Entropy-Based Image Registration and Construction of Statistical Appearance Models for 3D Medical Volumes

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This thesis is focused on the research of entropy based image registration and construction of statistical appearance models for 3D medical volumes. Medical image registration is an important task of medical image analysis since it can be widely applied for surgical navigation, serial-image analysis, and medical image fusion and so on. Medical image modeling is also an important research field and this technique can be applied to build organ database from medical images or support disease diagnosis. The contributions of this thesis can be divided into the following four aspects.

(1) A wavelet based multiresolution strategy was proposed for medical image registration. Mutual information (MI) is a widely used similarity measurement for registration; however since MI is lack of spatial information (SI), sometimes this makes registration failed. In the proposed method, wavelet transformation is applied to decompose the 3D medical images into low- and high-frequent coefficients which are used to calculate MI and SI respectively. A hybrid similarity measurement is formed by combining MI with SI in order to increase the accuracy of medical image registration. Additionally, since multiresolution is applied, registration time can be saved compared with traditional method.

(2) A parzen-window based normalized mutual information (NMI) algorithm was proposed for medical image registration. NMI is a more robust similarity measurement than MI since it can ensure success of registration even when the overlapping region is small. In traditional ways, NMI is calculated from a discrete joint histogram, so it is impossible to obtain the derivatives of NMI. In the proposed method, a continuous joint histogram is estimated by a parzen-window method, so the close form solution for the derivatives of NMI can be derived in order to make the gradient-based optimization methods to be used in image registration. Compared to the traditional methods, the proposed parzen-window based normalized mutual information algorithm can make registration perform faster.

(3) A 3D CT-MR non-rigid registration algorithm was developed for the MR-guided microwave thermocoagulation of liver tumors. In our registration algorithm, the parzen-window based normalized mutual information is applied as the similarity measurement. A traditional rigid transformation combined with free form deformation is used to estimate the significant non-rigid motions of the livers. Registration accuracy is evaluated by both phantom data and real clinical CT and MR volume pairs. The proposed registration method achieves the registration accuracy of 1.86mm±0.47mm and 1.45mm±0.27mm for the phantom data and the clinical data respectively. These results show that this non-rigid registration method is accurate enough for the coagulation of liver tumors. In future, we will apply the proposed method into the practical MR-guided interventional therapy of liver tumors.

(4) A method named as generalized *N*-dimensional principal component analysis (GND-PCA) was proposed to build the statistical appearance models directly from a few 3D medical volumes. PCA-based methods require that the 3D volumes should be firstly unfolded to be 1D vectors. Since the dimension of the unfolding vectors is large, the computing cost of traditional PCA method is huge. Additionally, since the number of training samples is usually much fewer than the dimension of the unfolded vectors, the appearance models constructed by the PCA method like eigenfaces method have bad performance on generalization. By using the proposed GND-PCA, the statistical appearance models for brain can be constructed from only 17 MR volumes. The leave-one-out tests show that the constructed models have good performance on generalization and the original brain volumes can be represented efficiently by few coefficients. In future, we will apply the proposed modeling method to construct database of medical images.