

SIMULATION AND TRAINING APPARATUS

TECHNICAL FIELD

[0001] The present disclosure relates to a simulator for the surgery training field. In particular,
5 the present disclosure relates to a simulation and training apparatus for the emulation of a c-arm machine.

BACKGROUND

[0002] Simulating and training physicians in surgery is desirable to attain the high level of competence and skill required and to reduce demand on supervision time. Training should be
10 performed in a realistic setting, allow feedback and develop fine motor skills, such as dexterity and coordination, without risk to either patients or the practitioner.

[0003] A c-arm machine is an imaging scanner intensifier which derives the name “c-arm” from the c-shaped arm used to connect an x-ray source to an x-ray detector. Although c-arm machines have radiographic capabilities, they are primarily used for fluoroscopic
15 intraoperative imaging during surgical, orthopaedic and emergency care procedures. c-arm machines provide high-resolution x-ray images in real time.

[0004] The x-ray source emits x-rays that penetrate the patient’s body. The image intensifier or x-ray detector detects the x-rays and converts the x-rays into a visible image which is then displayed on a c-arm monitor screen. Due to the real time imaging, a physician can check
20 anatomical details such as bones and the position of implants and instruments at any time. This also allows a physician to monitor the progress of surgery and immediately make any corrections as required.

[0005] X-ray dose is a concern for all c-arm manufacturers and operators, particularly when in use in general procedures and long minimally invasive procedures. One method for reducing
25 x-ray dose is the usage of an x-ray image intensifier. An x-ray image intensifier is an image intensifier that converts x-rays into visible light at higher intensity than fluorescent screens do. X-ray imaging systems use such intensifiers (like fluoroscopes) to allow converting low-intensity x-rays to a conveniently bright visible light output. Through its intensifying effect, the physician or viewer can more easily view the structure of the imaged object than fluorescent
30 screens alone. It thus requires lower absorbed doses due to more efficient conversion of x-ray

quanta to visible light. Despite the usage of an x-ray image intensifier, usage of a c-arm machine still emits high doses of x-ray.

[0006] It is thus desirable to provide a simulation apparatus for the emulation of a c-arm machine for training surgical techniques requiring the use of a c-arm machine without exposing the physician, patient or operator to doses of x-rays during training.

SUMMARY

[0007] There is provided according to an exemplary embodiment of the disclosure, a simulation apparatus comprising: a shell; an extendable arm housed within the shell, the extendable arm adapted to extend out of the shell; and a video camera connected to the extendable arm.

[0008] In an exemplary embodiment of the disclosure, the shell has a first circular arc of curvature with a first central angle. Optionally, the first central angle is between 30 to 150 degrees. Optionally, the extendable arm has a second circular arc of curvature with a second central angle. Optionally, the second circular arc of curvature corresponds with the first circular arc of curvature. Optionally, the second central angle is the same as the first central angle. Optionally, wherein the second central angle is more than 15 degrees but less than the first central angle.

[0009] In an exemplary embodiment of the disclosure, the video camera is connected at a distal end of the extendable arm. Optionally, the video camera comprises a collimated lens.

[0010] In an exemplary embodiment of the disclosure, the simulation apparatus further comprises an object, wherein the video camera captures at least one image of the object. Optionally, the video camera captures the at least one image based on ambient light reflected off the object.

[0011] In an exemplary embodiment of the disclosure, the simulation apparatus further comprises a lighting element located in a substantially direct line between the object and the video camera, wherein the video camera captures the at least one image based on emitted light from the lighting element reflected off the object.

[0012] In an exemplary embodiment of the disclosure, the simulation apparatus further comprises a lighting element located in a substantially direct line below the object, wherein the

video camera captures the at least one image based on light from the lighting element refracted through the object.

[0013] In an exemplary embodiment of the disclosure, the video camera transmits the at least one image to at least one computer. Optionally, the at least one computer projects the transmitted at least one image on at least one monitor. Optionally, the at least one computer comprises a network interface for remote communication. Optionally, the at least one monitor further displays at least one of: training instructions and guidance, training support, and training assessment, grading and qualification.

[0014] In an exemplary embodiment of the disclosure, the simulation apparatus further comprises a platform, the shell connected to the platform at a base of the shell. Optionally, the shell is adapted to rotate around the base of the shell. Optionally, the shell is adapted to move translationally relative to the platform.

[0015] In an exemplary embodiment of the disclosure, the simulation apparatus further comprises a phantom, the phantom mounted on the platform. Optionally, the simulation apparatus further comprises an anatomy model, the anatomy model mounted within the phantom. Optionally, the anatomy model is mounted on a model movement device.

[0016] In an exemplary embodiment of the disclosure, the simulation apparatus further comprises an anatomy model, the anatomy model mounted on the platform. Optionally, the anatomy model is mounted on a model movement device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In order for the present disclosure, to be better understood and for its practical applications to be appreciated, the following Figures are provided and referenced hereafter. It should be noted that the Figures are given as examples only and in no way limit the scope of the invention.

