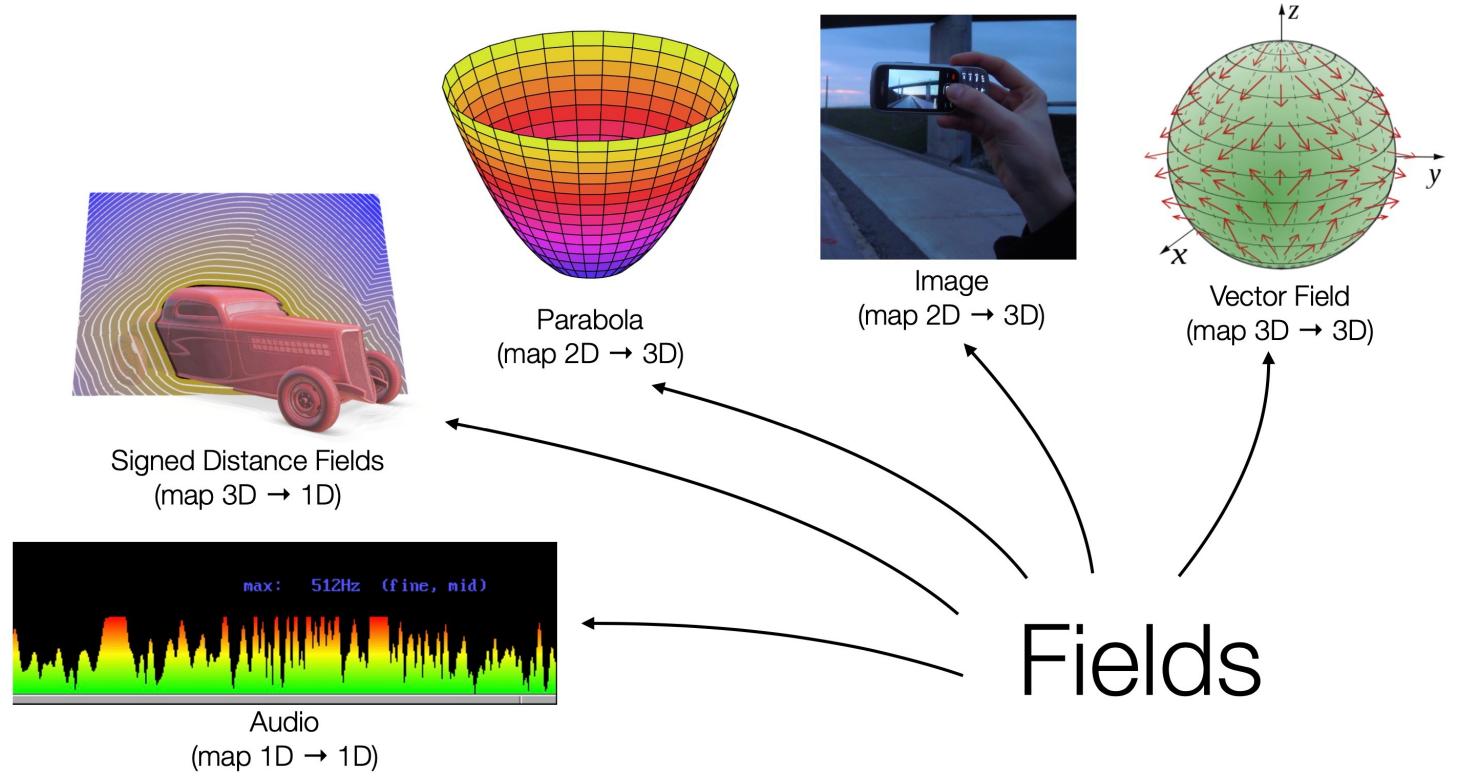
Neural Fields

CMPT 743 – Spring 2024

Aryan Mikaeili

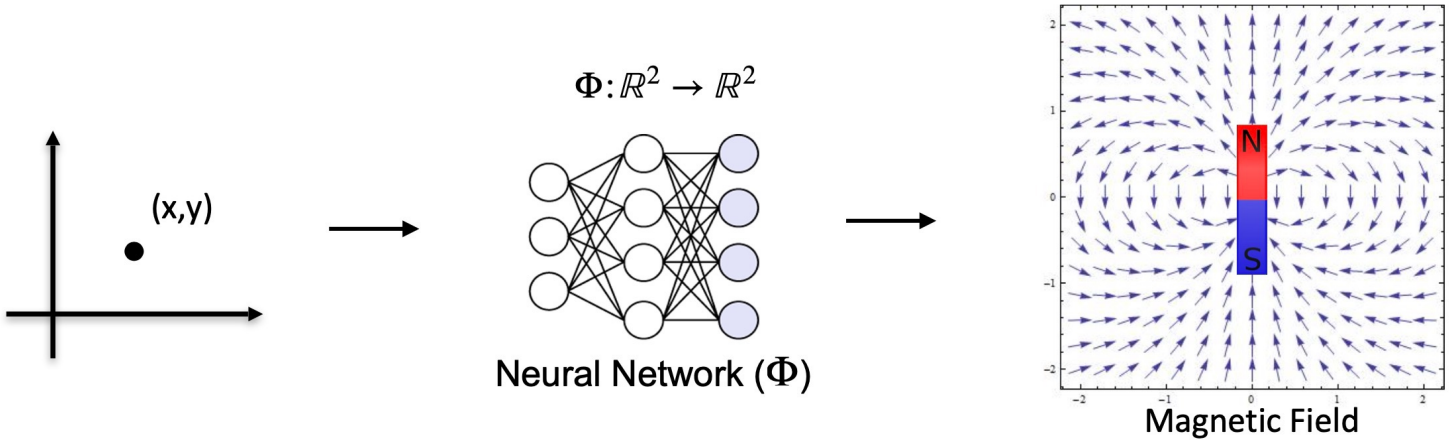
Intro

- What are Neural fields?
  - A map between coordinates and physical quantities



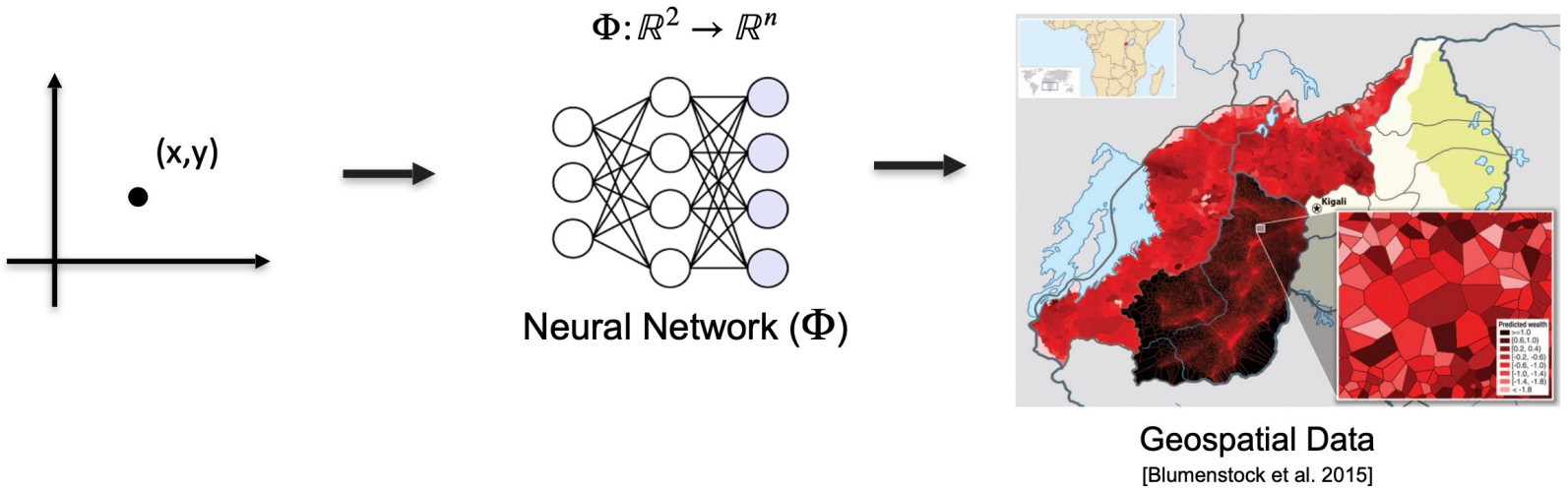
Intro

- What are Neural fields?
  - A map between coordinates and physical quantities
  - E.g. magnetic field induced by a magnet



