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(54) **METHOD, SYSTEM AND APPARATUS FOR SURFACE RENDERING USING MEDICAL IMAGING DATA**

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(52) **U.S. Cl.**

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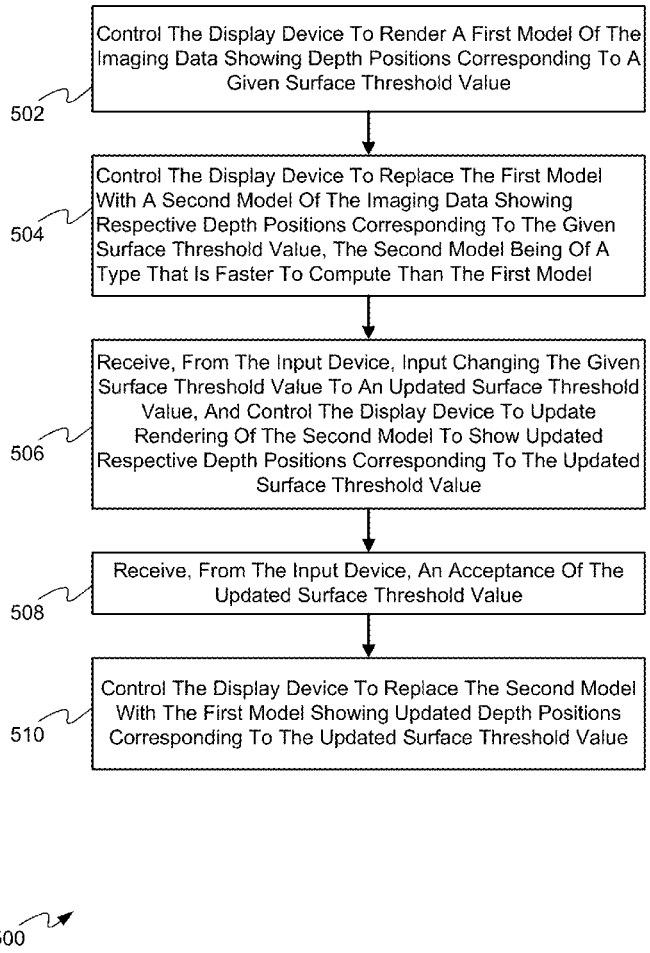
(57) **ABSTRACT**

A method, system and apparatus for surface rendering using medical imaging data is provided. A display device is controlled to render a first model of imaging data showing depth positions corresponding to a given surface threshold value, and further controlled to replace the first model with a second model of the imaging data showing respective depth positions corresponding to the given surface threshold value, the second model being faster to compute than the first model. The given surface threshold value is changed to an updated surface threshold value, for example using a slider input. The display device updates rendering of the second model to show updated respective depth positions corresponding to the updated surface threshold value. When an acceptance is received, the display device is controlled to replace the second model with the first model showing updated depth positions corresponding to the updated surface threshold value.



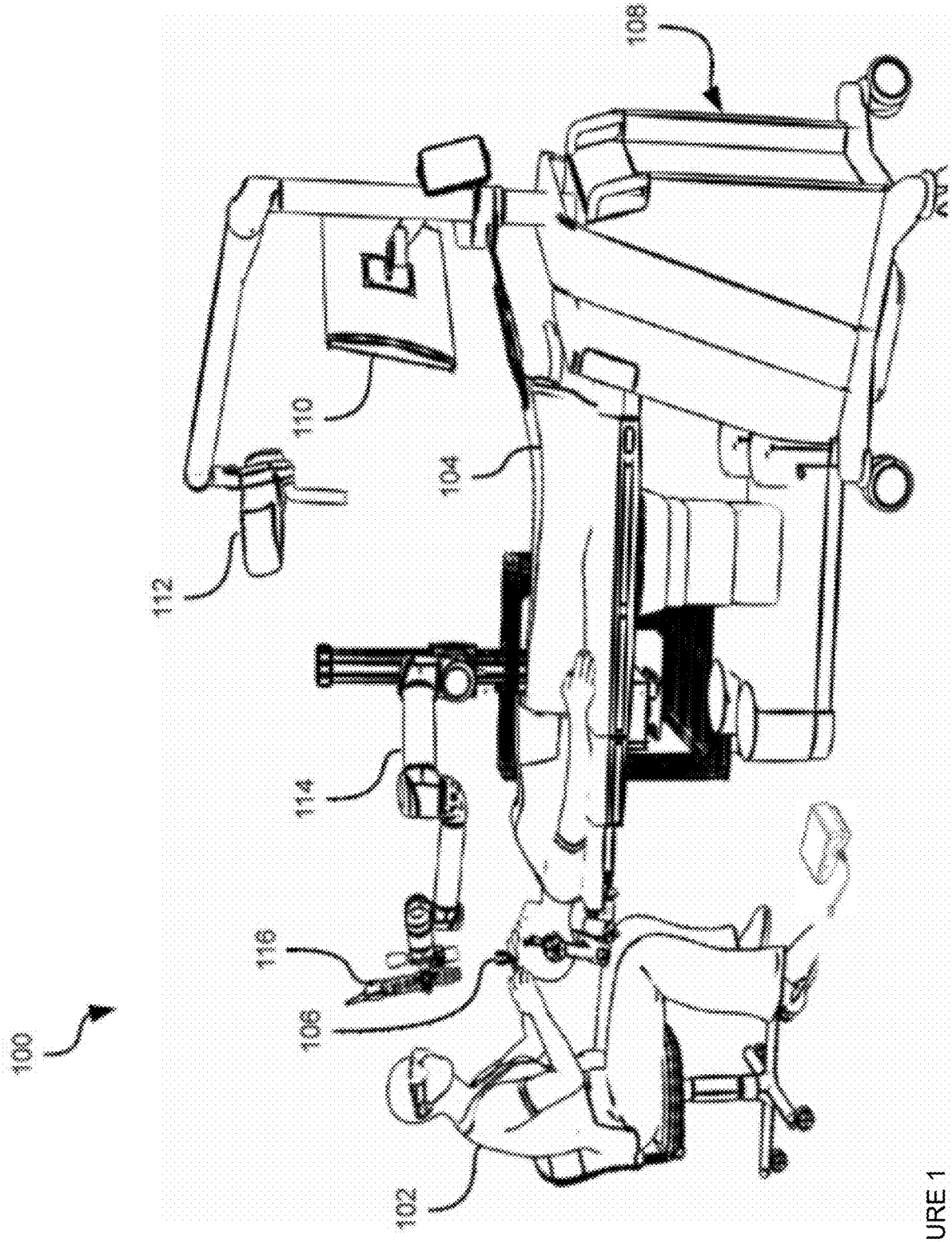


FIGURE 1

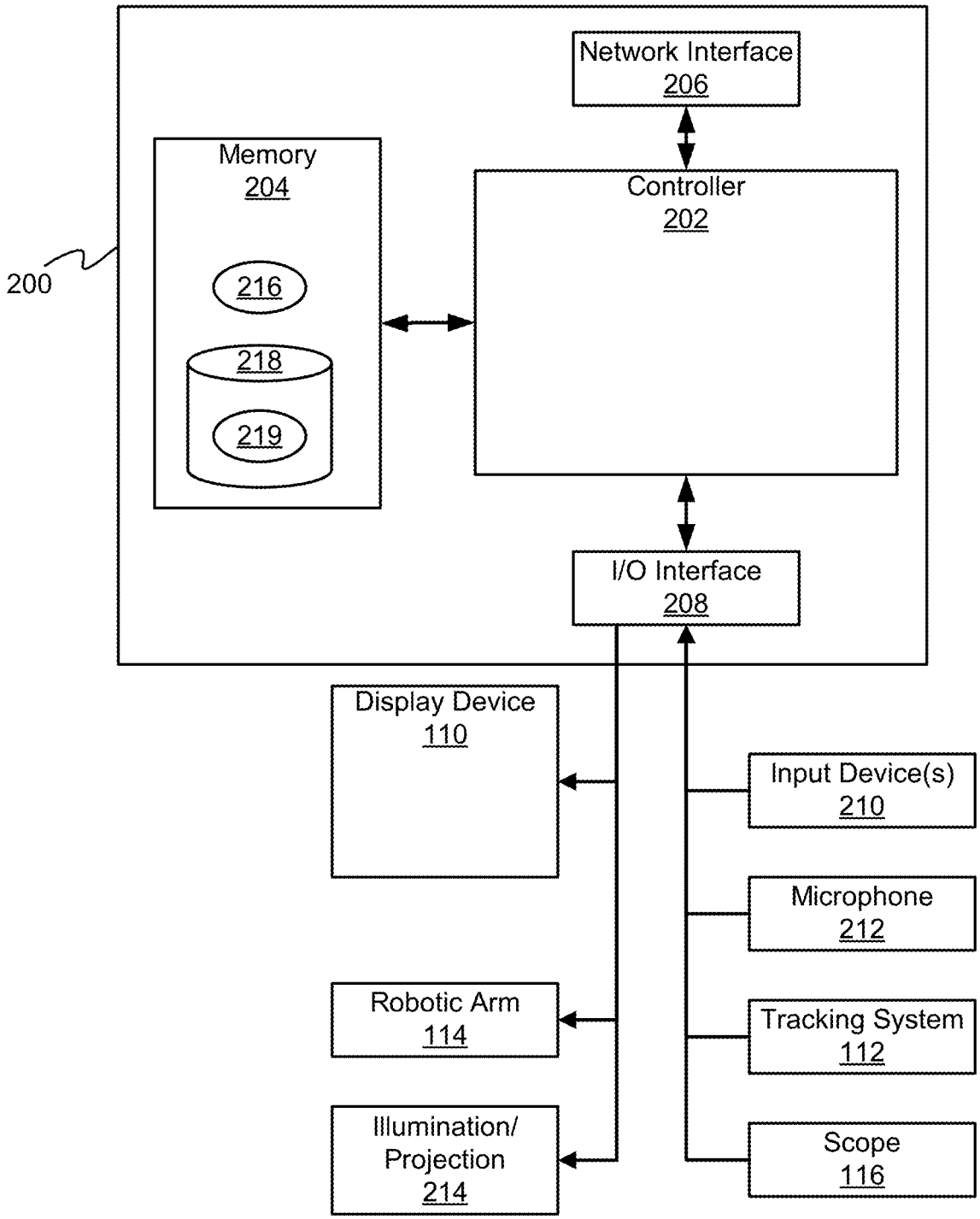

Network Interface
206
Memory
204
Controller
202
200
216
218
219
I/O Interface
208
Display Device
110
Input Device(s)
210
Microphone
212
Robotic Arm
114
Tracking System
112
Illumination/
Projection
214
Scope
116

