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# MAI645 - Machine Learning for Graphics and Computer Vision

**Marios Loizou, PhD**

Spring Semester 2025

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# 3D Vision

These notes are mainly based on the following works:

- Fei-Fei Li, Jiajun Wu, Ruohan Gao, **CS231n - Deep Learning for Computer Vision**, Stanford University
- Hao Su, Jiayuan Gu, Minghua Liu, **Tutorial on 3D Deep Learning**, University of California San Diego
- Evangelos Kalogerakis, **Deep learning architectures for 3D shape analysis and synthesis**, University of Massachusetts Amherst

# 3D Vision

Notes have been prepared by **Dr. Marios Loizou**

Research Associate at Visual Computing Group at

CYENS Centre of Excellence



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# Today's Agenda

- Who are we?
- What is 3D Vision
- Geometry
- 3D shape representations
- 3D shape datasets
- 3D Deep Learning architectures
- What we do


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# Who are we?

## Visual Computing Group at CYENS Centre of Excellence

**Melinos Averkiou**
MRG Leader

**Yiangos Georgiou**
Research Associate

**Marios Loizou**
Research Associate

**Yeshwanth Kumar Adimoolam**
Research Associate

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## What is 3D Vision: *Overview*

- **Teaching** the computer (**learning**) to **understand the 3D world** around it
- In 3D Vision the input data lie in the **3D space**, rather the 2D domain as in the case of images (2D Vision)
- Deep Learning algorithms and architectures are specifically designed to process this type of data

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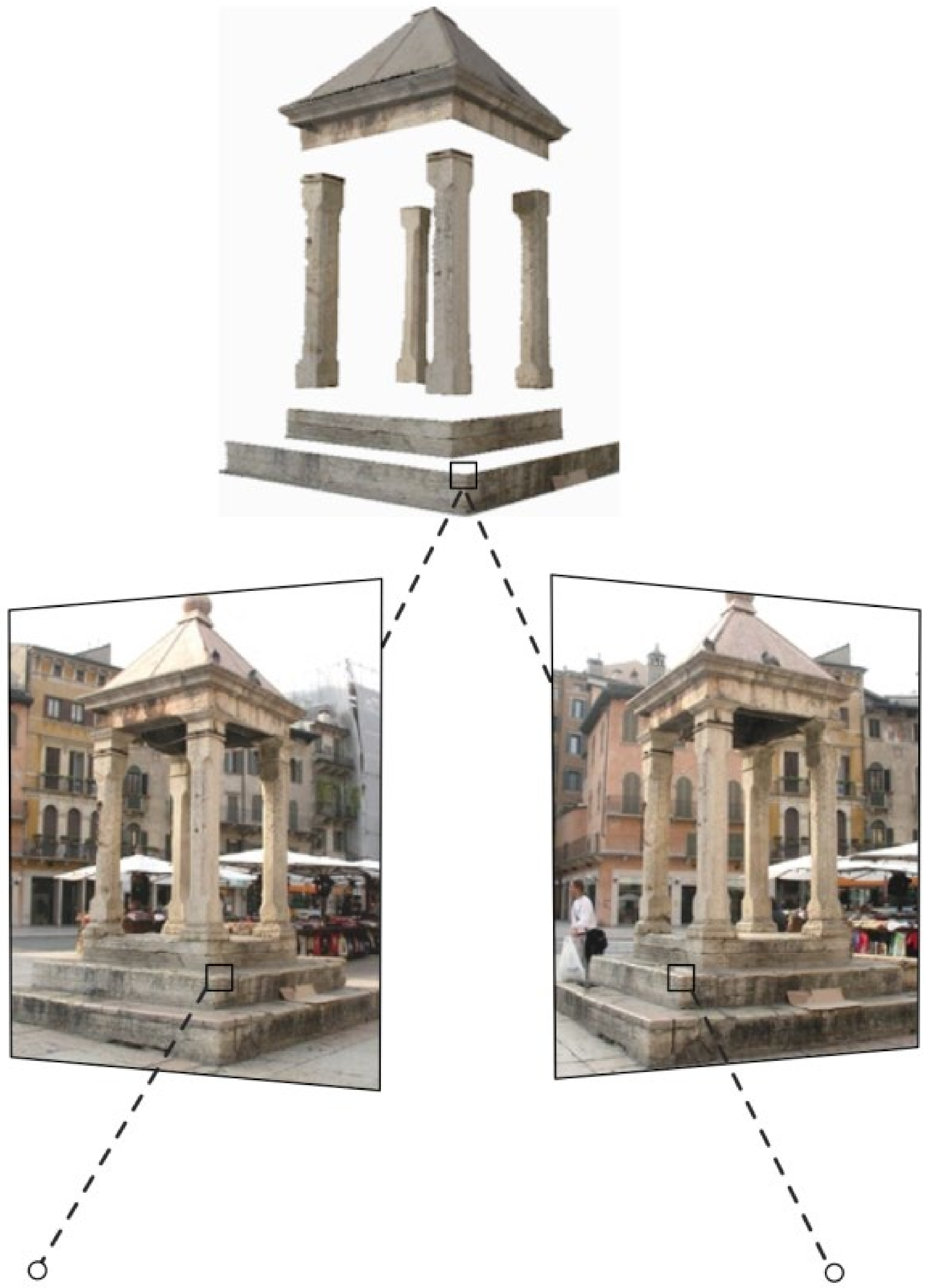
# What is 3D Vision: *Overview*

## Traditional 3D Vision

- Multi-view Geometry: Structure from Motion (SfM)



Hao Su et al.



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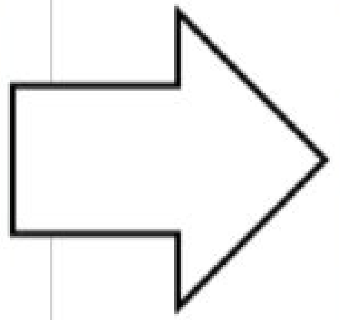
# What is 3D Vision: *Overview*

**Now**

- Acquire knowledge of the 3D world by **Learning**

Hao Su et al.



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# What is 3D Vision: *Tasks (a very small subset)*

## Object Classification


ShapeNetCore, Chang et al.

## What is 3D Vision: *Tasks (a very small subset)*

**Indoor Scene Segmentation**

ScanNet,
Angela Dai et al.

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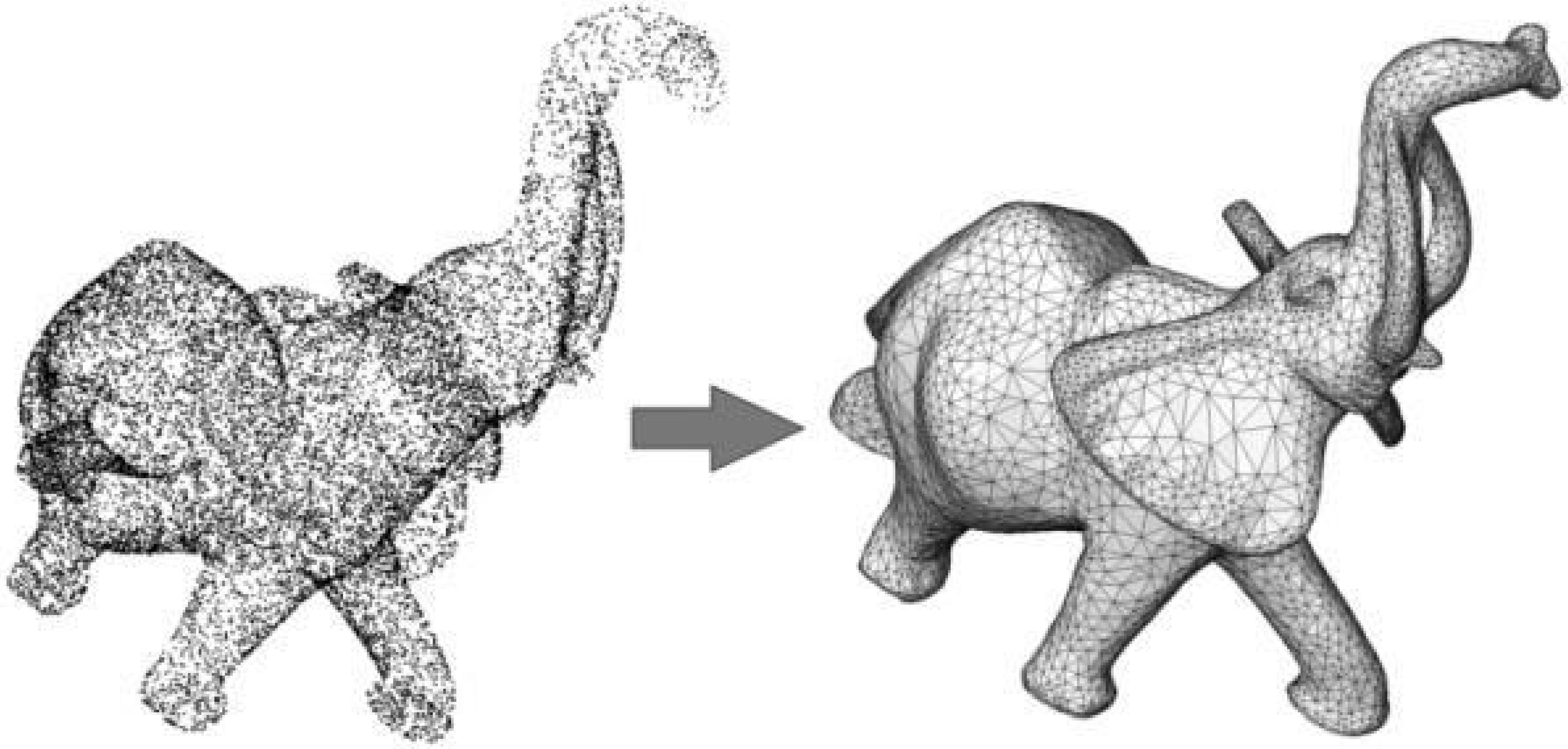
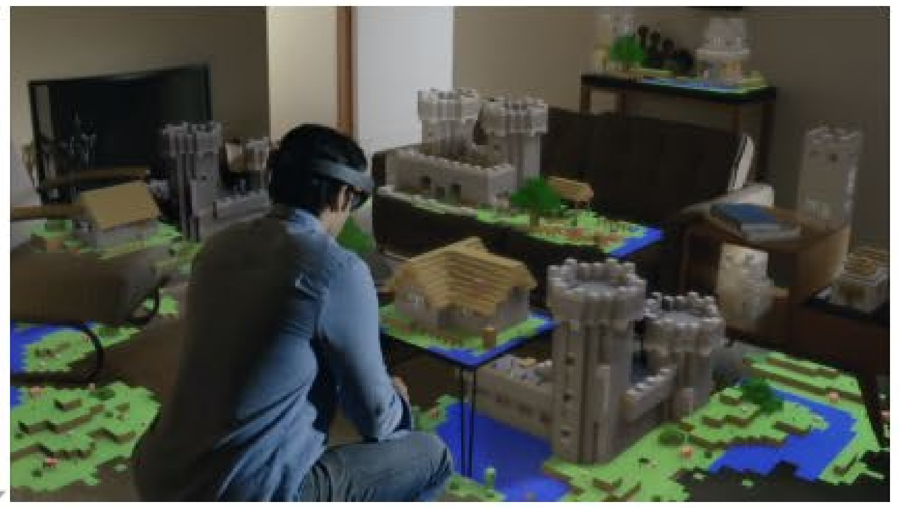
## What is 3D Vision: *Tasks (a very small subset)*

**Surface reconstruction**

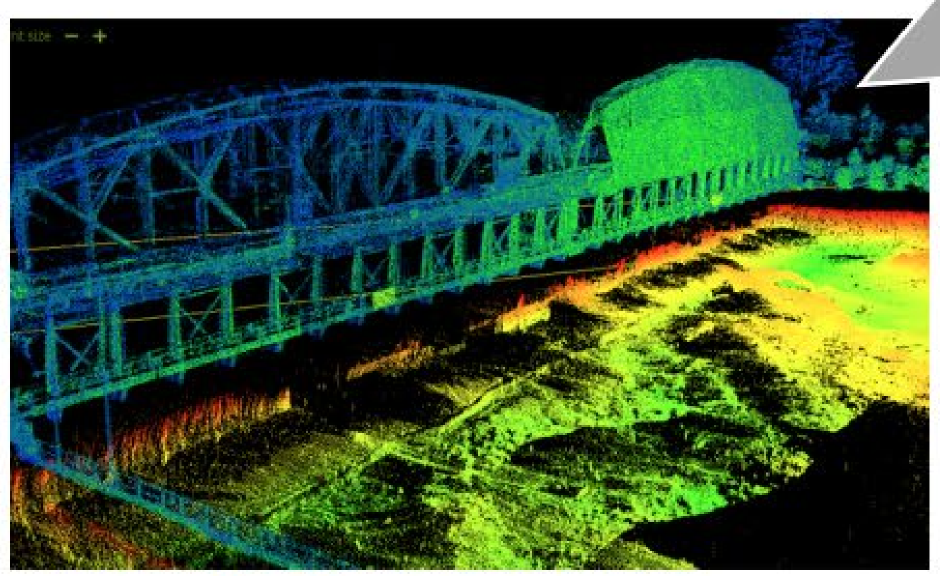


## What is 3D Vision: *Applications*

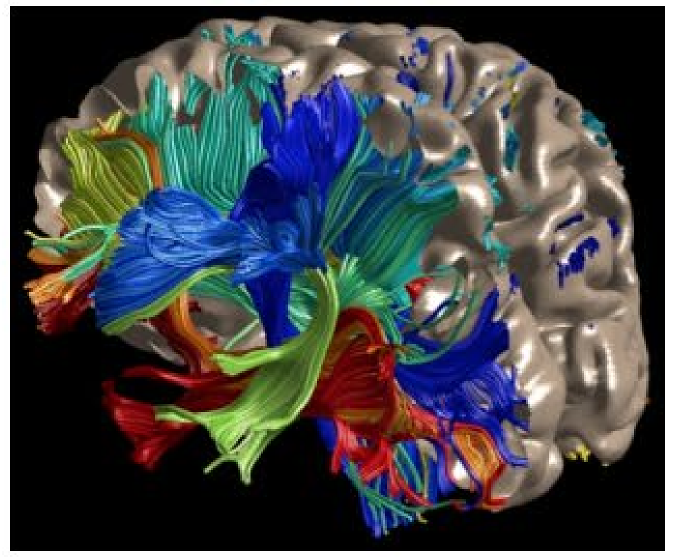

Robotics



Augmented Reality

Autonomous driving



Medical Image Processing

Hao Su et al.



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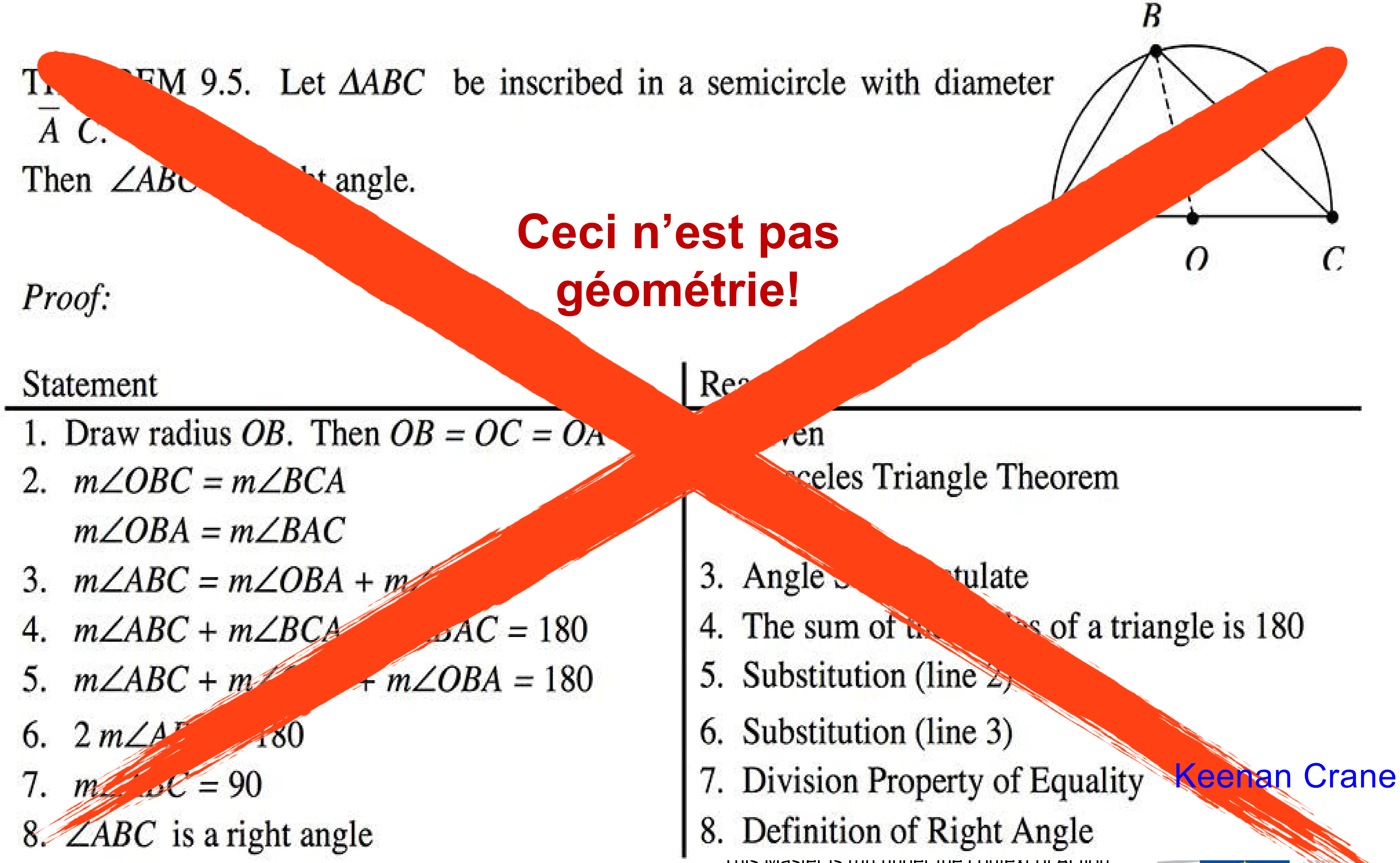
## Geometry: *Definition*

**Geometry** is the study of two-column proofs



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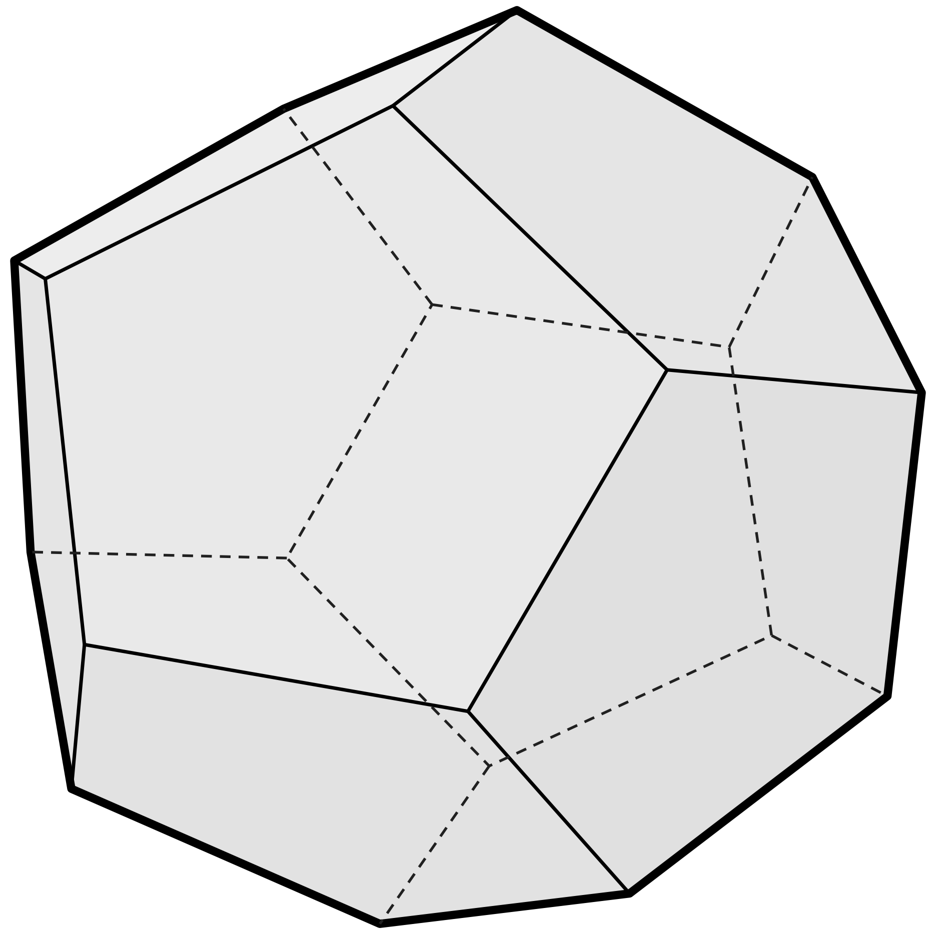
## Geometry: *Definition*

1. The study of **shapes**, sizes, patterns and positions

2. The study of **spaces** where some quantity can be measured

Earth measure

geometry



**Plato** *«… the earth is in appearance like one of those balls which have leather coverings in twelve pieces...»*

Keenan Crane

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## **Geometry:** *How to encode geometry?*

**IMPLICIT**

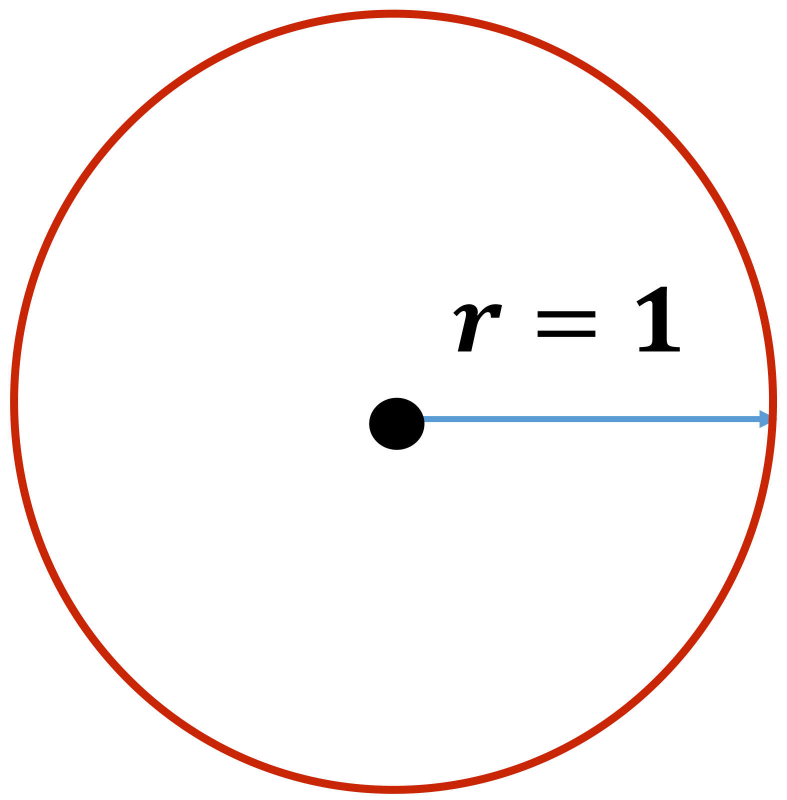
$x^2 + y^2 = 1$

**LINGUISTIC**

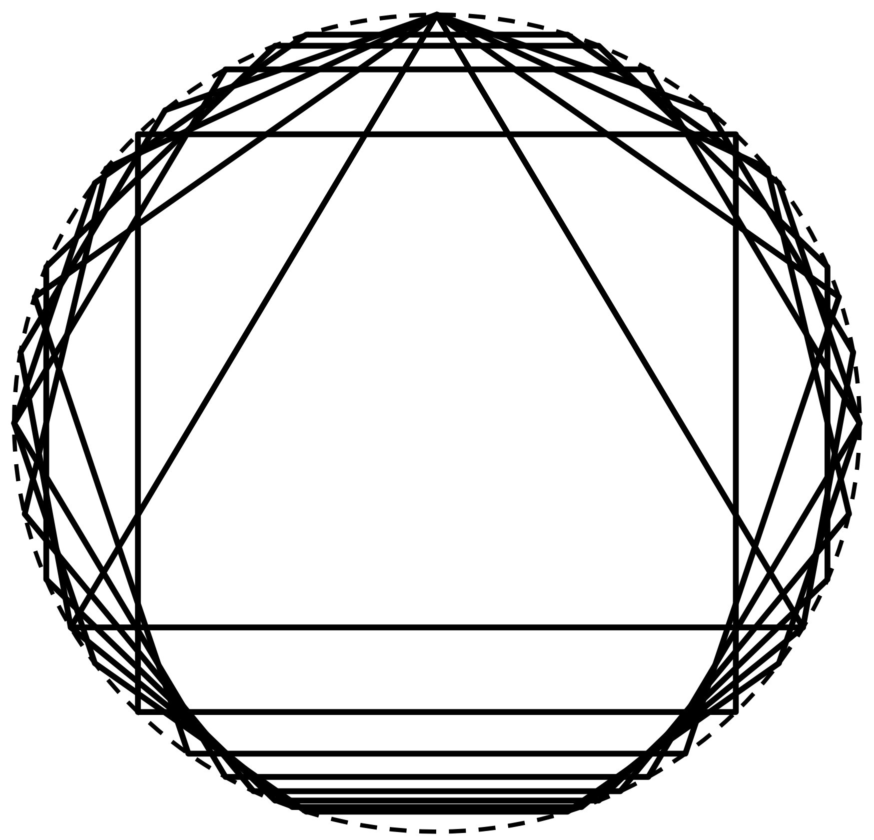
"*unit circle*"

**EXPLICIT**

$(\cos\theta, \sin\theta)$




**DISCRETE**



$n \to \infty$

Given all these options, what's the **best** way to encode geometry on a computer?

Keenan Crane



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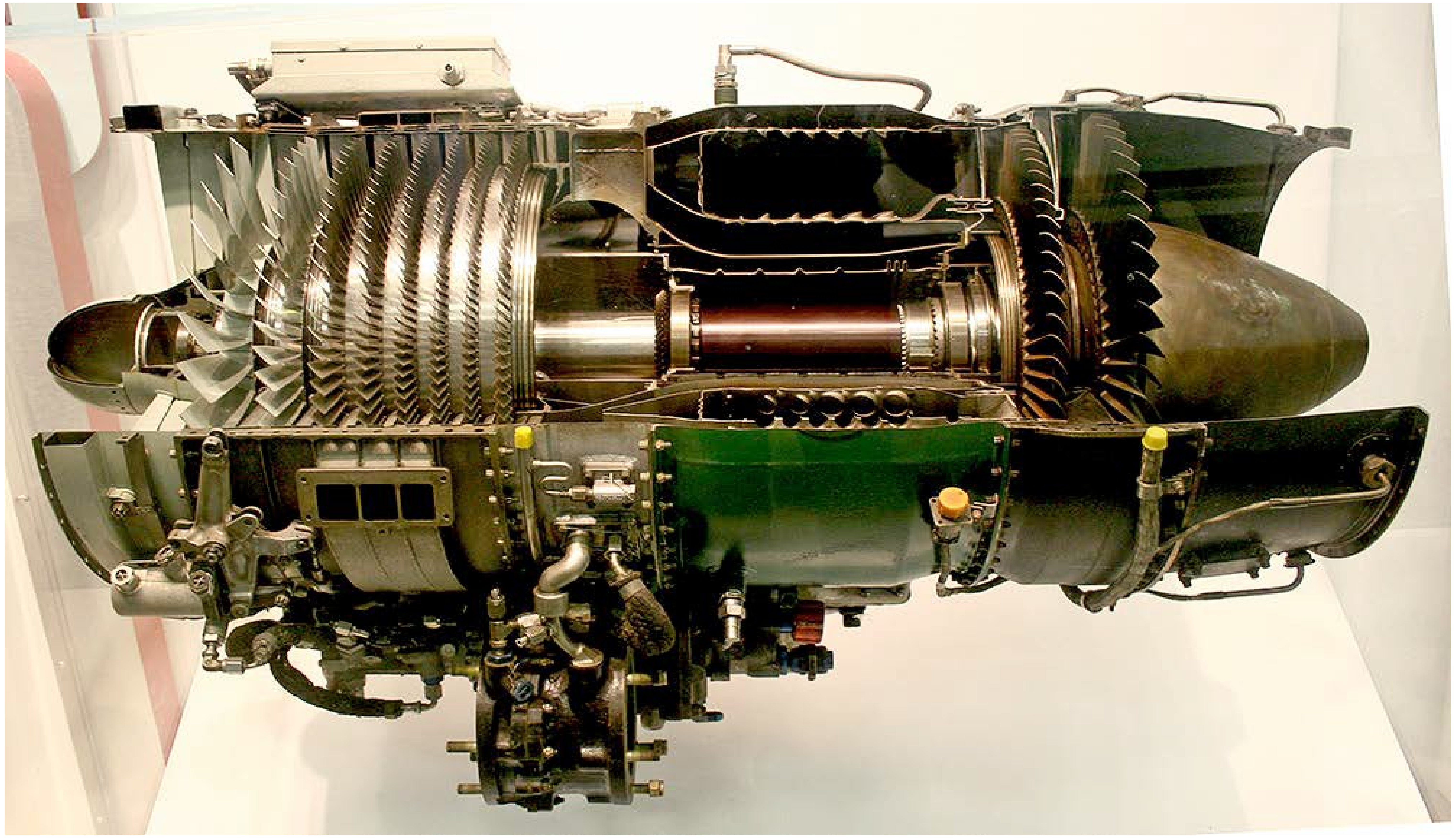
# **Geometry:** *Examples*

Keenan Crane

# Geometry: *Examples*



Keenan Crane

# Geometry: *Examples*

Keenan Crane

# Geometry: *Examples*

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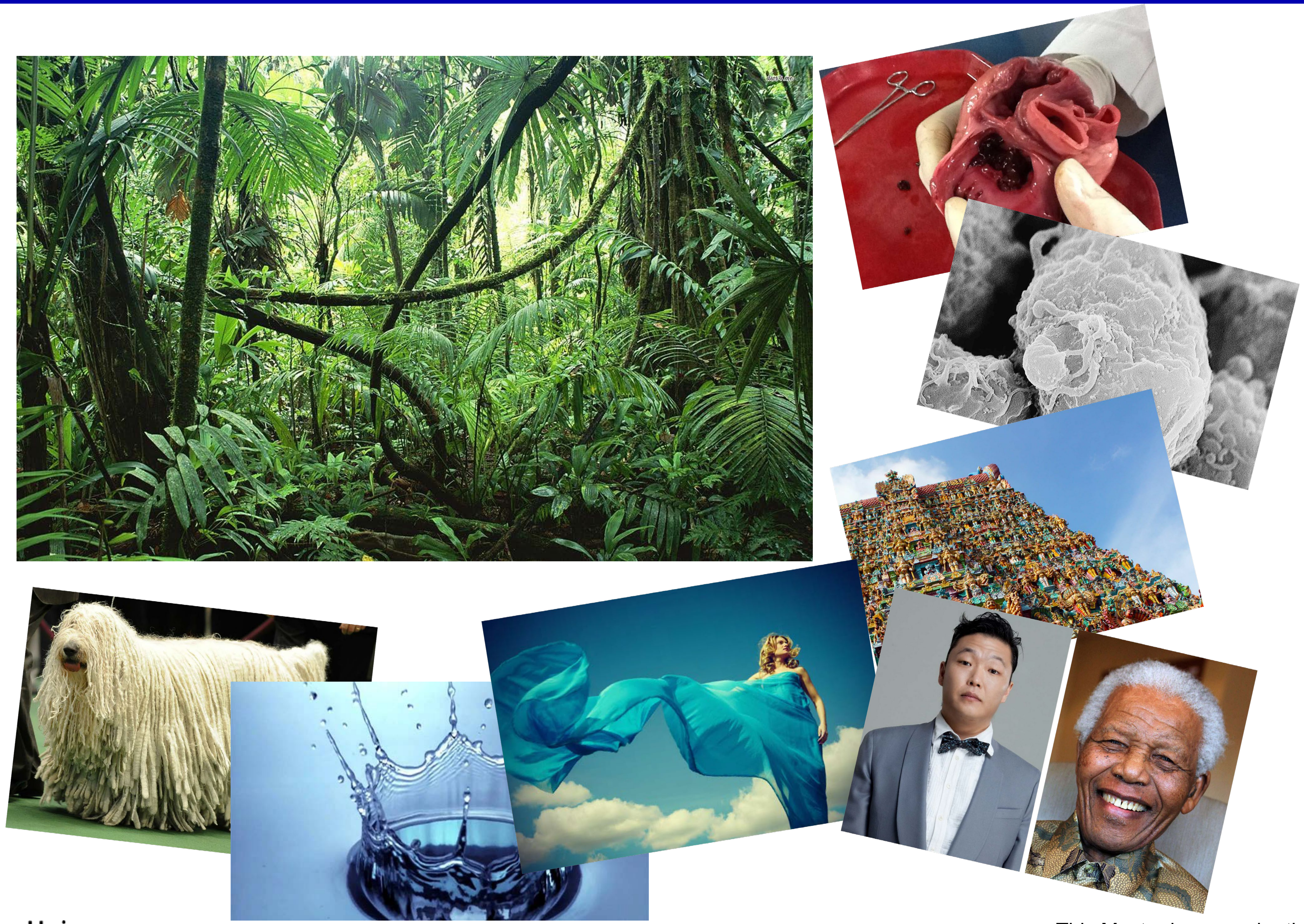
# Geometry: *Examples*

Keenan Crane

# Geometry: *Examples*



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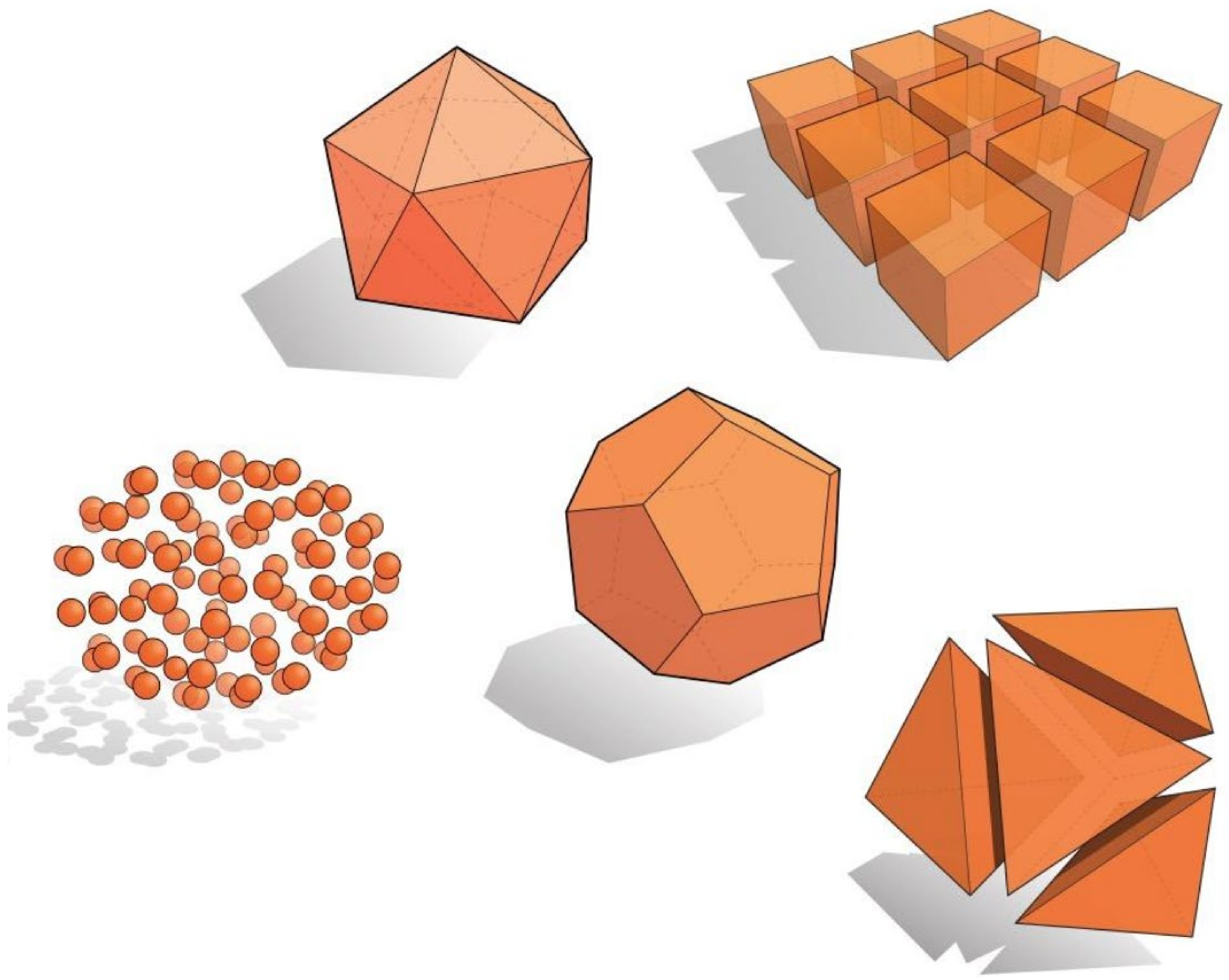
## 3D shape representations: *Many ways to represent geometry*

### Explicit
- point cloud
- polygon mesh
- …

### Implicit
- level sets
- distance functions
- …

- Voxels



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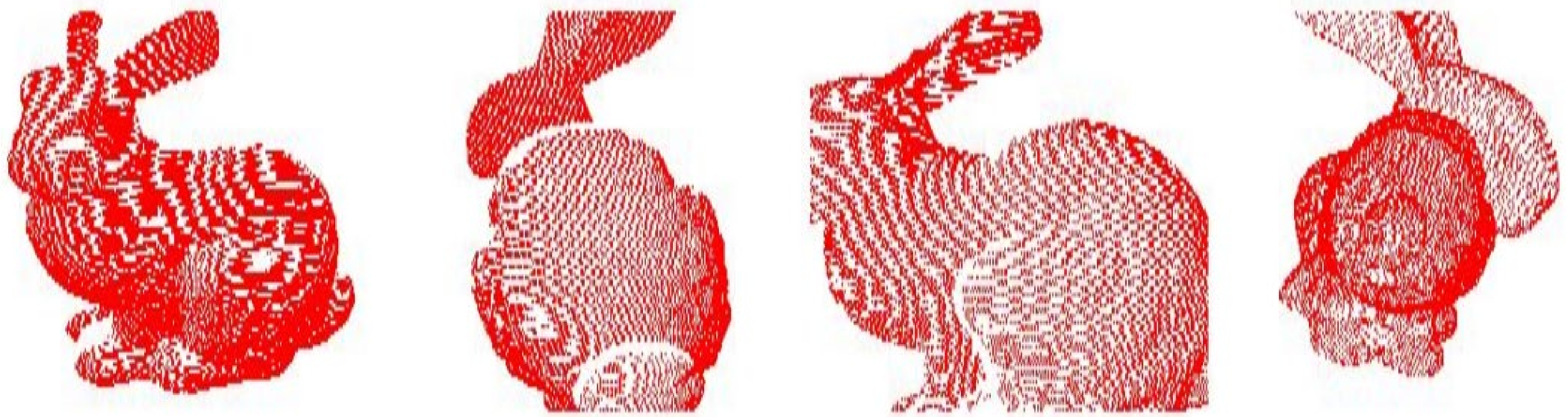
## 3D shape representations: *Point clouds*

