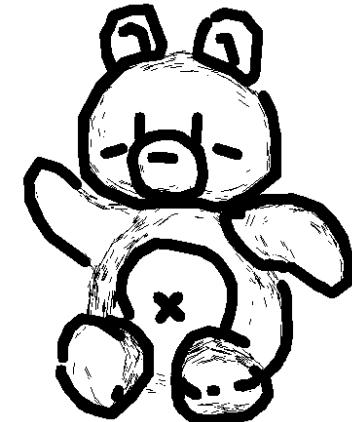


Week 3

# 3D Geometric Modeling

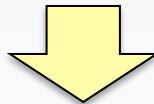


# 3D Geometric Modeling

## Challenge:

User interface is still mostly 2D.

How to complement missing information (depth)?



## Solution:

User interface and automatic inference  
leveraging domain specific knowledge.

# 3D Geometric Modeling

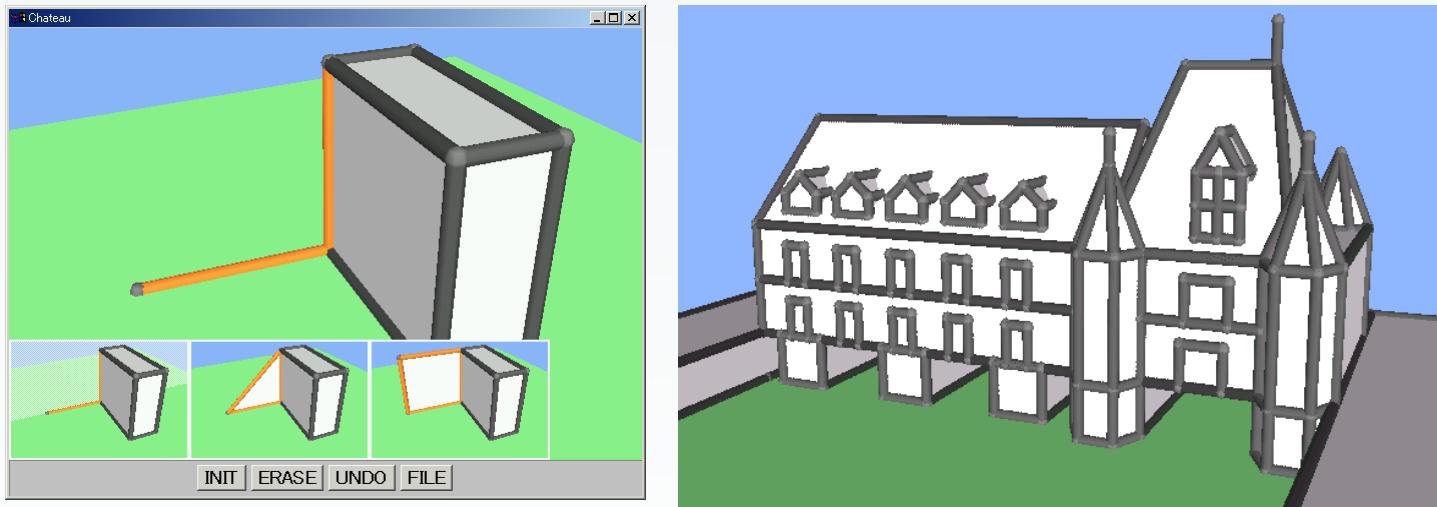
- Suggestive Interface
- Sketch-based Modeling
- Shape Control by Curves
- Flower Modeling
- Volumetric Textures

# 3D Geometric Modeling

- Suggestive Interface
- Sketch-based Modeling
- Shape Control by Curves
- Flower Modeling
- Volumetric Textures

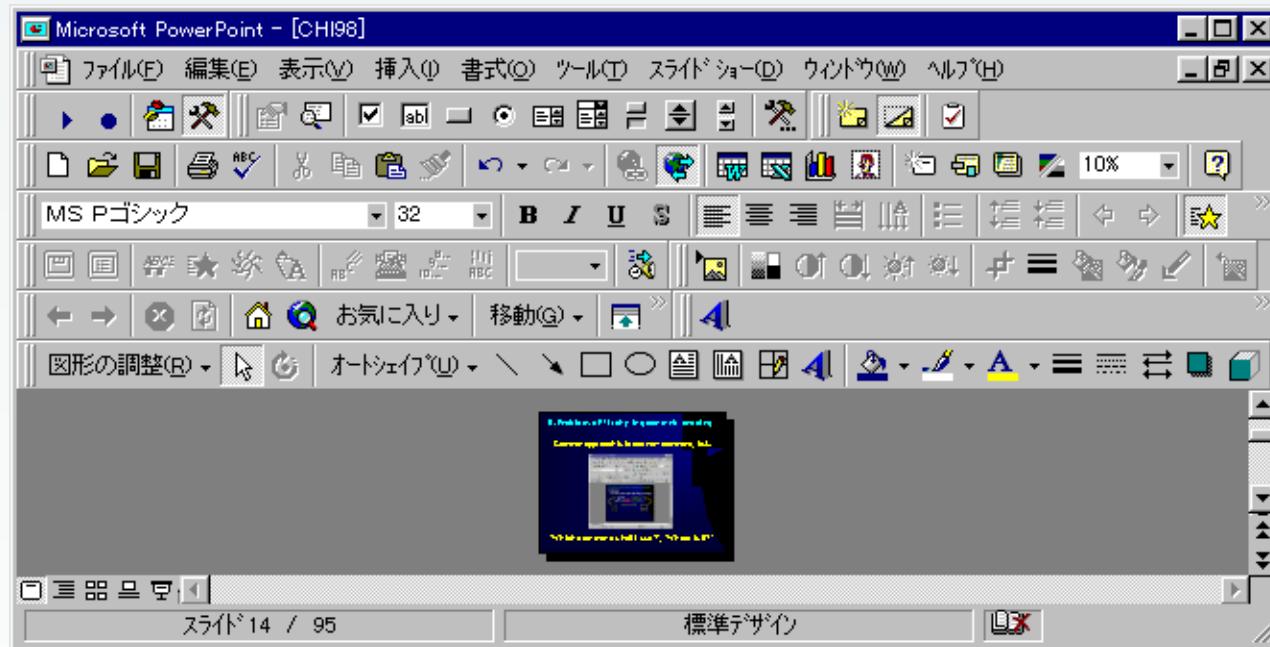
# Chateau: a suggestive interface for 3D modeling

Takeo Igarashi, John F. Hughes



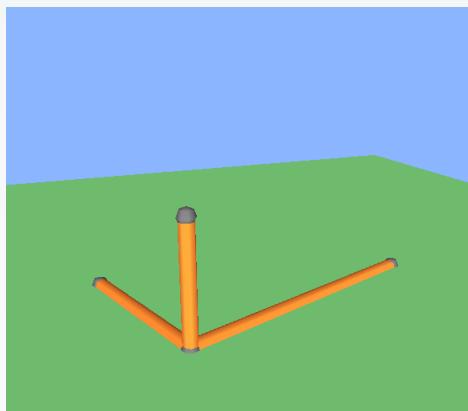
User interface using hints and suggestions

# Motivation



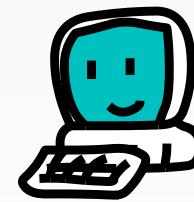
So many commands in nested menus!

# Our Approach



Hints

(arguments)



Suggestions

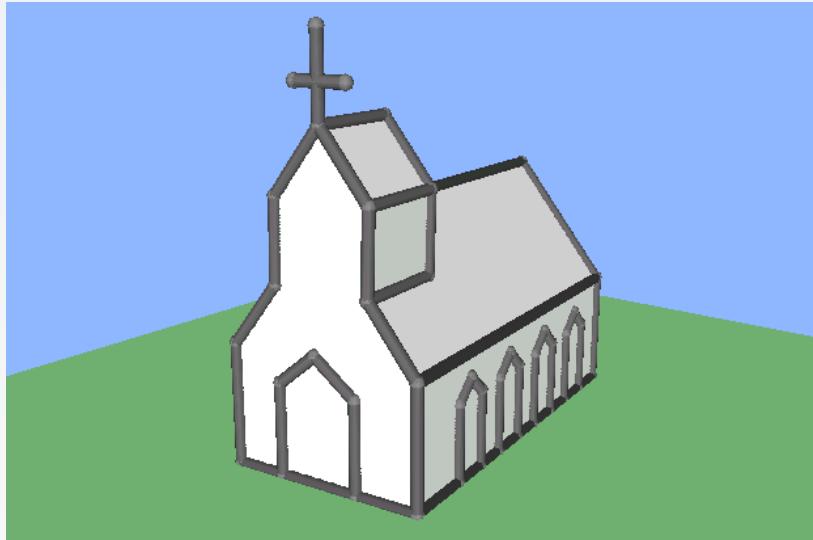
(commands)

