Image Guided Robotic Radical Prostatectomy

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INTRODUCTION

We present results of early trials of a system to overlay preoperative MRI onto endoscope video taken from a daVinci endoscope system during robotic radical prostatectomy. The endoscope is calibrated and tracked so that the MRI can be overlaid in the same coordinate system as the video data and projected onto the screen with the correct camera parameters. The system has two potential applications. The first is that it enables the surgeon to easily refer to the preoperative MRI during surgery. Secondly, it may serve as an initialisation for a model to video registration method to enable the preoperative data to be updated during the procedure. The system has been trialled in five patients, with overlay images provided to the surgeon during surgery in two cases. Further trials are ongoing.

MATERIALS AND METHODS

In order to overlay the MRI onto the endoscope screen it is necessary to register the preoperative MRI data to the video data. There are two approaches to doing this. The first of these is to register the endoscope image to the preoperative model directly using visible landmarks or surfaces. This has the advantage that it is not necessary to track the endoscope or the patient. This method has been used by a number of authors, a recent example of this method applied to robot assisted surgery is presented by Su et al. [1]. We do not wish to use this approach for two reasons. Firstly, it limits the period of time that image guidance is available. Secondly it requires surfaces or landmarks to be segmented from the preoperative image, a process that may be time consuming and/or inaccurate.

In preference to direct registration we attempt to first register the preoperative data to the patient in theatre so and locate in the coordinate system of an optical tracking system. We then track the endoscope with the optical tracking system. Thus we know where the endoscope is relative to the preoperative image. This approach is common in image guided surgery, typically fiducial markers are used to register the preoperative data in theatre, an example using magnetically tracked fiducial markers is given by Ukimara and Gill [2]. Our method avoids the need for implanted fiducial markers.

For robot assisted procedures the most common approach to endoscope tracking is to use the daVinci's own kinematic data, see Mourgues and Coste-Manière [3]. We track the endoscope with an optical tracker to try and improve tracking accuracy.

We use the pelvic bone to match the MRI data to the patient in theatre. As the prostate is closely coupled to the pelvic bone, motion of the prostate between the MRI scan and the start of the surgery is minimised. To enable this we have developed a novel shape model fitting method, see figure 1, to find the pelvic bone in the MRI.

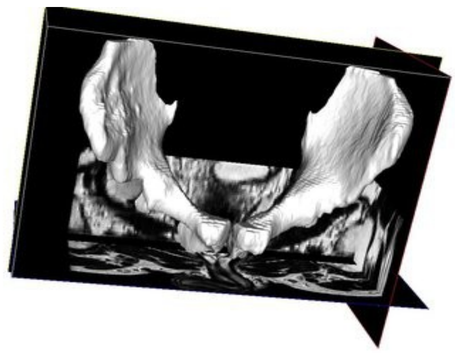

Figure 1. A statistical shape model based on the shape of the pelvis in 21 adult males is used to extract the shape of the pelvis from the preoperative MRI data.

The pelvic bone is found in theatre using a B-mode ultrasound tracked using an Optotrak Certus optical tracking system, see figure 2. Approximately 400 ultrasound slices of the patient's pelvis are then matched to the pelvic bone extracted from the MRI data using a point to volume registration algorithm. The algorithm has been shown to work on data collected in theatre. At present, however, the execution time is too long to be used in real time in theatre, though it should be straightforward to correct this with a parallel implementation. Real time clinical implementation to date has used a computer aided direct alignment of the MRI to the video data. This uses points predefined on the inner surface of the pubic arch and custom software to align the video and MRI in less than a minute.

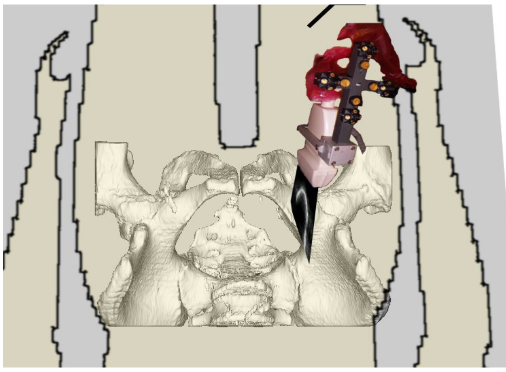

Figure 2. A series of ultrasound images of the patients pelvic bone are collected in theatre. The position of these in the theatre are determined using an optical tracking system to track a group of infrared emitting diodes attached to the probe.

