3D Deep Learning

Tutorial@CVPR2017

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July 26, 2017

Schedule

- Opening remark 1:30PM-1:40PM
- Deep learning on regular data (MVCNN&3DCNN) 1:40PM-2:45PM
- Break 2:45PM-3:00PM
- Deep learning on point cloud and primitives 3:00PM-4:15PM
- Break 4:15PM-4:30PM
- Deep learning on meshes (Intrinsic CNN) 4:30PM-5:45PM

Outline

Overview of 3D deep learning

3D deep learning algorithms

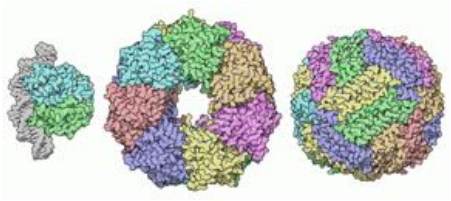
Outline

Overview of 3D deep learning

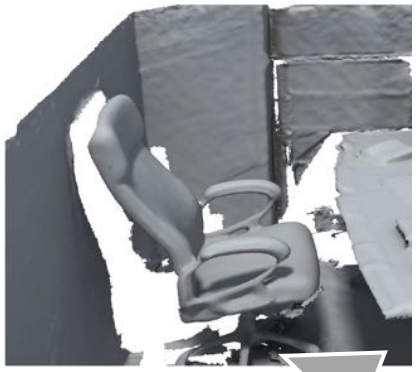
- Background
- 3D deep learning tasks

3D deep learning algorithms

The world around us is comprised of 3D geometry

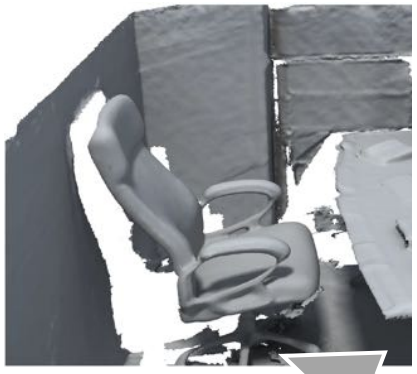


Broad applications of 3D data

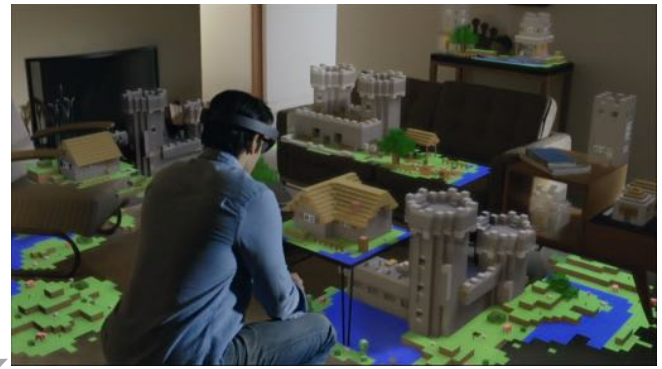


Robotics

Broad applications of 3D data

