



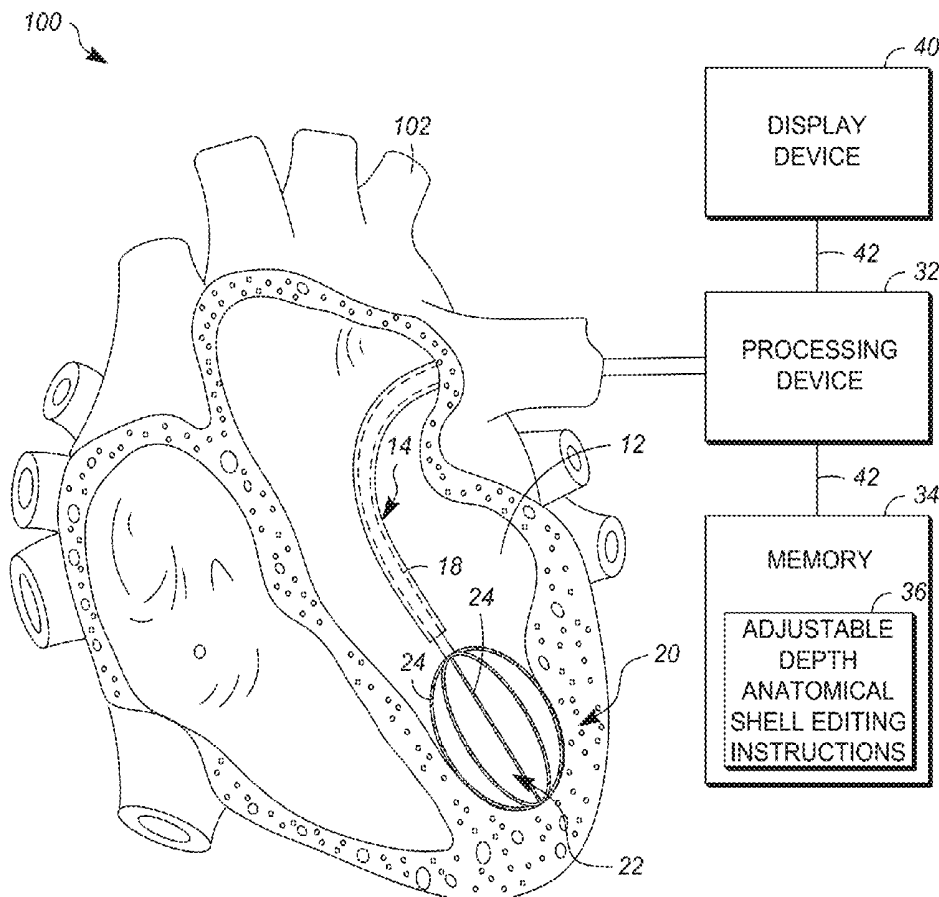
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(19) **United States**(12) **Patent Application Publication**
Perlman et al.(10) **Pub. No.: US 2017/0092013 A1**(43) **Pub. Date: Mar. 30, 2017**(54) **ADJUSTABLE DEPTH ANATOMICAL SHELL EDITING***A61B 5/053* (2006.01)*G06F 3/0484* (2006.01)(71) Applicant: **Boston Scientific Scimed Inc.**, Maple Grove, MN (US)(52) **U.S. Cl.**CPC *G06T 19/20* (2013.01); *G06F 3/04842* (2013.01); *G06F 3/04845* (2013.01); *A61B 5/742* (2013.01); *A61B 5/6858* (2013.01); *A61B 5/0538* (2013.01); *A61B 5/0536* (2013.01); *A61B 5/7475* (2013.01); *G06T 2200/24* (2013.01); *G06T 2210/41* (2013.01); *G06T 2219/2021* (2013.01)(72) Inventors: **Mordechai Perlman**, Cambridge, MA (US); **Daniel Klebanov**, Arlington, MA (US); **Ruslan R. Hristov**, Lexington, MA (US)(21) Appl. No.: **15/275,443**(57) **ABSTRACT**(22) Filed: **Sep. 25, 2016****Related U.S. Application Data**

(60) Provisional application No. 62/233,348, filed on Sep. 26, 2015.

Publication Classification(51) **Int. Cl.***G06T 19/20* (2006.01)*A61B 5/00* (2006.01)

Embodiments for adjustable depth anatomical shell editing are disclosed. In an embodiment, a method for adjustable depth anatomical shell editing comprises: outputting, to a display device, a first anatomical shell of a cardiac structure, wherein the first anatomical shell is based on a plurality of signals sensed by a mapping probe; receiving, from a user input device, a selection of a portion of the first anatomical shell; generating a modified anatomical shell that has the selected portion removed to an approximate depth from the first anatomical shell, wherein the approximate depth is finite; and outputting, to the display device, the modified anatomical shell.



