US 20170110032A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2017/0110032 A1

O'BRIEN et al.

(43) Pub. Date: Apr. 20, 2017

(54) **ULTRASOUND SIMULATION SYSTEM AND TOOL**

(71) Applicant: **VIRTAMED AG**, Schlieren (CH)

(72) Inventors: **Carolyn O'BRIEN**, Schlieren (CH); **Erika BEUDEKER**, Schlieren (CH)

(73) Assignee: **VIRTAMED AG**, Schlieren (CH)

(21) Appl. No.: **15/294,275**

(22) Filed: **Oct. 14, 2016**

Related U.S. Application Data

(60) Provisional application No. 62/242,322, filed on Oct. 16, 2015.

Publication Classification

(51) **Int. Cl.**

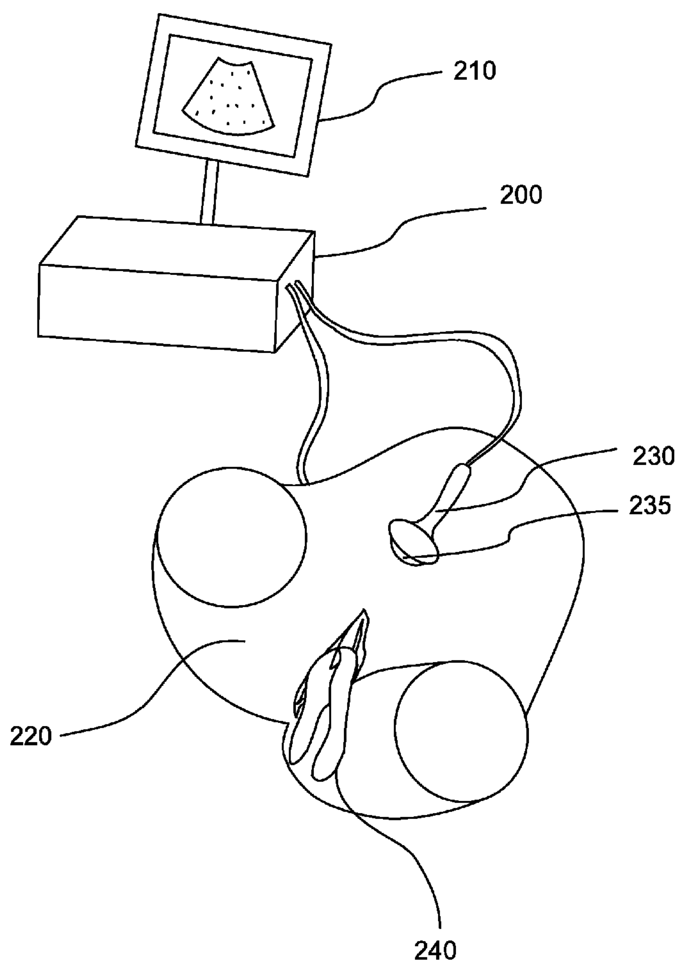
G09B 23/28	(2006.01)
G09B 23/30	(2006.01)
G09B 9/00	(2006.01)

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

CPC ***G09B 23/286*** (2013.01); ***G09B 9/00*** (2013.01); ***G09B 23/281*** (2013.01); ***G09B 23/30*** (2013.01)

(57) **ABSTRACT**

Embodiments of flexible ultrasound simulation devices, methods, and systems described herein may facilitate various medical procedure training by rendering realistic ultrasound images in accordance with the end user interaction with an anatomy model, an ultrasound probe replica and a medical tool. An ultrasound probe replica may be adapted with a low friction tip, such as a roller ball. A data processing unit may compute and display an accurate Virtual Reality/Augmented Reality (VR/AR) model and an ultrasound image in accordance with the position and orientation tracking of the VR/AR ultrasound simulator elements. The VR/AR ultrasound simulator may be adapted to realistically render the VR/AR model and the ultrasound image as a function of the user interaction with the VR/AR simulator elements.



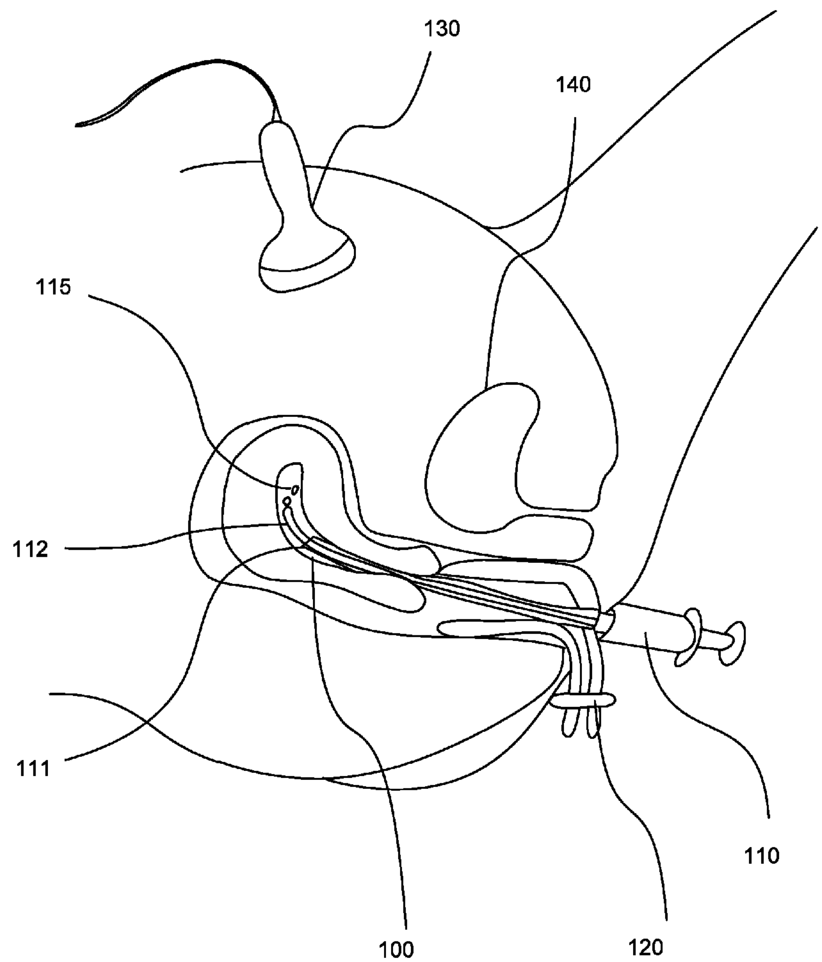


FIG. 1 (prior art)

