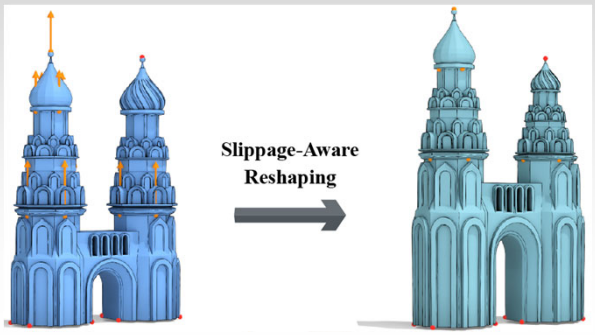
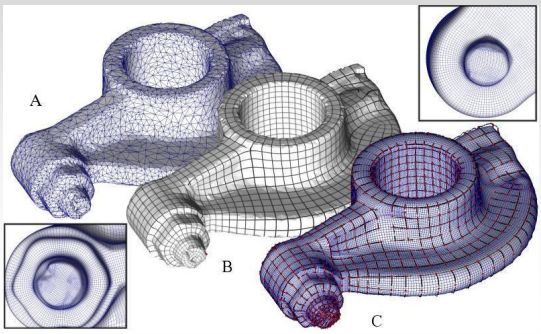
Computer Graphics: Modeling (CPCS 524)

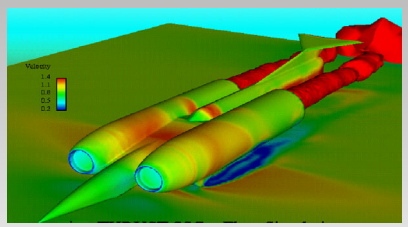
http://www.cs.ubc.ca/~sheffa/dgp

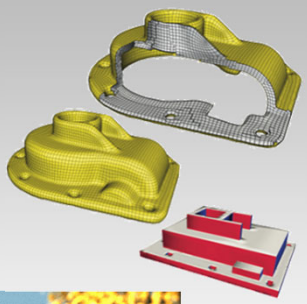




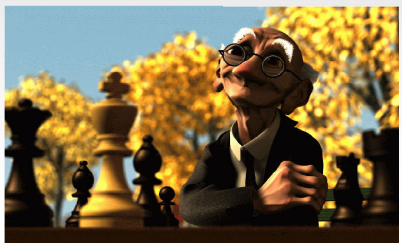
Geometry Processing

Shape is a basic property of most objects



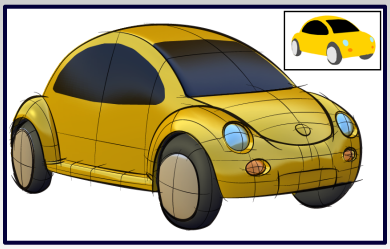


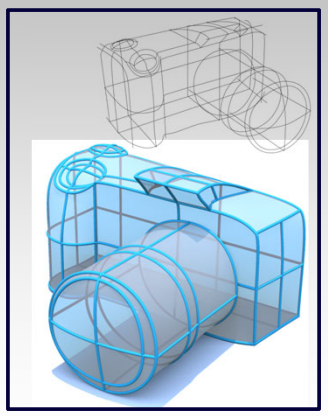
Geometry processing: ***computerized modeling & manipulation of 3D geometry***



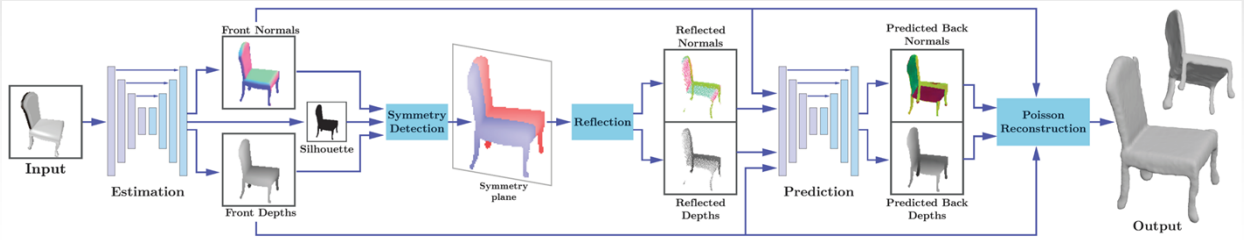
What is it about?

Creation & manipulation of geometry (3D or 2D)