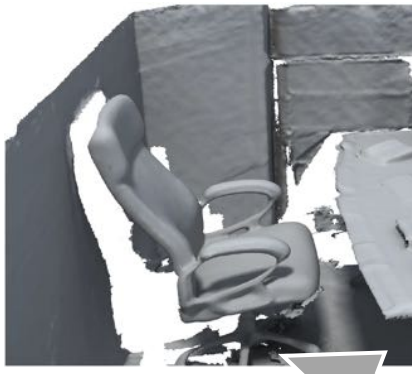


Robotics

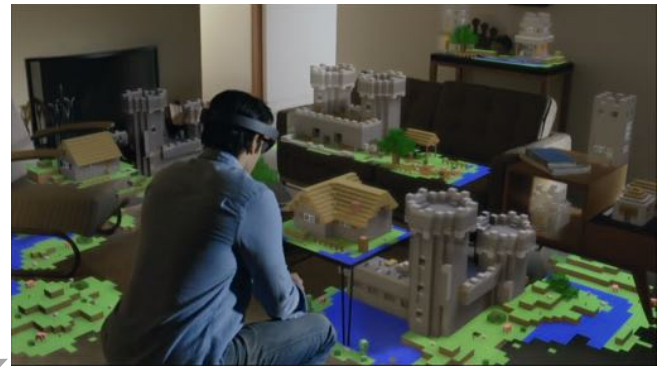


Augmented Reality

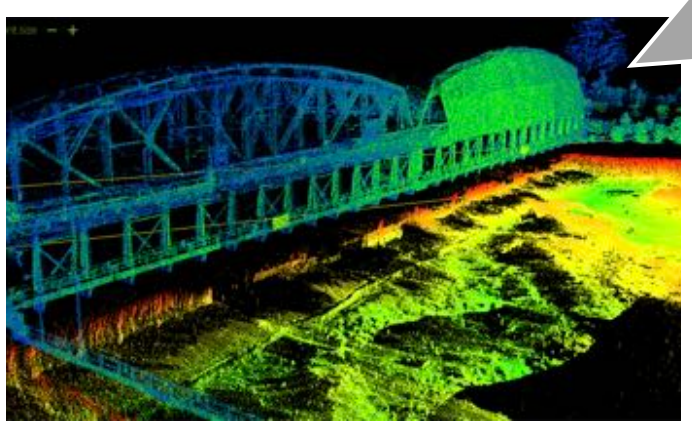
Broad applications of 3D data



Robotics



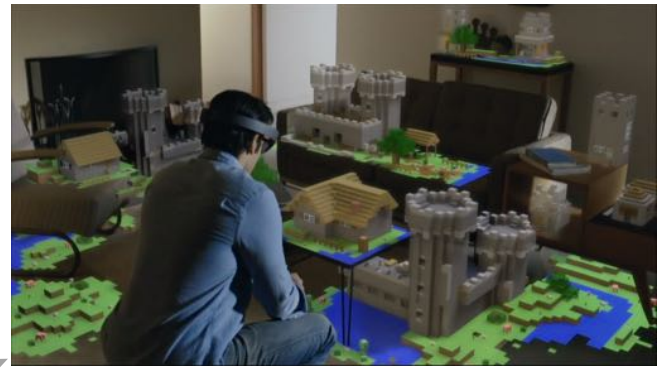
Augmented Reality



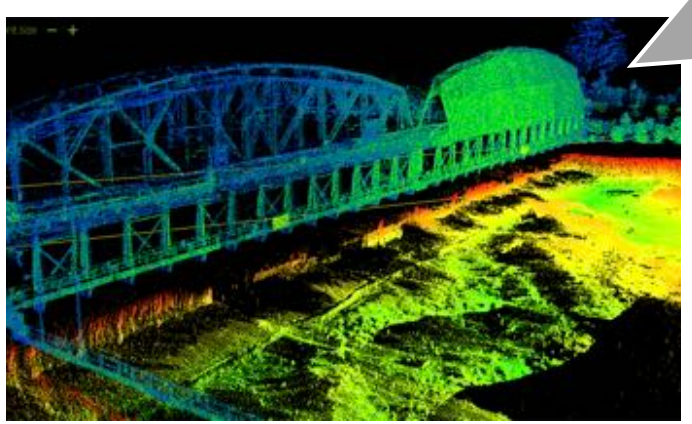
Autonomous driving

Broad applications of 3D data

Robotics



Augmented Reality



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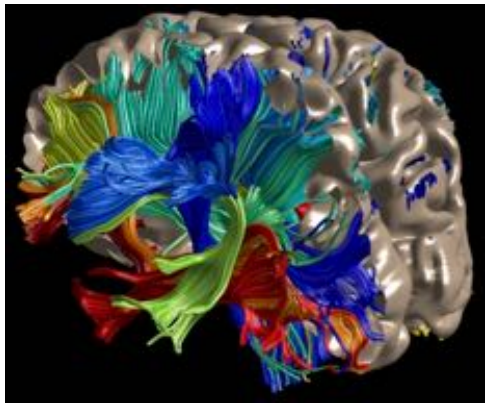
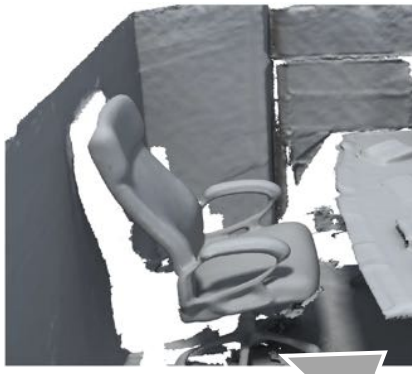
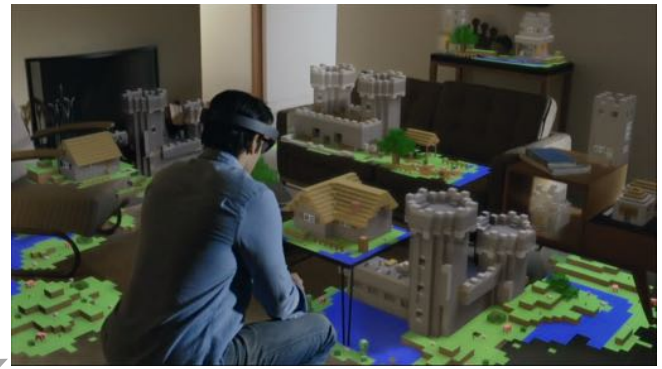


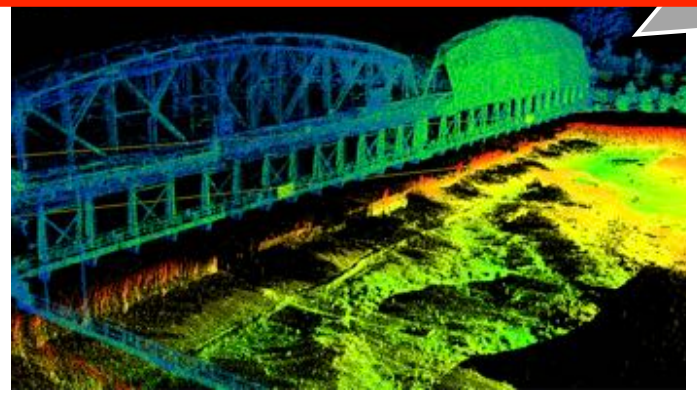
Medical Image Processing

Broad applications of 3D data

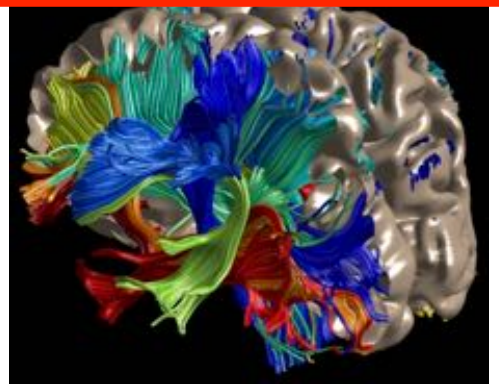




Historically, most 3D visual computing techniques focus on single models, lacking robustness



