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In-situ interaction in AR medical imaging

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Abstract. One application of augmented reality (AR) is AR medical imaging. This technique helps physicians in analyzing medical data and preparing surgical procedures. In this paper we present a preliminary report on our efforts to implement a set of in-situ interaction techniques in AR medical imaging, supporting display and interaction with AR data on the patient’s body. We briefly motivate our approach, review the state of the art and explain our ideas about displaying, tracking and interacting with in-situ AR medical data using tangible physical tools. We describe our current work, present our designed tools, scalpel and tweezers, and explain how they are integrated in a motion tracking system.

1 Introduction

Medical imaging is the collection of techniques and processes that create images of the human body, helping physicians in examining, revealing and diagnosing diseases, or preparing for a surgical procedure. Ultrasound, electroencephalography, magnetic resonance imaging and positron emission tomography are some examples of medical imaging techniques [3]. However, analyzing the data produced by these techniques requires considerable training and practice. Diagnosis based on data which is often multidimensional and multi-layered are not generally easy to perform and often happen offline and remotely from the patient. This causes separation in space and time of the medical practitioner’s action space and perception space [6]. The final outcome, arguably, is 10-30\% error rate in analysing different
medical data (mammography, barium enemas, obstetric ultrasound) [2].

Our paper is a preliminary report on in-situ interaction in augmented reality medical imaging. This project is an attempt to present the medical imaging data and to support physical interaction with the overlaid spatial data in a very intuitive and natural way using tangible interfaces (Figure 1). We believe that our approach can help physicians in analyzing medical images and in simulating surgical procedures.

2 Previous work

One of the first augmented reality medical application involved ultrasound medical imaging. In [5], Rosenthal et al. implemented an AR ultrasound visualization aiming at guidance during medical procedures (in this case, needle biopsy). Rosenthal et al. demonstrated that standard ultrasound-guided needle biopsies are less effective than biopsies performed using a 3D AR guidance system [5]. Others have explored medical virtual interaction using motion tracking. For example, some tools have been developed to simulate virtual liver surgery [4]. The interaction is completely virtual: no patient is involved (the interaction is not in-situ). A 3D virtual liver is displayed, and physicians can use tracked tools and a virtual reality interface to simulate a surgical procedure.

A recent effort suggests in-situ interaction [8], using a stereo head mounted display and a pointing tool to interact with the AR medical data. However, the focus of the work is on providing an accurate stereo head mounted device to display medical AR data on the patient's head and not on the physical tools physicians handle.

Our project is an attempt to move in-situ AR medical imaging toward a rich interactive tool, using simple and meaningful tangible user interaction techniques. That would allow the user to manipulate medical imaging data as if it is part the patient's body.

3 Design Goals

The goal of our project is to superimpose medical imaging data on a patient's body part and interact with the data displayed. Physicians would interact with the data using a set of tangible physical tracked tools. These tools would help physicians in viewing particular zones of the image and in simulating simple surgical procedures like biopsies, or aneurysm surgery [1]. When physicians interact with the AR data, the information will be updated on the AR display in real time. Figure 1 shows a conceptual view of our project. Three layers are necessary to achieve this goal: visualization, interaction and tracking. The visualization layer requires that we display and view AR medical data. The data should be overlaid correctly on the patient body part.

For the interaction layer we need to design a set of tangible physical tools that physicians will be able to use to interact with the data in a natural way. These tools will be based on physical tools and interaction metaphors that physicians
are familiar with. The last layer is to track the different physical entities that take part in the interaction. The physical tools, the patient’s body part, and the augmented reality window to the world need to be tracked. Their movements are mapped to the visualization layer in real time.

We believe that our project would help in creating an interactive methodology for accessing medical imaging data on the participant body, allowing physicians and surgeons to access, visualize and actively interact with visual layers of information as if these are physically attached to the patient’s body.

4 Current Implementation

In order to display AR data we use a tablet PC which, unlike an HMD, allows a more natural, although arguably weaker, user immersion. The physician is able to hold the tablet PC as a window to the augmented reality environment while moving naturally around the patient.

One crucial issue of the project is the tracking of the various physical entities that take part in the interaction: the window to the world, the physical tools and the patient. We currently use a Vicon [7] motion capturing system, consisting of six mocap cameras, for this purpose. Vicons offer high speed, high resolution, interference-free, real-time tracking, using both video and digital optical tracking techniques (Figure 2).

To interact with AR data, two tangible physical tools are used: a scalpel that will allow the user to simulate cutting into virtual tissues and tweezers that will allow the user to take virtual tissue samples.

Tracking of the physical tools is performed by attaching Vicon reflective markers to them (Figure 3). The physical tools have to be large enough so that cameras can track it. Indeed, Vicon markers may be occluded by the hand that holds the tool. However, physical tools which are too large feel toy-like and don’t provide the correct interactive experience we seek. The scalpel tool and the tweezers we selected are presented in Figure 3. The scalpel is based on a butter knife, is 23cm long and 2cm wide. The tweezers are based on a tea bag squeezer, are 13cm long and up to 6cm wide. We selected physical tweezers with a large physical opening magnitude to allow the system to track whether the tweezers are opened or closed. We put three markers on the scalpel in order to determine its yaw, pitch and roll. The tweezers needs attachment of four markers: three for their yaw, pitch and roll and one for their joint (and its resulting added degree-of-freedom).
Fig. 3. a) Tweezers and scalpel with their Vicon reflective markers, b) The tools and their 3D virtual representations.

Tracking also allows physicians to change automatically the tool mode, scalpel mode or tweezers mode. When a physical tool is recognized in the interaction space, the virtual tool is automatically activated.

5 Conclusion

The main objective of this work is to overlay AR data on the patient’s body and to interact with it, providing the user with an in-situ interaction environment. We are currently able to track two different tools (a scalpel and tweezers). We are still working on correct mapping of tools’s actions to the virtual AR medical application.

We believe that in-situ AR interaction will be able to enhance physicians’ ability to analyze medical imaging information by providing physicians an intuitive and natural way to examine medical data and helping physicians to perform a diagnosis or simulate a surgical procedure.

References