3DMatch
Learning Local Geometric Descriptors from RGB-D Reconstructions
Andy Zeng, Shuran Song, Matthias Nießner, Matthew Fisher, Jianxiong Xiao, Thomas Funkhouser
Matching Features in 3D Data with Local 3D Descriptors
Matching Features in 3D Data with Local 3D Descriptors

- Scan registration and loop closures for 3D reconstruction
- Model registration for pose estimation
- 3D mesh correspondence
Matching Local Features in 3D Scans is Hard

Partial Surfaces and Occlusion

Sensor Limitations

Point Density Changes

Other Anomalies
Matching Local Features in 3D Scans is Hard

Previous local 3D descriptors only address part of the problem.

Partial Surfaces and Occlusion
Sensor Limitations
Point Density Changes
Other Anomalies

FPFH [Rusu et al.]
Spin-Images [Johnson et al.]
SHOT [Salti et al.]

**Goal:** train a **data-driven local 3D descriptor** that learns from example correspondences on real 3D scans.
3DMatch: Data-Driven Local 3D Descriptor

3DMatch
3D ConvNet

match!

TDF

3D patch

TDF
3DMatch: Data-Driven Local 3D Descriptor

- contrastive $L_2$ loss
- descriptor
  - conv (3$^3$,512)
  - conv (3$^3$,512)
  - conv (3$^3$,256)
  - conv (3$^3$,256)
  - conv (3$^3$,128)
  - conv (3$^3$,128)
  - pool (2$^3$,64)
  - pool (2$^3$,64)
  - conv (3$^3$,64)
  - conv (3$^3$,64)
  - 30$^3$ patch
  - 30$^3$ patch

matches
non-matches
Training Data?

Problem: how do we get the training data?

- Manually label correspondences?
  - time consuming
  - prone to errors

Extremely Challenging
- Partial Surfaces and Occlusion
- Sensor Limitations
- Point Density Changes
- Other Anomalies

Is there a way to obtain training data automatically?
Self-Supervised Learning from RGB-D Reconstructions

frame #4903

long-range correspondence

frame #7459
Self-Supervised Learning from RGB-D Reconstructions

50+ RGB-D reconstructions

> 8 million correspondences

3 applications
Application #1: 3D Reconstruction
Application #1: 3D Reconstruction

3DMatch + RANSAC

geometric registration
Application #1: 3D Reconstruction

3DMatch + RANSAC

<table>
<thead>
<tr>
<th>Method</th>
<th>Error</th>
<th>Recall (%)</th>
<th>Precision (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson et al. (Spin-Images) [18]</td>
<td>85.7</td>
<td>3.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Rusu et al. (FFFH) [27]</td>
<td>61.3</td>
<td>17.8</td>
<td>10.4</td>
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<tr>
<td>2D ConvNet on Depth</td>
<td>38.5</td>
<td>44.9</td>
<td>14.0</td>
</tr>
<tr>
<td>Ours (3DMatch)</td>
<td>28.5</td>
<td>59.2</td>
<td>19.6</td>
</tr>
<tr>
<td>Zhou et al. [42]</td>
<td>51.1</td>
<td>51.1</td>
<td>23.2</td>
</tr>
<tr>
<td>Rusu et al. [27] + RANSAC</td>
<td>46.1</td>
<td>52.0</td>
<td>21.1</td>
</tr>
<tr>
<td>Johnson et al. [18] + RANSAC</td>
<td></td>
<td>65.1</td>
<td>25.2</td>
</tr>
<tr>
<td>Ours + RANSAC</td>
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</tbody>
</table>
Application #1: 3D Reconstruction

generalization requirement: low

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Choi <em>et al.</em> + FPFH</th>
<th>Choi <em>et al.</em> + 3DMatch</th>
</tr>
</thead>
<tbody>
<tr>
<td>fr1/desk</td>
<td>13.27</td>
<td>5.54</td>
</tr>
<tr>
<td>fr3/office</td>
<td>9.89</td>
<td>2.80</td>
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</tbody>
</table>

Table 2. **ATE RMSE** (cm) on the TUM SLAM benchmark.
Application #2: 6D Object Pose Estimation

<table>
<thead>
<tr>
<th>Method</th>
<th>Rotation (%)</th>
<th>Translation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline [44]</td>
<td>49.0</td>
<td>67.6</td>
</tr>
<tr>
<td>Johnson et al. [19] + RANSAC</td>
<td>45.5</td>
<td>65.9</td>
</tr>
<tr>
<td>Rusu et al. [28] + RANSAC</td>
<td>43.5</td>
<td>65.6</td>
</tr>
<tr>
<td>Ours (no pretrain) + RANSAC</td>
<td>53.8</td>
<td>69.1</td>
</tr>
<tr>
<td>Ours + RANSAC</td>
<td>61.0</td>
<td>71.7</td>
</tr>
</tbody>
</table>
Application #3: Mesh Correspondences
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Takeaways

3DMatch: Data-Driven Local 3D Descriptor

RGB-D Reconstructions as Training Data

Code & Benchmarks:
http://3dmatch.cs.princeton.edu
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