types of information on the quality of the specific beat dataset and/or likelihood that the beat data is good for inclusion in the map dataset (e.g., the map dataset 260 depicted in FIG. 2).

[0095] A beat acceptance process 308 aggregates the criteria and determines which beat datasets will make up the map dataset 310. As explained herein, in embodiments, beat datasets, which may include whole beats, whole cardiac electrical signals (e.g., EGMs), and/or extracted features, may be accepted and/or rejected during the beat acceptance process 308 based on determined conduction velocities (e.g., in a pre-filtering process).

[0096] Surface geometry data may be generated concurrently during the same data acquisition process using identical and/or different triggering and/or beat acceptance metrics employing a surface geometry construction process 312. This process constructs surface geometry using data such as electrode locations and catheter shape contained in the data stream. Additionally, or alternatively, previously collected surface geometry 316 may be used as an input to surface geometry data 318. Such geometry may have been collected previously in the same procedure using a different map dataset, and/or using a different modality such as CT, MRI, ultrasound, rotational angiography, and/or the like, and registered to the catheter locating system. The system per-

forms a source selection process 314, in which it selects the source of the surface geometry data and provides surface geometry data 318 to a surface map generation process 320. The surface map generation process 320 is employed to generate surface map data 322 from the map dataset 320 and surface geometry data 318.

[0097] The surface geometry construction algorithm generates the anatomical surface on which the electroanatomical map is displayed. Surface geometry can be constructed, for example, using aspects of a system as described U.S. patent application Ser. No. 12/437,794, entitled "Impedance Based Anatomy Generation" and filed on May 8, 2008; and/or U.S. Pat. No. 8,948,837, entitled "Electroanatomical Mapping" and issued on Feb. 3, 2015, the contents of each of which is incorporated by reference herein in its entirety. Additionally, or alternatively, an anatomical shell can be constructed by the processing unit by fitting a surface on electrode locations that are determined either by the user or automatically to be on the surface of the chamber. In addition, a surface can be fit on the outermost electrode and/or catheter locations within the chamber.

[0098] As described, the map dataset 310 from which the surface is constructed can employ identical or different beat acceptance criteria from those used for electrical and other types of maps. The map dataset 310 for surface geometry construction can be collected concurrently with electrical data or separately. Surface geometry can be represented as a mesh containing a collection of vertices (points) and the connectivity between them (e.g. triangles). Alternatively, surface geometry can be represented by different functions such as higher order meshes, non-uniform rational basis splines (NURBS), and/or curvilinear shapes.

[0099] The generation process 320 generates surface map data 322. The surface map data 322 may provide information on cardiac electrical excitation, cardiac motion, tissue proximity information, tissue impedance information, force information, and/or any other collected information desirable to the clinician. The combination of map dataset 320 and surface geometry data 318 allows for surface map generation. The surface map is a collection of values or waveforms (e.g., EGMs) on the surface of the chamber of interest, whereas the map dataset can contain data that is not on the cardiac surface. One approach for processing the map dataset 320 and surface geometry data 318 to obtain a surface map dataset 322 is described in U.S. Pat. No. 7,515,954, entitled "NON-CONTACT CARDIAC MAPPING, INCLUDING MOVING CATHETER AND MULTI-BEAT INTEGRATION" and filed Jun. 13, 2006, the contents of which is incorporated by reference herein in its entirety.

[0100] Alternatively, or in combination with the method above, an algorithm that applies acceptance criteria to individual electrodes can be employed. For example, electrode locations exceeding a set distance (e.g., 3 mm) from surface geometry can be rejected. Another algorithm can incorporate tissue proximity information using impedance for inclusion in the surface map data. In this case only electrode location whose proximity value is less than 3 mm might be included. Additional metrics of the underlying data can also be used for this purpose. For example, EGM properties similar to beat metrics such as, for example, conduction velocities, can be assessed on a per electrode basis. In this case metrics such as far field overlap and/or EGM consistency can be used. It should be understood that variations on the method to

project points from the map dataset **320** to the surface and/or to select appropriate points can exist.

