Journal of Fiber Bioengineering and Informatics 7:4 (2014) 507–516
doi:10.3993/jfbi12201404

Performance Comparison of Optimization Methods for Medical Image Registration ⋆

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Received 17 June 2014; accepted (in revised version) 30 October 2014; available online 17 December 2014

Abstract

In the process of medical image registration, the registration function (also so-called similarity metric) was taken as the objective function, and the multi-parameter optimization method as the tool for obtaining the optimal transformation parameters. In this paper, by the use of the mutual information as the registration function, the Powell method and the genetic algorithm were exerted to explore the optimal transformation parameters respectively, and their optimizing performances were evaluated and compared. The experimental results reveal that the Powell method can cater to both the mono- and multi-modality medical image registrations. Unfortunately, however, the genetic algorithm is not adopted for the medical image registration regardless of the registration accuracy or the running time and needs to be significantly improved.

Keywords: Medical Image Registration; Mutual Information; Optimization Method; The Powell Method

1 Introduction

Thanks to the rapid development and widespread use of the medical imaging technology and device for the modern clinic medicine such as surgical operation, disease diagnosis, computer-guided therapies and so on, the approaches to aligning medical images produced by diverse imaging devices have been one of the hot research fields in the medical image processing and is drawing more and more attention.

Medical image registration, theoretically originated from the use of remote sensing images in the military fields, is intrinsically a spatial geometrical transformation that enables the pixels or

⋆Project supported by the key Scientific Research Fund of Hunan Provincial Education Department, P. R. China (No. 13A064); the Construct Program of the key Discipline in Hunan University of Arts and Science; the Doctor Scientific Research Startup Project Foundation of Hunan University of Arts and Science.

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voxels representing the same structure in the medical images acquired from a different time, from a different scene or from a different modality to reach the space correspondence [1-4]. Over the past decade, great advancement has been made in the medical image registration technologies and many effective and applicable methods in practice have been introduced by the researchers around the world. Among these methods mentioned in the published literatures, the mutual information-based registration technology, as the classical and popular registration one, has been commonly and efficaciously used in the medical image registration [5-7]. Due to the use of the Mutual Information (MI) as the registration function, it is an automatic and accurate registration method without any prior segmentation. Alignment by maximization of mutual information to obtain the registration parameters needed to register was proposed by Paul et al. [8]. However, for the existence of mutual information function containing many local maxima, it easily traps into the local optima. So, the transformation parameters are not the global optimum ones. Fei [9], Slomka [10] and Radau [11], by using multi-parameter optimizations such as the Simplex and Powell methods, obtained the registration parameters [12, 13].

In this paper, the medical image registration and the mutual information technology are first introduced, then the optimization methods such as the Powell method and the Genetic Algorithm (GA) in detail are explained, finally their optimizing performances including two aspects of the registration accuracy and processing time assessed and compared.

2 Medical Image Registration

2.1 Process of Medical Image Registration

The medical Image registration consists of deforming a floating image to match a reference image. In particular, it includes four elements: feature space selection, spatial geometric transformation, registration function and transformation parameter optimization [1]. Among these four elements, the transformation parameter optimization is a very significant one because it occupies most of the running time of the medical image registration.

Suppose that the reference image $\boldsymbol{Ri}$ and floating image $\boldsymbol{Fi}$ are both of $M \times N$ pixels with the upper left pixel being $(1, 1)$ and the gray level being represented by L, the gray values at point (x, y) are $ri(x, y)$ and $fi(x, y)$ respectively, and T signifies the geometric transformation which maps the floating image $\boldsymbol{Fi}$ onto the physical space of the reference image $\boldsymbol{Ri}$. The medical image registration, in essence, is the process that optimizing the geometric transformation T enables the registration function between $\boldsymbol{Ri}$ and $\boldsymbol{Fi}$ to obtain the maximum results. Namely [14]

$$T_{optimal} = \arg\max_{T} S(\boldsymbol{Ri}, T(\boldsymbol{Fi})) \tag{1}$$

here S expresses the registration function between two images. If MI is selected as the registration function, then equation (1) can be rewritten by

$$T_{optimal} = \arg\max_{T} MI(\boldsymbol{Ri}, T(\boldsymbol{Fi})) \tag{2}$$

We note that, exploring an optimal transformation $T_{optimal}$ maximizes the MI. MI can be defined as follows

$$MI(\boldsymbol{Ri}, \boldsymbol{Fi}) = H(\boldsymbol{Ri}) + H(\boldsymbol{Fi}) - H(\boldsymbol{Ri}, \boldsymbol{Fi}) \tag{3}$$