Autonomous driving



Medical Image Processing

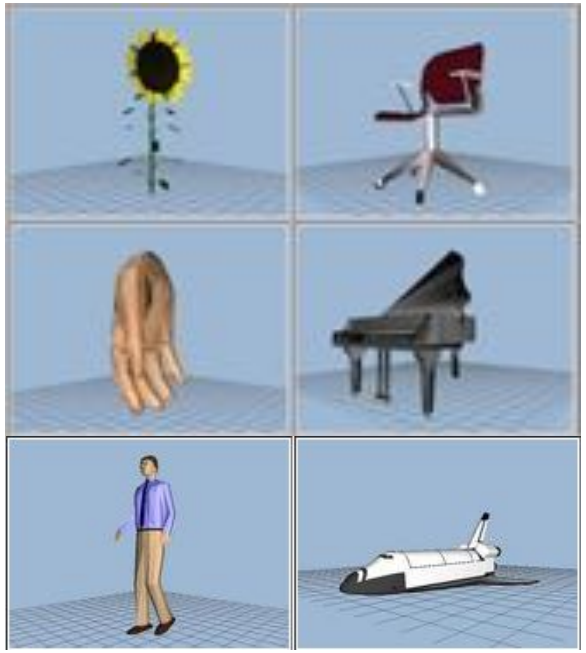
Lacking 3D data has been the major bottleneck

Status as of 2010:

Stanford bunny

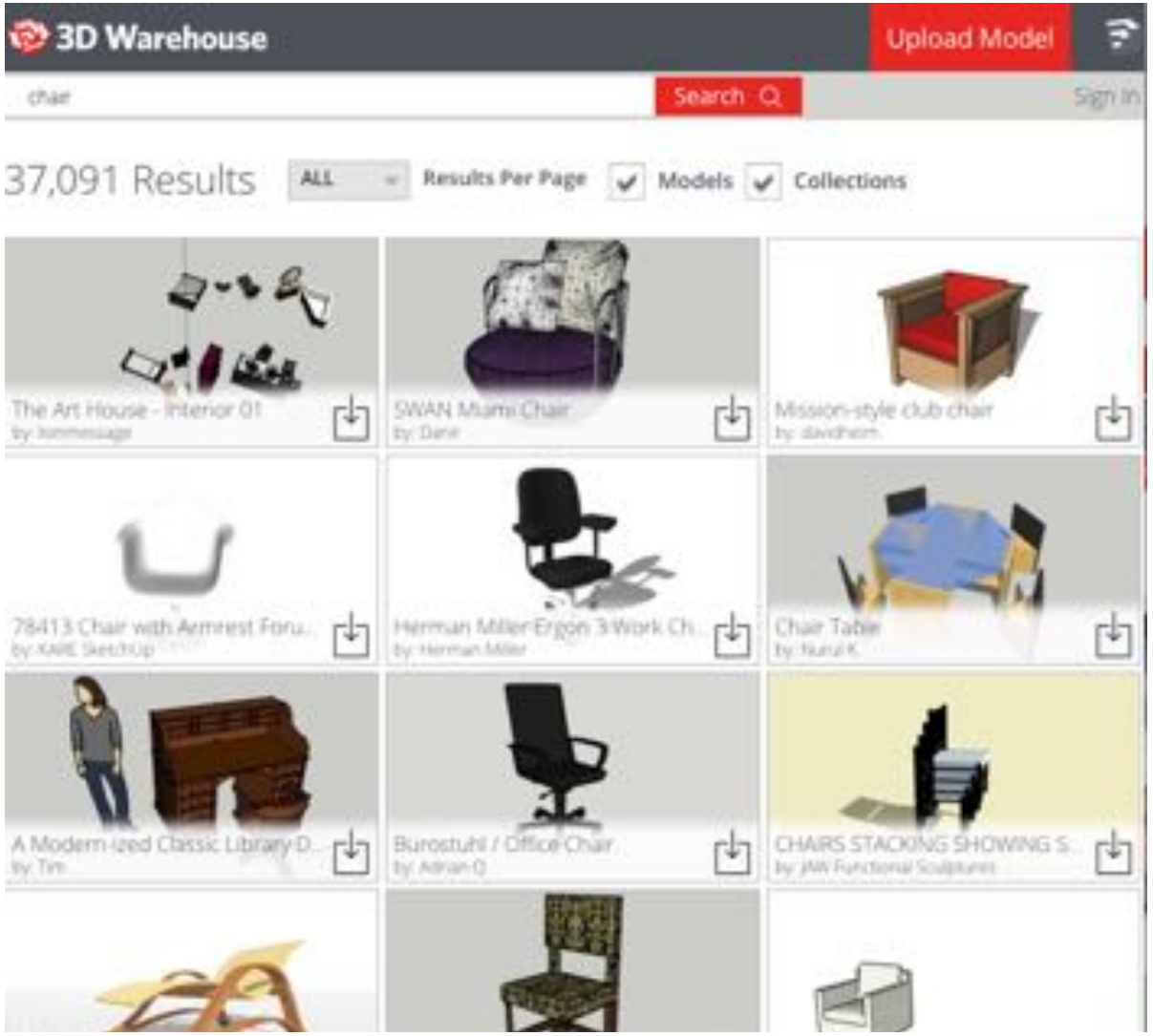
Utah teapot

1800 models in **90** categories



Princeton shape benchmark
[Shilane et al. 04]

Recent rise of Internet 3D models



Nowadays millions of 3D models in online repositories

Recent rise of Internet 3D models

Growing market of crowd-sourcing for 3D modeling

yobi3D

Clara.io

Google SketchUp

Sketchfab

TINKERCAD

.....