[0101] Once obtained, the surface map data **322** may be further processed to annotate desired features from the underlying data, a process defined as surface map annotation **324**. Once data is collected into surface map data **322**, attributes relating to the collected data may be automatically presented to the user. These attributes can be automatically determined and applied to the data by the computer system and are referred to herein as annotations. Exemplary annotations include activation time, the presence of double activation or fractionation, voltage amplitude, spectral content, and/or the like. Due to the abundance of data available in automated mapping (e.g., mapping completed by the computer system with minimal human input related to the incoming data), it is not practical for the operator to review and annotate data manually. However, human input can be a valuable addition to the data, and so when user input is provided it is necessary for the computer system to automatically propagate and apply it to more than one data point at a time. Further details of annotating desired features are disclosed, for example, in U.S. Pat. No. 8,948,837, entitled "ELECTROANATOMICAL MAPPING," which is hereby incorporated by reference in its entirety.

[0102] It may be possible to use the computer system to automatically annotate activation time, voltage, and other characteristics of individual EGMs. Activation time detection may use methods similar to those previously described to detect a trigger and can similarly benefit from the use of blanking and powered triggering operator. Desired annotations may include instantaneous potential, activation time, voltage amplitude, dominant frequency, a mean cycle length and/or other properties of the signal. Once computed, the annotations may be displayed superimposed on chamber geometry. In embodiments, the map may be post-filtered in a velocity-based filtering process **325**. That is, for example, the system may generate an activation map and estimate the velocity at each vertex of the activation map by finding the gradient of nearby map values. Then, the cardiac map may be annotated only at locations where the velocity is within a certain range.

[0103] In embodiments, a gap-filling surface map interpolation may be employed **326**. For example, in embodiments, a gap-filling interpolation may be employed where a distance between a point on the surface to a measured EGM exceeds a threshold. Displayed maps **328** can be computed and displayed separately, and/or overlaid on top of each other. As shown, the velocity-based filtering described above may alternatively be applied just before (or, e.g., as part of the process of) displaying the map **328**. In embodiments, for example, they system may generate a velocity mask by generating a separate velocity map (e.g., based on a generated activation map) having conduction velocity values associated with vertices that correspond to the vertices of the generated and annotated cardiac map. When the map is displayed **328**, only those portions of the map geometry and/or annotations are displayed that correspond to velocities that satisfy a particular condition.

[0104] FIG. 4 is a flow diagram depicting an illustrative method **400** for facilitating display of cardiac mapping information, in accordance with embodiments of the disclosure. Embodiments of method **400** may be performed, in whole or in part, by a mapping system (e.g., the mapping system **100** depicted in FIG. 1A). Embodiments of the

method **400** include receiving, from a mapping probe, a number of cardiac electrical signals (block **402**) and determining a number of signal features, each signal feature including a feature of one of the sensed cardiac signals (block **404**). Each of the sensed cardiac electrical signals (and, accordingly, features of each signal) corresponds to a respective point (e.g., location in space) where the cardiac electrical signal was sensed.

[0105] The sensed cardiac electrical signals can include a number of intracardiac EGMs. Examples of features of the cardiac electrical signals include, but are not limited to, activation times, minimum voltage values, maximum voltage values, maximum negative time-derivatives of voltages, instantaneous potentials, voltage amplitudes, dominant frequencies, peak-to-peak voltages, and/or the like. Each of the respective points at which a cardiac electrical signal is sensed has a corresponding set of three-dimensional position coordinates. For example, the position coordinates of the points may be represented in Cartesian coordinates. Other coordinate systems can be used, as well. In embodiments, an arbitrary origin is used and the respective position coordinates are defined with respect to the arbitrary origin. In embodiments, the point corresponding to each sensed cardiac electrical signal may be located on the endocardial surface of the heart and/or below the endocardial surface of the heart.

