

BSP-Net: Generating Compact Meshes via Binary Space Partitioning

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Google Research

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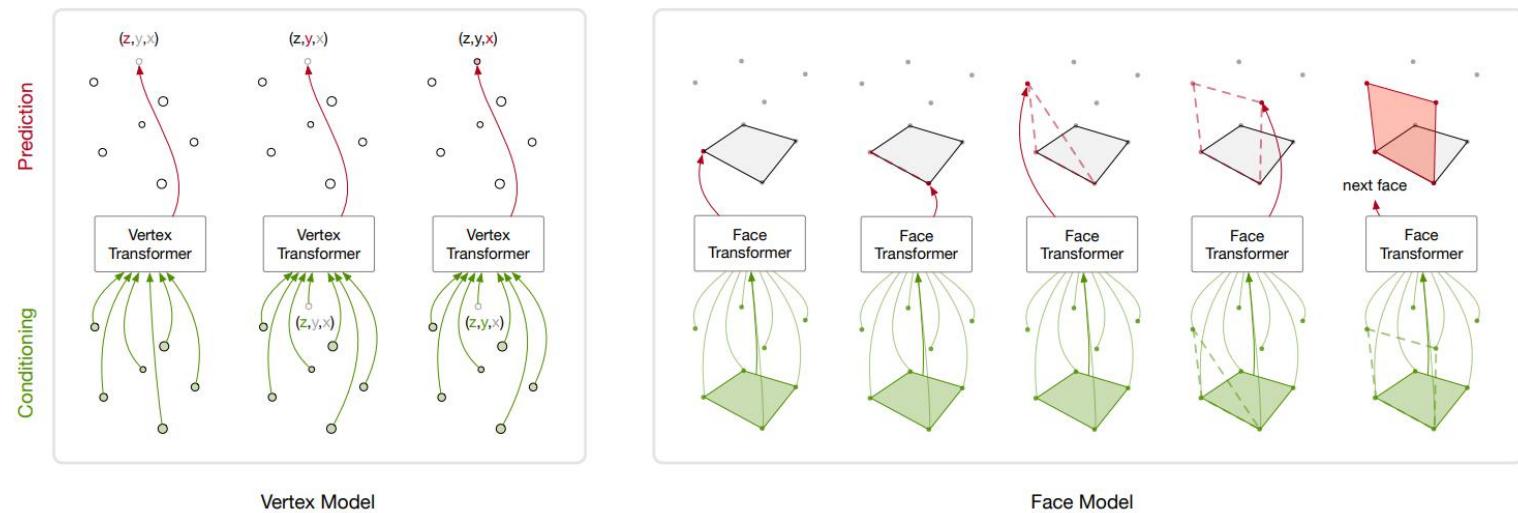
Presented by

陈之钦, 西蒙弗雷泽大学

Zhiqin Chen, Ph.D. student, Simon Fraser University

3D shape representations

Mesh



ShapeNet

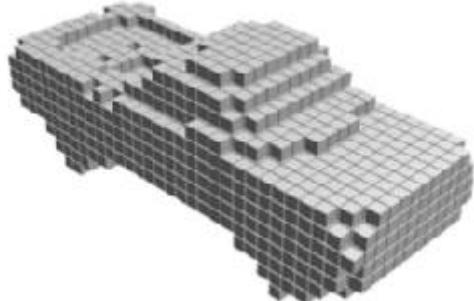
Chang et al, arXiv

PolyGen

Nash et al, arXiv

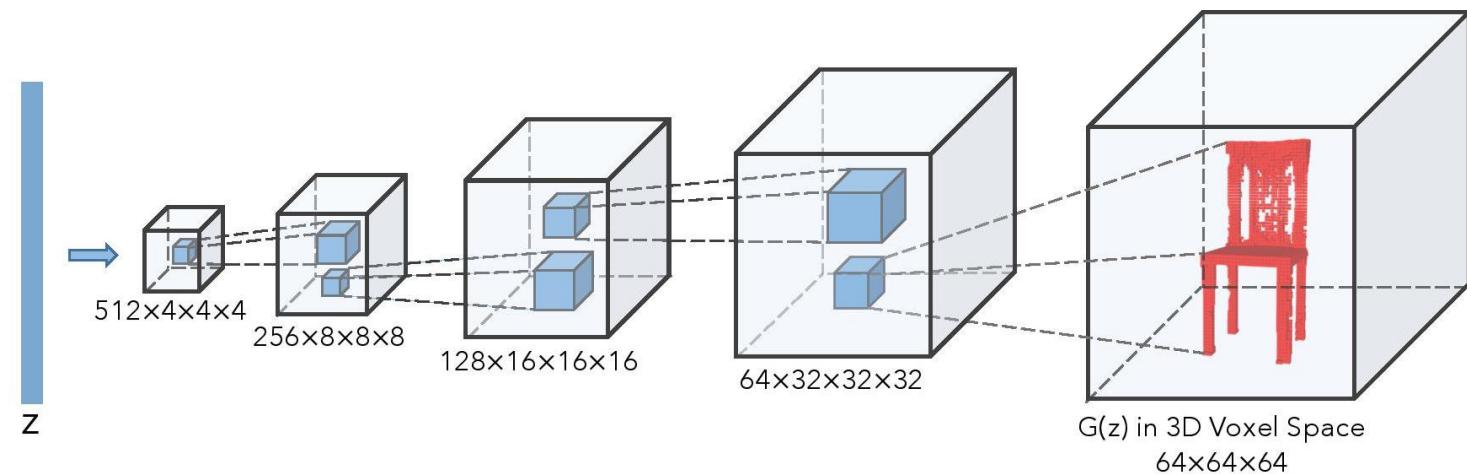
3D shape representations

Voxel



3D-R2N2

Choy et al, ECCV 2016



3DGAN

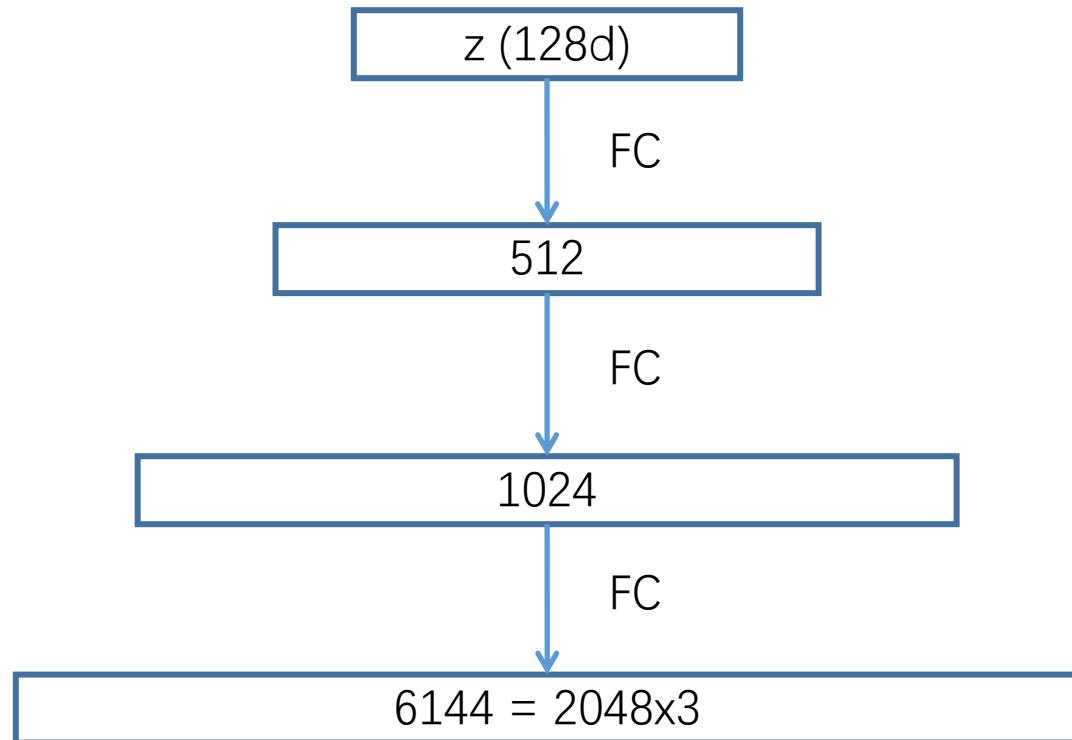
Wu et al, NIPS 2016

3D shape representations

Point cloud

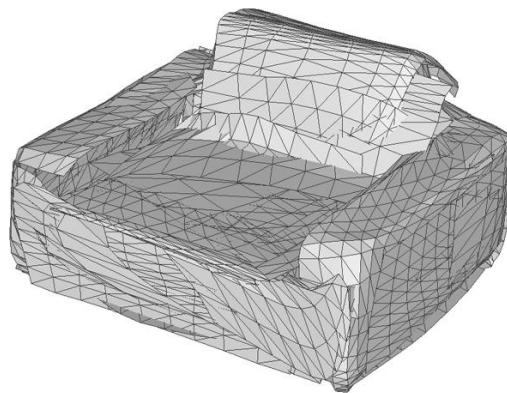


Learning Representations and Generative
Models for 3D Point Clouds
Achlioptas et al, ICML 2018



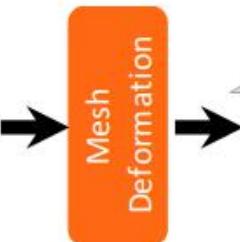
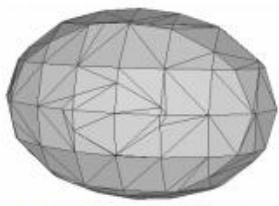
3D shape representations

Warping template meshes



3DN

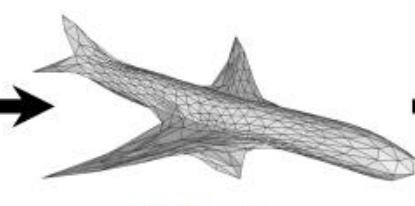
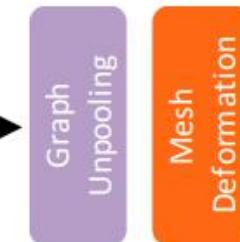
Wang et al, CVPR 2019



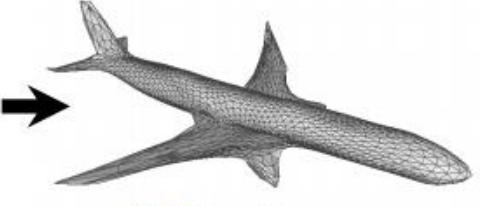
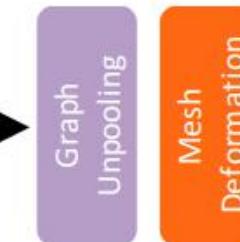
156 vertices