Intro

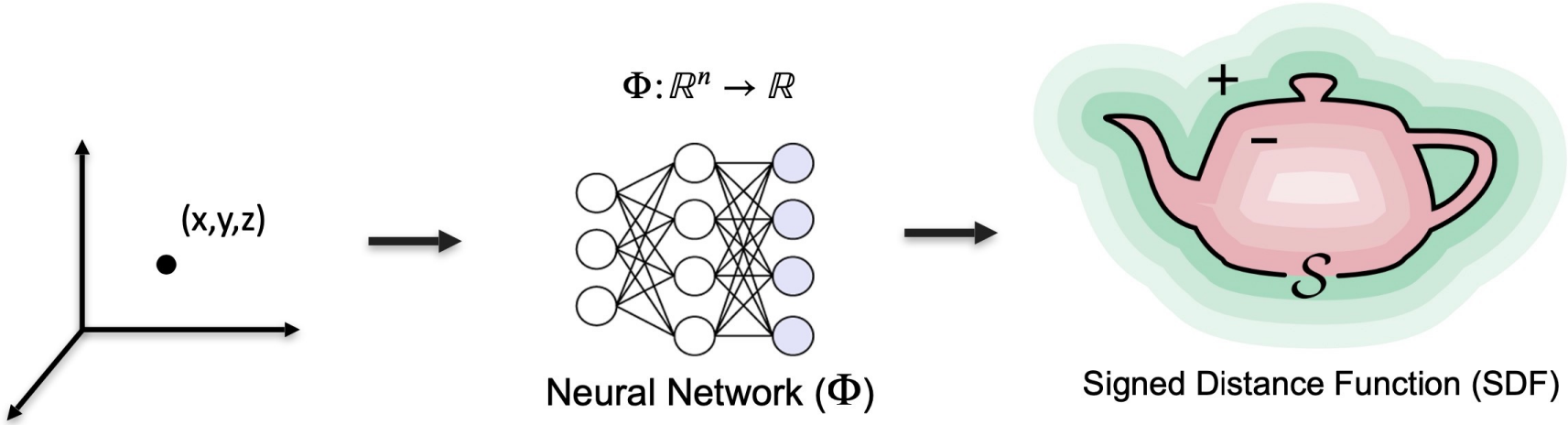
- What are Neural fields?
  - A map between coordinates and ~~physical~~ quantities
  - E.g. The average wealth in a country



Geospatial Data
[Blumenstock et al. 2015]

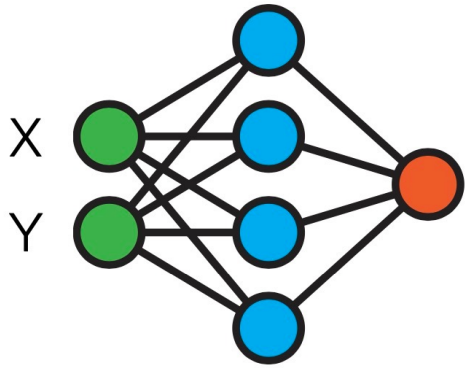
Intro

- What are Neural fields?
  - A map between coordinates and ~~physical~~ quantities
  - E.g. The signed distanc field to /Occupancy of the boundry of an object

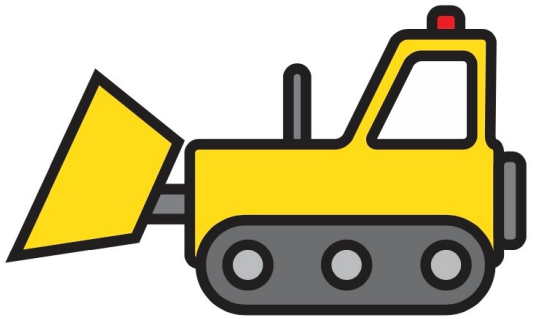


Terminology

Implicit Neural Representations



Coordinate-based Neural Networks

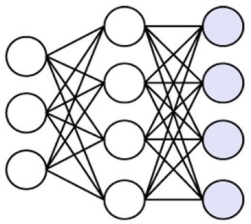


NeRFs

Terminology

- Field:
  - A quantity defined for all spatial/temporal coordinates
- Neural field:
  - A field that is [partially] parameterized by a neural network

MLP
Multi Layer Perceptron



coordinate input

nonlinearity

$$z^{(1)} = x$$

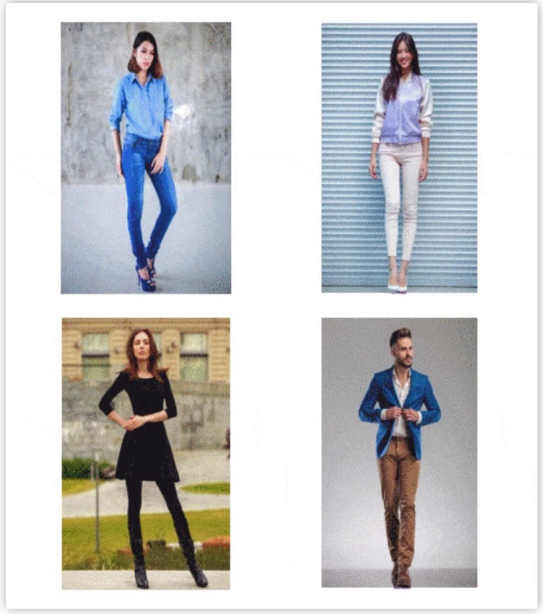
$$z^{(i+1)} = \sigma\left(W^{(i)} z^{(i)} + b^{(i)}\right), \quad \underbrace{i = 1, \ldots, k-1}_{\text{induction}}$$