[0018] Fig. 1A is a schematic illustration of a front perspective view of a simulation apparatus, in accordance with some embodiments of the present disclosure;

[0019] Fig. 1B is a schematic illustration of a back perspective view of a simulation apparatus, in accordance with some embodiments of the present disclosure;

[0020] Fig. 2A is a schematic illustration of a front perspective of a C-arm module in an extended configuration, in accordance with some embodiments of the present disclosure;

[0021] Fig. 2B is a schematic illustration of a back perspective of a C-arm module in a retracted configuration, in accordance with some embodiments of the present disclosure;

5 [0022] Fig. 3A is a schematic illustration of an exploded front view of a C-arm module, in accordance with some embodiments of the present disclosure;

[0023] Fig. 3B is a schematic illustration of an exploded back view of a C-arm module, in accordance with some embodiments of the present disclosure;

10 [0024] Fig. 4 is a schematic illustration of a C-arm module, a phantom module and an anatomy module within the phantom module, in accordance with some embodiments of the present disclosure;

[0025] Fig. 5 is a schematic illustration of a phantom module, in accordance with some embodiments of the present disclosure;

15 [0026] Fig. 6 is a schematic illustration of an anatomy module, in accordance with some embodiments of the present disclosure;

[0027] Fig. 7A is a schematic illustration of how light is reflected to capture images in a first alternative embodiment of an anatomy module with an opaque anatomy model, in accordance with some embodiments of the present disclosure;

20 [0028] Fig. 7B is a schematic illustration of how light is refracted through an anatomy model to capture images in a second alternative embodiment of an anatomy module with a translucent anatomy model, in accordance with some embodiments of the present disclosure;

[0029] Fig. 8 is a schematic illustration of an imaging module, in accordance with some embodiments of the present disclosure;

25 [0030] Fig. 9 is a schematic illustration of components in a simulation apparatus, in accordance with some embodiments of the present disclosure; and

[0031] Figs. 10A to 10F are schematic illustrations of a process of using a simulation apparatus in accordance with some embodiments of the present disclosure.

[0032] With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the disclosure. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the disclosure may be practiced.

- 5 [0033] Identical or duplicate or equivalent or similar structures, elements, or parts that appear in one or more drawings are generally labeled with the same reference numeral, optionally with an additional letter or letters to distinguish between similar entities or variants of entities, and may not be repeatedly labeled and/or described. References to previously presented elements are implied without necessarily further citing the drawing or description in which they appear.
- 10 [0034] Dimensions of components and features shown in the figures are chosen for convenience or clarity of presentation and are not necessarily shown to scale or true perspective. For convenience or clarity, some elements or structures are not shown or shown only partially and/or with different perspective or from different point of views.

DETAILED DESCRIPTION

- 15 [0035] In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those of ordinary skill in the art that the invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, modules, units and/or circuits have not been described in detail so as not to obscure the invention.
- 20 [0036] Although embodiments of the invention are not limited in this regard, the terms “plurality” and “a plurality” as used herein may include, for example, “multiple” or “two or more”. The terms “plurality” or “a plurality” may be used throughout the specification to describe two or more components, devices, elements, units, parameters, or the like. Unless explicitly stated, the method embodiments described herein are not constrained to a particular
- 25 order or sequence. Additionally, some of the described method embodiments or elements thereof can occur or be performed simultaneously, at the same point in time, or concurrently. Unless otherwise indicated, use of the conjunction “or” as used herein is to be understood as inclusive (any or all of the stated options).

- [0037] The present disclosure describes a simulation apparatus designed to emulate the
- 30 operation of a c-arm machine used to guide minimally invasive surgery at a surgical site. Instead of using harmful radioactive x-rays, the presently described simulation apparatus uses

harmless light sources of either diffused reflected ambient light or transmitted normal light rays. The purpose of the simulation apparatus is to provide a simulated environment at a surgical site similar to that provided by a c-arm machine for an operator, e.g., a surgeon, to practice the use of surgical devices and instruments to perform minimally-invasive surgeries guided by a c-arm machine, under zero radioactive risk in a safe and accurate approach. Such approach is beneficial to enable a physician or operator to attain a high level of competence and the skill required and to reduce demand on supervision time, as well as to develop fine motor skills, without risks.

[0038] Fig. 1A is a schematic illustration of a front perspective view of a simulation apparatus 100, while Fig. 1B is a schematic illustration of a back perspective view of a simulation apparatus 100, in accordance with some embodiments of the present disclosure. Simulation apparatus 100 may comprise an arm such as a C-arm module 200 and an imaging module 800. Simulation apparatus 100 may further comprise a phantom module 500 and an anatomy module 600. In some embodiments, each of the C-arm module 200, imaging module 800, phantom module 500 and anatomy module 600 are portable in that each module may be sized to fit within a standard luggage for portability. Portability of the various modules according to some embodiments enables an easy deployment of the simulation apparatus 100 since it may be transported via air using commercial transportation. In some embodiments of the disclosure, the C-arm module 200 comprises an extendable element, and the C-arm module 200 is rotatable, such that a video camera 804 of imaging module 800 connected to the extendable element can capture and provide a line of sight similar to that which is provided to an operator of a real c-arm machine. In some embodiments of the disclosure, the C-arm module 200 may be connected to a table or phantom module 500 such that the C-arm module 200 may be moved translationally relative to the table or phantom module 500.

