

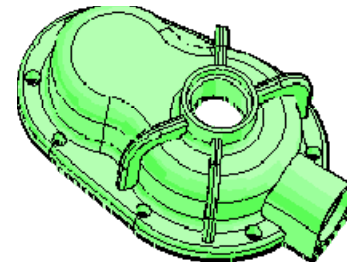
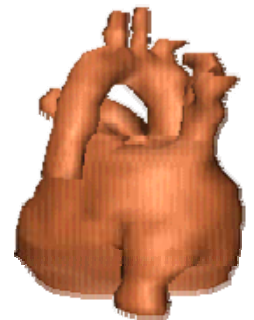
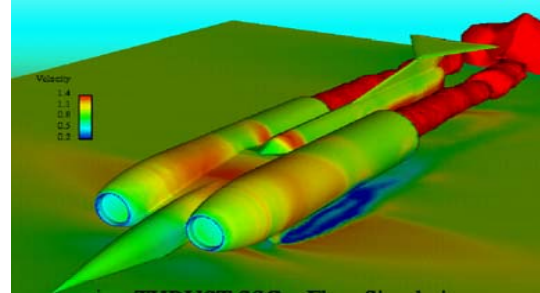
CS 523: Computer Graphics, Spring 2009

# Shape Modeling

Introduction and Overview

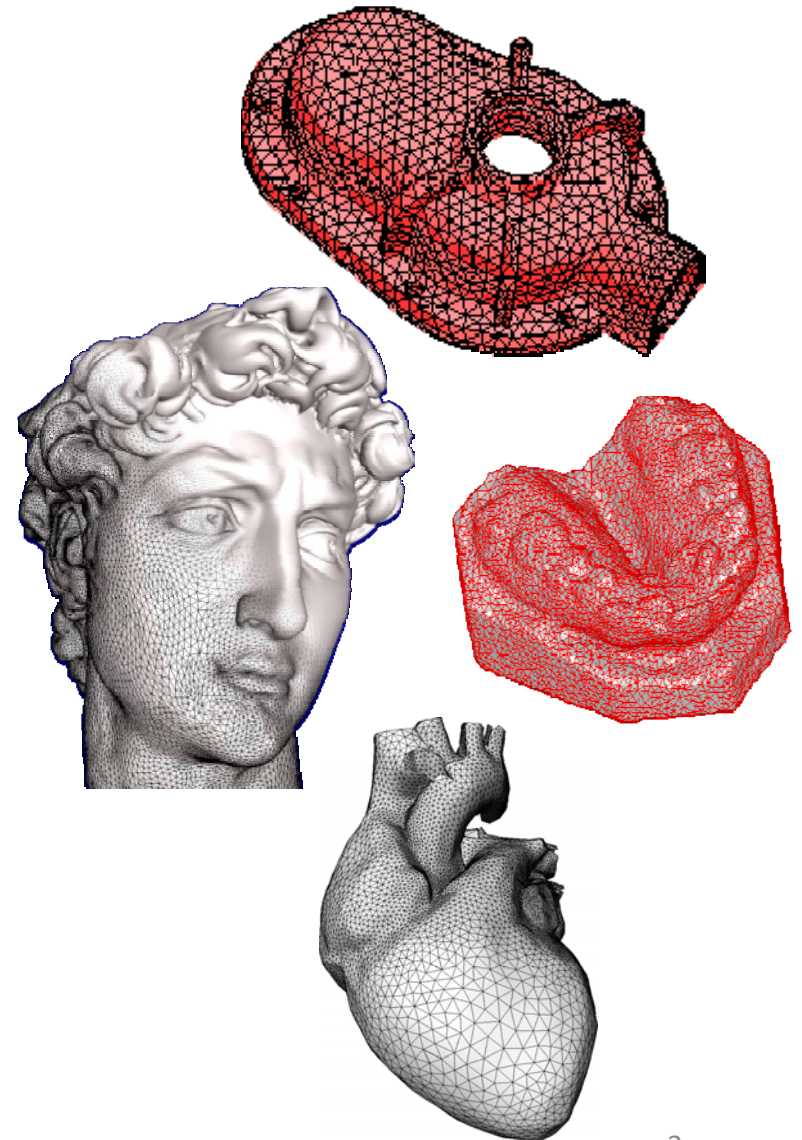
# Geometric Modeling

- To describe any real-life object on the computer – must start with shape (2D/3D)
- Geometry processing - computerized modeling of 3D geometry



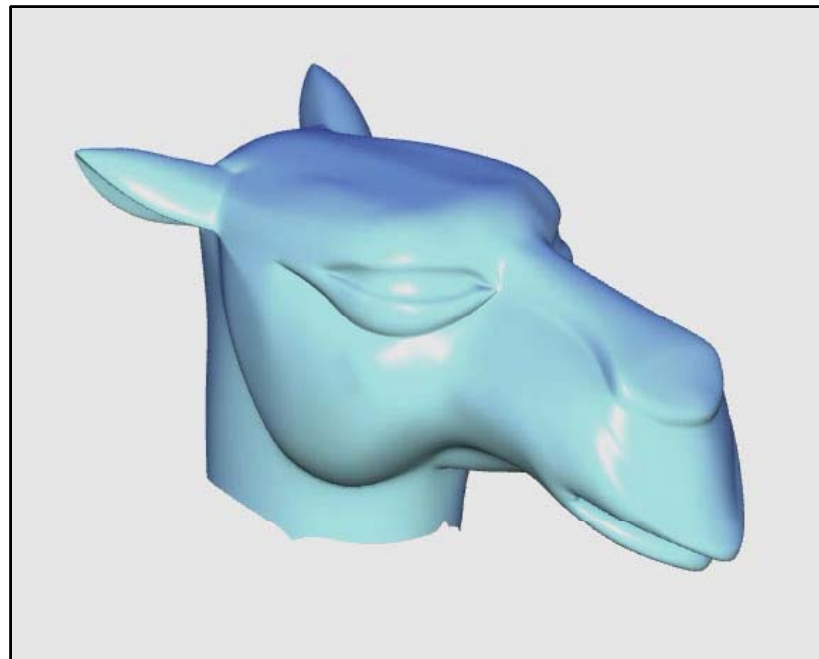
# Digital Geometry Processing

- Processing of discrete (polygonal mesh) models
  - Typically triangular
- Why discrete?
  - Simplicity – ease of description & transfer
  - Base data for rendering software/hardware
  - Output of most acquisition tools (CT, MRI, laser, etc..)
  - Input to most simulation/analysis tools



# Interactive shape modeling

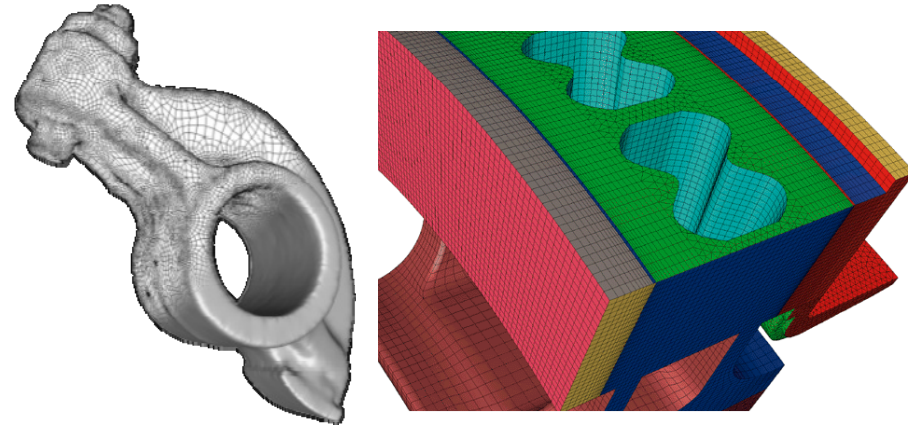
- Tools for design and editing of digital shapes
  - Interactive means fast algorithms
  - Intuitive – expected outcome



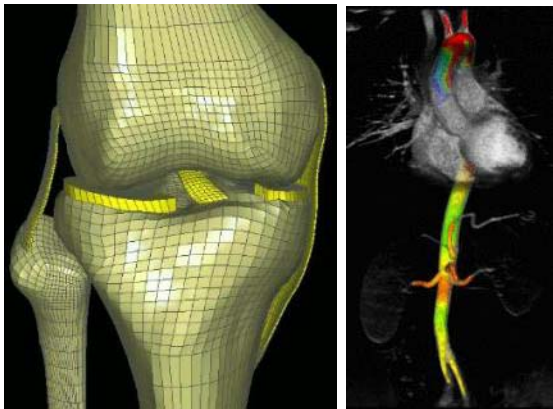
# Applications



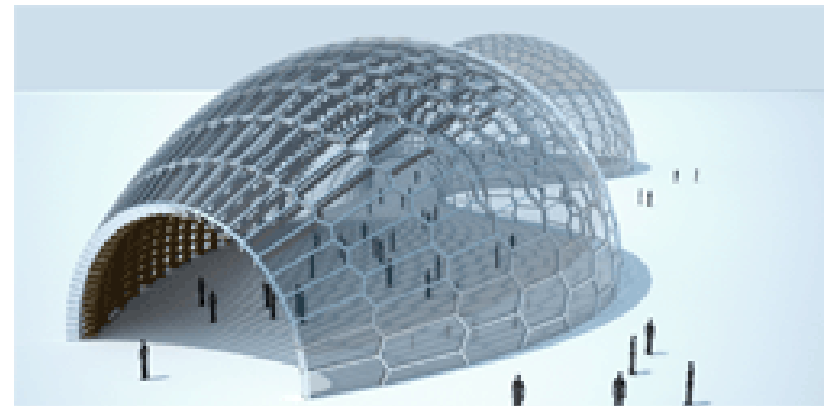
**Games/Movies**



**Engineering**



**Medicine/Biology**



**Architecture**

# Tools?

- Use techniques from both Math & CS
  - Differential geometry
  - Numerical linear algebra
  - Graph theory
  - ...
- ...Combined with a lot of intuition...
- Work on real data = Write/use a lot of code 😊