AtlasNet

Groueix et al, CVPR 2018



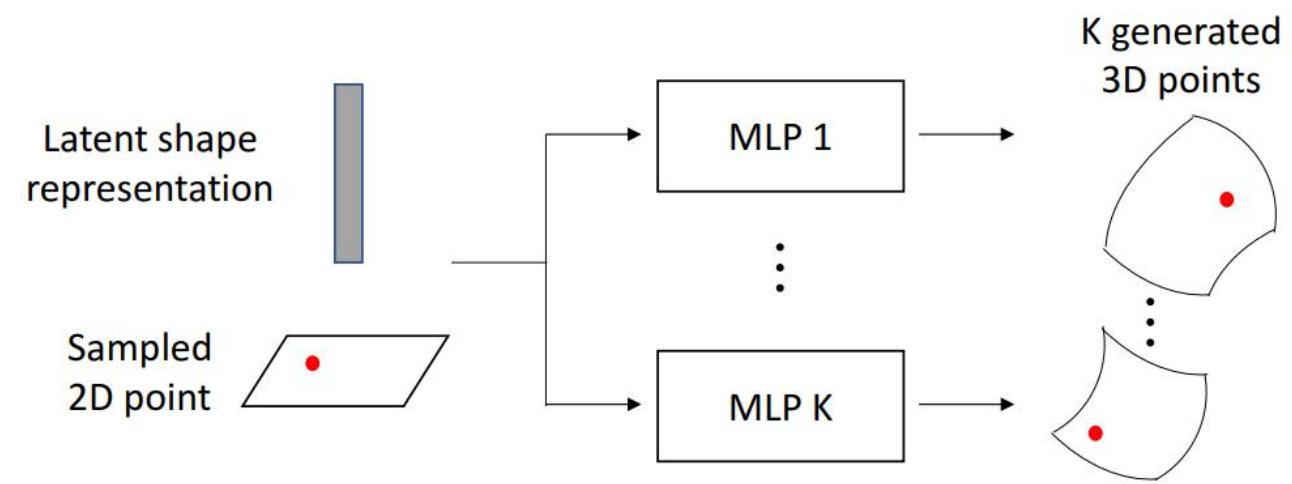
628 vertices



2466 vertices

Pixel2mesh

Wang et al, ECCV 2018



3D shape representations

implicit field



IM-NET

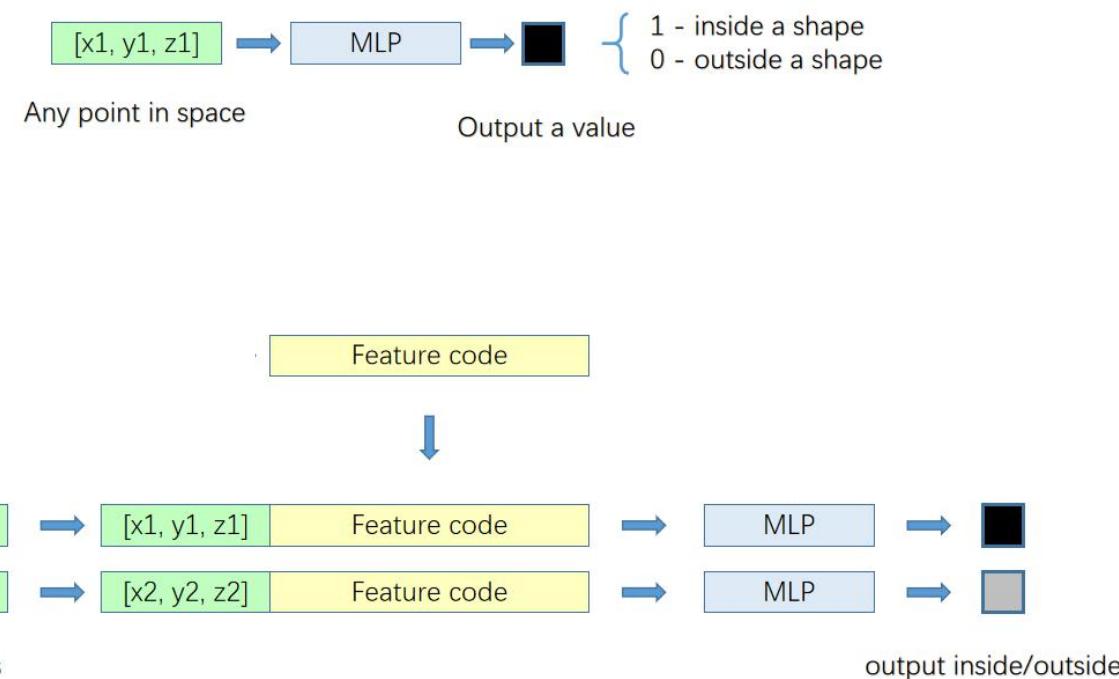
Chen & Zhang, CVPR 2019

OccNet

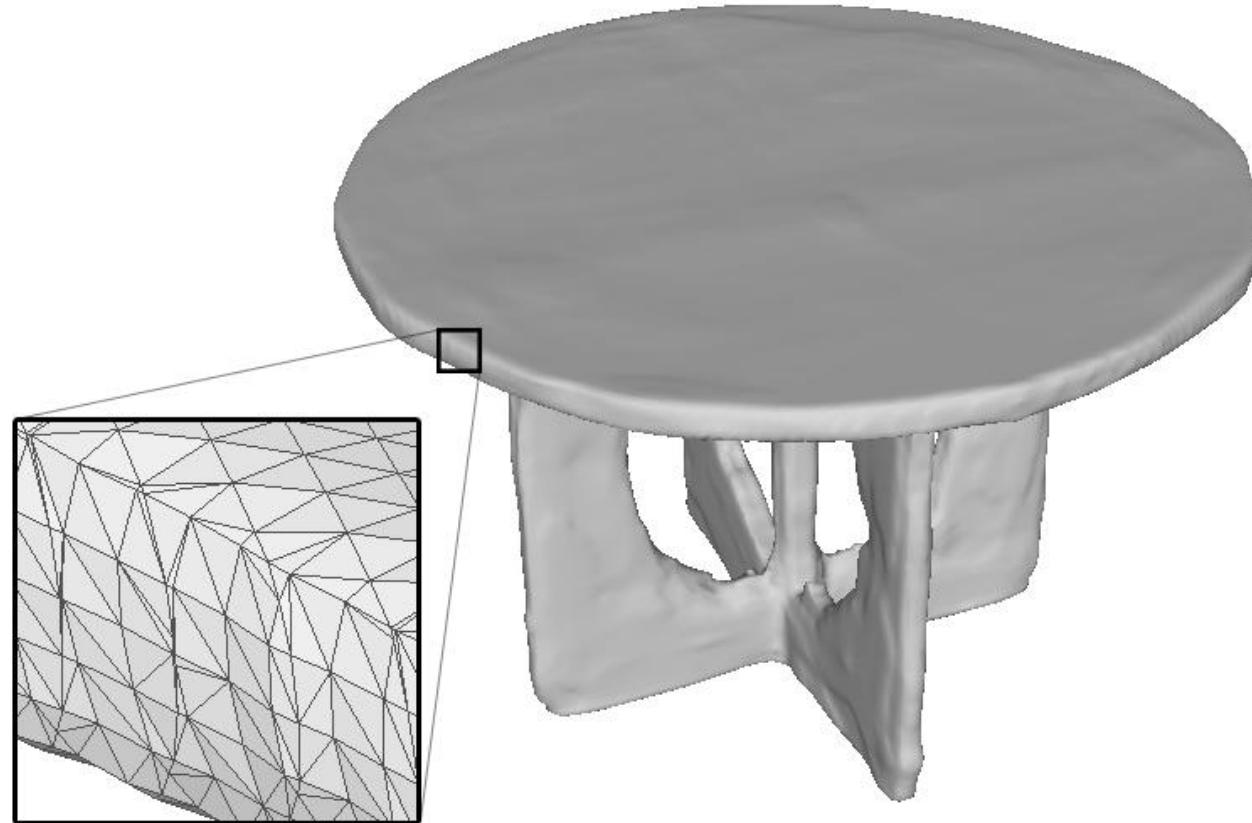
Mescheder et al, CVPR 2019

DeepSDF

Park et al, CVPR 2019

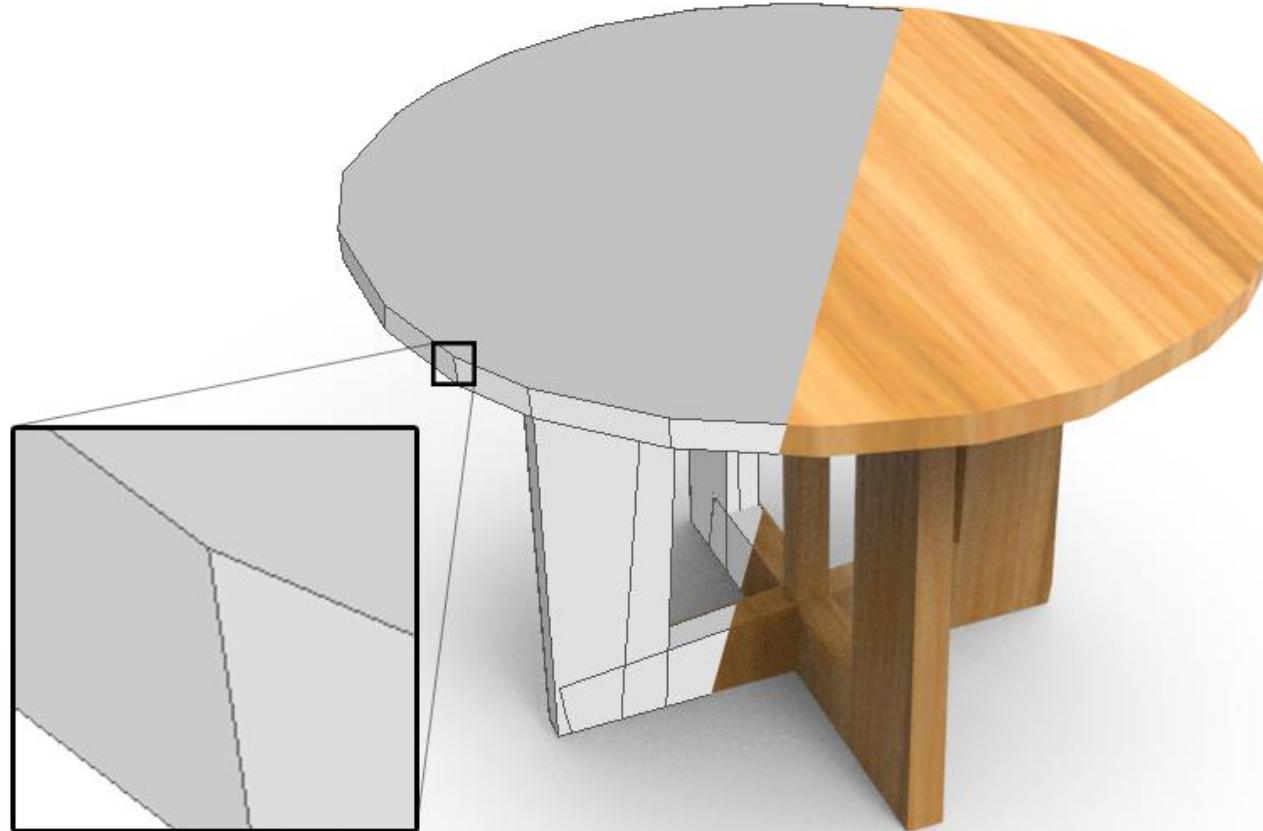


Compactness / low-poly / sharp details



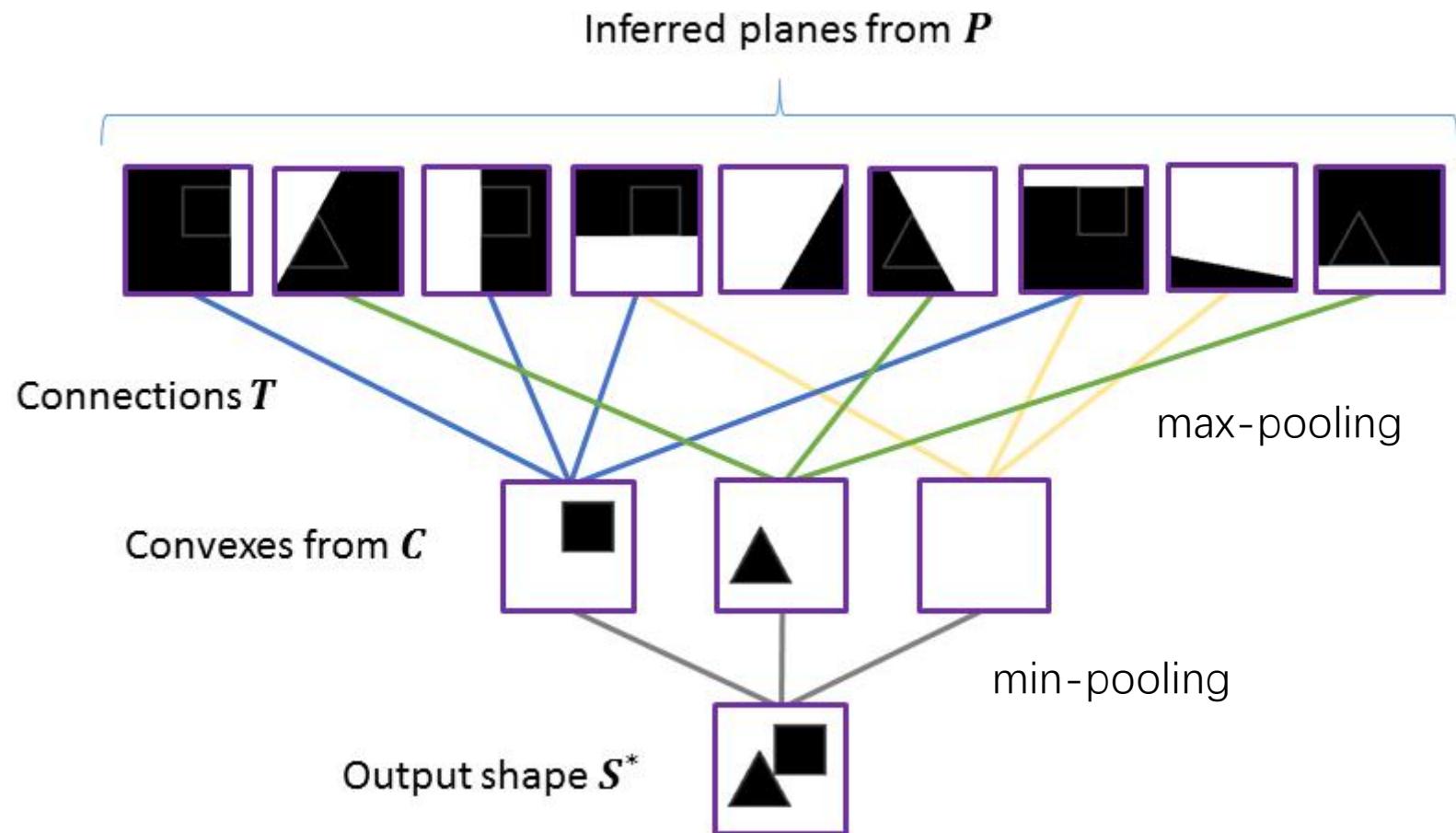
IM-NET output
(sampled at 256^3 , 91,542 vertices, 183,096 triangles)

Compactness / low-poly / sharp details

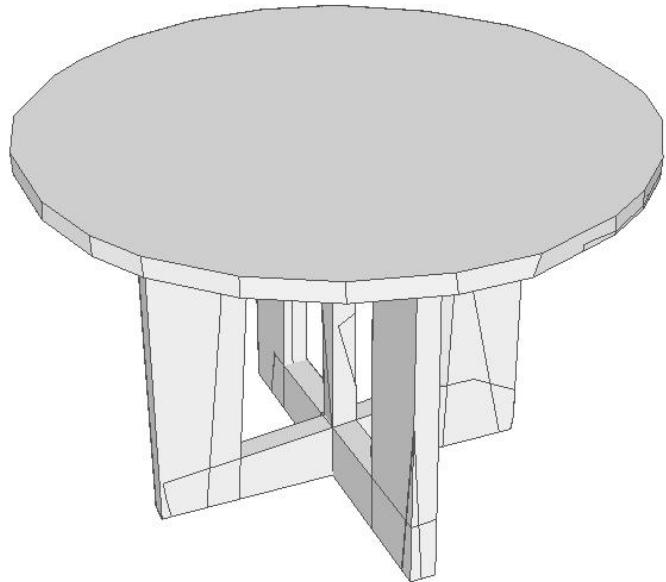
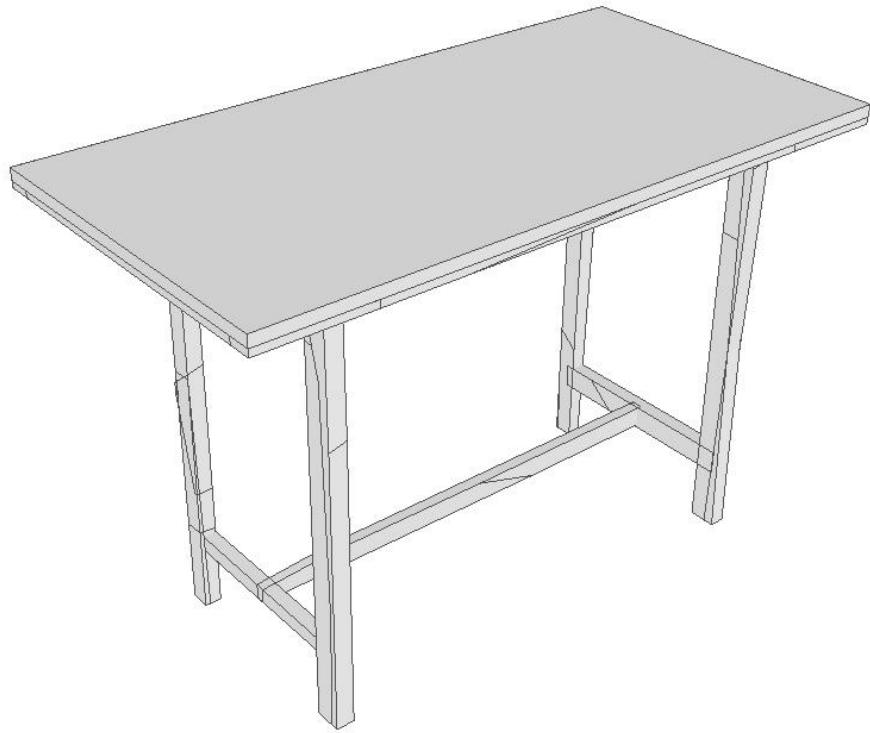


