Abstract:

Despite recent advancements in medical image acquisition that allow for the reconstruction of anatomies with 3D, 4D, and 5D renderings, the standard for anatomical and medical data visualization still relies heavily on the use of traditional 2D didactic tools (i.e., textbooks and slides) or, at best, the visualization of the native images in their 2D slice format. While these approaches have their merit in being cost effective and easy-to-disseminate, anatomy is implicitly 3D and when using 2D visualizations of more complex morphologies, interactions between structures are often missed. In medical practice, such as in the planning and execution of surgical interventions, professionals require an intricate knowledge of anatomical complexities, which are more easily, or only can be, elucidated with more natural, intuitive method of interacting with complex 3D volumetric datasets extracted from high-resolution CT or MRI datasets. Leveraging open source, high quality, 3D medical imaging datasets and the emerging popularity of 3D display technologies; affordable, consistent, and widely available 3D anatomical visualizations can be made. In this study we describe the design, implementation, and evaluation of a 3D interactive and stereoscopic visualization paradigm for human anatomy extracted from 3D medical images using an interactive stereoscopic table-top display. Using an Northern Digital Polaris Spectra tracking system, and a reverse projection screen, a multiple-viewing-angle interactive stereoscopic display was created. While this paradigm is sufficiently versatile to enable a wide variety of applications in need of 3D visualization, we designed our study in the context of an interactive game that allows users to explore the anatomy of various organs and systems by manipulating 3D virtual data. In analysis we aim to quantify and qualify users’ visual and motor interactions with virtual environments, as well as quantify their learning capabilities when employing this interactive display as a 3D didactic tool.

How do surgeons prepare for surgical interventions? Although every surgeon has their own ritualistic practices before entering the operating suite, it is a common practice amongst surgeons to review case details, related medical imagery and studies, and in some way visualize the surgical procedure they are about to perform. Ostensibly, the pre-operative objective of a surgeon is to simulate the surgery beforehand. However, the procedural tools that are most available to surgeons today make it difficult to most effectively prepare --- to simulate --- surgeries pre-operatively, especially as a growing number of complex surgeries are becoming increasingly minimally invasive \cite{kang2014stereoscopic} \cite{chan2013virtual}. The predominate forms of medical imagery used by surgeons in surgical preparation are Computed Tomography (CT) scans, Magnetic Resonance Imaging (MRI), and X-rays. ­These imaging tools only produce 2D interpretations of 3D data, which then requires the surgeon to translate the data from its 2D form into its useful 3D form \cite{ nam2012application} \cite{vaapenstad2013procedural}. Furthermore, in pre-operative preparation surgeons conventionally have access to tools such as cadavers and 3D anatomical models, but these tools are expensive, non-extensible, and not patient specific \cite{marescaux1998virtual}. Leveraging virtual environments and utilizing volume-rendered techniques to create 3D anatomical renderings from medical images; an extensible, patient specific, and cost efficient 3D procedural surgery simulator can be made \cite{ vaapenstad2013procedural} \cite{messier2016interactive}.

This is a specific application of virtual reality (VR) in medicine --- there is much potential for the application of virtual environments in medicine --- and many steps need to be made in order to realize this goal, and other VR goals in medicine \cite{ chan2013virtual}. Two of these steps are to evaluate, users’ motor and visual interactions with a virtual environment, and to evaluate users’ 3D learning benefits from stereoscopic displays. It is on these two steps that our proposed project is based.

In previous work we created “An Interactive 3D Virtual Anatomy Puzzle for Learning and Simulation”, which was developed for use with an Occulus Rift --- a head-mounted stereoscopic display --- and a 6-degrees-of-freedom (DoF) “space-mouse” \cite{messier2016interactive}. The purpose of our previous work was mainly to develop an entertaining, interactive, and useful didactic tool for young students (grades 6-12), a demographic that has very limited access to 3D didactic tools \cite{messier2016interactive} \cite{brewer2012evaluation}. In extension to this project we seek to apply our previously developed game to an interactive stereoscopic tabletop. Using a tracking system we have developed a multiple-viewing-angle and gesture operated platform for our puzzle game to be extended onto. From our newly developed system, we aim to study users’ motor and visual interactions with a virtual environment, and evaluate user training --- 3D spatial anatomy learning --- associated with playing our game.