Face Modeling From Frontal Face Image Based on Topographic Analysis

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1 Introduction

Accurate face representation and modeling could help improve the 3D face recognition. This research attempts to model the human face based on a single image input in a high level of accuracy. We developed a novel face modeling system using an explicit face surface representation, the so-called topographic representation, and a generic model individulization process, as outlined in Figure 1.

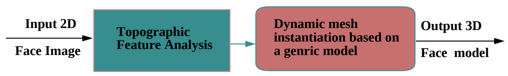
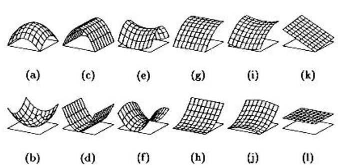


Figure 1: High-definition face modeling system

2 Topographic Representation

In order to drive a generic model to a facial surface, we need to make an explicit representation for the facial structure. Here the topographic primal sketch [Haralick et al. 1983] is explored to label facial surface features, where the face image is treated as a topographic terrain surface. We distinguish the topographic features of a face by twelve labels, as shown in Figure 2. Each pixel is assigned one of the topographic labels (e.g., ridge, ravine, hill, etc.) These topographic categories reveal the light intensity variations caused by the 3D intrinsic facial surface reflections, which are inherently capable of invariance under monotonic transformations. The topographic label classification is determined by the estimation of the *Hessian matrix*, which is formed by the first-order and second-order directional derivatives of the surface. We use Chebyshev polynomials to approximate the terrain surface. The eigenvalues (λ_1 and λ_2) of the matrix are the values of the extrema of the second directional derivative. The pixel labeling is based on the values of λ_1, λ_2, and their directions. For example, a pixel is labeled as a convex hill if the following condition is satisfied: $\lambda_1 < 0$, $\lambda_2 > 0$ and $|\nabla f| < T_G$. Since the skin "wave" is associated with the facial surface movement, the skin surface with a certain expression at a different time will have different shapes, resulting in the different label changes, for example, from the concave hill to convex hill, from the ridge saddle to ravine saddle. This is known as dynamic labeling along with shape change. We can imagine that the skin surface is represented as a topographic label "map", this "map" is changed along with the skin tissue movement. With surface feature classification, we can drive a dynamic model to fit to the facial surface.



(a) peak; (b) pit; (c) ridge; (d) ravine; (e) ridge saddle; (f) ravine saddle;
Hills: (g)convex; (h) concave; (i) convex saddle; (j) concave saddle; (k) slope; (l) flat.
(a)-(l): The center pixel in each example carries the indicated label.

Figure 2: Topographic labels for facial details representation.

3 3D Model Individulization

Recent advances on realistic face modeling rely on either morphable model database [Blanz and Vetter 1999], or multiple photographs. Here, we use only one input image and one generic model to create a 3D facial model with sufficient accuracy. We take the model as a dynamic structure, in which the elastic meshes are constructed from nodes connected by springs. The motion for the dynamic node system is formulated to a second-order differential equation [Terzopoulos and Waters 1993]. Differing from the traditional method, we fit the generic model onto the topographic surface of a face with a 3D external force for simulating the skin "wave" deformation: (1) In the image plane, an external force is exerted by the gradient of the topographic surface; (2) In the direction that is perpendicular to the image plane, a vertical spring with one end attached to node i and the other end able to slide along the topographic surface. We apply image data (*e.g.*, surface curvatures) as external force which deflect (or pull) the mesh perpendicular to the image plane so that its 3-D shape becomes consistent with the face surface. In addition to external forces applied, the fitting process incorporates a feedback procedure which automatically adjusts spring parameters c_k according to the topographic features that the spring covers. We use six types of topographic labels: ridge, ravine, convex hill, convex saddle hill, concave hill and concave saddle hill. The ridge and ravine labels signify the key features location (e.g., eyebrows, eyes, nose, nose-bridge and mouth). Hill labels represent the facial surface features which connect ridge or ravine regions. It makes sense to increase the stiffness c_k and the external force of spring k in areas close to the ravine and ridge lines and boundaries of different regions. As such, the mesh can distribute itself in both salient feature areas and facial surface "wave" areas. This dynamic modeling process creates a "tight" fitting model.

4 Result

The accurate representation of 3D face is demonstrated through both static and motion images. 370 face images and 5 video sequences have been modeled by our system. Figure 3 shows one example of the modeling process. The face model contains 3700 vertices. In the future, we will extend the work for applications of high-definition 3D face recognition.

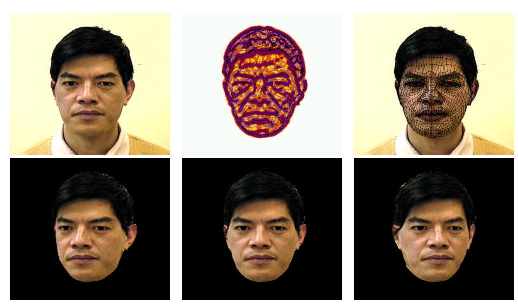


Figure 3: Face modeling example: [Top] Original face; Topographic map; Adapted model; [Bottom]: Different views of the created model.

References

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*Acknowledgment: this material is based upon work supported by the National Science Foundation under grant No. IIS-0414029.