# Organization

## People

- Andrew Nealen  
CBIM, room 21  
`nealen@cs.rutgers.edu`  
`http://www.cs.rutgers.edu/~nealen`  
Office hours: Tuesday, 3-5pm
- Teaching assistant:  
Xiaofeng Mi  
`xmi@cs.rutgers.edu`

# Organization

Web and communication

- Course website (external access to Wiki)  
`http://tinyurl.com/cs523-spring09`
- Wiki, archived mails, forum, etc...  
`http://sakai.rutgers.edu`
- Use mailing list  
`cs523-spring09@sakai.rutgers.edu`  
and Sakai forum for communication



# Organization

## Course materials

- No book covers all topics
  - Many of the topics are recent research results 😊
- I will link to relevant papers, presentations and tutorials on the course website
- Lecture slides will be available on the web shortly before each class
  - Makes sense to annotate them during the lectures

# Prerequisites

- Familiarity with basic calculus, linear algebra, and vector calculus
- Familiarity with a graphics API (e.g. OpenGL)
  - If not, learn quickly (for the sake of visualization)
- C/C++ coding skills
  - If Java is preferred, you will be on your own
- Capability to search Google and forums for useful information 😊

# Course Overview

## Topics

- Shape representations in computer graphics
  - Points, implicits, meshes + related data structures
- Shape acquisition and reconstruction
- Linear algebra tools for geometric modeling
- Differential geometry (normals, curvatures, ...)
- Digital geometry processing (smoothing etc.)
- Mesh deformation (space- and surface-based)
  - Approximately 40-50% of the course

# Grading

- **30% - Assignments** (can be done in pairs)
  - Assignment 1: Mesh processing “Hello World”. mesh data structure programming + rendering
  - Assignment 2: Basic local mesh operations + selection tools
- **40% - Final project** (can be done in pairs)
  - Implementation/extension of a space or surface based editing tool (makes use of assignments 1+2)
  - Includes proposal, report and presentation

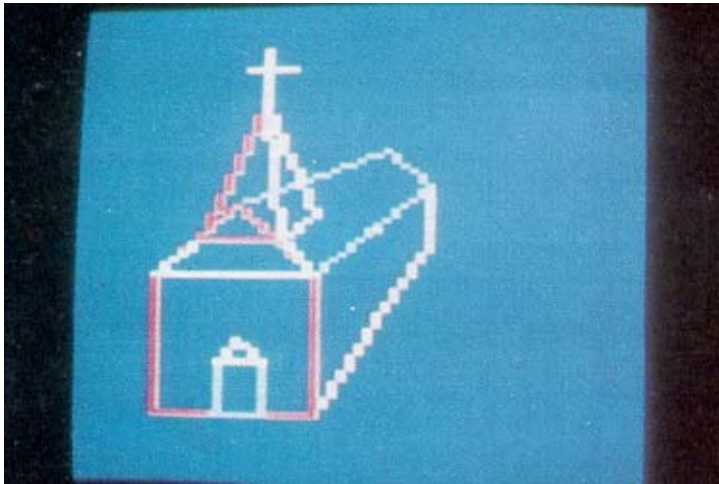
# Grading

- 20% - Paper presentation
  - Many possible sources: SIGGRAPH, Symposium on Geometry Processing (SGP), Shape Modeling International (SMI), Eurographics, see <http://kesen.huang.googlepages.com/>
  - 15-20 minute power point presentation + discussion with me (latest) one day before class
- 10% - Class participation
  - Feedback on peer paper presentation + application presentations, etc.