FIGURE 2

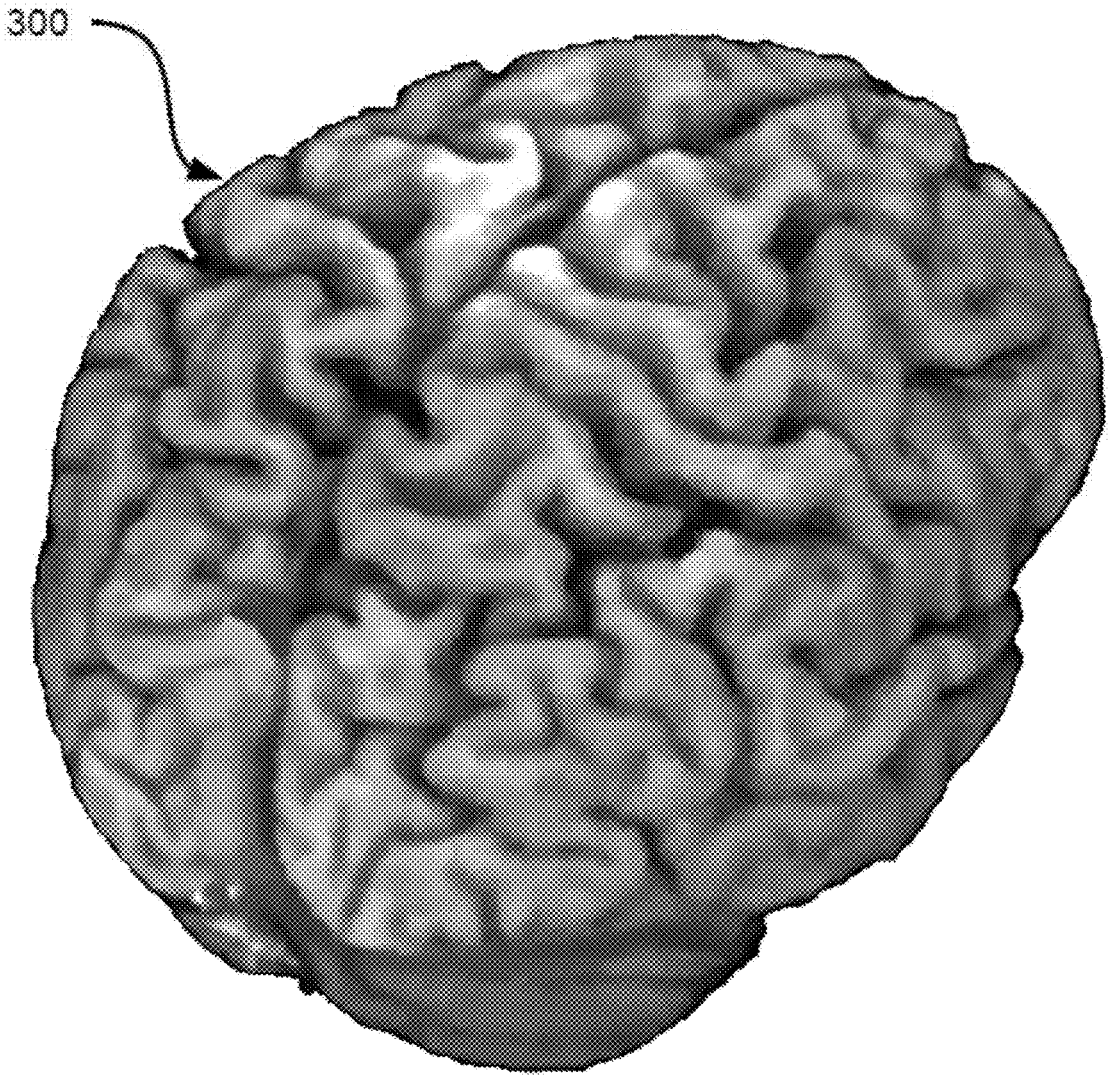


FIGURE 3

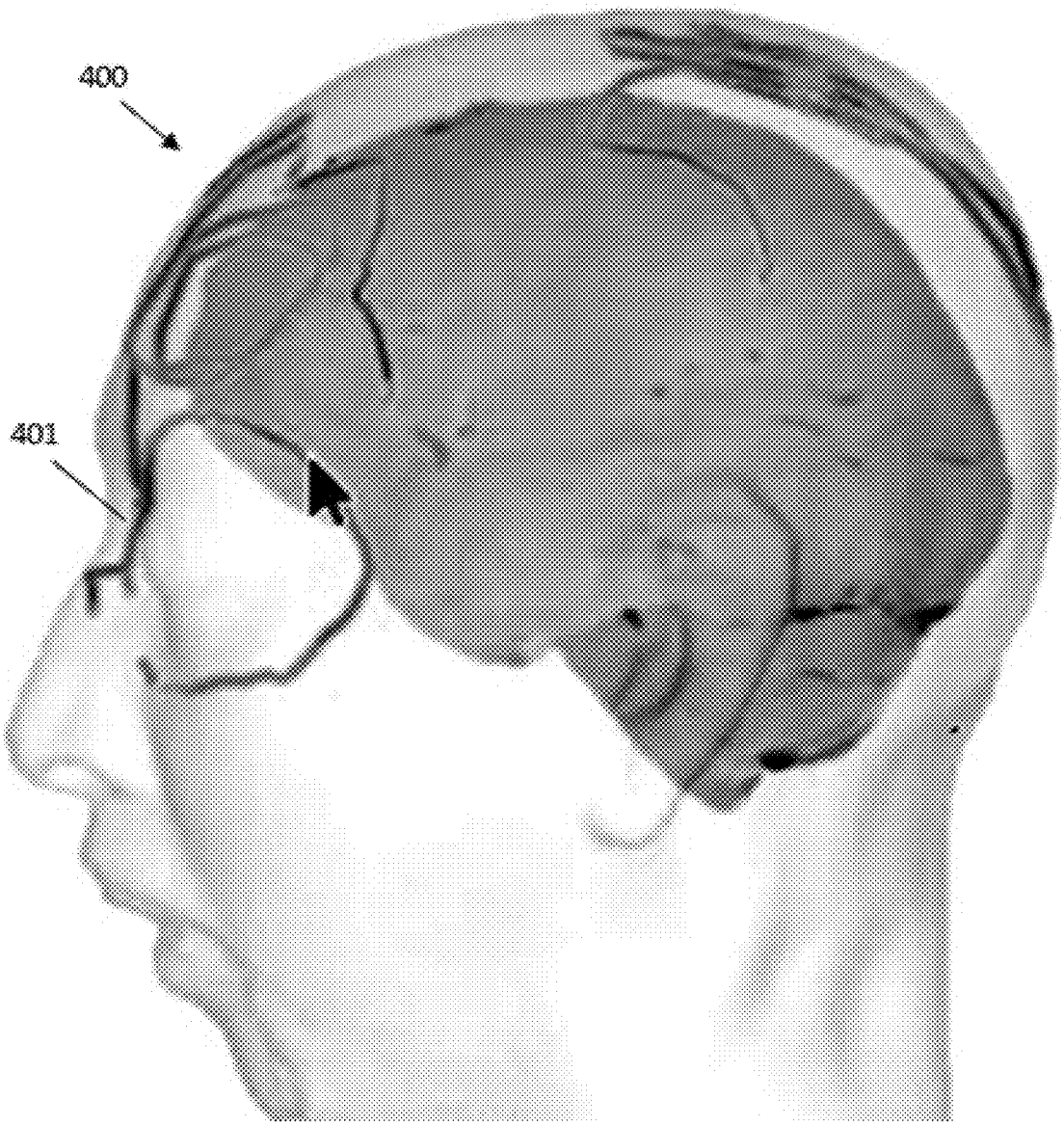


FIGURE 4

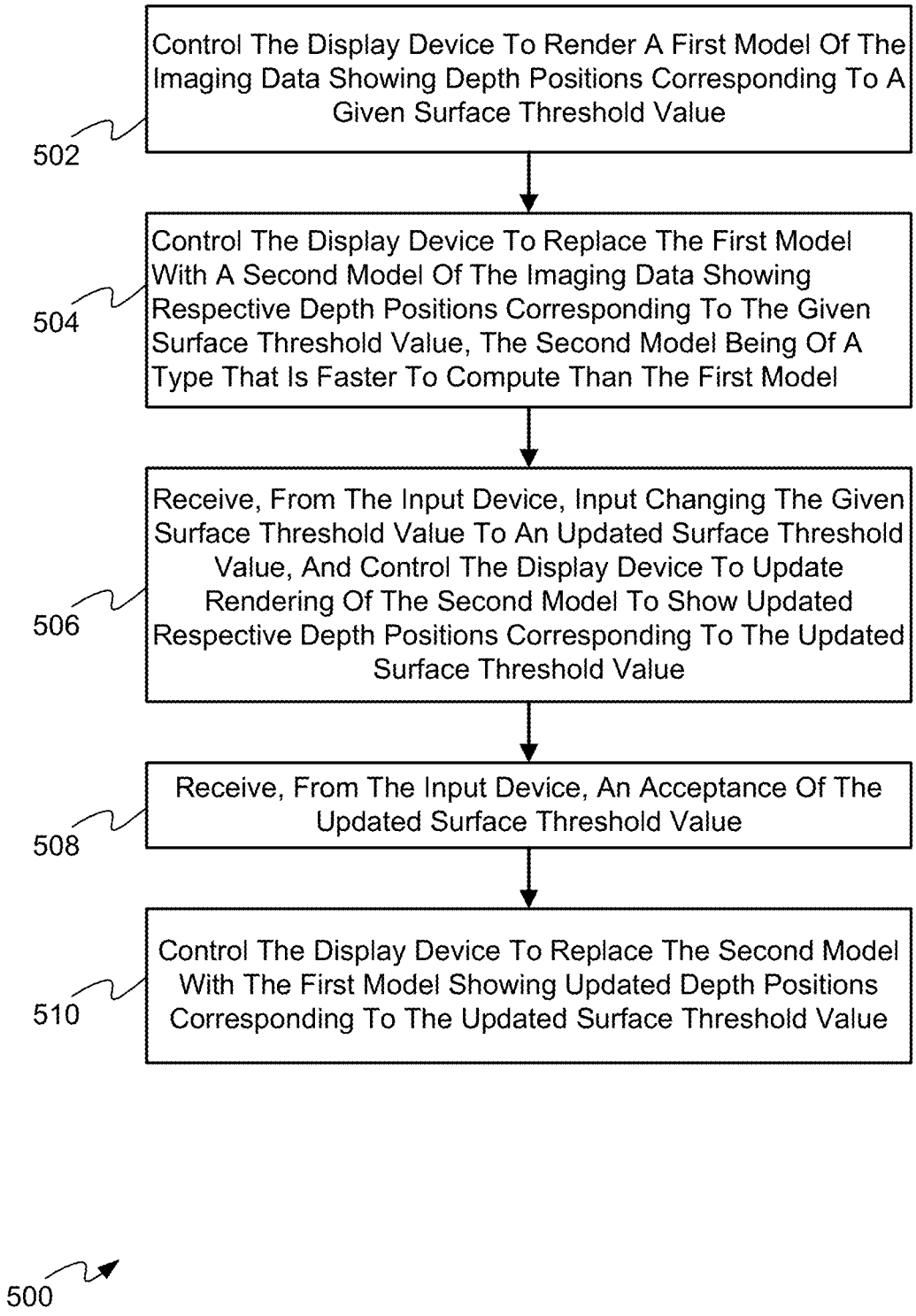
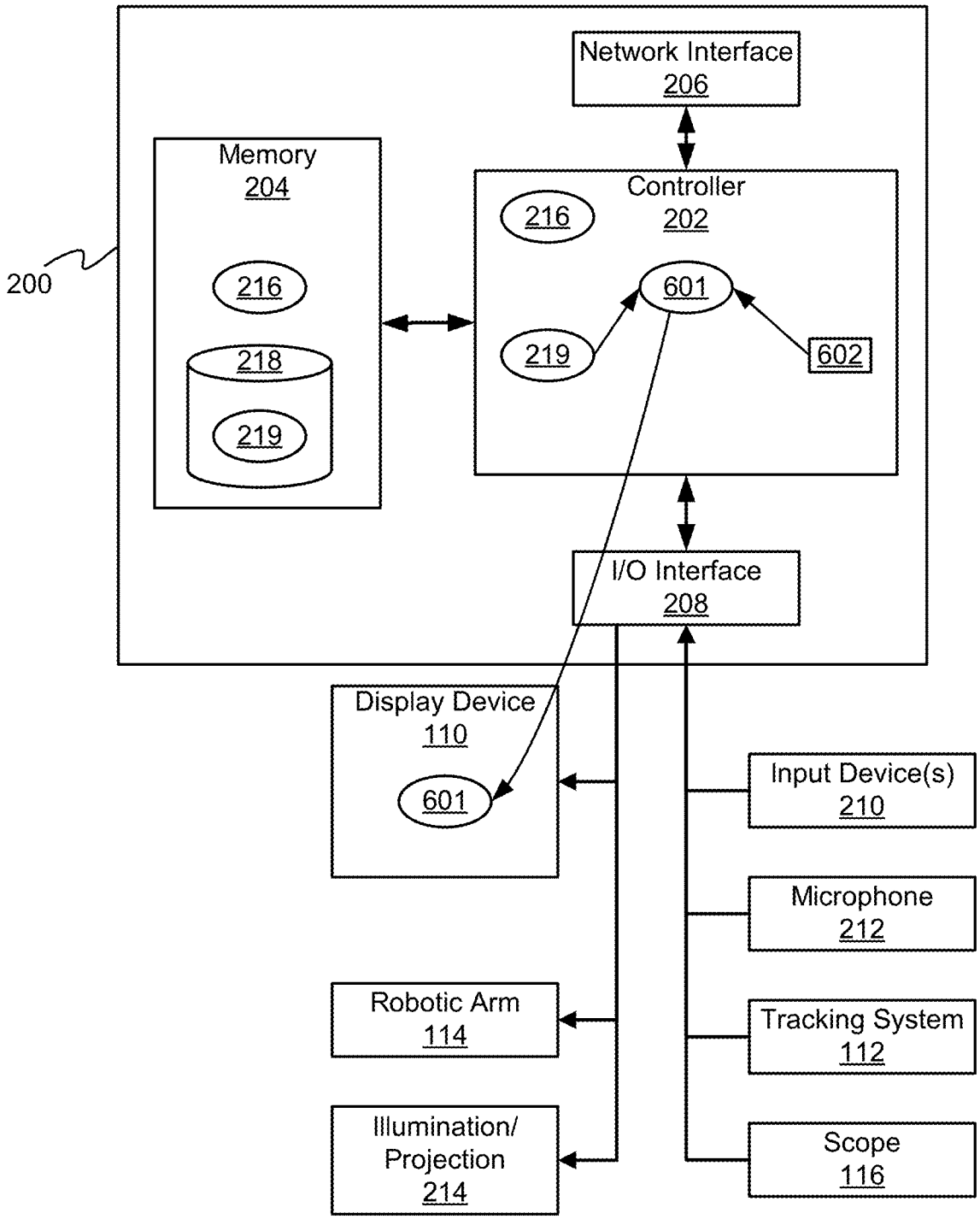

Control The Display Device To Render A First Model Of The Imaging Data Showing Depth Positions Corresponding To A Given Surface Threshold Value
502
Control The Display Device To Replace The First Model With A Second Model Of The Imaging Data Showing Respective Depth Positions Corresponding To The Given Surface Threshold Value, The Second Model Being Of A Type That Is Faster To Compute Than The First Model
504
Receive, From The Input Device, Input Changing The Given Surface Threshold Value To An Updated Surface Threshold Value, And Control The Display Device To Update Rendering Of The Second Model To Show Updated Respective Depth Positions Corresponding To The Updated Surface Threshold Value
506
Receive, From The Input Device, An Acceptance Of The Updated Surface Threshold Value
508
Control The Display Device To Replace The Second Model With The First Model Showing Updated Depth Positions Corresponding To The Updated Surface Threshold Value
510
500

FIGURE 5


Network Interface
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I/O Interface
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Display Device
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Input Device(s)
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Microphone
212
Robotic Arm
114
Tracking System
112
Illumination/
Projection
214
Scope
116

