MSCV6 Software Engineering Project

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Overview

Background

- Triangular mesh
- Applications: Gaming, animation, 3D scannning, etc
- Our project: Laplacian Mesh study, Spectral Analysis
- Making use of OpenGL and Eigen library

Mesh Laplacian

- To generate a Laplacian matrix by A matrix and D matrix

$$A_{ij} = \begin{cases} 1 & i \in N(j) \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

$$D_{ij} = \begin{cases} d_i & i = j \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

$$L_s = DL = D - A \tag{3}$$

- With Laplacian matrix we have:

$$Lx = \delta \tag{4}$$

where x is global coordinate and δ is the differential coordinate. This equation is useful for mesh editing and curvature analysis.

Mesh Laplacian-Cotangent weights

- Cotangent weights can be expressed as:

$$w_{ij} = \frac{1}{2}(\cot \alpha_{ij} + \cot \beta_i j) \tag{5}$$

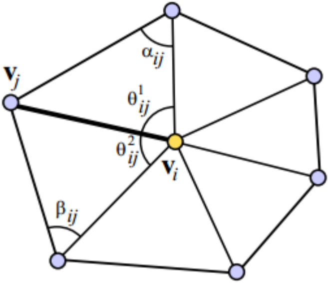

Figure : Taken from reference [1]

- With cotangent weights Harmonic Laplacian matrix can be calculated, which is useful for curvature analysis.

Spectral Analysis

- Eigenvectors and eigenvalues
- Using Eigen library to solve Eigen: SelfAdjointEigenSolver...
- Eigen sorting
- Colors as functions of eigenvectors

$$y = (b - a) \times (x - m)/(M - m) + a \tag{6}$$

- Mesh Compression: eigen space and frequency

$$[x_1, x_2, ..., x_n]^T = c_1 e_1 + c_2 e_2 + ... + c_{n-1} e_{n-1} + c_n e_n \tag{7}$$

- Projection in eigen space

$$P = x_1 e_1 + x_2 e_2 + x_3 e_3 + ... \tag{8}$$

Spectral Analysis - Colors as functions of eigenvectors

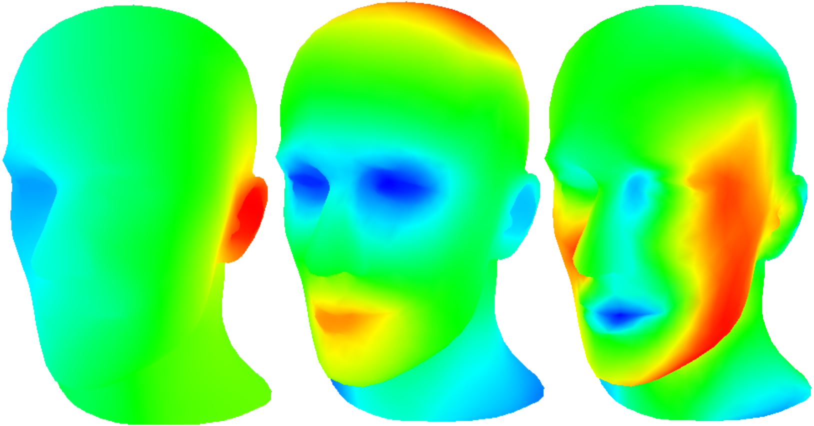

Figure : Results of the low, mid-level and high eigen vectors respectively

Spectral Analysis - Compression 1

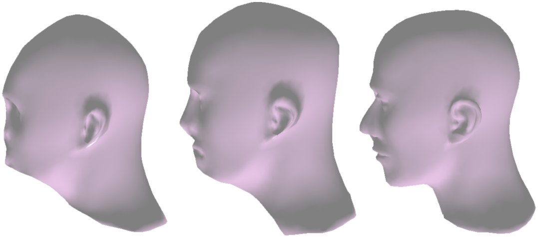

Figure : Results of high compression, mid-level compression and low-level compression

Spectral Analysis - Compression 2

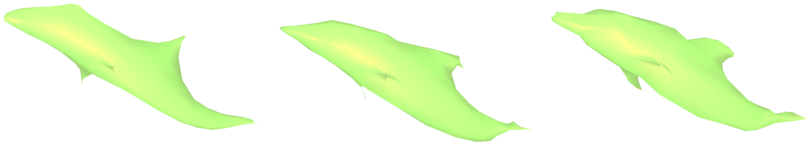

Figure : Results of high compression, mid-level compression and low-level compression

OpenGL and QT

- OpenGL to visualise 3D meshes and various processing done on it.
- OpenGL functions of lighting and materials.
- Previliges of signals and slots

Signal and Slots

- A way to communicate between GLWidgets and QWidgets
- SIGNALS ans SLOTS of different classes
- Qt Designer forms and windows

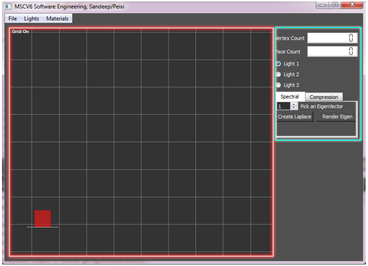

Figure : user interface

Arcball

- Someway to interact with 3D world
- Dragging with mouse
- Rotation and Zoom

Mapping Mouse Motion to Rotation

- Rotation axis and Rotation Angle
- Two vectors; Intial click, and every final Drag location

