SURFACE SIMPLIFICATION GUIDED BY MORPH-TARGETS

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Abstract: Many effective automatic surface simplification algorithms have been developed. These automatic algorithms create very plausible results in many cases, but at very low levels of detail they do not preserve the visual appearance of the original model very well. This could be improved if surface simplification algorithms were able to make use of semantic or high-level meaning of models. The idea of our new method using a morph-target-based surface simplification is to use distance information inside the morph-targets to acquire the relative importance of different surface regions without user guidance. Using this additional input the model is simplified by using modified quadric error metrics.

1 INTRODUCTION

An important field of activity at the Interactive Graphics Systems Group (GRIS) are conversational user interfaces where the primary goal is to give the computer a face to talk with. The goal is the development of software architectures to shift complex tasks to human like assistants (avatars) which can be incorporated on different stationary and mobile devices like laptops, PDAs and mobile phones. Our present work deals with scalability of animation and graphical representation of avatars to make our system available even on small platforms. More details are provided in (Berner and Rieger, 2005) and (Rieger, Taponecco and Berner, 2005). In this paper, we will focus on optimization strategies for the graphical representation of a conversational avatar.

During the last years many effective automatic surface simplification algorithms have been developed which generate a surface approximation of fewer polygons from complex models. These automatic algorithms create very plausible results in many cases, but at very low levels of detail they do not preserve the visual appearance of the original model very well. This could be improved if surface simplification algorithms were able to make use of semantic or high-level meaning of models. Kho and Garland introduced a user-guided mesh simplification (Kho and Garland, 2003) that allows the user to selectively control the relative importance of different surface regions. While this approach allows to preserve the visual appearance of the original model well, interaction from the user is required to achieve this result. The idea of morph-target-based surface simplification is the usage of distance information inside the morph-targets to acquire the relative importance of different surface regions without user guidance. Using this additional input data the graphical model is simplified by using the well known quadric error metrics (Garland and Heckbert, 1997) as the base simplification algorithm.

2 BACKGROUND

Many successful methods to simplify a given complex mesh are based on iterative edge contraction (Hoppe, 1996, Garland and Heckbert, 1997, Lindstrom and Turk, 1998). These approaches iteratively collapse edges in increasing order of cost, not regarding any semantc meaning of a differentiated region. On the other hand, there are amongst others three semi-automatic simplification methods "Zeta" (Cignoni, 1998) , "Semisimp" (Li and Watson, 2001) and "User-Guided Simplification" (Kho and Garland, 2003) which are using user interaction to produce improved simplification results. Zeta requires a precomputed sequence of simplifications as input. Users can selectively refine a model by locally changing error

thresholds. With Semisimp the user uses a vertex tree structure to provide segmented simplification.

Now, let's have a more detailed look at the User-Guided Simplification. The method of Kho and Garland modifies an input model in an interactive manner and produces a simplified version guided by geomety constraints. They use a quadric based simplification method as a base algorithm (Garland and Heckbert, 1997), working in the following way.

A given plane nv+d=0 with unit normal n and point v defines a quadric Q. Q is

$$Q=(A,b,c)=(nn^T,dn,d^2) \qquad (1)$$

The squared distance of a point v to the plane is:

$$Q(v)=v^T A v+2b^T v+c \qquad (2)$$

and the error at a vertex v to a set of planes is the sum of squared distances:

$$\Sigma\, Q_i(v)=(\Sigma Q_i)(v) \qquad (3)$$

During the initialization phase of the algorithm each vertex is assigned a quadric derived from the normal and the incident faces. For each possible edge contraction $(v_i,v_j) \rightarrow v_{ij}$ the optimal position and the contraction cost is computed by:

$$v_{ij}=-(A_i+A_j)^{-1}(b_i+b_j) \qquad (4)$$

and

$$Q(v_{ij})=Q_i(v_{ij})+Q_j(v_{ij})=(Q_i+Q_j)(v_{ij}) \qquad (5)$$

The new vertex after the edge collapse accumulates the quadrics by

$$Qv_{ij}=Q_i+Q_j \qquad (6)$$

The quality of the approximation is determined by the order of contractions, respectively by the costs. The main idea of the algorithm from Kho and Garland is to guide of the simplification by manipulating the quadric associated with each vertex. One way to do this is weighting the quadrics adaptively. This is done by the user painting on the surface of the geometric model. Based on this interactive input, the quadrics are weighted with a scalar at the initializing step:

