Polygonal Meshes

Thomas Funkhouser

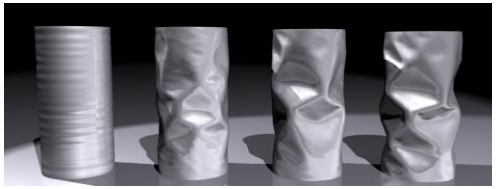
Princeton University

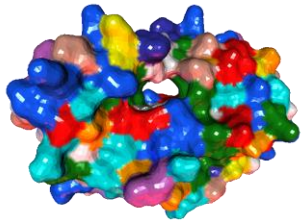
COS 526, Fall 2016

Digital Geometry Processing

Processing of 3D surfaces

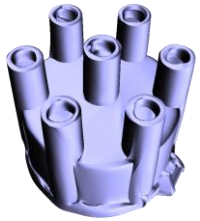
- Creation, acquisition
- Storage, transmission
- Editing, animation, simulation
- Manufacture
- Analysis





Applications

- Movies, games
- Computer-aided design
- Medicine, biology
- Art, history
- All fields with 3D data

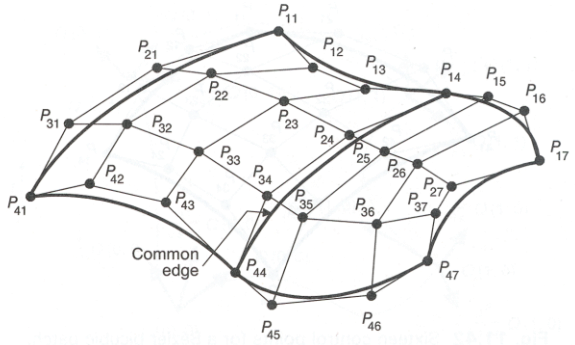


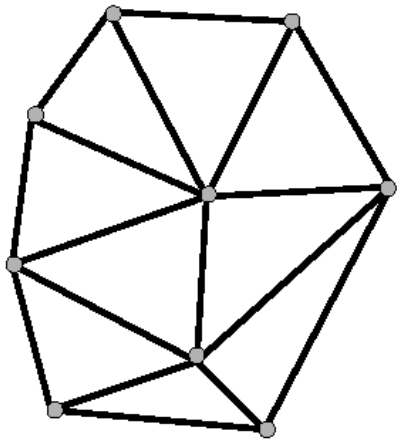
Sweldens

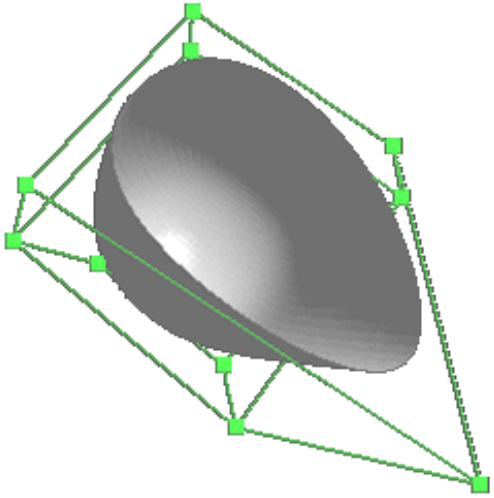
Digital Geometry Processing

Many possible surface representations

- Polygonal meshes
- Parametric surfaces
- Subdivision surfaces
- Implicit surfaces
- etc.



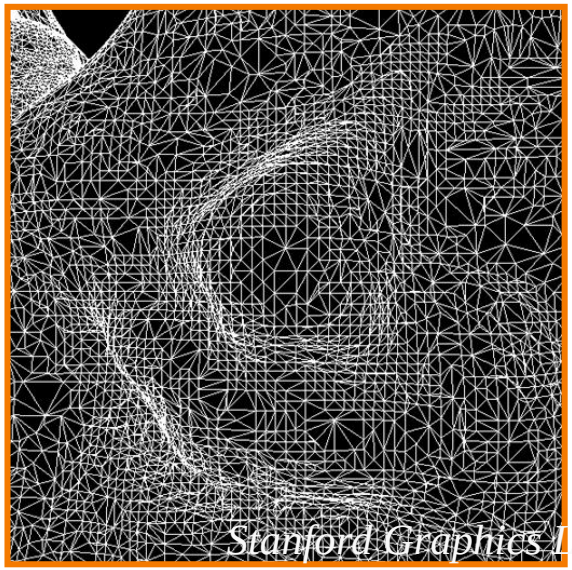




Digital Geometry Processing

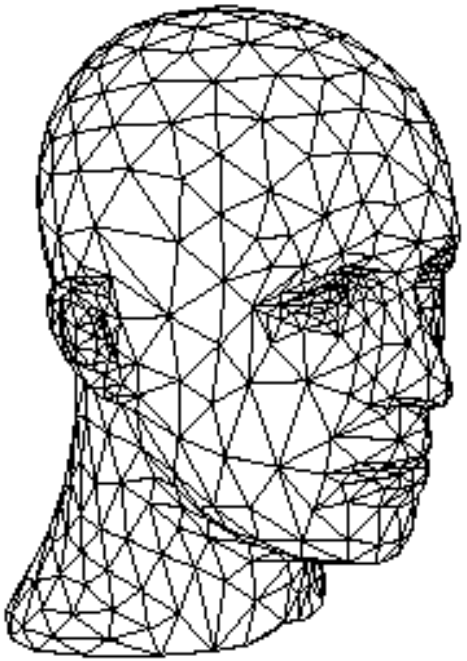
Let's focus on 3D polygonal meshes

- Simple, common representation
- Rendering with hardware support
- Output of many acquisition tools
- Input to many simulation/analysis tools



