Augmented Reality in the Operating Theatre of the Future

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Abstract. While an increasing number of operation planning systems enable surgeons to preoperatively define and plan complex surgical interventions, providing these planning data intraoperatively in a reasonable way is still a challenging task. We have developed a new system using projector based augmented reality for the intraoperative visualization of preoperatively defined surgical planning data. Projector based augmented reality in medical applications represents a new field of research and yet shows results that are superior to techniques based on head mounted displays. The projector is not only used for visualization, but also for initial registration of the patient whose further movements are continuously tracked and taken into account for projection.

Introduction

Within the Sonderforschungsbereich SFB 414 "Information Technology in Medicine - Computer and Sensor Supported Surgery", the Institute for Process Control and Robotics/Universität Karlsruhe investigates new concepts for computer and robot based cranio-facial surgery in close collaboration with the Department of Oral and Maxillo-facial Surgery/University of Heidelberg. While operation planning systems enable surgeons to preoperatively define and plan complex surgical interventions, the most important step from the planning to the actual surgical intervention consists of providing the planning data intraoperatively in a reasonable way. Great efforts are being made to directly visualize the surgical planning data in the operation area where Head Mounted Displays enjoy great popularity [1] but also show some basic disadvantages.

Projector-Based Augmented Reality

We have developed a new system for the intraoperative visualization of surgical planning data consisting of an off-the-shelf video projector, two CCD-cameras and a state-of-the-art PC. The most important preoperative task consists of calibrating both the video projector and the CCD-cameras within the same coordinate system. Intraoperative registration of the patient normally makes use of artificial screw markers attached to the patient's bone before acquiring the diagnostic image data. In developing the presented system, our goal was to registrate the patient's position without attaching unpleasant screw markers to its bone in a precedent surgery. This is accomplished by projecting a sequence of stripe patterns (coded light) on top of the region of interest with the aid of the integrated video projector. The resulting point cloud can be matched to the preoperatively segmented surface of the diagnostic image data (CT,

Fig. 1. Left: Phantom with projected planning data / Mid: Immediately after moving the phantom: planning data appear in wrong position / Right: After localizing the new marker positions, the projection is updated correctly.

MRI) on which the surgical plan was defined. This task is performed by a new algorithm which imitates the human strategy for the matching process of two corresponding surfaces by shifting one on top of the other where the surfaces remain in contact in at least three points. Afterwards, the fine tuning is realized by using the Iterative Closest Point algorithm described in [2]. The matching process provides an initial transformation from the coordinate system of the diagnostic image data to the initial position of the patient. Further movements are detected by observing artificial markers with the integrated cameras. The calculated transformations allow to continuously transfer the surgical planning data to the patient's coordinate system thus taking into account its actual position.

Results and Discussion

The described method enables the surgeon to visualize planning data on top of any preoperatively segmented and triangulated surface. The system allows to meet occlusion by simply moving around the video projector to an appropriate position since changes of position of the video projector are equivalent to those of the patient. Furthermore, the tracking system allows dynamic adjustment of the data to the patient's current position and therefore eliminates the need for rigid fixation with stereotactic frames or similar devices. While systems using HMDs generally require expensive navigation systems, the cost of the presented system is much lower than that of a corresponding system based on HMDs. Furthermore, it is currently superior to any HMD with regard to accuracy and resolution. The currently achieved accuracy of the projected surgical planning data is about ± 1.5 mm using a resolution of 0.33 mm or less. Current efforts concentrate on improving the accuracy and on increasing the update frequency (currently 1.6 Hz). While the surgeon performs the intervention without any interference of his general practice, all surgically involved persons are able to share the same augmented reality view on the projected data.

References

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