Shape-based Automatic Detection of a Large Number of 3D Facial Landmarks

Syed Zulqarnain Gilani, Faisal Shafait, Ajmal Mian
School of Computer Science and Software Engineering,The University of Western Australia.

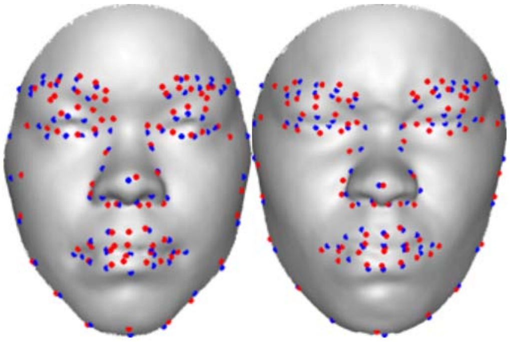

Figure 1: Our algorithm automatically detects an arbitrarily large number of facial landmarks by establishing dense correspondences between 3D faces. The figure shows 85 landmarks detected (red) on neutral and extreme anger expression of a subject from BU3DFE database [3]. The ground truth is represented by blue dots.

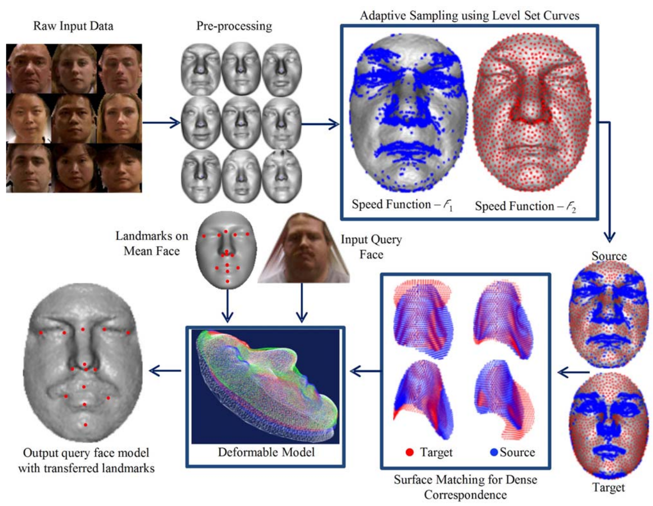

Figure 2: Block diagram of the proposed algorithm. Level set curves are evolved with adaptive speed functions to find seed points on preprocessed face scans. Seed points are matched by minimizing the bending energy of their neighbourhood patches to find dense correspondences. A deformable model is then constructed and fitted to unseen faces to transfer correspondences and hence landmarks.

Due to the non-invasive nature of shape acquisition, 3D morphometric analysis based on facial landmarks is becoming a tool of choice in the fields of anthropometry, human biology and medicine. A major bottleneck in large-scale 3D facial morphometric analysis is the manual annotation of biologically significant landmarks, which in turn is a limiting factor in research on huge datasets, or where the number of required landmarks is large. Thus, there is an urgent need for a robust technique that is able to automatically detect a large number of biologically significant landmarks.

Current landmarking techniques have focused on a sparse set of facial landmarks and detect these landmarks by exploiting their intrinsic characteristics. We cast the problem of facial landmarking as a sub-problem of 3D dense correspondence. This enables us to detect a large number of fiducial landmarks. The challenge of establishing dense correspondence is to find a mapping of a significant number of points on one surface to their equivalent points on the second surface. The 3D shapes generally have non-linear surface dissimilarities, making sparse correspondence insufficient for landmark localization. The challenge is further compounded by the unavailability of the ground-truth shape correspondence. Our method proceeds by evolving level set geodesic curves on each 3D facial surface and samples

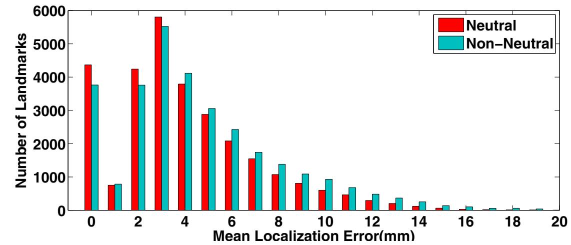

Figure 3: Histogram of mean localization error for 18 landmarks on 4,007 scans of FRGCv2 dataset (18×4007 Landmarks).

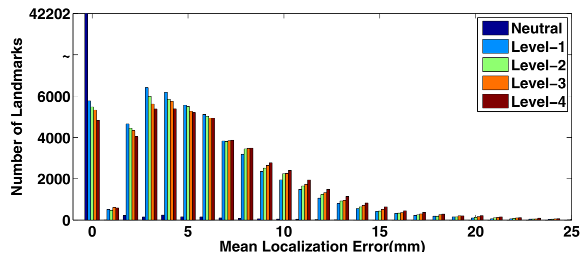

Figure 4: Error distribution histogram of 85 landmarks on 2,500 scans of BU3DFE dataset (83×2500 Landmarks). Notice that the mean error for majority of landmarks on neutral expression is less than $2mm$.

farthest location points [1]. These sample points are then mapped to their corresponding points on a reference 3D face by matching the surface around each point. A cost function defined over bending energy is minimised to select the best corresponding points. Finally, a morphable model based on the dense corresponding points is fitted to an unseen query face for transfer of correspondences. Figure 2 illustrates the complete algorithm. Our algorithm is hierarchical and evolves level set curves with adaptive speeds to detect even the most subtle feature points.

Our key contributions are the following. (1) Unlike existing methods, our algorithm is not designed for detecting specific landmarks that have discriminative geometric properties. Instead, we can detect any number of pre-defined landmarks including subtle landmarks that are difficult to detect manually or with feature matching algorithms. (2) We combine level set curve evolution with geometric speed functions to automatically extract effective seed points for dense correspondence. (3) With a hierarchical structure, our algorithm is capable of extracting thousands of corresponding points on a large set of faces.

We have performed extensive experiments on publicly available FRGCv2 [2] and BU3DFE [3] databases and have compared our results with six state-of-the-art methods. Existing methods have reported results on different number of landmarks, ranging from 6 to 14. Our method has achieved lower mean localization error than the competing methods on all of those landmarks. Furthermore, we report, for the first time, landmark localization on all 83 ground-truth points provided with the BU3DFE dataset. A histogram of error distribution, separately for the neutral and non-neutral scans of FRGCv2, is shown in Figure 3. The histogram of error distribution for each intensity level of the six facial expressions in BU3DFE database is shown in Figure 4.

[1] Gabriel Peyré and Laurent Cohen. Geodesic computations for fast and accurate surface remeshing and parameterization. In *Elliptic and Parabolic Problems*, pages 157–171. Springer, 2005.

[2] P.J. Phillips, P.J. Flynn, T. Scruggs, K.W. Bowyer, et al. Overview of the face recognition grand challenge. In *IEEE CVPR*, 2005.

[3] Lijun Yin, Xiaozhou Wei, et al. A 3D facial expression database for facial behavior research. In *Automatic Face and Gesture Recognition*, pages 211–216, 2006.

This is an extended abstract. The full paper is available at the Computer Vision Foundation webpage.