Evaluation of INPRES – Intraoperative Presentation of Surgical Planning and Simulation Results

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Abstract. In this paper we present fundamental results of the first evaluation of INPRES in a laboratory environment. While the system itself – an HMD-based approach for intraoperative augmented reality in head and neck surgery – has been described elsewhere several times, this paper will focus on methods and outcome of recently accomplished test procedures.

1. Introduction

Intraoperative Presentation of surgical planning and simulation results is scarcely available in operation rooms today. One goal of our work is to improve this situation by means of augmented reality. More general, our idea is to reduce risks and to enhance accuracy in challenging steps of computer-aided surgery [1].

The INPRES approach is based on a Sony Glasstron see-through head-mounted display (HMD) for overlay of computer-generated information over the view on a real patient. Display device and patient are being tracked using an NDI Polaris navigation system. It can be supplemented by a self-developed marker-based tracking approach based on a RemoteReality panoramic camera. This optical device and a miniature stereo camera system are mounted on top of the glasses. Further hardware equipment include a pointer device tracked by Polaris, a rigid body for HMD calibration, fiducials for the self-made tracking system and bone markers for registration of the patient with preoperatively acquired radiological images or planning data.

Intraoperative INPRES processing begins with a calibration of the see-through HMD, followed by a marker-based registration of virtual and real objects. Afterwards optical tracking and data overlay are started, including detection of occlusions in the augmentation results by means of the miniature cameras. Earlier publications present the overall system concept and realization details [2,3] as well as evaluation results of single constituents of INPRES like the see-through device [4] and the tracking approaches [5].
2. Methods

The goal of the overall evaluation process of INPRES is to acquire feedback on relevant issues from clinical end users of the system on the one hand and from engineers and computer scientists involved in the development on the other hand. Items to be explored include system accuracy, behavior in respect to time and usability inside the operation room. Further aspects are influences of the system on the intraoperative setup and vice versa, adaptations of surgical procedures caused by INPRES and problems due to contamination of the glasses with blood or other material. For the laboratory tests described here, we focused on accuracy, time performance and usability questions.

The latter issue was examined by means of a questionnaire. The subjects were asked to judge the complexity and quality of INPRES, to comment on unexpected problems occurring during the tests, and to give their personal estimation of accuracy and suggestions for system modifications or enhancements. Time behavior could not be measured analytically during the evaluation procedure and was estimated by the test persons instead. As time lags lead to severe misalignments in augmented reality, it was to be expected that the testers would be able to detect them easily.

For analytical determination of the system accuracy a special test body called X-Wing was built (see figure 1, left side). It is equipped with markers and can be tracked by Polaris, it also contains eight reference points for measuring translational errors and a scale for estimating rotational errors in the augmentation of a test pattern suited to the X-Wing. The test procedure begins with calibration of the HMD and registration of the virtual test pattern to the real X-Wing. Then Polaris tracking and image overlay are started. Divergences in the image overlay can be recorded using the pointer device: The test person has to mark the real-world position of virtual points displayed within the glasses (see figure 1, right side). Aberrations between the marked point corresponding to a virtual one and the actual position of the appropriate point in the real world are determined by means of an Euclidian distance calculation.

![Figure 1. The X-Wing test body (left) and Dr Jakob Brief during the evaluation process](image)

3. Results

The test procedure described above has been executed by six test persons who have been taken from medical and technical project staff but have not been very familiar with INPRES before. Since the first usage of an augmented reality system often leads to
handling errors, each test person was asked to perform the evaluation procedure two times for learning purposes and five times for the acquisition of test results.

Table 1 shows the outcome of the accuracy tests concerning different parts of the INPRES system. Regarding time behavior, the system showed sufficient results but still offered a slight latency of about ten to a hundred milliseconds. The analysis of the questionnaires about usability and integration into the operation room indicated that INPRES could already be used intraoperatively. Nevertheless, we received various useful hints for an optimization of our approach.

<table>
<thead>
<tr>
<th>Feature tested</th>
<th>Average deviation</th>
<th>Max. deviation</th>
<th>Min. deviation</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracking (NDI Polaris)</td>
<td>0.15 mm</td>
<td>0.39 mm</td>
<td>0.07 mm</td>
<td>0.11 mm</td>
</tr>
<tr>
<td>Registration</td>
<td>1.14 mm</td>
<td>2.12 mm</td>
<td>0.34 mm</td>
<td>0.45 mm</td>
</tr>
<tr>
<td>INPRES (overall system)</td>
<td>1.46 mm</td>
<td>4.07 mm</td>
<td>0.42 mm</td>
<td>0.88 mm</td>
</tr>
</tbody>
</table>

The outcome presented here and further details of the evaluation are part of a request submitted to the ethics commission of the University Medical Center in Heidelberg. This application is still pending by now, but will be processed before Christmas 2002. The overall outcome of the evaluation will be presented on MMVR conference.

4. Conclusion

The first evaluation of the INPRES system took place in a laboratory environment in order to acquire data on system accuracy, time behavior and usability. Test results have been promising and encourage us to proceed in the development of our prototype system. We now hope for a positive vote in answer to our request submitted to the ethics commission in Heidelberg. Afterwards, intraoperative tests of the system will be performed in spring 2003.

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References