FIGURE 6

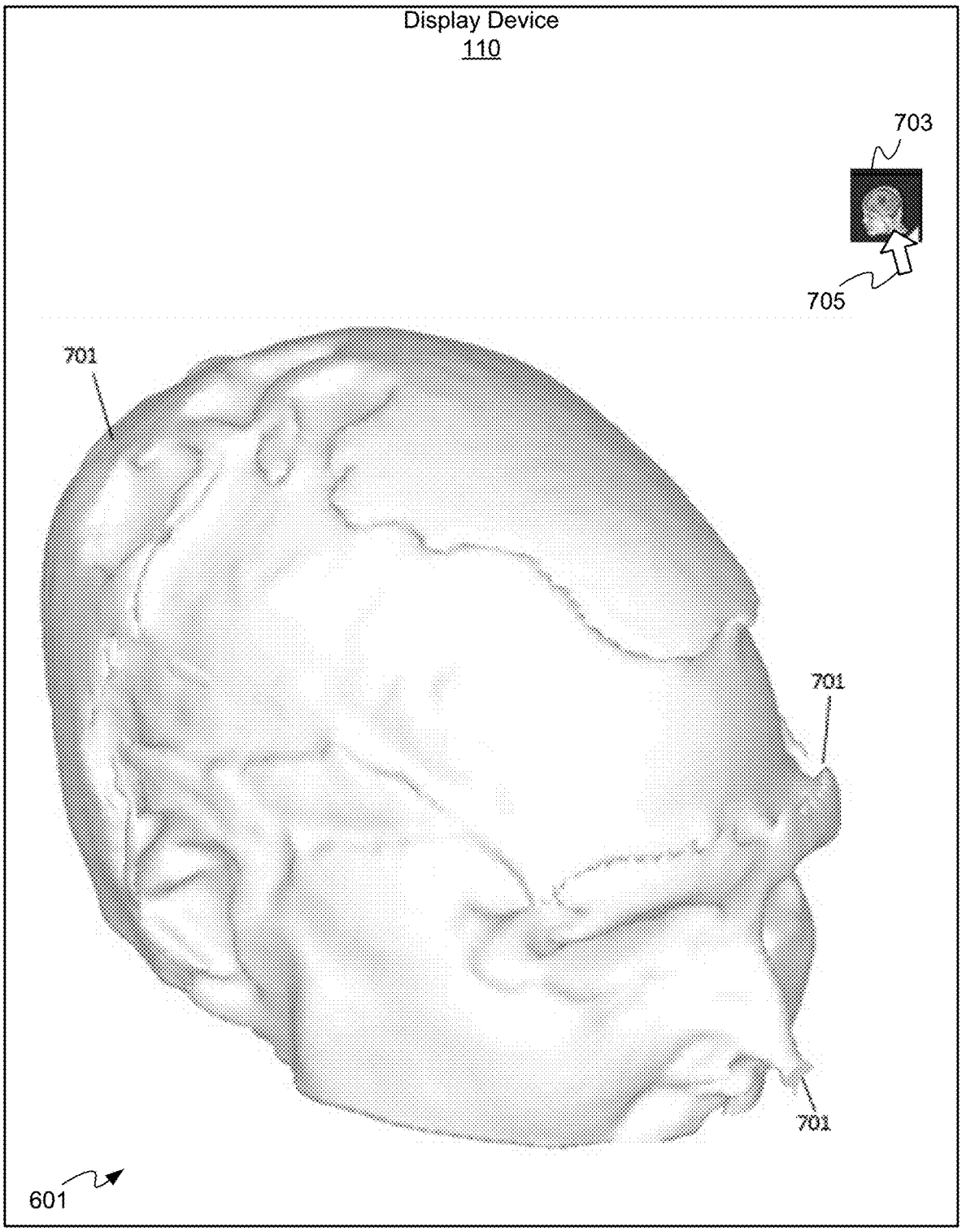


FIGURE 7

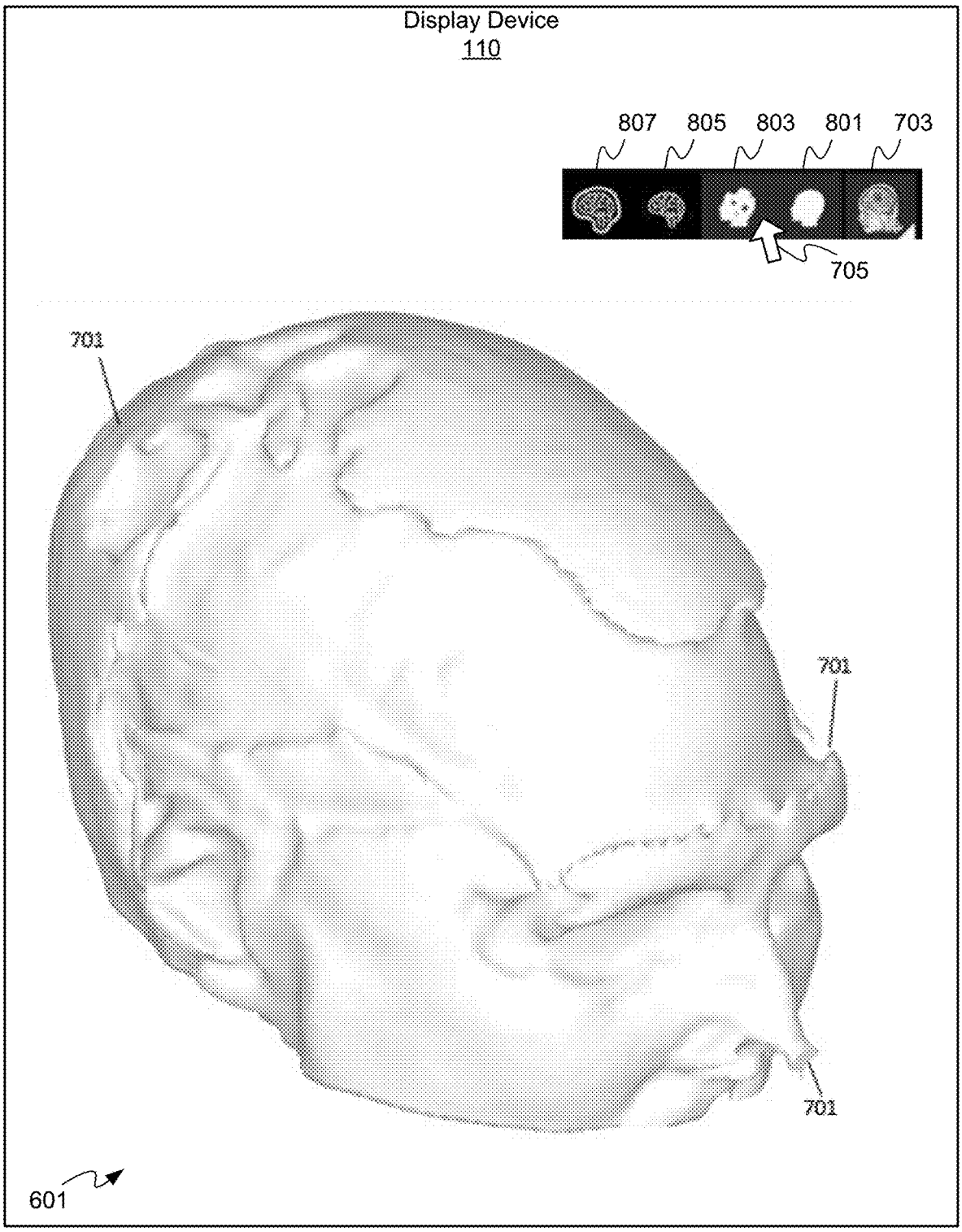
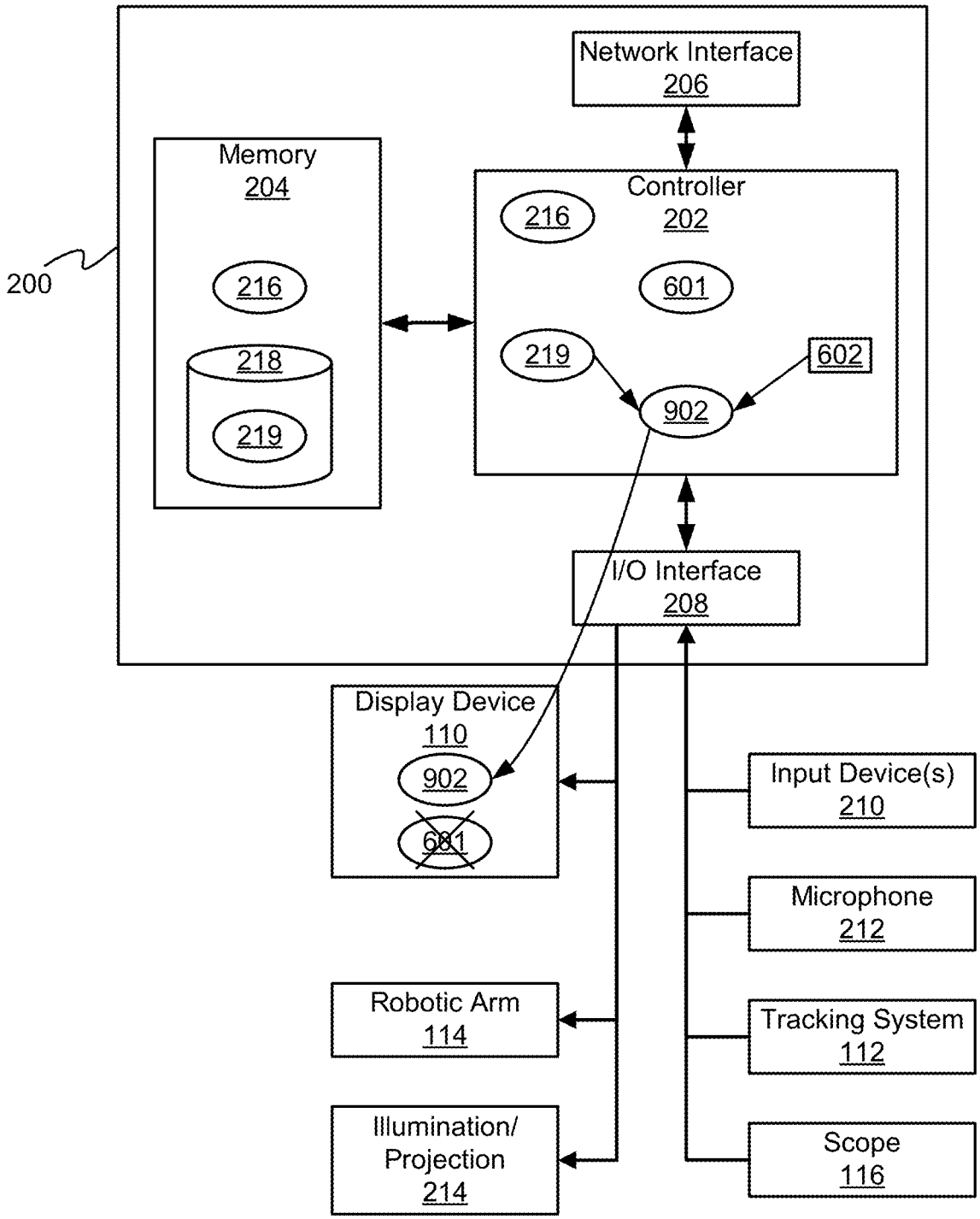


FIGURE 8


Network Interface
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I/O Interface
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Display Device
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Input Device(s)
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Microphone
212
Robotic Arm
114
Tracking System
112
Illumination/
Projection
214
Scope
116

