Real Time Imaging with Automatic Slice Positioning Controlled by an Interventional Assistance System

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Introduction

In interventional MRI instruments need to be tracked and visualized in nearly real time to monitor the access to the target organ and to avoid complications in the vicinity of risk organs. Therefore, typically real-time MRI pulse sequences are used (e.g. trueFISP or FLASH), and device position and orientation is measured automatically using small marker systems at the devices. When percutaneous interventions are performed in closed-bore MRI systems, access to the target organ is particularly difficult due to the limited space in the magnet. For this application a commercial robotic assistance system has been developed, which can hold and orient a device (e.g. a needle) using a robotic arm with small passive localizers at the instrument holder. In this work we describe a real-time pulse sequence where slice position and orientation are controlled directly by the robotic assistance system. Through a network interface the robot continuously transfers measured device coordinates to the MRI host computer where slice position and orientation are updated. Compared to slice tracking with MR marker coils [1] this direct control system is simpler to realize and does not require any additional rf hardware.

Materials and Methods

The real-time coordinate control system was implemented on a clinical 1.5 T whole body MR scanner (Siemens Symphony, Erlangen, Germany) and a fully MR compatible robotic assistance system (Innomotion, Innomedic, Herxheim, Germany). The assistance system consists of a pneumatically driven robotic arm, which is mounted on an arc to fit into the 60 cm bore of a solenoid MR system. Position and orientation of the arm, which has an instrument holder at its distal end, are continuously measured by the robot hardware using optical sensors for five of the six degrees of freedom.

A dedicated TCP/IP network interface was developed through which the hardware control computer of the robot system transferred the current device coordinates to the MRI host after each controlled motion. On the MRI console the coordinates were received using a separate control process, which was initiated by the start of the real time pulse sequence. Upon reception of the new robot coordinates the MR slice position display as well as the current imaging protocol were updated, such that the acquisition of the next MR image was performed with the new position information. Initially, coordinate systems of robot and MR were co-registered using the integrated laser positioning. Real-time images of the robot head were displayed using the conventional inline display of the MR system and an MR compatible in-room monitor.

For real-time imaging a FLASH pulse sequence with the following parameters was used: $\alpha = 20°$, TR = 4.3 ms, TE = 2.07 ms, FOV = 375×400 mm², matrix: 192×256, 4/8 half Fourier, TA/image: 657 ms. In a phantom setup the precision of the motion was measured by comparing the transferred coordinates with the measured positions of the passive markers at the robot head. Additionally, the position update was visually assessed using a transverse slice orientation where the marker system at the robot head is fully visible only when the position of imaging slice and robot head coincide.

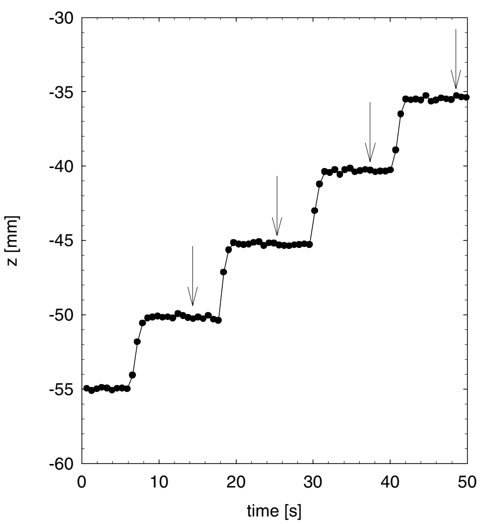

Fig. 1: Position of the robot head as a function of time. Arrows mark the time when updated robot coordinates were transferred to the MRI software after a 5 mm shift in z-direction.

Results and Discussion

The result of a phantom measurement is shown in Fig. 1. The robot head was shifted along the z-axis in steps of 5 mm and the robot motion was finished after about 2 s. Five seconds later the coordinates were transferred to the MR console (arrow), where a slice position update was performed (one image acquisition time). After gradient nonlinearity correction the slice position could be reproduced with a precision of Δz = -0.11±0.22 mm. The position update could also be confirmed visually as the markers became visible in the MR images (Fig. 2).

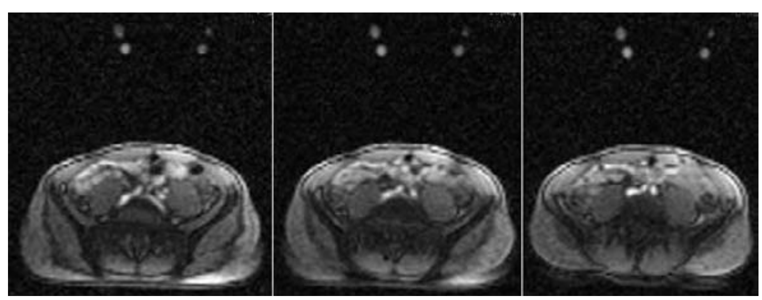

Fig 2: Volunteer experiment showing the motion of the robot head. After the new coordinates were transferred to the MRI system the slice position was updated and the passive markers became visible.

In this prototype setup a robot-initiated automatic slice positioning was integrated in a real-time pulse sequence using a separate control process. This process interacts with the slice positioning of the MR scanner and can thus be combined with any pulse sequence. The 8 s latency between start of robot motion and slice position update will be significantly shortened in future versions. The proposed automatic slice positioning can help to shorten procedure times as well as increase procedure safety, since visual control over the device trajectory is maintained throughout the intervention.

References: [1] Bock M, et al. *ISMRM 2005*, p. 2662