[0106] Embodiments of the method **400** also include determining a number of conduction characteristics, each of the conduction characteristics based on one or more of the plurality of signal features (block **406**). In embodiments, the conduction characteristics may be activation gradients or conduction velocities. A conduction characteristic may be "based on" one or more of the plurality of signal features according to the post-filter method and/or the pre-filter method described above with regard to FIG. 2. That is, the term "based on" implies derivation at some level, but is not meant to imply a direct calculation or other determination. Any number of calculations and/or other types of determinations, transformations, aggregations, and/or the like, may be interposed between a characteristic (e.g., a value, classification, etc.) and a fact upon which it is based. For example, a conduction characteristic may be determined by performing a calculation using one or more values (e.g., activation times, differences between activation times, etc.) associated with a map vertex, where those values may be derived from some other information (e.g., activation times may be features of a signal). In embodiments of the "post-filter" method, a conduction characteristic may be determined based on a difference between two activation times, each of which may actually be determined by aggregating information from multiple cardiac signals and/or signal features. As another example, conduction characteristics based on one or more signal features may include a conduction characteristic corresponding to a propagation vector for an activation signal that is determined using activation times corresponding to electrical signals sensed by three electrodes (i.e., a conduction characteristic determined using the pre-filter method). In addition to the description given above, each of these methods are described in more detail below in FIGS. 5 and 6, respectively.

[0107] Embodiments of the method **400** also include causing a display device to display, based on the conduction characteristics, a cardiac map of at least a portion of one or more cardiac structures (block **408**). In embodiments, the

cardiac map may be generated based, at least in part, on the cardiac electrical signal features and may include an anatomical shell and a representation of at least one of the signal features. In embodiments, the cardiac map may also be generated, at least in part, using any number of other signals, techniques, and/or the like. For example, embodiments may utilize impedance mapping techniques to generate one or more portions of the cardiac map such as, for example, an anatomical shell upon which electrical signal features are represented. In embodiments, a surface may be fitted on one or more of the points associated with the cardiac electrical signals to generate a shell representing the endocardial surface of the one or more cardiac structures. In embodiments, a surface may also be fitted on one or more of the points associated with the cardiac electrical signals to generate a shell representing an epicardium surface or other excitable cardiac tissue. In embodiments, one or more of the cardiac electrical signal features at the corresponding points can be included on the shell to generate a cardiac map of the one or more cardiac structures. For example, embodiments may include displaying annotations on the cardiac map that represent features, extracted from the cardiac electrical signals and/or derived from other features, such as, for example, activation times, minimum voltage values, maximum voltage values, maximum negative time-derivatives of voltages, instantaneous potentials, voltage amplitudes, dominant frequencies, peak-to-peak voltages, and/or the like.

[0108] FIG. 5 is a flow diagram depicting another illustrative method 500 for facilitating display of cardiac mapping information, in accordance with embodiments of the present disclosure. Embodiments of method 500 may be performed, in whole or in part, by a mapping system (e.g., the mapping system 100 depicted in FIG. 1A). Embodiments of the method 500 include receiving, from a mapping probe, a number of cardiac electrical signals (block 502) and determining a number of signal features, each signal feature including a feature of one of the sensed cardiac signals (block 504). Each of the sensed cardiac electrical signals (and, accordingly, features of each signal) corresponds to a respective point (e.g., location in space) where the cardiac electrical signal was sensed.

[0109] The sensed cardiac electrical signals can include a number of intracardiac EGMs. Examples of features of the cardiac electrical signals include, but are not limited to, activation times, minimum voltage values, maximum voltage values, maximum negative time-derivatives of voltages, instantaneous potentials, voltage amplitudes, dominant frequencies, peak-to-peak voltages, and/or the like. Each of the respective points at which a cardiac electrical signal is sensed has a corresponding set of three-dimensional position coordinates. For example, the position coordinates of the points may be represented in Cartesian coordinates. Other coordinate systems can be used, as well. In embodiments, an arbitrary origin is used and the respective position coordinates are defined with respect to the arbitrary origin. In embodiments, the point corresponding to each sensed cardiac electrical signal may be located on the endocardial surface of the heart and/or below the endocardial surface of the heart.