$$Q_i \leftarrow w_i Q_i \qquad (7)$$

Thereby the vertices of the colored regions gain higher costs than before. Thus the order of contraction is rearranged via the weights, which are dependant from the interactively marked regions of the mesh. You can see an example from Kho and Garland in Figure 1.
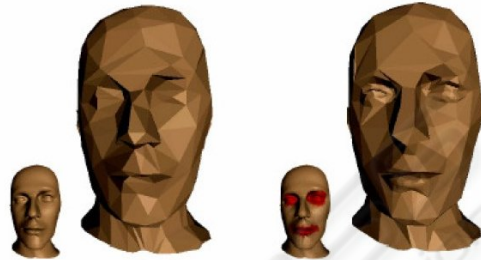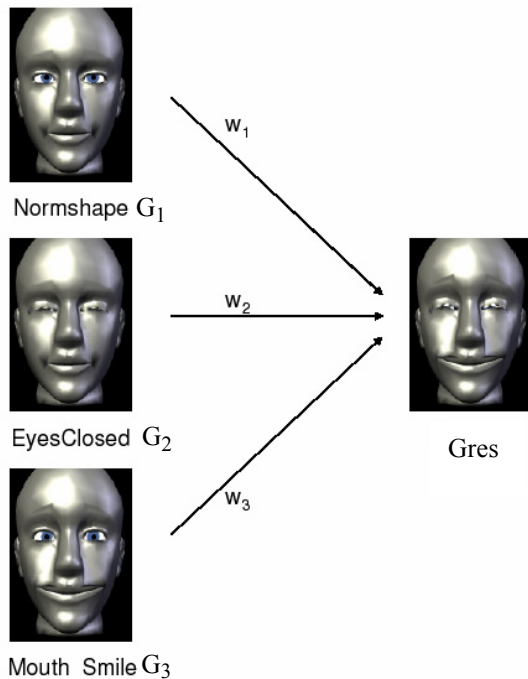

Figure 1: Simplified models, interactively improved.

3 SIMPLIFICATION WITH MORPH-TARGETS

The key idea behind the animation with morph targets is to combine different geometries corresponding to given weights during an animation (see Figure 2). During a time intervall the weights are changing and thus the geometric objects will be animated. In our example the different morph targets G_1:"normal shape", G_2:"eyes closed" and G_3:"mouth smile" were combined regarding different weights (w_1, w_2, w_3) to the resulting geometry $G_{res.}$, which results in a smiling head while closing the eyes. Using a combination of morph-targets, an avatar animation system can run different animations, let the face speak or show emotions. Even all possible combinations can be activated by choosing the corresponding weights for the individual geometry.

$$G_{res}= w_1*G_1+w_2*G_2+w_3*G_3$$

Figure 2: Combination of morph-targets.

The algorithm used for the morph-target-based mesh simplification is implemented as an extension of the quadric error metrics algorithm from Garland and Heckbert using adaptive weighting of quadrics. The interactive drawing on the mesh from Kho and Garland is replaced by an automatic procedure based on the existing morph-targets.

The key idea is that regions with a great distance between the neutral morph-target and the others are more animated. This implies more importance for the visual appearance during an animation. Therefore, this regions should be presented in more details after a mesh simplification. This is done by assigning bigger weights to have bigger contraction costs and the face would be more detailed at that regions after the simplification. The differences of the morph-targets are used to weight the quadrics at the initialization step. The scalars w_i in (7) are computed on the basis of the distances to each morph-target.

For every vertex the distance **D** between the morph-target **mt** and the neutral morph-target is computed. Then all the distances belonging to one vertex are summed up. Thus every vertex is provided with a distance sum **DS**.

$$DS=\Sigma\ D_{mt} \qquad\qquad (8)$$

Now the vertices are sorted by their distances **DS** and weights w_i are given depending on the position of the vertex inside the resulting order sequence of vertices.