[0039] In some embodiments of the present disclosure, C-arm module 200 may comprise a C-arm shell 212 housing an extendable arm 208 (see. Figs. 2A, 2B, 3A, 3B) that emulates and provides the mechanical functions of the arm of a c-arm machine, and a C-arm module head 204 housing a video camera 804 simulating the imaging functions of an x-ray image intensifier or detector in a real c-arm machine (see Figs. 2A, 2B, 3A, 3B). The C-arm module 200 emulates the movement of the c-arm, the x-ray tube and x-ray image intensifier of a c-arm machine such that the C-arm module head 204 housing video camera 804 can be moved and fixed with the lateral and rotational positioning required along two linear axes (x and y) and two rotational

axes (x (orbit) and y (tilt)). Although not illustrated in the figures, C-arm module 200 may further comprise at least one motor that actuates movement of the C-arm module 200, the motors connected to and controlled by computer 808 of imaging module 800 (see Fig. 9). In some embodiments, although not illustrated in the figures, C-arm module 200 may further
5 comprise at least one sensor, the at least one sensor connected to computer 808 of imaging module 800 (see Fig. 9) and adapted to provide information on the position or angle of C-arm module 200. The components of C-arm module 200 are discussed in detail below in relation to Figs. 2A, 2B, 3A and 3B.

[0040] In some embodiments of the present disclosure, imaging module 800 may comprise the
10 video camera 804 (Fig. 3A) housed within the C-arm module head 204 of the C-arm module 200, the video camera 804 capturing at least one image of an object. The object may be an anatomy model 604 (see Fig. 4 and 6). The video camera 804 may then transmit the at least one image to at least one computer 808 (see Fig. 8) which projects or displays the transmitted at least one image on at least one monitor 812 (see Figs. 8 and 9). Imaging module 800 thus
15 provides real-time capturing and imaging of the object to simulate and display images to an operator, e.g., a radiographer or surgeon, in a form similar to that provided by a real c-arm machine. Video camera 804 may preferably comprise collimated lens to capture the at least one image. Computer 808 of imaging module 800 may further display a user interface (see Figs. 10A, 10B, 10C, 10D, 10E, 10F) that allows an operator to interact with the images
20 transmitted from video camera 804. The computer 808 of imaging module 800 may include computer software which inverts colour and manipulates image qualities like brightness, contrast, zoom and snap, which are similar to functions commonly used with actual fluoroscopic image functions.

[0041] In some embodiments of the present disclosure, the phantom module 500 may comprise
25 a phantom 504 mounted on a table or platform 512, such as simulated operating table with at least one phantom stand 528. Phantom 504 of the phantom module 500 is a model of a human body and provides the outer visual of a human body surface and contour to house a desired surgical site. In some embodiments, the phantom 504 is a model of an animal body. In some embodiments, the phantom 504 is a model of an organ of a human or animal body.

[0042] The platform 512 is modelled as a miniaturised operating table with at least one, and
30 preferably two, rail 524 adapted for the mounting of surgical devices. In some embodiments, the platform 512 is modelled as a section of a real operating table. The C-arm module 200 and

the imaging module 800 may be detachably mounted on rail 524 of phantom module 500 and preferably on rail 524 distal from the operator. Alternatively, C-arm module 200 and imaging module 800 may be detachably mounted onto any surface, including a surgical table or an operating table, as an alternate surgical site.

5 [0043] In some embodiments of the present disclosure, anatomy module 600 may comprise at least one anatomy model 604 (see Figs. 4 and 6). Anatomy module 600 may be placed within phantom 504 of phantom module 500 or on any surface for imaging with imaging module 800. Anatomy model 604 may be an opaque or translucent model of tissue and/or organ structure to be simulated as being operated on. Anatomy model 604 may be mounted on a model movement
10 device 608 (see Figs. 4 and 6) that moves anatomy model 604 to emulate the motion of a real tissue or organ due to breathing or other physiological functions of a subject.

[0044] In some embodiments of the present disclosure, a surgical instrument 104 may be held by a surgical instrument holder 108, the surgical instrument holder 108 removably mounted on a support arm 112 and attached to the rail 524 of platform 512 of phantom module 500 with a
15 support arm clamp 116 on support arm 112. Alternatively, surgical instrument 104 may be held by support arm 112. Alternatively, the support arm clamp 116 may be attached to any other surface, including an operating table or a surgical table. In some embodiments of the disclosure, the surgical instrument 104 is a needle. In some embodiments of the disclosure, the surgical instrument 104 is a surgical probe. In some embodiments of the present disclosure the surgical
20 instrument holder may be placed directly on the phantom 504 without the use of the support arm 112. It will be understood that the disclosure is not limited to the surgical instrument holder 108 and surgical instrument 104 as shown and that various other surgical instrument holders and surgical instruments may be used in connection with the simulation and training apparatus shown herein. Examples of surgical instruments include surgical drills, laser apparatus,
25 laparoscopes, endoscopes and other diagnostic or surgical apparatus or instruments. In some embodiments of the present disclosure, although not illustrated in the figures, simulation apparatus 100 may be connected to an external power source and powered by approximately 110 or 220 volts.