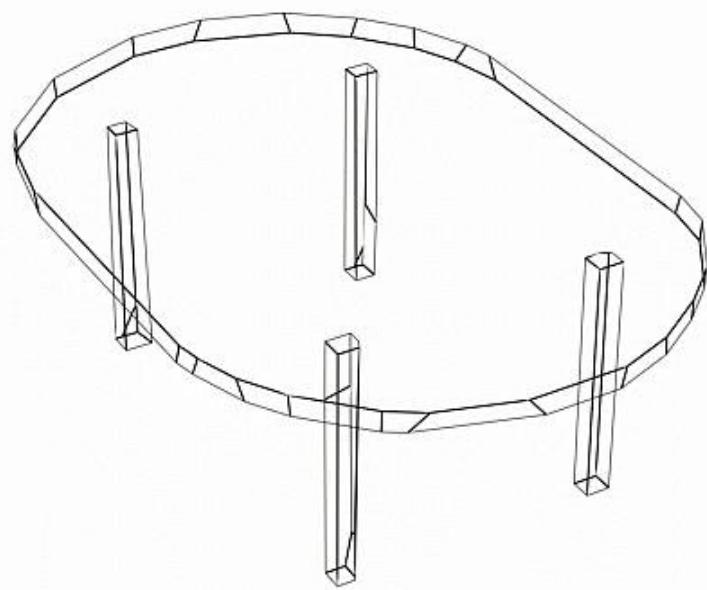
(392 vertices, 219 polygons or 600 triangles)

Represent shapes as Binary Space Partitioning trees



*CSG operations – Constructive Solid Geometry operations





Network architecture

Network

Point coordinates

$$\mathbf{x}_{n \times 4}$$

Voxels / Images

Encoder

Feature code

MLP

Plane parameters

$$L_0$$

$$\mathbf{P}_{p \times 4}$$

Signed distances

$$L_1$$

$$\mathbf{D} = \mathbf{x} \mathbf{P}^T$$

Binary matrix

$$\mathbf{T}_{p \times c}$$

\otimes max-pooling

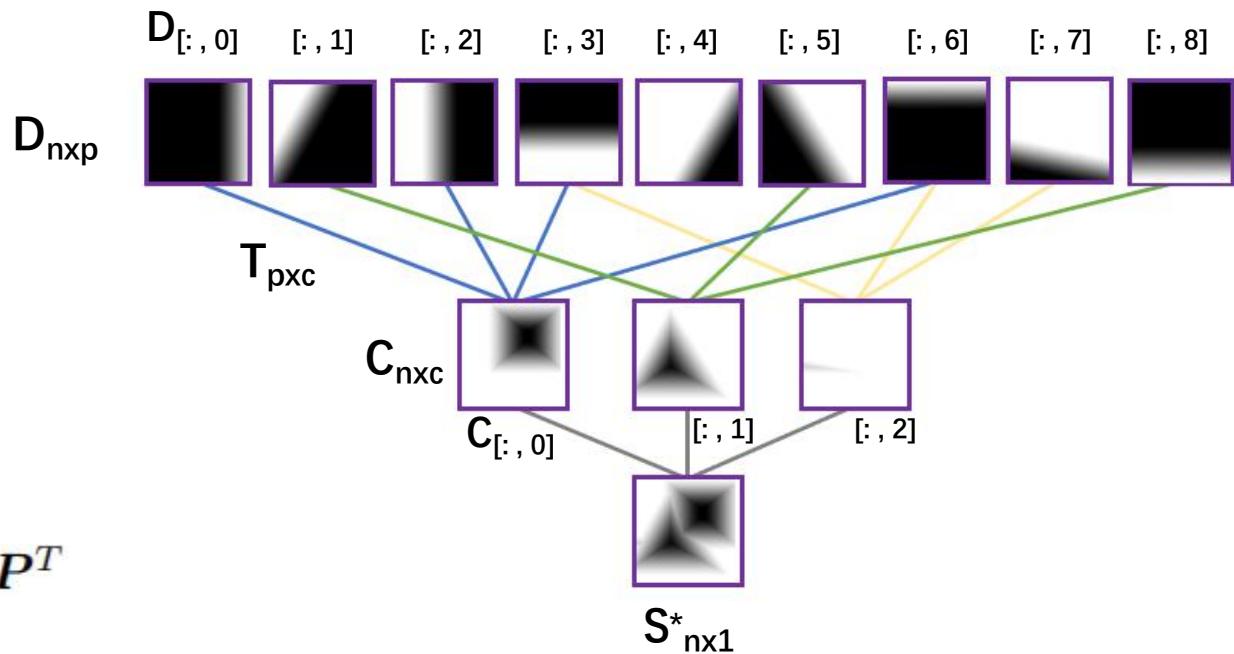
Convexes

$$L_2$$

\square min-pooling

Shape

$$L_3$$

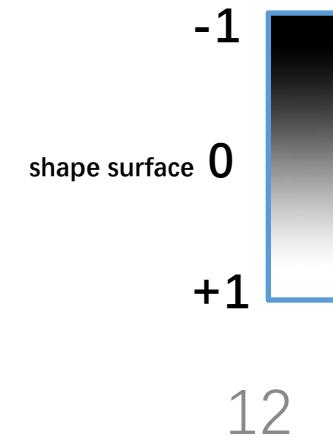


$$C_j(\mathbf{x}) = \max_i(D_i T_{ij})$$

$$\begin{cases} < 0 & \text{inside} \\ > 0 & \text{outside} \end{cases}$$

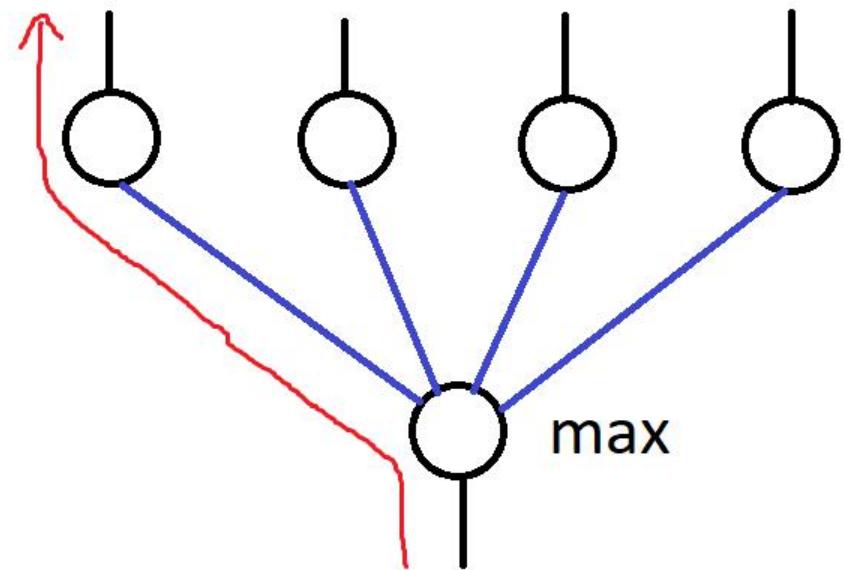
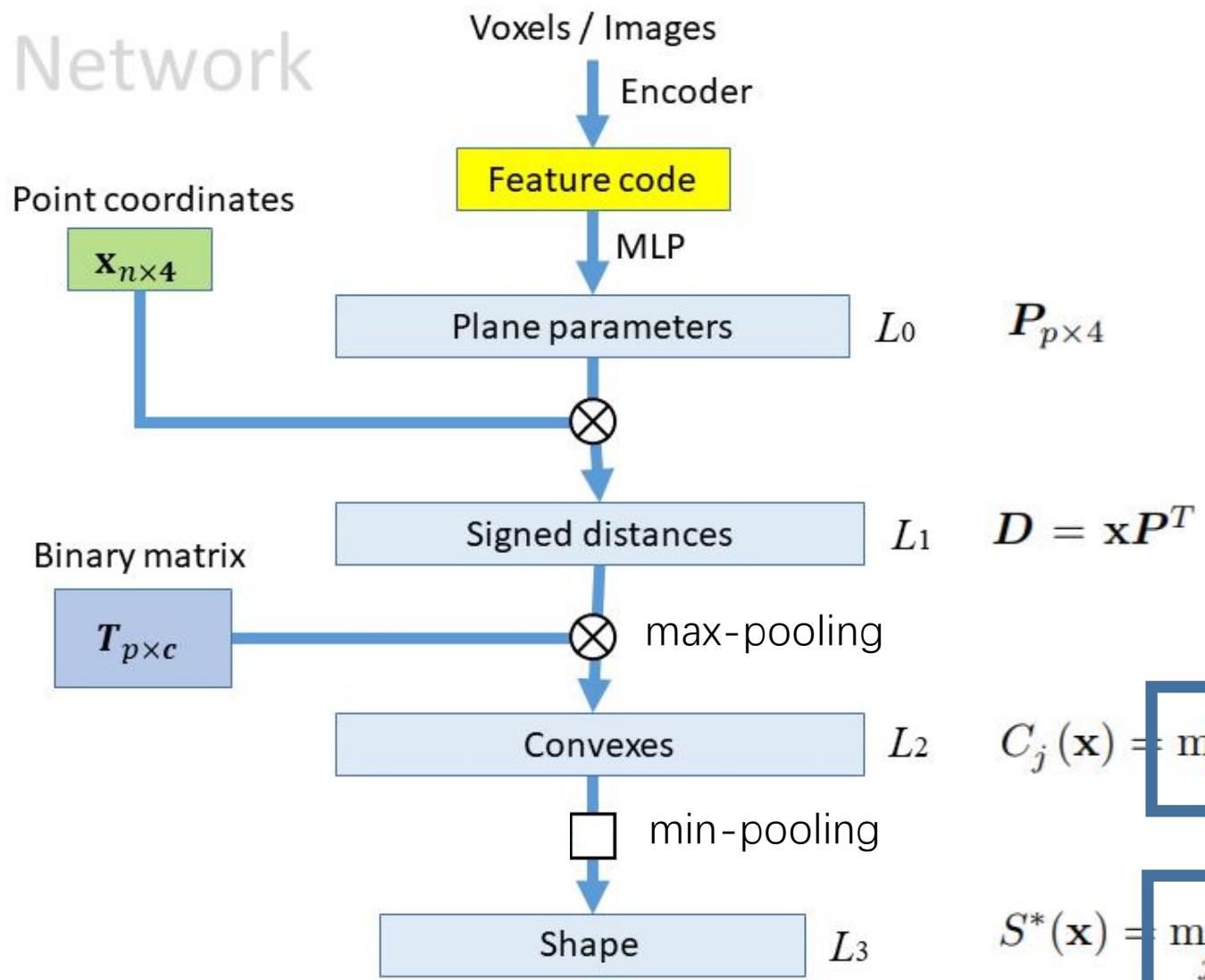
$$S^*(\mathbf{x}) = \min_j(C_j(\mathbf{x}))$$

$$\begin{cases} < 0 & \text{inside} \\ > 0 & \text{outside} \end{cases}$$



Network architecture

Network

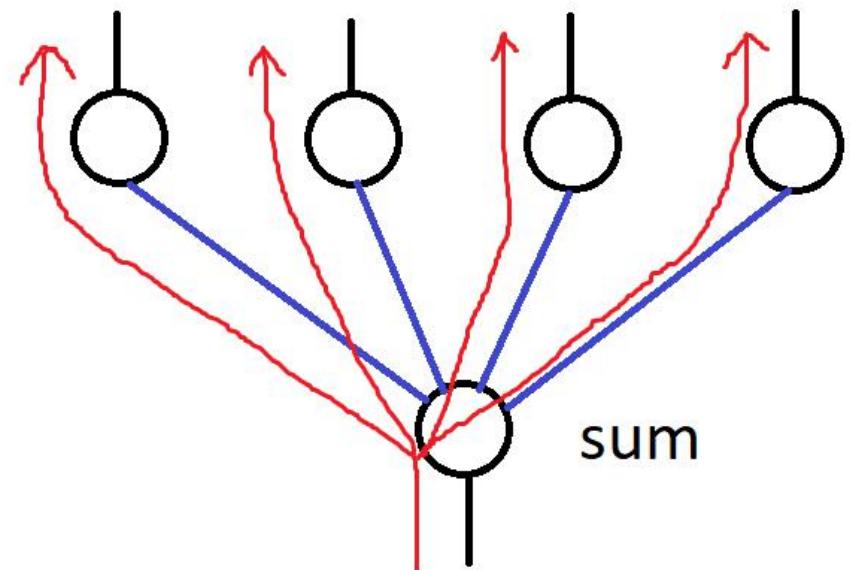
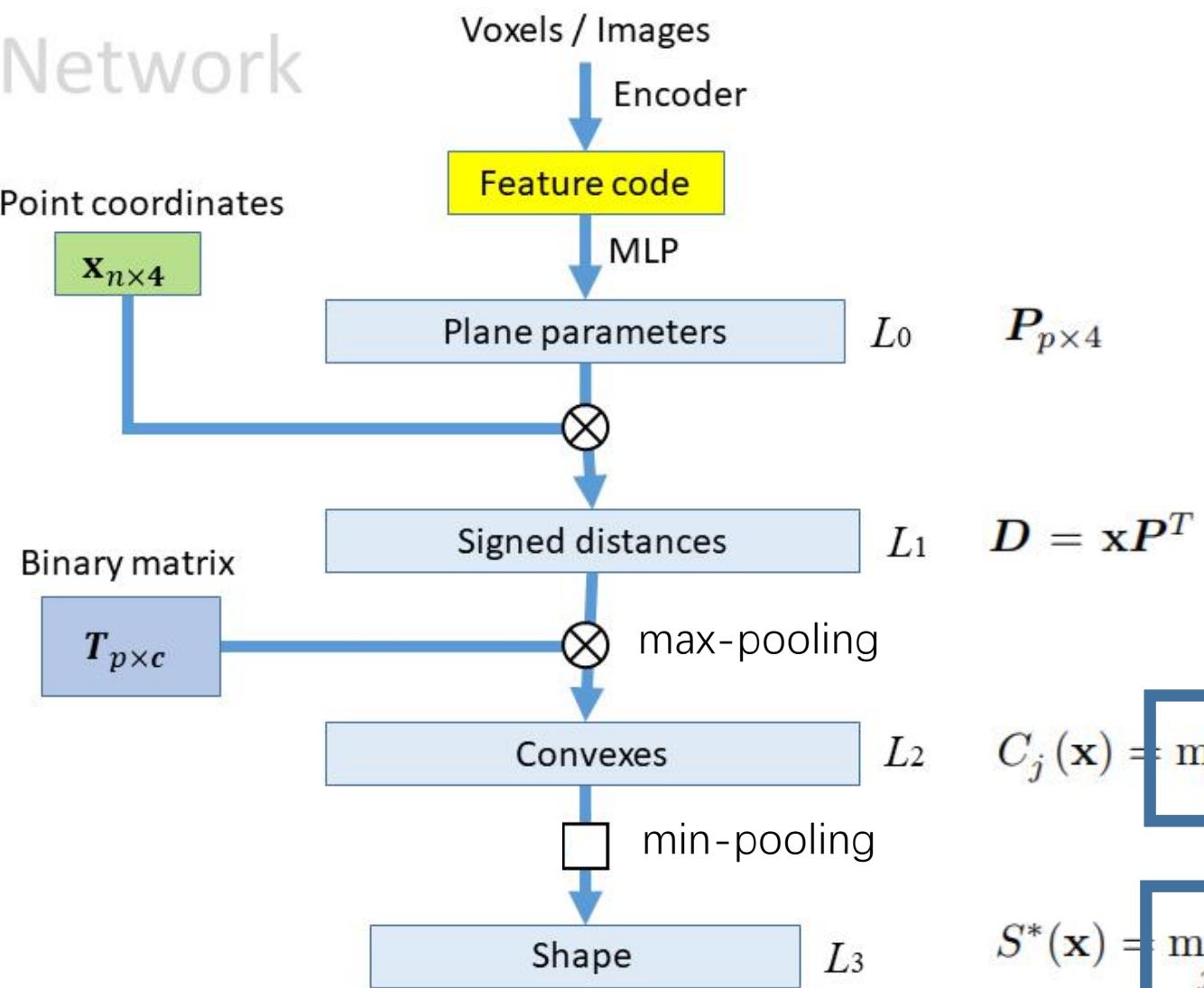


$$C_j(\mathbf{x}) = \max_i(D_i T_{ij}) \quad \begin{cases} < 0 & \text{inside} \\ > 0 & \text{outside} \end{cases}$$

$$S^*(\mathbf{x}) = \min_j(C_j(\mathbf{x})) \quad \begin{cases} < 0 & \text{inside} \\ > 0 & \text{outside} \end{cases}$$