$$f(x) = W^{(k)} z^{(k)} + b^{(k)}$$

field output

Applications in Vision/Graphics

- Lift 2D images into 3D structure

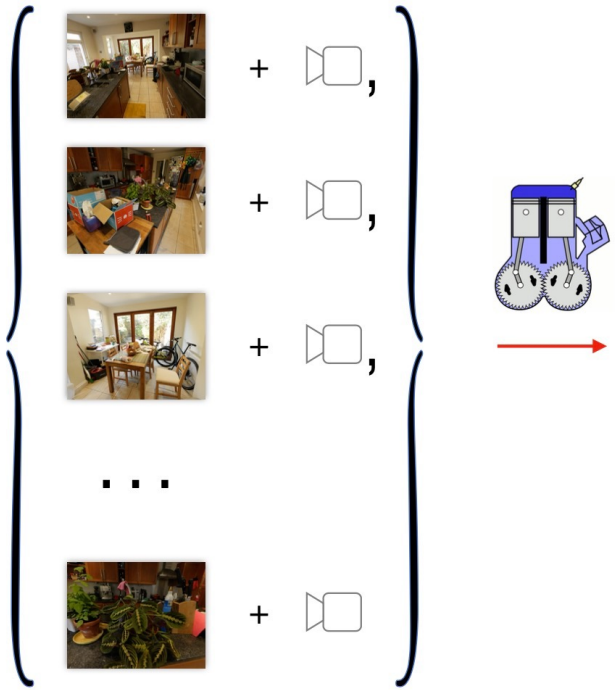


[Saito et al. 2020 PiFU]

[Chan et al. 2021 EG3D]

