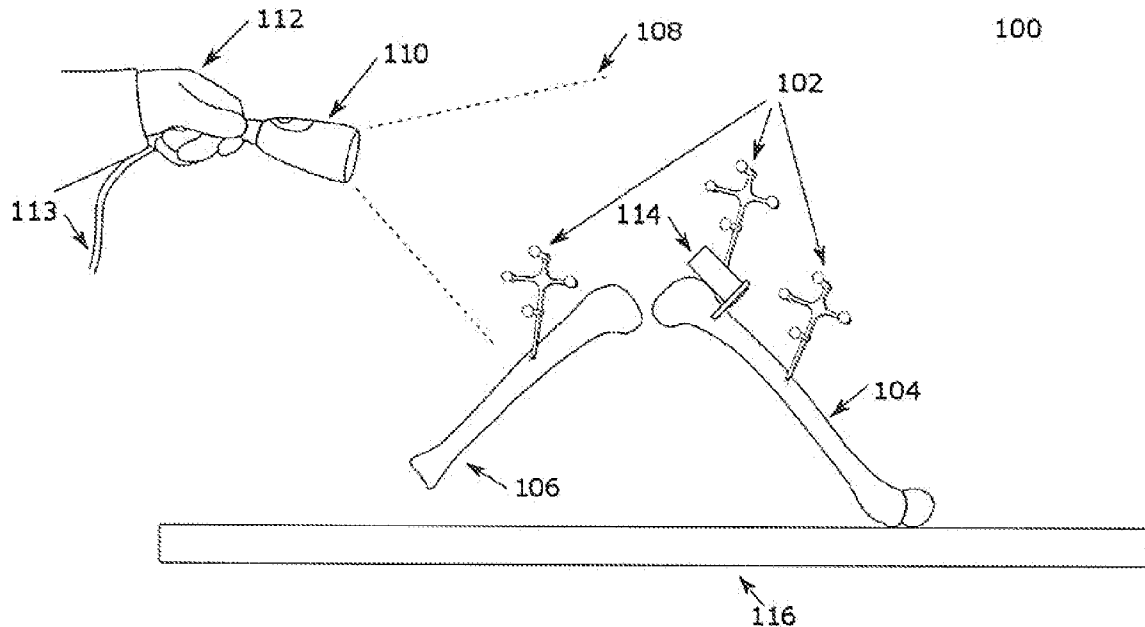




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HLADIO et al.(10) **Pub. No.: US 2016/0128783 A1**(43) **Pub. Date: May 12, 2016**(54) **SURGICAL NAVIGATION SYSTEM WITH
ONE OR MORE BODY BORNE
COMPONENTS AND METHOD THEREFOR****Publication Classification**(51) **Int. Cl.**
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FANSON, ON (CA)(21) Appl. No.: **14/926,963**(22) Filed: **Oct. 29, 2015****Related U.S. Application Data**(60) Provisional application No. 62/072,041, filed on Oct.
29, 2014, provisional application No. 62/072,030,
filed on Oct. 29, 2014, provisional application No.
62/084,891, filed on Nov. 26, 2014, provisional appli-
cation No. 62/072,032, filed on Oct. 29, 2014.(57) **ABSTRACT**

A system for performing a navigated surgery comprises a first target attached to a patient at a surgical site and a second target at the surgical site. An optical sensor is coupled to the user and detects the first target and second target simultaneously in a working volume of the sensor. An intra-operative computing unit (ICU) receives sensor data concerning the first target and second target, calculates a relative pose and provides display information. The sensor can be handheld, body-mounted or head-mounted, and communicate wirelessly with the ICU. The sensor may also be mountable on a fixed structure (e.g. proximate) and in alignment with the surgical site. The ICU may receive user input via the sensor, where the user input is at least one of sensor motions, voice commands, and gestures presented to the optical sensor by the user. The display information may be presented via a (heads-up) display unit.