Network architecture

Network

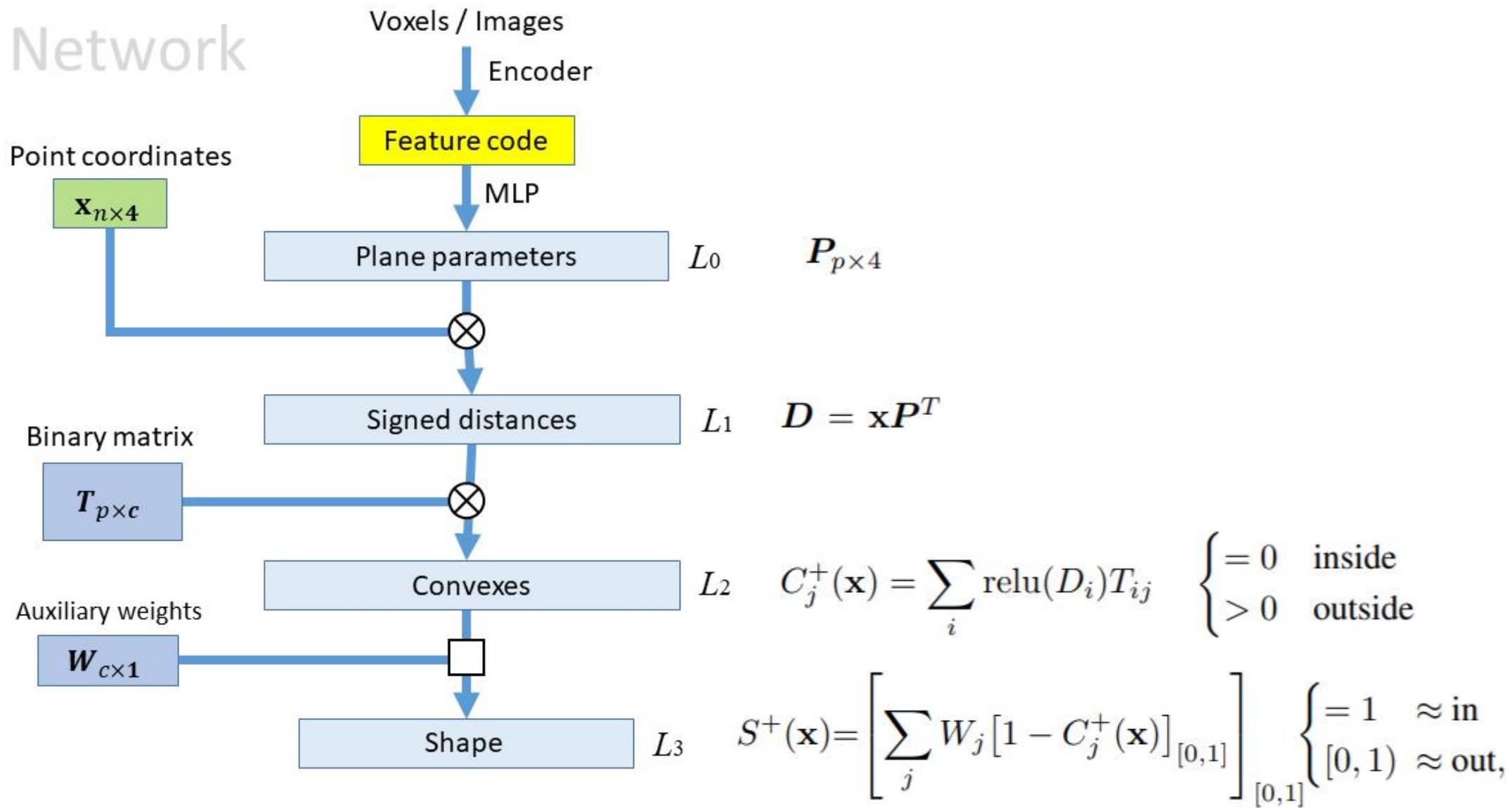


$$C_j(\mathbf{x}) = \max_i(D_i T_{ij}) \quad \begin{cases} < 0 & \text{inside} \\ > 0 & \text{outside} \end{cases}$$

$$S^*(\mathbf{x}) = \min_j(C_j(\mathbf{x})) \quad \begin{cases} < 0 & \text{inside} \\ > 0 & \text{outside} \end{cases}$$

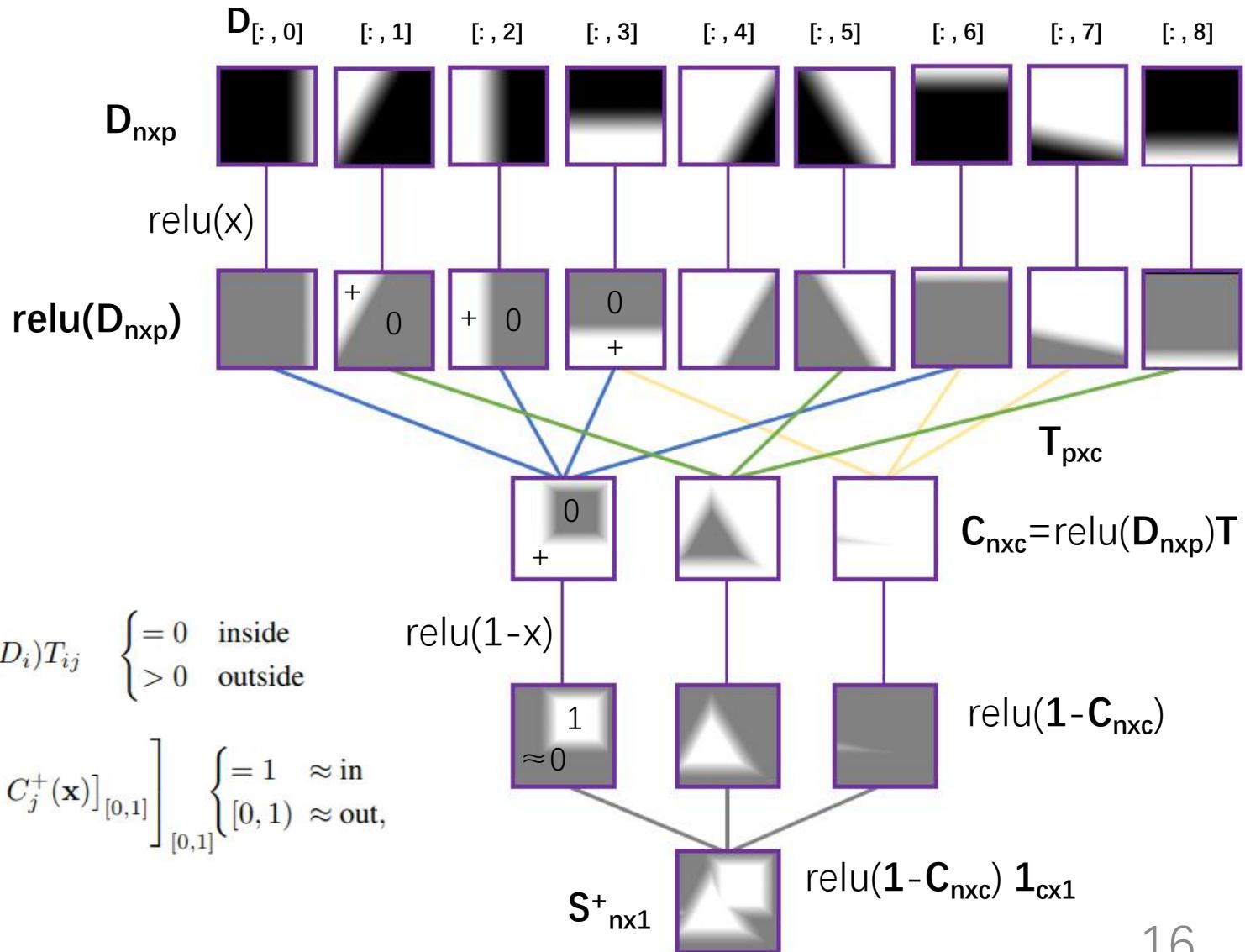
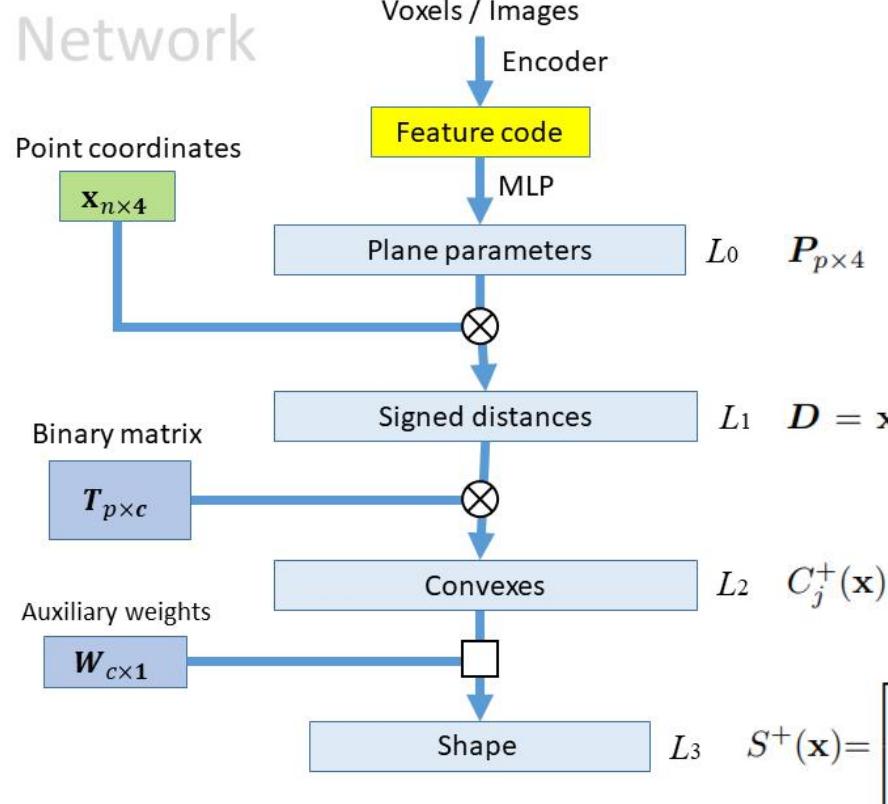
Replacing max/min with weighted sum

Network



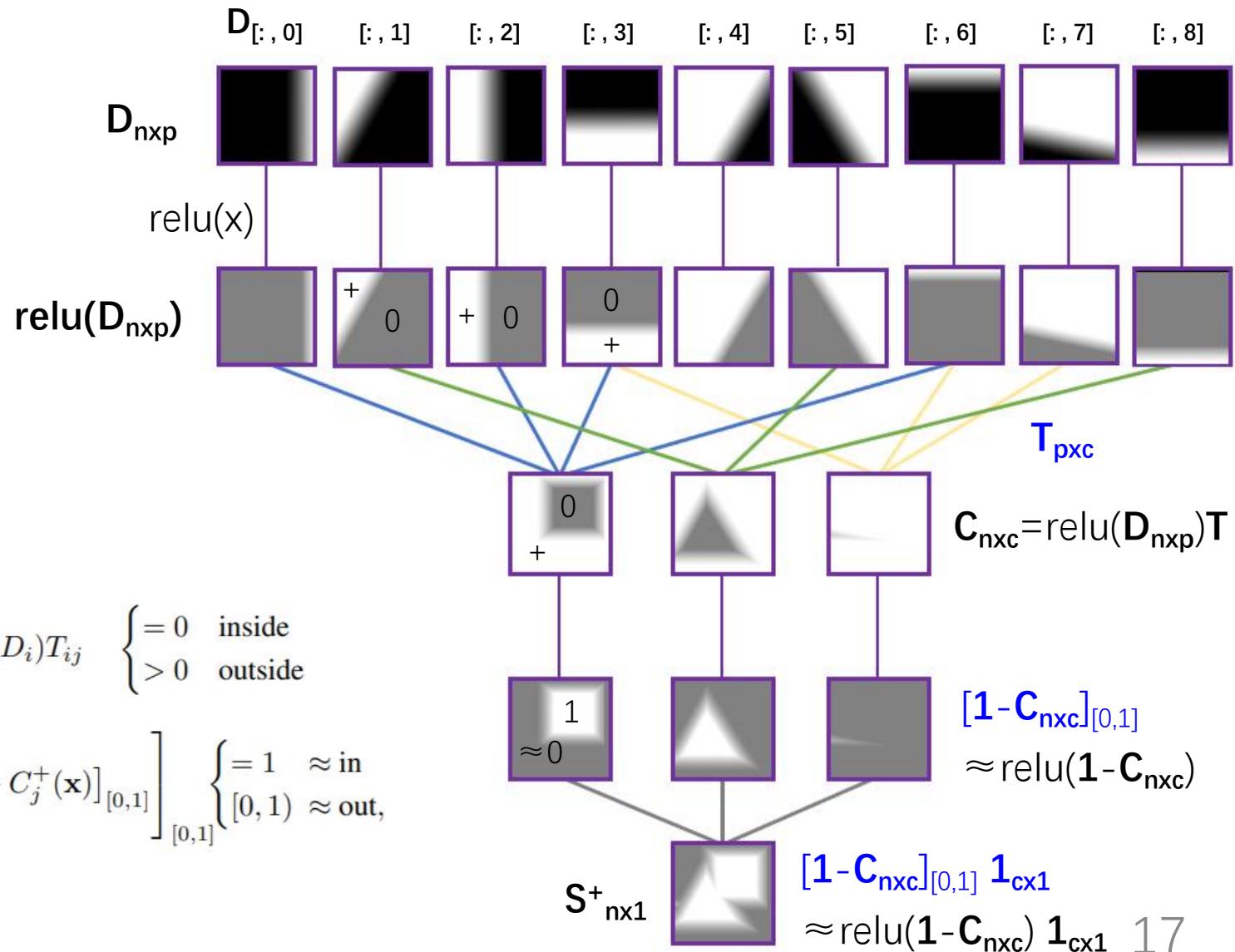
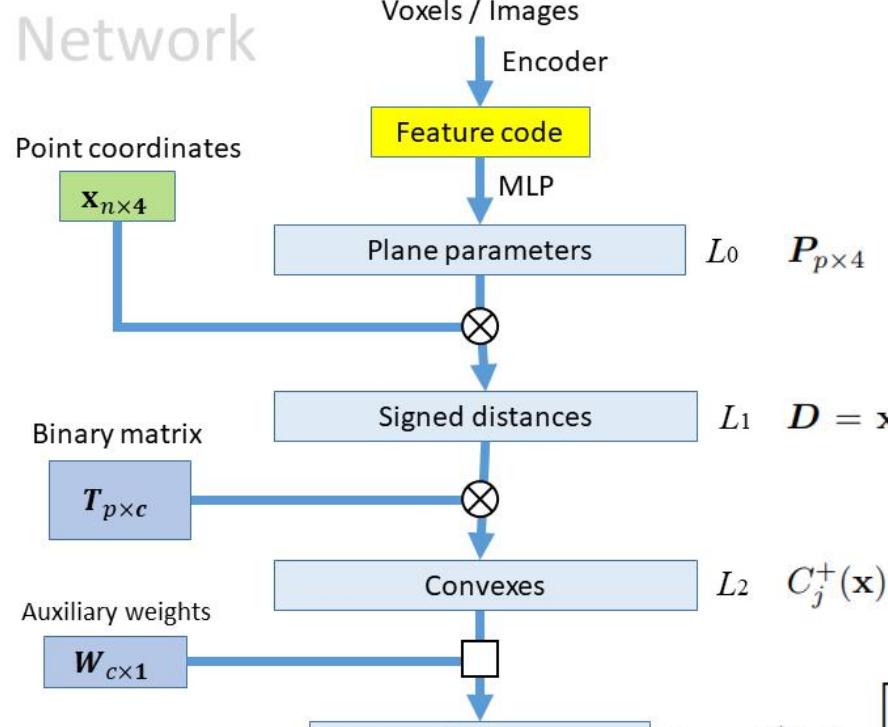
Replacing max/min with weighted sum

