Variational Image Registration with Local Properties

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Abstract. In this paper we are concerned with elastic medical image registration. By spatially varying parameters, a displacement field can be reached which is adapted to local material properties. In addition, it enables the introduction of discontinuities within the displacement field inbetween different anatomical structures, like bones and soft tissue. The capability of this approach is demonstrated by various academic examples.

1 Introduction

Nonrigid image registration is a challenging field of growing importance in medical imaging. The task is to find a vector field of displacements such that each point in a template image can be mapped onto a corresponding point in a reference image in a 'meaningful' manner.

By the notion 'meaningful' often a type of constraint is meant which both preserves the topology and prescribes identical elastic properties throughout the image domain. However, there exist several cases where changes in topology are essential and/or where anatomical structures behave different from each other. For instance, structures which are connected in one image may be disconnected in the other image, like the brain-skull interface subject to a brain shift. Furthermore, structures may move along each other and thereby causing discontinuities, like the liver or a joint and their surrounding tissues. In addition, soft tissue is of different elasticity compared to bone structures and therefore behaves different. Also, preservation of shape or volume may be a reasonable property.

Typically, the wanted displacement is computed subject to a smoothness constraint. For example, the constraint is realized by a regularization based on the linear elastic potential of the displacement. In general, the constraint is applied globally with one global regularization parameter and – for the elastic regularizer – with elastic properties independent from the image position. Usually, such a method provides satisfactory results due to the underlying physical model. Nonetheless it fails in cases described above, since a global regularization does not allow for any local changes in topology or material properties. Therefore, in this note a 'meaningful' transformation enables changes in topology, supports local material properties, possibly approximates a shape or volume preservation

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