Nowadays millions of 3D models in online repositories

Recent rise of Internet 3D models

Growing market of crowd-sourcing for 3D modeling

Clara.io

fab

An opportunity of Data-driven 3D Visual Computing

TINKERCAD

.....

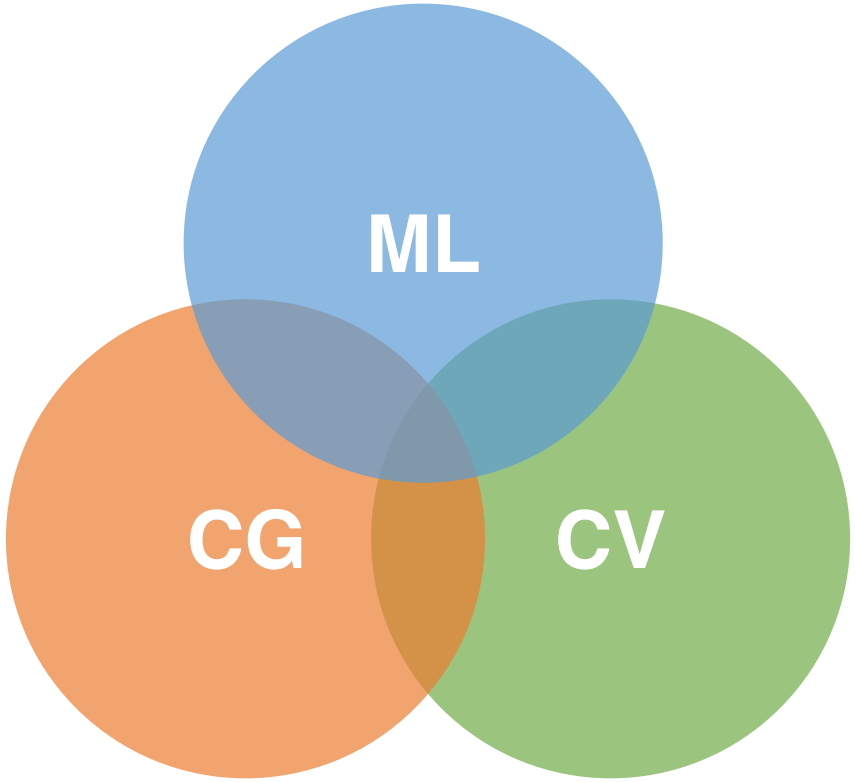
Nowadays millions of 3D models in online repositories

intel
REALSENSE
TECHNOLOGY

> 30,000,000 units

The surge of 3D deep learning

- Arguably started from **2015** along with of big 3D datasets (ShapeNet & ModelNet)
- Very active due to huge industry interests!



- Robotics
- Autonomous driving
- Virtual/augmented reality
- Smart manufacturing
- …

3D deep learning tasks

3D geometry analysis

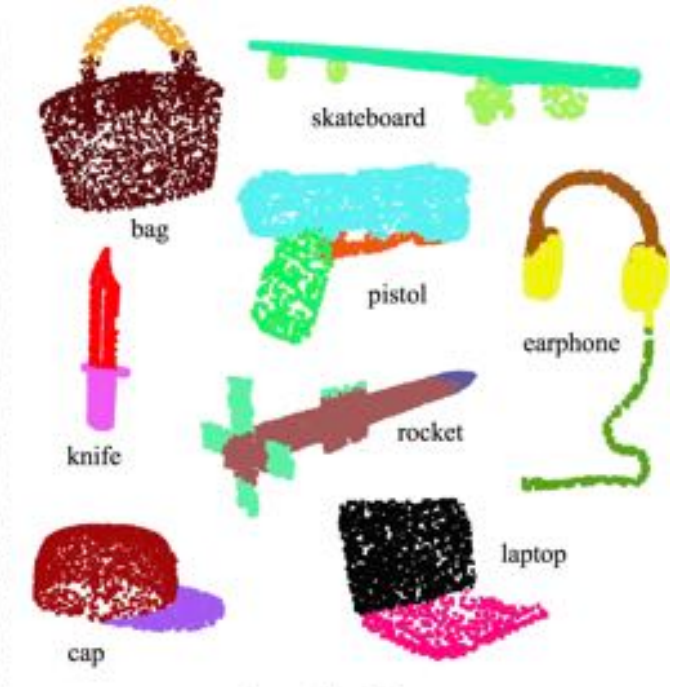
3D-assisted image analysis

3D synthesis

3D deep learning tasks

3D geometry analysis

Classification



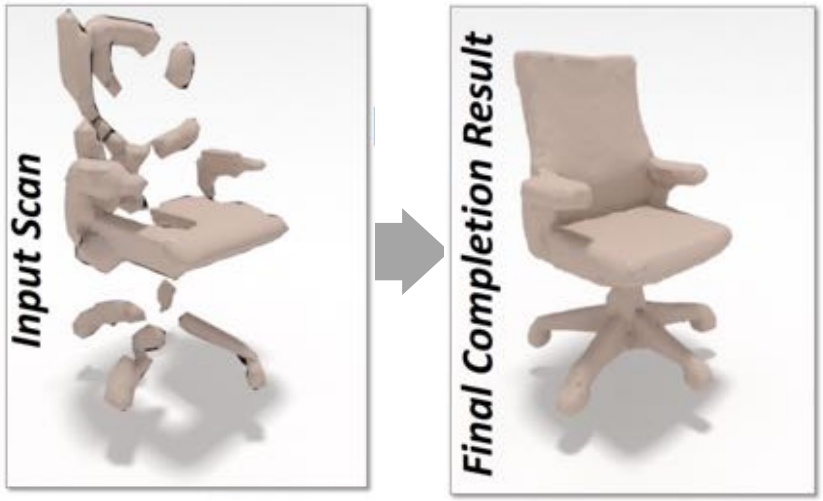
Parsing
(object/scene)

