User-Centered Design Recommendations for Augmented Reality in Navigated Spinal Procedures

Faculty of Information
University of Toronto
Research Team:
Carly Warren
Abeera Ali
David Gafni
Daipayan Guha
Mayan Murray
Hendrik Ophardt

Abstract

Intra-operative navigation may be employed in spinal procedures to assist in guiding the placement of instrumentation used to stabilize the spine via internal fixation. Navigation has been shown to reliably increase the accuracy of pedicle screw placement at all regions of the spine (Mason et al., 2014). Current navigation systems work by tracking the standard spinal surgical tools' location with respect to the intra-operative patient anatomy that is digitally registered to a pre- or intra-operatively acquired imaging dataset (X-rays or CT). The current navigation user interface displays the position of the tools relative to the registered CT scan on a single 2D display, with separate panels for each orthogonal axis. This design paradigm is consistent across all current commercially available systems. Augmented reality (AR) has the potential to improve patient outcome, surgeon comfort, and trainee learning during spinal procedures that rely on navigated spinal instrumentation (NSI procedures). This is theoretically achieved by providing surgeons with context-specific overlaid information that is otherwise not readily accessible within the surgical field or on a 2D display monitor. The development of AR technology for spinal procedures is in its early infancy, with no commercial devices available at present.

As the operating room is a highly constrained and safety-critical environment, human and technological components must work seamlessly together in an efficient workflow. Surgical tools must be designed to suit both human users and the relevant surgical procedures. While navigation is proven to be useful and effective, current methods of displaying navigation content place a significant cognitive burden on surgeons, and particularly surgical trainees, as utilizing the system requires demanding mental manipulation of displayed 2D images into a 3D representation (Norman,1988). AR in NSI procedures has the potential to display contextual and complex information efficiently, thereby reducing mental workload and improving surgeon comfort and patient safety. An understanding must therefore be obtained, in the context of NSI procedures, of the

typical tools, cognitive steps and physical movements that are performed by surgeons in the course of a standard NSI procedure with current technologies. Discerning what content the current navigation system displays that the surgeons heavily rely on, and how his information should be translated to an AR environment in such a way that it is most useful and least disruptive for the surgeons, is an important question that remains unanswered. In this study, we identify the components and cognitive steps required to carry out a navigated spinal instrumentation procedure. The aim of this work is to identify requirements for surgeons carrying out NSI procedures, to inform and direct the future design of a prototype AR system; including the content to be displayed and the AR interaction techniques. Translation of these functionalities to a more efficient AR environment requires an understanding of the tools, cognitive steps and physical manipulations that are required to carry out an NSI procedure. This investigation is necessary in order to best integrate an AR device into the surgical and training workflow, while providing useful and relevant information as needed.