# Computer Graphics

The big picture

- 3D graphics programming in 1979



approx. 25 triangles



approx. 50 x 100 pixels

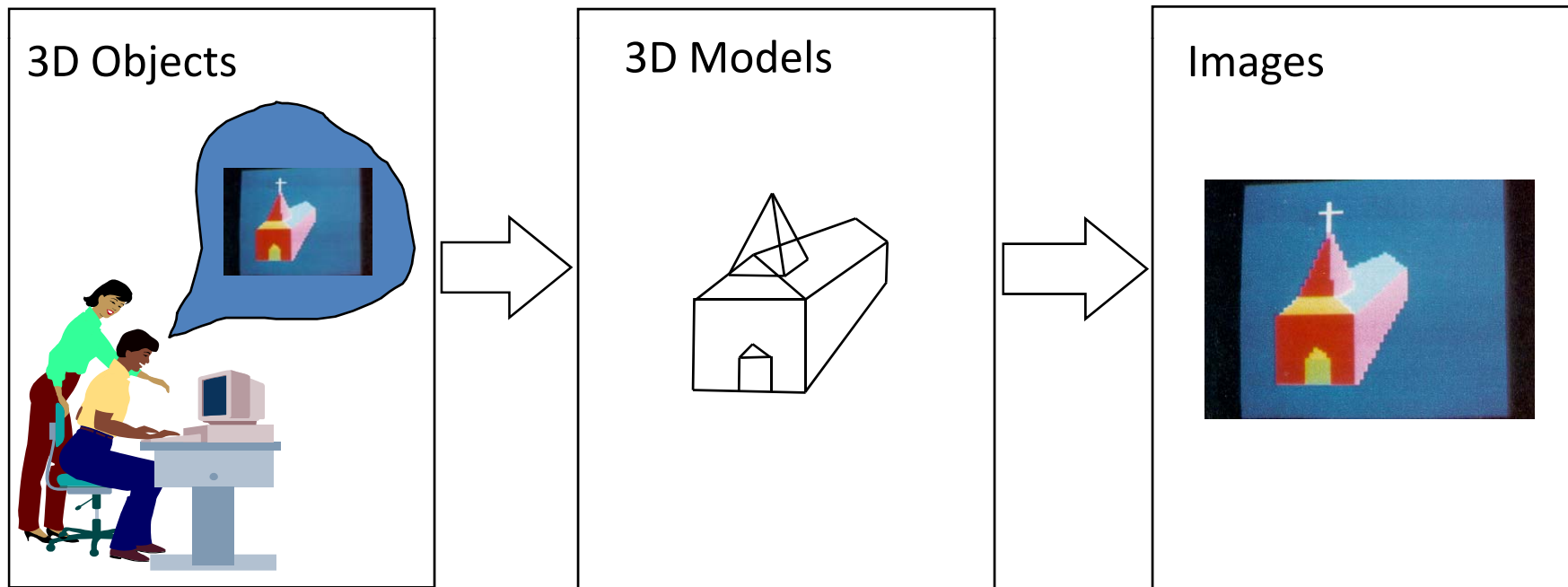
# Computer Graphics

The big picture

- Common workflow

Modeling

Rendering



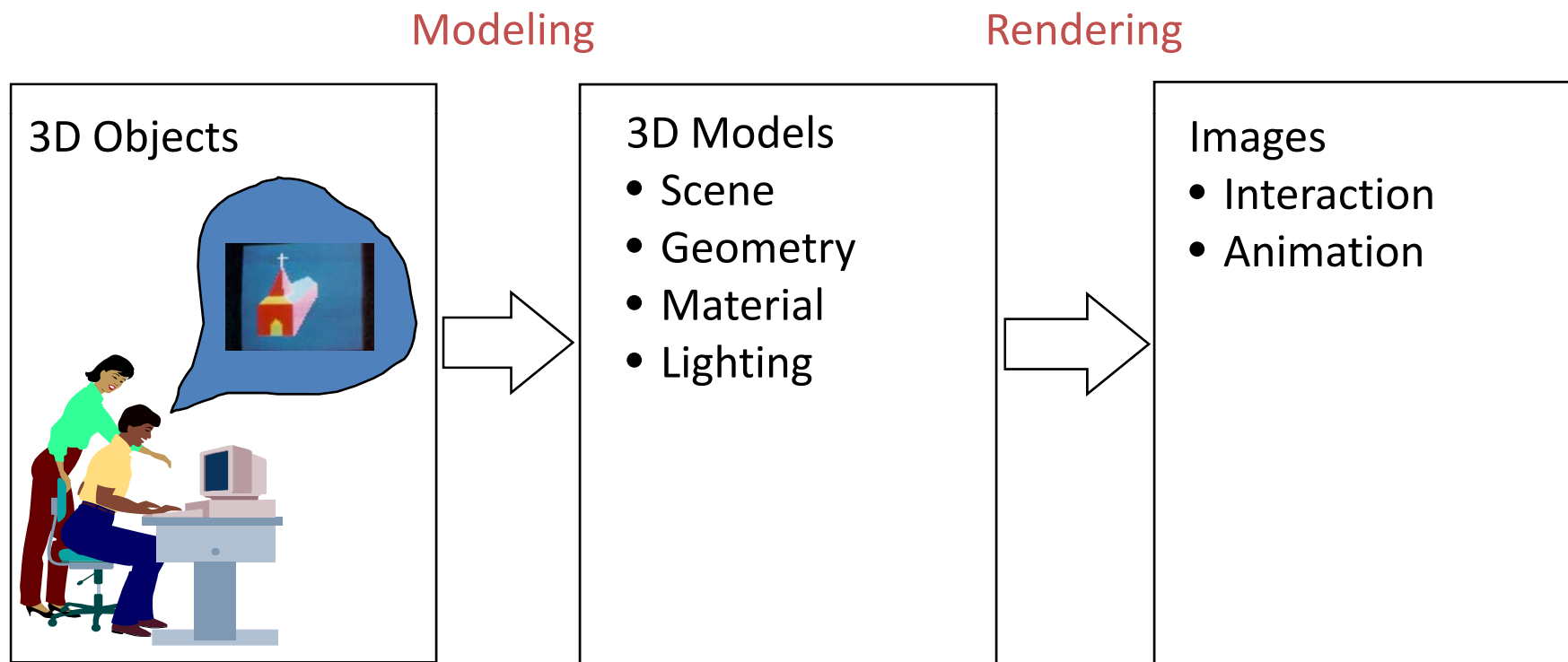
approx. 25 triangles

approx. 50 x 100 pixels

# Computer Graphics

The big picture

## ■ Common workflow

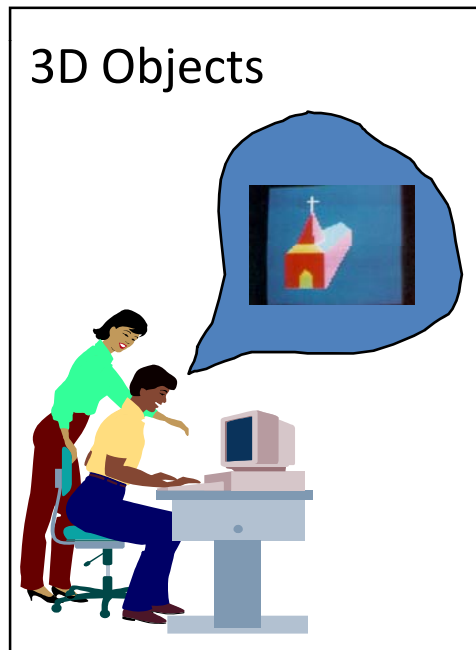




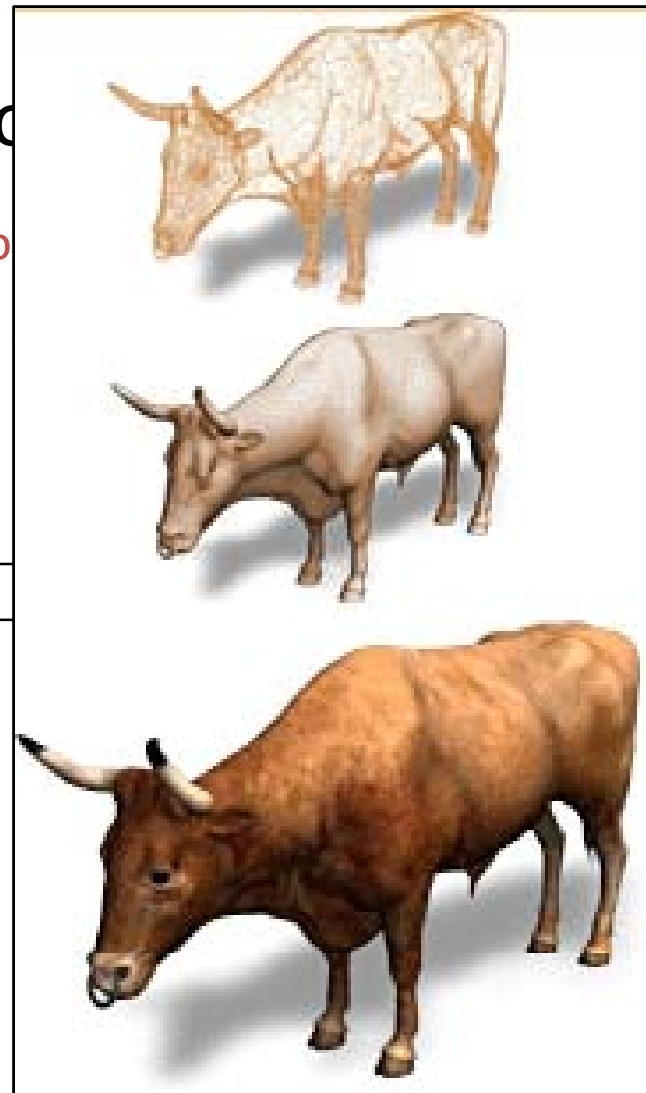
# Computer Graphics

The big picture

## Common workflow



Modeling



