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A Regression Model for Registering Multimodal Images

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Abstract

We propose a new multimodal image registration method when using different imaging modalities separately. The proposed method first aligns corresponding extracted geometric features (continuous curves), and then estimate the deformation vector field as spatial stochastic processes. The resulting deformation has the advantage of registering the given data in such a way that the corresponding curves-regions match as being sufficiently smooth over the whole image domain. Experimental results on both synthetic and real data show that the proposed method matches the state-of-the-art.

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Keywords: Elastic registration; Regression; Gaussian random field; Stochastic process; Smooth deformation vector field; Multimodal registration; Manifold embedding.

1. Introduction

The recent advances in imaging have led to an increased need for image registration methods which are used in a large number of applications including medical imaging, computer vision, graphics, etc. The image registration problem consists of mapping a target image to a reference image under certain constraints. The estimated deformation can be based on intensity (gray-scale level correspondences), geometry (features or landmarks) or both [1]. The registration problem can be rephrased as a variational or statistical problem where several different models are available to predict the deformation vector field on the whole image domain. Thus, one has to build an efficient model that best matches the given landmarks (points, curves, surfaces, etc.) accurately, e.g. as being smooth enough [2].

In medical imaging, registration and fusion are required for combining different modalities for monitoring of diseases, treatment validation, and comparison of the patient's data with anatomical atlases. In this paper, we focus on curves-based multi-modal registration for the preoperative, non-invasive diagnosis of endometriosis and we refer to [1] for general cases. In this context, the two modalities (MRI and TVUS) have different intensity distributions (see the example in Figure 1), which makes the intensity-based methods inaccurate. On the other hand, one can easily define common geometric features of corresponding organs in the two images (e.g. ovary and bladder outlines shown in

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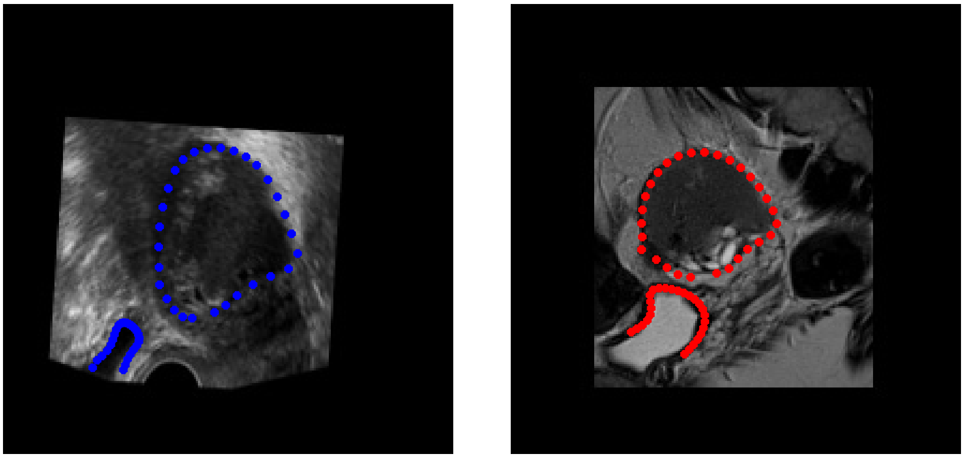

Fig. 1. Two examples of extracted curves (sampled for improved visualization) from multimodal images representing same disease: ultrasound left and MRI right.

Figure 1 sampled with a finite set of points for improved visualization), and use these landmark curves for registration purposes.

Landmark-based image registration has been solved by different numerical methods, among which kernel-based methods play a prominent role. In particular, the use of Thin Plate Splines (TPS) or TPS-based transformations was first proposed by Bookstein[3], and is still commonly used. Despite its popularity, one of its main drawbacks is its sensitivity to landmark locations and point correspondences. Recently, several methods have been proposed to overcome these issues[4], but unfortunately, without taking into account the invariance to curve re-parametrization and the local structure of data. Note that when the landmarks are discrete points, there is no re-parameterization issue. But, in the problem at hand, we are given curve landmarks that represent outlines of different organs, and thus, their parameterization plays an important role. Thus, the proposed method attempts to solve the **curves-based registration** problem by first computing optimal deformations between corresponding curves using geodesic paths under a parameterization-invariant elastic metric[5]. Then, using the optimal deformation vector fields defined on the landmark curves, we adopt a flexible interpolation technique, giving rise to adaptive (in smoothness and scale) local mappings, that can handle large and local deformations[6].

The rest of this paper is organized as follows. Section 2 describes the problem formulation and section 3 presents an application of the proposed method to register multimodal images. We close this paper with a brief conclusion in section 4.

2. Problem Formulation

2.1. Brief on Random Fields

The random fields' theory (also random functions, spatial stochastic processes) can be found in literature (e.g.[7,8]) with the introduction of stationary and second order stationary random functions and the use of Sobolev spaces. The short description in this section is limited to necessary notions that enable statistical inference on partial realization of random field, as it is usually the case in features-based registration as well as prediction problems. Indeed, spatial data