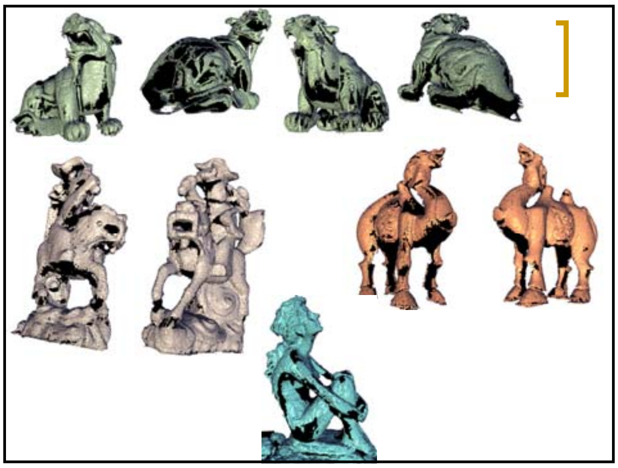
Large and Accurate reconstructions

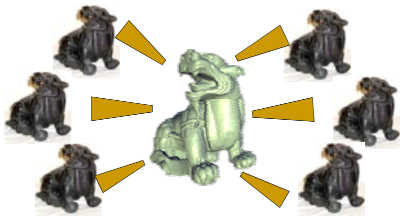
Towards Ideal Surface Reconstruction

Daniel Cohen-Or



Structured Light Scanners

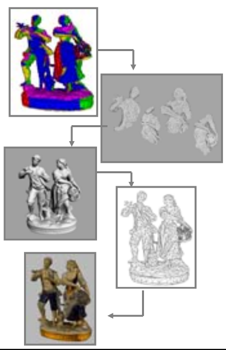
- Acquired in few seconds (<30s)
- Few structured light shots (<12)



The 3D scanning

- **3D Scanning, many challenges**:
  - **Acquisition** of multiple views
  - **Registration** of range maps
  - **Consolidation**
  - **Surface tessellation**

Involve extensive user intervention



Imperfect Acquisition

- The problem of coverage:
  - Large missing parts
  - Non-uniform sampling
  - Outliers
  - Noisy data
  - Orientation

Complex Topology

- Large Acquisition Holes


play

The talk includes

- Completion of Large missing parts
- Consolidation of point clouds
- Registration of noisy data

Competing Fronts for Coarse–to–Fine Surface Reconstruction (Sharf et al. Eurographics 2006)

Topology-aware Reconstruction

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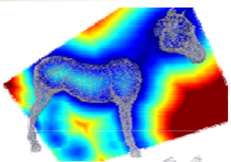
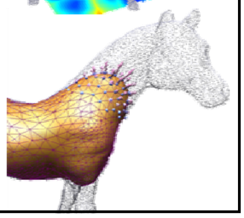
Deformable model

- Implicit coarse guidance field or attraction field
- Explicit deformable model (a mesh)

Deformable Model Reconstruction

- Watertight guarantee
- Topology control

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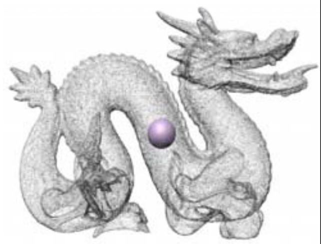

Competing Fronts Overview

- Incremental steps
- Multiple fronts
- Front control
- Coarse-to-fine

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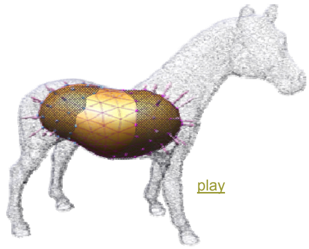
Mesh Fronts

- *front*: set of connected vertices not *ε-close* to zero level-set



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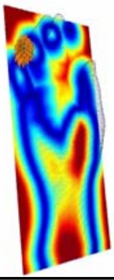
Attraction Field

- Vertex Attraction (E_a)
  - Outward normal direction
  - Unsigned field speed
- Uphill evolution