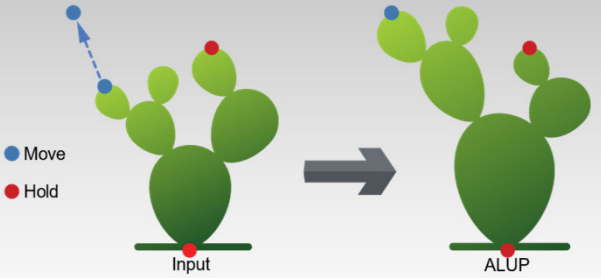


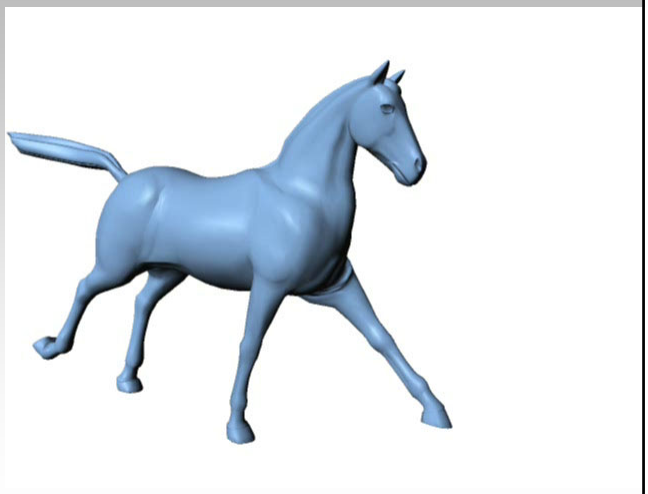


Geometry Reconstruction: raw geometry to mesh



Deformation/Animation (physics free)





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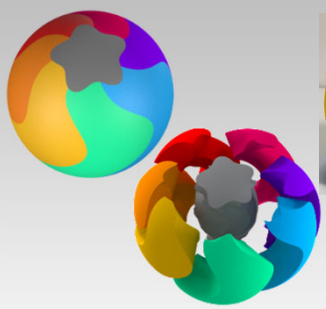
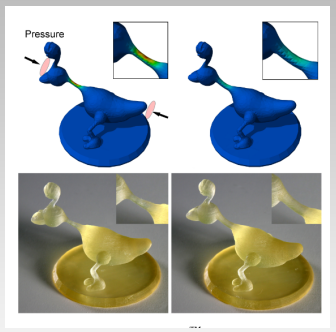
Fabrication





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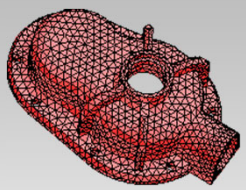
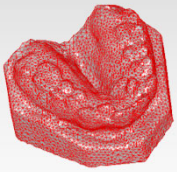
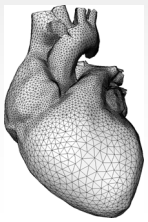
Geometry Representation: Meshes

Focus on discrete (polygonal mesh) models

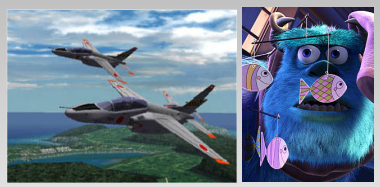
- Typically triangular

Why?

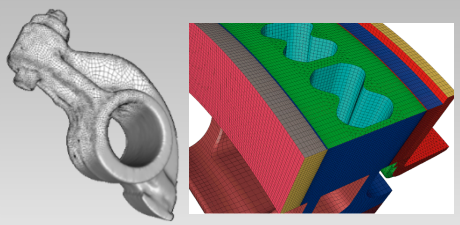
- Simplicity – ease of description & transfer
- Base data for rendering software/hardware
- Input to most simulation/analysis tools
- Output of most acquisition tools (CT, MRI, laser, etc..)
- Alternatives: Implicit/volumetric (e.g. SDF), splines/BREP, …

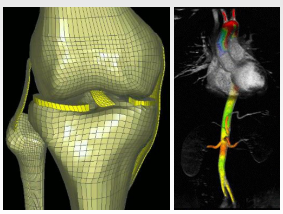
Applications



Games/Movies



Engineering



Medicine/Biology

Architecture

Tools?

Use techniques from both Math & CS

- Differential geometry
- Computational geometry
- Graph theory
- Machine learning
- ...

...Combined with a lot of intuition...

Work on real data = Write a lot of code ☺

Course Processes

Course Info

Instructor (me): Alla Sheffer

- Office: ICICS/CS x651
- e-mail: sheffa@cs.ubc.ca
- Office hours (virtual unless requested otherwise) by appointment

TA: Jinfan Yang

- *Office hours by appointment*

Web page: www.cs.ubc.ca/~sheffa/dgp

- Includes all course material
- Piazza page (link from course page)
  - *Info on all changes & news*
  - ***Please check OFTEN***

Grading

60% - Assignments

- Use in-house mesh data-structure/GUI
  - *Minimal/sufficient*
- 15% - Assignment 1: Mesh Data-Structures/Subdivision
  - *Out*
- 15% - Assignment 2: Mesh Simplification
- 15% - Assignment 3: Mesh Parameterization
- 15% - Assignment 4: Mesh Deformation

Grading

10% - Paper presentation

- 15min presentation + 15min discussion
- Can reuse original author material
  - *Adjust to fit 15min*
  - *Separate core from details*
  - *Can ask me for early feedback (**recommended**)*
- Discussion (50+% of grade)
  - *Summarize/Analyze core-ideas/contribution/limitations*
  - *Be ready to answer detailed questions*
- Grade partly based on peer feedback
  - *Upload (private) on piazza after each presentation*
- Everyone (not just presenter) **MUST** read paper
  - *Prepare at least one question/comment for the discussion*

Grading

10% - Participation

- Regular classroom participation (ask, answer, opine)
- Paper discussions
  - *Reading presented papers (before presentation)*
  - *Be ready to ask at least one question/make a comment*
  - *Goal: Learn critical reading*
- Peer feedback for presentations (piazza, private)