- Simplest representation: **only points**, no connectivity



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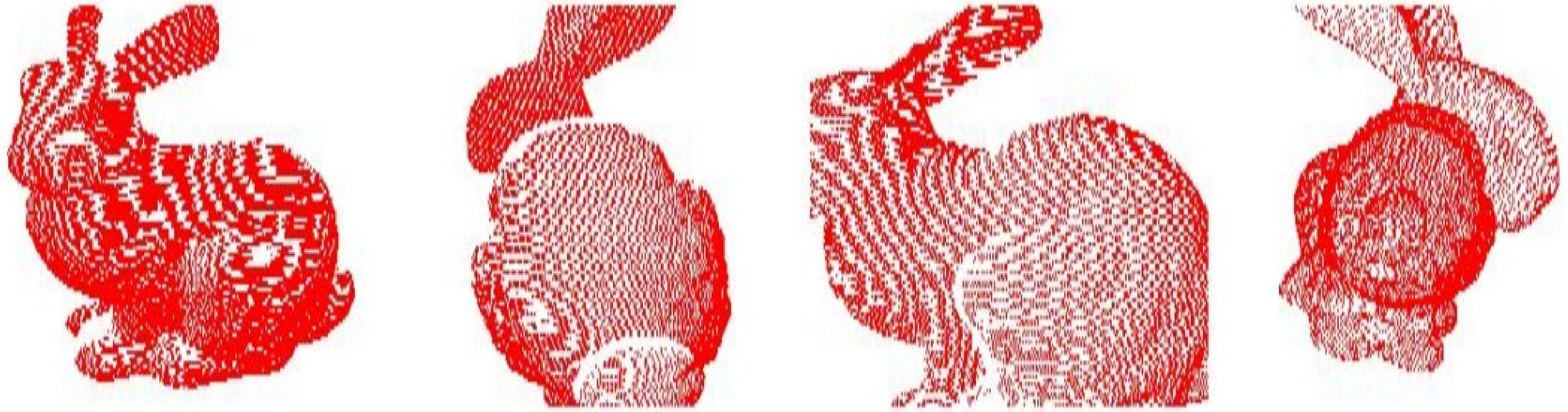
## 3D shape representations: *Point clouds*

- Simplest representation: **only points**, no connectivity
- Collection of $(x, y, z)$ coordinates, possibly with **normal** (perpendicular to the underlying surface)



List of $N$ **unordered** points

$$\left.\begin{array}{ll} p_1 & x_1, y_1, z_1, n_{x_1}, n_{y_1}, n_{z_1} \\ p_2 & x_2, y_2, z_2, n_{x_2}, n_{y_2}, n_{z_2} \\ p_3 & x_3, y_3, z_3, n_{x_3}, n_{y_3}, n_{z_3} \\ \vdots & \vdots \\ p_N & x_N, y_N, z_N, n_{x_N}, n_{y_N}, n_{z_N} \end{array}\right.$$

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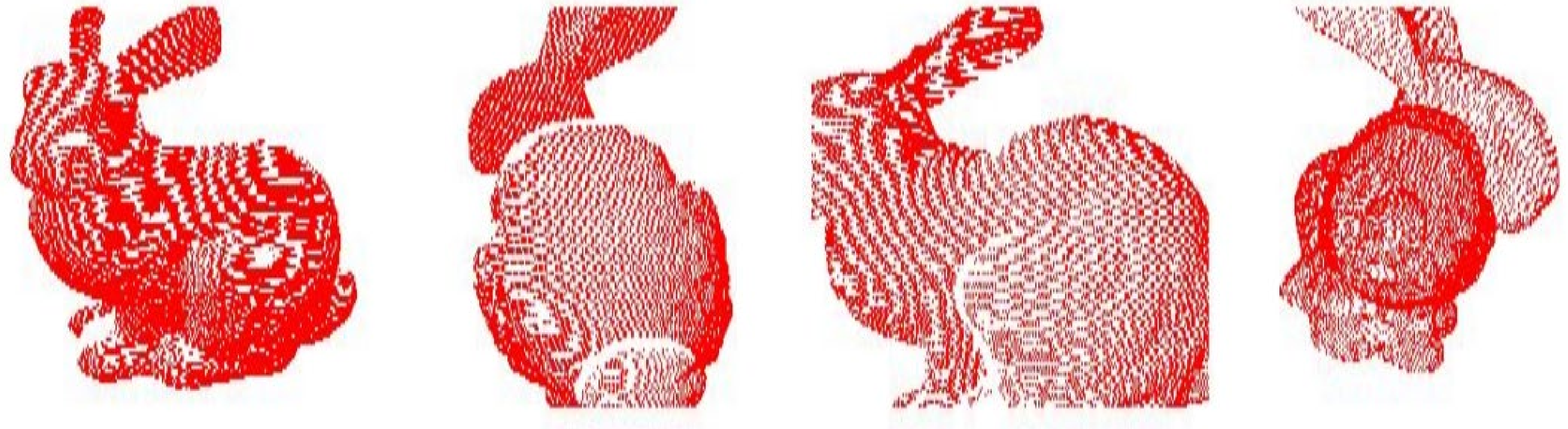
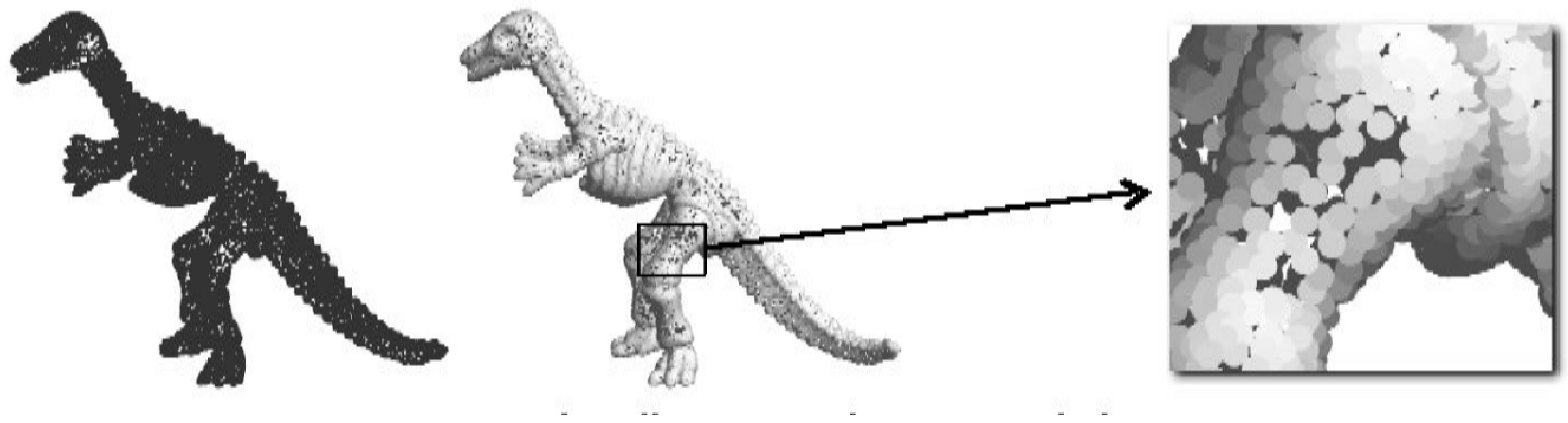
## 3D shape representations: *Point clouds*

- Simplest representation: **only points**, no connectivity
- Collection of $(x, y, z)$ coordinates, possibly with **normal** (perpendicular to the underlying surface)
- Points with orientation (normal) are called **surfels**





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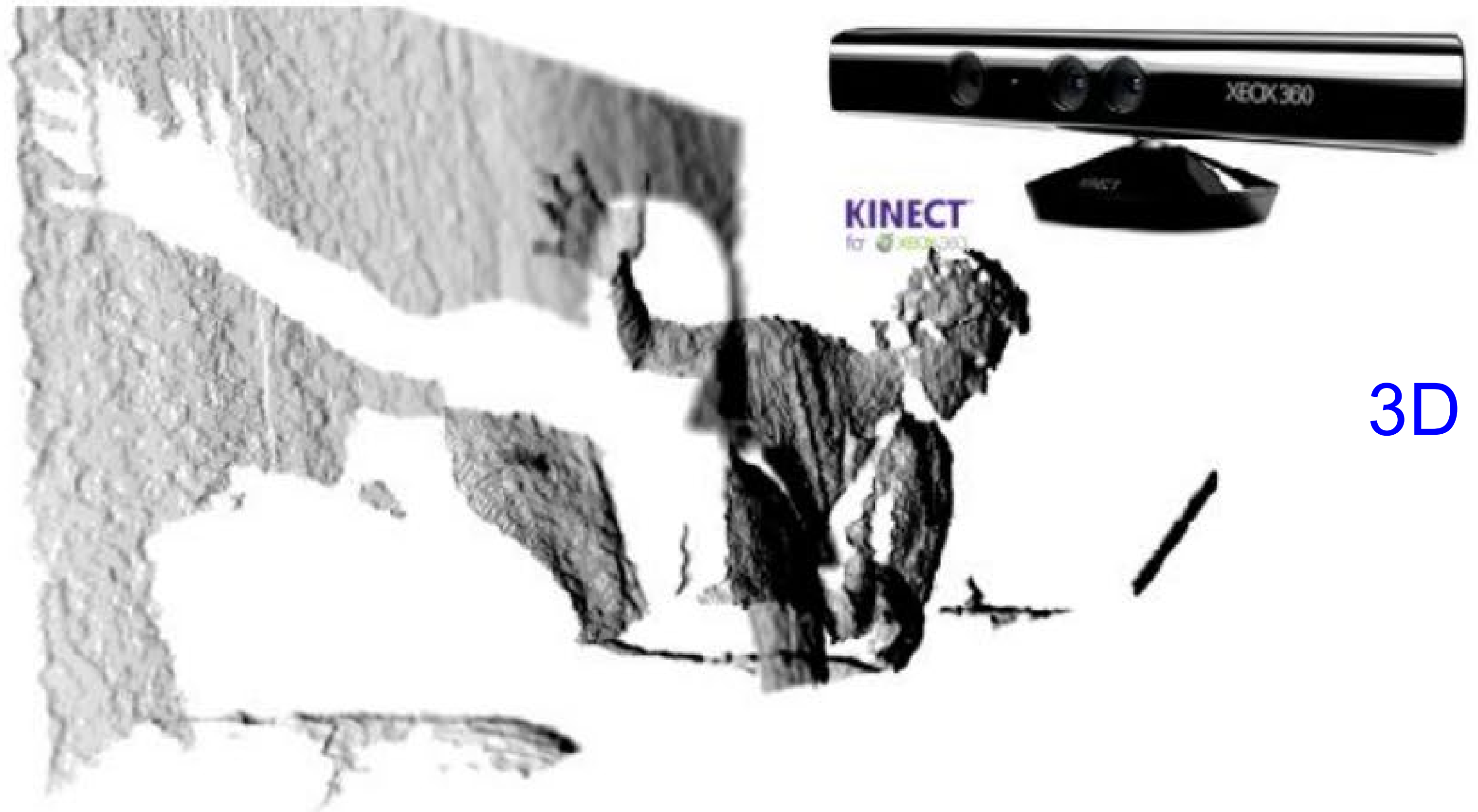
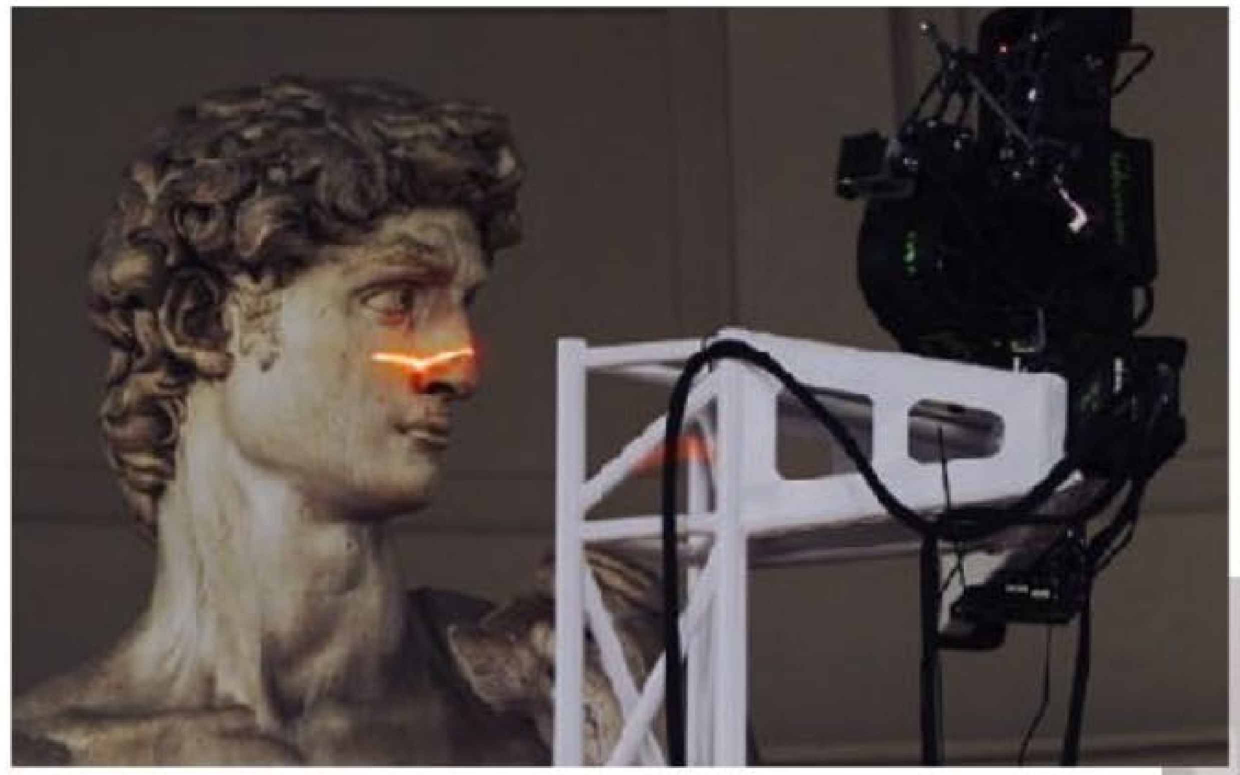
# 3D shape representations: *Point clouds acquisition*




3D Depth sensor

Laser triangulation rangefinder



3D Laser scanner

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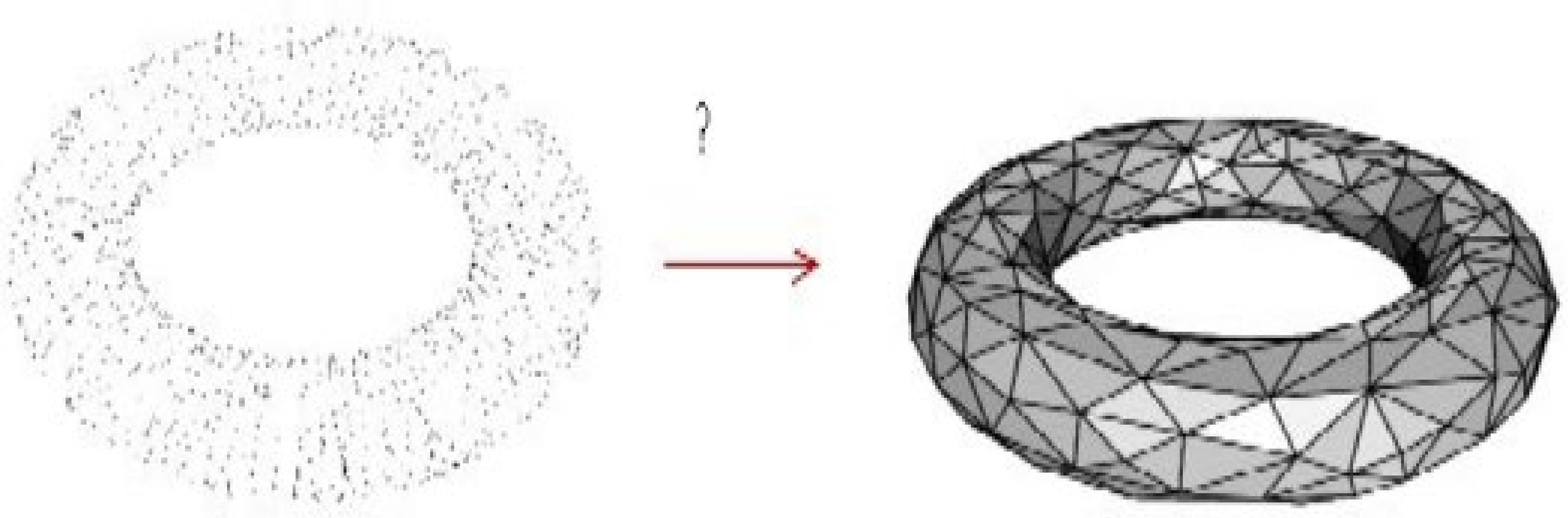
## 3D shape representations: *Point clouds pros & cons*

- Pros:
  - ✓ Easily represents any kind of geometry
  - ✓ Useful for large datasets

- Cons
  - x Incomplete/noisy point clouds
  - x No topological information

Incomplete scans




No topology

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## 3D shape representations: *Polygonal Meshes*

- A 3D polygonal mesh is the **structural build** of a **3D model** consisting of **polygons**
- **Boundary representation** of objects



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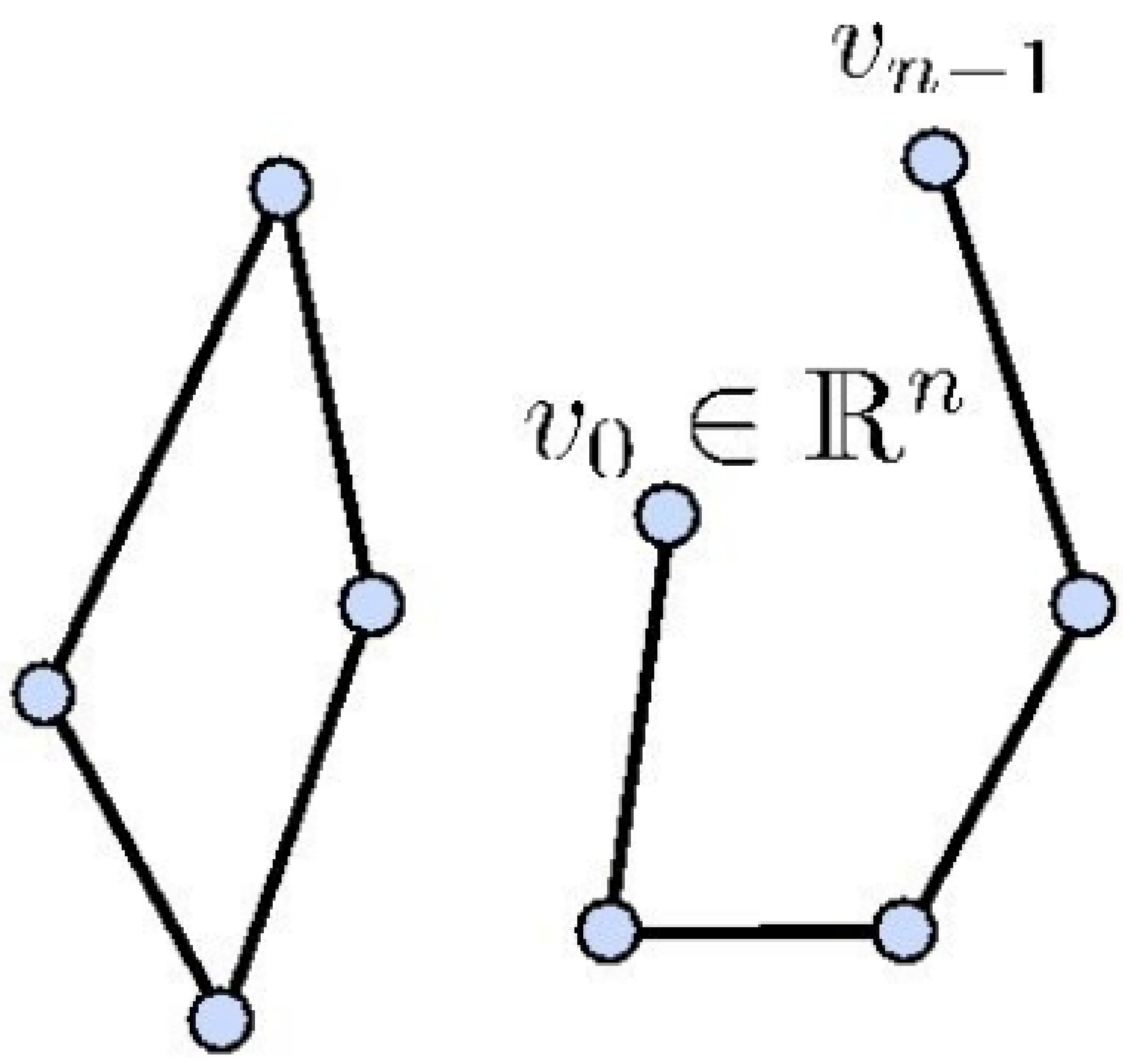
## 3D shape representations: *Polygonal Meshes*

- Polygon:
  - **Vertices**: $v_0, v_1, \cdots, v_{n-1}$
  - **Edges**: $\{(v_0, v_1), \cdots, (v_{n-2}, v_{n-1})\}$

- Types of polygons:
  - **Closed**: $v_0 = v_{n-1}$
  - **Planar**: all vertices on a plane
  - **Simple**: not self-intersecting

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## 3D shape representations: *Polygonal Meshes*

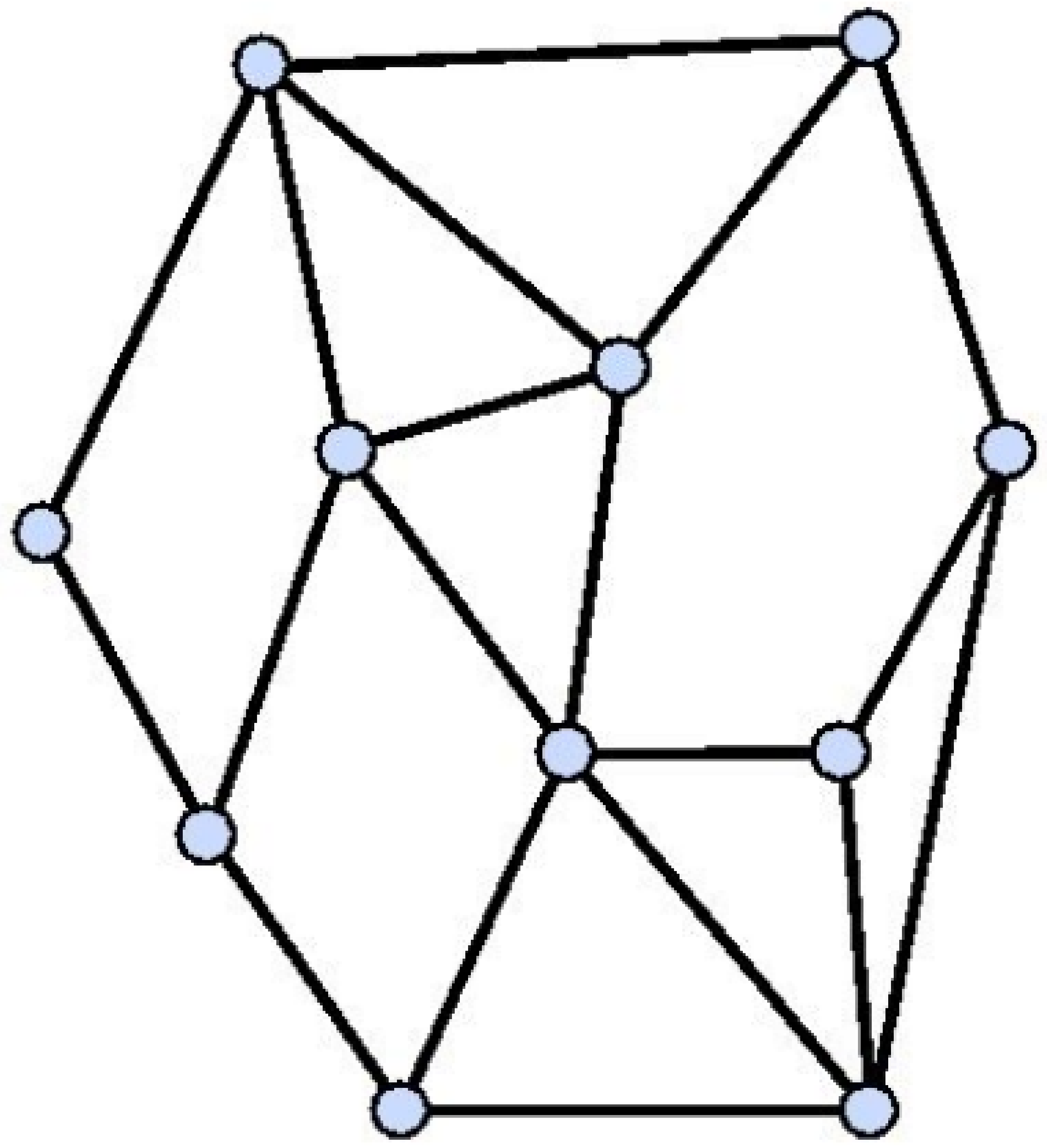
- Polygonal Mesh:
  - A finite set $M$ of **closed, simple** polygons $Q_i$

$$\boldsymbol{M} = <\boldsymbol{V}, \boldsymbol{E}, \boldsymbol{F}>$$

$\boldsymbol{V}$ = set of vertices

$\boldsymbol{E}$ = set of edges

$\boldsymbol{F}$ = set of faces



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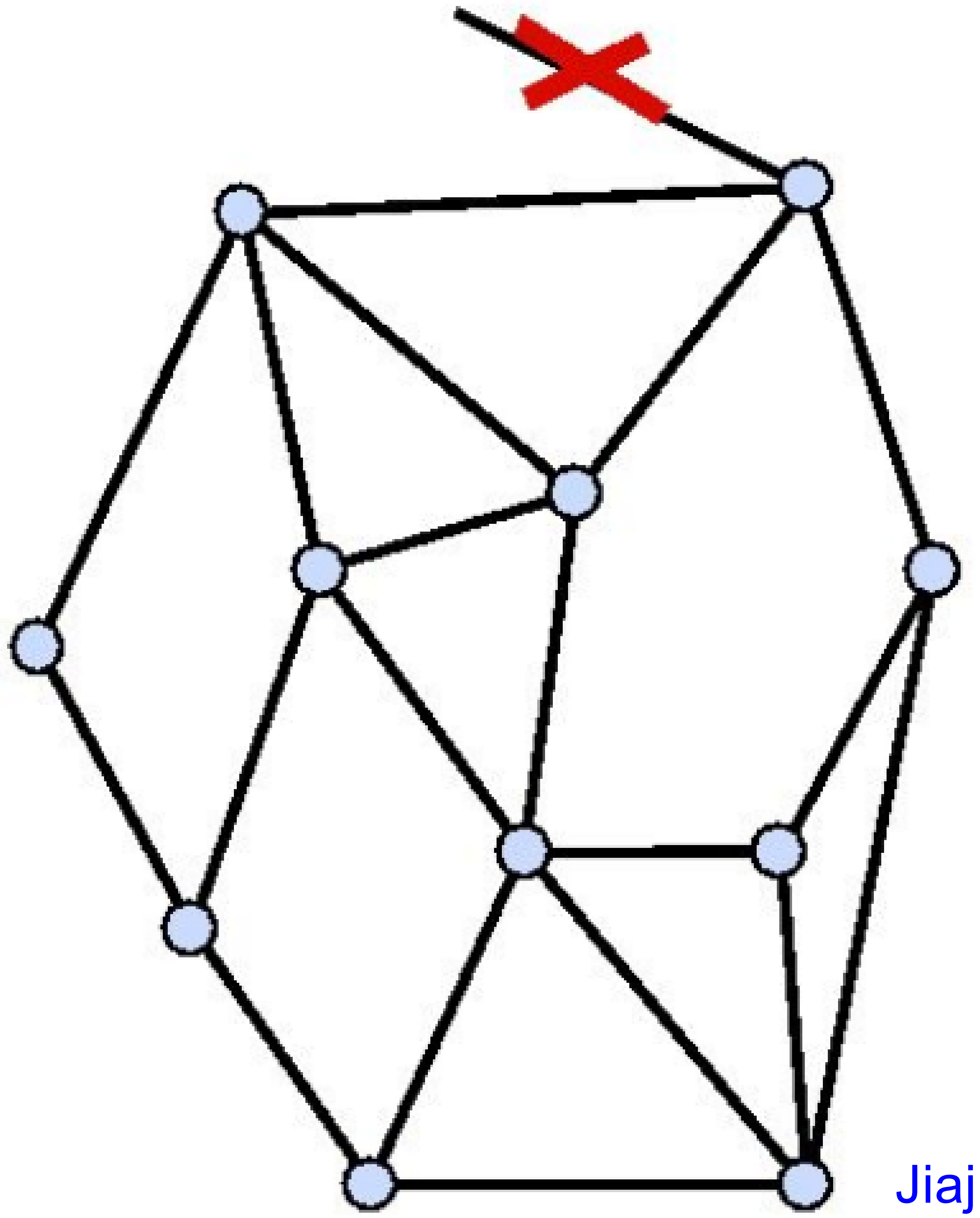
## 3D shape representations: *Polygonal Meshes*

- Polygonal Mesh:
  - A finite set $M$ of **closed, simple** polygons $Q_i$
  - Every **edge** belongs to **at least one polygon**



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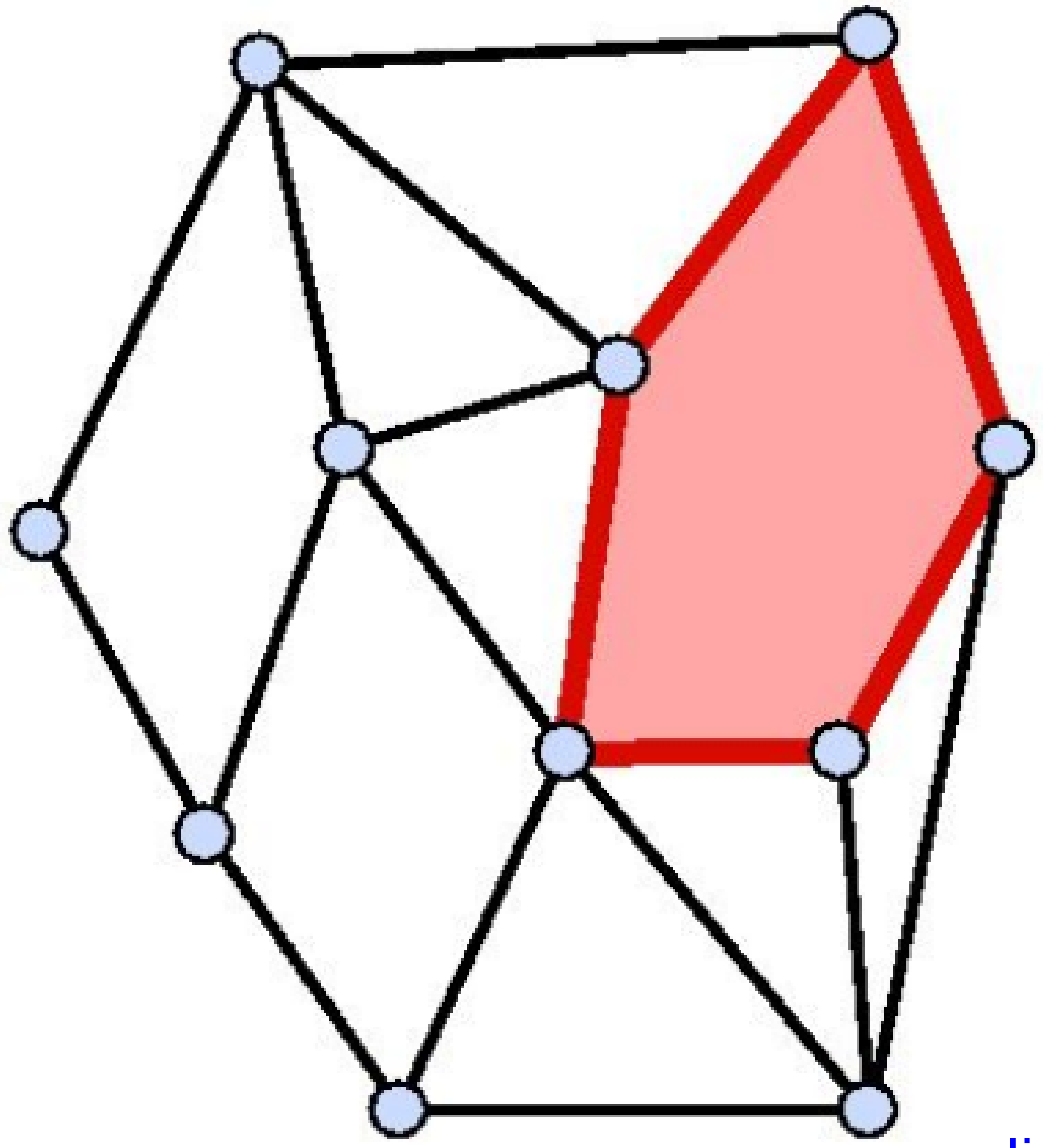
## 3D shape representations: *Polygonal Meshes*

- Polygonal Mesh:
  - A finite set $M$ of **closed, simple** polygons $Q_i$
  - Every **edge** belongs to **at least one polygon**
  - Each $Q_i$ defines a **face** of the polygonal mesh



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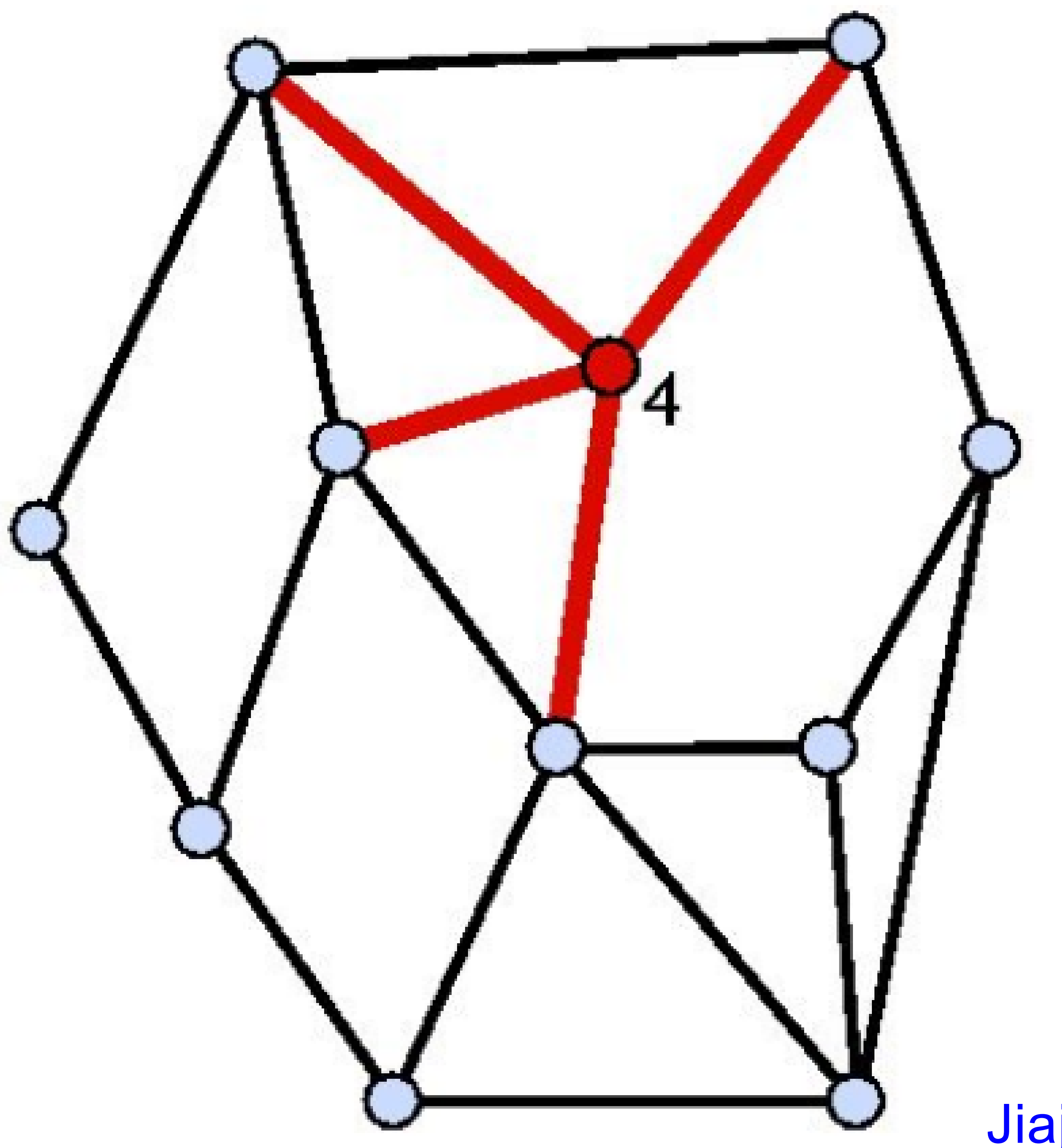
## 3D shape representations: *Polygonal Meshes*

- Polygonal Mesh:
  - A finite set $M$ of **closed, simple** polygons $Q_i$
  - Every **edge** belongs to **at least one polygon**
  - Each $Q_i$ defines a **face** of the polygonal mesh
  - Vertex **degree** or **valance** = number of incident edges

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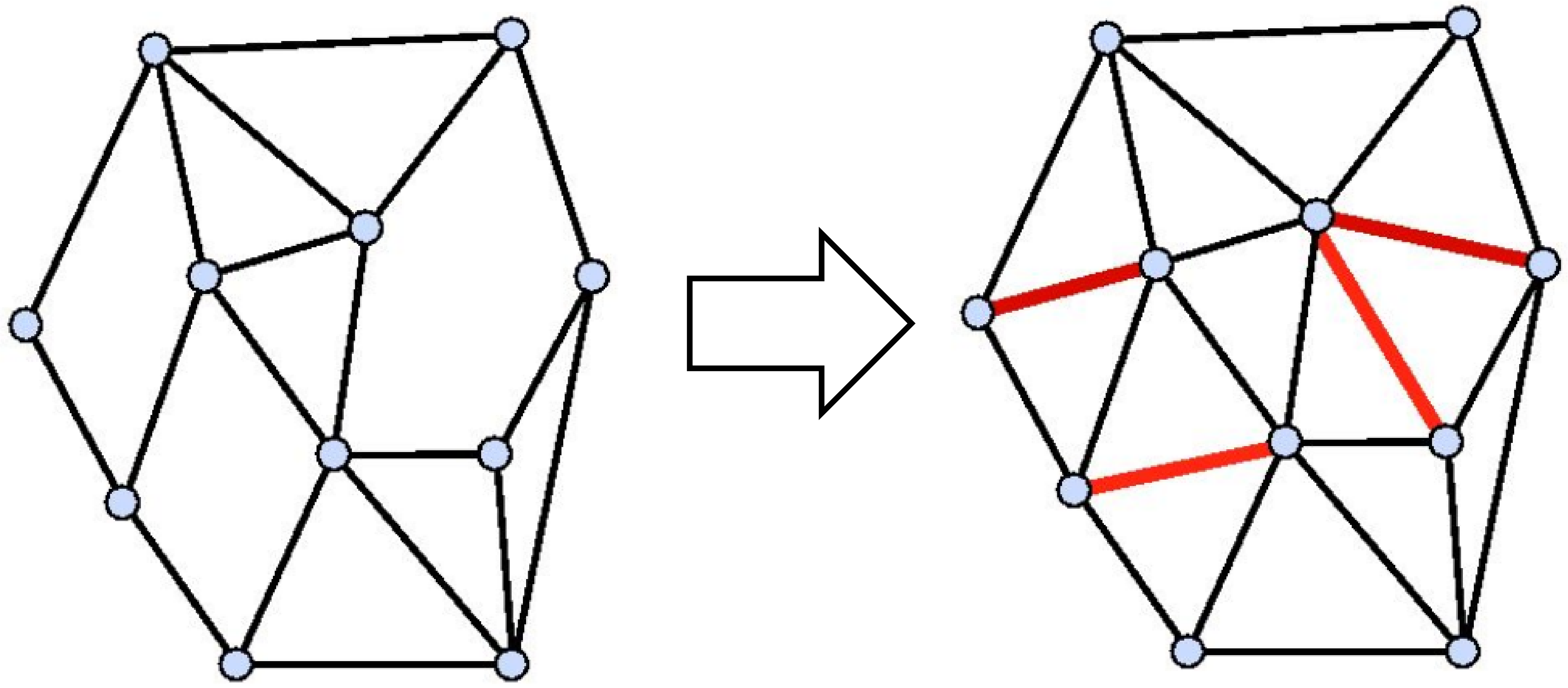
## 3D shape representations: *Polygonal Meshes*