Correspondence

3D deep learning tasks

3D synthesis

Monocular
3D reconstruction



Shape completion

Shape modeling

3D deep learning tasks

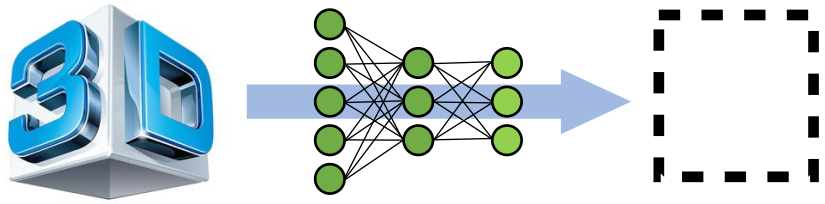
3D-assisted image analysis

Cross-view image retrieval

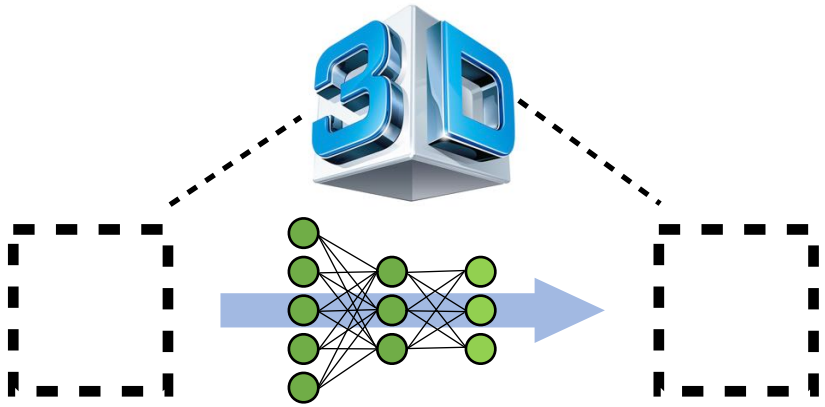
Intrinsic decomposition

All about **Data** and **Network**

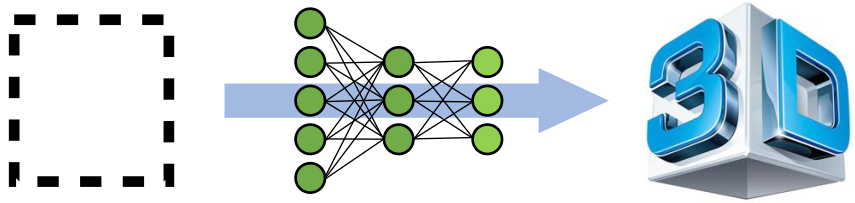
3D geometry analysis



3D-assisted image analysis

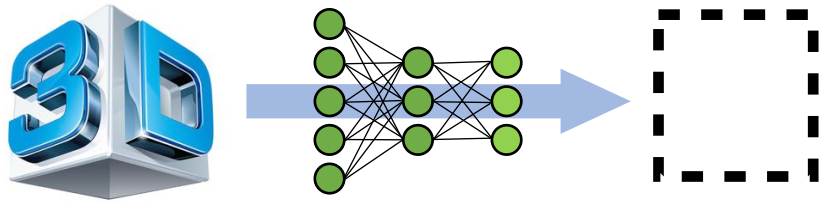


3D synthesis

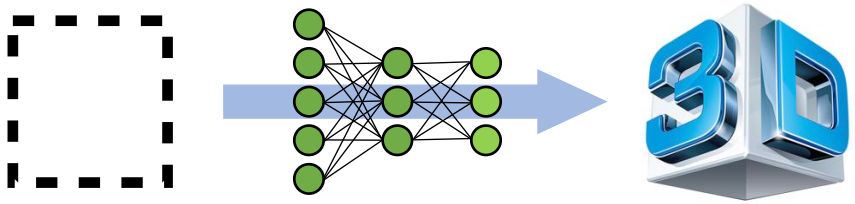


All about **Data** and **Network**

3D geometry analysis



3D synthesis



Outline

Overview of 3D deep learning

3D deep learning algorithms

- 3D Representation issue
- Deep learning on different 3D representations

The representation issue of 3D deep learning

Images: Unique representation with regular data structure

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
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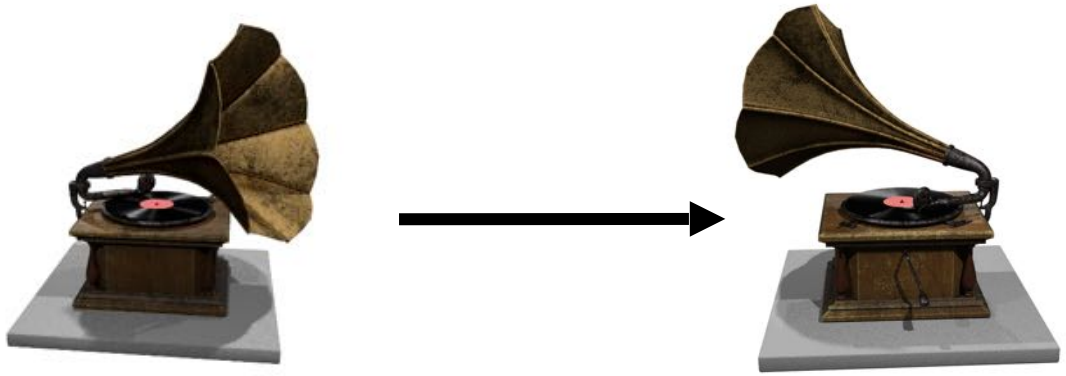
30	56	50	64	4	59	6	13
58	47	45	31	39	15	62	54

