Deep Learning on
3D Point Clouds

Deep Learning in Remote Sensing

Episode-4

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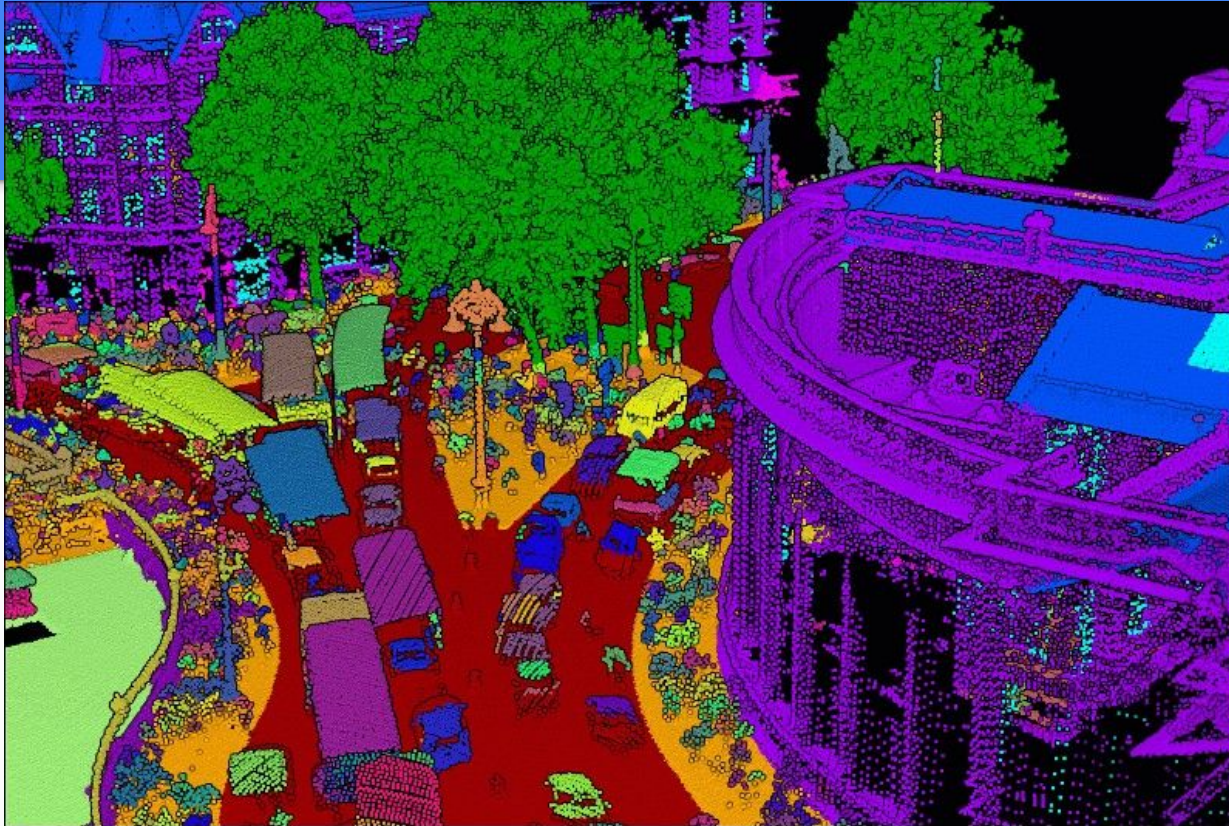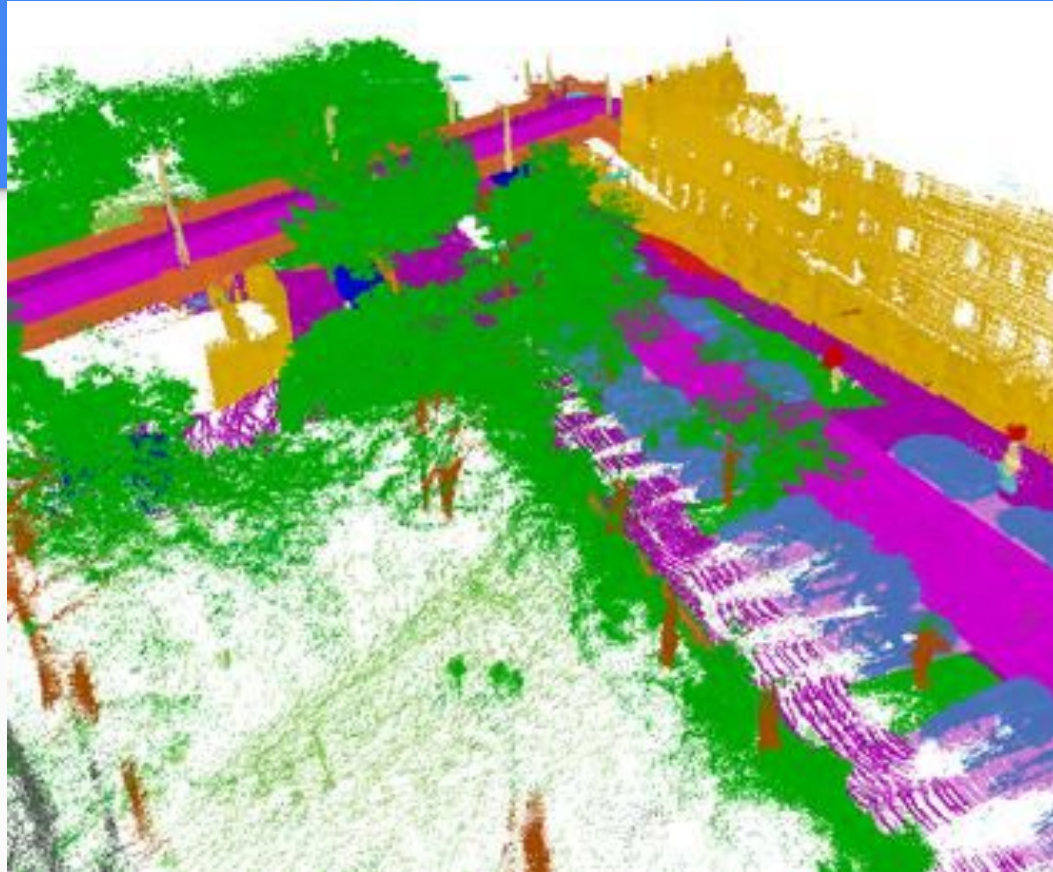iremkomurcubm@gmail.com

