Brown Bag Session

Neural Implicit Representations & NeRF

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How can we represent 3D volume data for Deep Learning?

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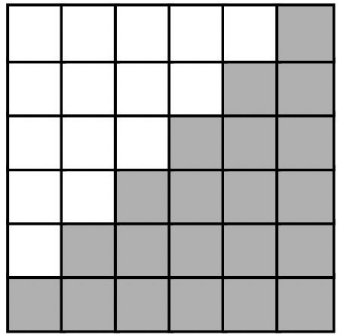
Voxels

We define a 3D grid where each voxel (or cube) can be part of the object represented in different colors

- Straight forward format that can be processed with 3D Convs
- Resolution is limited by the grid
- High resolution objects get very large
- Processing with 3D Convs is very slow



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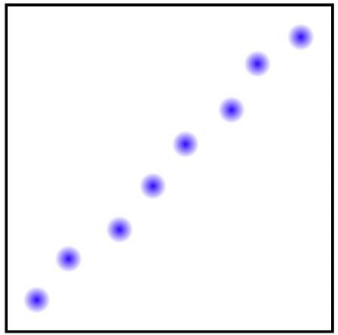
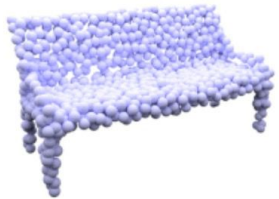
Points

We define a list of 3D points that sit on the surface of the object represented in different colors

- Low storage size with very high resolution
- We don’t know how the points are connected
- The number of points varies making it hard to represent it as an output of a neural network





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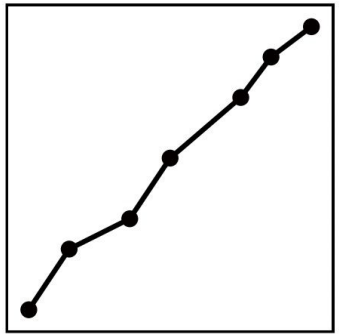
Meshes

We define a list of 3D points and how they are connected to make up the surface

- Low storage size and can easily calculated normals
- Resolution usually lower than point clouds
- Even harder to learn as a neural network output because the data has order that needs to be learned



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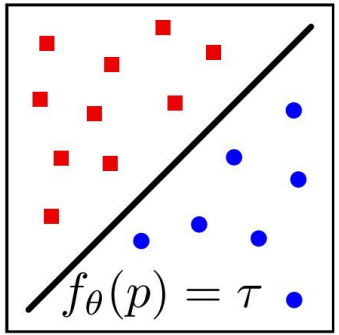
Implicit Functions

We train a fully connected neural network to represent the object through its decision boundary

- Unlimited (continuous) resolution
- Made to easily integrate with neural networks
- Storage size is currently larger than other formats
- Storage size has to be defined before training through the architecture



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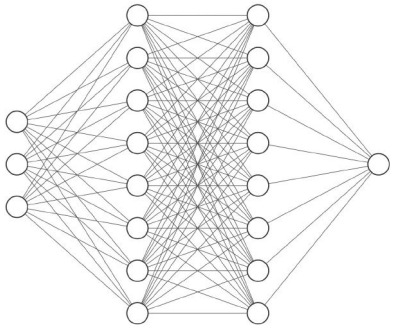
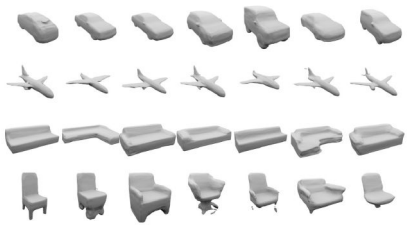
3D Shape Representation

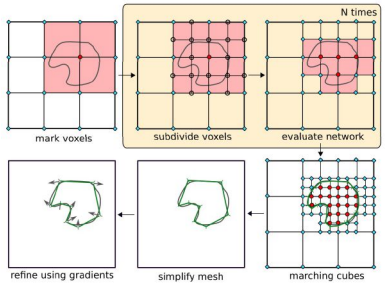
Occupancy Networks, Mescheder et al. CVPR 2019

(x, y, z) →  → (p_{in})



F_θ

Fully connected
Neural network



Take a 3D coordinate and predict whether or not it's inside the object

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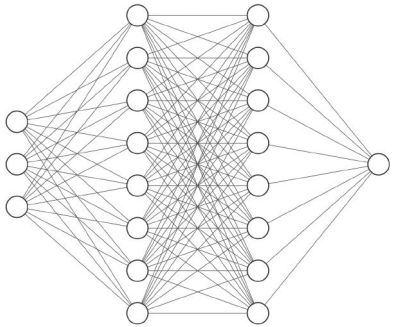
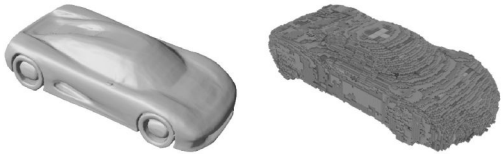
3D Shape Representation

