ProjectDR: Augmented Reality System for Displaying Medical Images Directly onto a Patient

Ian Watts
University of Alberta
Edmonton, Canada
watts1@ualberta.ca

Pierre Boulanger
University of Alberta
Edmonton, Canada
pierreb@ualberta.ca

Greg Kawchuk
University of Alberta
Edmonton, Canada
gkawchuk@ualberta.ca

ABSTRACT

The internal anatomy of a patient can be difficult for clinicians and other patients to visualize and analyzed in context. The ability to project medical images (CT and MRI scans) directly onto a patient's body helps those viewing these images to recover missing anatomical context for more accurate interpretation. This paper proposes such a system. Various types of images can be displayed using volume rendering techniques for realistic visualization of the internal anatomy and 3D models from segmented images. Calibration is performed on multiple systems to obtain an accurate common coordinate system, as well as correcting visual distortions from the cameras and the projector. This projected AR system provides a common perspective that is not tied to an individual point-of-view which can be used by others such as a surgical team. The system is easily extendable to other display technology and has many potential applications including education, surgical planning, laparoscopic surgery, and entertainment.

CCS CONCEPTS

• **Human-centered computing → Displays and imagers**;

KEYWORDS

Projected Augmented Reality, 3D tracking, medical display

ACM Reference Format:
Ian Watts, Pierre Boulanger, and Greg Kawchuk. 2017. ProjectDR: Augmented Reality System for Displaying Medical Images Directly onto a Patient. In *Proceedings of ACM VRST conference, Gothenburg, Sweden, November 2017 (VRST'17),* 2 pages.
https://doi.org/10.1145/3139131.3141198

1 INTRODUCTION

Visualizing and finding the internal structures of the human body is a challenging task. Typically, imaging modalities such as CT and MRI are viewed as 2D slices or as 3D volumes with depth and transparency using volume rendering techniques. Unfortunately viewing these images on a remote 2D screen without the patient as a reference result in a loss of context especially when dealing with surgical procedures. Augmented Reality (AR) offers some solution to this problem by augmenting virtual images with real objects like the human body.

Most AR systems use screens or tablets to augment objects by using images from its camera where targets are located and tracked to augment the video stream with graphic information. The problem with those system is that the information is only visible through the display screen making it difficult to apply to situations where a clinician's hands must be free to manipulate other objects (e.g. surgeons). Some systems use a semi-transparent mirror which allow virtual objects to be displayed over a patient while not obscuring the view behind them. The main issue with this approach is that the intermediate mirror can reduce the capability of the surgeon to use surgical tools. In other systems, Head Mounted Displays (HMD) can be used to insert virtual objects directly into the user's field-of-view. Recently the HoloLens system from Microsoft have been used to augment patient with medical images. These systems require a separate HMD for each person involved as well as the inconvenience of wearing the device which is incompatible with operating room (OR) conditions due to the need for sterilization. In surgical procedures, a different approach to standard AR systems is needed that must be OR compatible and allow the surgeon to perform his/her procedures without interference. One solution to this problem is to develop an AR system that would projected directly graphic information onto a patient skin without the need to be tethered. There are a few AR systems that use projection techniques to display medical information. The closest to our system has been described by Wen et al. which uses a pico-projector and a motion capture system to project patient specific vascular structure on a pig skin during surgery. The method registers the imaging data to the actual organ and accounts for projector distortion. They can also compensate for radiometric changes on the skin and uses real-time update to compensate for slight movements of the skin due to breathing. Using the body as projection screen bridges the gap between seeing and feeling, so that the user can touch the objects they see under the surface. The internal anatomy captured by the medical images can be seen in the location it was captured. With this approach, no hardware is in the way, leaving the hands free for interaction. This projected AR system provides a common perspective that is not tied to an individual point-of-view which can be used by the surgical group. In this paper, we describe ProjectDR, a projection based AR system that displays medical information directly onto a patient skin.

2 HARDWARE SYSTEM

The required computer hardware used for this system includes a 3D tracking system for global positioning, a range sensor to digitize the curved surface, a projector to display the images, and a computer