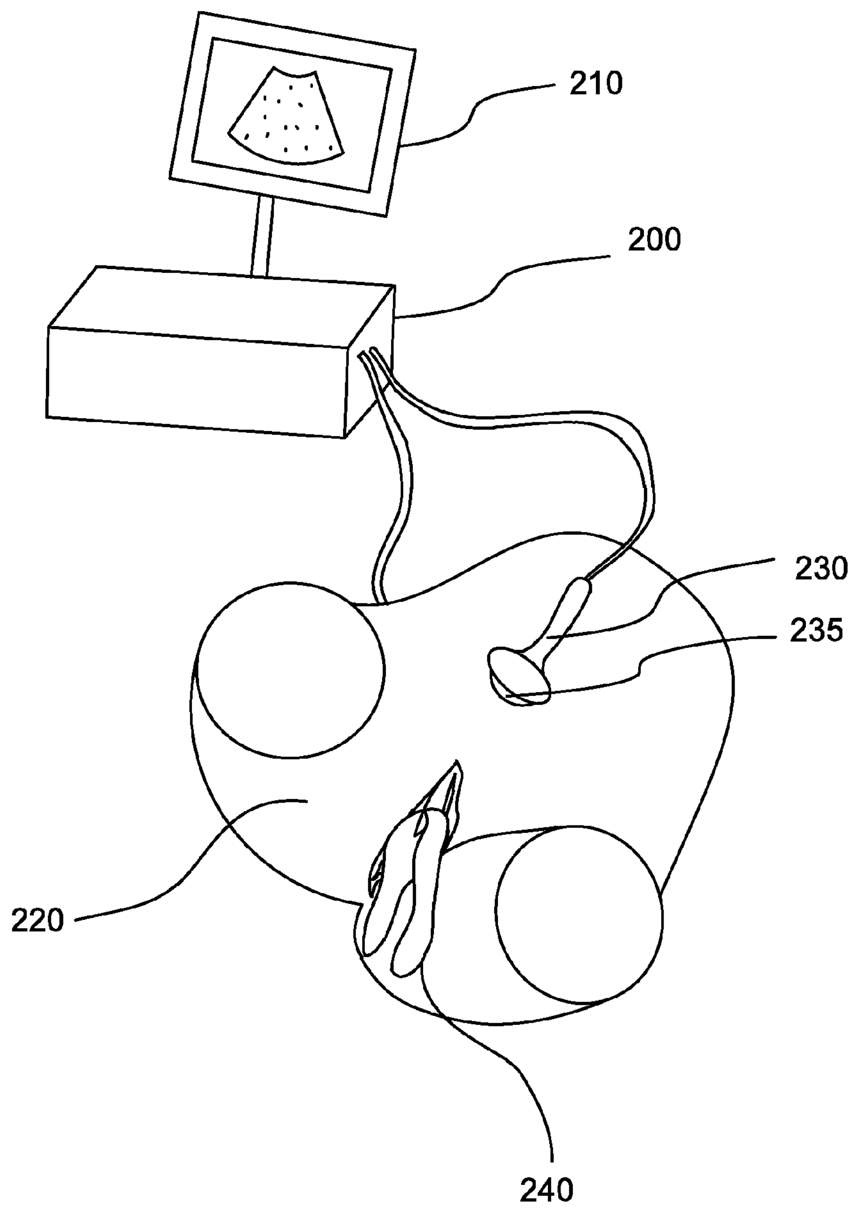
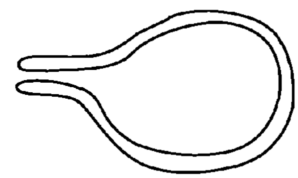


FIG. 2

a)



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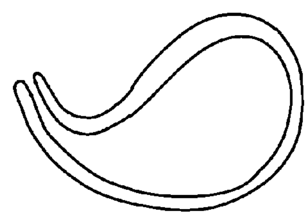

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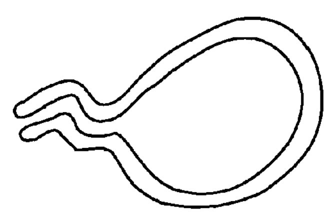

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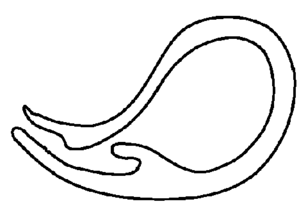