Capturing a 3D World
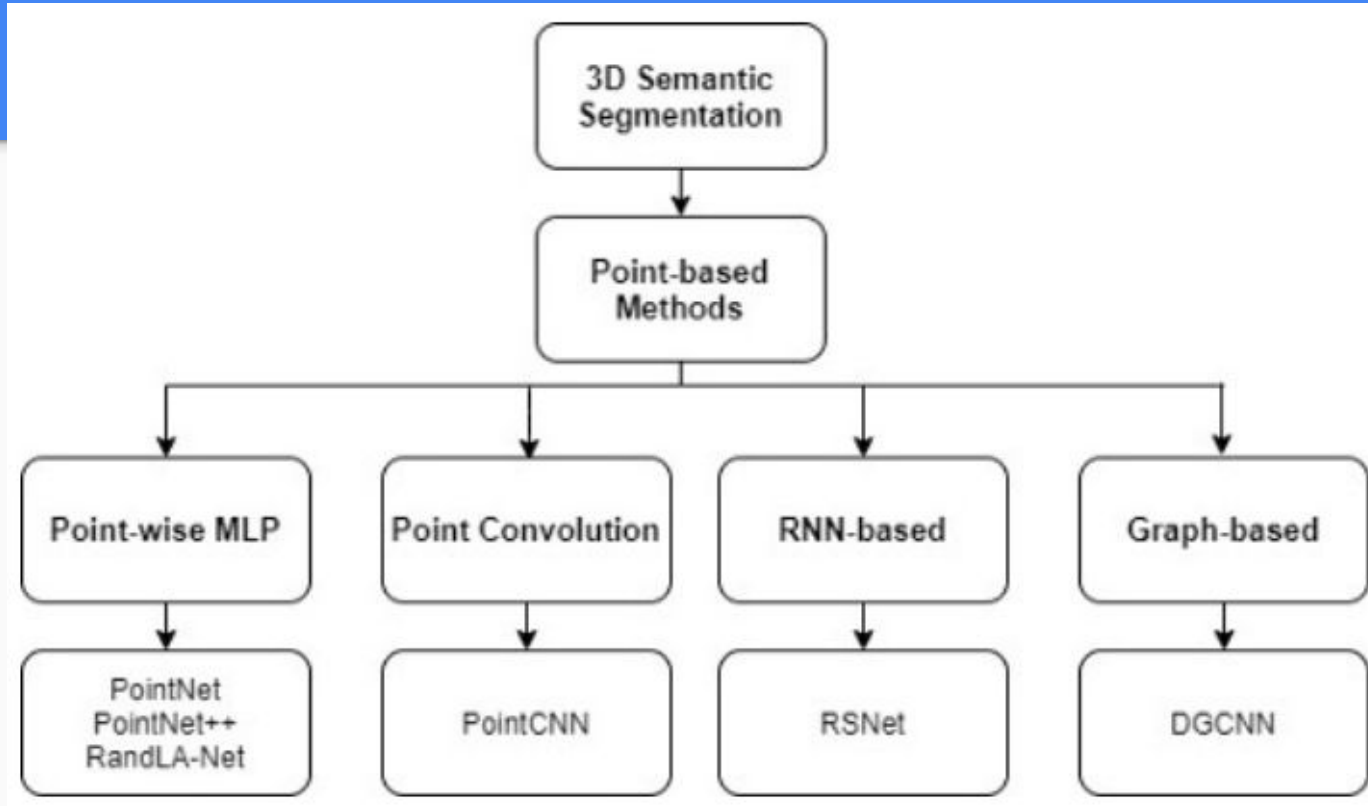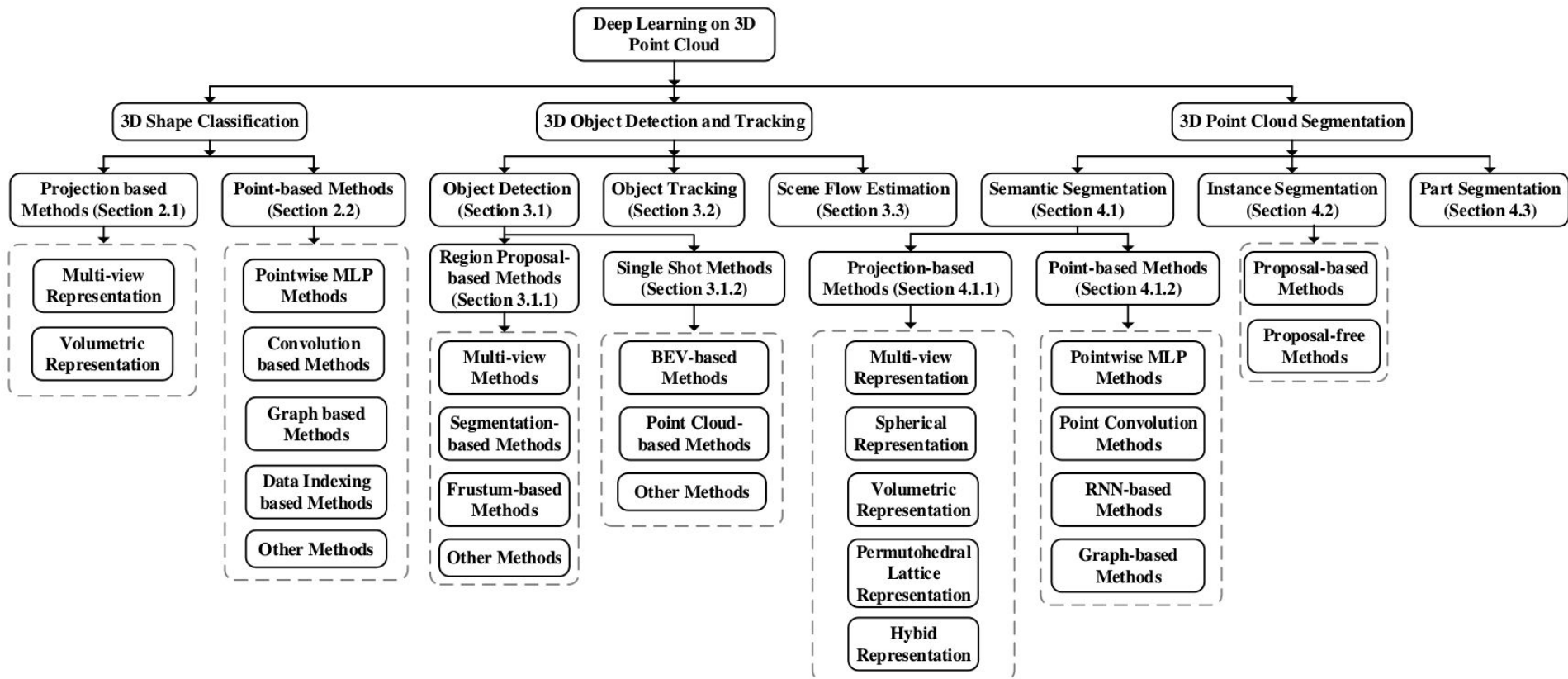

