Using Heat Diffusion Approach in the Reconstruction of Noisy Meshes

Eduardo Costa - 2019-82118 &
Eduardo Melo - 2019-82473

Seoul National University
Department of Electrical and Computer Engineering

Professor: Young Min Kim

서 울 대 학 교
SEOUL NATIONAL UNIVERSITY

Introduction

This project consists on the reconstruction of noisy meshes, using a linear filter and a heat diffusion filter to determine which of these approaches obtains better results. To do this, various noise functions are applied to the original mesh, and then both filters are applied to the obtained noisy meshes in order to try and recover the original mesh, as similar as possible. An example of this project objective is found in figure 1.

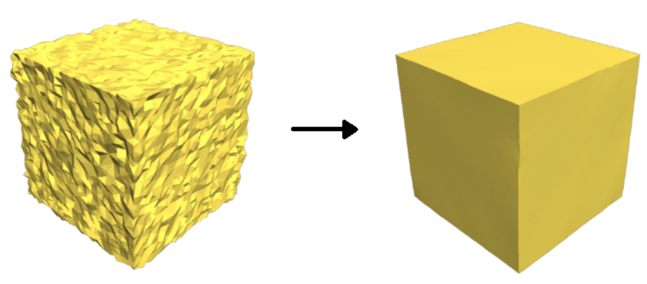

Figure 1: An example of the objective of this project

Noise Functions

In figure 2, it's observable the original mesh.

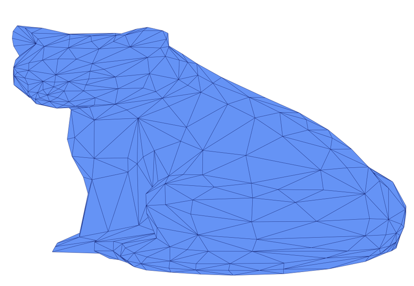

Figure 2: Original mesh

The noise functions consist on translating every vertex of the mesh in a given direction, and a certain distance.
The distance is given by 2 random functions with an uniform and gaussian distribution, respectively.
The direction is given by the normals of the original mesh, or computed using the center of mass of the mesh, where each direction of each vertex traverses the center of mass. The directions of the vertices of the meshes can be seen in figure 3.

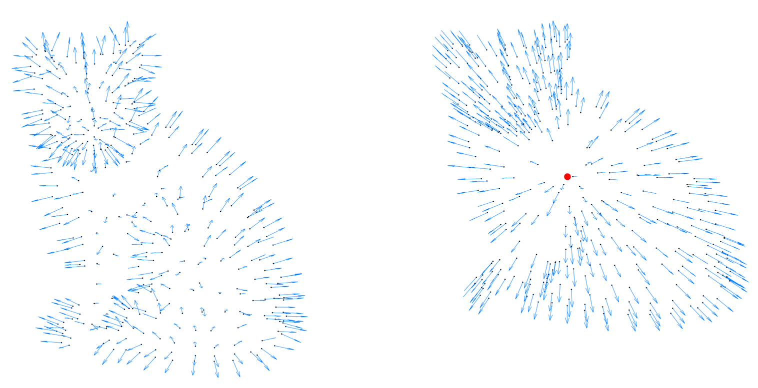

Figure 3: Left: Normals of the mesh. Right: Directions computed using the CoM (red)

This originates 4 different types of noise, depicted in figure 4.

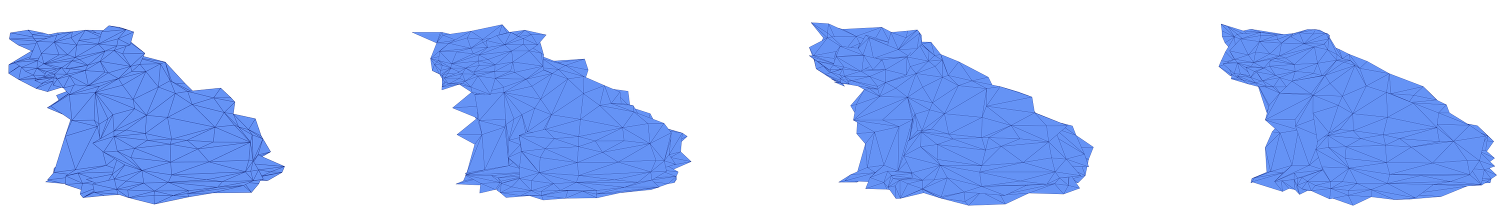

Figure 4: Noisy meshes. From left to right:
Uniform, Normals ; Gaussian, Normals ; Uniform, CoM ; Gaussian, CoM

Linear Filter

The linear filter used in this project does an average of the positions of the neighbours $\sum_{neighbours} P_j / N_{neighbours}$ of each vertex P_i and assigns that value as the new vertex value. This process can be expressed using the normalized adjacency matrix $A_n = D^{-1}A$, where A and D are the adjacency and degree matrix of the input mesh. The filtering can then be applied iteratively using $X_{t+1} = A_n X_t$.

