An improved image registration and bias field correction coupled method for Brain MR images

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Abstract. Bias field causes considerable difficulty in the quantitative analysis of brain magnetic resonance (MR) images. Image registration is a necessary pre-processing step before quantitative analysis of brain MR data. A novel variational optical flow approach for image registration is proposed in this paper. The advantages of our method are as follows. First, we coupled bias correction and optical flow image registration within the unified variational framework in order to reduce the effect of bias field. Second, the regularization term based on the non-local information is proposed, which is able to preserve the image structure feature during the registration process. Moreover, we could recover the corrected target image through the estimated bias field. Experiments on synthetic and real brain images demonstrate the advantages of our method over Horn and Schunck(HS) model in terms of both efficiency and accuracy.

Keywords: optical flow; bias field correction; Non-local information; medical image registration.

1 Introduction

Image registration aims to geometrically match up two or more images of the same scene, taken at different times, from different viewpoints, or by different sensors, for structure localization, difference detection, and many other purposes. For brain MR image registration, many scholars proposed kinds of registration methods, such as mutual information based methods [1], intensity based methods [2]. The displacement field based on image registration is similar to the velocity field based on the optical field. Based on this idea, Palos and Hellier [3] have introduced the optical field to image registration. This method is based on the intensity information of the image, which can obtain more smoothed displacement. In order to obtain accurate results, many scholars have proposed many improved methods [4-7]. However, these improved models assumed that the optical flow field is continuous and smooth, which makes them hard to find the accurate edge information. Zach and Pock presented the dual method for small optical flow computation based on variational models [8],
which allows the displacement field discontinuities in the edge regions and robust to varying intensities. However, it is sensitive to the bias field.

2 Image registration and bias field correction coupled framework

In order to obtain accurate registration results and estimates the bias field, we present this framework:

\[
E^{\text{log-BHS}} = \int_{\Omega} \left( I_{\text{log}}(x,y,t) - B - I_{\text{log}}(x + \Delta x, y + \Delta y, t + \Delta t) \right)^2 dx dy
\]  

(1)

Compared with traditional optical flow based model, the registration and bias correction are coupled into a unified variational framework. The bias correction can improve the accuracy of the registration and the registration can make the bias correction more accurate.

We introduce the image non-local structural information to guide the optical flow. The proposed non-local optical flow regularization method as follows:

\[
u = \omega * u, \quad v = \omega * v
\]

(2)

Where \(\omega(i,j)\) is non-local kernel weight, which measured similarity between neighborhoods of image pixel \(i\) and neighborhood of image pixel.

3 Experimental results

Fig 1. Registration and bias correction on a brain MR image. (a) the target image; (b)registration image; (c)result of the HS model; (d) result of our model; (e) estimated bias field ; (f) corrected target image.
Fig. 1 shows the result on a brain MR image, which contain 3% noise, 20% bias field. Fig. 1(a) is the target image. Fig. 1(b) is the registration image. Fig. 1(c) shows the result of the HS model, which iterates 1000 times. Analysis of registration result could be seen, which keeps the target image structure information better in contrast strong places, but makes registration result serious blurred in low contrast areas. Fig. 1(d) shows the result of our model by iterated 1000 times. Compared to the HS model, The non-local image information could maintain image detail features and image consistency. Fig. 1(e) and Fig. 1(f) show bias field and the corrected image.

4 Conclusions

In this paper, we propose a new coupled variational model for brain MR image registration and bias field correction. We define energy functional with bias field correction, which mergers bias field correction and image registration into the unified framework to reduce the influence of bias field. Our model designs non-local information regularization to keep image structure feature information and image consistency. Another advantage of our method is that it can obtain the corrected target image.

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References