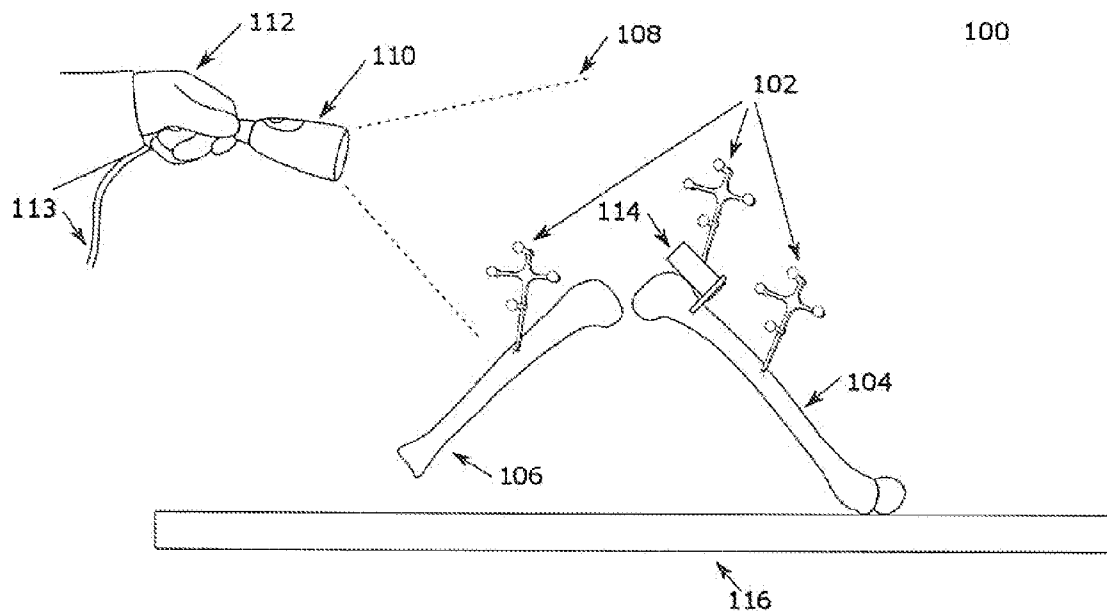


Figure 1

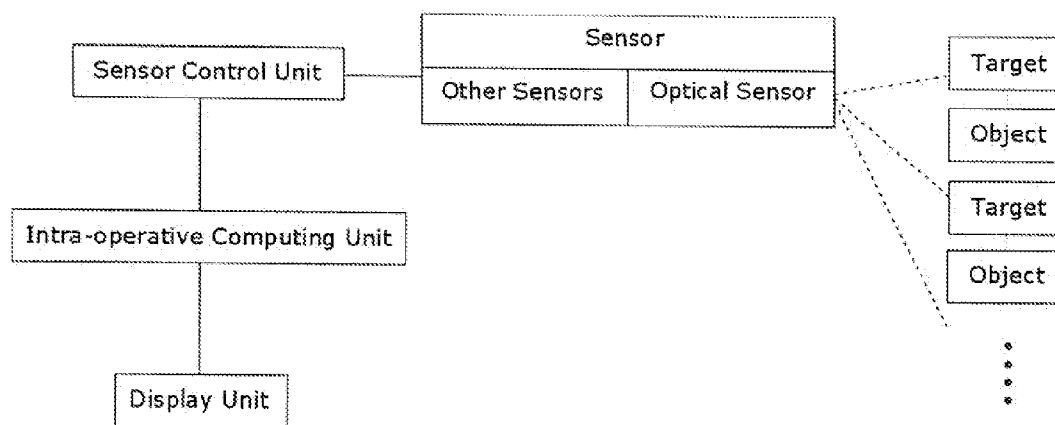


Figure 2

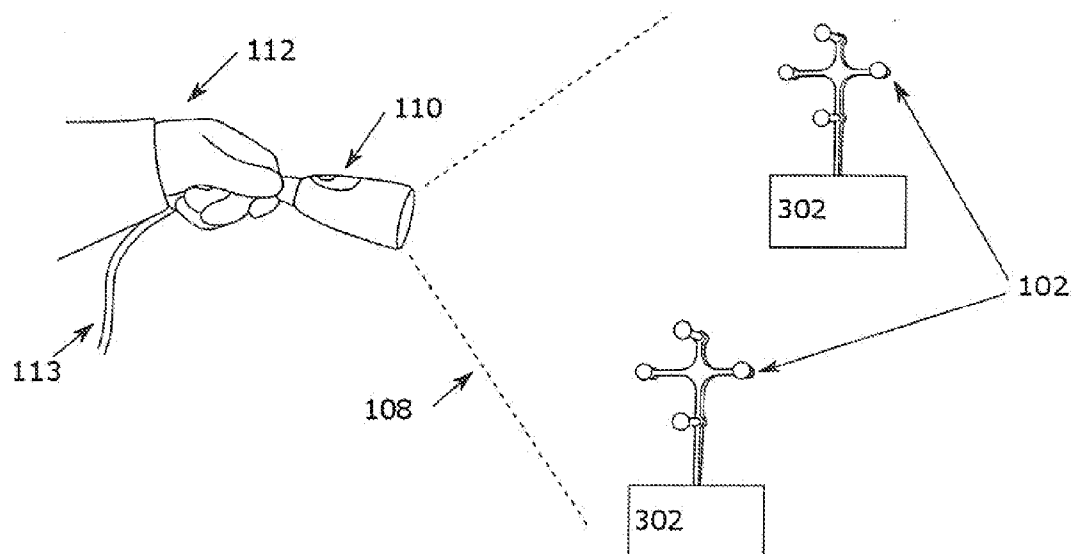


Figure 3

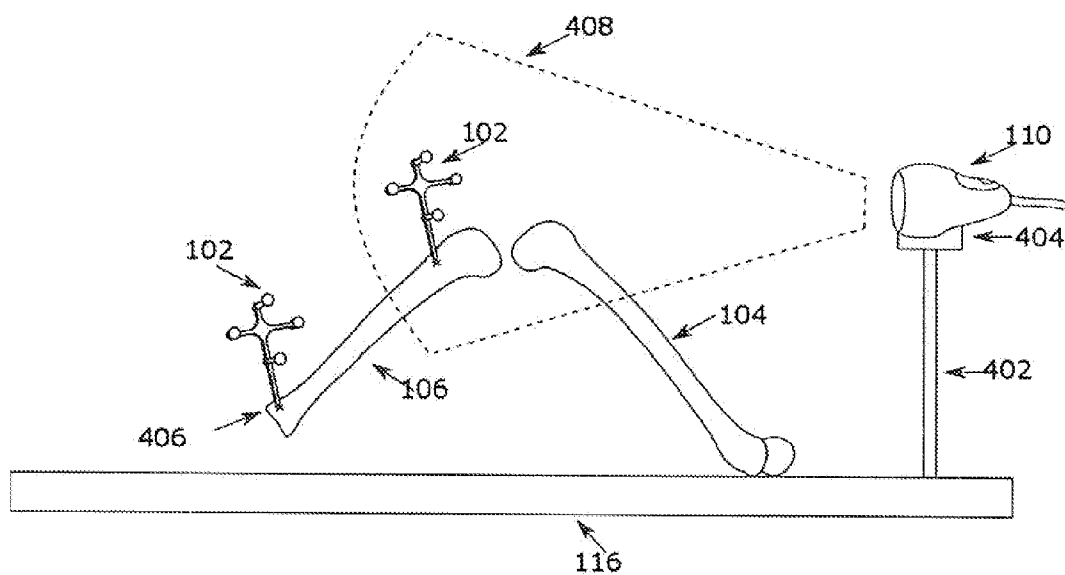


Figure 4a

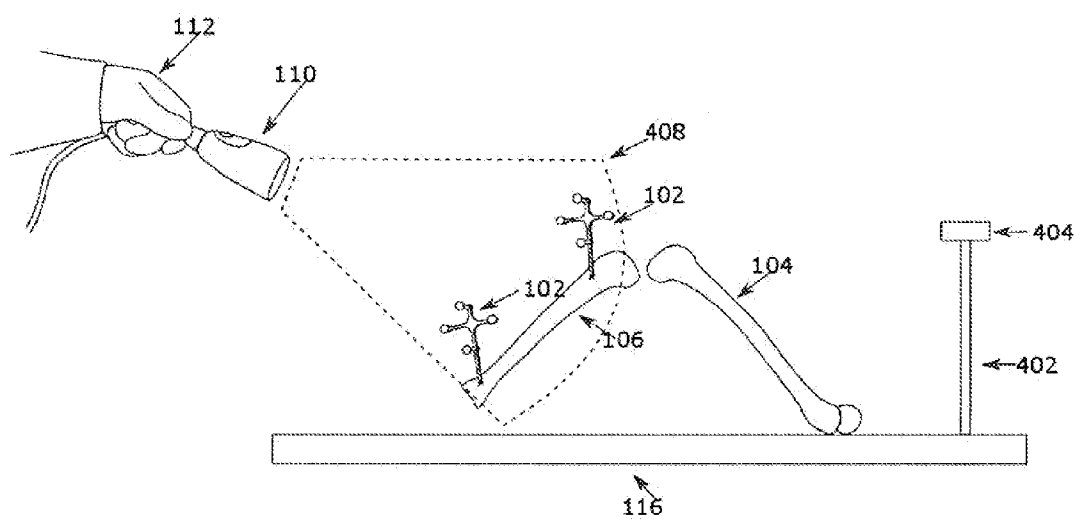


Figure 4b

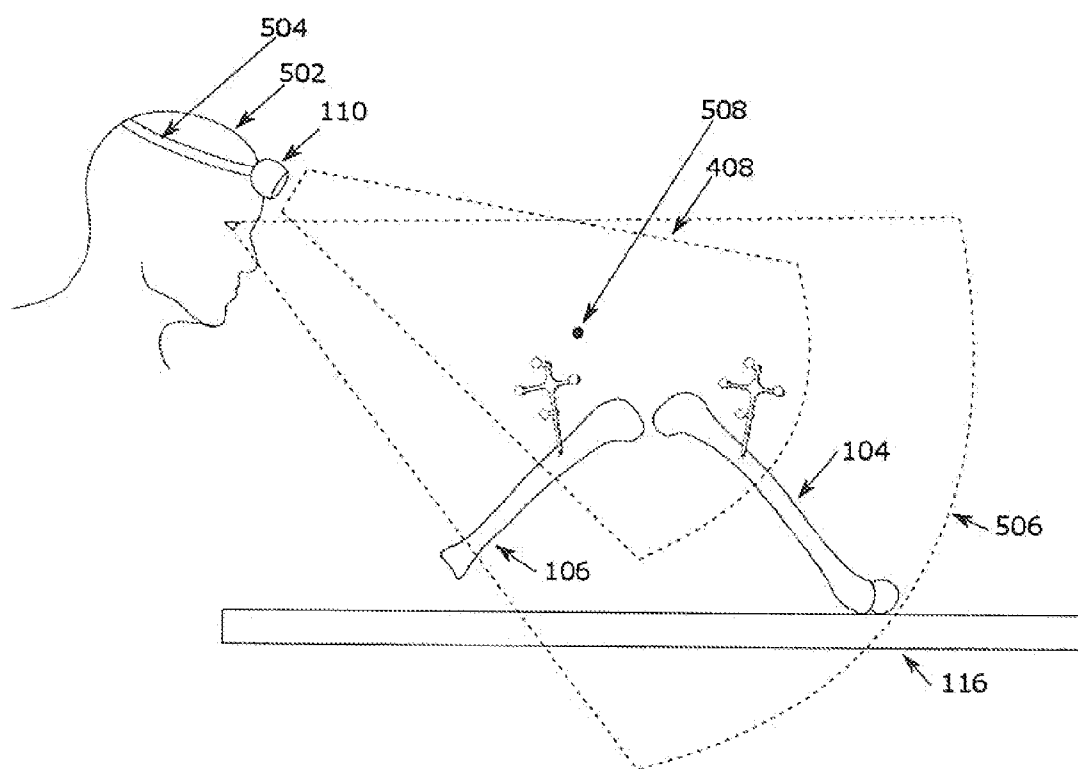


Figure 5

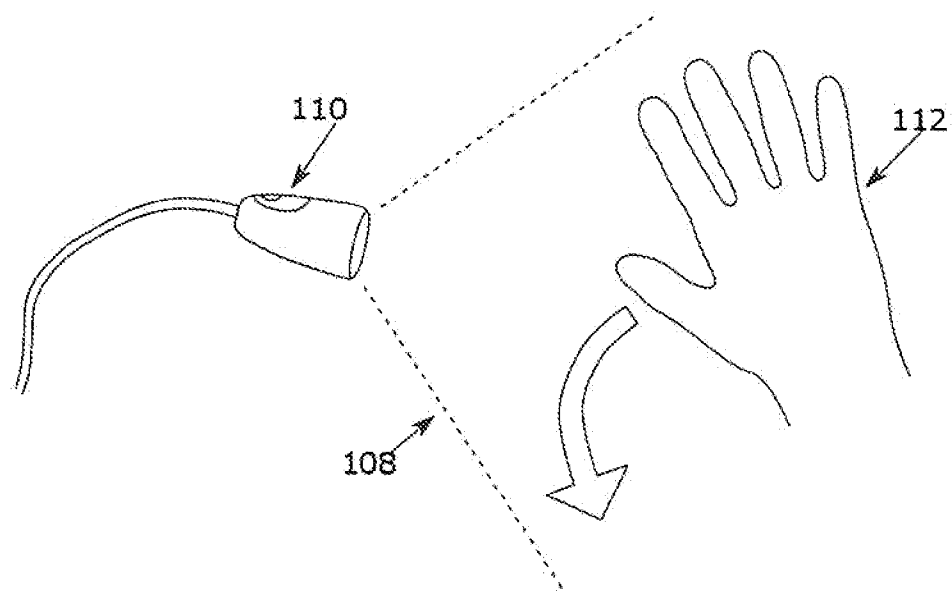


Figure 6

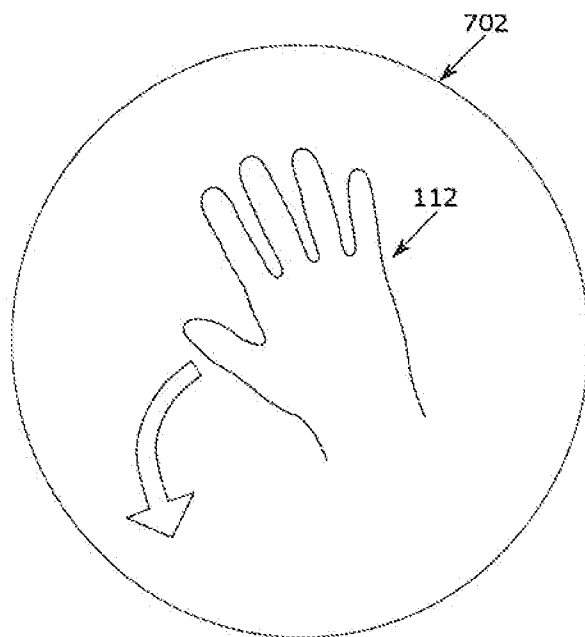


Figure 7

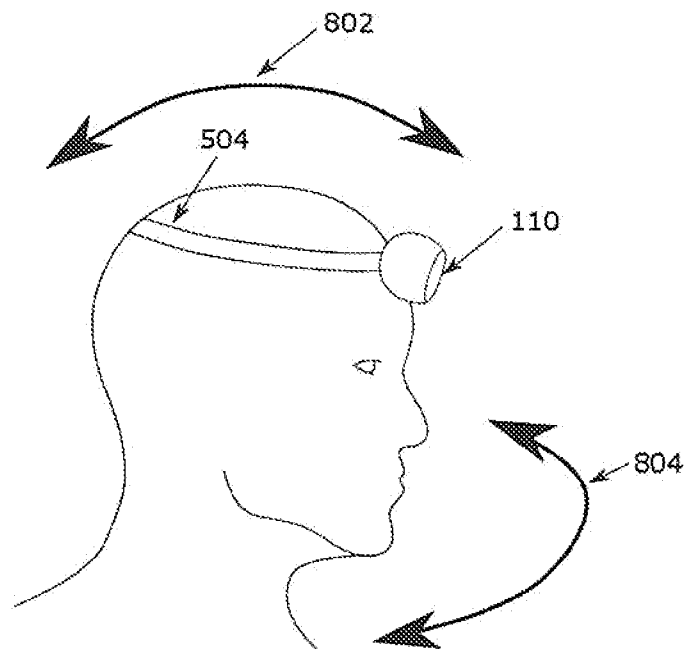


Figure 8

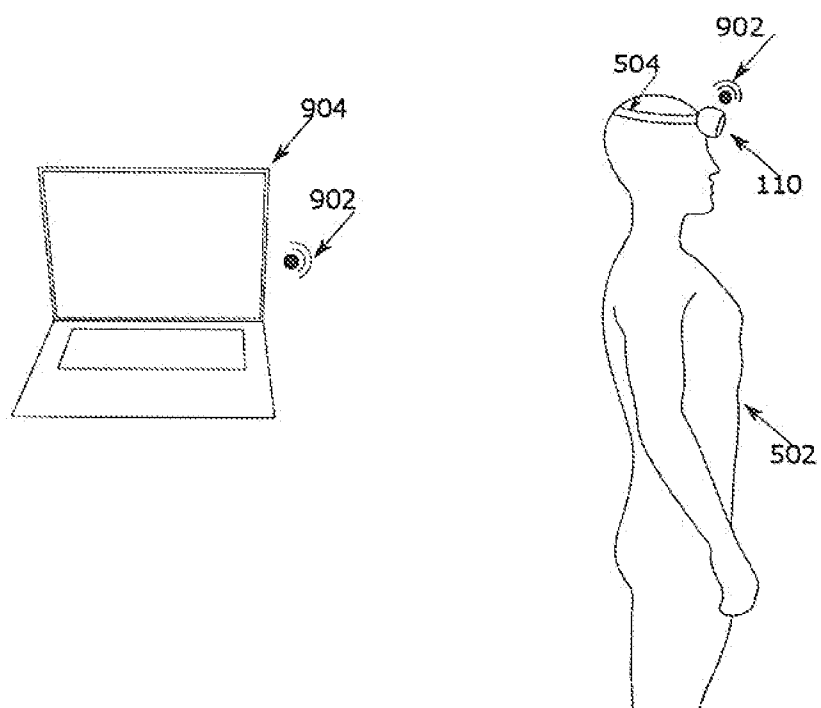


Figure 9

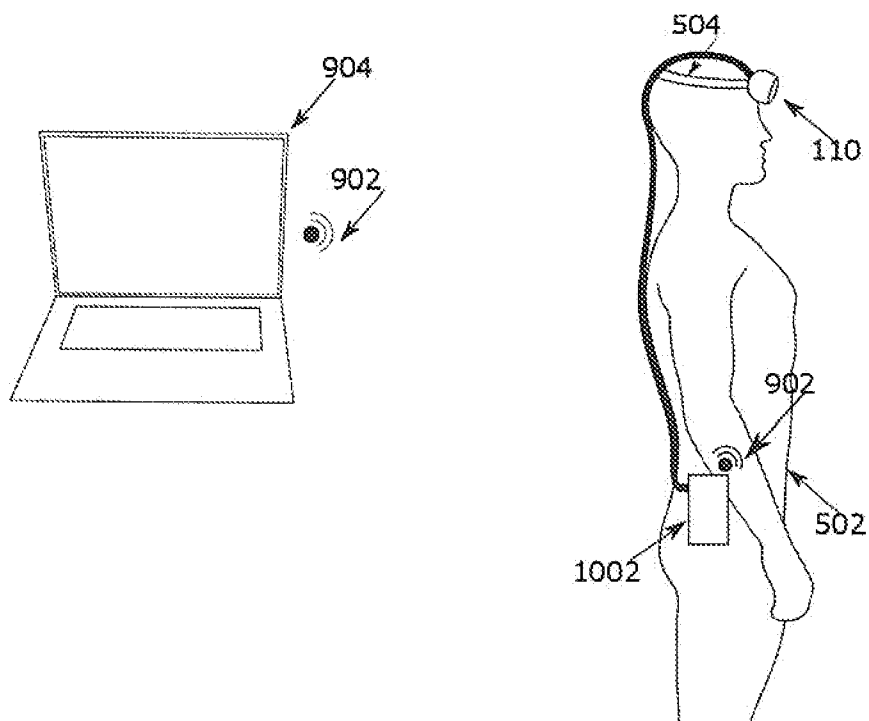


Figure 10

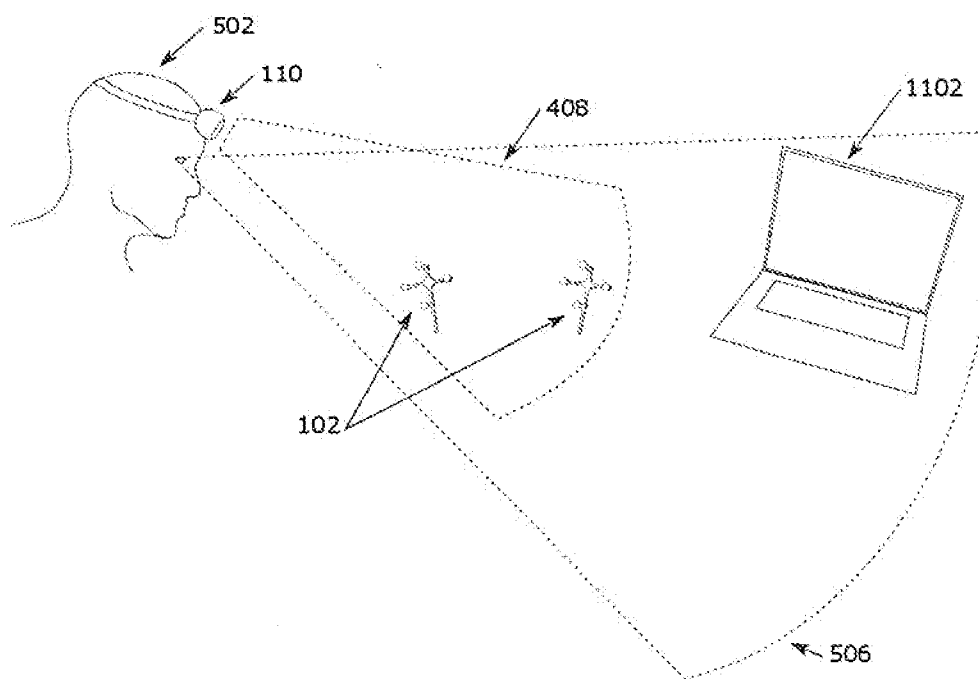


Figure 11

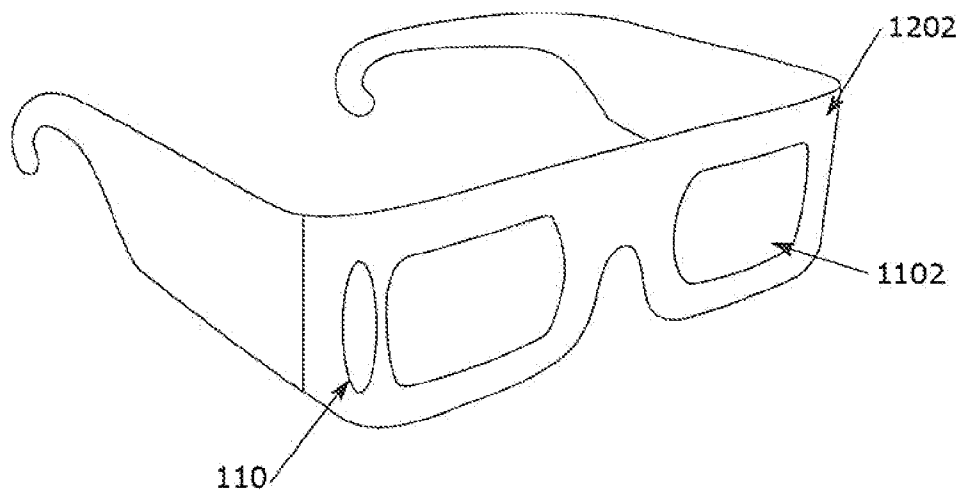


Figure 12

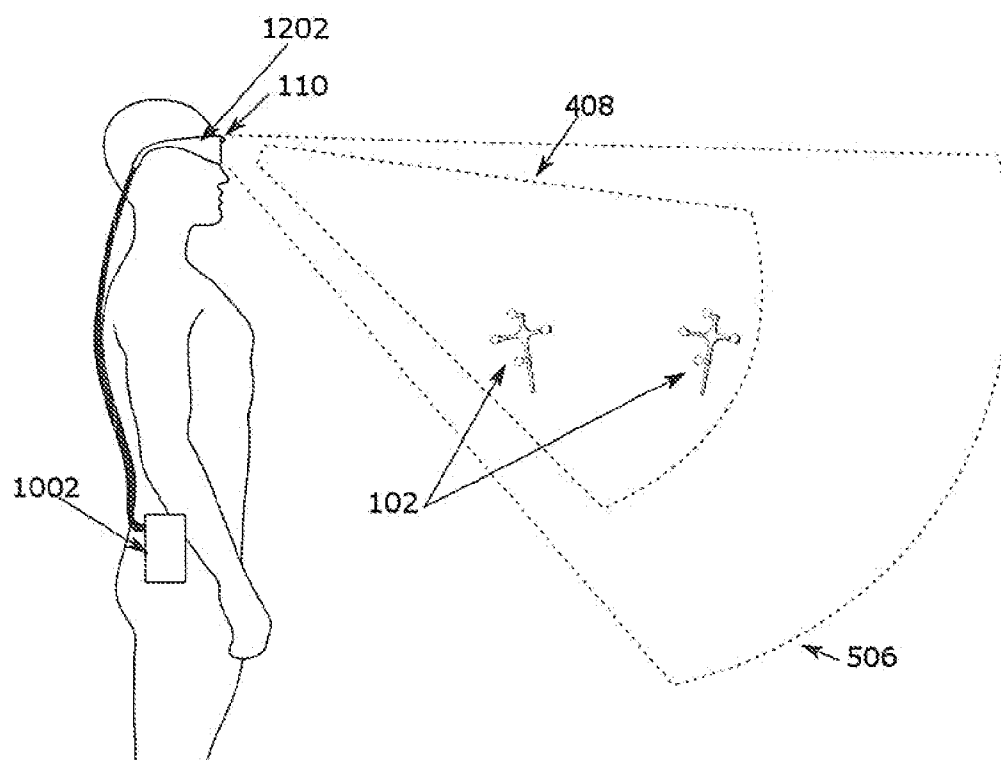


Figure 13

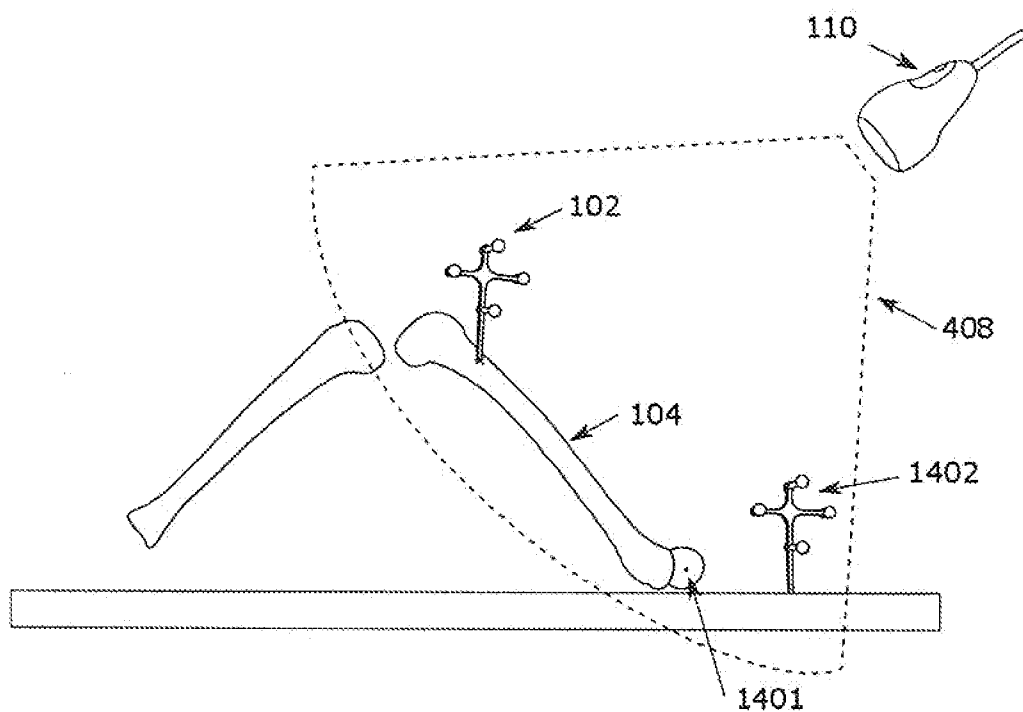


Figure 14

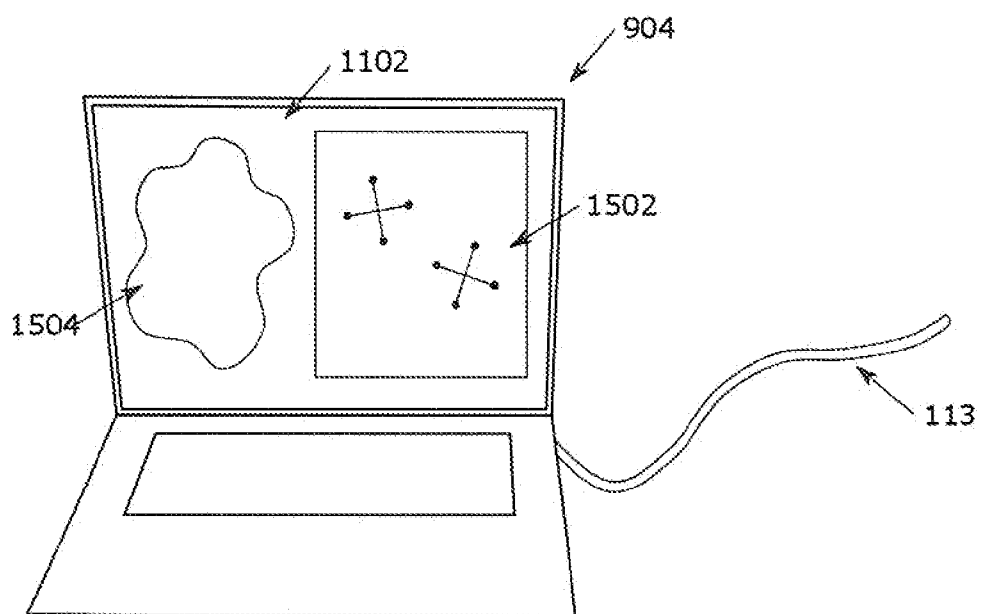


Figure 15

SURGICAL NAVIGATION SYSTEM WITH ONE OR MORE BODY BORNE COMPONENTS AND METHOD THEREFOR

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. provisional application No. 62/072,041 titled “Systems, Methods and Devices for Anatomical Registration and Surgical Localization” and filed on Oct. 29, 2014, the entire contents of which are incorporated herein by reference.

[0002] This application claims priority to U.S. provisional application No. 62/072,030 titled “Devices including a surgical navigation camera and systems and methods for surgical navigation” and filed on Oct. 29, 2014, the entire contents of which are incorporated herein by reference.

[0003] This application claims priority to U.S. provisional application No. 62/084,891 titled “Devices, systems and methods for natural feature tracking of surgical tools and other objects” and filed on Nov. 26, 2014, the entire contents of which are incorporated herein by reference.