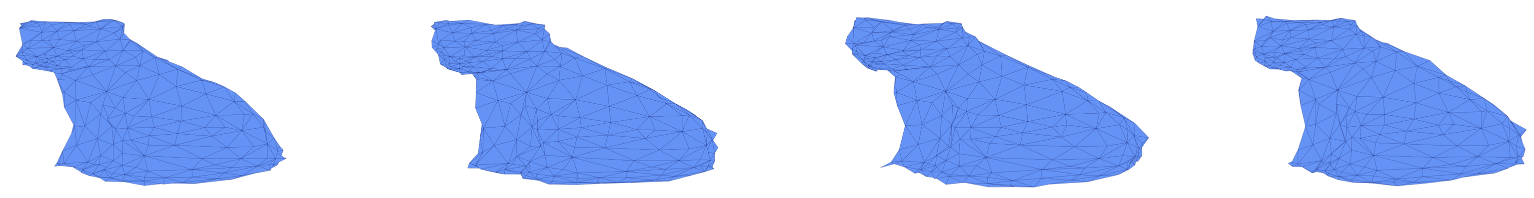

Figure 5: Reconstructed noisy meshes with linear filtering. From left to right:
Uniform, Normals ; Gaussian, Normals ; Uniform, CoM ; Gaussian, CoM

Heat Diffusion Filter

The heat diffusion equation is given by $\frac{\partial u}{\partial t} = \alpha \nabla^2 u$. The process of diffusion on a mesh is equivalent to applying a filter on the mesh, since the normalized laplace operator calculates neighbourhood averages of points. We can adapt the equation to be solved on a graph by using the normalized laplacian operator $L_n = D^{-1}(D - A)$. The equation can then be aproximated iteratively by $X_{t+1} = X_t - dt L_n X_t$ for a chosen timestep dt.

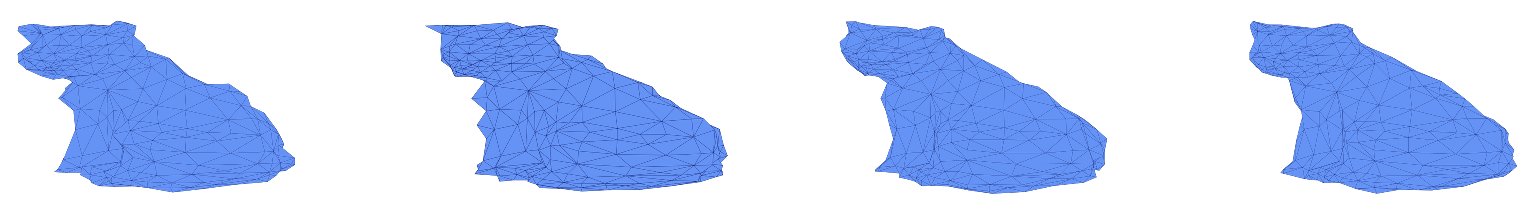

Figure 6: Reconstructed noisy meshes with heat diffusion filtering. From left to right:
Uniform, Normals ; Gaussian, Normals ; Uniform, CoM ; Gaussian, CoM

Results

The table 1 contains the SNRs of the previously obtained meshes.

Table 1: Signal noise ratio of the reconstructed meshes

Mesh	Uniform Normals	Gaussian Normals	Uniform CoM	Gaussian CoM
SNR of Linear Filter	30.7	30.7	30.1	30.6
Heat Diffusion	33.6	34.2	32.0	33.6

References

[1] Xianfang Sun, Paul L. Rosin, Ralph R. Martin, and Frank C. Langbein: "Fast and Effective Feature-Preserving Mesh Denoising", Member, IEEE

[2] Shin Yoshizawa Alexander Belyaev Hans-Peter Seidel: "Smoothing by Example: Mesh Denoising by Averaging with Similarity-based Weights", Computer Graphics Group, MPI Informatik, Saarbrücken, Germany