Introduction to Geometric Modeling

CS 395: Advanced Computer Graphics

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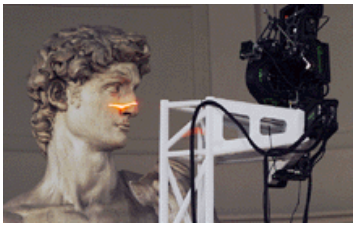
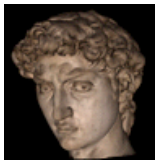
Representation of Objects

- Raw Data
  - Point Cloud
  - Range Image
  - Polygon Soup
- Surfaces
  - Mesh
  - Subdivision
  - Parametric
  - Implicit
- Solids
  - Voxels
- High-level structures
  - CSG
  - Generative Model
  - Scene graph

Range Image

- Set of 3D points mapping pixels of depth image
  - Acquired from range scanner
  - 3D Fax Machine (http://graphics.stanford.edu/projects/faxing/)

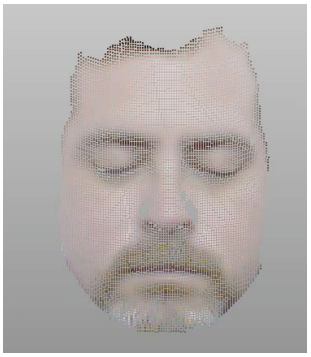


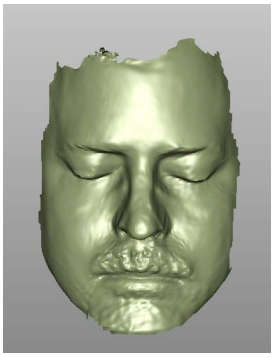
http://graphics.stanford.edu/projects/mich/

Point Cloud

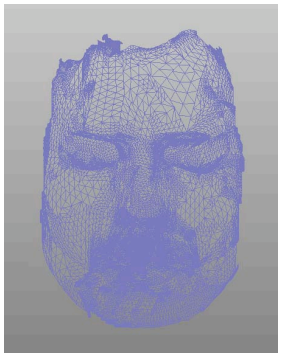
- Unstructured set of 3D point samples
  - Acquired from range finder, computer vision, etc



Original Point Cloud from Minolta 700 VVD file



Nurbs surface generate with Geomagic Studio 3.0 from polygonal model.



Mesh of polygonal surface generated from nurbs surface.

http://lcv.stat.fsu.edu/research/geometrical_representations_of_faces/CURVATURE/

Flow: http://www.reptilelabour.com/software/flow/

- f l o w allows one to interactively construct sophisticated particle systems and render the results either in real-time via OpenGL or off-line by a RenderMan compliant renderer.

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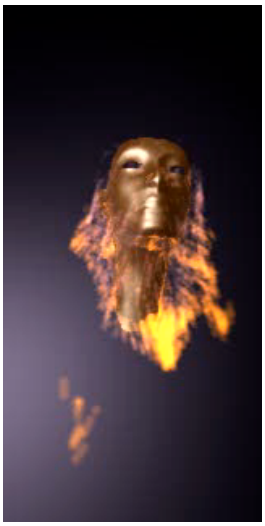
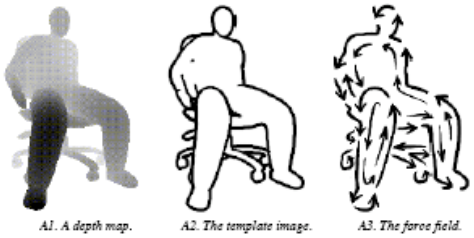
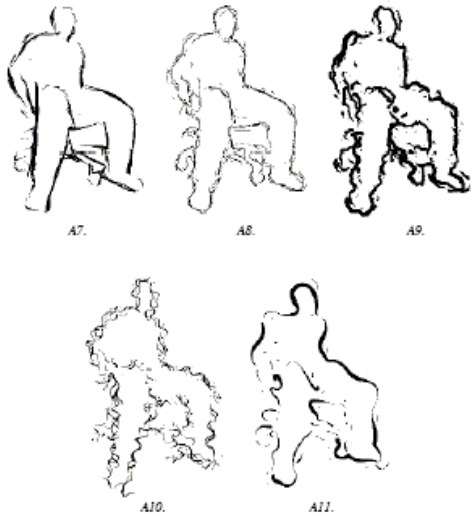


