Motion Detection and Correction Using Non-marker-attached Optical System during MRI Scanning

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Introduction: Patient motion is a major challenge for MRI scanning. Thus, techniques have been proposed for motion detection and correction, which basically can be divided into two kinds: navigator based and external device based. Navigator based methods [1] usually need extra time with sequence dependence. Breath belts, the most popular external device based motion detection techniques, suffer from drifting and cannot provide accurate absolute motion measurement [2]. Recently, optical marker-tracking techniques [3] has been proved to be capable of measuring the exact motion of rigid imaging targets, usually head, to improve the image quality. However, markers are needed to be attached on subjects, which are easy to fall off and discomfort patients [3, 4]. More importantly, such marker-attached methods can hardly deal with non-rigid motion. In this study, a non-attached motion tracking system based on structured light 3D measurement technique [5] with accurate distance measurement is proposed for motion correction with the merits of high accuracy, sequence independence and no patient interaction.

Methods: Principle: The theory of optical motion detection method was based on triangle measurement, as shown in **Fig. 1**. The height of the subject (h) could be calculated based on the laser position (d) in the image plane of the camera (**Fig.** 1), using a simple triangle calculation, $h = \frac{dkH}{D+dk}$ (k was the length ratio of real object and image, H was the distance between the camera and the reference plane, and D was the distance between the camera and the laser projector). Hardware: The optical motion tracking system was set up inside the bore of 3T whole body MR scanner (Philips Achieva R3.2.1, Best, the Netherlands). A laser (GM-CR02, Apinex, Canada) projected a green cross line on the subject, which was captured by a MR-compatible camera (MRC, Germany). Calibration of optical system: In order to get the relationship between h and d, calibration was performed by recording the laser position (d) of subjects of known heights (h), which were fitted utilizing nonlinear least square curve fitting (Matlab, R2010b, USA). Image acquisition: A phantom and a volunteer were scanned for 2D MRI, using 8-channel neck coil and knee coil, respectively. Motion were introduced manually during the phantom scan. And the knee of the volunteer was also scanned with intentional motion. The imaging parameters were: Fast Field Echo (FFE), TR/TE = 500 / 5.2 ms, flip angle = 20°, FOV = 200×200 mm^2, resolution = 1.0 mm, slice thickness = 5 mm. Data collection: Video data were collected at a rate of 30 fps and processed using LabView (Version 2013, US). The shift of laser in the video, and consequently the distance shifted, was calculated and recorded. Meanwhile, the time of each scanned k-space position was recorded in scan log files. By comparing the two files with synchronized time stamps, corrupted k-space data can be located. Image Reconstruction: Corrupted k-space lines were deleted and then resynthesized based on SPIRiT algorithm [6].

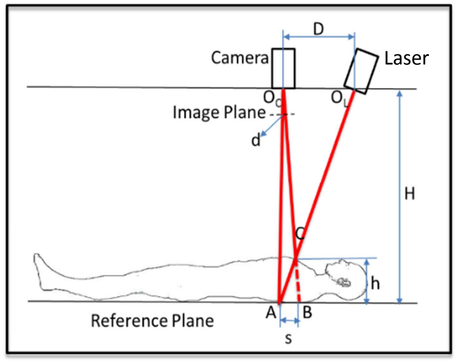

Fig. 1. Optical motion tracking system. Camera can capture the projected laser shift caused by the height (h) changing of patient

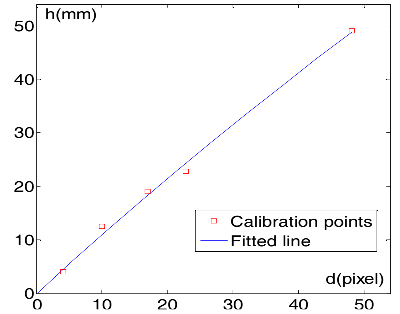

Fig. 2. Relationship between height of subject (h) and pixel shift (d), obtained by calibration using subjects with known heights (h). Line was fitted using nonlinear least square curve

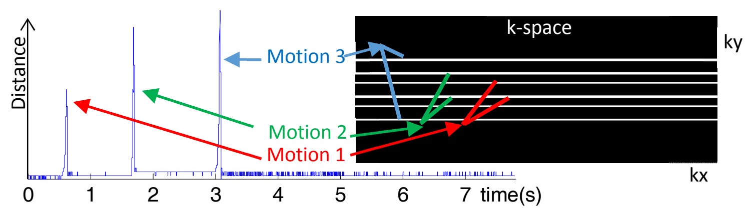

Fig. 4. Pixel shifting of laser across time during phantom scanning. Three motions were detected (left). The corresponding corrupted k-space lines were localized (white lines, right), deleted and resynthesized using SPIRiT algorithm.

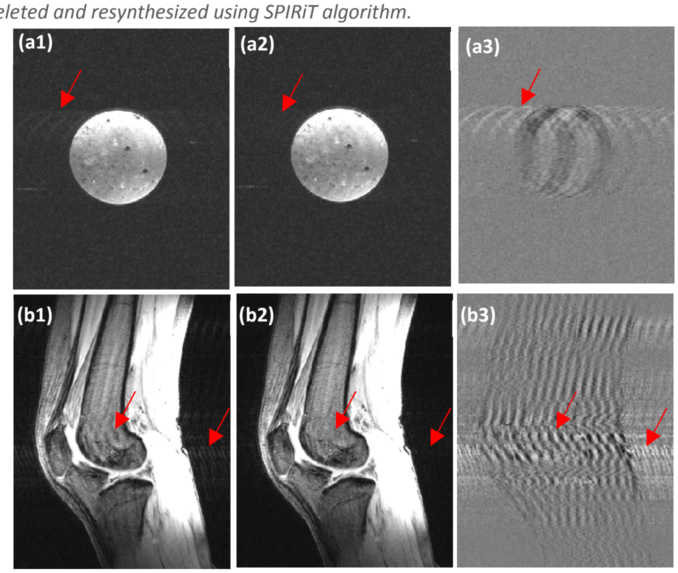

Fig. 3. Phantom (a) and knee (b) original images with motion (1), reconstructed image removing motion (2) and difference image (original – reconstructed)× 5 (3). Red arrows show motion artifacts removed after

Results: After calibration, a nonlinear fitted curve was obtained between pixel (d) and height (h), with which unknown h could be further calculated accurately for each pixel position d (**Fig. 2**). The image processing time of the optical system was less than 50ms for each frame. For the phantom scanning, manually introduced motion can be readily detected by tracking the shifting of laser and matched to corresponding corrupted k-space lines (**Fig.** ***3***). As shown in **Fig. 4** a, the motion artifact outside phantom in the phase encoding direction was successfully removed after removing and replace the corrupted k-space lines. The motion during knee scanning showed artifact both inside the bone area and outside the knee, which were removed effectively after motion correction (red arrows in **Fig. 4** b).

Discussion: We have demonstrated that the proposed non-marker-attached optical motion detection system is capable of detecting motion and removing motion artifacts by retrospective reconstruction. Since the absolute height can be measured without any marker, the proposed method can handle the imaging target tends to be corrupted by non-rigid motion, such as carotid and abdomen motion.

Reference: [1] Pipe J.G., 1999, MRM, 42(5): 963-9. [2] Taylor AM, et al., 1999, JMRI, 9(3): 395-401. [3] Maclaren J, et al., 2013, MRM, 69(3):621-36. [4] Chan CF, et al., 2009, JMRI, 29(1): 211-216. [5] Chen H, et al., 2010, J Biomed Opt, 15(2): 026013. [6] Lustig M, et al., 2010, MRM, 64(2):457-71