Network



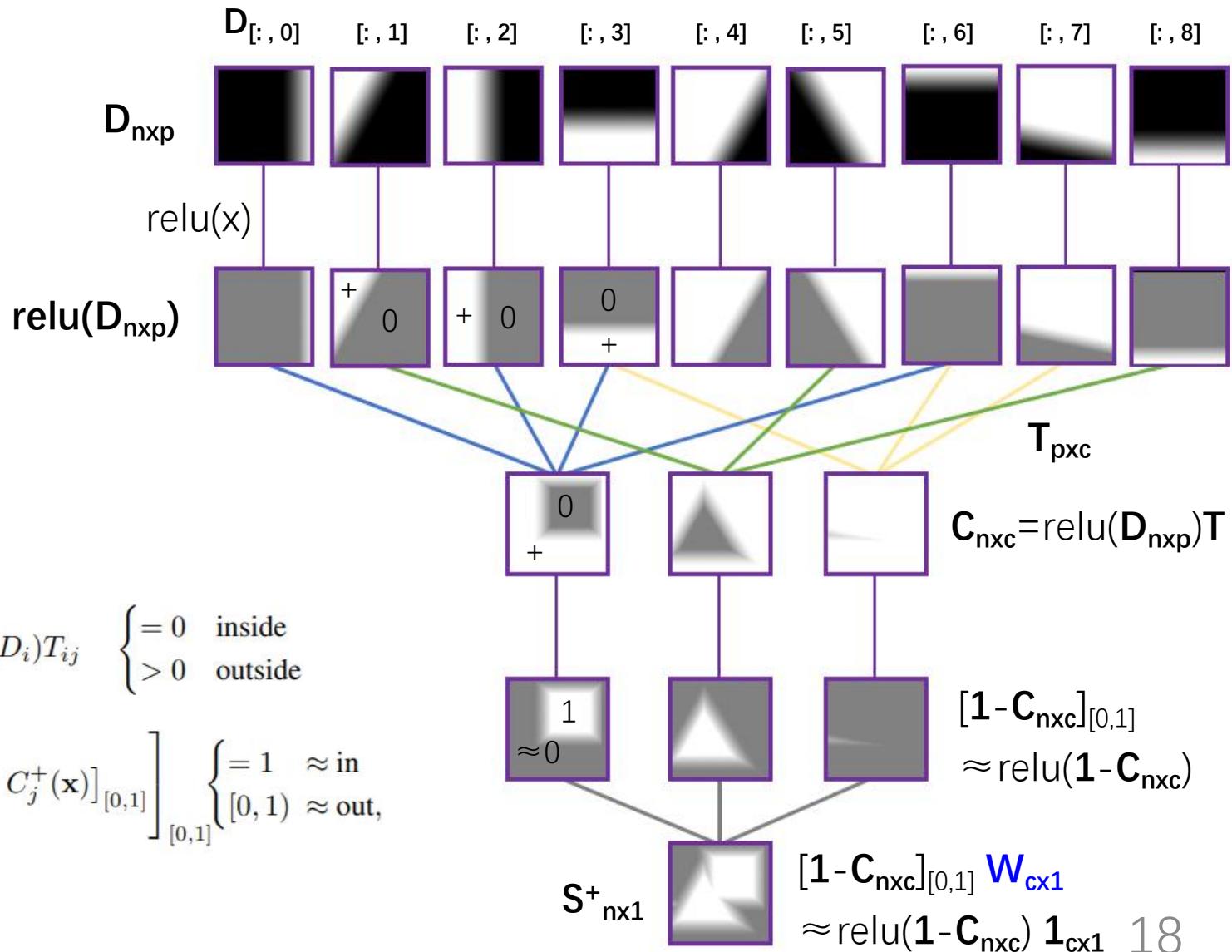
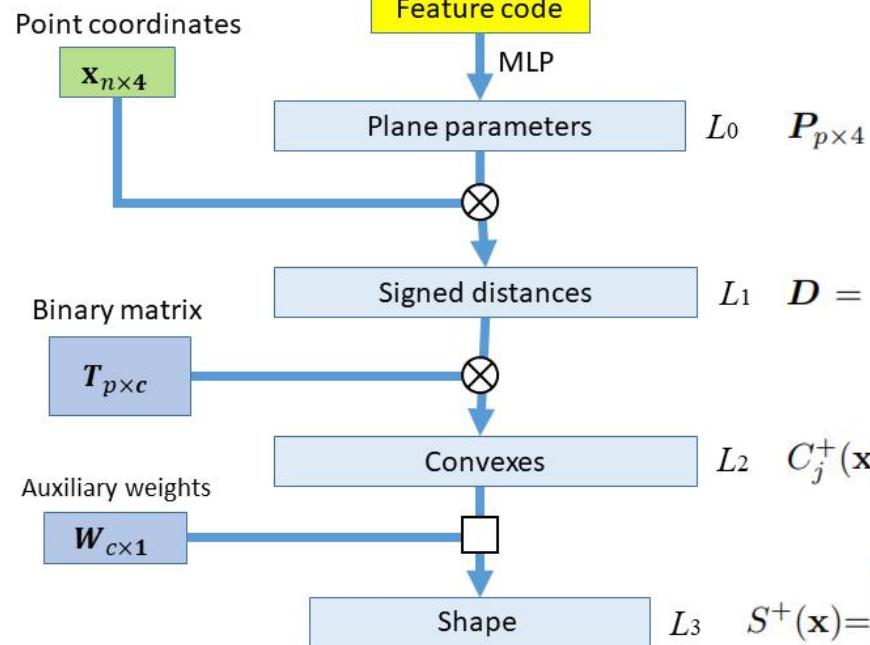
Replacing max/min with weighted sum

Network



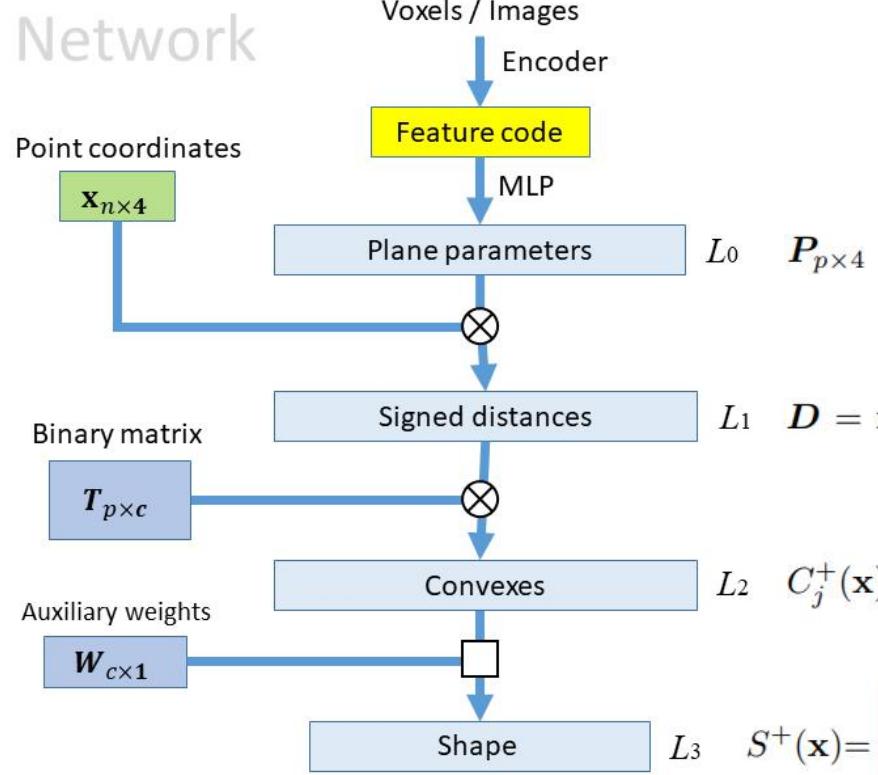
Replacing max/min with weighted sum

Network

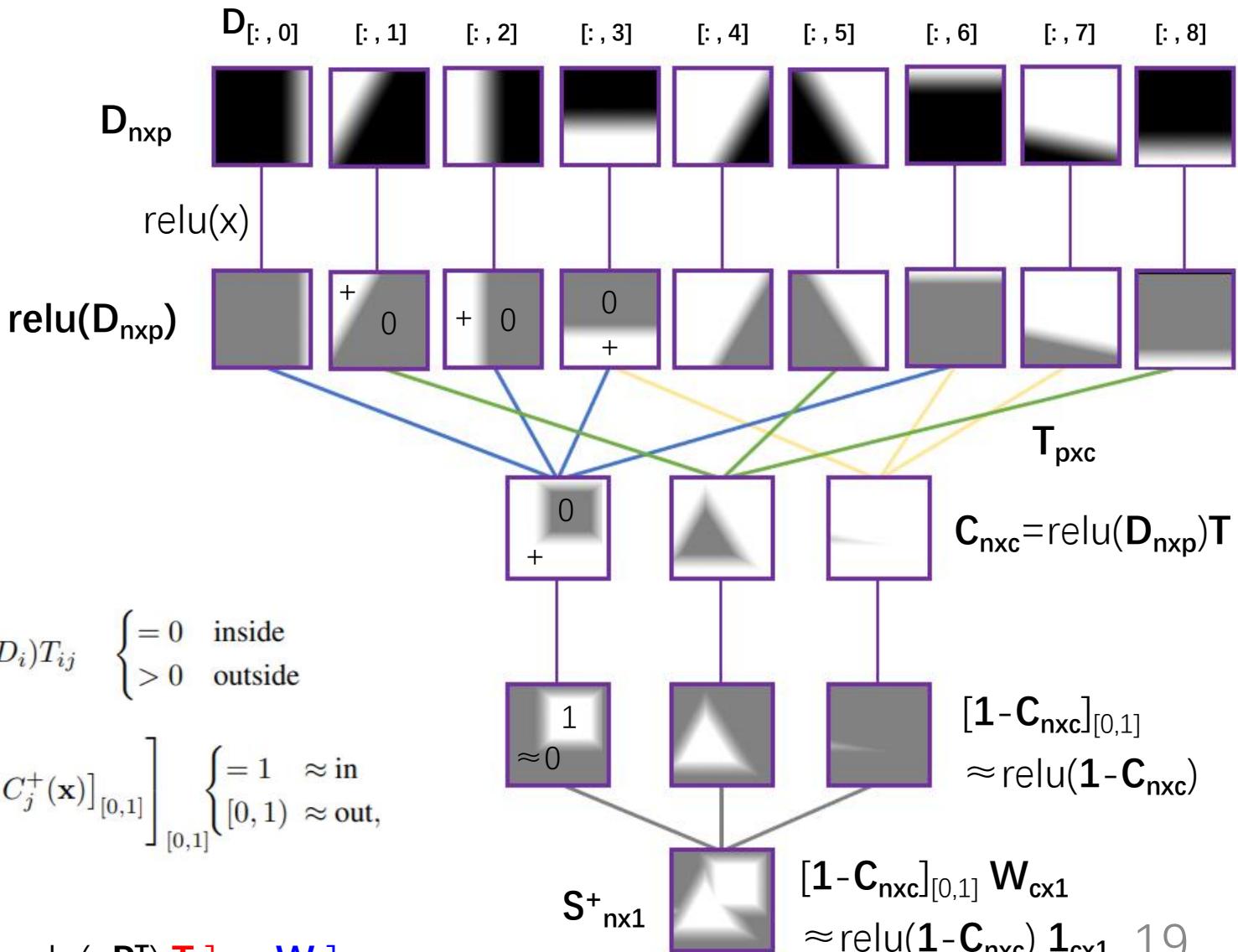


Replacing max/min with weighted sum

Network

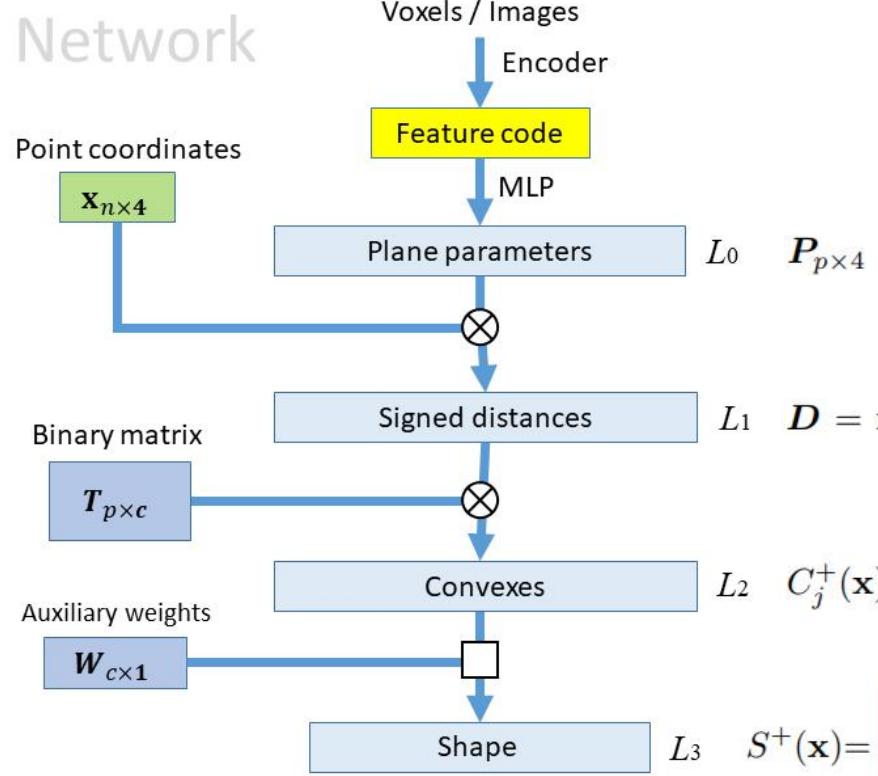


$$[[1 - \text{relu}(\mathbf{x}\mathbf{P}^T) \mathbf{T}]_{[0,1]} \mathbf{W}]_{[0,1]}$$