[0110] Embodiments of method 500 also include generating a cardiac map (block 506). In embodiments, the cardiac map may be generated based, at least in part, on the cardiac electrical signal features and may include an anatomical

shell and a representation of at least one of the signal features. In embodiments, the cardiac map may also be generated, at least in part, using any number of other signals, techniques, and/or the like. For example, embodiments may utilize impedance mapping techniques to generate one or more portions of the cardiac map such as, for example, an anatomical shell upon which electrical signal features are represented. In embodiments, a surface may be fitted on one or more of the points associated with the cardiac electrical signals to generate a shell representing the endocardial surface of the one or more cardiac structures. In embodiments, a surface may also be fitted on one or more of the points associated with the cardiac electrical signals to generate a shell representing an epicardium surface or other excitable cardiac tissue. In embodiments, the surface geometry of the shell can be represented as a mesh containing a collection of vertices (points) and the connectivity between them (e.g. triangles). Alternatively, surface geometry can be represented by different functions such as higher order meshes, non-uniform rational basis splines (NURBS), and/or curvilinear shapes.

[0111] In embodiments, one or more of the cardiac electrical signal features at the corresponding points can be included on the shell to generate a cardiac map of the one or more cardiac structures. For example, embodiments may include displaying annotations on the cardiac map that represent features, extracted from the cardiac electrical signals and/or derived from other features, such as, for example, activation times, minimum voltage values, maximum voltage values, maximum negative time-derivatives of voltages, instantaneous potentials, voltage amplitudes, dominant frequencies, peak-to-peak voltages, and/or the like. If a cardiac map other than an activation map is produced as part of block 506, embodiments of method 500 also include generating an activation map having a set of vertices (block 508).

[0112] Embodiments of method 500 include determining conduction characteristics based on the activation times that are extracted from the cardiac electrical signals (block 510). As stated above, in embodiments, conduction characteristics may be activation gradients or conduction velocities. Determining conduction characteristics based on gradients of activation times may be referred to herein, interchangeably, as a “post-filter” method for determining conduction characteristics.

[0113] In embodiments, to determine conduction characteristics based on gradients of activation times, two or more activation time differences for each vertex of the activation map may be computed. The activation time differences of a vertex may be computed with respect to the activation times of surrounding vertices. Location differences of a vertex may also be computed with respect to the locations of surrounding vertices. Using the two or more activation time differences and the corresponding location differences, the activation time gradient for a vertex may be estimated using a least-squares fit. The term “least-squares gradient” may be used, interchangeably, to refer to calculating a single gradient from the two or more activation time differences and location differences using least-squares. The direction of the activation propagation will be the direction of the least-squares gradient. Furthermore, when comparing the least-squares gradient for two different vertices, the vertex with the least-squares gradient that has the larger magnitude will be the vertex that has slower conduction velocity. This is

because the differences in activation times surrounding a first vertex that has slow propagation between the first vertex and neighboring vertices will be greater than the differences in activation times surrounding a second vertex that has fast propagation between the second vertex and neighboring vertices.

[0114] In embodiments, a conduction velocity for a vertex may be determined from the activation time gradient by calculating the reciprocal of the activation time gradient. In these embodiments, when comparing the least-squares gradient for two different vertices, the vertex with the least-squares gradient that has the smaller magnitude will be the vertex that has slower conduction velocity.

[0115] Embodiments of method 500 include determining a set of conduction characteristics that satisfy a condition (block 512). In embodiments, the condition may be selected based on whether the conduction characteristic is a conduction velocity or an activation time gradient and what portion of a cardiac map a physician and/or technician would like to see. For example, as described above, reentry of an activation signal, which may result in an arrhythmia, may be due to a slow pathway. As such, the condition for the conduction characteristics may be set to distinguish between a propagation speed that is typical of healthy cardiac tissue and a propagation speed that is typical of unhealthy cardiac tissue. To distinguish between propagation speeds, a range of conduction characteristic values that is typical of unhealthy cardiac tissue may satisfy the condition and/or conduction characteristic values that are above or below a threshold value may satisfy the condition.

[0116] For example, when the conduction characteristic are activation time gradients and when comparing the activation time gradient for two different vertices, the vertex with the activation time gradient that has the larger magnitude will be the vertex that has slower conduction velocity. Accordingly, in embodiments, the activation gradient may satisfy the condition when the activation gradient is no less than a threshold. And, conversely, when the conduction characteristics are conduction velocities and when comparing the conduction velocities for two different vertices, the vertex with the conduction velocity that has the smaller magnitude will be the vertex that has slower conduction velocity. Accordingly, in embodiments, the conduction velocity may satisfy the condition when the conduction velocity is no greater than a threshold. As another example, healthy cardiac activation may propagate at a speed of approximately 0.5 millimeters (mm) per millisecond (ms); and, unhealthy cardiac activation may propagate at roughly half the speed, e.g., approximately 0.25 mm/ms. As such, in embodiments where conduction velocity is used, a conduction velocity that is below 0.4 mm/ms and/or within 0.15 mm/ms of 0.25 mm/ms may satisfy the condition. These are only examples, however, and not meant to be limiting.

