Hemispherical Constrained Surface Controller for 3D Navigation

M. J. Graves[1], and D. J. Lomas[1]
[1]Radiology, University of Cambridge and Addenbrooke's Hospital, Cambridge, United Kingdom

Introduction

The lack of simple and intuitive controllers to navigate the image plane in 3D data volumes has been identified as one of the limiting factors in the further development of real-time interactive MRI. Although many graphical user interface methods and specialised controllers [1-4] have been developed they rely either on visually distracting interactions that draw the operator's visual attention away from the output image or provide too many degrees of freedom that results in rapid disorientation. This problem has been addressed in other 3D applications such as construction machinery control and real-time ultrasound systems where the operators rely upon non-visual spatial feedback and knowledge of their environment to inform them where the image plane is relative to a reference surface. In ultrasound the reference surface is the patient's skin and this constraint combined with the spatial sense feedback through the operator's hand regarding the transducer orientation together with knowledge of internal human anatomy allows for rapid and virtually automatic navigation of the upper abdomen with no need for re-orientation devices such as book marks or orthogonal reference plane displays. This allows the operator both to concentrate on the output image for diagnostic information and to make rapid fine positional changes to account for respiration and other physiological changes during the examination.

In earlier work, based on this concept of non-visual feedback, a constrained surface controller (CSC) for real-time MRI was constructed as a proof of principle using a planar surface. An initial evaluation demonstrated improved usability in comparison to standard methods in both multi-planar reformatting of previously acquired data as well as interactive control of a scanner [5].

The aim of this work was to extend the principle of a constrained surface controller to a constrained hemispherical surface in order to facilitate navigation of a specific organ such as the kidney or the heart whilst still avoiding disorientation.

Methods

A yoke based electro-mechanical controller was designed that would output information regarding the orientation of a handle about a hemispherical reference surface (Figure 1). Orientation information was obtained by mounting two solid-state 3D microelectromechanical inertial sensors (MTx, Xsens Technologies BV, Enschede, The Netherlands) within the device. The user is first required to identify the centre of rotation as well as the effective radius of the hemisphere (R) within the imaging volume. Sensor 1 (S1) was located at the centre of the controller (yellow outline S1 on Figure 1), the output from which was used to determine the point on the hemispherical surface that would act as the centre of rotation for sensor 2 (S2) (yellow outline S2 on Figure 1). S1 provides for ±130° of elevation rotation and 360° of azimuthal rotation. S2 provides for 90° of rotation about S1 y-axis and ±90° about the x-axis. In comparison with ultrasound, for example, when the controller is aligned sagittally (Figure 1A) a rotation about S1 is similar to moving the ultrasound transducer around the patients' torso, whilst rotation about S2 is similar to rotating the ultrasound transducer about that position (Figure 2). The orientation outputs were interfaced to a custom written volumetric reformatting tool written in Matlab.

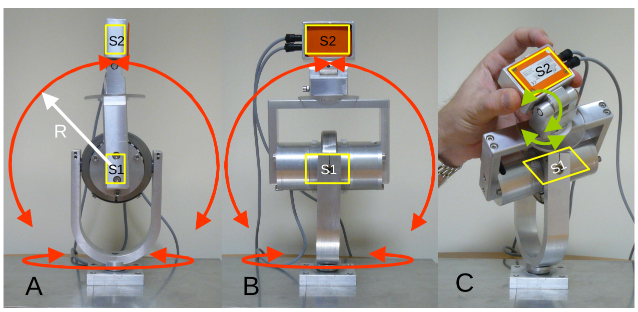

Figure 1. Hemispherical CSC. A. Side elevation, B) Front evelvation C) Oblique orientation. S1 and S2 represent the two sensors. R is the user defined hemisphere radius.

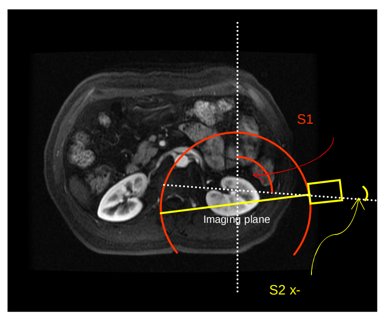

Figure 2. Controller angulations with centre of hemisphere positioned over left kidney. The user defines the centre and radius.

Figure 3. Long axis of left kidney obtained using the controller.

The controller was evaluated by four Radiologists with extensive experience of performing ultrasound examinations. Starting from a standard central axial position in the 3D dataset the subjects were asked to user with system to obtain an image through the kidney in whichever plane they felt would generate the maximal renal length (Figure 3), in a similar fashion to measuring renal length during an ultrasound examination. They were also asked to perform the same task using a 3D reformatting tool on a standard MR workstation (Advantage Windows, GE Healthcare, Buc, France). The time to obtain the required views using both systems was recorded together the measured length of the kidney on the saved reformatted images. The measurements were repeated three times.

Results

The mean time to obtain the required views was 18±2s for the workstation and 12±5s for the controller. The mean length of the kidney was 118±1mm for the workstation and 118±2mm for the controller.

Conclusion

This work demonstrates that a constrained surface controller using a hemispheric surface can be used to rapidly navigate the image plane of a 3D MRI dataset with similar performance to a standard imaging workstation. The study is limited by the small numbers but also by the virtual impossibility of overcoming the bias of previously learned behaviour with the routinely used workstations; however this is partly offset by the prior experience with ultrasound which is an advantage for using the CSC controller. Further development will integrate the controller into the MRI scanner to provide interactive hemispherical geometry control.

References

[1] Kerr AB, et al. Magn Reson Med 1997;38:355-367. [2] Debbins JP, et al. Magn Reson Med 1996;36:588-595. [3] Hardy CJ, et al. Magn Reson Med 1998;40:105-111. [4] Yi D, et al. MICCAI 2004: 430-437. [5] Lomas DJ, et al. Proc ISMRM 2007: 724.

Acknowledgements

Cambridge Enterprise Proof of Concept Fund. Colin Gautrey and David Cobb for mechanical construction of the controller. Addenbrooke's Charitable Trust