Particle Systems Examples

- Cassidy Curtis



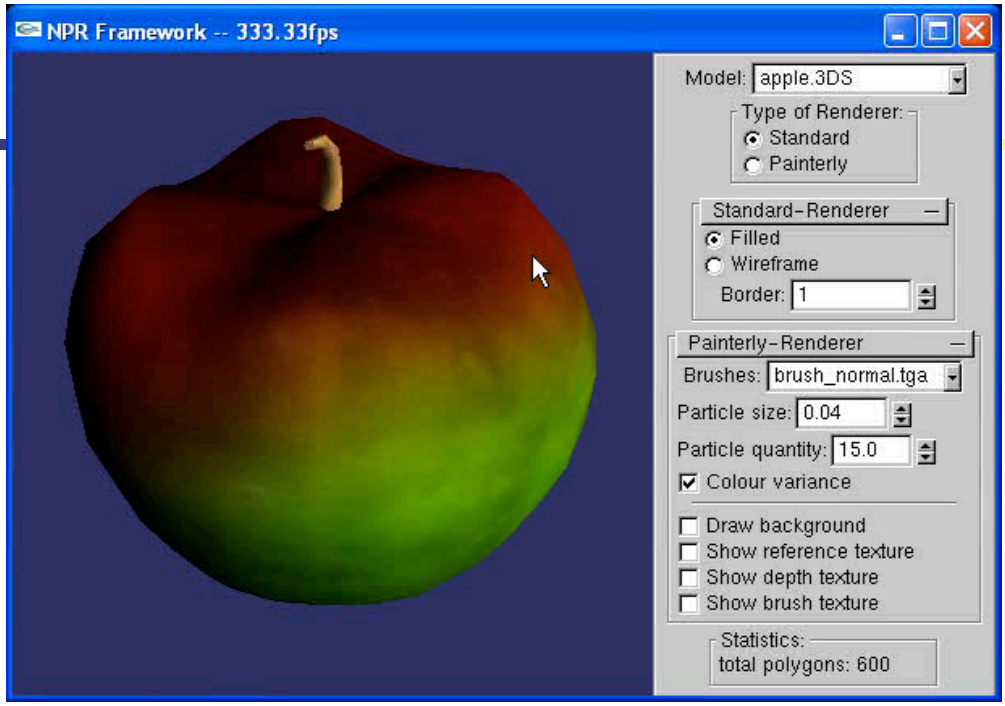
A1. A depth map. A2. The template image. A3. The force field.



A7. A8. A9. A10. A11.

Particle Systems Examples

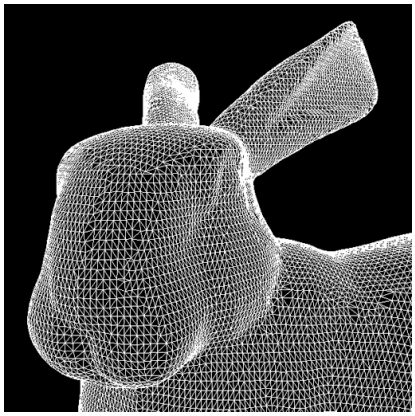
- Barbara Meier



Painterly Rendering for Realtime Applications (2003) by Daniel Sperl is a realtime implementation in the Cg language of painterly rendering inspiried by Meier.
http://www.incognitek.com/painterly/
The site includes a thesis (in German, PDF 1.1MB), a paper (in English, PDF 1MB), images, movies, source code and an application.

Mesh

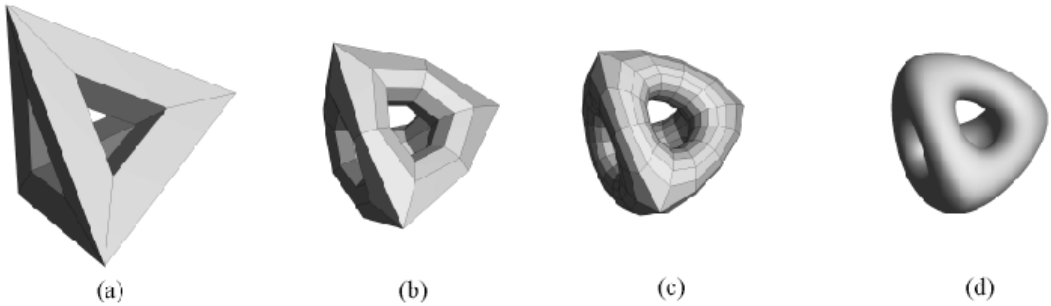
- Connect set of polygons (usually triangles)
  - May not be closed