3D Polygonal Meshes

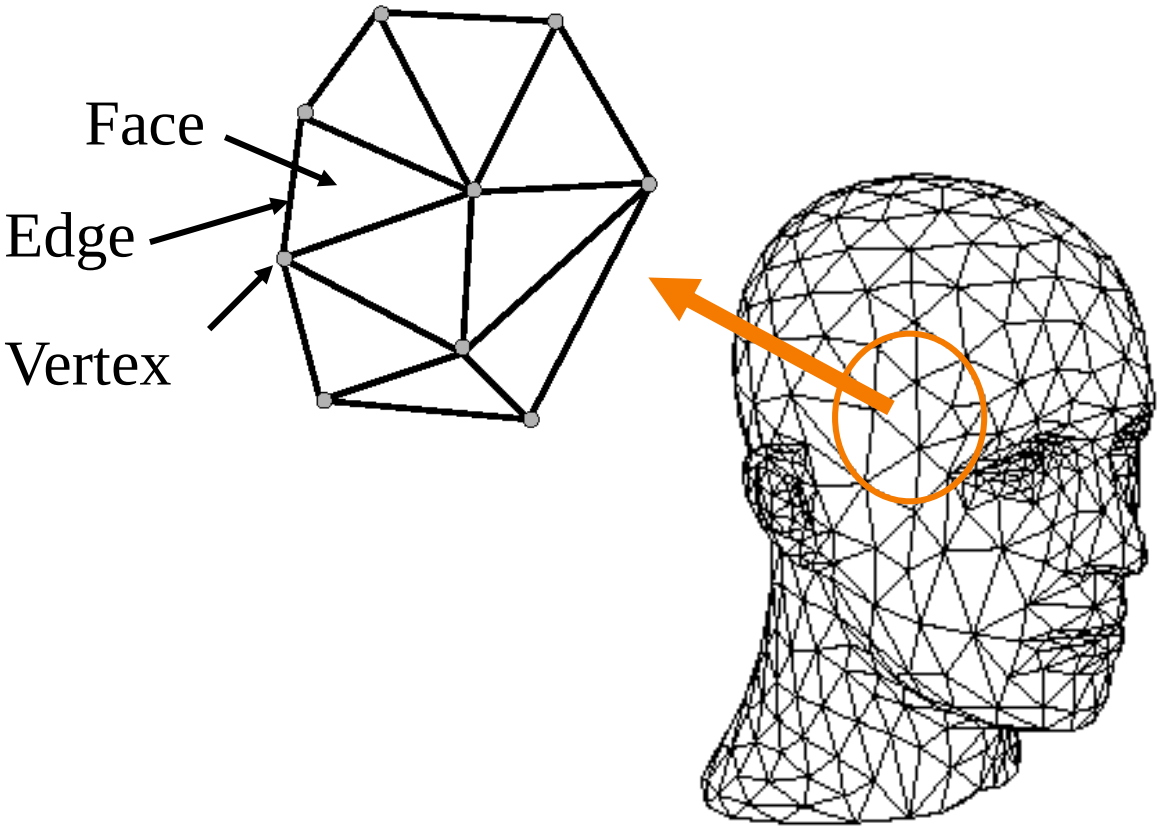
Set of polygonal faces representing a 2D surface embedded in 3D



Zorin & Schroeder, SIGGRAPH 99, Course Notes

3D Polygonal Meshes

Set of polygonal faces representing a 2D surface embedded in 3D



Zorin & Schroeder, SIGGRAPH 99, Course Notes

Outline

Acquisition

Processing

Analysis

Outline

Acquisition ←

Processing

Analysis

Polygonal Mesh Acquisition

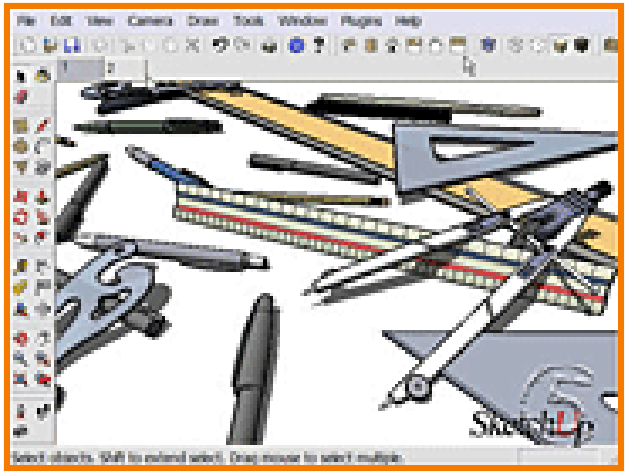
Interactive modeling
- Polygon editors
- Interchange formats

Scanners
- Laser range scanners
- CAT, MRI, etc. (isosurfaces)

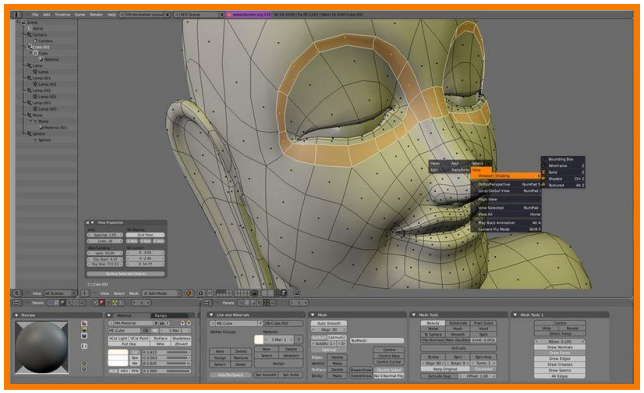
Simulations
- Physical processes

Polygonal Mesh Acquisition

- Interactive modeling
  - ➢Polygon editors
  - Interchange formats
- Scanners
  - Laser range scanners
  - CAT, MRI, etc. (isosurfaces)
- Simulations
  - Physical processes



Sketchup



Blender

Polygonal Mesh Acquisition

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Scanners

- Laser range scanners
- CAT, MRI, etc. (isosurfaces)

Simulations

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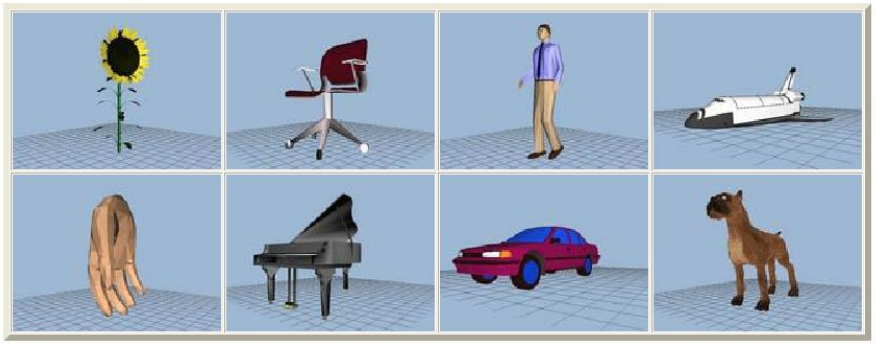

Princeton Shape Benchmark

Polygonal Mesh Acquisition

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- Polygon editors
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Scanners
- ➢Laser range scanners
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Simulations
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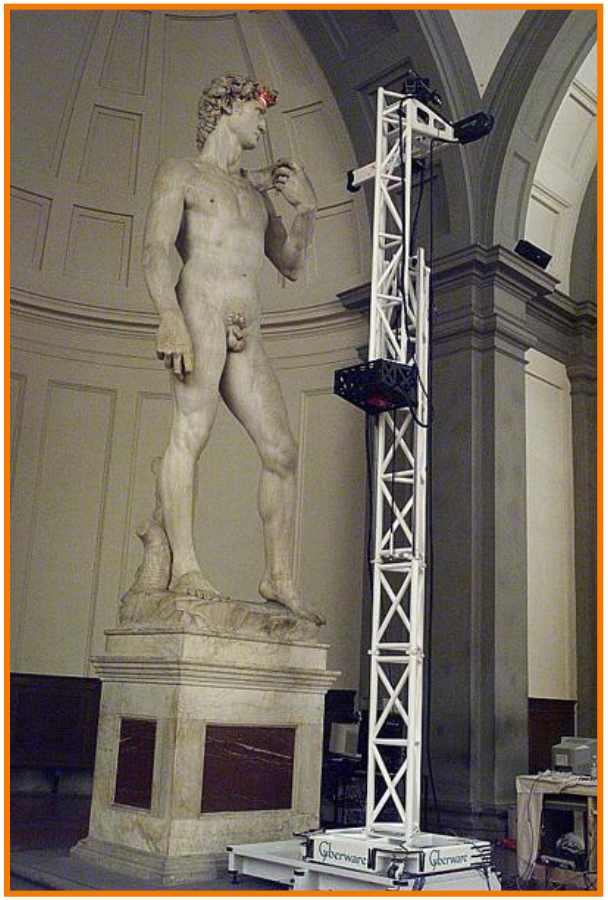