Rendering

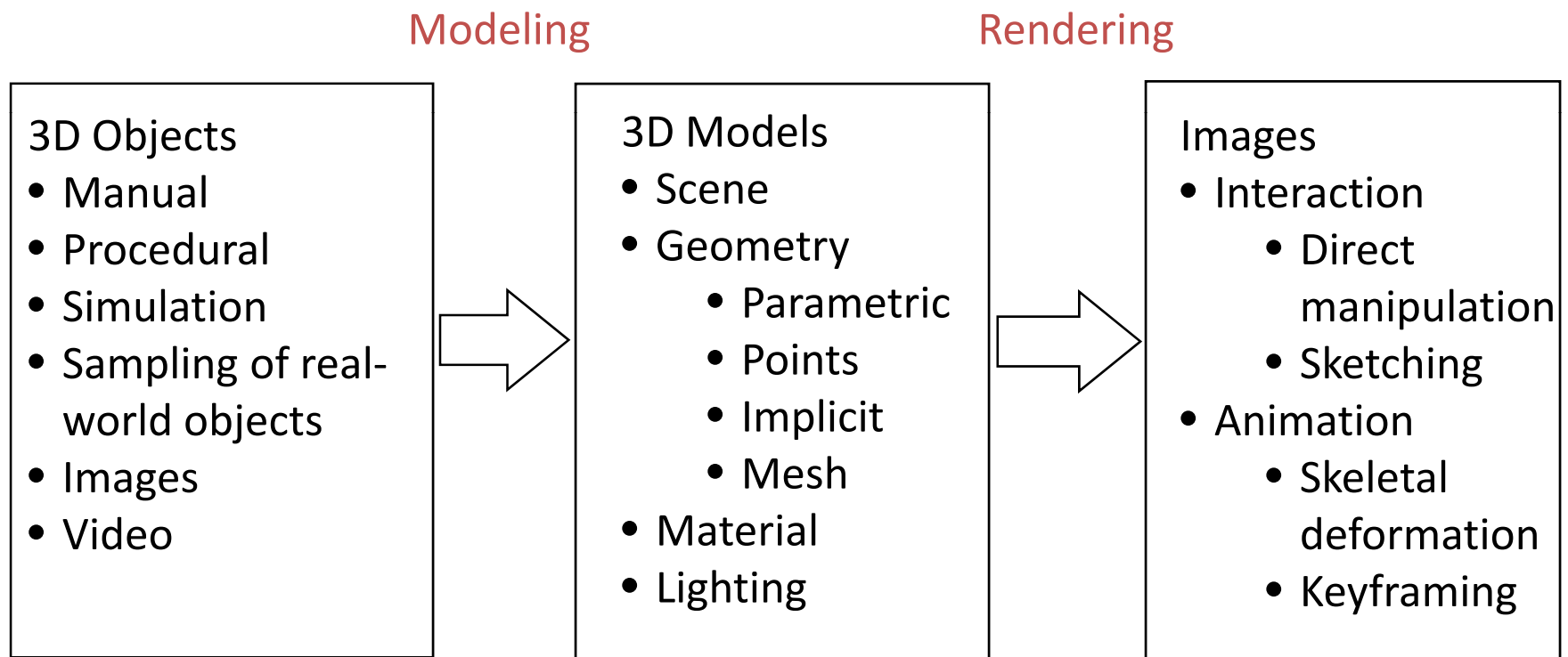
Images

- Interaction
- Animation

# Computer Graphics

The big picture

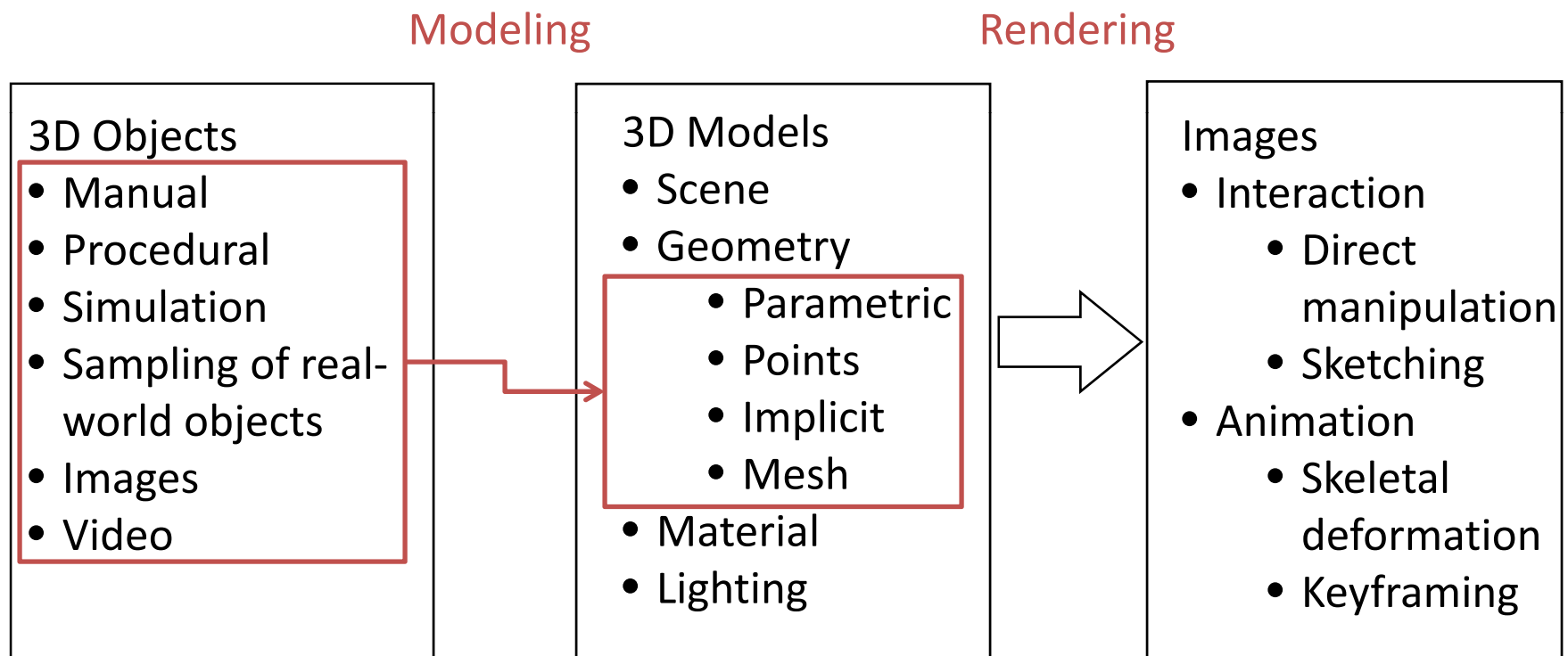
## ■ Common workflow



# Computer Graphics

The big picture

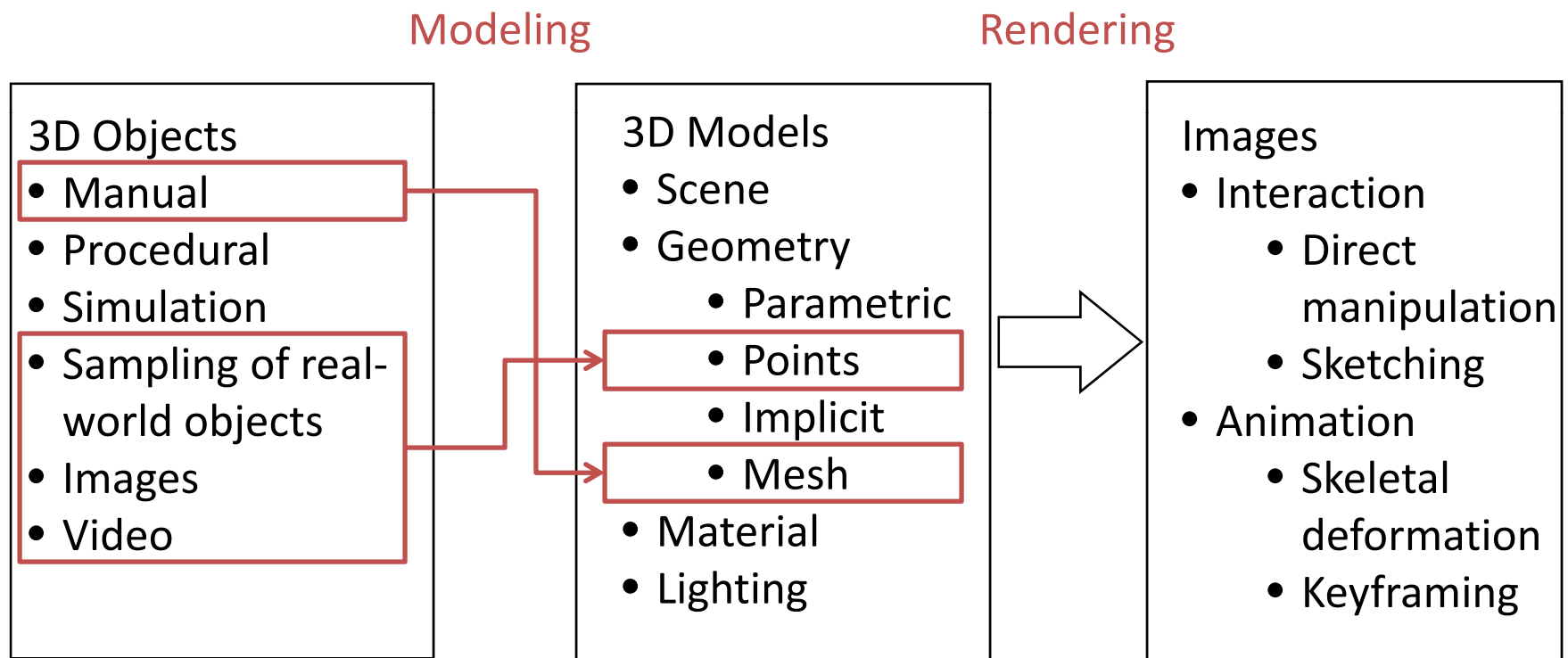
## ■ Model creation



# Computer Graphics

The big picture

## ■ Model creation



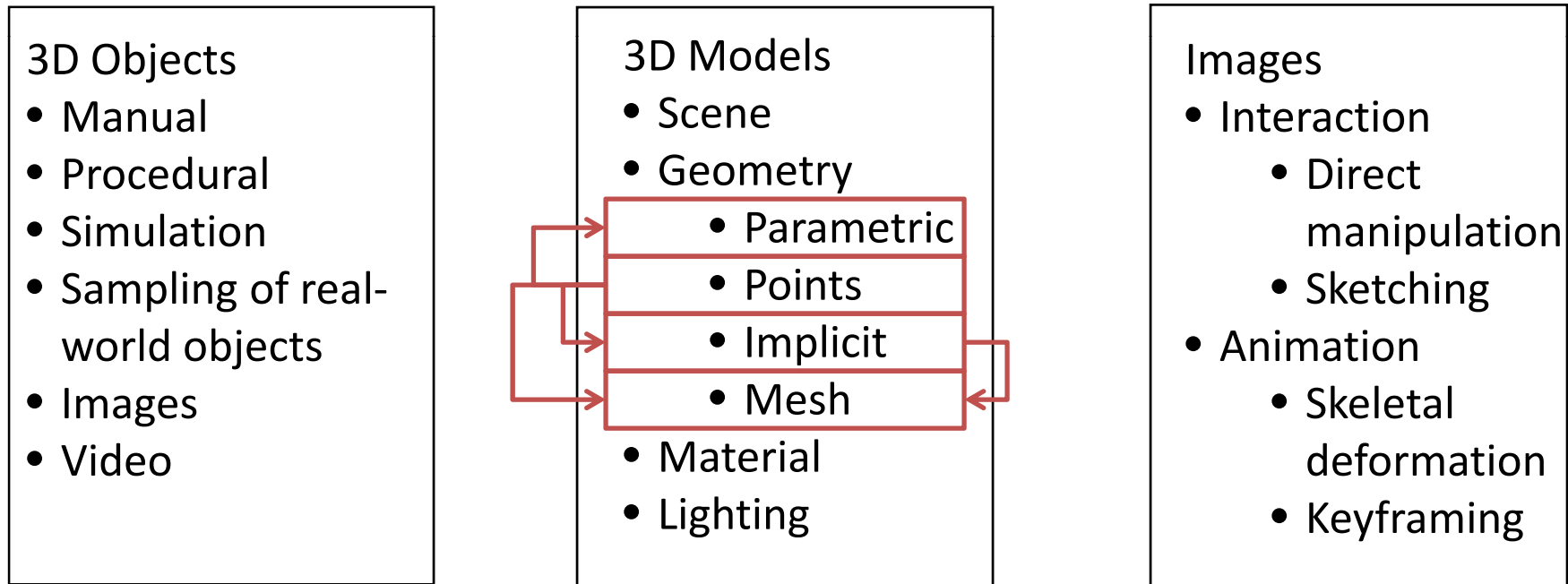
# Computer Graphics

The big picture

## ■ Model representation and conversion

Modeling

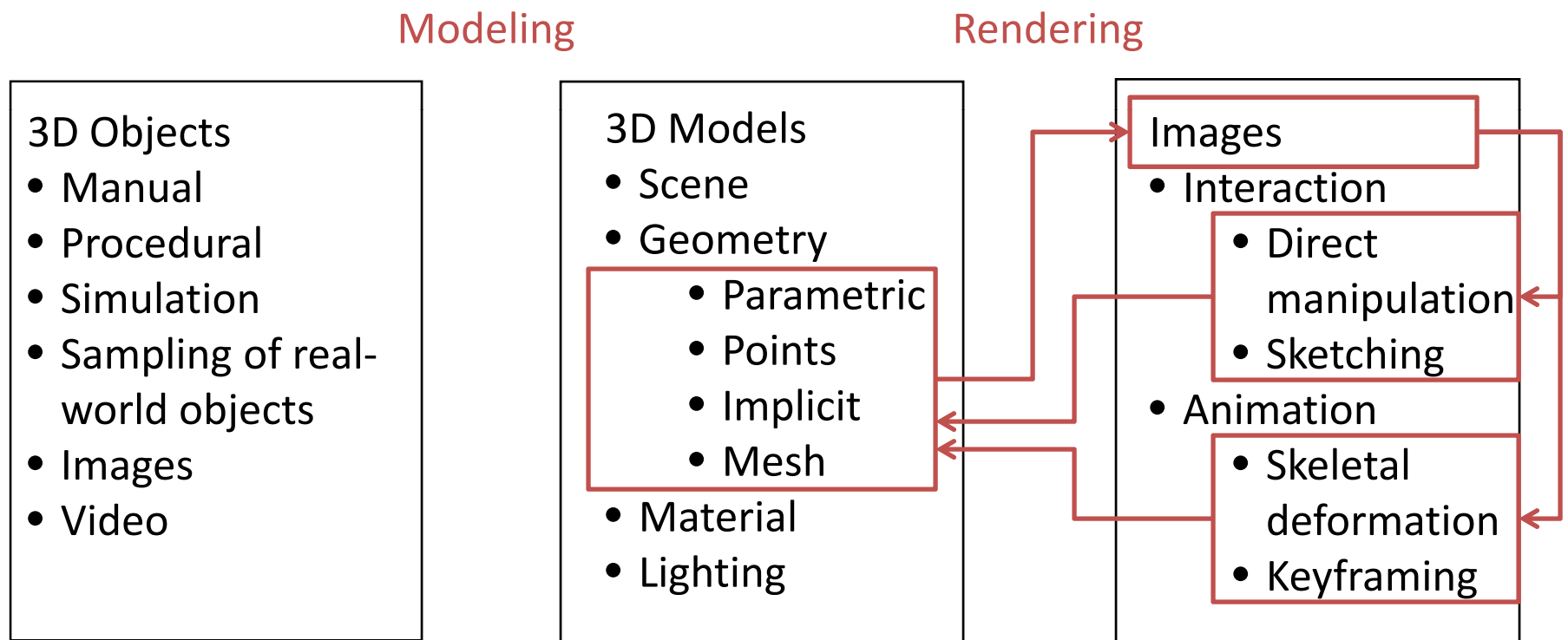
