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(54) Title: SYSTEM AND METHOD FOR AUTOMATIC MUSCLE MOVEMENT DETECTION

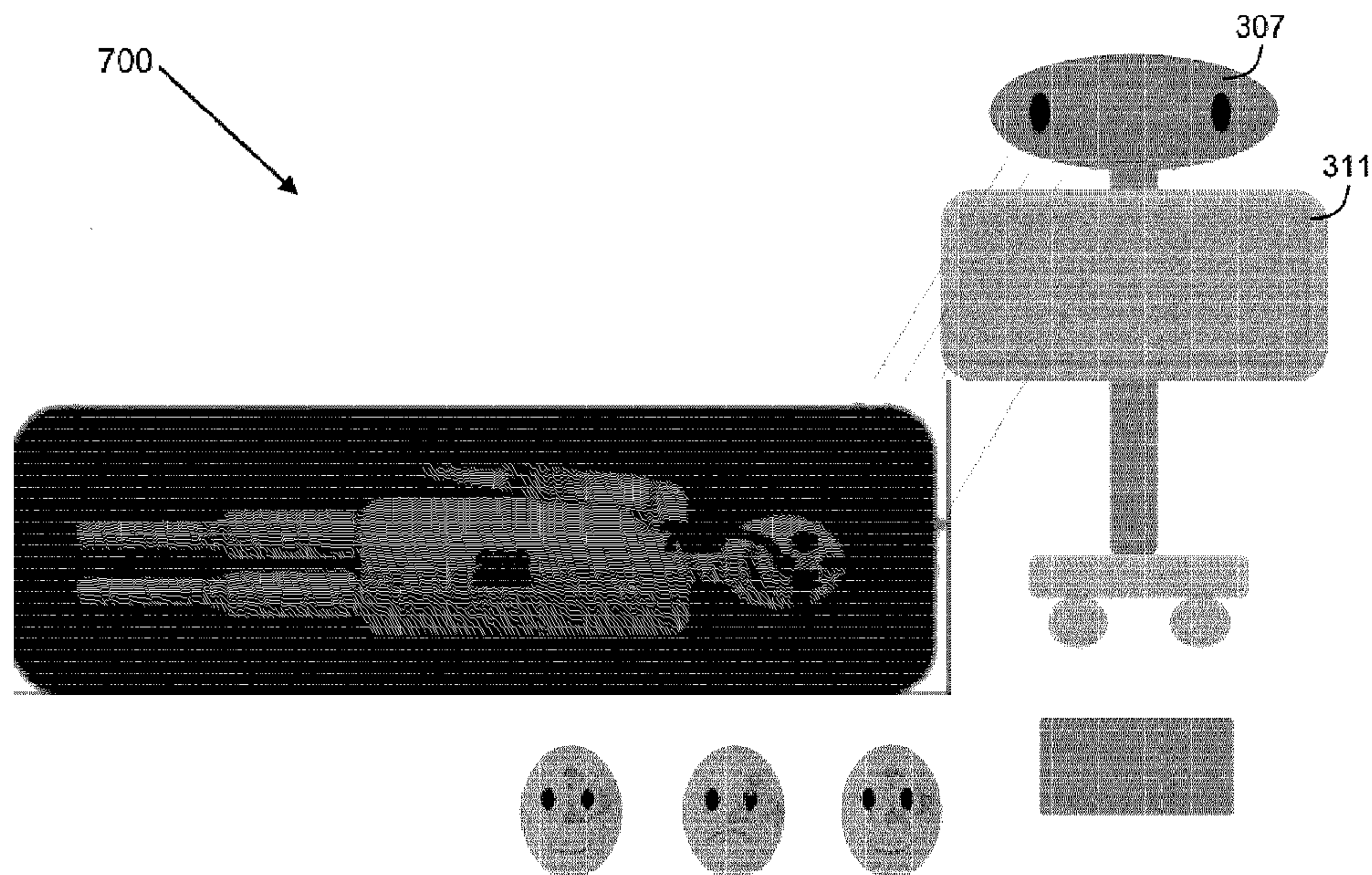


FIG. 7

(57) **Abrégé/Abstract:**

A medical navigation system is provided for detecting movement of a subject, the system having an optical tracking system including a camera, a display, and a controller electrically coupled to the optical tracking system and the display. The controller has a processor coupled to a memory and is configured to receive a data signal from the optical tracking system and recognize and continuously monitor optical tracking markers on the subject within a field of view of the camera, and provide an alert on the display when movement of the optical tracking markers on the subject falls within predefined parameters.

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(54) Title: SYSTEM AND METHOD FOR AUTOMATIC MUSCLE MOVEMENT DETECTION

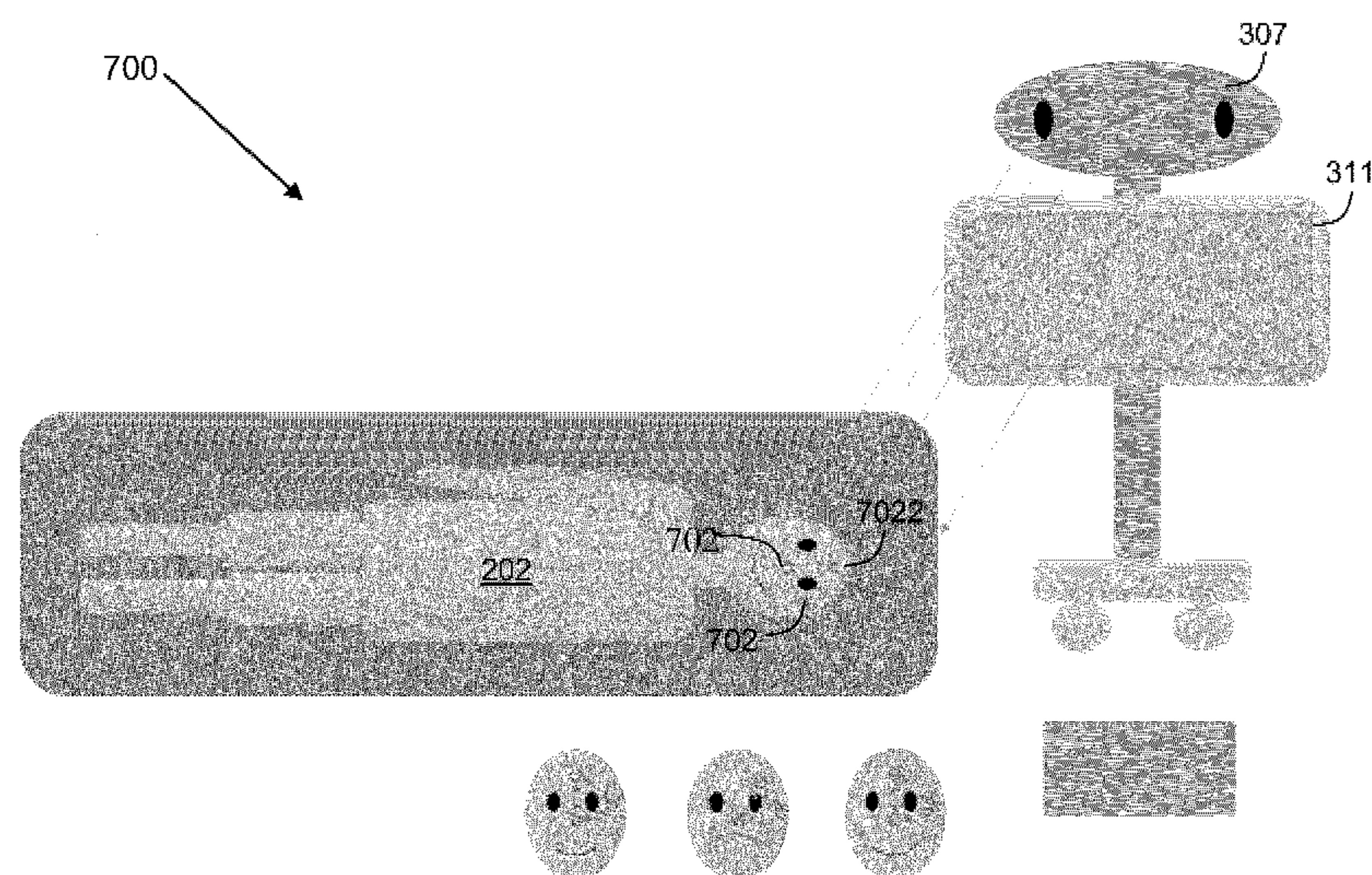


FIG. 7

(57) Abstract: A medical navigation system is provided for detecting movement of a subject, the system having an optical tracking system including a camera, a display, and a controller electrically coupled to the optical tracking system and the display. The controller has a processor coupled to a memory and is configured to receive a data signal from the optical tracking system and recognize and continuously monitor optical tracking markers on the subject within a field of view of the camera, and provide an alert on the display when movement of the optical tracking markers on the subject falls within predefined parameters.

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SYSTEM AND METHOD FOR AUTOMATIC MUSCLE MOVEMENT DETECTION

TECHNICAL FIELD

[0001] The present disclosure is generally related to image guided medical procedures, and more specifically to a system and method for automatic detection of muscle movement.

BACKGROUND

[0002] The present disclosure is generally related to image guided medical procedures using a surgical instrument, such as an optical scope, an optical coherence tomography (OCT) probe, a micro ultrasound transducer, an electronic sensor or stimulator, or an access port based surgery.

[0003] In the example of a port-based surgery, a surgeon or robotic surgical system may perform a surgical procedure involving tumor resection in which the residual tumor remaining after is minimized, while also minimizing the trauma to the intact white and grey matter of the brain. In such procedures, trauma may occur, for example, due to contact with the access port, stress to the brain matter, unintentional impact with surgical devices, and/or accidental resection of healthy tissue. A key to minimizing trauma is ensuring that the surgeon is aware of what is transpiring in the operating room and observes important signs when performing surgery such as patient muscle twitches or tremors.

[0004] FIG. 1 illustrates the insertion of an access port into a human brain, for providing access to internal brain tissue during a medical procedure. In FIG. 1, access port 12 is inserted into a human brain 10, providing access to internal brain tissue. Access port 12 may include such instruments as catheters, surgical probes, or cylindrical ports such as the NICO BrainPath™. Surgical tools and instruments may then be inserted within the lumen of the access port in order to perform surgical, diagnostic or therapeutic procedures, such as resecting tumors as necessary. The present disclosure applies equally well to catheters, deep

brain stimulation (DBS) needles, a biopsy procedure, and also to biopsies and/or catheters in other medical procedures performed on other parts of the body.