FIGURE 9

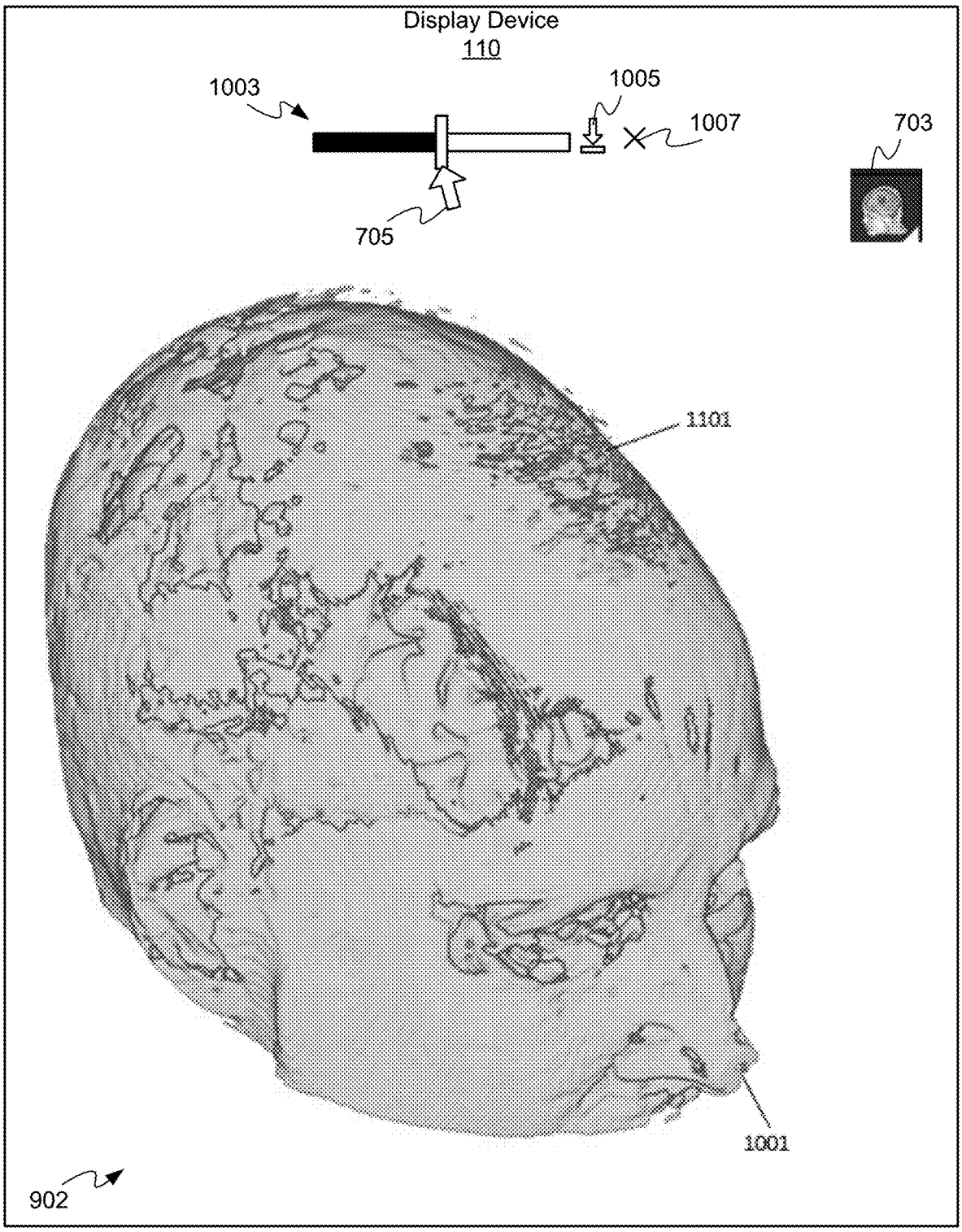


FIGURE 10

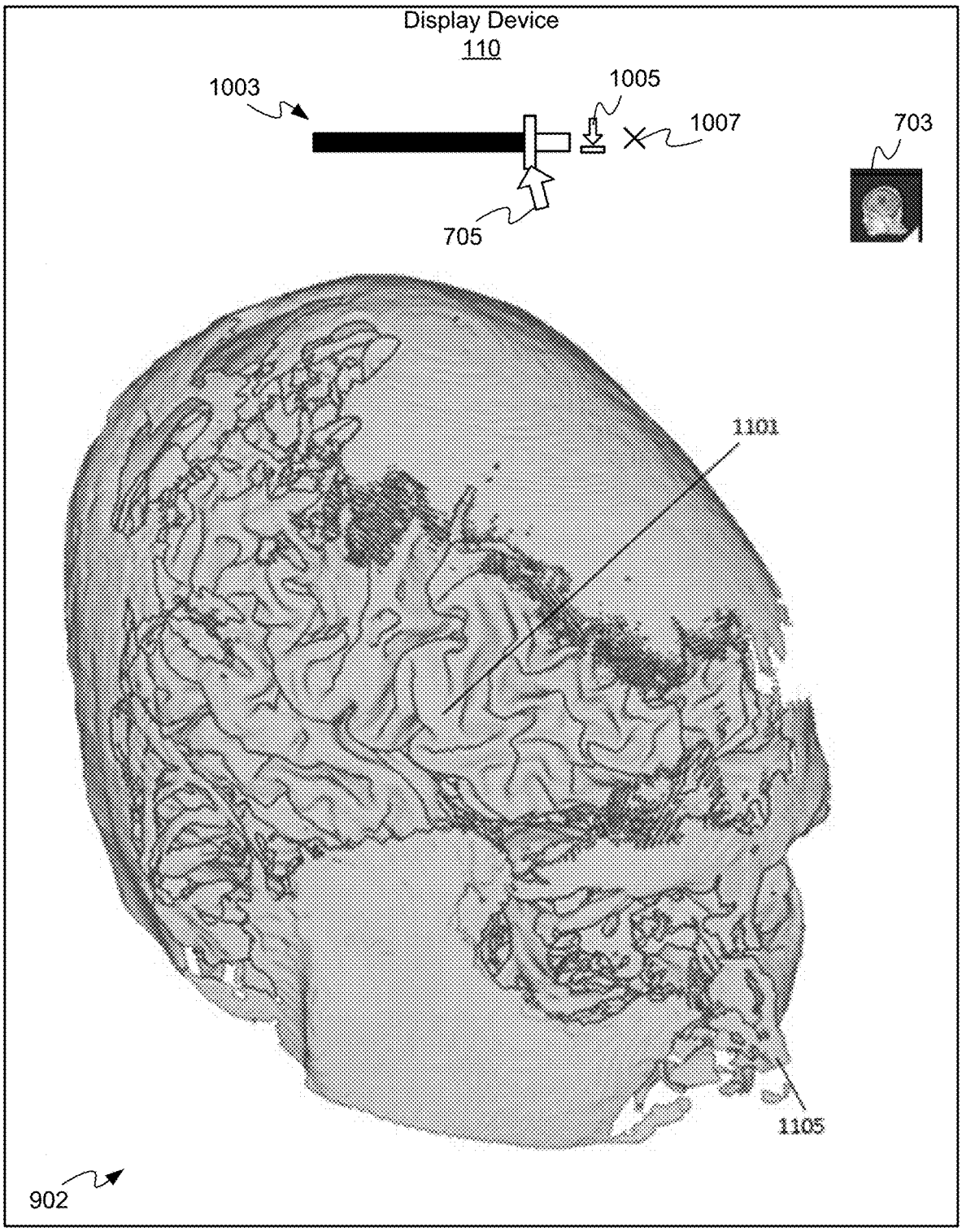


FIGURE 11

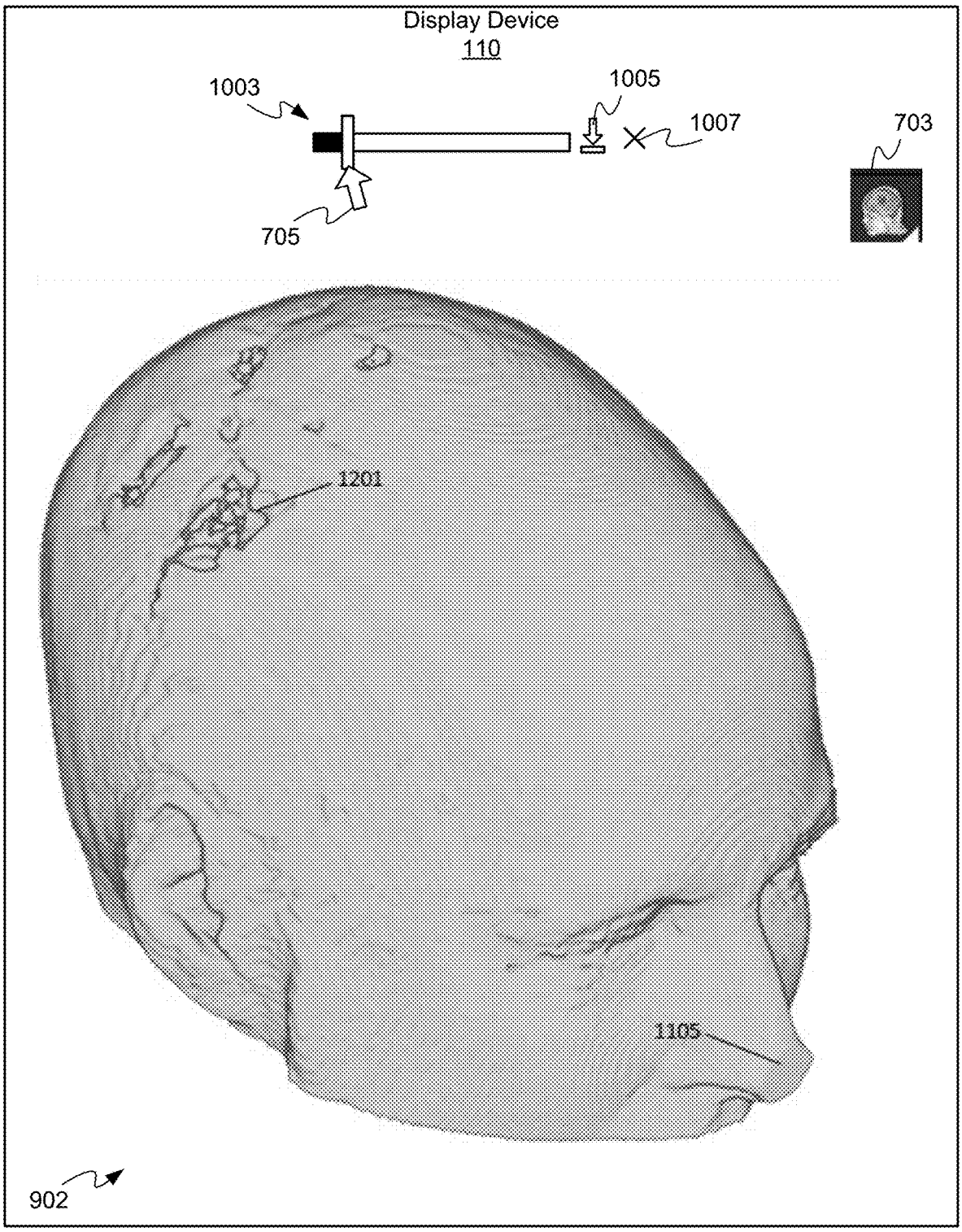
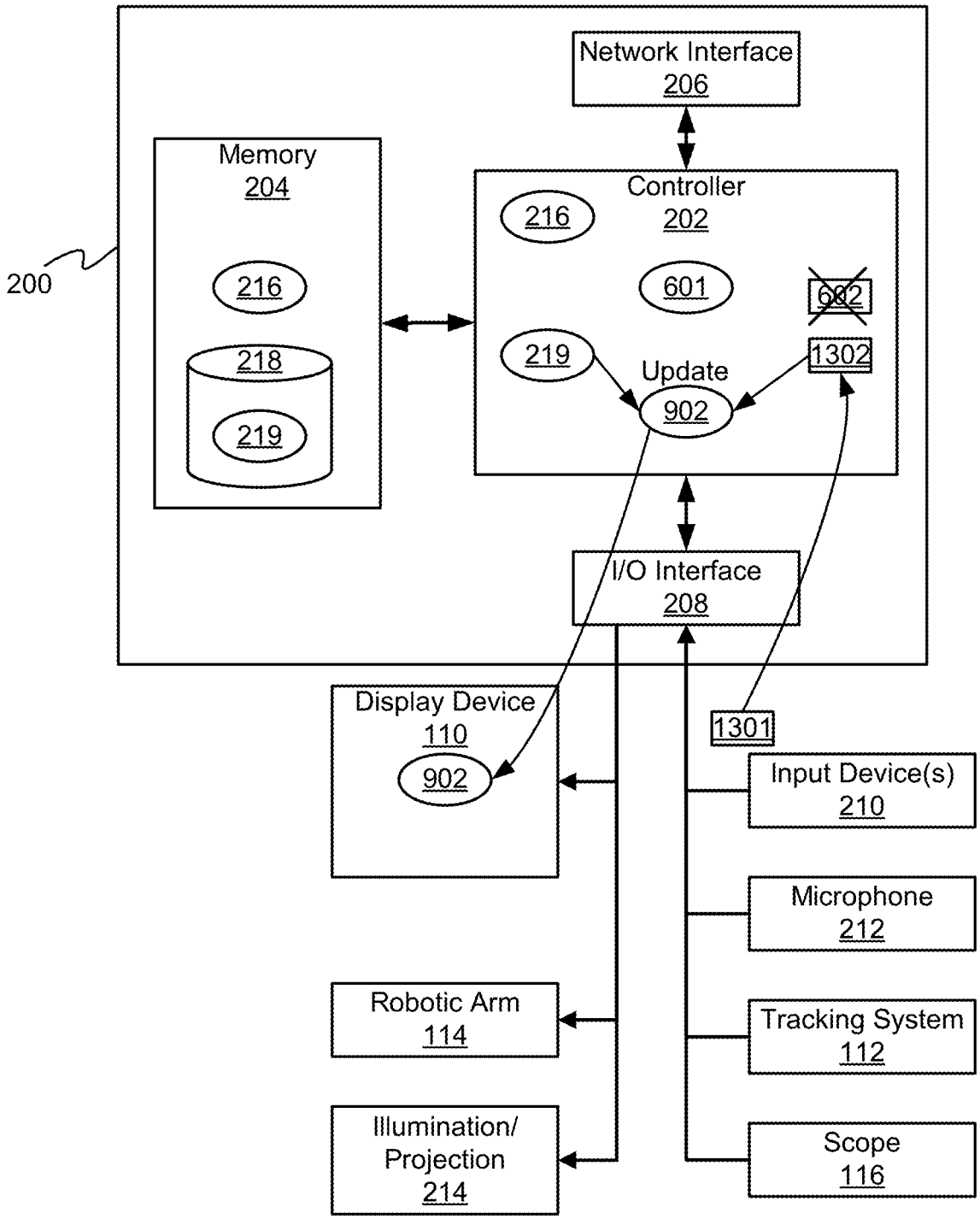