# Demo

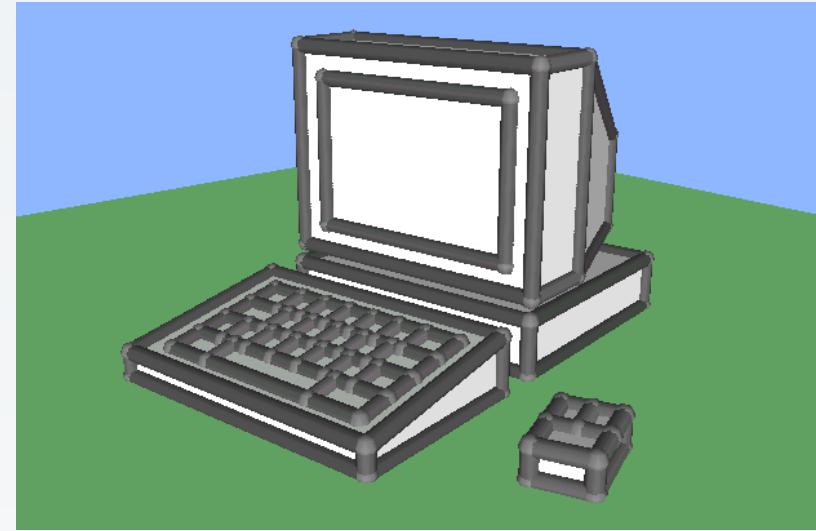
Chateau



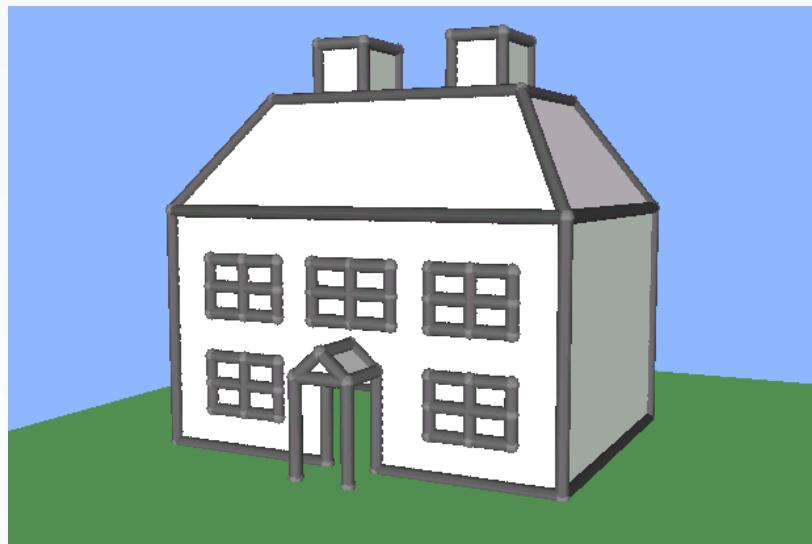
THE UNIVERSITY OF TOKYO



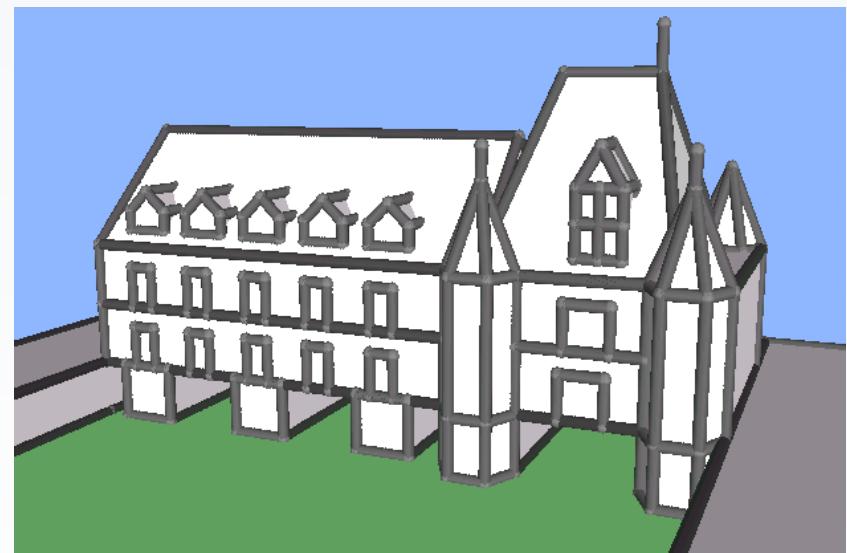
~5 min



~7 min

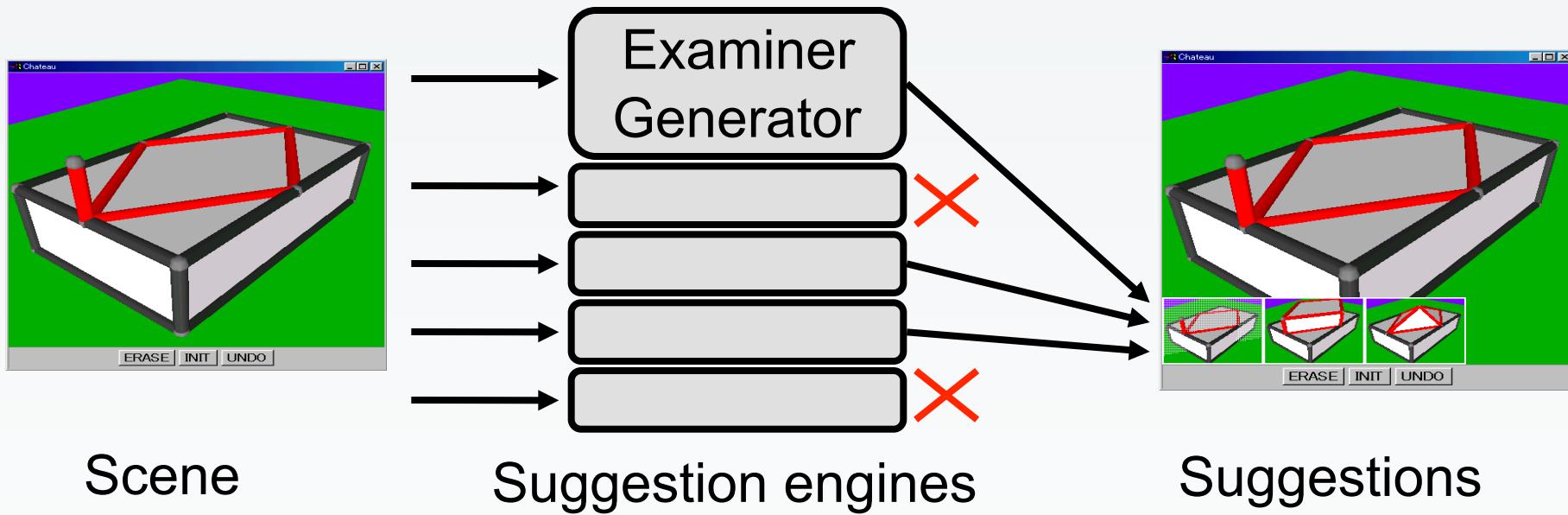


~9 min



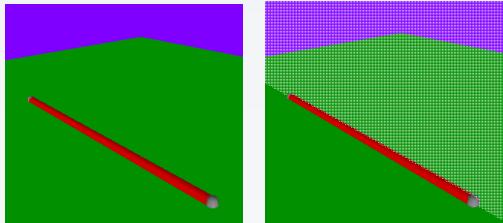
~30 min

# Implementation

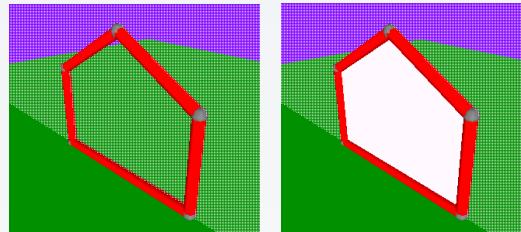


Each engine observes the scene and generates a suggestion when the scene matches its input pattern.

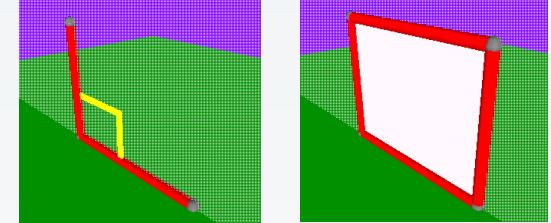
# Suggestion Engines (1/3)



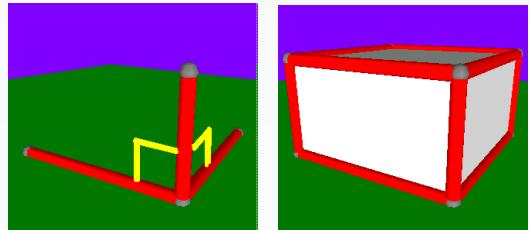
Drawing Plane



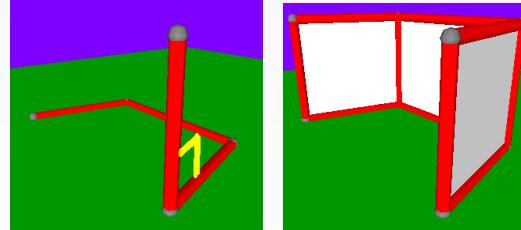
Polygon



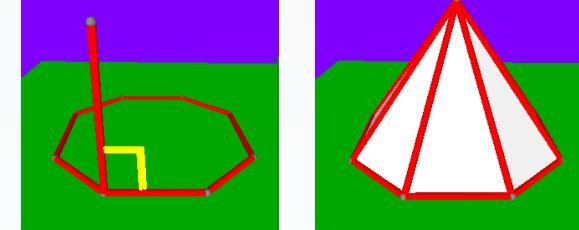
Rectangle



Box

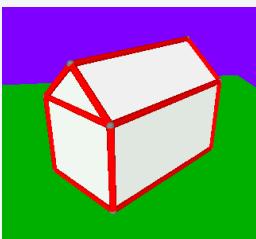
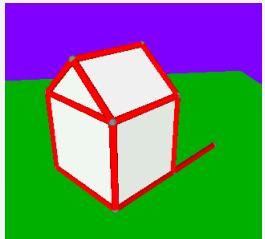


Extrusion

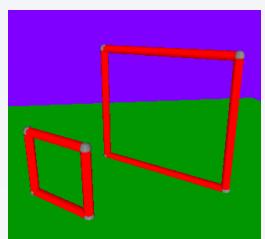


Pyramid shape

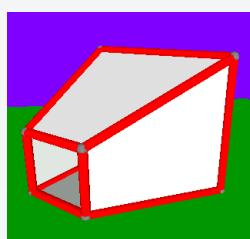
# Suggestion Engines (2/3)



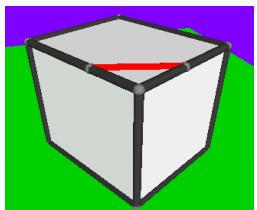
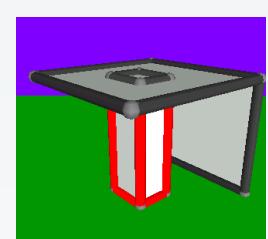
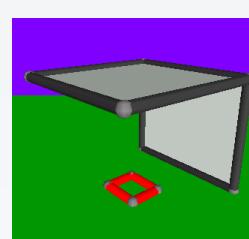
Resizing



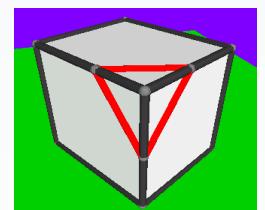
Bridges



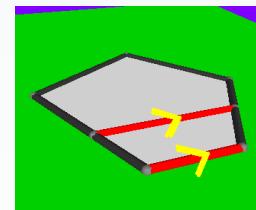
Extrusion



Chamfer

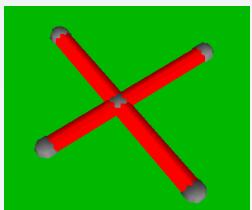
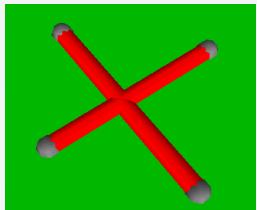


Corner Cutting

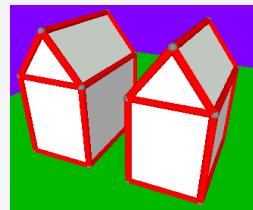
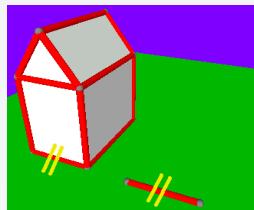


Trimming

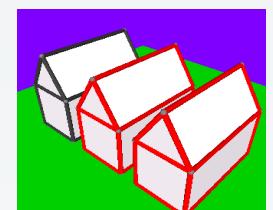
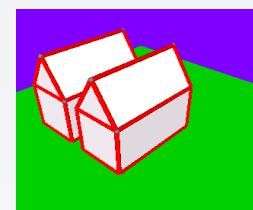
# Suggestion Engines (3/3)



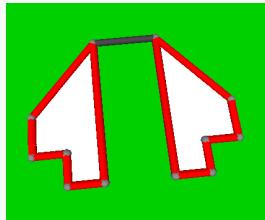
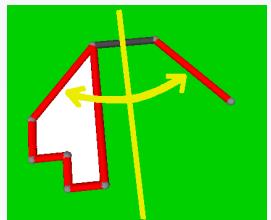
Intersection



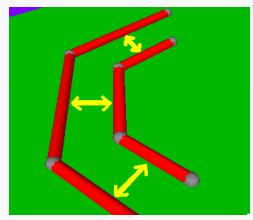
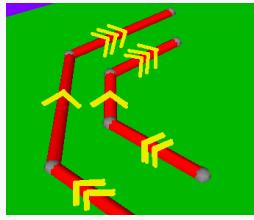
Duplication



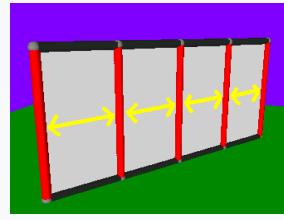
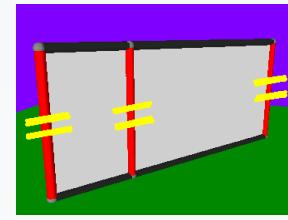
Repeated duplication



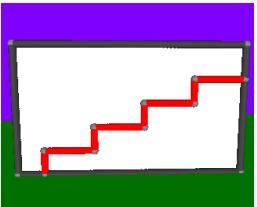
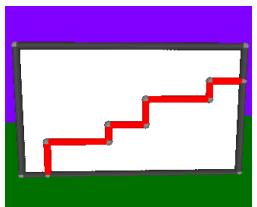
Mirror image



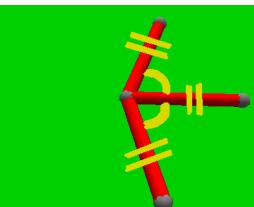
Equal gaps



Equal division

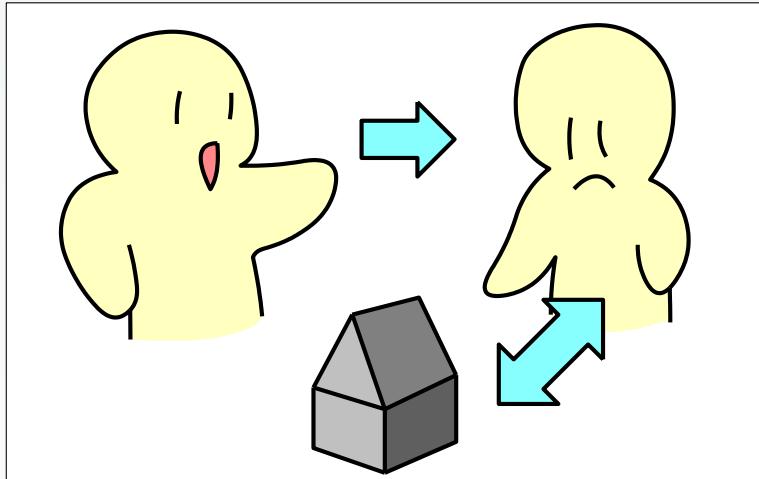


Stairs



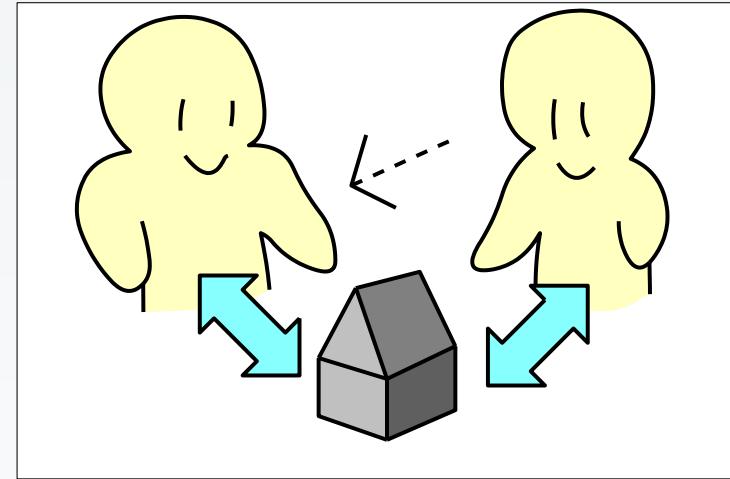
Angular symmetry

# Concept



Explicit Commands

Traditional UI



Implicit Communication

Suggestive UI

# Future Work

Other applications (e.g. PowerPoint)



Roughly aligned



Suggest



Align left



Align center

# To Learn More...

## The original paper:

- Igarashi and Hughes. A Suggestive Interface for 3D Drawing. UIST 2001.



## Sketching 3D scenes:

- Zeleznik, et al. SKETCH: An Interface for Sketching 3D Scenes. SIGGRAPH 1996

[Zeleznik, et al. 1996]

(Figure obtained from

<http://graphics.cs.brown.edu/research/sketch/>  
(with permission)

## Showing multiple candidates:

- Marks, et al. Design galleries: A general approach to setting parameters for computer graphics and animation. SIGGRAPH 1997.