Digital Michelangelo Project
Stanford

Polygonal Mesh Acquisition

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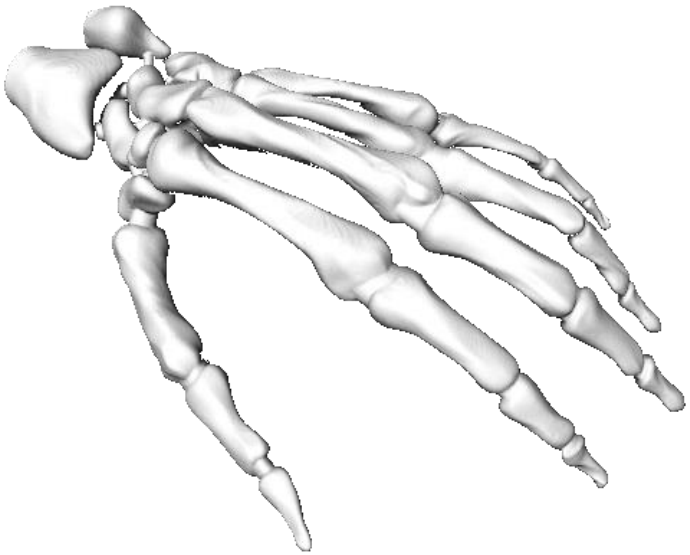

Large Geometric Model Repository
Georgia Tech

Polygonal Mesh Acquisition

Interactive modeling
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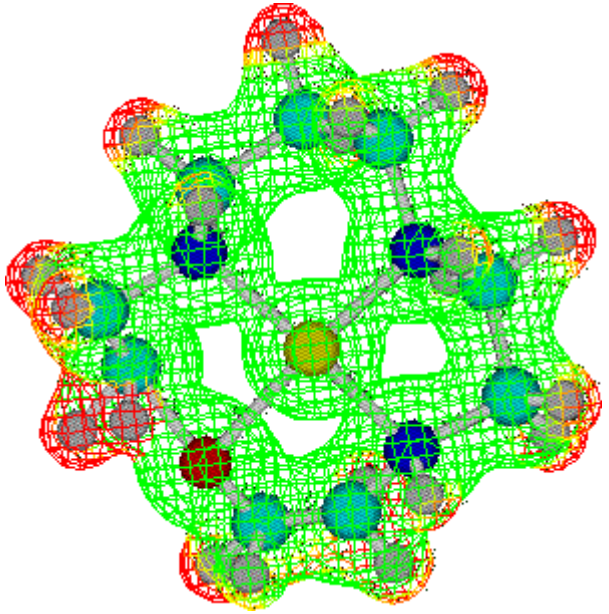
Simulations
- ➢Physical processes



MIT

Outline

Acquisition

Processing ←

Analysis

Polygonal Mesh Processing

- Storage
  - Compression
  - Transmission
- Analysis
  - Parameterization
  - Differential geometry
  - Feature detection
  - Segmentation
- Editing
  - Smoothing, sharpening, etc.
  - Deformation
  - Completion

Polygonal Mesh Processing

Storage
- ➢Compression
- Transmission

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Lossy Compression
(Simplification)

Garland

Polygonal Mesh Processing

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Polygonal Mesh Processing

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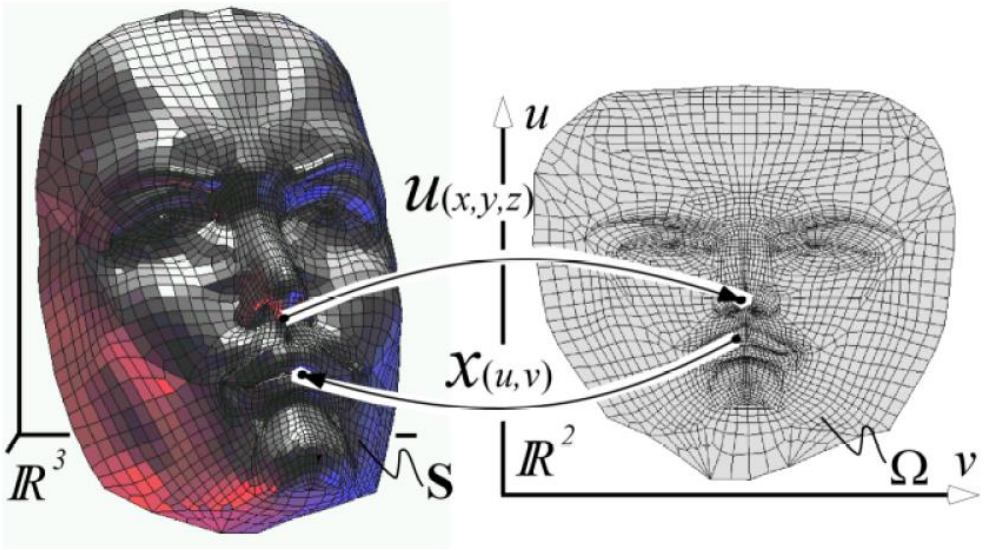

Editing
- Smoothing, sharpening, etc.
- Deformation
- Completion

Sheffer

Polygonal Mesh Processing

Storage
- Compression
- Transmission

Analysis
- Parameterization
- ➢Differential geometry
- Feature detection
- Segmentation

Editing
- Smoothing, sharpening, etc.
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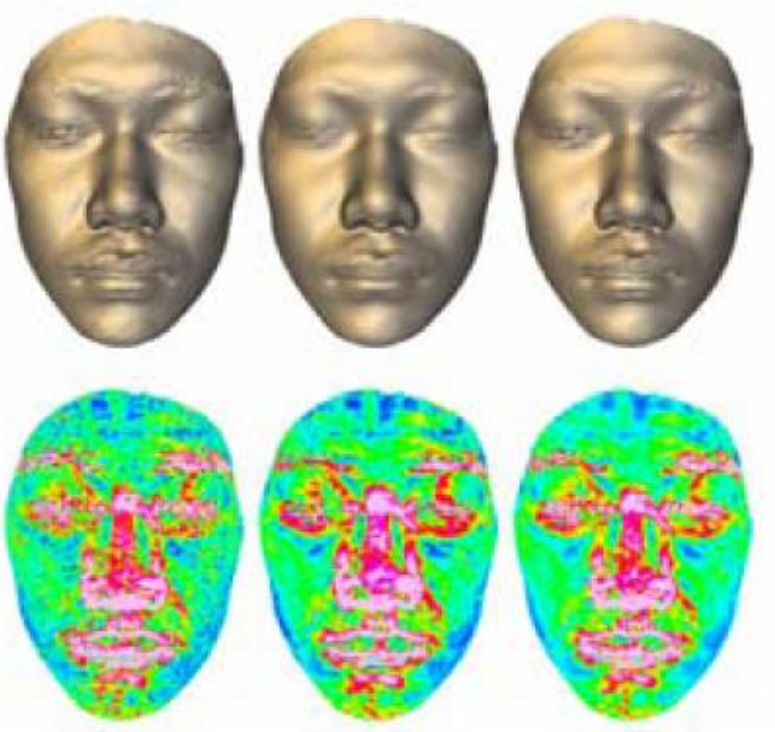
- Completion