Rendering



# Computer Graphics

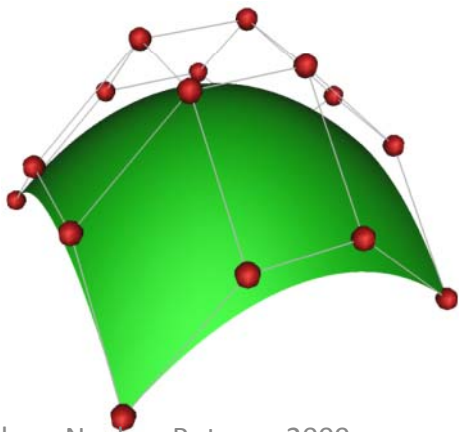
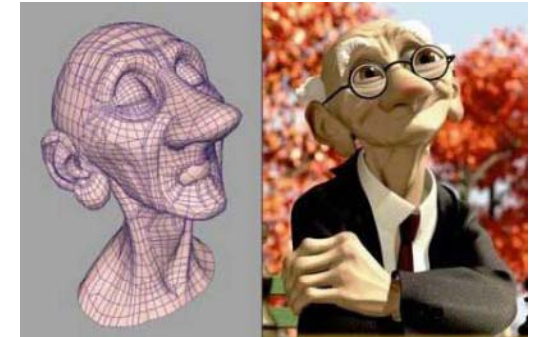
The big picture

## ■ Model modification and editing loop

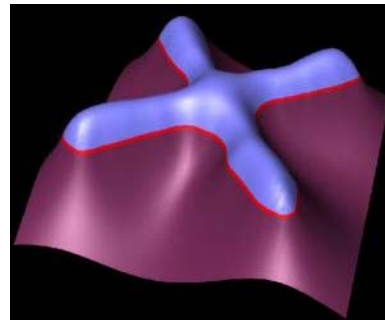


# Course Topics

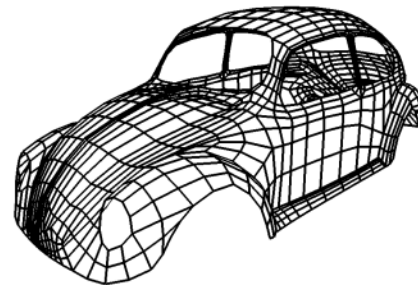
- Shape representation
  - Parametric surfaces
  - Subdivision surfaces
  - Implicits



Andrew Nealen, Rutgers, 2009

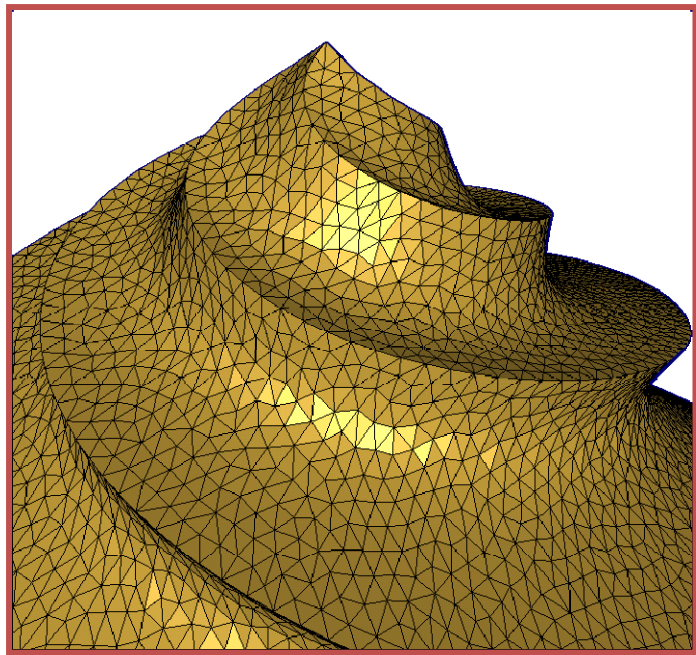


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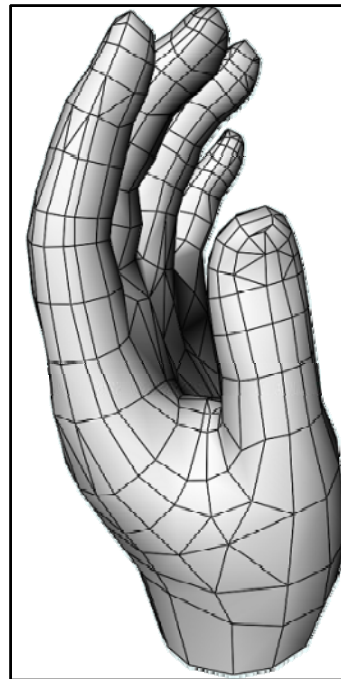


