Interactive Gesture based Cataract Surgery Simulation

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***Abstract*—India's medical education domain is one of the largest in the world. Medical Simulation aims to provide a medically accurate simulation that benefits the medical students to learn and understand any medical cases. Medical Simulations facilitates students with interactive learning and real-time feedback which does not risk the patient's life. Simulations can be performed any number of time until they have build their knowledge base and confidence in the given medical case. We propose a medically realistic cataract surgery simulation developed with a game engine. The users will be able to interact and use the on screen elements using hand gestures. A Motion recognition device captures every hand movement of the users and the simulation responds accordingly to provide feedback in real-time. Every movement is accurately tracked in the simulation and has a significant outcome on the subject based on the type of simulation. The simulated medical procedures for cataract surgery include using Surgical Tools, Surgical Procedures, Artificial Lens Implantation etc. Medical Simulation is being designed to provide an easy to use learning environment to replicate the clinical scenarios and allow features such as interactively practicing and providing feedbacks for medical skills development.**

Keywords—Cataract Simulator, Motion Recognition, Simulator, Game engine, Gesture Recognition, 3D Simulation.

I. INTRODUCTION

In the last decade, India has witnessed a technical overhaul in order to provide enhanced healthcare for her patients. Adopting latest laboratory techniques, many medical institutions have transformed into state-of-the-art medical facilities. In-spite of all these technological advancements, experts estimates a large number of deaths worldwide and in India every year as a result of medical negligence and errors from the doctors. This is where pedagogical use-fullness of animations and interactive simulations in healthcare becomes inevitable.

Simulation has been defined as "A situation in which a particular set of conditions is created artificially in order to study or experience something that exists in reality". In recent years, world has witnessed interactive computer simulations gaining momentum as a cutting-edge educational technique that took the conventional learning to a whole new dimension. As a developing nation, India is faced with an unprecedented shortage of qualified / experienced teaching resource and infrastructure [1]. Several researches in the recent past proved successful adoption of a combination of technology and pedagogy in the form of interactive simulations to counter this challenge [1]. Use of interactive simulations provides a safe cost effective augmented learning environment, which could be developed to simulate and teach multi-disciplinary learning objectives. New opportunities are unearthed with the advancement of technology. Like any other domains in education, medical domain also significantly increased its use of technology for teaching and assessments [4]. Simulations based learning and assessments has been found effective and useful in various fields such as training emergency response personnel [3], clinical training for nursing students [2]

Interactive Medical Simulation using Leap Motion is an application which simulates cataract surgery procedure. It provides an interactive surgery learning and instant evaluation system that is designed with a perspective to make medical learning not just effective one but accessible and affordable which otherwise requires expensive electronic mannequins or haptics devices [5] assisted by a computer software or are conventionally limited to controlled classroom sessions using a cadaver. Most of the clinical experiments cannot be done on patients considering the safety factor, that's why simulators play a major role in clinical training. High cost and low availability of medical simulators is still a barrier in the medical field. This is where our application comes in handy.

The overall functioning of the medical simulator is illustrated in Fig. 1. Prior to simulation, a video clip and a gesture recognition working environment is provided that assists the users. User's hand gestures are captured by a small USB peripheral device called Leap Motion. The data in terms of hand and finger movements, corresponding orientation and coordinates are communicated to the host computer, where it is analyzed by the Leap Motion controller. Unity is a game development engine fully integrated with a complete set of intuitive tools and rapid workflows to create interactive 3D and 2D contents. Hand Gesture recognition software and game engine can be connected and accessed through scripting. Every action performed by a user has a specific outcome on the simulator. Unlike other simulators, design of this medical simulator allows the users to perform any actions just like the way anyone could do in a real world that is in accord to the defined laws of physics. Actions can have positive, negative or neutral outcomes with respect to the users hand / finger movements. These outcomes are evaluated by the medical simulator engine to provide a feedback duly to the users either by altering the simulated environment or changing the subject's state/ behavior.

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Any steps in the cataract procedure could be repeated or redone until the learner feels adequate dexterity is gained, which otherwise is not possible in real life situation. The application has a well-defined UI which helps the users to choose between the Simulator and the tutorials. Tutorials include instructions and walkthroughs about the tools and procedures. Supplementary materials like video tutorials and another interactive tutorial are also made available.

II. EXISTING SYSTEM

Virtual reality simulator for phacoemulsification surgery and training focuses on the research and development of a cataract surgery simulator. It goes with the aim to serve the purpose of providing repetitive training on the main procedures of phacoemulsification surgery. A 3D eye model and surgical instruments are generated as in the virtual surgical environment. The system is equipped with a pair of haptic device to provide actual sensation. The surgical training is shown in Figure 2. Modeling system identifies and updates the eye model according to the inputs from the Haptic device which is then displayed on the computer screen. Major drawbacks are high configuration system, high cost haptic devices.