Polygonal Mesh Processing

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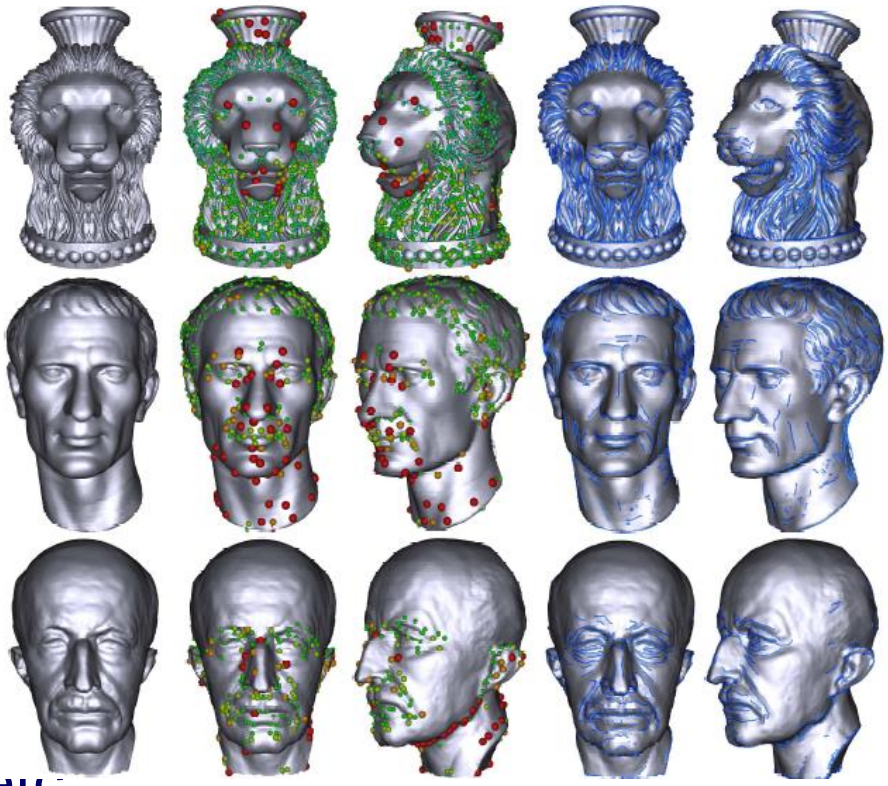

Novatnek et al.

Polygonal Mesh Processing

Storage
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Analysis
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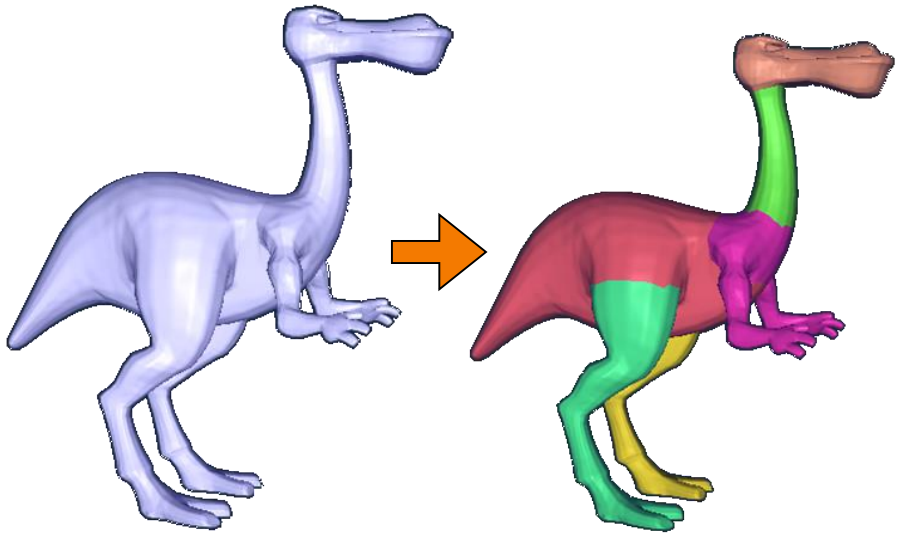
- Feature detection
- ➢Segmentation



Editing
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- Completion

Katz & Tal

Polygonal Mesh Processing

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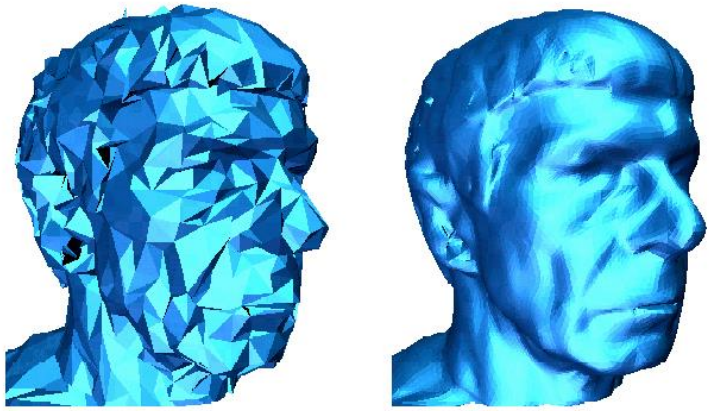
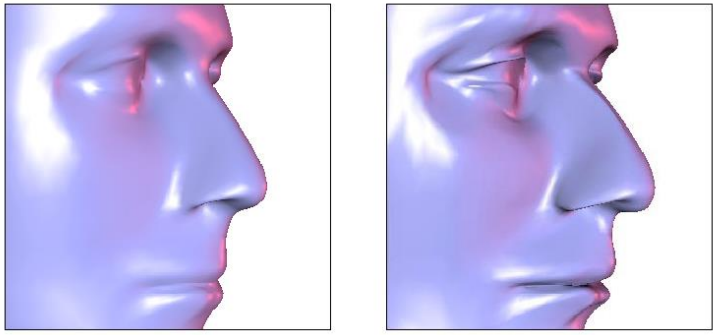


Smoothing



Sharpening

Desbrun

Polygonal Mesh Processing

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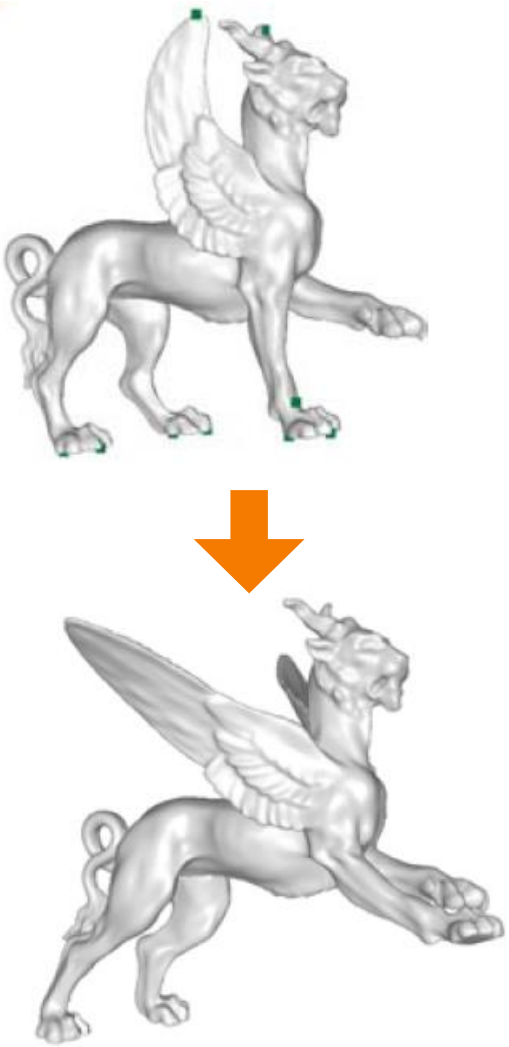

