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Deformable image registration with geometric changes

Key words: Geometric changes, Image registration, Sparsity, Traumatic brain injury (TBI)

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Introduction

- Geometric changes present a number of difficulties in deformable image registration.

- We propose a global deformation framework to model geometric changes whilst promoting a smooth transformation between source and target images. To achieve this, we have developed an innovative model which significantly reduces the side effects of geometric changes in image registration, and thus improves the registration accuracy.

Main contribution

Our key contribution is the introduction of a sparsity-inducing norm, which is typically L1 norm regularization targeting regions where geometric changes occur. This preserves the smoothness of global transformation by eliminating local transformation under different conditions. Numerical solutions are discussed and analyzed to guarantee the stability and fast convergence of our algorithm.

Algorithm flow

Initialize p, q, b, c
for i=1:M **do**
    Forward image registration (source: $\boldsymbol{I}_0$; target: $\boldsymbol{I}_1$)
        Step 1: Update dual variable u in forward registration by Eq. (8)
        Step 2: Update incremental variable Δp by Eq. (11)
        Step 3: Compute sparsity term b by Eq. (12)
    Backward image registration (source: $\boldsymbol{I}_1$; target: $\boldsymbol{I}_0$)
        Repeat steps 1–3 for updating u in backward registration, Δq, and c
end

Experimental results

Table 1 Comparison of the average registration MSEs obtained using four different methods

Method	Average registration MSE	
	Forward	Backward
Consistent image registration	0.089	0.144
LDDMM	0.070	0.134
SVF	0.091	0.156
Proposed	0.040	0.048

Table 2 Processing time of forward registration obtained using four different methods

Method	Processing time (s)
Consistent image registration	4.8
LDDMM	960.0
SVF	7.0
Proposed	6.6

Conclusions

- Experimental results on real TBI image data demonstrated that our proposed approach can effectively reduce the side effects of geometric change. The sparsity-inducing penalty made a significant contribution to global deformation computation.