**Automatic registration of an optical navigation system with an MR system using active markers with high accuracy**

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## Introduction:

In MR guided neurosurgery, the actual position of the lesion and the surgical device is monitored to prevent the injury of sensitive structures. So far, interventional procedures are either done freehand, using stereotactic frames or employing optical navigation in frameless stereotaxy [1]. The latter method offers detailed image information during the intervention, but needs an additional registration step of the MR and navigation data. For this purpose, either external markers (MR visible liquids), or internal landmarks (bony structures) are used. The disadvantage of this approach is that user interaction is necessary with a pointer of the optical navigation system to locate the markers or landmarks (Fig. 1). During surgery, such a user interaction is prone to errors, and markers or landmarks are often not accessible under surgical wraps. In this work, we propose a combination of markers that can be localized by the MR-system as well as the optical navigation system. Such a combination allows registration of the MR-image data with the navigation system without any user-interaction. An MR-marker consists of an active micro-coil that can be localized actively with an MR-pulse sequence. We have improved this sequence to minimize dislocation effects from spurious signals and provide localization with high accuracy.

## Materials and Methods:

An optical navigation system (Localite) was installed in the RF-cabin close the 1.5 T MR scanner (Intera, Philips Medical Systems) (Fig. 1). The use of two independent in-room displays and controls allows for in-room interaction of the MR scanner and the navigation system. For automatic registration active MR-markers and markers of the optical navigation system were placed in a defined geometric configuration (Fig. 2). The active MR markers consist of water filled (cylinder with 2.5 mm diameter/length) micro-coils, which are connected to separate receive channels. The automatic determination of the marker position involved a pulse sequence and subsequent data processing. The pulse sequence employed a non-selective RF pulses and readout field gradients along the three axes to encode the position of the micro-coils [2]. An add-subtract scheme is used to avoid errors due to off-resonance effects [3]. In order to reduce dislocation effects caused by the large patient/phantom volume, an additional spoiler gradient was applied. The gradient area was determined to provide a 90 deg. phase shift over 2.5 mm volume resulting in the cancelling of signal in a large volume. The localization data was Fourier transformed and peaks were located with quadratic fitting for sub-pixel accuracy. The set-up allows to connect a multi-element receive coil for imaging and up to six independent active markers for automatic registration. The reproducibility of the determination of the position of MR-markers was tested on phantoms. The automatic registration of the MR-image data with the navigation system was tested on phantoms and healthy volunteers and compared with results using user interaction. The automatic registration procedure consisted of three steps: 1. The positions of the active MR-markers were determined during image acquisition and were transferred (together with the image) to the optical navigation system. 2. The patient was moved out of the MR-scanner into the line-of-sight of the optical navigation system to localize the optical markers. 3. Automatic registration was performed on the navigation system by taking the fixed geometric configuration into account.

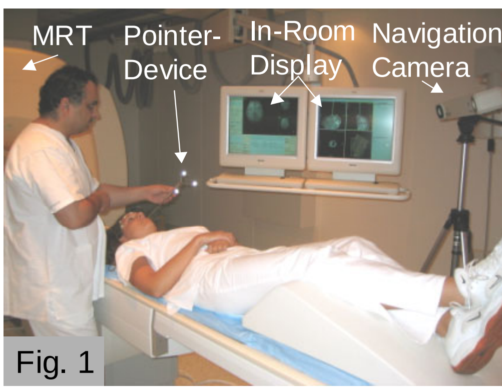


Fig. 1


Fig. 2

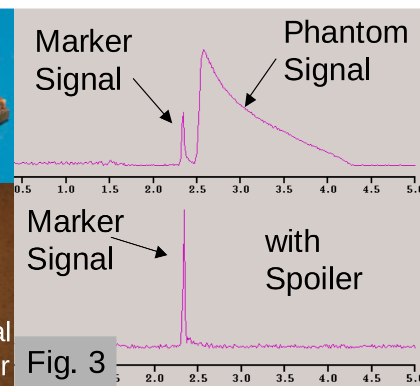


Fig. 3

## Results and Discussion:

Figure 3 shows the influence of the additional spoiler gradient. In this experiment, an active MR-marker was placed directly on a phantom, resulting in an additional signal from the phantom. The additional spoiler gradient efficiently reduced the amplitude of the distortion signal received by the micro-coils (Fig. 3b). Since the signal from large patient volume is significantly reduced, this method allows the use of markers with a small water volume and thus allows the determination of the position with high accuracy. The overall accuracy depends on several factors, like the accuracy of the position determination of the active MR markers as well as the accuracy of the optical navigation system. IN addition a proper placement of the both markers are essential. The standard deviation in determination of marker positions was found to be less than 0.5 mm. The overall accuracy of the registration was found to be in the sub-millimeter range, which is similar to results performed with standard registration with user-interaction.

## Conclusion:

The combination of optical markers with active MR-markers allows an automatic registration without any user-action and thus reduces potential user-errors in a clinical working situation. An automatic registration is of high importance for the clinical workflow in neurosurgery and allows repetitive registrations if changes in the set-up occur. The usage of markers with small water volume in combination with an additional spoiler gradient provides the determination of the positions with high accuracy. The overall accuracy of the automatic registration was in the sub-millimeter range, as required in neurosurgical applications.

## Acknowledgment:

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