Artifact Removal in Carotid Imaging based on Motion Measurement using Structured Light

Huijun Chen[1], Jin Liu[2], Zechen Zhou[3], Chun Yuan[2], Peter Boernert[4], and Jinnan Wang[5]

[1]Tsinghua University, Beijing, Beijing, China, [2]University of Washington, Seattle, WA, United States, [3]Tsinghua University, Beijing, China, [4]Philips Research Europe, Hamburg, Germany, [5]Philips Reserach North America, Seattle, WA, United States

Purpose:

Motion induced artifact is a common cause of unsatisfactory image quality in carotid artery imaging: previous study found that motion was the most significant contributor to low image quality (1). Monitoring and quantifying motion in the neck area is more challenging than in other body parts due to the complex non-rigid motion pattern. Although a number of attempts have been made to measure neck motions using internal navigators, our experience shows that it becomes very challenging to measure the body displacement based on navigator signal when the rigid-body assumption does not hold. In order to monitor and quantify motions in the neck area, external device becomes an intriguing alternative. Structured light based (2) motion detection system has been recently developed for MR (3). It was selected for motion tracking in carotid imaging because of its capability in accurately measuring distance changes.

Methods:

<u>Structured light motion detection system and calibration</u> The structured light motion detection system is shown in Fig.1a. A laser line is projected onto the subject's body to assist motion detection. As a result, the anterior-posterior translation (Δh) can be recorded as motion of the laser line (Δd) on the captured images. With the knowledge of H, D and zoom ratio k, Δh can be quantified as: $\Delta h = \Delta dkHD/(D + dk)^2$.

To ensure accurate measurement, the system was firstly calibrated by imaging a set of objects with different thickness. The actual thickness of such objects were measured using a caliber and served as the ground truth for calibration.

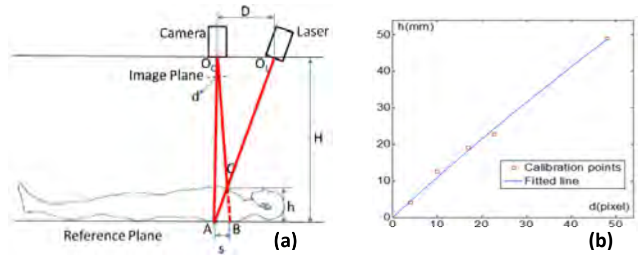

Fig. 1 Structured light motion detection system setup (a) and the system calibration plot based on objects with known thickness (b).

<u>MR Imaging</u> The carotid arteries of two healthy volunteers were scanned using 8-ch carotid coil and a whole-body 3T scanner (Philips Achieva R3.2.1, Best, the Netherlands). Standard 2D FFE sequence was used for imaging: TR/ TE = 500 / 5.2 ms, flip angle = 20°, FOV = 200×200 mm^2, resolution = 1.0×1.0 mm^2, slice thickness = 5 mm. Both motion and k-space data acquisition times were recorded and used for retrospective motion correction. The volunteers were instructed to cough during the data acquisition, in order to simulate this common cause of motion during clinical carotid scans.

<u>Motion correction</u> With the motion information measured by the structured-light system, the raw data were reconstructed in two steps: 1) By eliminating the corrupted k-space lines acquired during coughing and reconstructing missing lines using established parallel imaging algorithms (3); 2) incorporating the bulk body shift measurement, before and after each motion, into reconstruction. This way, the artifacts caused by location shifts induced motions can also be compensated.

Results and Discussions:

<u>Calibration</u> The calibration results were shown in Fig.1b. As expected, the structured light measured thickness matched well with the theoretical curve. The fitted curve will be used for the following distance measurements in vivo.

<u>Motion Detection and Correction</u> All the voluntary coughing were captured and quantified by the system (Fig.2g), with a sampling frequency of every 33ms. Besides, the system was also able to measure the bulk body shift distance after abrupt body motion.

With the intentional coughing, significant amount of motion artifacts were observed on the original MR scans (Fig.2a&d): their appearances also resemble those in clinical scans. After removing and reconstructing motion corrupted k-space lines, the amount of ghosting stripes outside of the neck area were reduced (Fig.2e&h). The carotid artery, however, was still impacted by artifacts and the boundaries can't be easily delineated. After factoring body shift information into k-space segments, the carotid artery boundaries becomes better delineated (Fig.2c&f).

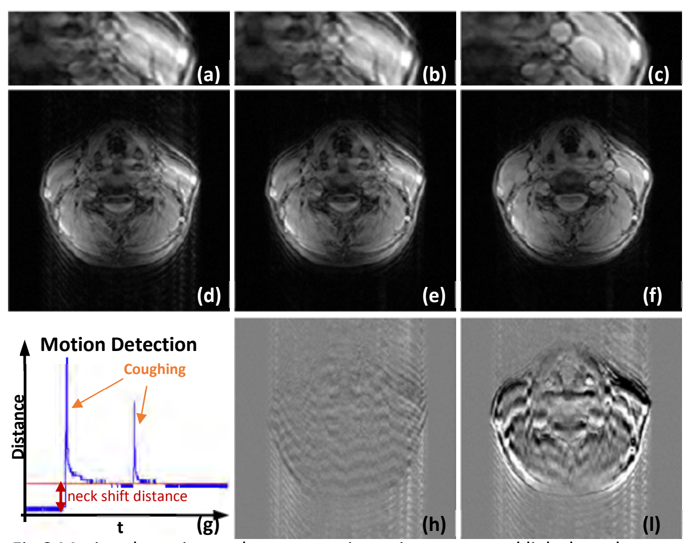

Fig.2 Motion detection and compensation using structured light based motion tracking system. Images (a)-(c) are the zoomed carotid artery images of the original scan (a), after removing corrupted data (b) and after removing corrupted data and compensating neck shift (c); (d)-(h) are the corresponding full FOV image; (g) is the motion recorded by the structured light system; (h) is the difference between (d) and (e); (I) is the difference between (d) and (f).

Conclusions:

Two key pieces of information, time of motion and bulk body shifts, are needed for effective motion correction in carotid artery imaging due to the complex motion patterns in the area. Structured light based motion detection technique has been demonstrated, for the first time, to provide both pieces of information. Initial results in this study showed that the knowledge of such can effectively help reduce the motion artifacts in carotid images.

References:

1. Sun J et al. ISMRM 2011, #3317 2. Chen H et al. J BioMed Opt (2010);15:026013 3. Liu et al. ISMRM 2015 (submitted) 4. Lustig M et al. MRM 2010; 64:457-71.