Pose and Expression-Invariant 3D Face Recognition using Elastic Radial Curves

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In this work we explore the use of shapes of elastic radial curves to model 3D facial deformations, caused by changes in facial expressions. We represent facial surfaces by indexed collections of radial curves on them, emanating from the nose tips, and compare the facial shapes by comparing the shapes of their corresponding curves. Using a past approach on elastic shape analysis of curves, we obtain an algorithm for comparing facial surfaces. We also introduce a quality control module which allows our approach to be robust to pose variation and missing data. Comparative evaluation using a common experimental setup on *GAVAB* dataset, considered as the most expression-rich and noise-prone 3D face dataset, shows that our approach outperforms other state-of-the-art approaches.

On 3D facial surfaces, we extract radial curves as features and apply elastic shape analysis in order to keep the intrinsic surface attributes under isometric deformations even when the mouth is open. In other words, our choice of representation is based on ideas followed previously in [5] and [2] but using a collection of radial curves to represent a surface and not iso-curves. Our main contribution in this paper is an extension of the previous elastic shape analysis framework [3] of opened curves to surfaces which is able to model facial deformations dues to expressions, even with an open mouth face. We demonstrate the effectiveness of our approach by comparing the state of the art results. However, unlike previous works dealing with large facial expressions, especially when the mouth is open [4][1] which require lips detection, our approach mitigates this problem without any lip detection. Indeed, besides the modeling of elastic deformations, the proposed shape analysis-based framework solves the problem of opening of the mouth without any need to detect lip contours as in [4] and [1].

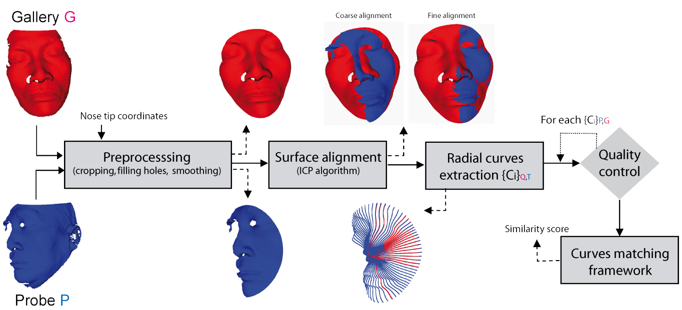

Figure 1: Overview of the proposed method.

Figure 1 illustrates the overall proposed 3D face recognition method. First of all, the probe **P** and the gallery **G** meshes are preprocessed. This step is essential to improve the quality of raw images and to extract the useful part of the face. It consists of a Laplacian smoothing filter to reduce the acquisition noise, a filling hole filter that identifies and fills holes in input mesh, and a cropping filter that cuts and returns the part of the input mesh inside of a specified sphere. Then, a coarse alignment is performed based on the translation vector formed by the tips of the noses. This step is followed by a finer alignment based on the well-known ICP algorithm in order to normalize the pose. Next, we extract the radial curves emanating from the nose tip and having different directions on the face. Within this step, a quality control module inspects the quality of each curve on both meshes and keeps only the *good* ones based on defined criteria. In order to improve matching and comparisons between the extracted curves, we advocate the use of elastic matching. Actually, facial deformations dues to expressions can be attenuated by an elastic matching between facial curves. Hence, we obtain algorithm for computing geodesics between pair wise of radial curves on gallery and probe meshes. The length of one geodesic measures the degree of similarity between one pair of curves. The fusion of the scores on good quality common curves, produced similarity score between the faces **P** and **G**.

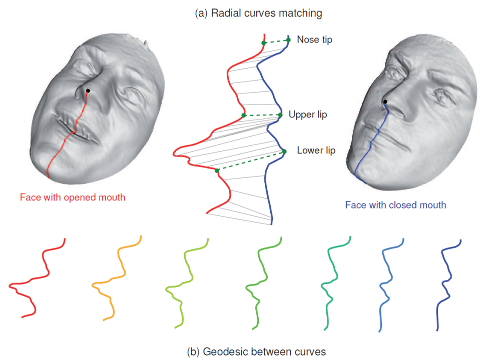

Figure 2: Matching and geodesic deforming radial curves in presence of expressions.

An example of this idea is shown in Figure 2, where we take two radial curves from two faces and compute a geodesic path between them in $\mathscr{S}$. The middle panel in the top row shows the optimal matching for the two curves obtained using the dynamic programming, and this highlights the elastic nature of this framework. For the left curve, the mouth is open and for the right curve, it is closed. Still the feature points (upper and bottom lips) match each other very well. The bottom row shows the geodesic path between the two curves in the shape space $\mathscr{S}$ and this evolution looks very natural under the elastic matching. Since we have geodesic paths denoting optimal deformations between individual curves, we can combine these deformations to obtain full deformations between faces. Comparative evaluation using a common experimental setup on *GAVAB* dataset, considered as the most expression-rich and noise-prone 3D face dataset, shows that our approach outperforms other state-of-the-art approaches.

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