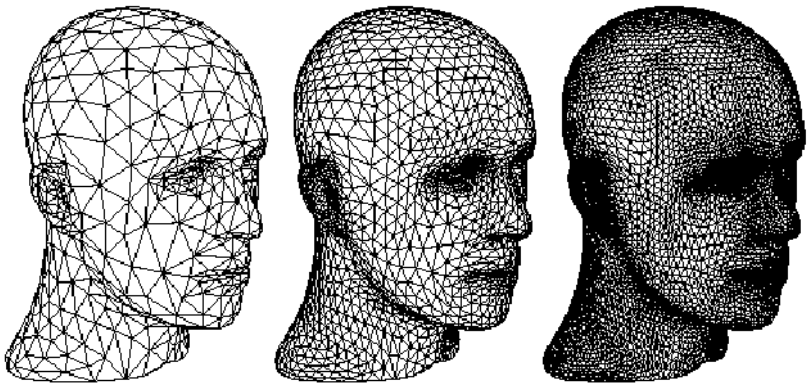
http://www.cc.gatech.edu/projects/large_models/bunny.html

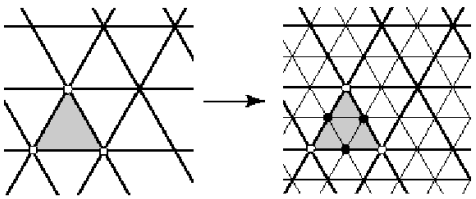
Subdivision Surface

- Coarse mesh & subdivision rule
  - Define smooth surface as limit of sequence of refinements
    - http://www.mrl.nyu.edu/publications/subdiv-course2000/S



Subdivision Surfaces



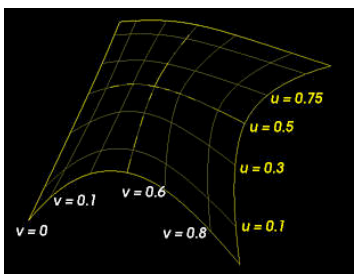


Polygon Soup

- Unstructured set of polygons
  - Created with interactive modeling systems?
- Advantages:
  - Simple to read, write, transmit, etc
  - Common output of CAD modelers
  - Format required for OpenGL
- Disadvantage:
  - No information about neighbors
  - No open/closed information
  - No guarantees on degeneracies

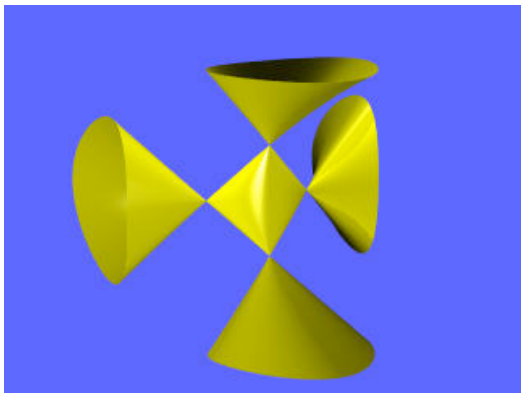
Parametric Surface

- Bezier
- NURBS: Non-Uniform Rational B-Spline

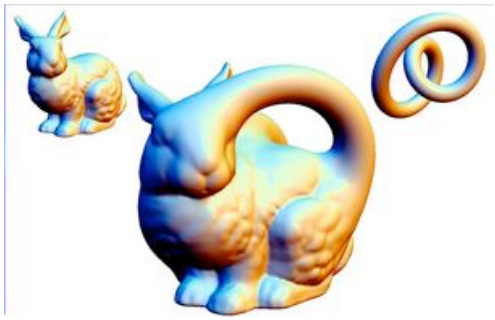


Boundary Representation

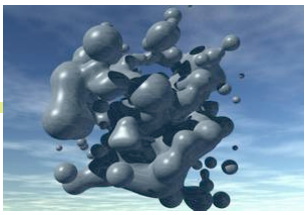
- Implicit Surfaces & Functional Representation
  - F(x1, x2, x3) = c (surface)
  - F(x1, x2, x3) <= c (solid)



