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(54) Title: SYSTEMS AND METHODS FOR DETECTION OF OBJECTS WITHIN A FIELD OF VIEW OF AN IMAGE CAPTURE DEVICE

(57) Abstract: Robotic surgical systems and methods of operating robotic surgical systems are included. The methods include directing light at an optical element configured to be detected by an image capture device of the robotic surgical system, the optical element configured to reflect light having a wavelength within a predetermined range, detecting, using an image capture device capturing images of the optical element, an absence or a presence of the reflected light from the optical element, and providing a notification, in response to the detection by the image capture device of the absence of the reflected light from the optical element.



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SYSTEMS AND METHODS FOR DETECTION OF OBJECTS WITHIN A FIELD OF VIEW OF AN IMAGE CAPTURE DEVICE

BACKGROUND

[0001] Robotic surgical systems are increasingly being used in minimally invasive medical procedures. Typically, robotic surgical systems include a surgeon console located remote from one or more robotic arms to which surgical instruments and/or cameras are coupled. The surgeon console may be located on another side of the operating room from the robotic arms, in another room, or in another building, and includes input handles or other input devices for receiving inputs from a surgeon. The inputs are communicated to a central controller, which translates the inputs into commands for manipulating the robotic arms in the vicinity of the patient.

[0002] To view a surgical site, the surgeon console may include a stereoscopic display, sometimes referred to as a three-dimensional (3D) display. In some configurations, in conjunction with a corresponding pair of stereoscopic eyeglasses worn by the surgeon, such displays facilitate depth perception in an image by presenting the image to the surgeon as a pair of distinct images separately provided to the left and right eyes, respectively, replicating the effect of the offset between the left and right eyes, which results in a difference in what is seen in the display by each eye. The different images seen in the display by each eye are perceived as differences in the depths of the objects in the images. In other configurations, the stereoscopic display is viewed without the need for eyeglasses.

[0003] The surgeon console may further include a camera positioned to capture images of the surgeon. The captured images may be used to track eye or head position of the surgeon to detect instances in which the surgeon is not looking at the display. In some configurations of the robotic

system, the central controller may generate signals or block generated signals to prevent the movement of instruments, in response to the detected eye or head position of the surgeon.

SUMMARY

[0004] Robotic surgical systems and methods for operating robotic surgical systems are provided. According to an aspect of the present disclosure, the robotic surgical system includes a robotic arm, a surgeon console, a processor, and a memory. The surgeon console includes a light source, an optical element configured to reflect light having a wavelength within a predetermined range, an image capture device configured to detect the light reflected by the optical element, and a notification device configured to provide a notification. The processor is operatively coupled to the robotic arm and in communication with the console. The memory has instructions stored thereon, which when executed by the processor, cause the processor to detect by the image capture device an absence or a presence of the light reflected by the optical element, and cause the notification device to provide the notification, in response to the image capture device detecting the absence of the light reflected by the optical element.

[0005] In another aspect of the present disclosure, the robotic surgical system of includes a wearable device including the optical element.

[0006] In another aspect of the present disclosure, the optical element includes a diffusive/reflective element.

[0007] In another aspect of the present disclosure, the diffusive/reflective element includes a plurality of partitions. In still another aspect of the present disclosure, the optical element includes

a film including a transparency having a reflective element configured to reflect light having a wavelength within the predetermined range.

[0008] In still another aspect of the present disclosure, the optical element includes a film including a transparency having a first diffusive element configured to reflect light having a wavelength within a first predetermined range to permit a first shape to be visually perceived and a second diffusive element configured to reflect light having a wavelength within a second predetermined range to permit a second shape to be visually perceived, and the image capture device is configured to detect the first shape and the second shape, and the notification device is further configured to provide the notification, in response to the image capture device detecting the absence of the first shape.

[0009] In another aspect of the present disclosure, the surgeon console further includes an input handle, and the memory has further instructions stored thereon, which when executed by the processor, cause the processor to generate a signal, in response to a manipulation of the input handle, and disable the input handle, in response to the image capture device detecting the absence of the light reflected by the optical element. In still another aspect of the present disclosure, the memory has further instructions stored thereon, which when executed by the processor, cause the processor to disable the input handle, in response to the image capture device detecting the absence of the light reflected by the optical element for a time period greater than a threshold time period.

[0010] In another aspect of the present disclosure, the memory has further instructions stored thereon, which when executed by the processor, cause the processor to cause the notification device to provide the notification, in response to the image capture device detecting the absence of the light reflected by the optical element for a time period greater than a threshold time period.

[0011] In accordance with another aspect of the present disclosure, a method of operating a robotic surgical system is provided and includes directing light at an optical element configured to be detected by an image capture device of the robotic surgical system, the optical element configured to reflect light having a wavelength within a predetermined range, detecting, using an image capture device capturing images of the optical element, an absence or a presence of the reflected light from the optical element, and providing a notification, in response to the detection by the image capture device of the absence of the reflected light from the optical element.

[0012] In another aspect of the present disclosure, the optical element is disposed on a wearable device.

[0013] In another aspect of the present disclosure, the optical element includes a diffusive/reflective element.

[0014] In another aspect of the present disclosure, the diffusive/reflective element includes a plurality of partitions.

[0015] In another aspect of the present disclosure, the optical element includes a film including a transparency having a reflective element configured to reflect light having a wavelength within the predetermined range.

[0016] In another aspect of the present disclosure, the optical element includes a film including a transparency having a first diffusive element configured to reflect light having a wavelength within a first predetermined range to permit a first shape to be visually perceived and a second diffusive element configured to reflect light having a wavelength within a second predetermined range to permit a second shape to be visually perceived, and the method further includes detecting

an absence or presence of the first shape and the second shape, using the image capture device, and providing the notification, in response to the image capture device detecting the absence of the first shape.

[0017] In another aspect of the present disclosure, the method further includes generating a signal, in response to a manipulation of an input handle of the robotic surgical system, and disabling the input handle, in response to the image capture device detecting the absence of the light reflected by the optical element.

[0018] In another aspect of the present disclosure, the method further includes disabling the input handle, in response to the image capture device detecting the absence of the light reflected by the optical element for a time period greater than a threshold time period.

[0019] In another aspect of the present disclosure, the method further includes causing the notification device to provide the notification, in response to the image capture device detecting the absence of the light reflected by the optical element for a time period greater than a threshold time period.