[0004] This application claims priority to U.S. provisional application No. 62/072,032 titled “Devices, systems and methods for reamer guidance and cup sealing” and filed on Oct. 29, 2014, the entire contents of which are incorporated herein by reference.

FIELD

[0005] The present application relates to computer-assisted surgery and surgical navigation systems where One or more targets and the one or more objects to which the targets are attached are tracked by an optical sensor, such as one borne by the body of the user (e.g. hand, head etc.) The present application further relates to gestural control for surgical navigation systems.

BACKGROUND

[0006] The field of computer-assisted surgery (or “computer navigation”) creates systems and devices to provide a surgeon with positional measurements of objects in space to allow the surgeon to operate more precisely and accurately. Existing surgical navigation systems utilize binocular cameras as optical sensors to detect targets attached to objects within a working volume. The binocular cameras are part of large and expensive medical equipment systems. The cameras are affixed to medical carts with various computer systems, monitors, etc. The binocular-based navigation systems are located outside a surgical sterile field, and can localize (i.e. measure the pose of) targets within the sterile field. There are several limitations to existing binocular-based navigation systems, including line-of-sight disruptions between the cameras and the objects, ability to control computer navigation software, cost, and complexity.

BRIEF SUMMARY

[0007] In one aspect, a system is disclosed for performing a navigated surgery. The system comprises a first target attached to a patient at a surgical site and a second target at the surgical site. An optical sensor is coupled to the user and detects the first target and second target simultaneously in a working volume of the sensor. An intra-operative computing unit (ICU) receives sensor data concerning the first target and second target, calculates a relative pose and provides display

information to a display unit. The sensor can be handheld, body-mounted or head-mounted, and communicate wirelessly with the ICU. The sensor may also be mountable on a fixed structure (e.g. proximate thereto) with the working volume in alignment with the surgical site. The ICU may receive user input via the sensor, where the user input is at least one of sensor motions, voice commands, and gestures presented to the optical sensor by the user. The display information may be presented via a heads-up or other display unit.

[0008] There is provided a system for performing a navigated surgery at a surgical site of a patient where the system comprises: a first target configured to be attached to the patient at the surgical site; a second target at the surgical site; a sensor configured to be coupled to a user, the sensor comprising an optical sensor configured to detect the first target and second target simultaneously; and an intra-operative computing unit (ICU) configured to: receive, from the sensor, sensor data concerning the first target and second target; calculate the relative pose between the first target and second target; and based on the relative pose, provide display information to a display unit.

[0009] The second target may be a static reference target. The second target may be attached to one of: a surgical instrument; a bone cutting guide; and a bone.

[0010] The sensor may be configured to be at least one of: handheld; body-mounted; and head-mounted.

[0011] A sensor working volume for the sensor may be in alignment with a field of view of the user.

[0012] The sensor may communicate wirelessly with the ICU.

[0013] The sensor may be communicatively connected by wire to a sensor control unit and the sensor control unit is configured to wirelessly communicate with the ICU.

[0014] The sensor may be further configured to be mountable on a fixed structure.

[0015] The ICU may be further configured to present, via the display unit, where the targets are with respect to the sensor field of view. The ICU may be further configured to present, via the display unit, an optical sensor video feed from the optical sensor. The ICU may be further configured to receive user input via the sensor by at least one of receiving motions of the sensor, where the sensor has additional sensing capabilities to sense motions; receiving voice commands, where the sensor further comprises a microphone; and receiving gestures presented to the optical sensor by the user, the gestures being associated with specific commands.

[0016] The system may further comprise a display unit wherein the display unit is further configured to be positionable within a field of view of the user while the optical sensor is detecting the first target and second target. The display unit may be a surgeon-worn heads up display.