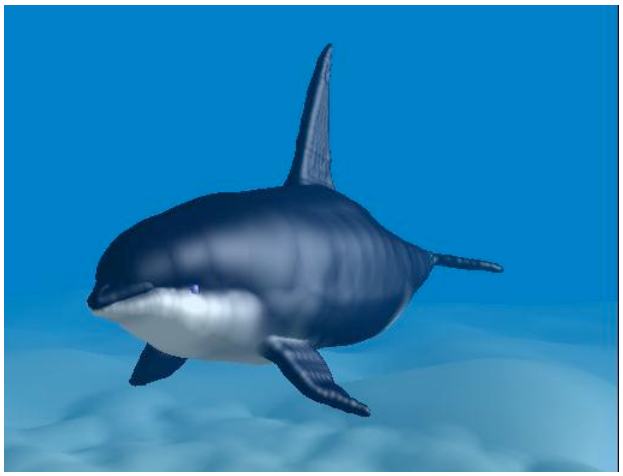
$8x^2 - xy^2 + xz^2 + y^2 + z^2 - 8 = 0$

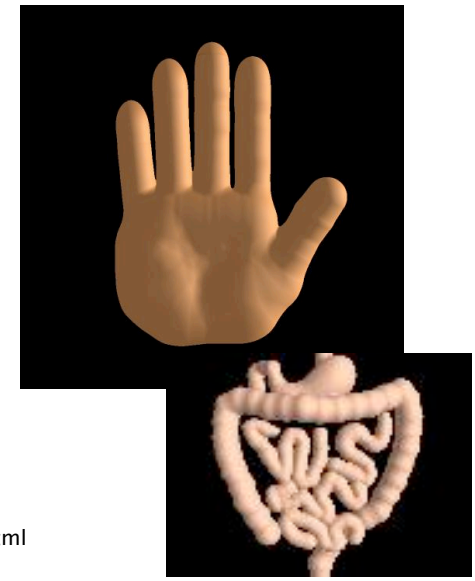


Implicit Surfaces



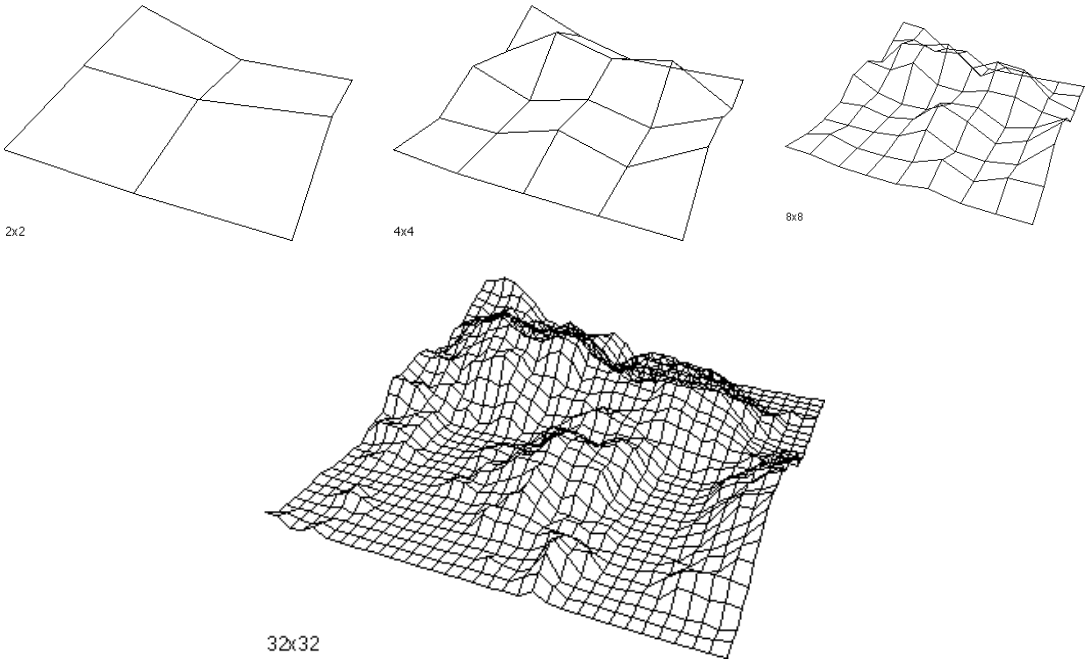
- Metaballs, Blobbies, "Soft Objects" = Implicit surfaces