# Course Topics

- Shape representation
  - Polygonal meshes



Andrew Nealen, Rutgers, 2009



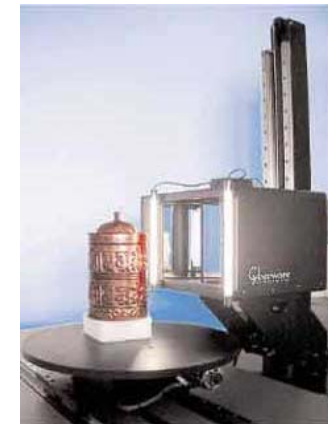
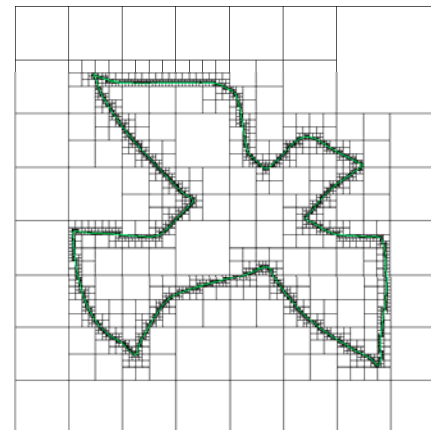
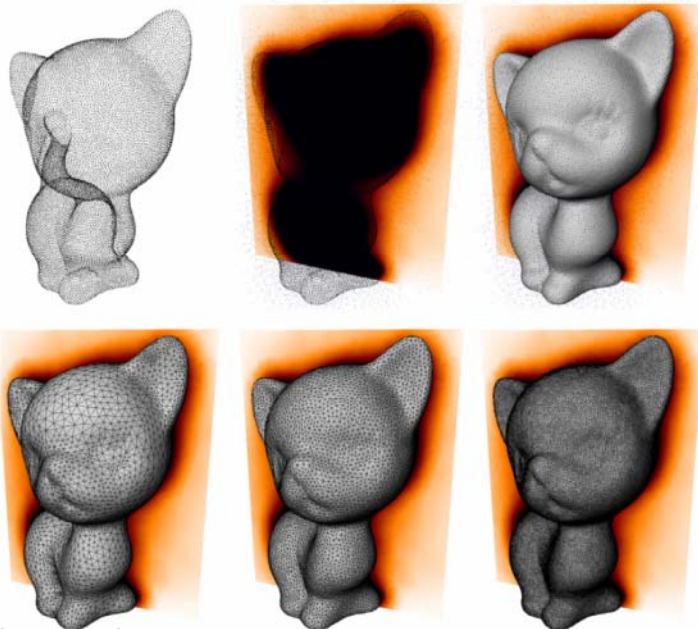
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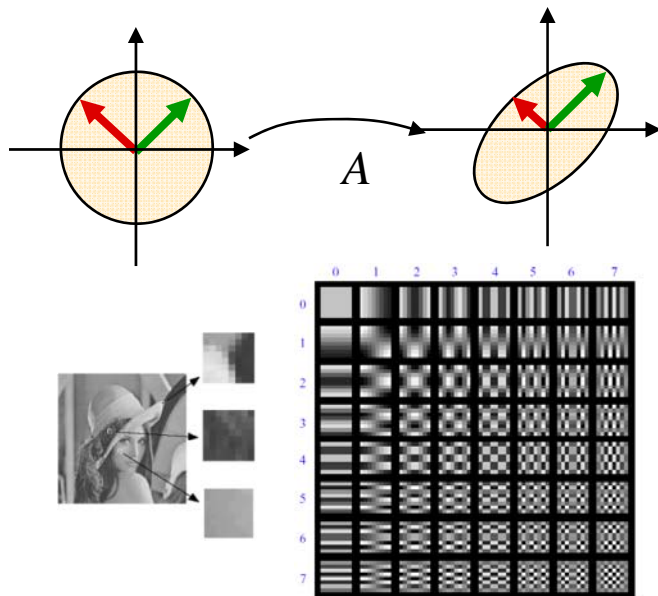
# Course Topics

- Shape acquisition
  - Scanning/imaging
  - Reconstruction



# Course Topics

- Mathematical tools
  - Revisit linear algebra: transformations, spectral decomposition, PCA, SVD
  - See where these are used!

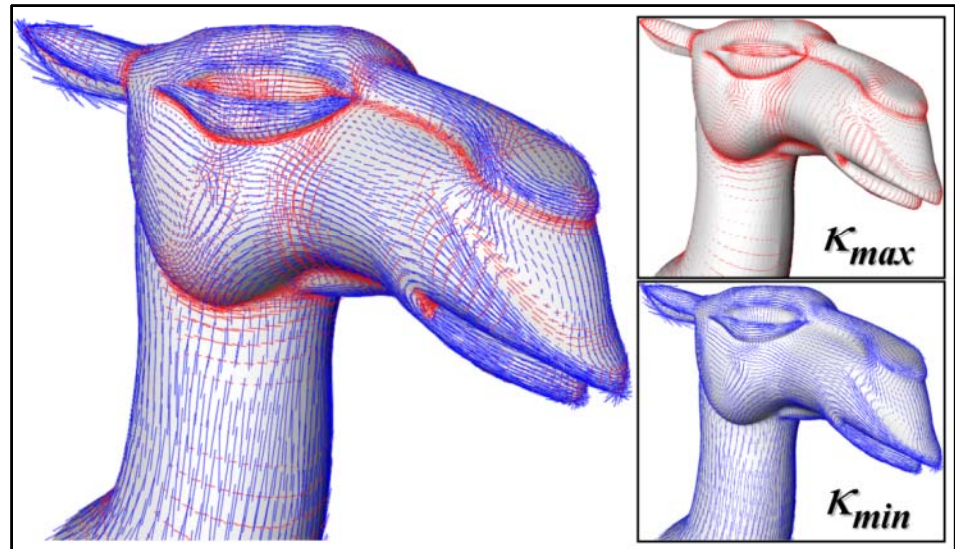
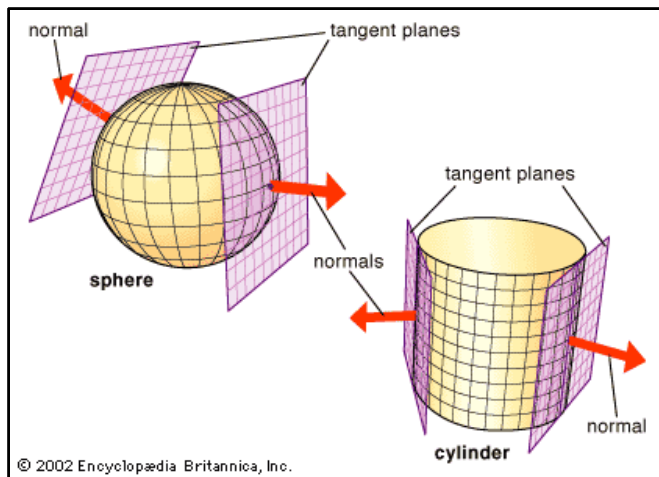


$$\begin{matrix} & \overbrace{\phantom{A}}^n \\ \underbrace{\phantom{A}}_m & = & U & \Sigma & V^T \end{matrix}$$

The diagram shows the SVD decomposition of matrix  $A$  into  $U$ ,  $\Sigma$ , and  $V^T$ . The matrix  $\Sigma$  is shown as a square with a diagonal of singular values  $\sigma_1, \sigma_2, \dots, \sigma_n$ .

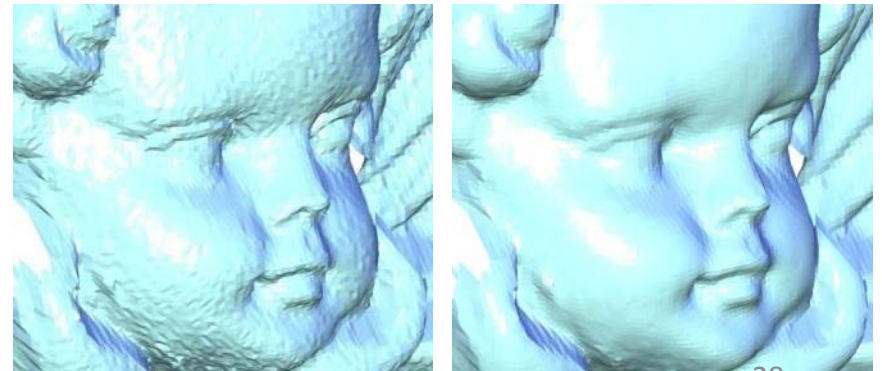
# Course Topics

- Mathematical tools
  - Differential geometry – continuous and discrete
  - Our main tool to analyze and understand shapes



