3D Human face modeling from un-calibrated images

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Head modeling should be considered as a special case in the general problem of 3D object modeling. The reason is two fold. On one hand the symmetric form of human face and the subtle anthropological relations between facial features makes even slight deformations unacceptable. On the other hand, the geometric properties of human faces are very near to each other. This means creating the face model of a specific person needs very accurate measurements.

One solution to this problem which makes use of the similarities between different faces and their anthropological properties is starting with a generic model. This model may be considered as the average geometric model of distinct faces.

Our algorithm takes advantage of this fact and tries to deform a generic model to a specific face. The deformation process requires local re-triangulation in the areas with high curvatures. This is achieved by locally applying Delaunay triangulation method. Our system starts with obtaining a sequence of images from the person to be modeled. The locations of five feature points are provided by the user in these images. Auto calibration of the camera provides the intrinsic camera parameters. Then it proceeds with obtaining and reconstructing some interest points from the face and deforming the generic mesh using these points.

Geometric Head Modeling

This section describes in detail the proposed algorithm for geometric modeling of human faces. Our algorithm has the following features.

Input:

> Two sets $S1$ and $S2$ of 3D points from the surface of the face. First group of points are labeled with the ID number of the related facial feature and the position of the point in the feature. As an example a point in this group may be given as p(*Nose; Tip*). Second group of points are not labeled.
>
> A generic model of the human face in the form of a 3D mesh.
>
> Texture values given in cylindrical format.

Output: Textured 3D model of a specific face.

The input points are obtained in two stages. In the first stage 9 points of the facial features are located in the images and their 3D positions are obtained. This step involves locating and matching the feature points and their reconstruction. Second set of input points are random points from facial areas in the images. The points in this group are obtained by applying an interest point detector (Harris corner detector) and then finding the corresponding point in the second image and reconstructing the 3D point. In the first two steps the generic mesh is scaled so that each face segment between facial features corresponds to the size of the same region in the images. Step 3 and 4 deforms features and face surface and step five refines the mesh. The five steps in details are as follows.

1. Global scaling the generic mesh.
2. Local scaling the generic mesh.
3. Coarse deformation.
4. Fine deformation.
5. Mesh smoothing.

Since the mesh model and the input points may be in different sizes, first step performs a scaling operation based on the maximum and minimum coordinate values of the points in the input set. No local displacement of the facial features is done here. Facial feature sizes and locations are different in each face. The generic mesh is divided into four layers which are separated by the corners of lips, nose tip, and corners of eyes. The vertices corresponding to these boundary points are displaced to match their true values. The locations of the remaining intermediate vertices are computed by interpolating over the displacement of the boundary vertices. The values of the boundary vertices are given as the first input set of 3D points. In this step the 3D points from the first group are used to deform the generic mesh. In coarse deformation step since the points are labeled, we displace the corresponding feature vertices and bring them to the locations given by these input points. Two main issues are considered in this displacement:

1. Anthropological relationship between face features should be preserved.
2. Displacing a vertex should not create unrealistic warps such as corners with sharp curvatures.

To impose both restrictions we are considering the mesh as an interconnected set of vertices in which displacing a vertex affects other (specially neighboring) vertices. Therefore moving a facial feature or one of its vertices in a direction imposes a force on all vertices connected to it drawing them in the same direction. This force is simulated by considering the links connecting the vertices as mass less spring in equilibrium states. Total force generated by the springs around a vertex determines its new position. Our aim by introducing the spring term is avoiding sharp sparks in locations with high rate of change and small edges. However, unwanted warps in the mesh can not be avoided by just considering the spring like connections between vertices. In this specific mesh deformation application we have the advantage of knowing the general form of the face *apriori*. Therefore to preserve the topology of the mesh we have added a second restriction using the principal curvatures at a given point on a surface which measures the maximum and minimum bending of the surface at that point. To find out the principal curvatures we are comparing the normals to facets about a vertex and the minimum and maximum angles between these normals define the curvature. Drawing a vertex to a new position may cause encroaching on a link by another one. This makes small concave holes and artificial crease lines when mapping texture to facets. Our solution to this degeneracy is gradual displacement of each node and propagating the displacement to the neighboring nodes. For each point in the second set of the 3D points, a similar deformation is necessary. However in this step we are not sure about the vertex correspondences between new points and mesh vertices. Furthermore there may be no corresponding vertex for a 3D point at all. The latter case requires a re-triangulation in that part of the mesh. Therefore this step starts with a search for finding the nearest vertex to the position of a 3D point from the second set. In this step, we do not expect a drastic change in the form of the generic mesh because it has been already undertaken three deformation steps and the new points should add slight modifications. We are considering a threshold in the distance between the 3D point and the nearest vertex. This threshold value bans large changes in the mesh. If the 3D point is within the open ball $B(k; t)$ defined by the nearest vertex k and threshold *t*, then the vertex is moved towards the 3D point using the same algorithm as used in step 3. However, the point may be near to the outer surface of the mesh but far from any vertex in it. This generally happens when a surface with low curvature has been linearly approximated by a large facet which gets far from the real surface in mid parts of the facet. Hence the new 3D points aim at refining surface by a better approximation of the volume space occupied by the mesh. In these cases we are inserting the new point as a new vertex to the mesh. The insertion however, considers several possible cases depending on the location of the vertex and topology of the mesh in that region.

Texture Mapping

Texture mapping is the last part of the human face modeling. To have a view independent texture map, we construct the texture on a virtual cylinder enclosing the face model. For each vertex on the face mesh, we compute the blending weight of each image based on the angle between surface normal and the camera direction. If the vertex is invisible, its weight is set to 0.0.