Sheffer

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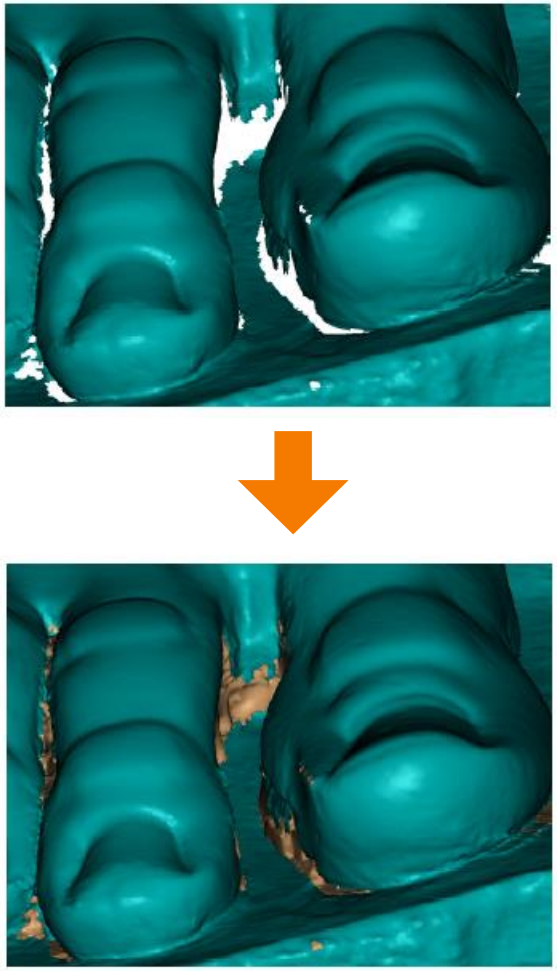

Podolak

Outline

Acquisition

Processing

Analysis ←

Mesh Analysis

Examples:

- Feature detection
- Segmentation
- Labeling
- Registration
- Matching
- Retrieval
- Recognition
- Classification
- Clustering
- Functionality

Mesh Analysis

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- ➢ Feature detection
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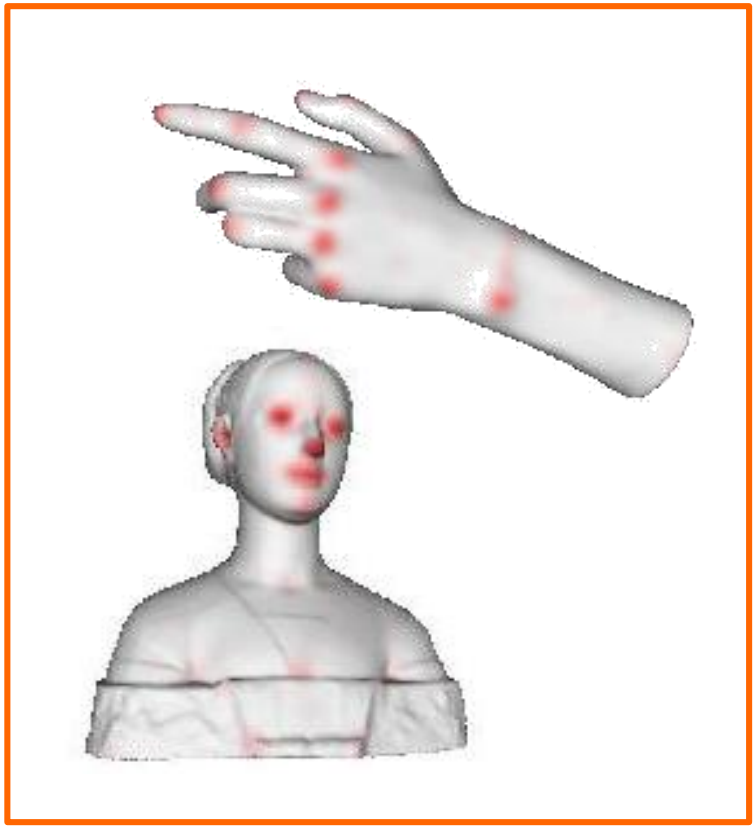

Schelling Points

"How can we find significant geometric features robustly?"

Mesh Analysis

Examples:

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- ➢Segmentation
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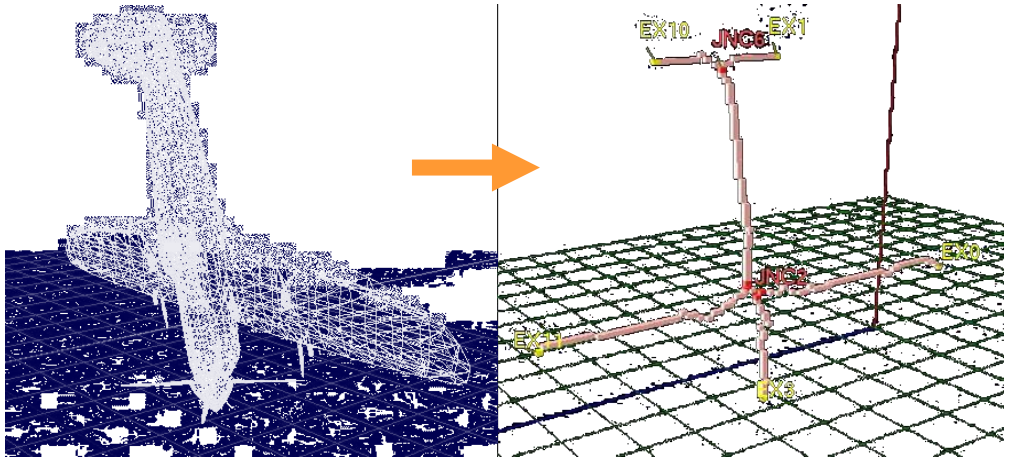

Input Mesh

Skeletal Graph

"How can we decompose a 3D model into its parts?"