[0020] Further details and aspects of exemplary embodiments of the present disclosure are described in more detail below with reference to the appended figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Embodiments of the present disclosure are described herein with reference to the accompanying drawings, wherein:

[0022] FIG. 1 is a schematic illustration of a robotic surgical system, in accordance with the present disclosure;

[0023] FIG. 2 is a perspective view of a portion of a display system for implementation into the robotic surgical system of FIG. 1, in accordance with the present disclosure;

[0024] FIG. 3 is a simplified view of a marker and an image capture device for use in robotic surgical system of FIG. 1, in accordance with an embodiment;

[0025] FIG. 4 is a simplified view of a marker and an image capture device for use in robotic surgical system of FIG. 1, in accordance with another embodiment;

[0026] FIG. 5 is a simplified view of a marker and an image capture device for use in robotic surgical system of FIG. 1, in accordance with still another embodiment;

[0027] FIG. 6 is a simplified view of a marker on a headset and an image capture device for use in robotic surgical system of FIG. 1, in accordance with an embodiment;

[0028] FIG. 7 is functional block diagram of the robotic surgical system, in accordance with the present disclosure;

[0029] FIG. 8 is a flow diagram of a method for determining positions of a surgeon relative to a display device of the robotic surgical system, in accordance with the present disclosure; and

[0030] FIG. 9 is a flow diagram of another method for determining the position of a surgeon relative to a display device of the robotic surgical system, in accordance with the present disclosure.

DETAILED DESCRIPTION

[0031] The present disclosure employs optical elements or markers and cameras or image capture devices to determine a position of an object or a person. As will be described in greater detail below, when the markers are detected by the camera or image capture devices, the locations of the detected markers are used to calculate the position of the object or person. Embodiments of the present disclosure are now described in detail with reference to the drawings in which like reference numerals designate identical or corresponding elements in each of the several views. As used herein, the term “clinician” refers to a doctor, a nurse, or any other care provider and may include support personnel. Throughout this description, the term “proximal” refers to the portion of the device or component thereof that is farthest from the patient and the term “distal” refers to the portion of the device or component thereof that is closest to the patient.

[0032] With reference to FIG. 1, a robotic surgical system 10 is provided, which is configured for use on a patient “P” lying on an operating table “T” for the performance of a minimally invasive surgical operation. In accordance with an embodiment, the robotic surgical system 10 generally includes a plurality of robotic arms 12 configured to receive commands from a controller 30 for manipulating one or more of the robotic arms 12 in response to an input received at a remotely-located surgeon console 40.

[0033] Each of the robotic arms 12 is made up of a plurality of members connected through joints coupled to and extending from a base 18. Each base 18 provides different locations from

which each robotic arm 12 extends. For example, the base 18 may be made up of a plurality of movable carts. In another embodiment, all of the robotic arms 12 extend from a single base. In an embodiment, connected to a distal end of each robotic arm 12 is a surgical assembly 14, which includes a surgical instrument holder 16 that is configured to removably couple with a surgical instrument 20. Each robotic arm 12 may include a surgical instrument 20 configured for a different purpose. For example, one robotic arm 12 may include a surgical instrument including a grasping jaw instrument 20, while another robotic arm 12 may include a surgical instrument including scissors. Other suitable instruments 20a, 20b include, but are not limited to, staplers, clip applicators, suture passers, spatulas, and the like.

[0034] Although four robotic arms 12 are depicted, the surgical system 10 may include fewer or more than four robotic arms 12. In this regard, the additional robotic arms (not shown) are likewise connected to the controller 30 and are telemanipulatable via the console 40. Accordingly, one or more additional surgical assemblies 14, surgical instrument holders 16, and/or surgical instruments 20a, 20b may also be attached to the additional robotic arms. In another embodiment, one or more of the robotic arms 12 includes an image capture device 66 positioned over the surgical site “S”, an image capture device 66 disposed in the surgical site “S” (not shown) or the like. The image capture devices 66 capture visual images, infra-red images, ultrasound images, X-ray images, thermal images, and/or any other known real-time images of the surgical site “S”. In still another embodiment, one or more of the image capture devices 66 are not attached to the robotic arms 12 and are placed at predetermined locations around the operating room. In any case, the image capture devices 66 transmit captured imaging data to the controller 30 which creates images of the surgical site “S” and/or the operating room in real-time from the imaging data and transmits

the images to the display device 44 for display. In another embodiment, the displayed images are two-dimensional renderings of the data captured by the image capture devices.

[0035] The robotic arms 12 may be driven by electric drives (not shown) that are connected to the controller 30. According to an embodiment, the controller 30 is configured to activate drives, for example, via a computer program, such that the robotic arms 12 and the surgical assemblies 14, surgical instrument holders 16, and/or surgical instruments 20a, 20b corresponding to the robotic arms 12, execute a desired movement received through the console 40. The controller 30 may also be configured to regulate movement of the robotic arms 12 and/or of the drives.

[0036] The controller 30 may control a plurality of motors 32 with each motor configured to drive a pushing or a pulling of one or more cables, such as cables (not shown) coupled to the surgical instrument 20. In use, as these cables are pushed and/or pulled, the one or more cables effect operation and/or movement of the surgical instruments 20a, 20b. The controller 30 coordinates the activation of the various motors 32 to coordinate a pushing or a pulling motion of one or more cables in order to coordinate an operation and/or movement of one or more surgical instrument 20. In an embodiment, each motor 32 is configured to actuate a drive rod or a lever arm to effect operation and/or movement of surgical instruments 20a, 20b in addition to, or instead of one or more cables.

[0037] The controller 30 includes any suitable logic control circuit adapted to perform calculations and/or operate according to a set of instructions. The controller 30 can be configured to communicate with a remote system (not shown) either via a wireless (e.g., Wi-Fi, Bluetooth, LTE, etc.) and/or wired connection. The remote system can include data, instructions and/or information related to the various components, algorithms, and/or operations of console 40. The

remote system can include any suitable electronic service, database, platform, cloud, or the like. The controller 30 may include a central processing unit operably connected to memory 34. The memory may include transitory type memory (e.g., RAM) and/or non-transitory type memory (e.g., flash media, disk media, etc.). In some embodiments, the memory is part of, and/or operably coupled to, the remote system.