Image source: Florent Poux,
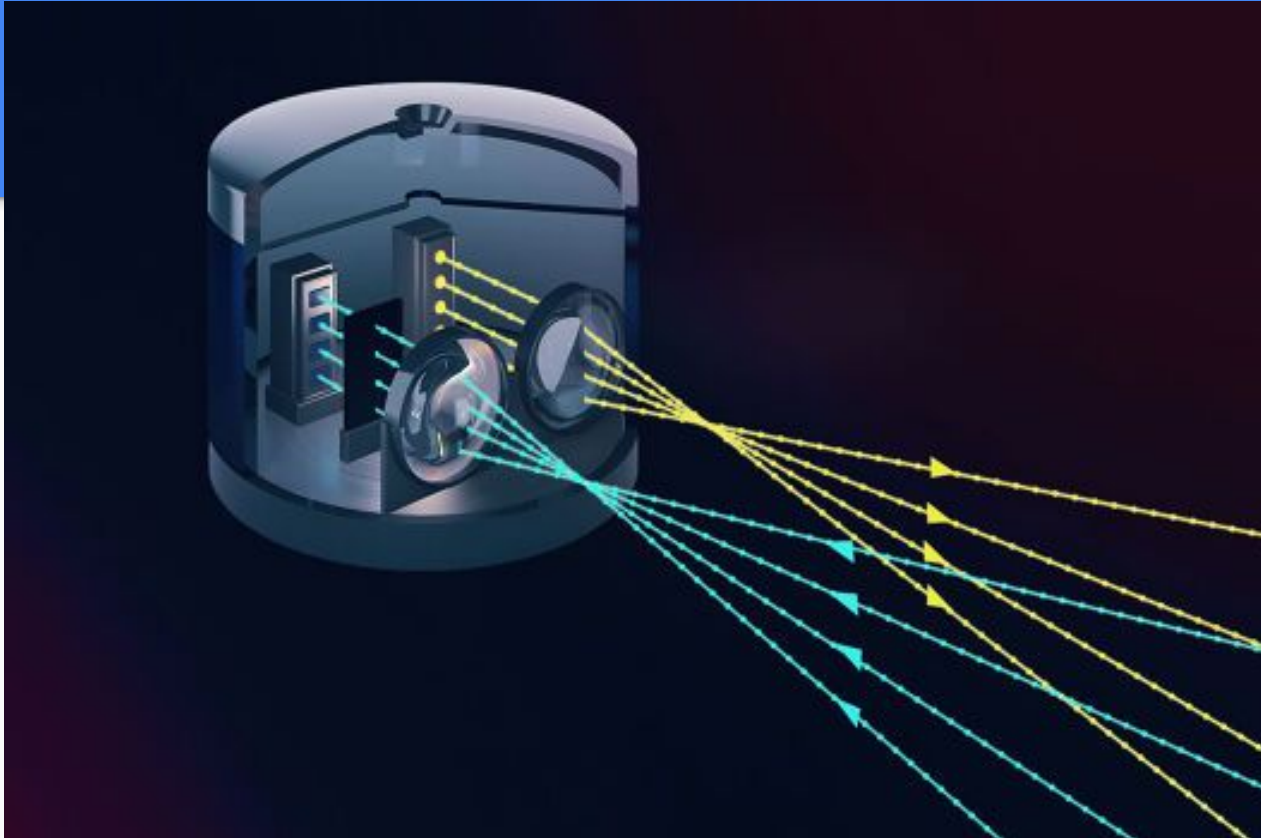Medium, Towards Data Source

Capturing a 3D World

Paperswithcode, 3D Semantic Segmentation

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3D Problems and Deep Learning Techniques

Source: Medium, Rucha Apte, 3D Point Cloud Semantic Segmentation Using Deep Learning Techniques

Deep Learning on 3D Point Cloud

- **3D Shape Classification**
  - **Projection based Methods (Section 2.1)**
    - Multi-view Representation
    - Volumetric Representation
  - **Point-based Methods (Section 2.2)**
    - Pointwise MLP Methods
    - Convolution based Methods
    - Graph based Methods
    - Data Indexing based Methods
    - Other Methods

- **3D Object Detection and Tracking**
  - **Object Detection (Section 3.1)**
    - **Region Proposal-based Methods (Section 3.1.1)**
      - Multi-view Methods
      - Segmentation-based Methods
      - Frustum-based Methods
      - Other Methods
    - **Single Shot Methods (Section 3.1.2)**
      - BEV-based Methods
      - Point Cloud-based Methods
      - Other Methods
  - **Object Tracking (Section 3.2)**
  - **Scene Flow Estimation (Section 3.3)**

- **3D Point Cloud Segmentation**
  - **Semantic Segmentation (Section 4.1)**
    - **Projection-based Methods (Section 4.1.1)**
      - Multi-view Representation
      - Spherical Representation
      - Volumetric Representation
      - Permutohedral Lattice Representation
      - Hybrid Representation
    - **Point-based Methods (Section 4.1.2)**
      - Pointwise MLP Methods
      - Point Convolution Methods
      - RNN-based Methods
      - Graph-based Methods
  - **Instance Segmentation (Section 4.2)**
    - Proposal-based Methods
    - Proposal-free Methods
  - **Part Segmentation (Section 4.3)**

