Improving Depth Perception in Medical AR
A Virtual Vision Panel to the Inside of the Patient

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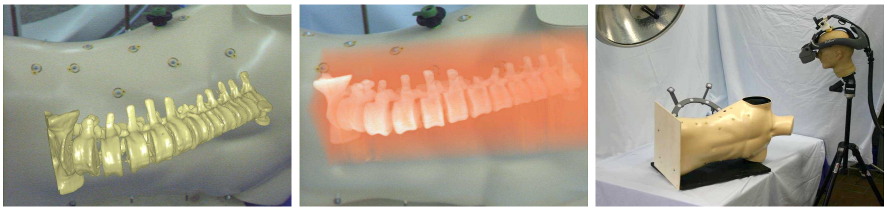
Abstract. We present the in-situ visualization of medical data taken from CT or MRI scans in real-time using a video see-through head mounted display (HMD). One of the challenges to improve acceptance of augmented reality (AR) for medical purpose is to overcome the misleading depth perception. This problem is caused by a restriction of such systems. Virtual entities of the AR scene can only be presented superimposed onto real imagery. Occlusion is the most effective depth cue [1] and let e.g. a correctly positioned visualization of the spinal column appear in front of the real skin. We present a technique to handle this problem and introduce a *Virtual Window* superimposed onto the real skin of the patient to create the feeling of getting a view on the inside of the patient. Due to motion of the observer the frame of the window covers and uncovers fragments of the visualized bones and tissue and enables the depth cues motion parallax and occlusion, which correct the perceptive misinformation. An earlier experiment has shown the perceptive advantage of the window. Therefore seven different visualization modes of the spinal column were evaluated regarding depth perception. This paper introduces the technical realization of the window.

1 Introduction

Real-time in-situ visualization of medical data is getting increasing attention and has been a subject of intensive research and development during the last decade [2], [3], [4]. Watching a stack of radiography is time and space consuming within the firm work flow in an operating room (OR). Physicians have to associate the imagery of anatomical regions with their proper position on the patient. Medical augmented reality allows for the examination of medical imagery like radiography right on the patient. Three dimensional visualizations can be observed by moving with a head mounted display around the AR scene. Several systems [5, 2, 6] that are custom made for medical procedures tend to meet the requirements for accuracy and to integrate their display devices seamlessly into the operational work flow.

Fig. 1. Opaque surface model occludes real thorax. Therefore it is perceived in front of the body although the vertebrae is positioned correctly. Even if the visualization is semi-transparent like the direct volume rendered vertebrae we do not perceive the bones at their proper position. Right figure shows some components of our AR setup including a plastic phantom and the HMD



2 State of the art and new contribution

Depth perception has become a major issue of current research in medical AR. Virtual data is superimposed on real imagery and visual depth perception is disturbed (Fig. 1). The problem has been identified as early as 14 years ago in the first publication about medical augmented reality [7]. This group tasked the problem by rendering a "synthetic hole" ... "around ultrasound images in an attempt to avoid conflicting visual cues." In an earlier paper Tobias Sielhorst et al. described an experiment that evaluated seven different visualization modes for the spinal column regarding depth perception [8]. This paper describes the technical realization of one of the winners of the evaluation. This is a virtual window that can be overlaid onto the skin and provides a bordered view onto the spinal column inside the patient. Due to the virtual window depth perception of the visualized medical data can be corrected.

3 Method

Medical data taken from a CT or MRI scan is presented using a stereoscopic video see-through HMD. The whole tracking system that allows for tracking the observer wearing the HMD, the patient and several surgical instruments is described at [8]. We use direct volume rendering and presegmented surface models to visualize the data.

3.1 Position the window

Placing the window to get the desired view into the patient can be performed without touching or moving the patient. While positioning the window, the observer wearing the HMD views a frame (Fig. 2) and guides it to the area of interest by moving his or her head. When the frame is at the desired position, the window can be set by key press. The size is adjustable by mouse interaction, which can be performed by an assistant on an external monitor that shows a copy of the imagery presented by the displays of the HMD. The window adopts the shape of the skin. Therefore we add an augmentation of the skin presented as a surface model. The frame of the window defines the borders of a structured 2D grid consisting of a certain number of grid points. For every grid point a so-called picking algorithm examines the depth buffer at its corresponding pixel and recalculates three dimensional information of the nearest virtual object, which is in our case the surface model of the skin. After determination of their position in 3D space, the grid points are connected to compose a transparent surface. When the window surface is defined, it is used to mask the part of the scene, which is inside the thorax. Therefore we employ the so-called stencil buffer. The stencil buffer is an additional buffer besides the color buffer and depth buffer found on modern computer graphics hardware and can be used to limit the area of rendering. In our application the area is limited to the window when the visualized tissue or bones are drawn. Finally the window surface itself is rendered.

