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MEDICAL AUGMENTED REALITY BASED ON COMMERCIAL IMAGE GUIDED SURGERY

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Abstract- Utilizing augmented reality for applications in medicine has been a topic of intense research for several years. A number of challenging tasks need to be addressed when designing a medical AR system. These include the import and management of medical datasets and preoperatively created planning data, the registration of the patient with respect to a global coordinate system, and accurate tracking of the camera used in the AR setup as well as the respective surgical instruments. Most research systems rely on specialized hardware or algorithms for realizing augmented reality in medicine.It can be expensive or very time-consuming to implement. In this paper, we propose an alternative approach of building a surgical AR system by harnessing existing, com-mercially available equipment for image guided surgery (IGS). We describe the prototype of an augmented reality application, which receives all necessary information from a device for intraoperative navigation. However, a meaningful augmentation of the surgical view with a 3D visualization of planning data which allows reliable comparisons of distances and spatial relations is still an open request

I. INTRODUCTION

Augmented reality (**AR**) is a live direct or indirect view of a physical, real-world environment whose elements are *augmented* (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data. It is related to a more general concept called mediated reality, in which a view of reality is modified (possibly even diminished rather than augmented) by a computer. As a result, the technology functions by enhancing one's current perception of reality. By contrast, virtual reality replaces the real world with a simulated one. Augmentation is conventionally in real-time and in semantic context with environmental elements, such as sports scores on TV during a match. With the help of advanced AR technology (e.g. adding computer vision and object recognition) the information about the surrounding real world of the user becomes interactive and digitally manipulable. Information about the environment and its objects is overlaid on the real world. This information can be virtual or real, e.g. seeing other real sensed or measured information such as electromagnetic radio waves overlaid in exact alignment with where they actually are in space. Augmented reality basically brings out the components of the Digital world into our perceived Real world. Darqi is a company that works on AR products. The best example of AR is their new AR Helmet for construction workers. This helmet displays essential information about the construction sites to help the workers.

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II. EXPERIMENT AND RESULT

A. Components of a Medical AR System

- **Camera/Instrument Tracking:** Any AR application hasto measure in real-time the spatial pose of the camera or the user's head. Marker tracking is a video-based method which approximates this pose by analyzing artificalfiducials in the video stream. Whereas marker tracking is a software-only solution, magnetic and external optical tracking systems consist of additional hardware. However their accuracy and trackable volumes usually surpass the capabilities of marker tracking. In most medical AR systems, it is also necessary to track surgical instruments.

- **Patient Registration:** In order to correctly overlay virtual elements for the display of medical information, the patient needs to be registered with respect to a global co-ordinate system.

- **Creation of Preoperative Planning Data:** Image datain medicine usually originates from 3D scanning devices like CT or MRI and is stored according to the DICOM standard, which can be notoriously complex. For many applications it is useful to additionally provide preoperative planning data. Such information can consist of trajectories and target points for an intervention, or specifically generated 3d models.

B. The VectorVision IGS system

*VectorVision*is the current passive, optical-tracking IGS platform of *BrainLAB* consisting of a PC, a touchscreen display and two infrared cameras. Special marker spheres that are rigidly attached to every object to be tracked reflect infrared light. The position of each marker sphere is calculated via triangulation, which allows the touchscreen to display the 3D model of the surgical tool at the correct location in the 3D dataset. Disregarding the fact that soft tissue can slightly modify shape and position over time, the technically possible accuracy achievable to-day is in the order of magnitude of 1 mm.

To enable the interaction of research systems with an existing IGS product, developers are provided with a specific, well-suited interface: *VectorVision Link (VVL)* is an easy-to-use TCP/IP-based interface integrated into the BrainLAB*VectorVisionCranial* system. The API is based on the Visualization Toolkit (VTK) and can be accessed through various programming languages. Among other information, the 3D medical image sets of the patient and thepositions of the currently tracked tools can be downloaded for processing by an external system. In return, new image sets and 2D bitmaps can be uploaded and used by the surgeon during the intervention.

Figure 1: VectorVision IGS system.

C. The New Augmented Reality System

In this paper, we describe a novel video see-through system for medical AR, which is based on a VectorVision image guided surgery device. We show that all of the tasks described in Section 2 can be performed by this system.

D. Camera Tracking

A standard webcam is used for the acquisition of video images. It is necessary to find a method for tracking the web-cam using the given equipment. The VectorVision system is capable of tracking several surgical instruments using its infrared camera system. Thus one infrared marker instrument clamp is attached to the webcam (see Figure 2). The pose of the instrument clamp measured by the IGS system is received using the VectorVision Link interface.

Figure 2: Webcam with one passive infrared marker instrument clamp attached.

The major difficulty of using tracked instrument data for tracking the webcam is the fact that the pose information delivered by the IGS system does not directly correspond to that of the camera. Only pose information in relation toa hypothetical surgical instrument is available, as shown in Figure 3. Here, **pos** denotes the position of the instrument's tip. The direction of the instrument is given as vector **dir**, with **norm** being a plane normal perpendicular to it. It is then necessary to transform this pose into the camera pose using an additional one-time calibration step, which we have devised.

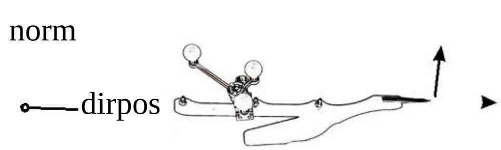

Figure 3: 6-DOF instrument data delivered by image guidedsurgery.