FIG. 3

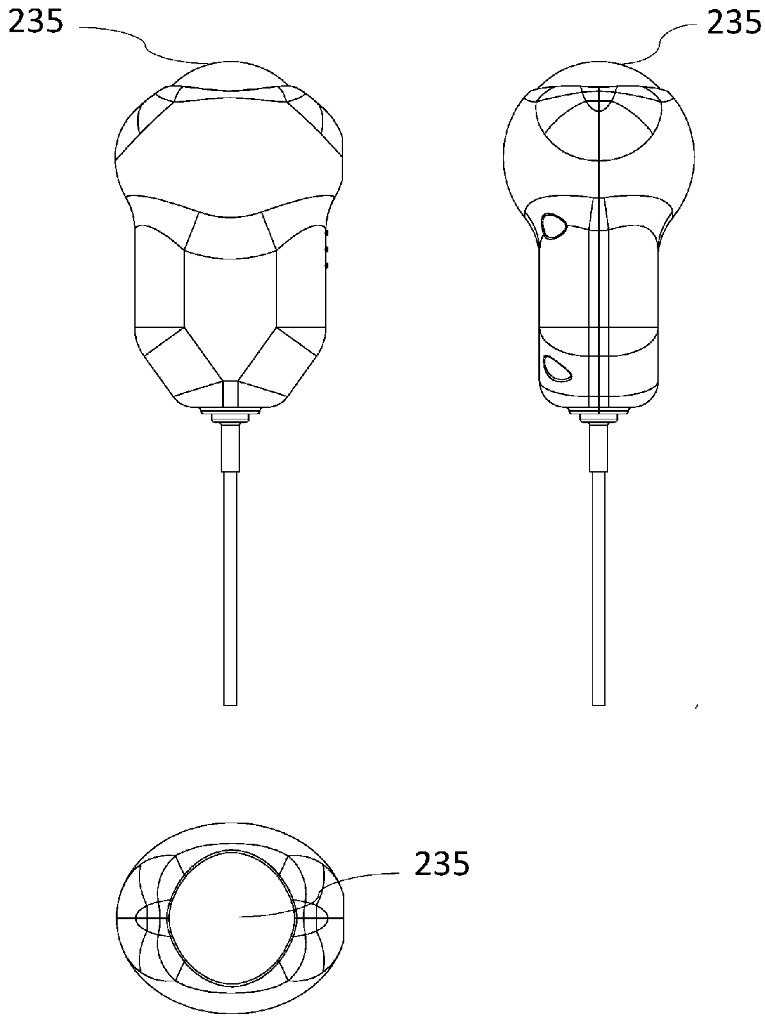

FIG. 4

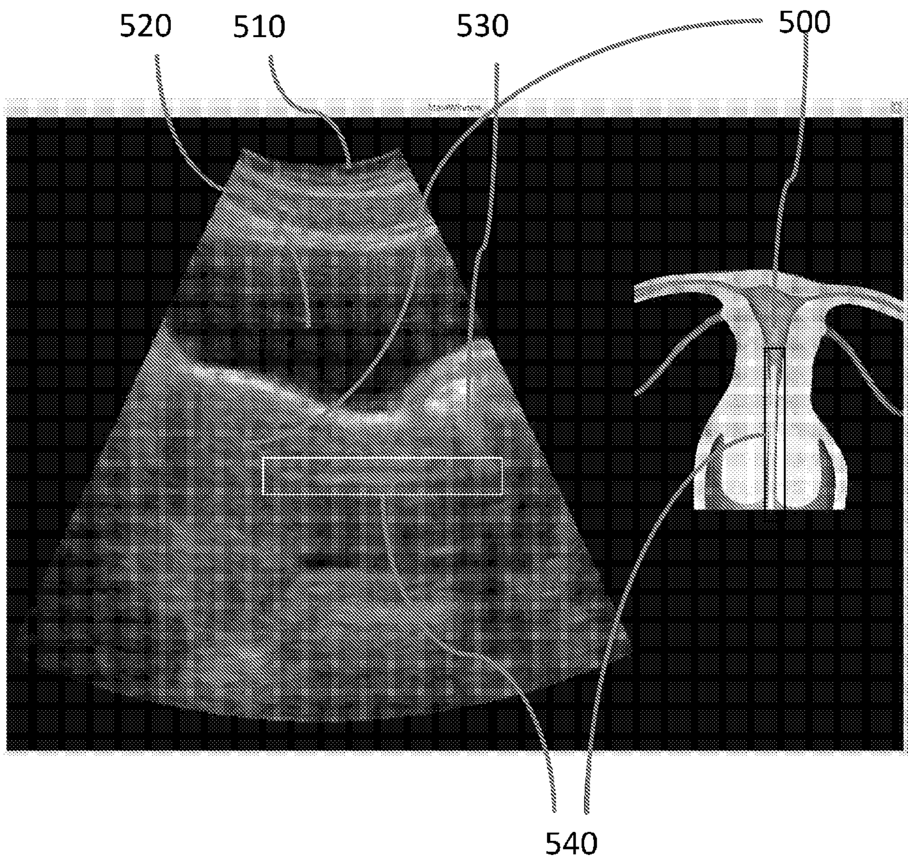

FIG. 5

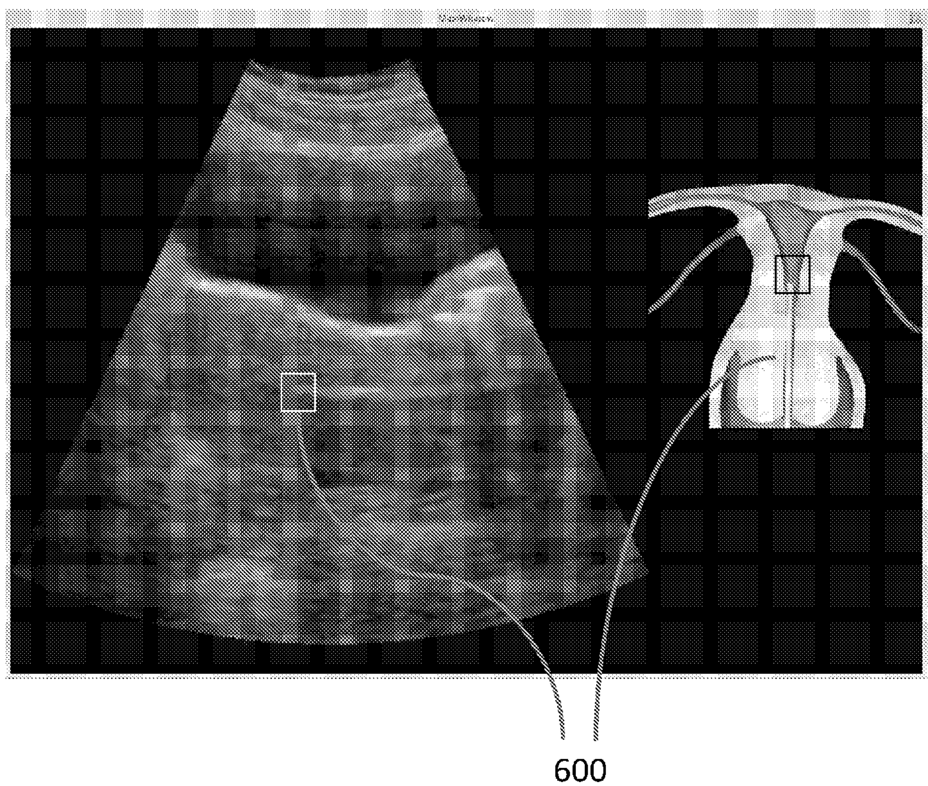

FIG. 6

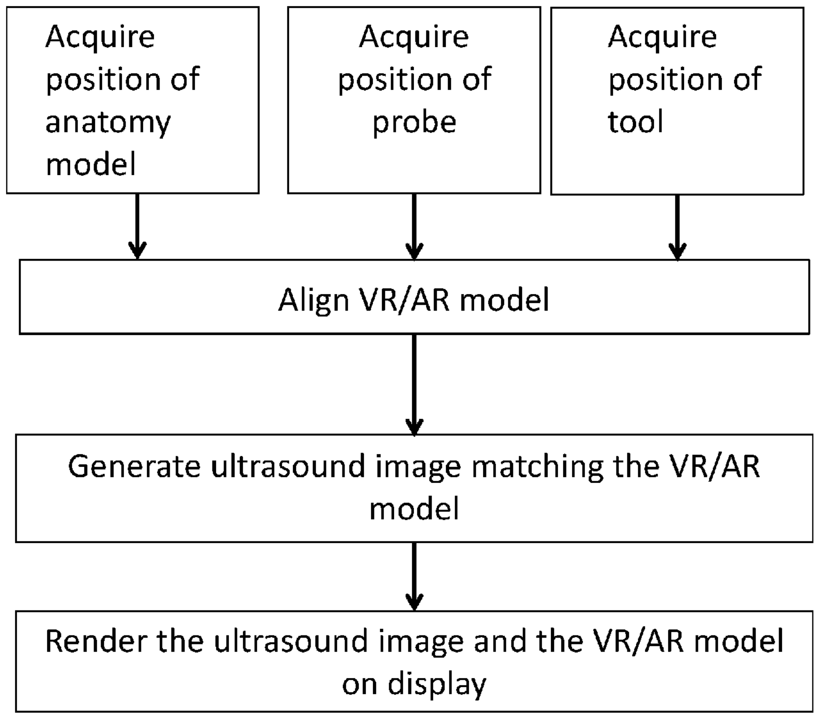
Acquire position of anatomy model
Acquire position of probe
Acquire position of tool
Align VR/AR model
Generate ultrasound image matching the VR/AR model
Render the ultrasound image and the VR/AR model on display

FIG. 7

ULTRASOUND SIMULATION SYSTEM AND TOOL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to 62/242,322 filed on Oct. 16, 2015, which is herein incorporated by reference in its entirety.

FIELD

[0002] The present invention relates to computerized medical simulation in general, and more specifically to virtual reality and/or augmented reality simulation devices and systems for medical training purposes.

BACKGROUND

Virtual Reality/Augmented Reality Medical Simulation

[0003] Medical imaging has become more and more used for both diagnostic/examination and therapeutic purposes in a number of medical applications, such as endoscopy for surgery, or ultrasound imaging for various gynecology and/or obstetrics applications, for instance in the embryo transfer procedure for In Vitro Fertilization (IVF). These new techniques may require dedicated training for physicians and surgeons to master the indirect hand-eye coordination required by the imaging system as well as the manipulation of the imaging tools in addition to the conventional medical instruments and procedures for a diversity of patient anatomies as may be encountered in medical practice. Computerized medical procedure training simulators may enable the physicians and trainees to develop and improve their practice in a virtual reality environment before actually practicing in the operation room.