Havener Eye Institute developed EYESI Surgical simulator which provides a three-dimensional virtual environment which help the students to experience a real time surgical situation. EYESI Simulator is shown in Figure 3. This also allows trainees to encounter and deal with various types of pathologies and surgical complications. But this technology is valued at $176,000.

Considering the price sensitive Indian educational economy, our Cataract simulator mitigates the problems with the existing systems in terms of market cost, system specification and hardware requirements. The application can be deployed on many major releases of Windows, Mac and Ubuntu. A low cost motion recognition device like Leap Motion Controller is the only hardware requirement to run the simulator. The simulator also has support for multiple languages like English, Hindi, Malayalam and Tamil. The system uses the best features of Unity3D and Leap motion together, which results in a cost effective and an efficient system in the market.

III. PROPOSED SYSTEM

This section gives insight into the concepts used in the new Cataract simulator and how various modules interact together. We will be briefing about the hand movement recognition, general processes in the simulator and it's working. The input to the simulator is the hand / finger coordinates (X, Y, Z) which we obtain from the motion recognition device. Device coordinate system and Game engine coordinate system are different. So the device coordinates should be mapped to the game engine coordinates and corresponding movements actuates the subject in the simulator. Every user movements within the device range are caprtured and these movements are accurately mapped in the simulation engine which inturns alter the state of the subject or the simulation environment. Surgical procedures will be done on 3D eye model in the simulator using appropriate tools. The equipment will be moved according to our hand movements. Appropriate warnings and recommendations are provided to guide the user.

The specific features of our cataract simulator are as follows:

- Users will be provided with tutorials.
- Short audio instructions and explanations about the procedures.
- Warnings and instruction messages are shown at appropriate times.
- Multiple camera views to provide different perspective.
- Level progress is shown duly.
- Supports multiple Indian languages like Hindi, Malayalam, and Tamil.

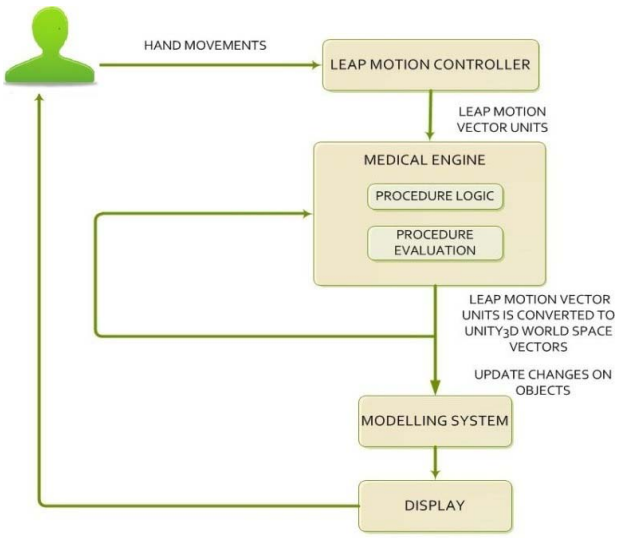

Fig. 1 Architectural Diagram

A. Hand Movement/ Gesture Recognition

Hand and finger motions are transformed into gestures to interact with the objects in the simulation. Mainly there are three gestures regulated and programmed in the system. Some of these gestures includes

1. Open hand gesture for normal course of actions.
2. Grab gesture to hold the surgical tools.
3. Squeeze gesture.

The hand movements/ gestures are recognized using the gesture recognition device. These are small USB peripherals

that provide coordinates in units of real world millimeters. These devices capture all user actions and interact with the simulator with the help of a controller object specific to the simulation environment. This controller object automatically binds to the gesture recognition service.

Fig 2. Hand interaction with the Cataract Simulator

B. Objects and Animations

Objects are those to which users interacts in a simulator. Objects specific to the simulator are 3D model of an eye and surgical tools. The eye model includes several child objects, which are Eyeball, Cornea, Iris, Lens and Pupil. There are nine tools used in the actual procedure which are Eye dropper, Canula, Side-port-blade, IA Hand piece, Lidocane Injector, Viscoelastic tool, Keratome, Phaco tool, Lens Injector. All objects in the simulator are supposed to behave just like in the real world and hence considered as rigid body, which adheres tothe laws of physics. The rigid body can receive forces and torque to make objects interact in a realistic way. Animations are used to show changes happening to the objects such as structural changes, changes in visual attribute etc. while performing the simulation. This augments the user experience and helps to give a realistic feel.

C. Object Interaction and Collision

Collision is the common technique used to identify interactions among various objects. Collision detection identifies collision of various objects and triggers a response which brings a change in the simulation environment. Every object (rigid body) will act according to the external forces from other objects. Every object implements a collider to detect the collision from external objects. Appropriate properties are defined so as to make the object trigger events when users interact with the system during the simulation.

