Patch-Graph Reconstruction for Piecewise Smooth Surfaces

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Motivation

• Surface reconstruction remains unsolved
• Nice solutions for smooth surfaces
• Hard problem at sharp creases
  – man-made objects
Bayesian Point Cloud Reconstruction

- Statistically motivated surface reconstruction approach
- Bayesian reasoning
  - data saliency + prior assumptions
- Feature preservation
  - curvature-based heuristic

[P. Jenke, M. Wand, M. Bokeloh, A. Schilling, W. Straßer: Bayesian Point Cloud Reconstruction, Eurographics `06, 2006]
Bayesian Point Cloud Reconstruction

- Limitations
  - Performance
    - optimization over surfel positions
  - Stability
    - global approach
    - feature detection heuristic

<table>
<thead>
<tr>
<th></th>
<th># Data points</th>
<th># Rec. points</th>
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Table 1: Computation time and model complexity.
**Data Structure**

- **Surfel**
  - position
  - normal

- **Patch**
  - coordinate frame
    - normal + tangential directions
  - basis functions + coefficients
    
      \[
      f(u, v) = \sum_{i=1}^{\|B\|} c_i b_i(u, v)
      \]
  - subset of data points
Reconstruction Pipeline

- Noisy 3d data
- Initialization
- Segmentation
- Feature line extraction
- Meshing
Initialization

• Data preprocessing
  – normal estimation
    • Principle Component Analysis (PCA)
  – noise estimation

• Extraction of patches
  – resampling to $\varepsilon$-spacing
  – assembly of data points

• Topology graph
• Free parameters
  – basis function coefficients
• Bayes rule
  – likelihood
    • data points attract patch surface
  – priors
    • consistency potential
    • curvature penalty

\[
p(M|D) = \frac{p(D|M)p(M)}{p(D)}
\]
Optimization II

• Data fitting

• Consistency
  – between adjacent patches

• Curvature penalty
Segmentation I

• Invalid patches
  – data fitting is insufficient

• Patch segmentation
  – RANSAC (random sample consensus)
    • planes, spheres and cylinders

Segmentation II

- Patch subdivision
  - new coordinate systems
  - subset of assigned data points
- Topology graph update
Feature-/Border-Points

• Feature points
  – criterion: close disconnected patches
  – project patch centers to other patch

• Border points
  – later talk ...
Feature-/Border-Lines

- Estimate tangent direction (PCA)
- Assemble snakes
- Connect snakes with corners
- Smooth
Meshing

Mesh front growing

[J. Daniels, L. K. Ha, T. Ochotta, and C. T. Silva: *Robust smooth feature extraction from point clouds*, Proceedings Shape Modelling International (SMI ’07), 2007.]
Results

- Comparison to previous work


Results – Synthetic
Results – Scanner Data
### Results - Timings

<table>
<thead>
<tr>
<th>Model/ #points</th>
<th>Init #patches</th>
<th>Segment/ #patches</th>
<th>Optimization</th>
<th>Features</th>
<th>Triangulation</th>
</tr>
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<tbody>
<tr>
<td>carved o./20k</td>
<td>0.3s/156</td>
<td>3.8s/230</td>
<td>0.4s</td>
<td>0.1s</td>
<td>0.5s</td>
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<tr>
<td>block/100k</td>
<td>2.9s/604</td>
<td>22.2s/838</td>
<td>5.9s</td>
<td>1.6s</td>
<td>1.1s</td>
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<tr>
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<td>3.4s/1706</td>
<td>17.1s/1962</td>
<td>10.7s</td>
<td>2.5s</td>
<td>2.6s</td>
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<tr>
<td>ra/200k</td>
<td>8.0s/1619</td>
<td>30.6s/1849</td>
<td>8.5s</td>
<td>6.0s</td>
<td>4.1s</td>
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<td>elevator/120k</td>
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<td>52.8s/771</td>
<td>1.5s</td>
<td>6.3s</td>
<td>0.6s</td>
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[JWB*06]

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**Table 1:** Computation time and model complexity.
Conclusions/Future Work

• Extension of *Bayesian Point Cloud Reconstruction*
  – patches instead of surfels
  – patch graph connectivity
  – RANSAC for segmentation

• Improvements
  – adaptive patch size

Thank you for your attention!