[0038] The controller 30 can include a plurality of inputs and outputs for interfacing with the components of the console 40, such as through a driver circuit. The controller 30 can be configured to receive input signals and/or generate output signals to control one or more of the various components (e.g., one or more motors and/or the display device 44) of the console 40. The output signals can include, and/or can be based upon, algorithmic instructions which may be pre-programmed and/or input by a user. The controller 30 can be configured to accept a plurality of user inputs from a user interface (e.g., switches, buttons, touch screen, etc. of operating the console 40) which may be coupled remote to the system 10.

[0039] The memory 34 can be directly and/or indirectly coupled to the controller 30 to store instructions and/or databases including pre-operative data from living being(s) and/or anatomical atlas(es). The memory 34 can be part of, and/or or operatively coupled to, the remote system 10.

[0040] To provide the input to the controller 30, the surgeon console 40 includes various input devices. In an embodiment, the surgeon console 40 includes input handles 70 or input pedals configured to be manipulated by the surgeon through actuation. In particular, the surgeon uses his or her hands to grip and move the input handles 70 and the movement of the input handles 70 are translated via the controller 30 to thereby provide a corresponding movement to the robotic arms

12 and/or surgical instruments 20a, 20b. The surgeon steps on the input pedals to provide a selection to provide further controls of the robotic arms 12 or the surgical instruments 20a, 20b.

[0041] The display device 44 is set up to display two- or three-dimensional images received from the image capture devices 66. In an embodiment in which three-dimensional images are provided, the display device 44 is configured to provide the three-dimensional images for viewing either with or without specialized viewing lenses provided, for example, in the form of a head set 50, such as one configured as glasses or another suitable configuration.

[0042] The head set 50 includes markers 64 disposed thereon. In an embodiment, the detection of the markers 64 indicates that the eyes of the surgeon wearing the head set 50 are directed at the display device 44. The markers 64 on the head set 50 may be configured in a similar manner to those included on the surgical assemblies 14, surgical instrument holders 16, surgical instruments 20a, 20b, and/or the distal end of the robotic arm 12. According to an embodiment, the one or more markers 64 are placed at specific locations on the head set 50 such that detection of the markers 64 indicates that the surgeon's head is positioned in a particular manner, for example, looking forward at the display device 44. To detect the markers 64, the surgeon console 40 includes an image capture device 48 mounted to the display device 44 or at another location to allow the image capture device 48 to be directed at the surgeon during system operation. The image capture device 48 may include one or more filters 52, such as a band pass optical filter, for the detection of the markers 64, in an embodiment.

[0043] FIG. 2 is a perspective view of a portion of a display system for implementation into the robotic surgical system 10, showing an example arrangement of the display device 44, the head set 50, a light source 54, the image capture device 48, and audio devices 68, in accordance with

various embodiments herein. In an embodiment, the display device 44 includes a screen 70 and one or more layers 72 disposed in front of the screen 70. The screen 70 includes pixels that direct visual content displayed by certain pixels to certain eyes of the surgeon by way of the one or more layers 72. In particular, the one or more layers 72 may include a lenticular lens layer. For example, the lenticular lens layer includes a plurality of vertical lenses disposed over corresponding pixel rows configured to be directed at an angle suitable to permit the visual content of a first set of pixels to be perceived by a first eye of the surgeon and a second set of pixels to be perceived by a second eye of the surgeon.

[0044] A light source 54 is configured to provide light and may be mounted along an edge of the display device 44 (as illustrated in FIG. 1) or positioned adjacent, above or below the display device 44. The light source 54 may provide light in the visible and/or invisible spectrum (such as ultraviolet, infrared or the like) to be reflected by markers 64, which may be included at predetermined locations on the head set 50. The markers 64 may be optical elements including mechanisms to permit the visibility of reflected light when viewed at an angle that is within a predetermined range of angles, in accordance with an embodiment, for detection by the image capture device 48. In an embodiment, the display system is configured such that a notification is provided audibly, for example, by the audio devices 68, tactilely or visually via the display device 44, if the markers 64 are not detected.

[0045] As illustrated in FIG. 3, the marker 64 is made up of a reflective element 300 and a diffusive element 302. The reflective element 300 may include a mirror, and the diffusive element 302 may be a tube-shaped element having a rectangular cross-sectional shape, to permit limiting the visibility of the marker 64 by the image capture device 48 by restricting the light reflected by

the reflective element 300. Specifically, travel of the reflected light may be restricted horizontally by a first angle β and vertically by a second angle α . Although depicted as having a rectangular cross-sectional shape, the tube-shaped element may have a different cross section shape. In another embodiment, as illustrated in FIG. 4, the marker 64 includes a reflective element 400 and a diffusive element 402, which includes a plurality of tube-shaped elements having rectangular cross-sectional shapes. The tube-shaped elements are substantially identical to each other extending in the same direction and cooperate to limit the light reflected by the reflective element 400 to allow the marker 64 to be detected by the image capture device 48.

[0046] In accordance with another embodiment, the markers 64 may be optical elements including mechanisms to permit the visibility of reflected light when viewed at an angle that is within a predetermined range of angles, for example, as depicted in FIG. 5. Here, the marker 64 has a reflective element 500 and a diffusive element 502, where the diffusive element 502 is in the form of a film with a transparency configured to limit viewing of the marker 64 to the predetermined range of angles. In an embodiment, the diffusive element 502 is configured to allow light directed within a range relative to the reflective element 500 to reflect (for example, a range of viewing angles including an angle substantially perpendicular to the reflective element 500) and to thereby be visible to the image capture device 48. Light directed at the diffusive element 502 at an angle that is outside of the range of viewing angles is not reflected by the reflective element 500 and hence, is not visible to the image capture device 48.

[0047] In another embodiment, as depicted in FIG. 6, the markers 64 are configured to reflect light within a particular range of wavelengths (for example, visible or invisible). In such an embodiment, the image capture device 48 includes a bandpass optical filter 52 selected to

correspond to the particular range of wavelengths of the markers 64. Thus, the image capture device 48 detects the markers 64 when the wavelength of light reflected from the markers 64 passes through the bandpass optical filter 52 thereby permitting the image capture device 48 to view the markers 64. The markers 64 are illustrated as being disposed on a head set 50 in the form of a pair of eyeglasses, in this embodiment. It will be appreciated that the markers 64 alternatively may be included on a headband or other wearable or may be stickers that are placed on various locations of the user's face or head.