[0117] Embodiments of method 500 also include causing the display of a cardiac map having representations of signal features corresponding to the set of conduction characteristics that satisfy the condition (block 514). The cardiac map that is displayed may be generated as described above in block 506. In embodiments, however, only signal features that correspond to the set of conduction characteristics that satisfy the condition may be displayed. As such, it may be easier for a physician and/or technician to identify especially relevant portions of the cardiac map (e.g., slow pathways), which may result in faster and more accurate treatment of a

patient. In embodiments, the cardiac map may be displayed on a display device, for example, the display device 118 shown in FIG. 1 above.

[0118] FIG. 6 is a flow diagram depicting another illustrative method for facilitating display of cardiac mapping information, in accordance with embodiments of the present disclosure. Embodiments of method 600 may be performed, in whole or in part, by a mapping system (e.g., the mapping system 100 depicted in FIG. 1A). Embodiments of the method 600 include receiving, from a mapping probe, a number of cardiac electrical signals (block 602) and determining a number of signal features, each signal feature including a feature of one of the sensed cardiac signals (block 604). Each of the sensed cardiac electrical signals (and, accordingly, features of each signal) corresponds to a respective point (e.g., location in space) where the cardiac electrical signal was sensed.

[0119] The sensed cardiac electrical signals can include a number of intracardiac EGMs. Examples of features of the cardiac electrical signals include, but are not limited to, activation times, minimum voltage values, maximum voltage values, maximum negative time-derivatives of voltages, instantaneous potentials, voltage amplitudes, dominant frequencies, peak-to-peak voltages, and/or the like. Each of the respective points at which a cardiac electrical signal is sensed has a corresponding set of three-dimensional position coordinates. For example, the position coordinates of the points may be represented in Cartesian coordinates. Other coordinate systems can be used, as well. In embodiments, an arbitrary origin is used and the respective position coordinates are defined with respect to the arbitrary origin. In embodiments, the point corresponding to each sensed cardiac electrical signal may be located on the endocardial surface of the heart and/or below the endocardial surface of the heart.

[0120] Embodiments of method 600 include determining conduction characteristics using the activation times corresponding to electrical signals sensed by three electrodes (block 606). In embodiments, conduction characteristics may be activation gradients or conduction velocities. In embodiments, using a least-squares fit computation, the relative activation times and positions extracted from one or more cardiac signals can be used to determine the propagation vector for the activation signal. Similar to above, the direction of the propagation vector is the direction of propagation of the activation signal and the reciprocal of the magnitude of the propagation vector corresponds to the conduction velocity of the activation signal. In embodiments, the signal used to determine the activation time gradients and/or the conduction velocities may be from a signal cycle (or “beat”). Determining conduction characteristics based on activation times corresponding to cardiac electrical signals sensed by three electrodes may be referred to herein, interchangeably, as a “pre-filter” method for determining conduction characteristics.

[0121] In embodiments, determining conduction characteristics using the pre-filter method may have advantages. For example, in general, a cardiac map is generated from signals that are sensed from multiple beats. One or more of these signals may be used as one or more references and the other signals that are sensed may be aligned relative to the one or more reference signals. During this alignment process, noise may be introduced because the alignments of the signals may not exact due to slight aberrations in the signals

sensed from different beats. Using the pre-filter method, however, this alignment noise is not introduced since the cardiac signal from which the activation times are extracted may be from a single beat.