# 3D Geometric Modeling

- Suggestive Interface
- Sketch-based Modeling
- Shape Control by Curves
- Flower Modeling
- Volumetric Textures

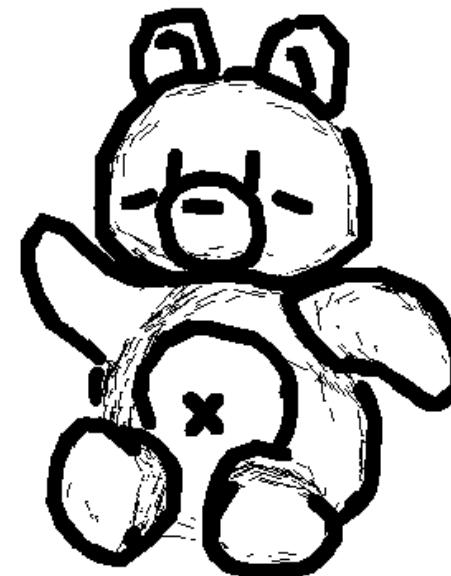
SIGGRAPH 99  
Impact paper

# Teddy: A Sketching Interface for 3D Freeform Design

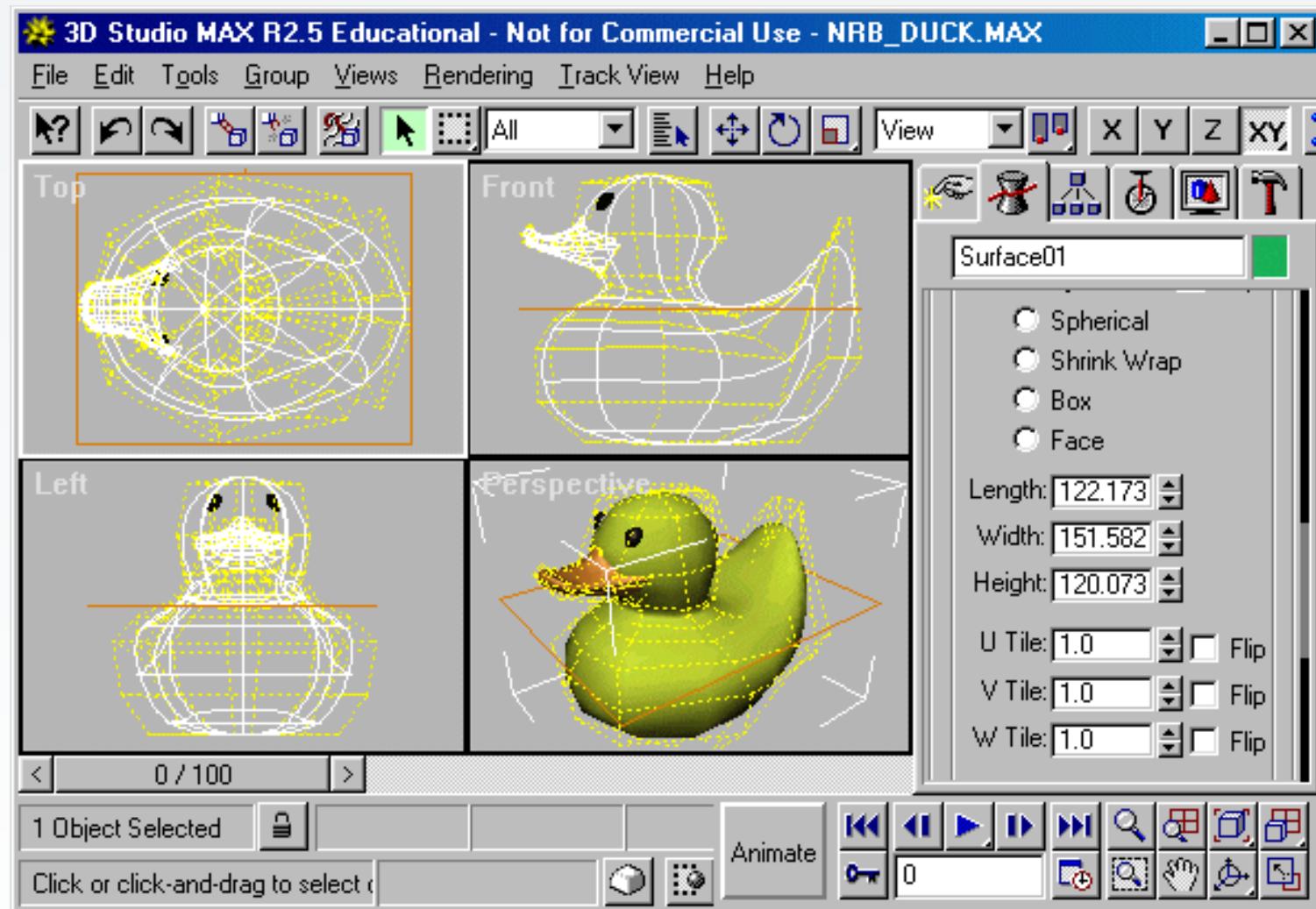
Takeo Igarashi

Satoshi Matsuoka

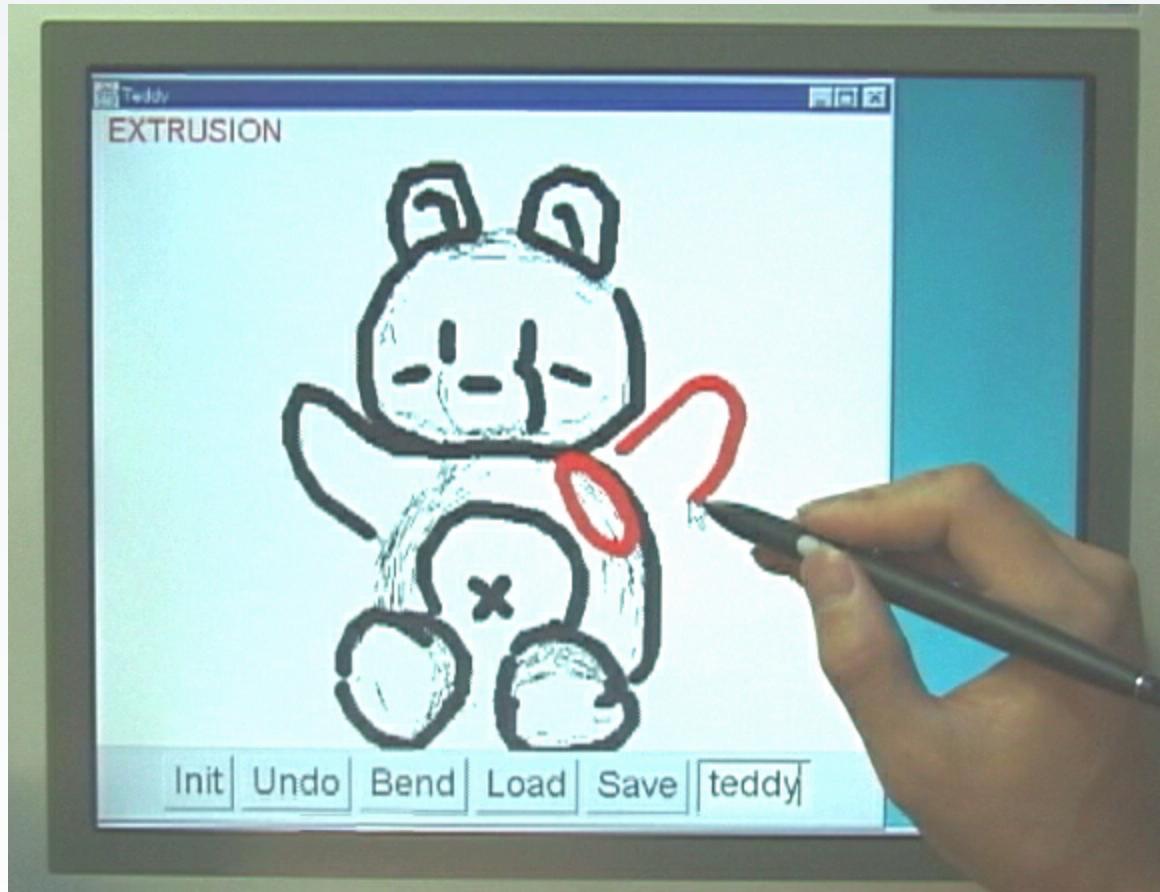
Hidehiko Tanaka



# 3D modeling is difficult



# Sketching is easy!

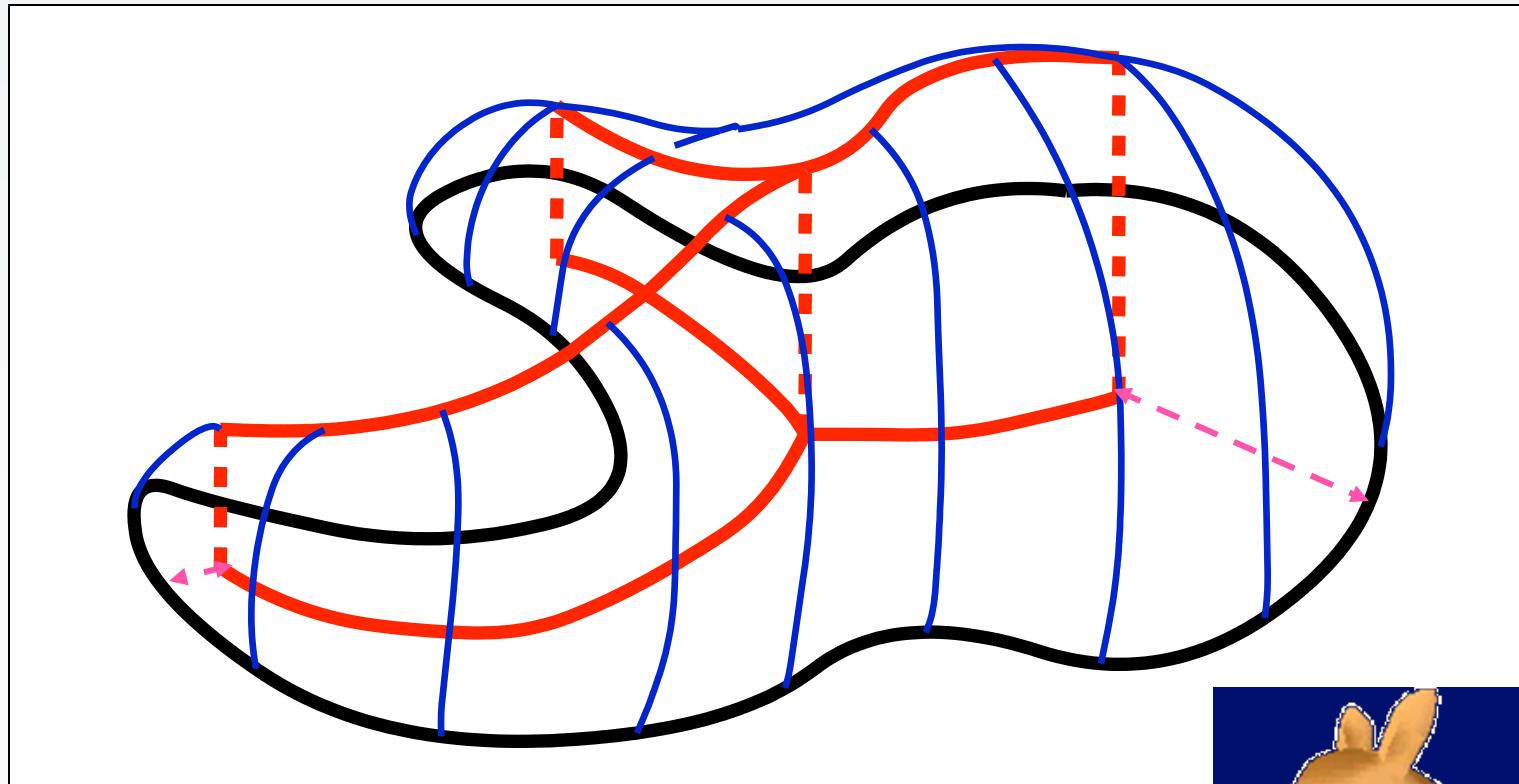


# Demo



[teddy](#) [video](#)