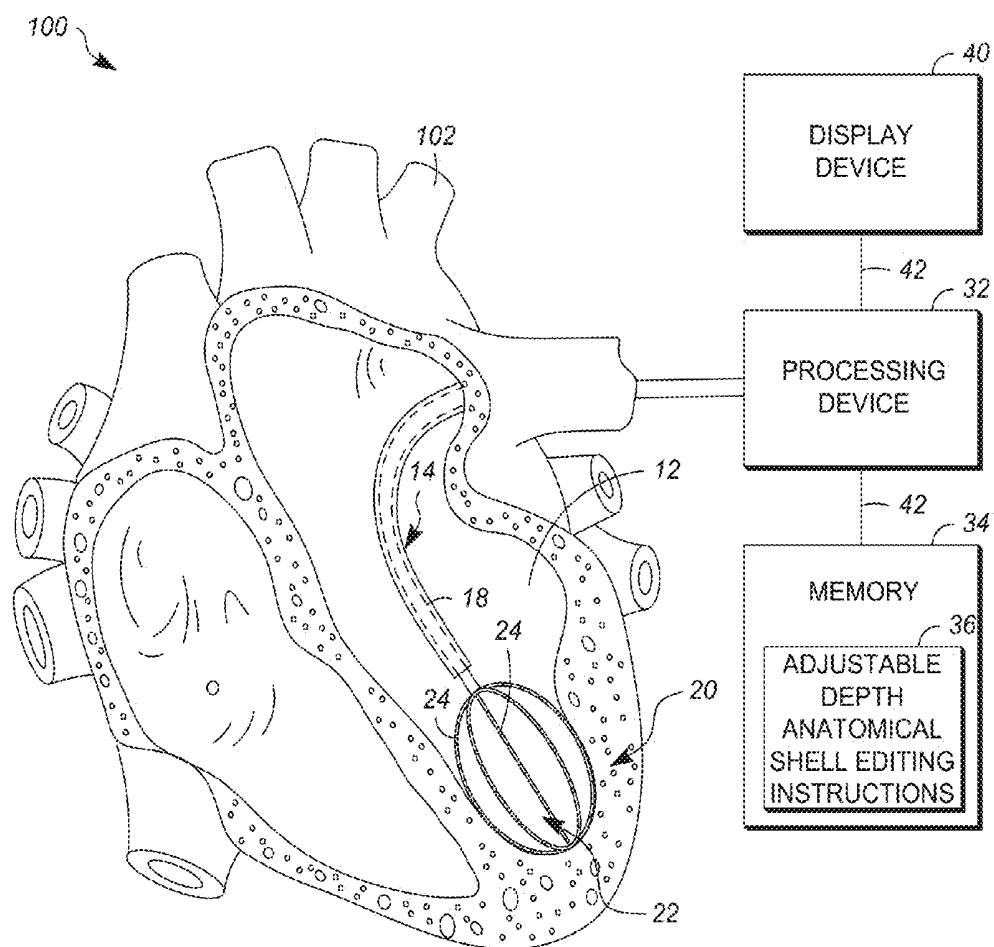


FIG. 1

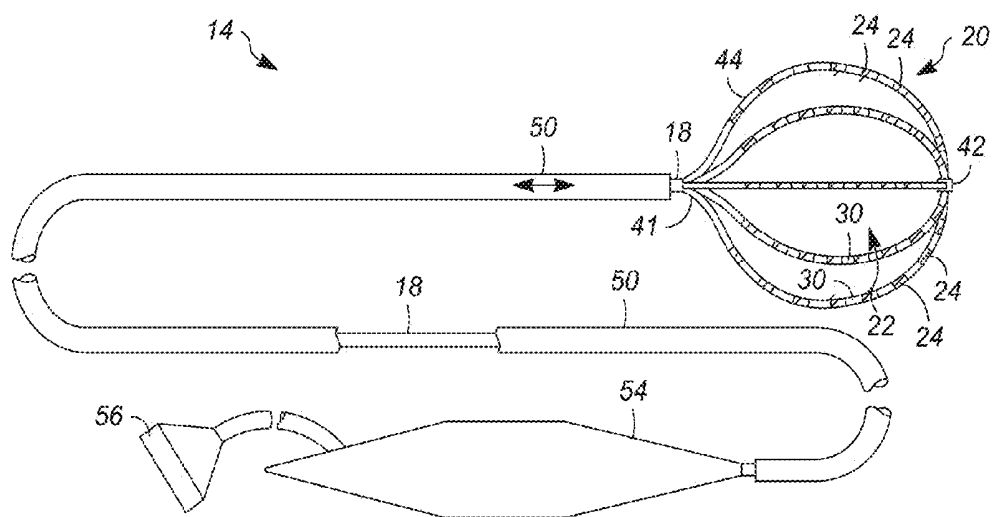


FIG. 2

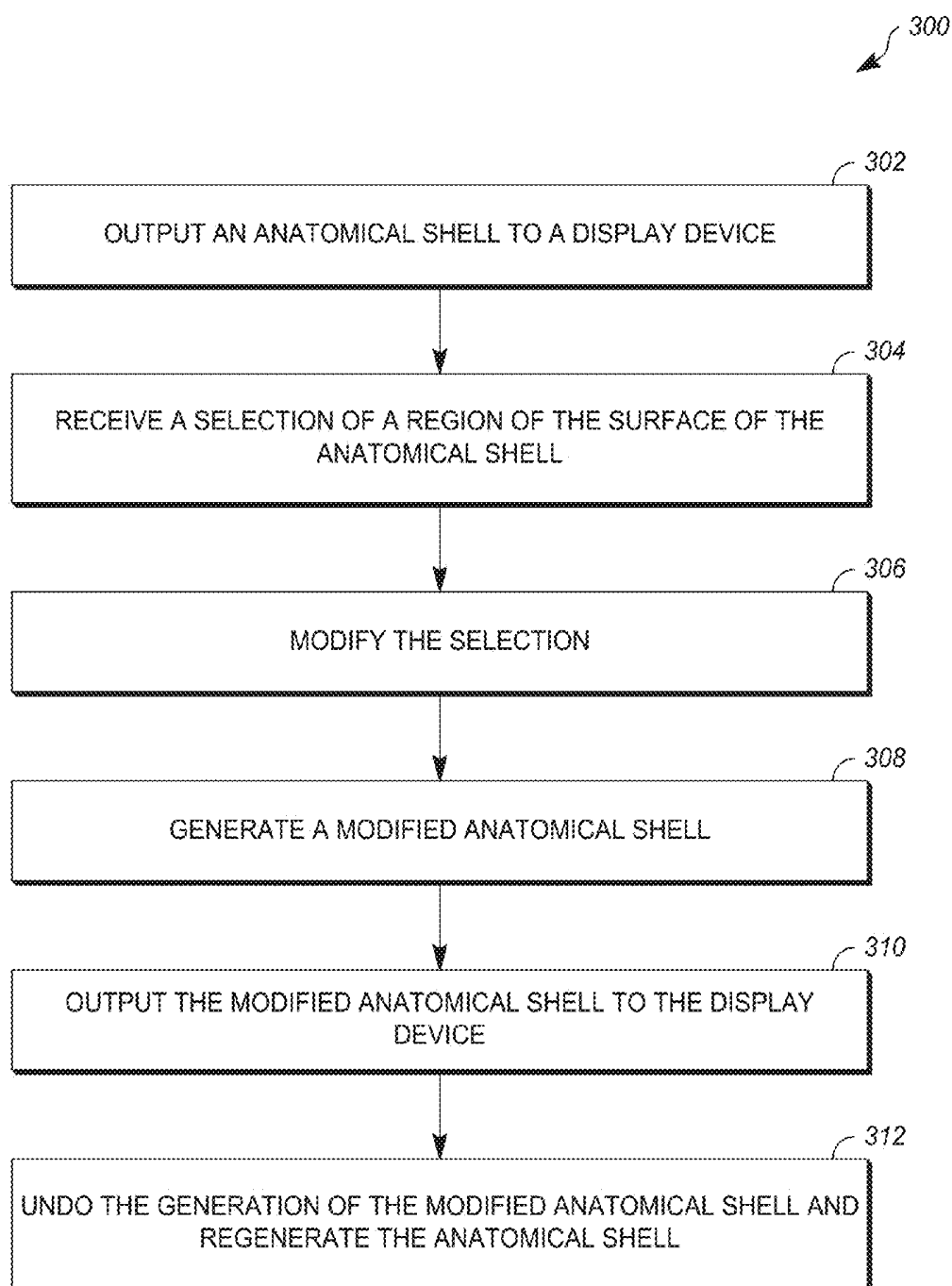


FIG. 3

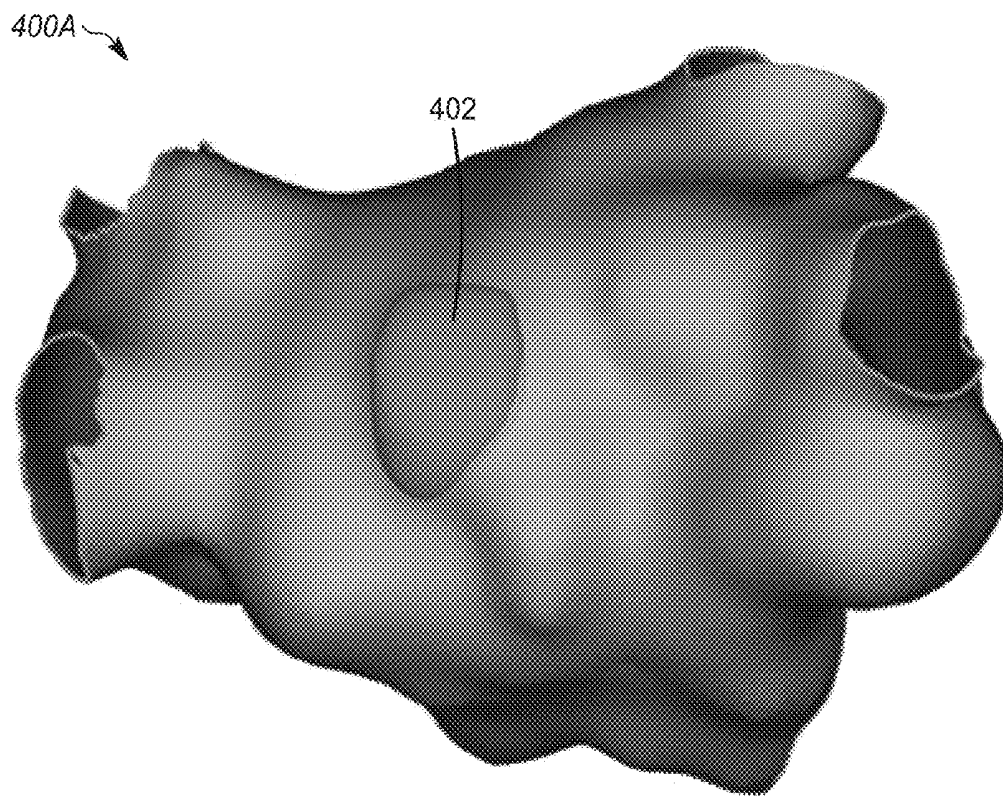


FIG. 4A

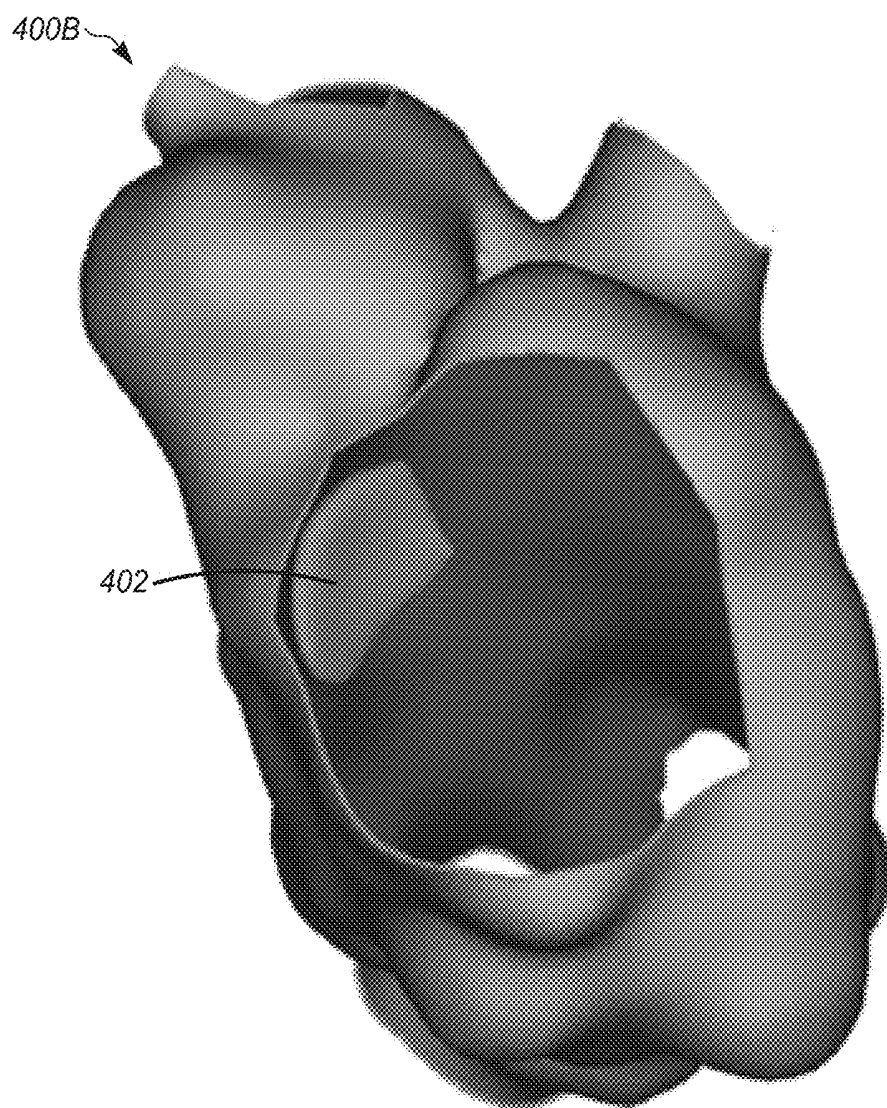


FIG. 4B

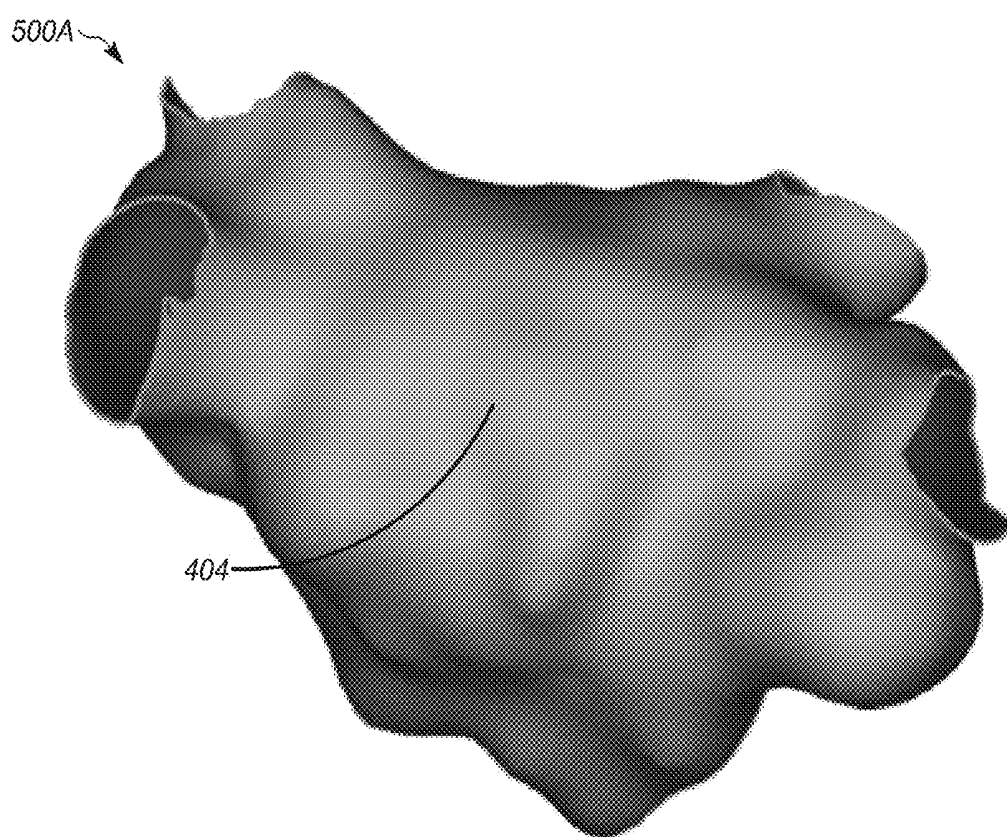


FIG. 5A

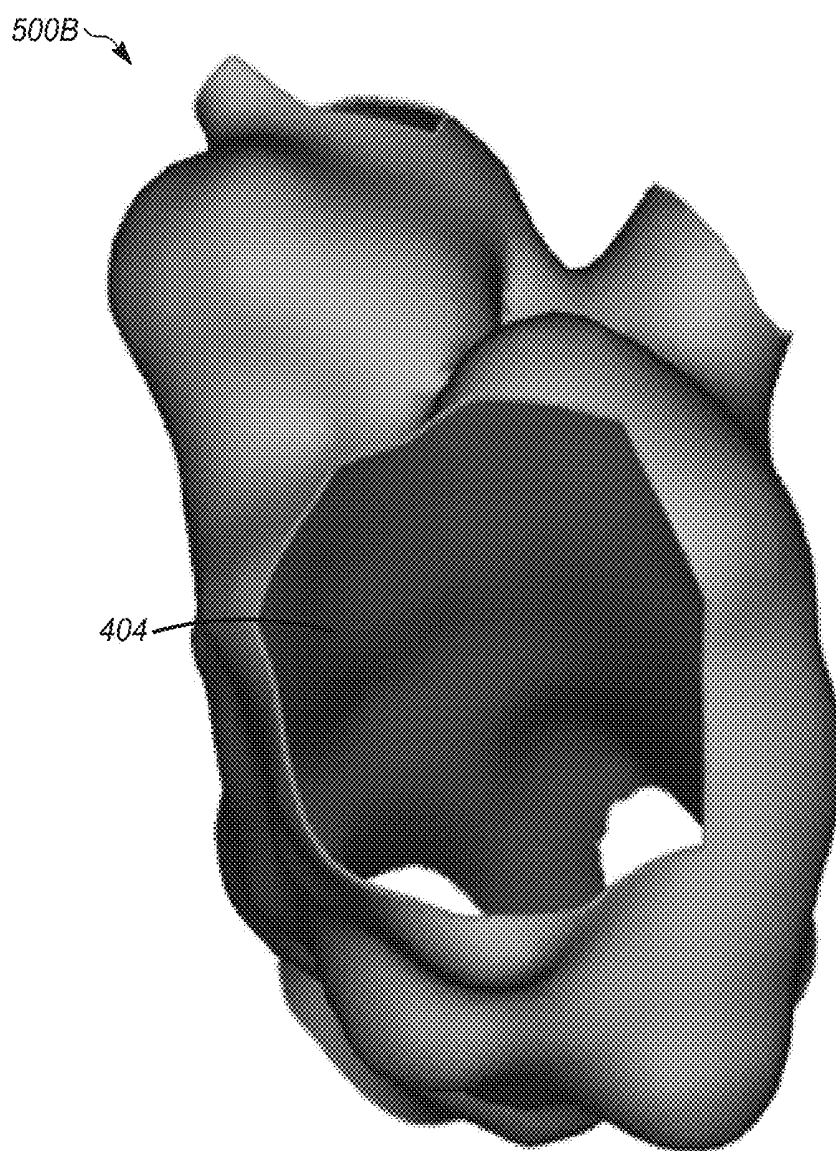


FIG. 5B

ADJUSTABLE DEPTH ANATOMICAL SHELL EDITING

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Provisional Application No. 62/233,348, filed Sep. 26, 2015, which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure generally relates to cardiac mapping systems and methods. More specifically, the present disclosure relates to editing anatomical shells.

BACKGROUND

[0003] Diagnosing and treating cardiac disorders often involve the introduction of a catheter into a cardiac chamber through the surrounding vasculature. The catheter has a plurality of sensors, located on the catheter's distal end. Information received from the plurality of sensors can be used to construct an anatomical shell, which is a graphical representation of the cardiac chamber. The anatomical shell can be used by a physician or other medical professional for treating cardiac disorders.

[0004] When constructing the anatomical shell of a cardiac chamber, various issues can occur. For example, in some instances, the catheter can be pushed against the wall of the cardiac chamber, which stretches the chamber and results in a slightly distorted version of the chamber. As another example, some cardiac protrusions that project inwardly from the endocardium surface of the cardiac chamber are not shown on the anatomical shell.