A custom built collar was fitted to the endoscope to allow it to be tracked with the same optical tracking system as was used for the ultrasound. Results indicate that this gives similar accuracy to using the daVinci's own kinematics. The endoscope is calibrated to determine the projection parameters (focal lengths and distortion) of the endoscope lens.

A slice of the preoperative MRI can now be projected onto endoscopic video. To date this projection has been done on a laptop computer adjacent to the surgeons console, with plans to integrate it into the console in the future. Figure 3 shows an example overlay.

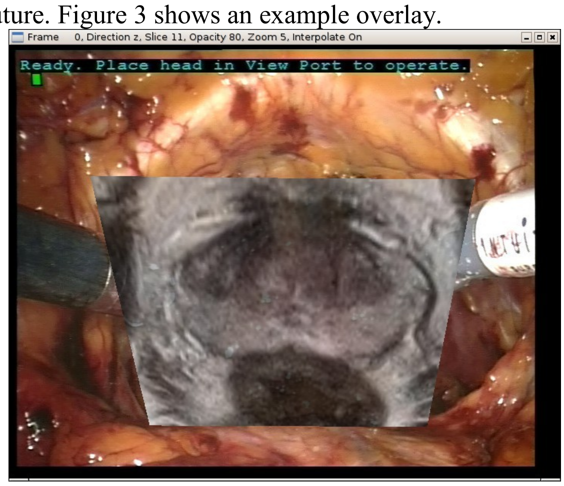

Figure 3. A transverse MRI slice projected onto endoscopic video. The surgeon can move through the MRI volume, change the slice direction and opacity.

RESULTS

The accuracy of the system components has been analysed using phantom, cadaver and real data. The system can project a point on the MRI with an accuracy of around 20 pixels on screen. This is visualised in Figure 4. The chief source of projection error is the endoscope tracking accuracy.

The system has been tested on five patients to date with more pending. In the last two cases real time overlay was achieved enabling the surgeon to refer to the overlaid MRI during the procedure.

DISCUSSION

Image guidance during endoscopic procedures is an expanding area of research. The daVinci robot provides a good platform on which to build an image guidance system, though the method presented here is compatible with any endoscopic system. Extension of our method to utilise the 3D projection of the daVinci should, in theory, be straight forward.

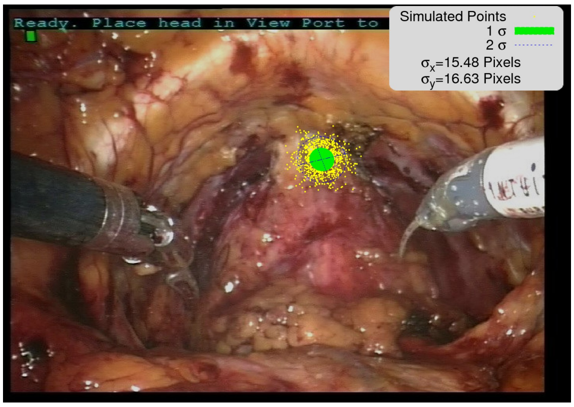

Figure 4. Projection accuracy is around 20 pixels. Here a single point (near the apex of the prostate) has been projected onto the screen 1000 times under the influence of our system errors, giving a visualisation of the size of the system error.

Our system does not correct for movement of the prostate. However, our results indicate that it still provides the surgeon with a useful reference that can be used to aid intra-operative decision making. The ability to refer rapidly to the MRI to visualise tumour locations is useful even though the alignment is not exact.

Work is ongoing to improve the accuracy of the various components, to better integrate them into the theatre environment, and to reduce the time taken for the automatic registration. We are also looking at ways to measure any improvement in surgical outcome.

REFERENCES

[1] L. Su, B. P. Vagvolgyi, R. Agarwal, C. E. Reiley, R. H. Taylor, and G. D. Hager, "Augmented Reality During Robot-assisted Laparoscopic Partial Nephrectomy: Toward Real-Time 3D-CT to Stereoscopic Video Registration," Urology, vol. 73, pp. 896-900, 2009

[2]Ukimura, O. and Gill, I. S., "Image-Fusion, Augmented Reality, and Predictive Surgical Navigation",Urologic Clinics of North America Volume 36, Issue 2, Pages 115-123 (May 2009), 115–123

[3] Mourgues, F. and Coste-Manière, E., "Flexible Calibration of Actuated Stereoscopic Endoscope for Overlay in Robot Assisted Surgery", in MICCAI , Vol. 2488 of LNCS , Springer, pp.25–34