FIGURE 12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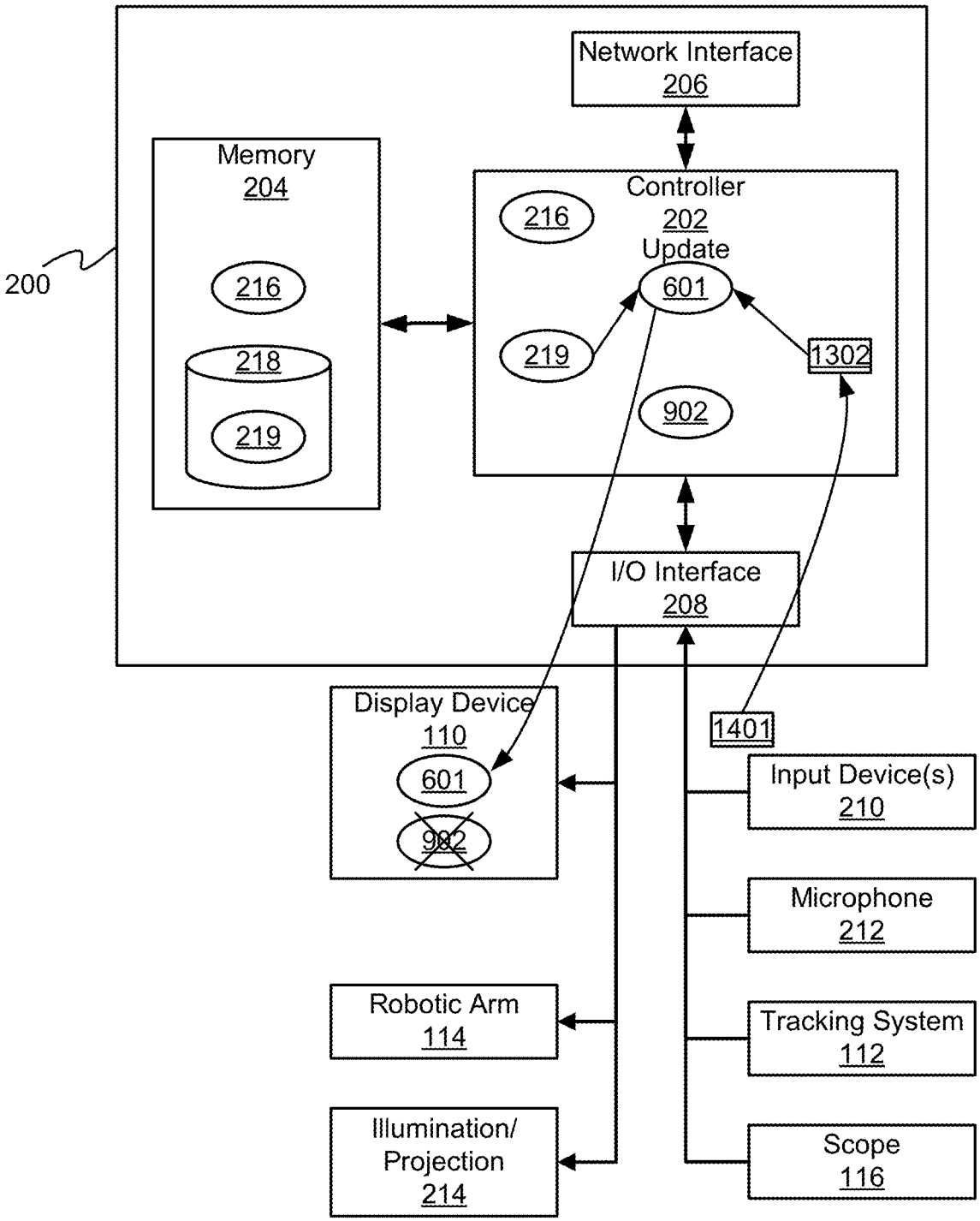
Memory
204
216
218
219
200
Controller
202
216
601
602
219
Update
1302
902
I/O Interface
208
Display Device
110
902
1301
Input Device(s)
210
Microphone
212
Robotic Arm
114
Tracking System
112
Illumination/
Projection
214
Scope
116

FIGURE 13


Network Interface
206
Memory
204
216
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200
Controller
202
216
Update
601
219
1302
902
I/O Interface
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Display Device
110
601
902
1401
Input Device(s)
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Microphone
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Robotic Arm
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Tracking System
112
Illumination/
Projection
214
Scope
116

FIGURE 14

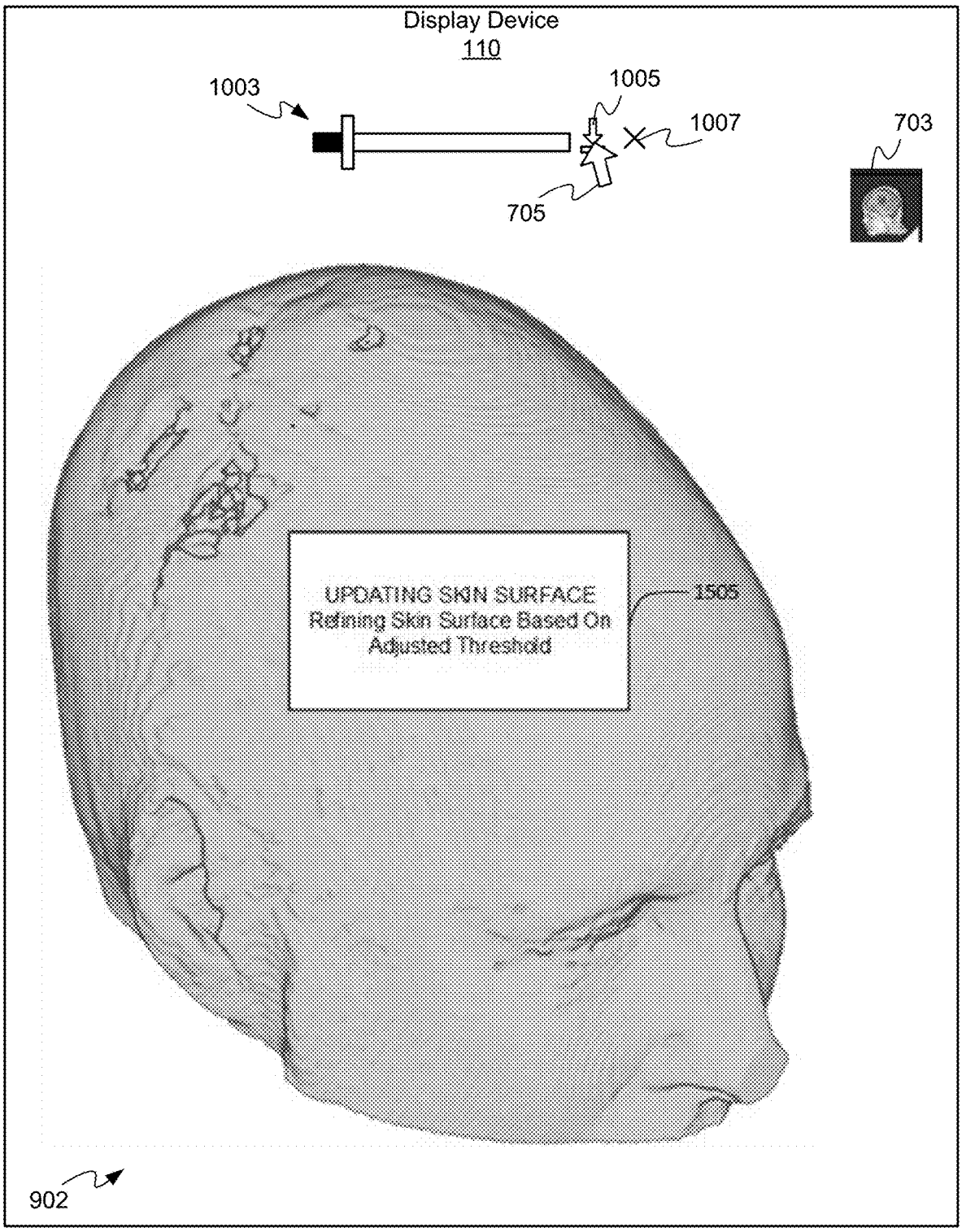
Display Device
110
1003
1005
1007
703
705
UPDATING SKIN SURFACE
Refining Skin Surface Based On
Adjusted Threshold
1505
902

FIGURE 15

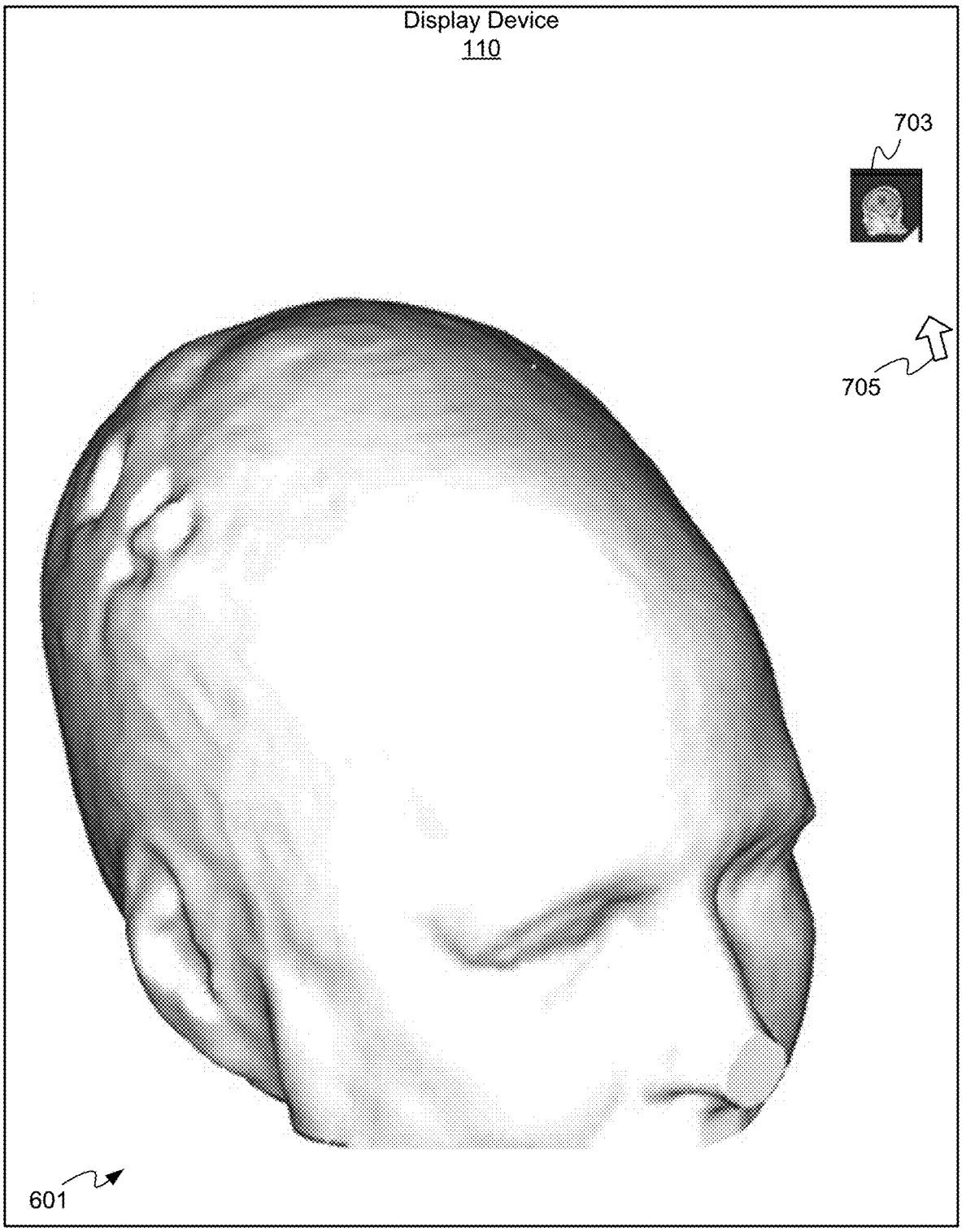

FIGURE 16

METHOD, SYSTEM AND APPARATUS FOR SURFACE RENDERING USING MEDICAL IMAGING DATA

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present specification claims priority from U.S. patent application Ser. No. 16/597,704 filed Oct. 9, 2019, which in turn claims priority from U.S. Pat. No. 10,470,825, filed Aug. 16, 2017, the contents of each of which are incorporated herein by reference.

FIELD

[0002] The specification relates generally to medical imaging, and specifically to a method, system and apparatus for surface rendering using medical imaging data.

BACKGROUND

[0003] Minimally invasive surgical techniques can reduce the risk of injury to patients, in comparison with traditional surgical techniques. However, accurate surface rendering (e.g. skin, cortical surfaces and the like) at an image rendering device can be critical when planning a surgery and/or performing a skin or brain surface based registration during a navigated procedure. Such surfaces may be determined based on the contents of a volumetric magnetic resonance (MR) imaging scan or computerized tomography scan using an algorithm that determines portions of imaging data that represent patient tissue and portions that represent regions adjacent patient tissue (e.g. air/hair/padding etc.). While such algorithms may do a reasonable job of extracting a surface, errors in the imaging data may cause the algorithms to inaccurately extract a surface. For example, in MR imaging, signal inhomogeneity may lead to a "cratered" skin surface appearance in the rendering of the imaging data. While this can be addressed by forcing the extraction algorithm to use a lower threshold value to extract a surface, the imaging datasets are generally very large and models used to extract surfaces must be carefully refined surgical purposes, causing the image rendering device to operate inefficiently when the extraction is performed repeatedly. For example, even a single adjustment to a threshold value may require the imaging device to use tens of seconds to re-determine a surface, and the imaging device will not be able to provide any indication of whether the adjustment was successful until the algorithm has completed. This causes the image rendering device to operate inefficiently, especially when several adjustments to the threshold value are made to achieve an acceptable result.