[0005] Conventional systems may allow for manual editing of the anatomical shell, which may include selecting a region of the surface of the anatomical shell to remove. Removal of the selected region of the surface also causes all of the points that lay below that region of the surface to be removed, to an infinite depth—that is, any points that lay inward the selected region of the surface are also removed. This may result in the undesirable removal of regions of the surface of the anatomical shell that lie inward the selected region and leaves a hole in the anatomical shell.

SUMMARY

[0006] Embodiments of the subject matter disclosed herein include cardiac mapping systems that allow a user to perform adjustable depth anatomical shell editing.

[0007] In an Example 1, a processor-implemented method for adjustable depth anatomical shell editing comprises: outputting, to a display device, an anatomical shell of a cardiac structure, wherein the anatomical shell is based on a plurality of signals sensed by a mapping probe; receiving, from a user input device, a selection of a region of the surface of the anatomical shell; generating a modified anatomical shell by removing a portion of the anatomical shell, the removed portion of the anatomical shell comprising the selected region of the surface and extending inward to an editing depth, the editing depth comprising at least one finite depth; and outputting, to the display device, the modified anatomical shell.

[0008] In an Example 2, the method according to Example 1, wherein generating the modified anatomical shell comprises generating a new surface region on the modified

anatomical shell, corresponding to the selected region, wherein the new surface region is disposed at the editing depth.

[0009] In an Example 3, the method according to either Example 1 or 2, further comprising: receiving, from the user input device, a command to undo the generation of the modified anatomical shell; regenerating the anatomical shell; and outputting the regenerated anatomical shell to the display device.

[0010] In an Example 4, the method according to any of Examples 1-3, further comprising receiving, from the user input device, a user input specifying a target depth, wherein the editing depth is determined based on the target depth.

[0011] In an Example 5, the method according to Example 4, wherein the target depth is at least 1 millimeter and at most 5 millimeters.

[0012] In an Example 6, the method according to any of Examples 1-5, further comprising receiving, from the user input device, a selection modification, wherein the selection modification comprises a modified selected region, the modified selected region comprising a sub-region of the selected region or the selected region and an additional region of the surface of the anatomical shell, wherein the removed portion of the anatomical shell comprises the modified selected region.

[0013] In an Example 7, the method according to any of Examples 1-6, further comprising: receiving, from the user input device, a command to display a selection tool on the user interface; and receiving, from the user input device, a selection of a size of the selection tool.