[0004] Advanced medical procedure simulators may be based on a virtual reality ("VR") and/or a mixed or augmented reality ("AR") simulation apparatus by which the physician can experiment a medical procedure scenario. The VR/AR system may compute and display a visual VR/AR model of anatomical structures in accordance with physician gestures and actions to provide various feedback, such as visual feedback. In a VR system, an entire image may be simulated for display to a user, and in an AR system, a simulated image may be overlaid or otherwise incorporated with an actual image for display to a user. Various patient models with different pathologies can be selected. Therefore, natural variations as encountered over the years by practicing doctors can be simulated for a user over a compressed period of time for training purposes. The medical simulation procedure can be recorded and rehearsed for evaluation purpose. The VR/AR simulation system can also compute and provide various metrics and statistics.

[0005] VR/AR simulation systems such as the one described in U.S. Pat. No. 8,992,230 include a human anatomy model of a joint of organ in real size. The VR/AR simulation system may further comprise a medical instrument to more realistically simulate the medical procedure. The model is further adapted with sensors for tracking the position and/or orientation of both the anatomy model and the medical instrument. As described in U.S. Pat. No. 8,992,230, calibration units may be further used to automatically setup and align the VR/AR simulation system to a diversity of anatomy models and medical procedure training scenarios without requiring a cumbersome, manual calibration procedure each time a new model is adapted to the system.

