# Report on Multiresolution Modeling Through a Remeshing Approach

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In this report, the details of an approach to Multiresolution Modeling is exposed and explained through the process of remeshing based on the article “A Remeshing Approach to Mulresolution Modeling“ [1]. Firstly, the increasing and crucial importance of the mathematical treatment of this approach for shape editing must be understood.

The process of shape editing consists in adding a deformation to the mesh conserving its details once a handle area has been selected and the zones of deformation have been well defined. The handle area of the surface will be moved and this will modify the triangles located at the zones of deformation. Firstly, this modification must be applied on a remeshed base surface which will not contain the high-frequency detailed surface that exists in the original mesh.

Instead of implementing the shape editing (insertion of deformations), this project has been developed for treating the remeshing process of the original mesh, allowing the retrieval of the low-frequency surface which drives from a full-detailed mesh to a mesh with loss of data.

However, the high-frequency data is recoverable through this project. For obtaining the base surface applying gradually the steps of remeshing, the user must use the keyboard shortcuts ‘+’ (further remeshing) and ‘-’ (less remeshing).

Under the aim of remeshing a given 3D object mesh to prepare it for the future addition of deformations (not covered here) as specified above, the following treatment has been implemented:

1. Insertion of a decomposition operator;
2. Remeshing of the base mesh (mesh gradually with less details such as sharp points);
3. Reconstruction of the mesh.

For the first step of the algorithm, the 3D object represented by its mesh, usually composed by triangles holding different areas and sides’ length, was decomposed into a base mesh describing a low frequency surface and a high-frequency detailed mesh.

Secondly, all the remeshing and further treatment is applied on the low-frequency surface. The overall implementation of this project has been developed under this process of remeshing which concerns four steps of treatment explained below.

1. **The Average Edge Length Step (Step 0)**

   The average legth side is calculated by analysing each triangle of the loaded mesh and computing the mean of the three lengths.

The variable which holds this mesh is designated by ‘l_average’. This value denominated by ‘l’ will be used for the next operations during remeshing. For calculating the average length of sides, the function zero_step() was implemented.

**2. The Adjustment of Edges’ Lengths (Step 1)**

For each triangle, the sides are evaluated in such a way that if an edge is longer than 4/3l (4/3 of the average length, the edge must be split up at its midpoint. This is done by connecting the respective opposing vertex to the edge’s midpoint creating, from one original triangle, two triangles (one edge longer than 4/3l) or three triangles for two connections (two edges longer than 4/3l) or four triangles for three connections (three adges longer than 4/3l) from one original triangle.

This has been carefully done using the function first_step() which receives the most recently obtained average length of the edges, considering that shared edges do not need to be evaluated again (more than one time). After this, the edges are recomputed. The result of this transformation is stored in the variable one_mesh.

**3. The Removal of Short Edges (Step 2)**

All edges are evaluated for their lengths. In case of an edge shorter than 4/5l is found, then this edge must be collapsed. Consequently the neighboring triangles will share one commun vertex which is fundamental for the next step that must find edges with deviation from valence 6 (or 4 on boundaries). This is done by using the function second_step() which receives as paremeter the average length of the edges. After this, the edges are recomputed.

The result is stored in the variable two_mesh.

**4. The Minimization of Deviation from Valence 6/4 (Step 3)**

This step concentrates itself on finding all the vertex with valence in a range very below 6 or very above 6 to eliminate the deviation from valence 6 by flipping the edges. This operation is done in the interior of meshes. For the boundaries, the indication is to minimize the deviation from valence 4. Valence 6 is intended to represent vertices shared by more than 6 or less than 6 triangles.

The flipping of the edges which presents itself as an important operation to achieve the minimization of the deviation desired is done using the function third_step() followed by the recomputation of edges, neighbors and normals.

The result is stored in the variable three_mesh.

