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Adaptive Non-rigid Registration and Structure from Motion from Image Trajectories

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Abstract This paper addresses the problem of registering a known 3D model to a set of 2D deforming image trajectories. The proposed approach can adapt to a scenario where the 3D model to register is not an exact description of the measured image data. This results in finding a 2D–3D registration, given the complexity of having both 2D deforming data and a coarse description of the image observations. The method acts in two distinct phases. First, an affine step computes a factorization for both the 2D image data and the 3D model using a joint subspace decomposition. This initial solution is then upgraded by finding the best projection to the image plane complying with the metric constraints given by a scaled orthographic camera. Both steps are computed efficiently in closed-form with the additional feature of being robust to degenerate motions which may possibly affect the 2D image data (i.e. lack of relevant rigid motion). A further extension of the approach allows to compute the full 3D deformations of the shape given the first initial (rigid) registration. This step results in solving a Non-rigid Structure from Motion (NRSfM) problem using the 3D known shape as a prior. Experimental results show the robustness of the method in registration tasks such as pose estimation and 3D reconstruction when degenerate image motion is present.

Keywords 2D-3D non-rigid registration · Structure from Motion · Factorization · GSVD

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1 Introduction

The non-rigid registration and reconstruction of 3D models from images is a problem of great relevance in several life science and engineering tasks. In general, the complexity of such problem rises from the ambiguity of decoupling the image motion created by the deformations and the overall rigid transformation and camera projection of the imaged shape. The work of Yezzi and Soatto (2003) is one of the first attempts towards the formalisation of such ambiguity in a theoretical framework. Their study introduces the use of a *shape average* of the deforming body which is used to distinguish the local deformations (a diffeomorphism) from the overall rigid motion. The identification of such shape average is the key factor which allows the computation of the transformations that the image shape is subject to. However, this shape has to be defined uniquely among all the possible set of observed shape in the image sequence. The chosen shape average as defined in Yezzi and Soatto (2003) is the one that moves with a global rigid motion and that minimises the deformation necessary to produce the observed image motion in the sequence.

In this paper, the studied registration problem has a close relation with the concept of shape average. In detail, we study the problem of registering a 3D model to a set of 2D trajectories extracted from an image sequence. The challenge is represented by the fact that the 3D model to register may not be an exact description of the 2D motion shown in the image sequence as exemplified in Fig. 1 in a face analysis domain. The aim here is to provide a new set of computational tools in order to find an optimised shape average which can adapt to the new information provided by the image sequence. This problem occurs more often thanks to the rapid advancements of the modern sensor technologies. Nowadays, it is a more likely occurrence to have avail-