[0005] In the example of a port-based surgery, a straight or linear access port 12 is typically guided down a sulci path of the brain. Surgical instruments would then be inserted down the access port 12. Optical tracking systems, used in the medical procedure, track the position of a part of the instrument that is within line-of-site of the optical tracking camera.

[0006] Conventional systems have not offered good solutions for ensuring that a surgeon sees all of the reactions of a patient during the performance of a medical procedure. It would be desirable to have a system that helps a surgeon detect changes in facial pose or other muscle positions to detect an onset of a seizure, muscle twitching, etc., to assist the surgeon with clinical decision making in the context of the procedures mentioned above.

SUMMARY

[0007] One aspect of the present disclosure provides a medical navigation system for detecting movement of a subject, the system having an optical tracking system including a camera, a display, and a controller electrically coupled to the optical tracking system and the display. The controller has a processor coupled to a memory and is configured to receive a data signal from the optical tracking system and recognize and continuously monitor optical tracking markers on the subject within a field of view of the camera, and provide an alert on the display when movement of the optical tracking markers on the subject falls within predefined parameters.

[0008] Another aspect of the present disclosure provides a medical navigation system for detecting movement of a subject, the system having a video system including a camera, a display, and a controller electrically coupled to the video system and the display. The controller has a processor coupled to a memory and is configured to receive a data signal from the video system and recognize and continuously monitor a portion of the subject within a field of view

of the camera, and provide an alert on the display when movement of the portion of the subject falls within predefined parameters.

[0009] Another aspect of the present disclosure provides a medical navigation system for detecting movement of a subject, the system having a three dimensional (3D) scanner system including a 3D scanner, a display, and a controller electrically coupled to the 3D scanner system and the display. The controller has a processor coupled to a memory and is configured to receive a data signal from the 3D scanner system and recognize and continuously monitor a portion of the subject within a field of view of the 3D scanner, and provide an alert on the display when movement of the portion of the subject falls within predefined parameters.

[0010] A further understanding of the functional and advantageous aspects of the disclosure can be realized by reference to the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Embodiments will now be described, by way of example only, with reference to the drawings, in which:

[0012] FIG. 1 illustrates the insertion of an access port into a human brain, for providing access to internal brain tissue during a medical procedure;

[0013] FIG. 2 shows an exemplary navigation system to support minimally invasive surgery;

[0014] FIG. 3 is a block diagram illustrating a control and processing system that may be used in the navigation system shown in Fig. 2;

[0015] FIG. 4A is a flow chart illustrating a method involved in a surgical procedure using the navigation system of FIG. 2;

[0016] FIG. 4B is a flow chart illustrating a method of registering a patient for a surgical procedure as outlined in FIG. 4A;

[0017] FIG. 5 is an exemplary navigation system similar to FIG. 2 illustrating system components of an exemplary surgical system that may be used for automatic muscle movement detection;

[0018] FIG. 6 is perspective drawing illustrating a conventional end effector holding a camera;

[0019] FIG. 7 is a block diagram illustrating an exemplary patient context in an operating room where automatic muscle movement detection may be provided; and

[0020] FIG. 8 is a flow chart illustrating a method of automatic muscle movement detection that may be implemented by the system of FIGS. 5 and/or 7.

DETAILED DESCRIPTION

[0021] 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.

[0022] 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.

[0023] As used herein, the term “exemplary” means “serving as an example, instance, or illustration,” and should not be construed as preferred or advantageous over other configurations disclosed herein.

[0024] As used herein, the terms “about”, “approximately”, and “substantially” are meant to cover variations that may exist in the upper and lower limits of the ranges of values, such as variations in properties, parameters, and dimensions. In one non-limiting example, the terms “about”, “approximately”, and “substantially” mean plus or minus 10 percent or less.

[0025] Unless defined otherwise, all technical and scientific terms used herein are intended to have the same meaning as commonly understood by 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 phrase “access port” refers to a cannula, conduit, sheath, port, tube, or other structure that is insertable into a subject, in order to provide access to internal tissue, organs, or other biological substances. In some embodiments, an access port may directly expose internal tissue, for example, via an opening or aperture at a distal end thereof, and/or via an opening or aperture at an intermediate location along a length thereof. In other embodiments, an access port may provide indirect access, via one or more surfaces that are transparent, or partially transparent, to one or more forms of energy or radiation, such as, but not limited to, electromagnetic waves and acoustic waves.

[0027] As used herein the phrase “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. Intraoperative, as defined herein, is not limited to surgical procedures, and may refer to other types of medical procedures, such as diagnostic and therapeutic procedures.

[0028] Embodiments of the present disclosure provide imaging devices that are insertable into a subject or patient for imaging internal tissues, and methods of use thereof. Some embodiments of the present disclosure relate to

minimally invasive medical procedures that are performed via an access port, whereby surgery, diagnostic imaging, therapy, or other medical procedures (e.g., minimally invasive medical procedures) are performed based on access to internal tissue through the access port.

[0029] Referring to FIG. 2, an exemplary navigation system environment 200 is shown, which may be used to support navigated image-guided surgery. As shown in FIG. 2, surgeon 201 conducts a surgery on a patient 202 in an operating room (OR) environment. A medical navigation system 205 comprising an equipment tower, tracking system, displays and tracked instruments assist the surgeon 201 during his procedure. An operator 203 is also present to operate, control and provide assistance for the medical navigation system 205.

[0030] Referring to FIG. 3, a block diagram is shown illustrating a control and processing system 300 that may be used in the medical navigation system 200 shown in FIG. 3 (e.g., as part of the equipment tower). As shown in FIG. 3, in one example, control and processing system 300 may include one or more processors 302, a memory 304, a system bus 306, one or more input/output interfaces 308, a communications interface 310, and storage device 312. Control and processing system 300 may be interfaced with other external devices, such as tracking system 321, data storage 342, and external user input and output devices 344, which may include, for example, one or more of a display, keyboard, mouse, sensors attached to medical equipment, foot pedal, and microphone and speaker. Data storage 342 may be any suitable data storage device, such as a local or remote computing device (e.g. a computer, hard drive, digital media device, or server) having a database stored thereon. In the example shown in FIG. 3, data storage device 342 includes identification data 350 for identifying one or more medical instruments 360 and configuration data 352 that associates customized configuration parameters with one or more medical instruments 360. Data storage device 342 may also include preoperative image data 354 and/or medical procedure planning data 356. Although data storage device 342 is shown as a single device in FIG. 3, it will be understood that in other embodiments, data storage device 342 may be provided as multiple storage devices.

[0031] Medical instruments 360 are identifiable by control and processing unit 300. Medical instruments 360 may be connected to and controlled by control and processing unit 300, or medical instruments 360 may be operated or otherwise employed independent of control and processing unit 300. Tracking system 321 may be employed to track one or more of medical instruments 360 and spatially register the one or more tracked medical instruments to an intraoperative reference frame. For example, medical instruments 360 may include tracking markers such as tracking spheres that may be recognizable by a tracking camera 307. In one example, the tracking camera 307 may be an infrared (IR) tracking camera. In another example, a sheath placed over a medical instrument 360 may be connected to and controlled by control and processing unit 300. In another example, camera 307 may be a video camera.

[0032] Control and processing unit 300 may also interface with a number of configurable devices, and may intraoperatively reconfigure one or more of such devices based on configuration parameters obtained from configuration data 352. Examples of devices 320, as shown in FIG. 3, include one or more external imaging devices 322, one or more illumination devices 324, a robotic arm 305, one or more projection devices 328, and one or more displays 311, and a scanner 309, which in one example may be a three dimensional (3D) scanner.

[0033] Exemplary aspects of the disclosure can be implemented via processor(s) 302 and/or memory 304. For example, the functionalities described herein can be partially implemented via hardware logic in processor 302 and partially using the instructions stored in memory 304, as one or more processing modules or engines 370. Example processing modules include, but are not limited to, user interface engine 372, tracking module 374, motor controller 376, image processing engine 378, image registration engine 380, procedure planning engine 382, navigation engine 384, and context analysis module 386. While the example processing modules are shown separately in FIG. 3, in one example the processing modules 370 may be stored in the memory 304 and the processing modules may be collectively referred to as processing modules 370.

[0034] It is to be understood that the system is not intended to be limited to the components shown in FIG. 3. One or more components of the control and processing system 300 may be provided as an external component or device. In one example, navigation module 384 may be provided as an external navigation system that is integrated with control and processing system 300.

[0035] Some embodiments may be implemented using processor 302 without additional instructions stored in memory 304. Some embodiments may be implemented using the instructions stored in memory 304 for execution by one or more general purpose microprocessors. Thus, the disclosure is not limited to a specific configuration of hardware and/or software.

[0036] While some embodiments can be implemented in fully functioning computers and computer systems, various embodiments are capable of being distributed as a computing product in a variety of forms and are capable of being applied regardless of the particular type of machine or computer readable media used to actually effect the distribution.

[0037] At least some aspects disclosed can be embodied, at least in part, in software. That is, the techniques may be carried out in a computer system or other data processing system in response to its processor, such as a microprocessor, executing sequences of instructions contained in a memory, such as ROM, volatile RAM, non-volatile memory, cache or a remote storage device.

[0038] A computer readable storage medium can be used to store software and data which, when executed by a data processing system, causes the system to perform various methods. The executable software and data may be stored in various places including for example ROM, volatile RAM, nonvolatile memory and/or cache. Portions of this software and/or data may be stored in any one of these storage devices.

[0039] Examples of computer-readable storage media include, but are not limited to, recordable and non-recordable type media such as volatile and non-volatile memory devices, read only memory (ROM), random access memory (RAM), flash memory devices, floppy and other removable disks, magnetic disk

storage media, optical storage media (e.g., compact discs (CDs), digital versatile disks (DVDs), etc.), among others. The instructions may be embodied in digital and analog communication links for electrical, optical, acoustical or other forms of propagated signals, such as carrier waves, infrared signals, digital signals, and the like. The storage medium may be the internet cloud, or a computer readable storage medium such as a disc.

[0040] At least some of the methods described herein are capable of being distributed in a computer program product comprising a computer readable medium that bears computer usable instructions for execution by one or more processors, to perform aspects of the methods described. The medium may be provided in various forms such as, but not limited to, one or more diskettes, compact disks, tapes, chips, universal serial bus (USB) keys, external hard drives, wire-line transmissions, satellite transmissions, internet transmissions or downloads, magnetic and electronic storage media, digital and analog signals, and the like. The computer useable instructions may also be in various forms, including compiled and non-compiled code.