LiDAR

3D Cloud Point

2D image

3D model

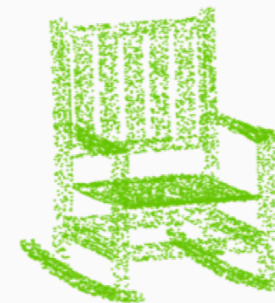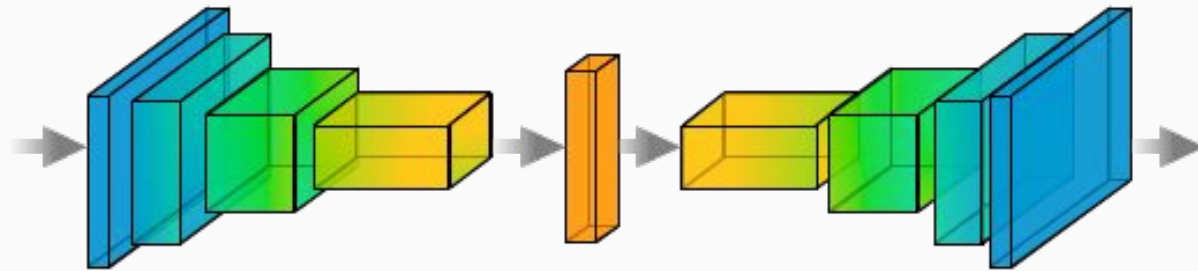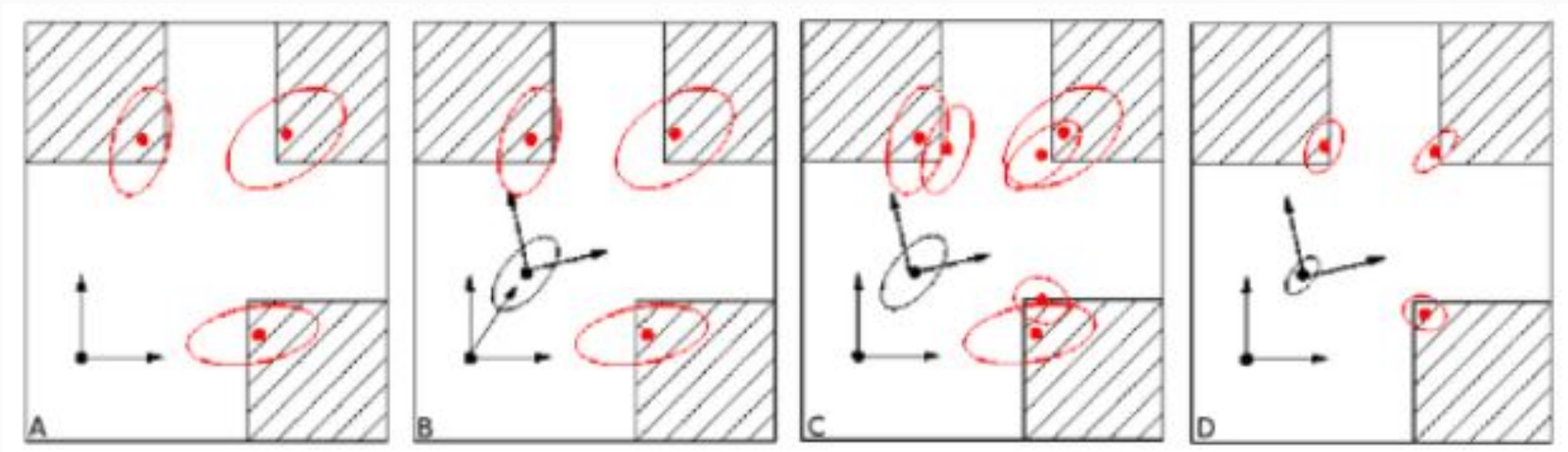| 1 | 44 | 33 | 12 | 20 | 23 | 35 | 14 |
51	16	40	32	46	48	28	17
29	60	3	63	49	55	36	7
52	22	26	41	38	10	61	53
2	24	19	11	34	43	5	8
57	9	37	42	25	21	27	18
30	56	50	64	4	59	6	13
58	47	45	31	39	15	62	54

Pixel
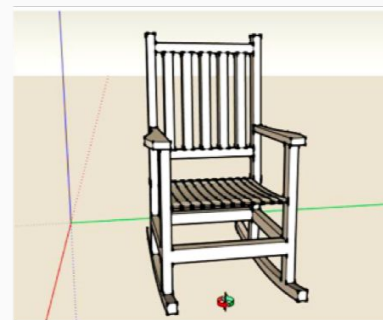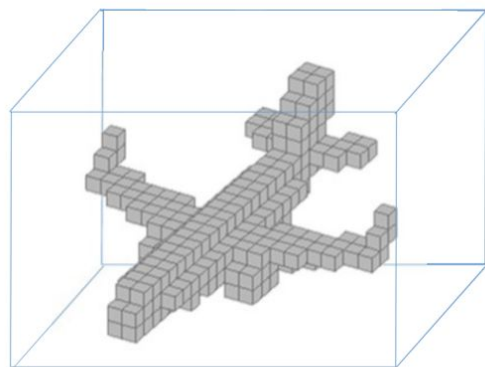
Polygonal mesh
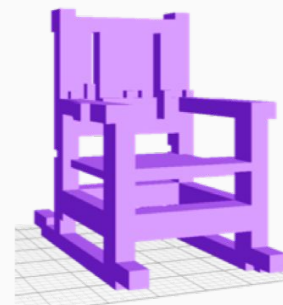
Voxel (volumetric pixel)

Point cloud

Shape embedding

Image source: Medium, Create 3D Model
from a Single 2D image in Pytorch, Phúc Lê
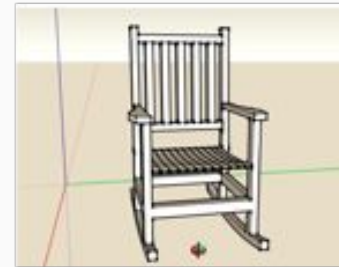
Can be computed from images: stereo, SfM, SLAM

Simultaneous localization and mapping(SLAM)