[0006] A passive feedback VR/AR simulation system such as for instance the one described in U.S. Pat. No. 8,992,230 may also be used with a diversity of medical procedure training scenarios, some of which may possibly result in a mismatch between an anatomy model surface as touched by the trainee and a virtual environment surface as computed by the VR/AR simulation system and rendered on the screen. In order to further improve the passive haptic experience and increase the realism in such medical training scenarios, the VR/AR simulation system may be further adapted with space warping methods and systems as described in US patent application US20140071165.

Ultrasound Imaging Simulation

[0007] Most prior art ultrasound simulation solutions have been developed based on interpolative ultrasound simulation, as used for instance by a number of commercial ultrasound training simulators such as Medsim (http://www.medsim.com/), EchoCom (http://www.echocom.de) and MedCom/Sonofit (http://www.sonofit.de). These prior art simulators use a set of collected 2D images for each case, which are reconstructed into 3D volumes per case in an offline "case generation" stage with minor differences between individual methods in how the 3D volumes and their corresponding graphical models are generated. For instance, Dror Aiger and Daniel Cohen-Or described the use of deformable registration techniques for generating large 3D volumes from smaller swept scans in "Real-time ultrasound imaging simulation", *Real-Time Imaging,* 4(4):263-274, 1998. In "Augmented reality simulator for training in two-dimensional echocardiography", *Computers and Biomedical Research,* 33:11-22, 2000, M. Weidenbach, C. Wick, S. Pieper, K. J. Quast, T. Fox, G. Grunst, and D. A. Redel proposed to register the recorded patient-specific volumes to a generic 3D anatomical heart model, which they thus call augmented training. All the above methods present the user a non-deformable model of the anatomy. In other words, although the images may change with the transducer position/orientation in some simulators, they do not change according to the trainee's interaction with the mannequin or the virtual model, which negatively impacts the simulation realism.

Deformable Interactive Ultrasound Simulation

[0008] Compared to non deformable solutions, deformable, interactive ultrasound simulation may generate a better sense of simulator realism and consequent trainee immersion. In "B-mode ultrasound image simulation in deformable 3-D medium", *IEEE Trans Medical Imaging,* 28(11): 1657-69, November 2009, O. Goksel and S. E. Salcudean introduced the first interpolative simulator that allows for deformation by using a fast mapping technique for image pixels to be simulated, from the deformed simulation tissue coordinates to a nominal recorded volumetric coordinate frame. This method combines an input (reconstructed) 3D volume and interactive, volumetric tissue deformation models such as the finite element method and has been further applied to prostate brachytherapy simulation as published in Orcun Goksel, Kirill Sapchuk, and Septimiu E. Salcudean, "Haptic simulator for prostate brachytherapy with simulated needle and probe interaction", IEEE Trans Haptics, 4(3): 188-198, May 2011. It has also been applied to a transrectal ultrasound training application with fluoroscopy imaging as published in Orcun Goksel, Kirill Sapchuk, William James Morris, and Septimiu E. Salcudean, "Prostate brachytherapy training with simulated ultrasound and fluoroscopy images", IEEE Trans Biomedical Engineering, 60(4):n2002-12, April 2013.

[0009] However, the latter methods by Goksel et al. only used a virtual patient model for simplicity. In a passive haptic VR/AR medical simulator, a physical anatomy model (mannequin) is further used with medical tools or instruments to simulate the medical procedure training as realistically as possible. For example in a state of the art embryo transfer IVF medical procedure as represented by FIG. **1**, tools such as an ultrasound probe **130**, a speculum **120**, and an embryo transfer catheter **112** may be used. As described for instance by http://www.advancedfertility.com/ivf-embryo-transfer-catheter.htm, a stiffer outer steath (catheter guide) is first used to guide the soft and flexible inner embryo transfer catheter **112** through the cervical canal to the proper location in the uterine cavity **100**. Once at the right location, the transfer catheter **112** is loaded with the embryos **115** which are propulsed with the embryo transfer syringe **110** into the uterine cavity **100**. The whole procedure requires very careful gesture as any misposition or wound to the uterine may result in the failure of the IVF, which is a very costly and time-consuming procedure for the patients. The IVF embryo transfer procedure is conducted under ultrasound imaging supervision, by means of an abdominal ultrasound probe **130**. The user manipulates the abdominal ultrasound transducer **130** by pressing it on the belly skin and positioning and orienting it to optimize the ultrasound imaging capture. A jelly is used to facilitate the ultrasound propagation as well as the manipulation of the ultrasound transducer in contact with the patient skin. In general, a moderately full bladder **140** is advisable for better ultrasound imaging quality, which will more or less deform with the probe compression on the above patient skin. The speculum tool **120** is usually made of metal and thus acts as a shield to the ultrasound waves, which also results in specific artefacts into the ultrasound images.

[0010] As known to those skilled in the art, the simulation of such a complex ultrasound procedure may raise specific issues to ensure a realistic virtual-physical dualism, e.g. the image should appear only when the ultrasound probe physically touches the anatomy model also emanating only from the curved surface of contact. Deformation of the ultrasound images and its components such as the skin (high compression), the bladder (moderate compression) and the uterine, the speculum and the catheter (no compression) needs to be synchronized with the user manipulation of the ultrasound probe, so the latter interaction remains as realistic as possible.

[0011] In "Patient-Specific Interactive Ultrasound Image Simulation with Soft-Tissue Deformation", PhD thesis, University of California Los Angeles, 2013, K. Petrinec proposed to adapt a commercially available ultrasound simulator (www.sonosim.com) to further simulate the deformation of soft tissues when in contact with the ultrasound probe, based on the Goksel method. In this simulator, only 3-DOF motion trackers are used to track the ultrasound probe orientation—that is, the probe is assumed to be positioned at a given 3D static position over a mannequin, and the system does not track its translational movement.