This is done by grouping the vertices inside three areas of the sequence. The first of the three with least distances is weighted with 0.33, the second with 0.66 and the third with 1.0. This gives for N vertices:

Table 1: Distance dependent quadric weights.

Index	Weights	Distances
<= 1/3 N	0.33	small
1/3 N< Index < 2/3 N	0.66	middle
>= 2/3 N	1.0	great

Thus at the initialization step of the simplification the weighting of the quadrics $Qi \leftarrow w_iQi$ is modified depending of the distances of the vertices related to the neutral morph-target. More animated regions with greater distances get higher weights and therefore higher contraction costs which implies a delayed contraction of those areas.

4 RESULTS

The new simplification method was integrated inside an existing avatar animation system, described in (Berner, 2004). The animation system is devided in three components: One for the graphical representation, one for the speech synthesis and one for controlling the behavior of the avatar. All these components are driven from an external dialog control giving commands to the avatar like "speak this sentence" or "do this gesture".

The subject discussed in this paper affects only the representation component. The complexity of the animated face could be changed at different levels. The user has the possibility to select more than ten different levels of complexity and the system simplifies the face of the avatar with the quadric based method of Garland and Heckbert or with our new morph-target guided simplification. In a later version of the system the different levels
should be selected automatically depending on the actual performance conditions. A detailed description for this method can be found in (Berner and Rieger, 2005).

The first idea to evaluate the results was to look at the reduced heads. But using our present model of the head, the reduced results were difficult to distinguish. In Figure 3 the original head with 3128 triangles is shown, in Figure 4 a reduced one with 878 triangles, produced from the running avatar animation system.
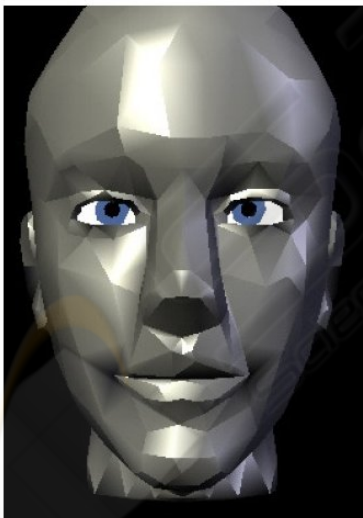

Figure 3: Head, not simplified (3128 triangles).

Figure 4: Head, simplified (878 triangles).

As mentioned, it is not easy to remark the different results of the two algorithms in an obvious manner. To compare the results of the different algorithms in an objective way, we used a tool called MESH (Aspert et al., 2002), which can compare different meshes using the Hausdorff-Distance. The differences between the meshes are colored, blue is a little difference, green a middle one and yellow a bigger. We compared the simplified head with the original and expected a greater discrepancy in the animated regions using the original algorithm from Garland and Heckbert. In Figure 5 the comparison between the basic quadric based algorithm and our new one is shown. The figure on the right hand side, is the result of our simplification algorithm where the head is reduced to 878 triangles. You can see more blue (dark) areas in the animated regions defined by the distances of the morph-targets. This is most obvious at the cheeks.
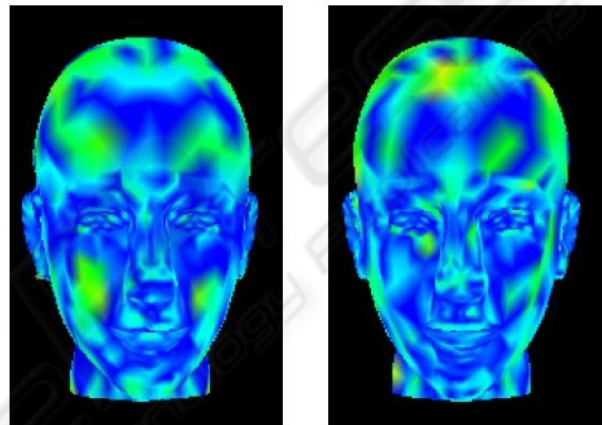

Figure 5: Comparison of the output.