[0041] According to one aspect of the present application, one purpose of the navigation system 205, which may include control and processing unit 300, is to provide tools to the neurosurgeon that will lead to the most informed, least damaging neurosurgical operations. In addition to removal of brain tumours and intracranial hemorrhages (ICH), the navigation system 205 can also be applied to a brain biopsy, a functional / deep-brain stimulation, a catheter / shunt placement procedure, open craniotomies, endonasal /skull-based / ear nose throat (ENT), spine procedures, and other parts of the body such as breast biopsies, liver biopsies, etc. While several examples have been provided, aspects of the present disclosure may be applied to any suitable medical procedure.

[0042] Referring to FIG. 4A, a flow chart is shown illustrating a method 400 of performing a surgical procedure using a navigation system, such as the medical navigation system 205 described in relation to FIG. 2. At a first block 402, the surgical plan is imported.

[0043] Once the plan has been imported into the navigation system at the block 402, the patient is affixed into position using a body holding mechanism. The head position is also confirmed with the patient plan in the navigation system (block 404), which in one example may be implemented by the computer or controller forming part of the equipment tower of medical navigation system 205.

[0044] Next, registration of the patient is initiated (block 406). The phrase "registration" or "image registration" refers to the process of transforming different sets of data into one coordinate system. Data may include multiple photographs, data from different sensors, times, depths, or viewpoints. The process of "registration" is used in the present application for medical imaging in which images from different imaging modalities are co-registered. Registration is used in order to be able to compare or integrate the data obtained from these different modalities.

[0045] Those skilled in the relevant arts will appreciate that there are numerous registration techniques available and one or more of the techniques may be applied to the present example. Non-limiting examples include intensity-based methods that compare intensity patterns in images via correlation metrics, while feature-based methods find correspondence between image features such as points, lines, and contours. Image registration methods may also be classified according to the transformation models they use to relate the target image space to the reference image space. Another classification can be made between single-modality and multi-modality methods. Single-modality methods typically register images in the same modality acquired by the same scanner or sensor type, for example, a series of magnetic resonance (MR) images may be co-registered, while multi-modality registration methods are used to register images acquired by different scanner or sensor types, for example in magnetic resonance imaging (MRI) and positron emission tomography (PET). In the present disclosure, multi-modality registration methods may be used in medical imaging of the head and/or brain as images of a subject are frequently obtained from different scanners. Examples include registration of brain computerized tomography (CT)/MRI images or PET/CT

images for tumor localization, registration of contrast-enhanced CT images against non-contrast-enhanced CT images, and registration of ultrasound and CT.

[0046] Referring now to FIG. 4B, a flow chart is shown illustrating a method involved in registration block 406 as outlined in FIG. 4A, in greater detail. If the use of fiducial touch points (440) is contemplated, the method involves first identifying fiducials on images (block 442), then touching the touch points with a tracked instrument (block 444). Next, the navigation system computes the registration to reference markers (block 446).

[0047] Alternately, registration can also be completed by conducting a surface scan procedure (block 450). The block 450 is presented to show an alternative approach, but may not typically be used when using a fiducial pointer. First, the face is scanned using a 3D scanner (block 452). Next, the face surface is extracted from MR/CT data (block 454). Finally, surfaces are matched to determine registration data points (block 456).

[0048] Upon completion of either the fiducial touch points (440) or surface scan (450) procedures, the data extracted is computed and used to confirm registration at block 408, shown in FIG. 4B.

[0049] Referring back to FIG. 4A, once registration is confirmed (block 408), the patient is draped (block 410). Typically, draping involves covering the patient and surrounding areas with a sterile barrier to create and maintain a sterile field during the surgical procedure. The purpose of draping is to eliminate the passage of microorganisms (e.g., bacteria) between non-sterile and sterile areas. At this point, conventional navigation systems require that the non-sterile patient reference is replaced with a sterile patient reference of identical geometry location and orientation.

[0050] Upon completion of draping (block 410), the patient engagement points are confirmed (block 412) and then the craniotomy is prepared and planned (block 414).

[0051] Upon completion of the preparation and planning of the craniotomy (block 414), the craniotomy is cut and a bone flap is temporarily removed from the skull to access the brain (block 416). Registration data is updated with the navigation system at this point (block 422).

[0052] Next, the engagement within craniotomy and the motion range are confirmed (block 418). Next, the procedure advances to cutting the dura at the engagement points and identifying the sulcus (block 420).

[0053] Thereafter, the cannulation process is initiated (block 424). Cannulation involves inserting a port into the brain, typically along a sulci path as identified at 420, along a trajectory plan. Cannulation is typically an iterative process that involves repeating the steps of aligning the port on engagement and setting the planned trajectory (block 432) and then cannulating to the target depth (block 434) until the complete trajectory plan is executed (block 424).

[0054] Once cannulation is complete, the surgeon then performs resection (block 426) to remove part of the brain and/or tumor of interest. The surgeon then decannulates (block 428) by removing the port and any tracking instruments from the brain. Finally, the surgeon closes the dura and completes the craniotomy (block 430). Some aspects of FIG. 4A are specific to port-based surgery, such as portions of blocks 428, 420, and 434, but the appropriate portions of these blocks may be skipped or suitably modified when performing non-port based surgery.

[0055] When performing a surgical procedure using a medical navigation system 205, as outlined in connection with FIGS. 4A and 4B, the medical navigation system 205 must acquire and maintain a reference of the location of the tools in use as well as the patient in three dimensional (3D) space. In other

words, during a navigated neurosurgery, there needs to be a tracked reference frame that is fixed relative to the patient's skull. During the registration phase of a navigated neurosurgery (e.g., the step 406 shown in FIGS. 4A and 4B), a transformation is calculated that maps the frame of reference of preoperative MRI or CT imagery to the physical space of the surgery, specifically the patient's head. This may be accomplished by the navigation system 205 tracking locations of fiducial markers fixed to the patient's head, relative to the static patient reference frame. The patient reference frame is typically rigidly attached to the head fixation device, such as a Mayfield clamp. Registration is typically performed before the sterile field has been established (e.g., the step 410 shown in FIG. 4A).

[0056] FIG. 5 is a diagram illustrating components of an exemplary surgical system that is similar to FIG. 2. FIG. 5 illustrates a navigation system 205 having an equipment tower 502, tracking system 504, display 506, an intelligent positioning system 508 and tracking markers 510 used to tracked instruments or an access port 12. Tracking system 504 may also be considered an optical tracking device, tracking camera, video camera, 3D scanner, or any other suitable camera or scanner based system. In FIG. 5, a surgeon 201 is performing a tumor resection through a port 12, using an imaging device 512 (e.g., a scope and camera) to view down the port at a sufficient magnification to enable enhanced visibility of the instruments and tissue. The imaging device 512 may be an external scope, videoscope, wide field camera, or an alternate image capturing device. The imaging sensor view is depicted on the visual display 506 which surgeon 201 uses for navigating the port's distal end through the anatomical region of interest.

[0057] An intelligent positioning system 508 comprising an automated arm 514, a lifting column 516 and an end effector 518, is placed in proximity to patient 202. Lifting column 516 is connected to a frame of intelligent positioning system 508. As seen in FIG. 5, the proximal end of automated mechanical arm 514 (further known as automated arm 514 herein) is connected to lifting column 516. In other embodiments, automated arm 514 may be connected to a horizontal beam, which is then either connected to lifting column 516 or directly

to frame of the intelligent positioning system 508. Automated arm 514 may have multiple joints to enable 5, 6 or 7 degrees of freedom.

[0058] End effector 518 is attached to the distal end of automated arm 514. End effector 518 may accommodate a plurality of instruments or tools that may assist surgeon 201 in his procedure. End effector 518 is shown as holding an external scope and camera, however it should be noted that this is merely an example and alternate devices may be used with the end effector 518 such as a wide field camera, microscope and OCT (Optical Coherence Tomography), video camera, 3D scanner, or other imaging instruments. In another example, multiple end effectors may be attached to the distal end of automated arm 518, and thus assist the surgeon 201 in switching between multiple modalities. For example, the surgeon 201 may want the ability to move between microscope, and OCT with stand-off optics. In a further example, the ability to attach a second, more accurate, but smaller range end effector such as a laser based ablation system with micro-control may be contemplated.

[0059] In one example, the intelligent positioning system 508 receives as input the spatial position and pose data of the automated arm 514 and target (for example the port 12) as determined by tracking system 504 by detection of the tracking markers on the wide field camera on port 12. Further, it should be noted that the tracking markers may be used to track both the automated arm 514 as well as the end effector 518 either collectively or independently. It should be noted that a wide field camera 520 is shown in FIG. 5 and that it is connected to the external scope (e.g., imaging device 512) and the two imaging devices together are held by the end effector 518. It should additionally be noted that although these are depicted together for illustration of the diagram that either could be utilized independently of the other, for example where an external video scope can be used independently of the wide field camera 520.

[0060] Intelligent positioning system 508 computes the desired joint positions for automated arm 514 so as to maneuver the end effector 518 mounted on the automated arm's distal end to a predetermined spatial position

and pose relative to the port 12. This redetermined relative spatial position and pose is termed the "Zero Position" where the sensor of imaging device 512 and port 12 are axially aligned.

[0061] Further, the intelligent positioning system 508, optical tracking device 504, automated arm 514, and tracking markers 510 may form a feedback loop. This feedback loop works to keep the distal end of the port 12 (located inside the brain) in constant view and focus of the end effector 518 given that it is an imaging device as the port position may be dynamically manipulated by the surgeon during the procedure. Intelligent positioning system 508 may also include a foot pedal for use by the surgeon 201 to align the end effector 518 (i.e., holding a videoscope) of automated arm 514 with the port 12.

[0062] Referring to FIG. 6, a conventional end effector 518 is shown attached to automated arm 514. The end effector 518 includes a handle 602 and a scope clamp 604. The scope clamp 604 holds imaging device 512. The end effector also has wide field camera 520 attached thereto, which in one example could be a still camera, video camera, or 3D scanner used to monitor muscles of the patient for movement, tremors, or twitching.

[0063] Referring to FIG. 7, a block diagram is shown illustrating an exemplary patient context 700 in an operating room where automatic muscle movement detection may be provided. FIG. 7 shows a medical navigation system 205 that may be used for detecting movement of a subject, such as patient 202. The medical navigation system 205 includes an optical tracking system including a camera 307, a display 311, and a controller 300 (shown in FIG. 3) electrically coupled to the optical tracking system and the display 311. The controller 300 has a processor, such as processor 302 (FIG. 3) coupled to a memory, such as memory 304 (FIG. 3). The controller is configured to receive a data signal from the camera 307 of the optical tracking system and recognize and continuously monitor optical tracking markers 702 on the subject within a field of view of the camera 307 and provide an alert on the display 311 when movement of the optical tracking markers 702 on the subject falls within predefined parameters.