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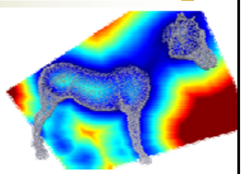
Initialization

- Guidance field:
  - RBF distance-field



- Deformable model *D*:
  - sphere mesh placed in interior

Competing fronts

- Coarse-to-Fine
  - Initial coarse reconstruction
  - Incremental fine detail recovery
- Adaptation control
  - Tension factor
  - Triangle density

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Starting position invariance

- Flexible evolution
- Multiple fronts

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Coarse-to-fine Competition

- Topology ambiguity solution:
  - **First:** hole – complete
  - **Next:** narrow tunnel - intrude

Topology ambiguity

- Coarse-to-fine Competition :
  - hole - complete
  - narrow tunnel - intrude

Coarse-to-fine Competition

Power-crust Competing-fronts

Coarse-to-fine Competition

- 3D scenario

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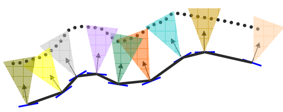
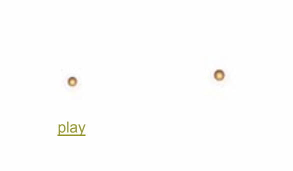
Final Projection

- ε-close vertices: normal project
- far-vertices: interpolate





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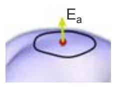
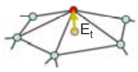
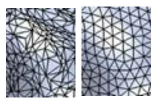
Evolution Parameters

- Attraction (E_a)
  - Outward normal direction
  - Unsigned distance field speed
- Tension ($w \cdot E_t^i$)
  - Smoothness factor
- Laplace system:
- Local remeshing and subdivision





$$\arg\min_{v_i} \left\{ \sum_{v_i \in front} (w \cdot E_t^i + E_a^i)^2 \right\}$$



ε-close Stop Criteria

- *satisfied* points: points *ε-close* to model
- *"wake up"* procedure for *unsatisfied* points:
  - Fronts revived and subdivided
  - Tension released

Topology Aware

- High genus cases:
  - Collision detection
  - Merge fronts

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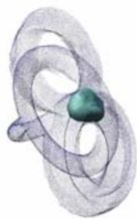
Tunnel

Results



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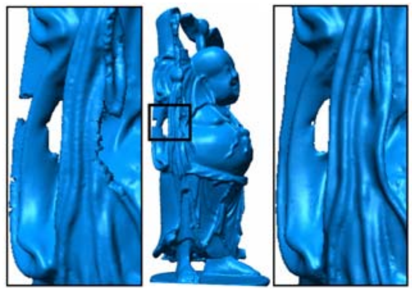
Limitations



User Interaction!

- An ill posed problem: infinite surfaces pass through or near the data points

- Reconstructed object is not necessarily the expected one!
- UI for correct interpretation!

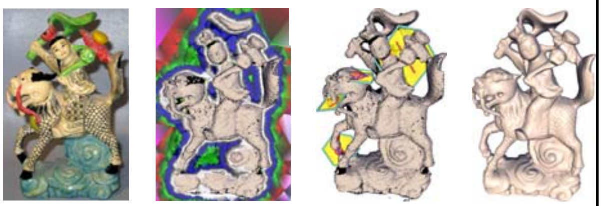
Topology-aware

So far:

- Watertight guarantee
- Heuristics (Coarse–to–fine)

- Topology aware – but…

Interactive Topology-aware Surface Reconstruction (Sharf et al.)

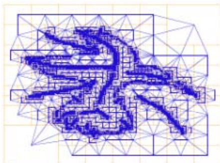


Interactive Topology-aware

- Automatic detection of ill conditioned cases
- Ask the user for inside/outside constraints
- Resolve locally and achieve expected shape.