[0012] More recently, as described in US20150154890, Sonosim further introduced a 5-DOF tracking solution for this simulator by adding a translation sensor as a patch that can be applied over a live body or an anatomy model, in association with an electronic tag, so that the probe translation over a curved surface may be further tracked. From a passive haptic perspective, one major drawback of this solution is the lack of realism when manipulating the probe compared to a real ultrasound procedure, as no ultrasound gel can be used with this probe according to its instructions of use (http://sonosim.com/support/). In particular, friction of the rigid plastic virtual probe tip over the anatomy model surface significantly increases when the user has to push the probe to compress the skin and get a better ultrasound image. This friction is much lower in a real procedure where ultrasound gel or jelly is used to improve the ultrasound capture, but in general, it is not desirable to use any liquid or gel in a training setup due to the overhead required to clean it.

[0013] There is therefore a need for better ultrasound simulation devices, methods and systems that facilitate a diversity of ultrasound training procedures without requiring an expensive hardware setup and cumbersome registration and calibration procedures.

BRIEF SUMMARY

[0014] It is an object of the invention to provide a VR/AR ultrasound simulation system comprising a data processing unit, a display in communication with the data processing unit, an anatomy model and a tool, wherein the tool is adapted to interact with low friction with a surface of the anatomy model. The tool may be adapted to roll over a surface of the anatomy model. The tool may be a replicate of an ultrasound probe, such as an abdominal probe or a vaginal probe. The surface of the anatomy model may be deformable. The VR/AR ultrasound simulation system may comprise a position and orientation sensor configured and positioned to sense a position and/or orientation of the anatomy model, and/or a position and orientation sensor configured and positioned to sense a position and/or orientation of the tool.

[0015] It is a further object of the invention to provide a medical simulation tool, wherein the tool is adapted to interact with low friction with a surface of an anatomy model. The tool tip or end, may be adapted with a roller ball or with a low friction material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** illustrates an IVF embryo transfer procedure as known in the prior art.

[0017] FIG. **2** illustrates an ultrasound simulator adapted to simulate an IVF embryo transfer procedure.

[0018] FIG. **3** shows four cervix and uterine anatomy models corresponding to some anatomy shapes that may be encountered in IVF embryo transfer medical practice.

[0019] FIG. **4** shows engineering views of an exemplary ultrasound simulation probe adapted to provide realistic passive haptic feedback without requiring the use of ultrasound gel over the anatomy model.

[0020] FIG. **5** shows a first screen capture of an ultrasound simulation rendering for the IVF embryo transfer procedure training.

[0021] FIG. **6** shows a second screen capture of an ultrasound simulation rendering for the IVF embryo transfer procedure training.

[0022] FIG. **7** illustrates a flow chart of an ultrasound simulation method in accordance with different possible embodiments.

DETAILED DESCRIPTION

[0023] Embodiments of flexible ultrasound simulation devices, methods, and systems will now be described in more detail with reference to an exemplary medical simulation of an IVF embryo transfer procedure, as illustrated on FIG. **1**. FIG. **2** shows a partial view of an ultrasound simulator system comprising a data processing unit **200**, a display screen **210**, and an anatomy model **220**, according to an embodiment of the invention. For the purpose of illustration, in FIG. **2**, a pelvic model **220** of the human female anatomy is shown, but other models can be used as well. Examples of models can be found in the catalogues of specialized anatomic model suppliers such as Limbs&Things, Bristol, UK. Some models may be representative of the human anatomy. Other models may be representative of an animal anatomy, e.g. for veterinary training purpose.

[0024] The anatomy model **220** may be made of plastic or any other suitable material. Preferably, the anatomy model **220** is made of a flexible material, such as flexible plastic, so that it can deform under pressure. In some embodiments, the anatomy model **220**, or parts of the anatomy model, may be interchanged with another similar anatomy model corresponding to different simulated patient characteristics or pathologies. For instance in an IVF embryo transfer training simulator, various combinations of cervix canal models (straight, tortuous, with a trap . . .) and uterus types (axial, anteverted, retroverted . . .) may be used to simulate more or less challenging variations of the patient pelvic organs anatomy. FIG. **3** shows four different cervix models: a) base cervix case with axial uterus, b) cervix entrance deflected down 40 degrees in an anteverted uterus, c) tortuous S-shaped cervix with axial uterus and d) trap cervix with 20 degrees anteverted uterus.

[0025] In some embodiments, the anatomy model **220**, or parts of the anatomy model, such as for instance the cervix canal and/or the uterine in an OB/GYN training application, may be manufactured in the training room by using a manufacturing unit. Examples of such manufacturing units are well known to those skilled in the art of rapid prototyping; they may be based on additive manufacturing, such as 3D printing, or substractive manufacturing, such as CNC milling.

[0026] In some embodiments, the anatomy model may also be manufactured according to a specific patient anatomy. Examples of manufacturing units as used in emerging medical applications are described for instance in Popescu, A. T.; Stan, O.; Miclea, L., "3D printing bone models extracted from medical imaging data", 2014 *IEEE International Conference on Automation, Quality and Testing, Robotics,* vol., no., pp. 1,5, 22-24 May 2014. Patient specific anatomy models may also comprise specific patient pathologies. Patient specific anatomy models may be manufactured and interchanged with the anatomy model **220**. Patient specific anatomy models may enable the physicians and trainees to develop and improve their practice in a virtual reality environment before actually performing the medical procedure. Furthermore, in order to support other medical procedures with ultrasound imaging, patient specific anatomy models may be interchanged with the anatomy model **220**, such as for instance a bladder, a womb, an upper torso, a lower torso, or a joint model. In some embodiments the patient specific model may comprise parts of the anatomy model **220**. The patient specific model may be manufactured by the manufacturing unit. In some embodiments the patient specific model may be created with additive manufacturing, such as 3D printing, or substractive manufacturing, such as CNC milling.