Mesh Analysis

Images courtesy of Ayellet Tal, Technion & Princeton University

Examples:

- Feature detection
- Segmentation
- ➢Labeling
- Registration
- Matching
- Retrieval
- Recognition
- Classification
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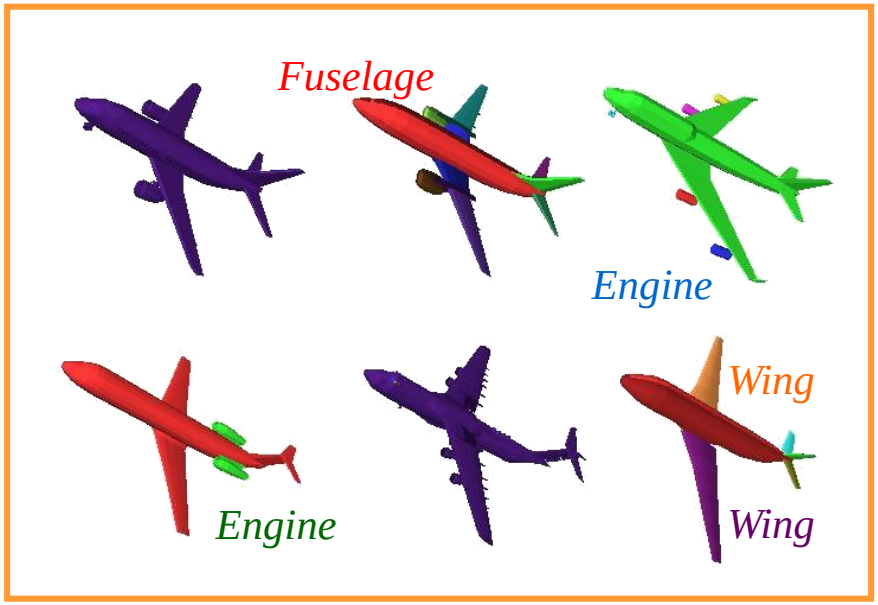

Semantic Labels

(Golovinskiy, Lee, et al.)

"How can we decompose a 3D model into its parts?"

Mesh Analysis

Images courtesy of Emil Praun

Examples:

- Feature detection
- Segmentation
- Labeling
- ➢Registration
- Matching
- Retrieval
- Recognition
- Classification
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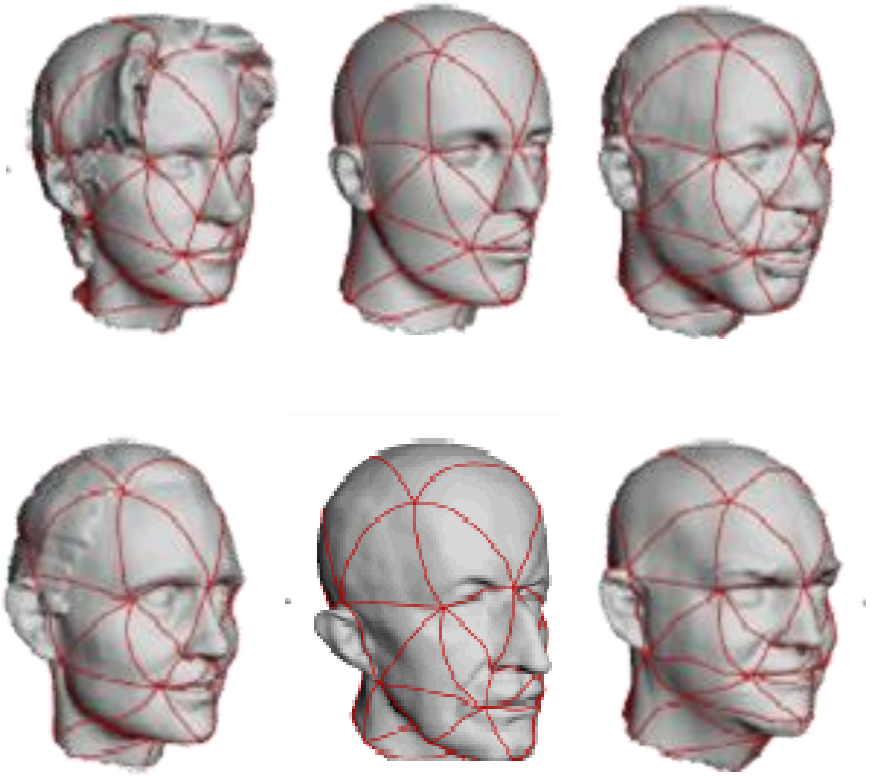

"How can we align features of 3D models?"

Mesh Analysis

Examples:

- Feature detection
- Segmentation
- Labeling
- Registration
- ➢Matching
- Retrieval
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- Classification
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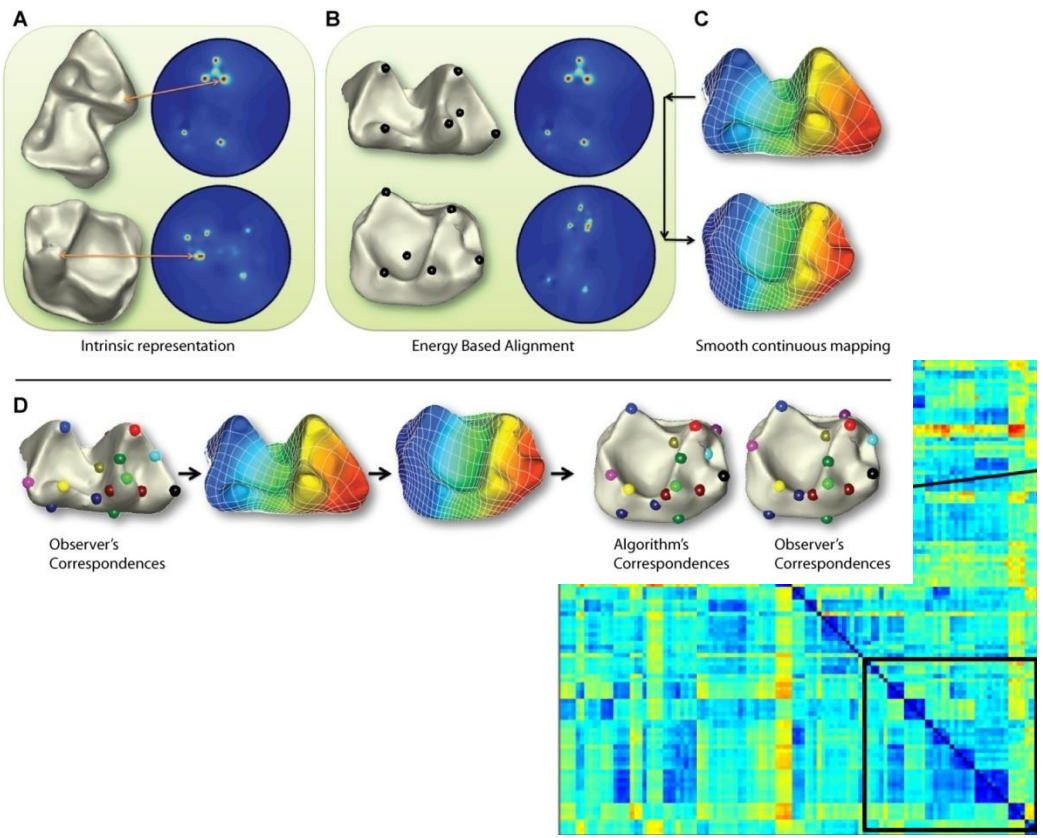


"How can we compute a measure of geometric similarity?"