- Polygonal Mesh **Triangulation**:
  - Polygonal mesh where every face is a triangle → **triangular mesh**
  - Simplifies data structures
  - Simplifies rendering
  - Simplifies algorithms
  - Each face is planar and convex
  - Any polygon can be triangulated



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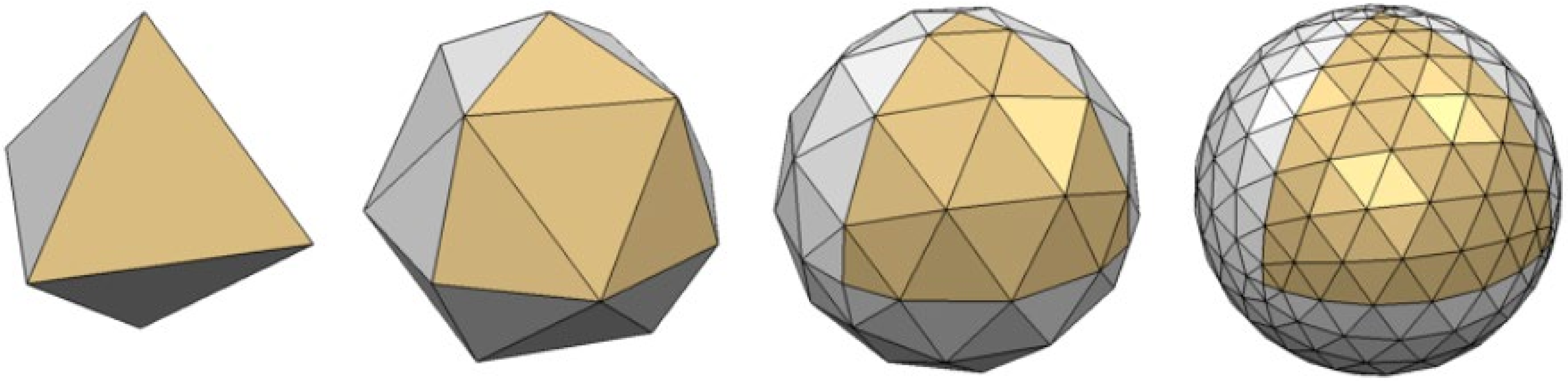
## 3D shape representations: *Polygonal Meshes*



- A polygonal mesh consists of **three kinds** of **mesh elements**: **vertices**, **edges** and **faces**
- **Mesh connectivity** or **topology**: describes the incidence relation amongst mesh elements
- **Mesh geometry**: specifies the position and other geometric characteristics of each vertex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## 3D shape representations: *Polygonal Meshes*

- **Data Structures**:
  - What should be stored?
    - **Geometry**: 3D coordinates
    - **Connectivity**: Adjacency relationships
    - **Attributes**:
      - Normal, color, texture coordinates
      - Per vertex, face, edge

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## 3D shape representations: *Polygonal Meshes*

- **Indexed Face Set**
  - Used in formats like OBJ and OFF
  - Storage
    - Vertex: position
    - Face: vertex indices
  - No explicit neighborhood info

| Vertices | | | |
|---|---|---|---|
| v0 | x0 | y0 | z0 |
| v1 | x1 | x1 | z1 |
| v2 | x2 | y2 | z2 |
| v3 | x3 | y3 | z3 |
| v4 | x4 | y4 | z4 |
| v5 | x5 | y5 | z5 |
| v6 | x6 | y6 | z6 |
| ... | ... | ... | ... |

| Triangles | | | |
|---|---|---|---|
| t0 | v0 | v1 | v2 |
| t1 | v0 | v1 | v3 |
| t2 | v2 | v4 | v3 |
| t3 | v5 | v2 | v6 |
| ... | ... | ... | ... |

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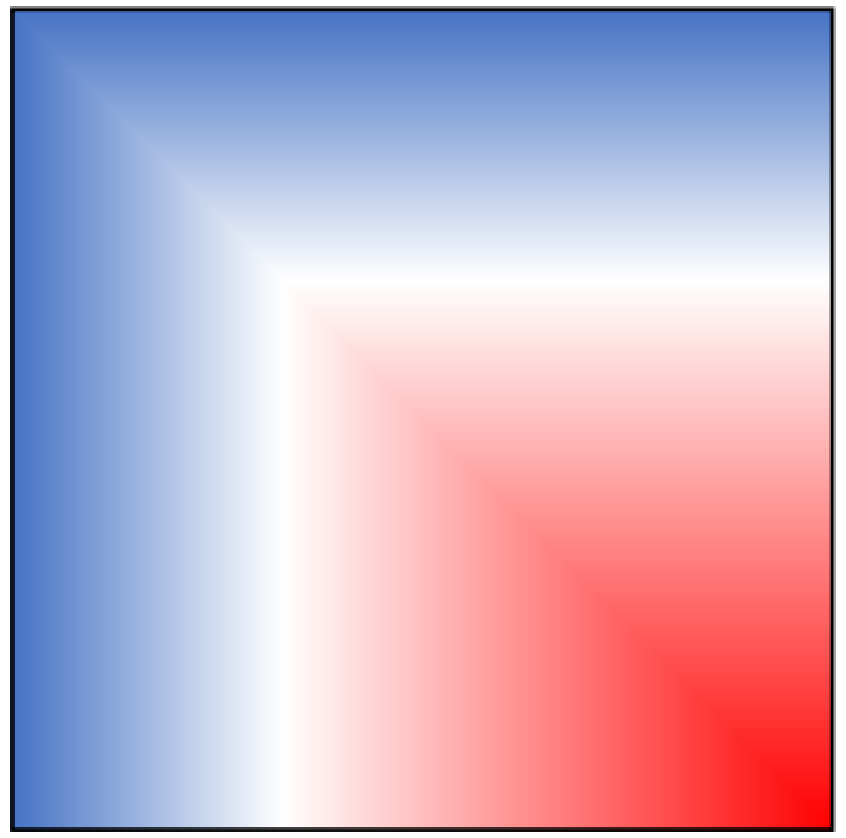
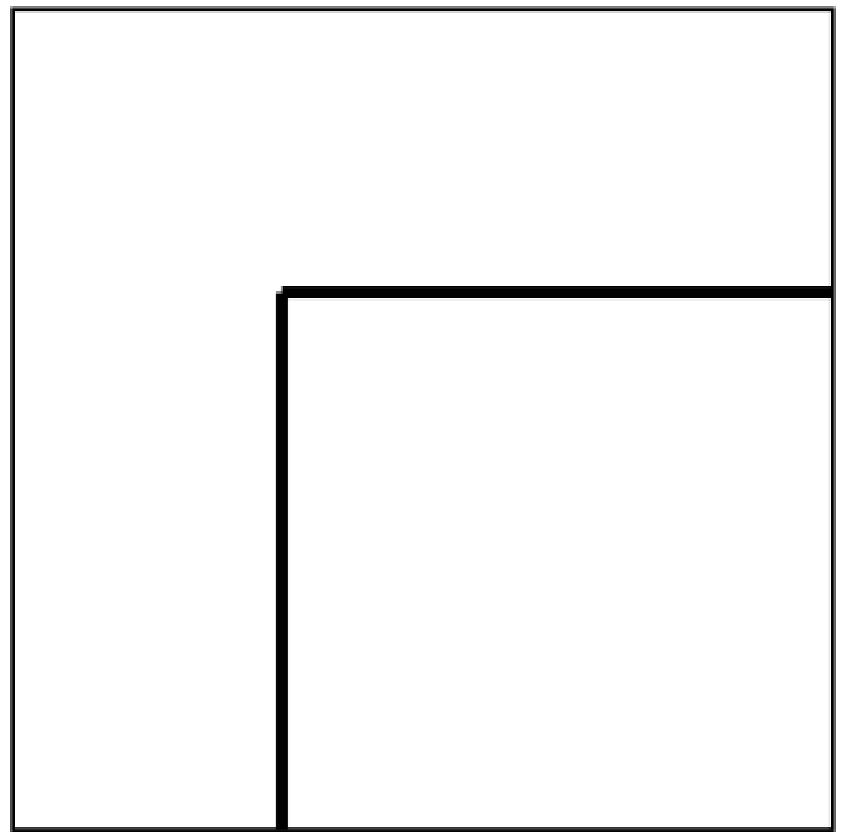
## 3D shape representations: *Implicit Functions*

- **Implicit function**
  - Classifies arbitrary $3D$ points as inside / outside the shape



Implicit function



Explicit Shape

Justin Solomon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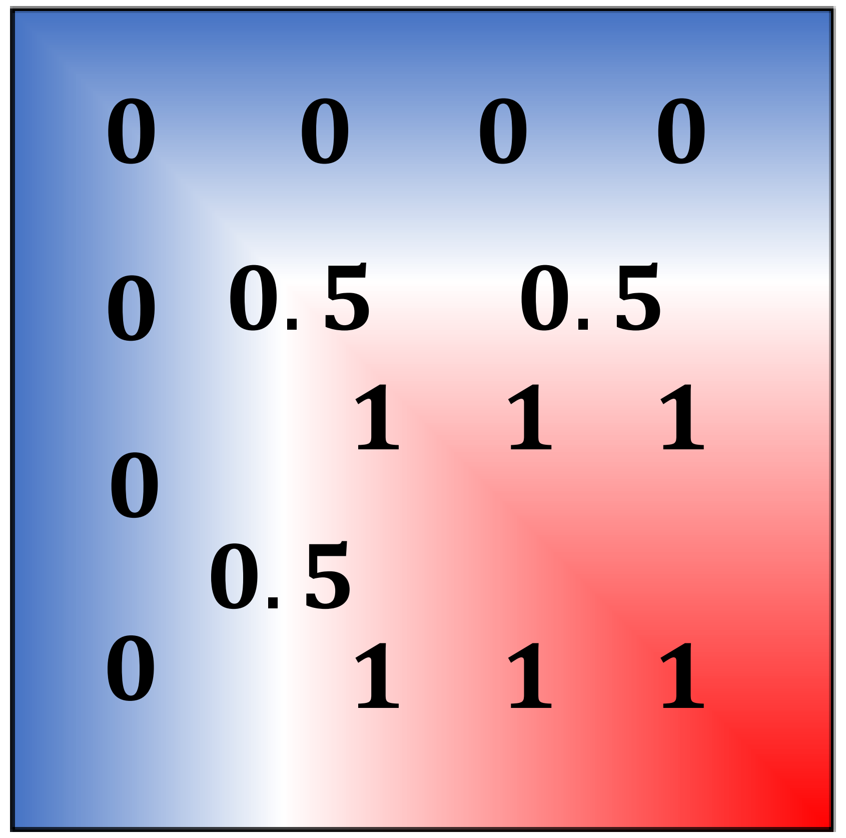
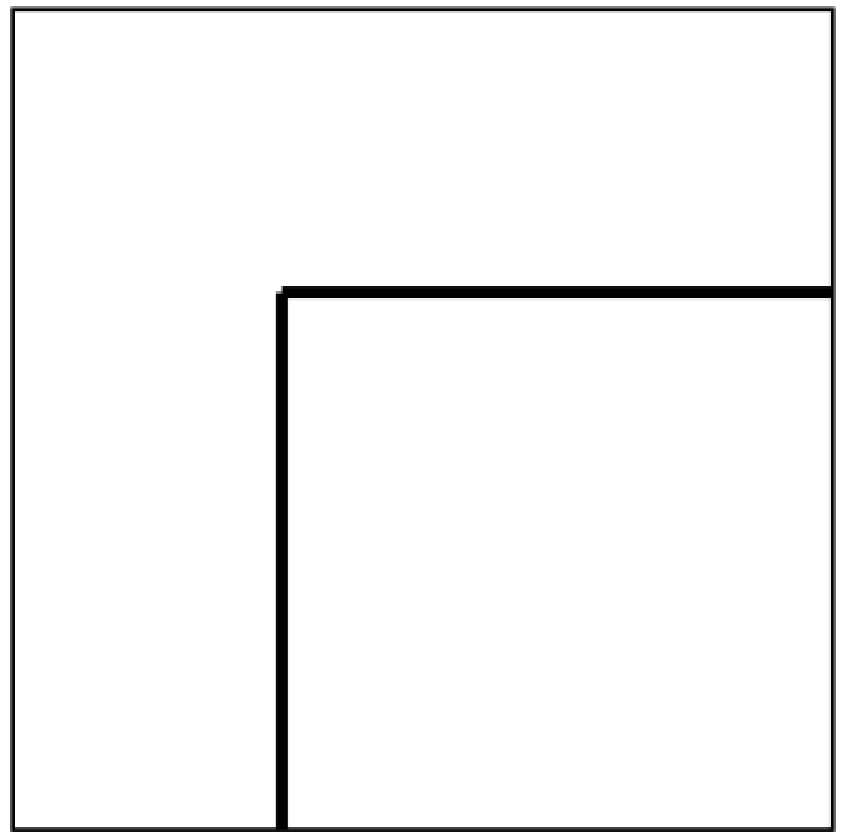
## 3D shape representations: *Implicit Functions*

- **Implicit function**
  - Classifies arbitrary $3D$ points as inside / outside the shape
  - **Occupancy function**:
    $$o : \mathbb{R}^3 \rightarrow \{0,1\}$$
  - The surface of the 3D object is the **level set**:
    $$\{x\colon \boldsymbol{o}(x) = \frac{1}{2}\}$$



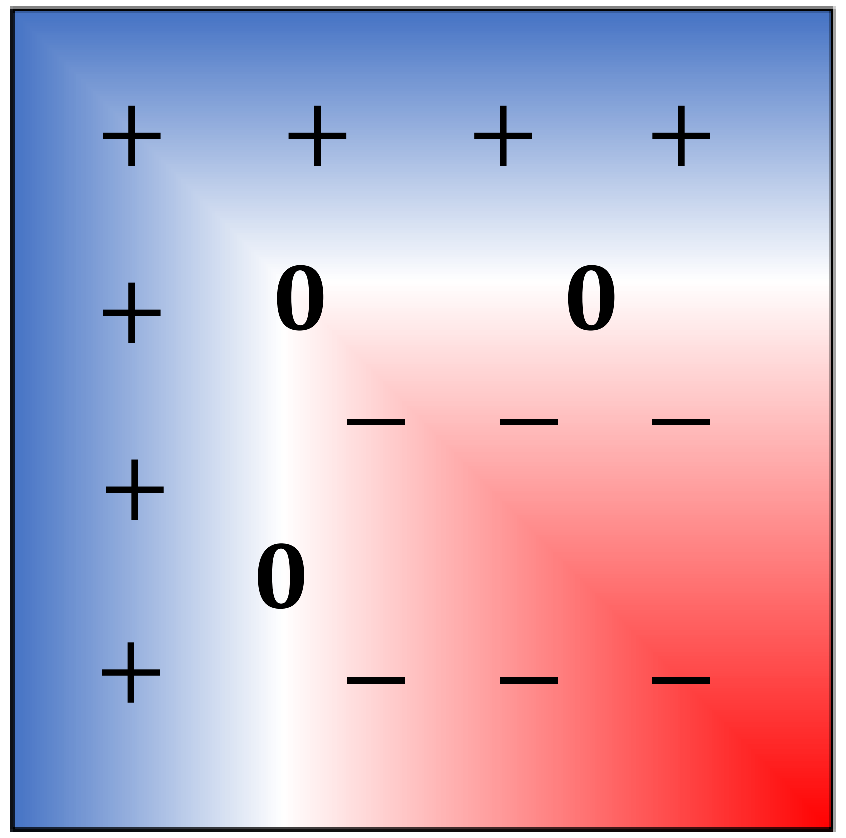
Implicit function


Explicit Shape

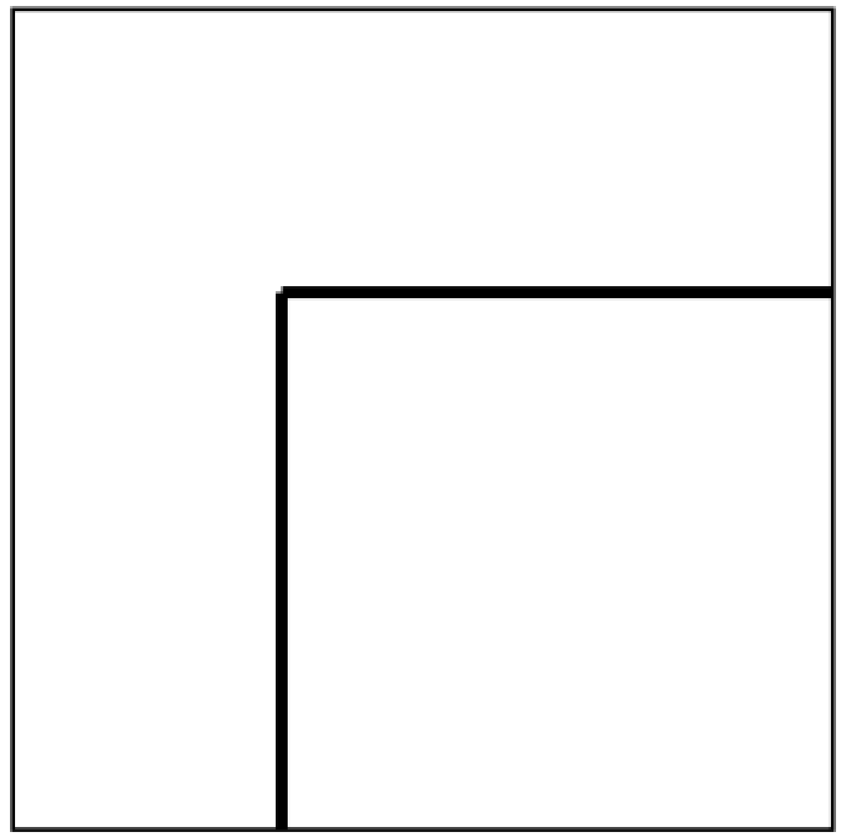
Justin Solomon

# 3D shape representations: *Implicit Functions*

- **Implicit function**
  - Classifies arbitrary $3D$ points as inside / outside the shape
  - **Signed Distance Function:** Euclidean distance to the surface of shape; sign gives inside / outside
  - The surface of the 3D object is the **level set**:
    $$\{x: \boldsymbol{SDF}(x) = 0\}$$




Implicit function

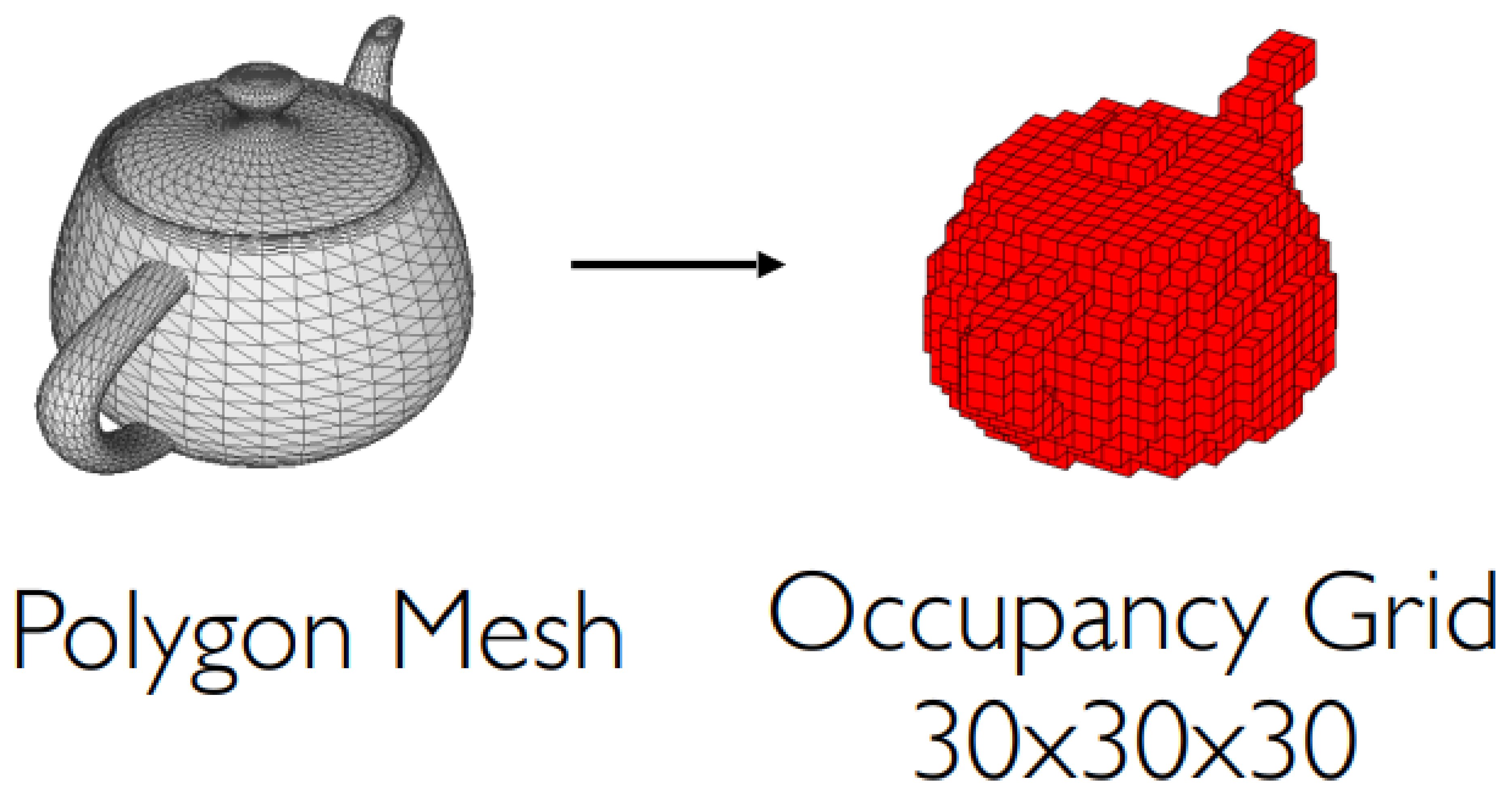


Explicit Shape

Justin Solomon

# 3D shape representations: *Volumetric Grid*

- **Volumetric Grid**
  - Represent a shape with a $V \times V \times V$ grid of occupancies or SDFs
  - Conceptually simple → just a 3D **regular Euclidean** grid
  - Like an image
    - Pixels –> Voxels
  - Straightforward to apply 3D convolutions




Hao Su et al.

# Today's Agenda

- Who are we?
- What is 3D Vision
- Geometry
- 3D shape representations
- 3D shape datasets
- 3D Deep Learning architectures
- What we do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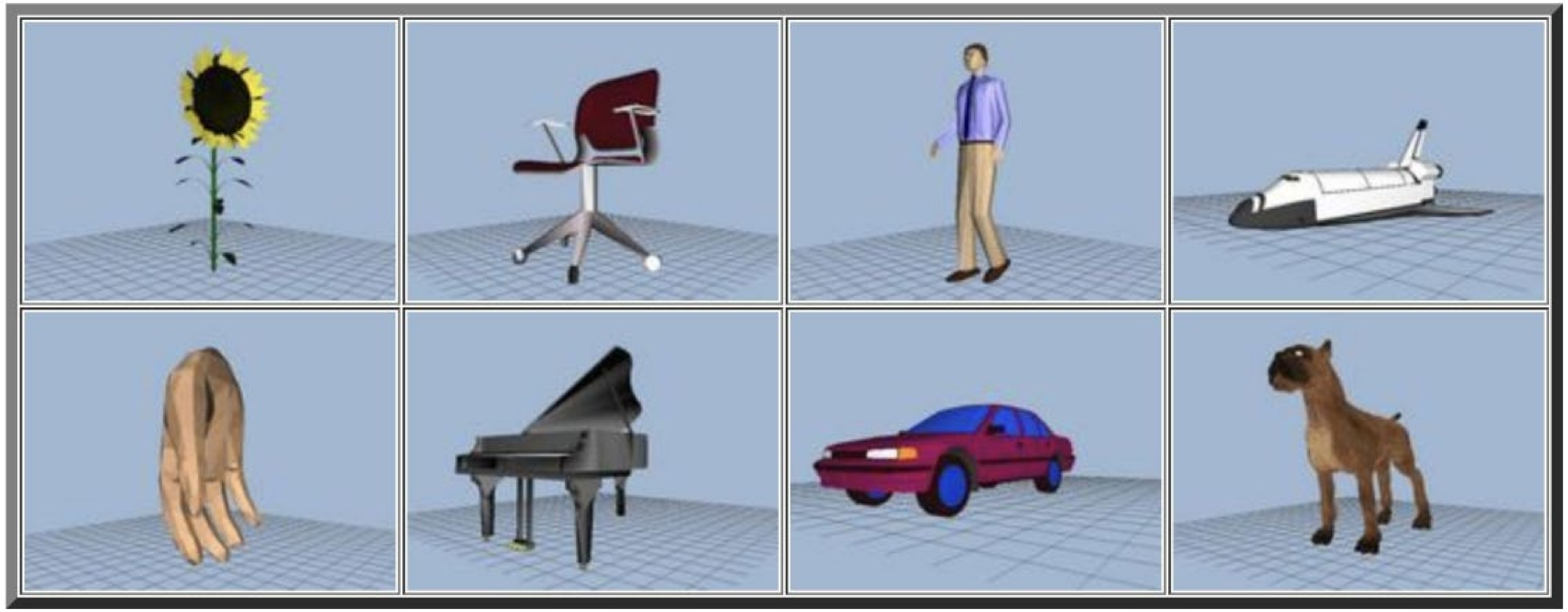
## 3D shape datasets: *Datasets for 3D Objects*

- **Princeton Shape Benchmark**
  - # Models: 1,814
  - # Categories: 182



Shilane et al., 2004

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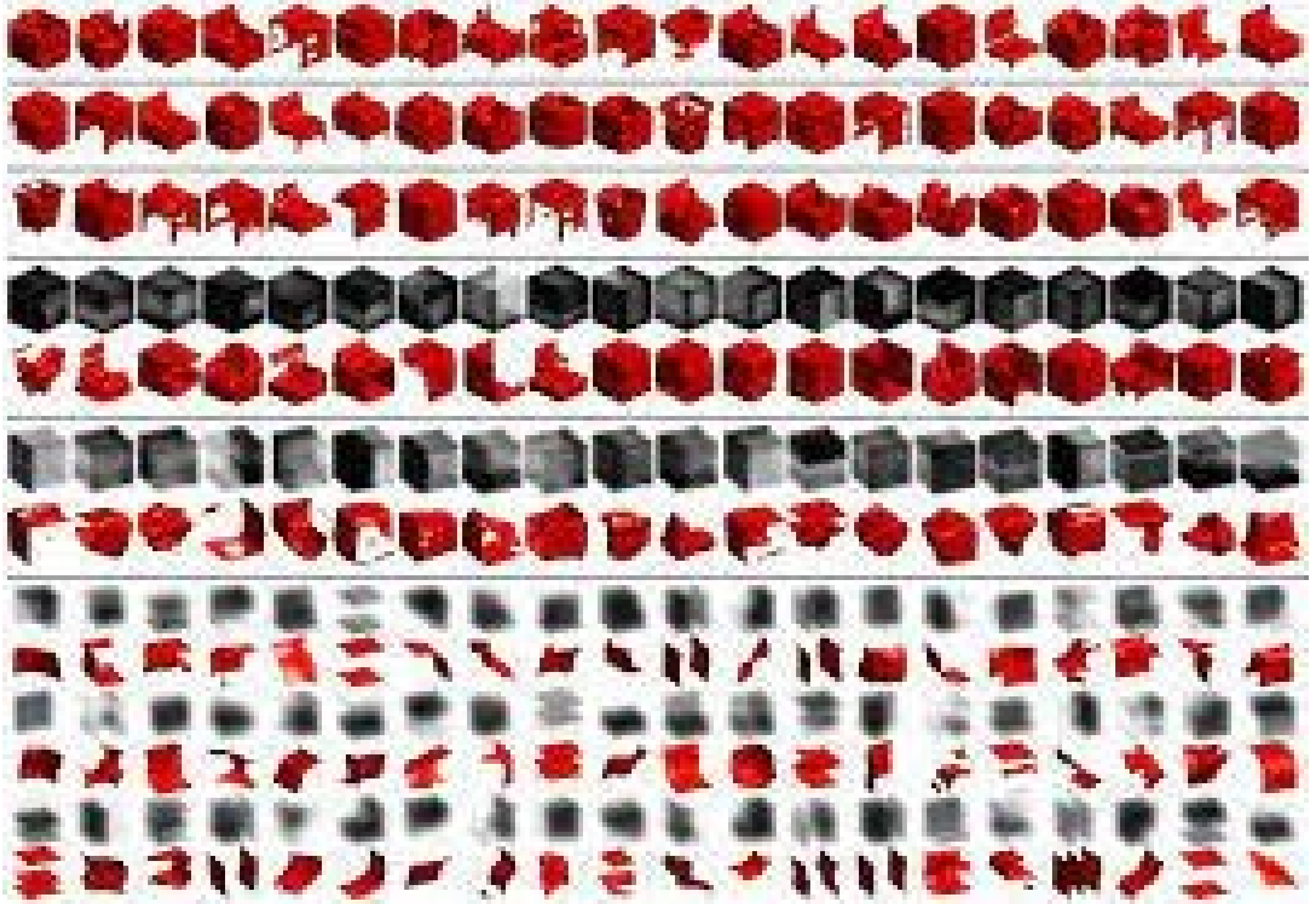
## 3D shape datasets: *Datasets for 3D Objects*

- **ModelNet40 and ModelNet40**
  - # Models: 12,311
  - # Categories: 40
- **ModelNet10** (subset of ModelNet10)
  - # Models: 4,899
  - # Categories: 10



Z. Wu et al., 2015

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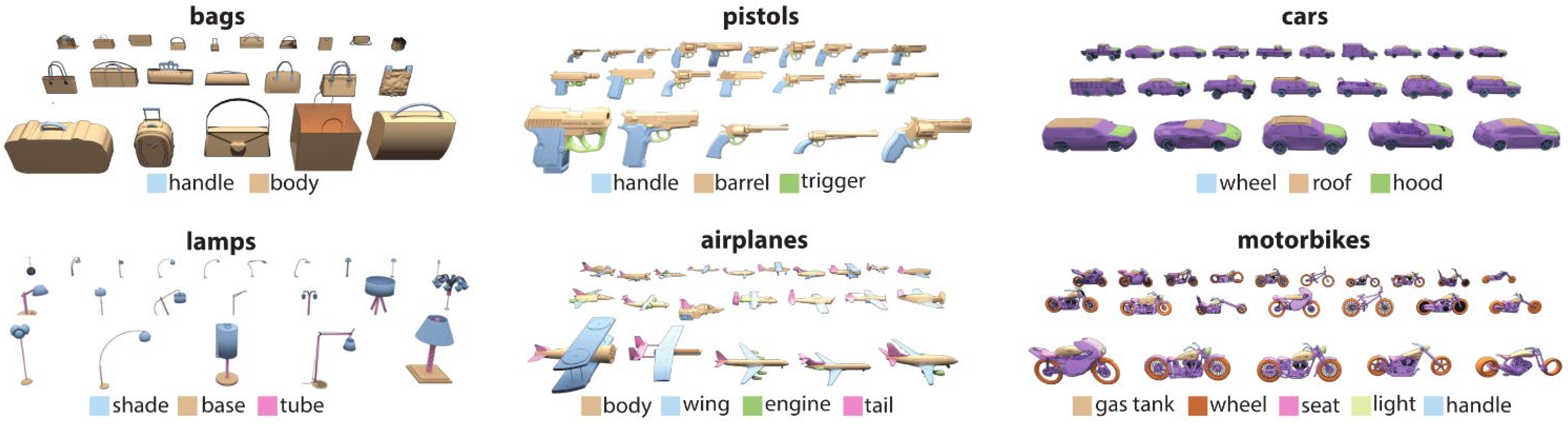
## 3D shape datasets: *Datasets for 3D Objects*

- **ShapeNet**
  - # Models: 3M (not publicly available)
- **ShapeNetCore** (subset of ShapeNet)
  - # Models: 51,300
  - # Categories: 55

Change et al., 2015

## 3D shape datasets: *Datasets for 3D Objects Parts*

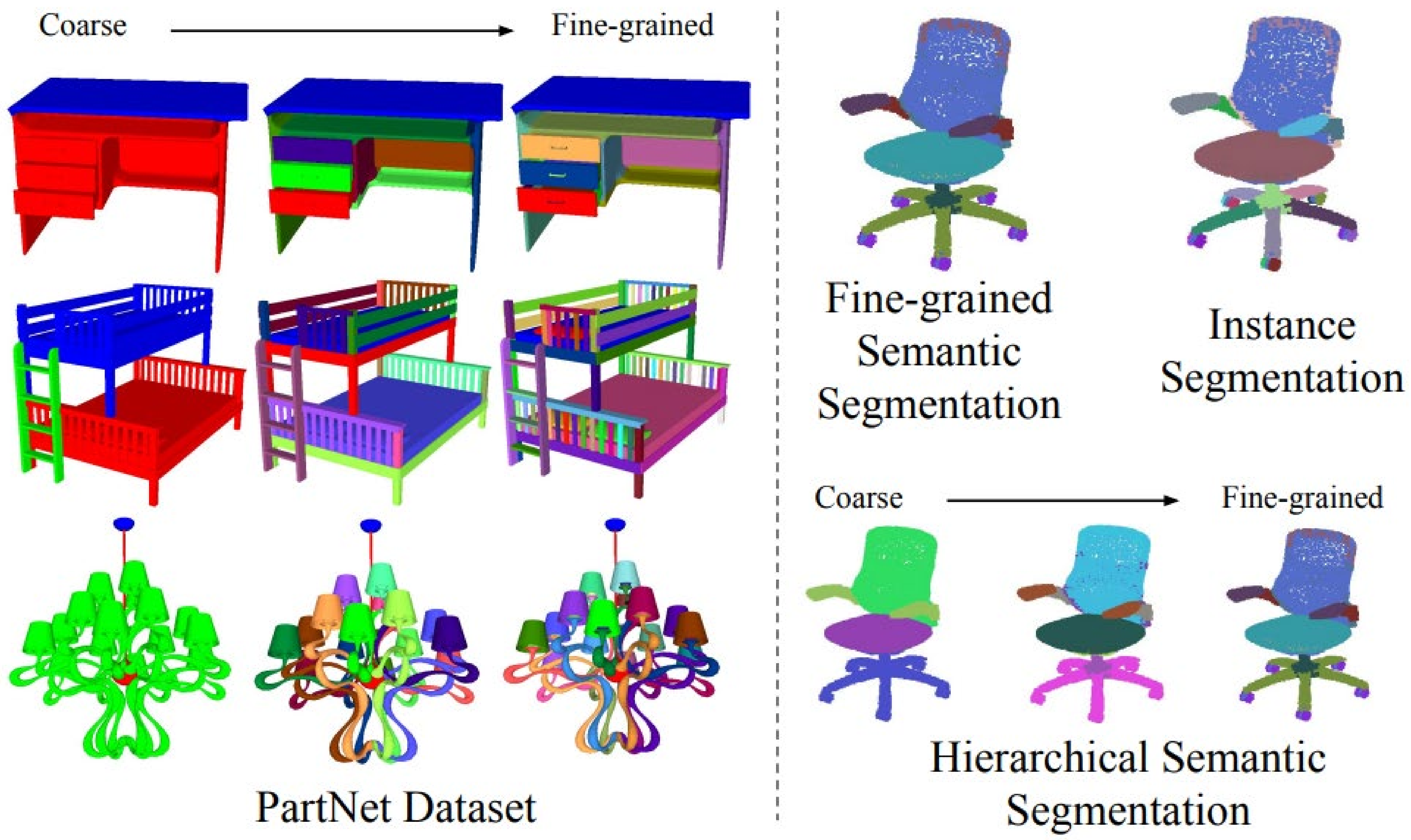
- **ShapeNet-Part** (subset of ShapeNet)
  - # Models: 16,881
  - # Categories: 16
  - # Semantic parts: 50




Yi et al., 2016

## 3D shape datasets: *Datasets for 3D Objects Parts*

- **PartNet** (subset of ShapeNet)
  - # Models: 26,671
  - # Categories: 24
  - # Part instances: 573,585
  - # Semantic parts: 480
  - Fine-grained
  - Hierarchical




Mo et al., 2019

## 3D shape datasets: *Datasets for 3D Objects*

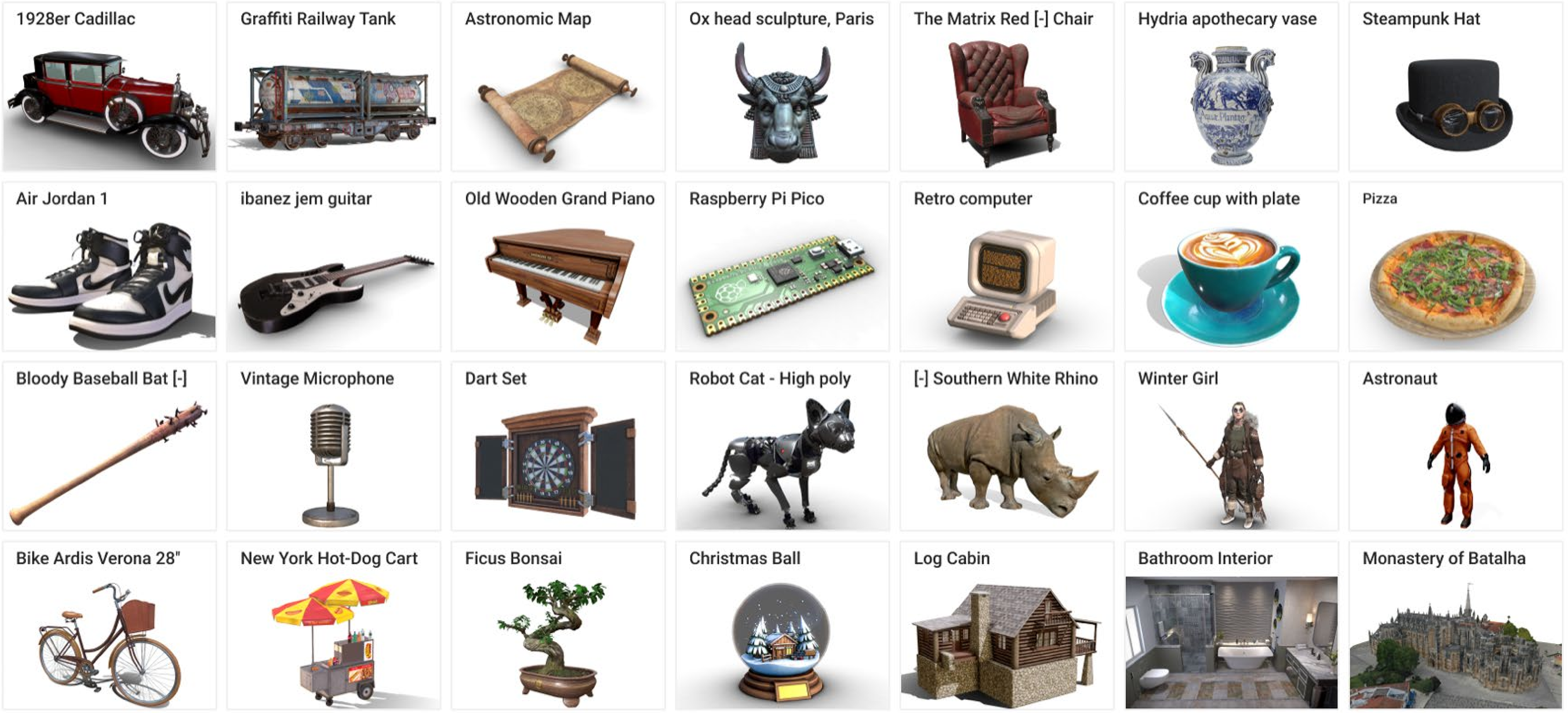
- **Pix3D**
  - # Images: 10,069
  - # Models: 395 (2D-3D aligned)