3.2 Window design & perceptive advantage

The window was equipped with some design features to intensify the depth cues. Certain material parameters let the window appear like glass. Highlight effects due to the virtual light conditions support depth perception. Highlights on the window change the color of objects behind the window or even partially occlude these objects. The window plane is mapped with a simply structured texture, which enhances the depth cue motion parallax. Due to motion of the observer the texture on the window seams to move relatively faster than objects behind the window. The background of the virtual objects seen through the window can be set to transparent or opaque.

Cutting et al. summarized the most important binocular and monocular depth cues [1]. Our AR scene is perceived binocularly with the two color cameras mounted on the HMD. Stereopsis is realized by the slightly different perspectives of the two cameras. Convergence is predefined by the orientation of the cameras. The window enhances perceptive information about depth because it partially occludes the vertebrae. The frame of the window covers and uncovers parts of the spinal column while the observer is moving. The latter depth cue motion parallax is after occlusion and stereopsis the third most effective source of information about depth [1].

4 Results

The virtual window helps to overcome the misleading depth perception caused by the superimposed virtual spinal column onto the real thorax. Regarding depth perception an earlier experiment [8] compared seven different visualization modes of the spinal column including the virtual window. The virtual window was evaluated as one of the best methods. The method of posing the window interactively into the scene has the advantage that the surgeon or personnel of the OR do not have to touch the patient or use a further instrument that has to be kept sterile and wasts space. The observer wearing the HMD can easily position and

Fig. 2. Volume rendered spinal column and setup of the window. Frame can be guided by head movement to the required area

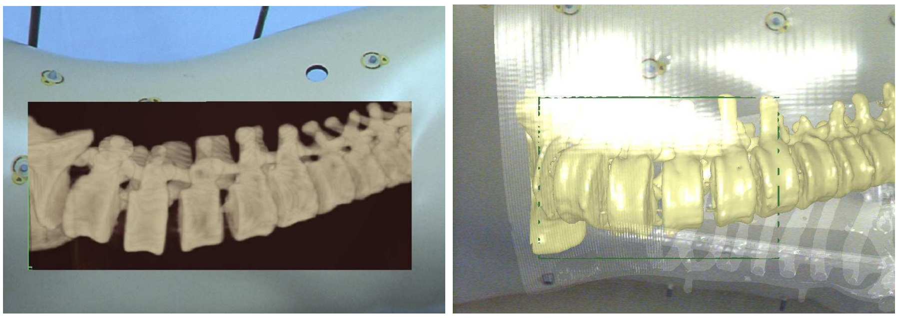
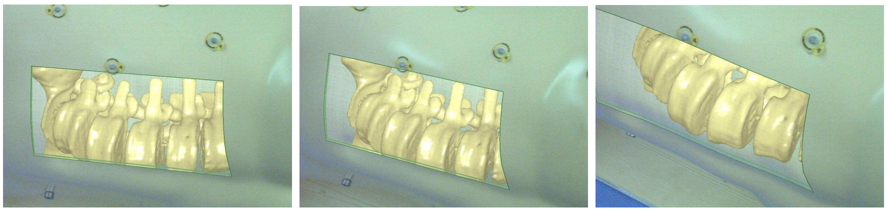


Fig. 3. Sequence shows the window from different perspectives with a surface model of the spinal column



reposition the window by moving his or her head. Figures 3 show a sequence while the observer is moving the HMD respective the thorax with the attached window.

5 Discussion

We presented the virtual window regarding spine surgery to provide a intuitive view on the visualization of the vertebrae. However, the window can be used for further medical application, which will be part of our future work. Future work will also concern the optimization of setting up the window to avoid wasting precious time in the medical work flow, variation and evaluation of different designs, i.e. shape of the window and structure of the texture mapped on the window plane, to achieve the best depth perception and integration of augmented surgical instruments.

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