[0064] The predefined parameters may include a muscle movement indicative of a patient event, a muscle twitch indicative of a patient event, a large muscle movement, or a muscle tremor indicative of a patient event. The patient event signifies a physiological state of the patient that is of concern. For example, certain muscle tremors that are observed on a patient might indicate that the patient is about to have a seizure. In another example, certain muscle twitches observed on the face of a patient during a brain surgery might be indicative that the surgeon is making contact with a portion of the brain of the patient where great care should be taken. When a surgeon is performing a procedure on the brain of the patient 202, it is important that the surgeon be aware of the reaction of the patient to the procedure being performed. Muscle twitches or tremors are an important symptom of this reaction that the surgeon should be aware of. The medical navigation system 205 may therefore continuously and/or automatically monitor the patient 202 for muscle tremors or twitches and provide an alert to the surgeon when such a tremor or twitch is detected. In one example, the alert may be provided on the display 311. In other examples, the alert may be provided in the form of an audio alert or a vibratory alert.

[0065] In one example, each of the optical tracking markers 702 on the subject is identifiable by the medical navigation system 205 as unique. The optical tracking markers 702 may take the form of stickers placed on the skin of the patient 202 and could differ from each other by shape, size, reflectivity, and/or color. While three optical tracking markers 702 are shown located on a face of the subject by way of example, any suitable number of optical tracking markers may be used such as two markers, three markers, four markers, five markers, or more. The tracking markers 702 may be located on any suitable body part such as on the face, on the fingers or toes, or even on the chest of the subject, depending which muscles the surgeon wishes to monitor for movement. Further, different types of optical tracking markers may be used such as active optical tracking markers such as light emitting diodes (LEDs) or passive optical tracking markers. The configuration illustrated in FIG. 7 may be particularly

advantageous because no registration of the optical tracking markers 702 on the subject is needed prior to detecting the twitch or tremor and providing the alert.

[0066] In another example, a medical navigation system 205 may be used for detecting movement of a subject, such as patient 202. The medical navigation system 205 may include a video system including a camera, such as a video camera, a display, such as display 311 (FIG. 3), and a controller, such as controller 300 (FIG. 3), electrically coupled to the video system and the display 311. The controller 300 has a processor, such as processor 302 (FIG. 3) coupled to a memory, such as memory 304 (FIG. 3). The controller is configured to receive a data signal from the video camera of the video system and recognize and continuously monitor a portion of the subject within a field of view of the camera and provide an alert on the display 311 when movement of the portion of the subject falls within predefined parameters. The video camera may be mounted in a position similar to that of camera 307. Alternatively, the video camera may be mounted on an end effector, such as end effector 518 that may be attached to intelligent positioning system 508, which may allow the intelligent positioning system 508 to position the video camera in a suitable position for monitoring the appropriate muscles of the patient 202. Intelligent positioning system 508 may also automatically adjust the position of the video camera throughout the medical procedure, either to maintain the appropriate muscles within its field of view or to focus on different muscles when so directed by the surgeon, or both.

[0067] When a video camera is used instead of optical markers and an optical tracking system, the predefined parameters may include a muscle movement indicative of a patient event, a muscle twitch indicative of a patient event, a large muscle movement, or a muscle tremor indicative of a patient event. The patient event signifies a physiological state of the patient that is of concern. For example, certain muscle tremors that are observed on a patient might indicate that the patient is about to have a seizure. In another example, certain muscle twitches observed on the face of a patient during a brain surgery might be indicative that the surgeon is making contact with a portion of the brain of the patient where great care should be taken. When a surgeon is

performing a procedure on the brain of the patient 202, it is important that the surgeon be aware of the reaction of the patient to the procedure being performed. Muscle twitches or tremors are an important symptom of this reaction that the surgeon should be aware of. The medical navigation system 205 may therefore continuously and/or automatically monitor the patient 202 for muscle tremors or twitches and provide an alert to the surgeon when such a tremor or twitch is detected. In one example, the alert may be provided on the display 311. In other examples, the alert may be provided in the form of an audio alert or a vibratory alert.

[0068] In another example, a medical navigation system 205 may be used for detecting movement of a subject, such as patient 202. The medical navigation system 205 may include a three dimensional (3D) scanner system including a 3D scanner, such as 3D scanner 309 (FIG. 3), a display, such as display 311 (FIG. 3), and a controller, such as controller 300 (FIG. 3), electrically coupled to the 3D scanner system and the display 311. The controller 300 has a processor, such as processor 302 (FIG. 3) coupled to a memory, such as memory 304 (FIG. 3). The controller is configured to receive a data signal from the 3D scanner 309 of the 3D scanner system and recognize and continuously monitor a portion of the subject within a field of view of the 3D scanner 309 and provide an alert on the display 311 when movement of the portion of the subject falls within predefined parameters. The 3D scanner 309 may be mounted in a position similar to that of camera 307. Alternatively, the 3D scanner 309 may be mounted on an end effector, such as end effector 518 that may be attached to intelligent positioning system 508, which may allow the intelligent positioning system 508 to position the 3D scanner 309 in a suitable position for monitoring the appropriate muscles of the patient 202. Intelligent positioning system 508 may also automatically adjust the position of the 3D scanner 309 throughout the medical procedure, either to maintain the appropriate muscles within its field of view or to focus on different muscles when so directed by the surgeon, or both.

[0069] When a 3D scanner is used instead of optical markers and an optical tracking system, the predefined parameters may include a muscle

movement indicative of a patient event, a muscle twitch indicative of a patient event, a large muscle movement, or a muscle tremor indicative of a patient event. The patient event signifies a physiological state of the patient that is of concern. For example, certain muscle tremors that are observed on a patient might indicate that the patient is about to have a seizure. In another example, certain muscle twitches observed on the face of a patient during a brain surgery might be indicative that the surgeon is making contact with a portion of the brain of the patient where great care should be taken. When a surgeon is performing a procedure on the brain of the patient 202, it is important that the surgeon be aware of the reaction of the patient to the procedure being performed. Muscle twitches or tremors are an important symptom of this reaction that the surgeon should be aware of. The medical navigation system 205 may therefore continuously and/or automatically monitor the patient 202 for muscle tremors or twitches and provide an alert to the surgeon when such a tremor or twitch is detected. In one example, the alert may be provided on the display 311. In other examples, the alert may be provided in the form of an audio alert or a vibratory alert.

[0070] Referring now to FIG. 8, a flow chart is shown illustrating a method 800 of automatic muscle movement detection that may be implemented by a medical navigation system 205, shown by way of example in the system of FIGS. 2, 3, 5 and/or 7, and as particularly described above in connection with FIG. 7. In one example, the method 800 may be implemented by a controller, such as controller 300 (FIG. 3), which has a processor, such as processor 302 (FIG. 3) coupled to a memory, such as memory 304 (FIG. 3) and a display 311.

[0071] At a first block 802, the controller 300 of the medical navigation system 205 receives a data signal from a camera or scanner. Depending on the particular implementation, the data signal may be provided by an optical tracking system including a camera 307, a video camera, or a 3D scanner system including 3D scanner 309.

[0072] Next, at a block 804, the controller 300 continuously monitors aspects within the field of view of the camera or scanner. Where an optical

tracking system is used, the controller 300 monitors the tracking markers 702, which in one example may each be uniquely identifiable by the system 205 based on different shapes, sizes, reflectivities, or colors, and monitors the distances in between the tracking markers 702 relative to each other. A facial twitch would change the distances between the tracking markers 702, which provides the system 205 with data for analysis. In another example, where a video camera or 3D scanner system is used, the system 205 may monitor facial features, muscle positions, or the positions of appendages or fingers or toes directly.

[0073] Next, at a block 806, the controller 806 checks to see if the predefined parameters have been satisfied. For example, in the case where an optical tracking system is used and the tracking markers 702 are being monitored, the controller 300 may check for changing distances between the tracking markers 702 relative to each other that meet predefined frequency and/or magnitude thresholds that would be indicative of a muscle twitch, tremor, or an impending seizure. In another example, where a video camera or 3D scanner system is used, the controller 300 may monitor facial features, muscle positions, or the positions of appendages or fingers or toes directly and may also check frequency and/or magnitude thresholds of muscle movement that would be indicative of a muscle twitch, tremor, or an impending seizure. If muscle movement, tremors, or twitches are not detected that meet the predefined parameters (e.g., thresholds), then the method 800 returns to the block 804.

[0074] If muscle movement, tremors, or twitches are detected that meet the predefined parameters (e.g., thresholds), then the method 800 continues at the block 808 where an alert is provided to the surgeon. As described above, the alert could be in any suitable form, for example by way of a visual alert on the display 311, or by way of an auditory or vibratory alert.

[0075] Some methods of twitch detection are known to those skilled in the relevant arts. One area that is generally known in the art is the detection of a twitch or facial gesture. A twitch or facial gesture may be detected using

cameras and 3D scanners. Facial movement can be detected and analyzed using software methods and other techniques at a particular facial landmark.

[0076] For example, a facial landmark may include any one of an eye, an eyebrow, a mouth area, a forehead area, lips, cheeks and a nose or any combination thereof. A facial movement may include any one of a blink gesture, a wink gesture, an ocular movement, a smile gesture, a frown gesture, a tongue protrusion gesture, an open mouth gesture, an eyebrow movement, a forehead wrinkle gesture, and a nose wrinkle gesture, or any combination thereof. Suitable methods for detecting facial gestures or movement can be found, for example in US Patent No. 8,457,367, the entirety of which is hereby incorporated by reference.

[0077] As described in connection with the method 800, one method of detecting and differentiating a twitch from other facial movement includes checking frequency and/or magnitude thresholds of muscle movement that could be indicative of a muscle twitch, tremor, or an impending seizure. Another method may include using machine learning and facial analysis software such as ShoreTM, an object and facial recognition engine offered by FraunhoferTM, which trains the system by accessing a stored database of over 10000 annotated faces to provide high recognition rates. A further facial movement detection method may incorporate the use of neural networks, as described by Ma, L. and Khorasani, K., "Facial expression recognition using constructive feedforward neural networks." *IEEE Systems, Man, and Cybernetics, Part B*: Volume: 34, Issue: 3, (June 2004) pp.1588-1595, the entirety of which is hereby incorporated by reference.

[0078] A further exemplary facial movement detection method may be used such as error-correcting output code (ECOC) Classifiers and Platt Scaling, as described by Smith, Raymond S. and Windeatt, Terry, "Facial Expression Detection using Filtered Local Binary Pattern Features with ECOC Classifiers and Platt Scaling" *JMLR: Workshop and Conference Proceedings 11* (2010), pp. 111-118, the entirety of which is hereby incorporated by reference.