Written Exercise 3

COS 526 - Written Exerc

www.cs.princeton.edu/courses/archive/fall16/cos526/exercise3/exercise3.html

Advanced Computer Graphics, Fall 2016

Written Exercise 3: Analysis of Shape Collections

Due on Sunday, Nov 20 at 11:59PM

Imagine that a natural history museum gives you a collection of triangle meshes acquired with a 3D laser scanner (e.g., scans of fossils). Each mesh in the collection is labeled to indicate in which of two categories it is a member (e.g., species A and specied B).

The curator of the museum then asks you to design a computer system that can identify the salient differences between meshes in the two categories. She wants the system to produce an accurate category prediction for new meshes based on similarities to ones in the collection and wants it to provide visualizations indicating which regions of the surface meshes are salient for distinguishing the categories.

Unfortunately, the differences in surface shapes between categories can be quite subtle, either because only small parts of the surface are different (e.g., a deviation in the shape of an eye socket), or because differences are due to long-range, low-frequency warps that are difficult to observe visually (e.g., small differences in the curvature of a skull).

a) Please describe the overall design of your proposed system, possibly with a flow-chart diagram outlining the flow of data through your system if it has multiple steps.

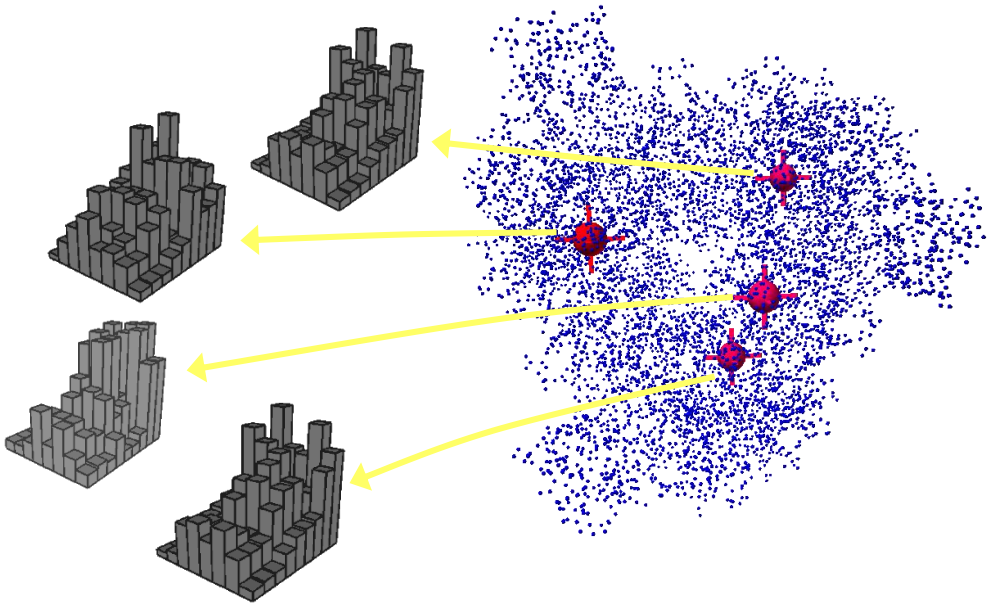
b) Please describe the 2-3 most important algorithms in your system. For each, please explain what subproblem it is addressing (e.g., alignment, feature detection, etc.), what algorithm you have chosen to address the subproblem, and why you think that algorithm is addressing the curator's problem.

Your entire answer should fit within 1-2 pages. Please save/scan your answers into a pdf file named `written_exercise3.pdf` and submit it to CS dropbox.

Mesh Analysis

Examples:

- Feature detection
- Segmentation
- Labeling
- Registration
- Matching
- ➢Retrieval
- Recognition
- Classification
- Clustering
- Functionality



Harmonic Shape Descriptors

"How can we find similar 3D shapes in a database?"

Mesh Analysis

Images courtesy of Florida State Univ.

Examples:

- Feature detection
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- Labeling
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- Matching
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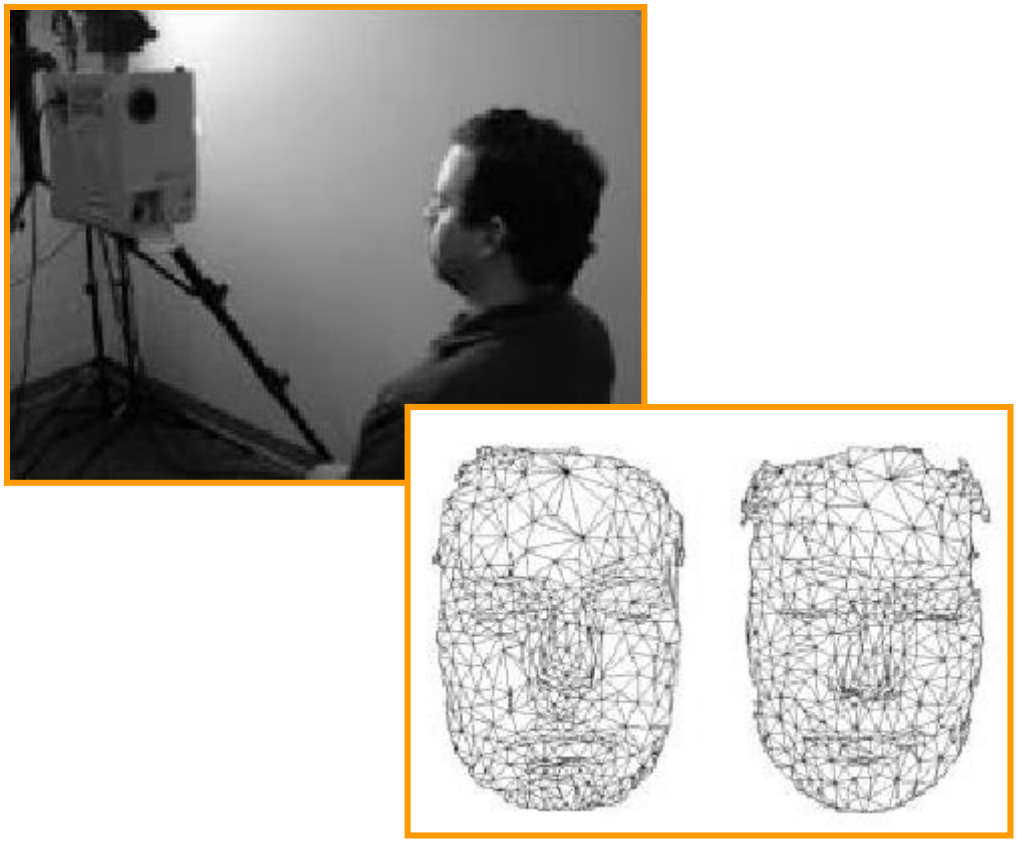
- Functionality



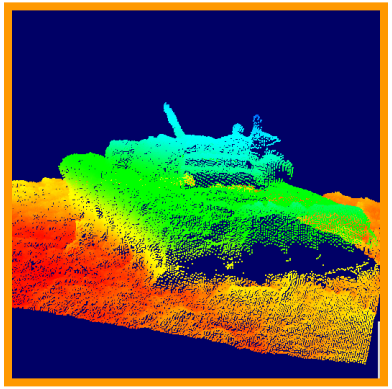
"How can we find a given 3D model in a large database?"