Sun et al., 2018

# 3D shape datasets: *Datasets for 3D Objects*

- **Objaverse 1.0**
  - # Models: 800,000+
  - # Categories: 21,000
  - Captions
  - Tags
  - Animations




Deitke et al., 2022

# 3D shape datasets: *Datasets for 3D Objects*

- **Objaverse-XL**
  - # Models: 10M+
  - Captions
  - Tags
  - Animations
  - CLIP embeddings

Deitke et al., 2023

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## 3D shape datasets: *Datasets for Indoor 3D Scenes*

- **Large-scale Scanned Real Scenes: ScanNet**
  - # Views: 2.5M
  - # RGBD scans: 1,500
  - 3D camera poses
  - Surface reconstruction
  - Instance-level semantic segmentations

Dai et al., 2017

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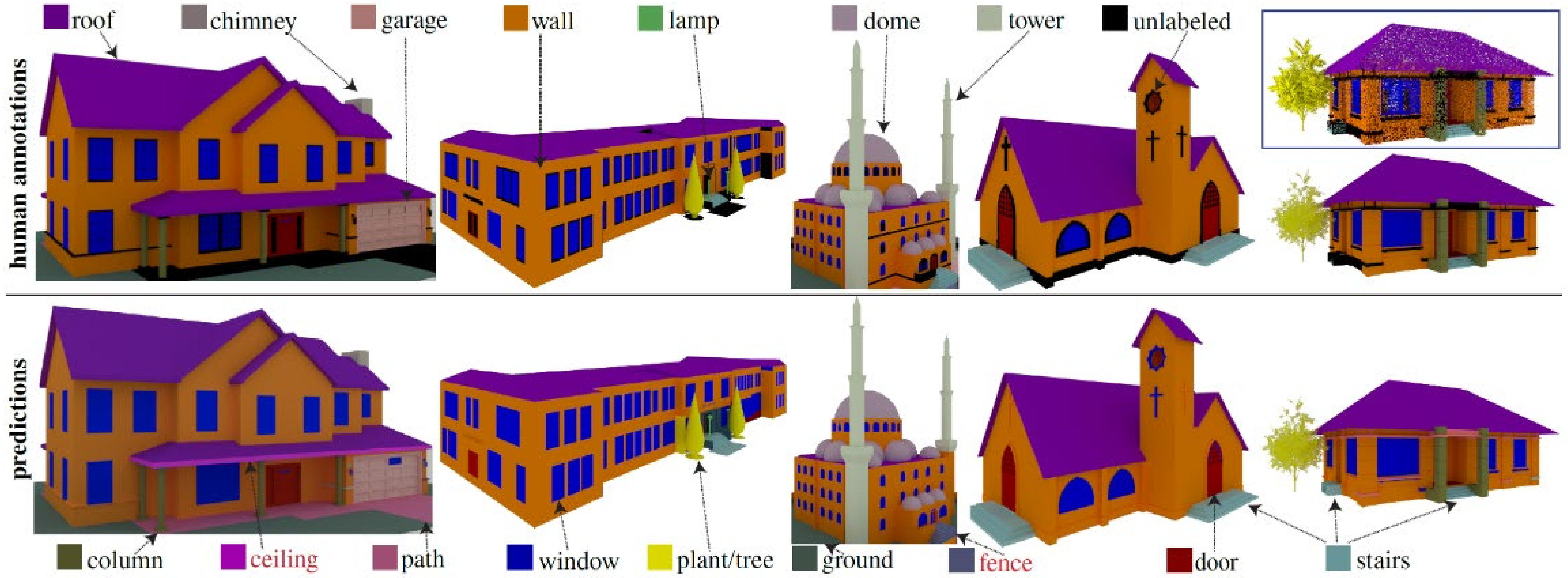
# 3D shape datasets: *Datasets for 3D Buildings*

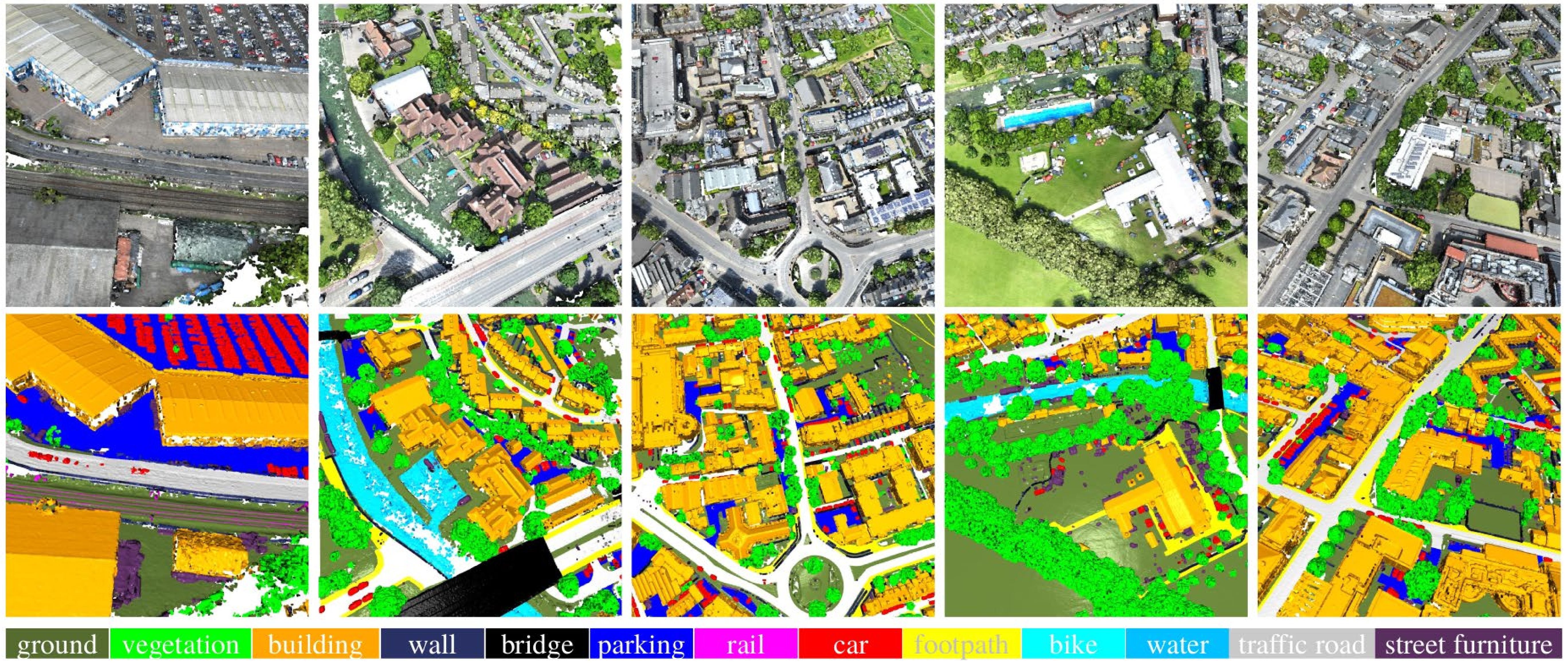
- **BuildingNet**
  - # Models: 2,000
  - # Semantic Components: 292K
  - # Semantic Parts: 31
  - Semantic segmentation
  - Surface reconstruction




Selvaraju et al., 2021

# 3D shape datasets: *Datasets for Urban Areas*

- **SensatUrban**
  - # Points: 3B
  - # Semantic Classes: 13




Qingyong et al., 2022

Figure 3: Examples of our SensatUrban dataset. Different semantic classes are labeled by different colors.

# Today's Agenda

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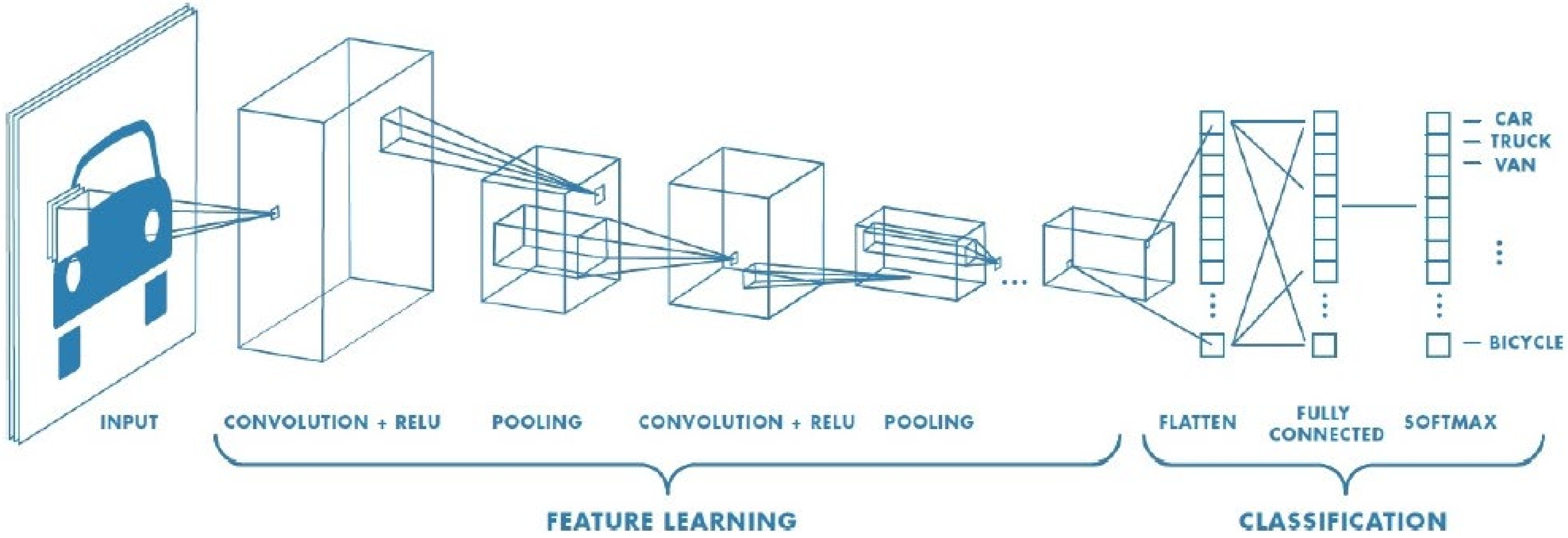
# 3D DL architectures: *2D architectures "success story"*

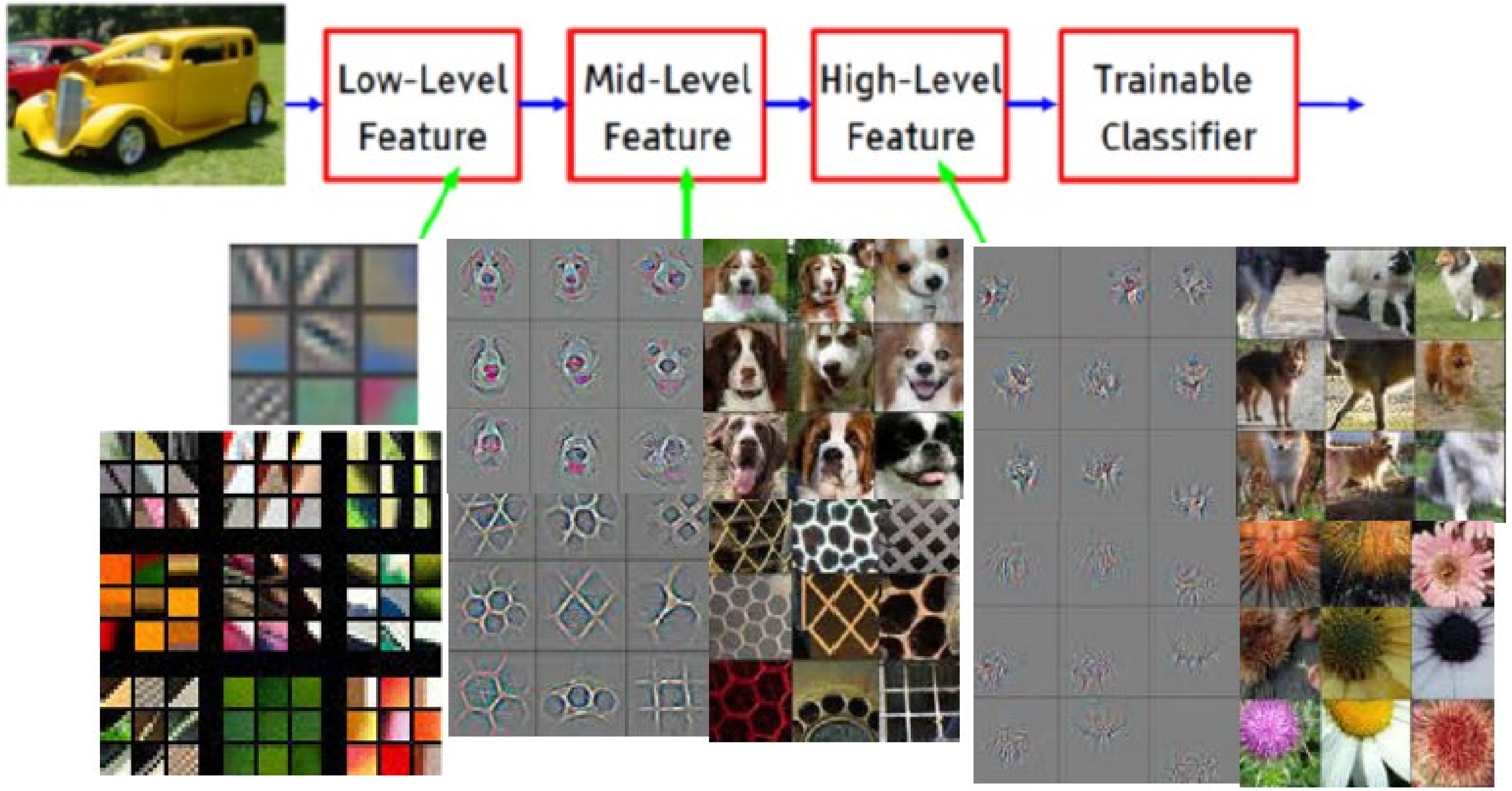
Layers of **convolutional filters** trained to extract descriptors + **learned functions** that map descriptors to high-level concepts




Kalogerakis E.

## 3D DL architectures: *2D architectures "success story"*

Can capture various **low-level** and **high-level** features through hierarchical representation learning. **Very good performance** in 2D vision tasks (class., seg., obj. det.…)

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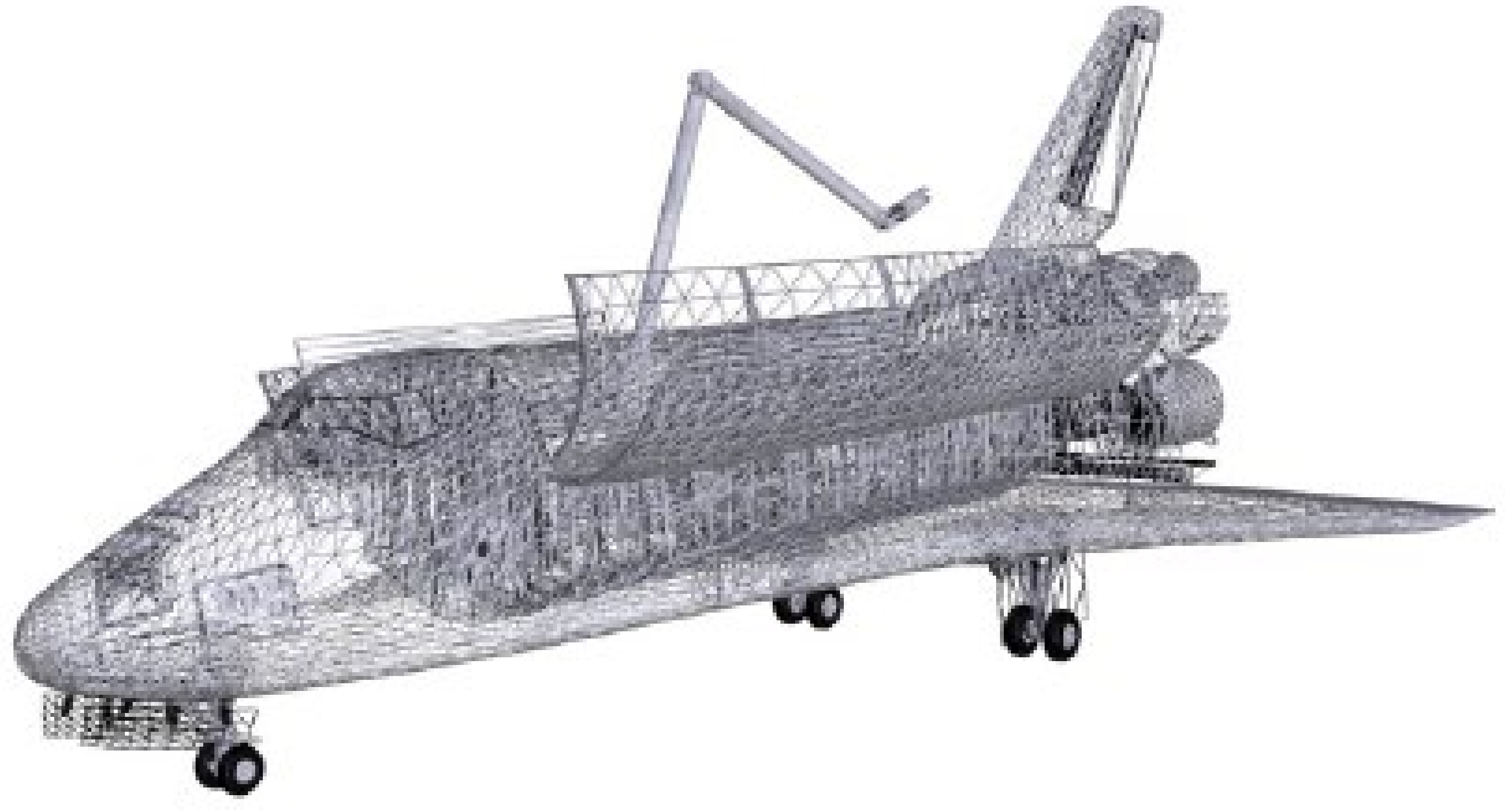
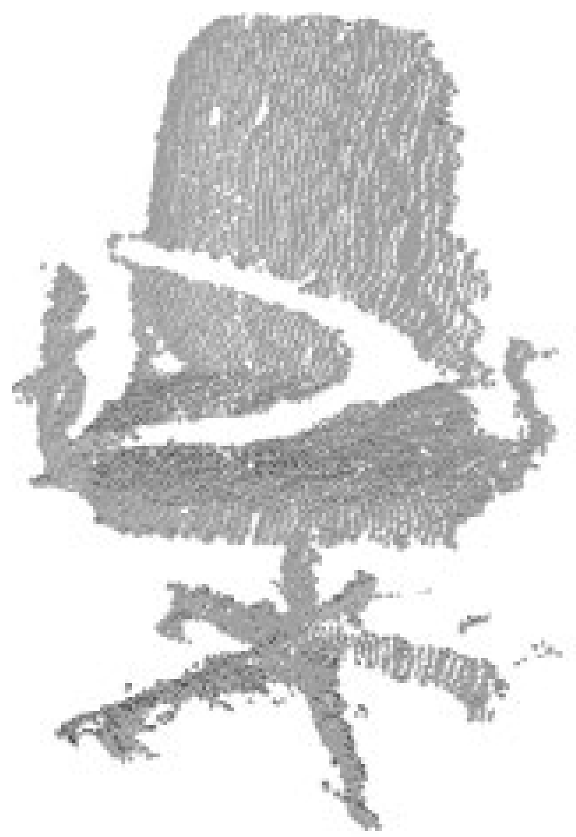
## 3D DL architectures: *Challenges – How do we apply convnets in 3D shapes*

Geometric representations are **irregular** and **unordered**: arbitrary point order, different #points, different #neighbor per point etc.



Polygon mesh



Point clouds

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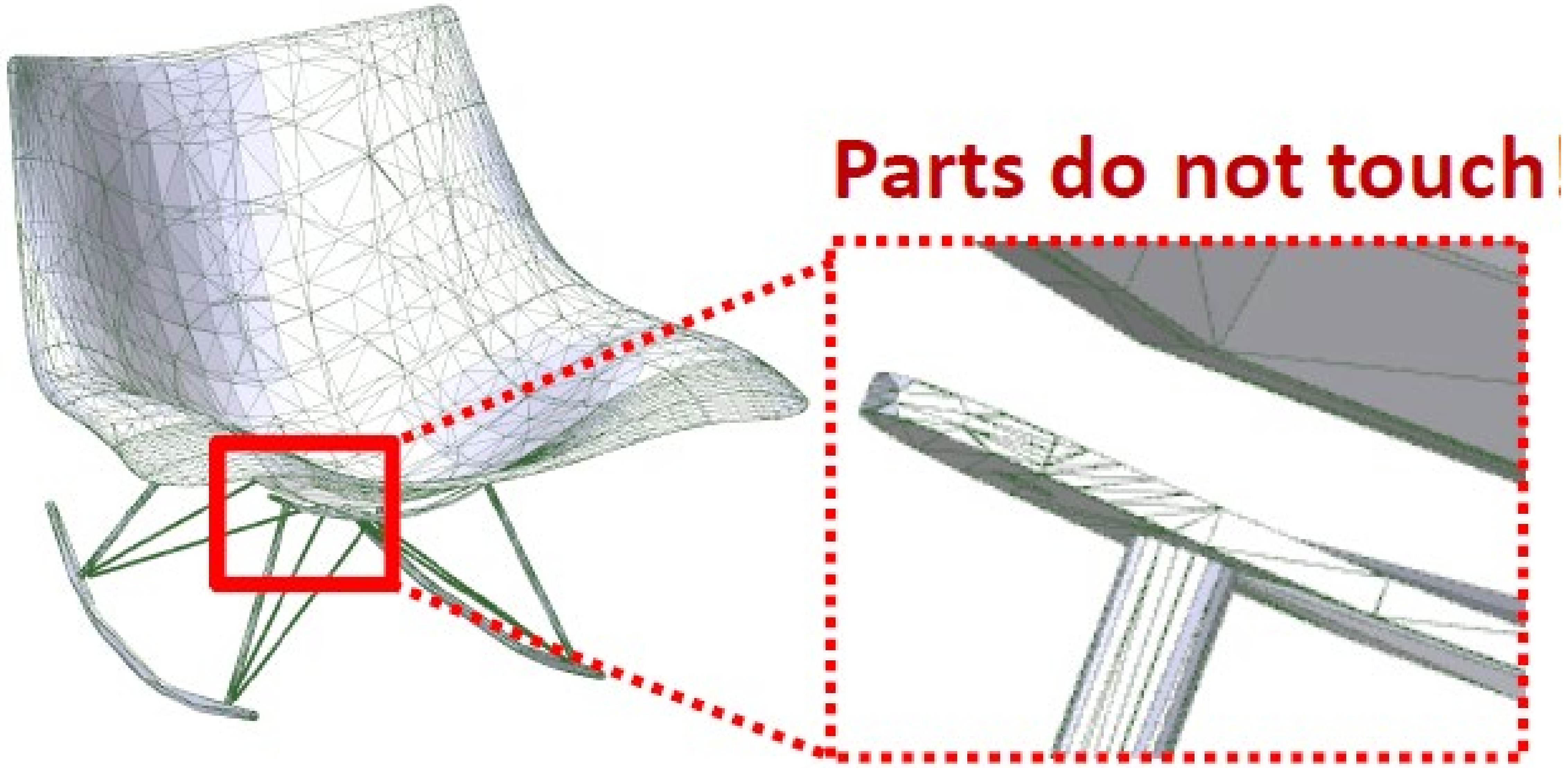
# 3D DL architectures: *Challenges – Artifacts*

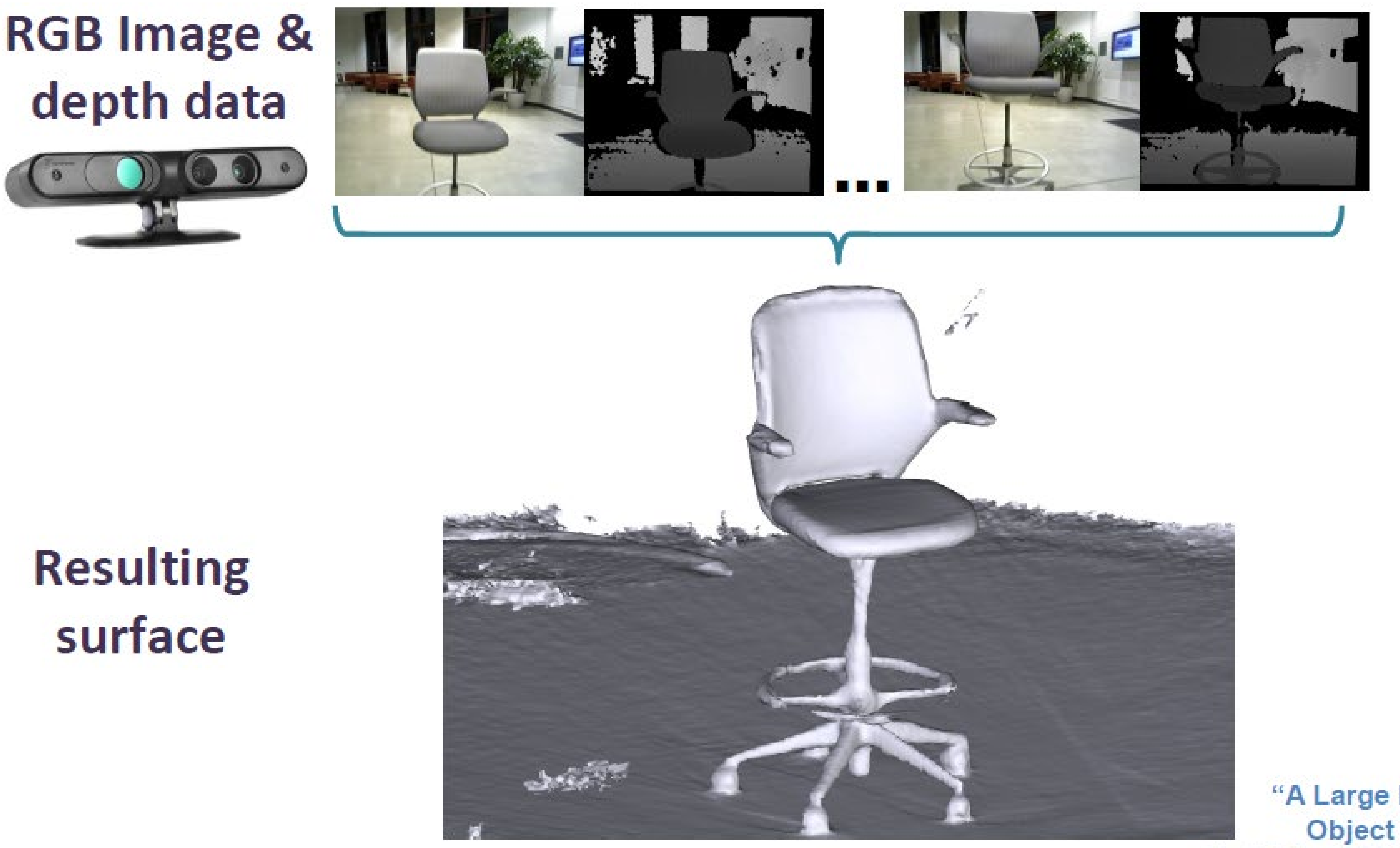
3D models can have several **artifacts**




Kalogerakis E.

## 3D DL architectures: *Challenges – Noise*

Scanned surfaces have **noisy** and **missing parts**




"A Large Dataset of Object Scans"
Choi, Zhou, Miller, Koltun 2016

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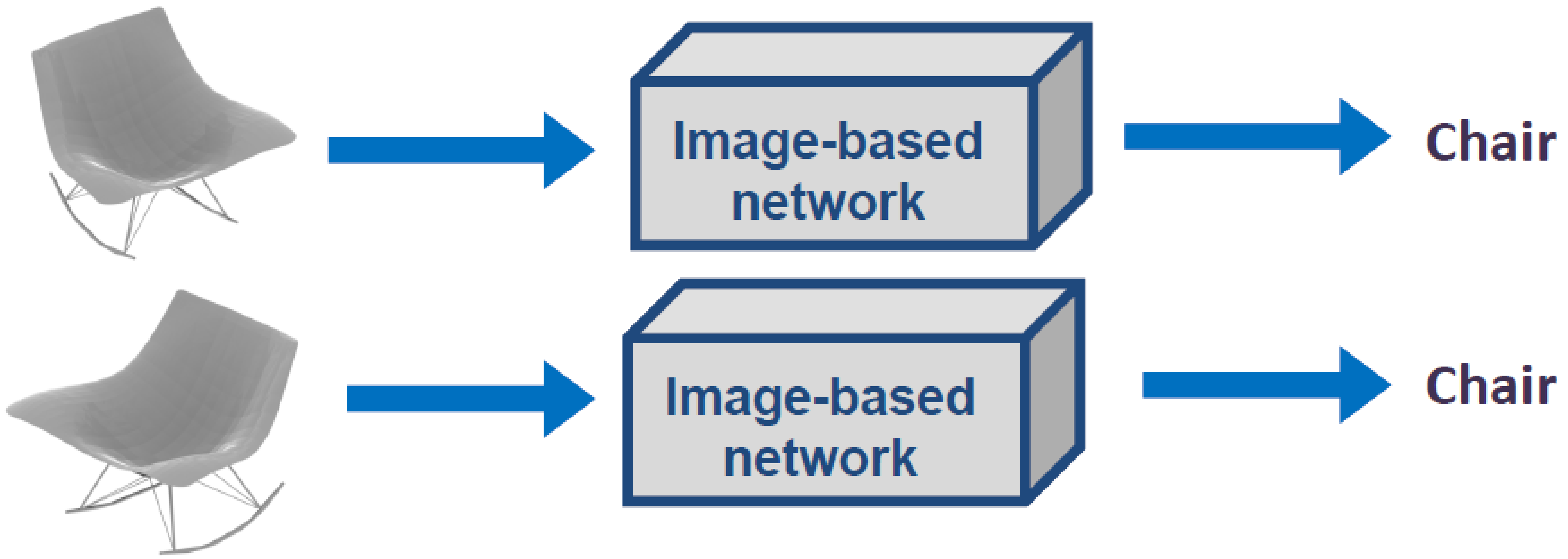
# 3D DL architectures: *Multi-view approach*

Image-based networks can process individual shape renderings

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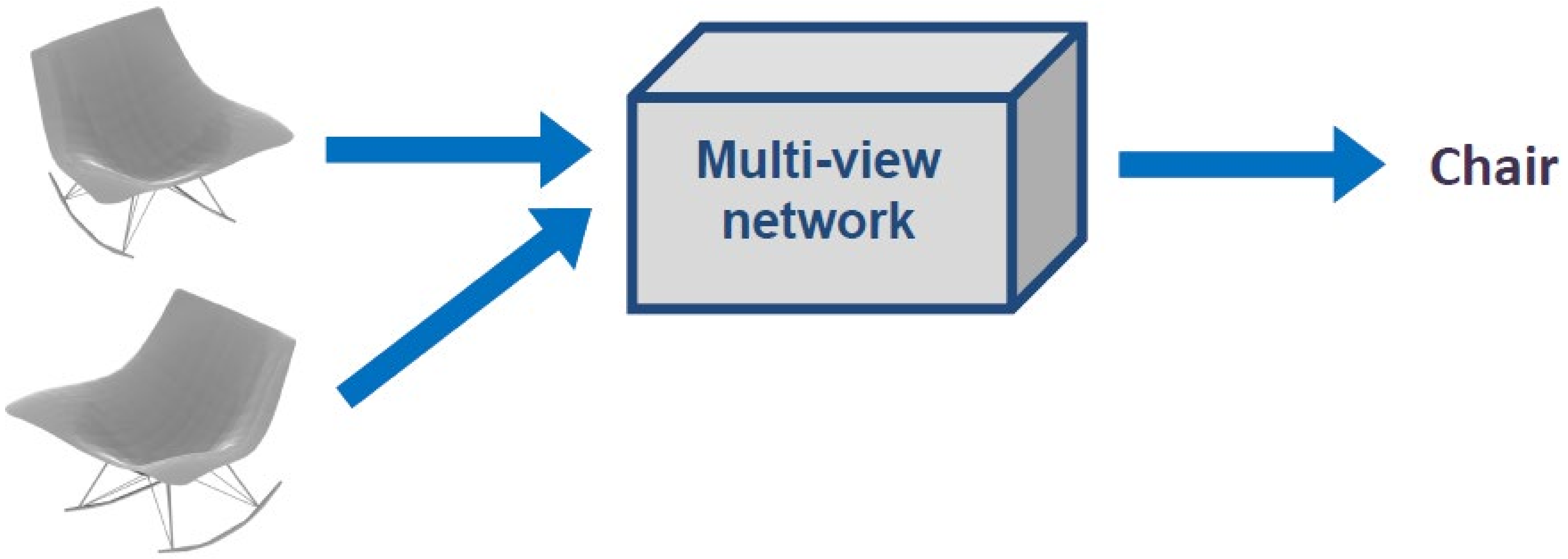
## 3D DL architectures: *Multi-view approach*

Image-based networks can process individual shape renderings

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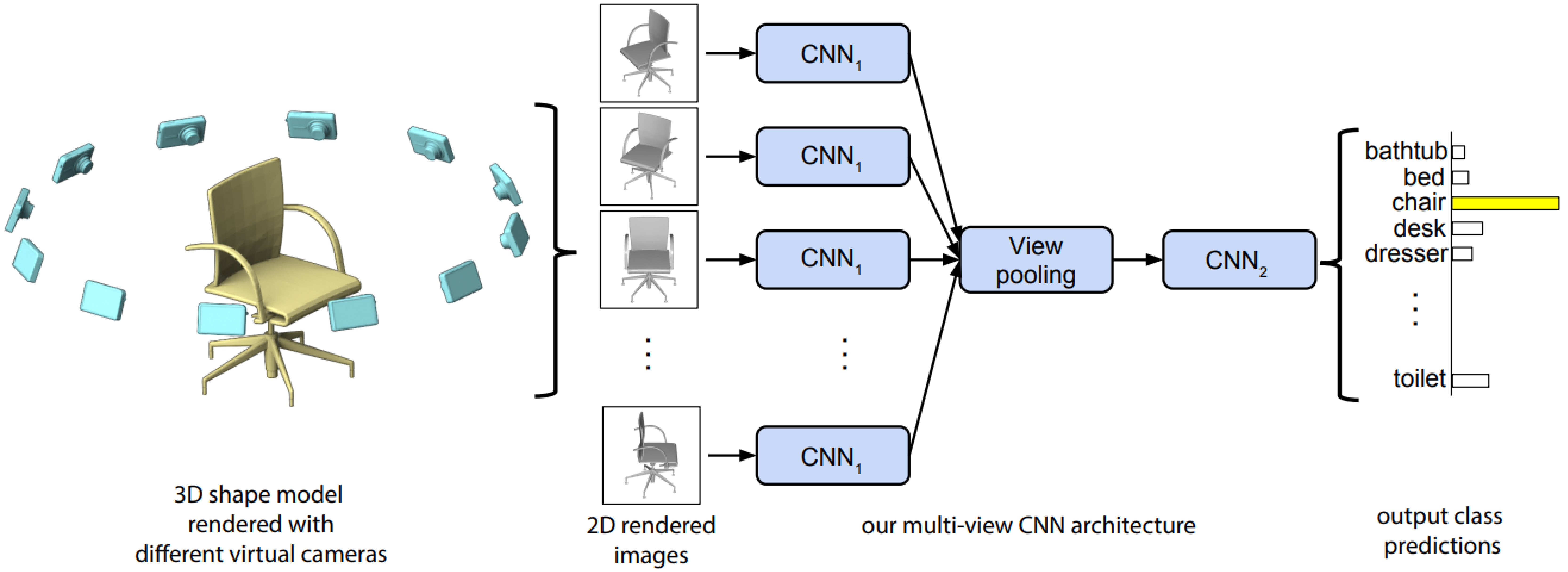
# 3D DL architectures: *Multi-view approach*