# Course Topics

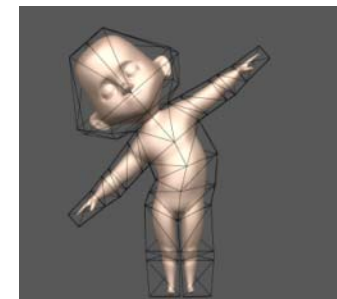
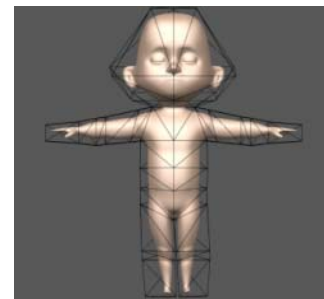
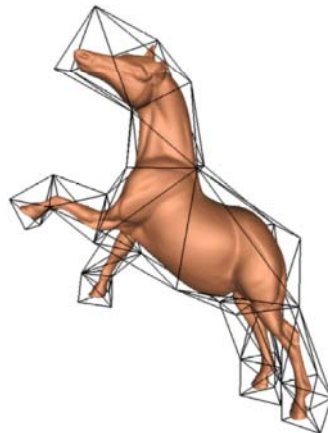
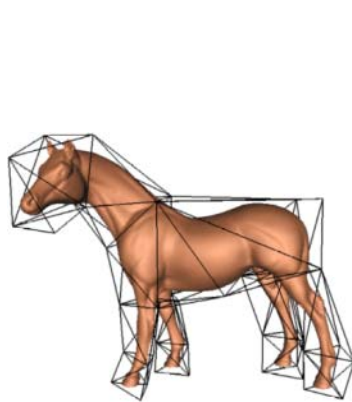
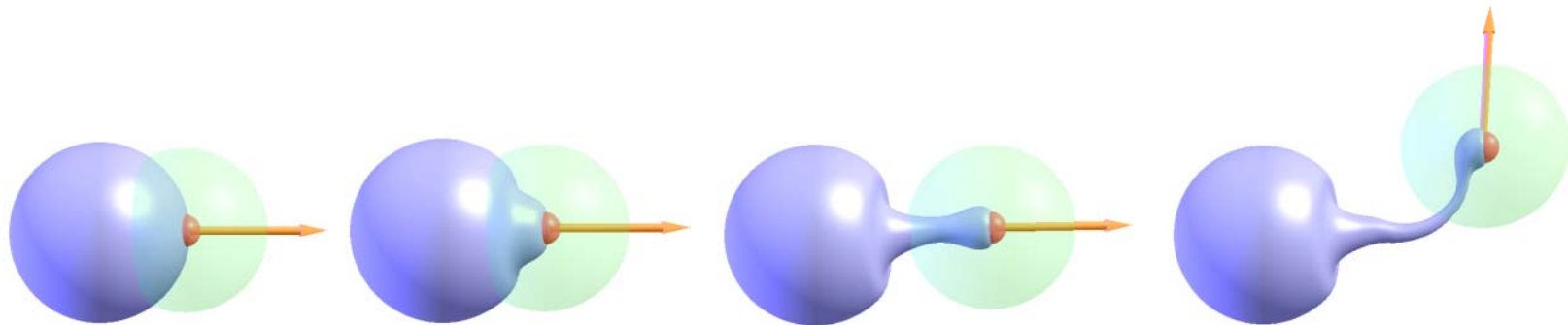
- Digital geometry processing
  - Denoising, smoothing, simplification/remeshing, parameterization, compression





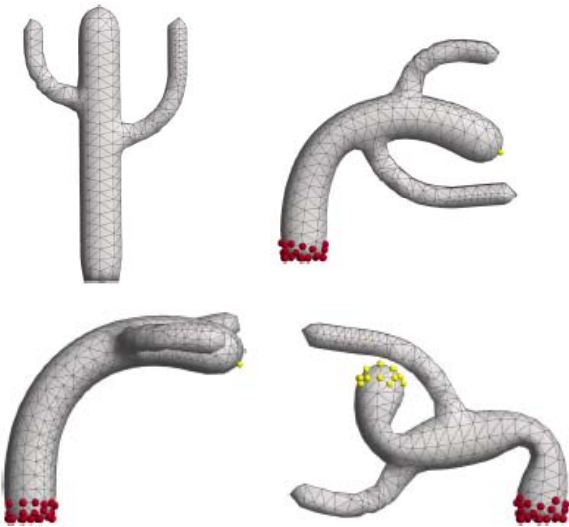
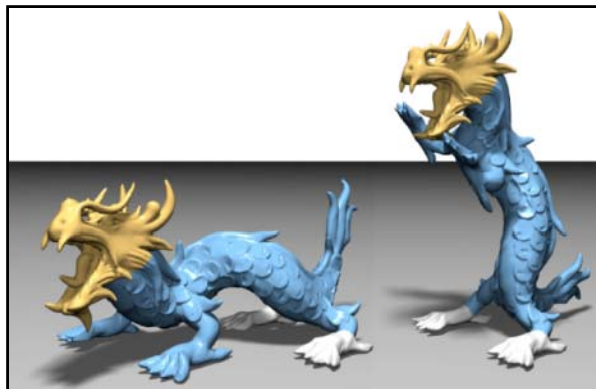
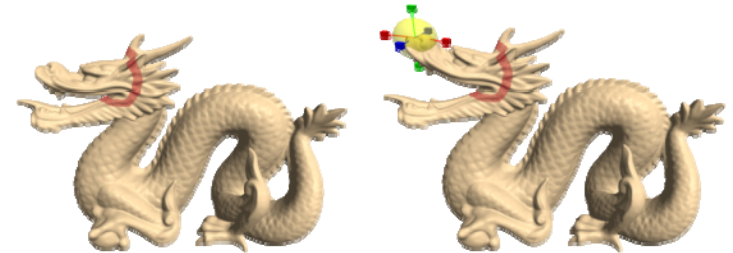
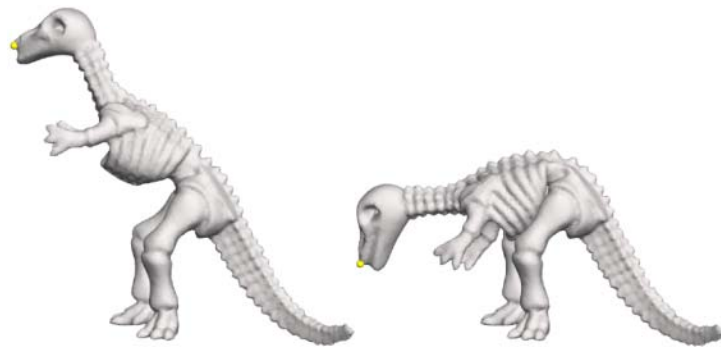
# Course Topics

- Shape modeling and deformation
  - Space warps/ Freeform deformations



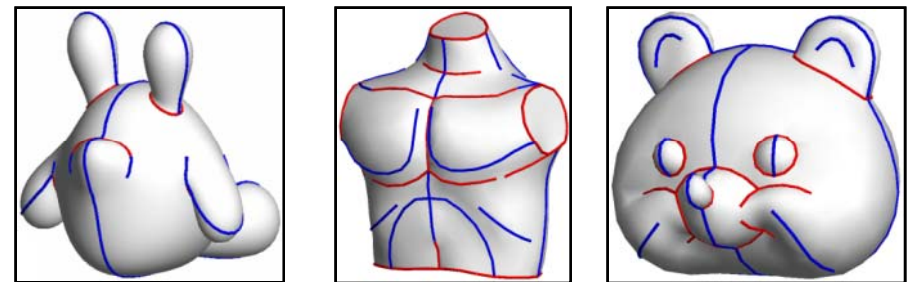
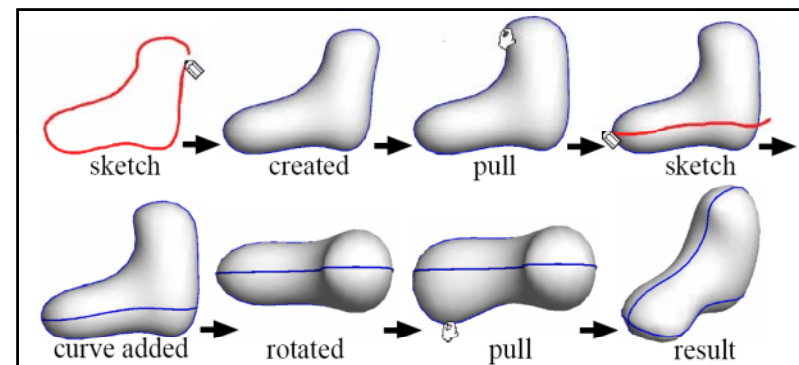
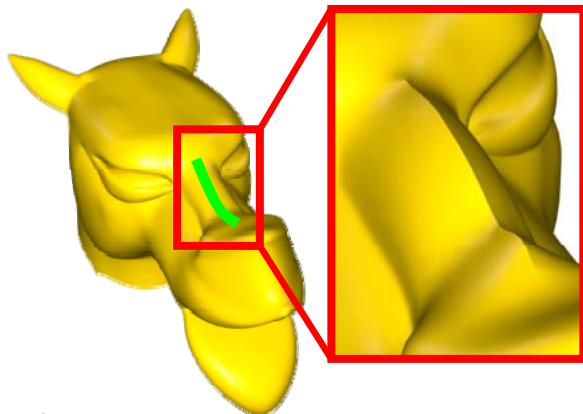
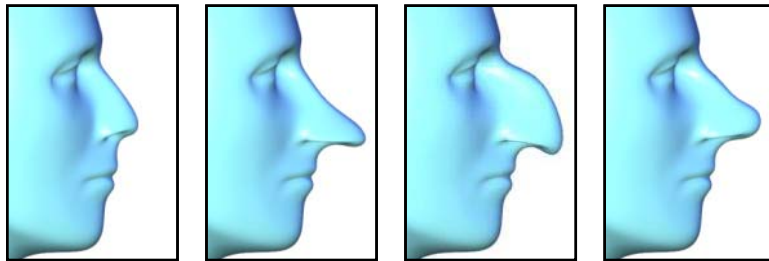
# Course Topics