Grading

20% - Final project

- Two options
  - *Pre-defined (Individual)*
    - Description on the web end of October
    - Likely topic: ***Remeshing***
  - *Free-form (Individual or Pair)*
    - e.g. based on paper you or someone else presented
- Includes implementation (65%), proposal (5%), written report (20%) & presentation (10%)
  - *Presentation scheduled **during** exam period.*

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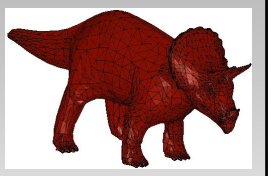
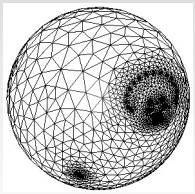
Course Topics

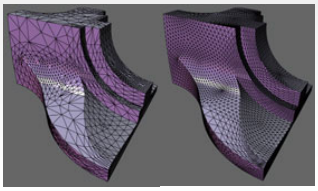
Syllabus (provisional)

1. Intro to meshes – terminology, topology, etc..
2. Subdivision
3. Simplification
4. Deformation/Editing
5. Differential geometry for meshes
6. Parameterization

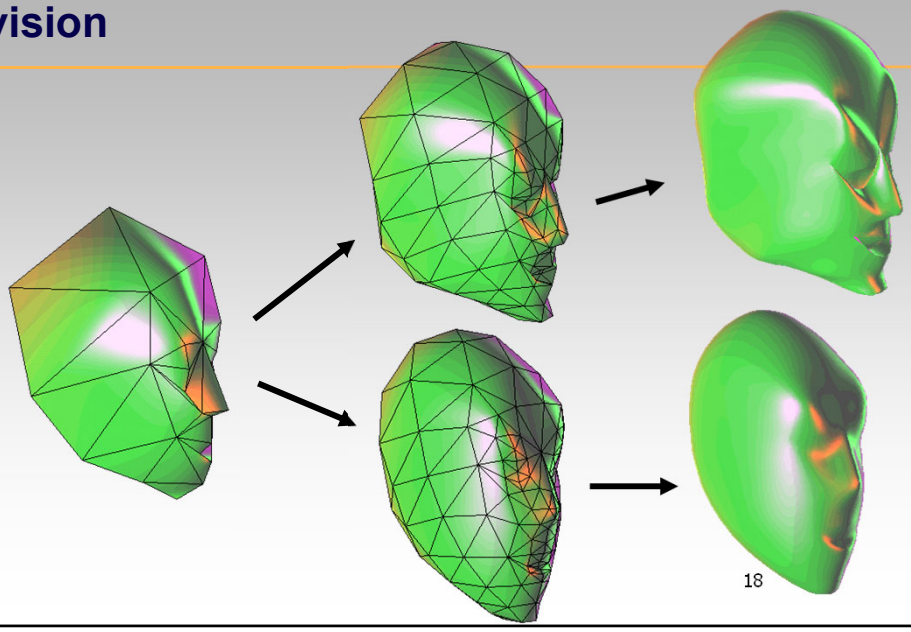
7. Meshing/Remeshing/Smoothing
8. Reconstruction
9. State of the Art
   - Fabrication
   - Perception-based geometry processing
   - 2D geometry (strokes & pixels)







Subdivision



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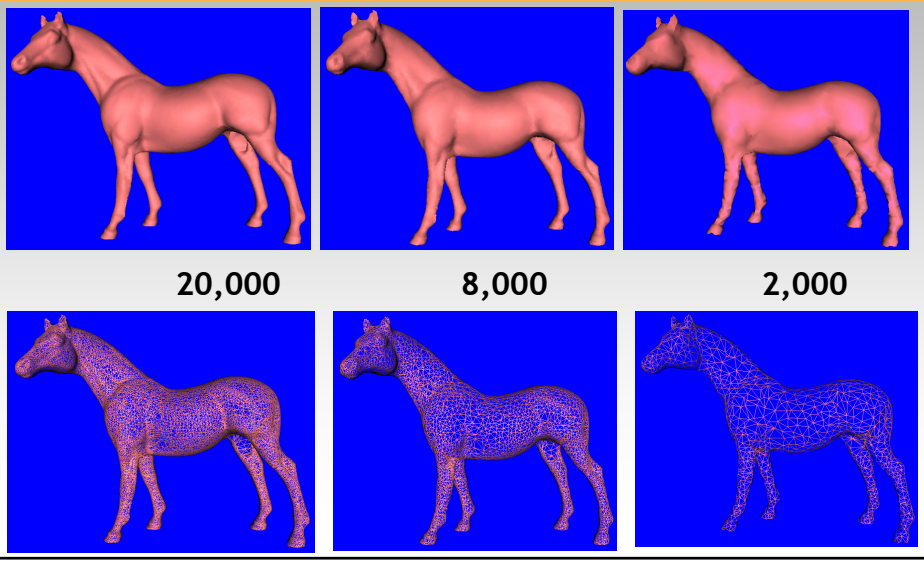
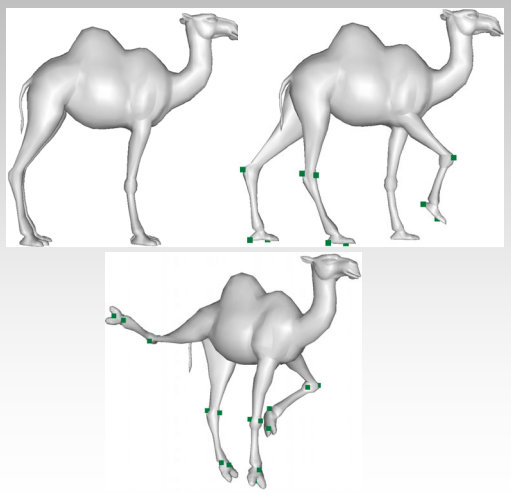
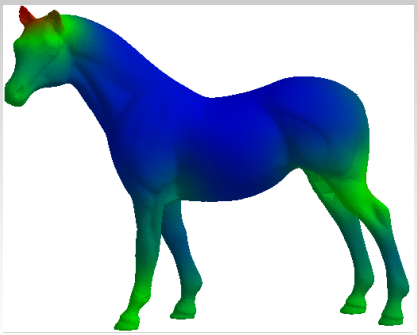
Mesh Simplification