[0079] While several examples of movement or twitch detection are provided that may be suitable for use in blocks 804-806 of method 800, any suitable known or yet to be developed method may be used according to the design criteria of a particular application.

[0080] In some examples, the system and method described herein could be used to monitor patients in post-operative states of recovery who are potentially alone in a recovery room and the medical navigation system 205 could, at the block 808, send an alert to a central hospital monitoring system to provide an alert within the hospital or the alert could be sent directly to a health care professional, for example by way of telephone call, text message, email message or other suitable communication to a smart phone or any other communication device. In another example, the system and method described herein could have applications in physiotherapy or in an intensive care unit where such monitoring could be advantageous.

[0081] The specific embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

We Claim:

1. A medical navigation system for detecting movement of a subject, comprising:
 - an optical tracking system including a camera;
 - a display; and
 - a controller electrically coupled to the optical tracking system and the display, the controller having a processor coupled to a memory, the controller configured to:
 - receive a data signal from the optical tracking system and recognize and continuously monitor optical tracking markers on the subject within a field of view of the camera; and
 - provide an alert on the display when movement of the optical tracking markers on the subject falls within predefined parameters,
 - wherein the predefined parameters is indicative of a patient event signifying a physiological state of the patient that is of concern.
2. The medical navigation system according to claim 1, wherein the predefined parameters include at least one of muscle movement indicative of a patient event, a muscle twitch indicative of a patient event, and a muscle tremor indicative of a patient event.
3. The medical navigation system according to claim 1, wherein each of the optical tracking markers on the subject is identifiable by the medical navigation system as unique.
4. The medical navigation system according to claim 1, wherein each of the optical tracking markers is selected from the group consisting of active optical tracking markers and passive optical tracking markers.
5. The medical navigation system according to claim 1, wherein at least three optical tracking markers located on a face of the subject.
6. The medical navigation system according to claim 1, wherein there are at

least three optical tracking markers located on at least one of fingers and toes of the subject.

7. The medical navigation system according to claim 1, wherein the alert is provided regardless of any registration of the optical tracking markers on the subject.

8. A medical navigation system for detecting movement of a subject, comprising:

a video system including a camera;

a display; and

a controller electrically coupled to the video system and the display, the controller having a processor coupled to a memory, the controller configured to: receive a data signal from the video system and recognize and continuously monitor a portion of the subject within a field of view of the camera; and

provide an alert on the display when movement of the portion of the subject falls within predefined parameters,

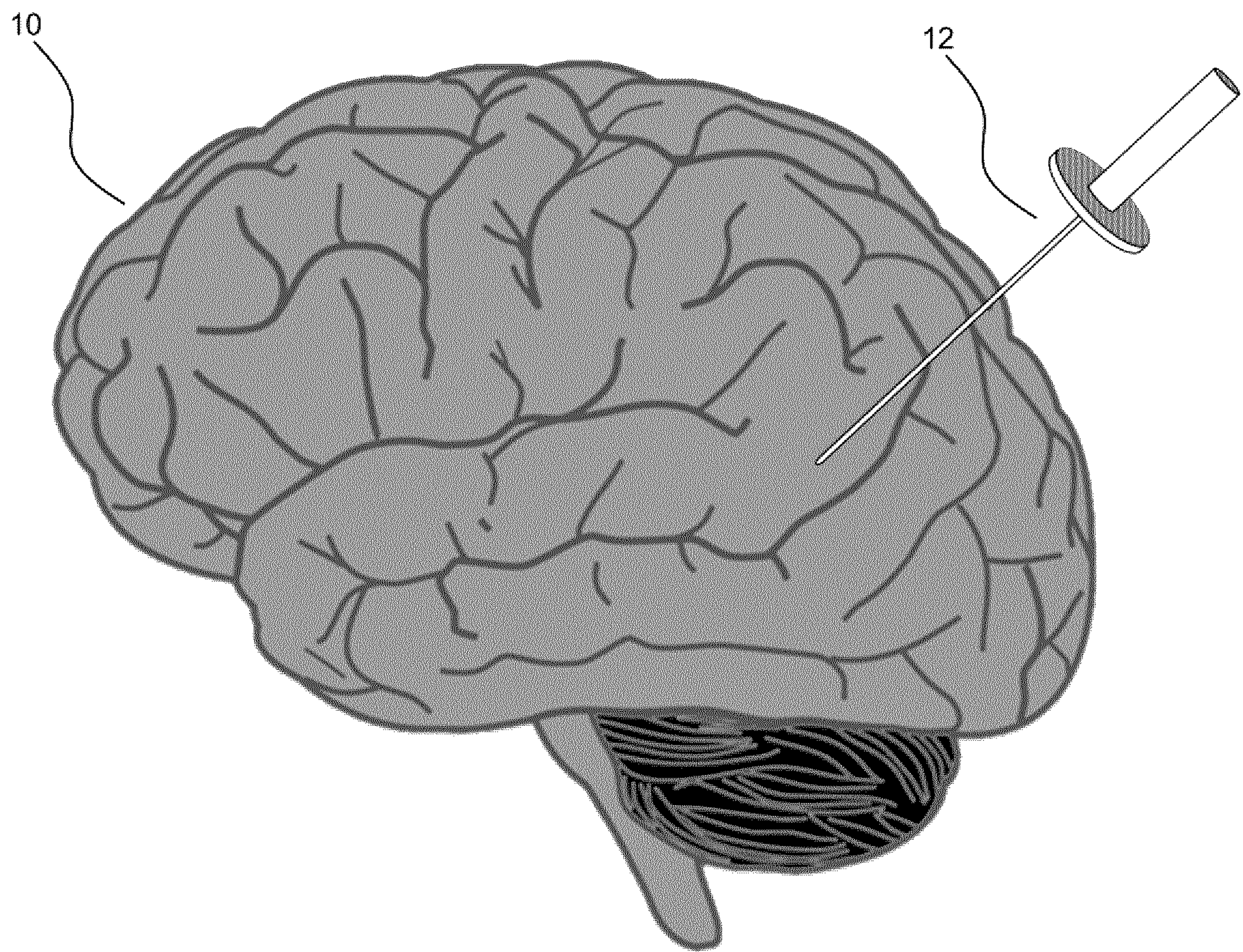
wherein the predefined parameters is indicative of a patient event signifying a physiological state of the patient that is of concern.

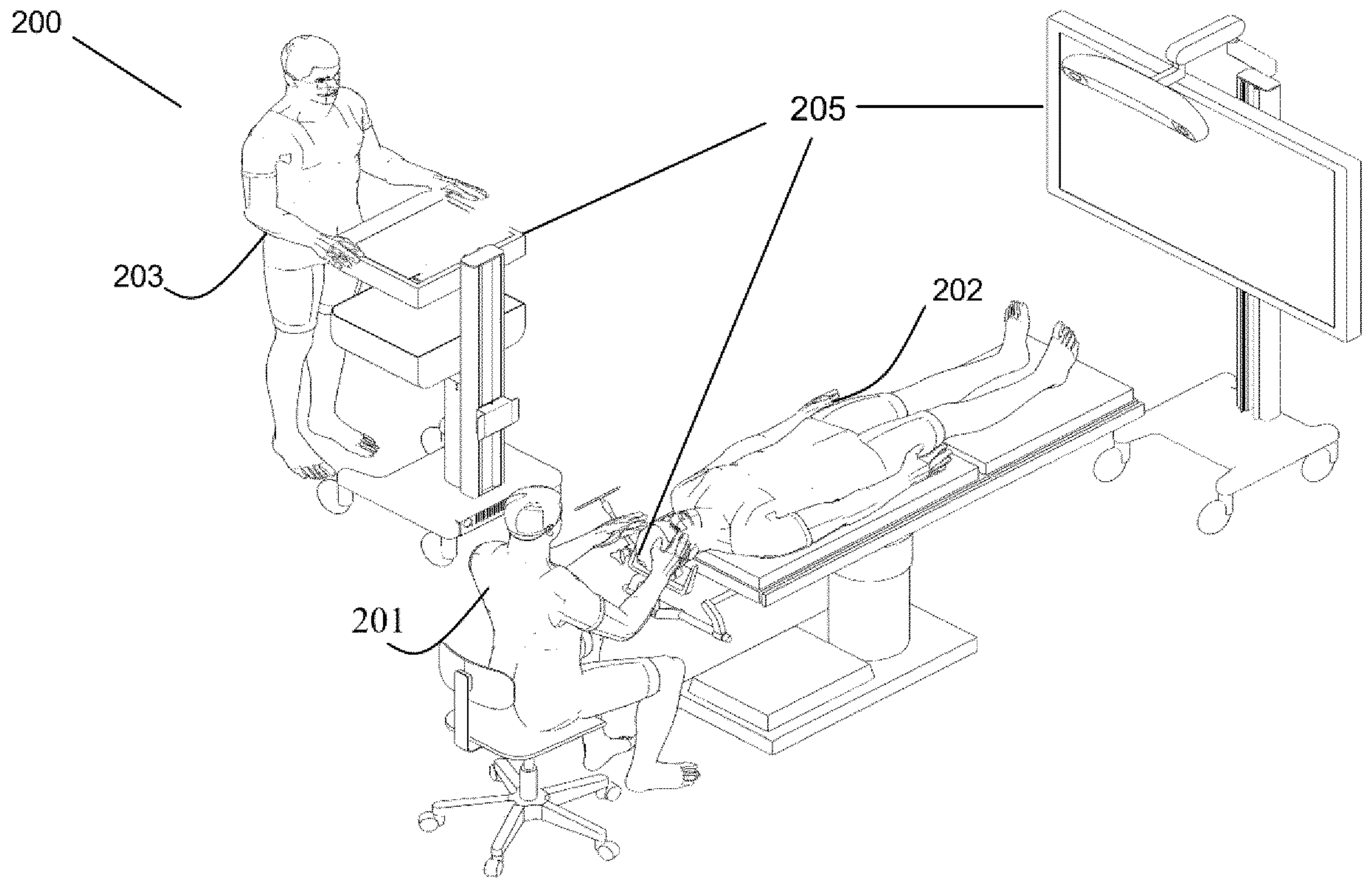
9. The medical navigation system according to claim 8, wherein the predefined parameters include at least one of muscle movement indicative of a patient event, a muscle twitch indicative of a patient event, and a muscle tremor indicative of a patient event.