D. Procedures and Implementation

A cataract is clouding of the lens which leads to decrease in vision. Visual loss occurs because of opacification of the lens which obstructs light from passing and being focused on the retina which can be treated with surgery. Cataract surgery, takes only an hour or less to perform. The surgery procedures are as follows:

- Dilate the pupil with eye drop.
- Paracentesis: A small incision through the clearcornea is created using side-port blade
- Anesthesia: Intracameral lidocaine is injected to anesthetize and decrease pain during manipulation.This is done using Canula.
- Viscoelastic Protection: Viscoelastic gel is then injected using Viscoat to protect the cornea.
- Main Incision: An Incision is created using Keratome through the clear cornea.
- Rhexis Creation: A capsule rent is created using utrata forceps and the thin capsule is peeled in a tangential manner.
- Nucleus division and phacoemulsification: Physically breaking central nucleus into smaller pieces by applying vibrations. The tool used is Phaco.
- Fragment Removal: The small fragments of the nucleus are removed using the same phaco tool. It is important to use Connor wand to protect the posterior capsule as we remove the nucleus pieces.
- Cortex Removal: The remaining material inside capsular bag is cortex, which is then removed with the IA hand piece.
- Inflate the capsule: Before inserting the lens implant, it is better to re-inflate the capsular bag with visco elastic using viscoat equipment.
- Insert Implant: The implant is folded up inside an injector and unfolds when injected into the capsular bag.
- Position Implant: Using connor wand, position the implant and thus the entire implant unfolds properly.
- Hydrate the incisions: Hydrate the edges of the incisions with BSS solution.
- Last step is to apply antibiotic and steroid eye drops.

Interactive Medical Simulator Using Leap Motion includes three different modules a video tutorial showing all the procedures and their error cases, tools and procedures and the Cataract simulator. Tools and Procedures module describes each and every procedure and the corresponding tool need to be used. Also it gives information about when and how to do the procedure.

Fig. 3. Tools and Procedures

The cataract simulator simulates all the medical procedures in cataract surgery. All the logics required for the simulator are in the medical engine, which evaluates all the steps. For every right procedure done by the user the medical engine allows the user to proceed further or to repeat the same. For every wrong procedure corresponding changes are reflected along with error messages. The medical engine also provides progress indicators for each step and rating for hand gestures.

V. CONCLUSION

The need for an accurate and low cost medical simulator is very important in clinical training. The interactive medical simulator using Leap Motion helps the medical students to repetitively practice surgical procedures. This is a very efficient, accurate and low cost learning technology. All surgical procedures simulated in this cataract surgery simulator are verified by qualified ophthalmologist and is deemed accurate for its adherence to the standard medical practices. The low cost and accuracy of the simulator makes it one of its kinds in the medical simulation sector. It cure up and deplete many pricks that was put forward by the existing systems. This is now implemented only for Cataract Simulation and it can be taken to the next level by creating more and more complex surgery procedures like organ transplantation. This can also be used to study how effective is virtual simulators in medical field.

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VII. REFERENCES

[1] Nedungadi, P., Raman, R., & McGregor, M. (2013). "Enhanced STEM learning with Online Labs: Empirical study comparing physical labs, tablets and desktops". FIE Conference, 2013 IEEE (pp. 1585-1590). IEEE.

[2] Brian C Parker, Florence Myrick (2008). "A critical examination of high-fidelity human patient simulation within the context of nursing pedagogy" International Nurse Education Conference, 2008

[3] Brian Joseph Veitch,Randy Joseph Billard, Anthony Patterson (2008). "Emergency Response Training Using Simulators". Offshore Technology Conference, USA, 2008.

[4] Ross J. Scalese MD, Vivian T. Obeso MD, S. Barry Issenberg MD (2007). "Simulation Technology for Skills Training and Competency Assessment in Medical Education". Journal of General Internal Medicine, Springer 2008 Volume 23, Issue 1 Supplement, pp 46-49.

[5] Coles, T.R, Meglan D, John, N. (2010). " The Role of Haptics in Medical Training Simulators: A Survey of the State of the Art " . Haptics, IEEE Transactions on (Volume:4 , Issue: 1) , Feb 2011.

[6] Chee Kiang Lama,⋆ , Kenneth Sundaraja , M. NazriSulaimanb "Virtual reality simulator for phacoemulsification cataract surgery education and training"ICCS 2013

[7] Beginning 3D Game Development with Unity 4,2nd Edition" by Sue Blackman

[8] Marco Agus, Enrico Gobbetti, Giovanni Pintore, GianluigiZanetti, Antonio Zorcolo "Real Time Simulation of Phaco-emulsification for Cataract Surgery Training" CRS4 – Italy

[9] Ophtobook-http://www.ophthobook.com/videos/cartoon-cataract-surgery-video