Application in Vision/Graphics

- Render a scene from novel viewpoints



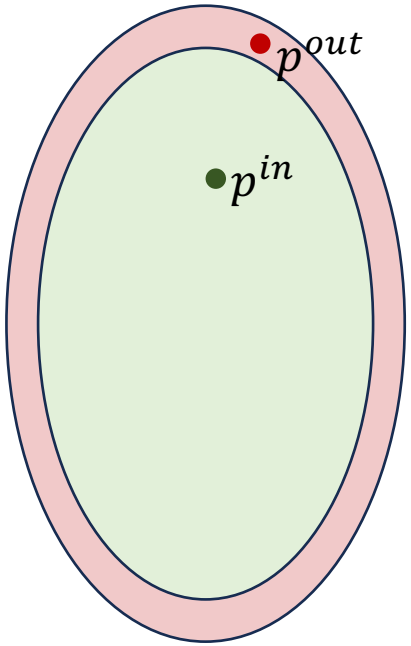
Application in Vision/Graphics

- Render a scene from novel viewpoints

NeRF 2020

ZipNeRF 2023

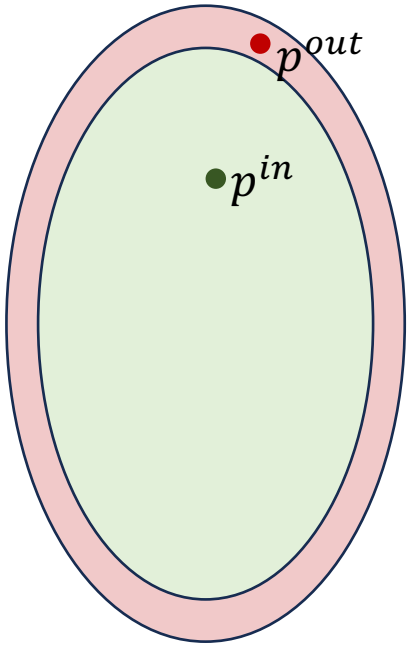
Occupancy fields



$$\phi(p^{in}) = -1$$

$$\phi(p^{in}) = +1$$

Occupancy fields



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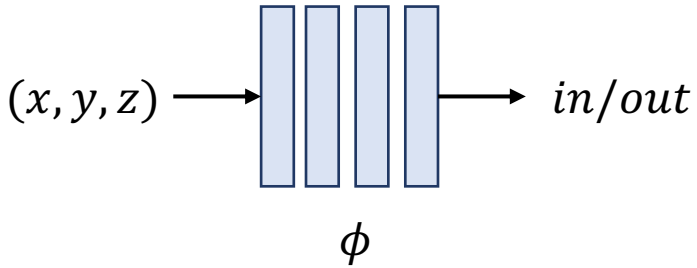
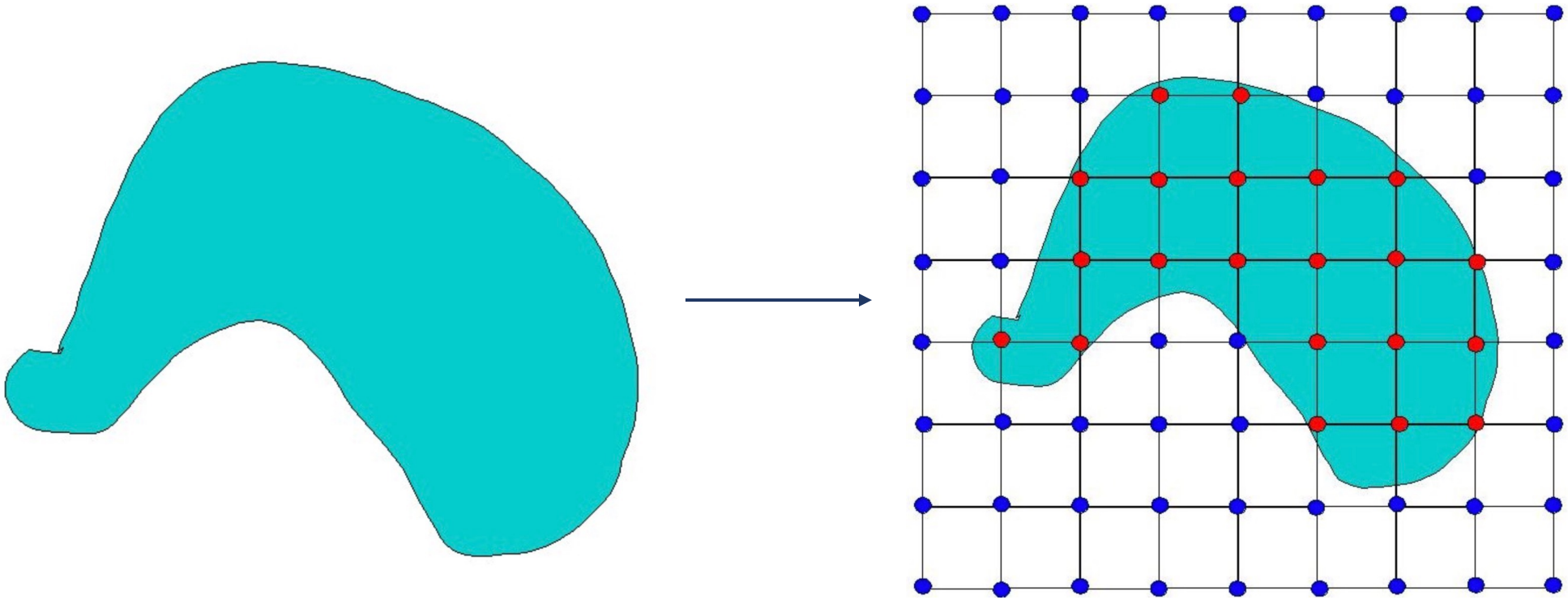


