The Ghost Anatomy Project

1/26/14: LITERATURE REVIEW

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Overview

The goal of this literature review was to understand the space of 3D interactive displays, and the need for these kinds of displays. The information from scholarly articles involving 3D displays, volumetric displays, and their relation to education and anatomy was then used to formulate the problem statement used in the Project Proposal for The Ghost Anatomy Project.

The following list of documents, links, and quotes referenced in the Annotated References section of this document were used to explore the space of 3D interfaces and their applications. Articles were grouped into the categories of Usefulness of Visualization in Anatomy, Effectiveness of Volumetric Displays, Applications of Volumetric Displays, and Volumetric Display Construction. Scholarly articles were accessed by Google Scholar or UW WorldCat. Each annotated reference is hyperlinked to the article source, and annotated in APA format. Key quotes from each article is posted as bullet points. For our needs, this format was most useful for the annotated references.

Problem Statement

The field of medicine, which saves, extends, and preserves lives, relies on a thorough understanding of the structure and processes of the human body. In anatomy courses, effective visualization of the human body contributes to success in learning the curriculum. Hands-on learning, such as dissection, enhances learning by increasing confidence in the subject matter (Johnson 2002), as well as in “verbal presentation, synthesis of anatomical concepts, appreciation of the clinical importance of anatomy, and the general development of professionalism” (Clough 1996). Because lectures are “largely passive activities for the student” (Johnson 2002), students rely on work in dissection laboratories “clear-up misunderstood points” (Yiou 2006) and achieve the balance between memorization and visualization they need to achieve success (Pandey 2007).

Despite their educational value, effective, hands-on visualization of the human body are subject to physical and economic constraints. According to Grossman and Balakrishnan (2008), physical specimens are restrained by “security and storage costs, leaking fluids, plus legislative issues, since they involve biological specimens.” Other physical means of human body visualization, such as plastic models or casts, cost thousands of dollars[1], and are thus limited in availability to students.

Desktop applications which virtualize the body, like BioDigital Human[2], fail to offer the benefits of a hands-on learning experiences which enhance “learning and confidence in the subject matter” (Johnson 2002). These such applications are limited to flat, two-dimensional displays which only render a subset of the visual cues humans require for a “truly rich perceptual experience” (Balakrishnan 2008). These cues, which contribute to visual richness, include “perspective, occlusion or interposition, light and shadows, relative size, motion parallax, and stereopsis to interpret depth and dimension” (Balakrishnan). Without a truly rich perceptual experience, students are deprived of more effective ways to study the human body.

Three-dimensional displays are capable of presenting information to students with a visual richness which can display the human body more realistically than two-dimensional displays. They enhance users’ sense of realism by providing a more “intuitive assessment of the spatial relationships” (Wang 2005), and all the “depth cues humans require” (Balakrishnan). Three-dimensional interfaces additionally allow for collaborative viewing and interaction from 360 degrees of freedom, encouraging collaborative learning (Grossman 2008). Research results from a study involving extensive interviews with anatomy experts has suggested that 3D volumetric displays would be “great for education, diagnosis, and in particular, surgical planning,” with a “huge range of prospects” and “almost no end of encouraging future applications” (Grossman 2008). According to Blundell (1993), “potential applications for such displays are widespread and include fields from scientific and medical research is to engineering design and education.” The potential of 3D interfaces in anatomy is additionally confirmed by Lee (2013), who notes that “while the BioDigital Human does not have the capability to project 3D images in a realistic 3D environment, it is not difficult to imagine that 3D holographic technology can further enhance the realistic visualization and interactivity of 3D interactive medical visualization programs.”

Resources

1 http://www.shopanatomical.com/Deluxe_Female_Muscle_Figure_23_part_Life_Size_p/3b-b51.htm
2 https://www.biodigitalhuman.com/

Annotated References

Usefulness of Visualization in Anatomy

[Importance of dissection in learning anatomy: personal dissection versus peer teaching]

Johnson, J. H. (2002). Importance of dissection in learning anatomy: personal dissection versus peer teaching. Clinical Anatomy, 15(1), 38-44.