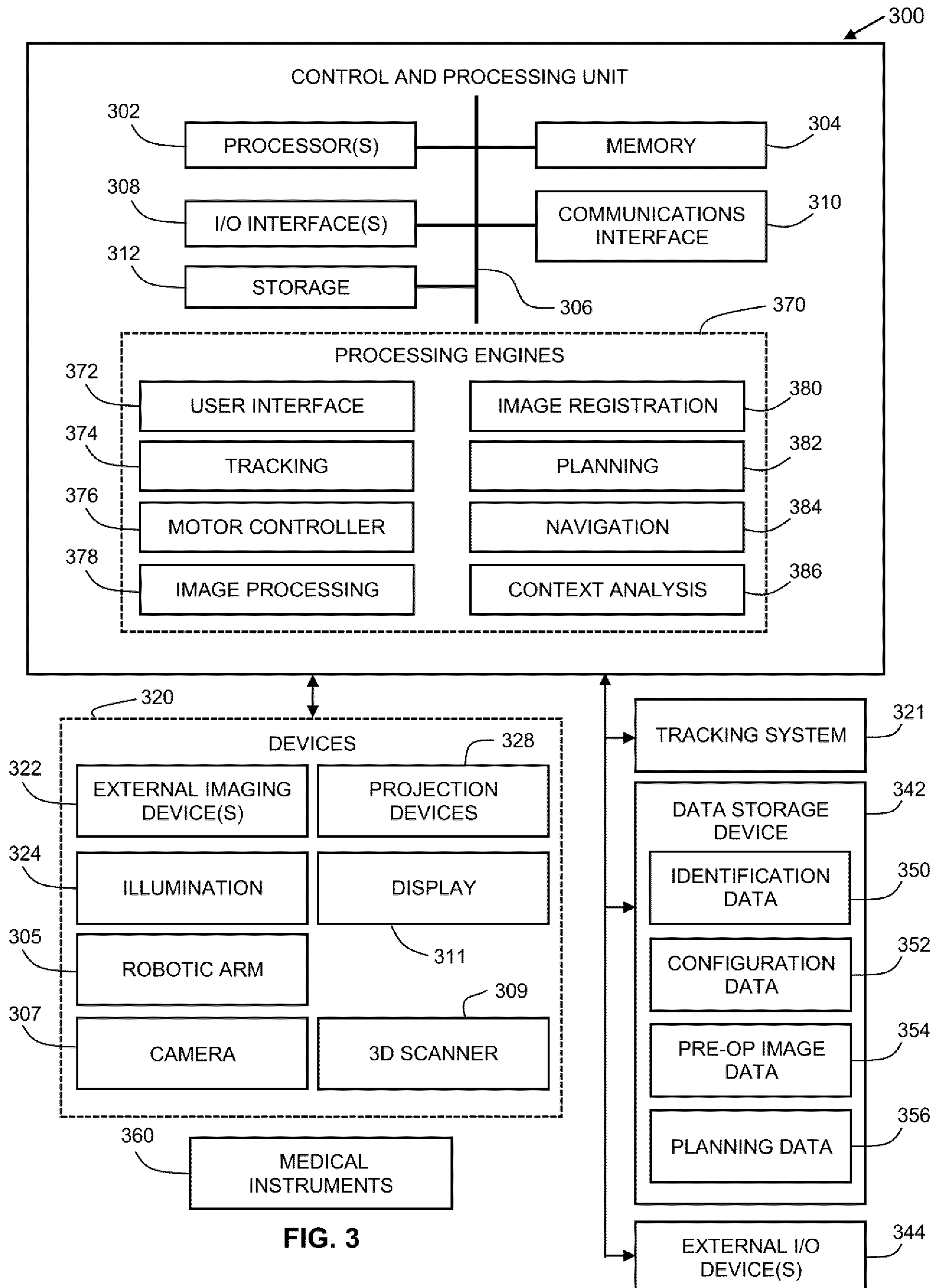
10. The medical navigation system according to claim 8, wherein the movement of portion of the subject includes at least movement of part of a face of the subject.

11. The medical navigation system according to claim 8, wherein the movement of portion of the subject includes at least movement of fingers and toes of the subject.

12. A medical navigation system for detecting movement of a subject, comprising:
- a 3 dimensional (3D) scanner system including a 3D scanner;
 - a display; and
 - a controller electrically coupled to the 3D scanner system and the display, the controller having a processor coupled to a memory, the controller configured to:
 - receive a data signal from the 3D scanner system and recognize and continuously monitor a portion of the subject within a field of view of the 3D scanner; and
 - provide an alert on the display when movement of the portion of the subject falls within predefined parameters,
 - wherein the predefined parameters is indicative of a patient event signifying a physiological state of the patient that is of concern.
13. The medical navigation system according to claim 12, wherein the predefined parameters include at least one of muscle movement indicative of a patient event, a muscle twitch indicative of a patient event, and a muscle tremor indicative of a patient event.
14. The medical navigation system according to claim 12, wherein the movement of a portion of the subject includes at least movement of a part of a face of the subject.
15. The medical navigation system according to claim 12, wherein the movement of a portion of the subject includes movement of fingers and toes of the subject.