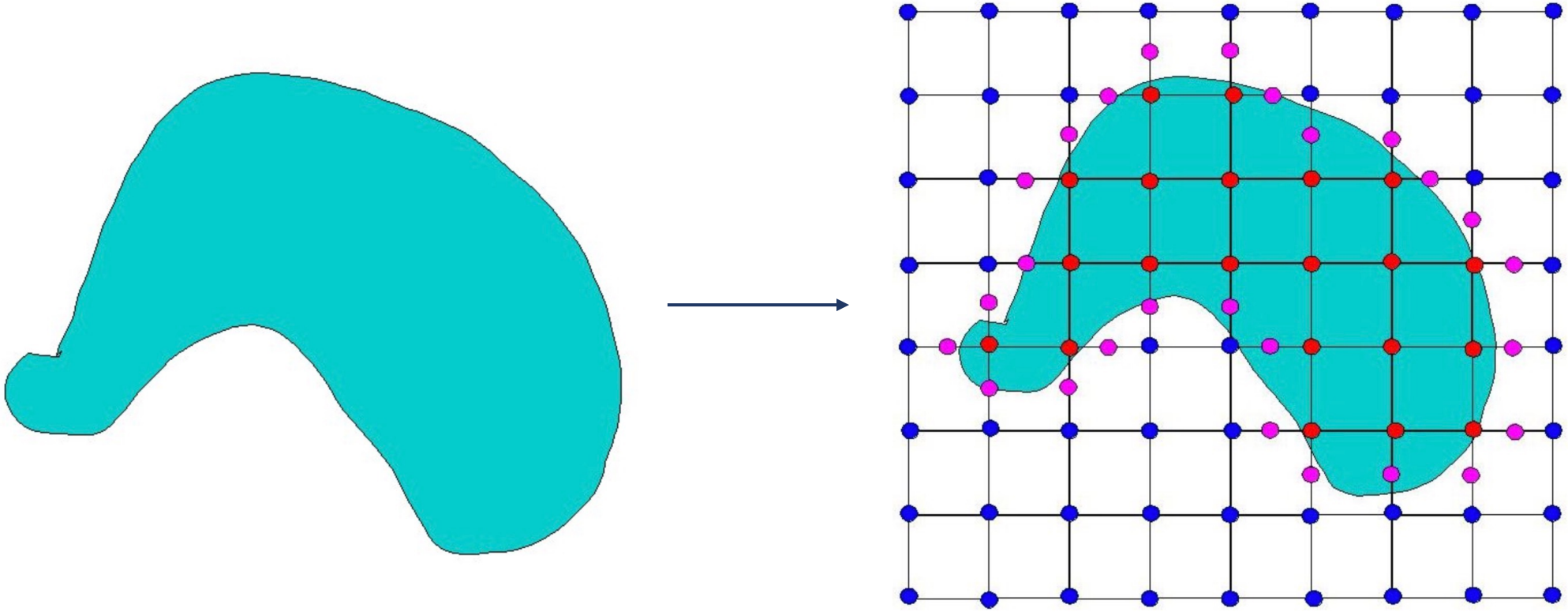
Occupancy fields

- How to reconstruct shape from Occupancy fields?