SUMMARY

[0004] An aspect of the specification provides a device comprising: a memory storing imaging data, the imaging data comprising three-dimensional imaging data of an object; a display device; an input device; and a controller configured to: control the display device to render a first model of the imaging data showing depth positions corresponding to a given surface threshold value; control the display device to replace the first model with a second model of the imaging data showing respective depth positions corresponding to the given surface threshold value, the second model being faster to compute than the first model; receive, from the input device, input changing the given surface threshold value e to an updated surface threshold value, and control the display device to update rendering of the second model to show updated respective depth positions corresponding to the updated surface threshold value; receive, from the input device, an acceptance of the updated surface threshold value; and control the display device to replace the second model with the first model showing updated depth positions corresponding to the updated surface threshold value.

[0005] Another aspect of the specification provides a method comprising: controlling, using a controller, a display device to render a first model of imaging data showing depth positions corresponding to a given surface threshold value, the imaging data comprising three-dimensional imaging data of an object; controlling, using a controller, the display device to replace the first model with a second model of the imaging data showing respective depth positions corresponding to the given surface threshold value, the second model being faster to compute than the first model; receiving, at the controller, from an input device, input changing the given surface threshold value to an updated surface threshold value, and controlling, using the controller, the display device to update rendering of the second model to show updated respective depth positions corresponding to the updated surface threshold value; receiving, at the controller, from the input device, an acceptance of the updated surface threshold value; and controlling, using the controller, the display device to replace the second model with the first model showing updated depth positions corresponding to the updated surface threshold value.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[0006] Embodiments are described with reference to the following figures, in which:

[0007] FIG. **1** depicts an operating theatre, according to a non-limiting embodiment.

[0008] FIG. **2** depicts a computing device of the operating theatre of FIG. **1**, according to a non-limiting embodiment.

[0009] FIG. **3** depicts an image of a volume of tissue maintained by the computing device of FIG. **2**, according to a non-limiting embodiment.

[0010] FIG. **4** depicts another image of a volume of tissue maintained by the computing device of FIG. **2**, according to a non-limiting embodiment.

[0011] FIG. **5** depicts a method of surface rendering using medical imaging data, according to a non-limiting embodiment.

[0012] FIG. **6** depicts the device of FIG. **2** generating a first model of a surface using a given surface threshold value, according to a non-limiting embodiment.

[0013] FIG. **7** depicts a display device controlled to render the first model of a surface, according to a non-limiting embodiment.

[0014] FIG. **8** depicts input being received to initiate rendering of a second model of the surface, the second model being of a type that is faster to compute than the first model, according to a non-limiting embodiment.

[0015] FIG. **9** depicts the device of FIG. **2** generating the second model of the surface using the given surface threshold value, according to a non-limiting embodiment.

[0016] FIG. **10** depicts the display device controlled to render the second model of the surface using the given surface threshold value, according to a non-limiting embodiment.

[0017] FIG. **11** depicts the surface threshold value being adjusted at the display device using the second model of the surface, according to a non-limiting embodiment.

[0018] FIG. **12** depicts the surface threshold value being further adjusted at the display device using the second model of the surface, according to a non-limiting embodiment.

[0019] FIG. **13** depicts the device of FIG. **2** updating the surface threshold value, according to a non-limiting embodiment.

[0020] FIG. **14** depicts the device of FIG. **2** updating the first model using an updated surface threshold value, according to a non-limiting embodiment.

[0021] FIG. **15** depicts the display device during updating of the first model using an updated surface threshold value, according to a non-limiting embodiment.

[0022] FIG. **16** depicts the display device controlled to render the first model of a surface as updated using the updated surface threshold value, according to a non-limiting embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0023] Various embodiments and aspects of the disclosure will be described with reference to details discussed below. The following description and drawings are illustrative of the disclosure and are not to be construed as limiting the disclosure. Numerous specific details are described to provide a thorough understanding of various embodiments of the present disclosure. However, in certain instances, well-known or conventional details are not described in order to provide a concise discussion of embodiments of the present disclosure.

[0024] As used herein, the terms, "comprises" and "comprising" are to be construed as being inclusive and open ended, and not exclusive. Specifically, when used in the specification and claims, the terms, "comprises" and "comprising" and variations thereof mean the specified features, steps or components are included. These terms are not to be interpreted to exclude the presence of other features, steps or components.

[0025] Unless defined otherwise, all technical and scientific terms used herein are intended to have the same meaning as commonly understood to one of ordinary skill in the art. Unless otherwise indicated, such as through context, as used herein, the following terms are intended to have the following meanings:

[0026] As used herein the term "intraoperative" refers to an action, process, method, event or step that occurs or is carried out during at least a portion of a medical procedure. The term "preoperative" as used herein refers to an action, process, method, event or step that occurs or is carried out before the medical procedure begins. The terms intraoperative and preoperative, as defined herein, are not limited to surgical procedures, and may refer to other types of medical procedures, such as diagnostic and therapeutic procedures.

[0027] FIG. **1** depicts a system **100** that includes a surgical operating theatre in which a healthcare worker, for example a surgeon **102** operates on a patient **104**. Specifically, surgeon **102** is shown conducting a minimally invasive surgical procedure on the brain of patient **104**. Minimally invasive brain surgery involves the insertion and manipulation of instruments into the brain through an opening that is significantly smaller than the portions of skull removed to expose the brain in traditional brain surgery techniques. The description below makes reference to the brain of patient **104** as an example of tissue to which the techniques herein may be applied. It will be understood, however, that those techniques may also be applied to a wide variety of other tissues. Thus, when the brain of patient **104** is mentioned below, it is simply an example of the various tissues in connection with which the systems and methods herein may be implemented.

[0028] The opening through which surgeon **102** inserts and manipulates instruments is provided by an access port **106**. Access port **106** typically includes a hollow cylindrical device with open ends. During insertion of access port **106** into the brain (after a suitable opening has been drilled in the skull), an introducer (not shown) is generally inserted into access port **106**. The introducer is typically a cylindrical device that slidably engages the internal surface of access port **106** and bears a conical atraumatic tip to allow for insertion of access port **106** into the sulcal folds of the brain. Following insertion of access port **106**, the introducer may be removed, and access port **106** may then enable insertion and bimanual manipulation of surgical tools into the brain. Examples of such tools include suctioning devices, scissors, scalpels, cutting devices, imaging devices (e.g. ultrasound sensors) and the like.

[0029] Also shown in FIG. **1** is an equipment tower **108** supporting a computing device (not shown) such as a desktop computer, as well as at least one display device **110** connected to the computing device for displaying images provided by the computing device.

[0030] Equipment tower **108** also supports a tracking system **112**. Tracking system **112** is generally configured to track the positions of one or more reflective markers (not shown) mounted on access port **106**, any of the above-mentioned surgical tools, or any combination thereof. Such markers, also referred to as fiducial markers, may also be mounted on patient **104**, for example at various points on the head of patient **104**. Tracking system **112** may therefore include a camera (e.g. a stereo camera) and a computing device (either the same device as mentioned above or a separate device) configured to locate the fiducial markers in the images captured by the camera, and determine the spatial positions of those markers within the operating theatre. The spatial positions may be provided by tracking system **112** to the computing device in equipment tower **108** for subsequent use.

[0031] The nature of the markers and the camera are not particularly limited. For example, the camera may be sensitive to infrared (IR) light, and tracking system **112** may include one or more IR emitters (e.g. IR light emitting diodes (LEDs)) to shine IR light on the markers. In other examples, marker recognition in tracking system **112** may be based on radio frequency (RF) radiation, visible light emitted from devices such as pulsed or un-pulsed LEDs, electromagnetic radiation other than IR or visible light, and the like. For RF and EM-based tracking, each object can be fitted with markers having signatures unique to that object, and tracking system **112** can include antennae rather than the above-mentioned camera. Combinations of the above may also be employed.

[0032] Each tracked object generally includes three or more markers fixed at predefined locations on the object. The predefined locations, as well as the geometry of each tracked object, are configured within tracking system **112**, and thus tracking system **112** is configured to image the

operating theatre, compare the positions of any visible markers to the pre-configured geometry and marker locations, and based on the comparison, determine which tracked objects are present in the field of view of the camera, as well as what positions those objects are currently in. An example of tracking system **112** is the "Polaris" system available from Northern Digital Inc.

[0033] Also shown in FIG. **1** is an automated articulated arm **114**, also referred to as a robotic arm, carrying an external scope **116** (i.e. external to patient **104**). External scope **116** may be positioned over access port **106** by robotic arm **114**, and may capture images of the brain of patient **104** for presentation on display device **110**. The movement of robotic arm **114** to place external scope **116** correctly over access port **106** may be guided by tracking system **112** and the computing device in equipment tower **108**. The images from external scope **116** presented on display device **110** may be overlaid with other images, including images obtained prior to the surgical procedure. The images presented on display device **110** may also display virtual models of surgical instruments present in the field of view of tracking system **112** (the positions and orientations of the models having been determined by tracking system **112** from the positions of the markers mentioned above).

[0034] Before a procedure such as that shown in FIG. **1** (which may be, for example, a tumor resection), preoperative images may be collected of patient **104**, or at least of patient **104**'s brain or portions thereof. Such preoperative images may be collected using any of a variety of imaging modalities, such as Magnetic Resonance Imaging (MRI), Optical Coherence Tomography (OCT), ultrasound, Computed Tomography (CT), optical spectroscopy and the like. For each of the above-mentioned imaging modalities, various imaging techniques may be used. Polarization Sensitive OCT and OCT elastography are exemplary uses of the OCT modality. Diffusion MRI (also referred to as diffusion tensor imaging, DTI) is an example use of the MRI modality. Raman spectroscopy is an example use of optical spectroscopy. A variety of other examples of the above modalities will also occur to those skilled in the art.

[0035] Preoperative images may be used for planning purposes. During the procedure, additional images (referred to as intraoperative images) may be collected of the brain of patient **104**, using any suitable ones of the above-mentioned modalities (it will be apparent to those skilled in the art that some imaging modalities are less suitable or unsuitable for preoperative use, while other imaging modalities are less suitable or unsuitable for intraoperative use).

[0036] An example of a planning activity that may be performed using preoperative images is the selection of entry locations and trajectories for surgical tools through the patient tissue (e.g., the brain of patient **104**) to a target, such as a tumour to be resected. As will be apparent to those skilled in the art, surgical tools such as access port **106** may reach targeted areas via a wide variety of trajectories from the outer surface of the brain or other tissue. Some of those trajectories may be more suitable than others, for example due to reduced interference with cortical tissue, vascular tissue, or the like. As will be described in further detail below, the computing device housed in equipment tower **108** can perform various actions to process and render medical imaging data such as the above-mentioned preoperative images, selecting and implementing visual filters to distinguish between tissue types in the images.

[0037] Before a discussion of the functionality of the computing device, a brief description of the components of the computing device will be provided. Referring to FIG. **2**, a computing device **200** is depicted, including controller **202** interconnected with a non-transitory computer readable storage medium such as a memory **204**.

[0038] Controller **202** can comprise a processor and/or a plurality of processors, including but not limited to one or more central processors (CPUs) and/or one or more processing units; either way, controller **202** comprises a hardware element and/or a hardware processor. Indeed, in some embodiments, controller **202** can comprise an ASIC (application-specific integrated circuit) and/or an FPGA (field-programmable gate array) specifically configured to implement specific projection mapping previsualization functionality. Hence, device **200** is preferably not a generic computing device, but a device specifically configured to implement specific surface rendering functionality and/or image rendering functionality and/or medical imaging functionality. For example, device **200** and/or controller **202** can comprise a computer executable engine configured to implement specific surface rendering functionality and/or medical imaging functionality.

[0039] Hence, controller **202** and memory **204** are generally comprised of one or more integrated circuits (ICs), and can have a variety of structures, as will now occur to those skilled in the art (for example, more than one CPU can be provided). Memory **204** can be any suitable combination of volatile (e.g. Random Access Memory ("RAM")) and non-volatile (e.g. read only memory ("ROM"), Electrically Erasable Programmable Read Only Memory ("EEPROM"), flash memory, magnetic computer storage device, or optical disc) memory. In the present example, memory **204** includes both a volatile memory and a non-volatile memory. Other types of non-transitory computer readable storage medium are also contemplated, such as compact discs (CD-ROM, CD-RW) and digital video discs (DVD).

[0040] Computing device **200** also includes a network interface **206** interconnected with controller **202**. Network interface **206** allows computing device **200** to communicate with other computing devices via a network (e.g. a local area network (LAN), a wide area network (WAN) or any suitable combination thereof). Network interface **206** thus includes any necessary hardware for communicating over such networks, such as radios, network interface controllers (NICs) and the like.

[0041] Computing device **200** also includes an input/output interface **208**, including the necessary hardware for interconnecting controller **202** with various input and output devices. Interface **208** can include, among other components, a Universal Serial Bus (USB) port, an audio port for sending and receiving audio data, a Video Graphics Array (VGA), Digital Visual Interface (DVI) or other port for sending and receiving display data, and any other suitable components.