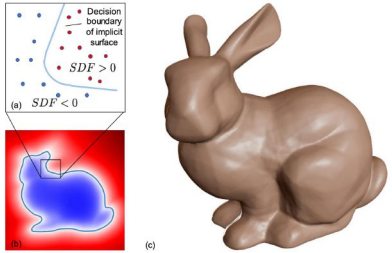
DeepSDF, Park et al. CVPR 2019

(x, y, z) $\longrightarrow$  $\longrightarrow$ $(d_{surface})$

F_θ

Fully connected
Neural network





Take a 3D coordinate and predict its distance from the surface

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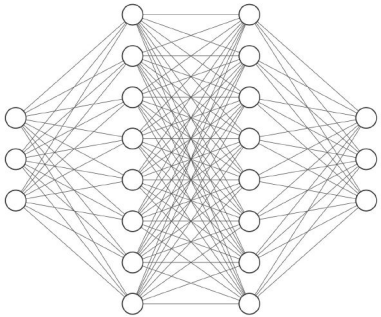
3D Object Representation

(x, y, z) $\longrightarrow$  $\longrightarrow$ (r, g, b)

F_θ

Fully connected
Neural network

Take a point coordinate and predict its color in the volume or scene

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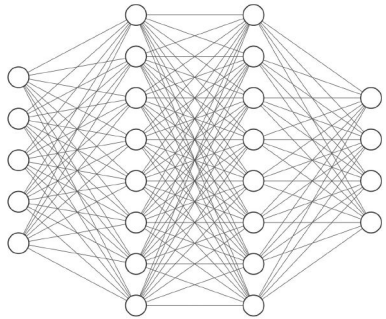
Scene Rendering & View Synthesis

NeRF, Mildenhall et al. ECCV 2020

$$(x, y, z, \alpha, \beta) \longrightarrow \longrightarrow (r, g, b, \sigma)$$



F_θ

Fully connected
Neural network

Take a point and the viewing direction to predict its appearence

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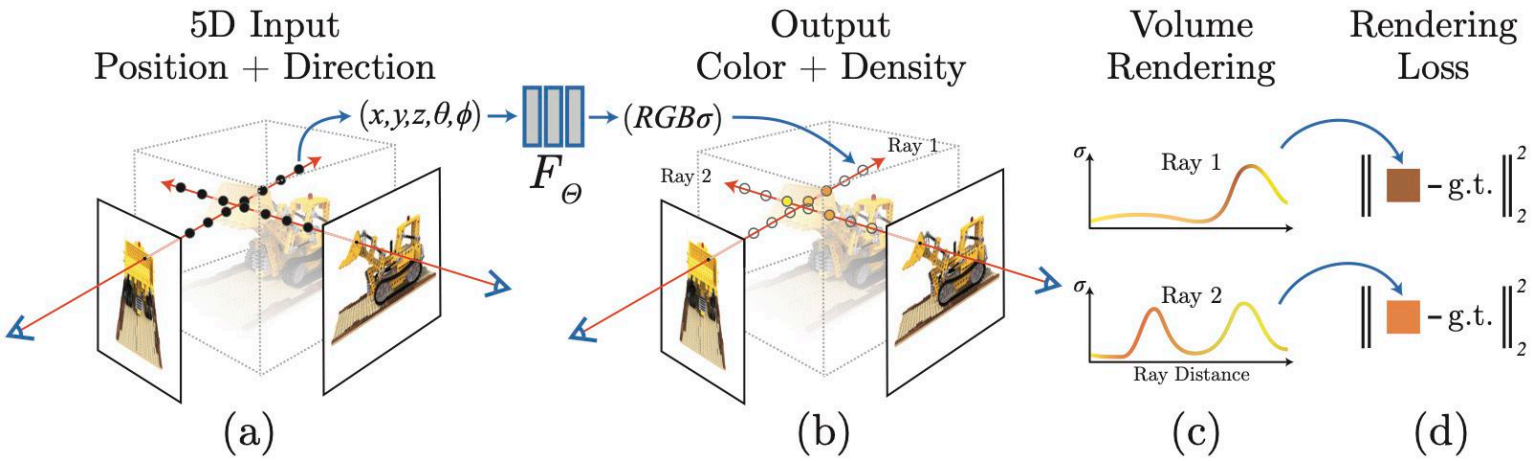
Scene Rendering & View Synthesis

NeRF, Mildenhall et al. ECCV 2020



Take a pixel coordinate and predict its color in the image

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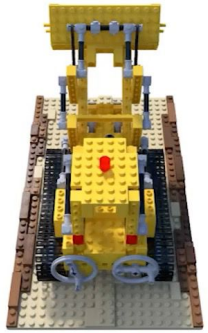
So, this is really all we need to create these cool results?