[0045] Fig. 2A is a schematic illustration of a front perspective of a C-arm module 200 in an
30 extended configuration, while Fig. 2B is a schematic illustration of a back perspective of a C-arm module 200 in a retracted configuration, in accordance with some embodiments of the present disclosure. Fig. 3A is a schematic illustration of an exploded front view of a C-arm

module, while Fig. 3B is a schematic illustration of an exploded back view of a C-arm module, in accordance with some embodiments of the present disclosure. C-arm module 200 may comprise an extendable arm 208 enclosed within a C-arm shell 212, the extendable arm 208 connected at a distal end 210 to a C-arm module head 204 by a support mount 216. C-arm shell 212 may comprise a left arm groove cover 220 and right arm groove cover 224, the left arm groove cover 220 and right arm groove cover 224 connected longitudinally by a bottom arm groove cover 228 along an inner circumference of the left arm groove cover 220 and right arm groove cover 224. Left arm groove cover 220 and right arm groove cover 224 may be shaped such that C-arm shell 212 has a first circular arc of curvature with a first central angle although other shapes may be implemented. The first central angle may be between 30 to 150 degrees, and preferably 90 degrees, to emulate a c-arm. The first circular arc of curvature of C-arm shell 212 may have a radius of between 5 and 80 cm, and preferably between 40 and 60 cm, to simulate a real c-arm machine. Alternatively, for maximum portability, the first circular arc of curvature of C-arm shell 212 may have a radius of between 5 and 50 cm, which is approximately two-thirds of the radius of the c-arm of a real c-arm machine. Preferably, C-arm shell 212 may further comprise at least one arm handle 232 for an operator to grasp and move C-arm shell 212.

[0046] In some embodiments of the present disclosure, the sides of the extendable arm 208 facing left arm groove cover 220 and right arm groove cover 224 may each comprise an indentation 236 proximate to C-arm module head 204, each of the indentations 236 housing a stationary portion of a damper roller 240, the damper roller 240 comprising a rotating wheel 244 protruding out of indentation 236.

[0047] In some embodiments of the present disclosure, extendable arm 208 housed within C-arm shell 212 may have a second circular arc of curvature with a second central angle. Preferably, the second circular arc of curvature corresponds with the first circular arc of curvature such that when the extendable arm 208 is extended out of C-arm shell 212 along orbit path A, the C-arm module head 204 and the extendable arm 208 extends along the same arc as C-arm shell 212. The second circular arc of curvature may have a central angle of between 30 and 150 degrees, and preferably 90 degrees. Preferably, the second central angle may correspond with the first central angle. Alternatively, the second central angle may be more than 15 degrees but less than the first central angle such that the extendable arm 208 fits within C-arm shell 212. Preferably, extendable arm 208 extends in a direction towards the operator

when in use. The extension of extendable arm 208 is designed to emulate the fixed arc and movement of a real c-arm machine, while increasing the portability of simulation apparatus 100 by using reducing the space required for C-arm module 200 as compared to a full c-arm machine which has a large semi-circle arc.

5 [0048] In some embodiments of the present disclosure, extendable arm 208 may have a cross-section similar to a capital letter "T", each end of the arm of the capital letter "T" resting on rotating wheel 244 mounted on the left arm groove cover 220 and right arm groove cover 224 such that extendable arm 208 rolls on rotating wheels 244 when extendable arm 208 is extended out of C-arm shell 212. Extendable arm 208 may further comprise an extension 248 protruding
10 at substantially a midpoint of either sides of the stem of the "T" shaped cross-section of extendable arm 208, extension 248 sitting on top of protrusions 252 running longitudinally along the extendable arm 208 facing sides of the left arm groove cover 220 and right arm groove cover 224. Extendable arm 208 may further comprise an extendable arm handle 260 for the operator to hold and move the extendable arm 208. Although not illustrated in the figures,
15 extendable arm 208 may further comprise an orbit degree scale to indicate the extend of orbit movement.

[0049] In some embodiments of the present disclosure, C-arm module head 204 may comprise a camera cylinder 264 housing a video camera 804 (see Fig. 3A and 3B), the video camera 804 connected to the computer 808 of imaging module 800 (see Fig. 9). Video camera 804 will be
20 discussed further below in relation to imaging module 800. Video camera 804 may be mounted on a camera mount plate 268 within camera cylinder 264, with a vent cover 272 covering the top of camera cylinder 264. Although the housing of video camera 804 is described as a camera cylinder 264, any hollow shape or housing may be implemented. Optionally, C-arm module head 204 may further comprise a laser pointer (not shown) to assist an operator in the alignment
25 of C-arm module head 204 and video camera 804 with anatomy model 604. Such laser pointer may be connected inline with the video camera 804 extending the visible laser beam perpendicular to the video camera 804 line of sight.

[0050] In some embodiments of the present disclosure, bases of left arm groove cover 220 and right arm groove cover 224 of C-arm shell 212 may be inserted or connected into a tilt axle
30 cover 276, the tilt axle cover 276 comprising two flanges adapted to receive the bases of left arm groove cover 220 and right arm groove cover 224. Tilt axle cover 276 may further be connected to a lock plate 280, tilt axle cover 276 and lock plate 280 comprising corresponding

u-shaped arc openings 284. Lock plate 280 may be connected to a damper connecting plate 288 located at a base of the bottom arm groove 228, the damper connecting plate 288 not obscuring the u-shaped arc openings 284 in lock plate 280 and tilt axle cover 276. Lock plate 280 may comprise a tilt indicator pointer 256 to indicate to an operator the extent or degree which the C-arm shell 212 and the extendable arm 208 are tilted relative to a vertical line.