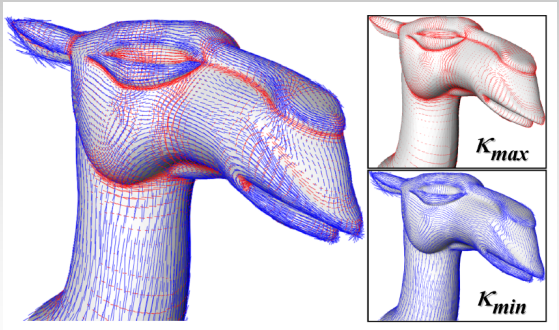


Deformation

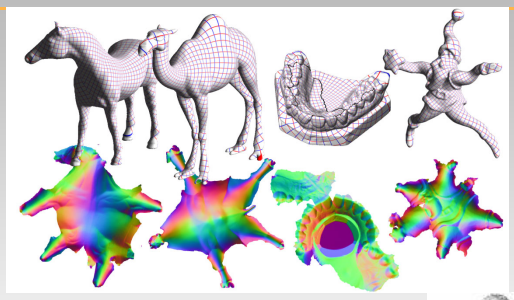


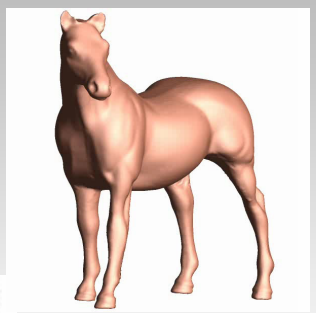
Differential Geometry

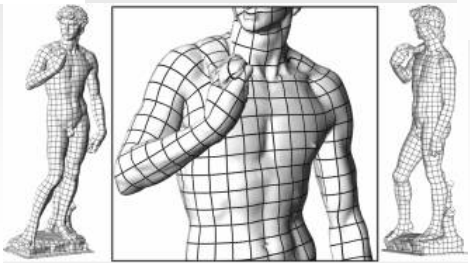




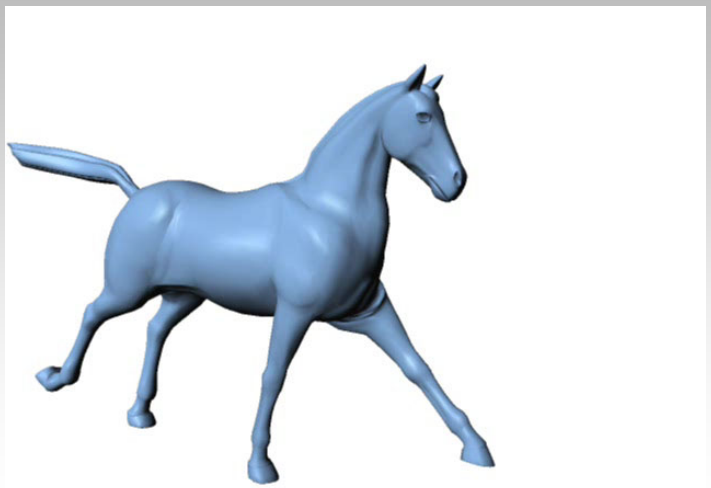
Parameterization



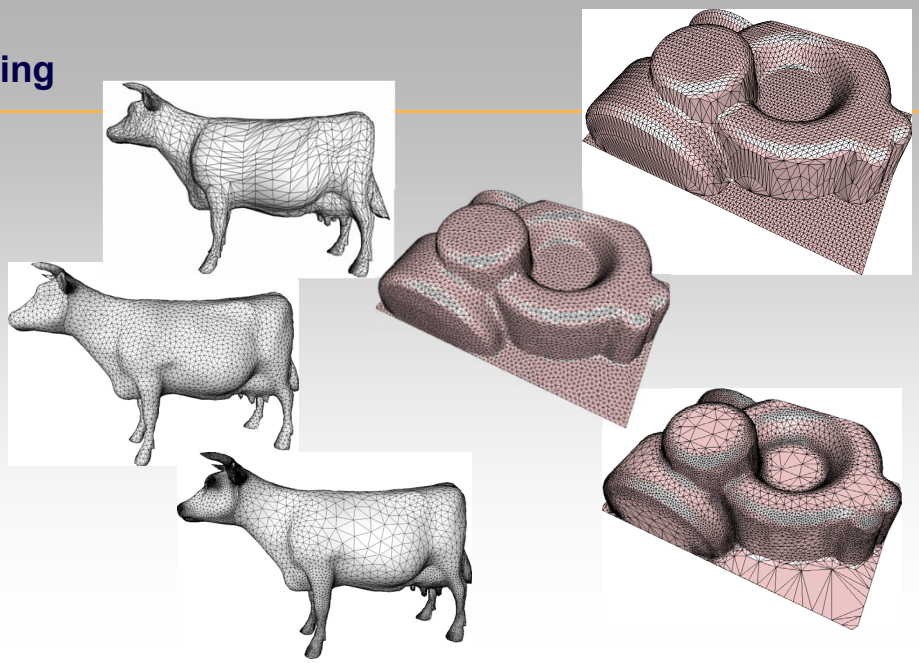




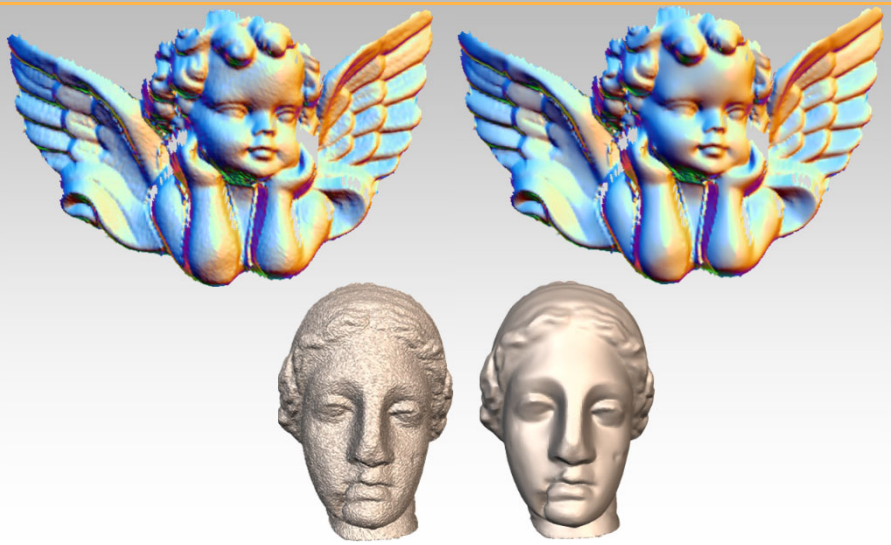
Applications of Parameterization: Morphing/Properties Transfer



