Reference surface constrained navigation controller for 3D image data & real-time MRI

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Introduction

At the 2006 ISMRM Real-time workshop the lack of an intuitive and simple 3D navigation controller was identified as limiting further real-time applications development. Although real-time MRI offers the ability to control several image parameters, image plane navigation is probably the most important. Currently available methods have proven difficult to use and disorientating for several reasons. Typically graphical user interface (GUI) interactions are required that distract operator attention from the output image. This includes conventional mouse and GUI based methods for locating the image plane e.g. line drawing [1] placing points [2] and selecting reference icons [3]. Specialized controllers have been proposed to overcome these limitations and typically provide 6 degrees of freedom for image plane control e.g. Spaceball [3], 3D and 6DoF mice [3], articulated arm [4]. These avoid distracting interactions with a GUI but can be rapidly disorientating in use. To address this problem several groups use a previously acquired 3D data set on which the active image plane location is mapped to provide a visual location feedback to the operator [3,4]. However as the feedback is visual it again creates an operator distraction - taking their attention away from the output image.

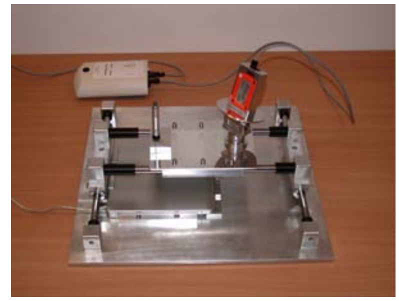

Fig. 1: Planar Surface Controller

The ability to move a 2D planar image freely through the body has already been achieved in the different diagnostic field of real-time 2D ultrasound. Here the operator uses a combination of their knowledge of the internal anatomy of the subject and tactile and spatial cues from the hand manipulating the transducer to move the image plane in a predictable and "automatic" way. No visual distractions through mouse – GUI interactions occur and image plane tracking feedback on a 3D display is not required. Real-time ultrasound has two important features lacking in many of the proposed MRI solutions. Firstly transducer motion and the edge of the imaging plane are both constrained by a surface, namely the skin surface, and secondly the orientation and spatial location of a hand manipulated physical controller device is directly correlated with the output image. These constraining features provide predictability and allow sonographers to develop and highly refine their coordination so they can concentrate primarily on the output image for diagnostic information and "forget" the transducer movements, which eventually become unconscious actions. The aim of this work was to create a controller for navigating a 2D image plane through 3D image data (previously acquired and real-time MRI acquisition) that uses a constrained reference surface with directly correlated spatial and orientation control information (in a similar fashion to an ultrasound transducer) thereby avoiding the problems of disorientation and distraction of current methods.

Fig.2: Double oblique plane illustrating both the middle and right hepatic veins.

Methods

An electro-mechanical controller was designed that would output information regarding the translation and orientation of a rectangular handle above a planar reference surface. The design allowed matching of the handle orientation with that of the selected 2D imaging plane in the relevant 3D image space. A steel and aluminium frame was constructed with a platform mounted on a free running set of X-Y guides. On the platform the handle was mounted to allow rotation in one axis along its inferior edge (+/- 90degrees) and rotation of the handle about the same edge (360degrees) permitting any oblique plane to be selected in relation to the reference surface - in a similar fashion to an ultrasound transducer above the skin surface. X-Y translation information over the reference surface was obtained by mounting a graphics tablet (Graphire, Wacom) within the guides and below the platform to which the tablet pen was attached. Handle orientation information was obtained by mounting an MTi orientation sensor (Xsens technologies BV, Holland) within in the handle and using the quaternion output (to avoid gimbal lock). The tablet and orientation outputs were interfaced through their respective drivers on a standard PC and first tested through an in-house interface (using Matlab) controlling a 2D planar reformat of 3D data. Secondly the controller was interfaced to a prototype real-time MR FIESTA sequence in a proprietary iDrive interface within the bore of a whole body 1.5T MRI system (GEHC Excite HDX, 12m5). The controller interface outputs rotation matrix updates via a UDP sockets approach directly to the Scanner Applications Gateway Processor (AGP) to allow real-time geometry updates of the sequence.

Results

The planar controller is shown in Figure 1 with the "handle" containing the orange orientation sensor. Initial evaluation allowed the rapid location of complex oblique planes in both previously acquired 3D data sets (post i.v. gadolinium enhanced 3D T1w interpolated – LAVA) and using the real-time interface with a FIESTA sequence in a human volunteer without disorientation or the need to displace visual attention from the output image. (Figures 2 and 3).

Fig. 3: An oblique plane through the right iliac fossa illustrating loops of large and small bowel

Conclusion

This work demonstrates that it is possible to create an intuitive and easy to use controller for navigating 3D imaging data (such as from MRI and CT or as part of an interactive real-time MRI system) that allows the operator to concentrate visually on the output image for diagnostic information without disorientation or distraction by other interactions such as using mouse driven GUIs or reliance on positional feedback from a 3D reference data display. Further work is planned to refine, extend and evaluate the concept more formally.

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] Stainsby et al. Proc ISMRM 2004: 537

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