Virtual Interactive Human Anatomy: Dissecting the Domain, Navigating the Politics, Creating the Impossible

Weiquan Lu
National University of Singapore
21 Lower Kent Ridge Rd
Singapore 119077
Lu.weiquan@nus.edu.sg

Suresh Pillai
National University of Singapore
21 Lower Kent Ridge Rd
Singapore 119077
Suresh_pillai@nuhs.edu.sg

Kanagasuntheram Rajendran
National University of Singapore
21 Lower Kent Ridge Rd
Singapore 119077
antrajen@nuhs.edu.sg

Yoshifumi Kitamura
Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai
980-8577 Japan
kitamura@riec.tohoku.ac.jp

Ching-Chiuan Yen
National University of Singapore
21 Lower Kent Ridge Rd
Singapore 119077
didyc@nus.edu.sg@nus.edu.sg

Ellen Yi-Luen Do
Georgia Institute of Technology
North Avenue, Atlanta
GA 30332, USA
ellendo@gatech.edu

CHI'17 Extended Abstracts, May 06-11, 2017, Denver, CO, USA
ACM 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3050431

Figure 1. Conceptual image showing the vision of the VIHA system.

Figure 2. Using the HTC VIVE headset and controllers in fully immersive VR.

Figure 3. Picking out individual anatomical structures using the HTC VIVE wireless controller.

Abstract
Cadaveric dissection has been the gold standard in the teaching of anatomy in medical schools around the world. Cadaveric dissection allows a medical student to understand the spatial relationships of different parts in the body in ways that a typical 2D representation cannot, due to its ability to provide an authentic learning experience which engages all the senses. However, in the modern times that we live in, the availability of suitable cadavers for medical education is low, and there is an urgent need to supplement the practice of cadaveric dissection with more sustainable and economical methods of teaching. Virtual Reality (VR) may serve as a suitable supplement owing to its ability to simulate an immersive 3D environment. However, the authentic learning experience is difficult to recreate in VR, due to the lack of design guidelines. This project is an early exploration into designing active learning interactions for learning anatomy.

Author Keywords
Virtual Reality; Interaction; Active Learning; Physicality; Medical; Anatomy

ACM Classification Keywords
H.5.1. Information interfaces and presentation (Artificial augmented and virtual realities)

Figure 4. Picking out grouped anatomical structures using the “Group” mode.

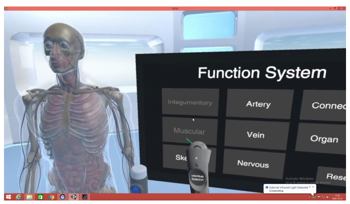

Figure 5. The body is available as a whole continuous set of anatomical structures, with individual body parts loosely coupled with the rest of the structures. The structures can be hidden by functional grouping, but the contextual associations are maintained with no explicit compartmentalization.

Figure 6. A guided tutorial encourages learner reflection

Introduction

The Virtual Interactive Human Anatomy (VIHA) project is a joint project between the Yong-Loo-Lin School of Medicine and the Keio-NUS CUTE Center, both situated at the National University of Singapore. The aim of the project was to develop a virtual reality (VR) system for facilitating the learning of Human Anatomy, so as to explore learning facilitation methods beyond the traditional 2D representations of anatomical structures, whether found in atlases, textbooks, or even computer and tablet interfaces that represent 3D content on 2D displays. The three year project was implemented in phases, with the Phase 1 dedicated to an exploration of suitable VR platforms and approaches, and the Phase 2 dedicated to the development of the software. We are currently in Phase 3, which is usability testing and refinement, and is the final phase of the project before launch in July 2017. At launch, the system will be used by medical students in the Yong-Loo-Lin School of Medicine as part of their anatomy studies.

Background

The idea for this work came out from discussions critically examining the role of cadaveric dissection in anatomy learning. The idea of interaction was at the core of these discussions, with words like “authentic”, “embodied”, “corresponding / congruent” and “contextual” serving as additives to the main term. Participants in the discussion compared approaches such as PowerPoint slides and other desktop application click-through(s), and tablet apps with “swipe-to-pan, rotate and pinch to zoom”, as well as other typical interaction methods. The consensus of the discussions was that none of these interaction methods recreated the cadaveric dissection experience to a suitable degree. So, just what was provided by cadaveric dissection that was missing from current approaches? It certainly was not the visual display, as most of these approaches enabled the same amount of information to be displayed. In fact, the visuals that cadaveric dissection provides are of less fidelity than a digital application that can provide full color reproduction of the anatomy of a living person; cadavers usually do not look and feel like their living counterparts, and they certainly do not move or smell like them. Anyone who has been in an anatomy dissection hall can attest to this. So, if cadavers are such poor surrogates for the living human body, why then are their dissections considered the gold standard?

