

Latency in Medical Augmented Reality Systems

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Abstract

Although Augmented Reality (AR) applications in surgery are of increasing importance, overlay error due to latency seems to restrict the applicability of head mounted AR devices significantly. Realistic head movement statistics in the operating theater is important to discuss the necessities of further development.

We determined head movement velocities during a surgical intervention and implemented automated latency detection.

We found 90% of the surgeons and the assistants rotational head movements smaller than 10 deg/sec. Latency was found to be about 0.1 sec.

1 Introduction

Attempts to integrate augmented reality in medical interventions can be found in literature for several years [3, 2, 5].

Especially head mounted systems suffer from misalignment due to latency, [1, 4]. The latency is caused by fast head movements, and the effect is intensified by the distance from the patient to the surgeon.

In [4] the authors state that preclinical experiments should help to clarify whether it is necessary to reduce the delay in the graphical representation.

Additionally such a study should also include several methods to deal with latency. These can be algorithms to predict the movement, e.g. predictive filtering [1], or, feedback for the surgeon, in a situation of higher head movement and consequently higher displacement.

The velocities, that are to be expected in the operating theater are important for choice and implementation of such methods. Objective tests of such methods require at least semi automatic latency measurement.

We present head movement data, patient to surgeon distance from an intervention in maxillofacial surgery. Furthermore a simple automated latency determination procedure is presented.

2 Materials and Methods

2.1 Head movements

Head movements of the surgeon and the assistance were measured during an intervention in cranio-maxillo-facial surgery. The measurements were done using an Polaris optical tracking system (NDI, Ontario, Ca).

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2.1.1 Head Set

A 6 dof tracker probe (Traxtal, Toronto, Ca) was mounted to a head set, which was worn by the surgeon respectively the assistance.

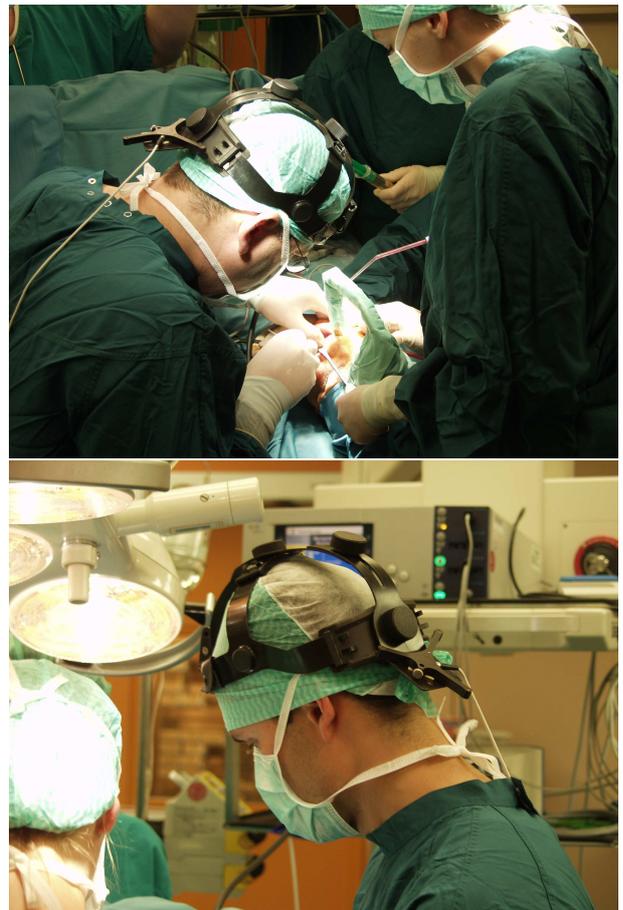


Figure 1: Surgeon and assistance wearing the head set with the tracker probe mounted during the intervention .

2.1.2 Data Processing

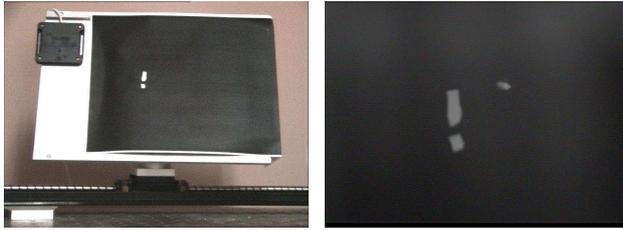
In the situation of an surgical intervention it is not possible to ensure that the optical tracking system has always a free line of sight. Therefore position data and time stamp were saved if and only if visibility was ensured. Consequently the assignment of the data set number and the time stamp were discontinuous. Furthermore the software allowed to distinguish phases during the intervention in which the surgeon communicated with the team especially the operating room nurse from the phases of focusing to the patient.

For the evaluation procedure we first had to determine continuous parts of data among the phases where the sur-

geon focused on the patient. From this data we derived the head motion velocity.