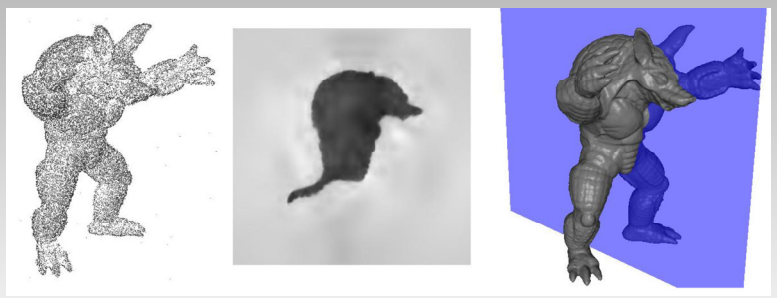
Remeshing

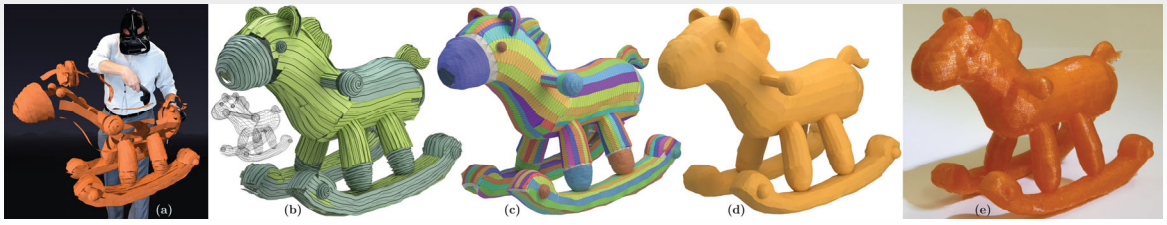


Smoothing/Fairing

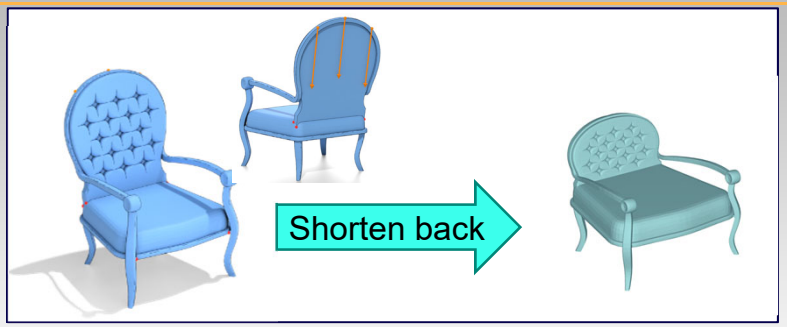


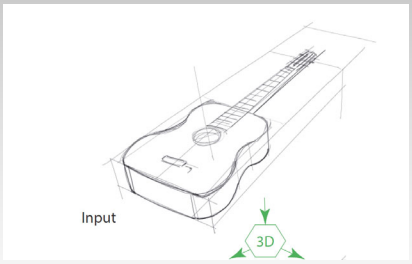
Reconstruction





Perception-Based Geometry Processing





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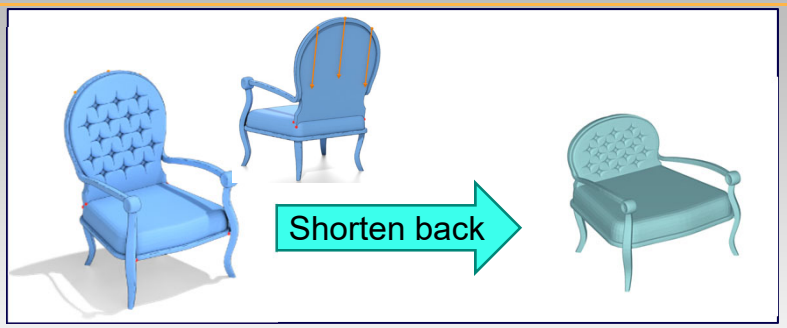
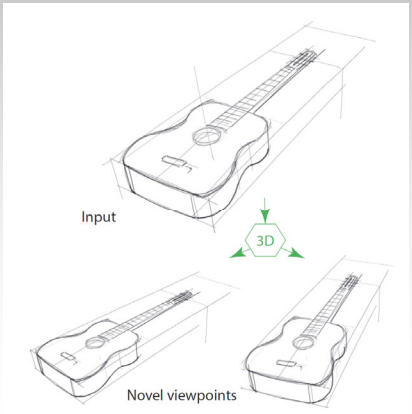
Perception-Based Geometry Processing





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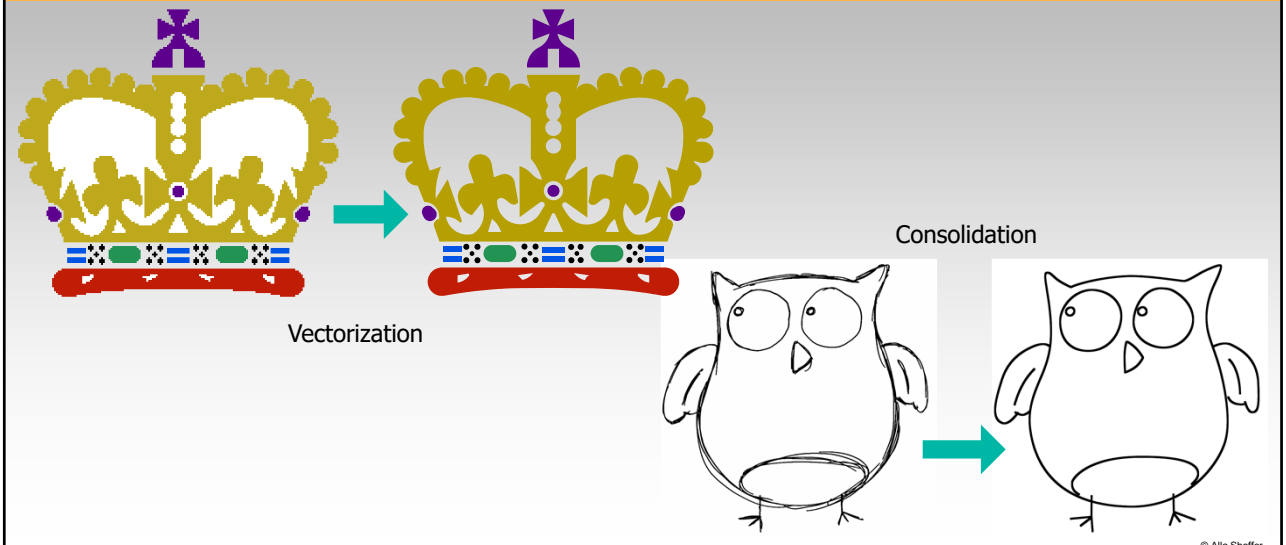
2D Geometry



Topic Teaser: Marching Cubes

Reconstruction from Volume Data: Marching Cubes

Voxel – cube with values at eight corners

- Each value is above or below isovalue α

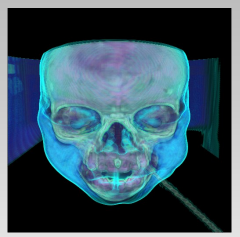
Volume data: voxel grid with values at vertices

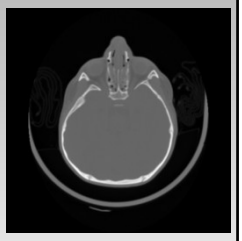
- Defines implicit function in 3D
  - *interpolate grid values*

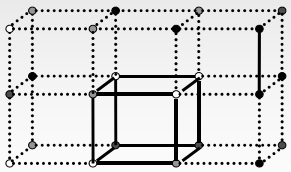
Shape defined by isosurface

- isosurface = set of points with constant isovalue α
- separates values above α from values below

Reconstruction – Extract triangulation approximating isosurface







Voxels

Voxel – cube with values at eight corners

- Each value is above or below isovalue α

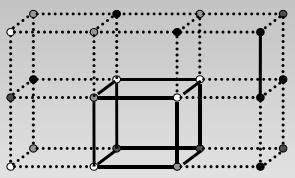
2^8=256 possible configurations (per voxel)

