

A Mesh Simplification Algorithm Applied To Mpeg-4 Compliant 3D Facial Models

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ABSTRACT

This paper describes of an efficient mesh simplification algorithm, based on the iterative edge contraction, applied to MPEG-4 compliant 3D animated faces.

Among the several simplification techniques available in literature, the one offering the best trade-off between quality of the simplified model and simplification time has been selected and briefly described.

In the following pages, it will be shown that rather complex 3D facial models, optionally textured, can be simplified in real-time in order to adapt the rendering performances to the hardware capabilities, still maintaining the compliance with the MPEG-4 specifications on facial animation.

1.INTRODUCTION

Recently, the interest around mesh simplification has increased significantly. The idea of having a virtual 3D model at different resolutions is not a new concept: Clark [10] introduced the concept more than 25 years ago.

However, most significant achievements in this area have been obtained in recent years, when several techniques have been proposed by many researchers, like the "vertex decimation" (Shroeder et al. [1]), the "vertex clustering" (Rossignac and Borrel [11]), the "iterative contraction" (Hoppe et al. [2] and Garland et al. [3]).

In this paper, a simplification technique is applied to MPEG-4 animated faces, to prove how it is possible to reduce the model complexity even during an animation, still preserving a correct interpretation of the facial animation parameters defined by MPEG-4.

2.ITERATIVE EDGE CONTRACTION AND QUADRIC ERROR METRIC

The algorithm proposed by Garland et al in [3] is

based on two main concepts: the Iterative Contraction of Edges and the Quadric Error Metric. The algorithm processes the original surface and iteratively removes vertices and faces from the model. At each step, a single operation consisting of the contraction of a pair of vertices, is performed (see fig. 1).

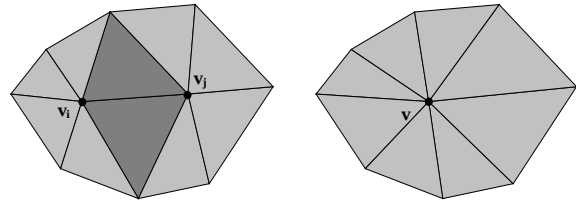


Figure 1: Contraction of two vertices with a common edge: (left) before and (right) after contraction

This operation, written in [3] as $(v_i, v_j) \rightarrow v$, where v_i and v_j are the original vertices and v is the contraction result, modifies the model surface in three steps:

- 1) v_i and v_j are moved to the new position v .
- 2) all the occurrences of v_j are replaced with v_i
- 3) v_j and all the degenerated faces are removed.

The first step actually modifies the surface geometry, the second modifies the surface topology, and the last one removes elements that are not necessary anymore. The algorithm is initialized by selecting all the possible pairs of vertices candidate for the contraction (for instance, all the vertices which share a common edge), and then assigning a cost for the contraction to every pair. Hence, the contractions are performed starting from the one with the minimum associated cost, obviously updating all the remaining contraction costs at every step.

Many algorithms based on the iterative edge contraction have the structure described above. A cost value is associated to each pair of vertices according to various different criteria. Each contraction introduces an approximation error on the mesh, which is typically proportional to the cost associated to the contraction.

Evidently, the definition of the contraction cost is a key issue. In literature, many methods for the estimation of the error introduced by a surface approximation have been proposed (e.g. [2], [1], [9], [6].).

However, the metric that best fits the purpose of simplifying a facial model in real-time is once again suggested in [3]. The proposed technique, the quadric error metric, satisfies both real-time requirements and the quality of the simplified surface.

The term quadric is introduced by Garland et al. because, if we define $Q(\mathbf{v})$ the function representing the error introduced after a vertex pair is collapsed, the surfaces defined by $Q(\mathbf{v}) = \epsilon$ are quadric surfaces. With this metrics, when a pair of vertices $(\mathbf{v}_i, \mathbf{v}_j)$ is collapsed, the resulting quadric for the new vertex $\mathbf{v}$ is given by $Q = Q_i + Q_j$, being Q_i and Q_j the quadrics associated to $\mathbf{v}_i$ and $\mathbf{v}_j$ respectively.

The cost of the contraction $(\mathbf{v}_i, \mathbf{v}_j) \rightarrow \mathbf{v}$ is then computed as $Q(\mathbf{v}) = Q_i(\mathbf{v}) + Q_j(\mathbf{v})$.

It is clear why the described metrics is very efficient in terms of computation burden and in terms of memory requirements: in fact each vertex is associated with a quadric and this is the only information needed to evaluate the approximation error.