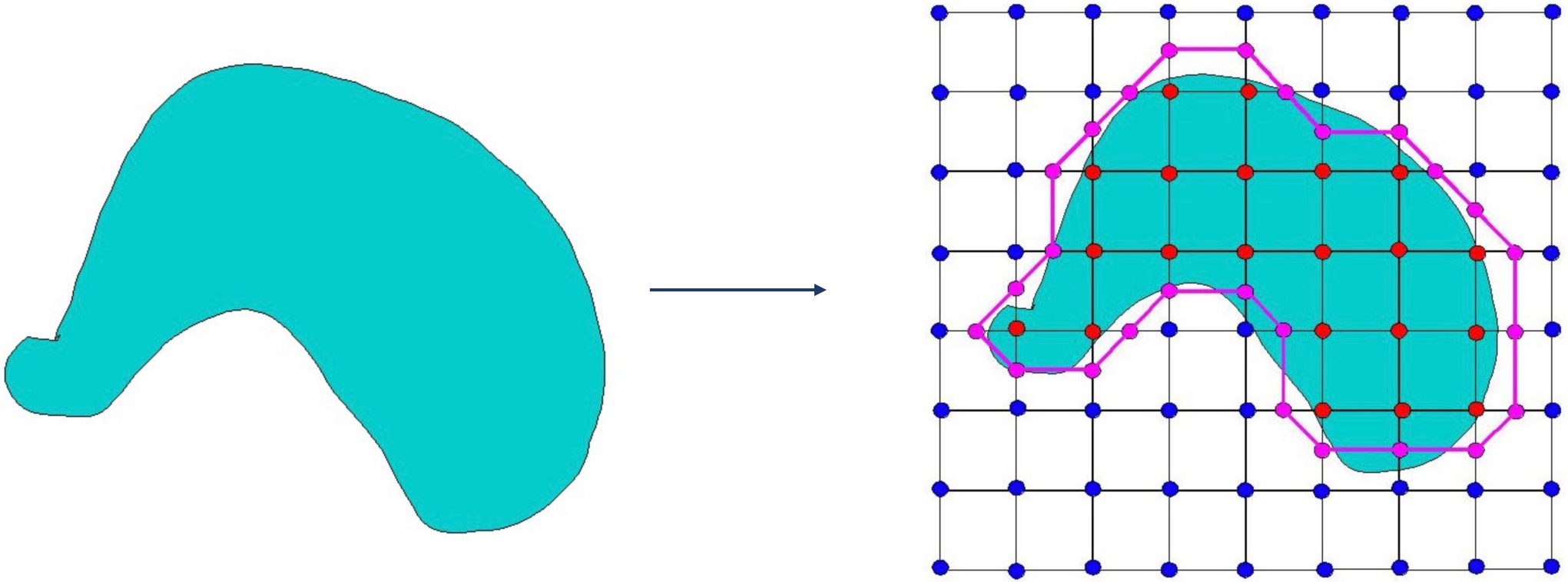
Occupancy fields

- Marching cubes [squares] algorithm



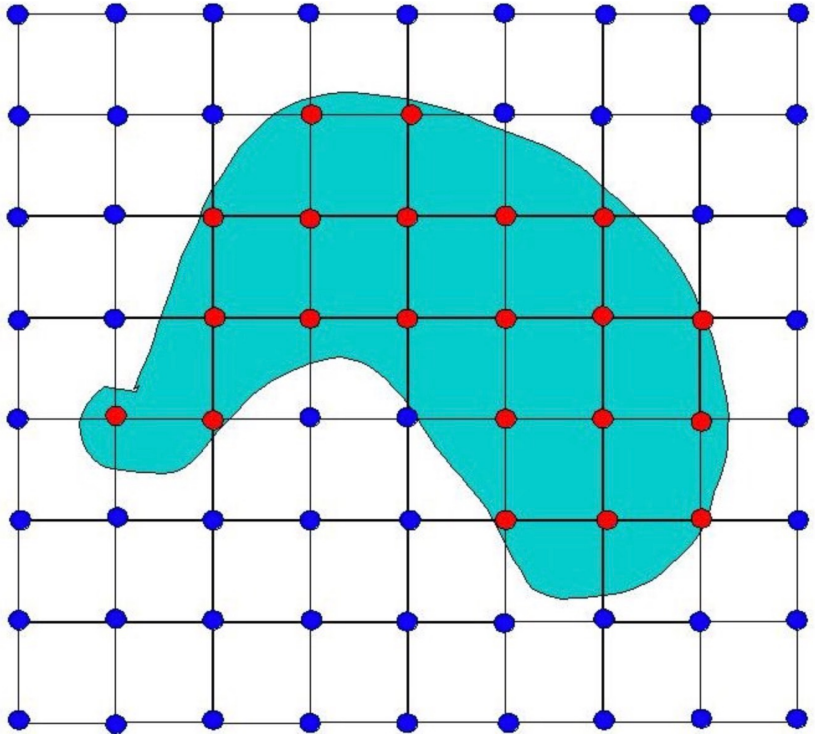
Occupancy fields

- Marching cubes [squares] algorithm



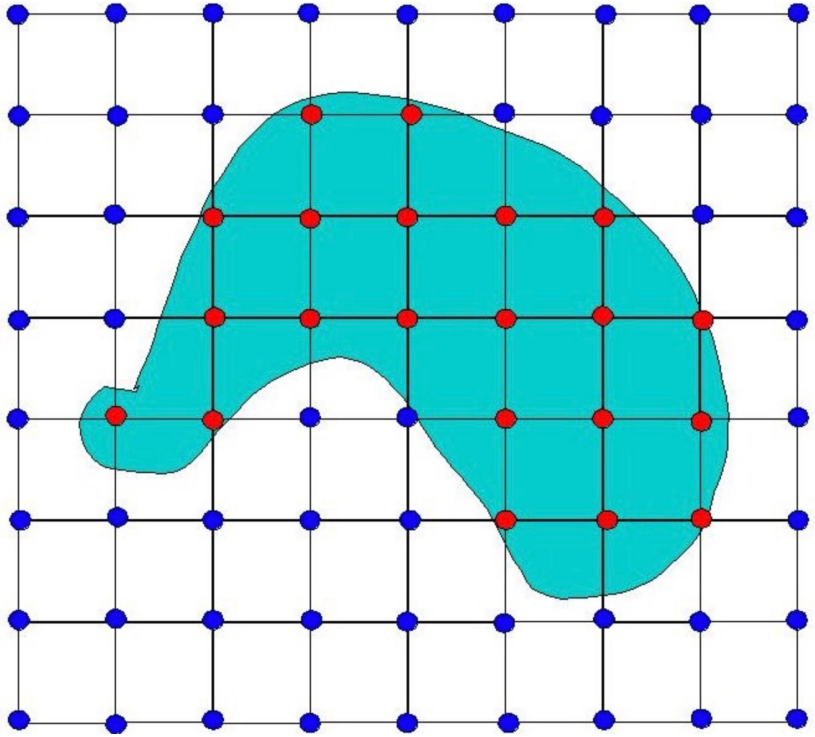
Occupancy fields