[0014] In an Example 8, a mapping system comprises: a display device configured to display an anatomical shell of a cardiac structure based on a plurality of signals sensed by a mapping probe; a user input device configured to receive input from a user; and a processing device coupled to the display device and the user input device, wherein the processing device is configured to: receive, from the user input device, a selection of a region of the surface of the anatomical shell; generate a modified anatomical shell by removing a portion of the anatomical shell, the removed portion of the anatomical shell comprising the selected region of the surface and extending inward to an editing depth, the editing depth comprising at least one finite depth; and output the modified anatomical shell to the display device.

[0015] In an Example 9, the mapping system according to Example 8, wherein the processing device is further configured to generate a new surface region on the modified anatomical shell, corresponding to the selected region, wherein the new surface region is disposed at the editing depth.

[0016] In an Example 10, the mapping system according to either Examples 8 or 9, wherein the processing device is further configured to: receive, from the user input device, a command to undo the generation of the modified anatomical shell; regenerate the anatomical shell; and output the regenerated anatomical shell to the display device.

[0017] In an Example 11, the mapping system according to any of Examples 8-10, wherein the processing device is further configured to receive, from the user input device, a user input specifying a target depth, wherein the editing depth is determined based on the target depth.

[0018] In an Example 12, the mapping system according to Example 11, wherein the target depth is at least 1 millimeter and at most 5 millimeters.

[0019] In an Example 13, the mapping system according to any of Examples 8-12, wherein the processing device is configured to determine the editing depth based on the target depth and a contour of the selected region of the surface of the anatomical shell.

[0020] In an Example 14, the mapping system according to any of Examples 8-13, wherein the processing device is further configured to: receive, from the user input device, a selection modification, wherein the selection modification comprises a modified selected region, the modified selected region comprising a sub-region of the selected region or the selected region and an additional region of the surface of the anatomical shell, wherein the removed portion of the anatomical shell comprises the modified selected region.

[0021] In an Example 15, the mapping system according to any of Examples 8-14, wherein the processing device is further configured to: receive, from the user input device, a command to display a selection tool on the user interface; and receive, from the user input device, a selection of a size of the selection tool.

[0022] In an Example 16, a processor-implemented method for adjustable depth anatomical shell editing, the method comprising: receiving a plurality of signals sensed by a mapping probe; generating, using the processor, an anatomical shell of a cardiac structure, wherein the anatomical shell is generated based on the plurality of signals; outputting, to a display device, the anatomical shell of the cardiac structure; receiving, from a user input device, a selection of a region of the surface of the anatomical shell; generating a modified anatomical shell by removing a portion of the anatomical shell, the removed portion of the anatomical shell comprising the selected region of the surface and extending inward to an editing depth, the editing depth comprising at least one finite depth; and outputting, to the display device, the modified anatomical shell.

[0023] In an Example 17, the method of Example 16, wherein generating the modified anatomical shell comprises generating a new surface region on the modified anatomical shell, corresponding to the selected region, wherein the new surface region is disposed at the editing depth.

[0024] In an Example 18, the method of Example 16, further comprising: receiving, from the user input device, a command to undo the generation of the modified anatomical shell; regenerating the first anatomical shell; and outputting the regenerated anatomical shell to the display device.

[0025] In an Example 19, the method of Example 16, further comprising receiving, from the user input device, a user input specifying a target depth, wherein the editing depth is determined based on the target depth.

[0026] In an Example 20, the method of Example 19, wherein the target depth is at least 1 millimeter and at most 5 millimeters.

[0027] In an Example 21, the method of Example 19, further comprising determining the editing depth based on the target depth and a contour of the selected region of the surface of the anatomical shell.

[0028] In an Example 22, the method of Example 21, further comprising: receiving, from the user input device, a selection modification, wherein the selection modification comprises a modified selected region, the modified selected region comprising a sub-region of the selected region or the selected region and an additional region of the surface of the anatomical shell, wherein the removed portion of the anatomical shell comprises the modified selected region.

[0029] In an Example 23, the method of Example 21, further comprising: receiving, from the user input device, a command to display a selection tool on the user interface; and receiving, from the user input device, a selection of a size of the selection tool.

[0030] In an Example 24, a mapping system comprising: a display device configured to display an anatomical shell of a cardiac structure based on a plurality of signals sensed by a mapping probe; a user input device configured to receive input from a user; and a processing device coupled to the display device and the user input device, wherein the processing device is configured to: receive, from the user input device, a selection of a region of the surface of the anatomical shell; generate a modified anatomical shell by removing a portion of the anatomical shell, the removed portion of the anatomical shell comprising the selected region of the surface and extending inward to an editing depth, the editing depth comprising at least one finite depth; and output the modified anatomical shell to the display device.

[0031] In an Example 25, the mapping system of Example 24, wherein the processing device is further configured to generate a new surface region on the modified anatomical shell, corresponding to the selected region, wherein the new surface region is disposed at the editing depth.

[0032] In an Example 26, the mapping system of Example 24, wherein the processing device is further configured to: receive, from the user input device, a command to undo the generation of the modified anatomical shell; regenerate the anatomical shell; and output the regenerated anatomical shell to the display device.

[0033] In an Example 27, the mapping system of Example 24, wherein the processing device is further configured to receive, from the user input device, a user input specifying a target depth, wherein the editing depth is determined based on the target depth.

[0034] In an Example 28, the mapping system of Example 27, wherein the target depth is at least 1 millimeter and at most 5 millimeters.

[0035] In an Example 29, the mapping system of Example 24, wherein the processing device is configured to determine the editing depth based on the target depth and a contour of the selected region of the surface of the anatomical shell.

[0036] In an Example 30, the mapping system of Example 29, wherein the processing device is further configured to: receive, from the user input device, a selection modification, wherein the selection modification comprises a modified selected region, the modified selected region comprising a sub-region of the selected region or the selected region and an additional region of the surface of the anatomical shell, wherein the removed portion of the anatomical shell comprises the modified selected region.

[0037] In an Example 31, the mapping system of Example 29, wherein the processing device is further configured to: receive, from the user input device, a command to display a selection tool on the user interface; and receive, from the user input device, a selection of a size of the selection tool.

[0038] In an Example 32, one or more computer-readable media having computer-executable instructions embodied thereon that, when executed by a processor, cause the processor to: output, to a display device, an anatomical shell of a cardiac structure, wherein the anatomical shell is based on a plurality of signals sensed by a mapping probe; receive, from a user input device, a selection of a region of the surface of the anatomical shell; receive, from the user input

device, a user input specifying a target depth, wherein the editing depth is determined based on the target depth; receive, from the user input device, a command to remove a portion of the anatomical shell; generate a modified anatomical shell by removing the portion of the anatomical shell, the removed portion of the anatomical shell comprising the selected region of the surface and extending inward to an editing depth, the editing depth comprising at least one finite depth; and output, to the display device, the modified anatomical shell.

[0039] In an Example 33, the media of Example 32, wherein the instructions further cause the processor to: receive, from the user input device, a command to undo the generation of the modified anatomical shell; regenerate the first anatomical shell; and output the regenerated anatomical shell to the display device.