[0122] Another advantage to the pre-filter method may be when generating a cardiac map. For example, when constructing an activation map, instead of only determining the most prevalent activation time for a specific point (or vertex) and using that activation time to generate an activation map, a direction, as determined using the pre-filtered conduction characteristic, may be associated with each activation time. As such, if two different activation times are extracted from cardiac signals over multiple beats at approximately the same frequency and position, eliminating one of the activation times may be easier to do based on the direction associated with the activation time and an expected activation propagation. For example, assume a first activation time of 10 ms (relative to a reference time) and a second activation time of 20 ms (relative to the reference time) are extracted from a cardiac signal at a vertex. Further assume that the first activation time has a direction of 45 degrees relative to a reference angle and the second activation time has a direction of 90 degrees relative to the reference angle. If activation signals surrounding the vertex have a direction of 45 relative to a reference angle, then the second activation time may be discarded because it has a direction that does not match the directions of activation signals surrounding the vertex. Accordingly, the pre-filter method may be used to improve certain cardiac maps by rejecting some extracted features that do not align with other extracted features.

[0123] Embodiments of method 600 include determining a set of conduction characteristics that satisfy a condition (block 608). In embodiments, the condition may be selected based on whether the conduction characteristic is a conduction velocity or an activation time gradient and what portion of a cardiac map a physician and/or technician would like to see. For example, as described above, reentry of an activation signal, which may result in an arrhythmia, may be due to a slow pathway. As such, the condition for the conduction characteristic may be set to distinguish between a propagation speed that is typical of healthy cardiac tissue and a propagation speed that is typical of unhealthy cardiac tissue. To distinguish between propagation speeds, a range of conduction characteristic values that is typical of unhealthy cardiac tissue may satisfy the condition and/or conduction characteristic values that are above or below a threshold value may satisfy the condition.

[0124] For example, when the conduction characteristic are activation time gradients and when comparing the activation time gradient for two different vertices, the vertex with the activation time gradient that has the larger magnitude will be the vertex that has slower conduction velocity. Accordingly, in embodiments, the activation gradient may satisfy the condition when the activation gradient is no less than a threshold. And, conversely, when the conduction characteristics are conduction velocities and when comparing the conduction velocities for two different vertices, the vertex with the conduction velocity that has the smaller magnitude will be the vertex that has slower conduction velocity. Accordingly, in embodiments, the conduction velocity may satisfy the condition when the conduction velocity is no greater than a threshold. As another example, healthy cardiac activation may propagate at a speed of approximately 0.5 millimeters (mm) per millisecond (ms);

and, unhealthy cardiac activation may propagate at roughly half the speed, e.g., approximately 0.25 mm/ms. As such, in embodiments where the conduction characteristic is a conduction velocity, a conduction velocity that is below 0.4 mm/ms and/or within 0.15 mm/ms of 0.25 mm/ms may satisfy the condition. These are only examples, however, and not meant to be limiting.

[0125] Embodiments of method 600 also include generating a cardiac map (block 610). In embodiments, the cardiac map may be generated based, at least in part, on the cardiac electrical signal features and may include an anatomical shell and a representation of at least one of the signal features. In embodiments, some signal features may be rejected based on the determined pre-filtered conduction characteristic, as described above in the discussion of block 606 and, therefore, not used to generate the cardiac map. In embodiments, the cardiac map may also be generated, at least in part, using any number of other signals, techniques, and/or the like. For example, embodiments may utilize impedance mapping techniques to generate one or more portions of the cardiac map such as, for example, an anatomical shell upon which electrical signal features are represented. In embodiments, a surface may be fitted on one or more of the points associated with the cardiac electrical signals to generate a shell representing the endocardial surface of the one or more cardiac structures. In embodiments, a surface may also be fitted on one or more of the points associated with the cardiac electrical signals to generate a shell representing an epicardium surface or other excitable cardiac tissue. In embodiments, the surface geometry of the shell can be represented as a mesh containing a collection of vertices (points) and the connectivity between them (e.g. triangles). Alternatively, surface geometry can be represented by different functions such as higher order meshes, non-uniform rational basis splines (NURBS), and/or curvilinear shapes.

[0126] In embodiments, one or more of the cardiac electrical signal features at the corresponding points can be included on the shell to generate a cardiac map of the one or more cardiac structures. For example, embodiments may include displaying annotations on the cardiac map that represent features, extracted from the cardiac electrical signals and/or derived from other features, such as, for example, activation times, minimum voltage values, maximum voltage values, maximum negative time-derivatives of voltages, instantaneous potentials, voltage amplitudes, dominant frequencies, peak-to-peak voltages, and/or the like.