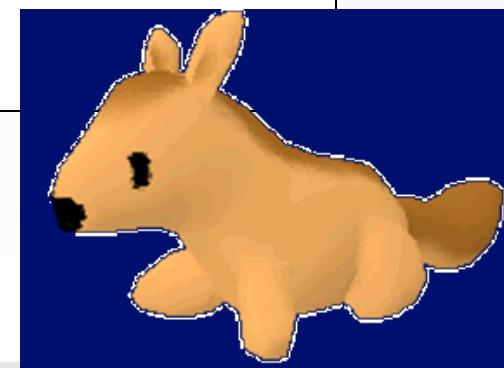
# Algorithm



1. Find axes

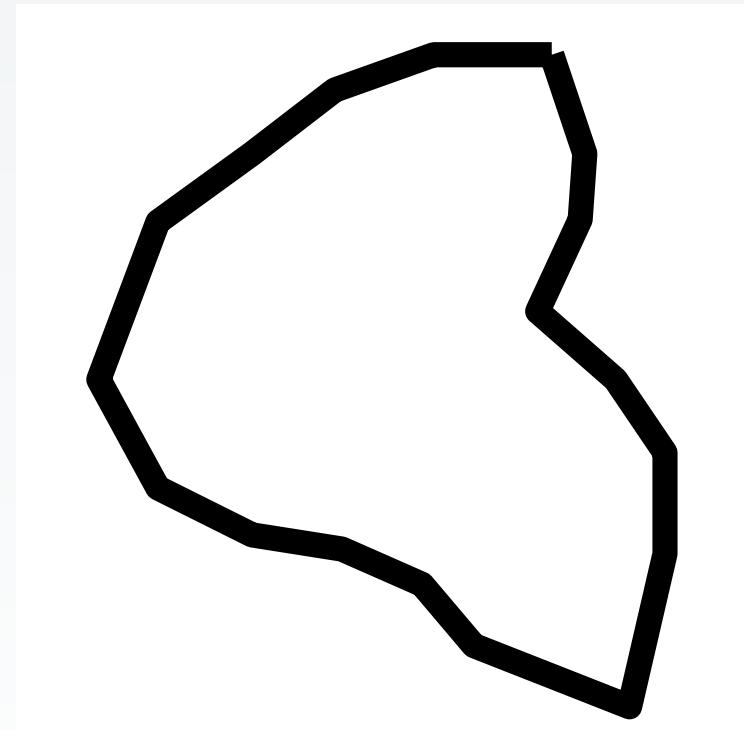
2. Elevate axes

3. Wrap polygon and axes



# Creation

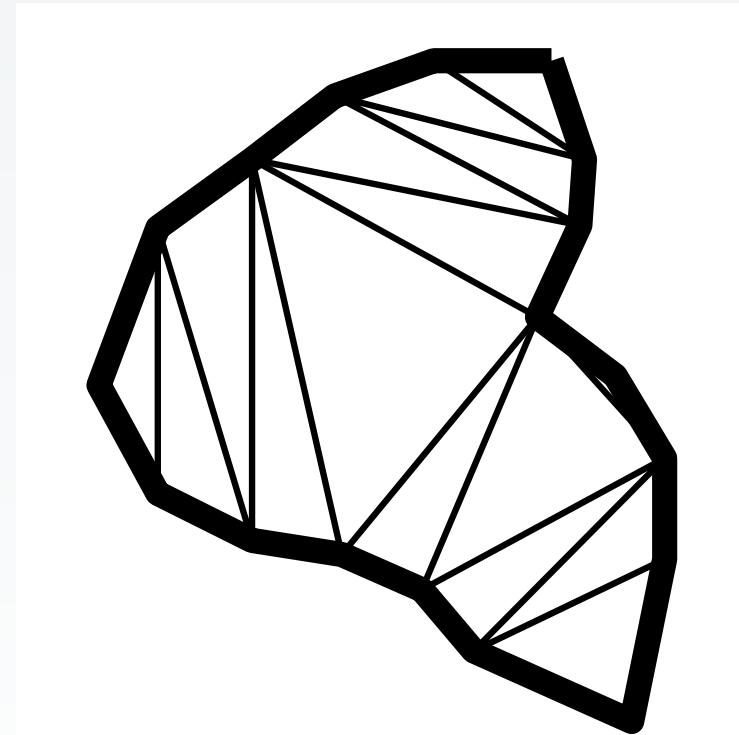
## -Finding axes-



Input 2D polygon

# Creation

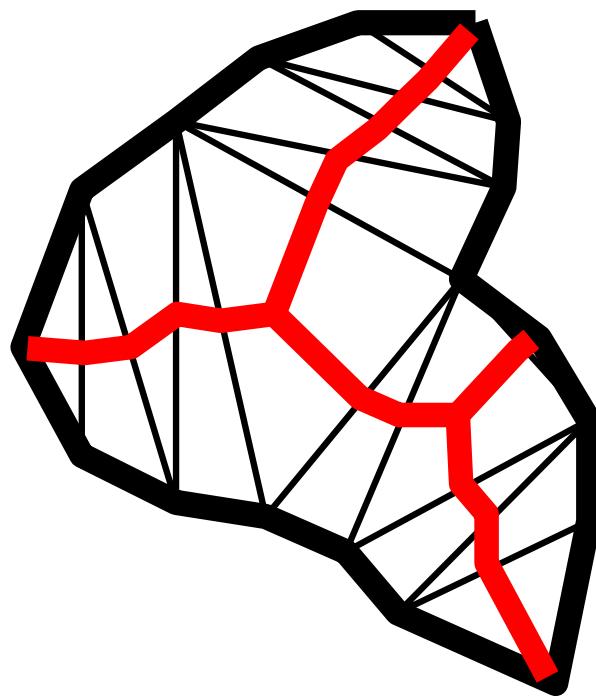
## -Finding axes-



Constrained Delaunay Triangulation

# Creation

-Finding axes-

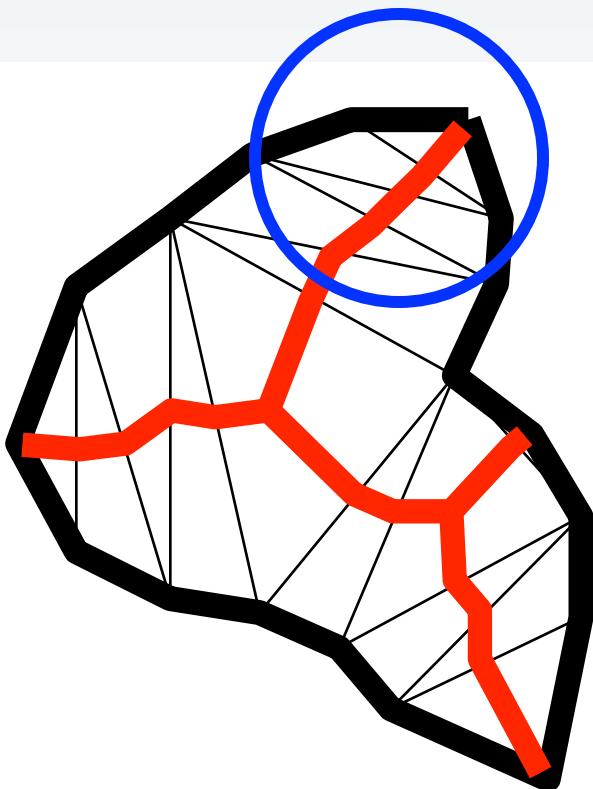


Chordal axis (connecting mid-points)

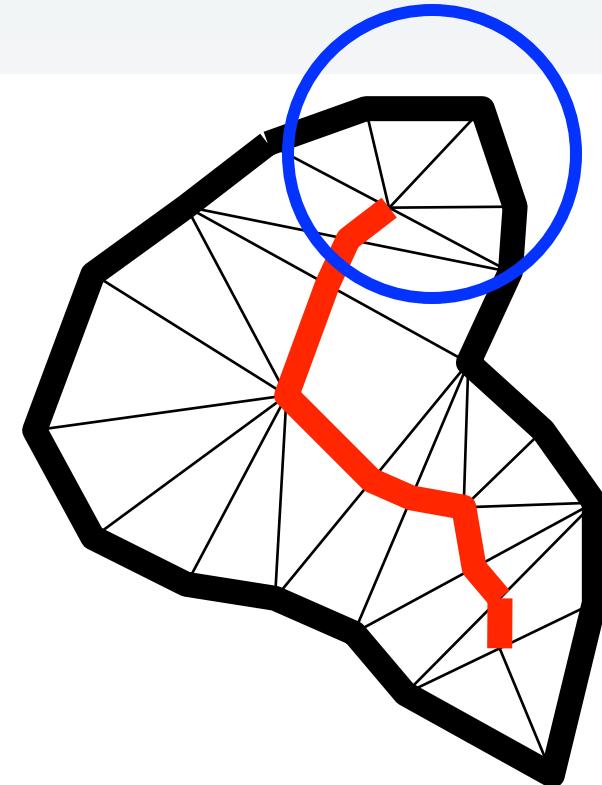
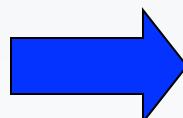
[Prasad 1997]

# Creation

-Finding axes-



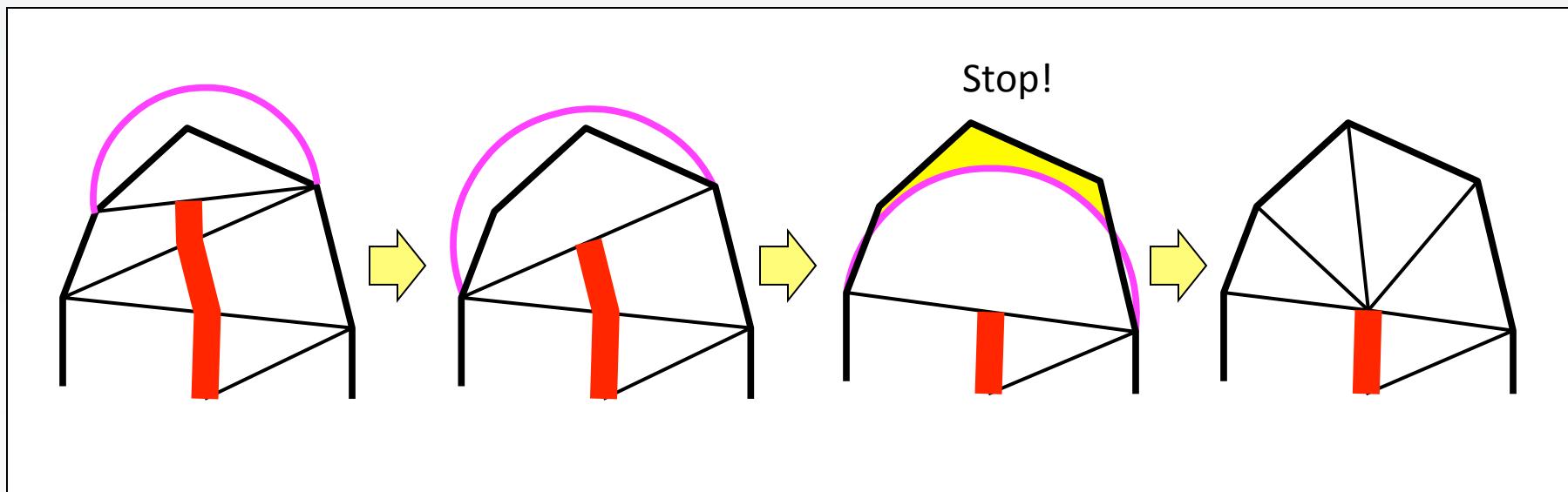
Before trimming



After trimming

# Creation

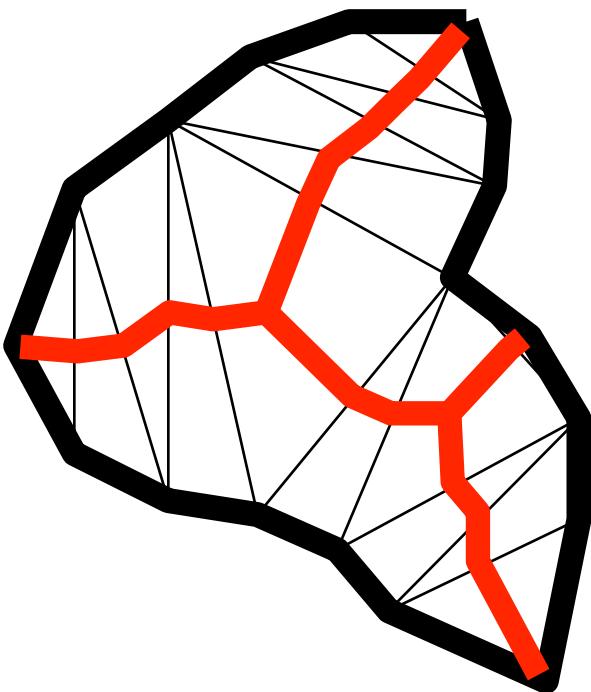
## -Trimming-



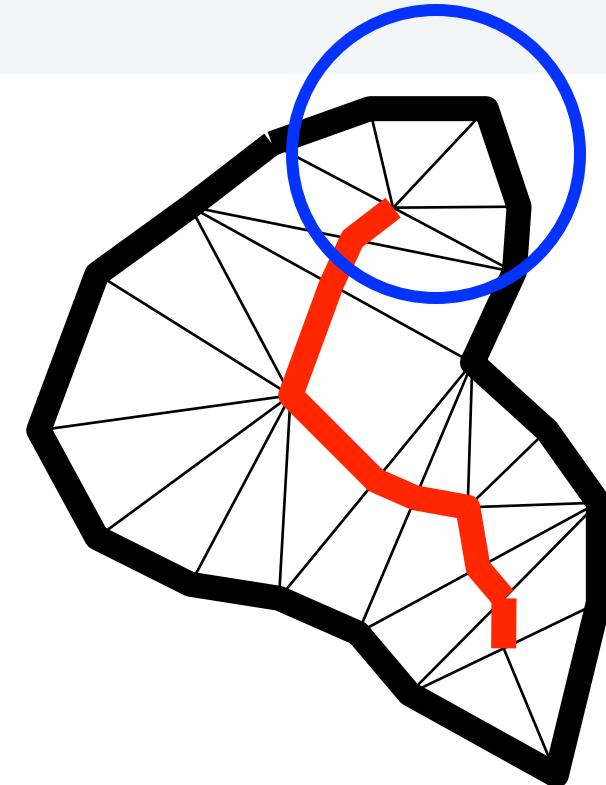
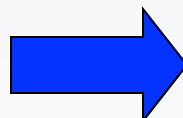
Starting from each terminal,  
search for the first significant edge.

# Creation

-Finding axes-

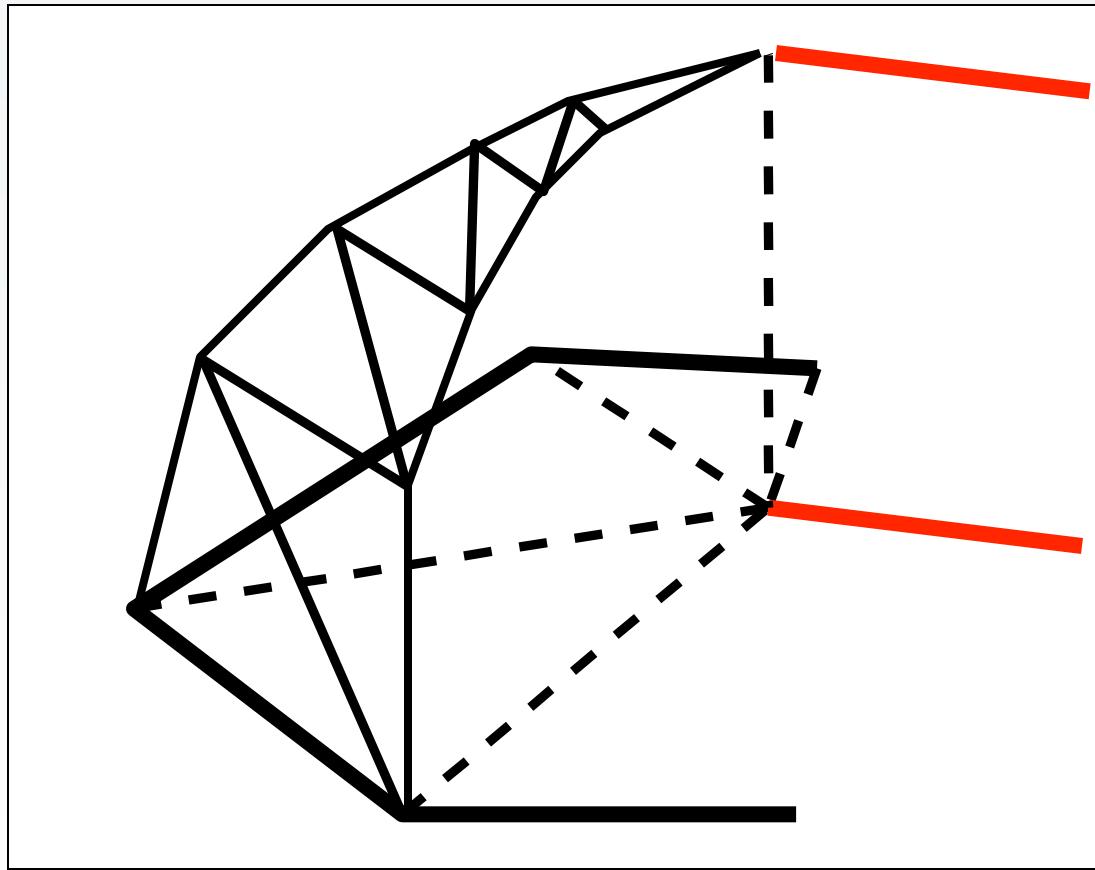


Before trimming



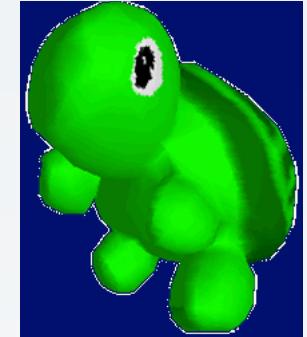
After trimming

# Creation -Wrapping-

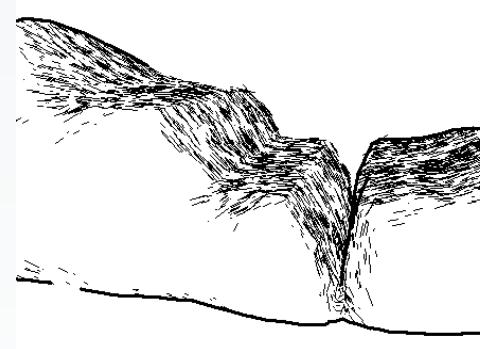
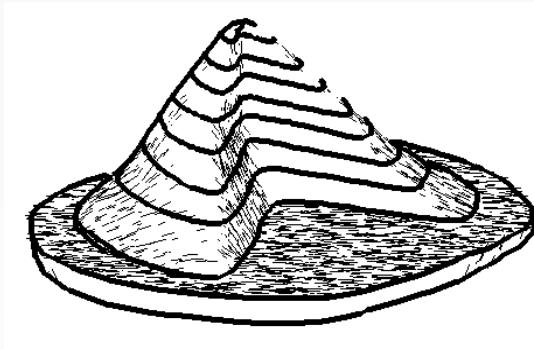


Lift the axes, and generate 3D faces along the spine.