[0048] FIG. 7 is simplified block diagram of the robotic surgical system 10 of FIG. 1. The robotic surgical system 10 includes a controller 720, a tower 730, and a console 740. The controller 720 is configured to communicate with the tower 730 to thereby provide instructions for operation, in response to input received from the console 740.

[0049] The controller 720 generally includes a processing unit 722, a memory 724, a tower interface 726, and a console interface 728. The processing unit 722, in particular by means of a computer program stored in the memory 724, functions in such a way to cause components of the tower 730 to execute a desired movement according to a movement defined by input devices 742 of the console 740. In this regard, the processing unit 722 includes any suitable logic control circuit adapted to perform calculations and/or operate according to a set of instructions. The processing unit 722 may include one or more processing devices, such as a microprocessor-type of processing device or other physical device capable of executing instructions stored in the memory 724 and/or processing data. The memory 724 may include transitory type memory (e.g., RAM) and/or non-transitory type memory (e.g., flash media, disk media, etc.). The tower interface 726 and console interface 728 communicate with the tower 730 and console 740, respectively,

either wirelessly (e.g., Wi-Fi, Bluetooth, LTE, etc.) and/or via wired configurations. Although depicted as separate modules, the interfaces 732, 734 may be a single component in other embodiments.

[0050] The tower 730 includes a communications interface 732 configured to receive communications and/or data from the tower interface 726 for manipulating motor mechanisms 734 to thereby move robotic arms 736a-736d. In accordance with an embodiment, the motor mechanisms 734 are configured to, in response to instructions from the processing unit 722, receive an application of current for mechanical manipulation of cables (not shown) which are attached to the robotic arms 736a-736d to cause a desired movement of a selected one of the robotic arms 736a-736d and/or an instrument coupled to one of the robotic arms 736a-736d. The tower 730 also includes an image capture device 738, which captures real-time images and transmits data representing the images to the controller 730 via the communications interface 732.

[0051] To aid the surgeon in manipulating the devices of the tower 730, the console 740 has an input device 742, a display 746, a computer 748, and a camera 750. The input device 742 is coupled to the computer 748 and is used by the clinician to provide an input. In this regard, the input device 742 may be a handle or pedal, or other computer accessory, such as a keyboard, joystick, mouse, button, trackball or other component. The computer 748 includes a processing unit and memory, which includes data, instructions and/or information related to the various components, algorithms, and/or operations of the tower 730 and can operate using any suitable electronic service, database, platform, cloud, or the like. The display 746 receives instructions from the computer 748 to display information received from the image capture device 738 and/or

from the communications interface 732. The camera 750 captures images of the surgeon at the console 740.

[0052] The markers 64 described briefly above are useful for implementing various positioning and safety mechanisms. In an example, during surgery, it may be advantageous for the system 10 to be aware of the positioning of the surgeon relative to the display device 44. Turning now to FIG. 8, a flow diagram of a method 800 is provided for determining the positioning of the surgeon relative to the display device 44 of the robotic surgical system 10, in accordance with an embodiment. The method 800 may be implemented, at least in part, by the processing unit 722 executing instructions stored in the memory 724 (FIG. 7). Additionally, the particular sequence of steps shown in the method 800 of FIG. 8 is provided by way of example and not limitation. The steps of the method 800 may be executed in sequences other than the sequence shown in FIG. 8 without departing from the scope of the present disclosure. Further, some steps shown in the method 800 of FIG. 8 may be concurrently executed instead of sequentially executed.

[0053] With reference to FIG. 8, light from the light source 54 is directed toward the markers 64 at step 802. As noted above, the markers 64 are disposed on the surgeon's head or face, for example, on the head set 50. Thus, depending on the positioning of the surgeon's head or face, the markers 64 may or may not reflect the light from the light source 54. For example, in an embodiment, a plurality of the markers 64 are included on the head set 50 at specific locations such that detection of all of the markers 64 indicates that the surgeon's eyes are directed at the display device 44. In another embodiment, the marker or markers 64 at least partially cover the head set 50 to form a specific shape, and detection of the specific shape indicates that the surgeon's eyes are directed at the display device 44.

[0054] In any case, to determine whether the one or more markers 64 are detected, the image capture device 48 captures images of the surgeon at step 804. Based on the images from step 804, a determination is made as to whether all of the markers 64, whether they be a plurality of the markers 64 disposed at the specific locations or one or more markers 64 forming a specific shape, are detected at step 806. If the markers 64 are detected, the method 800 iterates a step 804 to capture additional images of the surgeon using the image capture device 48. If all of the markers 64 are not detected, a notification is provided by the system 10 at step 808 indicating that the surgeon's eyes are not directed at the display device 44. The notification may be provided after a time period threshold has been surpassed, in an embodiment. For example, the notification may begin after the markers 64 are undetected for a period, such as 1 second, 3 seconds, and the like. The time period may be longer or shorter in other embodiments. In an example, the system 10 may provide an audible notification, via audio devices 68, a tactile notification and/or a visual notification. In accordance with an embodiment, in addition to providing the notification, the system 10 prevents inputs from being received at the input handles 70 or other input devices, such as pedals (if included).

[0055] In another example of using the markers 64, in order to provide additional control of the robotic arms 12, the system 10 is configured to further prevent unintended movement by using one or more markers on the head set 50 worn by the surgeon to determine whether the surgeon's eyes are directed at the display device 44. In this regard, the system 10 is configured to capture image data including the head set 50 (on which the one or more markers 64 are disposed) via the camera 48 and to detect the markers 64 within the captured image data. Turning now to FIG. 9 is, a flow diagram of a method 900 of determining a position of the surgeon's head relative to the display device 44 is provided, in accordance with an embodiment. The method 900 may be

implemented, at least in part, by the processing unit 722 executing instructions stored in the memory 724 (FIG. 7). Additionally, the particular sequence of steps shown in the method 900 of FIG. 9 is provided by way of example and not limitation. The steps of the method 900 may be executed in sequences other than the sequence shown in FIG. 9 without departing from the scope of the present disclosure. Further, some steps shown in the method 900 of FIG. 9 may be concurrently executed instead of sequentially executed.