[0017] There is provided a computer-implemented method for performing a navigated surgery at a surgical site of a patient. The method comprises receiving, by at least one processor of an intra-operative computing unit (ICU), sensor data from a sensor where the sensor data comprises information for calculating the relative pose of a first target and a second target, wherein the sensor is coupled to a user and comprises an optical sensor configured to detect the first target and second target simultaneously, and wherein the first target is attached to the patient at the surgical site and the second target is located at the surgical site calculating, by the at least one processor, the relative pose between the first target

and second target; and based on the relative pose, providing, by at least one processor, display information to a display unit.

[0018] In this method a sensor working volume of the sensor may be in alignment with a field of view of the user and the first target and second target are in the sensor working volume.

[0019] The method may further comprise receiving, by the at least one processor further sensor data from the sensor, wherein the sensor is attached to a fixed structure such that the sensor volume is aligned with the surgical site when the sensor is attached.

[0020] The method may further comprise, receiving, by the at least one processor, user input from the sensor for invoking the at least one processor to perform an activity of the navigated surgery. The user input may comprise a gesture sensed by the sensor.

[0021] There is provided a method comprising: aiming an optical sensor, held by the hand, at a surgical site having two targets at the site and within a working volume of the sensor, one of the two targets attached to patient anatomy, wherein the optical sensor is in communication with a processing unit configured to determine a relative position of the two targets and provide display information, via a display unit, pertaining to the relative position; and receiving the display information via the display unit. This method may further comprise providing to the processing unit user input via the sensor for invoking the processing unit to perform an activity of the navigated surgery.

[0022] Additional objects and advantages of the disclosed embodiments will be set forth in part in the description that follows, and in part will be obvious from the description, or may be learned by practice of the disclosed embodiments. The objects and advantages of the disclosed embodiments will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[0023] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosed embodiments as claimed.

[0024] The accompanying drawings constitute a part of this specification. The drawings illustrate several embodiments of the present disclosure and, together with the description, serve to explain the principles of the disclosed embodiments as set forth in the accompanying claims.

BRIEF DESCRIPTION OF DRAWINGS

[0025] Embodiments disclosed herein will be more fully understood from the detailed description and the corresponding drawings, which form a part of this application, and in which:

[0026] FIG. 1 illustrates use of a surgical navigation, system in Total Knee Arthroplasty (TKA);

[0027] FIG. 2 shows in a block diagram an interaction between various components of a surgical navigation system;

[0028] FIG. 3 shows use of a sensor with multiple targets in accordance with an embodiment;

[0029] FIG. 4a shows use of a sensor in a handheld mode as an example for clarity;

[0030] FIG. 4b shows use of a sensor in a non-handheld mode as an example for clarity;

[0031] FIG. 5 illustrates, as an example for clarity, use of the system where a center of the working volume of a sensor attached to a surgeon is substantially centered with respect to a site of surgery;

[0032] FIG. 6 shows a gesture of a hand sensed by a sensor;

[0033] FIG. 7 illustrates an image, as seen by a sensor when configured to sense a gesture of a hand;

[0034] FIG. 8 illustrates motions of a body detected by a sensor attached to the body in accordance with an embodiment;

[0035] FIG. 9 shows a sensor communicating wirelessly with an intra-operative computing unit (ICU);

[0036] FIG. 10 shows a sensor communicating with an ICU through a sensor control unit (SCU);

[0037] FIG. 11 shows a sensor attached to a surgeon's head such that the working volume of the sensor is within the surgeon's field of view;

[0038] FIG. 12 shows a sensor integrated with heads-up display glasses;

[0039] FIG. 13 shows heads-up display glasses (with integrated sensor) connected by a cable to a SCU mounted on a surgeon;

[0040] FIG. 14 shows a use of a static reference target as an example for clarity; and

[0041] FIG. 15 shows a display of an ICU depicting a video feed as seen by an optical sensor, when viewing the targets.

[0042] It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity.

DEFINITIONS

[0043] Field of View (FOV): The angular Span (horizontally and vertically) that an optical sensor (e.g. camera) is able to view.

[0044] Degrees of Freedom (DOF): independent parameters used to describe the pose (position and orientation) of a rigid body. There are up to 6 DOF for a rigid body: 3 DOF for position (i.e. x, y, z position), and 3 DOF for orientation (e.g. roll, pitch, yaw).

[0045] Pose: The position and orientation of an object in up to 6 DOF in space.

[0046] Working Volume: A 3D volume relative to an optical sensor within which valid poses may be generated. The Working Volume is a subset of the optical sensor's field of view and is configurable depending on the type of system that uses the optical sensor.

DETAILED DESCRIPTION

[0047] In navigated surgery, targets are affixed to a patient's anatomy, as well as to surgical instruments, such that a relative position and orientation between the sensor and the target may be measured. Total Knee Arthroplasty (TKA) will be used as an example in this disclosure to describe a navigated surgical procedure. As illustrated in FIG. 1, a system 100 is used for navigation in TKA. Targets 102 are affixed to a patient's anatomy (i.e. a femur bone 104 and a tibia bone 106 that are part of a knee joint) and located within a field of view 108 of a sensor 110 that is held by a hand 112. The sensor 110 is connected to an intra-operative computing unit (ICU) by a cable 113. Additionally, targets 102 are affixed to surgical instruments (in this case, a distal femoral cutting guide 114).

In navigated TKA, a relative pose between the femur **104** and tibia **106** may allow a surgeon to track the kinematics of a knee joint during a range-of-motion test. Furthermore, as relative pose between the distal femur cutting guide **114** and the femur **104** may allow a surgeon to precisely align the cutting guide **114** with respect to the femur **104** to achieve desired cut angles. The patient rests on an operating table **116**. Applicant's U.S. Pat. No. 9,138,319 B2 issued Sep. 22, 2015 and entitled "Method and System for Aligning a Prosthesis During Surgery" describes operations and methods to register components (such as an optical sensor to a patient's bone (for example a pelvis)), measure relative poses and track objects in a Total Hip Arthroplasty (THA) scenario, the contents of which are incorporated herein by reference. Similar methods and systems as described therein are applicable to TKA.

Sensor System Architecture

[0048] The architecture of a surgical navigation system is shown in FIG. 2. Multiple targets are affixed to objects (anatomy, instruments, etc.) within a sterile field. The targets provide optical positional signals, either through emitting or reflecting optical energy. The positional signals are received by a sensor, comprising an optical sensor. The optical sensor preferably includes a monocular camera (comprising a lens, an imager etc.), illuminating components, and various optics as applicable (e.g. IR filter, if the optical sensor operates in the IR spectrum). The optical sensor is configured to detect a target. The optical sensor is configured and focused in order to function according to the relatively large working volume. This is unlike endoscopic applications, where an endoscope is configured to view a scene inside a body cavity. Where the scene is very close (e.g. <5 cm) to the endoscope optics. Furthermore, endoscopes are used to visualize tissue, whereas the present optical sensor is used to measure relative pose between targets and objects.

[0049] The sensor may also include, other sensing components. For example, positional sensing components, such as accelerometers, gyroscopes, magnetometers, IR detectors, etc. may be used to supplement, augment or enhance the positional measurements obtained from the optical sensor. Additionally, the sensor may be capable of receiving user input, for example, through buttons, visible gestures, motions (e.g. determined via an accelerometer), and microphones to receive voice commands etc. The sensor may include indicators that signal the state of the sensor, for example, green LED to signify sensor is on, red LED to signify error.

[0050] The sensor may be in communication with a sensor control unit (SCU). The SCU is an intermediate device to facilitate communication between the sensor and an intra-operative computing unit (ICU).

[0051] The ICU may comprise a laptop, workstation, or other computing device having at least one processing unit and at least one storage device, such as memory storing software (instructions and/or data) as further described herein to configure the execution of the intra-operative computing unit. The ICU receives positional data from the sensor via the SCU, processes the data and computes the pose of targets that are within the working volume of the sensor. The ICU also performs any further processing associated with the other sensing and/or user input components. The ICU may further process the measurements to express them in clinically-relevant terms (e.g. according to anatomical registration). The ICU may further implement a user interface to guide a user through a surgical workflow. The ICU may further provide the

user interface, including measurements, to a display unit for displaying to a surgeon or other user.

