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MR/TRUS data fusion for improved diagnosis and staging

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BACKGROUND

Prostate cancer diagnosis is typically achieved through a series of PSA, DRE and TRUS biopsy procedures. As the cost, ease and availability of imaging changes, MR becomes a candidate for casual prostate cancer screening.

Current approaches to the fusion of MRI and US information tend to rely on manual intervention or bespoke technology.

Our research concerns automatic segmentation and matching of the prostate across modalities; including registration between common 2D TRUS and 3D MR. The outcome of this fusion will form the basis for clinical evaluation with respect to diagnosis and localisation of prostate cancer.

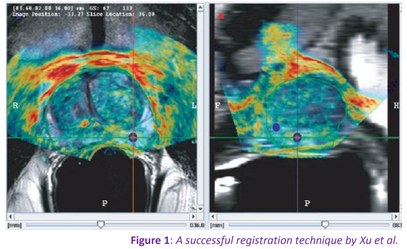


Figure 1: *A successful registration technique by Xu et al. Unfortunately it is dependent on fiducial markers.*

Ultrasound is a notoriously difficult imaging modality; by introducing information from MR we can provide urologists with a means of performing highly targeted biopsies where this is not typically possible. Not only could this work improve the accuracy of biopsy, but also provide further information for staging, thus enhancing clinical decision making ,leading to the most effective therapy.

PROJECT GOALS

The two main aims of the project are:

Improved localisation – which will lead to better targeted biopsy, forgoing typical ten-core or sextant biopsy protocol. The end result being more accurate diagnosis with a low chance of false-negative biopsy results.

Improved staging – TRUS does not provide adequate detail for staging, but fusion with MR may highlight features such as extracapsular extension or allow for monitoring of cancer spread; both within and around the prostate.

This will be achieved through fusion of traditional TRUS and MR image data, using novel techniques that avoid the use of manual intervention or third-party hardware such as electromagnetic 3D spatial trackers.

IMAGE PRE-PROCESSING

In computer vision, the stages involved in processing data are often referred to, as the **image processing pipeline**. This describes the sequence of actions performed by a computer program to process the image. One of the first steps is usually pre-processing, where a variety of operations can be performed to enhance image data.

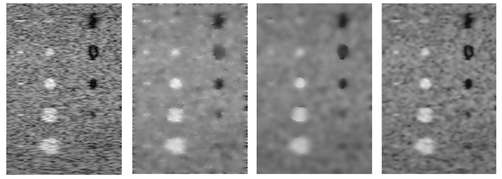


***Figure 2**: An example of different noise reduction algorithms.*

This is particularly important with ultrasound data, a modality known for being extremely noisy.

A plethora of techniques are available to handle image noise, but few specific to ultrasound – which suffers from a combination of noise types.

Whilst MR data is generally "cleaner", the ultrasound needs much more work to enhance its usefulness for further stages such as segmentation.

PROSTATE SEGMENTATION

One of our first tasks was to work on automatically separating the prostate boundary from the rest of the image; a process known as segmentation.

One basic technique is known as active contours, and in the images below highlights the benefits that ultrasound denoising can have for such methods. In the images the green line represents the manual segmentation and the red line represents the automatic segmentation.

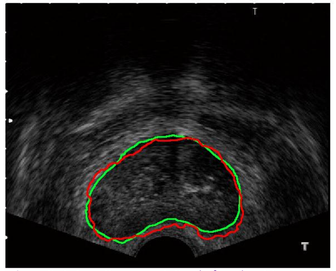


***Figure 3**: Automatic segmentation before denoising.*

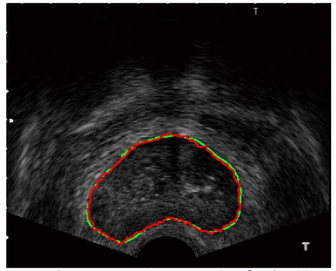


***Figure 4**: Automatic segmentation after denoising.*

Identifying anatomical regions is a crucial step before registering two different images. As such we have research methods for segmenting not only the prostate boundary, but also the internal zones.

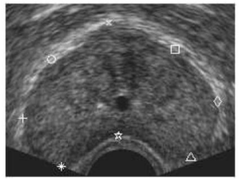
IMAGE REGISTRATION

Image registration concerns fitting one or more images to another.

This is a significant challenge for our project due to the high amount of variation between TRUS and MR.

These differences include:

- Viewing plane
- Dimensionality (2D vs 3D)
- Quality
- Anatomical changes due to motion, compression, time, etc



Another major issue is deciding appropriate points for correspondence that can be used to align images. Height and width measurements of the prostate are used to initiate this selection. Alternative options are manual point selection or fiducial markers.

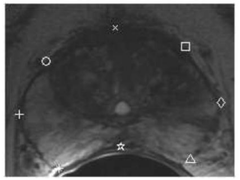


***Figure 5**: Our collaborators have developed a semi-automatic technique that finds corresponding points for TRUS frames (top) and MR slices (bottom).*

Our approach avoids manual intervention by using groupwise registration techniques . We iteratively transforming a group of sample images towards an average, thus providing a series of transforms to fit one to the other.

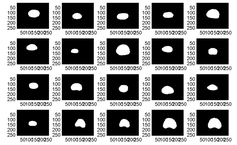


Figure 6: set of prostate boundaries prior to transformation.

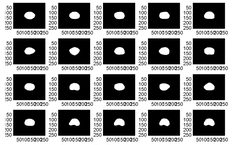


***Figure 7**: Prostate boundaries after transformation towards an average. Note the change in size, shape and position.*

Once registration can be reliably achieved we will be able to look at the mutual information – co-dependent variables indicative of specific stages of cancer progression.

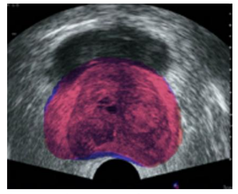


***Figure 8:** Early attempts at fitting MR prostate boundaries to US image. Note changes in shape and size.*

SUMMARY

We are working towards a fully automatic means of combining MR and TRUS image data for superior localisation and diagnosis. To date we have worked on enhancing ultrasound data for segmentation and investigated TRUS frame and MR slice registration. Next we will be focussing on registration between MR volumes (3D) and conventional TRUS (2D).

REFERENCES

- "Coping with Noise in Ultrasound", Roscoe et al, Medical Image Understanding and Analysis 2012, p191-198
- "Real-time MRI-TRUS fusion for guidance of targeted prostate biopsies" Xu et al, Computer Aided Surgery, 13 p255-264 2008
- "Weighted likelihood function of multiple statistical parameters to retrieve 2D TRUS-MR slice correspondence for prostate biopsy", Mitra et al. IEEE International Conference on Image Processing 2012