The representation issue of 3D deep learning

3D has many representations:

- multi-view RGB(D) images
- volumetric
- polygonal mesh
- point cloud
- primitive-based CAD models

The representation issue of 3D deep learning



Novel view image synthesis

3D has many representations:

multi-view RGB(D) images

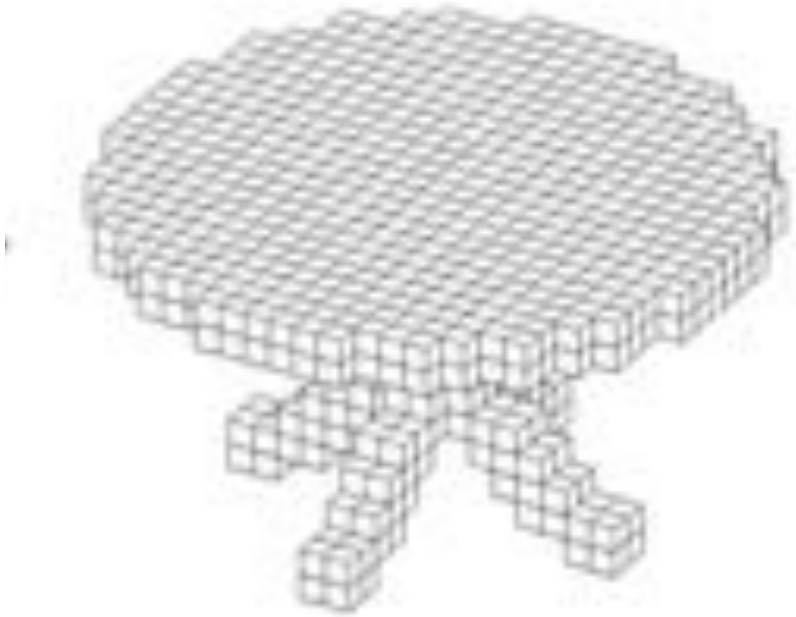
volumetric

polygonal mesh

point cloud

primitive-based CAD models

The representation issue of 3D deep learning



3D has many representations:

multi-view RGB(D) images

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The representation issue of 3D deep learning

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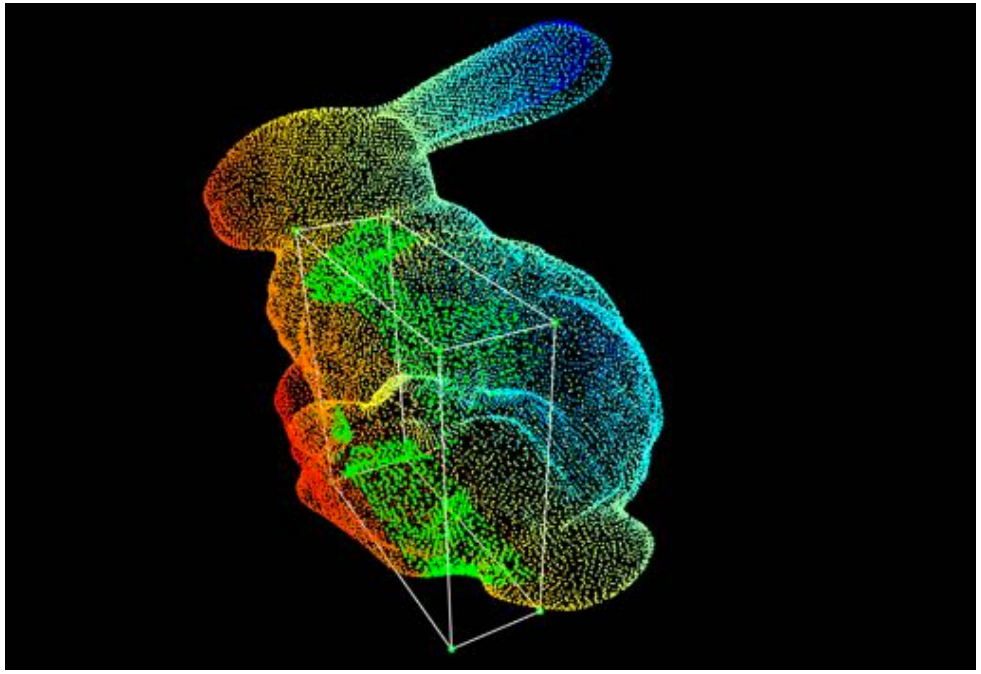

