A surgical simulator for training surgeons in a few tasks related to minimally invasive surgery

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ABSTRACT

The present invention relates to a surgical simulator that may be used to train surgeons for minimally invasive surgery. The simulator makes use of the Boundary Element Method together with a simulation approach that was proposed in an academic paper authored by this inventor. Moreover, the simulator makes use of the boundary element codes developed by this inventor. The simulator consists of a computer screen, a keyboard, a mouse, a haptic device, and a multicore CPU. The simulator would include the geometry of representative human kidney and human liver. The simulator has provisions for moving and changing the orientation of the liver and the kidney, and detecting the collision between the liver or the kidney and the mouse pointer. The simulator also has provisions for interactively displaying the deformed shape of the liver or the kidney, depending on the position of the mouse pointer (mouse cursor (pointer) represents the tip of surgical tools). The simulator can be used to train surgeons in the following tasks: eye-hand coordination, manipulating 3D objects while deformation of the objects is observed on 2D screens.

TECHNICAL FIELD

The present invention relates to a surgical simulator that may be used to train surgeons for minimally invasive surgery.

BACKGROUND

Just as flight simulators are be used to train pilots, surgical simulators are used to train surgeons in some surgical procedures (e.g., eye-hand coordination, manipulating 3D objects or organs using surgical tools, palpation). The main application of surgical simulators is to train surgeons for minimally invasive surgery (e.g., laparoscopic surgery).

The Boundary Element Method (BEM) is a well-known numerical technique, and a lot of material (including textbooks) is available on the topic of the BEM as a numerical technique.

Many surgical simulators that are based on technologies other than the Boundary Element Method (e.g., the Finite Element Method) are already available, e.g., the reference [3] describes the development of a simulator that enables a surgeon to practice the techniques for robotic surgery. Here, a sphere-filled model (not the Boundary Element Method) is used to model biological organs.

A few surgical simulators that use the Boundary Element Method are also available already, e.g., the simulator discussed in [4]. But none of these simulators (i.e., simulators based on the Boundary Element Method) are true products in the sense that the relevant sources (references) do not describe the simulators (products) properly and completely. The literature (or prior art) on these simulators are just rough explanations of concepts, not the complete details of the products. Moreover, these so-called simulators cannot be used for real-world applications since they are not real products in the first place. Also, the academic papers that mention them (prior art) do not present real-world applications (they present only academic applications).

However, no product that uses the novel approach proposed in this inventor's paper [1] is available as prior art. Moreover, no product that uses the codes developed by this inventor [2] is available as prior art.

Hence this invention is about the development of a simulator that uses the Boundary Element Method together with a simulation approach that was proposed in an academic paper [1] authored by this inventor. Moreover, for the purpose of the numerical simulations, this invention utilizes only the codes [2] developed entirely by this inventor.

SUMMARY

The present invention is about a surgical simulator that may be used to train surgeons in some surgical procedures related to minimally invasive surgery.

While the previous simulators (prior art) have used numerical techniques like the finite element method, and/or computational techniques like making use of spring-mass models, the present simulator makes use of the boundary element method. Also, the present simulator uses a simulation approach that was proposed in an academic paper authored by this inventor, while none of the earlier surgical simulators have used the same approach. Moreover, the present simulator makes use of the boundary element codes developed by the inventor, not the boundary element codes developed by someone else.

The present simulator can be used to train surgeons in the following tasks: eye-hand coordination, manipulating 3D objects while deformation of the objects is observed on 2D screens.

DETAILED DESCRIPTION OF THE PRODUCT

In this section, hardware and software is specified first. The specification of the product (invention) is clearly mentioned afterwards. The user interface of the product (invention) is explained next. A short discussion on validating the product is presented later. Novelty, inventive step, and commercial applications of the invention are clearly highlighted at the end of the present section (i.e., Detailed description of the product).

Hardware (readily available)

Screen: 22 inch LED Monitor (Dell E2215HV)
Keyboard: Wired USB Standard Keyboard (Logitech K120)
Mouse: USB Mouse (Quantum Qhm222)
Haptic device: Geomagic® Touch™ X Haptic Device
CPU: AMD 16 core processor (AMD Opteron 6274)

Software (readily available)

Operating system: Windows 10

Other software: Drivers and other software supplied with Geomagic® Touch™ X Haptic Device, the commercial software package MATLAB (for 3D rendering and collision detection), the codes developed by the present inventor (freely available from [2])

Files: STL (stereolithography) files which represent the geometry of representative human kidney and human liver

Specification of the product

The hardware and software mentioned above are readily available. The hardware mentioned above plus the software mentioned above, together with software developed specifically for the present product (invention) make up the new product. The purpose of the software that is developed specifically for the present invention is to bind together all the other software to form the user interface for the new product, and this software is not available elsewhere. The specifications of this user interface are presented in the next subsection titled "User interface". Of course, the individual elements (i.e., hardware, software, user interface) of the product, if considered alone, do not possess enough novelty and/or enough inventive steps. However, when all the elements (i.e., hardware, software, user interface) are put together to form a product, the product (invention) is found to possess sufficient novelty, the invention is found to involve inventive step that is significant, and the product is found to have useful and important commercial applications. The product (invention) may be used to train surgeons in the following tasks: eye-hand coordination, manipulating 3D objects while deformation of the objects is observed on 2D screens.