- hands-on dissection enhances learning and confidence in the subject matter
- The explosion of knowledge to be learned by medical students and the pressures on faculty for academic pursuits have put curricular, student, and faculty time at a premium. lectures are largely passive activities for the student.
- Johnson (2002) notes that "the explosion of knowledge to be learned by medical students and the pressures on faculty for academic pursuits have put curricular, student, and faculty time at a premium."

[Evaluation of a surgical simulator for learning clinical anatomy]

Hariri, S., Rawn, C., Srivastava, S., Youngblood, P., & Ladd, A. (2004). Evaluation of a surgical simulator for learning clinical anatomy. *Medical education*, *38*(8), 896-902.

- New techniques in imaging and surgery have made 3-dimensional anatomical knowledge an increasingly important goal of medical education. This study compared the efficacy of 2 supplemental, self-study methods for learning shoulder joint anatomy to determine which method provides for greater transfer of learning to the clinical setting.
- Our results show that this surgical simulator is at least as effective as textbook images for learning anatomy and could enhance student learning through increased motivation. These findings provide insight into simulator development and strategies for learning anatomy. Possible explanations and future research directions are discussed.

[Applying problem-based learning to the teaching of anatomy: the example of Harvard Medical School]

Yiou, R., & Goodenough, D. (2006). Applying problem-based learning to the teaching of anatomy: the example of Harvard Medical School. surgical and Radiologic Anatomy, 28(2), 189-194.

- Traditional aspects of the teaching of anatomy, such as work in dissection laboratories, are given an important role as they are aimed to clear-up misunderstood points.

[Testing knowledge of human gross anatomy in medical school: An applied contextual-learning theory method]

Clough, R. W., & Lehr, R. P. (1996). Testing knowledge of human gross anatomy in medical school: An applied contextual-learning theory method.Clinical anatomy, 9(4), 263-268.

- Our program demonstrates that the learning of applicable human anatomy is facilitated in a contextual-learning environment. Moreover, by learning anatomy in this way, other equally beneficial attributes are afforded the medical student, including, but not limited to, increases in communication skills, confidence in verbal presentation, synthesis of anatomical concepts, appreciation of the clinical importance of anatomy, and the general development of professionalism.

Medical students' learning of anatomy: memorisation, understanding and visualisation

Pandey, P., & Zimitat, C. (2007). Medical students' learning of anatomy: memorisation, understanding and visualisation. *Medical education*, *41*(1), 7-14.

- Students perceived successful learning of anatomy as hard work, involving various combinations of memorisation, understanding and visualisation.
- Approaches to learning correlate positively with the quality of learning. Successful learning of anatomy requires a balance between memorisation with understanding and visualisation. Interrelationships between these three strategies for learning anatomy in medicine and other disciplines require further investigation.

Evaluation of the Effectiveness of Volumetric Displays

An evaluation of depth perception on volumetric displays

Grossman, T., & Balakrishnan, R. (2006, May). An evaluation of depth perception on volumetric displays. In *Proceedings of the working conference on Advanced visual interfaces* (pp. 193-200). ACM.

- Our results show that volumetric displays enable significantly better user performance in a simple depth judgment task, and better performance in a collision judgment task, but in its current form does not enhance user comprehension of more complex 3D scenes.
- Before conducting our study, volumetric displays were known to have a number of beneficial properties unique to the technology: Consistent depth information: accommodation and convergence cues are consistent, so users do not suffer from asthenopia. Minimal hardware requirements: special glasses, head mounted devices, and head tracking technology are unnecessary. 360° viewing angle: Imagery can be viewed from any angle, allowing simultaneous viewing by multiple users.

Collaborative interaction with volumetric displays

Grossman, T., & Balakrishnan, R. (2008, April). Collaborative interaction with volumetric displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 383-392). ACM.