## Multi-view Convolutional Neural Networks for 3D Shape Recognition




Hang Su et al.
ICCV 2015

# 3D DL architectures: *Multi-view approach*

## Multi-view Convolutional Neural Networks for 3D Shape Recognition

Hang Su et al.
ICCV 2015

# 3D DL architectures: *Multi-view approach*

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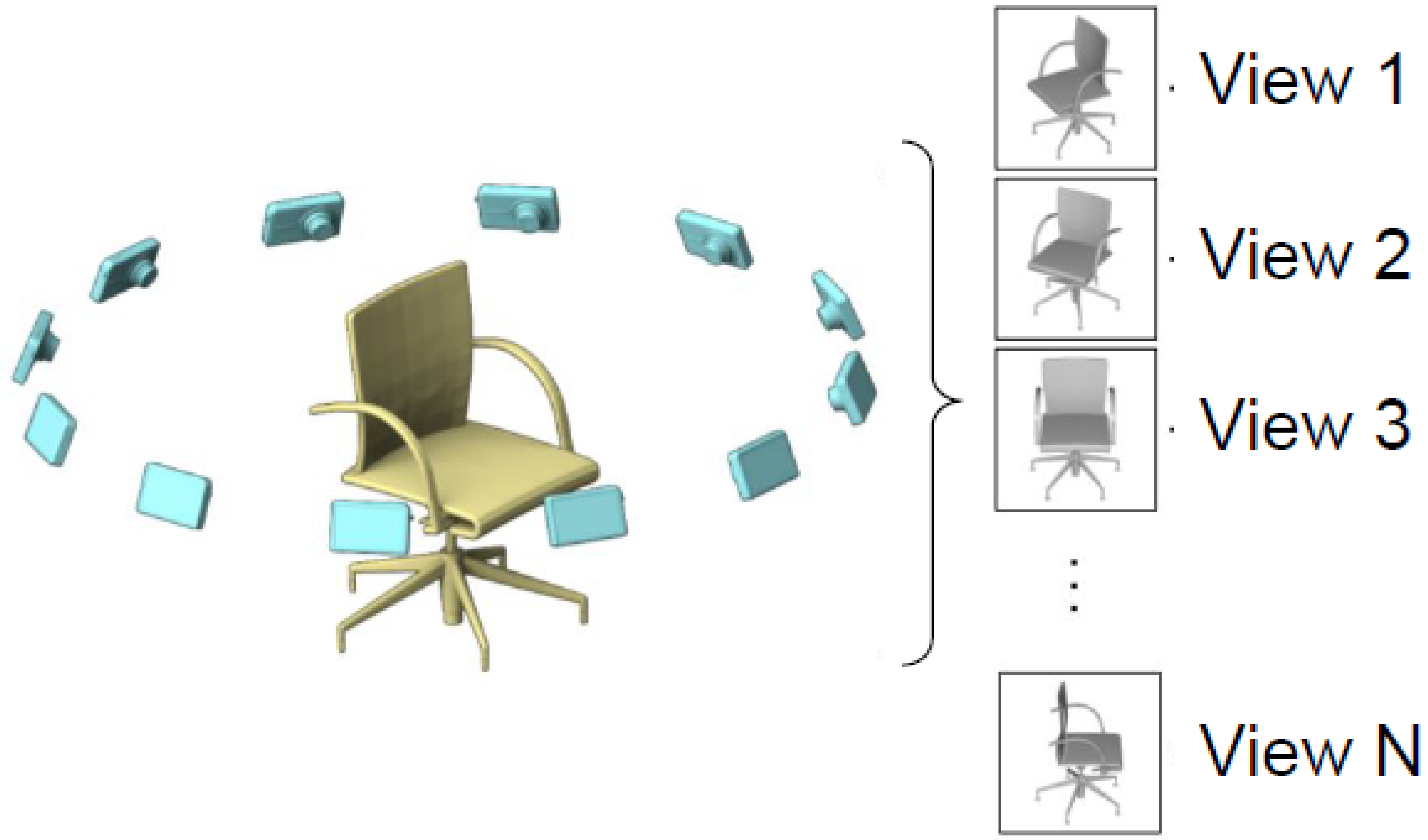
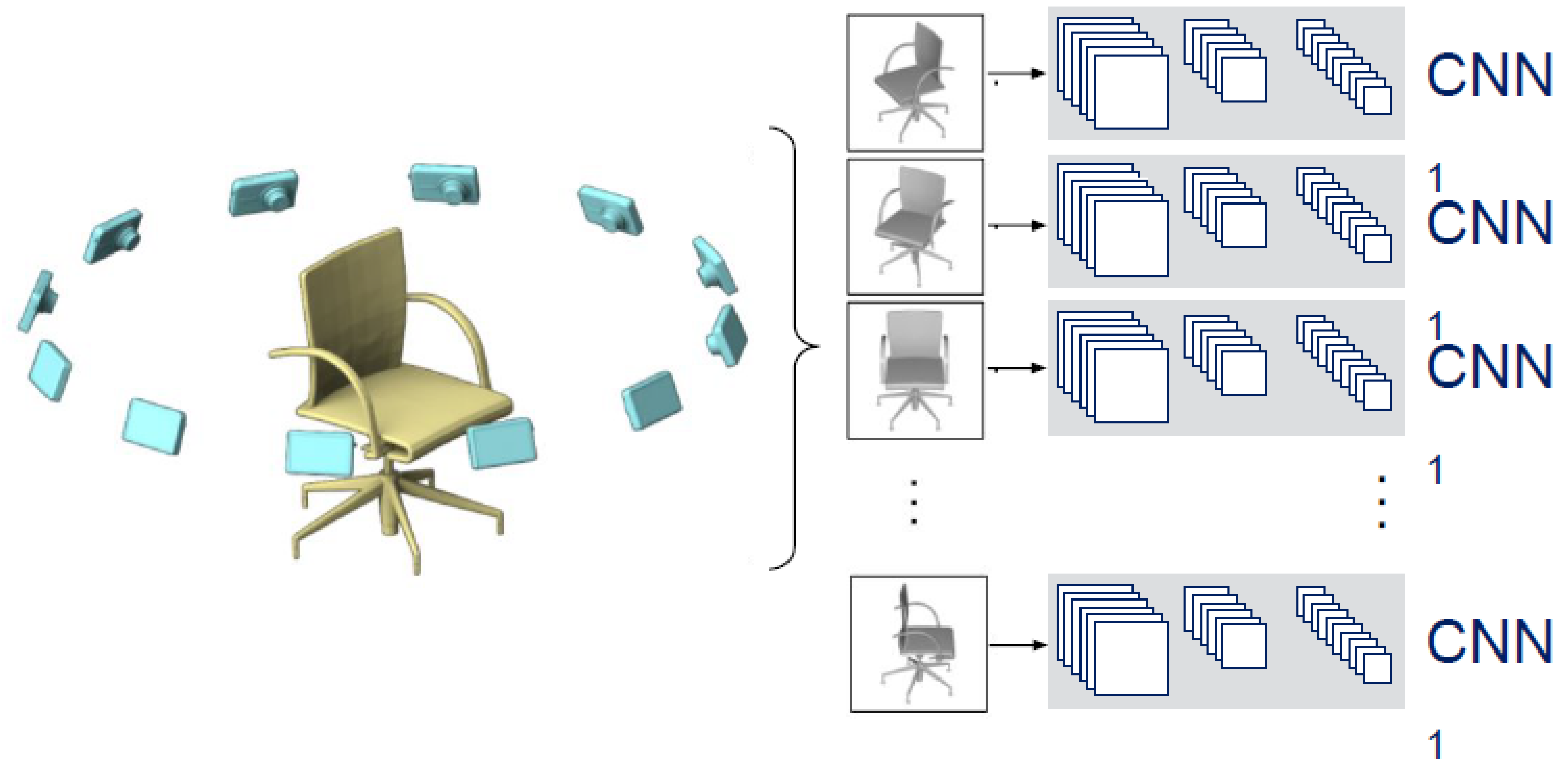



Hang Su et al.
ICCV 2015

# 3D DL architectures: *Multi-view approach*

## Multi-view Convolutional Neural Networks for 3D Shape Recognition




CNN$_1$: a ConvNet extracting image features

Hang Su et al.
ICCV 2015

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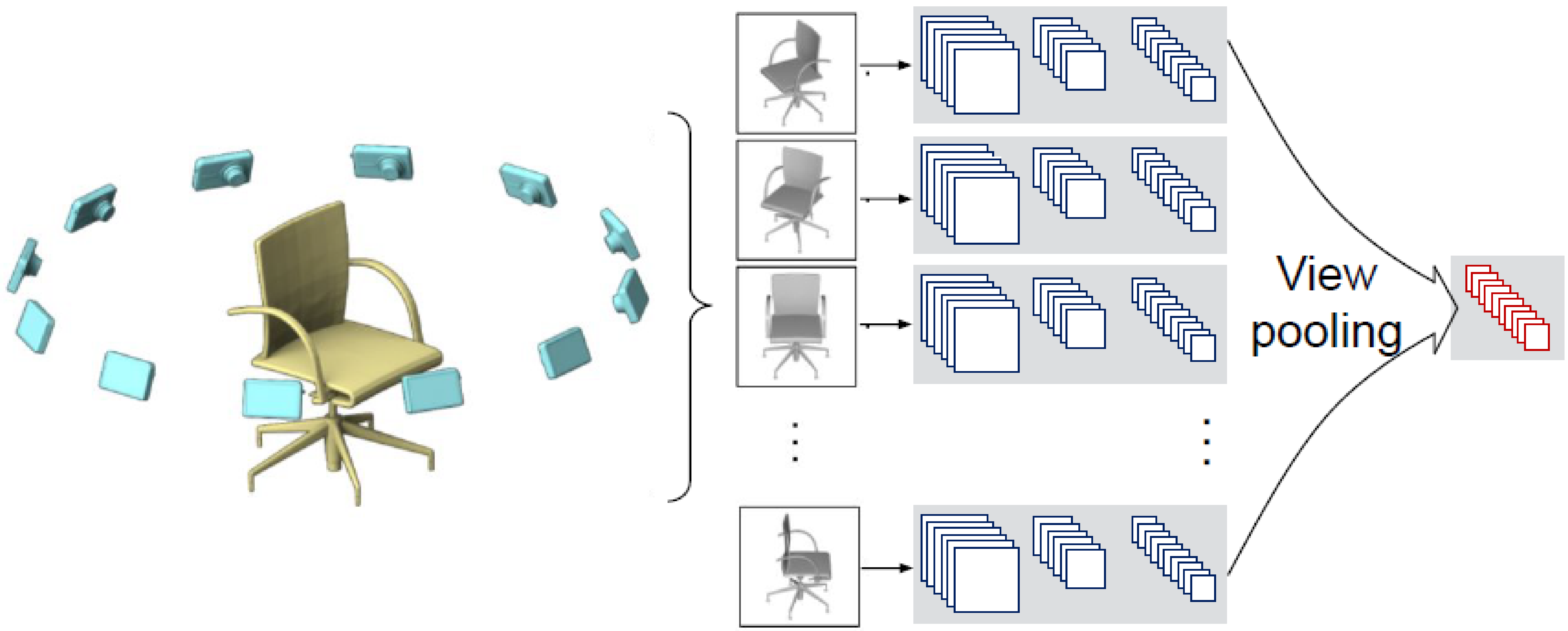
# 3D DL architectures: *Multi-view approach*

## Multi-view Convolutional Neural Networks for 3D Shape Recognition

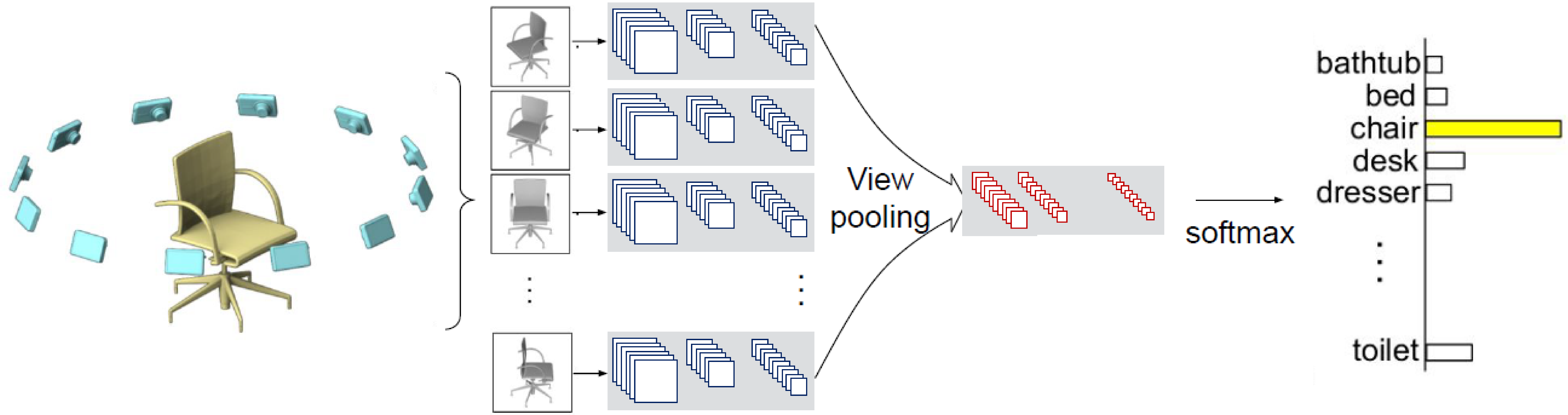



View pooling: element-wise max-pooling across all views

Hang Su et al.
ICCV 2015

# 3D DL architectures: *Multi-view approach*

## Multi-view Convolutional Neural Networks for 3D Shape Recognition




CNN$_2$: a second ConvNet producing shape descriptors

Hang Su et al. ICCV 2015



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# 3D DL architectures: *Multi-view approach*

## Multi-view Convolutional Neural Networks for 3D Shape Recognition

### ModelNet40: Classification & Retrieval

| Method | Classification (Accuracy) |
|---|---|
| Spherical Harmonics **[Kazhdan et al.]** | 68.2% |
| LightField **[Chen et al.]** | 75.5% |
| Volumetric Net **[Wu et al.]** | 77.3% |
| ImageNet-trained CNN (VGG-M, 1 view) | 83.0% |
| Multi-view convnet (MVCNN) | **90.1%** |

Hang Su et al.
ICCV 2015

# 3D DL architectures: *Multi-view approach*

## Multi-view Networks

- Pros:
  - ✓ Good performance
  - ✓ Can leverage vast literature of image classification
  - ✓ Can use pretrained features
- Cons
  - x Need projection
  - x Issue with noisy and/or incomplete input, e.g., point cloud

Jiajun Wu



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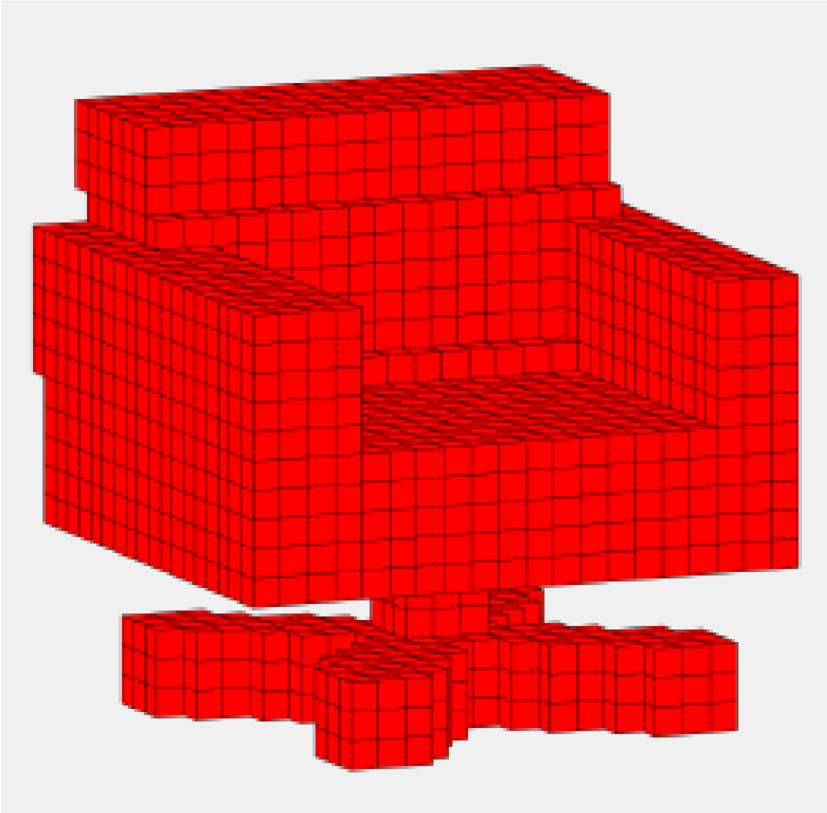
## 3D DL architectures: *Volumetric approach*

**Voxelization**: Convert shape to 3D regular volumetric grid

3D polygon mesh

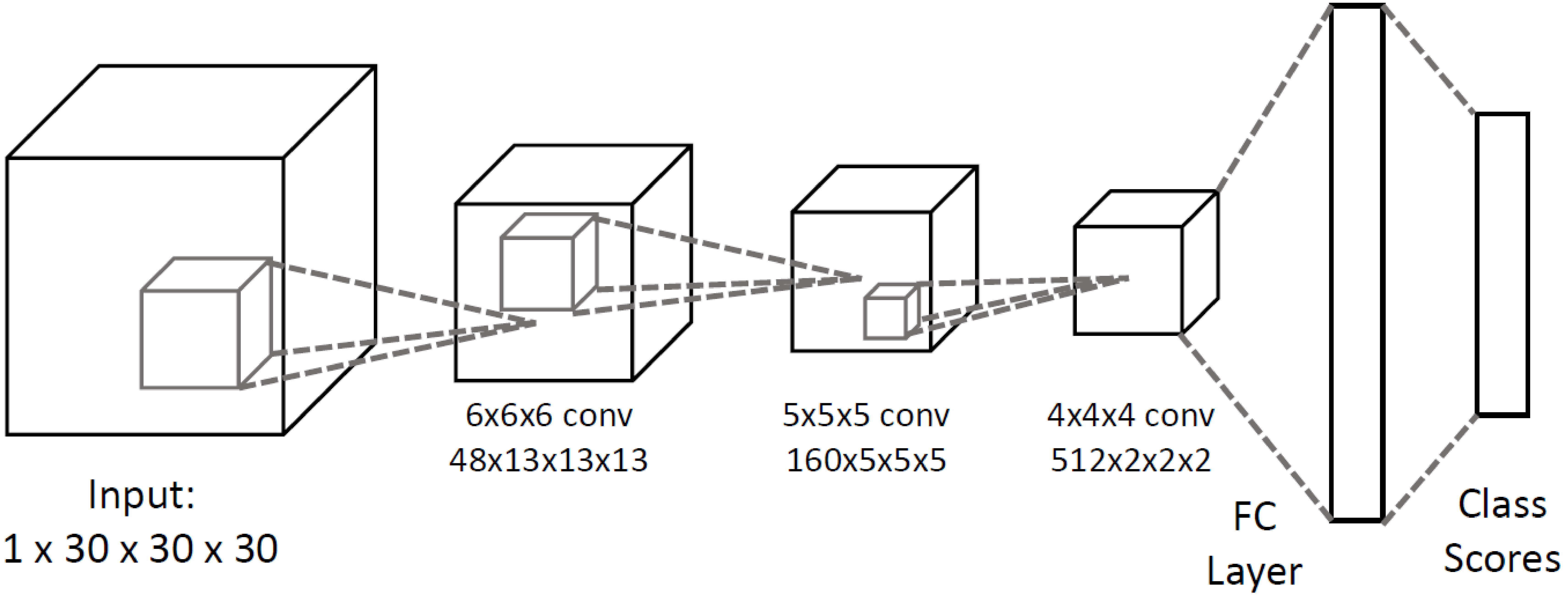


Voxels

Kalogerakis E.

# 3D DL architectures: *Volumetric approach*

## Processing Voxel Inputs –> **3D Convolution**

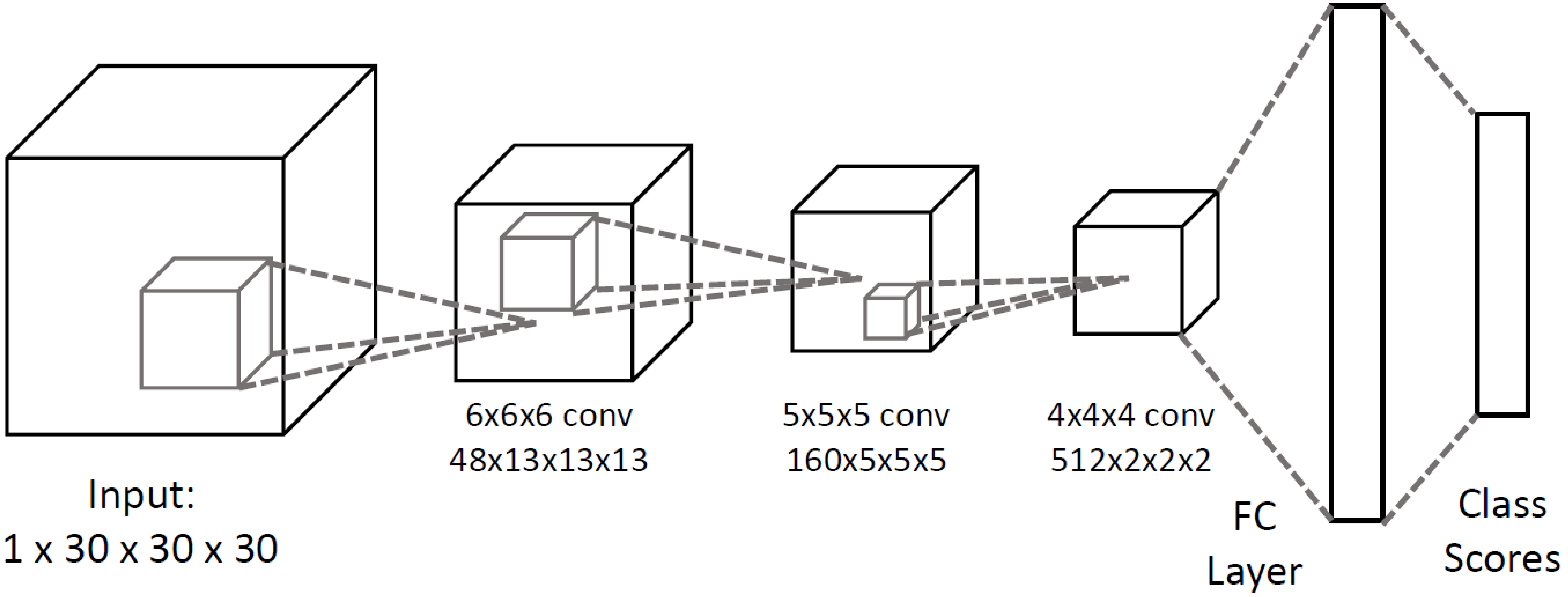



"3D ShapeNet", Wu et al., CVPR 2015

## 3D DL architectures: *Volumetric approach*

Processing Voxel Inputs –> **3D Convolution**

Computationally and memory expensive! Requires low-res input




"3D ShapeNet", Wu et al., CVPR 2015

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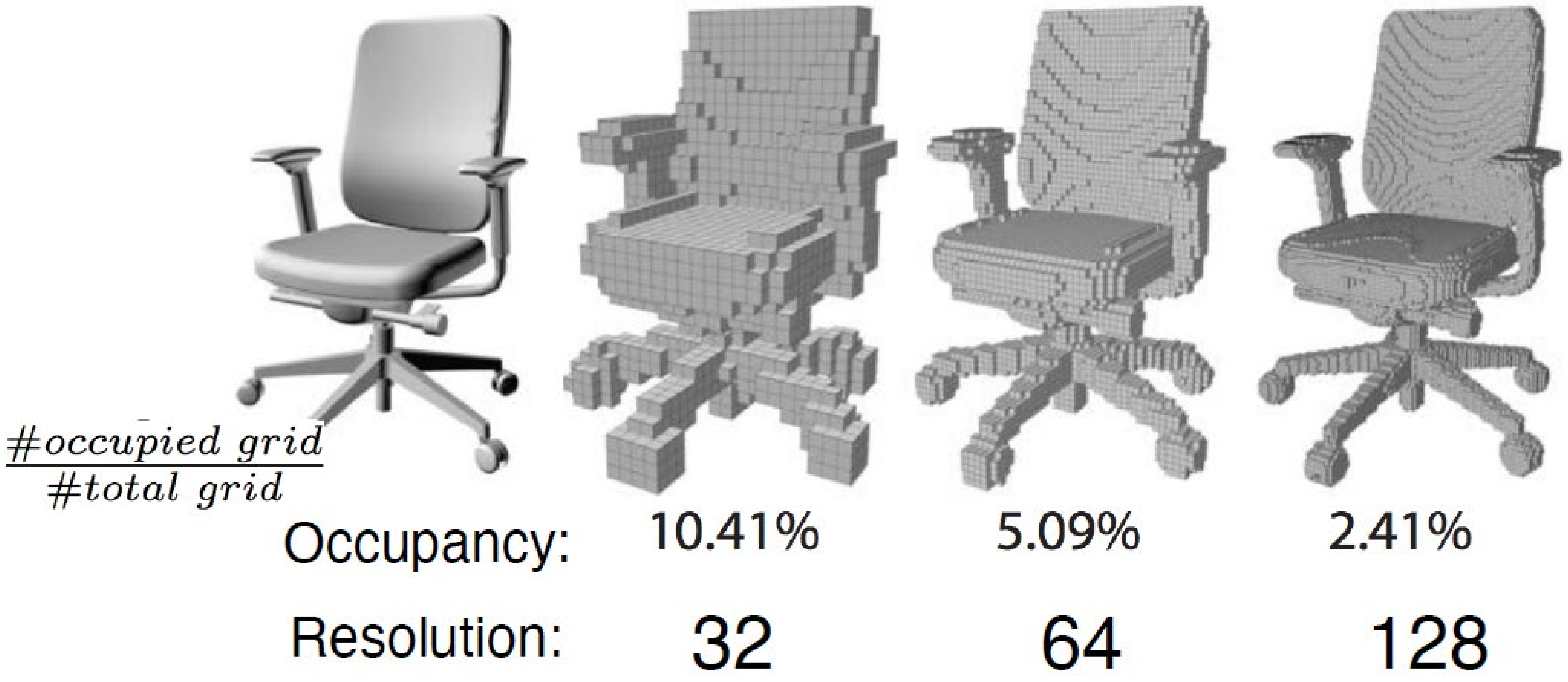
## 3D DL architectures: *Volumetric approach*

### Sparsity of 3D data

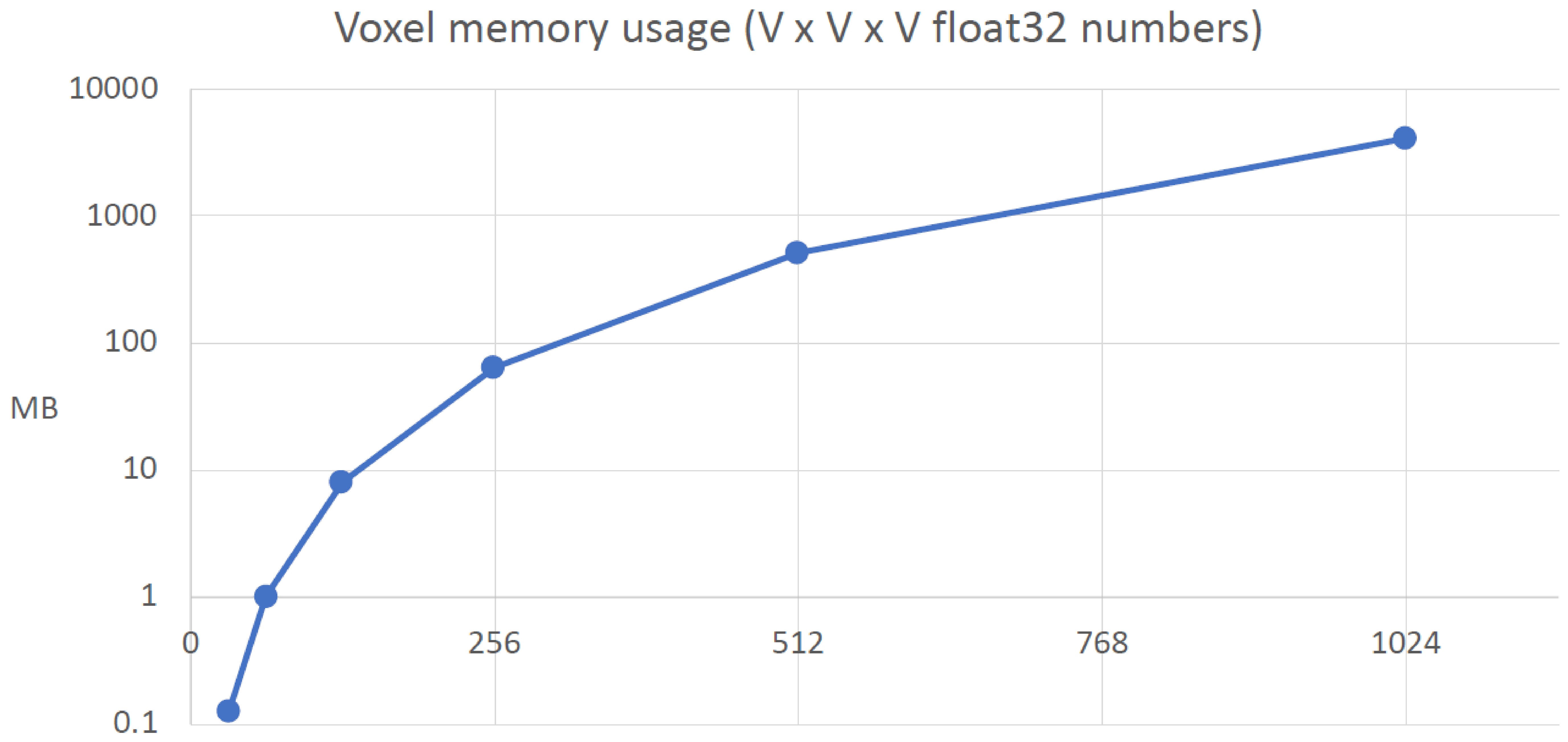



Running convolution on so much empty space is wasteful!

Hao Su et al.

# 3D DL architectures: *Volumetric approach*

## Memory usage



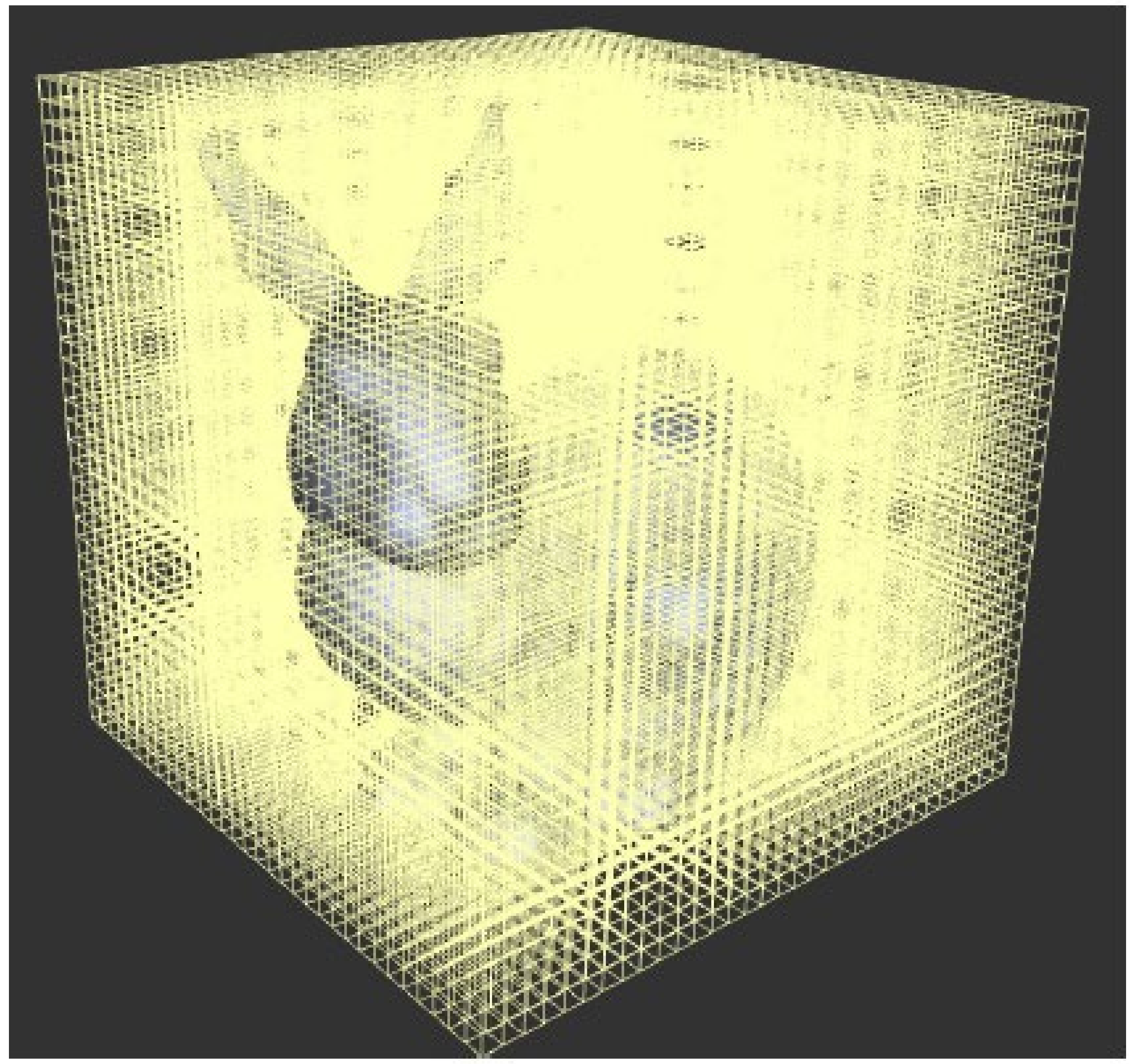

Storing $1024^3$ voxel grid takes 4GB of memory!

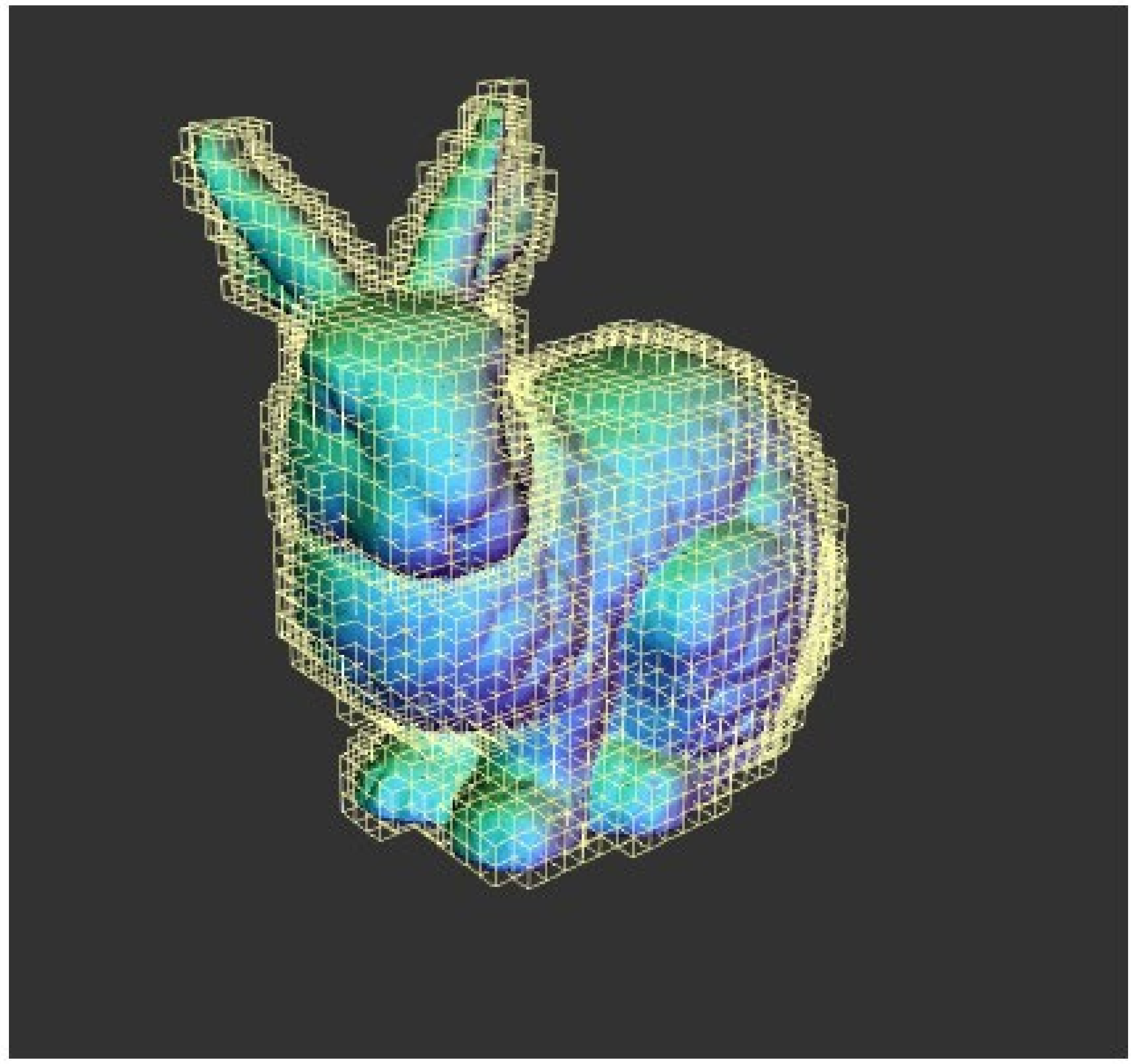
Justin Solomon

## 3D DL architectures: *Volumetric approach*

Solution –> **Octave Tree Representations**

- Store the sparse surface signals
- Constrain the computation near the surface





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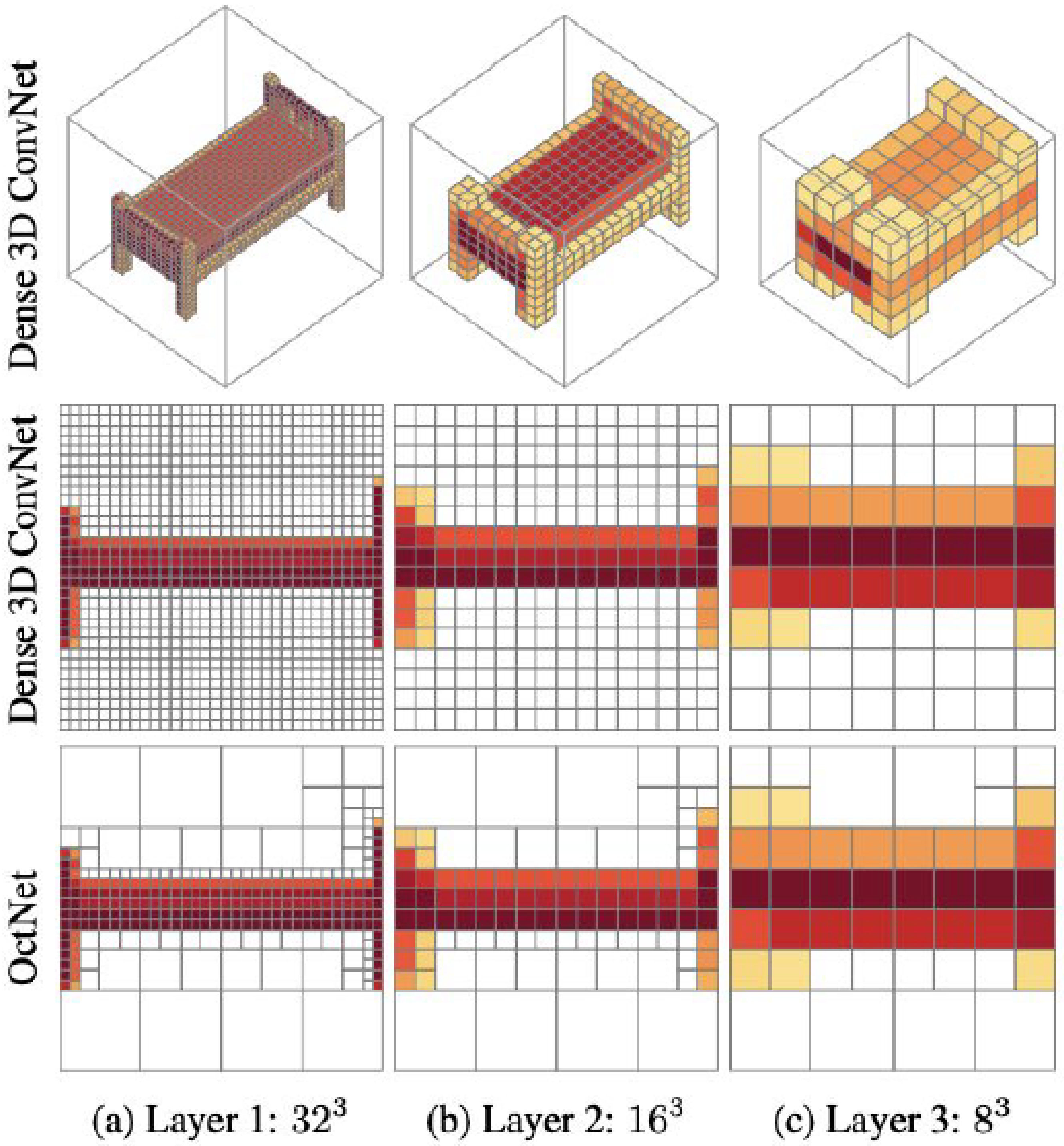
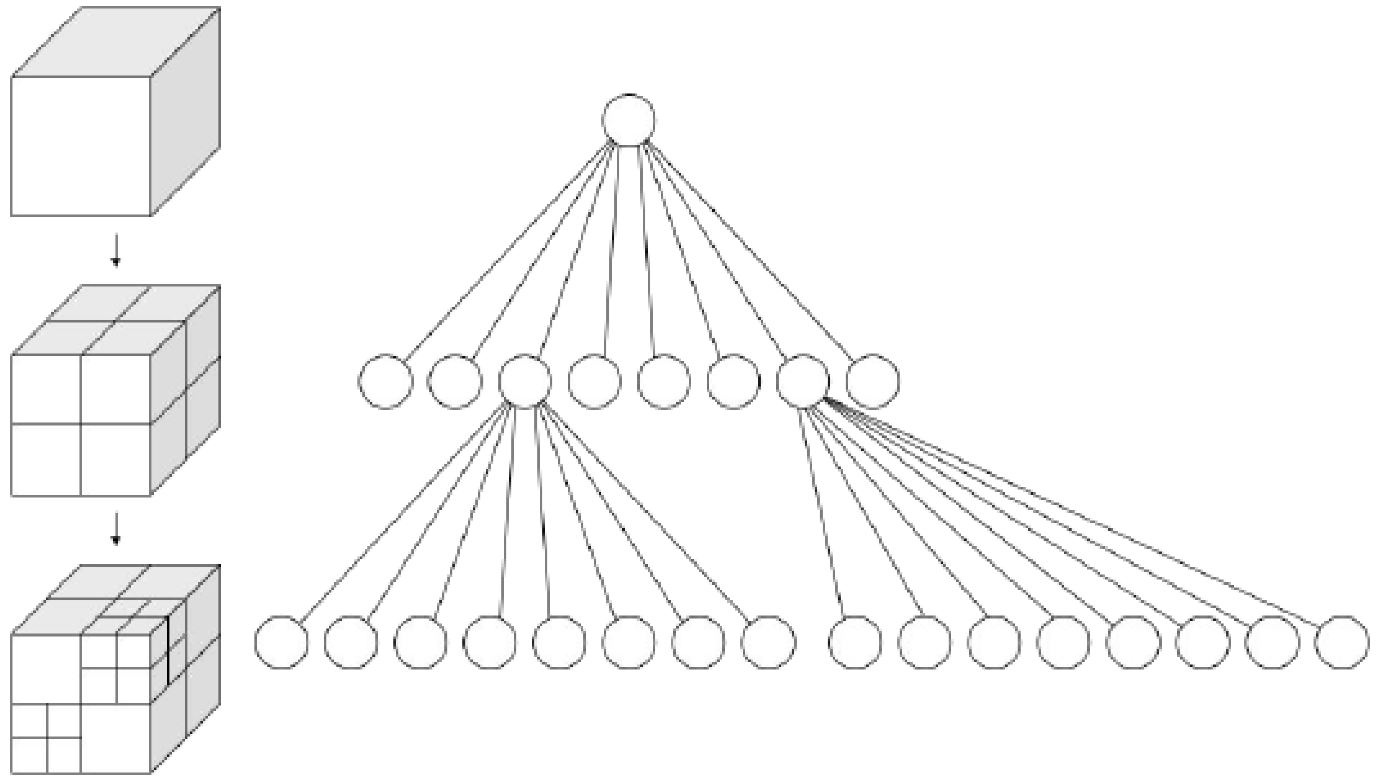
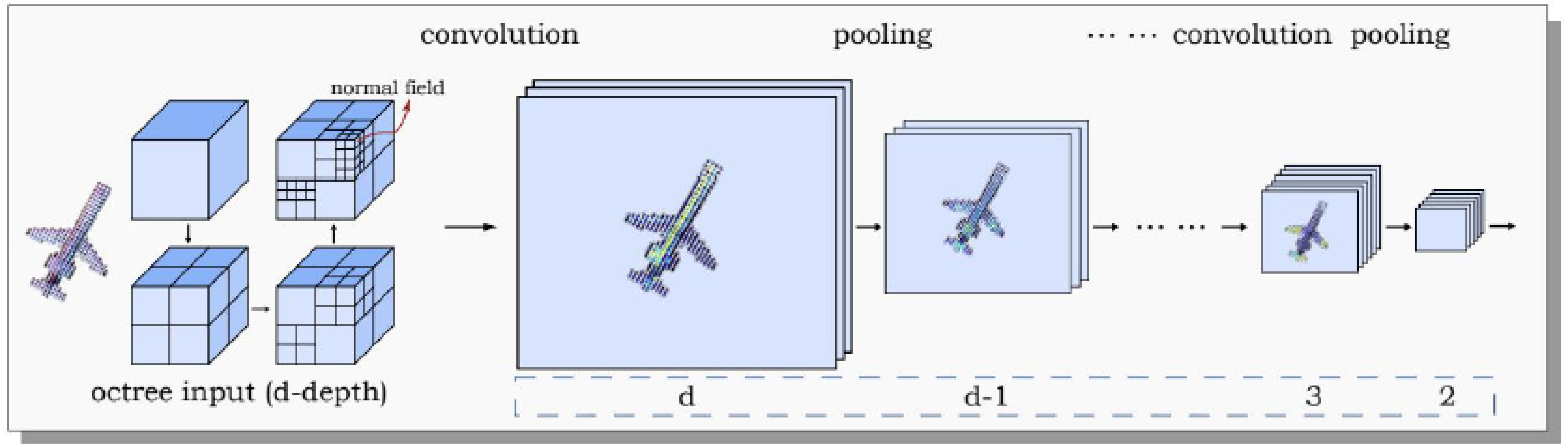
# 3D DL architectures: *Volumetric approach*