Handheld Camera Embodiment

[0052] In one embodiment, a sensor is configured for hand-held use. As depicted in FIG. 3, the sensor **110** may localize two or more targets **102**, in order to compute a relative pose between the targets **102**. The targets **102** are attached to objects **302** and the relative pose between the objects **302** can also be calculated. In relation to navigated TKA, the objects could be the femur **104** and the tibia **106**, or the femur **104** and the cutting guide **114**.

[0053] Furthermore, both handheld and non-handheld modes may be supported for use of the sensor within the same surgery. This is illustrated in FIG. 4a and FIG. 4b. For example, during a TKA, it may be preferable to leave the sensor **110** mounted to a fixed structure **402** for the majority of the procedure with the use of a releasable mechanical connection **404**, such as the one described in U.S. 20140275940 titled "System and method for intra-operative leg position measurement", the entire contents of which are incorporated herein. However, during a step to localize a malleolus **406** of the patient's anatomy, the sensor **110** can be removed from its fixed structure **402** if the malleolus **406** is outside the working volume **408** of the optical sensor in the sensor **110**. The sensor **110** can be held in a user's hand **112** to bring the malleolus **406** within its working volume **408**, as shown in FIG. 4b.

[0054] This system configuration has several advantages. This system does not have a wired connection to objects being tracked. This system further allows the sensor to be used for pose measurements of the targets at specific steps in the workflow, and set aside when not in use. When a target is outside of or obstructed from the working volume of the sensor, while the sensor is attached to a static/fixed position, the position of the sensor can be moved, using the sensor in handheld mode, to include the target in its working volume. The sensor may comprise user input components (e.g. buttons). This user input may be a part of the surgical workflow, and may be communicated to the ICU. Furthermore, indicators on the sensor could provide feedback to the surgeon (e.g. status LED's indicating that a target is being detected by the sensor). Also, in handheld operation, it may be preferable for a surgical assistant to hold the sensor to align the sensor's working volume with the targets in the surgical site, while the surgeon is performing another task.

Body Mounted Embodiment

[0055] As illustrated in FIG. 5, in addition to handheld configurations, the sensor **110** may be mounted onto a surgeon **502** (or other user) using a sensor mounting structure **504**. The sensor mounting structure **504** may allow the sensor to be attached to a surgeon's forehead (by way of example, shown as a headband). The sensor **110** is preferably placed on the sensor mounting structure **504** such that the working volume **408** of the sensor **110** and the surgeon's visual field of view **506** are substantially aligned, i.e. the majority of the working volume **408** overlaps with the field of view **108** of the sensor **110**. In such a configuration, if the surgeon **502** can see the targets **102**, the sensor **110** (while mounted on the sensor mounting structure **504**) will likely be able to do so as well. This configuration allows the surgeon to rapidly and intuitively overcome line-of-sight disruptions between the sensor

110 and the targets **102**. In this configuration, it is desirable that the optical sensor in the sensor **110** has a working volume **108** that is approximately centered about the nominal distance between a surgeon's forehead (or other mounting, location) and the surgical site. The working volume **108** of the sensor **110** is preferably large enough to accommodate a wide range of feasible relative positions between the mounting position on the surgeon and the surgical site.

Description of Various User Input Options

[0056] In the previously described embodiments, the sensor in the surgical navigation system is mounted on the surgeon's body. For reasons of sterility and ergonomics, it may not be feasible to use buttons on the sensor in order to interact with the intra-operative computing unit. Hand gestures may be sensed by the optical system and used as user input. For example, if the sensor can detect a user's hand in its field of view, the system comprising the sensor, SCU, ICU, and a display unit, may be able to identify predefined gestures that correspond to certain commands within the surgical workflow. For example, waving a hand from left to right may correspond to advancing the surgical workflow on the display unit of the ICU; snapping fingers may correspond to saving a measurement that may also be displayed on the display unit of the ICU; waving a hand back and forth may correspond to cancelling an action within the workflow; etc. According to FIG. 6, a user interacts with the system using a hand wave gesture within the field of view **108** of the sensor **110**. These gestures are recognized by the sensor and by image processing software executed by the ICU. When mounted on the surgeon's forehead, the hand gestures may be performed by another user within the surgery and need not necessarily be performed by the surgeon. Furthermore, using hand gestures as user input is not limited to a system where the sensor is placed on the surgeon's body. It is also possible to use gesture control in any system where the sensor is mounted on the operating table, on the patient, hand-held, etc.

[0057] In FIG. 7, an image **702** of a sensor as seen by the optical sensor is illustrated. In addition to gesture control, the ICU may receive comments via voice controls (e.g. via a microphone in the sensor or in the ICU itself). In another embodiment, as shown in FIG. 8, body motions (e.g. head nods **802** or shakes **804**) can be detected by the sensor **110** with additional sensing components, e.g. an embedded accelerometer. The body motions are sensed and interpreted to send signals to the ICU which may communicate wirelessly with the sensor **110**. For example, nodding **802** may signal the surgeon workflow to advance, shaking **804** may signal the surgeon workflow to go back one step or cancel an action, etc.

Wireless Sensor Architecture

[0058] Reference is now made to FIG. 9. When the sensor is mounted on a surgeon **502**, the sensor may be wireless to allow the surgeon **502** to move freely around the operating room. In one embodiment, the sensor **110** communicates wirelessly **902** with the ICU **904**, the ICU configured to receive wireless signals **902** from the sensor.

[0059] Reference is now made to FIG. 10. In another embodiment, the sensor **110** is connected by wire to a Sensor Control Unit (SCU) **1002**. The SCU **1002** further communicates wirelessly **902** with the ICU **904**. The SCU **1002** contains a mounting structure **504** such that it may be mounted on the surgeon **502**. For example, the sensor **110** may be

mounted to the forehead of the surgeon **502**, and the SCU **1002** may be attached to the belt of the surgeon **502** under a surgical gown. The SCU **1002** may have a battery to power the sensor, as well as its own electronics. The SCU **1002** may have an integrated battery, and the SCU **1002** may be charged between surgeries, such as on a charging dock. Multiple SCU's may be available such that if an SCU loses power during surgery, it can be swapped out for a fully charged SCU. Where a wireless sensor is implemented, any wireless protocol/technology may be used (e.g. WiFi, Bluetooth, ZigBee, etc).

[0060] It will be appreciated that a sensor mounted on a surgeon's body need not necessarily be sterile. For example, the surgeon's forehead is not sterile. This is advantageous since a sensor may not be made from materials that can be sterilized, and by removing the sensor from the sterile field, there is no requirement to ensure that the sensor is sterile (e.g. through draping, autoclaving, etc.).

Display Positioning

[0061] Reference is now made to FIG. 11. In one embodiment, the sensor **110** is attached to a mounting structure **504** to the forehead of the surgeon **502**, and the working volume **408** of the sensor **110** is substantially contained within the surgeon's field of view **506**. The sensor **110** is configured to detect targets **102** within its working volume **408** such that the relative pose between the targets **102** may be calculated by the ICU **904**. The ICU **904** may comprise a display unit. In this embodiment, the display unit **1102** is also included in the surgeon's field of view **506**. This is advantageous where real-time measurements based on the pose of the targets **102** are provided to the surgeon **502** via the display unit **1102**. The targets **102** and the display unit **1102** are simultaneously visible to the surgeon **502**. The display unit **1102** may be positioned within the surgeon's field of view **506**, for example, by being mounted to a mobile cart.

[0062] In another embodiment, the display unit **1102** is a heads-up display configured to be worn by the surgeon **502**, and be integrated with the sensor **110**. The heads-up display is any transparent display that does not require the surgeon to look away from the usual field of view. For example, the heads-up display may be projected onto a visor that surgeon's typically wear during surgery. A head-mounted sensor allows the surgeon to ensure that the targets are within the working volume of the sensor without additionally trying to look at a static display unit within the operating room, and with a heads-up display, the display unit is visible to the surgeon regardless of where they are looking.

