Microscope Tracking in an Open MRI for MR Guided Neurosurgery

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Abstract

MR imaging during brain surgery has the advantage of providing real-time images of the treated tissue without having to correct for shifts in brain or other tissue, during surgery. The main control-tool during the surgical procedure is still the microscope. This study will introduce a method for merging the "MR view" with the "microscopic view" by tracking the microscope to guide interactive real-time acquisitions. Following calibration of the tracking device a reproducibility study yielded an accuracy of ± 3mm.

Introduction

MR-guided neurosurgical interventions are becoming more frequent and popular due to the development of a variety of open MRI systems [1-3]. The increasing number of procedures has been paralleled by the integration of techniques available in modern, conventional operation rooms (OR) into the MRI-OR. One such technique is spatial tracking of a microscope, which is used to locate the focal spot of the microscope with respect to images previously acquired for surgical planning. While surgery in the conventional OR has to rely on data acquired prior to surgery, which cannot take into account tissue changes, such as a shift of the brain, real time MR tracking of the position of the microscope will provide actual, real-time images during the intervention.

This study describes the installation and calibration of a tracking instrument on an MR compatible microscope. The results of calibration to establish the precision of the microscope tracking in an open MRI system will also be discussed.

Methods

All experiments were performed in the open 0.5T MRI scanner (GE Signa SP; *General Electric Medial Systems, Milwaukee, WI*), shown in Fig.1.A and a free floating, MR compatible microscope system, SMED 3-MR, with Möller-Wedel-Optics (*Studer Medical Engineering AG, Switzerland*) which had a focal length of 300mm (Fig.1.B).

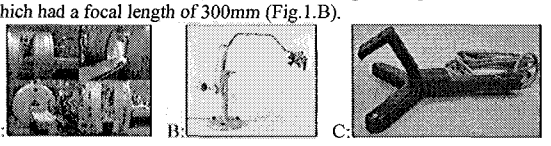

Fig.1: GE Signa SP open MRI scanner (A) and MR compatible microscope SMED 3-MR by Studer Medical Engineering (B) equipped with new connection piece (C).

A connection piece (Fig.1.C) was developed which allowed the 3-LED handpiece of a tracking system (*Image Guided Technologies, Flashpoint 500*) to be coupled to the optics of the SMED microscope (Fig.2.A). The connection piece is designed such that the normal vector *N* of the handpiece-plane is tilted by 30deg with respect to the optical axis of the microscope *M* (Fig.2.B). Furthermore, *N*, *M*, mid point of the handpiece and focal spot of the microscope are in the same plane (Fig.2-C).

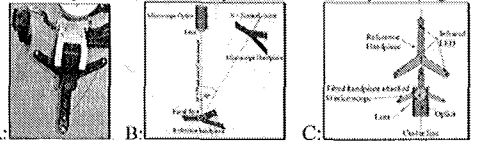

Fig.2: Handpiece connected to SMED optics (A) with defined relations to the focal spot of the microscope (B, C).

The calibration of the microscope requires knowledge of the spatial coordinates of every handpiece-LED with reference to the focal spot of the microscope. These data were acquired using a calibrated handpiece which was adjusted so that the focal spot of the microscope was exactly equivalent to the geometrical center of the reference handpiece (Fig.2.B, C). A similar handpiece was connected to the microscope, thus two sets of data allowed the normal and transverse normal vectors of each handpiece, as well as the spatial coordinates of each LED in reference to the center of the magnet, to be defined. For all data sets, this information was provided by the *Flashpoint* computer.

Spatial coordinates of each LED of the microscope-handpiece, with respect to the focal spot, were determined by a subtraction of the reference coordinates from the microscope handpiece coordinates. These spatial coordinates could then be used to obtain the absolute spatial location of the focal spot of the microscope with respect to the magnet coordinates.

Fine-tuning of the LED coordinates was performed by comparing the *Flashpoint* coordinates with MRI coordinates on phantom images (Fig. 3.A). MRI coordinates were determined using pre-acquired, re-sliced 3D data. Processing was performed on a LOCALITE PC (*Localite, St.Augustin, Germany* [4]). The distance between the actual focal spot and the tracked position was measured and the calibration files were corrected for the determined error. During all calibration measurements the highest zoom-factor (32-times) of the microscope was used, yielding a negligible depth of focus.

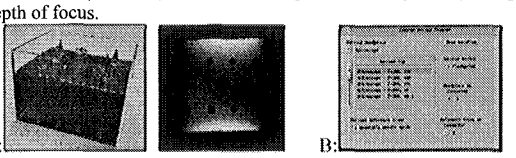

Fig.3: A: Calibration Phantom with one of the MRI images. B: Choice of different zoom factors for microscope tracking.

The calibration was completed by checking the focal spot for all other available zoom factors (3.5-, 6-, 11- and 20-times, Fig.3.B). Finally, a single point in a phantom was focussed with the microscope five times, with the microscope been repositioned between measurements in order to verify the reliability and reproducibility of the tracking method.

Results & Discussion

Even though calibration was both cumbersome and time consuming, the results were very reliable. During calibration of the different zoom factors it was observed, that the focal length of the microscope changed by up to ΔF=37 ± 3.5mm, when changing from 32-times to 3.5-times zoom (Tab.1). As expected, reproducibility decreased with smaller magnifications due to the increasing depth of focus, however, the results are still very close to the variability of *Flashpoint* coordinates (about ± 1.5mm) known from previous measurements.

Zoom Factor	32	20	11	6	3,5
ΔF [mm]	Ref. ± 1.5	2 ± 1.5	4.7 ± 3	18 ± 3.5	37 ± 3.5

Tab.1: Variation of focal length and reproducibility of tracking results with decreasing magnification.

Conclusion

We think that microscope tracking could be a helpful tool in distinguishing pathological from healthy tissue, identifying microscopic anatomical features on MR images or vice versa. In addition, 'driving' the real-time acquisition with the microscope may also prove to be useful. Figure 4 shows how a microscope image, a real-time acquisition with active microscope and re-sliced MR data could look when placed beside each other. A clinical trial needs to be performed to assess the usefulness of this technique.

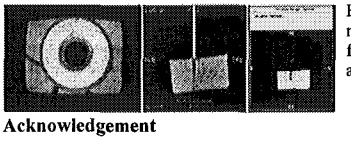

Fig.4: Parallel display of microscope view re-sliced image from 3D data and real-time acquired image.

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