- reduced to 15 (symmetry and rotations)

Each voxel is either:

- Entirely inside isosurface
- Entirely outside isosurface
- Intersected by isosurface

MC main observation: Can extract triangulation independently per voxel



Basic MC Algorithm

For each voxel produce set of triangles

- Based on above/below corner configuration
- Empty for non-intersecting voxels
- Approximate surface inside voxel

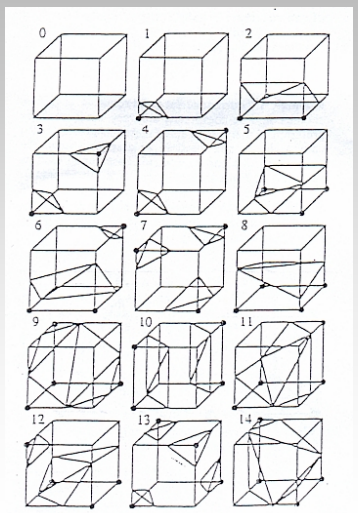


Figure 2. Configurations.

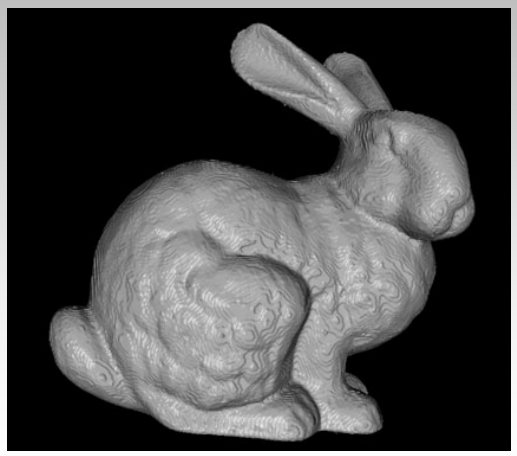
Configurations

For each configuration add 1-4 triangles to isosurface

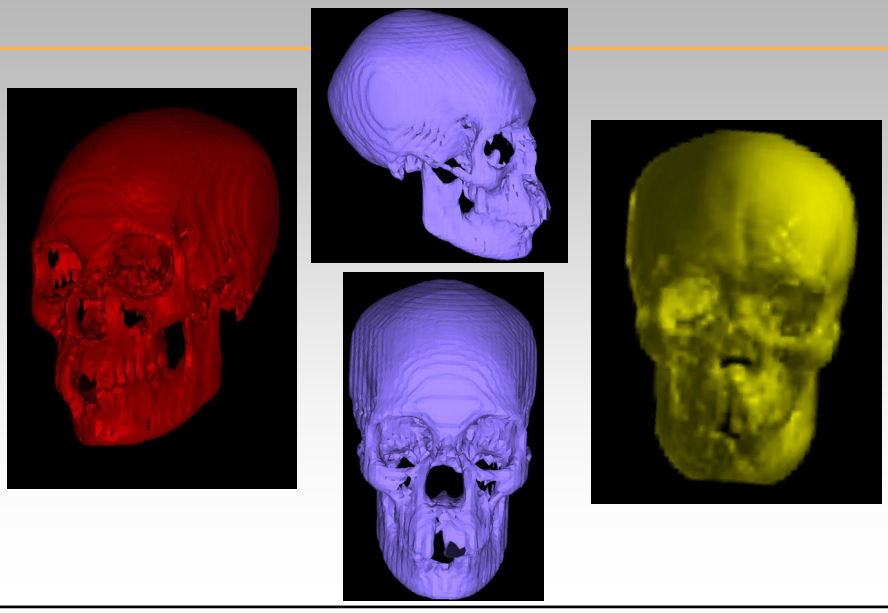
Isosurface vertices computed by:

- Interpolation along edges (according to grid values)
  - *better shading, smoother surfaces*
- Default – mid-edges

Example



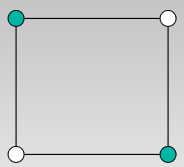
Example



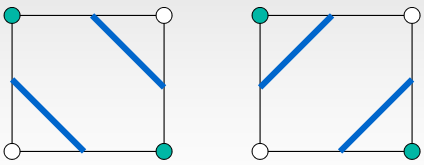
We have a problem….

Ambiguous Faces

- Face containing two diagonally opposite marked grid points and two unmarked ones



- Two locally valid interpretations



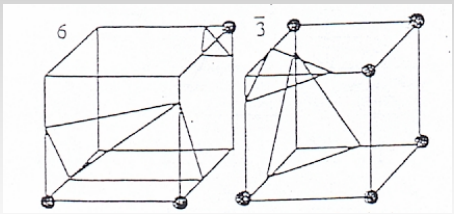
- Fine in 2D, problem in 3D

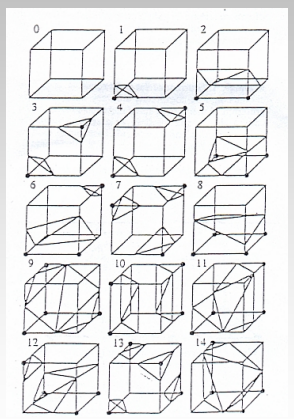
Consistency Problem

Can produce non-manifold results

- Isovalue surfaces with “holes”

Example:





- Voxel with configuration 6 sharing face with complement of configuration 3

Consistency

Problem:

- Connection of isosurface points on shared face done one way on one face & another way on the other

Need consistency → use different triangulations

If choices are consistent get topologically correct surface

Solution

- For each problematic configuration have more than one triangulation
- Distinguish different cases by choosing pairwise connections of four vertices on common face

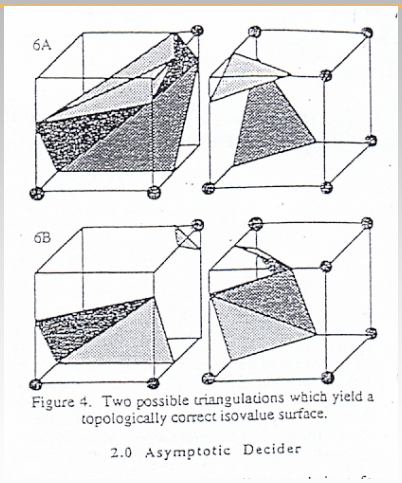
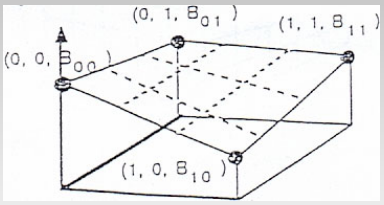


Figure 4. Two possible triangulations which yield a topologically correct isovalue surface.

2.0 Asymptotic Decider

Asymptotic Decider

- Select connectivity that better fits implicit function
- Use bilinear interpolation to approximate function
  - 2D extension of linear interpolation



$$B(s,t) = \begin{pmatrix} 1-s & s \end{pmatrix} \begin{pmatrix} B_{00} & B_{01} \\ B_{10} & B_{11} \end{pmatrix} \begin{pmatrix} 1-t \\ t \end{pmatrix}$$

$$\{(s,t): 0 \le s \le 1, \quad 0 \le t \le 1\}$$

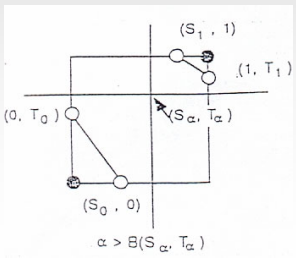
- B_{ij} - isovalues at face corners

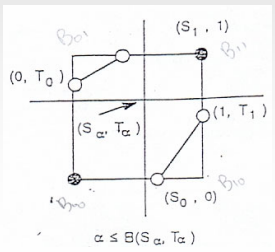
Asymptotic Decider

E.g. B_{00} & B_{11} above α

Test value at face "center" (S_α, T_α)

- If $\alpha > B(S_\alpha, T_\alpha)$
  - *connect $(S_1,1)$-$(1,T_1)$ & $(S_0,0)$-$(0,T_0)$*
- else
  - *connect $(S_1,1)$-$(0,T_0)$ & $(S_0,0)$-$(1,T_1)$*





Asymptotic Decider

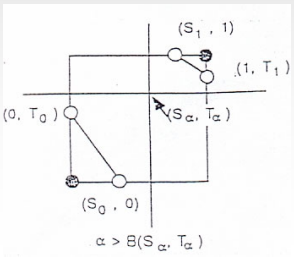
Choice of "center":

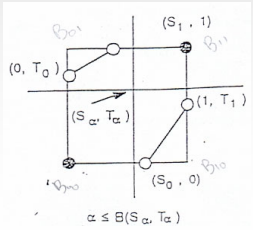
$$S_\alpha = \frac{B_{00} - B_{01}}{B_{00} + B_{11} - B_{01} - B_{10}}$$

$$T_\alpha = \frac{B_{00} - B_{10}}{B_{00} + B_{11} - B_{01} - B_{10}}$$

- Related to contour curves asymptotic behaviour

$$B(S_\alpha, T_\alpha) = \frac{B_{00}\,B_{11} + B_{10}\,B_{01}}{B_{00} + B_{11} - B_{01} - B_{10}}$$





Various Cases

Some configurations have no ambiguous faces → no modifications

Other configurations need modifications according to number of ambiguous faces

- Apply decoder to each face to decide on triangulation template

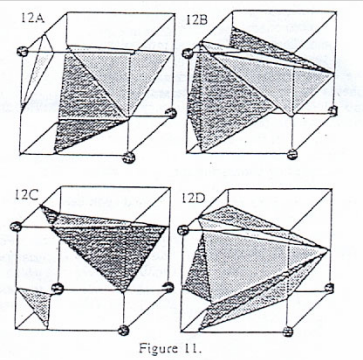


Figure 11.

Remarks

Add considerable complexity to MC

No significant impact on running time or total number of triangles produced

New configurations occur in real data sets

- But not very often

Config	Example 1	Example 2	Example 3
0	263,519	285,074	110,993
1	7,705	1,912	1,673
2	8,710	2,065	2,421
3A	60	0	6
3B	46	0	6
4	28	0	0
5	5,611	1,228	1,143
6A	20	0	0
6B	47	0	0
7A	3	0	0
7B,D	3	0	0
7C	3	0	0
8	4,637	906	1,146
9	1,003	304	261
10A,C	13	0	0
10B,D	1	0	0
11	36	0	0
12A,C	7	0	0
12B,D	4	0	0
13	0	0	0
14	69	0	0

Table 1. Frequency of configurations