[0051] In some embodiments of the present disclosure, C-arm module 200 may further comprise a c-arm tilt base 292. C-arm tilt base 292 may comprise a damper 296, a damper housing 304, a damper front cover 308, a damper top 312, and at least one damper side cover 324. Damper 296 may be mounted on a wall of damper housing 304 proximal to a base of C-arm shell 212. Damper front cover 308 may cover a front face of damper housing 304 distal from damper 296, damper top 312 may cover a top of damper housing 304 and damper side covers 324 may flank either side of damper housing 304. C-arm shell 212 may be rotatably coupled to damper 296 through a damper coupling 316 and a damper coupling bushing 320, such that C-arm shell 212 may rotate relative to the c-arm tilt base 292 along an axis of rotation path B, and the C-arm module head 204 can tilt along path C. Damper housing 304 may further comprise at least one damper housing handle 326 for an operator to grasp and move c-arm tilt base 292.

[0052] In some embodiments of the present disclosure, a tilt lock handle 328 may be connected to c-arm tilt base 292 by inserting of shaft 332 of tilt lock handle 328 into u-shaped arc opening 284 of tilt axle cover 276, through a boss pin 336 and at least one boss pin washer 340, through opening 284 of lock plate 280 and into lock pin 344 through a washer, lock pin 344 connected to a wall of damper housing 304 proximate to tilt axle cover 276. When tilt lock handle 328 is rotated, the shaft 332 of tilt lock handle 328 is tightened into lock pin 344, thus locking the position of C-arm shell 212 relative to c-arm tilt base 292. In some embodiments of the present disclosure, there may be protractor markings 384 along opening 284 of tilt axle cover 276 and/or on damper top 312 proximate to C-arm shell 212 to assist an operator to read the tilt angle of C-arm shell 212.

[0053] In some embodiments of the present disclosure, c-arm tilt base 292 may be mounted on a slider mount 348 such that the c-arm tilt base 292 slides translationally along the slider mount 348 along path D perpendicular to operator. Preferably, c-arm tilt base 292 may be mounted on slider mount 348 via a tongue-and-groove arrangement. In some embodiments of the present disclosure, slider mount 348 may comprise a valley 352 and c-arm tilt base 292

may further comprise a slider plate 356. A screw may be inserted into a hole of slider plate 356 and protrude into valley 352 of slider mount 348, thus restricting the extent of translational movement of c-arm tilt base 292 along slider mount 348 as the screw protruding from slider plate 356 into valley 352 would prevent c-arm tilt base 292 from sliding beyond the valley 352 of slider mount.

[0054] In some embodiments of the present disclosure, slider mount 348 may be movably mounted onto the rail 524 of the platform 512 of phantom module 500 such that slider mount 348 slides translationally along rail 524 along path E. Preferably, slider mount 348 may further comprise two sets of adjacent rail slider rollers 360. Preferably, each of the adjacent rail slider rollers 360 are mounted on post plugs 364 sandwiched between two plug plates 368. The sets of adjacent rail slider rollers 360 are arranged parallel to each other so that rail 524 fits between the two sets of rail slider rollers 360. Each set of adjacent rail slider rollers 360 may be connected to c-arm tilt base 292 either directly or through a spacer plate 372 and washers 376. Spacer plate 372 may further be connected to a bottom plug plate 380 to cover up rail slider rollers 360 beyond the plug plates 368. The bottom plug plate 380 may be further connected to vertical adjustable support legs (not shown) to support the C-arm module 200 if required.

[0055] Alternatively, slider mount 348 may be mounted onto any surface with rails, including an operating table or surgical table.

[0056] Fig. 4 is a schematic illustration of a C-arm module 200, a phantom module 500, and an anatomy module 600 within the phantom module 500, in accordance with some embodiments of the present disclosure. Phantom module 500 may comprise a phantom 504. In some embodiments, phantom 504 may be shaped as a human or an animal. In some embodiments, phantom 504 may be shaped as a part of an organ of a human or an animal. In some embodiments, phantom 504 may be shaped as a part of a human or an animal, for example as the torso area. Anatomy module 600 may comprise an anatomy model 604. Preferably, anatomy module 600 is located within a phantom 504 of the phantom module 500, positioned such that the anatomy model 604 of anatomy module 600 is located under a window 508 in phantom 504. In certain embodiments, anatomy module 600 may be placed on any surface for imaging by imaging module 800 without phantom module 500. In some embodiments, the simulation apparatus 100 is used without a phantom 504.

[0057] Fig. 5 is a schematic illustration of a phantom module 500, in accordance with some embodiments of the present disclosure. Phantom module 500 may comprise a hollow phantom 504 with a window 508. Window 508 may be located anywhere on phantom 504 as long as anatomy model 604 is visible to video camera 804. Window 508 may comprise a clear plastic film (not shown) which may simulate the location of the skin of the human or animal. Although not illustrated in the figures, window 508 may comprise an x-ray film of a desired organ or tissue. Window 508 may vary in size depending on the procedure simulated such that the operator is able to see anatomy model 604 (see Fig. 4) to the extent necessary for the performance of the simulation. In some embodiments, window 508 size is designed to allow sufficient view to video camera 804 so as to simulate the field of view the operator may see using a real c-arm machine's associated video screen. Phantom 504 may be mounted on a platform 512 with at least one phantom stand 528. Platform 512 is designed as a miniaturised operating table and may comprise a table top 516 and two table stands 520 connected longitudinally to opposite ends of table top 516, each table stand 520 comprising a rail 524 connected longitudinally to table stand 520. Rail 524 is adapted to allow various modules and/or surgical instruments to clamp onto. Phantom 504 may be replaced with actual, animal, or artificial tissue or organ specimens for simulated surgery, study or training.