[0063] In another embodiment, as illustrated in FIG. 12, the sensor **110** is integrated with heads-up display glasses **1202** (such as the Google Glass™ product from Google Inc.) Since the sensor **110** and the display unit **1102** are integrated into one device, there is no longer a need for a dedicated display unit, thus reducing cost and complexity. This embodiment is also advantageous since by default, it places the sensor's working volume within the surgeon's field of view.

[0064] In another embodiment, as illustrated in FIG. 13, the heads-up display glasses **1202** (with integrated sensor) are connected by a cable to a SCU **1002**, the SCU **1002** attached to a surgeon **502**. In this embodiment, the SCU **1002** may also comprise the ICU (that is, it may perform the intra-operative computations to generate display information to be displayed on the heads-up display glasses). The SCU may include a battery, e.g. a rechargeable battery. In this embodiment, the

SCU need not communicate wirelessly with any other device, since the entire computational/electronic system is provided by the SCU, heads-up display glasses and sensor. That is, the entire surgical localization system is body-worn (with the exception of the targets and their coupling means).

Static Reference Target to Overcome Limitations of Non-Fixed Sensor

[0065] In a body-mounted or handheld camera configuration, the sensor is not required to be stationary when capturing relative pose between multiple targets. However, some measurements may be required to be absolute. For example, when calculating the center of rotation (COR) of a hip joint, a fixed sensor may localize a target affixed to the femur as it is rotated about the hip COR. The target is constrained to move along a sphere, the sphere's center being the hip COR. Since the sensor is in a fixed location, and the hip COR is in a fixed location, the pose data from rotating the femur may be used to calculate the pose of the hip COR relative to the target on the femur. In TKA, the pose of the hip COR is useful for determining the mechanical axis of a patient's leg.

[0066] In an embodiment where the sensor may not be fixed, a second stationary target is used as a static reference to compensate for the possible motion of the sensor. In FIG. 14, a target **102** is affixed to a femur **104** that has a static hip COR **1401**. The sensor is not necessarily stationary, as it may be body-mounted or hand-held. A static reference target **1402** is introduced within the working volume **408** of the sensor **110**. The static reference target **1402** must fulfill two conditions: 1) it must remain stationary during steps executed to measure the hip COR **1401**, and 2) it must be within the working volume **408** of the sensor **110** simultaneously with the target **102** attached to the femur **104** while the hip COR **1401** is measured. In this example, the static reference target **1402** may be simply placed on the OR bed **116** or mounted to a fixed docking structure **402**. To measure the hip COR **1401** the femur is rotated about a pivot point of the hip joint while the sensor **110** captures poses of the target **102** and poses of the static reference target **1402**. The poses of the static reference target **1402** are used to compensate for any movement of the sensor **110** as it is used in hand-held or body-mounted mode. This embodiment is described relative to measuring hip COR in the context of TKA; however, this embodiment is meant to be example for clarity. There are many other embodiments that will be evident to those skilled in the art e.g. tool calibration, verification of the location of a tip of a tool, etc.).

Working Volume Alignment Feedback

[0067] Where the surgeon has direct control over the working volume of the optical sensor (i.e. in the body-mounted or handheld configurations), it may be advantageous to display the video feed as seen by the optical sensor to the surgeon via the display unit. This visual feedback may allow the surgeon to see what the optical sensor "sees", and may be useful in a) ensuring that the target(s) are within the working volume of the sensor, and b) diagnosing any occlusions, disturbances, disruptions, etc. that prevents the poses of the targets from being captured by the ICU. For example, a persistent optical sensor image feed may be displayed. This is illustrated in FIG. 15, where a laptop (integrated ICU **904** and display **1102**) is shown to display a video feed **1502** (showing two targets within the image) of the optical sensor. Alternative graphics may be shown in addition to or instead of the raw

video feed **1502** of the optical sensor. For example, simplified renderings of the targets (e.g. represented as dots) may be displayed within a window on the display instead of the video feed **1502**. In another example, a virtual overlay may be displayed on the raw video feed **1502** of the optical sensor, in which the overlay includes colours and shapes overlaid on the target image.

[0068] Various embodiments have been described herein with reference to the accompanying drawings. It will however, be evident that various modifications and changes may be made thereto, and additional embodiments may be implemented, without departing from the broader scope of the disclosed embodiments as set forth in the claims that follow.

We claim:

1. A system for performing a navigated surgery at a surgical site of a patient, the system comprising:

a first target configured to be attached to the patient at the surgical site;

a second target at the surgical site;

a sensor configured to be coupled to a user, the sensor comprising an optical sensor configured to detect the first target and second target simultaneously; and an intra-operative computing unit (ICU) configured to:

receive, from the sensor, sensor data concerning the first target and second target;

calculate the relative pose between the first target and second target; and

based on the relative pose, provide display information to a display unit.

2. The system of claim **1** wherein the second target is a static reference target.

3. The system of claim **1** wherein the second target is attached to one of:

a surgical instrument;

a bone cutting guide; and

a bone.

4. The system of claim **1**, wherein the sensor is configured to be at least one of:

handheld;

body-mounted; and

head-mounted.

5. The system of claim **1**, wherein a sensor working volume for the sensor is in alignment with a field of view of the user.

6. The system of claim **1**, wherein the sensor communicates wirelessly with the ICU.

7. The system of claim **1**, wherein the sensor is communicatively connected by wire to a sensor control unit and the sensor control unit is configured to wirelessly communicate with the ICU.

8. The system of claim **1**, wherein the sensor is further configured to be mountable on a fixed structure.

9. The system of claim **1**, wherein the ICU is further configured to present, via the display unit, where the targets are with respect to the sensor field of view.

10. The system of claim **9**, wherein the ICU is further configured to present, via the display unit, an optical sensor video feed from the optical sensor.

11. The system of claim **9**, wherein the ICU is further configured to receive user input via the sensor by at least one of:

receiving motions of the sensor, where the sensor has additional sensing capabilities to sense motions;

receiving voice commands, where the sensor further comprises a microphone; and

receiving gestures presented to the optical sensor by the user, the gestures being associated with specific commands.

12. The system of claim **1** further comprising a display unit wherein the display unit is further configured to be positionable within a field of view of the user while the optical sensor is detecting the first target and second target.

13. The system of claim **12** wherein the display unit is a surgeon-worn heads up display.

14. A computer-implemented method for performing a navigated surgery at a surgical site of a patient, the method comprising:

receiving, by at least one processor of an intra-operative computing unit (ICU), sensor data from a sensor where the sensor data comprises information for calculating the relative pose of a first target and a second target, wherein the sensor is coupled to a user and comprises an optical sensor configured to detect the first target and second target simultaneously, and wherein the first target is attached to the patient at the surgical site and the second target is located at the surgical site;

calculating, by the at least one processor, the relative pose between the first target and second target; and

based on the relative pose, providing, by at least one processor, display information to a display unit.

15. The method of claim **14**, wherein a sensor working volume of the sensor is in alignment with a field of view of the user and the first target and second target are in the sensor working volume.

16. The method of claim **14**, further comprising receiving, by the at least one processor further sensor data from the sensor, wherein the sensor is attached to a fixed structure such that the sensor volume is aligned with the surgical site when the sensor is attached.

17. The method of claim **14** further comprising, receiving, by the at least one processor, user input from the sensor for invoking the at least one processor to perform an activity of the navigated surgery.

18. The method of claim **17** wherein the user input comprises a gesture sensed by the sensor.

19. A method comprising:

aiming an optical sensor, held by the hand, at a surgical site having two targets at the site and within a working volume of the sensor, one of the two targets attached to patient anatomy, wherein the optical sensor is in communication with a processing unit configured to determine a relative position of the two targets and provide display information, via a display unit, pertaining to the relative position; and

receiving the display information via the display unit.

20. The method of claim **19**, further comprising providing to the processing unit user input via the sensor for invoking the processing unit to perform an activity of the navigated surgery.

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