- Do we need neural networks?
  - Directly optimize field values on grid nodes



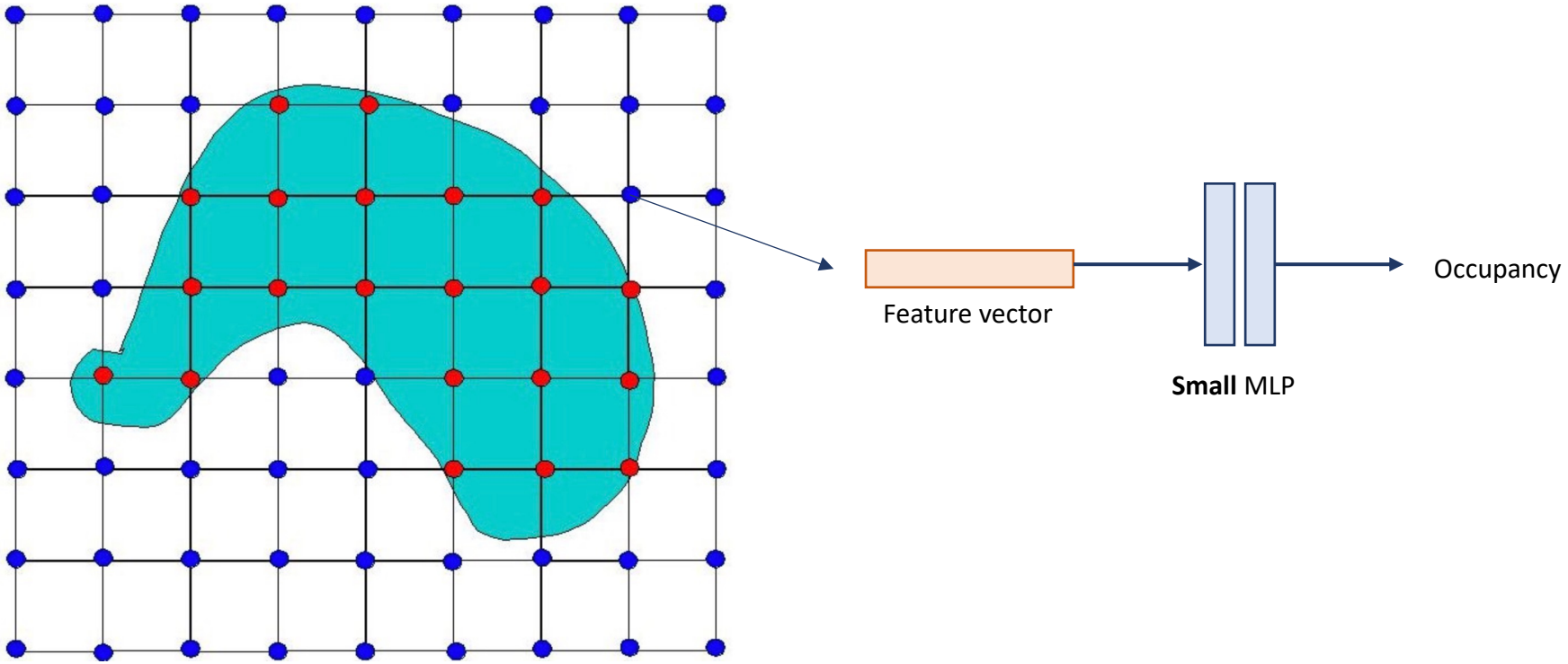
Occupancy fields

- Do we need neural networks?
  - Directly optimize field values on grid nodes
- Pros:
  - Faster training