[0127] Embodiments of method 600 also include causing the display of a cardiac map having representations of signal features corresponding to the set of conduction characteristics that satisfy the condition (block 614). The cardiac map that is displayed may be generated as described above in block 610. In embodiments, however, only signal features that correspond to the set of conduction characteristics that satisfy the condition may be displayed. As such, it may be easier for a physician and/or technician to identify especially relevant portions of the cardiac map (e.g., slow pathways), which may result in faster and more accurate treatment of a patient. In embodiments, the cardiac map may be displayed on a display device, for example, the display device 118 shown in FIG. 1 above.

[0128] Various modifications and additions can be made to the exemplary embodiments discussed without departing

from the scope of the present disclosure. For example, while the embodiments described above refer to particular features, the scope of this disclosure also includes embodiments having different combinations of features and embodiments that do not include all of the described features. Accordingly, the scope of the present disclosure is intended to embrace all such alternatives, modifications, and variations as fall within the scope of the claims, together with all equivalents thereof.

We claim:

1. A system for facilitating display of cardiac mapping information, the system comprising:

a mapping probe configured to sense a plurality of cardiac electrical signals; and

a processing unit configured to:

receive the plurality of cardiac electrical signals;
determine a plurality of signal features, each of the plurality of signal features comprising a feature of one of the plurality of cardiac electrical signals;
determine a plurality of conduction characteristics, each of the plurality of conduction characteristics based on one or more of the plurality of signal features; and

generate, based on the plurality of signal features and the corresponding plurality of conduction characteristics, a cardiac map, the cardiac map comprising an anatomical shell and a set of annotations representing at least a portion of the plurality of signal features.

2. The system of claim 1, wherein a first annotation of the set of annotations is associated with a first map point lying on the anatomical shell, and wherein the processing unit is configured to generate the first annotation by performing an interpolation based on a set of vectors, wherein each of the set of vectors is associated with an additional map point and comprises one of the plurality of electrical signal features and a corresponding one of the plurality of conduction characteristics.

3. The system of claim 1, wherein the processing unit is further configured to determine a set of conduction characteristics, of the plurality of conduction characteristics, that satisfy a condition, wherein the set of annotations comprises a representation of each of the plurality of signal features that corresponds to one of the set of conduction characteristics that satisfy the condition and wherein the cardiac map does not include a representation of a signal feature that does not correspond to one of the set of conduction characteristics that satisfy the condition.

4. The system of claim 3, wherein a conduction characteristic satisfies the condition when the conduction characteristic is within a particular range.

5. The system of claim 3, wherein the conduction characteristics are conduction velocities and wherein a conduction characteristic satisfies the condition when the conduction characteristic is no greater than a threshold.

6. The system of claim 3, wherein the conduction characteristics are activation gradients and wherein an activation gradient satisfies the condition when the activation gradient is no less than a threshold.

7. The system of claim 1, wherein each of the plurality of signal features comprises at least one of an activation time, a minimum voltage value, a maximum voltage value, a maximum negative time-derivative of voltage, an instantaneous potential, a voltage amplitude, a dominant frequency, a mean cycle length, and a peak-to-peak voltage.

8. A system for facilitating display of cardiac mapping information, the system comprising:

a mapping probe configured to sense a plurality of cardiac electrical signals; and

a processing unit configured to:

receive the plurality of cardiac electrical signals;
determine a plurality of signal features, each of the plurality of signal features comprising a feature of one of the plurality of cardiac electrical signals;
determine a plurality of conduction characteristics, each of the plurality of conduction characteristics based on one or more of the plurality of signal features;

determine a set of conduction characteristics, of the plurality of conduction characteristics, that satisfy a condition; and

provide, for presentation on a display device, a cardiac map, the cardiac map comprising an anatomical shell and a representation of each of the plurality of signal features that corresponds to one of the set of conduction characteristics that satisfy the condition.

9. The system of claim 8, wherein the cardiac map does not include a representation of a signal feature that does not correspond to one of the set of conduction characteristics that satisfy the condition.

10. The system of claim 8, wherein a conduction characteristic satisfies the condition when the conduction characteristic is within a particular range.