The position $\mathbf{v}$ of the new vertex introduced as a consequence of a collapse is optimal if, for a given quadric Q , $Q(\mathbf{v})$ is minimized. The position of the new vertex is sub-optimal in the other cases. Among them, it is relevant the case when, after contracting the pair $(\mathbf{v}_i, \mathbf{v}_j)$, the new vertex is placed in $\mathbf{v}_i$ or $\mathbf{v}_j$. With this approach, that is the one selected in the proposed work, the simplified model is in fact composed by a subset of the vertices of the original model.

Finally, the simplification algorithm also allows preserving discontinuities in the original model, like open edges or borders between different face materials. These elements have a significant visual importance, because they often represent the most significant details of the model. In order to preserve them, the algorithm adds a large penalty factor to the quadric of each vertex of the edge/border to be preserved.

3.SIMPLIFICATION OF MPEG-4 COMPLIANT FACE MODELS

The simplification algorithm described above has been applied to MPEG-4 compliant face models, and integrated into the animation software known

as Facial Animation Engine (FAE) [4].

In order to comply with the MPEG-4 specifications on both the original and simplified models, and also to guarantee a successful integration of the animation and simplification algorithms, the following requirements have been imposed:

- the properties of the simplified model must be preserved in order to allow its animation, i.e. the animation rules that the FAE automatically computes for the original model must still be valid without additional computations on the simplified model;
- the feature points [4] must be preserved, as well as borders between different parts of the face (like lip contours);
- when possible, the symmetry of the face has to be exploited to reduce the simplification time (once a vertex pair is selected for contraction, it's likely that the next pair selected is the symmetric pair).

The simplification criteria are controlled by only two parameters: the desired number of faces on the simplified model and the maximum error allowed during a contraction. While the first parameter has a clear meaning, it is important to spend few words on the second one. The error threshold proved to be a rather good objective criterion for defining the subjective quality of a face model, and is therefore useful to avoid the removal of a too high number of faces during the simplification process.

3.1.Animation of the simplified model

Since the FAE computes the animation rules as a function of the vertex spatial position and not as a function of the mesh topology, it was decided to adopt a sub-optimal strategy for the placement of a new vertex after a collapse of a pair. Therefore, given the contraction $(\mathbf{v}_i, \mathbf{v}_j) \rightarrow \mathbf{v}$, $\mathbf{v}$ is located in $\mathbf{v}_i$ or in $\mathbf{v}_j$; in other words, during a contraction, one of the two vertices is removed, all the other remaining unchanged.

After the FAE has loaded the original model and has computed the animation rules, it is possible to start the simplification process without the need to compute the animation rules again, since the position of the model vertices is not modified (fig.2).

3.2.Preservation of materials, open edges and feature

Especially in the model of a human face it is essential to preserve edges between regions of different colors (or materials). In figure 3 is shown a simplification of the Oscar model, in use at the DSP Lab of DIST, without preservation of borders. From the reported

images it is evident the fact that borders between regions may cause loss of subjective quality even at the very first steps of the simplification process. For instance, in the central image of figure 3, the loss of the pupil shape represents an unacceptable degradation of the subjective quality of the simplified model.

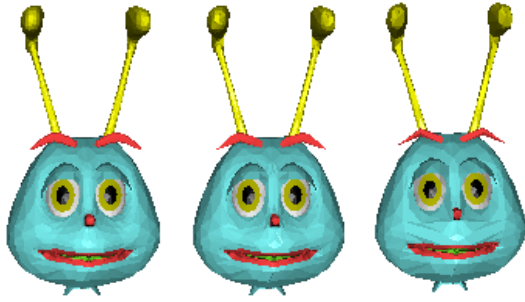


Figure 2: Example of animation of the Anty model: (left) original, (center) simplified to 60% and (right) to 40%.

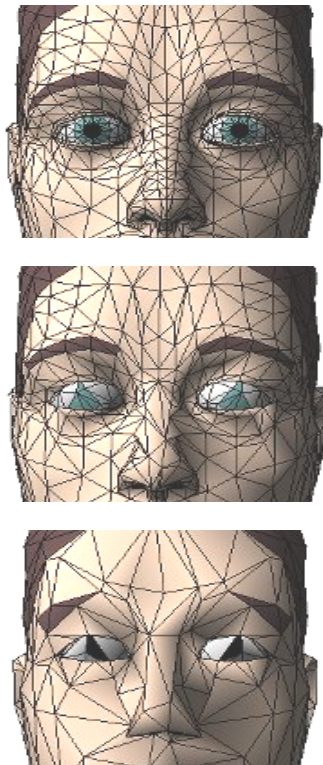


Figure 3: Simplification of the Oscar model: (top) original with 2444 polygons, (center) simplified to 1944 polygons, (bottom) simplified to 840 polygons, without border preservation.

