Hyperelastic Image Registration

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Abstract

Image registration is one of the challenging problems in image processing, where ill-posedness is one of the troublemakers and reasonable regularization is crucial. This talk presents hyperelasticity as a regularizer and introduces a new and stable numerical implementation. On one hand, hyperelastic registration is an appropriate model for large and highly non-linear deformations, for which a linear elastic model needs to fail. On the other hand, the hyperelastic regularizer yields very regular and diffeomorphic transformations. While hyperelasticity might be considered just an additional outstanding regularization option for some applications, it becomes inevitable for applications involving higher order distance measures like mass-preserving registrationn.

The talk gives a short introduction to image registration and hyperelasticity. The hyperelastic image registration problem is phrased in a variational setting and an existence proof for a solution is given. However, the focus of the presentation is on a solid numerical scheme. A key challenge is an unbiased discretization of hyperelasticity which enables the numerical monitoring of variations of length, surface and volume of infinitesimal reference volumes. We resolve this issue by using a nodal based discretization with a special tetrahedral partitioning.

The potential of the hyperelastic registration is demonstrated in a direct comparison with a linear elastic registration on an academical example. The paper also presents a real life applications from 3D positron emission tomography (PET) of the human heart which requires mass-preservation and thus hyperelastic registration is an only option.