In Figure 6 the differences between the neutral morph-target and the animated ones are shown. There you can see, that the cheeks, the chin and the eyebrows are the most animated regions of the avatar. And the results above shows that the animated regions are better approximated than in the classical algorithm.
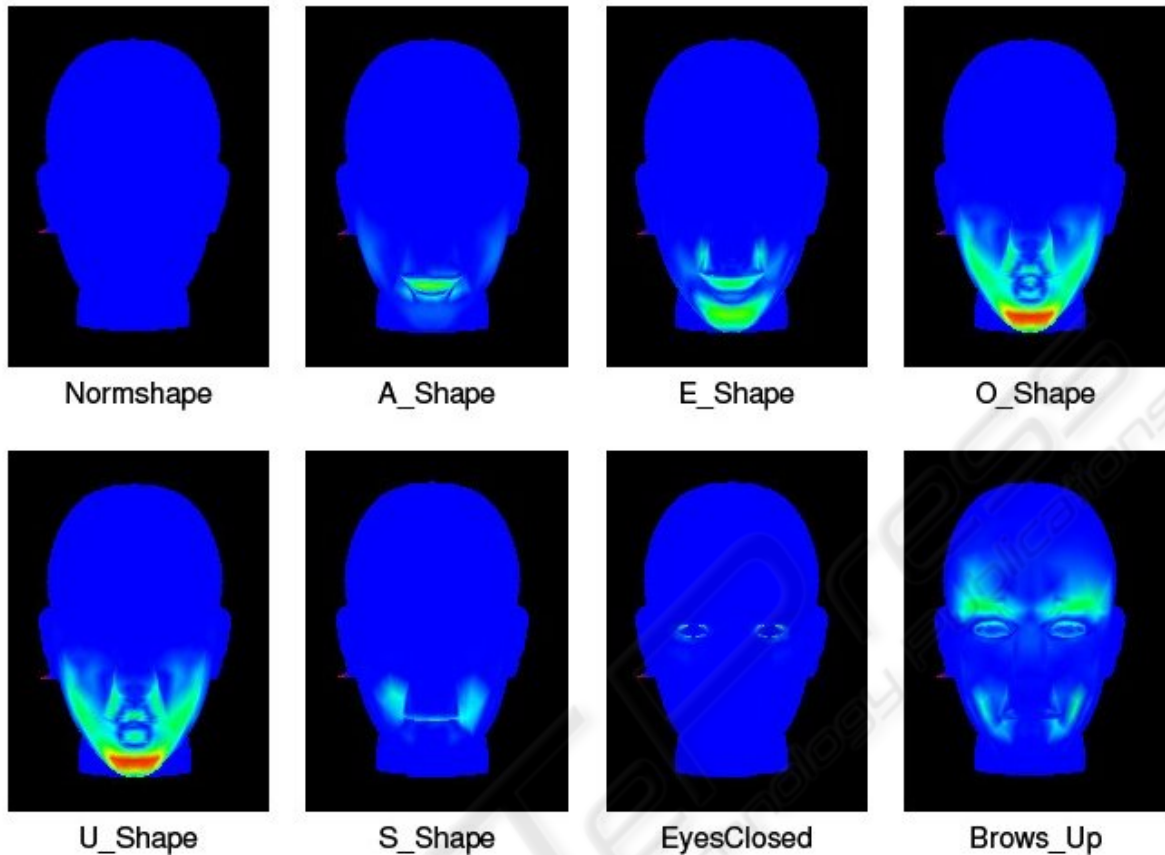
Figure 6: Comparison of the morph-targets.

5 CONCLUSION AND FUTURE WORK

We have developed an extension of the algorithm from Kho and Garland presented in the paper "User-Guided Simplification" (Kho and Garland, 2003). Our new approach uses the morph-targets related to the face animation to determine areas which are highly animated. Using a distance measure the quadrics of the simplification algorithm are weighted automatically at the initialization phase.

While our experimental results show that our idea works satisfactorily, there is still room for further development in different directions. The algorithm should be applied to other geometric models, which are more complex or animate other regions. Neverthenless it must not be a head. Also 3D scanned datasets should be involved in the testing of new models.

The strategy of weighting the quadrics should be more improved, this first one was only implemented for testing the fundamental method. It can be advanced for instance by regarding the number of existing vertices or the total amount of the distances. Even the function over the order sequence must not be linear. Another point is, that the not animated, but relevant regions could be included in the weighting. This could be the ears or the nose which are relative important to represent the visual appearance of a head.

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