Comparison of Image Registration Packages for Use in Radiotherapy Planning

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Introduction

Addenbrooke's Radiotherapy Department has three automatic image registration packages (all based on mutual information) available for use in multimodality radiotherapy treatment planning: Prosoma, Focal and RView. CT-MRI registration of brain images is the most common use of image registration in radiotherapy. This project compares the performance of the three packages to see which one is most suitable for this use.

Background

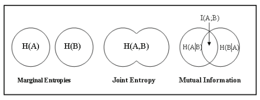
Mutual information is an intensity based metric and can be used to register images from different modalities. It provides a measure of the information that is common between two datasets (Studholme *et al 1999*).

Mutual information: difference between the sum of the entropies of the individual images and the joint entropy of the combined images at overlap. In image registration this is maximised.

Entropy: $H(A) = -\sum_{a} p_A(a) \log p_A(a)$

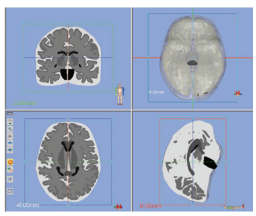
Joint Entropy: $H(A, B) = -\sum_{a,b} p_{AB}(a,b) \log p_{AB}(a,b)$

Mutual information: $I(A,B) = H(A) + H(B) - H(A,B)$



Ideally, registration accuracy should be within 1mm for radiotherapy planning (Veninga *et al* 2004). Any errors in registration will cause errors in the final treatment plan.

Methods

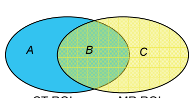


A. ImSimQA was used to create images of virtual phantoms. These were transformed with respect to each other and registered in Prosoma and RView with the advantage of a known 'gold standard' registration. Common MR artefacts were simulated along with limitations of the packages. It was not possible to import ImSimQA generated images of virtual phantoms into Focal. Instead, ImSimQA was used to transform a clinical image and a subset of tests were carried out on Focal in this way.

B. A Philips multislice MR phantom was scanned on both CT and MR. Images were registered using Prosoma and Focal. RView was unable to correctly import the majority of images from our CT scanners and therefore no further tests were carried out on this program. Five high contrast ROIs were outlined, each on one slice only (on both the CT and MR images). MATLAB was used to calculate the centroid, area and perimeter of each region along with the overlap of corresponding CT and MR regions. The percentage overlap (Equation 1), coefficient of agreement (Equation 2) and distance between the centre of corresponding CT and MR ROIs were then calculated as a measure of the accuracy of the registration.

Eqn 1:

$$percentage\ overlap = 100 \times \frac{B}{A+B+C}$$



where A is the area of the CT ROI not overlapping the MR ROI, C vice-versa and B is the overlapping region, as shown.

Eqn. 2:

$$X = \sqrt{\frac{a_{CT}}{a_{MR}} \times \frac{p_{CT}}{p_{MR}}}$$

where X is the coefficient of agreement, a is the area and p is the perimeter of corresponding CT and MR ROIs (Moore *et al* 2004).

C. The procedure in B was repeated on five CT-MR pairs of clinical images, outlining three ROIs on each. It was found that eyes were easer to outline due to their high contrast which lead to less variation between outlines and so the number of eyes outlined was increased to 18 (in 9 CT-MR pairs). The same analysis as in B was carried out on these 18 ROIs.

Results and Discussion

A. These tests did not uncover any large or unexpected errors in any of the image registration packages. The tests highlighted rotational and translational limits to the automatic registration of which the user should be aware. They also showed the importance of visually checking each and every registration in all three planes before using it clinically as errors can occur when not expected.

B. This test served as a test run for the tests to be carried out on clinical images and showed the method of outlining, exporting ROIs and analysing the data in MATLAB worked effectively.

C. The data for 18 ROIs showed that distances between centres of corresponding CT and MRI ROIs once registered were <1mm for 16 ROIs when Prosoma was used (range 0.06-1.41mm) and <1mm for 10 ROIs when Focal was used (range 0.21-3.15mm). Results of the statistical analysis on the percentage overlap, coefficient of agreement and distance between centres for the 18 pairs of CT and MR eye ROIs are shown in the table below:

	Percentage overlap			Coefficient of Agreement			Distance between centres (mm)		
	Prosoma	Focal	Difference	Prosoma	Focal	Difference	Prosoma	Focal	Difference
Average	**90.50%**	**84.36%**	**6.14%**	**0.98**	**0.95**	**0.03**	**0.63**	**1.12**	**-0.49**
Std. Dev	3.47%	8.07%	8.44%	0.04	0.07	0.06	0.34	0.81	0.88
Paired t-test:		**p=**	**0.007**		**p=**	**0.039**		**p=**	**0.030**

A paired Students t-test was carried out on the data to test the null hypothesis that there is no difference between Prosoma and Focal for the three calculated parameters, using a threshold p value of 0.05. For all three parameters Prosoma performed significantly better than Focal. Results showed corresponding ROIs of images registered using Prosoma had an average percentage overlap 6.14% higher than Focal, an average coefficient of agreement 0.03 higher than Focal and an average distance between centres 0.49mm less than Focal.

Conclusions

RView was unable to correctly import the majority of images from our CT scanners and so it was decided that it would not be a viable option for clinical registration at Addenbrooke's.

A t-test on the data from part C resulted in the null hypothesis being rejected for *all* parameters, indicating that there is a statistically significant difference between the registration accuracy of Prosoma and Focal with respect to the percentage overlap (p=0.01), coefficient of agreement (p=0.04) and distance between centres (p=0.03) of corresponding CT and MR ROIs. For all three parameters Prosoma performed significantly better than Focal.

Based on the analysis carried out, it is recommended that Prosoma be used for registration of CT and MR images of the brain for use in radiotherapy planning at Addenbrooke's.

Further Work

The work will be repeated on the image registration within Eclipse at the Norfolk and Norwich University Hospital to enable a comparison of this software with those already tested.

References

Moore C S, Liney G P and Beavis A W 2004 Quality Assurance of registration of CT and MRI data sets for treatment planning of radiotherapy for head and neck cancers *Journal. of Applied Clinical Medical Physics* 5:1 25-35

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