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Augmented Reality for Learning Anatomy

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Learning anatomy requires students to memorise a great deal of information and contextualize this within the range of body functions. Visualising the relationships in three dimensions of various organs and their interdependent functions is a major difficulty in this task. The system described in this paper is a development to assist students by providing an augmented reality version of the anatomical details under investigation that provides a structured learning approach to the material. This is a research project to investigate whether augmented reality (AR) with haptics is an effective tool to learn anatomy while providing equitable access to more engaging experiences.

Keywords: Anatomy, three dimensions, learning, interactive, computer, engagement.

Introduction

This research project is to investigate how effective learning experiences can be improved with a technology, called Augmented Reality (AR) with haptics. Generally speaking technology-aided learning provides flexible accessibility. An intuitive interactive method like AR with haptics is expected to provide more engaging and effective learning experiences.

Research background

Difficulty in Learning Anatomy

Anatomy can be a very important subject as fundamental towards many relevant fields, such as health science. (Dominguese, 2011; Sakellariou et. al., 2009). Contemporary educational methods for teaching complex anatomical regions are considered inadequate as they typically lack the depiction of a 3D spatial tissue in a three dimensional manner. As such, the majority of explanatory illustrations are diagrammatic, 2D representations of pre-determined angles of depiction (Sakellariou et. al., 2009). This usually requires a number of images to provide full description of 3D objects in a 2D way. Unfortunately it has made anatomy a difficult area to gain the necessary knowledge.

It is well known that people learn in different modes. Some people might learn better in, for example, a kinaesthetic way. However, this mode is usually restricted because of the current limits of the conventional learning environment including online learning with multi-media resources even with interaction. Due to these restrictions, learners have to adapt their way of learning to fit the circumstances of provision. However as technology advances, we can give access to new modes of learning. Also learners' acceptance and usage of technology has grown in a dramatic way.

One of the prominent problems in learning anatomy is that it is impossible for the trainee to investigate in depth the layered structures, their spatial relations and visit these complex structures from different angles that might enlighten their perception and understanding (Sakellariou et. al., 2009). There can't be a perfect teaching alternative to current education. All the efforts are to improve a limited area or two with the assistance of technology. One way to overcome current limitations would be through Augmented Reality (AR). Sakellariou et. al. (2009) pointed out that a virtual reality system with haptic feedback was found more engaging, interesting, easy to use and more efficient in elucidating spatial inter-relationships of structures.

Augmented Reality with Haptics in Anatomy

3D DVDs and interactive online learning systems are very common as auxiliary learning tools nowadays. The technology has advanced to augmented reality with an extra enhancement of haptic feedback. Many researchers (Liao et al., 2010; Nicolson et al., 2006; Temkin et al., 2006) have experimented with the use of augmented reality systems in different parts of anatomy. Sugand et al. (2010) noted that virtual simulations can be effective for university students to visualize and interact with internal organs. Moreover haptic feedback with kinesthesia and tactility provides palpatory training. Virtual Haptic Back (Howell et al., 2008) and the Haptic Cow (Kinnison et al., 2009) are unusual examples where haptic systems were evaluated for teaching. Both systems are highly accepted by students.

As Billinghurst (2002) noted, AR technology is suitable for application in education where this technology is a valuable and interactive tool in the academic process. A principal value of educational experiences in AR is the ability to support a smooth transition between two environments that are reality and virtuality.

Rosli et al. (2010) mentioned that AR was accepted as a tool to be more interesting and to develop learners' understanding of human organs further than the textbook from a survey of primary school students. Rosli et al. (2010) quotes "other science experiences also enhance the students to construct their intellect, thinking skill (Martin et al. 2009) and make them more confident to manipulate the machine". Likewise, the AR system will help the students gain enough practice with a close look and feel of the target anatomical part as a stepping-stone. The system may not a perfect method of learning; however it is a tool to minimize the gap between reality and the virtual world.

In summary, it is evident that educational effects (Nischelwitzer et al., 2007; Marshall, 2007; Chien et al., 2010) encourage AR with haptics to be a medium to deliver training in 3D-oriented topic areas, but it has been neither widely experimented with nor evaluated. Although Augmented Reality haptic interfaces provide very intuitive methods for viewing three dimensional information, it has been less used in AR applications (Billinghurst et al., 2009) such as anatomy.

