Flexible B-spline registration of thoracic CT data by disparity analysis

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Abstract: In this paper is described purposed free form deformation model for correction local displacements of pulmonary anatomic structures. This registration algorithm is fully automatic. The 3D disparity analysis is used to obtaining initialization transformation function. Further this function is updated by optimization algorithm and then the B-spline geometrical transformation is applied. The computation of disparity analysis is realized in spectral domain for lower computational complexity. Due to required low computational time and higher robustness of algorithm is performed image preregistration by the fast flexible registration based on disparity analysis too.

Key words: **Image pre-processing, flexible registration, disparity analysis, deformation field, pulmonary CT data.**

I. Introduction

The frequent investigative method which is using to obtain dynamic contrast data is four-dimensional (4D) computed tomography (CT) imaging. The data are images of the same scene, which are acquired at different times. To acquiring the correct information of the patient's anatomy and physiology of thoracic area, the acquisition scene movement and contrast changes during scanning must be taken into account. Local motion caused by breathing and heart activity can be estimated by flexible registration methods. The nonlinear registration can be described by equation

$$T(\boldsymbol{r}_{i,j,k}) = \boldsymbol{r}_{i,j,k} + \Delta\boldsymbol{r}_{i,j,k} \ , \tag{1}$$

where T is geometrical transformation, r is a position vector and Δr defines point deform in position coordinates *i, j, k.* The transformation field has space continuity C1. The main goal is to obtaining the velocity vector ($\Delta\boldsymbol{r}_{i,j,k}$), which has maximal value of criterial function C between reference I_{ref} and moving I_{mov} image defined by equation [1]

$$\Delta\boldsymbol{r}_{i,j,k} = \arg\max_{\Delta\boldsymbol{r}_{i,j,k}} C\left(I_{ref}(\boldsymbol{r}_{i,j,k}),\ I_{mov}\left(T_{\Delta\boldsymbol{r}_{i,j,k}}(\boldsymbol{r}_{i,j,k})\right)\right). \tag{2}$$

II. Method

In first step the data are undersampled with variant decimation factor depending on the data resolution. Due to this adaptivity are obtained 3D data with the constant size and model parameters depending on resolution are set to a fixed. Further the 3D uniform grid of control points (CPs) is created. The number of CPs defines spatial flexibility of local displacement and indicates level of computational complexity. To the estimate of large displacement the disparity analysis is used for each CP. Next step, smaller disparities are calculated on original size 3D data. Deformation values are updated by Nelder-Mead's optimization algorithm. This optimization model uses cosine local objective functions.

The algorithm can be described in these following steps:

- Undersampling with variant decimation factor
- Transformation functions estimate of large displacement (flexible pre-registration)
- Determining initialization deformation by 3D disparity analysis on original data
- Update deformation values for CPs by optimization algorithm
- B-spline approximation of transformation functions for each voxel
- Geometrical transformation

The 3D disparity analysis is realized by 3D nonlinear filter, where output of this filter is cosine criterial function Y. The computation is defined by equation:

$$Y = \frac{q_{i,j,k}}{\sqrt{p_{i,j,k}}}, \quad Q = [q_{i,j,k}] = H * A, \quad P = [p_{i,j,k}], \tag{3}$$

where A is sub matrix of fixed image, H is sub matrix of moving image rotated by 180° and P is the resulting matrix of the sequence: squaring elements of A and convolving the result with the matrix of ones, sized as H [1].

III. Conclusion

The proposed registration model is fully automatic with the permanent parameters settings. The first part is flexible preregistration and following initialization of deformation field by disparity analysis. Next, the optimization model based on simplex method is applied for updating of disparities values. For the geometrical transformation is utilized B-spline freeform deformation model with the linear interpolation.

The registration model can use segmentation mask, but this not strictly required. Nevertheless, results of registration with lung mask provide higher accuracy of estimate deformations.

The proposed model in sum is robust to settings and difference between other patient data and next strong point is low computational complexity. The average of time computation is 12 min per one patient (Intel Xeon CPU 2.53 GHz, RAM 48 GB). The algorithm was realized in programming environment Matlab®.

Reference

[1] JAN, Jiří. Medical image processing, reconstruction and restoration: concepts and methods. Boca Raton: Taylor, 2006, 730 s. ISBN 08-247-5849-8.