# Applications



- Teaching Geography



[teddy](#)

# To Learn More...

## The original paper:

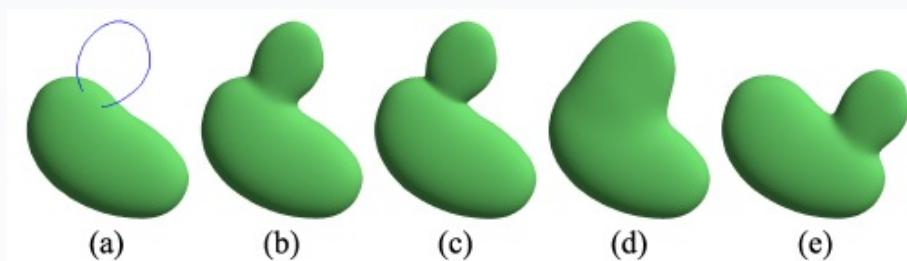
- Igarashi, et al. Teddy: A Sketching Interface for 3D Freeform Design SIGGRAPH 1999.

## Chordal axis:

- Prasad. Morphological analysis of shapes. CNLS newsletter 1997.

## Implicit Surfaces:

- Schmidt, et al. ShapeShop: Sketch-Based Solid Modeling with BlobTrees. SBIM 2005.



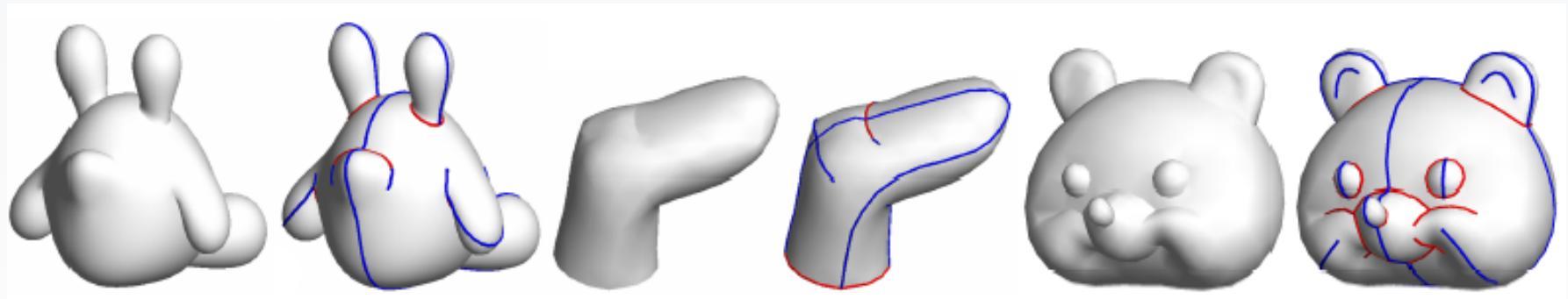
[Schmidt, et al. 2005]

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# 3D Geometric Modeling

- Suggestive Interface
- Sketch-based Modeling
- **Shape Control by Curves**
- Flower Modeling
- Volumetric Textures

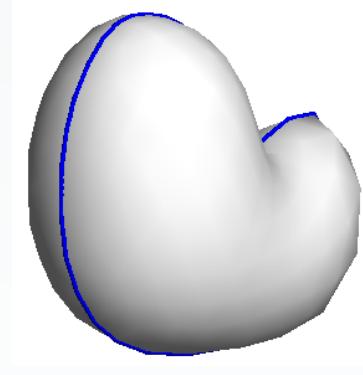
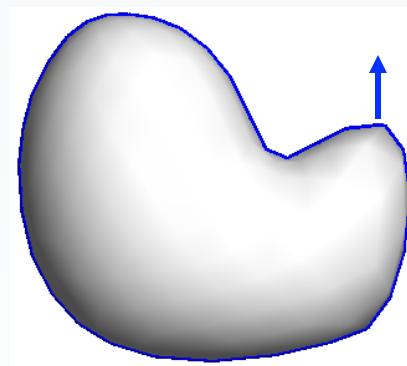
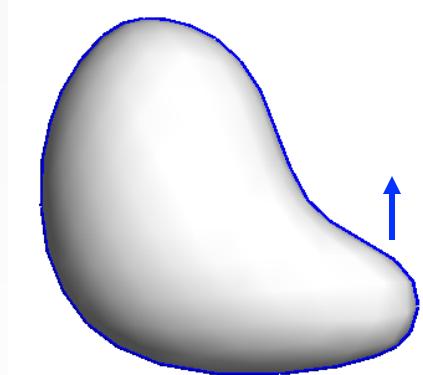
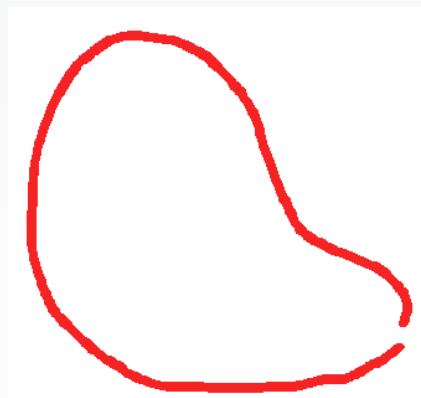
# FiberMesh: Designing Freeform Surfaces with 3D Curves



**Nealen, Igarashi, Sorkine, Alexa**

# Designing with “Curves”

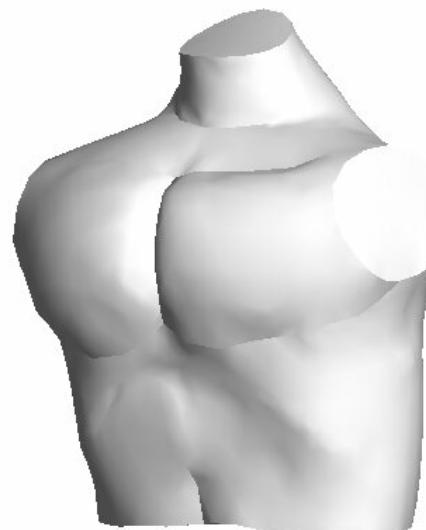
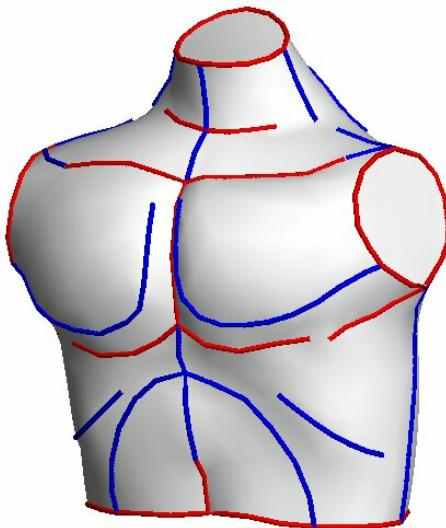
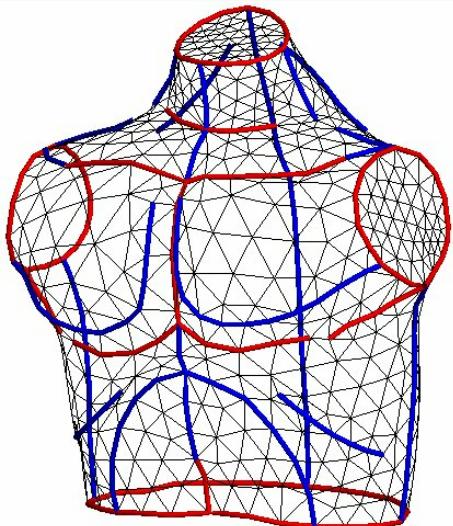
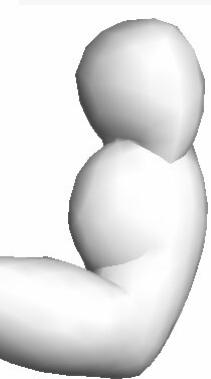
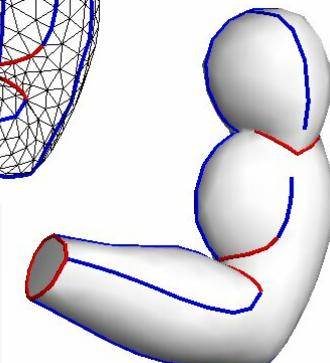
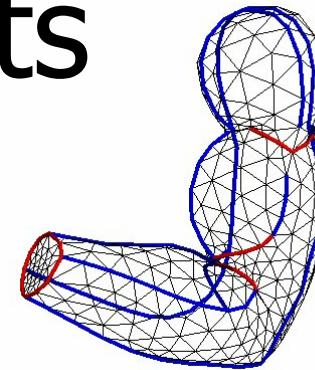
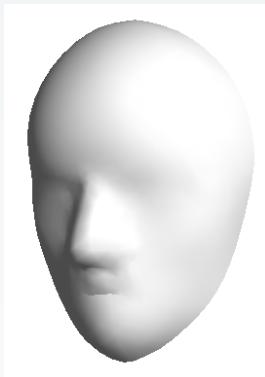
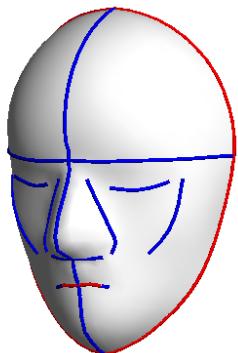
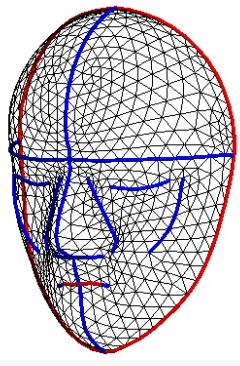
Original sketch stays and works as a handle.



# Demo

[fibermesh](#)

# Results



# Algorithm

## 1. Curve Deformation

Handle position -> Curve geometry

## 2. Surface Optimization

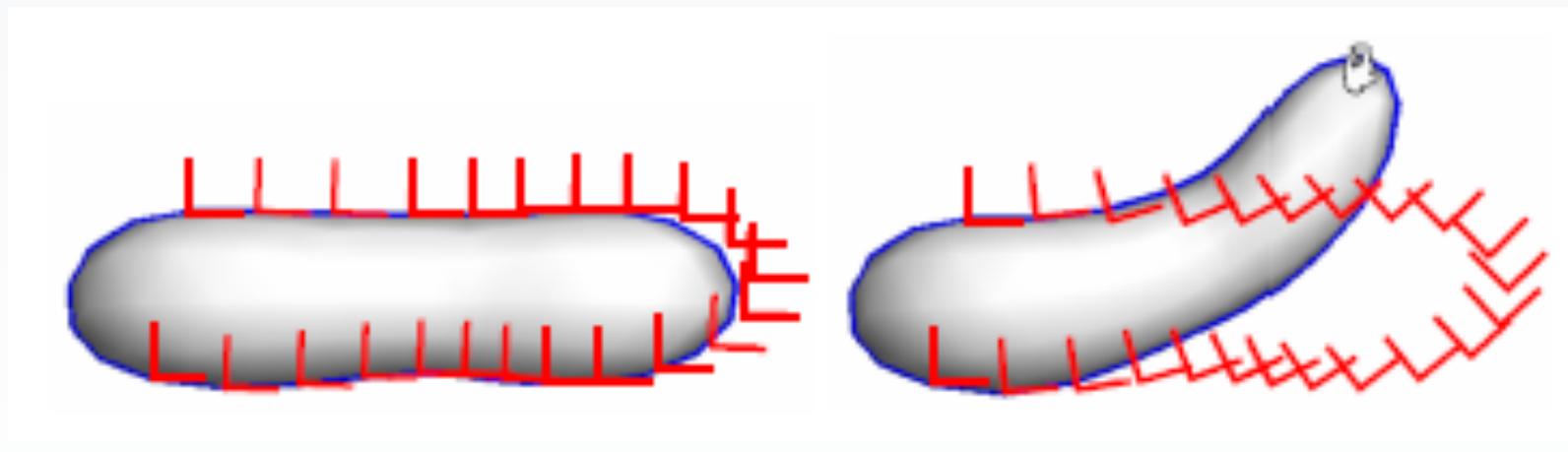
Curve geometry -> Surface Geometry

# 1. Curve Deformation

# Curve Deformation

Explicitly represent rotations with  $3 \times 3$  matrix.

Minimize the change of rotated laplacian and difference between neighboring rotations.



# Curve Deformation

Explicitly represent rotations with 3x3 matrix.