## **Octree**: Recursively Partition the Space




Riegler et al. OctNet. CVPR 2017



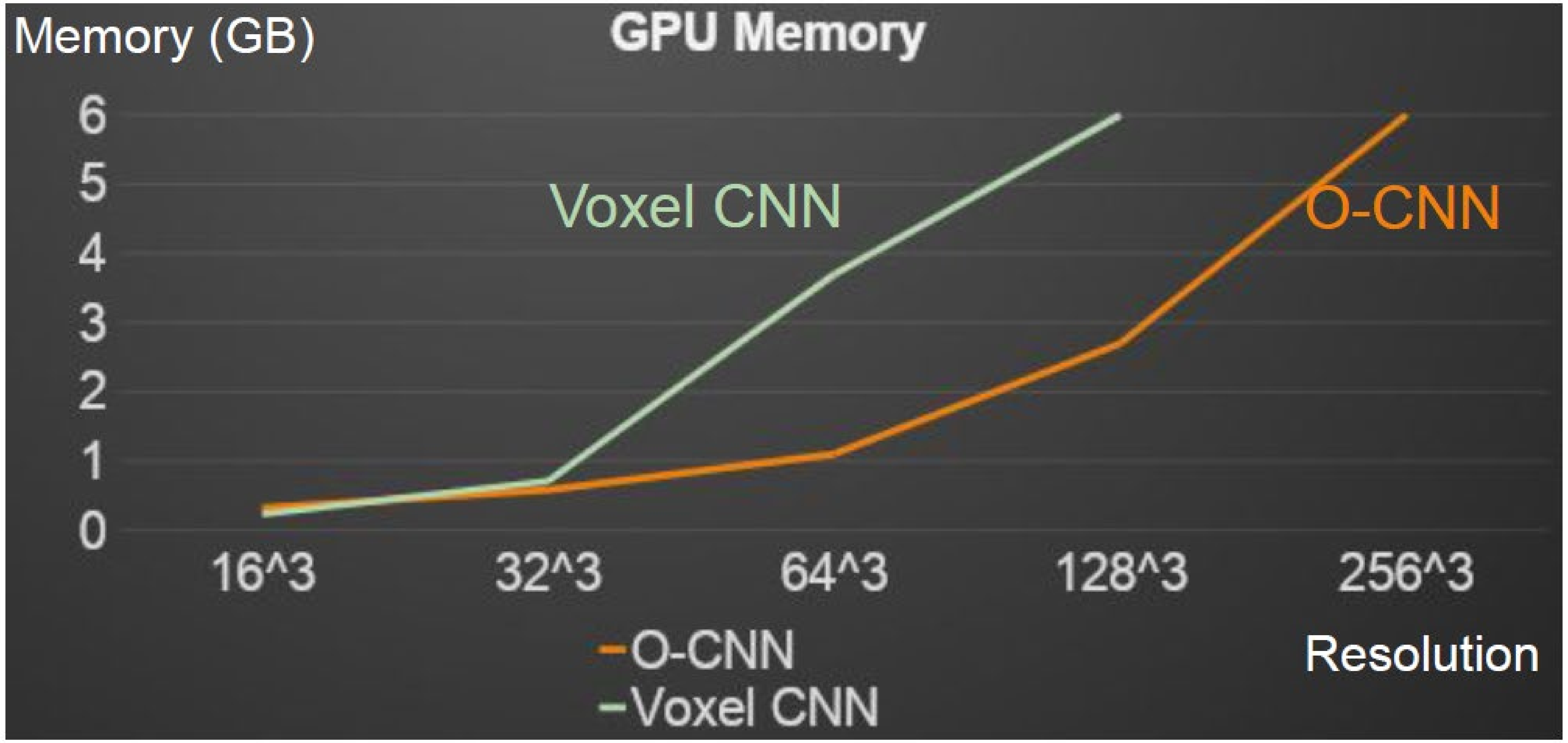



Wang et al. O-CNN. SIGGRAPH 2017

Hao Su et al.

# 3D DL architectures: *Volumetric approach*

## Memory Efficiency

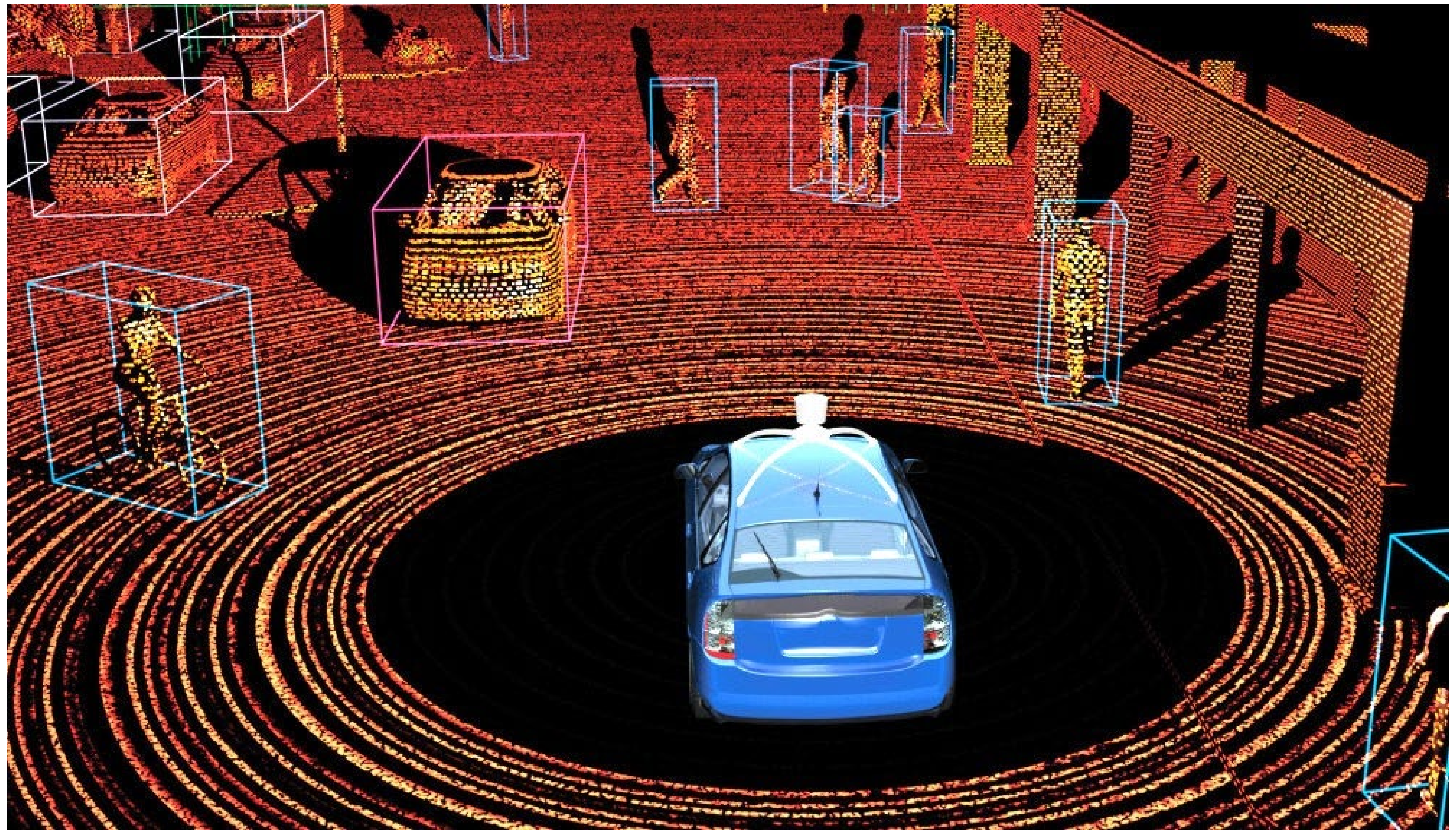



Hao Su et al.

## 3D DL architectures: *Point-based approach*

**Motivation**:

- Lots of **scanned data** are raw 3D point clouds
- **Process raw input**, i.e., point cloud, without any preprocessing



Kalogerakis E.



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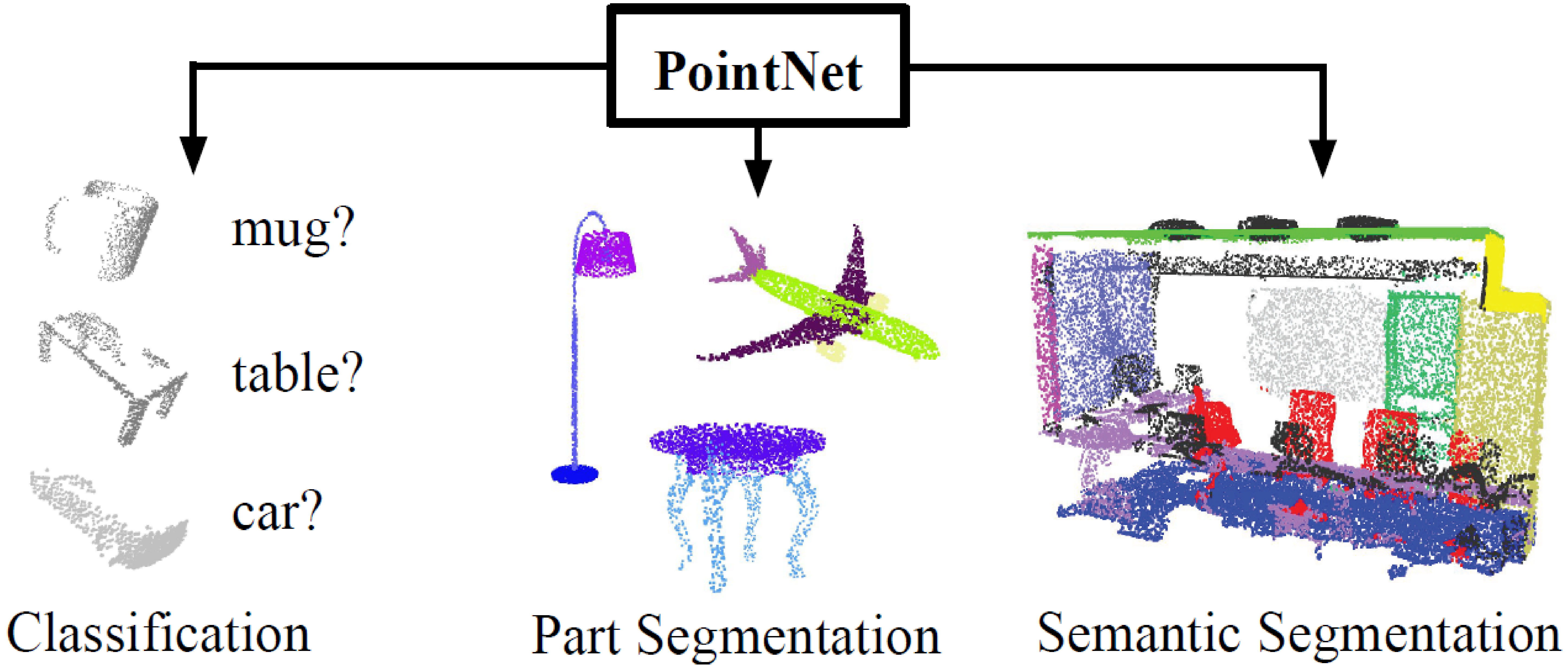
# 3D DL architectures: *Point-based approach*

## PointNet: (Qi et al., CVPR 2017)

- Processes input point clouds for various tasks

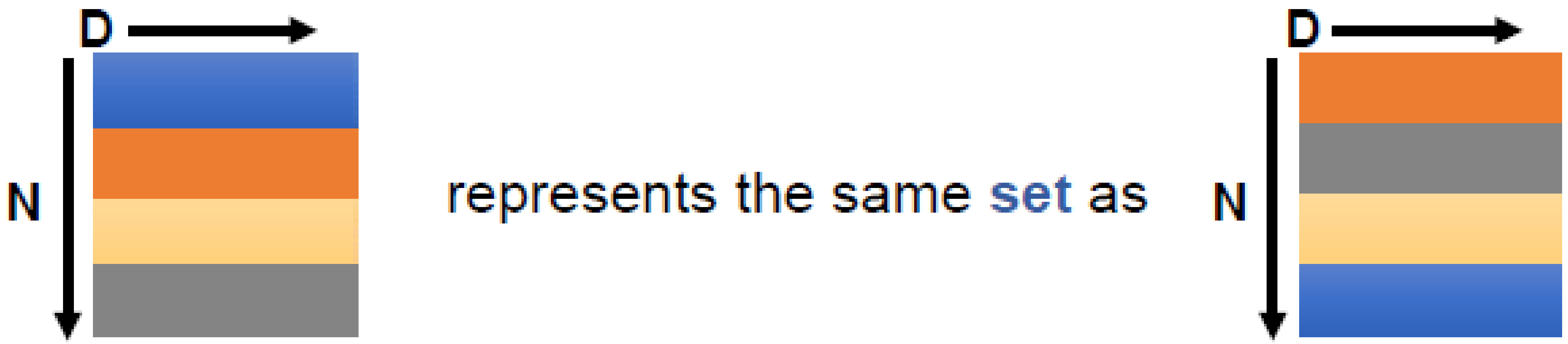



Hao Su

## 3D DL architectures: *Point-based approach*

Desired Properties of PointNet:

- **Permutation invariance**




2D array representation

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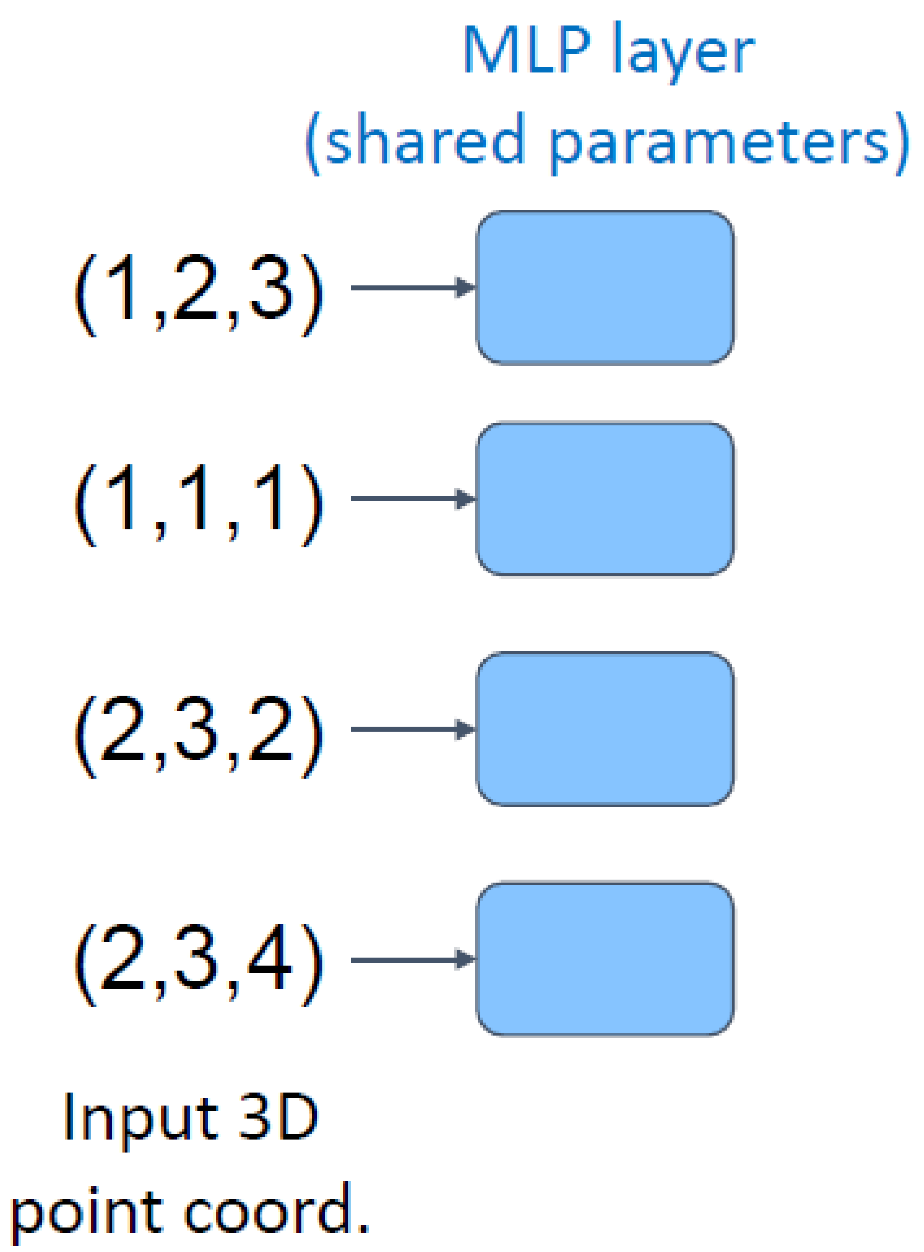
## 3D DL architectures: *Point-based approach*

# PointNet architecture:

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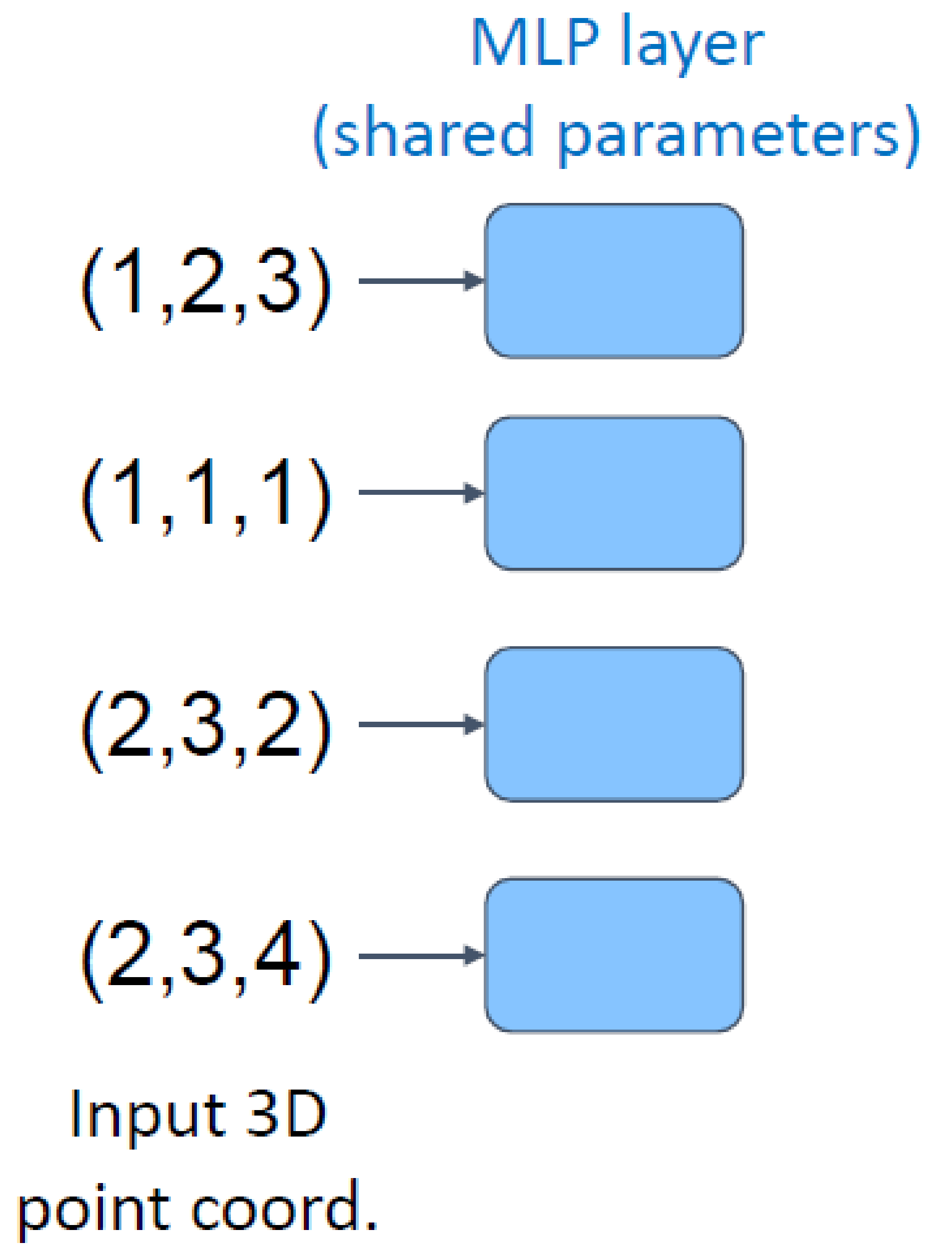
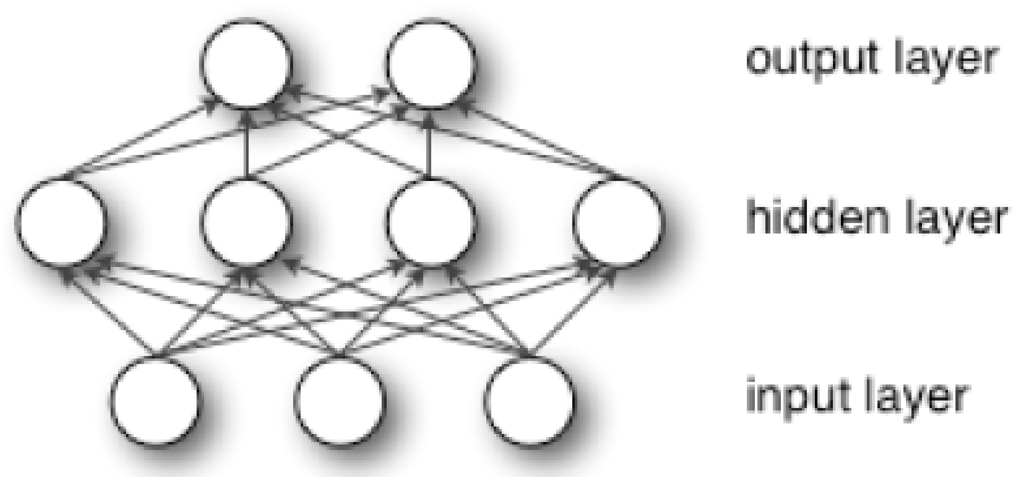
## 3D DL architectures: *Point-based approach*

# PointNet architecture:




Simply a fully connected NN
with one hidden layer,
3 inputs for 3D points, and T
outputs (T is layer parameter)

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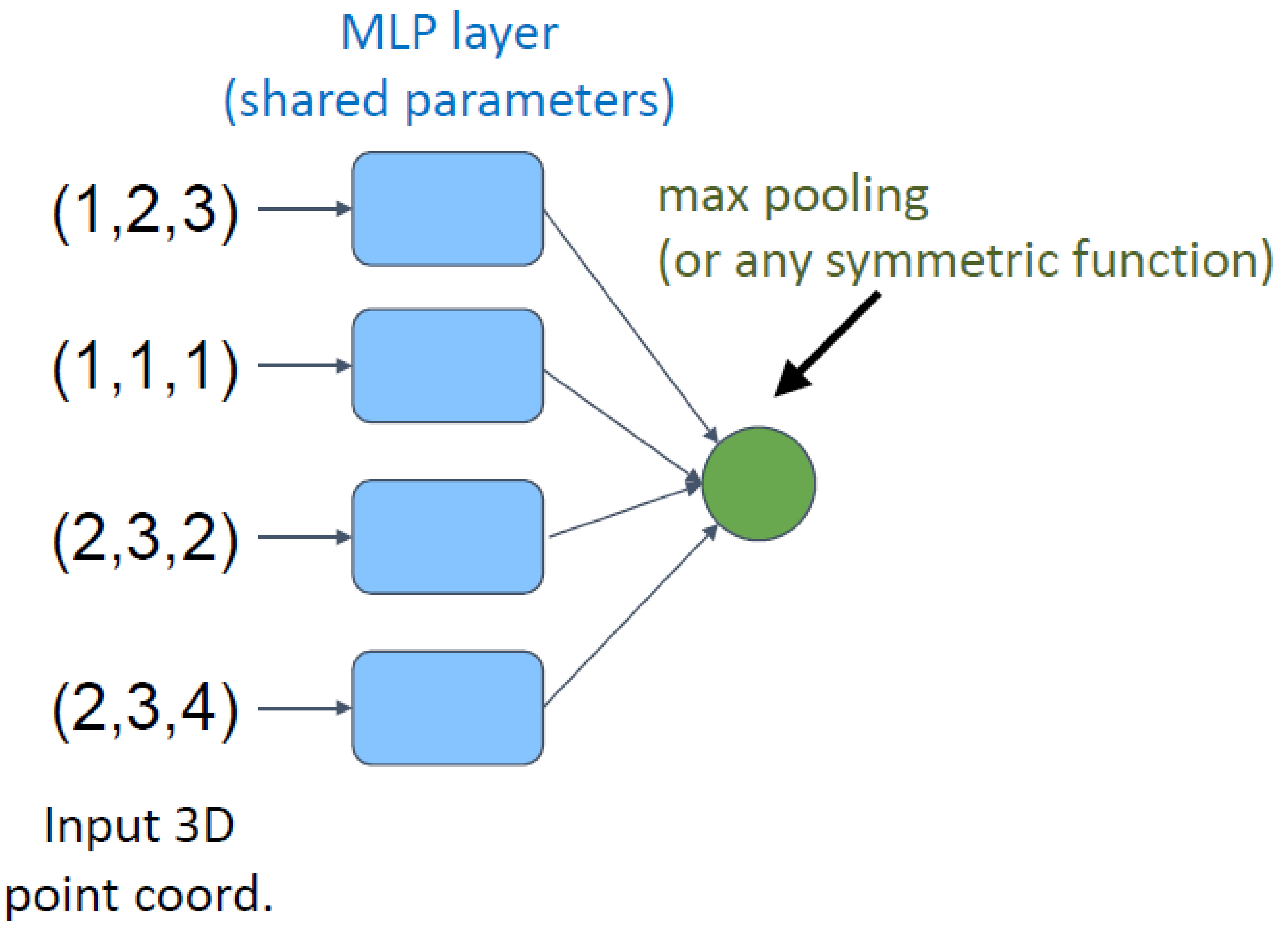
## 3D DL architectures: *Point-based approach*

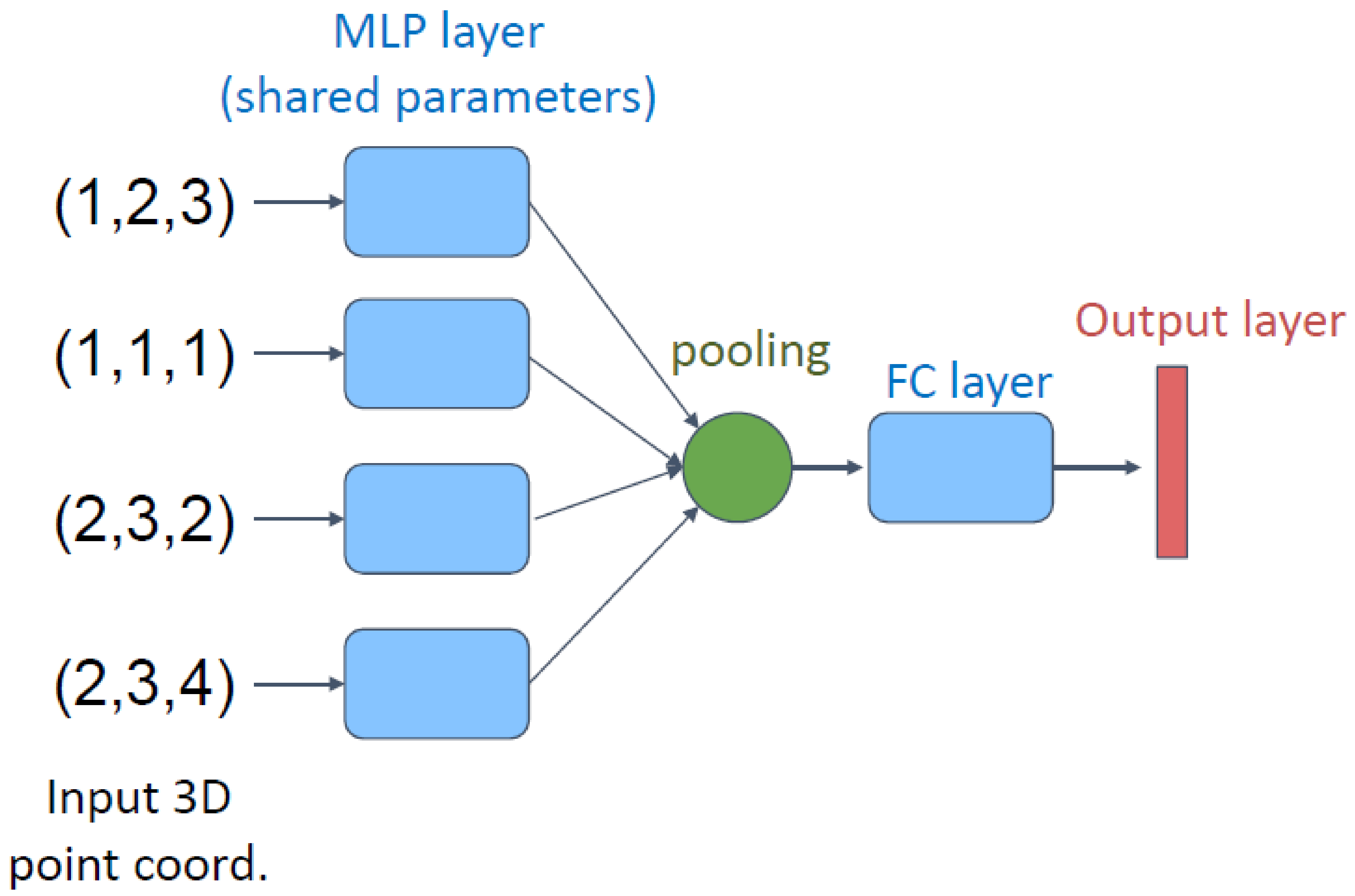
# PointNet architecture:




Kalogerakis E.

# 3D DL architectures: *Point-based approach*

## PointNet architecture:

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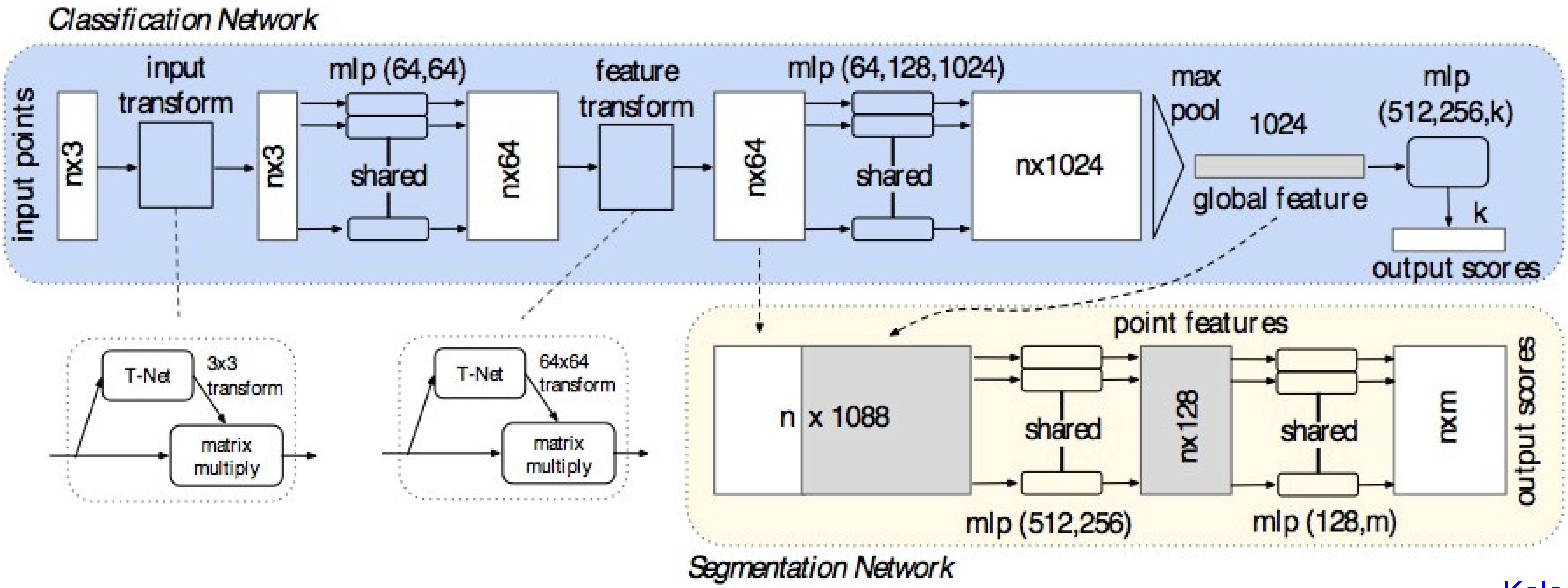
# 3D DL architectures: *Point-based approach*

## PointNet architecture:

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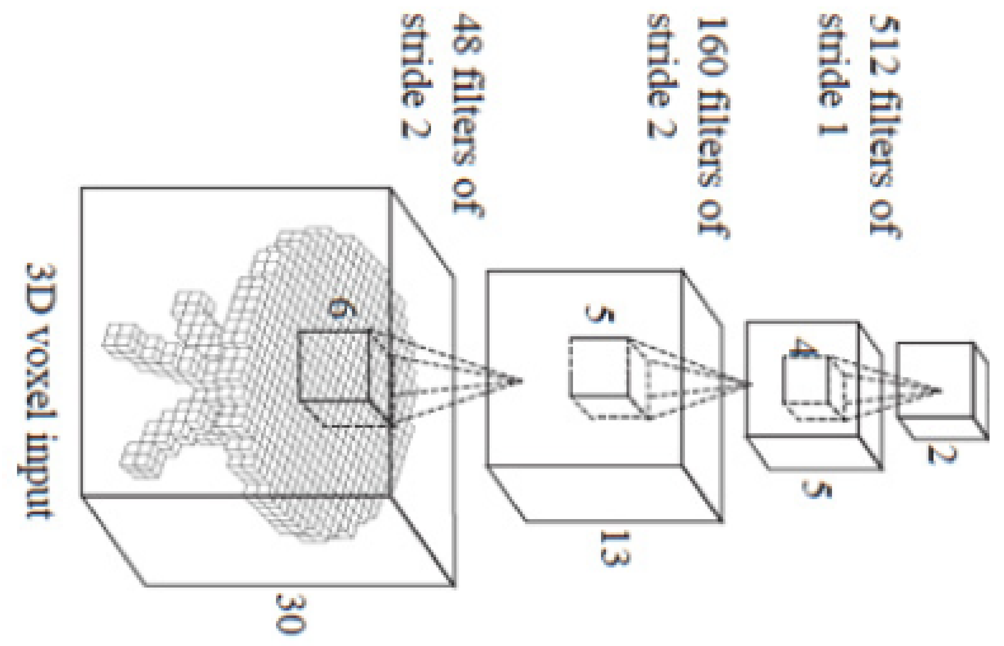
# 3D DL architectures: *Point-based approach*

## Limitations of PointNet

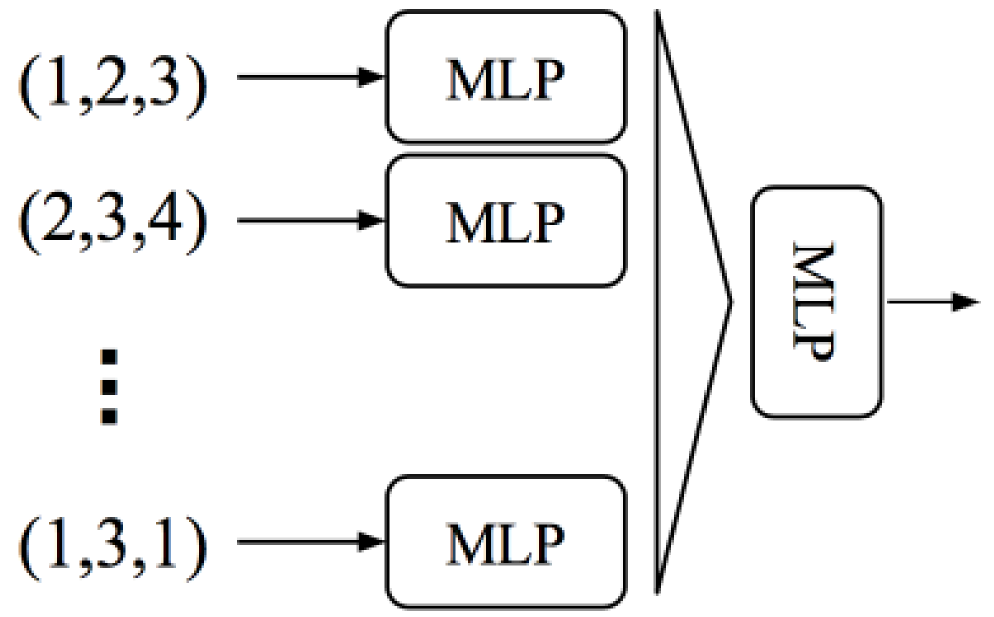
Hierarchical feature learning
Multiple levels of abstraction

v.s.