**FIG. 1**

**FIG. 2**



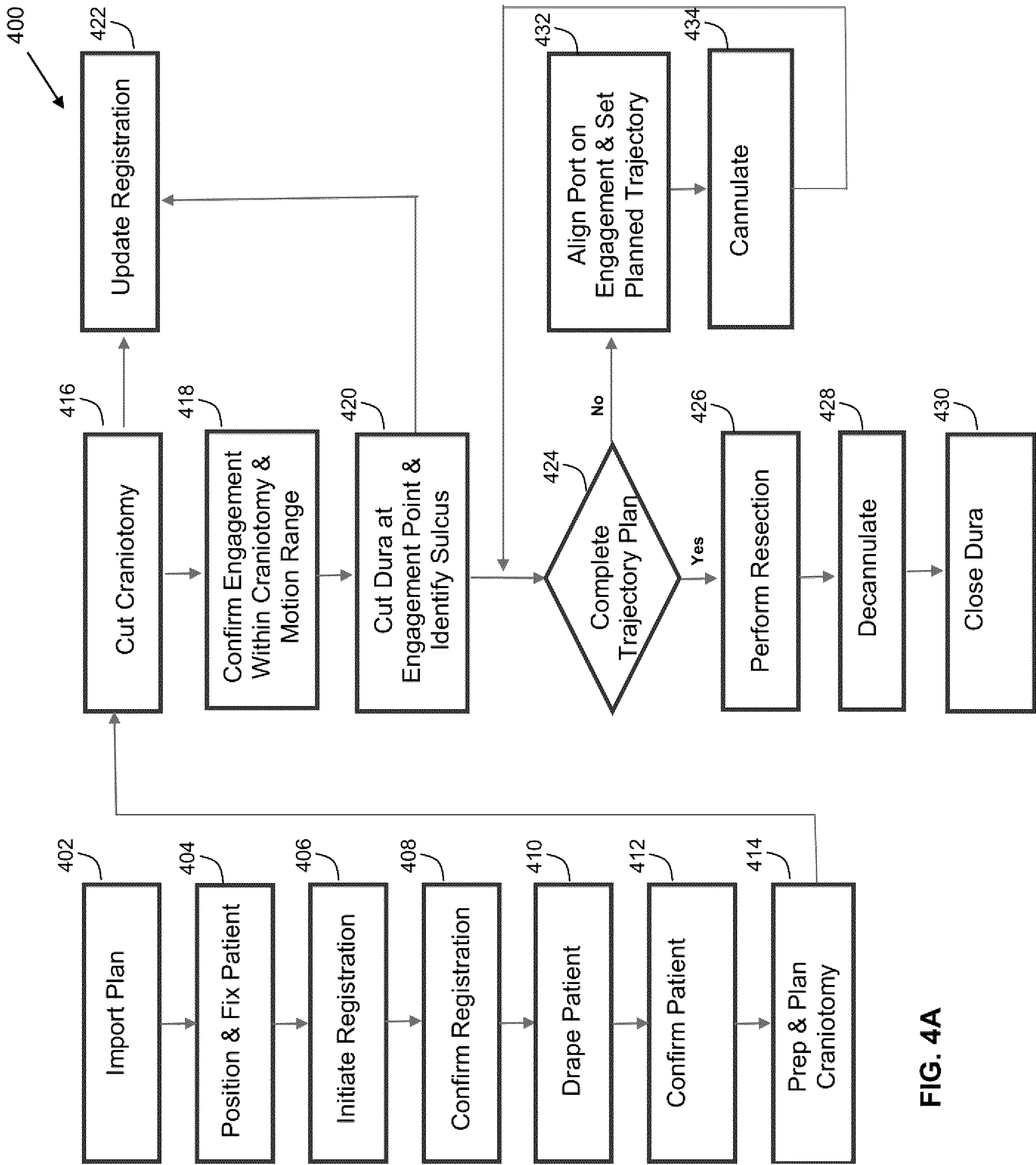


FIG. 4A

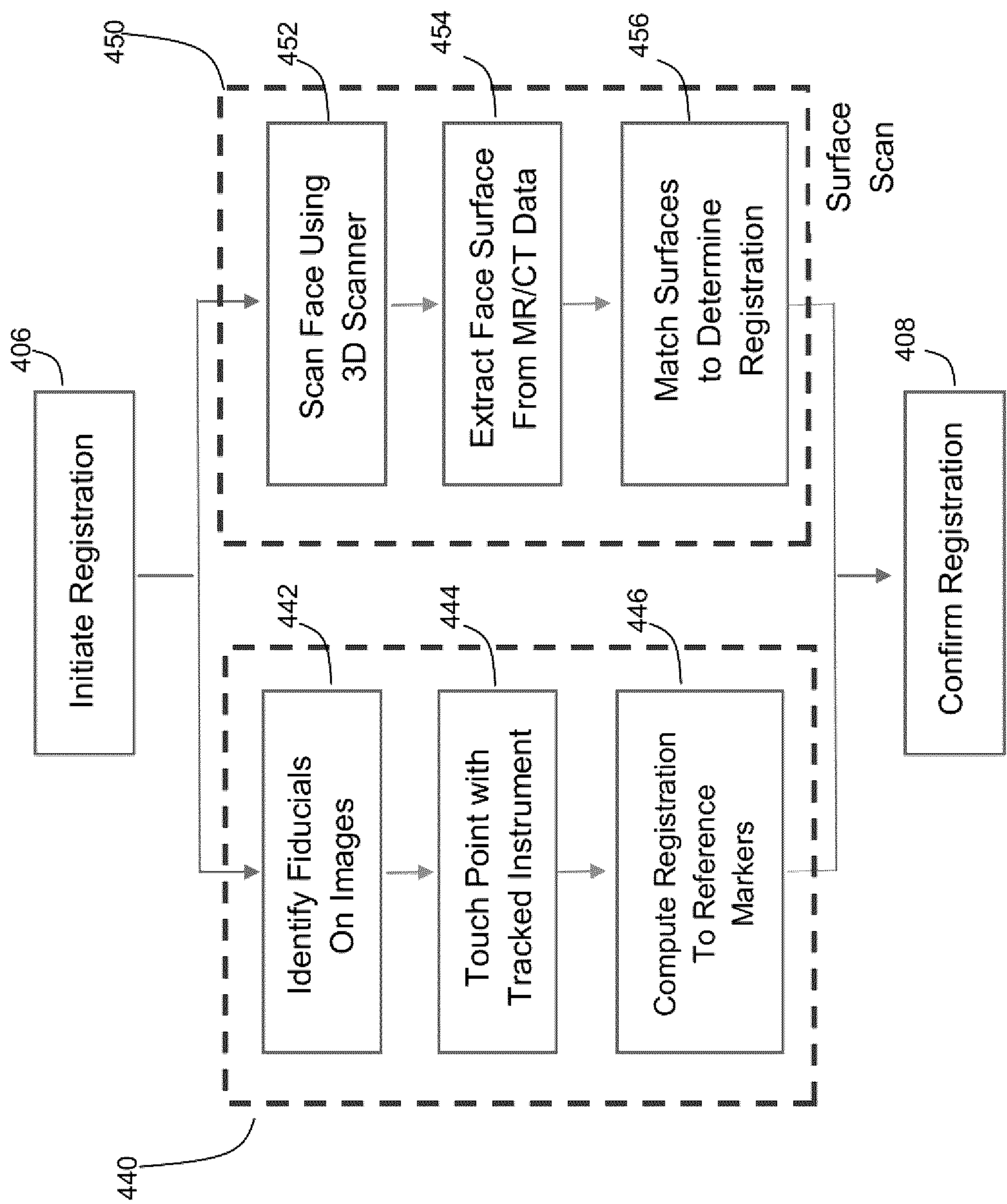


FIG. 4B

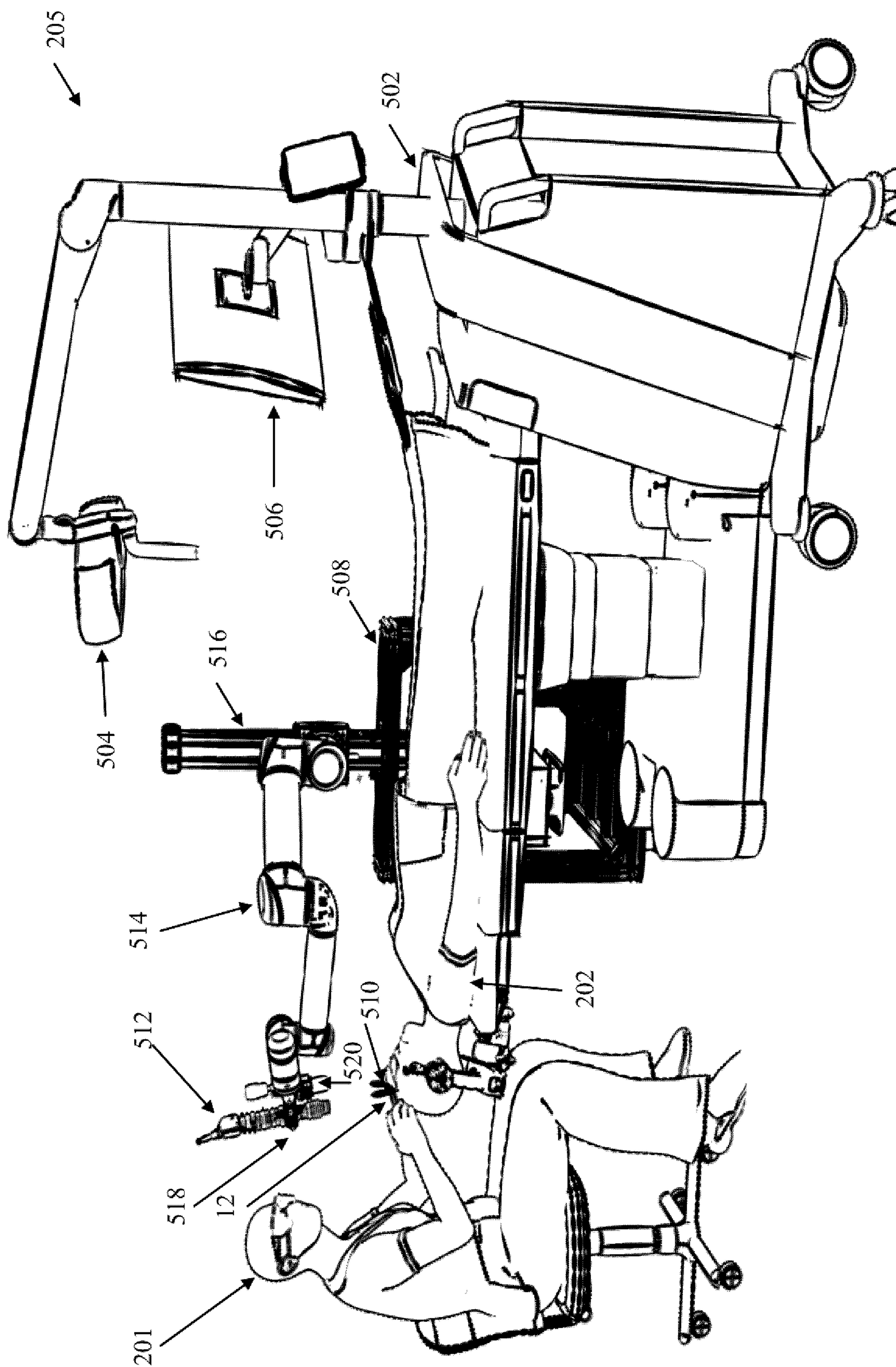


FIG. 5