[0058] Fig. 6 is a schematic illustration of an anatomy module 600, in accordance with some embodiments of the present disclosure. Anatomy module 600 may comprise at least one anatomy model 604. Anatomy model 604 may be opaque (see Fig. 7A) or translucent (see Fig. 7B). Anatomy model 604 may be either be placed within phantom 504 of phantom module 500, or optionally mounted on a model movement device 608 as depicted in Fig. 6 to move anatomy model 604. The movement of anatomy model 604 with model movement device 608 simulates surgical procedure with greater realism and to replicate the difficulty of certain surgeries due to physiological organ motions such as the periodic movement of of an organ, such a kidney during patient breathing. Model movement device 608 may comprise a model mount 612, on which anatomy model 604 is mounted onto, the model mount 612 adapted to move or slide along a slider 616. Model mount 612 may be movably connected to slider 616 through a tongue-and-groove arrangement. Movement of model mount 612 and the anatomy model 604 may be actuated by a pulley system controlled by a programmable logic module (PLC) 620. Alternatively, model movement device 608 may be a linear actuator and stepper motor assembly controlled by PLC 620 or a microcontroller. PLC 620 is programmed to allow an operator to set, through a user interface, the speed, frequency, range and amplitude of

movement of anatomy model 604, as well as stop and start movement of anatomy model 604, to simulate a variety of movement patterns based on the organ that anatomy model 604 is modelled after. For example, if anatomy model 604 is in the shape of a kidney, model movement device 608 may move anatomy model 604 linearly within a range of up to 5 cm at an average rate of between 12 to 25 cycles per minute, which simulates the movement of a kidney during normal breathing. Although not illustrated in the figures, anatomy module 600 may further comprise a control panel with control buttons connected to model movement device 608, the control buttons configured to start and stop movement of anatomy module 600 to emulate the controlled pausing of patient breathing by the anaesthetists to allow surgeon to operate accurately without affected by the organ movement.

[0059] In some embodiments of the present disclosure, the pulley system may comprise a motor 624, a first pulley 628 mounted on and controlled by motor 624, a second pulley 632, and a pulley belt 636 looped around the first pulley 628 and second pulley 632. The model mount 612 may be attached to pulley belt 636 such that movement of the pulley belt 636 causes movement of the model mount 612. PLC 620 may be connected to computer 808 of imaging module 800 (see Fig. 9). PLC 620 controls the movement of motor 624, which in turn rotates the first pulley 628 and moves the pulley belt 636. This movement of the pulley belt 636 moves the model mount 612 attached to the pulley belt 636. Anatomy model 604 thus moves linearly and translationally along path F parallel to the movement of pulley belt 636.

[0060] In some embodiments of the present disclosure, model movement device 608 may be turned on and off with a microswitch 640. Alternatively, model movement device 608 may be connected to and controlled by computer 808 of imaging module 800 (see Fig. 9).

[0061] In some embodiments of the present disclosure, anatomy module 600 may further comprise at least one lighting element 644. Lighting element 644 may be any lighting device. For example, lighting element 644 may be a circular light-emitting diode (LED) with a diameter larger than anatomy model 604, as depicted in Fig. 6. Lighting element 644 may be located at any position, including above anatomy model 604 (as depicted in Figs. 6 and 7A), or underneath the anatomy model 604 (as depicted in Fig. 7B). The position of lighting element 644 may differ depending on whether anatomy model 604 is opaque or translucent (see Figs. 7A and 7B). Lighting element 644 may be controlled independently with a switch on lighting element 644. Alternatively, lighting element 644 may be controlled by computer 808 of imaging module 800 (see Fig. 9). In some embodiments, lighting element 644 is connected to

a power source (not shown) such as a USB cable connected to computer 808. In some embodiments, lighting element 644 further comprises an internal power source, such as a battery (not shown).

[0062] Fig. 7A is a schematic illustration of how light is reflected to capture images in a first alternative embodiment of an anatomy module 600 with an opaque anatomy model 604, in accordance with some embodiments of the present disclosure. In a real c-arm machine, x-ray light from an x-ray source passes through a patient and is detected by an x-ray intensifier or detector located directly opposite the x-ray source. The path taken by the x-ray light in a real c-arm machine is illustrated in Fig. 7A as x-ray light pathway 704, with video camera 804 located within C-arm module 200 simulating an x-ray intensifier or detector in a real c-arm machine. In the first alternative embodiment of anatomy module 600 where anatomy model 604 is opaque, video camera 804 may capture at least one image of an object or anatomy model 604 based on ambient light from the surroundings. Ambient light travels to anatomy model 604 via ambient light pathway 708, reflects off anatomy model 604, travels to video camera 804 through reflected light pathway 712 and is captured by video camera 804. Alternatively, video camera 804 may capture at least one image of an object or anatomy model 604 based on emitted light from lighting element 644 reflected off anatomy model 604. In such an embodiment, lighting element 644 is located in a substantially direct line between anatomy model 604 and video camera 804 such that emitted light travels from lighting element 644 to anatomy model 604 via a emitted light pathway 716, reflects off anatomy model 604, travels to video camera 804 through reflected light pathway 712 and is captured by video camera 804. Opaque anatomy model 604 would appear brightly on the image captured by video camera 804, which matches the effect of x-ray imaging with a real c-arm machine where high-density regions like bones or stones will appear brightly on an x-ray image.