User interface

Geometry of either a representative human kidney or a representative human liver is displayed on the screen (monitor), through the rendering capabilities offered by the commercial software package MATLAB. The user interface also has provisions for moving and changing the orientation of the liver or the kidney. The position of the mouse cursor on the screen is sensed by MATLAB (3D position can be sensed, although the screen is 2D). The mouse cursor itself represents the surgical tool (or the tip of the surgical tool). The MATLAB checks whether the mouse cursor lies inside the undeformed geometry or whether the mouse cursor lies outside the undeformed geometry. In case the mouse cursor is found to lie inside the undeformed geometry, the geometry of the biological organ is substituted with the deformed geometry such that the mouse cursor would lie on the surface of the deformed geometry. The deformed geometry is displayed through the rendering capabilities available in MATLAB. The deformed geometry is obtained from the undeformed geometry by making use of the present inventor's boundary element codes [2]. The codes available from [2] use a simulation approach that was proposed in an academic paper [1] authored by this inventor. The simulation approach presented in [1] is to directly parallelize the boundary element simulations to make the simulations run on multicore computing systems. Also, this simulation approach (presented in [1]) does not make use of any type of precomputations. The codes [2] employ linear elastostatic boundary elements; the elements are of triangular shape, and constant elements are used; the collocation type (variant) of the boundary element method is employed.

Validation

The only reliable way of measuring the performance of a simulator is to obtain the feedback on the simulator from a large number of surgeons. The feedback can be collected once the device (simulator) is marketed. Since the simulator uses superior and proven technologies, it is expected to result in a quality product.

Novelty

1. A surgical simulator that uses the Boundary Element Method to achieve realistic simulations
2. A surgical simulator that uses the Boundary Element Method together with a simulation approach that was proposed in an academic paper authored by this inventor

3. A surgical simulator that uses the boundary element codes developed by this inventor

Inventive step

1. While the previous simulators have used numerical techniques like the finite element method, and/or computational techniques like making use of spring-mass models, the present simulator makes use of the boundary element method.
2. The present simulator uses a simulation approach that was proposed in an academic paper authored by this inventor, while none of the earlier surgical simulators have used the same approach.
3. The present simulator makes use of the boundary element codes developed by the inventor, not the boundary element codes developed by someone else.

Commercial applications

1. The simulator may be used to train surgeons in the following tasks: eye-hand coordination, manipulating 3D objects while deformation of the objects is observed on 2D screens.
2. Since the boundary element method is a physically based numerical technique, the simulator is expected to achieve realistic simulations (when compared to simulators that are based on computational techniques that are not physically based (e.g., spring-mass models).
3. The new simulator could be an alternative to the simulators that are already available in the market. Since the boundary element method is believed to be more efficient (for a given amount of the accuracy of results) when compared to other mesh based techniques (e.g., the finite element method), the new simulator is expected to be (comparatively) more efficient.

CLAIMS

1. A simulator that may be used to train surgeons on the following tasks is developed: eye-hand coordination, manipulating 3D objects while deformation of the objects is observed on 2D screens.

2. The simulator makes use of linear elastostatic boundary elements. The elements are of triangular shape, and constant elements are used. The collocation type (variant) of the boundary element method is employed.
3. The simulator makes use of the boundary element codes developed by the inventor. Also, the present simulator uses a simulation approach that was proposed in an academic paper authored by this inventor.
4. The simulator consists of a computer screen, a keyboard, a mouse, a haptic device (Geomagic® Touch™ X Haptic Device), and a multicore CPU. The multicore processor has one processor with 16 cores (AMD Opteron 6274).
5. The simulator would include the geometry of representative human kidney and human liver.
6. The simulator has provisions for moving and changing the orientation of the liver and the kidney, and detecting the collision between the liver or the kidney and the mouse pointer. The simulator also has provisions for interactively displaying the deformed shape of the liver or the kidney, depending on the position of the mouse pointer (mouse cursor (pointer) represents the tip of surgical tools).

REFERENCES

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