Minimize the change of rotated Laplacian and difference between neighboring rotations.

$$\arg \min_{\mathbf{v}, \mathbf{R}} \left\{ \sum_i \|\mathbf{L}(\mathbf{v}_i) - \mathbf{R}_i \delta_i\|^2 + \sum_{i,j \in E} \|\mathbf{R}_i - \mathbf{R}_j\|^2 + \right. \\ \left. \sum_{i \in C_1} \|\mathbf{v}_i - \mathbf{v}'_i\|^2 + \sum_{i \in C_2} \|\mathbf{R}_i - \mathbf{R}'_i\|^2 \right\},$$

# 2. Surface Optimization

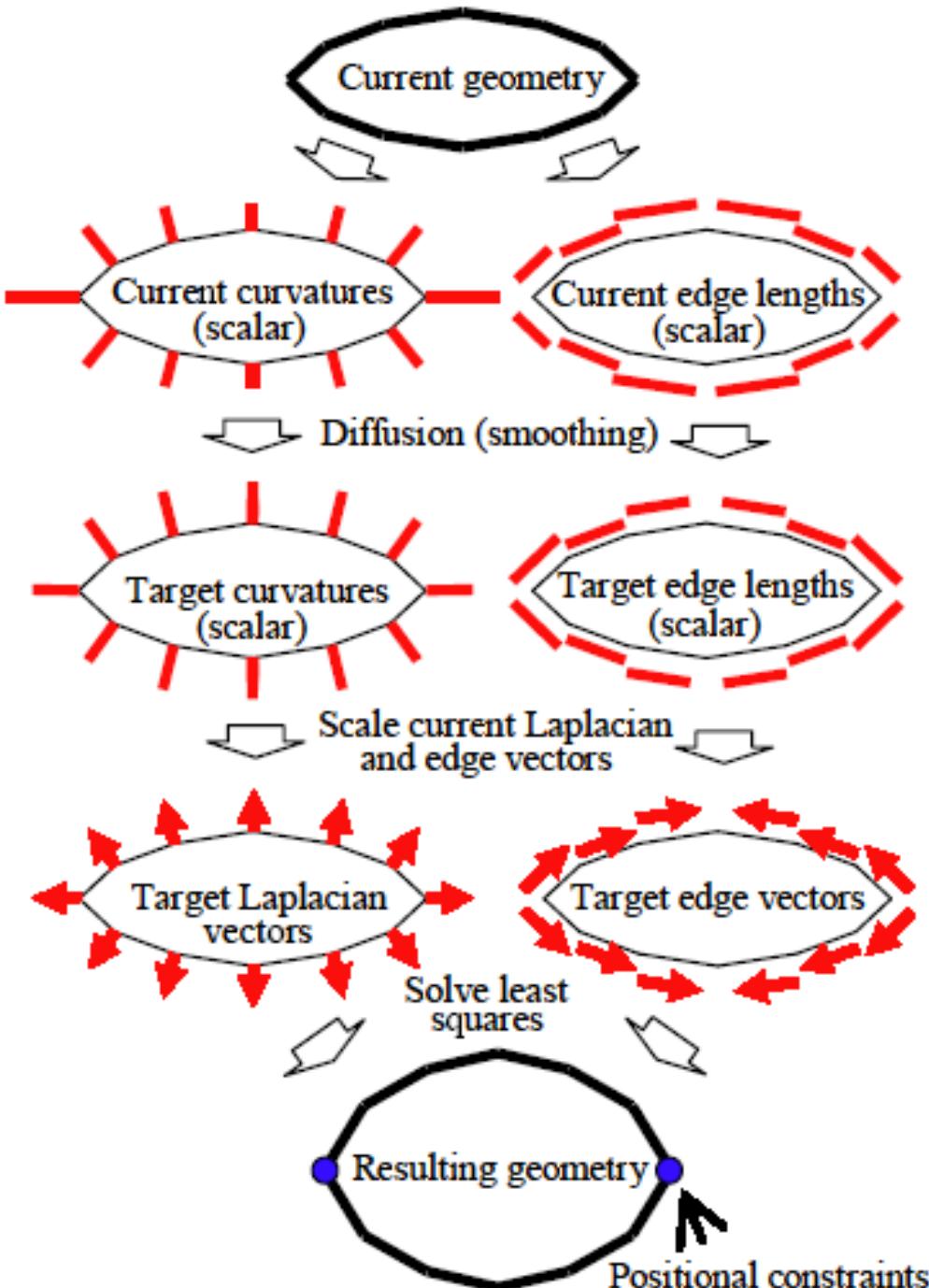
# Surface Optimization

Input: Curve geometry, mesh topology

Output: Smooth surface

Strategy: Minimize variation of curvature

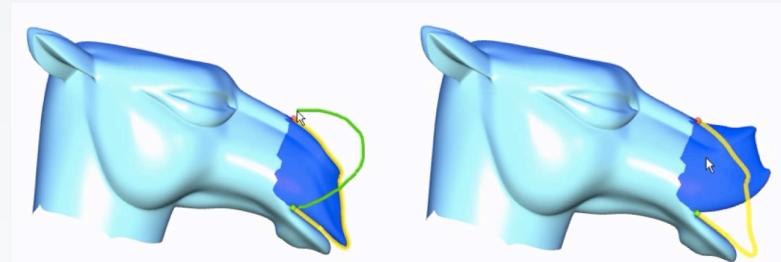
$$E_c = \int_S \left( \frac{d\kappa_n}{d\hat{e}_1} \right)^2 + \left( \frac{d\kappa_n}{d\hat{e}_2} \right)^2 dA,$$



# To Learn More...

## The original paper:

- Nealen, et al. FiberMesh: Designing Freeform Surfaces with 3D Curves. SIGGRAPH 2007.

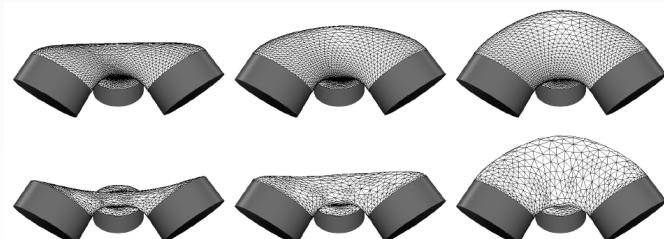


[Nealen 2005]  
(Figure obtained from

<http://igl.ethz.ch/projects/Laplacian-mesh-processing/sketch-mesh-editing/>  
with permission)

## Shape deformation:

- Nealen, 2005. A sketch-based interface for detail-preserving mesh editing. SIGGRAPH 2005.

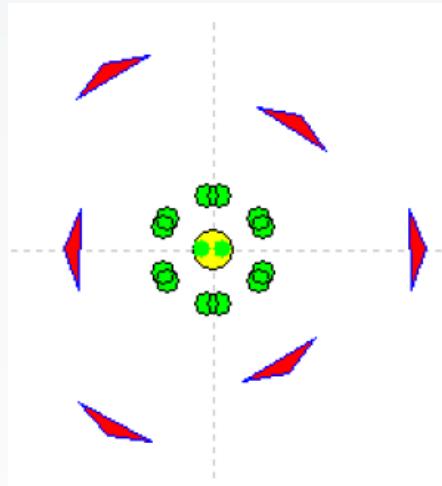


[Shneider and Kobbelt 2001]  
Copyright 2001 Elsevier. Included here by permission.

# 3D Geometric Modeling

- Suggestive Interface
- Sketch-based Modeling
- Shape Control by Curves
- **Flower Modeling**
- Volumetric Textures

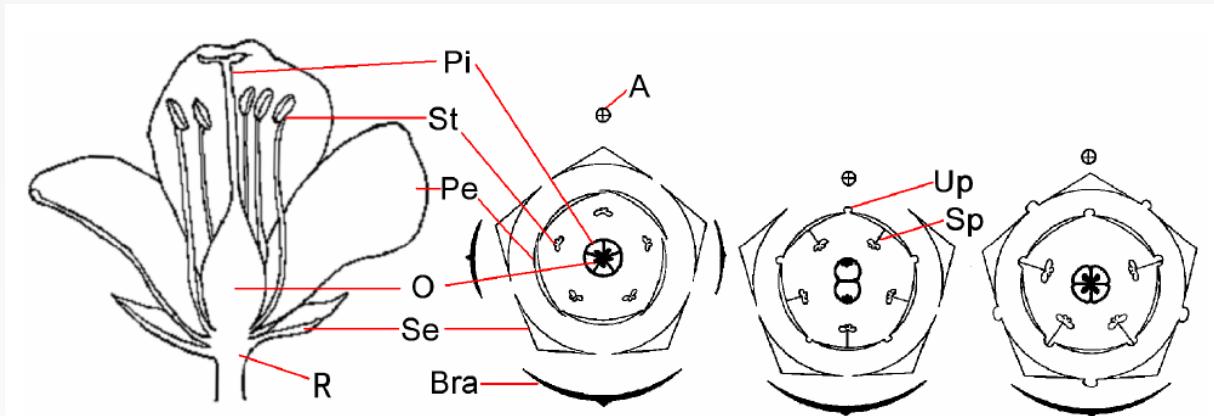
# Floral diagrams and inflorescences: Interactive flower modeling using botanical structural constraints



Takashi Ijiri, Shigeru Owada, Makoto Okabe, Takeo Igarashi

# Problem

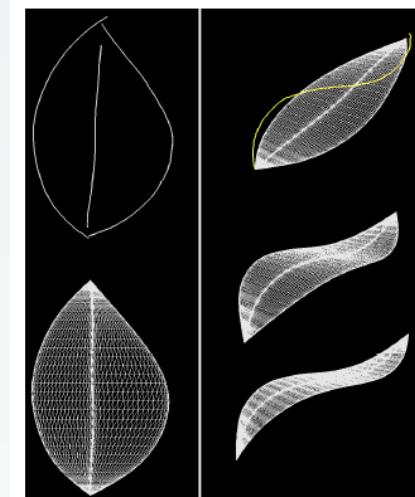
Flower modeling is difficult.



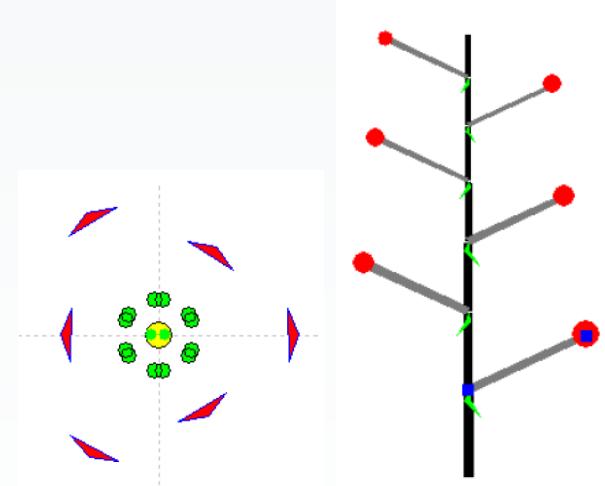
- Complicated geometry (element).
- Complicated structure (composition).

# Our Approach

- Complicated geometry (element).  
→ Specialized sketching interface



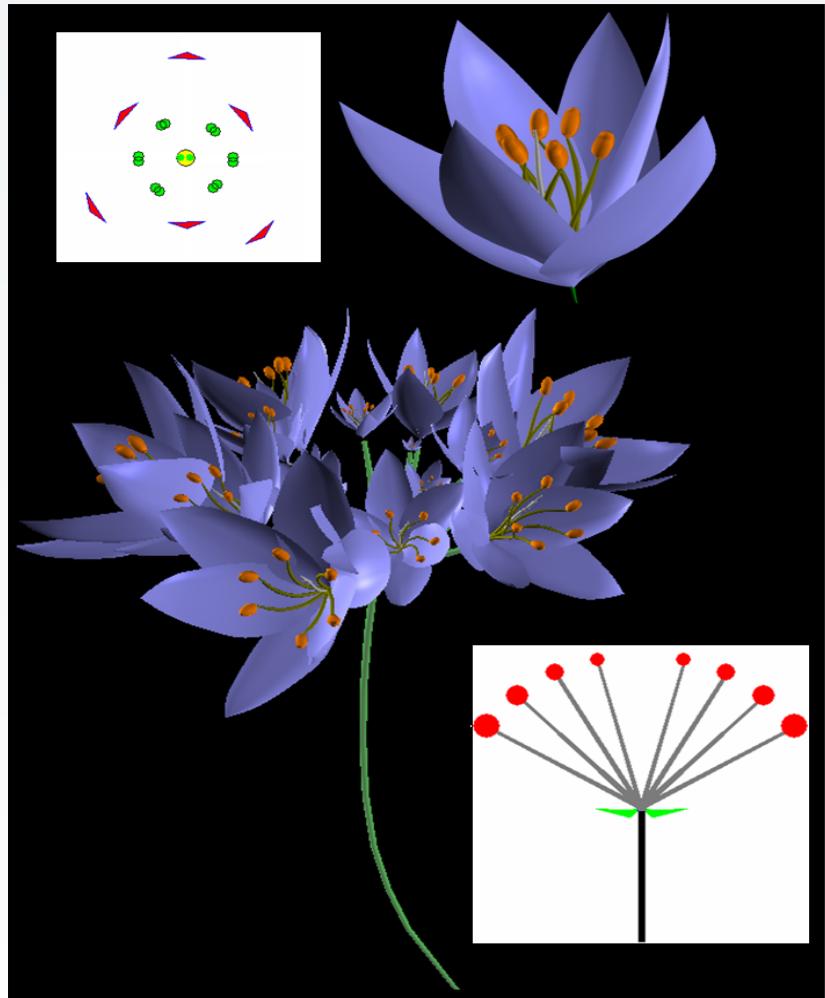
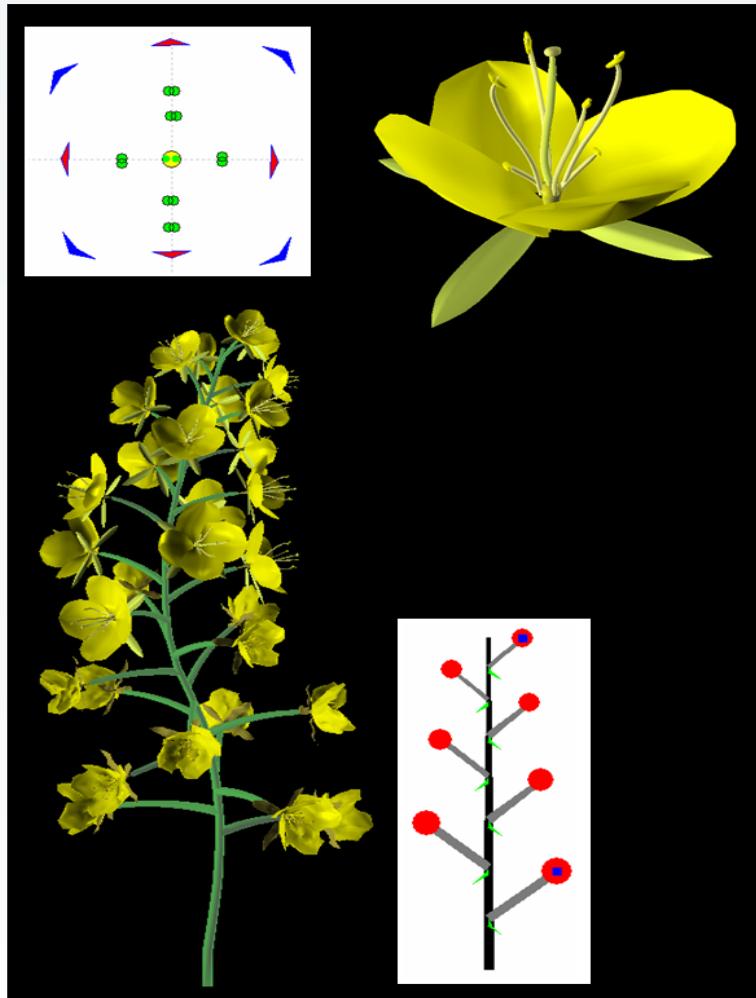
- Complicated structure (composition).  
→ Specialized structure editor