[0040] In an Example 34, the media of Example 32, wherein the instructions further cause the processor to receive, from the user input device, a selection modification, wherein the selection modification comprises a modified selected region, the modified selected region comprising a sub-region of the selected region or the selected region and an additional region of the surface of the anatomical shell, wherein the removed portion of the anatomical shell comprises the modified selected region.

[0041] In an Example 35, the media of Example 32, wherein the instructions further cause the processor to: receive, from the user input device, a command to display a selection tool on the user interface; and receive, from the user input device, a selection of a size of the selection tool.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] FIG. 1 is a schematic view of a system for mapping and viewing internal cardiac structures, in accordance with embodiments of the present disclosure.

[0043] FIG. 2 is a schematic view of a mapping probe for use in association with the system of FIG. 1, in accordance with embodiments of the disclosure.

[0044] FIG. 3 is a flow diagram depicting an illustrative processor-implemented method for adjustable depth anatomical shell editing, in accordance with embodiments of the disclosure.

[0045] FIGS. 4A-4B are images of an anatomical shell shown from different perspectives, in accordance with embodiments of the disclosure.

[0046] FIGS. 5A-5B are images of another anatomical shell shown from different perspectives, in accordance with embodiments of the disclosure.

[0047] 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.

[0048] 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

[0049] FIG. 1 is a schematic view of a mapping system 100 for mapping cardiac structures 102, in accordance with embodiments of the disclosure. 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. While this disclosure discusses using the mapping system to map cardiac structures 102, embodiments of the mapping system 100 may also, or alternatively, be used to map other organs and/or biological tissue including, but not limited to, kidneys, lungs, brains, gall bladders, livers, spleens, intestines, and/or the like.

[0050] The system 100 includes a mapping probe 14. The mapping probe 14 includes a flexible catheter body 18. When mapping cardiac structures 102, a physician or medical professional inserts the distal end of the catheter body 18 into a cardiac chamber (e.g., the left ventricle of the heart) of a patient. While the left ventricle of the heart is shown, alternatively, the distal end of the catheter body 18 can be deployed in other parts of the heart and/or surrounding vasculature, such as, e.g., the left atrium, the right atrium, or the right ventricle, the coronary sinus and its tributaries and the pulmonary artery. The distal end of the catheter body 18 has a multiple electrode structure 20. In the illustrated embodiments, the electrode structure 20 takes the form of a basket defining an open interior space 22. While the electrode structure 20 takes the form of a basket in the illustrated embodiments, this is only an example and other electrode structures can be utilized. For example, the electrode structure may include one or more electrodes (e.g., ablation electrodes, microelectrodes, ring electrodes, etc.) disposed on an ablation catheter, a diagnostic catheter, and/or the like.

[0051] As shown in FIG. 1, the electrode structure 20 includes a number of electrodes 24. The electrodes 24 are configured to sense electrical signals traversing the cardiac structure 102. The electrical signals can be sensed at any number of various locations in the patient’s heart such as, for example, on the endocardium surface of the heart and/or in the heart chamber below the endocardium surface. As used herein, a mapped representation of a signal that is sensed at a point inside a heart chamber is referred to as being below the endocardium surface. That is, for example, because the map includes an anatomical shell that represents an endocardium surface and, from the perspective of the viewer, a point that is located inside the chamber, and not on the endocardium surface, would appear to be below the mapped surface.

[0052] Each signal may be associated with a set of respective position coordinates that correspond to the location at which the signal was sensed. The respective electrical signals can include, but are not limited to, voltage magnitudes, activation signals and changes in activation signals over a period of time. Each of the respective position coordinates 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 signals may be sensed on the endocar-

dium surface as well as in the chamber enclosed by the endocardium surface, the respective position coordinates may be on the endocardium surface of the patient's heart and/or below the endocardium surface.

[0053] The electrodes **24** are electrically coupled to a processing device **32**. That is, each electrode **24** on the basket structure **20** may be communicatively coupled to the processing device **32**, via a wired and/or wireless connection. In embodiments where there is a wired connection, the wires (not shown) from each electrode may extend through the catheter body **18** of the mapping probe **14** and electrically couple each electrode **24** to the processing device **32**. In embodiments where there is a wireless connection, a transmitter (not shown) may be included in the mapping probe **14** which may transmit sensed signals from each electrode **24** on the basket structure **20** to a receiver (not shown) that is coupled to the processing device **32**.

[0054] Once the sensed signals are received by the processing device **32** from the electrodes **24**, the processing device **32** processes the sensed signals. The processing device **32** processes the sensed signals according to adjustable depth anatomical shell editing instructions **36**, which are stored on memory **34**. The processing device **32** 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 one of multiple processors or cores. The processed signals are displayed on a display device **40**. The display device **40** may include, but is not limited to, one of the following display devices: a cathode ray tube (CRT) display, a light emitting diode (LED) display, and/or a liquid crystal display (LCD) display.

[0055] The memory **34** may be 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 processing device **32** such as, for example, quantum state memory, and/or the like. Mapping instructions **36** may be programmed on the memory **34** 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.

[0056] The processing device **32**, the memory **34** and the display device **40** can be coupled together, directly and/or indirectly, by a bus **42**. Any number of additional components, different components, and/or combinations of components may also be coupled to the processing device **32**, memory **34** and display device **40**, via the bus **42**. The bus represents what may be one or more busses (such as, for example, an address bus, data bus, or combination thereof).

[0057] The illustrative mapping system **100** shown in FIG. **1** 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. **1** 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 memory **34** may be integrated with the processing device **32**.

[0058] FIG. **2** is a schematic view of a mapping probe **14** for use in association with the system **100** of FIG. **1**, in accordance with embodiments of the disclosure. The mapping probe **14** has a flexible catheter body **18**, the distal end of which carries the three-dimensional basket structure **20** that includes the mapping electrodes **24**. As stated above, the mapping electrodes **24** sense signals in a cardiac structure; and the sensed signals are sent to a processing device **32**, via a wired and/or wireless connection. The processing device **32** then processes the sensed signals and an anatomical shell is created, as described, for example, in the description corresponding to FIG. **3**, below.

[0059] The basket structure **20** comprises a base member **41** and an end cap **42** between which flexible splines **44** generally extend in a circumferentially spaced relationship. As discussed above, the basket structure **20** takes the form of a basket defining an open interior space **22**. In embodiments, the splines **44** are made of a resilient inert material, such as Nitinol metal or silicone rubber, and are connected between the base member **41** and the end cap **42** in a resilient, pre-tensed condition, to bend and conform to the tissue surface they contact. In the illustrated embodiments, eight splines **44** form the three-dimensional structure **20**. Additional or fewer splines **44** could be used in other embodiments, and the three-dimensional structure **20** 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 **44** carries eight mapping electrodes **24**. Additional or fewer mapping electrodes **24** could be disposed on each spline **44** in other embodiments of the three-dimensional structure **20**. In the illustrated embodiments, the three-dimensional structure **20** is relatively small (e.g., 40 mm or less in diameter). In embodiments, the three-dimensional structure **20** is larger (e.g., 40 mm in diameter or greater).