http://nis-lab.is.s.u-tokyo.ac.jp/~nis/img/sampl2.html

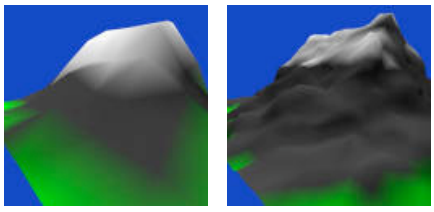
Fractals



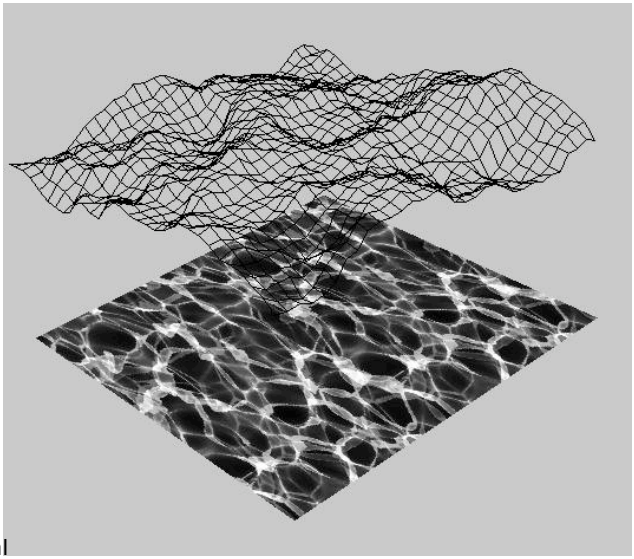
More Boundary Representations

- Fractals

http://home.flash.net/~djconnel/Vue/

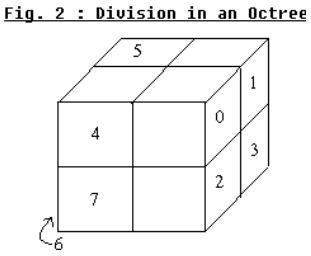


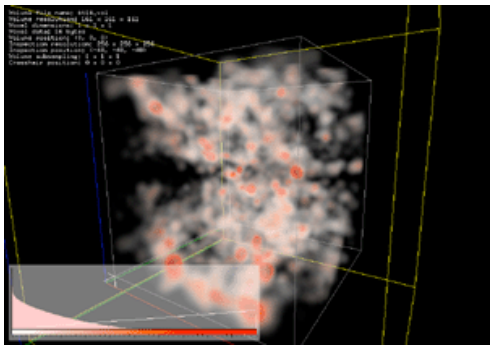
http://www.dgp.toronto.edu/~cwang/projects.html