[0027] The data processing unit **200** may comprise one or more central processing units ("CPU"), memory modules, controlling modules, and/or communication modules, for example. Other embodiments may include data processing units **200** with other configurations and combinations of hardware and software elements. A distributed data processing unit may be used. In some embodiments, a communication module of the data processing **200** may be connected to a manufacturing unit. In some embodiments, the data processing unit and the manufacturing unit may be combined in a single unit. Some or all of the data processing unit **200** components may be used to compute and display onto a display screen **210** a VR/AR simulation model that may correspond to a chosen medical procedure training scenario. Multiple display screens may also be used. The display screen **210** may comprise a touch interface to provide an interface for a physician during a simulation exercise. In other embodiments (not illustrated) the simulator cart may further comprise a camera.

[0028] In FIG. **2**, the anatomy model **220** may comprise at least one position and orientation sensor (not represented). As described in U.S. Pat. No. 8,992,230, said position and orientation sensor may be associated with at least one calibration unit. For example, six degree of freedom ("6DOF") miniaturized magnetic tracking sensors may be used. Other embodiments are also possible, e.g. optical tracking or motion tracking may be used. The anatomy model **220** may be connected to the data processing unit **200** through a connection such as a USB link, other standard wired or wireless connection, or other communication link. The data processing unit **200** may receive the sensor information from the anatomy model **220** and may calculate the virtual anatomy model **220** position and orientation in accordance with the sensor measurement. The data processing unit **200** may use the calculated model **220** position and orientation to generate a visual model and display the visual model onto the display screen **210**. As described in U.S. Pat. No. 8,992,230, the data processing unit **200** may compute the VR/AR model position and orientation by combining the absolute sensor measurement received from at least one anatomy model sensor with the pre-computed calibration data from the calibration unit associated with said sensor for the simulated VR/AR model.

[0029] FIG. **2** further shows a replica of an ultrasound probe **230** which may be used to simulate an ultrasound imaging capture. For the purpose of illustration, in the case of IVF embryo transfer simulation, the ultrasound probe replica **230** of FIG. **2** replicates the shape of a convex abdominal ultrasound transducer. Other probes may be replicated in other ultrasound training procedures, for instance a transvaginal or a transrectal probe. The replica may not need to be an exact replica of an ultrasound probe, but it may give a realistic haptic feedback similar to a real probe. The ultrasound probe replica **230** may be handled and put in contact with the anatomy model skin surface by the trainee. The trainee may also push the anatomy model **220** skin surface with the ultrasound probe replica **230** as in a real imaging procedure, and the anatomy model **220** skin surface may deform accordingly. The ultrasound probe replica **230** may be adapted to comprise at least one position and orientation sensor, possibly in association with a calibration unit, for instance as described in U.S. Pat. No. 8,992,230. The data processing unit **200** may receive the sensor information from the ultrasound probe replica **230** and may calculate the VR/AR model position and orientation in accordance with the model sensor measurement and the probe replica sensor measurement respectively.

[0030] FIG. **2** further shows a medical tool **240** appended to the anatomy model **220**. For the purpose of illustration, in the case of IVF embryo transfer simulation, the medical tool **240** of FIG. **2** is a speculum that can be inserted into the pelvic model **220** through the vulva portal of anatomy model. Other tools may be used, for instance an embryo transfer catheter, an embryo transfer syringe, a tenaculum or, a Hegra dilator. The medical tool **240** may be a standard medical tool suitable for various medical procedures, for instance a tenaculum tool that may be used in gynecology or in surgery. In some embodiments, the tool may be adapted to comprise at least one position and orientation sensor and one calibration unit associated with the position and orientation sensor, for instance as described in U.S. Pat. No. 8,992,230. In other embodiments, the position and orientation of the tool may be derived from the position and orientation of another element in the simulator system, such as an internal element to which the tool is mechanically bound without any remaining degree of freedom; for instance the tenaculum for steadying the cervix and uterus during the insertion of an intrauterine device is typically bound to the cervix position and orientation once steadying it. Thus, in some embodiments of the simulator system, a part of the anatomy model, for instance the cervix, rather than the tool, for instance the tenaculum, may be adapted to comprise at least one position and orientation sensor and one calibration unit associated with the position and orientation sensor, for instance as described for the femur or tibia parts in U.S. Pat. No. 8,992,230. Other embodiments are also possible to adapt the VR/AR ultrasound simulator to various medical practices, anatomy models, and tools.

[0031] The data processing unit **200** may receive the sensor information from the anatomy model **220** and may calculate the VR/AR model position and orientation in accordance with the anatomy model sensor measurement, the probe replica sensor measurement, and the tool sensor measurement respectively.

[0032] In a preferred embodiment, the tip, or end, attached to the tool body of the ultrasound probe replica **230** is further mechanically adapted to comprise a rolling part **235**, such as a roller ball, which may simulate a more realistic low friction motion, when the ultrasound probe replica **230** tip interacts with the anatomy model **220** surface. FIG. **4** shows the engineering views of a possible mechanical embodiment of a roller ball **235** which decreases the friction for different translational and rotational movements of the ultrasound probe replica **230** over the anatomy model **220** surface. Other embodiments than a roller ball are also possible, for instance a low friction material may be used at the tip **235** of the ultrasound probe replica **230**, or on the anatomy model **220** surface.

[0033] The data processing unit **200** may use the calculated VR/AR model position and orientation to generate a visual model and display the visual model onto the display screen **210**. As known to those skilled in the art, initial alignment of the VR/AR model with the position and orientation of the anatomy model **220**, the ultrasound probe replica **230** or the medical tool **240** may also require calibration. The methods and systems as described in U.S. Pat. No. 8,992,230 for an endoscopy simulation system may be used to calibrate the VR/AR ultrasound simulation system.