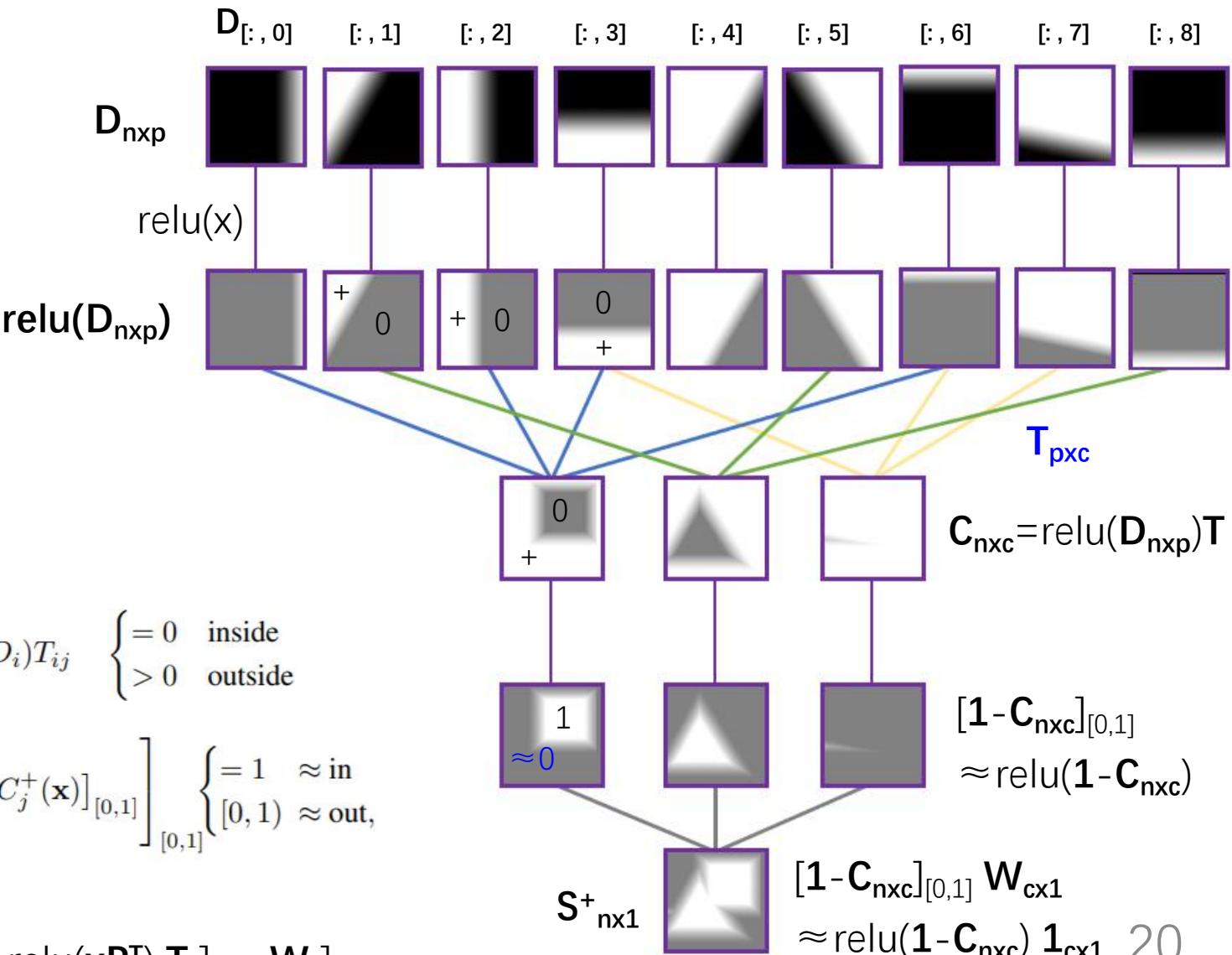


Replacing max/min with weighted sum

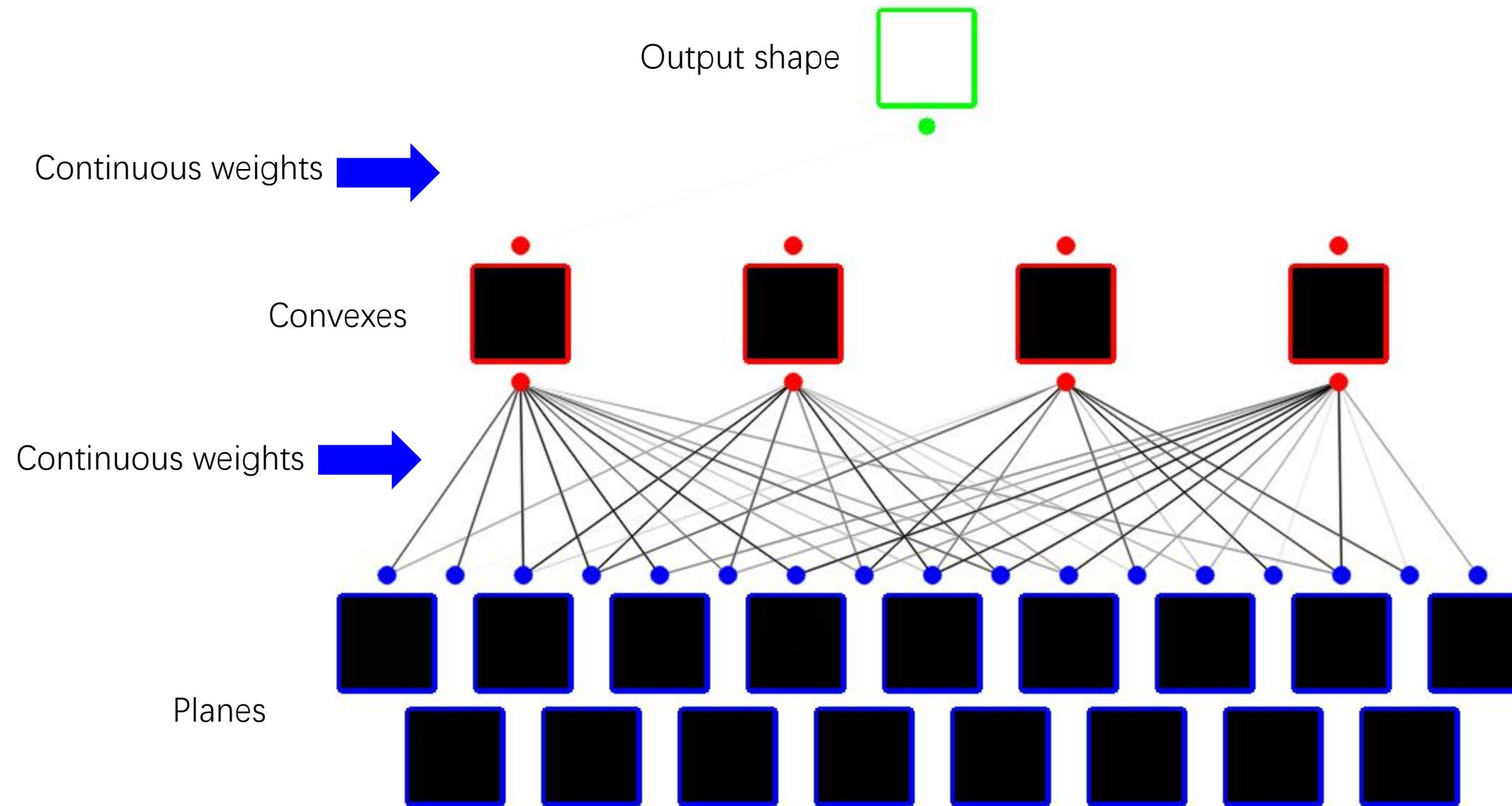
Network



$$[[\mathbf{1} - \text{relu}(\mathbf{xP}^T) \mathbf{T}]_{0,1} \mathbf{W}]_{0,1}$$