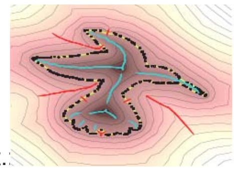
FEM Fields

- Underlying structure:
  - Dynamically adaptive octree
  - Dual hierarchical mesh graph
- Penalty functions:



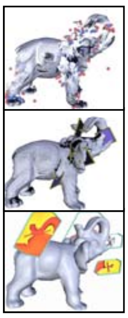
Implicit Formulation

- Goal: construct surface:
  - smooth
  - close to the input points
  - separates the in/out scribbles
- Implicit representation $u(p)$ s.t.:
  - $Z = u^{-1}(\{0\})$
  - $u(p) \approx 0$ for $p \in P^s$
  - $u(p) > 0$ for $p \in P^{in}$
  - $u(p) < 0$ for $p \in P^{out}$



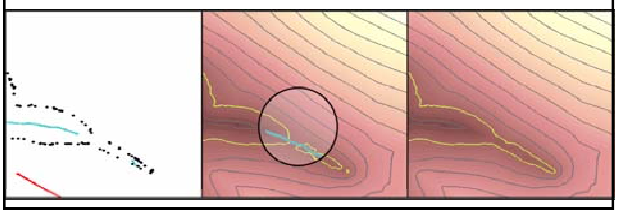
Method Overview

- Automatically generated, loose constraints
- Compute a smooth coarse approximation
- Analyze the implicit function and identify weak regions
- Allow the user to draw scribbles to specify local sign.



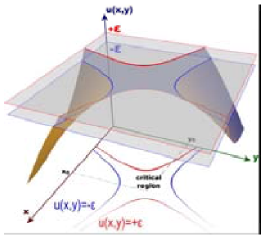
FEM Fields cont'd

- $\Psi_{\text{point constraints}} + \Psi_{\text{smoothness}}$ optimization problem:
- We solve using a fast sparse Cholesky factorization (CHOLMOD)
- Update factorization when user adds/removes constraints.



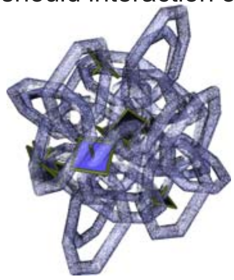
Topological Critical Points

- Topological non-stability detection: $u(p)$- ε and $u(p)$+ε have different topologies



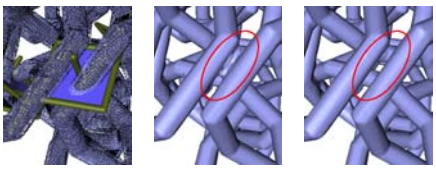
Topological Critical Points

- Where should interaction occur?



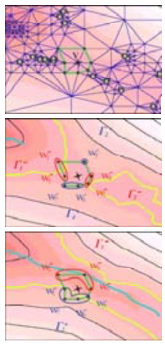
User Interface

- Provide 2D tablets at weak regions near zero level-set
- 2D tablets are located at critical points, perpendicularly to *critical lines*
- The user draws scribbles to correct or reinforce the topology



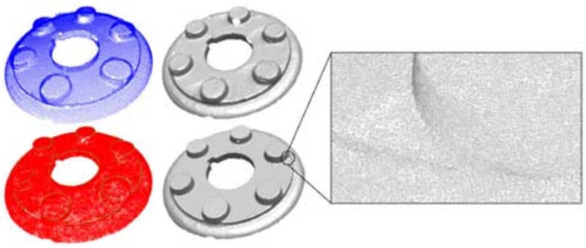
Weak Regions

- Discrete critical points (Morse):
  - Partition *link graph* into positive and negative groups
  - Detect critical points by number of connected groups

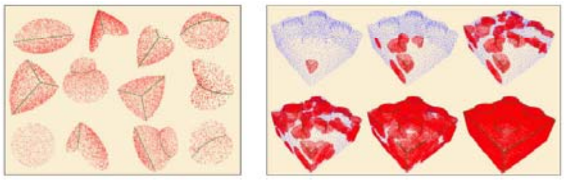


Video

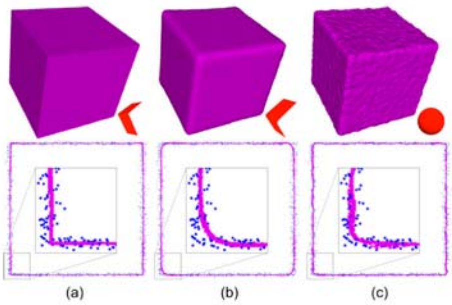
Surface Reconstruction using Local Shape Priors