- Volumetric displays possess a number of unique properties which potentially make them particularly suitable for collaborative 3D applications...Furthermore, interviews with experts in potential usage domains indicated that the techniques we developed can serve as a baseline for future collaborative applications for volumetric displays.
- The anatomy experts said the system would be great for education, diagnosis, and in particular, surgical planning, due to the number of elements involved with complex 3D relationships. The architect said the system had a “huge range of prospects”, with “almost no end of encouraging future applications”, and that it would be great to incorporate in the design process for understanding relationships
- 3D virtual platform which could replace or at least complement current physical processes. One anatomy professor discussed how “anatomy museums”, which display physical specimens inside enclosures for educational purposes, are burdened by security and storage costs, leaking fluids,

plus legislative issues, since they involve biological specimens. A volumetric display would not suffer from these drawbacks, while maintaining the affordances of an enclosed physical 3D specimen.

- The architect commented that scaled-down physical models provide a necessary 3D viewing modality, but often prohibit creative design, because any mistake is costly, with respect to time and the cost of materials. If the model was instead displayed virtually inside a volumetric display, then the designer could worry less about making specific mistakes, and concentrate more on the creative design, while still obtaining the desired 3D viewing mode. The architect liked the ability to physically walk around the display, and said it would allow designers to use their "innate biological resources" to understand the spatial relationships of a model. This comment is validation for our location-sensitive interaction design goal.

User Interfaces for Volumetric Displays

Balakrishnan, R., Fitzmaurice, G. W., & Kurtenbach, G. (2001). User interfaces for volumetric displays. *Computer*, *34*(3), 37-45.

- Volumetric displays,4 which enable true 3D image visualization, hold the promise of enhancing rendered 3D graphics' sense of realism by providing all the depth cues humans require.

Volumetric three-dimensional display systems

Blundell, B. G., & Schwarz, A. J. (2000). Volumetric three-dimensional display systems. *Volumetric Three-Dimensional Display Systems, by Barry G. Blundell, Adam J. Schwarz, pp. 330. ISBN 0-471-23928-3. Wiley-VCH, March 2000.*, *1*.

- Pg. 306: In view of the challenges posed by the implementation of volumetric systems and the interesting nature of this type of work, the continuation of research in this area seems assured. Unfortunately, considerable uncertainty surrounds the application and acceptance of this technology.... It is equally difficult to predict the types of visualization devices that will gain widespread acceptance, although we were able to postulate an increasing need for systems that can depict increasingly complex types of information...The lack of widespread interest in volumetric display system technologies may indicate that such displays are not needed, or alternatively, that it is forseen that they cannot be made to operate at the required level of performance... As we have seen during the course of this book, many problems associated with the implementation of volumetric systems can be solved and the prospects for the development of the next generation of high-performance displays are most promising. Furthermore, volumetric systems offer to provide a unique solution in visualization of various types of information
- It examines the history, development, design, and future of these displays, and considers their potential for application to key areas in which visualization plays a major role. Drawing substantially on material that was previously unpublished or available only in patent form, the authors establish the first comprehensive technical and mathematical formalization of the field, and examine a number of different volumetric architectures.

Three-dimensional television, video and display technology

Javidi, B., & Okano, F. (Eds.). (2002). *Three-dimensional television, video, and display technologies*. Springer.

- This book explores the theory and applications of three-dimensional display technologies. It presents real-world data such as simulations and experimental results, to present the progress and evolution of stereoscopic interfaces. By bringing interface technologies into the third dimension, the gap between the digital and physical worlds could be potentially bridged.
- Page 5: When observing a 3-D image on a display unit, such factors as the viewing angle and viewing area (the field where a stereoscopic image can be observed) in addition to the image's direct depth clues will be important in order to retain the perception of reality and a sense of immersion
- Page 6: Stereoscopic images provide a strong sensation of reality because they have depth information, which most distinguishes them from 2D images

Applications of Volumetric Displays

An evaluation of using real-time volumetric display of 3D ultrasound data for intracardiac catheter manipulation tasks

Wang, A. S., Narayan, G., Kao, D., & Liang, D. (2005, June). An evaluation of using real-time volumetric display of 3D ultrasound data for intracardiac catheter manipulation tasks. In *Proceedings of the Fourth Eurographics/IEEE VGTC conference on Volume Graphics* (pp. 41-45). Eurographics Association.