[0060] In embodiments, a slidable sheath **50** is movable along the major axis of the catheter body **30**. Moving the sheath **50** forward (i.e., toward the distal end) causes the sheath **50** to move over the three-dimensional structure **20**, thereby collapsing the structure **20** 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 **50** rearward (i.e., toward the proximal end) exposes the three-dimensional structure **20**, allowing the structure **20** to elastically expand and assume the pre-tensed position illustrated in FIG. **2**. Further details of embodiments of the three-dimensional structure **20** 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.

[0061] In embodiments where the mapping probe **14** uses a wired connection, a signal wire (not shown) may be electrically coupled to each mapping electrode **24**. The wires may extend through the body **30** of the mapping catheter **20** into a handle **54**, in which they may be coupled to an external connector **56**, which may be, for example, a multiple pin connector. The connector **56** electrically couples the

mapping electrodes **24** to the processing system **32**. Further details on mapping systems and methods for processing signal 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.

[0062] It is noted that other electrode structures could be deployed on the distal end of a mapping catheter. It is further noted that the multiple mapping electrodes **24** may be disposed on more than one structure, rather than, for example, the single mapping probe **14** illustrated in FIG. **2**. 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.

[0063] Although the mapping electrodes **24** have been described as being carried by dedicated mapping probes, such as the mapping probe **14**, the mapping electrodes may be carried on non-mapping dedicated probes or multifunction probes. For example, an ablation catheter can be configured to include one or more mapping electrodes **24** disposed on the distal end of the catheter body and coupled to the signal processing system **32**.

[0064] FIG. **3** is a flow diagram depicting an illustrative processor-implemented method **300** for adjustable depth anatomical shell editing, in accordance with embodiments of the disclosure. Embodiments of the method **300** include outputting an anatomical shell to a display device (block **302**). The anatomical shell may be generated based on a number of signals sensed by a mapping probe. In embodiments, the mapping probe can have the same or similar characteristics to the mapping probe **14** described above in FIGS. **1** and **2**. Each of the respective signals sensed by the mapping probe has a corresponding set of three-dimensional position coordinates. For example, the position coordinates of the points may be represented in Cartesian coordinates. However, other coordinate systems may be used. In embodiments, an arbitrary origin is used and the respective position coordinates are defined with respect to the arbitrary origin. In some embodiments, the points have non-uniform spacing, while in other embodiments, the points have uniform spacing. In embodiments, the point corresponding to each sensed signal may be located on the endocardium surface of the heart and/or below the endocardium surface of the heart.

[0065] The anatomical shell may 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 the anatomical shell. In embodiments, a surface may be fitted on one or more of the points associated with the electrical signals to generate a shell representing the endocardium surface. In embodiments, one or more features of the electrical signals at the corresponding points can be included in the shell of the

endocardium surface. For example, embodiments may include displaying annotations on the shell that represent features extracted from the electrical signals such as, for example, voltages, activation amplitudes, signal sharpness and/or the like. As another example, a surface may be fitted on one or more of the points associated with the electrical signals to generate a shell representing an epicardium surface or other excitable cardiac tissue.

[0066] Embodiments of method **300** also include receiving, from a user input device, a selection of a region of the surface of the anatomical shell (block **304**). The user input device used to make the selection may include a mouse, a touchscreen and/or the like, that is used to manipulate a selection tool that is provided on a user interface provided by the display device. The selection tool may include, for example, a brush, a cursor for enclosing the selected region by drawing a freeform shape around the region, an expandable polygon selection tool, and/or the like, and may be, in embodiments, selected from a number of optional selection tools. In embodiments, the selection tool may have an adjustable size, behavior and/or other characteristics thereof. In this manner, for example, a user may select a desired selection tool and a size thereof. Selecting a region of the surface of the anatomical shell may include, for example, circling the region of the surface of the anatomical shell using a mouse or touchscreen device to manipulate a cursor, brushing over the region of the surface using an input device to manipulate a brush, and/or the like.

[0067] Examples of receiving selections of a portion of the first anatomical shell are shown in FIGS. **4A** and **4B**. In particular, FIG. **4A** is a right anterior oblique view of an anatomical shell **400A** that has a selected portion **402**; and, FIG. **4B** is a left lateral view of the anatomical shell with the same selected portion **402**. In embodiments, method **300** may include steps for generating FIG. **4B** from FIG. **4A**, or vice-versa. That is, method **300** may include receiving, from a user input device, a command to rotate the displayed anatomical shell after the portion **402** is selected. After the command is received, method **300** can include generating a rotated view of the first anatomical shell based on the command.

[0068] In some embodiments, method **300** may also include receiving, from an input device, a modification to the selection of the region of the surface of the anatomical shell (block **306**). A modification to the selection of the region is also referred to herein as a selection modification. In response to receiving the selection modification, the modified selection may be made of a region of the surface of the anatomical shell. Being able to modify the selection may be useful to a user that selected too big or too small of a region, for facilitating incremental selection, to facilitate more accurate selection, and/or the like. In embodiments, a modification to the selection may include a modification to the target depth of the selection, a modification to the size of the region of the surface selected, and/or the like. For example, in embodiments, the modification may include a selection of an additional region of the surface of the anatomical shell. As another example, in embodiments, the modification may include a selection of sub-region of the selected region of the surface of the anatomical shell. Similar to selecting a portion above, a mouse, touchscreen or the like can be used to modify the selection. In embodiments, modifying the selected portion may include deselecting the selected region and then reselecting a region. In

embodiments, modifying the selection may include modifying the selection by altering the boundaries of the selection. In embodiments this may be done, for example, by clicking on a portion of the border of the selected region and dragging the selected portion of the border to a new location. In embodiments that include a selection modification, the removed portion of the anatomical shell (discussed below, block 308) can be the modified selected region.

[0069] Embodiments of method 300 also include generating a modified anatomical shell (block 308). In embodiments, the modified anatomical shell is generated by removing a portion of the anatomical shell, where the removed portion of the anatomical shell includes the selected region (or modified selected region) of the surface and extending inward to an editing depth. The editing depth may include at least one finite depth and may vary, corresponding to the contour of the surface of the anatomical shell. That is, for example, the editing depth may be the distance, along an axis normal to the surface of the anatomical shell, between a point on the surface of the anatomical shell and a point inward from the surface (i.e., below the surface) of the anatomical shell. In that manner, the editing depth may be change with the contour of the surface.

[0070] According to embodiments, the editing depth may be adjustable and/or selectable. That is, for example, a user may input and/or select a target depth, via the user interface, such that the editing depth, corresponding to each point in the selected region, may be at least approximately equal to the target depth (e.g., equal to the target depth, within at least 0.1 millimeters of the target depth, within at least 0.5 millimeters of the target depth, within 1 millimeter of the target depth, and/or the like. In embodiments, the target depth may be less than one millimeter, at least one millimeter and no more than 10 millimeters, at least one millimeter and no more than 5 millimeters, and/or the like.