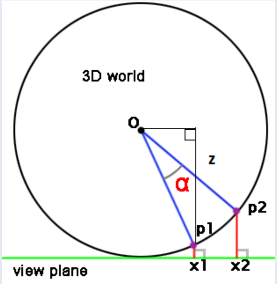

Figure : Arcball: looking the World from Top view

x1 and x2: initial and final mouse location,
α: rotation angle
p1 and p2: projections on sphere

$$z = \sqrt{1 - x1^2}$$

Lighting in OpenGL

- Overall appearance of 3D object
- Ambient, Diffuse, Specular

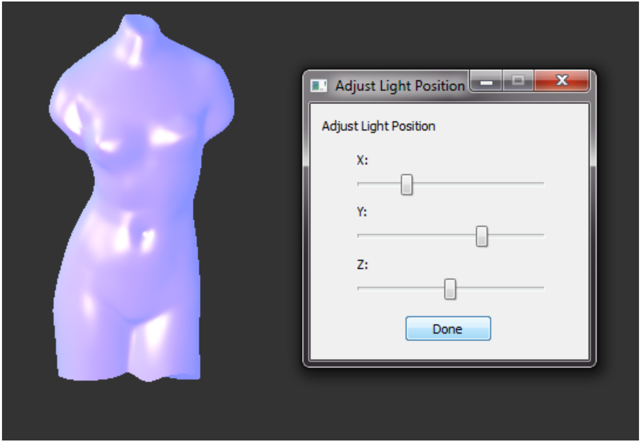

Figure :

Shading

- Basic OpenGL Shading Modes
- GL_FLAT and GL_SMOOTH
- GL_FLAT: low cost to compute
- GL_SMOOTH: Interpolate along the vertices

Shading in OpenGL

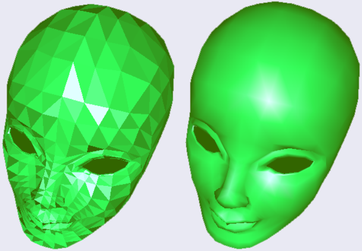

Figure : Results of Flat and Smooth shading

GUI Imeplementation

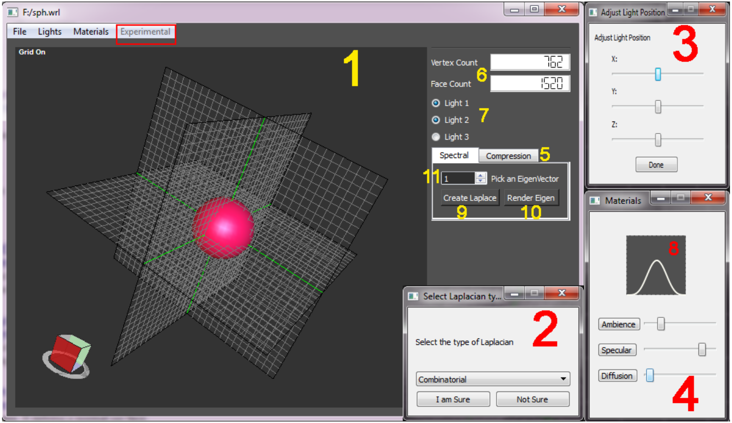

Figure : GUI

Past to Future

- Usable GUI
- Glut Abandoned
- Code refactored
- Mobile Light and Basic Material Editor
- Mesh operations
- Experimental Watermarking(Needs mesh saving)
- OpenGL selection and picking
- Nystrom Method to extract few leading Eigen components

Watermark

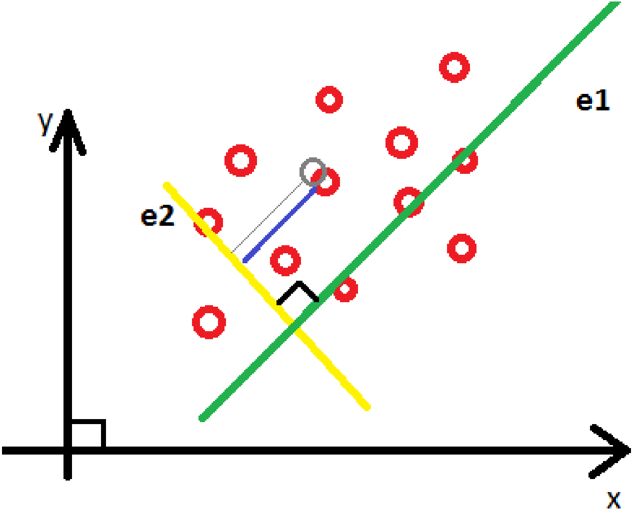

Figure : Watermark

Experimental Curvature Analysis

With cotangent Laplacian matrix and differential coordinate, the curvature image was calculated:

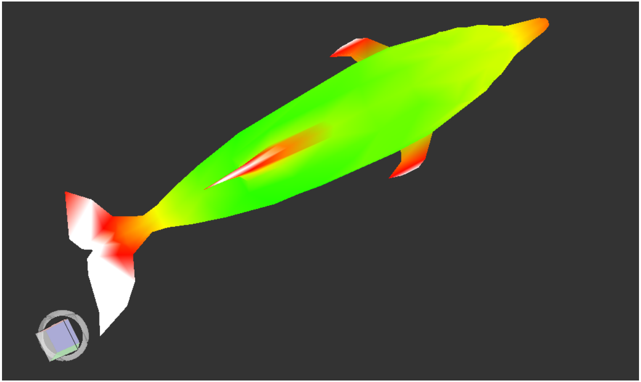

Figure : Curvature image with cotangent Laplacian matrix and differential coordinate

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The End