11. The system of claim 8, wherein the conduction characteristics are conduction velocities and wherein a conduction characteristic satisfies the condition when the conduction characteristic is no greater than a threshold.

12. The system of claim 8, wherein the conduction characteristics are activation gradients and wherein an activation gradient satisfies the condition when the activation gradient is no less than a threshold.

13. The system of claim 8, wherein each of the plurality of signal features comprises at least one of an activation time, a minimum voltage value, a maximum voltage value, a maximum negative time-derivative of voltage, an instantaneous potential, a voltage amplitude, a dominant frequency, a mean cycle length, and a peak-to-peak voltage.

14. The system of claim 13, each of the plurality of signal features comprising an activation time, and wherein the processing unit is configured to determine the plurality of conduction characteristics by:

determining a gradient associated with each of the plurality of activation times; and

determining the inverse of the gradient associated with each of the plurality of activation times.

15. The system of claim 14, wherein each of the plurality of signal features comprises an activation time associated with a single beat.

16. The system of claim 13, wherein the processing unit is configured to determine the plurality of conduction characteristics by performing a least-squares computation using at least three electrode activation times, wherein each of the at least three electrode activation times is associated with one of at least three non-collinear electrode locations.

17. A method for facilitating display of cardiac mapping information, the method comprising:

receiving, from a mapping probe, a plurality of cardiac electrical signals;

determining a plurality of signal features, each of the plurality of signal features comprising a feature of one of the plurality of cardiac electrical signals;

determining a plurality of conduction characteristics, each of the plurality of conduction characteristics based on one or more of the plurality of signal features; and

causing a display device to display, based on the plurality of conduction characteristics, a cardiac map, the displayed cardiac map comprising an anatomical shell and a representation of at least one of the plurality of signal features.

18. The method of claim 17, further comprising:

generating an activation map, the activation map comprising the anatomical shell, a plurality of vertices and a representation of each of a plurality of activation times at a vertices of the plurality of vertices;

determining activation time differences for each vertex, wherein each of the plurality of conduction characteristics is determined based on one or more of the activation time differences;

determining a set of conduction characteristics, of the plurality of conduction characteristics, that satisfy a condition, wherein a conduction characteristic satisfies the condition when the conduction characteristic is within a particular range; and

wherein the displayed cardiac map does not include a representation of a signal feature that does not correspond to one of the set of conduction characteristics that satisfy the condition.

19. The method of claim 18, wherein determining an activation time difference of a vertex includes performing a least-squares computation using at least three activation times associated with the vertex and at least two other map vertices of the activation map.

20. The method of claim 17, wherein determining the plurality of conduction characteristics includes: performing a least-squares computation using at least three electrode activation times, wherein each of the at least three electrode activation times is associated with one of at least three non-collinear electrode locations of the mapping probe.

* * * * *

专利名称(译)	使用速度信息自动映射		
公开(公告)号	US20170172508A1	公开(公告)日	2017-06-22
申请号	US15/383475	申请日	2016-12-19
[标]申请(专利权)人(译)	波士顿科学西美德公司		
申请(专利权)人(译)	BOSTON SCIENTIFIC SCIMED INC.		
当前申请(专利权)人(译)	BOSTON SCIENTIFIC SCIMED INC.		
[标]发明人	HULTZ PAUL PERLMAN MORDECHAI BENNETT NATHAN H STEWART BRIAN		
发明人	HULTZ, PAUL PERLMAN, MORDECHAI BENNETT, NATHAN H. STEWART, BRIAN		
IPC分类号	A61B5/00 A61B6/00 A61B5/042		
CPC分类号	A61B5/6858 A61B6/503 A61B5/0422 A61B5/6852 A61B5/0456 A61B5/046 A61B5/0464 A61B5/7239 A61B5/7253 A61B5/7264 A61B5/743 A61B2505/05		
优先权	62/270030 2015-12-20 US		
外部链接	Espacenet USPTO		

摘要(译)

用于促进心脏映射信息的显示的系统包括配置成感测心电信号的映射探针。该系统还包括处理单元，该处理单元被配置为接收心电信号；确定信号特征；并确定传导特性。处理单元还被配置为基于信号特征和相应的传导特性生成心脏图。