Global feature learning
Either one point or all points




**3D CNN (Wu et al.)**




**PointNet (vanilla) (Qi et al.)**

No local context for each point!

Hao Su et al.

# 3D DL architectures: *Point-based approach*

## Points in Metric Space

- Learn “**kernels**” in 3D space and conduct convolution
- Kernels have **compact spatial support**
- For convolution, we need to **find neighboring points**
- Possible strategies for range query
  - Ball query (results in more stable features)
  - k-NN query (faster)

Hao Su et al.

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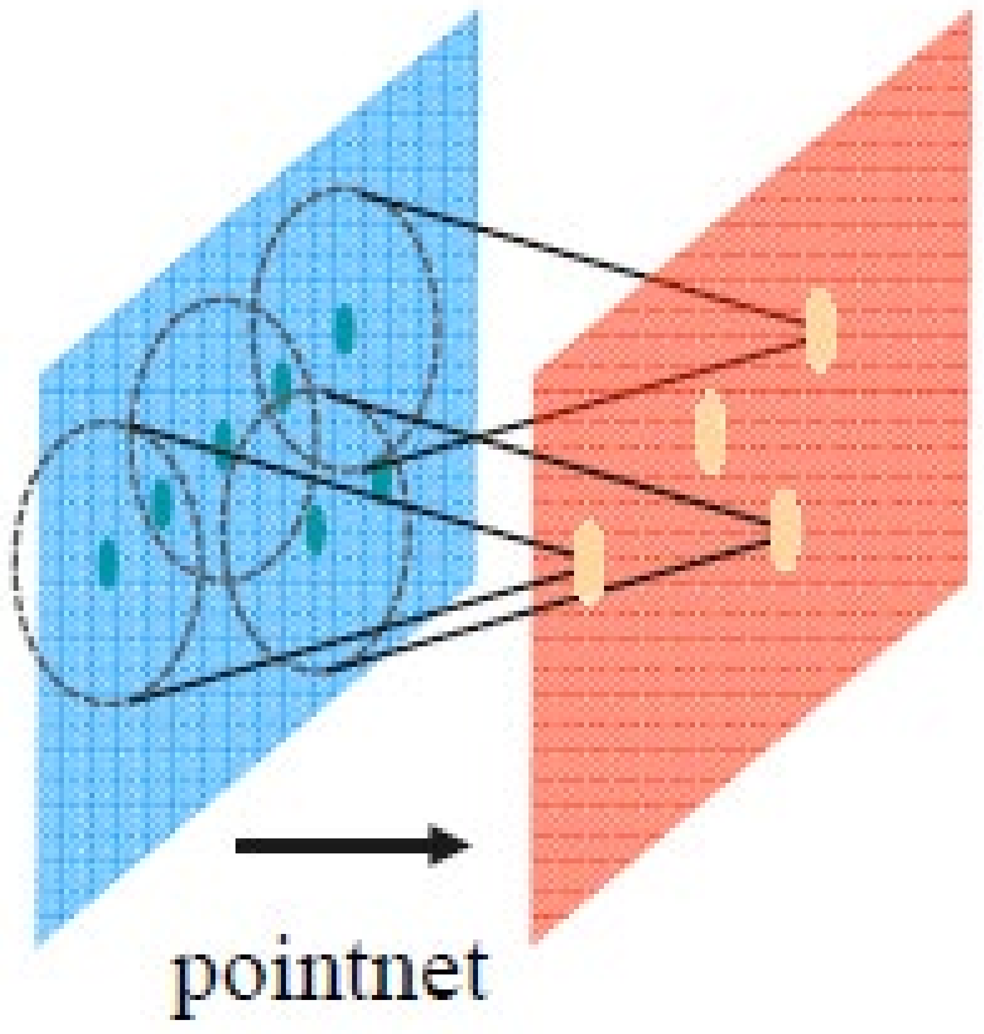
# 3D DL architectures: *Point-based approach*

**PointNet++:** (Qi et al., NIPS 2017)
- Use PointNet in local regions
- Aggregate local features by PointNet again

–> **Hierarchical feature learning**

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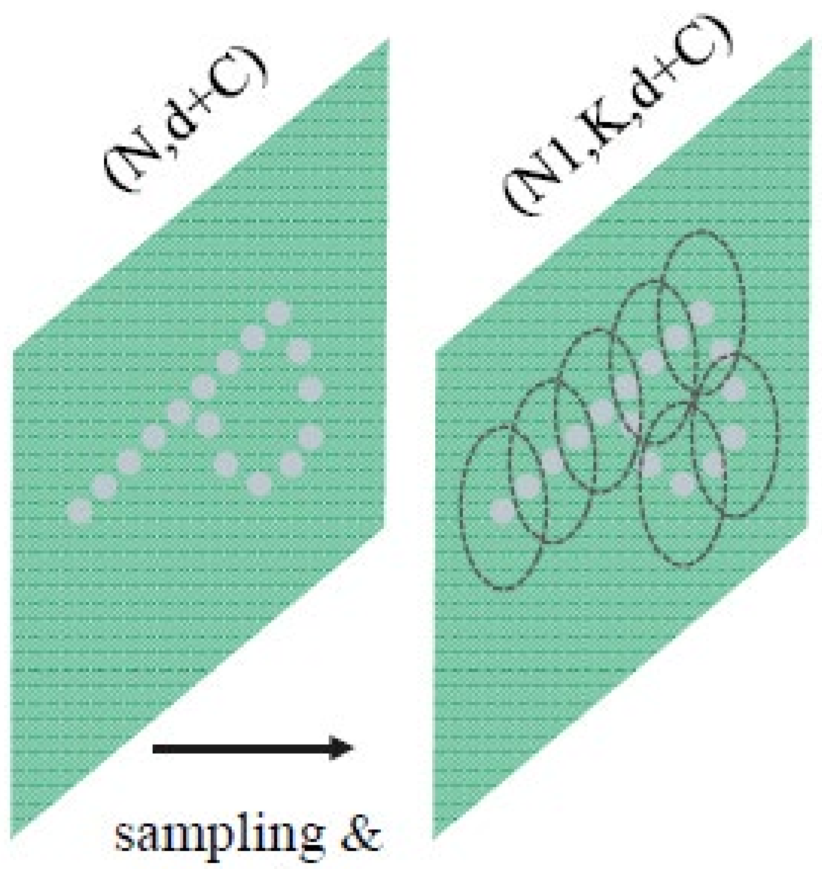
## 3D DL architectures: *Point-based approach*

PointNet++:

- **Sampling**: Farthest Point Sampling (FPS)
- **Grouping**: Radius-based ball query

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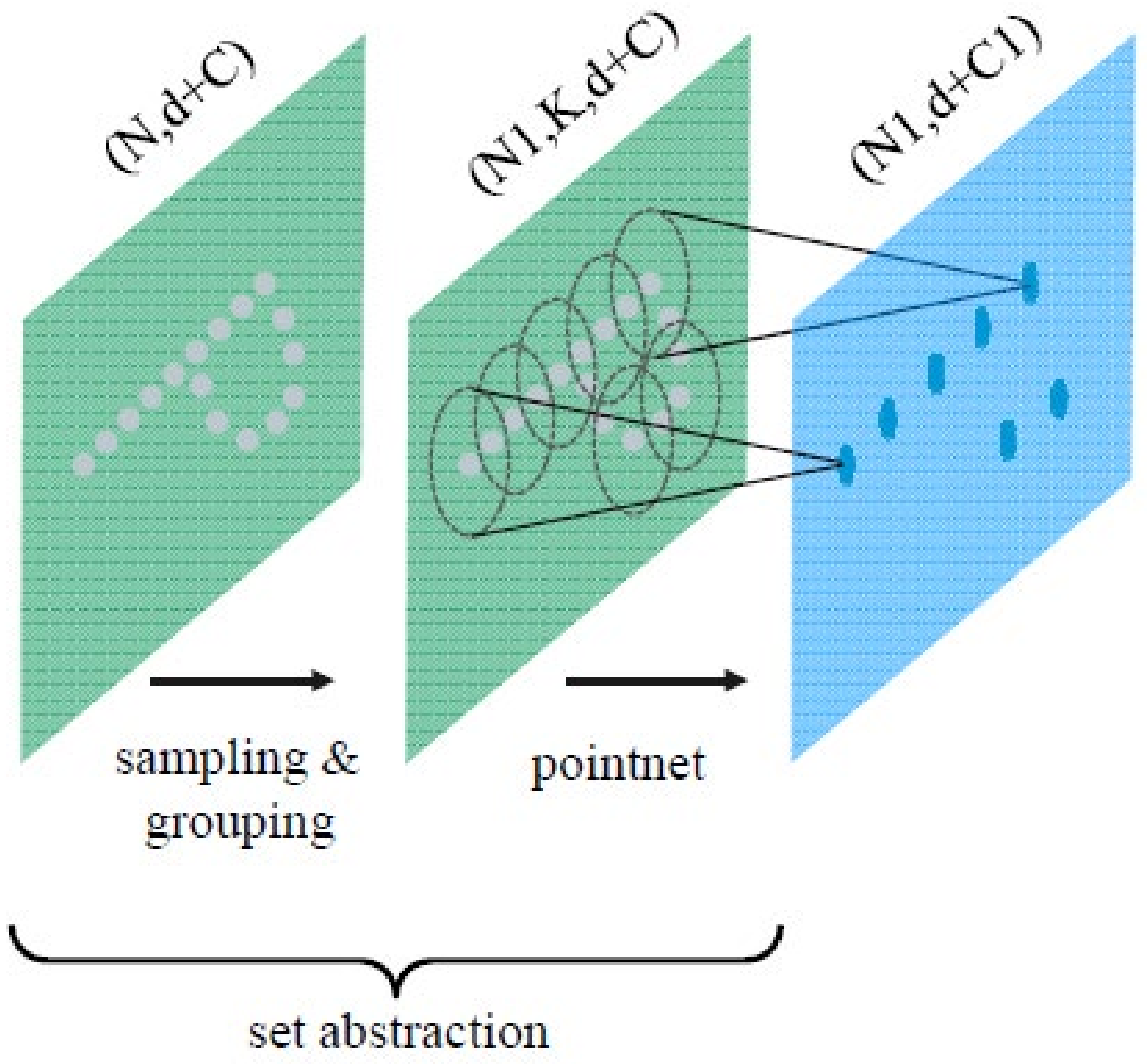
## 3D DL architectures: *Point-based approach*

PointNet++:

- Shared PointNet applied in each local region using local coordinates

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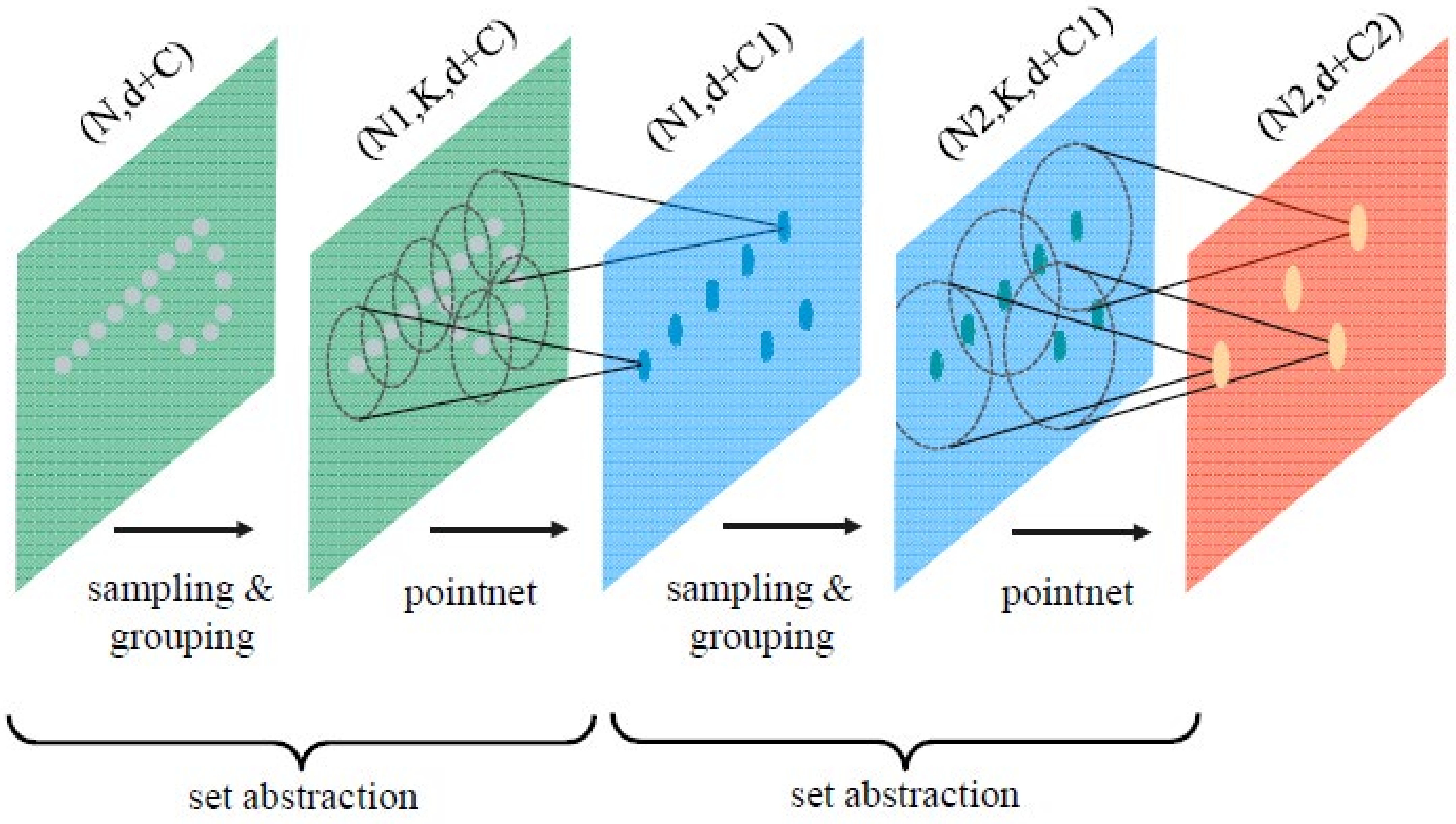
# 3D DL architectures: *Point-based approach*

PointNet++:

- Shared PointNet applied in each local region using local coordinates

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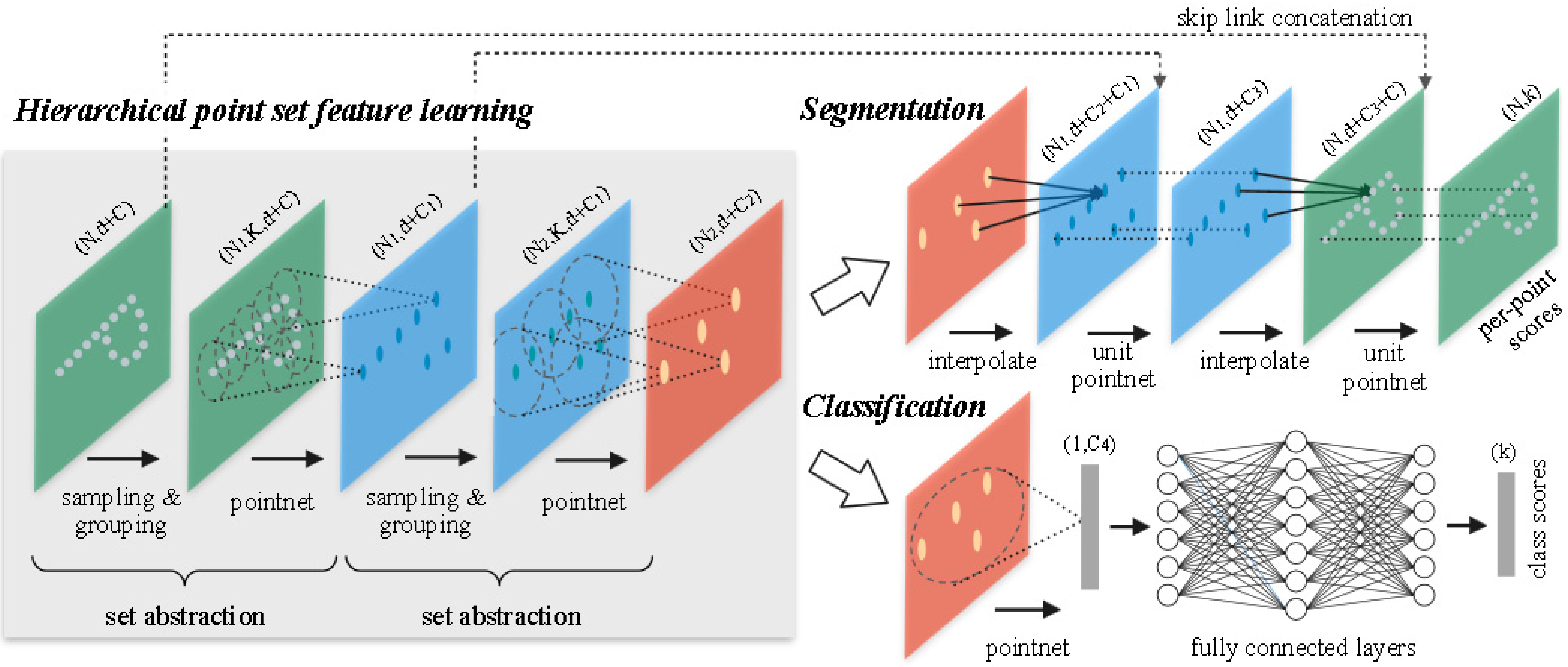
# 3D DL architectures: *Point-based approach*

## PointNet++ architecture




Qi et al., NIPS 2017



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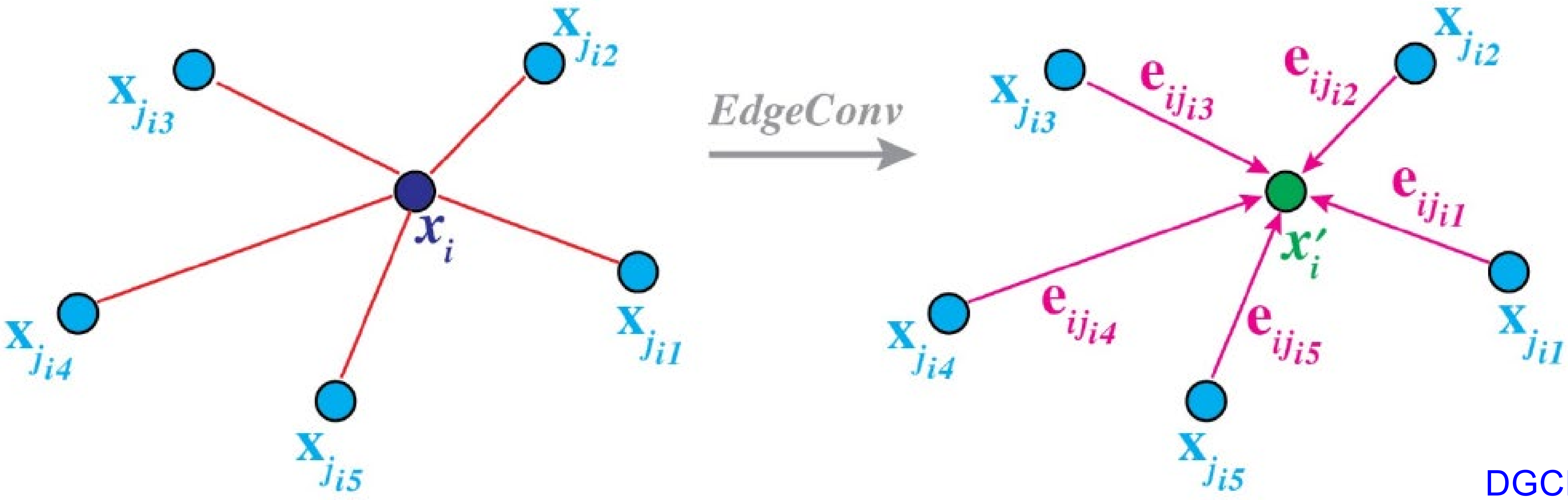
# 3D DL architectures: *Point-based approach*

## Point Convolution as Graph Convolution: **Dynamic Graph CNN**

- Points –> Nodes
- Neighborhood –> Edges
- Graph CNN for point cloud processing

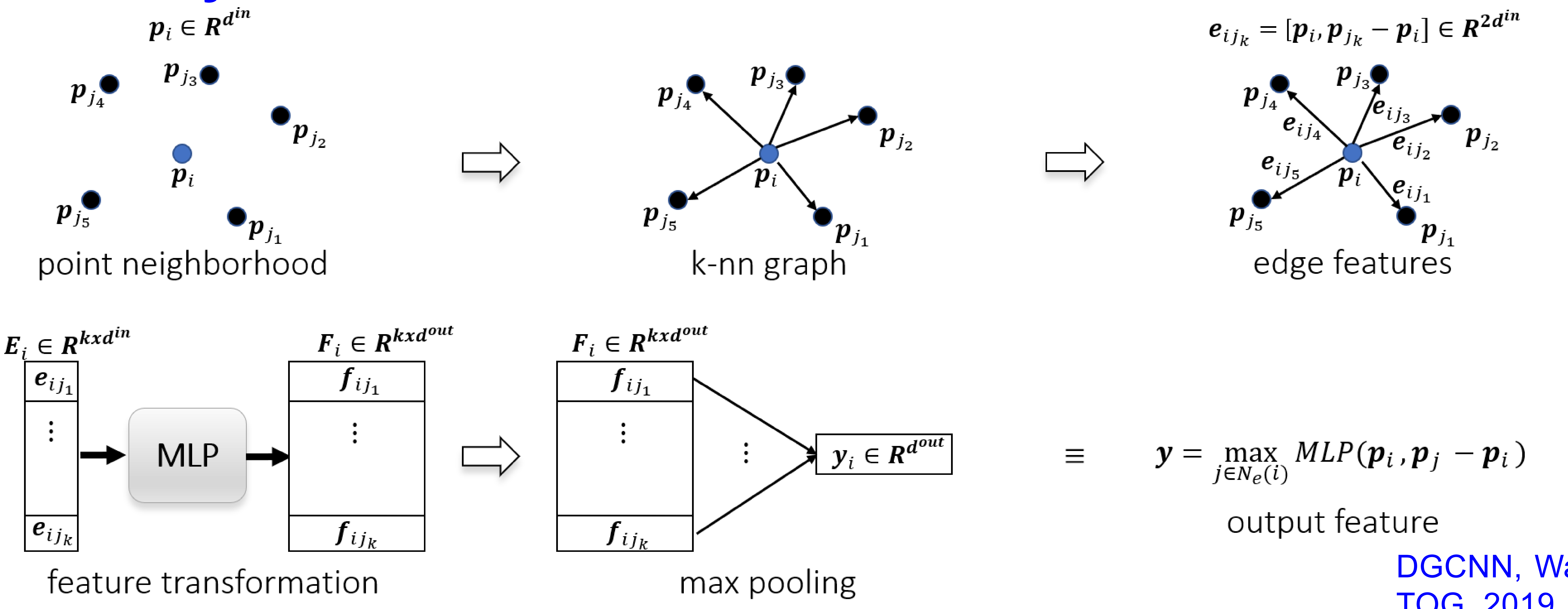



DGCNN, Wang et al., TOG, 2019

## 3D DL architectures: *Point-based approach*

# Dynamic Graph CNN

- **EdgeConv Layer**




DGCNN, Wang et al., TOG, 2019

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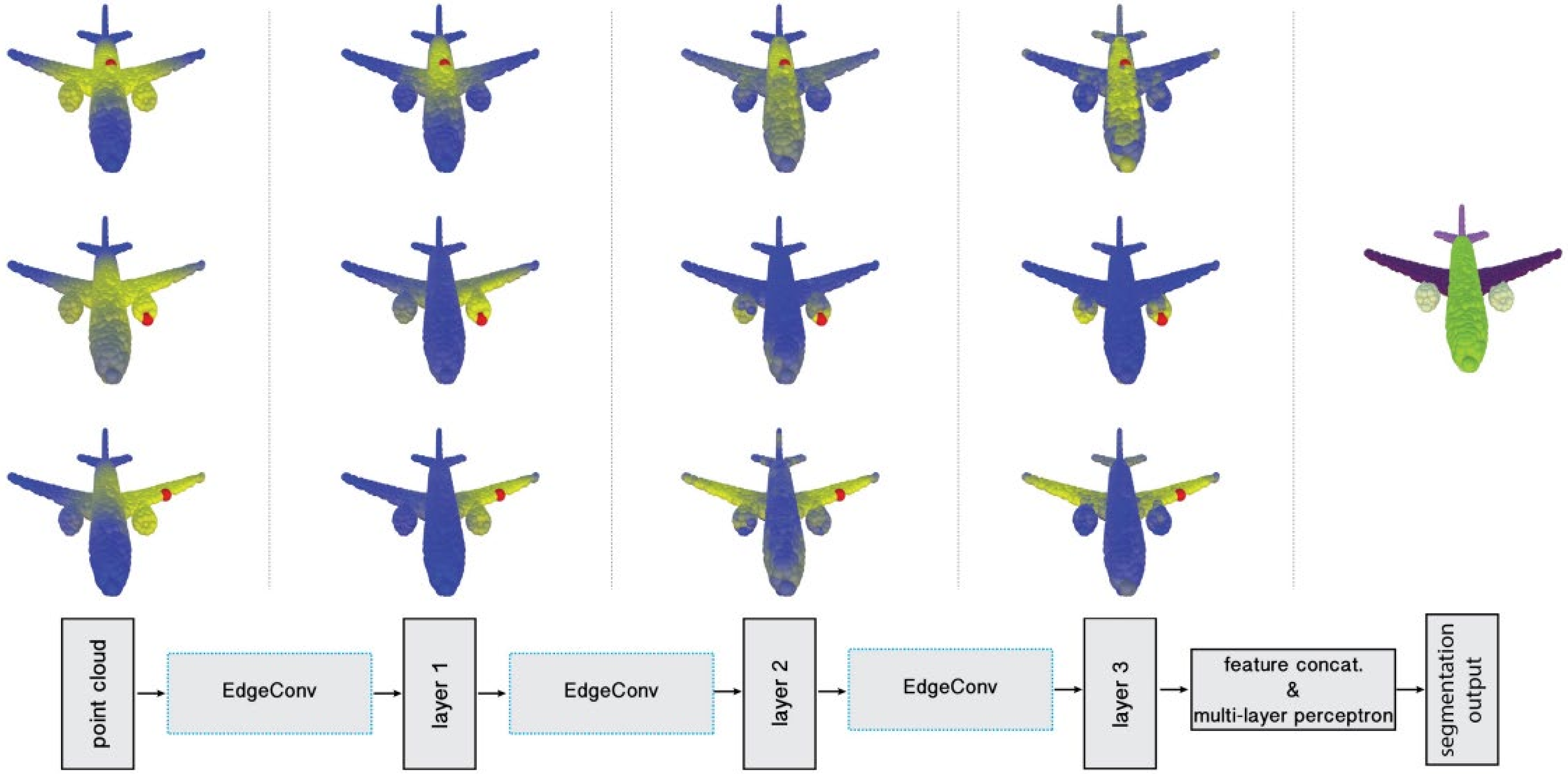
## 3D DL architectures: *Point-based approach*

# Dynamic Graph CNN:

- At each layer, each local graph is rebuilt upon the feature space of the previous EdgeConv layer




DGCNN, Wang et al., TOG, 2019

## 3D DL architectures: *Point-based approach*

Standard GCNs are not Geometry Aware:

- Note that points are **sampled** from surfaces
- Ideally, features describe the geometry of the underlying surface
- Should be **sample invariant**
- But GCNs lack design to address sample invariance
- **Solution**: Estimate the continuous kernel and point density for continuous convolution

Hao Su et al.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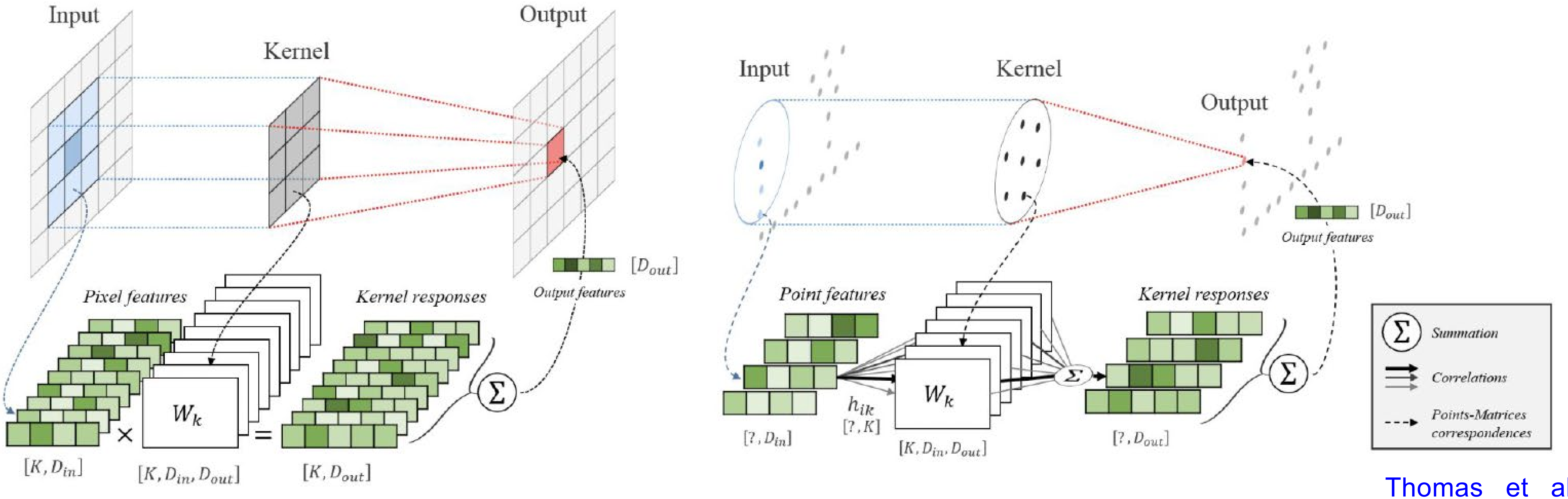
## 3D DL architectures: *Point-based approach*

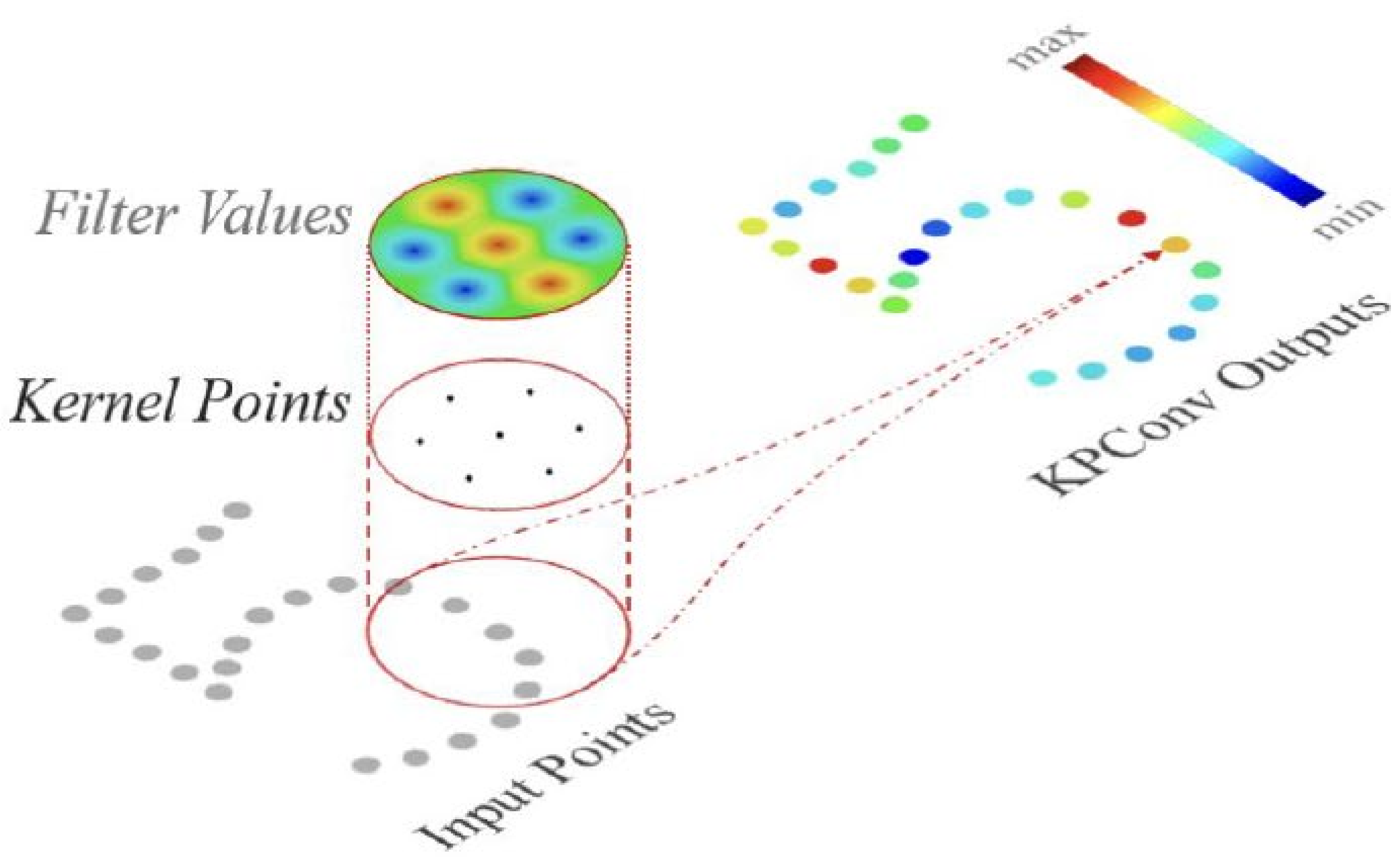
# Kernel Point Convolution (KPConv)




Thomas et al., ICCV, 2019

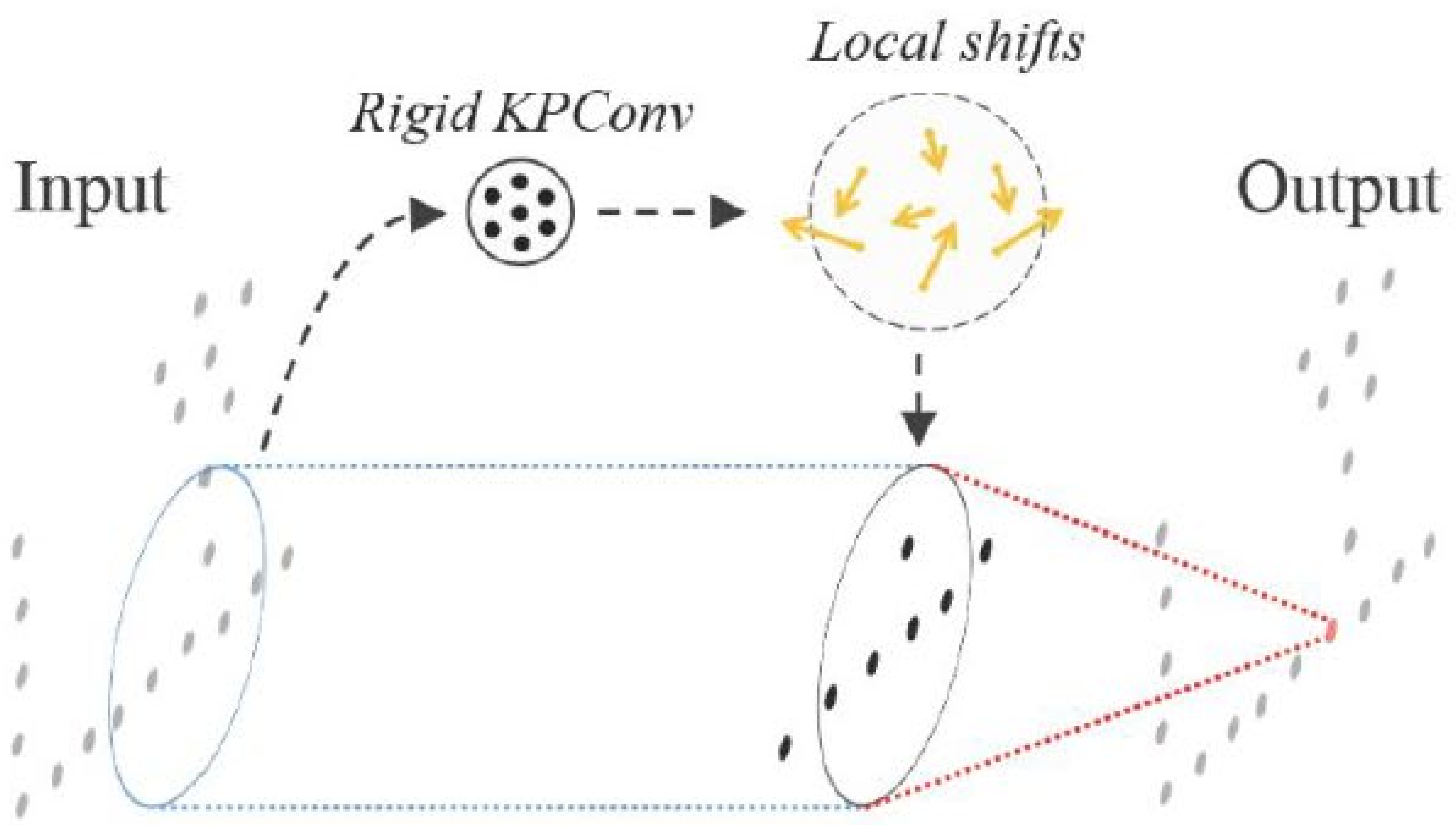
## 3D DL architectures: *Point-based approach*

# Kernel Point Convolution (KPConv)




Deformable point-based kernel

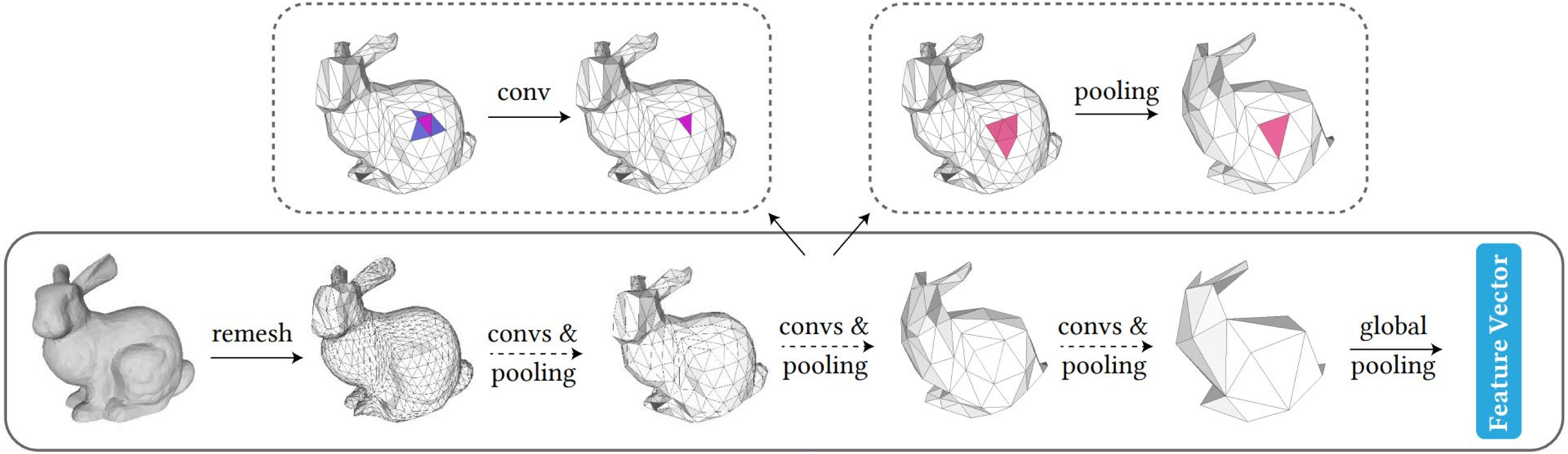
- 3D version of 2D deformable convolution




Hao Su et al.