[0042] Via interface **208**, computing device **200** is connected to one or more input devices **210** such as a keyboard and mouse, a microphone **212**, as well as scope **116** and tracking system **112**, mentioned above. Also via interface **208**, computing device **200** is connected to output devices including illumination or projection components **214** (e.g. lights, projectors and the like), as well as display device **110** and robotic arm **114** mentioned above. Other input (e.g.

touch screens) and output devices (e.g. speakers) will also occur to those skilled in the art.

[0043] It is contemplated that I/O interface **208** may be omitted entirely in some embodiments, or may be used to connect to only a subset of the devices mentioned above. The remaining devices may be connected to computing device **200** via network interface **206**.

[0044] Computing device **200** stores, in memory **204**, a surface extraction application **216** (also referred to herein as application **216**) comprising a plurality of computer readable instructions executable by controller **202**. When controller **202** executes the instructions of application **216** (or, indeed, any other application stored in memory **204**), controller **202** performs various functions implemented by those instructions, as will be discussed below. Controller **202**, or computing device **200** more generally, is therefore said to be "configured" or "operating" to perform those functions via the execution of application **216**.

[0045] Also stored in memory **204** are various data repositories, including a patient data repository **218**. Patient data repository **218** can contain a surgical plan defining the various steps of the minimally invasive surgical procedure to be conducted on patient **104**, as well as imaging data relating to patient **104**, such as MRI and CT scans, three-dimensional images of the brain of patient **104**, and the like. In the present embodiment, repository **218** includes at least imaging data **219** comprising three-dimensional imaging data and/or volumetric imaging data, and specifically of a volume of patient tissue having an outer surface, such as the skin of a patient and/or the brain of patient **104**. Indeed, the term "outer surface" as used herein may not refer only to an absolute outer surface of the patient (e.g. a patient's skin), but also to the outer surface of an object within the patient, such as the patient's brain. While imaging data **219** will be described herein with respect to magnetic resonance imaging data (MR imaging data), processes described herein can be applied to three-dimensional imaging data acquired using three-dimensional imaging technique.

[0046] Referring to FIG. **3**, an example image **300** of a volume of tissue stored in repository **218** is depicted, for example in imaging data **219**. The volume of tissue is the brain of patient **104** in the present example, and image **300** is a three-dimensional image of the brain of patient **104** obtained via MRI scanning. As seen in FIG. **3**, image **300** depicts an outer surface of the brain. Image **300** also includes image data depicting various internal structures of the brain (not visible in FIG. **3**), and may further include image data depicting structures surrounding the brain (such as the skull of patient **104**). In other words, the patient tissue depicted by the image **300** depicts a plurality of different tissue types.

[0047] Similarly, referring to FIG. **4** another example image **400** of a volume of tissue stored in repository **218** is depicted, for example in imaging data **219**. The volume of tissue is the head of patient **104** in the present example, and image **400** is a three-dimensional image of the head of patient **104**, as obtained via MRI scanning. As seen in FIG. **4**, image **400** depicts an outer surface of the head. Image **400** also includes image data depicting various internal structures of the brain, and may further include image data depicting structures surrounding the brain (such as the skull of patient **104**). In other words, as in the image **300**, the patient tissue depicted by the image **400** depicts a plurality of different tissue types.

[0048] Also depicted in FIG. **4** are markers **401** that have been overlaid on image **400** that indicate the outer surface of the head of patient **104**, markers **401** representative of physical markers placed on the head of patient **104** during surgery. In other words, for accurate placement of markers **401** on image **400**, rendering of skin of patient **104** has to be somewhat accurate as either the placement of markers **401** becomes inaccurate (which may make surgical planning difficult and/or dangerous) and/or impossible. Put another way, the markers **401** are rendered at the image **400** assuming that that skin on which corresponding physical markers are located has been registered at image **400** such that optical images of patient **104** captured during surgery using an optical camera (that include the physical markers) are aligned with image **400**. Such imaging techniques used in surgery hence rely on an accurate identification of a skin surface in image **400**. A similar issue may be present in image **300** when physical markers are placed on the surface of the brain of patient **104**, which are to be registered at the image **300**.

[0049] Turning to FIG. **5**, a method **500** of surface rendering using medical imaging data is depicted. Method **500** will be discussed in connection with its performance in system **100**, and particularly by the computing device **200**, via the execution of application **216** by controller **202**. As will be discussed in greater detail below, via the performance of method **500**, computing device **200** is configured to render imaging data **219** and update a surface threshold value using two models of the imaging data **219**.

[0050] At a block **502**, the controller **202** controls the display device **110** to render a first model of the imaging data **219** showing depth positions corresponding to a given surface threshold value (for example, an expected skin surface, an expected brain surface, and the like).

[0051] At a block **504**, the controller **202** controls the display device **110** to replace the first model with a second model of the imaging data **219** showing respective depth positions corresponding to the given surface threshold value. In general, the second model is of a type that is faster to compute and/or implement than the first model.

[0052] At a block **506**, the controller **202** receives, from the input device **210**, input changing the given surface threshold value to an updated surface threshold value, and control the display device **110** to update rendering of the second model to show updated respective depth positions corresponding to the updated surface threshold value.

[0053] At a block **508**, the controller **202** receives, from the input device **210**, an acceptance of the updated surface threshold value.

[0054] At a block **510**, the controller **202** controls the display device **110** to replace the second model with the first model showing updated depth positions corresponding to the updated surface threshold value.

[0055] Method **500** will now be discussed with reference to FIG. **6** to FIG. **16**.

[0056] Attention is next directed to FIG. **6**, which is substantially similar to FIG. **2**, with like elements having like numbers. However, in FIG. **6**, controller **202** is implementing application **216** and specifically block **502** of method **500**. In particular, controller **202** is generating a first model **601** of imaging data **219** using a given surface threshold value **602**.

[0057] First model **601** can comprise, for example, a geometric model of imaging data **219** including, but not

limited to, a polygon based mesh model and/or a three-dimensional mesh model and/or Bezier surface models and/or non-uniform rational B-spline (NURBS) models. Indeed, first model **601** can represents any three-dimensional model of a surface extracted from imaging data **219**, for example skin surface. In general, the first model **601** includes smoothing, removal of artifacts and noise, and/or processing to make the model topologically conform to an expected surface anatomy (e.g. a head anatomy, a brain anatomy, and the like; indeed, as described in detail below, whether a head surface, a brain surface, and the like can be selected using the input device **210**). Hence, the first model **601** is refined for use in a surgical procedure, but can require large processing and/or computation overhead.

[0058] Given surface threshold value **602** can comprise a value of an imaging signal intensity value that corresponds to a given surface type in imaging data **219**. For example, when imaging data **219** comprises MR imaging data, given surface threshold value **602** can comprise an MRI signal intensity value that corresponds to an estimate of a skin surface of patient **104**. Determination of given surface threshold value **602** can be based on a statistical analysis of volumetric imaging data **219** (e.g. that attempts to distinguish surfaces of a patient based on given rules) using application **216**, and/or given surface threshold value **602** may be received via input device **210**. While present embodiments are described with respect to given surface threshold value **602** comprising an MRI signal intensity that corresponds to skin of patient **104**, given surface threshold value **602** can be set to other MRI signal intensities that correspond to estimates of other types of surfaces in patient **104** including, but not limited to, to an estimate of a brain surface and/or a cortical surface of patient **104**.

[0059] FIG. **6** further depicts controller **202** controlling display device **110** to render first model **601** of imaging data **219** showing depth positions corresponding to given surface threshold value **602**. Put another way, the depth positions depicted in FIG. **6** corresponding to given surface threshold value **602** comprise an extracted surface from imaging data **219** and/or a surface extracted from imaging data **219** using a mesh algorithm, and the like.

[0060] For example, attention is next directed to FIG. **7**, which depicts display device **110** being controlled to render first model **601** and specifically a head of patient **104**. However, as is clearly seen in FIG. **7**, first model **601** includes various inaccuracies **701** as compared to the actual skin of patient **104**. For example, a rendering of the nose is poorly defined; further inaccuracies **701** include various pits and/or bumps and/or craters and/or artifacts in the skin surface which can be due to MRI signal inhomogeneity during an MRI scan of patient **104**.

[0061] While given surface threshold value **602** can be updated and in turn first model **601** can be regenerate and re-rendered to show an updated estimate of skin surface, each instance of generating first model **601** can result in a large and inefficient use of processing resources at device **200**. For example, when first model **601** comprises a mesh model, generation of such mesh models can be extremely time consuming (e.g. on the order of tens of seconds), especially when the mesh model is applied to large data sets that are typical MRI. While this issue could be at least partially addressed by using faster processors, and/or parallel processors and/or more processors, and the like, at device **200**, such an increase in processing resources is expensive and/or inefficient, and further requires more power to operate. Furthermore, such an upgrade in processing resources may not be feasible.

[0062] Hence, as also depicted in FIG. **7**, controller **202** controls display device **110** to render a virtual control **703** which, when actuated (for example, using a pointer **705**), causes device **200** and/or controller **202** to operate more efficiently to update the given surface threshold value **602** as described hereafter. It will be assumed hereafter that when pointer **705** is used to actuate virtual controls, and the like, at display device **110**, pointer **705** is being controlled by receipt of input at input device **210**.

[0063] For example, attention is next directed to FIG. **8**, which is substantially similar to FIG. **7**, with like elements having like numbers. However, in FIG. **8**, the virtual control **703** has been actuated which causes controller **202** to render four further virtual controls **801**, **803**, **805**, **807**. Actuation of virtual control **801** will cause controller **202** to control display device **110** to return to rendering first model **601** as depicted in FIG. **7** and/or cause controller **202** to control display device **110** to render first model **601** using an updated surface threshold value, determination of updated surface threshold values being described below.

[0064] Similarly, actuation of virtual control **805** will cause controller **202** to control display device **110** to render first model **601**, however using a given surface threshold value comprising an MRI signal intensity that corresponds to the cortical surface of the brain of patient **104**. In other words, in surgeries on a head of a patient, registration of outer skin of the patient and registration of a cortical surface of a brain of a patient are often the most used; hence, device **200** is specifically configured to provide convenient access to rendering both outer skin (e.g. via virtual control **801**) of a patient and cortical surface of a brain (e.g. via virtual control **805**) of a patient.

[0065] However, actuation of virtual controls **803**, **807** will cause controller **202** to change a respective termination threshold using a second model, as described hereafter. While only actuation of virtual control **803** will be described in detail with respect to updating skin registration, actuation of virtual control **807** will cause controller **202** to operate in a similar manner, however with respect to cortical surface registration. Hence, as further depicted in FIG. **8**, pointer **705** is actuating virtual control **803** which, in turn, causes controller **202** to implement block **504** of method **500**.

[0066] For example, attention is next directed to FIG. **9**, which is substantially similar to FIG. **2**, with like elements having like numbers. However, in FIG. **6**, controller **202** is implementing block **504** of method **500**. In particular, controller **202** is generating a second model **902** of imaging data **219** using given surface threshold value **602**.

[0067] Second model **902** can comprise a model of imaging data **219** that is faster to compute, as compared to first model **601**, for example, a ray-casting model of imaging data **219**. Such ray-casting models are generally faster to implement than the above described geometric (e.g. mesh) models and they may be computed on a graphics card, and the like. For example, ray-casting models are generally not as refined as geometric models. For example ray-casting models are not topologically closed with respect to, for example, head anatomy (e.g. a head surface), brain anatomy (e.g. a brain surface) and the like, and can have "floating" artifacts that can potentially cause problems with registration. Furthermore, such ray-casting models generally don't

include validation. Hence, such ray-casting models are generally unsuitable for use in surgeries, however such ray-casting models are faster to compute than the geometric models of the first model **601**, which are, in contrast closed topologically and are validated. Hence, the first model **601** is generally more refined than the second model **902** and/or the second model **902** is not refined as compared to the first model **601**.

[0068] However, as such a ray-casting model can be generated from the same imaging data **219** as a mesh model, and further uses the same termination thresholds to estimate surfaces (e.g. by using termination thresholds to terminate rays of a ray-casting model), determining the effect of updating a surface threshold value on surface extraction from imaging data **219** occurs faster with a ray-casting algorithm than with a mesh algorithm.

[0069] Hence, as also depicted in FIG. **9**, controller **202** is controlling display device **110** to replace first model **601** (e.g. a mesh model) with second model **902** (e.g. a ray-casting model) of imaging data **219**, second model **902** showing respective depth positions corresponding to given surface threshold value **602**, and second model **902** being of type that is faster to compute than first model **601**,

[0070] For example, attention is next directed to FIG. **10**, which is substantially similar to FIG. **8**, with like elements having like numbers. However, in FIG. **10**, display device **110** is being controlled to render second model **902** rather than first model **601**. Put another way, second model **902** has replaced first model **601** at display device **110** as compared to FIG. **8**.

[0071] Put another way, the depth positions depicted in FIG. **10** corresponding to given surface threshold value **602** comprise an extracted surface from imaging data **219** and/or a surface extracted from imaging data **219** using a ray-casting algorithm, and the like.

[0072] Indeed, further comparing FIG. **10** and FIG. **8**, controller **202** has aligned the rendering of first model **601** and second model **902** at display device **110**. In particular, the position and/or angle of second model **902** rendered at display device **110** as depicted in FIG. **10**, is the same and/or similar as the position and/or angle of first model **601** rendered at display device **110** as depicted in FIG. **9**. Indeed, in FIG. **8**, the position and/or angle of first model **601** may be adjusted using pointer **705** and when virtual control **803** is actuated, controller **202** replaces first model **601** with second model **902** at display device **110**, second model **902** aligned with first model **601**.

