

## Level Set Surface Editing Operators

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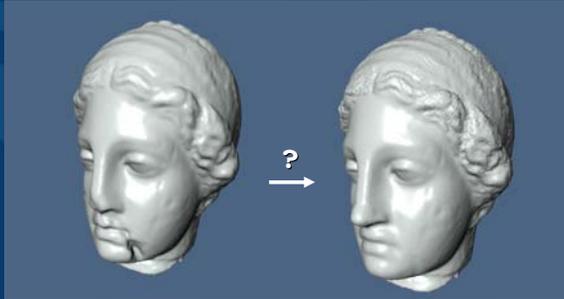
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## Outline

- Problem statement
- Short intro to Level Set Models
- Surface editing framework & operators
- Two editing sessions
- Wrap up

## Problem Statement



## Problem Statement



## Contributions

- **Design LS surface editing framework**
  - Single representation and numerous tools
- **Definition of new LS surface editing operators**
  - Automatic blending along intersection curves
  - Spatially constrained smoothing and embossing
- **User control over local surface properties**
- **User control of inward/outward surface movement**
- **New techniques for localized computation**

## Level Set Models

Implicit surface  $S(t) = \{\vec{x}(t) \in \mathbb{R}^3 \mid \phi(\vec{x}(t), t) = k\}$  [Osher & Sethian 1988]  
 Iso-value  $k$   
 Level set function  $\phi: \mathbb{R}^3 \times \mathbb{R}^+ \rightarrow \mathbb{R}$

Speed function

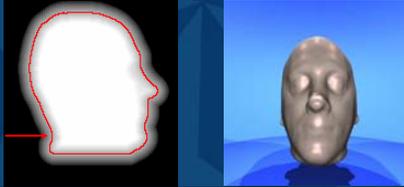
$$\frac{\partial \phi}{\partial t} + \vec{\nabla} \phi \cdot \frac{d\vec{x}}{dt} = 0 \Leftrightarrow \frac{\partial \phi}{\partial t} = \frac{d\vec{x}}{dt} \cdot \frac{\vec{\nabla} \phi}{|\vec{\nabla} \phi|} \vec{\nabla} \phi \equiv \Gamma(\vec{x}, \phi, \dots) |\vec{\nabla} \phi|$$

## How Level Sets Work:



- Initialize  $\phi$  as regular 3D sampling of signed distance function to initial geometry
- Propagate the time-dependent level set equation until convergence (steady-state)
- Surface is defined from zero-crossing of  $\phi$

$\phi(x,y)=0$



## Advantages of Level Set Models



- By construction, produce closed, non-self-intersecting surfaces
- Easily change topological genus
- Free of mesh connectivity and triangle quality issues
- No need to re-parameterize during deformation

## Disadvantages of Level Set Models



- No inherent parameterization ?
- Computationally expensive ?
- Cannot control genus ?
- Cannot represent fine, sharp features ?

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  - Not true: [Adalsteinsson & Sethian 1995]
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## Disadvantages of Level Set Models



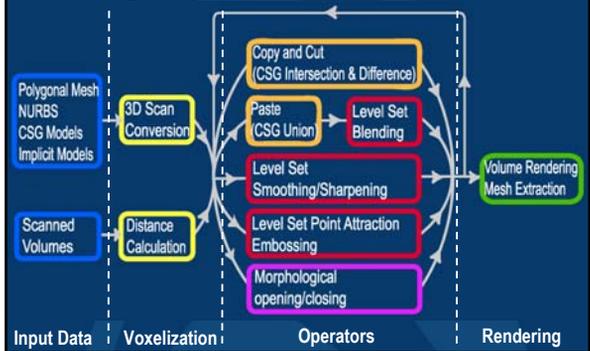
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# Disadvantages of Level Set Models



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  - True, but [Pedersen 1995, ...]
- **Computationally expensive ?**
  - Not true: [Adalsteinsson & Sethian 1995]
- **Cannot control genus ?**
  - Not true: [Han *et al.* 2001]
- **Cannot represent fine, sharp features ?**
  - Not true: [Friskien *et al.* 2000, Kobbelt *et al.* 2001]

# Level-Set Surface Editing Framework



# Speed Functions Building Blocks

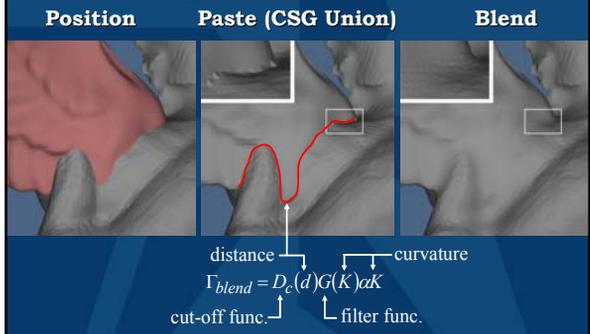


$$\frac{\partial \phi}{\partial t} = \Gamma(\vec{x}, \phi, \dots) \vec{\nabla} \phi$$