3D has many representations:

multi-view RGB(D) images

volumetric

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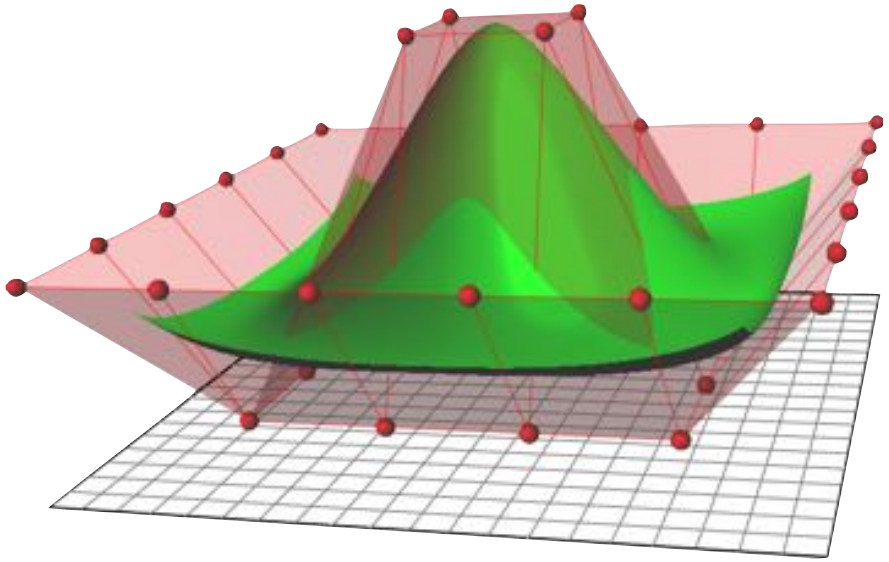


3D has many representations:

multi-view RGB(D) images

volumetric

polygonal mesh

point cloud

primitive-based CAD models

The representation issue of 3D deep learning

3D has many representations:

Rasterized form (regular grids)

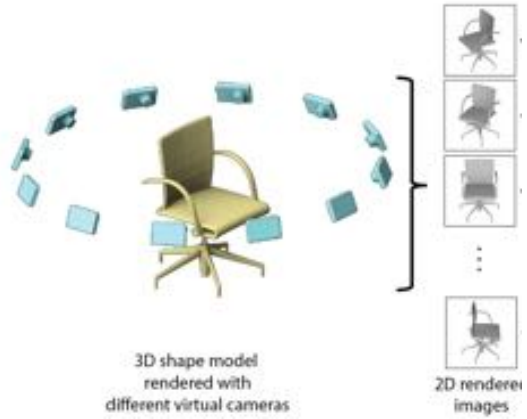
- multi-view RGB(D) images
- volumetric

Geometric form (irregular)

- polygonal mesh
- point cloud
- primitive-based CAD models

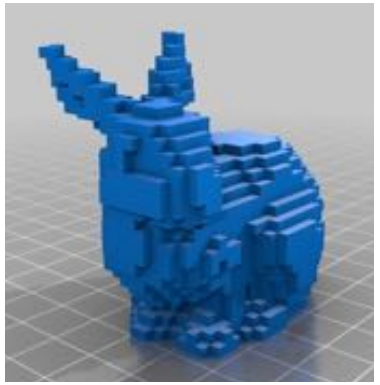
3D deep learning algorithms (by representations)

- Projec



Multi-view

[Su et al. 2015]
[Kalogerakis et al. 2016]
…



Volumetric

[Maturana et al. 2015]
[Wu et al. 2015] (GAN)
[Qi et al. 2016]
[Liu et al. 2016]
[Wang et al. 2017] (O-Net)
[Tatarchenko et al. 2017] (OGN)
…

3D deep learning algorithms (by representations)

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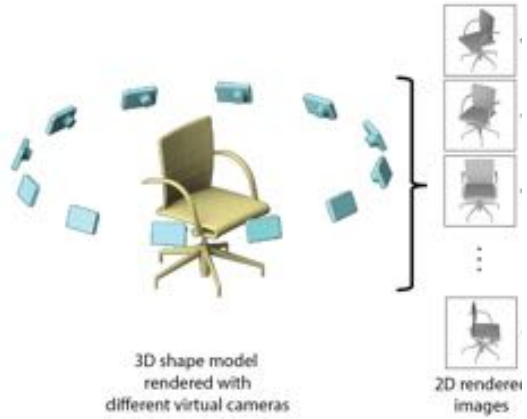

[Su et al. 2015]
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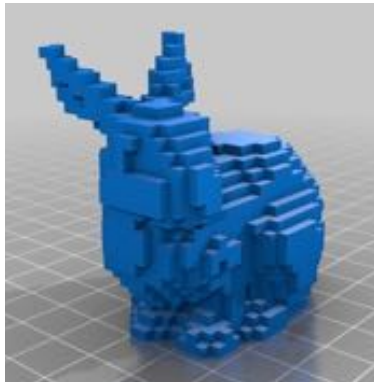
Multi-view



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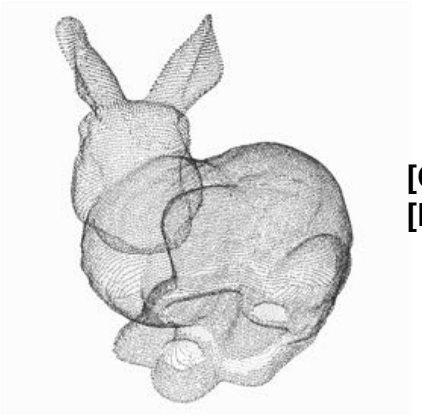
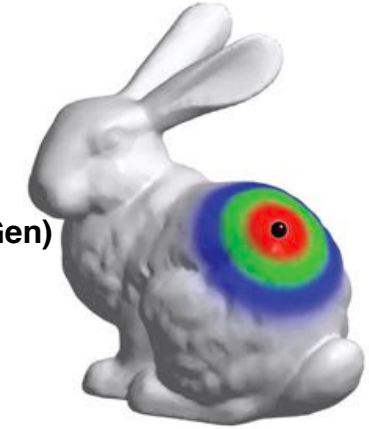
Volumetric