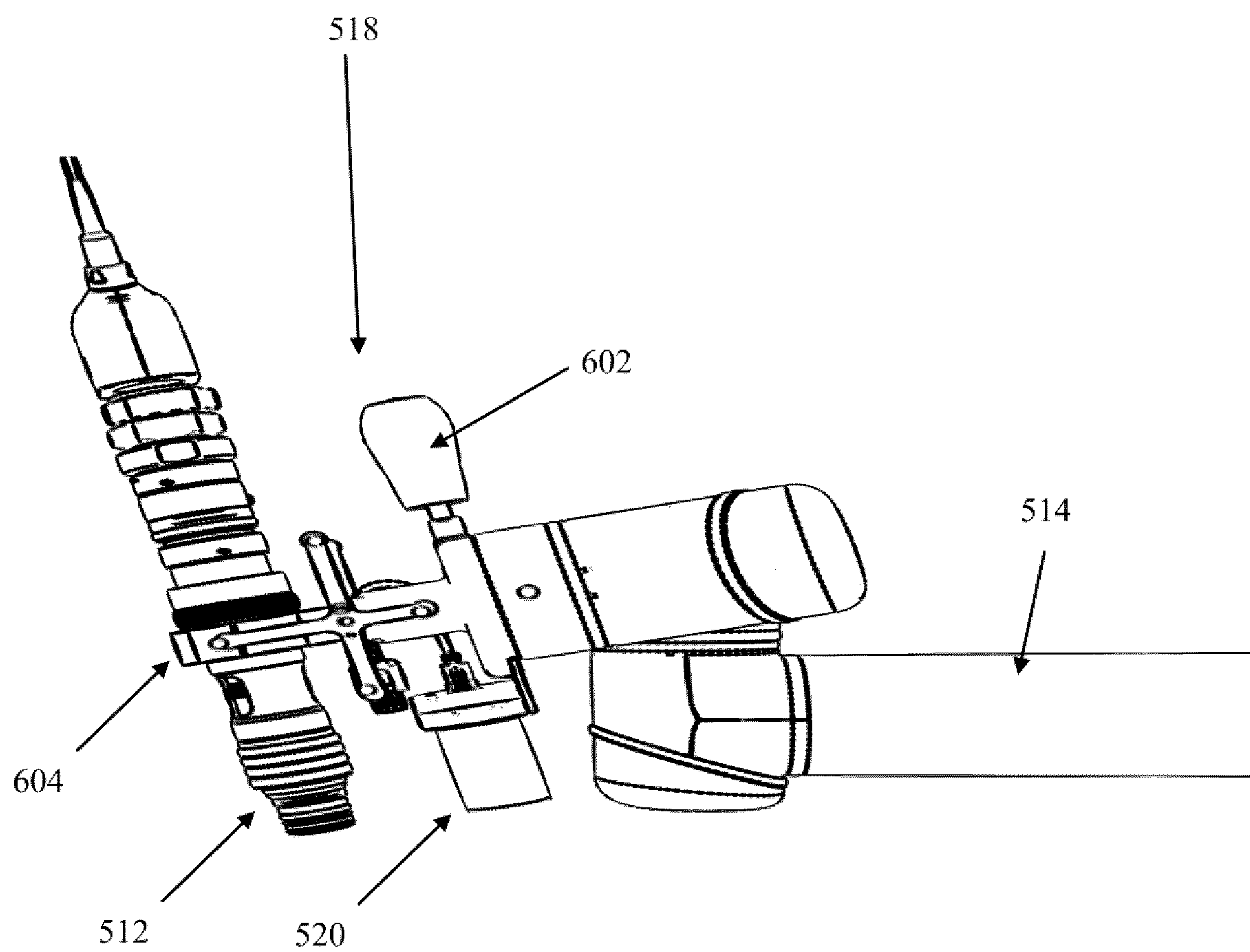


FIG. 6

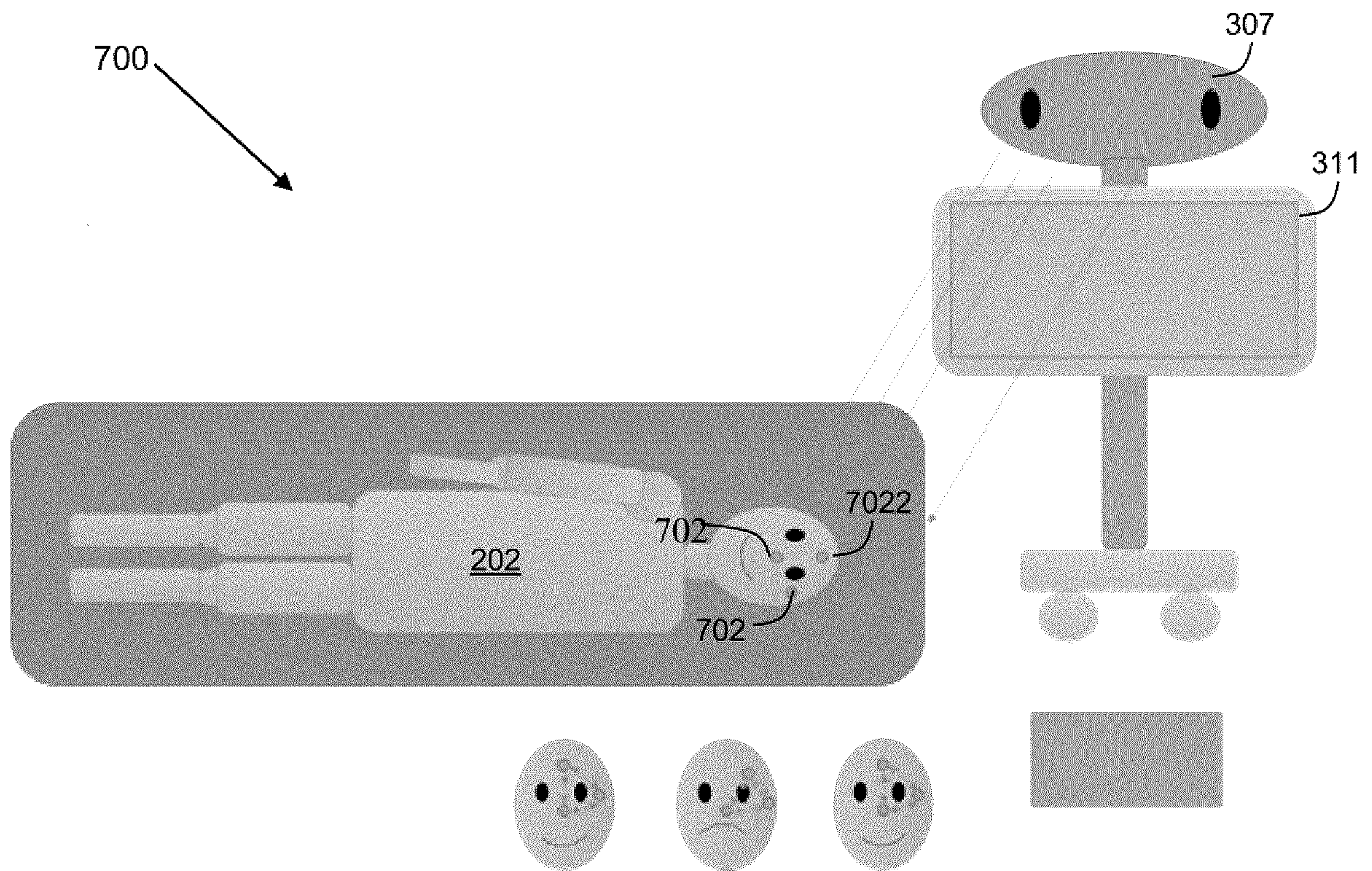
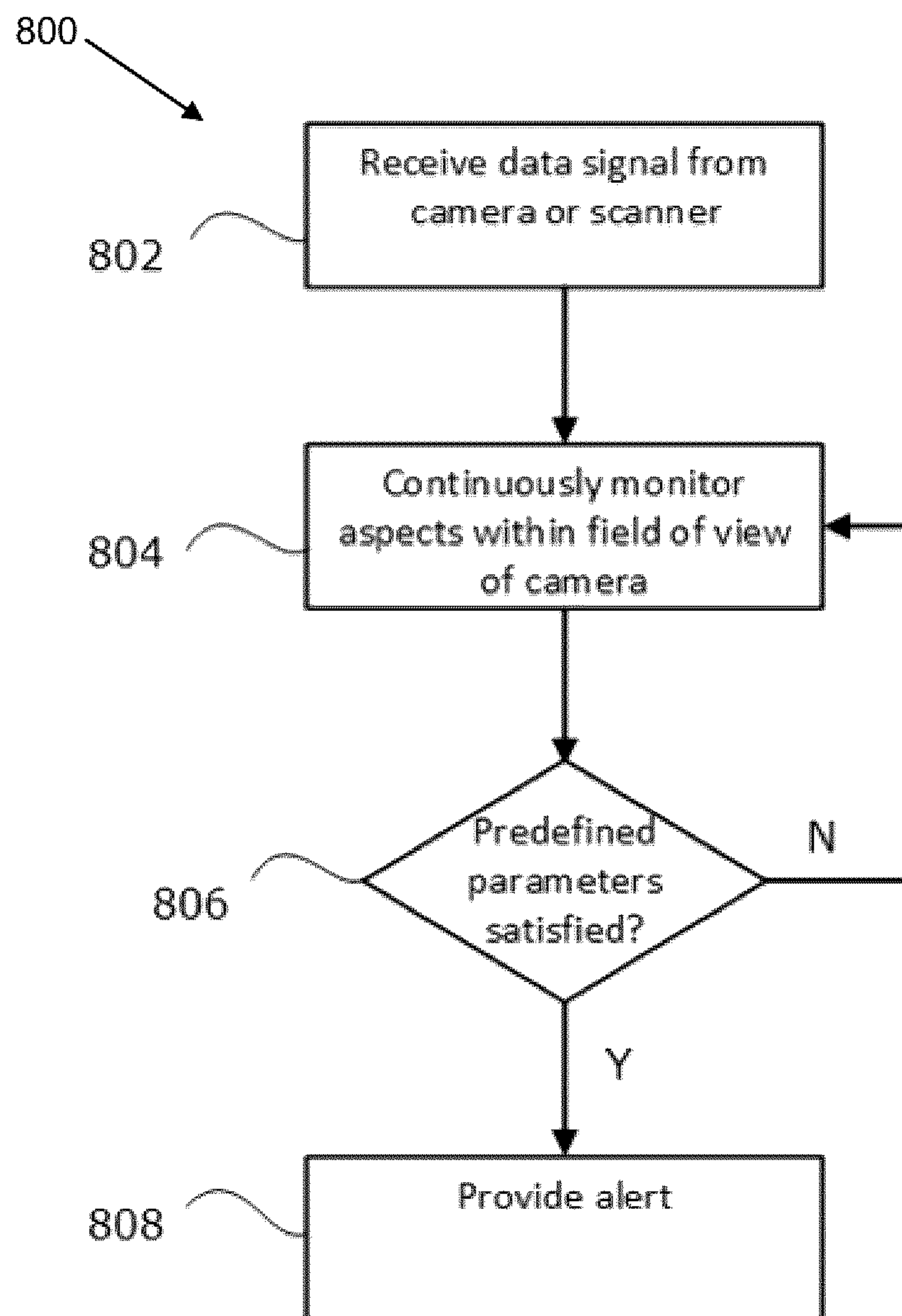


FIG. 7

**FIG. 8**

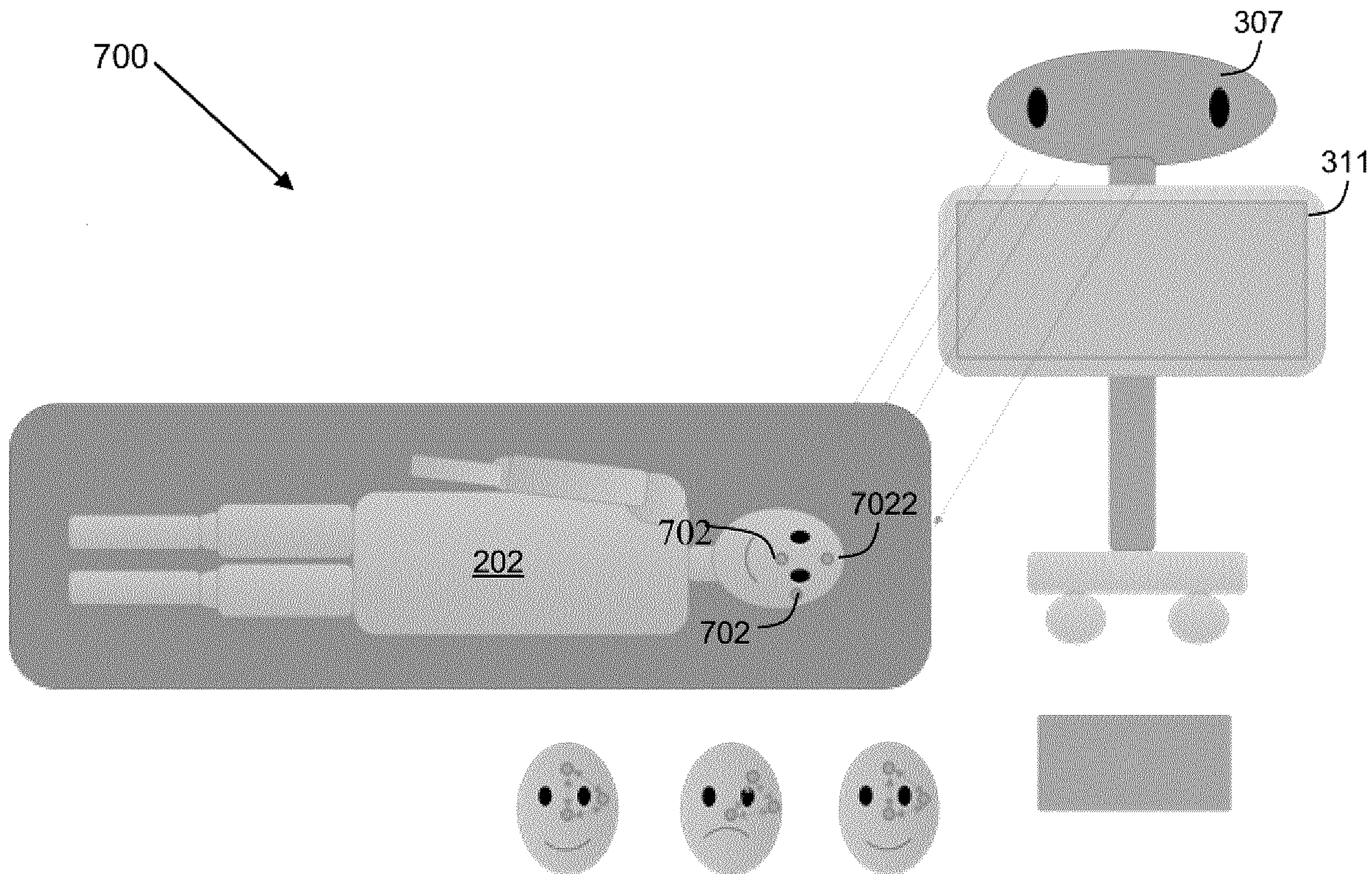


FIG. 7