Research aims

The main purpose of the current project is to investigate the use of interactive 3D anatomy pictures with haptic feedback to teach and test anatomy knowledge, of the abdomen in particular, and to compare the results with other existing learning methods such as 2D images, models (wet or freeze-dried specimens and bones), and interactive resources (web, CD/DVD).

Preliminary survey

Students enrolled in an anatomy unit were surveyed about their experiences of learning and applying anatomy. This was conducted informally over about 1.5 hours with the lecturer and a half an hour with 23 students (12 female, 6 international).

Conventionally the main resources for learning anatomy are textbooks, images (from textbooks, Computed Tomography (CT) scans or Magnetic Resonance Imaging (MRI) type of radiological images, and computer based images), integrated practical sessions (self-directed worksheets are used with models, e.g. dissemble & assemble models), and cadaver examinations that could be the most natural way of learning with haptic/kinesthetic experiences. The cadaver session is run with a group of 3-4 students to dissect the body, and then the group presents findings at a tutorial. Students spend up to 24 hours over 6 tutorials. Each student has 8 hours of dissection.

The students were asked:

- What aspect of learning anatomy do you find most difficult?
- What is your usual resource to study anatomy? Why? (e.g textbooks, DVDs with animations, anything else)
- What are the limitations with which you wish to enhance the resources?

A fortunate and interesting point is that the identified difficulties in learning anatomy are same from both the lecturer and also the group of students. Both agreed that the main difficulties are applying 2D concepts to 3D spatial practice.

The following points were gathered from feedback sheets on the most difficult aspects of learning anatomy. Students had difficulty with:

- visualization of what they have learned in lectures; 2D materials are not easy to reconstruct in 3D world
- visualizing and applying knowledge practically in clinical conditions
- relationships (separate organs are understood but fitting them together is difficult); the relationship of each organ to its surrounding structures
- dissection of cadaver could be one of best learning options (only a few students mentioned this), but too complicated, so sometimes confusing; limited time access only.
- They mentioned their preference to have a 3D version of the images in textbooks
- and 3D zooming in interactive software to explore deeper layers such as vessels and/or nerve structure.

Thirteen students mentioned the limitations of 2D presentation while a few other students commented indirectly about 2D issues of putting the separate organs together in more clinical/practical sense.

It was surprising that although DVDs and online resources are well developed, they did not seem to be utilized well. One of the reasons might be cost. Another issue for not being accepted by users could be another layer of learning the tool itself. Despite all the efforts to create a transparent user interface, there is a big gap between the tool and user acceptance of it.

These computer-based resources have different pedagogical approaches as well as varying technologically.

System description

Current learning of anatomy consists of 2D coloured images (i.e. textbooks), e-resources (similar with textbooks but interactivity is added on), and cadaver dissection. An expensive cadaver option may not be a best option for learning. In spite of its cost and the difficulty of providing multiple learning opportunities with it, there are still gaps between what we can learn from it and what we can apply to clinical situations. The first image is an example of an image in a textbook. The last two images are used by the new haptic interaction system. The 3D images are rotatable and zoomable with a haptic interface (See Figure 1 for examples).

Figure 1: Image from textbook, image of cadaver, 3D images from haptic interactive system

When a student's eyes view 2D images in a textbook, they are looking at a static image which has been drawn and coloured in a specific way. The image contains a 3D model taken from a set angle with a particular status where colour-coding may distinguish digestive and blood circulatory systems for instance. Sometimes these static images are more realistic, and are based on cadavers.

By contrast, in the proposed system, the student will be able to view the organ from any angle and at any magnification. Augmented information superimposed on the anatomical visual models will display further explanations about the function and structure of each organ. Different functions will enable the student to select from colouring schemes or cadaver-like views. Different layers of organs, blood vessels, nerves, can also be selected.

