Two degree-of-freedom (DOF) MRI-compatible motion generation system for MRI motion compensated algorithms evaluation

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INTRODUCTION: Physiological motions (i.e. respiration or heart activity) can corrupt MR image quality by generating artifacts. To overcome or decrease artifact generation in MR images, synchronization or image processing techniques taking into account these motions must be employed. To validate either new external non-invasive sensors for motion monitoring or motion compensated methods in MRI environment before their use in clinical conditions, a reproducible motion generation system has to be developed. Lack of commercially available solutions constrains research groups to develop their own MRI compatible mobile platforms. Most of them we find in literature are application-specific oriented and are characterized by a small range of motion types often limited to basic motions [1]. We need a flexible, easily programmable and multi-direction motion generation platform. Within this framework, we present a dynamic fully MRI-compatible motion generation platform which was developed to evaluate the influence of its generated motion on MR image quality of phantoms (maximum weight 10 kg) and to assess image processing algorithms used for motion artifacts removal. As an initial experiment, a 2D motion generated with the developed mobile platform was used to assess a motion compensated image processing tool [3].

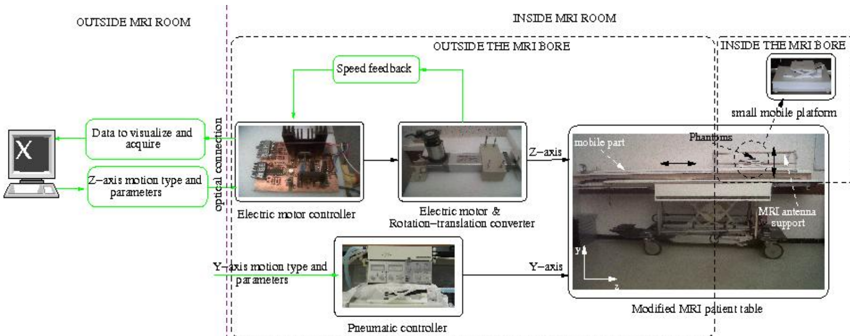

Figure 1: Schematic of the MRI-compatible mobile platform

MATERIALS AND METHODS: The platform schematic is shown in Figure 1. It is composed of two parts: the electric and pneumatic part allowing one-axis motion each. All controllers (electric and pneumatic) of the mobile platform are always located outside the MRI bore (magnetic field < 40 mT). The main part of the electric motor controller is a micro-processing unit (*Microchip dsPiC33F*) whose memory contains all types of motion and parameters needed to drive the electric motor. The electric part is connected via an optical fiber serial connection to a PC, which through a GUI interface defines the types of motion to generate and their corresponding parameters and allows visualizing and recording in real-time the chosen motion signal. On the other hand, the pneumatic controller acting on the pneumatic circuit of an anesthesia balloon is manually adjustable from MRI room and allows different types of motions characterized by different magnitudes, frequencies and signal duration (inhaling/exalting ratio). The mobile platform was used to generate a two-axis independent motion in sagittal plane (in Z and Y axis). Three phantoms of small size were placed on the top of the mobile part of the platform whereas one big size phantom was positioned on its static part as a motion reference object. Generated motion signals were captured with 2 types of motion sensors: pneumatic belt for measuring motion in Z-axis and accelerometer-based sensors for Z-, Y-axis and Z-Y plane measurements [3]. All signals were acquired and recorded with a home-made data acquisition system SAEC [5]. Moreover, simultaneously to the motion signals we acquired MR images of phantoms in order to evaluate the influence of generated motion on image artifacts production and their removal using motion compensated algorithms. It has been shown that only with the knowledge of motion, the process of artifact production can be canceled out thus allowing a good quality reconstruction of a motion compensated image [2]. The reconstruction algorithm, called GRICS (*Generalized Reconstruction by Inversion of Coupled Systems* [4]) initially developed for free breathing acquisitions and using a motion information provided by external sensors such as respiratory belts was used for artifact removal and 2D motion compensation evaluation. All image acquisitions were performed on a 3T MR scanner (*Signa HDxt, GE Healthcare, Milwaukee, WI*). A sagittal slice comprising all phantoms (mobile and static) was acquired with SSFP (*GE FIESTA*) sequences.

RESULTS: A snapshot of the motion signals generated with the developed mobile platform in 2D and captured with above mentioned sensors are presented in Figure 2 (top curve, signals Acc and Belt). The generated 2D motion is composed of two waves: modified sine wave with a rest at zero at the end of each period (Z-axis) and of a respiratory signal having unequal inhaling and exalting phases (Y-axis). Two bottommost signals from Figure 2 are estimated motion signals with GRICS reconstruction method using respectively Z- (from pneumatic belt) and Y-axis (from accelerometer) motions as respiratory and cardiac triggers [6]. It can be seen that these estimated motion signals correlate well in time with the reference signals. For Y-axis motion estimation (Fig 2, the middle curve), the Z-axis component of the estimated signal is very small and practically negligible. The same for the Z-axis motion estimation (Fig 2, the bottommost curve) where Y-axis component of the estimated signal is very small and not worth considering.

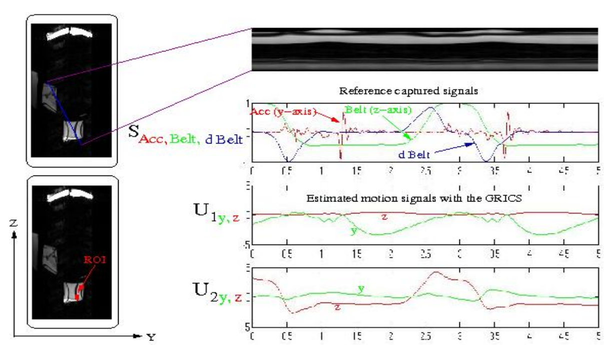

Figure 2: Motion contribution splitting and comparison with reference generated motion signals

CONCLUSION: We developed a fully MRI-compatible dynamic high-precision and flexible mobile platform which is capable of generating a variety of reproducible motions used to test and validate a wide range of MR motion sensors and to evaluate motion compensated image processing algorithms. The proposed platform generates 2D motions in the displacement / velocity ranges of 0–160 mm and 0–90 mm/s. As a future work, more degrees of freedom will be added as well a precise characterization of all generated motions.

REFERENCES: [1] Muro *et al*., NHGGZ. 61,pp. 1551-8 (2005); [2] Batchelor *et al.*, MRM. 54: 1273-1280 (2005) ; [3] Rousselet *et al*., ISMRM (2010) ; [4] Odille *et al.*, MRM. 60: 146-157 (2008) ; [5] Odille *et al.*, IEEE TBME, 54: 630-640(2007); [6] Vuissoz et al., ISMRM (2010):815.