[0071] In this manner, the modified anatomical shell may have the same shape as the anatomical shell, except that a portion 402 corresponding to a selected region is removed to an editing depth. In embodiments, a command may be received from a user input device to remove the portion 402. In other embodiments, when the region is selected, the portion 402 may be automatically removed. In embodiments, generating a modified anatomical shell that has the portion 402 removed to an approximate depth from the first anatomical shell 400A, 400B may include generating a new surface region on the modified anatomical shell, corresponding to the selected region, wherein the new surface region is disposed at the editing depth. That is, for example, the contour of the selected region may remain the same but appear to be moved inward by the editing depth. As described above, the term “inward” refers to the direction opposite the normal of a point on the surface of the anatomical shell 400A, 400B.

[0072] Embodiments of method 300 also include outputting the modified anatomical shell to the display device (block 310). FIGS. 5A, 5B are images of examples of generated modified anatomical shells 500A, 500B that were output to a display device. As can be seen in the images, the modified anatomical shells 500A, 500B include a new region 404 corresponding to the selected region 402, disposed at the editing depth. If the new region 404 is not generated on the modified anatomical shell 500A, 500B, the anatomical shell may include a hole to the editing depth where the selected region 402 is removed.

[0073] Embodiments of the method 300 may include receiving a command from a user input device to undo the generation of the modified anatomical shell. In response to receiving the command to undo the generation of the modified anatomical shell, the system may remove the modified anatomical shell and regenerate the anatomical shell (block 312). Similar to modifying the selected region in block 306, being able to undo generating the modified anatomical shell may be helpful if a user selects too big or too small of a region of the anatomical shell, selects a region that the user did not intend to select, and/or the like. The regenerated anatomical shell may be output to the display device for the user to view.

[0074] 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 processor-implemented method for adjustable depth anatomical shell editing, the method comprising:

receiving a plurality of signals sensed by a mapping probe;

generating, using the processor, an anatomical shell of a cardiac structure, wherein the anatomical shell is generated based on the plurality of signals;

outputting, to a display device, the anatomical shell of the cardiac structure;

receiving, from a user input device, a selection of a region of the surface of the anatomical shell;

generating a modified anatomical shell by removing a portion of the anatomical shell, the removed portion of the anatomical shell comprising the selected region of the surface and extending inward to an editing depth, the editing depth comprising at least one finite depth; and

outputting, to the display device, the modified anatomical shell.

2. The method of claim 1, wherein generating the modified anatomical shell comprises generating a new surface region on the modified anatomical shell, corresponding to the selected region, wherein the new surface region is disposed at the editing depth.

3. The method of claim 1, further comprising:

receiving, from the user input device, a command to undo the generation of the modified anatomical shell;

regenerating the first anatomical shell; and

outputting the regenerated anatomical shell to the display device.

4. The method of claim 1, further comprising receiving, from the user input device, a user input specifying a target depth, wherein the editing depth is determined based on the target depth.

5. The method of claim 4, wherein the target depth is at least 1 millimeter and at most 5 millimeters.

6. The method of claim 4, further comprising determining the editing depth based on the target depth and a contour of the selected region of the surface of the anatomical shell.

7. The method of claim 6, further comprising:
receiving, from the user input device, a selection modification, wherein the selection modification comprises a modified selected region, the modified selected region comprising a sub-region of the selected region or the selected region and an additional region of the surface of the anatomical shell, wherein the removed portion of the anatomical shell comprises the modified selected region.
8. The method of claim 6, further comprising:
receiving, from the user input device, a command to display a selection tool on the user interface; and
receiving, from the user input device, a selection of a size of the selection tool.
9. A mapping system comprising:
a display device configured to display an anatomical shell of a cardiac structure based on a plurality of signals sensed by a mapping probe;
a user input device configured to receive input from a user; and
a processing device coupled to the display device and the user input device, wherein the processing device is configured to:
receive, from the user input device, a selection of a region of the surface of the anatomical shell;
generate a modified anatomical shell by removing a portion of the anatomical shell, the removed portion of the anatomical shell comprising the selected region of the surface and extending inward to an editing depth, the editing depth comprising at least one finite depth; and
output the modified anatomical shell to the display device.
10. The mapping system of claim 9, wherein the processing device is further configured to generate a new surface region on the modified anatomical shell, corresponding to the selected region, wherein the new surface region is disposed at the editing depth.
11. The mapping system of claim 9, wherein the processing device is further configured to:
receive, from the user input device, a command to undo the generation of the modified anatomical shell;
regenerate the anatomical shell; and
output the regenerated anatomical shell to the display device.
12. The mapping system of claim 9, wherein the processing device is further configured to receive, from the user input device, a user input specifying a target depth, wherein the editing depth is determined based on the target depth.
13. The mapping system of claim 12, wherein the target depth is at least 1 millimeter and at most 5 millimeters.
14. The mapping system of claim 9, wherein the processing device is configured to determine the editing depth based on the target depth and a contour of the selected region of the surface of the anatomical shell.
15. The mapping system of claim 14, wherein the processing device is further configured to:
receive, from the user input device, a selection modification, wherein the selection modification comprises a modified selected region, the modified selected region comprising a sub-region of the selected region or the selected region and an additional region of the surface of the anatomical shell, wherein the removed portion of the anatomical shell comprises the modified selected region.
16. The mapping system of claim 14, wherein the processing device is further configured to:
receive, from the user input device, a command to display a selection tool on the user interface; and
receive, from the user input device, a selection of a size of the selection tool.
17. One or more computer-readable media having computer-executable instructions embodied thereon that, when executed by a processor, cause the processor to:
output, to a display device, an anatomical shell of a cardiac structure, wherein the anatomical shell is based on a plurality of signals sensed by a mapping probe;
receive, from a user input device, a selection of a region of the surface of the anatomical shell;
receive, from the user input device, a user input specifying a target depth, wherein the editing depth is determined based on the target depth;
receive, from the user input device, a command to remove a portion of the anatomical shell;
generate a modified anatomical shell by removing the portion of the anatomical shell, the removed portion of the anatomical shell comprising the selected region of the surface and extending inward to an editing depth, the editing depth comprising at least one finite depth; and
output, to the display device, the modified anatomical shell.
18. The media of claim 17, wherein the instructions further cause the processor to:
receive, from the user input device, a command to undo the generation of the modified anatomical shell;
regenerate the first anatomical shell; and
output the regenerated anatomical shell to the display device.
19. The media of claim 17, wherein the instructions further cause the processor to:
receive, from the user input device, a selection modification, wherein the selection modification comprises a modified selected region, the modified selected region comprising a sub-region of the selected region or the selected region and an additional region of the surface of the anatomical shell, wherein the removed portion of the anatomical shell comprises the modified selected region.
20. The media of claim 17, wherein the instructions further cause the processor to:
receive, from the user input device, a command to display a selection tool on the user interface; and
receive, from the user input device, a selection of a size of the selection tool.

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摘要(译)

公开了用于可调深度解剖壳编辑的实施例。在一个实施例中，一种用于可调深度解剖外壳编辑的方法包括：向显示设备输出心脏结构的第一解剖外壳，其中第一解剖外壳基于由绘图探针感测的多个信号；从用户输入设备接收对第一解剖壳的一部分的选择；产生修改的解剖外壳，其具有从第一解剖外壳移除到大致深度的所选部分，其中近似深度是有限的；并且向显示设备输出修改的解剖壳。