To answer the question above, we need to understand two attributes of anatomical study. First, anatomy focuses on the structure of organisms [4], or “where what is in the body in relation to everything else”. Since human bodies are inherently 3D structures, a good spatial understanding of “where what is” forms a crucial part of learning anatomy. This is where cadaveric dissection excels over any other form of representation. In particular, applications that map 3D representations to 2D interfaces are unable to express such spatial relationships without loss of information. For example, in order to rotate an object on a tablet PC, swiping left or right may be one of the ways to do so. However, swiping on a tablet surface is a 2D gesture, and therefore does not afford the additional third dimension that true rotation possesses. While this may seem trivial at first, this 3D to 2D mapping requires learners to mentally map 2D sensations back into 3D, and studies in other domains have shown that certain learners may have difficulty in performing such mental conversions [5]. Therefore, any application that strives to match the utility of cadaveric dissection, should

Figure 7. VIHA enables users to use free-hand interaction via the attached Leap Motion Controller.

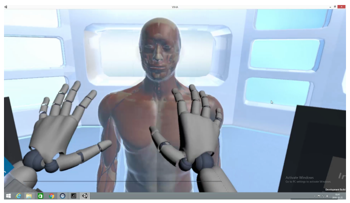

Figure 8. The user's hands are translated directly into the VR environment.

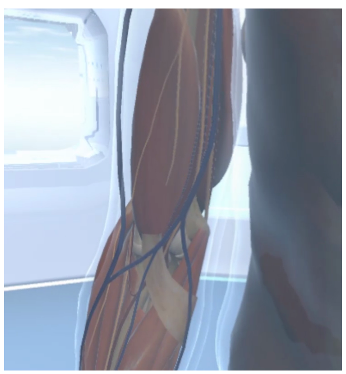

Figure 9. Anatomical structures are highly detailed and anatomically accurately reproduced, achieved by 3D artists working with anatomists.

strive to provide true 3D controls that correspond to the full range of human movements.

Next, the assertion of "where what is" in relation to everything else implies the need for contextual associations between anatomical parts to be maintained as much as possible. Therefore, applications that attempt to compartmentalize anatomical content violate this rule. This is probably why students have difficulties understanding anatomy from an atlas or textbook, not just because of the 2D-3D spatial mapping problem mentioned earlier, but also because such a medium artificially compartmentalizes the content, thereby creating false divisions in what essentially should be a continuous system.

Theoretical Foundations regarding Learning

Having discussed the need for true 3D interaction and a continuous representation of the body to provide contextualized associations, we can now discuss the theoretical foundations underlining system design. In our work, we adopt Mayer's definition of Learning being a change in knowledge due to experience [7], and knowledge in this case refers to a learner's mental model of the world. The learning facilitation method we use is called Active Learning, which is defined as activities that involve students in doing things and thinking about the things they are doing [2]. When students are doing things that involve Physicality [9], such as physically manipulating objects, or producing gestures and bodily posture changes, their cognitive engagement [6] increases. In turn, this results in an increase in a student's psychological investment in and effort directed toward learning. The activities involving Physicality also produce kinetic / kinesthetic details, along with other sensory details, that may be consciously or unconsciously committed to memory. Upon reflection of these experiences, either through the guidance of a teacher or an artificial agent, students then use these details, together with narrative as an instrument of the mind, to structure thought, shape memory, and make sense of the world. This process changes the learner's mental model of the world, resulting in learning. Guided by these theories, we began the construction of VIHA.