Haptic technology provides the sense of touch and controls of computer system through force (kinesthetic) or tactile feedback. Haptic feedback provides another dimension to understanding anatomy efficiently. The Phantom Omni (Figure 2) is one of the relatively cheap haptic devices available. Effects provide a way to render forces to the haptic device to simulate arbitrary sensations. Force effects can be started and stopped or triggered in response to events, like touching a shape or pressing a button on the haptic device. Unlike shape rendering, effects will persist until stopped or until the duration has elapsed for trigger effects. This device provides 6 degrees of freedom to drag, rotate, zoom-in and out, and touch. By pressing an organ which is displayed on the monitor students can compare different sensations and hardness of parts of organs or inside and outside of an organ. Other programmable functions such as dissection can be added to the system.

Also one of the main difficulties in understanding anatomy is the gap between illustrations *per se* in textbooks or learning resources and the actual body or cadavers. By implementing augmented reality, various conditions with shapes and colours can be displayed at users' selection.

This study will explore these new affordances of technology and evaluate their effectiveness in learning.

Methods

The current “integrated practical” anatomy learning session consists of five (5) work benches allocated with different resources. An additional work bench will be added for this experiment. The system will be developed with Visual Studio 2010 in C++. OpenGL will be used to create high quality 3D images. A Phantom Omni robotic tool will provide haptic feedback with 6 degrees of freedom and will utilise the Openhaptics tool kit (Itkowitz, Handley & Zhu, 2005) to interface with the anatomical visualisation data. In order to develop augmented representation of 3D information, marker-less augmented reality will be adapted. Instead of creating markers, the extracted patterns of the images from the textbook will retrieve the information to be superimposed.

A user-trial experiment is designed in an activity-based curriculum. A mixed experimental research design will be used to evaluate participants’ practical examination scores as well as their perception of the computer program’s effectiveness in helping them learn anatomy in the form of questionnaires and video recording. The user survey with questionnaires and video recording are currently undergoing the ethics approval.

In order to test user acceptance by human users in the subject area, two different interfaces will be implemented. One interface is to use a haptic device such as Phantom Omni (Figure 2) that provides different type of haptic feedback to the user depending on his selected activity. The other interface is to use the same system with commercially available game device, Xbox 360 Kinect. This will provide an interface with fingertip control (Figure 3), but without haptic feedback.

Figure 2: Phantom Omni robotic arm with ‘touch feedback’

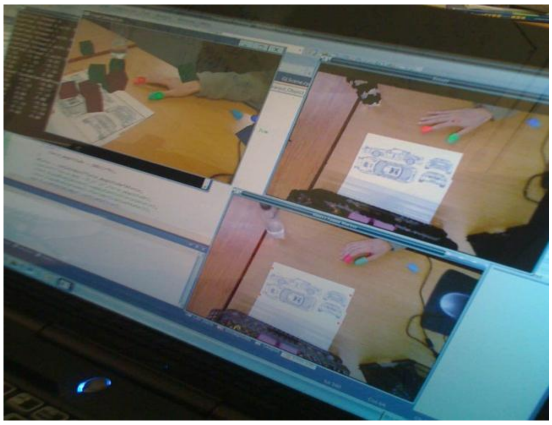

Figure 3: Xbox 360 Kinect detects coloured fingertips

The effectiveness of the AR system will be analysed by comparison of learning achievement measured by conventional academic assessment. User acceptance will be judged from videos showing how students used the system, and logs of their progress through the structured learning sequence.

Conclusion

This paper has described a problem in learning anatomy and how this project will aim to overcome some of the difficulties. Augmented reality is a relatively new area of research, so implementation and investigation are developing fields with emerging methodologies. Some comparisons of training using AR in the discipline of anatomy have shown promising results, with simulated human body organs providing better learning experiences (Leblanc et al., 2010). Activities in the museum sector have also shown that three dimensional objects can be better appreciated using a haptic interface (Butler & Neave, 2008) so this aspect of the current project appears promising. One novel feature of the proposed system is to incorporate a structured learning sequence based upon the anatomy lecturer's worksheets which will direct students through a series of investigations using explicit teaching. This will be followed by unstructured investigations using the affordances of the technology, and finally by an interactive quiz to verify learning. These aspects provide a good reason to hope the system will be effective when compared to traditional learning techniques.

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