- Shows medical use of 3D display
- "However, the need to present 3D data on a 2D display decreases the utility of 3D echocardiography because echocardiographers cannot readily appreciate 3D perspective on a 2D display without ongoing image manipulation. We evaluated the use of a novel strategy of presenting the data in a true 3D volumetric display"
- Further improvement is achieved by using a true 3D volumetric display, which allows for more intuitive assessment of the spatial relationships of catheters in three-dimensional space compared with conventional 2D visualization modalities.

Volumetric three-dimensional display systems: their past, present and future

Blundell, B. G., Schwarz, A. J., & Horrell, D. K. (1993). Volumetric three-dimensional display systems: their past, present and future. *Engineering Science and Education Journal*, *2*(5), 196-200.

- Many ideas for volumetric displays have been proposed over the past 60 years or so, and some of these are discussed in this article. Potential applications for such displays are widespread and include fields from scientific and medical research is to engineering design and education

[3D acquisition and modeling for flint artefacts analysis]

Loriot, B., Fougerolle, Y., Sestier, C., & Seulin, R. (2007, July). 3D acquisition and modeling for flint artefacts analysis. In *Optical Metrology* (pp. 66180G-66180G). International Society for Optics and Photonics.

- We are interested in accurate acquisition and modeling of flint artefacts. Current techniques require several operations. By using 3D scanners, we significantly reduce the number of operations related to data acquisition and completely suppress the prototyping step to obtain an accurate 3D model.

[3D Holographic Technology and Its Educational Potential]

Lee, H. (2013). 3D Holographic Technology and Its Educational Potential.*TechTrends*, *57*(4), 34-39.

- This live 3D holographic teleconference demonstrates the future of business communication, with the interactive and physical engagement of a face-to-face meeting.
- The Defense Advanced Research Projects Agency recently has completed a five-year program called “Urban Photonic Sandtable Display” that creates a real-time, color, 360-degree 3D holographic display to assist battle planners, allowing them to view a large-format, interactive 3D display without having to wear 3D glasses (DARPA, 2011). In addition to its 3D holographic quality, the program allows multiples users to view and interact with the image simultaneously, assisting team-based planning.
- The 3D holographic technology, coupled with voice recognition technology, showcases the possibility of a sophisticated intelligent tutoring system in the near future, offering interactive and individualized learning experiences for all students with different background knowledge and ability.
- While the BioDigital Human does not have the capability to project 3D images in a realistic 3D environment, it is not difficult to imagine that 3D holographic technology can further enhance the realistic visualization and interactivity of 3D interactive medical visualization programs
- In addition, the world’s first virtual shopping store recently opened its doors in Korea, where shoppers can select items by touching the LCD screens and check out at the counter where their groceries are packed and ready to be picked up (Kim, 2011). However, it is not difficult to imagine that the technology, when properly incorporated into the educational setting, has potential to transport students to a virtual world where they can submerge themselves in a rich learning environment, or test out the operations of a real-world process or system. Also, it holds promise for an effective teaching and learning tool to promote student-centered learning, placing students in the center of their learning environment and allowing them to interact with it and construct knowledge based on their own learning experience. (a) conducting activities in a risk-free environment; (b) facilitating collaboration and communication; and (c) allowing visualization of abstract or difficult concepts or ideas. Ghuloum (2010) surveyed 400 teachers from different levels of education in the UK to evaluate the effectiveness of 3D hologram technology as an educational tool.
- augmented reality is as effective as traditional teaching materials in helping 10-year-old students understand how the Earth and sun interact in 3D space to give rise to day and night (Kerawalla et al., 2006).

[Volumetric 3D Displays and Application Infrastructure]

Favalora, G. E. (2005). Volumetric 3D displays and application infrastructure.*Computer*, *38*(8), 37-44.

- With vendors lowering the barrier to adoption by providing compatibility with new and legacy applications, volumetric displays are poised to assume a commanding role in fields as diverse as medical imaging, mechanical computer-aided design, and military visualization.

[Three-Dimensional Displays: A Review and Applications Analysis]

Holliman, N. S., Dodgson, N. A., Favalora, G. E., & Pockett, L. (2011). Three-dimensional displays: a review and applications analysis. *Broadcasting, IEEE Transactions on*, *57*(2), 362-371.

