Correspondence of 3D polygonal shapes

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The Problem: To develop software to semi-automatically generate a correspondence between two three-dimensional colored surfaces (example shown in figure 1).

Motivation: If two objects can be set in correspondence, then a class of objects can be modeled in the following way. First all objects are set in correspondence, one by one, with an base object. These correspondences represent warpings of one object to other objects in the same class of instances. When these warpings are combined in a linear network as described in [5], we have then created a model of the object class. Novel objects in this class can be created by adjusting the parameters of the network and new objects can be expressed in terms of these warpings.

Previous Work: Similar networks have been successfully built for two-dimensional images. [2] used such a technique to synthesize images of a face under two pose-expression parameters. The important step is to build the correspondences. On images, optical flow algorithms have been found to work well where there are dense correspondences [2] [1]. When a set of correspondences has been built, pixel-wise correspondences can be built using linear combinations of prototypes as demonstrated in [4].

Thomas Vetter and Volker Blanz have already produced promising results generating correspondences between three-dimensional models of faces. By constructing a cylindrical representation of the object containing both radius and color information, they were able to produce good correspondences for faces using an optical flow algorithm. This algorithm has also performed well in the case of automobiles.

Approach: For our approach, we will work in the three-dimensional space of the object instead of projecting onto a two-dimensional surface. In this way, we hope to avoid problems with projections including distortion and difficulty in representing concave objects. However, this means that in the general case, we will have to solve the problem of warping one three-dimensional mesh into another.

Yet, there are a couple of important advantages we hope to exploit. The first is that the objects are similar (i.e. two different cars or two different faces). The second is that the objects can be colored by hand to aid in the correspondence.

Our approach is to first construct a “pyramid” of meshes (not unlike pyramid schemes for optical flow). This consists of a set of progressively simpler meshes each approximating the original. Currently, we are using an approximation to Hoppe’s progressive mesh technique [3] to construct these simpler objects. After constructing this set of the base object, we use gradient descent to minimize an energy term designed to measure the “distance” from the base object to the target object.

By first applying this energy minimization to the simplest mesh and then using the resulting correspondence as a starting point for minimizing the next mesh in the pyramid, we gain two advantages. The first is in running time. Minimizing the energy for fewer points takes less time and we can perform much of the needed morph with the simpler meshes. The second is in quality of the correspondence. By simplifying a mesh, we essentially remove the less important variables in its appearance. Thus, by first matching the most important control points in the mesh and then progressively building up to finer and finer detail, we can create a better correspondence.

Difficulty: In many cases, there is no clear “correct” solution to the correspondence problem. Often a feature on one object does not appear on another. Sometimes the shape of the target object cannot be expressed with the polygons of the original object. In general, when no perfect solution can be found, the difficulty is in mathematically defining which solutions are the better.

Impact: Building a linear model of a class of objects can have many benefits. One is as a design tool. Creating novel three-dimensional polygonal shapes for use in computer graphics is not a simple job. By combining known instances of the same class in such a network as described above, a user wishing to design a novel instance of the class can work with the parameters of the model to create the new shape (e.g. car, cup, face). The parameters of the network are