Medium, Sadık Kaplan

Deep Learning on 3D Point
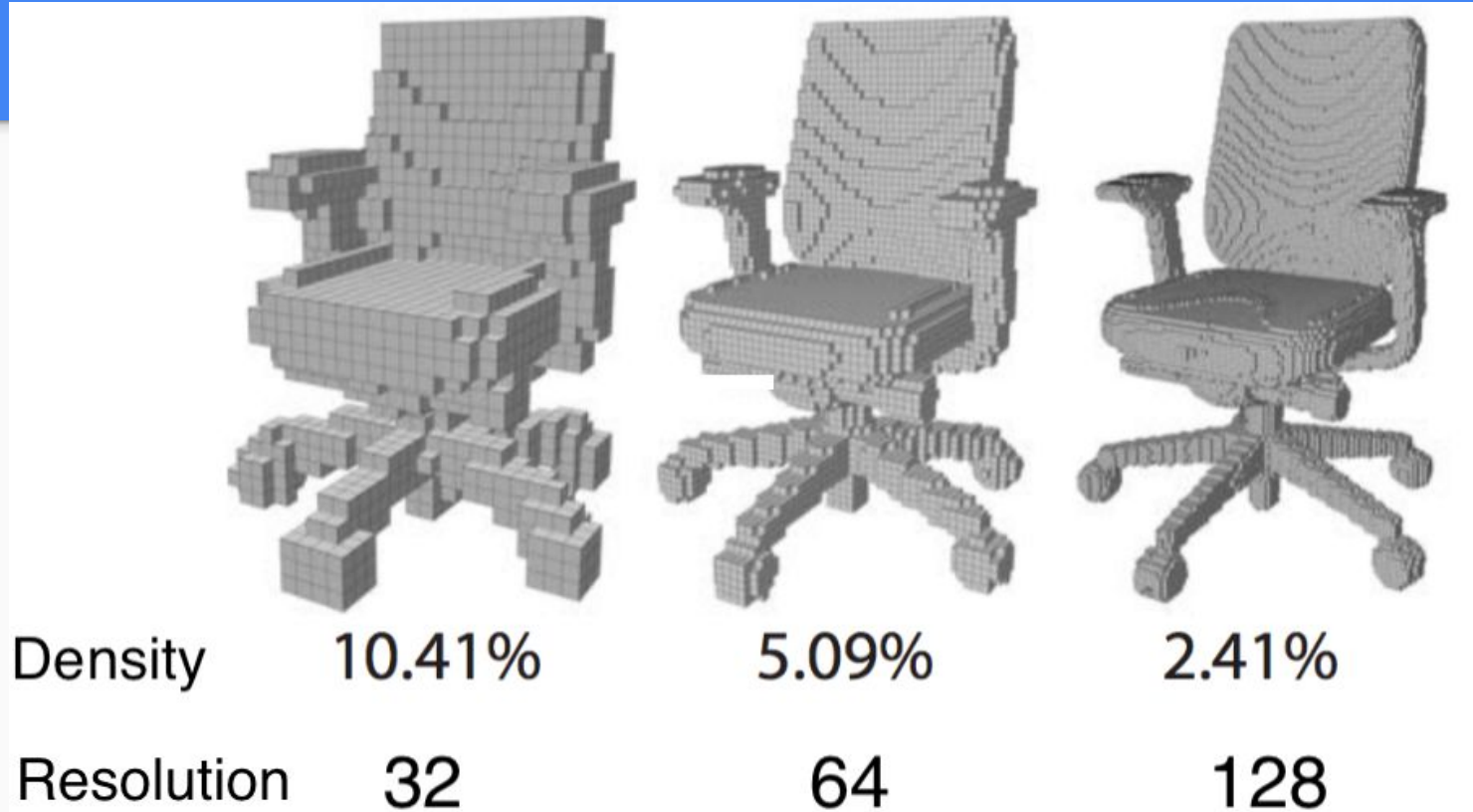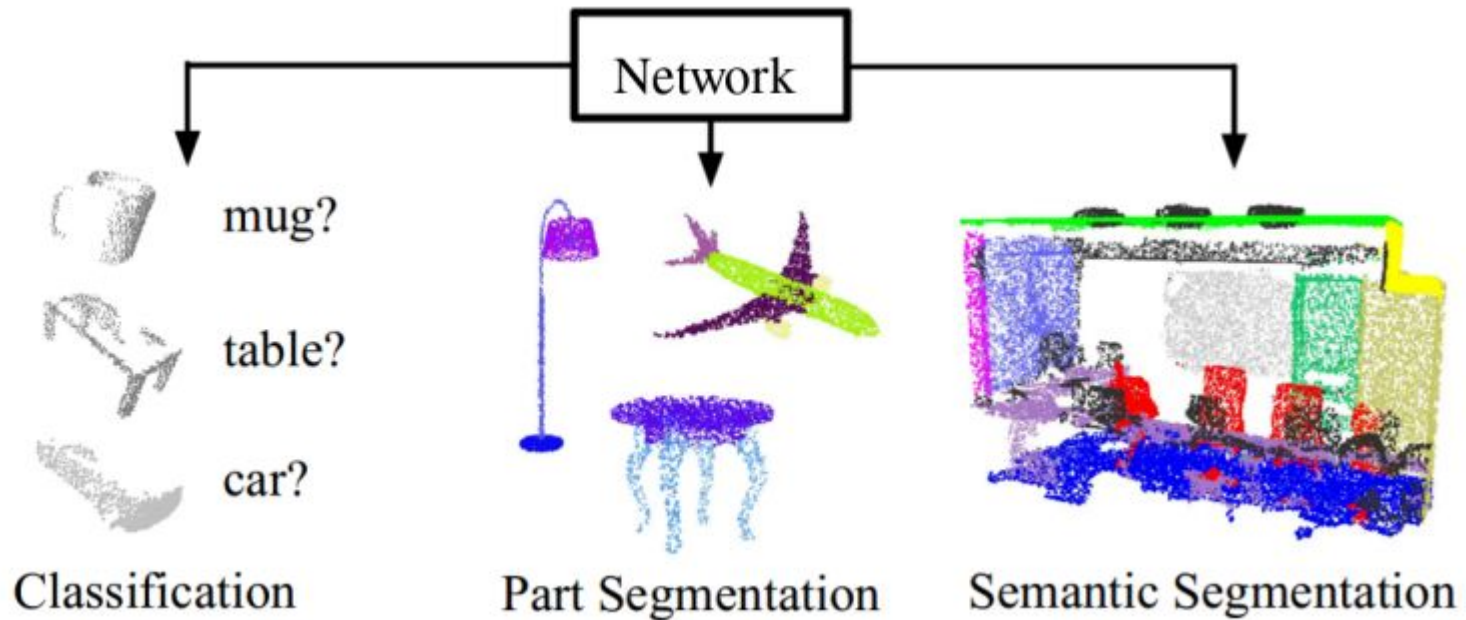
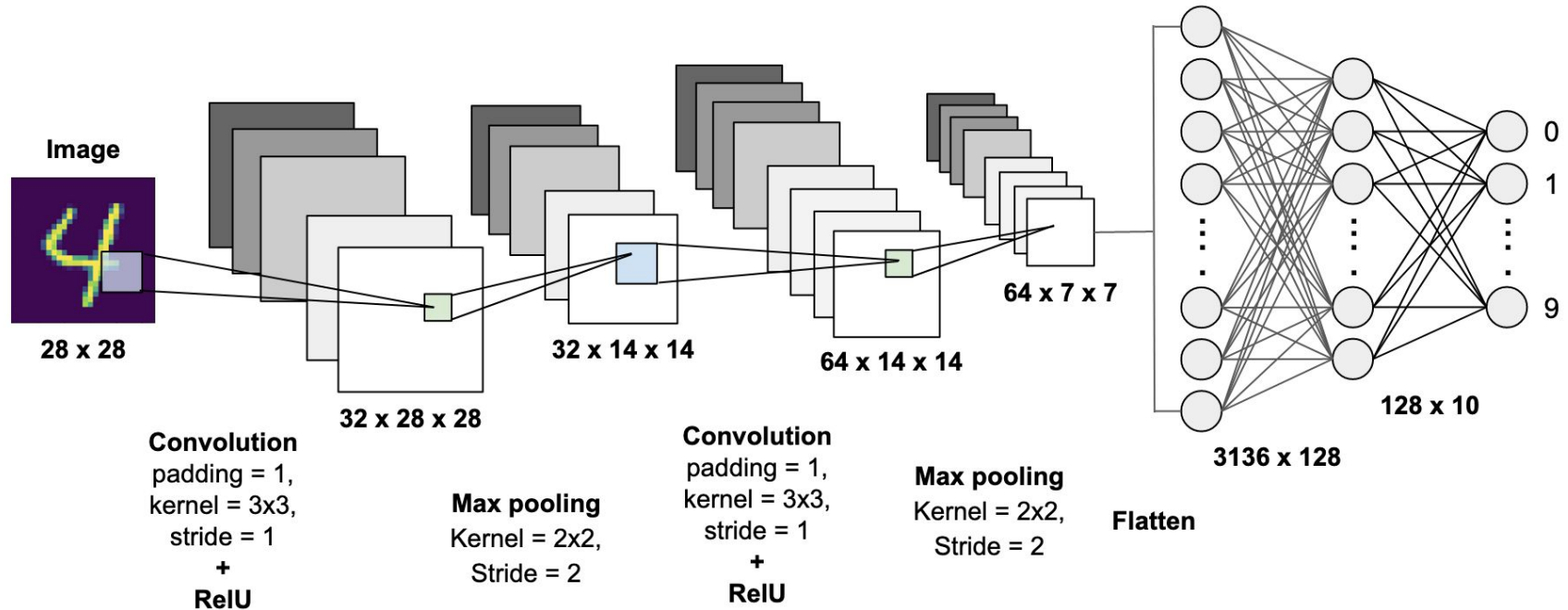Idea and generalization: 2D is important for 3D