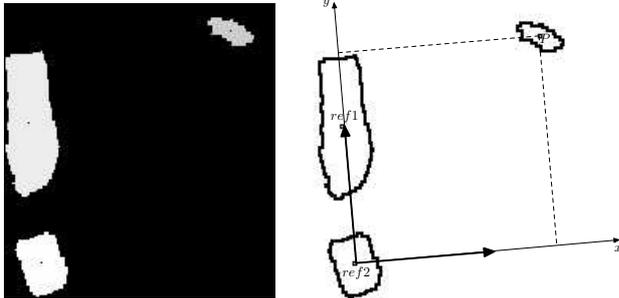
2.2 Latency

Latency measurement was done similar to the procedure described in [4]. A simple pattern consisting of two white regions with different size (and similar to an exclamation mark) were painted on a black sheet of paper used to define a reference coordinate system. This sheet was attached to an aluminum plate which was equipped with a Traxtal tracker probe, and mounted onto a spindle, see Fig. 2(a). The pattern was augmented with a point whose position was fixed in relation to the probe mounted onto the plate. This augmentation was also smaller in size than the two bars, which can be seen in an image taken with the internal camera of the HMD, Fig. 2(b).



(a) Pattern for delay measurement mounted on an aluminum plate.

(b) The third point is an augmentation, that should be fixed relative to the two other points.



(c) Pattern after thresholding, erosion, and segmentation. Centers of gravity are marked.

(d) Coordinate system built with *ref1* and *ref2*.

Figure 2: The pattern for delay measurement and the picture taken with the internal camera of the HMD.

We used the motorized spindle to move the grid with several velocities perpendicular to the optical axis of the HMD. Differences in the position of the augmentation in the reference coordinate system could be transformed in temporal delay.

The images were thresholded, eroded (twice with neighborhood 8), and segmented, Fig 2(c). Centers of mass for the three largest segments were calculated, these points were identified to be the two reference points and the augmentation, coordinates of the augmentation in relation to the reference points were derived Fig 2(d).

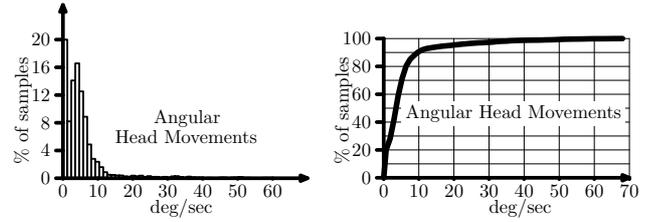
Radial difference between the average positions of the moved and the still images were used to determine the time delay.

3 Results

3.1 Head Movements

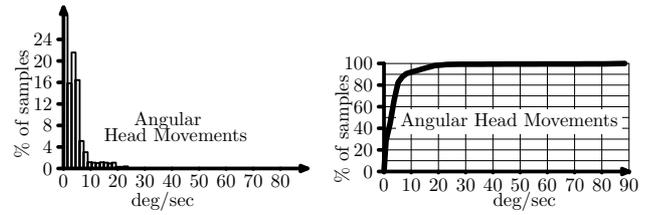
We acquired 22 data sets of the surgeon and of the assistance (11 each). More than 47000 positions were measured, assuming a frequency of 60 Hz, we had about 13 minutes of data.

The distance from the head of the surgeon to the field of intervention was about 30 cm.



(a) Histogram of head movements of the surgeon

(b) Distribution of head movements of the surgeon



(c) Histogram of head movements of the assistance

(d) Distribution of head movements of the assistance

Figure 3: The histogram and distribution of angular head movements of the assistance.

Figures 3 show the modest velocities, 80 % of the movements of the surgeon were slower than 6.4 deg/sec, 80 % of the assistants movements were slower than 5 deg/sec. 90 % of the values were smaller than 10 deg/sec, both for the assistant and the surgeon.

3.2 Delay

85 images were used to determine temporal delay. Among these 6 images were still images, the others were taken at 8 different velocities. Our Results, Tab 1, confirm the numbers in [4].

4 Discussion and Conclusions

We found that the head movements of the surgeon are almost always slower than 10°per second. A latency of 0.1 sec and an object distance of 30 cm results in a misalignment of $10 \times \frac{2\pi}{360} \times 300 \times 0.1 = 5.24\text{mm}$ in 90 % of usage. 80 % of the data deviate less than $6.4 \times \frac{2\pi}{360} \times 300 \times 0.1 = 3.35\text{mm}$.

Velocity [mm/s]	Spatial Shift [mm]	Temporal delay [s]
10.28	1.2437	0.12
12.98	1.5018	0.12
15.24	1.4106	0.09
17.92	1.7507	0.1
20.2	1.7742	0.09
22.88	2.0205	0.09
25.12	2.0277	0.08
27.85	2.6231	0.09

Table 1: Velocities, spatial, and temporal delay.

In an follow up we want to make a film during an intervention while the surgeon is wearing the HMD, using the internal camera of the HMD. This should provide information, whether the surgeon focuses on the operating field or not. This also will allow determination of alignment error and latency in real life.

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