# Video

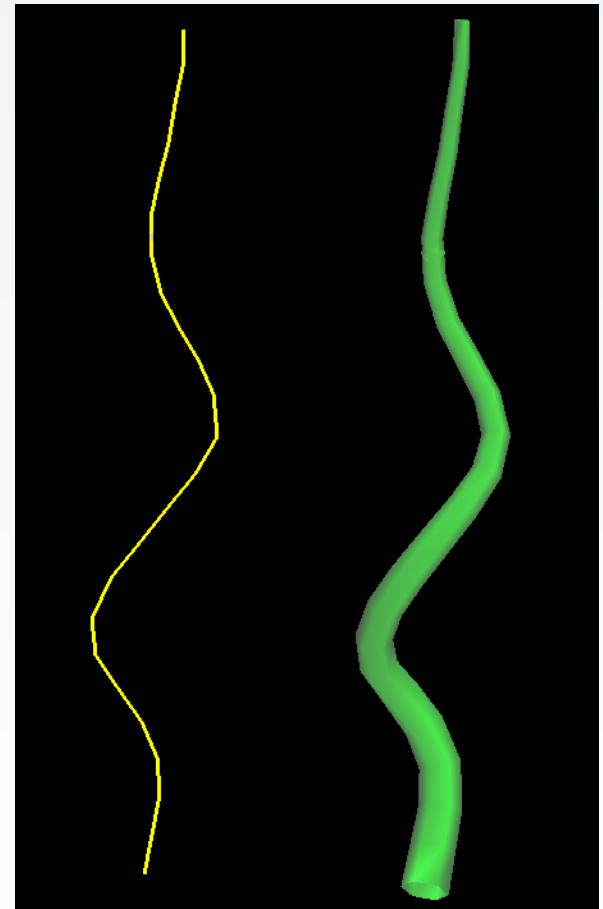
[flower](#)

# Results



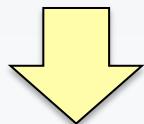
# Algorithm

2D stroke -> 3D stem  
How to infer depth?



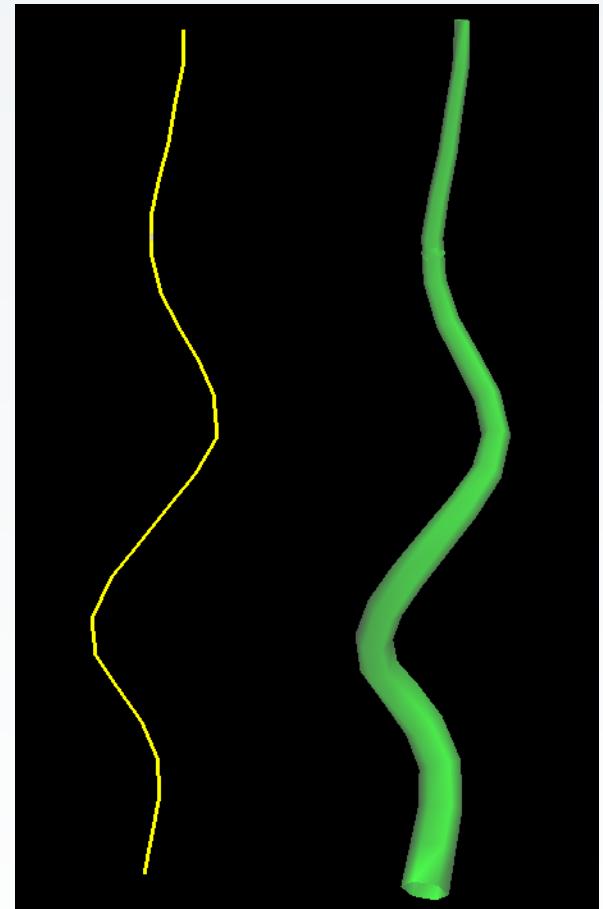
# Algorithm

2D stroke -> 3D stem  
How to infer depth?

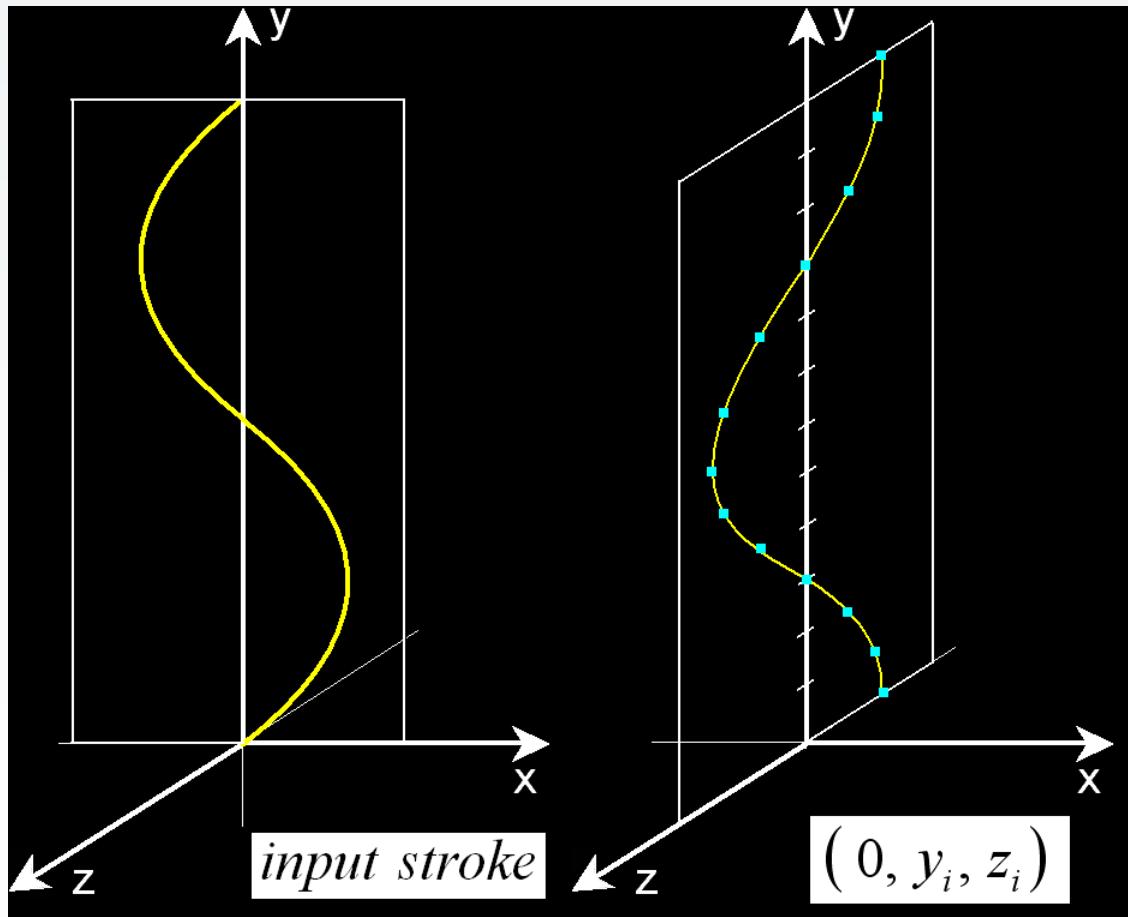


Constant curvature in 3D

$$\left( \frac{d^2 x}{dy^2} \right)^2 + \left( \frac{d^2 z}{dy^2} \right)^2 = const$$



# Constant Curvature in 3D



1. Project stroke onto x-y plane and resample

$$stroke = \{ v_i \mid v_i = (x_i, y_i, z_i), z_i = 0 \}$$

2. Suppose that curvature in 3D space is constant

$$\left( \frac{d^2 x}{dy^2} \right)^2 + \left( \frac{d^2 z}{dy^2} \right)^2 = const$$

$$const = \max_i \left( \left( \frac{d^2 x_i}{dy^2} \right)^2 \right)$$

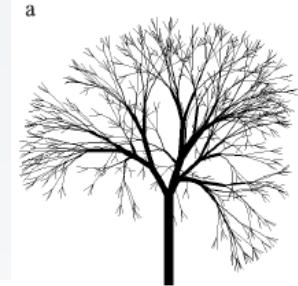
3. get second derivative of z along axis

4. Integrate and get z value

# To Learn More...

## The original paper:

- Ijiri, et al. Floral diagrams and inflorescences: Interactive flower modeling using botanical structural constraints. SIGGRAPH 2005.



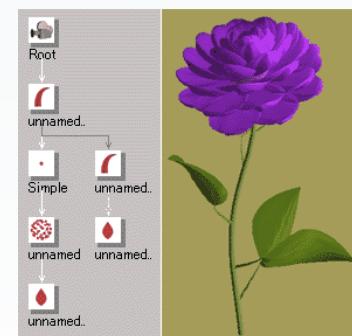
$\omega : ! (1)F(200)/(45)A$   
 $p_1 : A : * \rightarrow !(v_r)F(50)[\&(a)F(50)A]/(d_1)$   
 $\quad \quad \quad [\&(a)F(50)A]/(d_2)[\&(a)F(50)A]$   
 $p_2 : F(1) : * \rightarrow F(1*l_r)$   
 $p_3 : !(w) : * \rightarrow !(w*v_r)$

[Prusinkiewicz and Lindenmayer 1990]

(Figure obtained from  
<http://algorithmicbotany.org/papers/#abop> with permission)

## Plant modeling:

- Prusinkiewicz and Lindenmayer. The Algorithmic Beauty of Plants. Springer-Verlag 1990. (L-system)
- Lintermann and Deussen. A Modelling Method and User Interface for Creating Plants. CGF 1998. (xfrog.com)



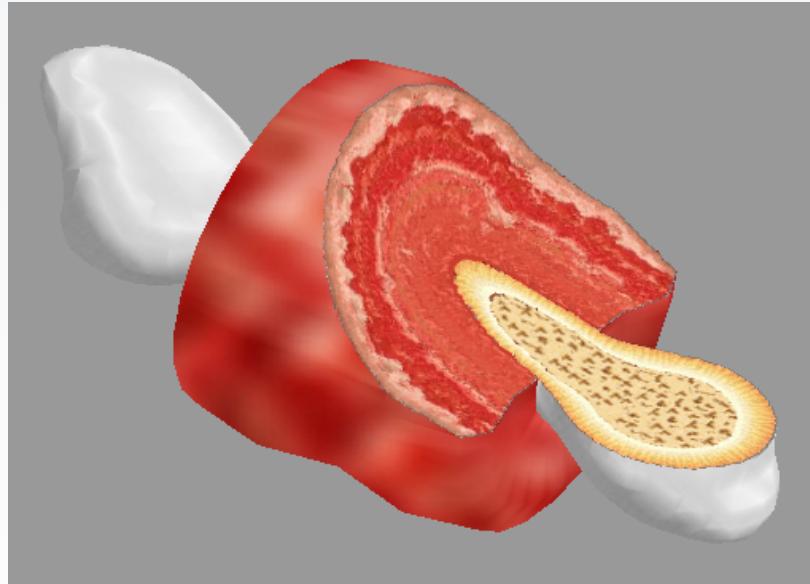
(C) Copyright Lintermann und Deussen GbR.

(Figure obtained from [http://www.oakcorp.net/xfrog/xfrog\\_lite.shtml](http://www.oakcorp.net/xfrog/xfrog_lite.shtml) with permission)

# 3D Geometric Modeling

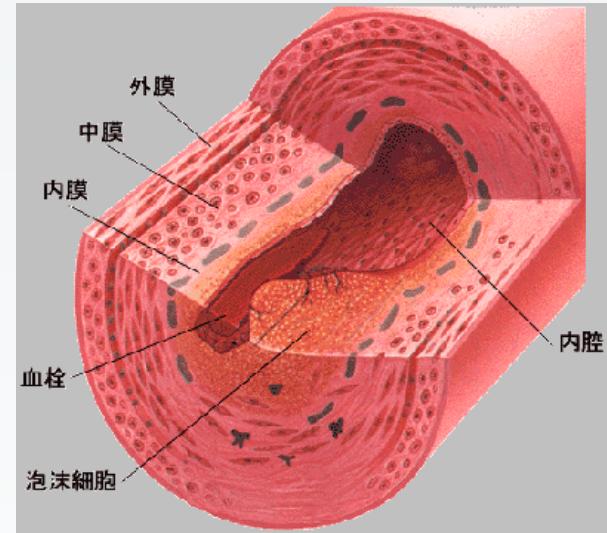
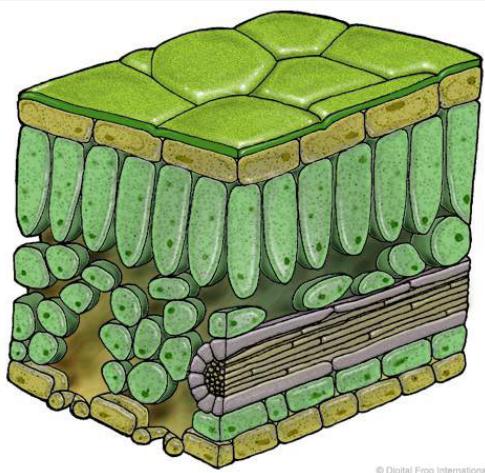
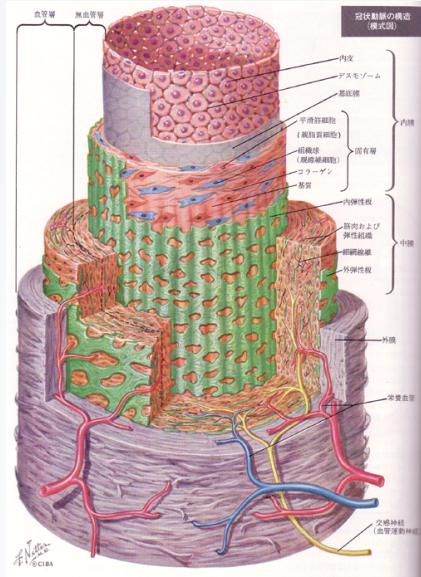
- Suggestive Interface
- Sketch-based Modeling
- Shape Control by Curves
- Flower Modeling
- Volumetric Textures