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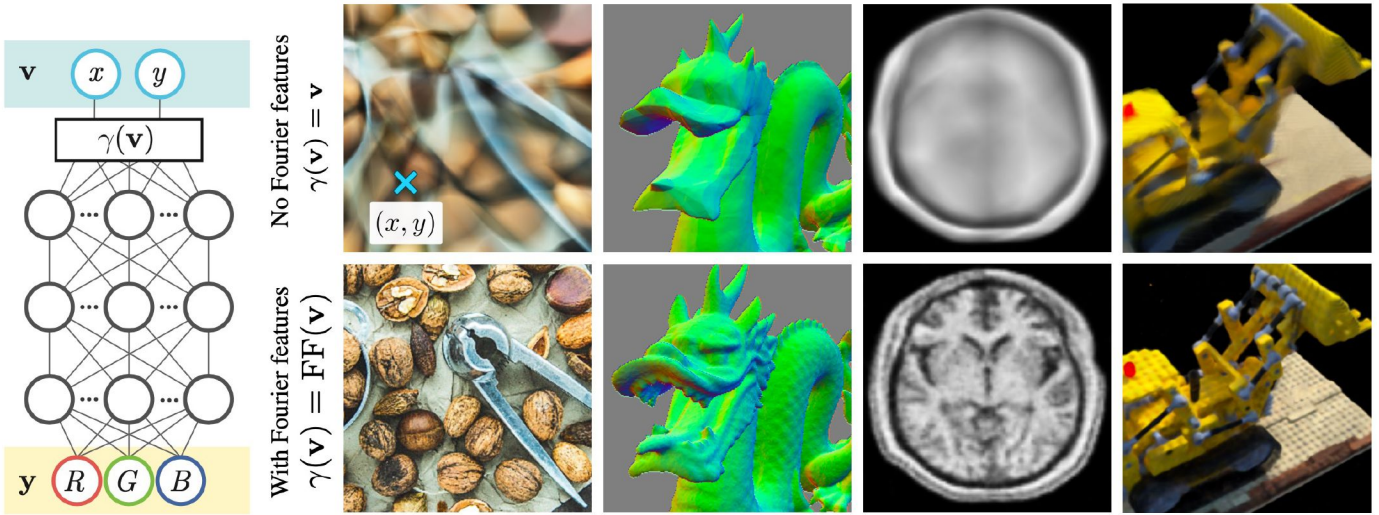
Well, almost....

Fourier Features Let Networks Learn High Frequency Functions in Low Dimensional Domains

Tancik et al. NeurIPS 2020



(a) Coordinate-based MLP

(b) Image regression $(x,y) \rightarrow$ RGB

(c) 3D shape regression $(x,y,z) \rightarrow$ occupancy

(d) MRI reconstruction $(x,y,z) \rightarrow$ density

(e) Inverse rendering $(x,y,z) \rightarrow$ RGB, density

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NeRF, Mildenhall et al. ECCV 2020

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NeRF, Mildenhall et al. ECCV 2020

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Nerfies, Park et al., 2021

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LIIF, Chen et al., CVPR 2021