[0056] In an embodiment, images of the surgeon are captured by the camera 48 at step 902. A determination is then made as to whether one or more of the markers 64 are detected in the captured images, at step 904. In an embodiment, the camera 48 is configured to detect whether the marker(s) 64 are within its field of view and positioned at a particular angle or location relative thereto. The detection of the markers 64 indicates that the eyes of the surgeon wearing the head set 50 on which the markers 64 are disposed are directed at the display device 44. In an embodiment, the markers 64 include diffusive and/or reflective material, and the camera 48 includes a corresponding filter 52 to allow visual perception of the marker 64 only when the marker 64 is presented at a certain angle. The markers 64 include those types in which the visibility of an optical target is restricted by walls or partitions thereby permitting the optical target to be visually perceived only when viewed at the certain angles. In another example, the markers 64 are constructed from a front surface mirror covered with an engineered transparency film limited to a specific range of angles within which light will be reflected. In another example, the markers 64 include a reflective material covered with an engineered diffuser to limit visibility of the markers 64 to specific angles in horizontal and/or vertical planes, such as those sold by ThorLabs of Newton, New Jersey. Thus, when the head set 50 worn by the surgeon is tilted at an angle permitting the light reflected off of

the markers 64 and filtered through the filter 52 on the camera 48 to be visible to the camera 48, the markers 64 are then detected. Otherwise, the markers 64 are not detected.

[0057] If a determination is made that the marker(s) 64 on the head set 50 are not detected, the system 10 disables movement of the robotic arms 12 and instruments 20a, 20b at step 906. In an example, inputs received from the input handles 70 are not communicated to the robotic arms 12 or instruments 20a, 20b. For example, when the surgeon actuates or moves the input handles 70, either signals are not generated or, if generated, the signals are not communicated to the robotic arms 12 and/or instruments 20a, 20b. In this way, when the surgeon is not looking at the display device 44, the system 10 is prevented from allowing operations which may affect the patient “P.” The disabling may occur after a time period threshold has been surpassed, in an embodiment. For example, the disabling may begin after the markers 64 are undetected for a period, such as 1 second, 3 seconds, and the like. The time period may be longer or shorter in other embodiments. Optionally, a notification is provided at step 908, either on the display device 44, audibly or tactilely to indicate that the surgeon should re-position his or her head to re-enable the functions of the robotic arms 12 and/or instruments 20a, 20b. If a determination is made that the markers 64 are not detected within the field of view of the camera 48, the systems 10 permits operation of the robotic arms 12 and instruments 20a, 20b as usual and iterates at step 902 to capture additional images.

[0058] In accordance with an embodiment, the disabling and enabling of the movement of the robotic arms 12 and/or instruments 20a, 20b depends on whether one of the markers 64 is detected. In another embodiment, the disabling and enabling of the movement of the robotic arms 12 and/or instruments 20a, 20b depends on whether all of the markers 64 included in a set of markers 64 on the head set 50 is detected.

[0059] The systems described herein may also utilize one or more controllers to receive various information and transform the received information to generate an output. The controller may include any type of computing device, computational circuit, or any type of processor or processing circuit capable of executing a series of instructions that are stored in a memory. The controller may include multiple processors and/or multicore central processing units (CPUs) and may include any type of processor, such as a microprocessor, digital signal processor, microcontroller, or the like. The controller may also include a memory to store data and/or algorithms to perform a series of instructions.

[0060] Any of the herein described methods, programs, algorithms or codes may be converted to, or expressed in, a programming language or computer program. A “Programming Language” and “Computer Program” includes any language used to specify instructions to a computer, and includes (but is not limited to) these languages and their derivatives: Assembler, Basic, Batch files, BCPL, C, C+, C++, Delphi, Fortran, Java, JavaScript, Machine code, operating system command languages, Pascal, Perl, PL1, scripting languages, Visual Basic, metalanguages which themselves specify programs, and all first, second, third, fourth, and fifth generation computer languages. Also included are database and other data schemas, and any other meta-languages. No distinction is made between languages which are interpreted, compiled, or use both compiled and interpreted approaches. No distinction is also made between compiled and source versions of a program. Thus, reference to a program, where the programming language could exist in more than one state (such as source, compiled, object, or linked) is a reference to any and all such states. Reference to a program may encompass the actual instructions and/or the intent of those instructions.

[0061] Any of the herein described methods, programs, algorithms or codes may be contained on one or more machine-readable media or memory. The term “memory” may include a

mechanism that provides (e.g., stores and/or transmits) information in a form readable by a machine such a processor, computer, or a digital processing device. For example, a memory may include a read only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, flash memory devices, or any other volatile or non-volatile memory storage device. Code or instructions contained thereon can be represented by carrier wave signals, infrared signals, digital signals, and by other like signals.

[0062] While several embodiments of the disclosure have been shown in the drawings, it is not intended that the disclosure be limited thereto, as it is intended that the disclosure be as broad in scope as the art will allow and that the specification be read likewise. Any combination of the above embodiments is also envisioned and is within the scope of the appended claims. Therefore, the above description should not be construed as limiting, but merely as exemplifications of particular embodiments. Those skilled in the art will envision other modifications within the scope of the claims appended hereto.

WHAT IS CLAIMED IS:

1. A robotic surgical system comprising:
 - a robotic arm;
 - a surgeon console including:
 - a light source,
 - an optical element configured to reflect light having a wavelength within a predetermined range,
 - an image capture device configured to detect the light reflected by the optical element, and
 - a notification device configured to provide a notification;
 - a processor operatively coupled to the robotic arm and in communication with the console; and
 - a memory having instructions stored thereon, which when executed by the processor, cause the processor to:
 - detect by the image capture device an absence or a presence of the light reflected by the optical element, and
 - cause the notification device to provide the notification, in response to the image capture device detecting the absence of the light reflected by the optical element.
2. The robotic surgical system of claim 1, further comprising a wearable device including the optical element.

3. The robotic surgical system of claim 2, wherein the optical element includes a diffusive/reflective element.
4. The robotic surgical system of claim 3, wherein the diffusive/reflective element includes a plurality of partitions.
5. The robotic surgical system of claim 3, wherein the optical element includes a film including a transparency having a reflective element configured to reflect light having a wavelength within the predetermined range.
6. The robotic surgical system of claim 3, wherein:
the optical element includes a film including a transparency having a first diffusive element configured to reflect light having a wavelength within a first predetermined range to permit a first shape to be visually perceived and a second diffusive element configured to reflect light having a wavelength within a second predetermined range to permit a second shape to be visually perceived, and
the image capture device is configured to detect the first shape and the second shape, and the notification device is further configured to provide the notification, in response to the image capture device detecting the absence of the first shape.
7. The robotic surgical system of claim 1, wherein:
the surgeon console further includes an input handle, and

the memory has further instructions stored thereon, which when executed by the processor, cause the processor to:

generate a signal, in response to a manipulation of the input handle, and
disable the input handle, in response to the image capture device detecting the absence of the light reflected by the optical element.