Voxel, Density and Resolution

| Density | 10.41% | 5.09% | 2.41% |
| Resolution | 32 | 64 | 128 |

Classification

Classification   Part Segmentation   Semantic Segmentation
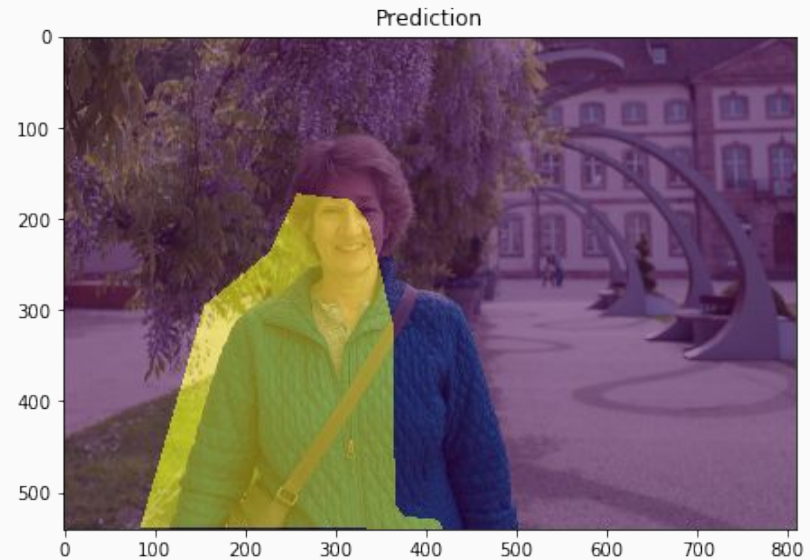
Example CNN

Source: Medium, becominghuman.ai , Shreyak

CNN and 3D

```
# point cloud1 and point cloud2 represent the same 3D structure
# even though they are represented differently in memory
```
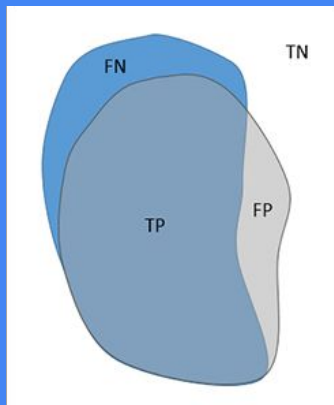
```
point cloud1 = [(x1, y1, z1), (x2, y2, z2),..., (xn, yn, zn)
point_cloud2 = [(x2, y2, z2), (x1, y1, z1),..., (xn, yn, zn)
```

```
2D projection == 3D coordinates (x,y,z) + binary mask (m)
```