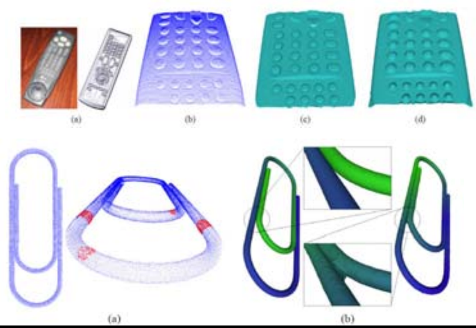
Surface Reconstruction using Local Shape Priors (SGP07)



Surface Reconstruction using Local Shape Priors

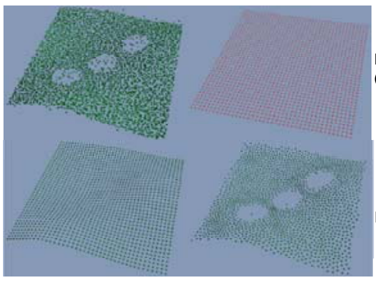


Surface Reconstruction using Local Shape Priors



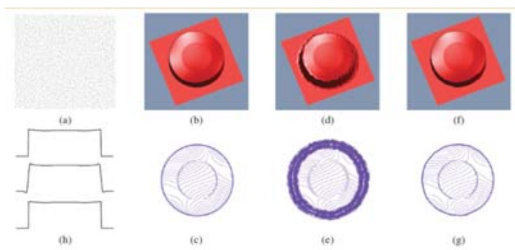
Parametrization-free projection (Lipman et al.)

SIGGRAPH2007



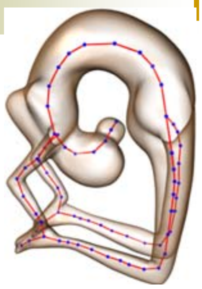
Lop07

Sharp Features, Faithful Reconstruction (Lipman et al. SGP07)



Skeleton extraction from incomplete point cloud

Andrea Tagliasacchi,
Hao Zhang,
Daniel Cohen-Or



SIGGRAPH 2009

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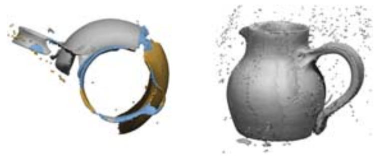
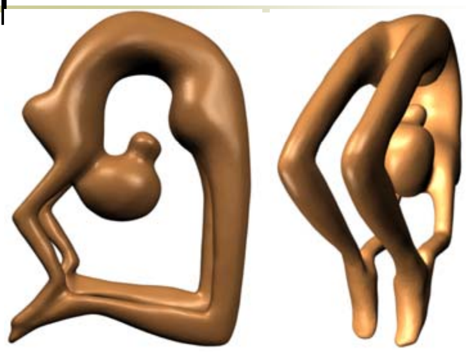
4-Points Congruent Sets for Robust Pairwise Surface Registration (Aiger et al.)

SIGGRAPH2008



4points

Skeleton aided reconstruction



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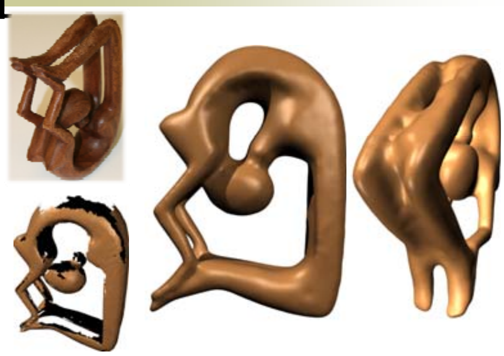
Direct reconstruction through RBF



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Thank you