Piecewise Non-rigid Registration of 3D MR and CT Images of the Spine

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The Problem: Our intention is to find a non-rigid transformation in 3D that provides a registration between three-dimensional MR and CT images of the spine (Figure 1.).

Motivation: 3D rigid-registration algorithms have reached a high performance level so that many of them are used in real life medical applications on a daily basis. However, the movement or the positional changes of anatomical structures, in general, cannot be merely described by rotation and translation; most of them deform in an elastic way. Hence, great research effort has been invested in examining different non-rigid algorithms that would describe a larger class of transformations. Piecewise-rigid transformation (rigid movement locally and non-rigid globally) is one of them. This type of registration seems to apply well to spine volumetric data as the individual vertebrae move in a very restricted way, however, their collection, the spine demonstrates a less controlled movement.

Typically, prior to widely performed spine procedures such as vertebroplasties and lumbar fusion, patients are imaged using both MR and CT. As these modalities are used to image different anatomical structures (CT is used to image bone, and MR is used to image soft tissue), displaying the registered 3D version of the scans would visualize a more complete image of the spine.

Previous Work: There has been extensive research completed in multi-modal 3D rigid registration. One of the most successful algorithms is based upon the maximization of mutual information between the volumes to be registered [1, 2]. Other efficient algorithms apply maximum-likelihood type objective functions [3].

Approach: We plan to address the given registration problem in the following way. First, by using an already available software package, we will obtain a rough segmentation of the input spine datasets. That will then allow us to run rigid registration on the corresponding vertebrae pairs. Here we have to take into consideration the fact that, in case of vertebrae, translation along and rotation about the axial direction have a very small attraction basin with respect to the currently applied objective function. Therefore, we are to apply some type of a feature-based or surface registration technique. Finally, we are to find an appropriate non-rigid transformation between the volumes that explains the movement of the spine as a whole given the individual rigid transfomrations. That could be achieved by computing 3D chamfer distance maps [4] with respect to the individual vertebrae and then interpolating the individual transformations weighted by the distances.

Initially, we are to experiment with maximizing mutual information as an objective function, but max-likelihood-type reward functions are also to be examined.

Impact: Computationally, this piecewise rigid registration algorithm would take us closer to address the more general problem of non-rigid registration by establishing a connection between locally rigid and globally non-rigid transformations.

In the medical field, the registration of CT and MR modalities would allow a more compact and more detailed representation of the anatomical structures before an intervention takes place or a diagnosis is set up.

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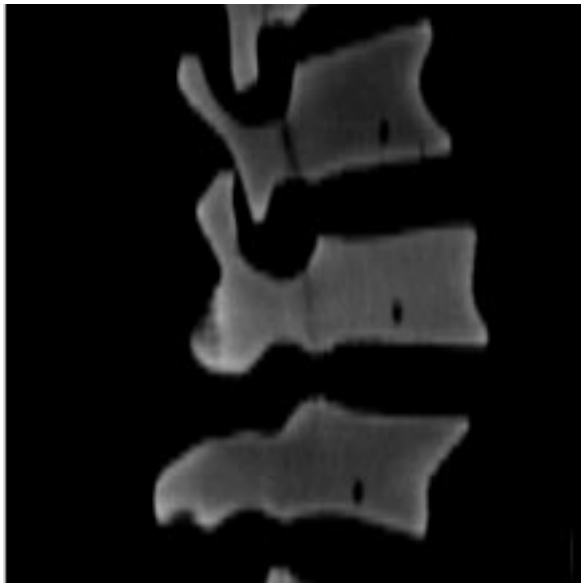
References:



(a) Sample CT image of the spine

(b) Sample MR image of the spine

[1] P. Viola and W. Wells. Alignment by Maximization of Mutual Information. *International Journal of Computer Vision* 1997; 24:137-154.

[2] W. Wells, P. Viola, H. Atsumi, S. Nakajima and R. Kikinis. Multi-modal Volume Registration by Maximization of Mutual Information. *Medical Image Analysis* 1996; 1:35-52.

[3] M. Leventon and E. Grimson. Multi-Modal Volume Registration Using Joint Intensity Distributions. *MICCAI 1998*.

[4] G. Borgefors. Distance Transformations in Digital Images. *Computer Vision, Graphics, and Image Processing* 1986; 34, 344-371.