# Volumetric Illustrations: Designing 3D Models with Internal Textures



S. Owada, F. Nielsen, M. Okabe, T. Igarashi

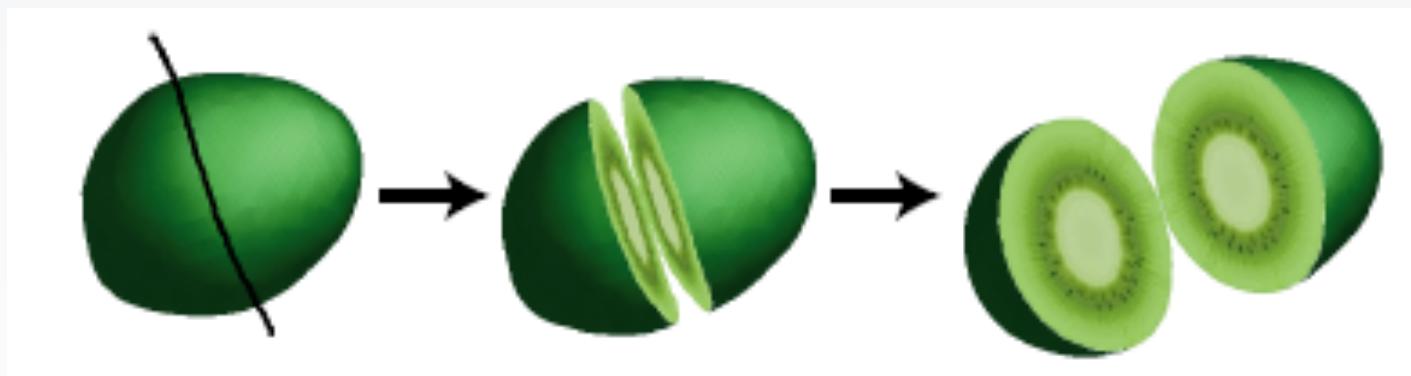
# Motivation



Carefully designed illustrations  
that shows internal structures

# Goal

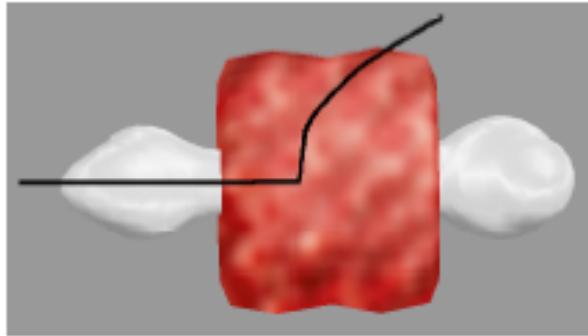
Design “cuttable” 3D models.



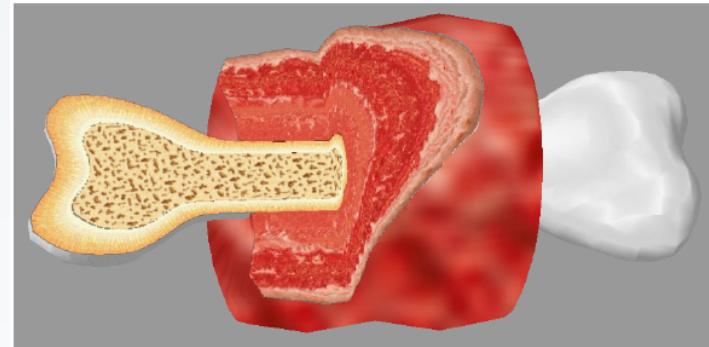
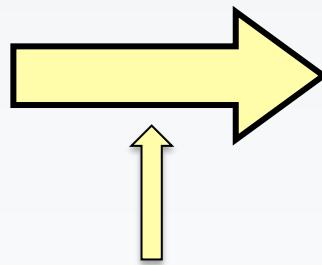
There was no interface for designing  
3D models with such internal textures.

# Approach

“Synthesize cross sections each time”



User Input (3D)



Result(3D)



Reference images (2D)

# Video & Demo

[volume](#)

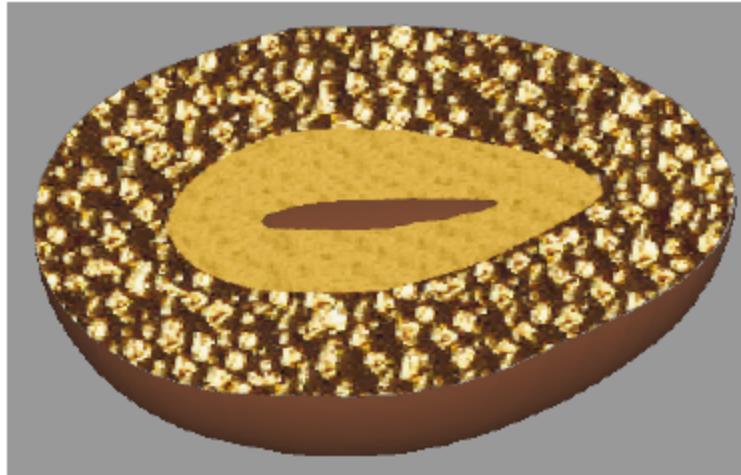


THE UNIVERSITY OF TOKYO

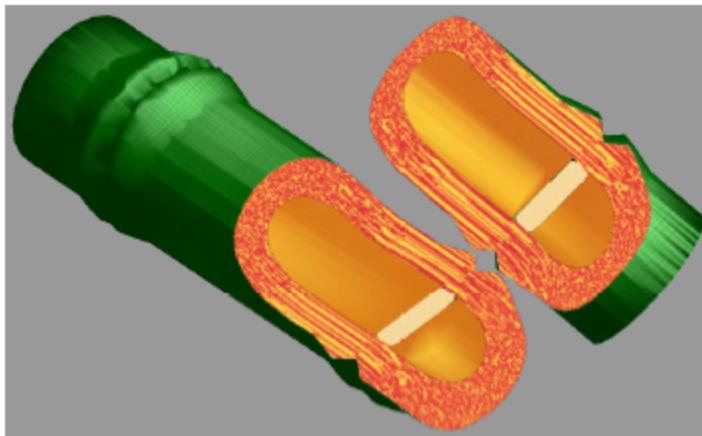
# Results



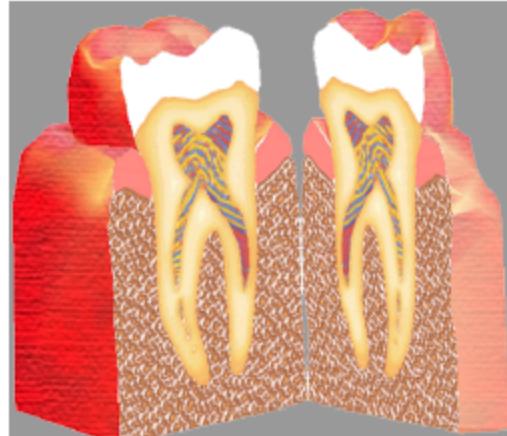
(a) Cucumber



(b) Nuts chocolate



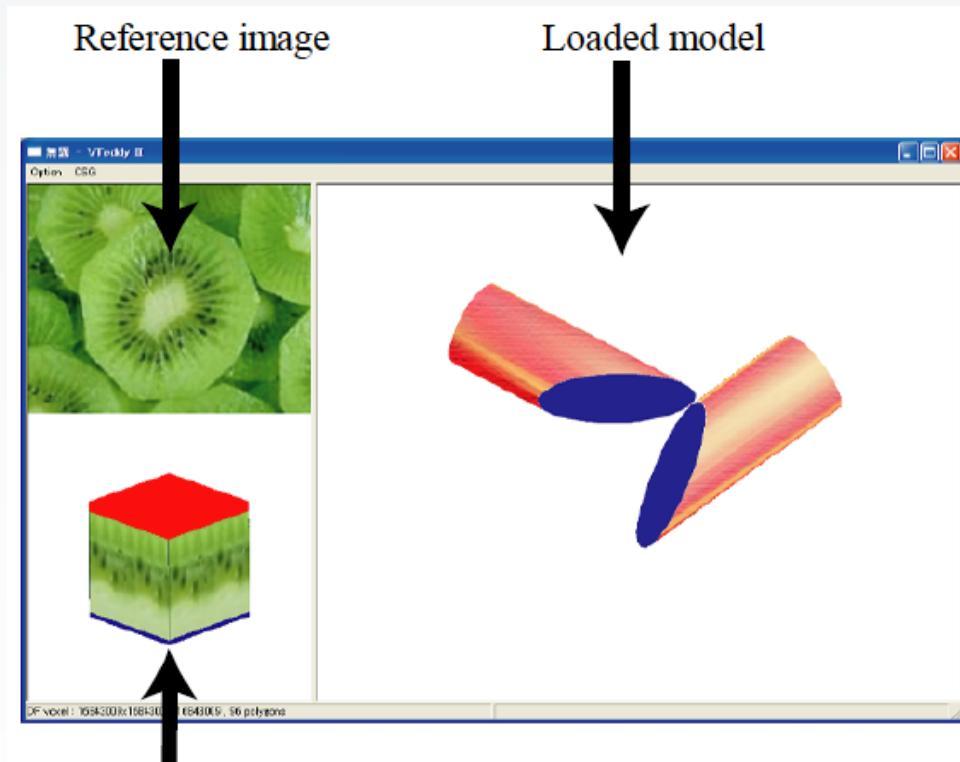
(c) Bamboo



(d) Tooth

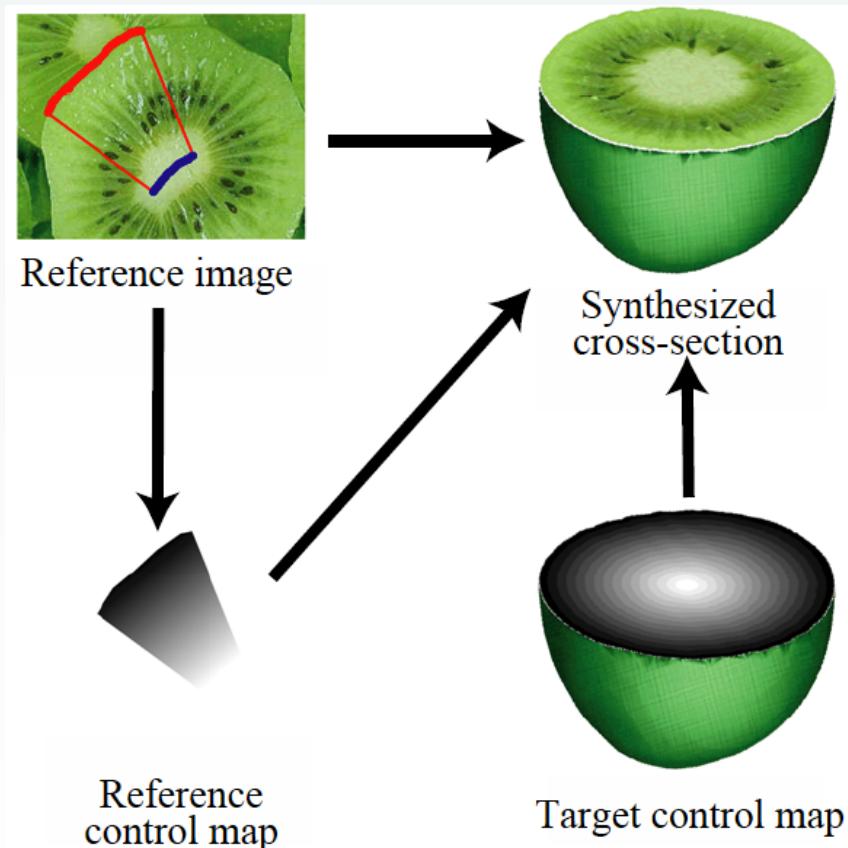
# Modeling

“Specify how to paste the image to the 3D model on a cross section”



# Algorithm

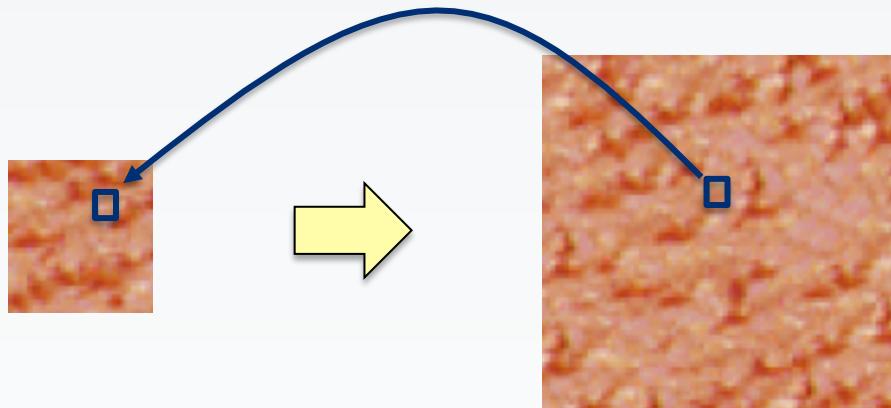
Synthesize texture on cross sections using reference images and hints.



# Texture Synthesis

Synthesize a larger texture from an exemplar.

[Efros and Leung 1999]



Start with random field. Then iteratively copy a pixel that has a similar context.

# To Learn More...

## The original paper:

- Owada, et al. Volumetric Illustration: Designing 3D Models with Internal Textures. SIGGRAPH 2004.

## Texture synthesis:

- Efros and Leung. Texture synthesis by nonparametric sampling. ICCV 1999.
- Barnes, et al. PatchMatch: A Randomized Correspondence Algorithm for Structural Image Editing. SIGGRAPH 2009.

## More recent 3D texture methods:

- Kopf, et al. Solid texture synthesis from 2d exemplars. SIGGRAPH 2007.
- Takayama, et al. Lapped Solid Textures:  
Filling a Model with Anisotropic Textures.  
SIGGRAPH 2008.



[Takayama, et al. 2008]

# 3D Geometric Modeling

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# Summary

## Challenge:

How to complement missing information (depth)?

## Solution:

User interface and automatic inference  
leveraging domain specific knowledge.

Architecture: Hard-coded rules

Organic shapes: Inflation algorithms

Flowers: Specialized editors

Cross sections: Texture synthesis