Speed function  $\Gamma = D_q(d)G(\gamma)F(\gamma)$

- **Distance-based cut-off function**
  - Regionally constrains speed function
- **Geometric property filter function**
  - Provides user control of local geometric properties
- **Function of geometric measure**
  - Maps geometric properties to surface speeds

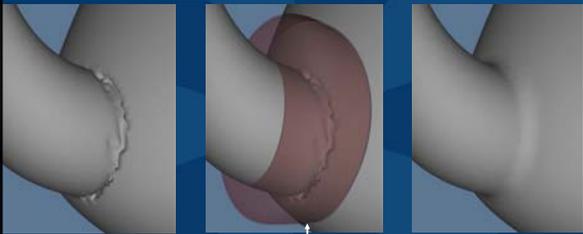
# Level-Set Blending



# Localized Smoothing



Teapot Spout      Regional constraining      Material added



$$\Gamma_{smooth} = D_s(d)G(K)\alpha K$$

# Localized Smoothing

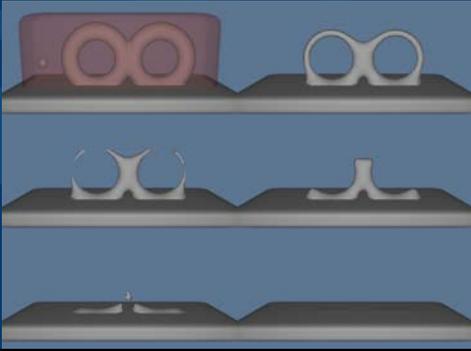


Spikes Regions smoothed (red)



## Topology Simplification

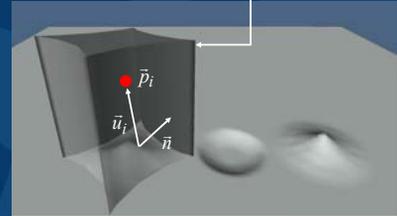
SIGGRAPH  
2002



## Point Embossing

SIGGRAPH  
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$$\Gamma_{emboss} = -\alpha\phi(\vec{p}_i, t)D_s(d)G(\pm\vec{n} \cdot \vec{u}_i)$$



## Point Embossing

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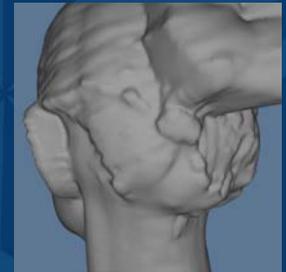
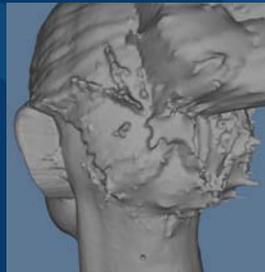


## Global Smoothing with a Morphological Opening

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Back of Female Head

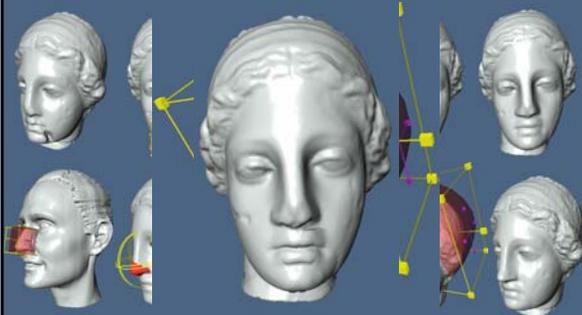
Erosion → Dilation



## Repairing a Greek Bust

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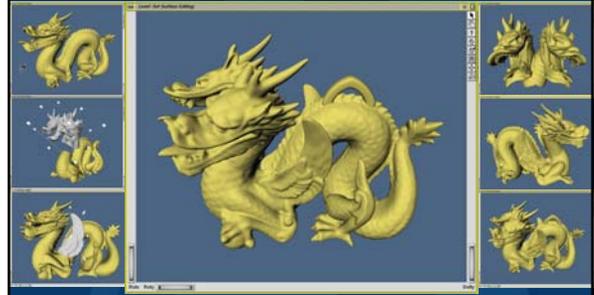
Repairing a Greek Bust



## Creating The Dragon

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2002

Creating The Dragon



## Summary



- **Robust:** No self-intersections and allows for changing topology
- **Fast:** LS computations are regionally constraint
- **Simple:** Speed functions encode the editing operators on a single data structure
- **Closed:** Editing operation can be applied repeatedly
- **General:** Can import many types of geometric models

## Future Work



- **Better representation of sharp features**
  - Implement adaptive Level Set methods
  - Improve mesh extraction
- **More control and operations**
  - Add control of topology
  - Add dragging, warping and sweeping
- **Improve rendering**
  - Incremental mesh extraction
  - Direct volume rendering

## Acknowledgement



- Thanks to Sean Mauch, Jason Wood (Leeds), David Johnson (Utah), Mathieu Desbrun (USC), Khrysaundt Koenig, and Katrine Museth
- Supported by NSF, ONR, NLM
- Datasets provided by Utah's Geometric Design and Computation Group, SCI Institute, Stanford's CG Lab, Caltech's Multires Modeling Group, Cyberware and Microsoft