E. One-time Calibration

A common reference coordinate system for the instrument clamp and the webcam is established at a given point of time using conventional marker tracking based on theARToolKit by Kato and others. An ARToolKit marker is placed in the trackable volume of the infrared cameras. The user then defines the positions of the marker corners in the coordinate system of the infrared camera using a standard pre-calibrated pointer tool (see Figure 4). Since the corners are defined in clockwise order, the marker coordinate system is the same one as used in the ARToolKit: Vectors **u** and **v** correspond to the x and y axes. The z axis points upward towards the viewer, creating a right-handed coordinate system. The transformation matrix from the VectorVision to the marker coordinate system, $A_{vvctomarker}$, is shown in Equation 1.

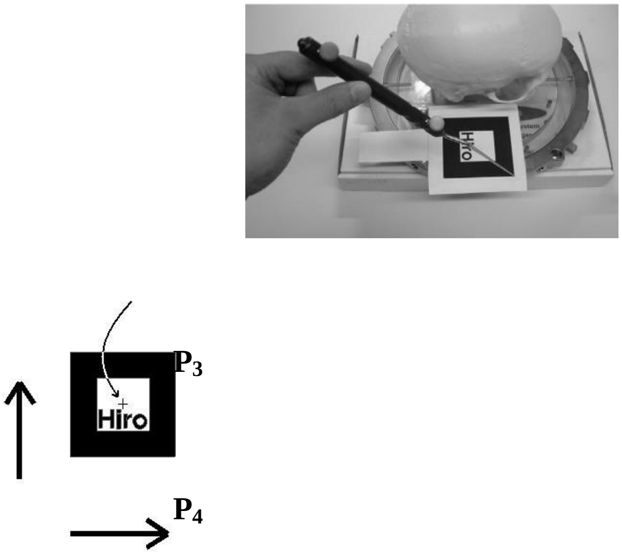

Figure 4: Marker corners are defined in a clockwise orderfrom P_1 to P_4.

$$\mathbf{u} := \frac{P4 - P1}{\left\| P_4 - P_1 \right\|} \qquad \mathbf{v} := \frac{P2 - P1}{\left\| P_2 - P_1 \right\|} \qquad \mathbf{c} := \frac{P1+P2+P3+P4}{4}$$

$$A_{vvctomarker} := \begin{pmatrix} \mathbf{u} & \mathbf{v} & \mathbf{u} \times \mathbf{v} & \mathbf{c} \end{pmatrix}^{-1} \quad (1)$$

The next step is the actual one-time calibration procedure. At one point of time, the webcam has to be positioned so that the optical marker can be recognized by the ARToolKit, while the infrared markers are seen by the VectorVision cameras simultaneously. When the calibration is performed, the current tracked instrument data is recorded. This pose information directly leads to the construction of matrix $A_{vvctoinsm}$ (see Equation 2), which describes a right-handed coordinatesystem with the (imaginary) instrument tip at its origin.

$$A_{vvctoinsm} := \begin{pmatrix} \mathbf{dir} & \mathbf{norm} & \mathbf{dir} \times \mathbf{norm} & \mathbf{pos} \end{pmatrix}^{-1} \quad (2)$$

F. Operation of the IGS-based AR System

After the one-time calibration step, only the data from the VectorVision infrared camera is required for tracking the webcam. For every frame that is generated by the AR system, the current tracked tool data is retrieved using theVectorVision Link. An $A_{vvctoinsm}$ matrix is computed (see Equation 2), and the final transformation matrix used forOpenGL camera setup is the result of the simple multiplication $Avvctocam=Ainsmtocam \cdot Avvctoinsm$. The image guided surgery system also provides support for the remaining tasksof medical AR. Several surgical tools can be tracked simultaneously in addition to the webcam. Methods for patient registration are available, e.g. the matching of anatomical landmarks, artificial fiducials attached to the patient, or 3D surface point clouds from a handheld laser device. It is possible to import DICOM datasets and to define target points or trajectories for interventions.

III. RESULT

We have implemented an application demonstrating the feasibility of IGS-based medical AR. Several images generated by the software are shown in Figure 6. Our tests showed that the system is capable of generating an augmented video stream at average frame rates of more than 10 fps using a webcam resolution of 640x480 pixels. We have measured an average latency of approximately 80 ms for receiving the tracked instrument data from the VectorVision system. Our camera tracking method delivers good accuracy, but sporadic visual mismatches result from the time lag between IGS marker registration and the generation of the augmented video. The range of our tracking method is limited to the viewing volume of the infrared cameras, and it is sensitive to occlusion of the marker clamps from their viewpoint. This makes our augmented reality application ill-suited for the use of head-mounted displays.

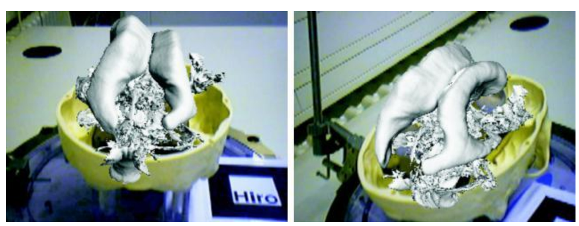

Figure 6: Several views generated by the AR system using a ventricle model generated from a MRI scan.

IV.CONCLUSION

We have presented a novel approach of realizing AR for medical applications. Unlike other research systems, our solution is based on existing medical equipment. The transition of AR into the clinical practice can be facilitated by the fact that IGS systems are ubiquitous, well tested, certified for medical settings, and easy to use. Since the VectorVision image guided surgery devices have been designed specifically for medicine, many practical problems like possible magnetic interference or working in a sterile environment have already been taken care of. An IGS-based augmented reality system benefits from these qualities. Utilizing image guided surgery for medical AR also reduces the costs and shortens the required setup procedures. Assuming that IGS equipment exists for a certain medical application, addition-ally only a standard computer system and webcam are necessary for building a basic AR system.

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