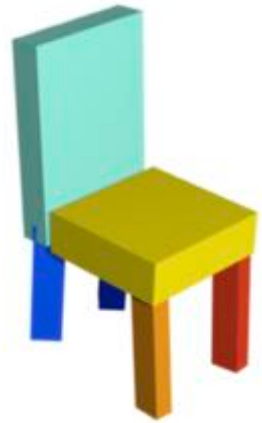
[Qi et al. 2017] (PointNet)
[Fan et al. 2017] (PointSetGen)

Point cloud



[Defferard et al. 2016]
[Henaff et al. 2015]
[Yi et al. 2017] (SyncSpecCNN)
…

Mesh (Graph CNN)

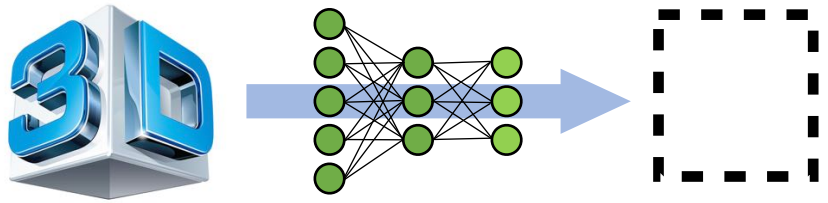


[Tulsiani et al. 2017]
[Li et al. 2017] (GRASS)

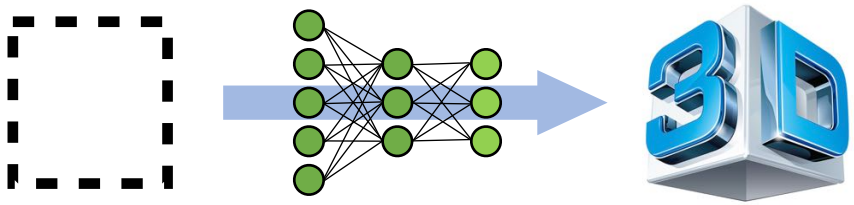
Part assembly

Cartesian product space of “task” and “representation”

3D geometry analysis

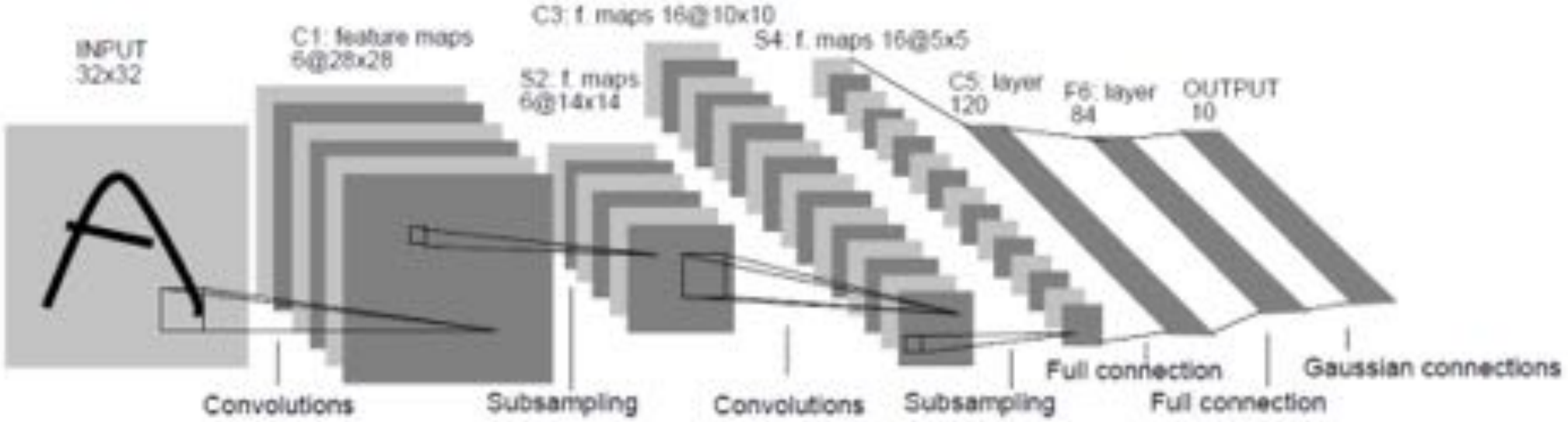


3D synthesis



Fundamental challenges of 3D deep learning

Can we directly apply CNN on 3D data?



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$$(f * g)[n] = \sum_{m=-M}^{M} f[n-m]g[m]$$

Fundamental challenges of 3D deep learning

3D has many representations:

Rasterized form (regular grids)

multi-view RGB(D) images

volumetric

- Can directly apply CNN
- But has other challenges

Fundamental challenges of 3D deep learning

3D has many representations:

Rasterized form
(regular grids)

multi-view RGB(D) images

volumetric

**Geometric form
(irregular)**

polygonal mesh

point cloud

primitive-based CAD models

Cannot directly apply CNN

Outline

Overview of 3D deep learning

3D deep learning algorithms

- Deep learning on regular structures
- Deep learning on meshes
- Deep learning on point cloud and parametric models

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