**5. Relocate Vertices on the Surface by Tangential Smoothing (Step 4)**

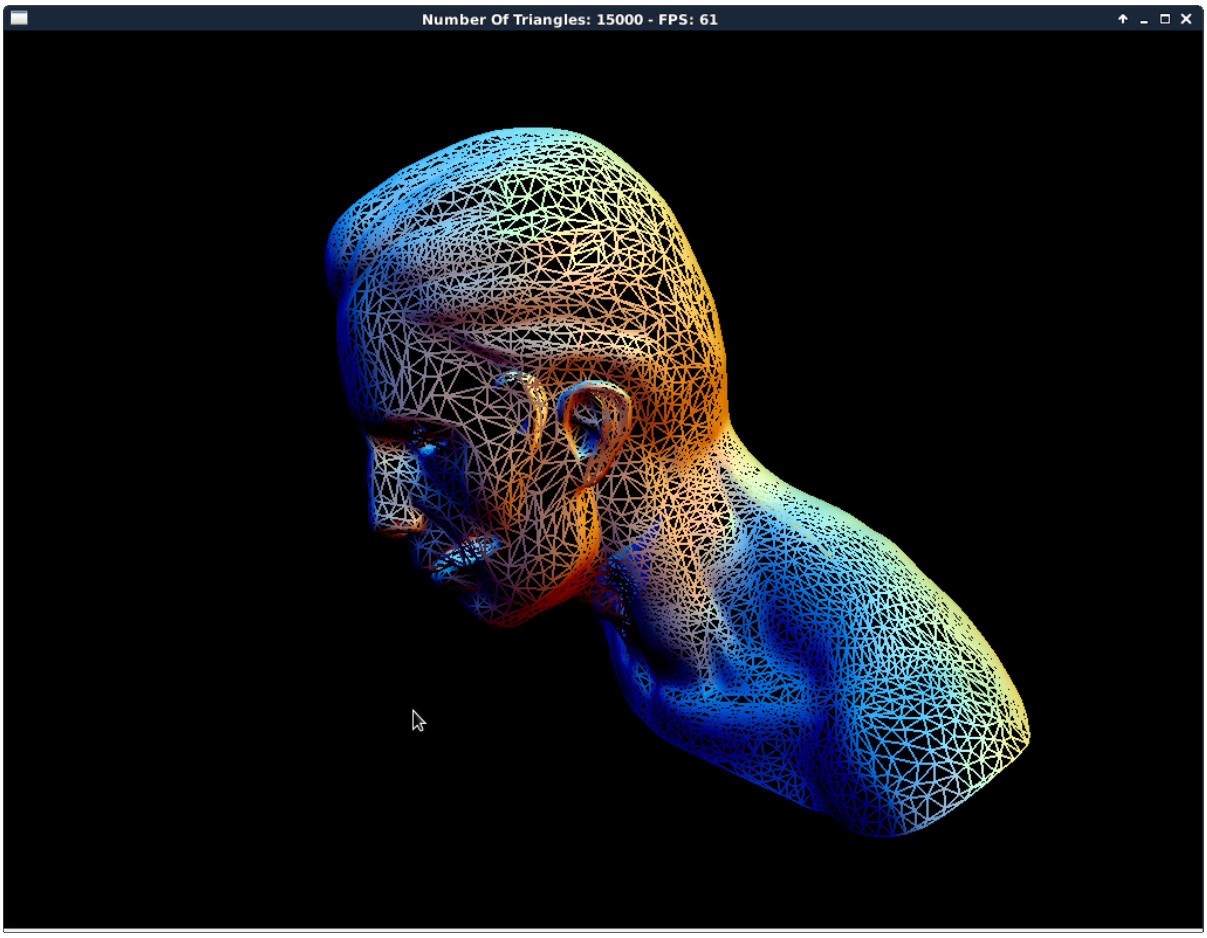
We apply the area-based tangential smoothing proposed by the authors instead of the traditional one in the fourth step of the algorithm. In the area-based tangential smoothing, each vertex $p$ is set a gravity equal to its Voronoi area $A(p)$. We calculate the Voronois areas as follows:

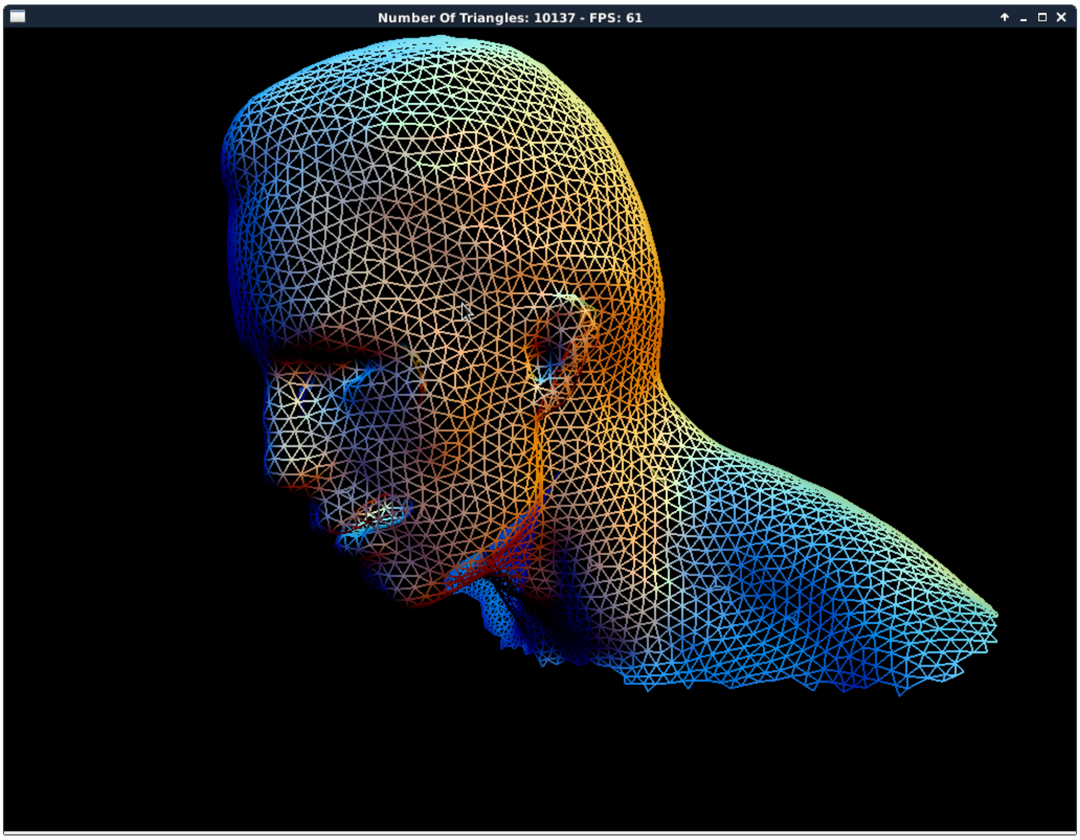
For each vertex $p$, we consider its neighboring vertices. For each pair of two adjacent neighbors $v_i$, $v_{i+1}$, we check the triangle formed by 3 vertices $p, v_i, v_{i+1}$. If the triangle is not obtuse, i.e. the circum-center $c$ is inside the triangle, we cummulate the two partial area of two triangle $pcv_i$ and $pcv_{i+1}$ to $A(p)$. Otherwise, we just connect the two midpoints of $pv_i$ and $pv_{i+1}$ and cummulate that area to the final area. Then a tangential smoothing process moves each vertex $p_i$ to its gravity-weighted centroid.

To ensure a tangential smoothing on the surface, the update vector is projected back into the tangent plane. You can reference the equations in the papers. We chose the damping factor 0.8.

At the end, the mesh obtained after the remeshing is regular in contrast with the original mesh which was irregular. The objective has been reached successfully.

Finally, the reconstruction step can be achieved by adding the high-frequency details to the low-frequency surface that has been remeshed appropriately. The expected result of this process is the achievement of a regular mesh with equalized Voronoi areas for each vertex.






**References:**

[1] Mario Botsch and Leif Kobbelt: “A Remeshing Approach to Multiresolution Modeling”, Computer Graphics Group RWTH Aachen University.
http://graphics.uni-bielefeld.de/publications/sgp04.pdf