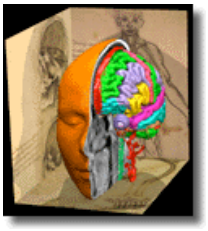


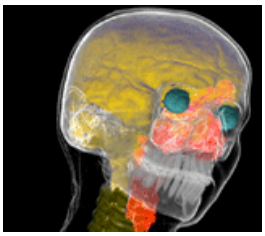
Volumetric Representation

- Voxel: uniform grid of volumetric samples
  - Acquired from CAT, MRI, etc



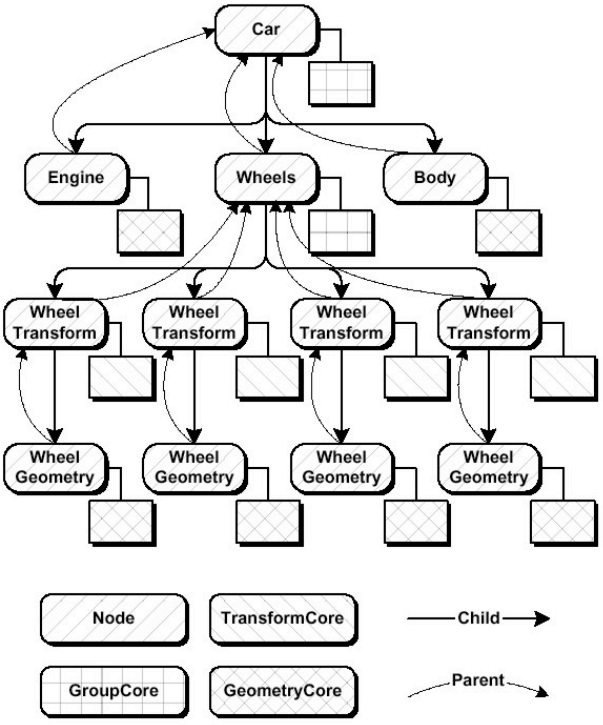






Scene Graph

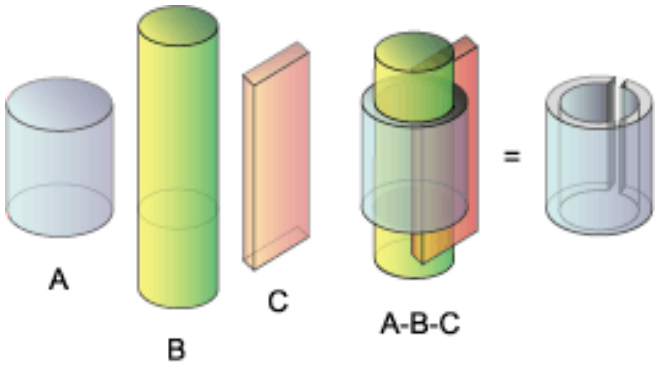
- Union of objects at leaf nodes



http://www.lsi.usp.br/~mkzuffo/PSI5787/opensg/scene_graph.jpg

Constructive Solid Geometry (CSG)

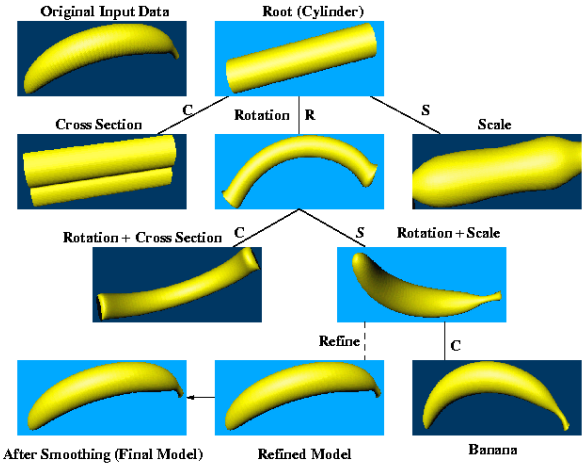
- Hierarchy of boolean set operations (union, difference, intersect) applied to simple shapes



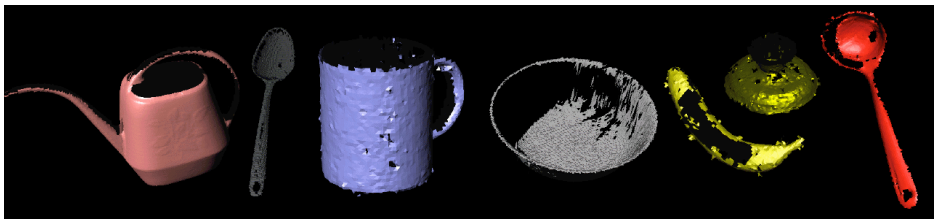
http://www.olympus.net/personal/mortenson/preview/definitionsc/constructivesolidgeometry.html

Generative Model

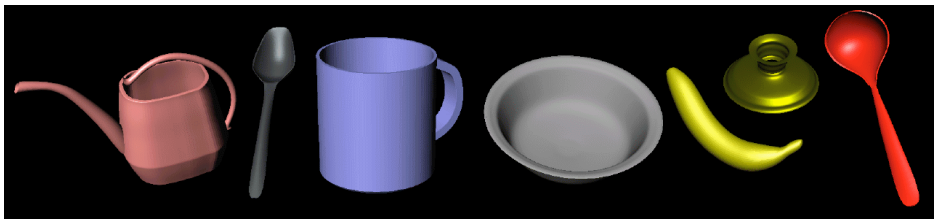
- Hierarchy of modifying curves
  - (Ramamoorthi et al.)



