

Progressive Deforming Meshes based on Deformation Oriented Decimation



Figure 1: A horse-gallop animation with 48 frames. Upper: The original animation with 16,843 faces. Bottom: 1,588 faces approximation.

1 Introduction

Progressive Meshes (PM) presented by Hoppe [1996] is a method for representing a static 3D model with continuous levels-of-details (LODs) based on iterative edge-collapse/vertex-split operations. Besides static models, animation models or so-called deforming meshes are more widely used recently. Some previous methods simplify the deforming meshes primarily only based on the geometric features, however, in this poster we take the temporal and geometric features together into consideration.

2 Deformation Oriented Decimation

Our deformation oriented decimation (DOD) algorithm is based on Garland and Heckbert’s QSlim algorithm [1997]. To measure the contraction cost for an edge, QSlim utilizes the quadratic error metric (QEM), which measures the total squared distance of a vertex to the two sets of planes. The area-weighted QEM error function Δ_{ij} for a vertex \mathbf{v} to replace the edge $(\mathbf{v}_i, \mathbf{v}_j)$ is

$$\Delta_{ij}(\mathbf{v}) = w_i \sum_{\mathbf{p} \in \mathbf{P}(\mathbf{v}_i)} \mathbf{v}^T (\mathbf{p}\mathbf{p}^T) \mathbf{v} + w_j \sum_{\mathbf{p} \in \mathbf{P}(\mathbf{v}_j)} \mathbf{v}^T (\mathbf{p}\mathbf{p}^T) \mathbf{v} = \mathbf{v}^T \mathbf{Q}_{ij} \mathbf{v},$$

where $w_i = A_i$ is the total area of triangles adjacent to \mathbf{v}_i , w_j is defined similarly, and $\mathbf{P}(\cdot)$ denotes a set of planes. Hence, the QEM cost QEM_{ij} for contracting an edge $(\mathbf{v}_i, \mathbf{v}_j)$ is defined as $\Delta_{ij}(\mathbf{u}_{ij})$, in which \mathbf{u}_{ij} is the vertex minimizing $\Delta_{ij}(\mathbf{v})$.

Mohr and Gleicher [2003] extended the simplification for static model to deforming meshes to provide a deforming sensitive decimation (DSD) method. The DSD contraction cost for edge $(\mathbf{v}_i, \mathbf{v}_j)$ is defined as

$$\text{DSD}_{ij} = \sum_{t=1}^f \text{QEM}_{ij}^t = \sum_{t=1}^f \mathbf{u}_{ij}^t{}^T \mathbf{Q}_{ij}^t \mathbf{u}_{ij}^t, \quad (1)$$

where \mathbf{u}_{ij}^t minimizes the QEM cost for the edge $(\mathbf{v}_i, \mathbf{v}_j)$ at frame t . Hence, DSD tends to preserve edges that belong to geometric features more often.

The DSD algorithm sums the QEM error metrics and is only concerned with the geometric features in each static model. This error-model ignores the features occurred during the deformation in the temporal domain. Hence, we propose a DOD metric which incorporates a deformation cost into the DSD cost. The deformation cost ξ_{ij} is defined to measure the deformation by its average edge length change. The average length change for an edge $(\mathbf{v}_i, \mathbf{v}_j)$ can be defined as $\bar{\Delta}_{ij} = \sum_{t=1}^{f-1} \Delta_{ij}^t$, where $\Delta_{ij}^t = |l_{ij}^{t+1} - l_{ij}^t|$ is the edge length change from frame t to $t+1$ and l_{ij}^t is the edge length of the edge $(\mathbf{v}_i, \mathbf{v}_j)$ at frame t . An edge with larger $\bar{\Delta}_{ij}$ means that, on average, this edge performs more deformation. If we contract it, the

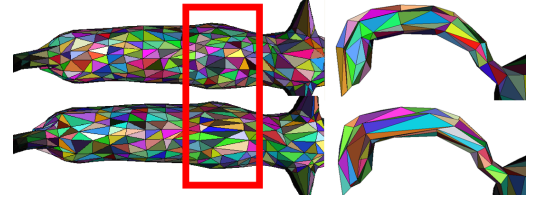


Figure 2: Upper: DOD result; Bottom: DSD result.

deformation performed by this edge will be lost. Hence, we should prefer to contract edges with smaller $\bar{\Delta}_{ij}$ first.

Similar to area-weighted QEM, we would like to assign higher weights to edges of the triangles with larger areas. Hence, we use the average area $\bar{A}_{ij} = \sum_{t=1}^f A_{ij}^t$ as the weight, where A_{ij}^t is the sum of areas of the two triangles sharing edge $(\mathbf{v}_i, \mathbf{v}_j)$. Thus, we define the deformation cost ξ_{ij} for an edge $(\mathbf{v}_i, \mathbf{v}_j)$ and the DOD cost as:

$$\xi_{ij} = w_{ij} * \bar{A}_{ij} * (\bar{\Delta}_{ij})^2, \text{ and } \text{DOD}_{ij} = \text{DSD}_{ij} + \xi_{ij}, \quad (2)$$

where w_{ij} is another weight defined as $w_{ij} = \frac{\max_t \Delta_{ij}^t - \bar{\Delta}_{ij}}{\sqrt{\frac{1}{f-1} \sum_{t=1}^{f-1} (\Delta_{ij}^t - \bar{\Delta}_{ij})^2}}$.

The denominator of the above equation is the standard deviation of length changes. This weight represents the normalized maximum deformation and helps to preserve the area with sudden large deformation.

3 Result

The result of our method is shown in Figure 2 (Upper) which shows two simplified deforming meshes. The left is a dog-walking animation which has a lot of motion around the neck; the right is a horse-gallop animation whose tail swings up and down constantly. For the both animation, the DSD method preserves excessive polygons on the face portion while takes less care on the deforming regions, but our method successfully preserves both more polygons and better triangulation for such deforming regions. Our results indicate that even regions are not geometric features across every frame, the deformation cost defined previously can handle the deforming aspect.

References

- GARLAND, M., AND HECKBERT, P. S. 1997. Surface simplification using quadric error metrics. In *Proceedings of SIGGRAPH 97*, 209–216.
- HOPPE, H. 1996. Progressive meshes. In *Proceedings of SIGGRAPH 96*, 99–108.
- MOHR, A., AND GLEICHER, M. 2003. Deformation sensitive decimation. Tech. rep., University of Wisconsin.

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