VRST'17, November 2017, Gothenburg, Sweden

ACM ISBN 978-1-4503-5548-3/17/11. . . $15.00
https://doi.org/10.1145/3139131.3141198

to track, process, and render images. One can see in Figure 1 the ProjectDR hardware configuration. In this system, global patient tracking is performed by an OptiTrack motion capture system from NaturalPoint. This system tracks reflective markers attached to the patient's skin using multiple infrared cameras. The reflective markers are organized into rigid bodies, where the positions of the markers are fixed relative to each other, and must be visible by at least two cameras. Surrounding the working area with cameras allows a full range of motion and orientation to be tracked and eventually to tack surgical tools and hand motions. The projector is positioned so that it shines onto the desired working area. The projector can be stationary, but it is also possible to track the position of the projector with markers or to fix the infrared cameras to the projector, allowing it to move during use. In addition to the global patient tracking system, a Kinect range sensor is used to capture the shape of the skin region where the information is projected. This range information is then used by the rendering algorithm to accommodate the skin surface which is not planar and requires adjustment of the image to prevent distortion. A custom mount was built so that the projector could be suspended over a table and moved by hand to deal with various situations. The ideal projector is a scanning laser system as there no focusing problem on curved surfaces. Unfortunately, most commercial laser scanning projectors suffer from low illumination power (100 lumen) and a lens based projector with a large depth-of-field was used instead.

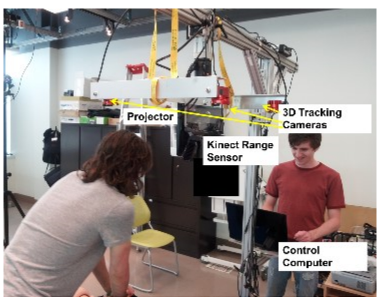

Figure 1: ProjectDR Hardware Configuration.

3 SOFTWARE

The purpose of the ProjectDR software is to render different perspectives of the scene and provide control over it. ProjectDR is written in C++ with an interface in Qt and QML. The positions of the markers on the targets are streamed to ProjectDR using the NaturalPoint Motive software and NatNet SDK. Movement of the markers then correspond to the movement of any associated models in the scene and are displayed by the projector. In addition, image distortion correction is applied to the image using the information provided by the Kinect range sensor. OpenSceneGraph was used to load and render models as it supports many common model types while still allowing direct control. For volume rendering, custom openGL code was written to work with OSG. This allows ProjectDR to display volumes and polygonal models simultaneously. The software provides three main views. The 'scene view' provides a zoomed-out view of all models in the scene and the projector. The 'model view' is for viewing and editing the position and orientation of individual models. For volume rendering, there are additional controls for creating a transfer function and viewing individual slices. The 'projector view' shows what is projected onto the real-world targets based on what a virtual camera sees in the scene from the same position and orientation as the projector. The motion tracking and projector require individual calibration, but all components must use the same coordinate system so that the virtual objects mesh with real world targets accurately. The OptiTrack has a coordinate system which corresponds closely to the real world and can be calibrated very accurately and is used to calibrate the other systems. The OptiTrack uses a fixed size calibration wand that is moved around the area viewed by its cameras so their position can be triangulated. A right triangle with reflective markers is used as a ground plane to set the origin point and direction of each axis. The scene in ProjectDR will use the same coordinates as the OptiTrack, so the origin and offsets of the models are the same as in the OptiTrack. For example, a reflective marker placed 10 cm away from the origin will appear as a dot 10 cm away from the origin in the same direction in the virtual scene.

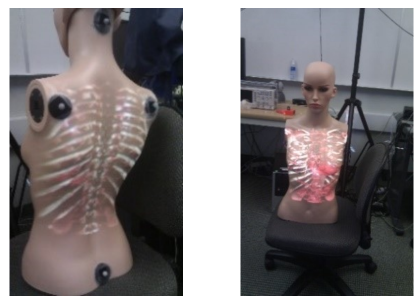

Figure 2: Project CT data on a moving test mannequin: (a) front view, (b) back view.

4 CONCLUSION

To demonstrate this system, we used medical images from the OsiriX DICOM Image Library and a set of 3D models created from a segmented CT scan. The system is composed of a single computer with an Intel I7-4770 and a NVidia GTX 770 GPU running both the tracking and projection. The global motion tracking is using 12 Flex 6 cameras running at 120hz in a wide ring around the targets. An Epson PowerLite 1771w projector was used for its large depth-of-field and high illumination (3000 lumens). The first test was to observe the vertebrae in the back (see Figure 2a and Figure 2b). This system can be used to teach clinicians the anatomy of the spine and the anatomy surrounding it. A clinician intending to palpate the spine relies upon their touch and knowledge of physical landmarks to locate a vertebra which is obscured by the skin. With ProjectDR, the CT image of the patient's actual spine can be displayed on their back. A CT scan of the thorax spine was used with a hand-crafted transfer function to show bones and some internal organs. Another application is for surgical planning. It is very important to know the specific anatomy of a patient while planning a surgical procedure. Presenting pre-operative images on the patient gives the surgeons greater context of the task at hand.