Improving the Convergence and Computational Efficiency of Deformable Image Registration Calculation by Incorporating Prior Knowledge

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Purpose/Objective(s): Conventional deformable registration treats all image volume equally and the calculations are "brute-force" in nature. In reality, some regions can be mapped between the moving and fixed images with higher confidence than others. In this work we investigate a strategy of using *a priori* knowledge of the system to reduce the dimensionality of the deformable image registration problem and to speed up the registration calculation.

Materials/Methods: The local deformation property is spatially heterogeneous and, in some special situations the local deformation and registration can be known *a priori* (such as the region in a bony structure). This knowledge can be incorporated to greatly facilitate the BSpline (or other models) deformable calculation. Our calculation consisted of two natural steps. First, a number of small cubic (0.5_1cm in size) control volumes are placed, either manually or automatically based on image intensity information, on the locally rigid regions (LRRs) of the moving image. A control volume typically resides in or close to a bony structure. Each control volume is mapped onto the moving image using a rigid transformation, which is computationally fast and robust. In the second stage, the pre-determined correspondence serves as *a priori* information for the BSpline deformable registration calculation. Specifically, the control volumes are included as part of the BSpline nodal points. However, in the process of warping the moving image to optimally match the two input images, only those deformations that do not modify the pre-established associations of the control volumes are permissible. This significantly reduces the search space and improves the convergence behavior of the gradient-based iterative optimization calculation. The proposed algorithm is evaluated by using digital phantoms and 4D CT images.

Results: A novel method of incorporating prior knowledge into deformable image registration has been developed. Comparison with the conventional BSpline calculation suggested that the new method can improve the computational efficiency. More importantly, because of the inclusion of existing information, the convergence behavior of the calculation is greatly improved. The digital phantom study, where the "ground truth" transformation exists, indicated that the computational accuracy of the proposed technique is well within 2.5mm. The registrations of the 4D lung and liver cases indicated the same level of success.

Conclusions: With the incorporation of *a priori* system knowledge, the deformable registration was made much simple and robust in comparison with the conventional "brute-force" approaches. Given the fact that there is an ever increasing need for efficient deformable image registration tools in IGRT, this technique may find widespread use in the clinics.