Image source: Medium, Create 3D Model from a Single 2D image in Pytorch, Phúc Lê

Performance Measures
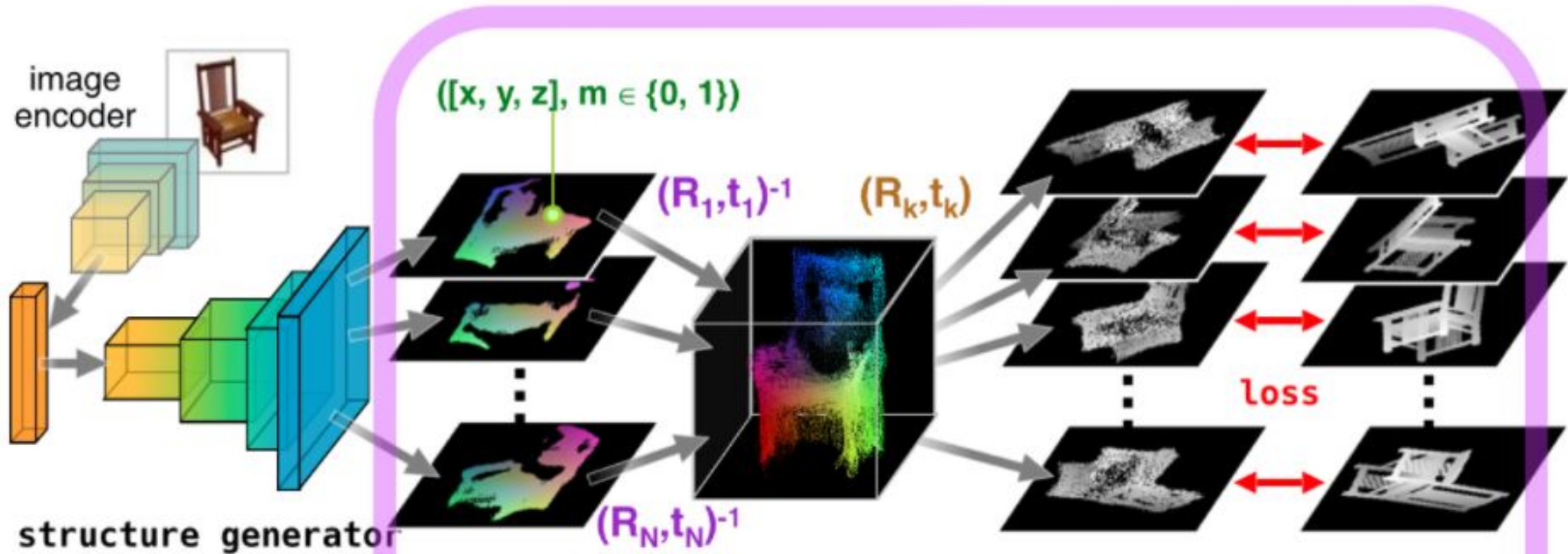
Ground Truth

Prediction

Actual = Yes | Actual = No

Predicted = Yes: TP | FP

Predicted = No: FN | TN

FN

TN

TP

FP

Some Performance Measures

$$PA = \frac{TP}{N}$$

$$MPA = \frac{\sum_{i=1}^{k} \frac{TP_i}{FP_i + TP_i}}{k}$$

$$IoU_i = \frac{TP_i}{FP_i + FN_i + TP_i}$$

Public Datasets

3D Shape Classification

- ModelNet (CVPR'15)
  - ModelNet10
  - ModelNet40
- PartNet (CVPR'19)
- ScanObjectNN

3D Object Detection

- KITTI (CVPR'12)
  - *3D objecct detection*
  - *BEV*
- ApolloScape (TPAMI'19)
- Argoverse (CVPR'19)
- A*3D (arXiv'19)
- Waymo (arXiv'19)

Public Datasets

3D Point Cloud Segmentation

- Semantic3D (ISPRS'17)
  - *semantic-8*
  - *reduced-8*
- S3DIS (CVPR'17)
- ScanNet (CVPR'17)
- NPM3D (IJRR'18)
- DublinCity (BMVC'19)
- SemanticKITTI (ICCV'19)
- nuScenes (CVPR'20)
- Toronto-3D (CVPRW'20)
- DALES (CVPRW'20)
- Campus3D (ACM MM'20)
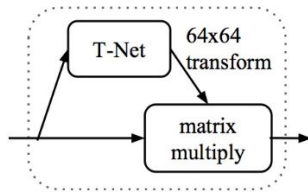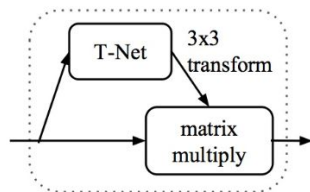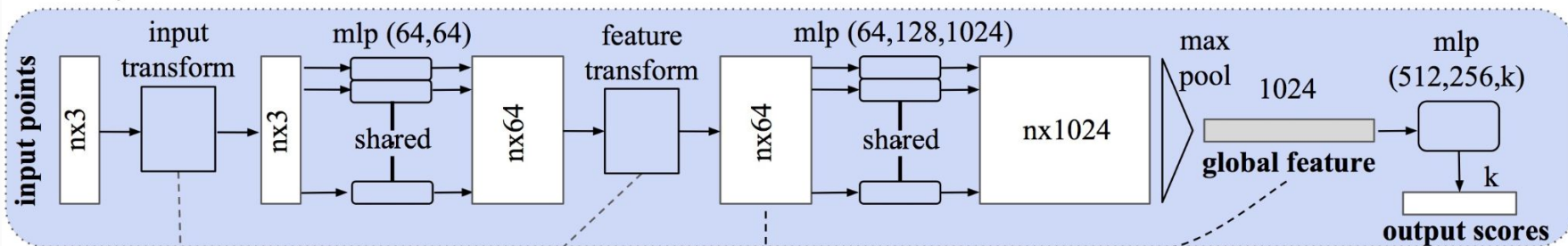- SensatUrban (CVPR'21)

Classification   Part Segmentation   Semantic Segmentation

Effective Neural Network for Point Cloud
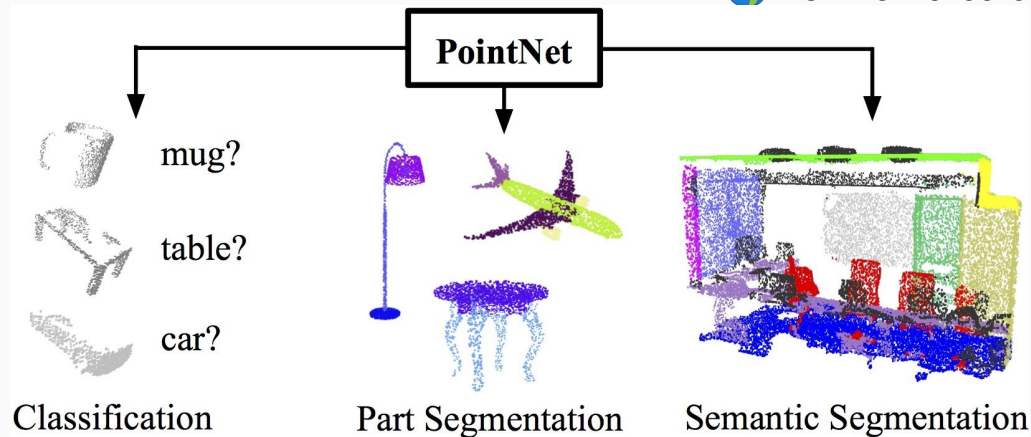
- PointNet
- PointNet++
- RandLA-Net
- PointCNN