For these reasons, it has been decided to preserve, during the simplification process, the borders of regions like irises, pupils, lips, nostrils and eyebrows. In addition to that, vertices associated to feature points and open edges, like the neck, have been preserved as well. In figure 4 the Oscar model is simplified again, with the same number of polygons as in figure 3, but this time preserving feature points and borders.

Preservation of feature points is necessary not only for the subjective quality of the simplified model, but also to guarantee a consistent animation. In fact, to the feature points are applied the model deformations described by means of the Facial Animation Parameters (FAP) [4] defined in MPEG-4.

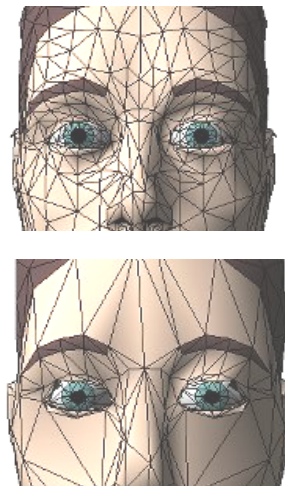


Figure 4: Simplification of the Oscar model: (top) simplified to 1944 polygons, (bottom) simplified to 840 polygons, with border preservation.

3.3.Texture

Let us consider now texture mapping. Texture is a image applied to the model surface in order to increase the realism of the virtual object; it does not modify or increase the complexity of the mesh itself but simply adds to it photographic details. The process of applying a texture to a surface is known as texture mapping. To map a texture onto a polygon, it is necessary to assign to each vertex of the polygon a pair of texture coordinates.

In literature, the problem of simplifying a textured model has been faced by Hoppe [5][7] and Gardland [8]. In their works, they extend the concept of quadric metric to keep into account material properties like texture. Though they often use a optimal criterion for positioning vertices generated by a collapse, the algorithm described in this paper still uses a sub-optimal criterion to guarantee real-time performances.

Therefore, as we have seen for the geometry simplification, if we consider the pair ($\mathbf{v}_i, \mathbf{v}_j$) and if the new vertex is located in $\mathbf{v}_i$, its texture coordinate will be that of $\mathbf{v}_i$; the same applies if the new vertex is located in $\mathbf{v}_j$. Figure 5 shows an example of simplified textured model: the textured simplified model is almost indistinguishable from the original.

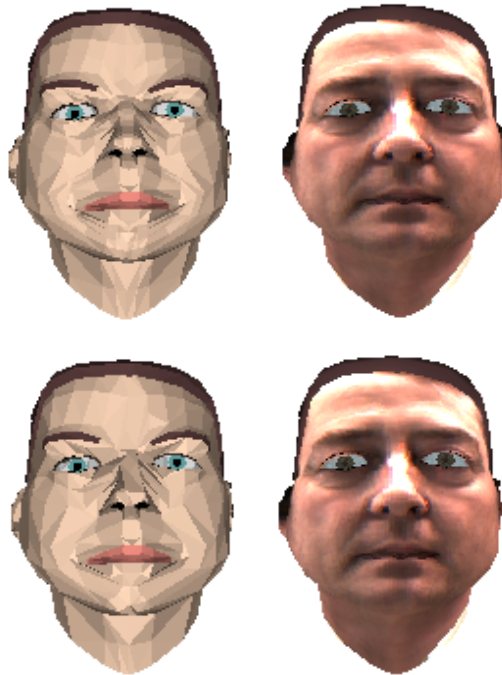


Figure 5: Simplification of a textured model: (top) non textured and textured original, (bottom) simplified to 60%.

4.CONCLUSIONS

This work describes our experiments about the use of mesh simplification algorithms with MPEG-4 animated faces. It has been proved that MPEG-4 compliant faces can be animated and simplified in real-time (a 5000 polygon model is simplified to 50% in 600ms on a Pentium II 233).

The target of this work is that of making MPEG-4 facial animation available on low-performances PC and portable devices, by simply scaling the model complexity and therefore increasing the rendering performances (up to 40% decrease in the rendering time with a model simplified to 50% on a Pentium II 233).

5.REFERENCES

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