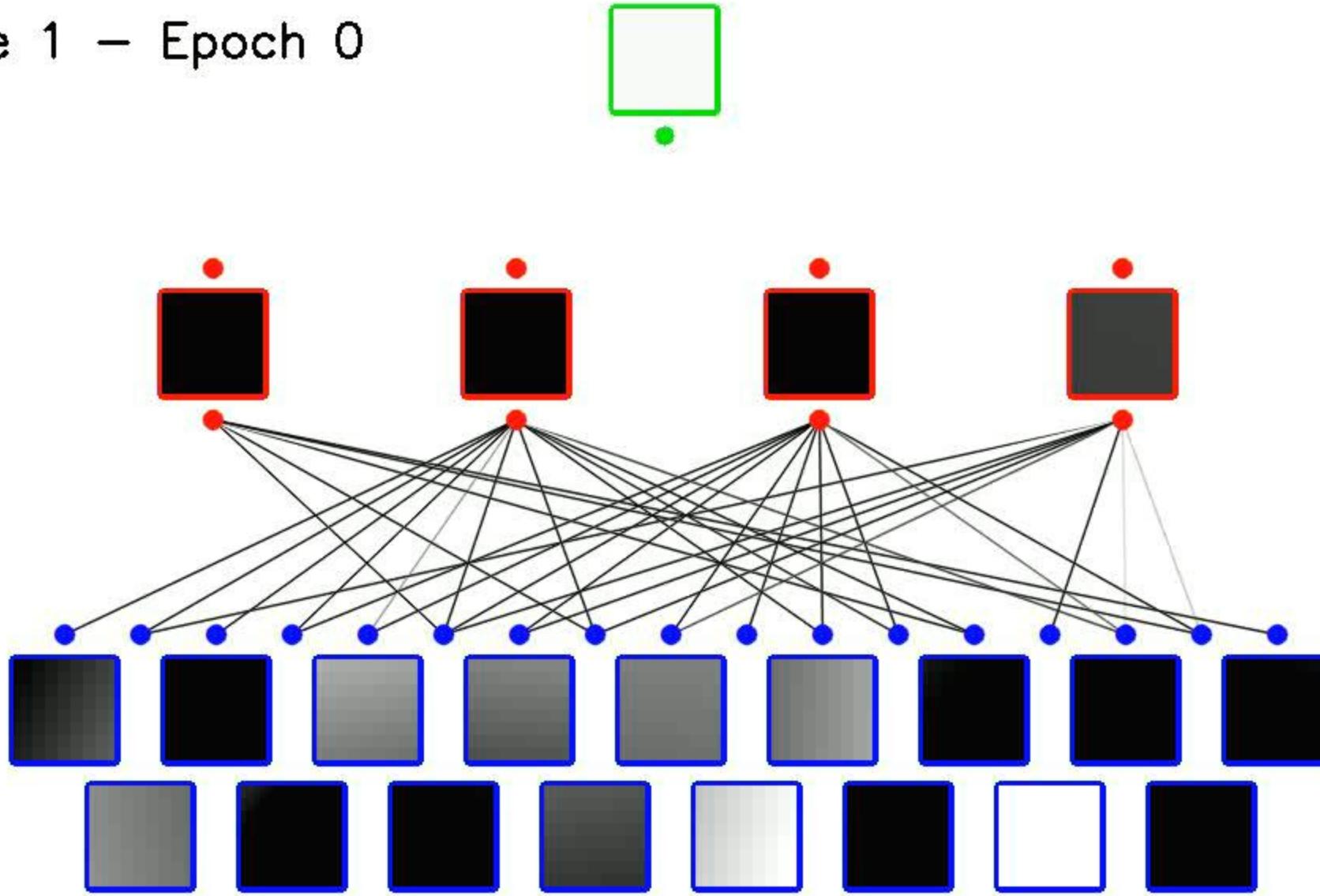


Visualizing training - Initialization



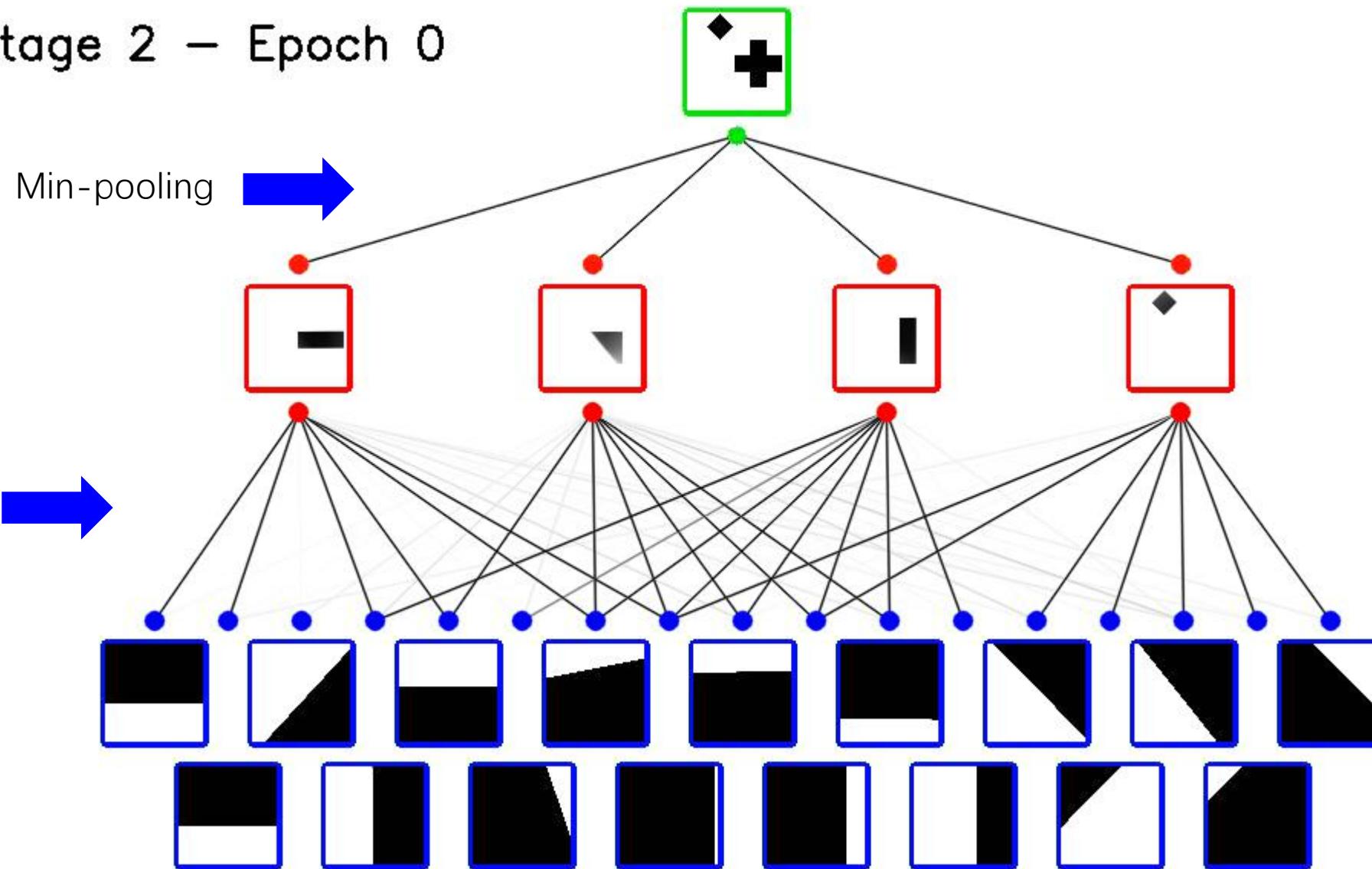
Visualizing training - Continuous phase

Stage 1 – Epoch 0



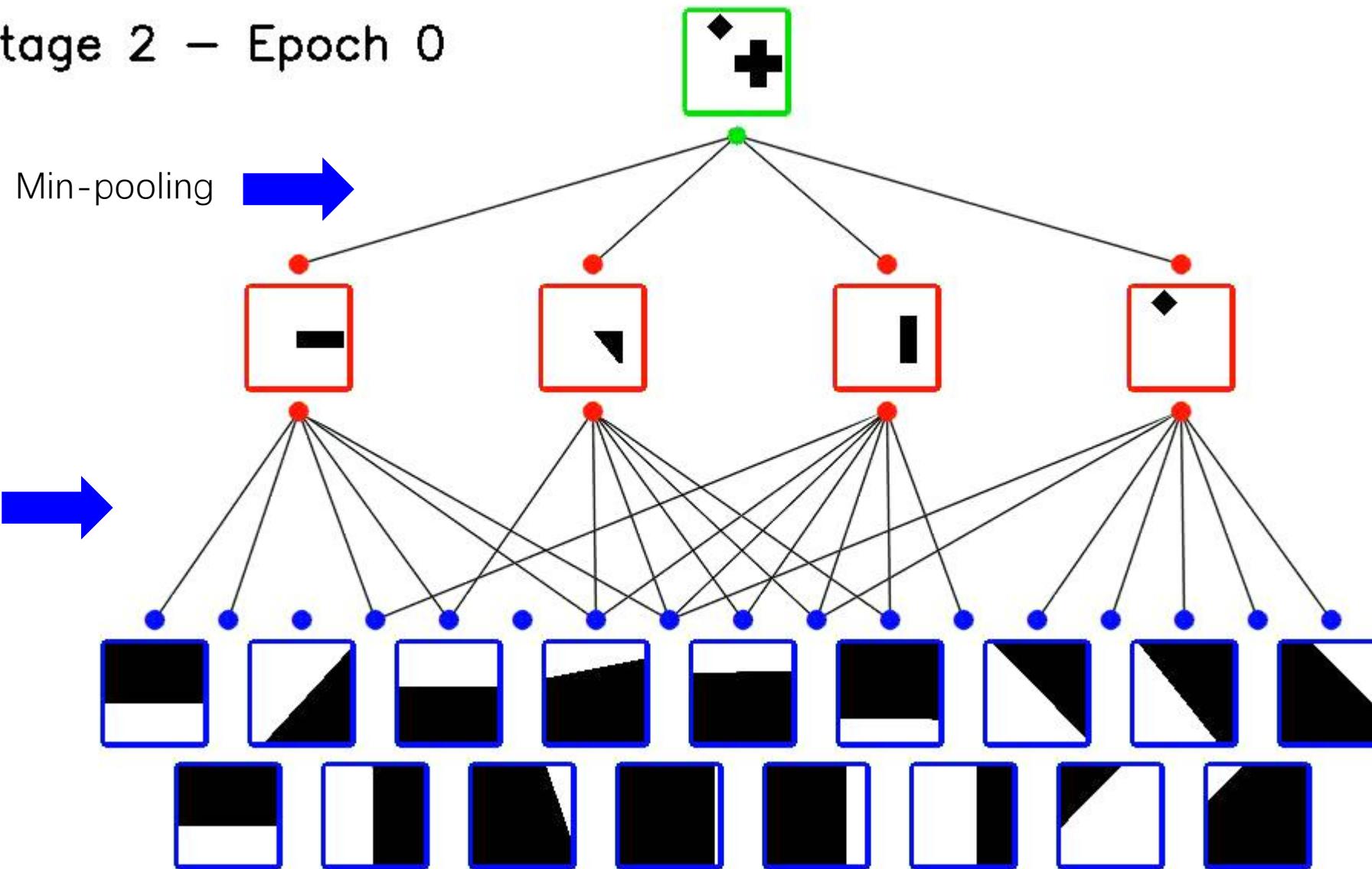
Visualizing training – Discrete phase

Stage 2 – Epoch 0



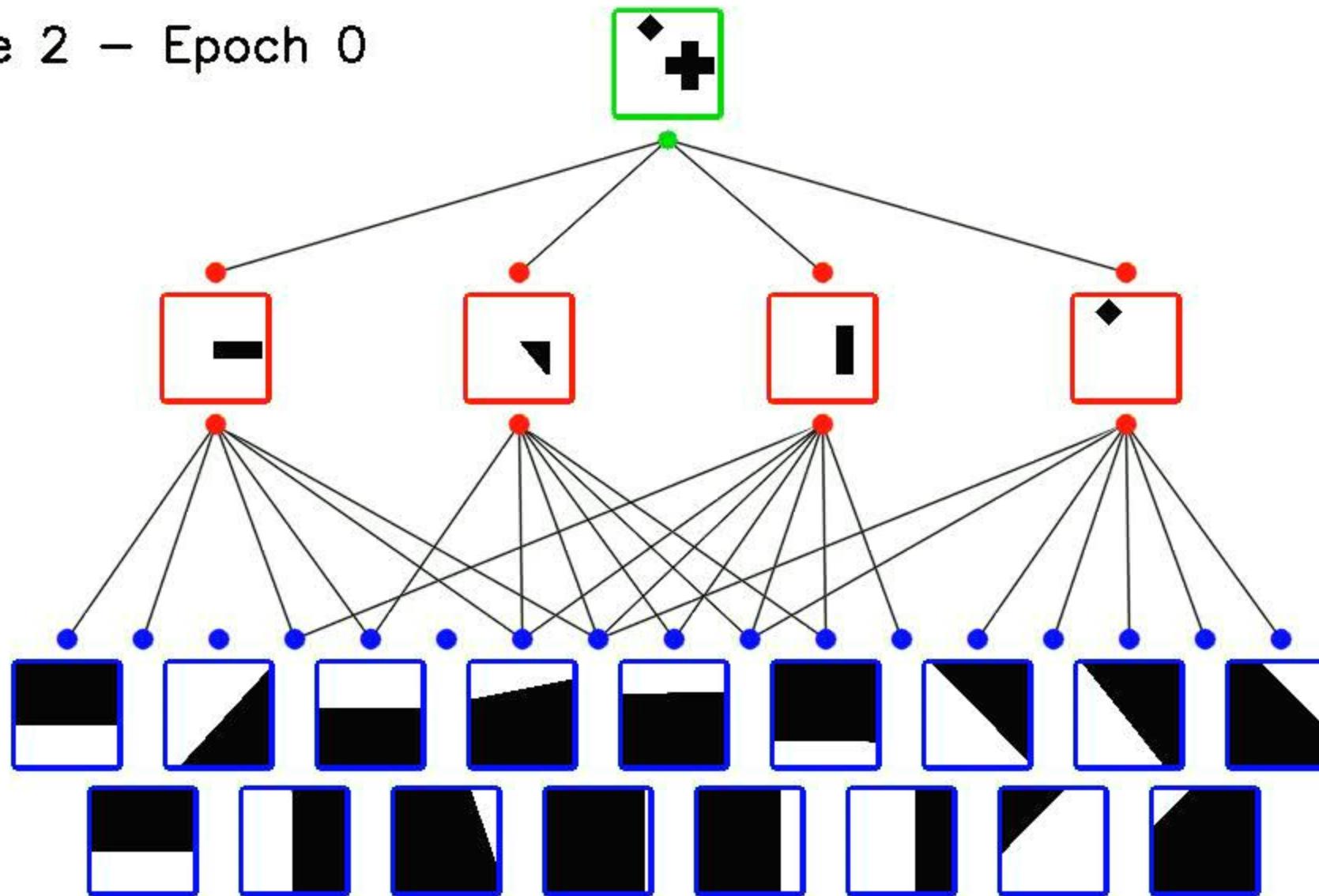
Visualizing training – Discrete phase

Stage 2 – Epoch 0

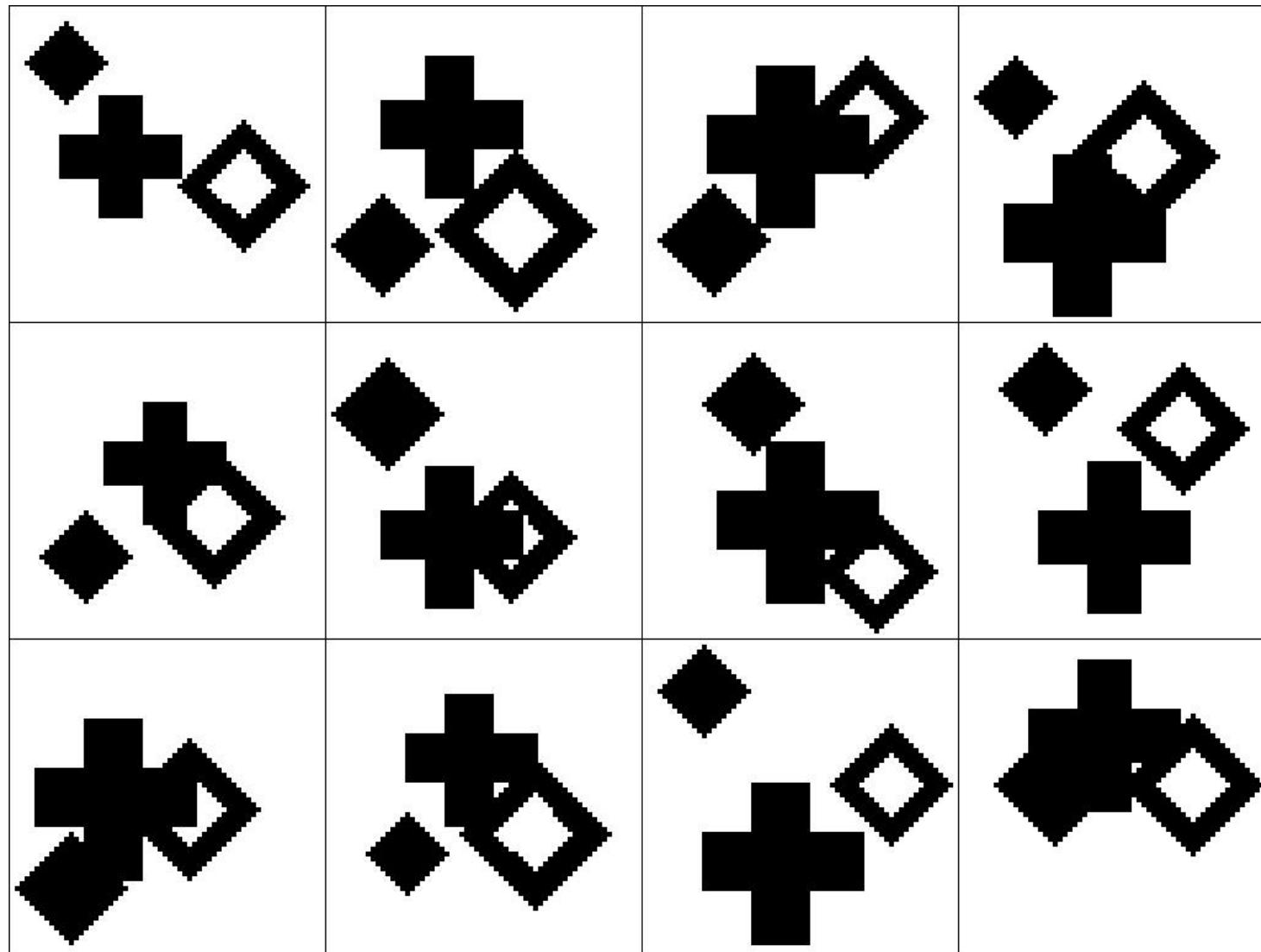


Visualizing training – Discrete phase

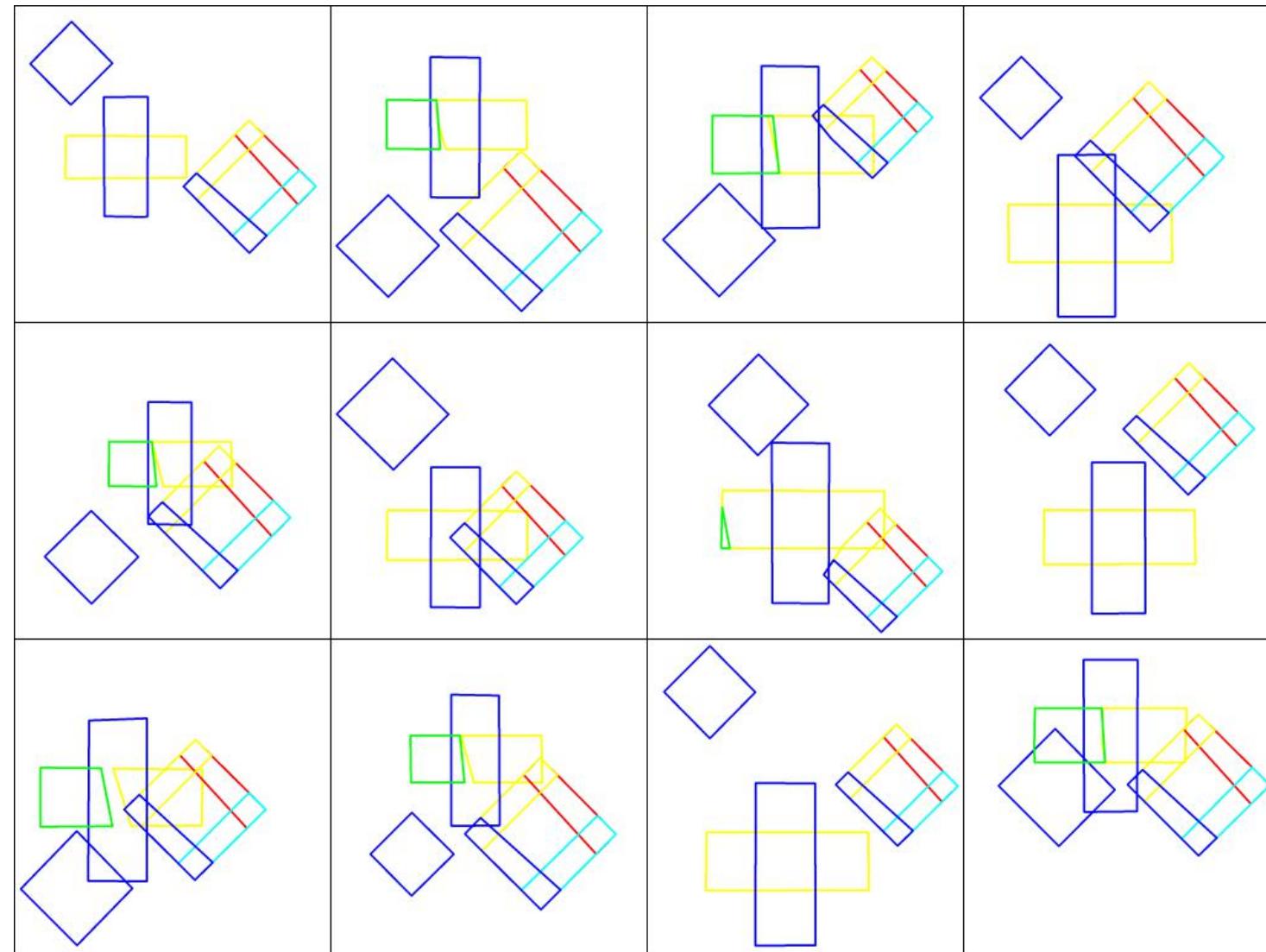
Stage 2 – Epoch 0



Toy dataset – 12 examples



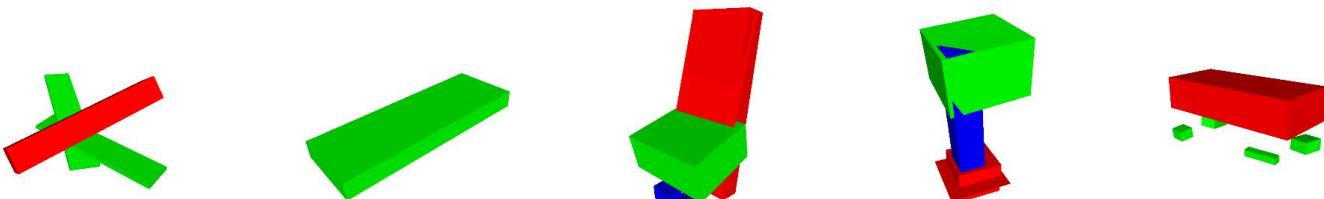
Toy dataset - Reconstruction



3D Reconstruction – Part Decomposition

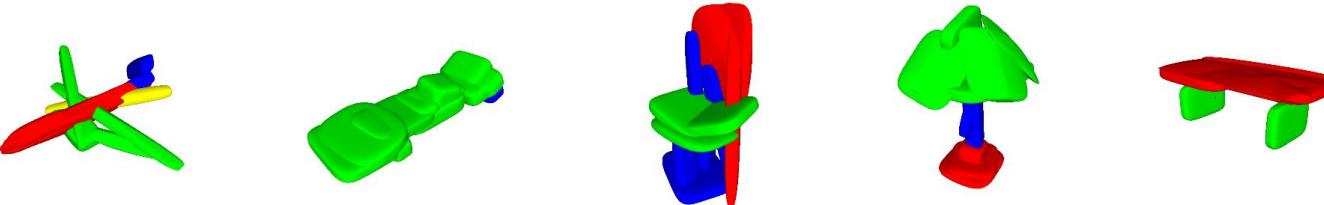
Volumetric Primitives

Tulsiani et al, CVPR 2017



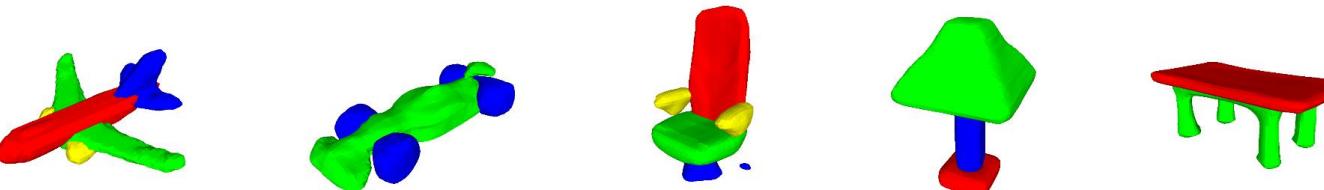
SuperQuadratics

Paschalidou et al, CVPR 2019



BAE-NET

Chen et al, ICCV 2019

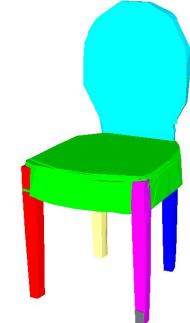
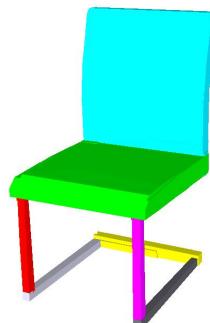
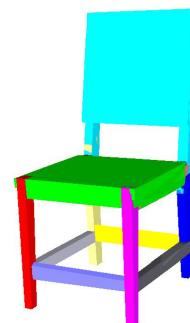