PointNet

http://stanford.edu/~rqi/pointnet/

Semantic Segmentation

http://stanford.edu/~rqi/pointnet/

Original Shape

Critical Point Sets

Upper-bound Shapes
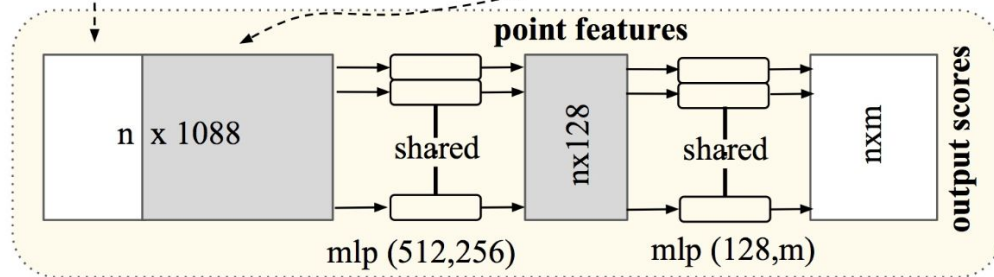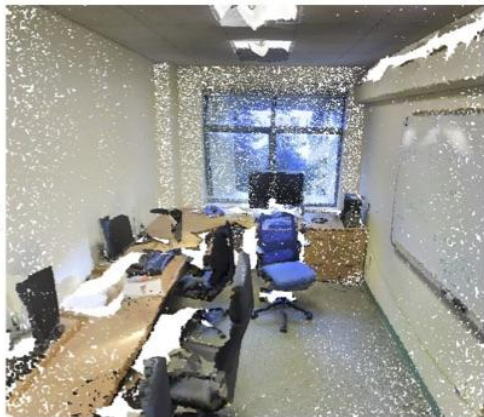
http://stanford.edu/~rqi/pointnet/
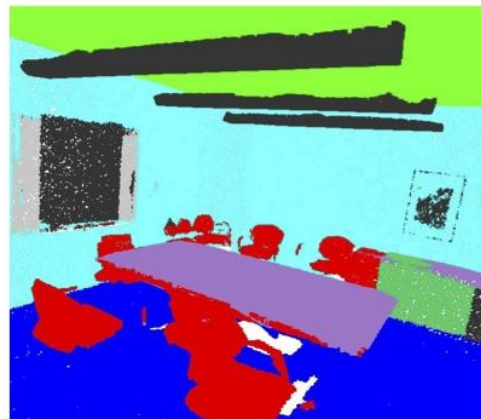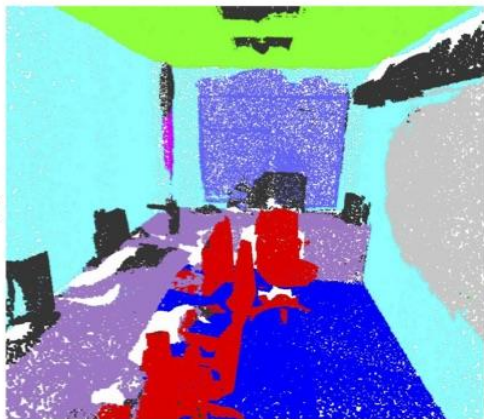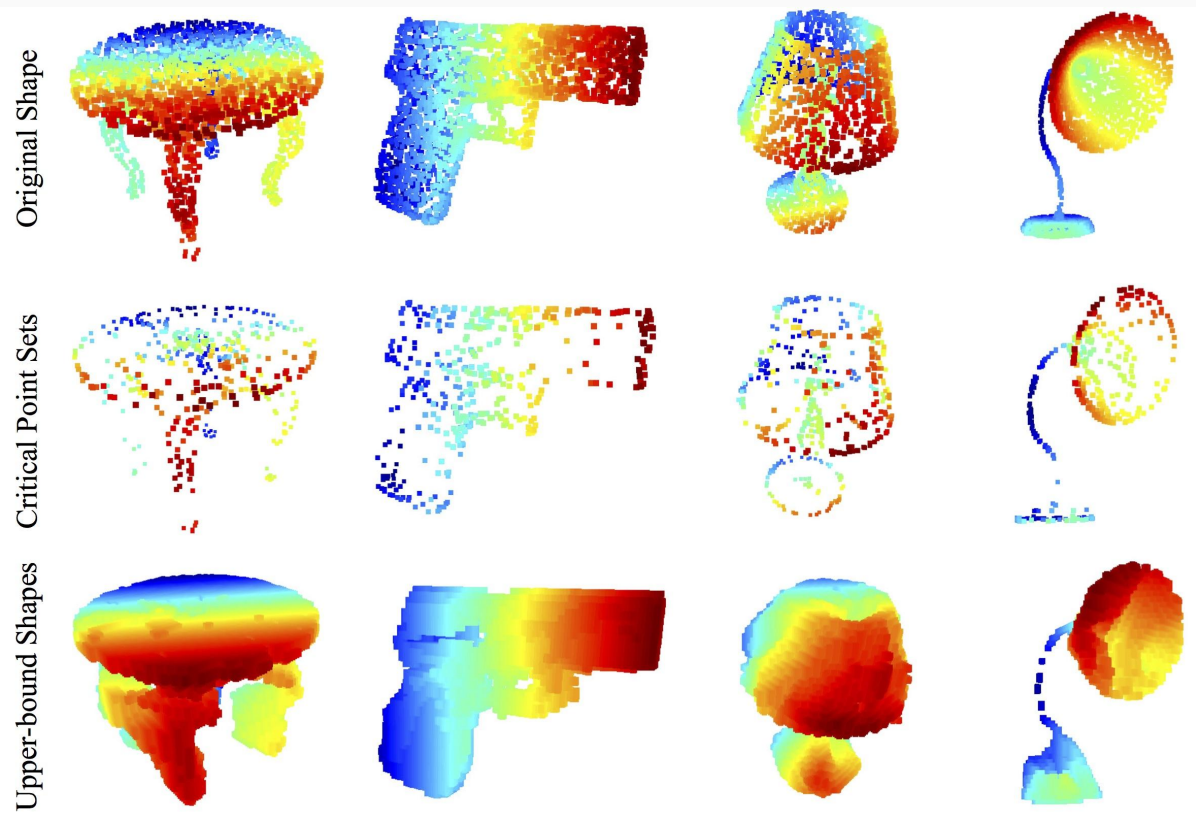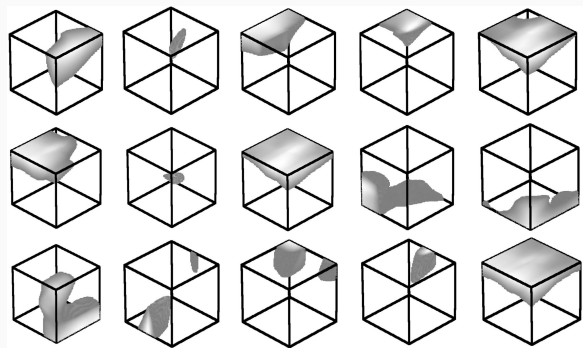
Video

If you want to watch the presentation please visit the video

https://www.youtube.com/watch?v=Fr11bsdCAvg&t=16s&ab_channel=UHUZAMCSCRS

THANKS

Does anyone have any questions?

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