[0063] Fig. 7B is a schematic illustration of how light is refracted through anatomy model 604 to capture images in a second alternative embodiment of an anatomy module 600 with a translucent anatomy model 604, in accordance with some embodiments of the present disclosure. When anatomy model 604 is translucent, lighting element 644 is located in a substantially direct line below the anatomy model 604 such that emitted light from lighting element 644 refracted by translucent anatomy model 604 travels to video camera 804 via refracted light pathway 720 to be captured by video camera 804. In this embodiment, translucent anatomy model 604 would appear as dark regions on the image captured by video

camera 804. As this image produced would be inverse to x-ray images obtained with a real c-arm machine, grayscale inversion may be applied with real-time image processing to simulate the effect of x-ray imaging with a real c-arm machine.

[0064] Fig. 8 is a schematic illustration of an imaging module 800, in accordance with some embodiments of the present disclosure. Imaging module 800 may comprise at least one monitor 812, at least one computer 808, at least one monitor holder 816, a monitor stand 820 and a clamp 824. Monitors 812 may be any display. Monitor 812 may be mounted on monitor stand 820 with monitor holder 816. Clamp 824 may be located at a base of monitor stand 820 distal from monitors 812. Monitor stand 820 may be mounted on rail 524 of phantom module 500 with clamp 824. Alternatively, monitor stand 820 may be mounted on any surface, including an operating table and a surgical table, with clamp 824. Preferably, computer 808 is a miniature computer capable of being mounted onto monitor 812 for portability. Although not depicted in Fig. 8, imaging module 800 may further comprise an input device 828 (see Fig. 9). Input device 828 may be a mouse, keyboard or joystick. Alternatively, input device 828 may be incorporated into monitor 812 such that monitor 812 is a touchscreen display.

[0065] Fig. 9 is a schematic illustration of components in a simulation apparatus 100, in accordance with some embodiments of the present disclosure. Computer 808 may comprise at least one storage 832, at least one processor 836 and at least one memory 840. Processor 836 may include at least one processing unit and may be configured to operate in accordance with programmed instructions that are stored in memory 840. The at least one memory 840 may interact with the at least one processor 836 and may include at least one volatile or non-volatile memory device. Memory 840 may be used to store an executable version of a software application useful to manipulate images obtained from video camera 804 or execute a software that displays on monitor 812. The software displayed on monitor 812 may display step-by-step training instructions and guidance on how to use the simulation apparatus 100, training support, as well as training assessment, grading and qualification relating to a surgical procedure to be trained and/or simulated. For example, where there are two monitors 812, the software may display on first monitor 812 still or real-time images or videos captured by video camera 804 and display on second monitor 812 an interface for training steps or guides (real sample x-ray images on the anatomy during procedure) or support (e.g., virtual extended line on needle) and training assessments and/or grading/feedback. Storage 832 may be a computable readable medium for storing instructions for operation of processor 836. In some embodiments, storage

832 may be separate from memory 840, though in other embodiments, storage 832 may be included in memory 840.

[0066] In some embodiments of the present disclosure, computer 808 may be connected to and receive input from input device 828. Computer 808 may also receive information from various other components of simulation apparatus 100, including video camera 804 and sensors (not shown). Computer 808 may receive information from video camera 804 through a wired connection (see Fig. 2A) or may receive information from video camera 804 wirelessly. Computer 808 may further be connected to and relay information to other components of simulation apparatus 100, including PLC 620, monitor 812 and lighting element 644. Computer 808 may display images on monitor 812, control PLC 620 as well as control lighting element 644. Although not illustrated in the figures, the at least one computer 808 may further comprise a network interface. The network interface allows the at least one computer 808 to communicate remotely with other computers to allow remote training, instruction, training assessment or training qualification. Although not illustrated in the figures, the at least one computer 808 may be connected to and control motors within C-arm module 200 which actuate movement of components within C-arm module 200.

[0067] Figs. 10A to 10F are schematic illustrations of a process of using a simulation apparatus 100 in accordance with some embodiments of the present disclosure. In some embodiments of the present disclosure, as shown in Fig. 10A, an operator assembles the simulation apparatus 100 by installing C-arm module 200, imaging module 800, phantom module 500 and anatomy module 600. Anatomy model 604 may be placed within phantom 504 of phantom module 500 and may be aligned directly under window 508 of phantom 504. C-arm module head 204 may be aligned approximately above window 508 of phantom 504. If phantom 504 of phantom module 500 is not required, anatomy module 600 may be placed directly on platform 512 of phantom module 500, with C-arm module head 204 aligned approximately above anatomy model 604.

[0068] In some embodiments of the present disclosure, as shown in Fig. 10B, the operator may then connect simulation apparatus 100 to an external power source and then turn on simulation apparatus 100, including the components of imaging module 800 such as computer 808 and monitor 812. The operator may optionally turn video camera 804 on at this step.