- We have reviewed the most important approaches to 3D display that have emerged over the past decade and have emphasized the application of the displays. We identify five application areas with distinctive display requirements and the characteristics of the displays that could in future work well for them.
- 1) 3D Cinema: Here the solution of a pair of 3D glasses per viewer and matching polarized or wavelength filtered projection seems suited to the viewing environment and cost constraints involved. Time-parallel solutions could help reduce temporal artifacts.
- 2) 3D Information Presentation and Advertising: In group presentation situations the glasses free multiview and volumetric displays could see long term success; providing viewing freedom and removing the need to wear glasses.
- 3) 3D TV Display: Glasses based solutions are available at the time of writing but in the long term 2D/3D switchable multiview displays may be an improvement. These allow automatic switching to and from 3D mode and remove the need for viewers to know where the glasses are, recent solutions have low crosstalk values which is a key quality criteria.
- 4) 3D Desktop Display: Here displays using glasses can work well, while autostereoscopic solutions that retain resolution are potentially attractive for a wide range of desktop tasks. Super-multiview could help resolve accommodation-vergence conflict resulting from the short viewing distance.
- 5) 3D Portable Display: For portable devices, cell phones and games systems, it seems likely that display users will wish to avoid the use of glasses and the ability to implement a {2D/3D} switching autostereoscopic display on a volume market cell phone has already been demonstrated. Fundamental challenges lie in developing content production and delivery tools that can cost effectively target the broad range of 3D displays that are becoming commercially successful [76].
- In conclusion, here are a few potential applications of 3D holographic technology in the educational setting that might change the way we teach and learn. Using gesture-controlled interactive 3D holograms, engineering students can design and build a car that runs on an engine that has not been tested in a real world setting. Tony Stark in Iron Man, for example, tests and tweaks virtual 3D mock-ups in his lab, and opens and reviews holographic data files of the Avengers Initiative team members in The Avengers, all through gestures and 3D holographic images. Similarly, medical students can use interactive 3D holographic images and collaboratively perform a surgical operation without risking lives or costing a cadaver. Using the technology similar to Live 360, students who are studying basic physics principles can immerse themselves in a 3D learning environment where they can interact with objects found in everyday life, test out basic physics principles, and improve their understanding of various scientific ideas and critical thinking skills. In such learning environment, 3D holographic technology is no longer a delivery method but an integral part of learning process that facilitates interaction among learners and construction of knowledge by learners using cognitive and social resources presented through the technology.

Operational Potential for 3D Displays in Air Traffic Control

Rozzi, S., Amaldi, P., Wong, W., & Field, B. (2007, August). Operational potential for 3D displays in air traffic control. In *Proceedings of the 14th European conference on Cognitive ergonomics: invent! explore!* (pp. 179-183). ACM.

- Overall 3D appeared to improve awareness of the relative position between aircraft-aircraft, aircraft-airspaces landmarks

Projection Volumetric Display using Passive Optical Scatterers

Nayar, S. K., & Anand, V. N. (2006). Projection Volumetric Display Using Passive Optical Scatterers.

- In this paper, we present a new class of volumetric displays that can be used to display 3D objects. The basic approach is to trade off the spatial resolution of a digital projector (or any light engine) to gain resolution in the third dimension

Display systems : design and applications

MacDonald, L. W., Lowe, A. C., Gallimore, J. J., & Nelson, T. J. (1999). Display Systems: Design and Applications. *Journal of the Society for Information Display*, *7*(4), 307-309.

- This book gives practical guidance on the latest technological developments and new application areas of displays which will enable the reader to gain an understanding of the current state of the art as well as the major trends that will shape future applications of displays and display systems.

Volumetric Display Construction

On Exemplar 3D Display Techniques

Blundell, Barry G. On Exemplar 3D Display Technologies. N.p.: Barry Blundell, 2012. Print.

- Perhaps the most obvious approach is to consider 3D displays as supporting image depiction techniques able to present synthetic spatial content in ways that are consistent with our natural perception of the 3D world in which we live. However, when considered in the context of scalable approaches able to operate satisfactorily across a broad range of applications, this seemingly simple objective is far from trivial. In this document, various useful terminology is briefly summarised, and this provides a framework for introductory discussion on a number of 3D paradigms and their application.