Mesh Analysis

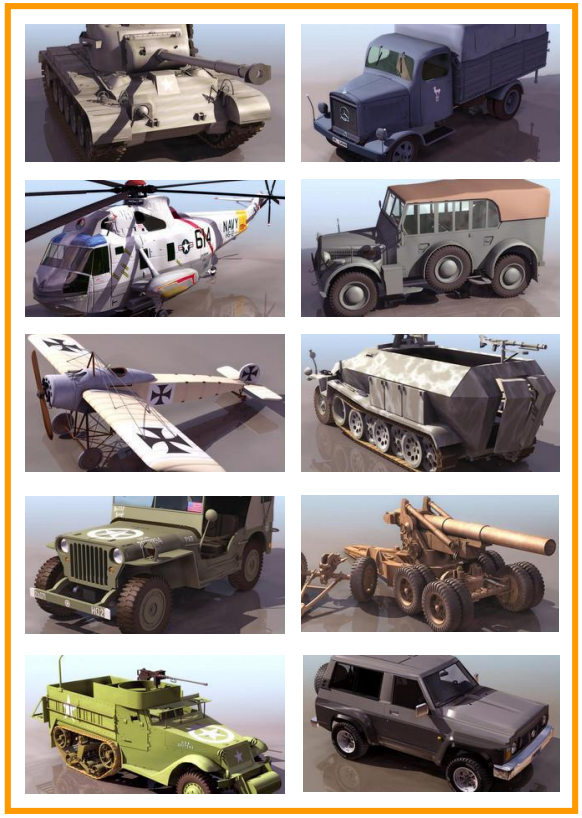
Images courtesy of Darpa E3D Project

Examples:

- Feature detection
- Segmentation
- Labeling
- Registration
- Matching
- Retrieval
- Recognition
- ➢Classification
- Clustering
- Functionality



Query



Classes

"How can we determine the class of a 3D model?"

Mesh Analysis

Images courtesy of Viewpoint

Examples:

- Feature detection
- Segmentation
- Labeling
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- Classification
- ➢ Clustering
- Functionality

"How can we learn classes of 3D models automatically?"

Mesh Analysis

Examples:

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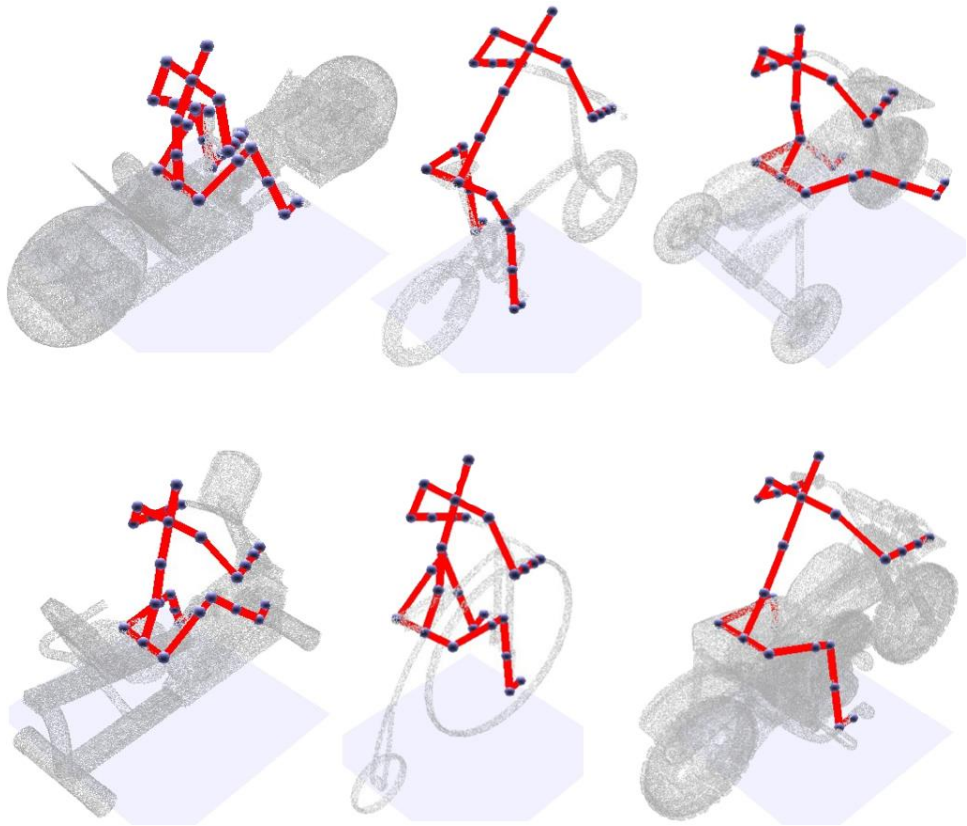
- ➢ Functionality



"Can we predict how an object might be used?"

Programming Assignment 3

COS 526 - Programming

www.cs.princeton.edu/courses/archive/fall16/cos526/assignment3/assignment3.html

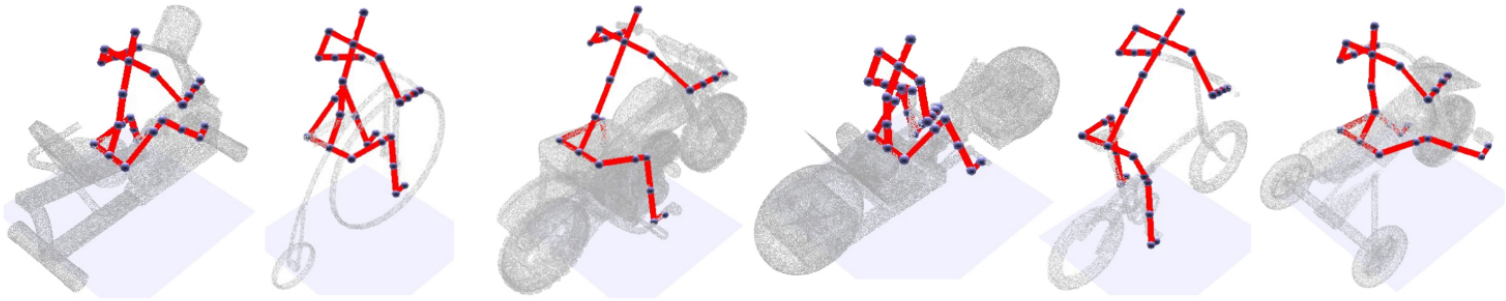
Advanced Computer Graphics, Fall 2016

Programming Assignment 3: Shape2Pose

Due on Wed Nov 30 at 11:59PM

Overview

In this assignment you will implement an algorithm for predicting the pose a human might assume when interacting with a given object. The input to your algorithm will be: 1) a 3D surface mesh, 2) an articulated body, and (optionally) 3) a set of mesh-pose pairs to use as training examples. The output will be a set of predicted poses (represented by a set of joint pivot angles) that the articulated figure might take when interacting with the surface. Ideally, the predicted poses (red) output by your program match the provided ground truth poses with small error.



The following is a list of features that you may implement -- the features in bold face are required. You may choose to implement any two of the others at your discretion. All functions are in render.cpp unless otherwise noted. In addition to implementing these features, you should submit images generated by your program to the art contest. The winner will get extra credit and a note on the course web page.

Upcoming Lectures

Mesh representation

Mesh processing

Mesh analysis