Statistical models with tolerance for abnormalities

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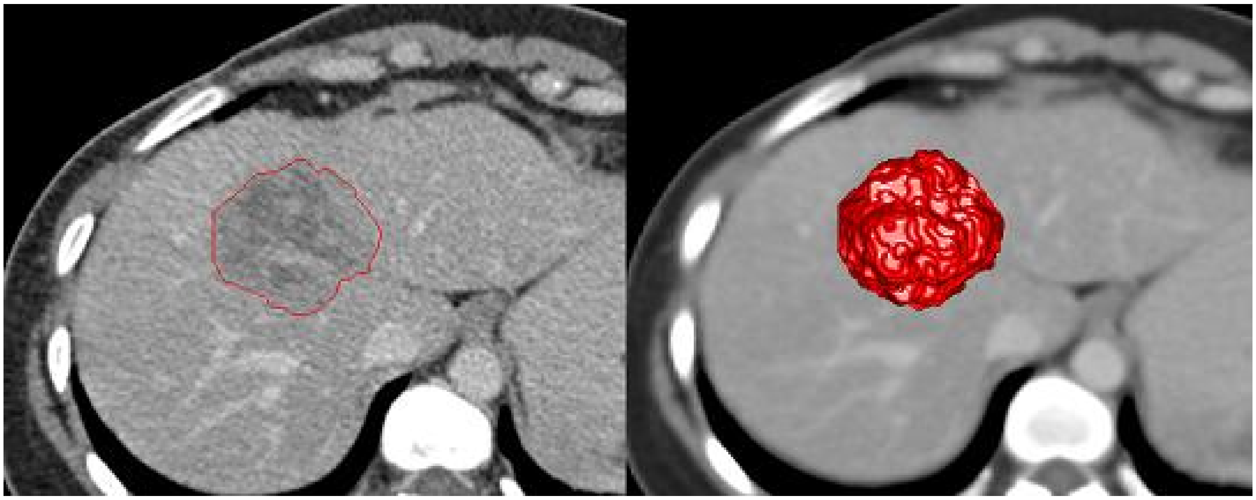
Background: Two of the primary problems with respect to the analysis of medical imagery are segmentation, which localizes the various structures found within an image and registration, which brings disparate images into correspondence. Due to the variations in patient anatomy, scan lines noise and other artifacts in these images, coupled with their complexity limits the effectiveness of simply image processing techniques. Statistical models have been widely used in medical image analysis to address these challenges whereby multiple sets of images are used to build up a distribution map of a given anatomical structure. This approach has been used to create a brain atlas for neurosurgery [1] and to develop a probabilistic model for automated liver segmentation [2].

The problems of segmentation and registration are complementary in that the solution of one aids in the solution of the other. If it was possible to segment all the anatomical structures in an image then the problem of registration simplifies to the problem of aligning the boundaries of two maps. Similarly, two images that are in perfect registration allow for full segmentation with the use of an anatomical atlas.

To obtain an accurate model of the anatomy, various modalities of medical imaging are often used in concert. Soft tissues are well imaged with magnetic resonance (MR) scans, while bone is more easily discernible in computed tomography (CT) scans. As well, each modality has its own noise signature and artifacts which adds to the challenge of alignment.

When developing a statistical model, training exemplars are taken from datasets that are essentially free from any abnormal structures. It is a significant challenge to apply these resulting statistical models to data which includes malformations. The medical application of this being computer aided diagnosis which would require an accurate delineation of the boundary between abnormal and normal structures. An example of this type of challenge is the 3D Liver Tumour Segmentation Challenge 2008 (`http://lts08.bigr.nl`) where the goal was to compare different algorithms to segment the liver tumours from contrast enhanced CT scans. A typical image is reproduced below.



Questions for the workshop participants: The intensity at any given point of a CT scan reflects the radiodensity at that point which is a measure of the mean attenuation of the tissue. This leads to what is known as the partial volume effect where the technique cannot differentiate between a thin layer of dense material and thicker layer of less dense material. This effect is not seen in MR images where different tissues are characterized by their different relaxation rates when responding to an electromagnetic pulse. However, different MRI machines produce different values and there are relative differences among images from different machines.

The question for the workshop participants is investigate how to combine the CT and MR modalities with these statistical models to 1) detect abnormal structures and 2) to help with the problem of both registration and segmentation of the underlying anatomy.

References

[1] M.M. Chakravarty, G. Bertrand, C.P. Hodge, A.F. Sadikot, and D.L. Collins, *The creation of a brain atlas for image guided neurosurgery using serial histological data*, Neuroimage **30** (2006), no. 2, 359–376.

[2] X. Zhou, T. Kitagawa, T. Hara, H. Fujita, X. Zhang, R. Yokoyama, H. Kondo, M. Kanematsu, and H. Hoshi, *Constructing a probabilistic model for automated liver region segmentation using non-contrast x-ray torso ct images*, Medical Image Computing and Computer-Assisted Intervention–MICCAI 2006 (2006), 856–863.