About 3D Volumetric Displays

Blundell, Barry G. *About 3D Volumetric Displays*. N.p.: Walker and Wood Limited, 2011. Print.

- In this monograph only a very brief summary of volumetric 3D display systems is possible. In its preparation I have attempted to highlight some of the important features of this display paradigm, and have endeavoured to summarise formalisms that I have found to be particularly useful during the many years that I have been involved in 3D display system research.

[The Design and Evaluation of Selection Techniques for 3D Volumetric Displays]

Grossman, T., & Balakrishnan, R. (2006, October). The design and evaluation of selection techniques for 3D volumetric displays. In *Proceedings of the 19th annual ACM symposium on User interface software and technology* (pp. 3-12). ACM.

- Volumetric displays, which display imagery in true 3D space, are a promising platform for the display and manipulation of 3D data. To fully leverage their capabilities, appropriate user interfaces and interaction techniques must be designed. In this paper, we explore 3D selection techniques for volumetric displays.

[Interaction Techniques using a Spherical Cursor for 3D Targets Acquisition and Indicating in Volumetric Displays]

Naito, M., Shizuki, B., Tanaka, J., & Hosobe, H. (2009, July). Interaction techniques using a spherical cursor for 3d targets acquisition and indicating in volumetric displays. In *Information Visualisation, 2009 13th International Conference* (pp. 607-612). IEEE.

- We present several innovative interaction techniques for 3D target acquisition and indication

[A volumetric 3D display based on a DLP projection engine]

Geng, J. (2012). A volumetric 3D display based on a DLP projection engine.*Displays*.

- Existing two-dimensional (2D) flat screen displays often lead to ambiguity and confusion in high-dimensional data/graphics presentation due to lack of true depth cues. Even with the help of powerful 3D rendering software, three-dimensional (3D) objects displayed on a 2D flat screen may still fail to provide spatial relationship or depth information correctly and effectively. Essentially, 2D displays have to rely upon capability of human brain to piece together a 3D representation from 2D images. Despite the impressive mental capability of human visual system, its visual perception is not reliable if certain depth cues are missing.

[Operational Potential for 3D Displays in Air Traffic Control]

Rozzi, S., Amaldi, P., Wong, W., & Field, B. (2007, August). Operational potential for 3D displays in air traffic control. In *Proceedings of the 14th European conference on Cognitive ergonomics: invent! explore!* (pp. 179-183). ACM.

- 3D virtual platform which could replace or at least complement current physical processes. One anatomy professor discussed how “anatomy museums”, which display physical specimens inside enclosures for educational purposes, are burdened by security and storage costs, leaking fluids, plus legislative issues, since they involve biological specimens. A volumetric display would not suffer from these drawbacks, while maintaining the affordances of an enclosed physical 3D specimen. (Grossman)
- While the BioDigital Human does not have the capability to project 3D images in a realistic 3D environment, it is not difficult to imagine that 3D holographic technology can further enhance the realistic visualization and interactivity of 3D interactive medical visualization programs (Lee)

- is not difficult to imagine that the technology, when properly incorporated into the educational setting, has potential to transport students to a virtual world where they can submerge themselves in a rich learning environment, or test out the operations of a real-world process or system. Also, it holds promise for an effective teaching and learning tool to promote student-centered learning, placing students in the center of their learning environment and allowing them to interact with it and construct knowledge based on their own learning experience. (a) conducting activities in a risk-free environment; (b) facilitating collaboration and communication; and (c) allowing visualization of abstract or difficult concepts or ideas. (Lee)
- 3D holographic technology is no longer a delivery method but an integral part of learning process that facilitates interaction among learners and construction of knowledge by learners using cognitive and social resources presented through the technology. (Holliman)
- With vendors lowering the barrier to adoption by providing compatibility with new and legacy applications, volumetric displays are poised to assume a commanding role in fields as diverse as medical imaging, mechanical computer-aided design, and military visualization (Favalora)
- potential of 3D to solve those gaps

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Yiou, R., & Goodenough, D. (2006). Applying problem-based learning to the teaching of anatomy: the example of Harvard Medical School. surgical and Radiologic Anatomy, 28(2), 189-194.