8. The robotic surgical system of claim 7, wherein the memory has further instructions stored thereon, which when executed by the processor, cause the processor to:

disable the input handle, in response to the image capture device detecting the absence of the light reflected by the optical element for a time period greater than a threshold time period.

9. The robotic surgical system of claim 1, wherein the memory has further instructions stored thereon, which when executed by the processor, cause the processor to:

cause the notification device to provide the notification, in response to the image capture device detecting the absence of the light reflected by the optical element for a time period greater than a threshold time period.

10. A method of operating a robotic surgical system, the method comprising:

directing light at an optical element configured to be detected by an image capture device of the robotic surgical system, the optical element configured to reflect light having a wavelength within a predetermined range;

detecting, using an image capture device capturing images of the optical element, an absence or a presence of the reflected light from the optical element; and

providing a notification, in response to the detection by the image capture device of the absence of the reflected light from the optical element.

11. The method of claim 8, wherein the optical element is disposed on a wearable device.

12. The method of claim 8, wherein the optical element includes a diffusive/reflective element.

13. The method of claim 12, wherein the diffusive/reflective element includes a plurality of partitions.

14. The method of claim 12, wherein the optical element includes a film including a transparency having a reflective element configured to reflect light having a wavelength within the predetermined range.

15. The method of claim 12, wherein the optical element includes a film including a transparency having a first diffusive element configured to reflect light having a wavelength within a first predetermined range to permit a first shape to be visually perceived and a second diffusive element configured to reflect light having a wavelength within a second predetermined range to permit a second shape to be visually perceived, and the method further comprises:

detecting an absence or presence of the first shape and the second shape, using the image capture device; and

providing the notification, in response to the image capture device detecting the absence of the first shape.

16. The method of claim 10, further comprising:

generating a signal, in response to a manipulation of an input handle of the robotic surgical system; and

disabling the input handle, in response to the image capture device detecting the absence of the light reflected by the optical element.

17. The method of claim 16, further comprising:

disabling the input handle, in response to the image capture device detecting the absence of the light reflected by the optical element for a time period greater than a threshold time period.

18. The method of claim 10, further comprising:

causing the notification device to provide the notification, in response to the image capture device detecting the absence of the light reflected by the optical element for a time period greater than a threshold time period.