Range Data Scans



Range Data



Recovered models

(Ramamoorthi et al. SIGGRAPH 1999))

Finding Data

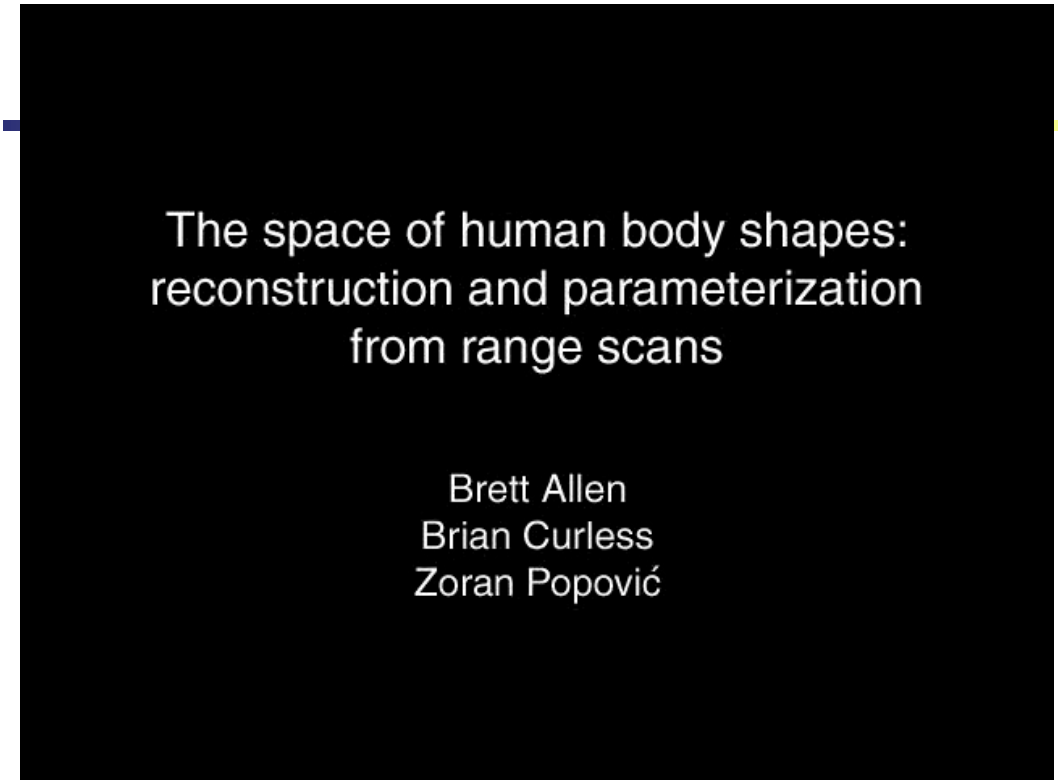
- http://www.cc.gatech.edu/projects/large_models/
- http://graphics.stanford.edu/data/mich/
- http://www.3dcafe.com

Credits

- http://www.cs.princeton.edu/courses/archive/spring00/cs598b/
- http://graphics.cs.ucdavis.edu/CAGDNotes/CAGD-Notes.html

The space of human body shapes: reconstruction and parameterization from range scans

Brett Allen Brian Curless Zoran Popović



Terminology

- **Optimization problem**
  - Object is to find the best of all possible solutions
  - More formally, find a solution in the feasible region which has the minimum (or maximum) value of the objective function.
  - Object Function Definition: A function associated with an optimization problem which determines how good a solution is, for instance, the total cost of edges in a solution to a traveling salesman problem.
- **Affine Transform**
  - Basic transformations of rotations, translations, reflections, and dilations, shear, etc.
  - Any transformation that is invertiable.