Virtual Reality or Augmented Reality

There were two camps in our ranks, one which advocated for Virtual Reality (VR), and the other which wanted Augmented Reality (AR). At the time that we had to make this decision, we were fully aware of the heated debates that raged on in the media. And even though some of us had been working in both domains (there is in fact only one domain, and it's a continuum [8]) for a long time, we understood that arguments were sometimes insufficient in convincing the politically motivated. Therefore, we referred back to the basic definitions of VR and AR. VR [3] could be defined as any system that fulfills the following three conditions: 1. Provides an immersive simulation of a 3D environment, 2. Is interactive in real time through software and hardware, 3. Is experienced or controlled by movement of the body. Any AR system [1] could also be defined with three conditions: 1. Combines real and virtual elements, 2. Is Interactive in real time, 3. Is registered in 3D. According to the definitions, the real consideration was whether or not we should use a fully immersive simulation environment, or we should allow the mixture of real-world and virtual-world elements. In a way, this was a discussion about the trade-off between fidelity and control. Specifically, VR provided full control over the virtual environment due to its fully

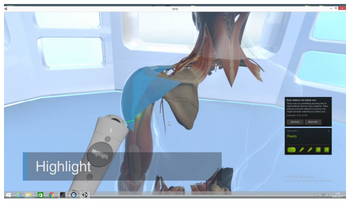

Figure 10. Other features include the ability to highlight anatomical structures for aiding in conversations with other learners.

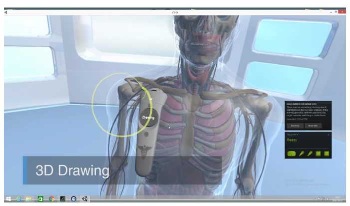

Figure 11. As well as having the ability to draw in 3D to facilitate the formation of common ground between other learners.

virtual 3D environment, while AR afforded less control due to the unpredictability of the real-world. However, AR provided higher fidelity in terms of representation, because it used the real-world in part of its interactions, which had the highest fidelity as compared to VR, which ultimately functioned in a fully immersive artificial environment. Based on what we understood from anatomy learning (as established earlier in the paper), fidelity may not be the most important factor. Instead, having strict control over the learning environment was more important. VR was thus chosen.

We present to you: VIHA

Based on the project requirements of providing a full continuous human body that can be dissected while maintaining contextual associations as much as possible, using true 3D controls that correspond to the full range of human movements, thereby facilitating the use of Physicality in the interactions, we implemented the VR project using Unity3D. To enable Physicality-based interactions, we built the system to run on the HTC VIVE VR platform. Aside from the head and hand tracking provided by the VIVE, we also used the Leap Motion Controller to enable free-hand manipulation.

Future Work

We hope to use the deployed system to study the correlation between interactions in VR and student learning outcomes.

Acknowledgements

This project is initiated and funded by the Yong Loo Lin School of Medicine at the National University of Singapore. This research is supported by the National Research Foundation, Prime Minister's Office, Singapore under its International Research Centres in Singapore Funding Initiative. This work is also supported in part by JSPS Bilateral Joint Research Project.

References

1. Ronald Azuma. 1997. A survey of augmented reality. *Presence: Teleoperators and Virtual Environments* 6, 4: 355–385.
2. Charles C. Bonwell and James A. Eison. 1991. *Active Learning: Creating Excitement in the Classroom*. ASHE-ERIC Higher Education Report No.1, Washington D.C: The George Washington University,School of Education and Human Development.
3. Dictionary.com. Virtual Reality. Retrieved November 17, 2016 from http://www.dictionary.com/browse/virtual--reality.
4. Henry Gray. 2017. Anatomy of the Human Body. *Bartleby.com*. Retrieved January 23, 2017 from http://www.bartleby.com/107/1.html.
5. T Ishikawa and K A Kastens. 2005. Why some students have trouble with maps and other spatial representations. *Journal of Geoscience Education* 53, 2: 184–197.
6. Helen M Marks. 2014. Student Engagement in Instructional Activity : Patterns in the Elementary , Middle , and High School Years. 37, 1: 153–184.
7. Richard E. Mayer. 2010. Applying the science of learning to medical education. *Medical Education* 44, 6: 543–549.
8. P Milgram, H Takemura, a Utsumi, and F Kishino. 1994. Mixed Reality (MR) Reality-Virtuality (RV) Continuum. *Systems Research* 2351, Telemanipulator and Telepresence Technologies: 282–292.
9. Sara Price and Yvonne Rogers. 2004. Let's get physical: The learning benefits of interacting in digitally augmented physical spaces. *Computers and Education* 43, 1–2 SPEC ISS.: 137–151.