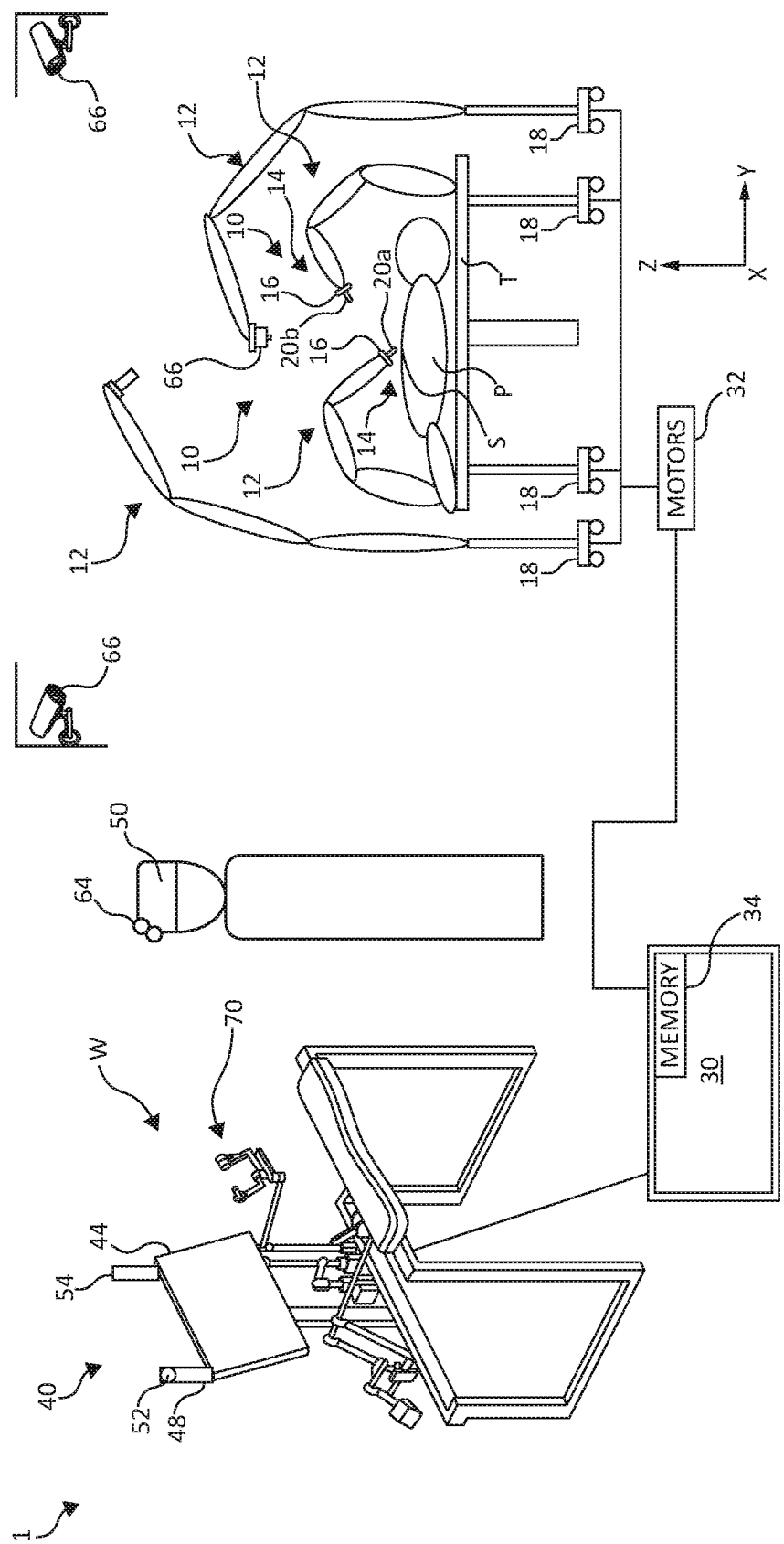


FIG. 1

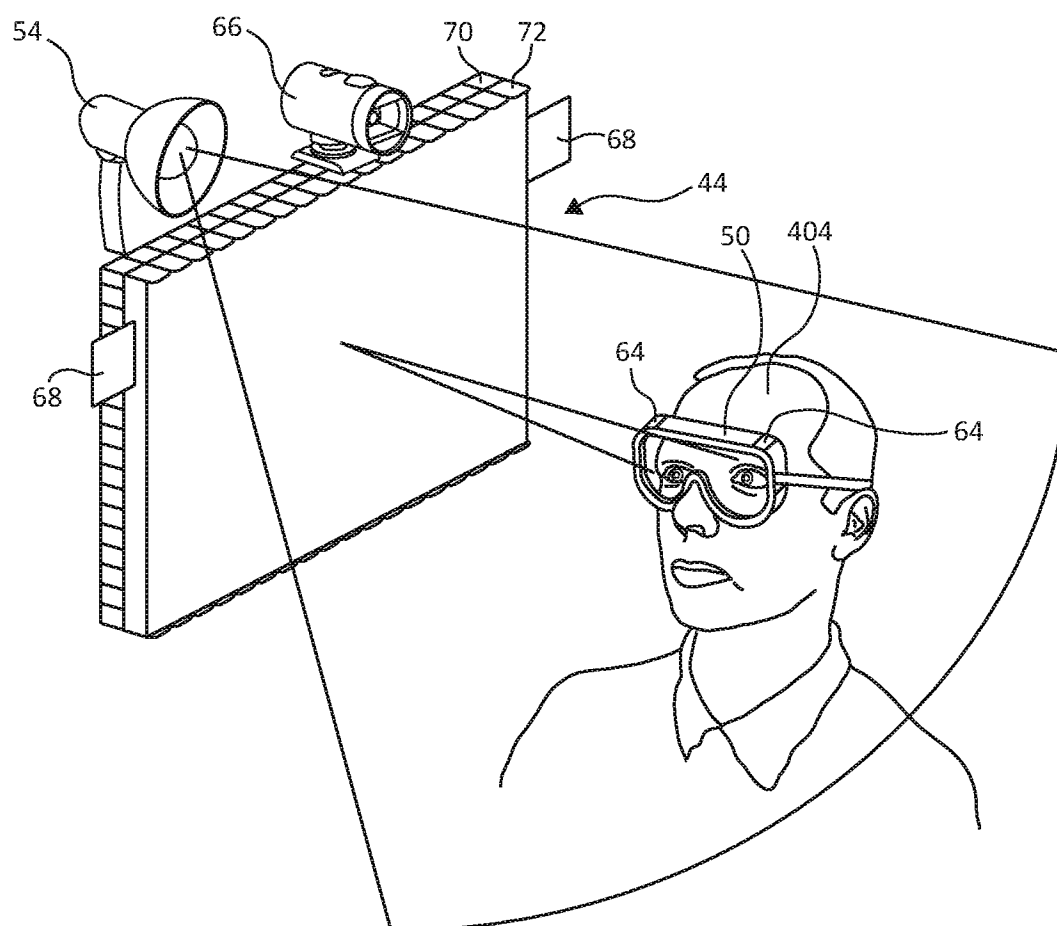


FIG. 2

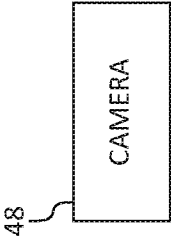


FIG. 3

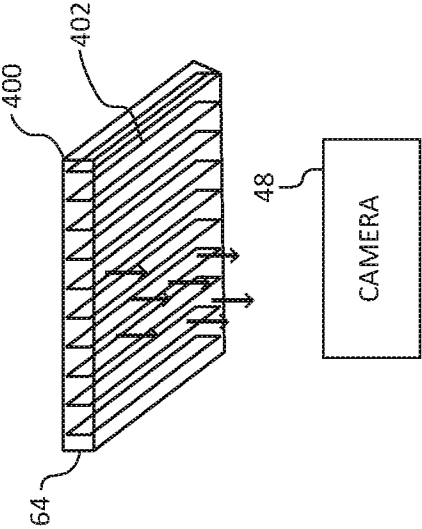


FIG. 4

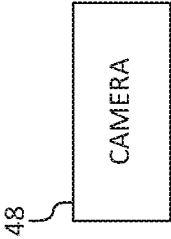
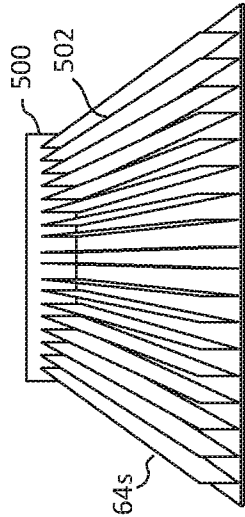