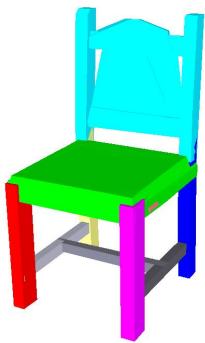
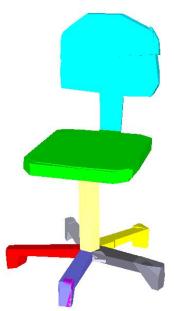
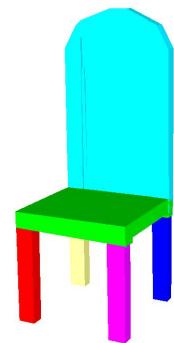
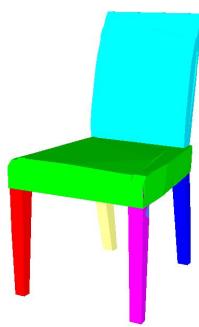
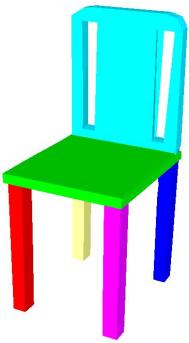


BSP-NET (ours)

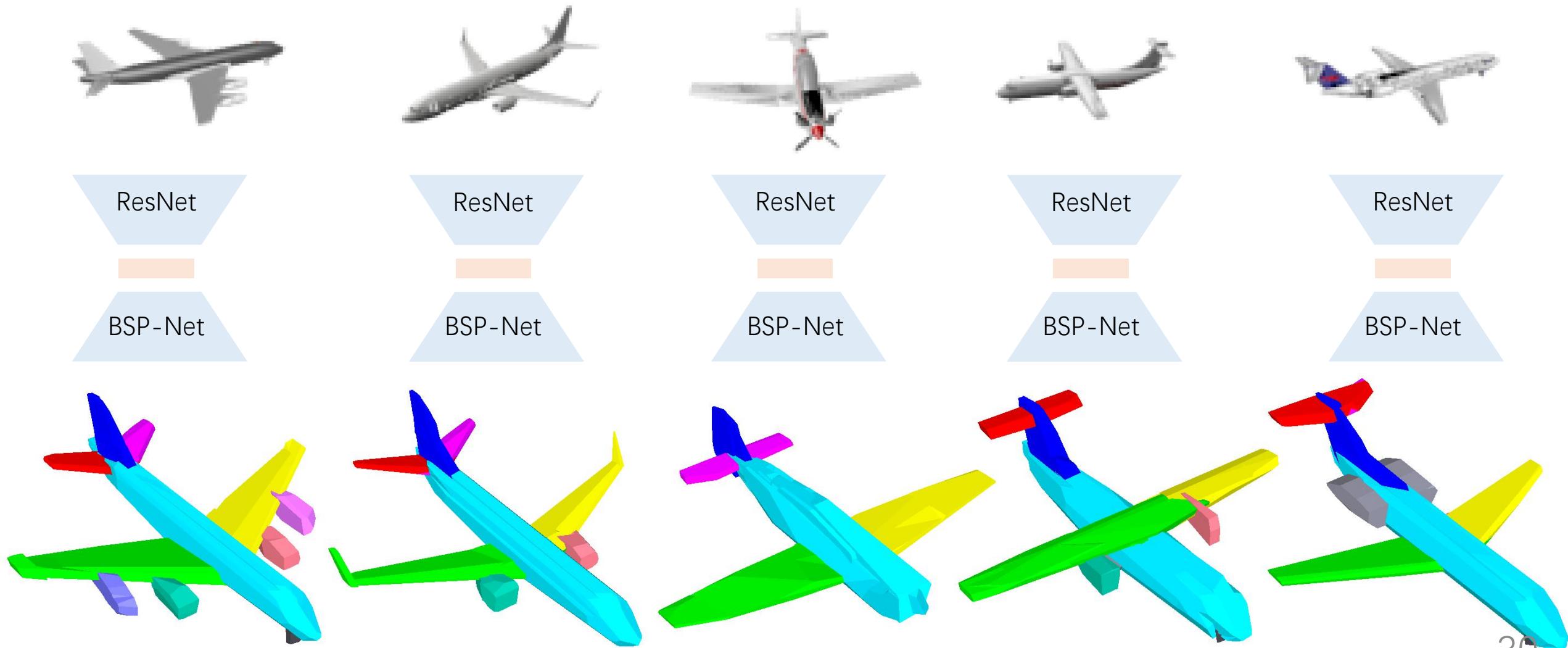


Reconstruction
ground truth

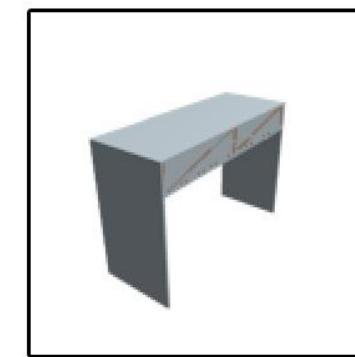




Single View Reconstruction (RGB→3D)

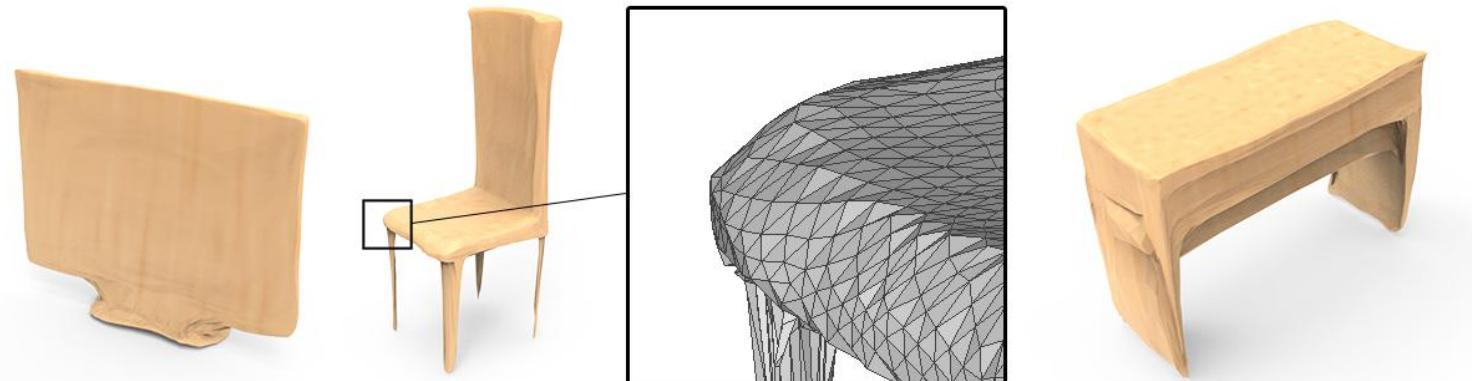


Input image



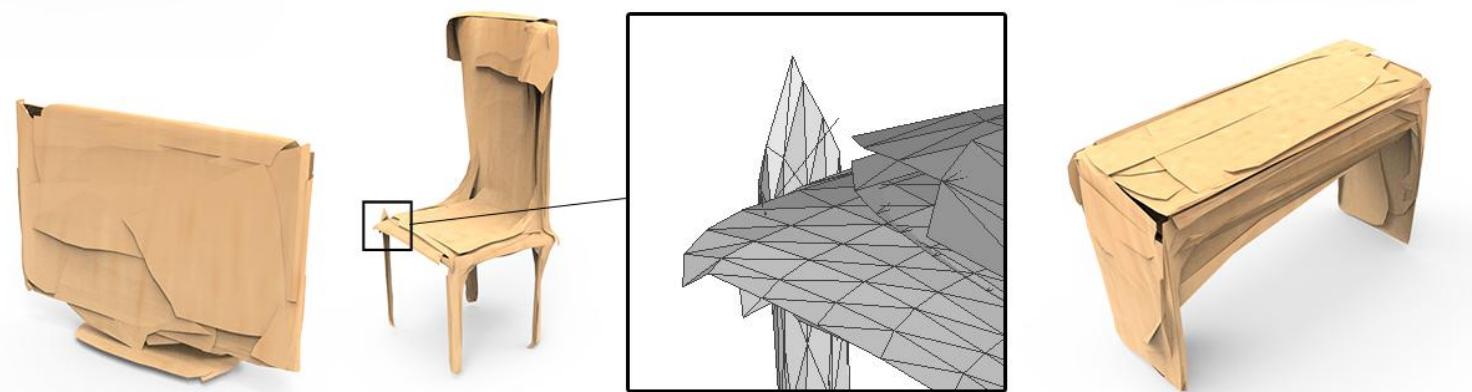
AtlasNet (1 sphere)

Groueix et al, CVPR 2018



AtlasNet (25 patches)

Groueix et al, CVPR 2018



Quantitative results

	CD	ECD	LFD	#V	#F
Atlas0	1.487	1.866	3644.91	7446	14888
Atlas25	1.170	2.069	3436.14	2500	4050
OccNet ₃₂	2.538	6.245	3795.23	1511	3017
OccNet ₆₄	1.950	6.654	3254.55	6756	13508
OccNet ₁₂₈	1.945	6.766	3224.33	27270	54538
IM-NET ₃₂	2.361	4.617	3700.22	1204	2404
IM-NET ₆₄	1.467	4.426	2940.56	5007	10009
IM-NET ₁₂₈	1.387	1.971	2810.47	20504	41005
IM-NET ₂₅₆	1.371	2.273	2804.77	82965	165929
Ours	1.432	0.743	2939.15	1191	1913

Thank you. Q&A