Unstructured Point Cloud
Segmentation and Classification

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2D to 3D

- Human vision
  - Stereo-vision, spatial info…
- Neural network
  - MLP, CNN, GCN…
- Devices
  - Depth camera, Lidar…
- Dataset
  - ShapeNet, ScanNet, S3DIS…

Point cloud
Point Cloud Processing

- Registration
- Primitive detection
- Volumetric
- Unordered point set
- Views
- Reconstruction
- Encoder
- Handcrafted features
- Point cloud
PointNet [1]

• Model has to be invariant to input permutation
  • Sort input into a canonical order
  • RNN with all kinds of permutation
  • Simple symmetric function

• Symmetric function
  • Attention sum
  • Average pooling
  • Max pooling

<table>
<thead>
<tr>
<th></th>
<th>accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLP (unsorted input)</td>
<td>24.2</td>
</tr>
<tr>
<td>MLP (sorted input)</td>
<td>45.0</td>
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<tr>
<td>LSTM</td>
<td>78.5</td>
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<tr>
<td>Attention sum</td>
<td>83.0</td>
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<tr>
<td>Average pooling</td>
<td>83.8</td>
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<tr>
<td>Max pooling</td>
<td><strong>87.1</strong></td>
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</table>
PointNet

Classification Network

Segmentation Network
PointNet Implementation

- Split dataset by rooms
- Sample rooms into blocks with area 1m x 1m
- 4096 points in each block
- 9-dim vector (xyz-rgb-normal)

<table>
<thead>
<tr>
<th></th>
<th>OA</th>
<th>mIoU</th>
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<tbody>
<tr>
<td>PointNet</td>
<td>78.62</td>
<td>47.71</td>
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PointNet Visualization

- Critical points
- Upper-bound shapes

- Network learns to summarize a shape by a sparse set of key points
- Key points lie near edges
Unorder Point Set

- Point-based
  - Neighborhood
  - RNN
  - Kernel
- Graph-based
  - GCN
- CNN
3D Recurrent Neural Networks with Context Fusion for Point Cloud Semantic Segmentation [2]

- Vicinity
  - Pointwise pyramid pooling
- Larger neighborhood
  - RNN
Attentional ShapeContextNet for Point Cloud Recognition [3]

- Vicinity
  - Shape context kernel
Large-scale Point Cloud Semantic Segmentation with Superpoint Graphs [4]

- Vicinity
  - Patch (PointNet)
- Larger neighborhood
  - Graph

- Linearity
- Planarity & scattering
- verticality
PointCNN: Convolution On X-Transformed Points [5]

• Vicinity
  • k-NN

- Similarity matrix
- Confidence map
Observation

• Partition the space
  • Pre-defined
  • Data driven

• Local & global features

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<tr>
<td>PointCNN</td>
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<td>65.39</td>
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<tr>
<td>SPG</td>
<td>85.50</td>
<td>62.10</td>
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<tr>
<td>3DRNN</td>
<td>86.90</td>
<td>56.30</td>
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<tr>
<td>SGPN</td>
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<td>54.35</td>
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<tr>
<td>A-SCN</td>
<td>81.59</td>
<td>52.72</td>
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Problem Definition

Point cloud $\xrightarrow{}$ BIM (building information modeling)

ceiling floor wall beam column window door table chair sofa bookcase board clutter

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Inspiration

• Geometry vs color
  • Uniform color but complex geometry
  • Complicated color but simple geometry

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<thead>
<tr>
<th>Feature name</th>
<th>Size</th>
<th>Description</th>
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<tbody>
<tr>
<td>mean offset</td>
<td>3</td>
<td>$\text{mean}_{m \in \delta(S,T)} \delta_m$</td>
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<tr>
<td>offset deviation</td>
<td>3</td>
<td>$\text{std}_{m \in \delta(S,T)} \delta_m$</td>
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<tr>
<td>centroid offset</td>
<td>3</td>
<td>$\text{mean}<em>{i \in S} p_i - \text{mean}</em>{j \in T} p_j$</td>
</tr>
<tr>
<td>length ratio</td>
<td>1</td>
<td>$\log \text{length}(S) / \text{length}(T)$</td>
</tr>
<tr>
<td>surface ratio</td>
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<td>$\log \text{surface}(S) / \text{surface}(T)$</td>
</tr>
<tr>
<td>volume ratio</td>
<td>1</td>
<td>$\log \text{volume}(S) / \text{volume}(T)$</td>
</tr>
<tr>
<td>point count ratio</td>
<td>1</td>
<td>$\log</td>
</tr>
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• Geometric proposal
• Color proposal

Superpoint  Superedge  Graph
Thank you