FIG. 5

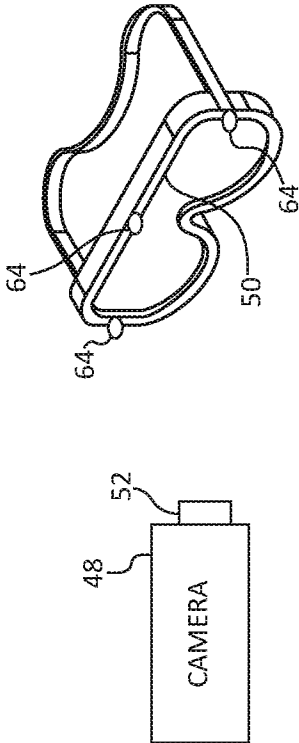


FIG. 6

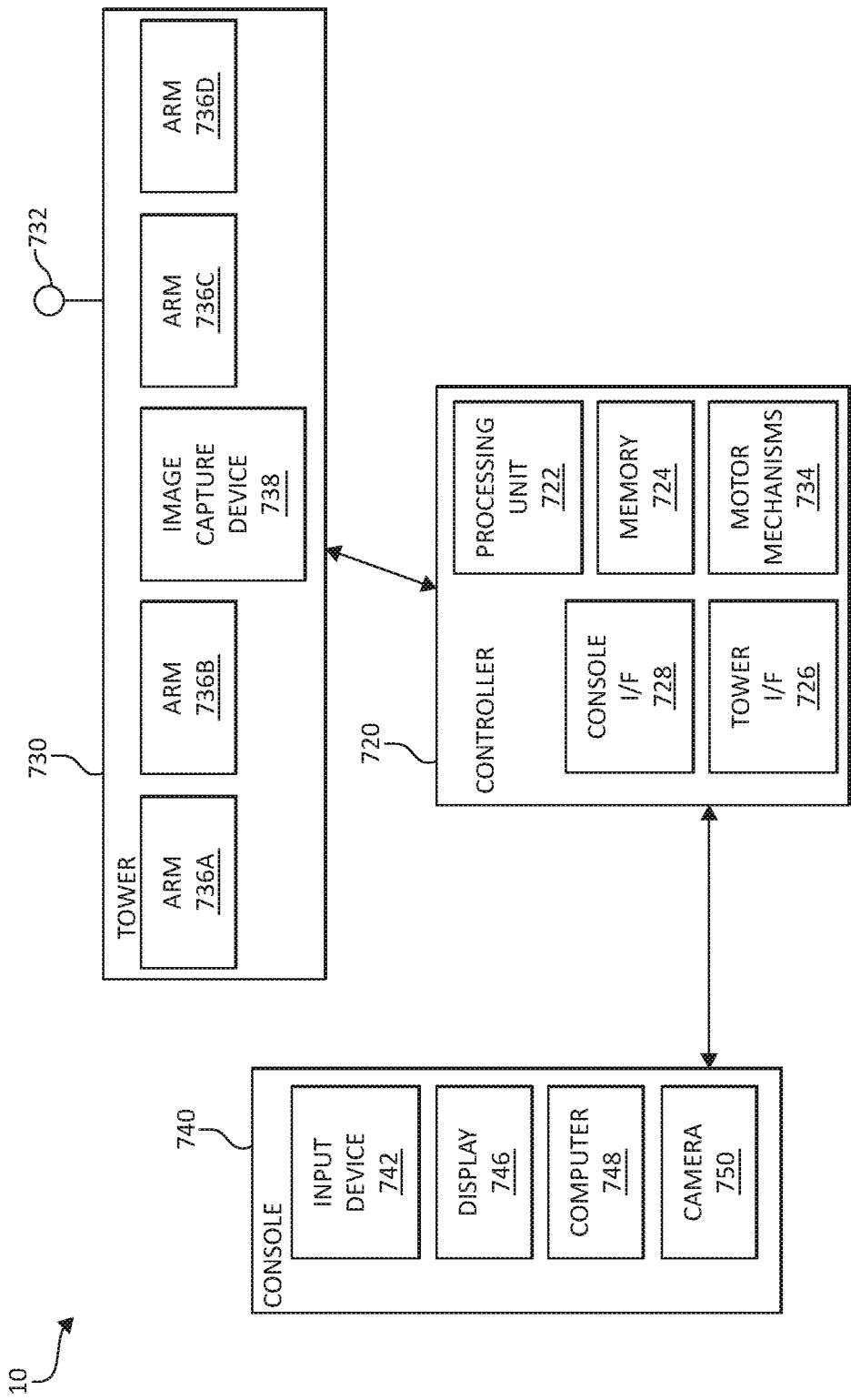
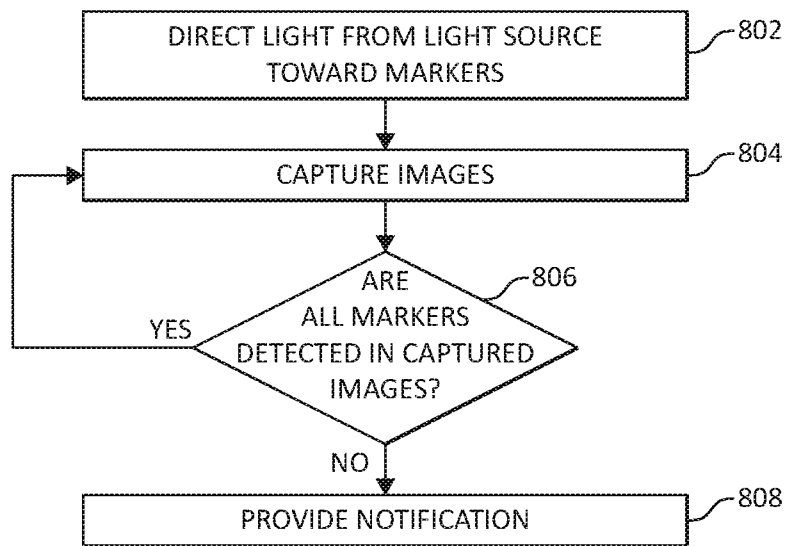
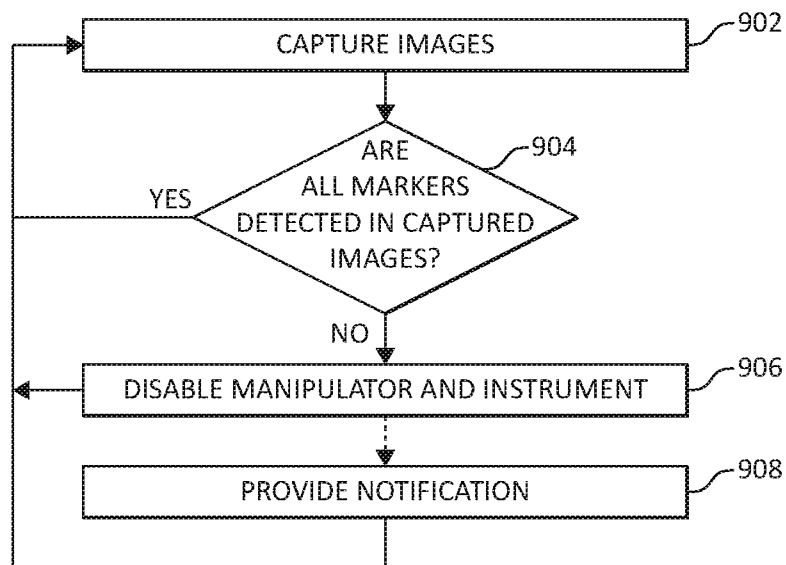


FIG. 7

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**FIG. 8****FIG. 9**