Image Registration with Auto-Mapped Control Volumes

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Purpose/Objective: Many image registration algorithms rely on the use of homologous control points on the two input image sets to be registered. In reality, the interactive identification of the control points on both images is tedious, difficult and often a source of error. The purpose of this work is to automate the selection of control points for both rigid and deformable image registrations and to demonstrate the utility of the new approach by using a few examples.

Materials/Methods: The registration of two images in our approach proceeds in two steps. First, a number of small control regions having distinct anatomical features are identified on the model image. Instead of attempting to find the correspondences of the control regions in the reference image through user interaction, in the proposed method, each of the control regions is mapped to the corresponding parts of the reference image by using an automated image registration algorithm. The conventional automated image registration algorithm is then used to complete the image registration process with the auto-determined control points. A normalized correlation function (intra-modality image registration) or a mutual information metric (inter-modality image registration) was used as the metric in both the selection of the control volumes and the final image registration. The deformable registration was modeled by free form deformations based on spline interpolation. The limited memory Broyden-Fletcher-Goldfarb-Shanno algorithm (L-BFGS) was used to optimize the metric function. The performance of the registration-in-registration approach was examined by registering CT and FLT-PET images of a rectal cancer patient, CT and MRI images of brain tumor patient, and two sets of images of a lung case acquired at two different respiratory phases. For each case, the convergence behavior of the algorithm was studied by registering the two input images with 100 randomly initiated relative positions. The performance of the registration was evaluated by comparing with the results obtained by using direct registration without the use of auto-mapped control volumes.

Results: An image registration algorithm with auto-mapped control regions has been proposed for intra- or inter-modality image registration. For each case, the convergence of the algorithm was confirmed by starting the registration calculation from 100 different initial conditions. The brain image registration suggested that the technique can match a CT and MRI images with an accuracy of 1 mm in the case of rigid body registration in less than a minute on a standard PC computer. Application of the technique to the clinical FLT-PET and CT registration showed a similar level of success. We found that the technique is especially valuable for improving the accuracy and calculation speed of deformable image registration. For the registration of CT images acquired at inhale/exhale phases of the lung patient, the BSpline calculation was speeded up by an order of magnitude with notable improvement in the registration quality.

Conclusions: The proposed method of determining the control points greatly reduces the complexity involved with the determination of homologous control points and allows us to minimize the subjectivity and uncertainty often occurring in the use of user-defined control points. Patient studies have indicated that the two-step registration technique is reliable and provides a valuable tool to facilitate both rigid and non-rigid image registration problem.