Terminology

- **Frobenius Norm**
  - Matrix norm of an matrix defined as the square root of the sum of the absolute squares of its elements: $\|A_F\| \equiv \sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n}|a_{ij}|^2}.$
- **Principal Component Analysis**
  - Takes cloud of data points & align them thru affine transformations maximizing or minimizing derivatives

Main Idea

- **Hole-filling models from Range Scans**
- **Line up 250 human body models**
  - **Each model has 250,000 to 350,00 triangles with per-vertex color**
  - **Fit model to artist made example surface**
- **Create new models by interpolating database**

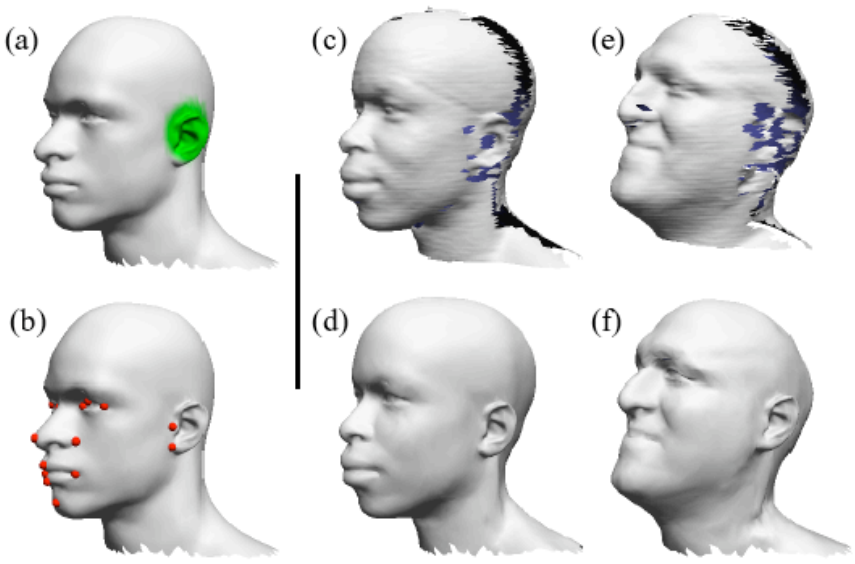
Aligning Algorithm

- **Optimization function**
  - Data Error
  - Smoothness Error
  - Marker Error

$$E = \alpha E_d + \beta E_s + \gamma E_m$$

  - At low resolution
    - Fit markers: $\alpha = 0, \beta = 1, \gamma = 10$
    - Allow data term to contribute: $\alpha = 1, \beta = 1, \gamma = 10$
  - At high resolution
    - More optimization: $\alpha = 1, \beta = 1, \gamma = 10$
    - Allow data term to dominate: $\alpha = 10, \beta = 1, \gamma = 1$

Hole Filling



New Models

Figure 7: Morphing between individuals. Each of the keyframe models (outlined) are generated from a Gaussian distribution in PCA space. These synthesized individuals have their own character, distinct from those of the original scanned individuals. The in-between models are created by linearly interpolating the vertices of the keyframes.

New Models

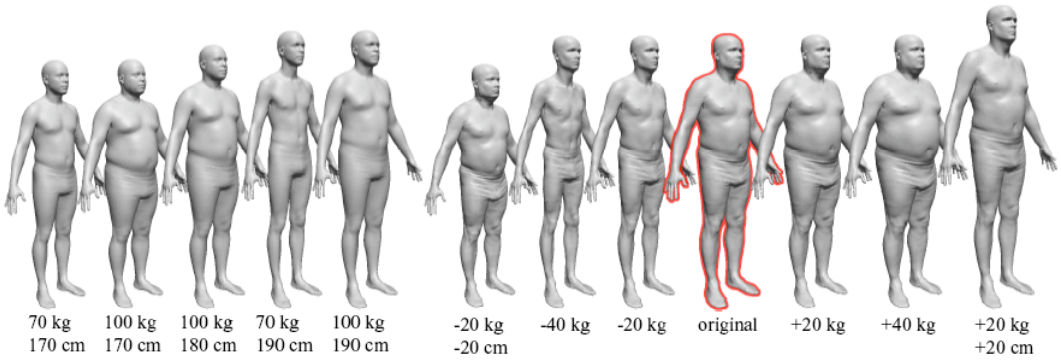


Figure 10: The left part of this figure demonstrates *feature-based synthesis*, where an individual is created with the required height and weight. On the right, we demonstrate *feature-based editing*. The outlined figure is one of the original subjects, after being parameterized into our system. The gray figures demonstrate a change in height and/or weight. Notice the double-chin in the heaviest example, and the boniness of the thinnest example.