[0034] In an ultrasound simulation system, the ultrasound image also needs to be rendered as realistically as possible. The data processing unit **200** may use the calculated VR/AR model position and orientation to identify a slice to be rendered from a reconstructed 3D ultrasound volume or a 3D ultrasound generation model and to render the simulated ultrasound image in real time onto the display screen **210**.

[0035] FIG. **5** shows a screen capture of the ultrasound image and the VR/AR model as rendered on display screen **210** by the data processing unit **200** in the embryo transfer procedure. The embryo transfer catheter tool **540** is rendered into the uterine cavity **500** on the ultrasound image **530** on the left as well as on the VR/AR model computer graphics representation on the right. A moderately filled bladder **520** and abdominal skin layers **510** are also visible in the ultrasound image as in a real ultrasound capture. FIG. **6** shows a screen capture of the ultrasound image and the VR/AR model as rendered on display screen **210** by the data processing unit **200** at the next step in the embryo transfer procedure, where the trainee transfers the embryos **600** from the embryo transfer catheter into the uterine cavity.

[0036] In a possible embodiment, the data processing unit **200** may be adapted to implement the interpolative ultrasound simulation methods as proposed by Goksel et al. to render realistic ultrasound images by interpolating a 2D slice in a 3D ultrasound volume reconstructed from formerly registered ultrasound image records, such as MR or CT data records, in combination with real-time induced deformations due to the user interaction with the ultrasound simulator system. Other methods may be used, for instance the ultrasound simulation may use a ray-based generated ultrasound simulation with segmentation rather that interpolative ultrasound simulation methods, as known to those skilled in the art of ultrasound simulation. A diversity of different patient VR/AR models may also be used as the basis for a diversity of ultrasound practice training scenarios, for instance to represent different pathologies. In order to further improve the passive haptic experience and increase the realism in such diversity of medical training scenarios without requiring too many different setups of the underlying anatomy model, the VR/AR ultrasound simulation system and methods may be further adapted with space warping methods and systems as described in US patent application US20140071165.

[0037] FIG. **7** shows a general flowchart of the proposed VR/AR ultrasound simulation method, comprising the steps of:

[0038] Acquiring the position and orientation of the VR/AR simulator elements, such as the anatomy model parts, the ultrasound probe replica and any medical tools relevant to the ultrasound procedure training;

[0039] Aligning the VR/AR model to the tracked position and orientation of the VR/AR simulator elements;

[0040] Generating an ultrasound image matching the VR/AR model;

[0041] Rendering the ultrasound image and a computer graphics representation of the VR/AR model onto a display screen.

[0042] While a VR/AR ultrasound simulator for the IVF embryo transfer procedure has been detailed herein as an example for a better illustration of the disclosure, the proposed methods and systems can be generalized to any type of ultrasound simulations.

[0043] While a passive haptic VR/AR ultrasound simulator has been detailed herein as an example for a better illustration of the disclosure, the proposed methods and systems can be generalized to any type of hardware simulator setups. In particular, various position and orientation tracking means may be used, such as magnetic or optical tracking systems, or a mix of such systems. Various calibration procedures may also be used. Active haptic hardware may also be integrated into the VR/AR ultrasound simulator.

[0044] While a VR/AR ultrasound simulation method using interpolation from a reconstructed 3D ultrasound volume has been detailed herein as an example for a better illustration of the disclosure, the proposed methods and systems can be generalized to any type of ultrasound imaging simulations. In particular, generative ray-based simulation systems and methods may also be used for ultrasound image modeling.

[0045] While various embodiments of an IVF embryo transfer simulator have been described above, it should be understood that they have been presented by way of example and not limitation. It will be apparent to persons skilled in the relevant art(s) that the proposed methods and systems can be generalized to any type of ultrasound simulations. Various changes in form and detail can be made therein without departing from the spirit and scope. In fact, after reading the above description, it will be apparent to one skilled in the relevant art(s) how to implement alternative embodiments. Thus, the present embodiments should not be limited by any of the above-described embodiments.

[0046] In addition, it should be understood that any figures which highlight the functionality and advantages are presented for example purposes only. The disclosed methodology and system are each sufficiently flexible and configurable such that they may be utilized in ways other than that shown.

[0047] Although the term “at least one” may often be used in the specification, claims and drawings, the terms “a”, “an”, “the”, “said”, etc. also signify “at least one” or “the at least one” in the specification, claims and drawings.

[0048] Finally, it is the applicant’s intent that only claims that include the express language “means for” or “step for” be interpreted under 35 U.S.C. 112, paragraph 6. Claims that do not expressly include the phrase “means for” or “step for” are not to be interpreted under 35 U.S.C. 112, paragraph 6.

What is claimed is:

1. A simulation system comprising:

a data processing unit;

a display in communication with the data processing unit;

an anatomy model; and

a tool adapted to interact with low friction with a surface of the anatomy model.

2. The simulation system of claim **1**, wherein the tool is adapted to roll over a surface of the anatomy model.

4. The simulation system of claim **1**, wherein the tool is a replica of an ultrasound probe.

5. The simulation system of claim **4**, wherein the ultrasound probe is an abdominal probe.

6. The simulation system of claim **4**, wherein the ultrasound probe is a vaginal probe.

7. The simulation system of claim **1**, wherein the surface of the anatomy model is deformable.

8. The simulation system of claim **1**, further comprising a position and orientation sensor configured and positioned to sense a position and/or orientation of the anatomy model.

9. The simulation system of claim **1**, further comprising a position and orientation sensor configured and positioned to sense a position and/or orientation of the tool.

10. A tool for a medical simulation system comprising:

a body; and

a tip connected to the body and adapted to interact with low friction with a surface of an anatomy model.

11. The tool of claim **10**, wherein the tool tip is adapted with a roller ball.

12. The tool of claim **10**, wherein the tool tip is adapted with a low friction material.

13. The tool of claim **12**, wherein the surface of the anatomy model is deformable.

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