# 3D DL architectures: *Mesh-based approach*

## Subdivision-Based Mesh Convolution Networks (SubdivNet)

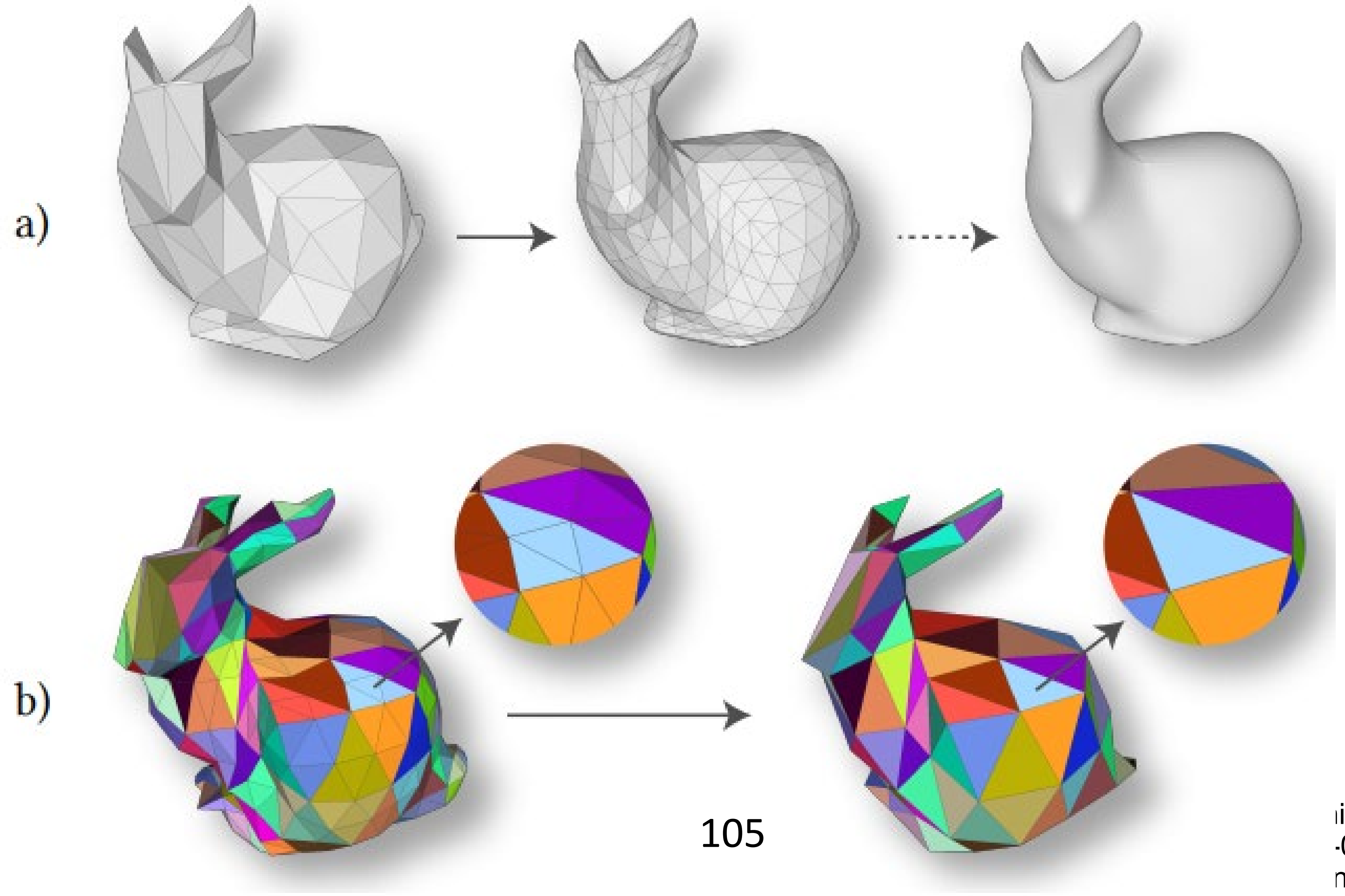



Shi-Min Hu et al., TOG, 2021

# 3D DL architectures: *Mesh-based approach*

SubdivNet:

- A **subdivision surface** provides a **hierarchical multi-resolution structure**, in which **each face** in a **closed triangle** mesh is exactly **adjacent to three faces**




Shi-Min Hu et al., TOG, 2021



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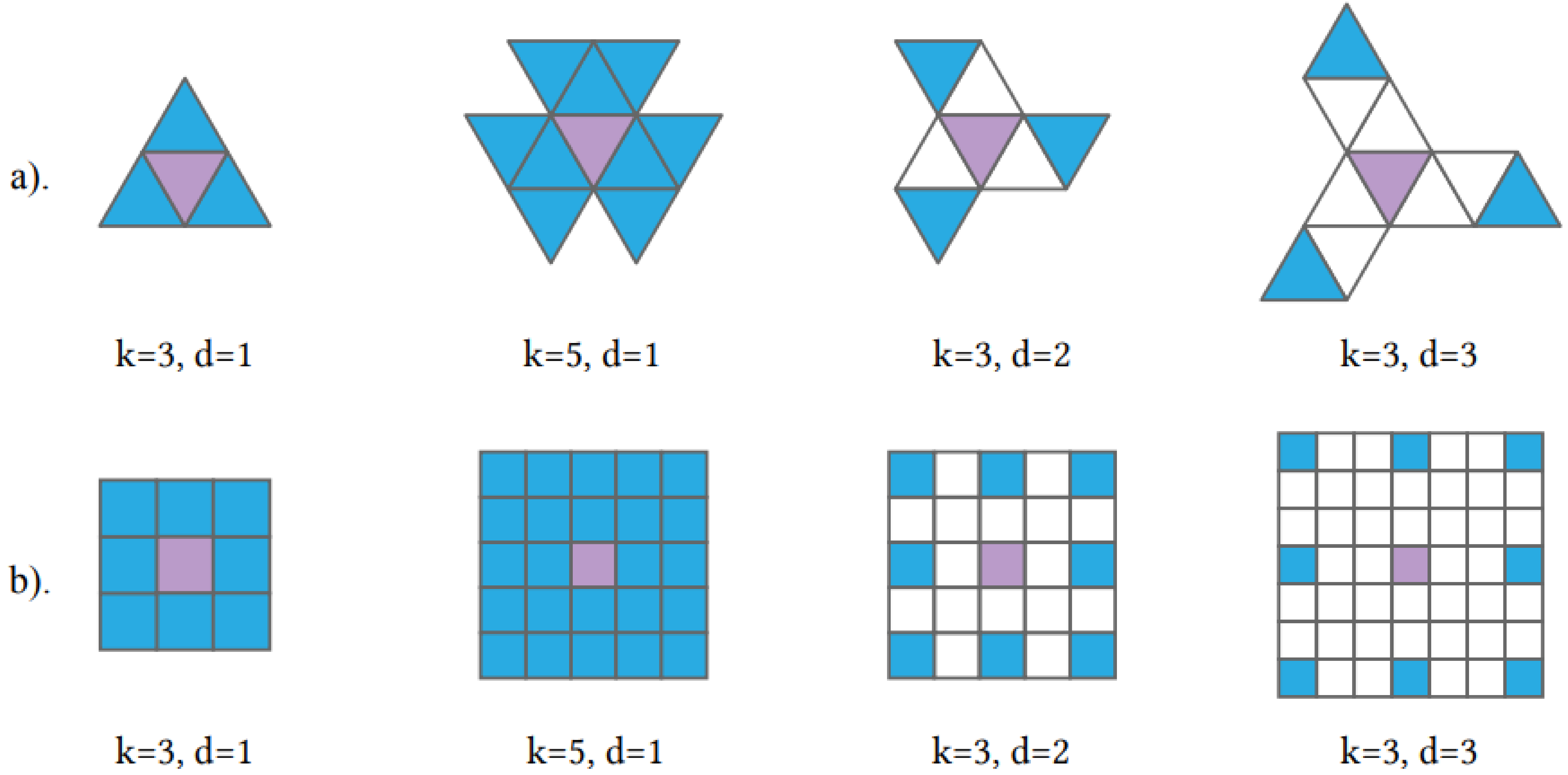
## 3D DL architectures: *Mesh-based approach*

SubdivNet:

- Can support **mesh convolution**

Mesh conv. kernels

2D conv. kernels




Shi-Min Hu et al., TOG, 2021

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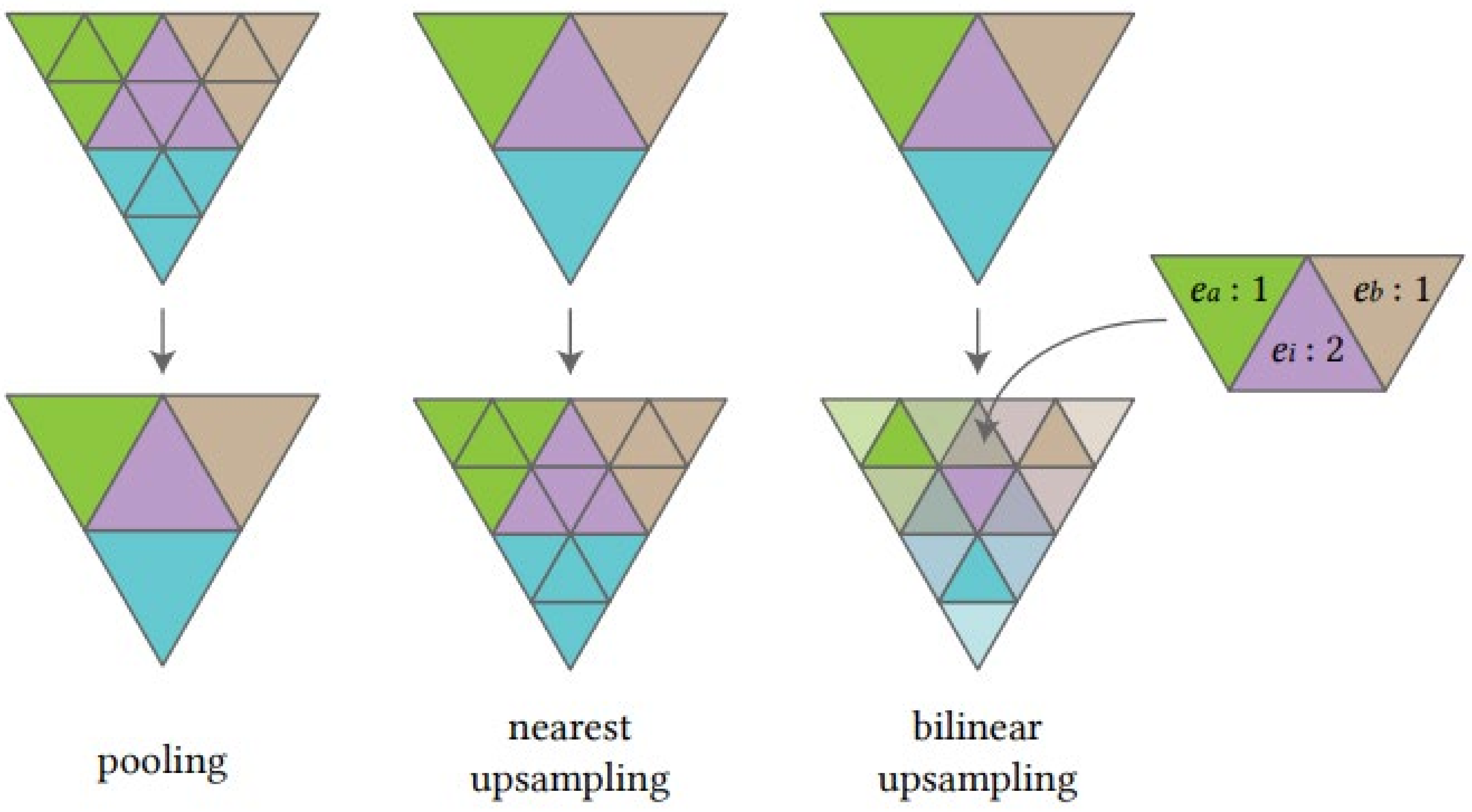
## 3D DL architectures: *Mesh-based approach*

SubdivNet:

- Can support **pooling** and **upsampling**




Shi-Min Hu et al., TOG, 2021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# Today's Agenda

- Who are we?
- What is 3D Vision
- Geometry
- 3D shape representations
- 3D shape datasets
- 3D Deep Learning architectures
- What we do


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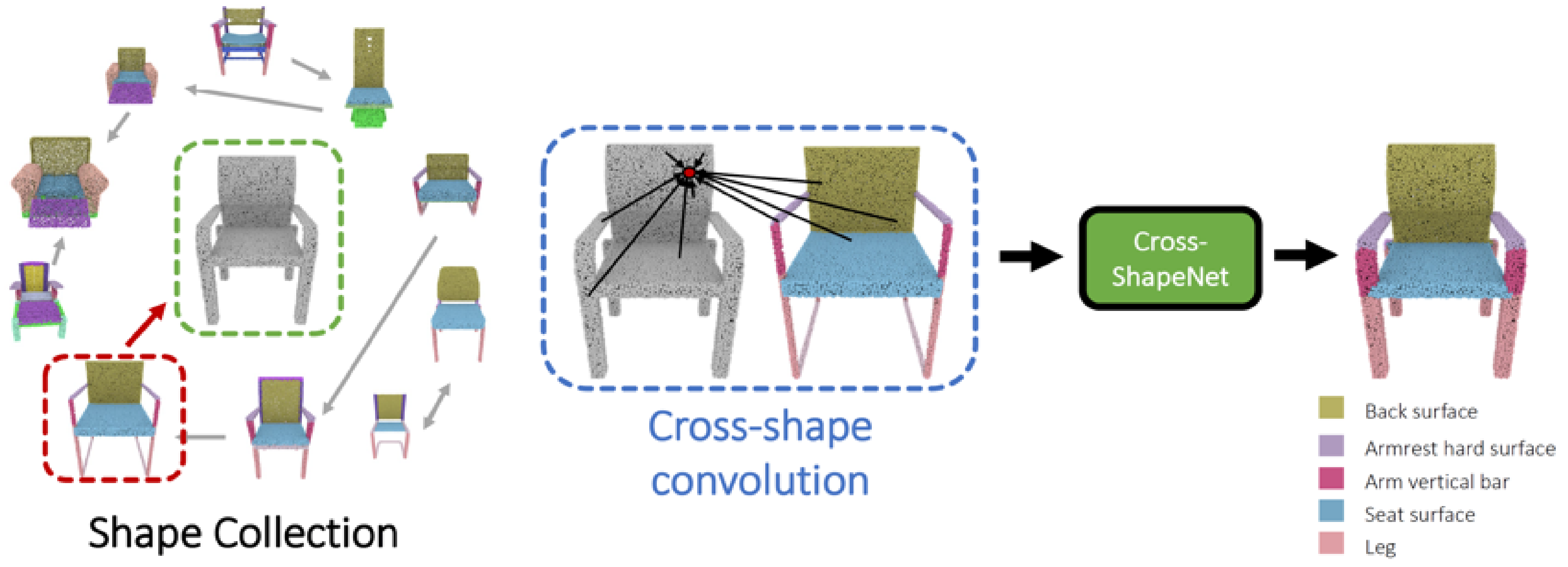
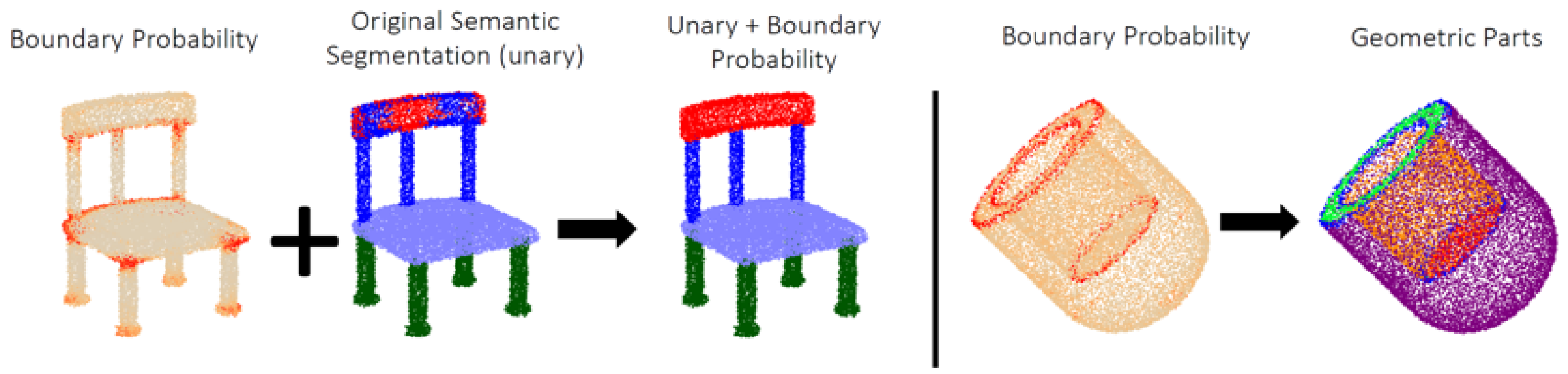
# What we do: *3D shape understanding*

## 3D Building Semantic Understanding

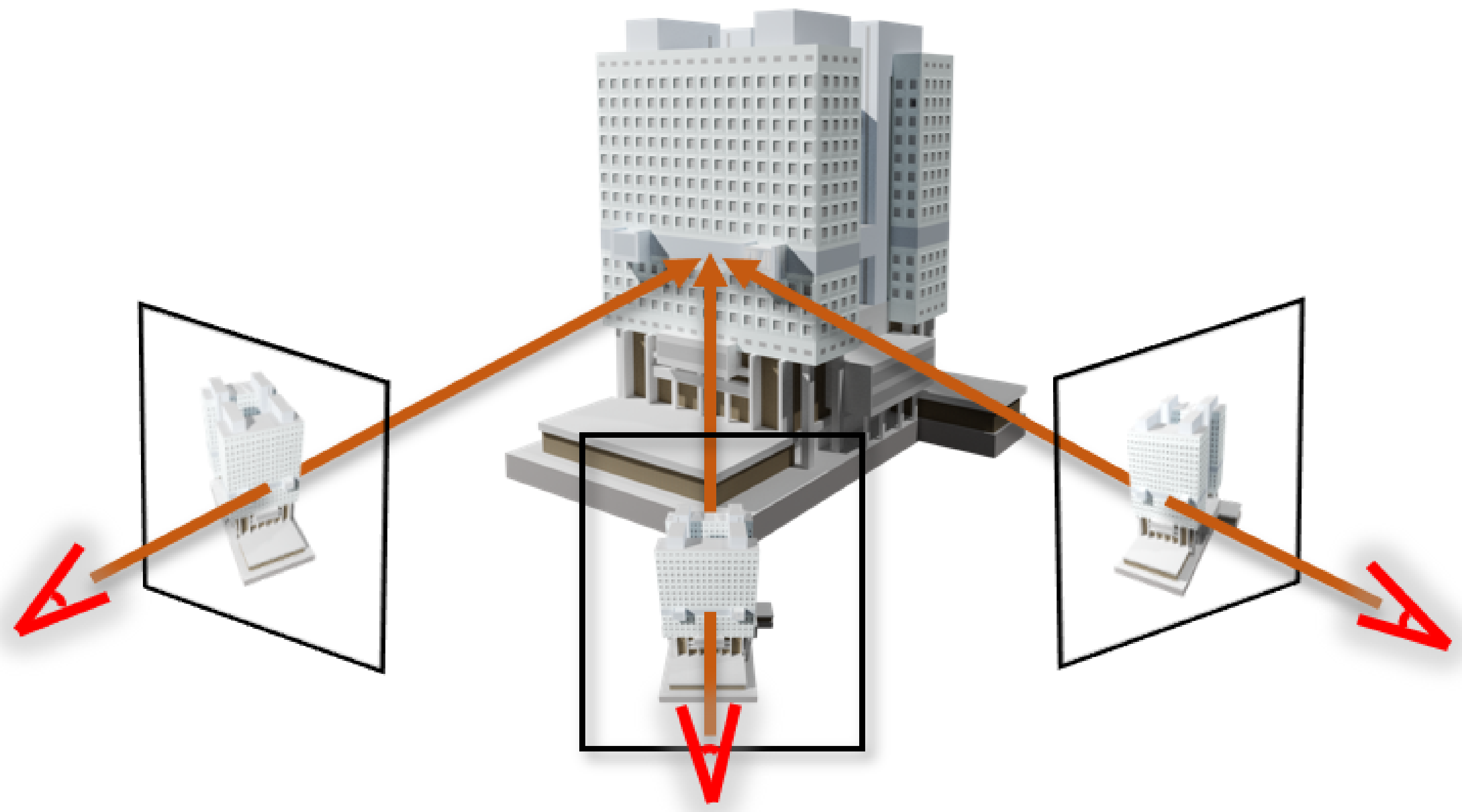
## Cross-shape semantic segmentation




## Geometric/Semantic Decomposition



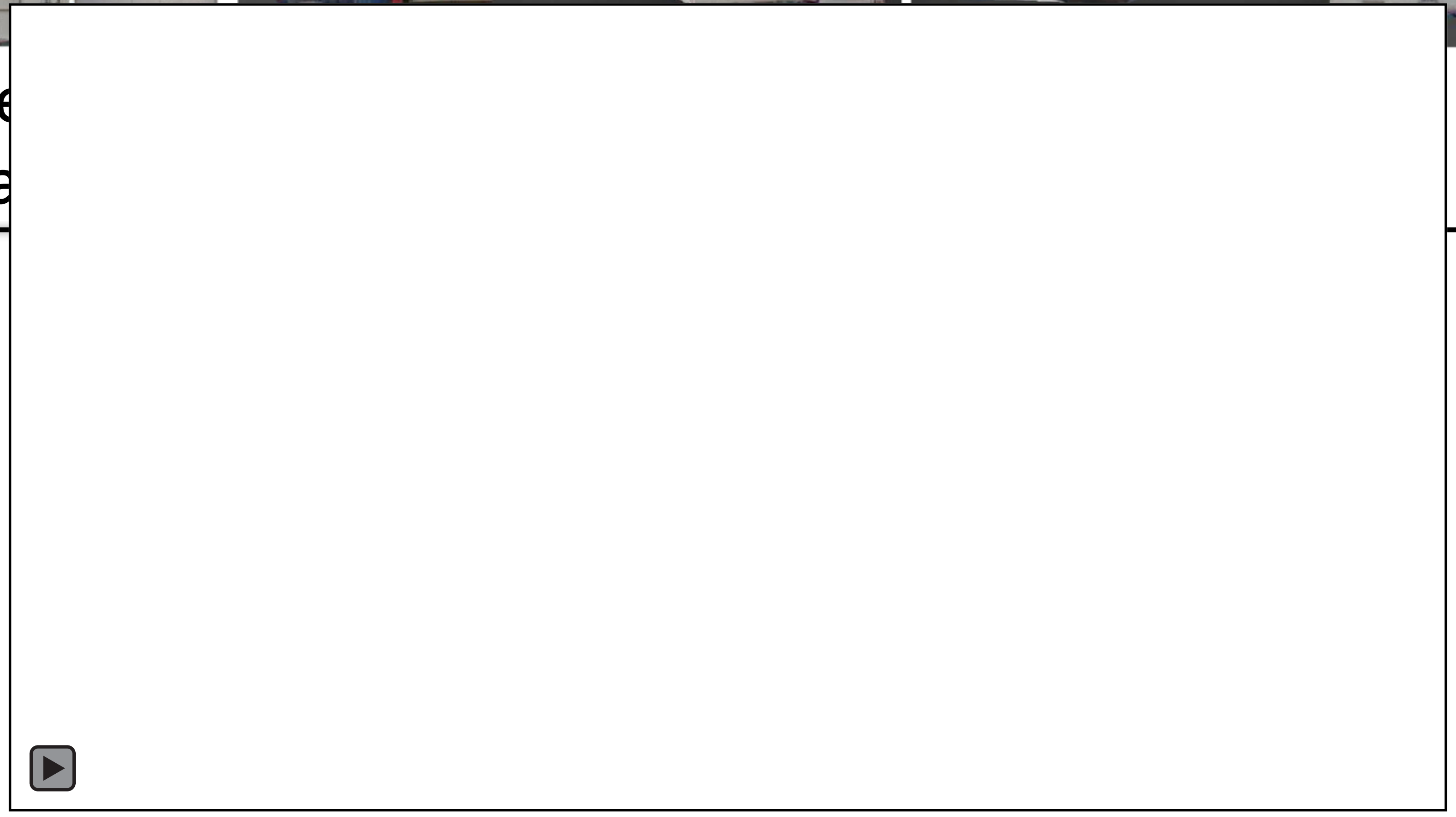

## Neural 3D Reconstruction



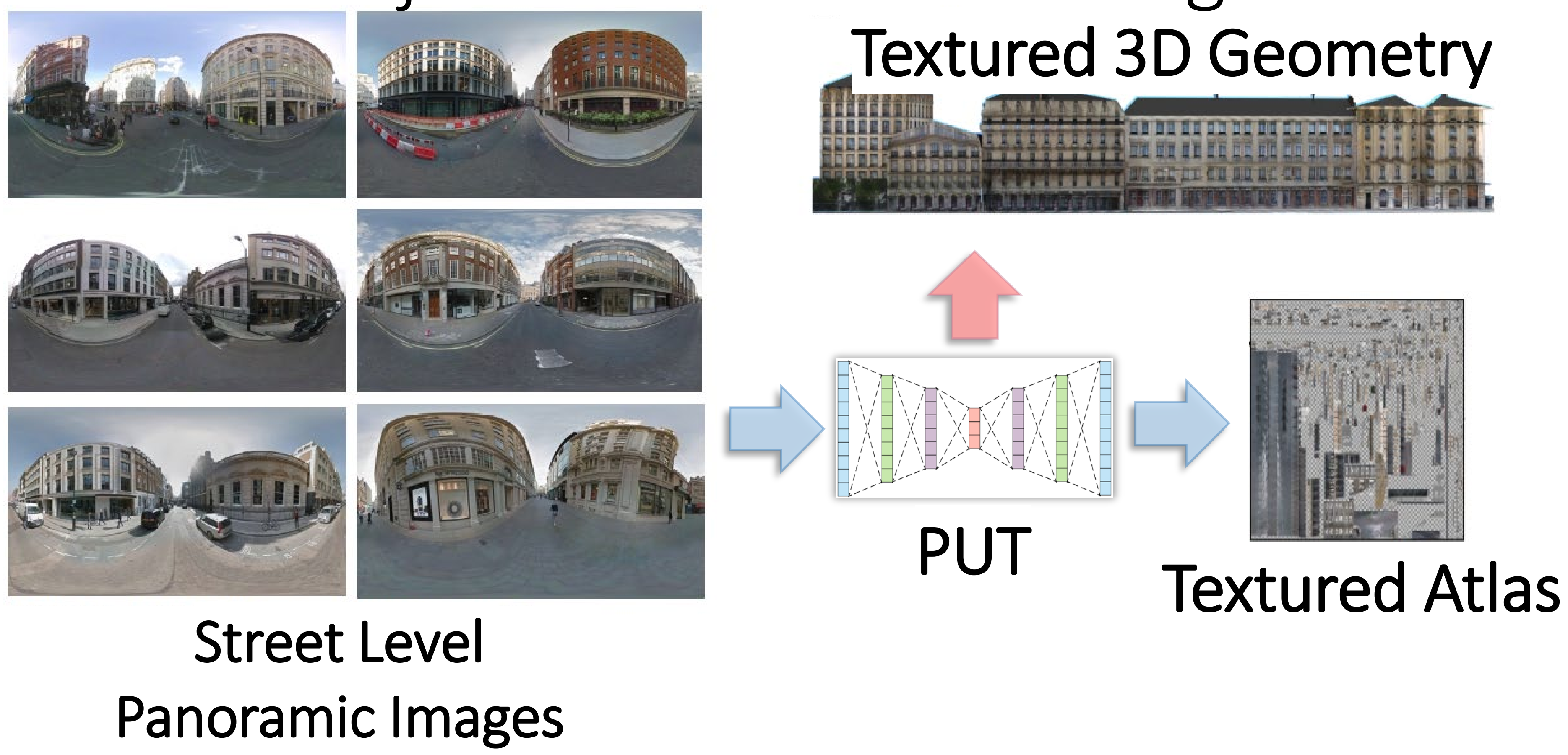
# What we do: *Texture Generation for 3D Data*

Single-View Guided Façade Synthesis

Re
Faça



Projective Urban Texturing




Surface Texture Generation via T2I Diffusion Models

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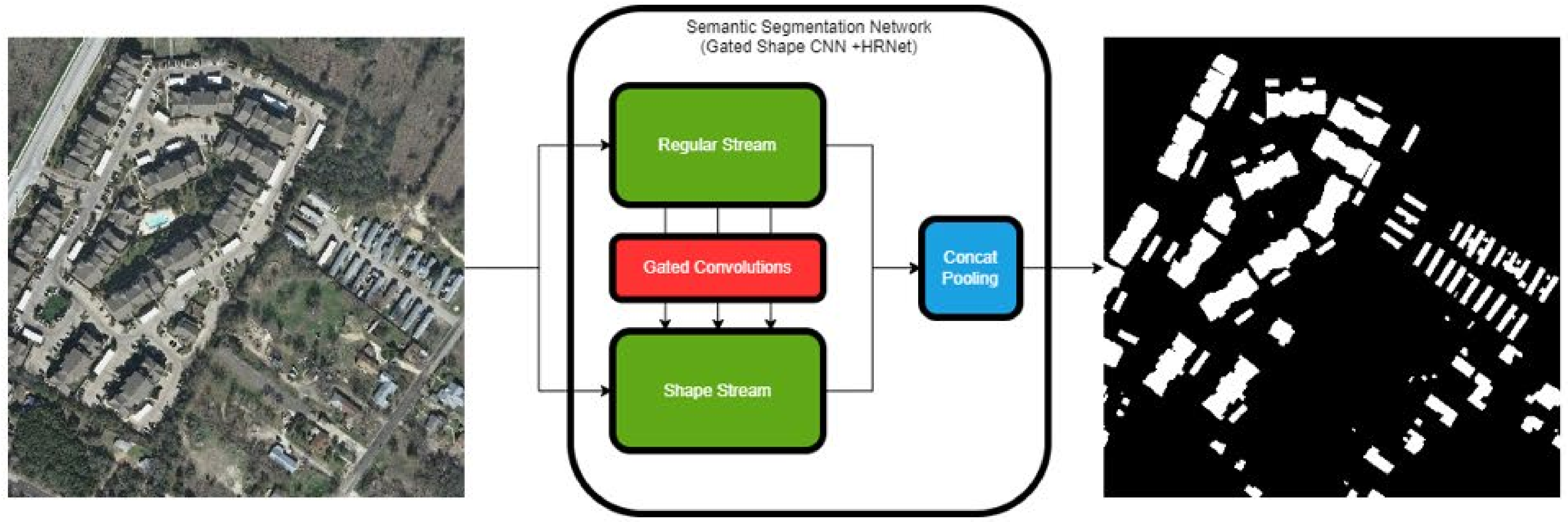
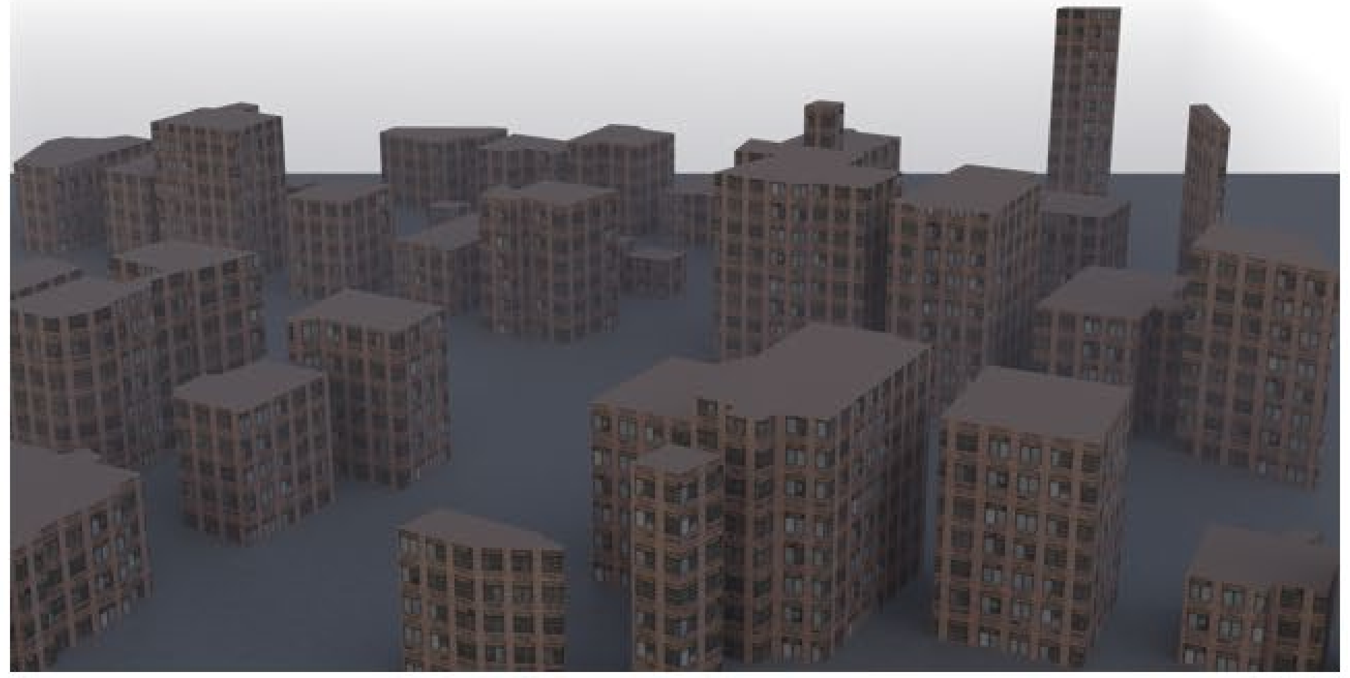
# What we do: *Urban Semantic Understanding from Remote Sensing Data Sources*

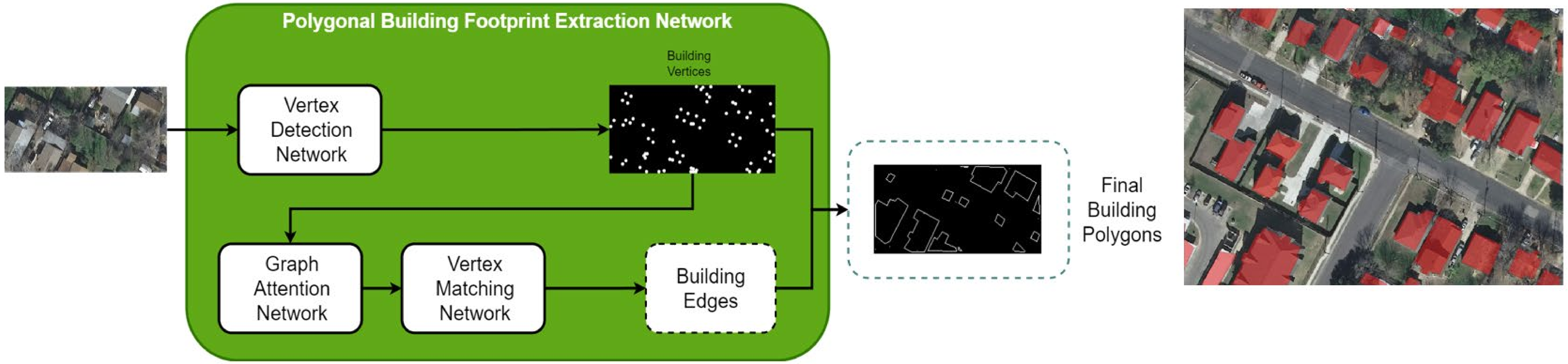
## Semantic Segmentation of Buildings




## Urban 3D Reconstruction



## Building Footprint Extraction

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# Research in Visual Computing

## Melinos Averkiou

**Team Leader**
**Visual Computing Group**

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**Research Interests:**

Geometry processing, acquisition, understanding and modeling of 3D geometry, deep learning for 3D objects, including part segmentation, material identification and style detection.

https://www.cyens.org.cy/en-gb/research/pillars-groups/visual-sciences/deep-camera/people/alessandro-artusi/

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# Thank you!


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