[0069] In some embodiments of the present disclosure, as shown in Fig. 10C, the operator may determine whether ambient light is sufficiently bright to deliver clear, reflected illumination of anatomy model 604. The operator may turn lighting element 644 on if they determine that there is insufficient ambient light.

- 5 [0070] In some embodiments of the present disclosure, as shown in Fig. 10D, the operator may use input device 828 to activate a software stored in computer 808 of imaging module 800. The operator may also turn video camera 804 on if the operator had not previously done so. The operator may adjust the position of C-arm module head 204 by sliding and/or rotating the C-arm module 200 using its features as described above to the angle required to align video
10 camera 804 with window 508. In some embodiments of the present disclosure, the operator may use a laser pointer within C-arm module head 204 to assist with the alignment of C-arm module head 204 and video camera 804 with anatomy model 604. The operator may view a video captured by video camera 804 and displayed on monitor 812 to further adjust and confirm the position of C-arm module head 204.
- 15 [0071] In some embodiments of the present disclosure, as shown in Fig. 10E, the operator may mount and secure at least one surgical instrument 104 onto rail 524 of platform 512 of phantom module 500 using support arm clamp 116 on support arm 112 holding surgical instrument holder 108. The operator may then start the surgical procedure, experiment, training or simulation.
- 20 [0072] In some embodiments of the present disclosure, as shown in Fig. 10F, the operator may rotate and lock the C-arm module 200 to new angles or positions for triangulation to anatomy model 604, or to obtain other views of the window 508 or anatomy model 604 from different angles or directions. The operator may further read the angle of tilt of C-arm module 200 by viewing protractor markings 384 on C-arm module 200. Once the operator is finished with
25 simulation apparatus 100, the operator may return the C-arm module 200 to its neutral or zero position. The operator may then close the software program running on computer 808, shut down computer 808, turn off all components of simulation apparatus 100, and turn off the main power. The operator may then detach support arm clamp 116 from rails 524 and disassemble simulation apparatus 100.
- 30 [0073] It should be appreciated that the above-described methods and apparatus may be varied in many ways, including omitting or adding steps, changing the order of steps and the type of

devices used. It should be appreciated that different features may be combined in different ways. In particular, not all the features shown above in a particular embodiment are necessary in every embodiment of the disclosure. Further combinations of the above features are also considered to be within the scope of some embodiments of the disclosure.

- 5 [0074] It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims, which follow.

CLAIMS

1. A simulation apparatus comprising:
a shell;
an extendable arm housed within the shell, the extendable arm adapted to extend out of
5 the shell; and
a video camera connected to the extendable arm.
2. The simulation apparatus of claim 1, wherein the shell has a first circular arc of curvature with a first central angle.
3. The simulation apparatus of claim 2, wherein the first central angle is between 30 to
10 150 degrees.
4. The simulation apparatus of claim 2, wherein the extendable arm has a second circular arc of curvature with a second central angle.
5. The simulation apparatus of claim 4, wherein the second circular arc of curvature corresponds with the first circular arc of curvature.
- 15 6. The simulation apparatus of claim 4, wherein the second central angle is the same as the first central angle.
7. The simulation apparatus of claim 4, wherein the second central angle is more than 15 degrees but less than the first central angle.
8. The simulation apparatus of claim 1, wherein the video camera is connected at a distal
20 end of the extendable arm.
9. The stimulation apparatus of claim 1, wherein the video camera comprises a collimated lens.
10. The simulation apparatus of claim 1, further comprising an object, wherein the video camera captures at least one image of the object.
- 25 11. The simulation apparatus of claim 10, wherein the video camera captures the at least one image based on ambient light reflected off the object.

12. The simulation apparatus of claim 10, further comprising a lighting element located in a substantially direct line between the object and the video camera, wherein the video camera captures the at least one image based on emitted light from the lighting element reflected off the object.
- 5 13. The simulation apparatus of claim 10, further comprising a lighting element located in a substantially direct line below the object, wherein the video camera captures the at least one image based on light from the lighting element refracted through the object.
14. The simulation apparatus of claim 10, wherein the video camera transmits the at least one image to at least one computer.
- 10 15. The simulation apparatus of claim 14, wherein the at least one computer comprises a network interface for remote communication.
16. The simulation apparatus of claim 14, wherein the at least one computer projects the transmitted at least one image on at least one monitor.
17. The simulation apparatus of claim 16, wherein the at least one monitor further displays
15 at least one of: training instructions and guidance, training support, and training assessment, grading and qualification.
18. The simulation apparatus of claim 1, further comprising a platform, the shell connected to the platform at a base of the shell.
19. The simulation apparatus of claim 18, wherein the shell is adapted to rotate around the
20 base of the shell.
20. The simulation apparatus of claim 18, wherein the shell is adapted to move translationally relative to the platform.
21. The simulation apparatus of claim 18, further comprising a phantom, the phantom mounted on the platform.
- 25 22. The simulation apparatus of claim 21, further comprising an anatomy model, the anatomy model mounted within the phantom.

23. The simulation apparatus of claim 22, wherein the anatomy model is mounted on a model movement device.
24. The simulation apparatus of claim 18, further comprising an anatomy model, the anatomy model mounted on the platform.
- 5 25. The simulation apparatus of claim 24, wherein the anatomy model is mounted on a model movement device.