- Shape modeling and deformation
  - Surface-based deformations



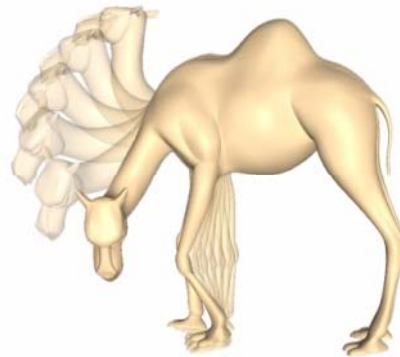
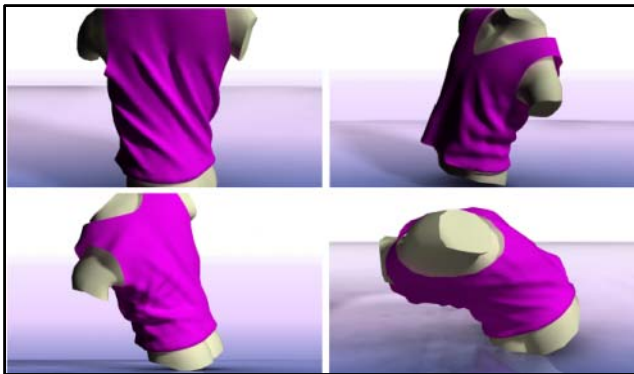
# Course Topics

- Sketch-based interfaces
  - Shape creation
  - Shape editing



# Course Topics

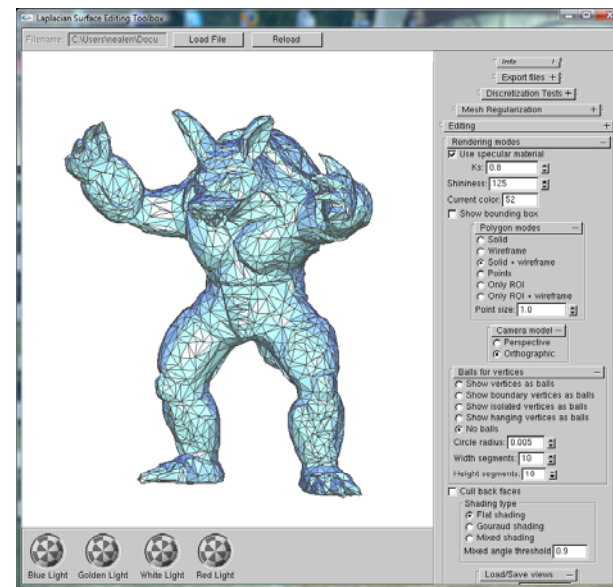
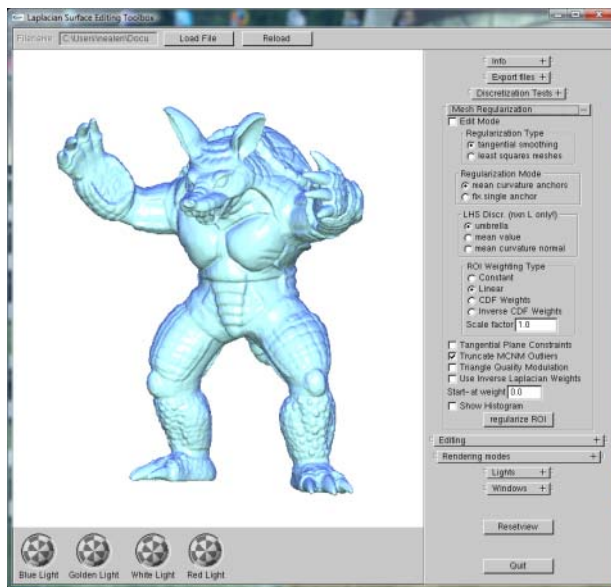
- More applications of geometric deformation
  - Skeleton-skin animation; morphing
  - Image/video retargeting





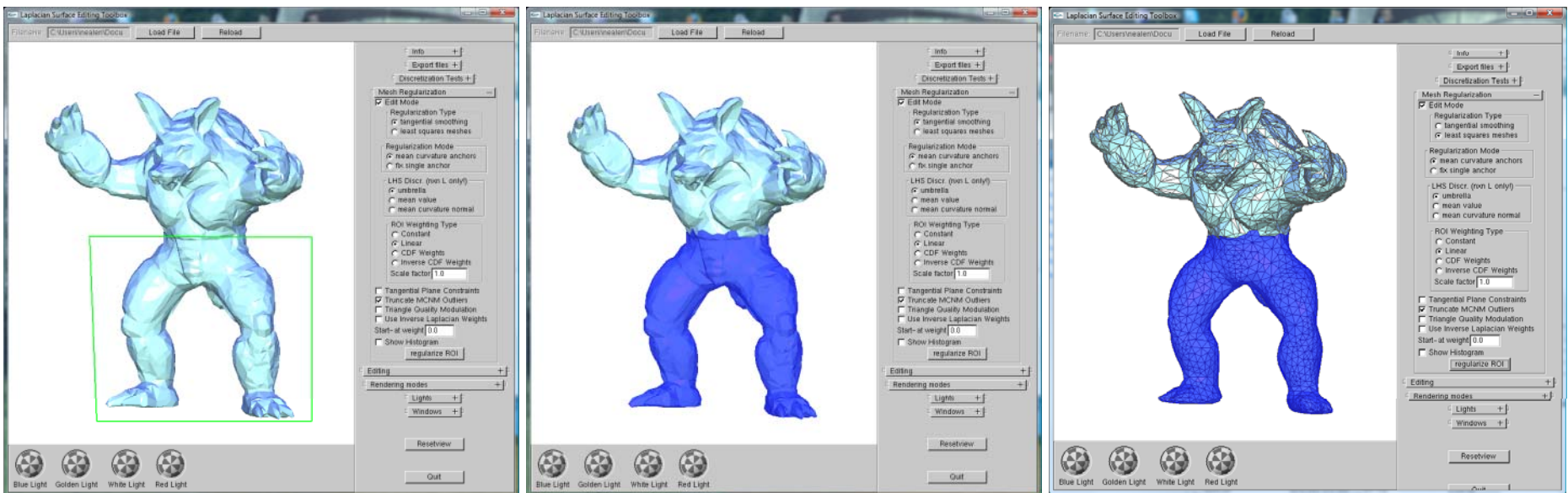
# Assignments

- Assignment 1: Mesh processing “Hello World”
  - Goals: learn basic mesh data structure programming + rendering (flat/gouraud shaded, wireframe) + basic GUI programming



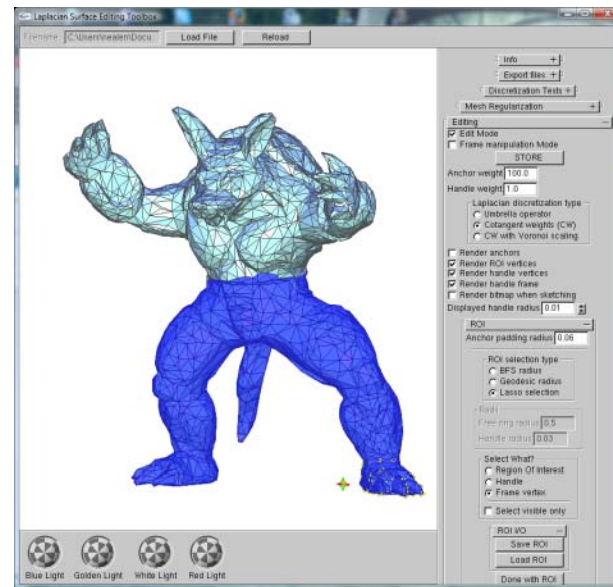
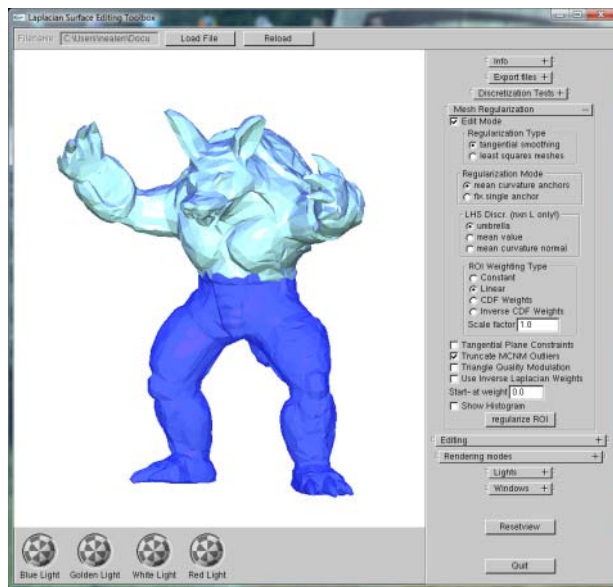
# Assignments

- Assignment 2: selection + operation tools
  - Goals: implement image-space selection tools and perform local operations (smoothing, etc.) on selected region



# Final Project

- Implementation/extension of a space or surface based editing tool
  - makes use of assignments 1 + 2
  - Your own suggestion, with instructor approval



# Final Project

- Includes written project report and presentation
  - Latex style files will be provided
  - Power Point examples will be provided