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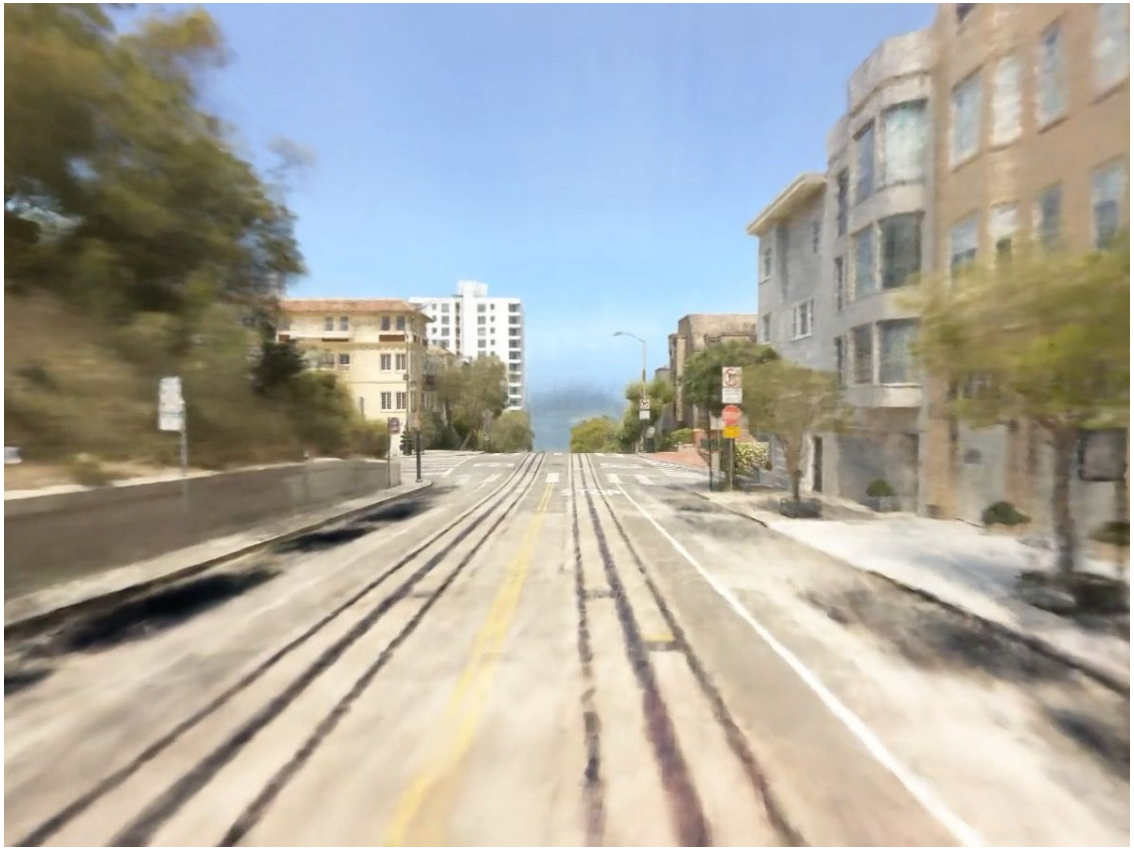
HumanNeRF, Weng et al., CVPR 2022



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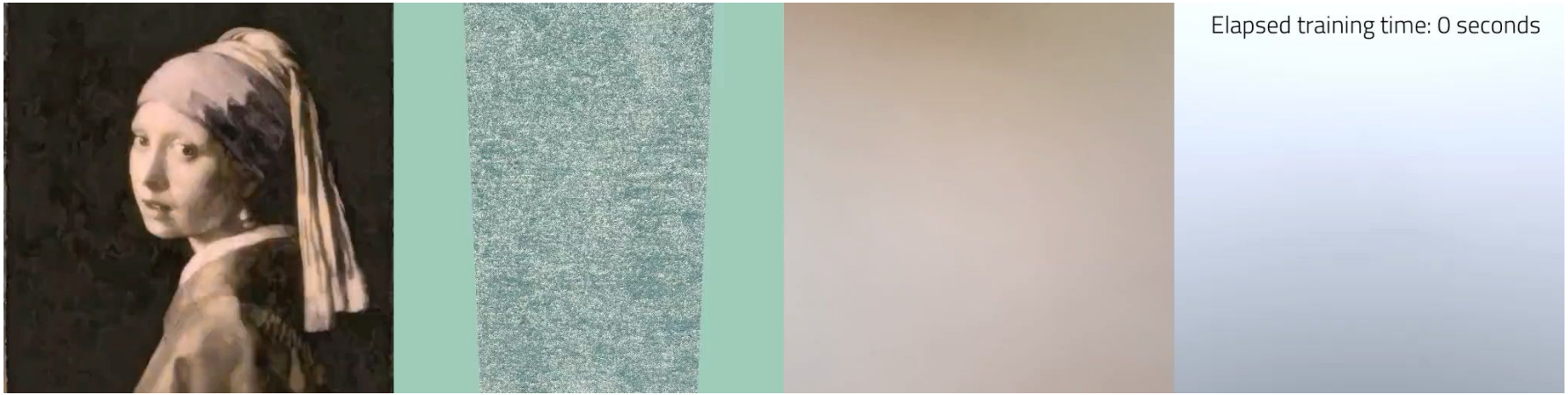
Block-NeRF, Tancik et al., 2022



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Instant NGPs, Müller et al. SIGGRAPH 2022

Thank You

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