[0073] As also depicted in FIG. **10**, second model **902** includes various inaccuracies **1001** of skin extraction similar to various inaccuracies **701**. Indeed, further comparing FIG. **10** and FIG. **8**, second model **902** being of type that is faster to compute than first model **601**. Hence, while second model **902** has a different appearance due, for example, a different technique for surface extraction, the extracted surface of FIG. **10** is similar to the extracted surface of FIG. **8**.

[0074] As also depicted in FIG. **10**, and further as a result of actuation of virtual control **803**, controller **202** controls display device **110** to stop rendering of virtual controls **801**, **803**, **805**, **807**, and renders a further virtual control, for example a slider **1003** which is used to change a surface threshold value as described below. Slider **1003** may be controlled using pointer **705**. However, present embodiments are not limited to sliders, and any type of input and/or input device may be used to change a surface threshold value including, but not limited to, an editable numeric field, and the like.

[0075] As also depicted in FIG. **10**, controller **202** further controls display device **110** to render virtual controls **1005**, **1007**. Virtual control **1005**, when actuated, causes controller **202** to accept an updated surface threshold value as changed using slider **1003**, and virtual control **1007**, when actuated, causes controller **202** to cancel changing of the surface threshold value.

[0076] Attention is next directed to FIG. **11**, which is substantially similar to FIG. **10**, with like elements having like numbers. However, in FIG. **11**, input is being received (e.g. via pointer **705** adjusting slider **1003**, as controlled via input device **210**), the input changing given surface threshold value **602** to an updated surface threshold value.

[0077] For example, comparing FIG. **11** with FIG. **10**, slider **103** is further to the right which causes a surface threshold value to be updated to an MRI signal intensity value that corresponds to deeper surface position in the head of patient **104** than the initial given surface threshold value **602**.

[0078] In particular, controller **202** controls display device **110** to update rendering of second model **902** to show updated respective depth positions corresponding to an updated surface threshold value as selected using slider **1003**. In other words, another surface is extracted from imaging data **219** using a ray-casting algorithm.

[0079] For example, as depicted in FIG. **11**, a rendering of a brain **1101** in imaging data **219** is visible, and furthermore in a region **1105** of the nose in imaging data **219**, there are holes in second model **902**, as there is space inside the nose in imaging data **219**, which has become visible with an adjusted surface threshold value.

[0080] However, slider **1003** may also be moved in an opposite direction. For example, attention is next directed to FIG. **12**, which is substantially similar to FIG. **1**, with like elements having like numbers. However, in FIG. **12**, input is being received (e.g. via pointer **705** adjusting slider **1003**, as controlled via input device **210**) which causes slider **103** to move left, which in turn causes a surface threshold value to be updated to an MRI signal intensity value that corresponds to less deep surface position in the head of patient **104** as compared to FIG. **11**.

[0081] In particular, controller **202** controls display device **110** to update rendering of the second model **902** to show updated respective depth positions corresponding to an updated surface threshold value as selected using slider **1003**.

[0082] For example, as depicted in FIG. **12**, a rendering of brain **1101** is no longer visible, and furthermore in region **1105** of the nose in imaging data **219**, the nose is solid; though a tip of the nose is cut off, such a cut off may be irrelevant when planning a surgery. Furthermore, comparing FIG. **12** with FIG. **10**, it is apparent that there are fewer inaccuracies, though a few inaccuracies **1201** remain, which can be due to MRI signal inhomogeneity, instrumentation issues, physical incisions, and the like. However, a majority of the extracted skin surface in the rendering of second model **902** in FIG. **12** is free of inaccuracies **1201**. Furthermore, pointer **705** may be used to rotate and/or reposition the rendering of second model **902** to provide a visual inspection of second model **902** from various angles and/or to view inaccuracies on others sides of the extracted skin surface.

[0083] In this manner, using slider **1003**, the effect of changing and/or updating the surface threshold value can be determined using second model **902**, until an acceptance of an updated surface threshold value is received via an actuation of virtual control **1005**. Furthermore, as second model **902** is of a type that is faster to compute than first model **601** (and/or as a ray-casting algorithm is faster than a mesh algorithm), each instance of updating of the surface threshold value causes second model **902** to be rendered in a time that is faster than if first model **601** were being rendered, making device **200** operate more efficiently than if first model **601** were being used to evaluate and/or update the surface threshold value. Indeed, in a successful prototype, each updating of second model **902** (e.g. using a ray-casting algorithm for second model **902**) occurred in a time on the order of <100 ms, whereas each updating of first model **601** occurred in a time on the order of 30-60 seconds (e.g. using a mesh algorithm for first model **601**).

[0084] Furthermore, FIG. **11** and FIG. **12** depict an example embodiment of block **506** of method **500**. Indeed, attention is next directed to FIG. **13**, which is substantially similar to FIG. **10**, with like elements having like numbers. However, FIG. **13** depicts controller **202** implementing block **506** of method **500**. In particular, controller **202** is receiving input **1301** from input device **210** which changes the given surface threshold value **602** to an updated surface threshold value **1302**, which is used to update second model **902** of imaging data **219** as depicted in FIG. **11** and FIG. **12**. In other words, input **1301** corresponds to slider **1003** being moved left and/or right, with updated surface threshold value **1302** being changed accordingly.

[0085] Similarly, in FIG. **13**, controller **202** is controlling display device **110** to update rendering of the second model **902** to show updated respective depth positions corresponding to updated surface threshold value **1302**, similar to as described above with respect to FIG. **11** and FIG. **12**.

[0086] Attention is next directed to FIG. **14**, which is substantially similar to FIG. **13**, with like elements having like numbers. However, FIG. **14** depicts controller **202** implementing blocks **508**, **510** of method **500**. In particular, in FIG. **14**, controller **202** is receiving, from input device **210**, input **1401** indicating an acceptance of updated surface threshold value **1302** (e.g. corresponding to a surface threshold value selected in FIG. **12**). Further in FIG. **14**, controller **202** is updating first model **601** with updated surface threshold value **1302** selected using second model **902**, and controlling display device **110** to replace second model **902** with first model **601** showing updated depth positions corresponding to the updated surface threshold value **1302**. Indeed, FIG. **14** and FIG. **9** further illustrate that controller **202** is further configured to exchange given surface threshold value **602** and updated surface threshold value **1302** between first model **601** and second model **902**.

[0087] Attention is next directed to FIG. **15** which is substantially similar to FIG. **12**, with like elements having like numbers. However, in FIG. **15**, block **508** has occurred via pointer **705** selecting virtual control **1005** to generate input **1401** and/or an acceptance of updated surface threshold value **1302**. In response, block **510** is being implemented to control display device **110** to replace second model **902** with first model **601** showing updated depth positions corresponding to updated surface threshold value **1302**. However, as second model **902** is of higher resolution than second model **902**, first model **601** takes more time and/or processing resources to update, and hence when virtual control **1005** is selected, second model **902** remains at display device **110** for the time needed to update first model **601**.

[0088] In the example depicted in FIG. **15**, controller **202** optionally controls display device **110** to render a notification **1505** while first model **601** is being updated, notification **1505** indicating that first model **601** is being updated based on an updated (e.g. adjusted) surface threshold value. As the example embodiment is directed towards skin extraction, notification **1505** indicates "Updating Skin Surface" and the like. However, notification **1505** may be adapted accordingly when a cortical surface is being updated.

[0089] Once controller **202** updates first model **601** using updated surface threshold value **1302**, controller **202** replaces second model **902** with updated first model **601** at display device **110**.

[0090] For example, attention is next directed to FIG. **16** which is substantially similar to FIG. **15**, with like elements having like numbers. However, in FIG. **16**, block **510** has been implemented and controller **110** has controlled display device **110** to replace second model **902** with first model **601** updated to show updated depth positions corresponding to updated surface threshold value **1302**.

[0091] For example, first model **601** depicted in FIG. **16** is similar to second model **902** as depicted in FIG. **12** and FIG. **15**, but at a higher resolution and generated using updated surface threshold value **1302** selected using second model **902** and slider **1003**. Furthermore, slider **1003** has been removed. Method **500** can be repeated, however, upon actuation of virtual control **703**. Furthermore, second model **902** may be rotated and the like using pointer **705**, for example to plan a surgical procedure.

[0092] Hence, described herein is a method, system and apparatus for surface rendering using medical imaging data that may result in an image rendering device, such as device **200**, to operate more efficiently in selecting an updated surface threshold value during surface extraction. For example, an extraction algorithm, and the like (e.g. application **216**), is used to generate a skin surface, and the like, using a default threshold based on statistical analysis of volumetric imaging data **219**. The skin surface is rendered at a display device according to a first model, such as a three-dimensional geometrical model and/or a mesh surface. To adjust the threshold, the first model is replaced at the display device with a second model that is faster to compute than the first model, such as a ray-casting rendering of the volumetric imaging data using the default threshold to terminate the rays in the ray-casting model. The second model appears similar to the first model, but is not necessarily identical. The threshold is adjusted (e.g. using a slider, an editable numeric field, and the like), and the second model is dynamically adjusted at the display device. When an adjusted threshold is accepted, the adjusted threshold is used by the extraction algorithm to extract a new skin surface in order to replace the first model, which is then rendered at the display device.

[0093] Those skilled in the art will appreciate that in some embodiments, the functionality of the application **216** may be implemented using pre-programmed hardware or firmware elements (e.g., application specific integrated circuits (ASICs), electrically erasable programmable read-only memories (EEPROMs), etc.), or other related components.

[0094] The scope of the claims should not be limited by the embodiments set forth in the above examples, but should be given the broadest interpretation consistent with the description as a whole.

1. A device for planning surgery using three-dimensional (3D) medical imaging data of an object, the device comprising:

a controller configured to:

control a display device to render a first model of the 3D medical imaging data showing depth positions corresponding to a given surface threshold value;

control the display device to render a second model of the 3D medical imaging data showing respective depth positions corresponding to the given surface threshold value, wherein the second model is faster to compute than the first model, and the second model replaces the first model at the display device and is otherwise aligned with the first model with respect to one or more of a position and angle;

control the display device to update rendering of the second model to show updated respective depth positions corresponding to an updated surface threshold value different from the given surface threshold value;

control the display device to replace the second model with the first model showing updated depth positions corresponding to the updated surface threshold value, and wherein the first model showing the updated depth positions is otherwise aligned with the first model, as originally rendered, with respect to one or more of a position and angle; and

provide one or more markers at one or more of the updated depth positions to assist with planning the surgery.

2. The device of claim **1**, wherein the first model comprises a mesh model.

3. The device of claim **1**, wherein the second model comprises a ray-casting model.

4. The device of claim **1**, wherein the updated surface threshold value is received via an input device.

5. The device of claim **1**, wherein the second model has not been refined as compared with the first model.

6. The device of claim **1**, wherein the given surface threshold value corresponds to an estimate of a skin surface or a brain surface of the object.

7. The device of claim **1**, wherein the controller is further configured to exchange the given surface threshold value and the updated surface threshold value between the first model and the second model.

8. The device of claim **1**, wherein the controller is further configured to change the given surface threshold value to the updated surface threshold value using a slider rendered at the display device.

9. The device of claim **1**, wherein the 3D medical imaging data is selected from a list comprising of computed tomography (CT) imaging data, positron emissions tomography (PET) imaging data, and 3D surface scanner imaging data.

10. The device of claim **1**, wherein the 3D medical imaging data comprises magnetic resonance imaging data, and the given surface threshold value and the updated surface threshold value each comprises a respective magnetic resonance imaging signal intensity value.

11. A method for planning surgery using three-dimensional (3D) medical imaging data of an object, the method comprising:

controlling, using a computing device, a display device to render a first model of the 3D medical imaging data showing depth positions corresponding to a given surface threshold value;

controlling, using the computing device, the display device to render a second model of the 3D medical imaging data showing respective depth positions corresponding to the given surface threshold value, wherein the second model is faster to compute than the first model, and the second model replaces the first model at the display device and is otherwise aligned with the first model with respect to one or more of a position and angle;

controlling, using the computing device, the display device to update rendering of the second model to show updated respective depth positions corresponding to an updated surface threshold value different from the given surface threshold value;

controlling, using the computing device, the display device to replace the second model with the first model showing updated depth positions corresponding to the updated surface threshold value, and wherein the first model showing the updated depth positions is otherwise aligned with the first model, as originally rendered, with respect to one or more of a position and angle; and

providing, using the computing device, one or more markers at one or more of the updated depth positions to assist with planning the surgery.

12. The method of claim **11**, wherein the first model comprises a mesh model, and the second model comprises a ray-casting model.

13. The method of claim **11**, wherein the updated surface threshold value is received via an input device.

14. The method of claim **11**, wherein the second model has not been refined as compared with the first model.

15. The method of claim **11**, wherein the given surface threshold value corresponds to an estimate of a skin surface or a brain surface of the object.

16. The method of claim **11**, further comprising exchanging the given surface threshold value and the updated surface threshold value between the first model and the second model.

17. The method of claim **11**, further comprising changing the given surface threshold value to the updated surface threshold value via a slider rendered at the display device.

18. The method of claim **11**, wherein the 3D medical imaging data is selected from a list comprising of computed tomography (CT) imaging data, positron emissions tomography (PET) imaging data, and 3D surface scanner imaging data.

19. The method of claim **11**, wherein the 3D medical imaging data comprises magnetic resonance imaging data, and the given surface threshold value and the updated surface threshold value each comprise a respective magnetic resonance imaging signal intensity value.

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