    - We don’t need to backpropagate through Neural net
  - Local control
    - Faster convergence
- Cons:
  - High memory consumption
    - Not compact as a neural network



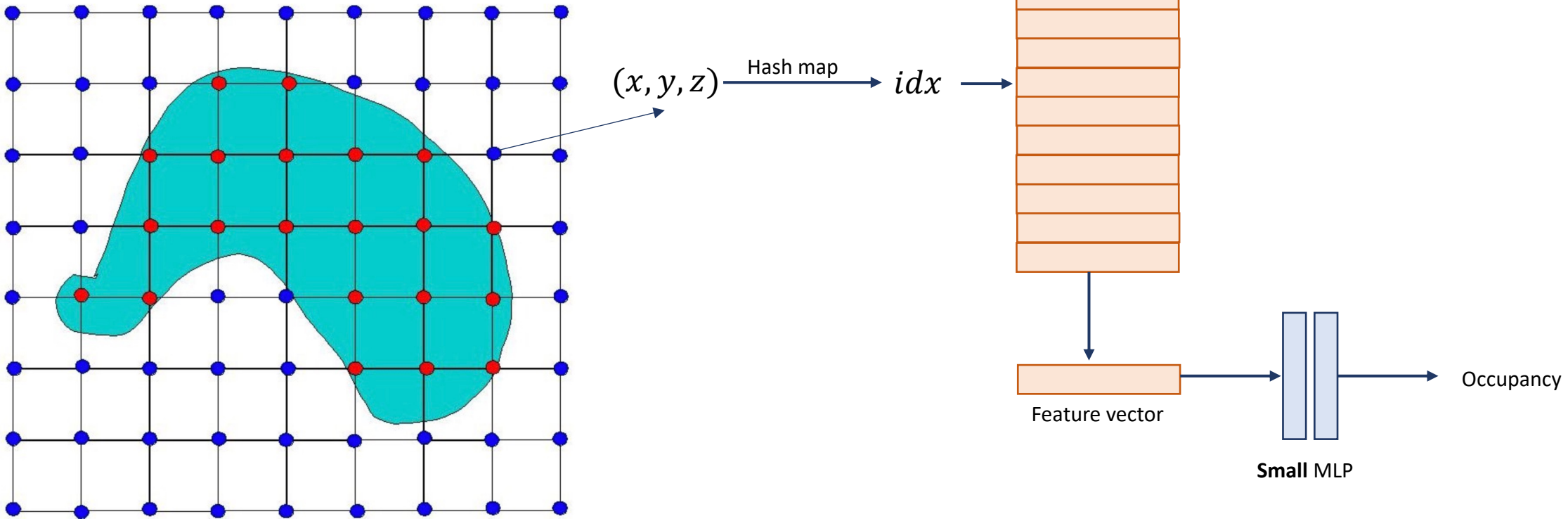
Occupancy fields

- Hybrid representation



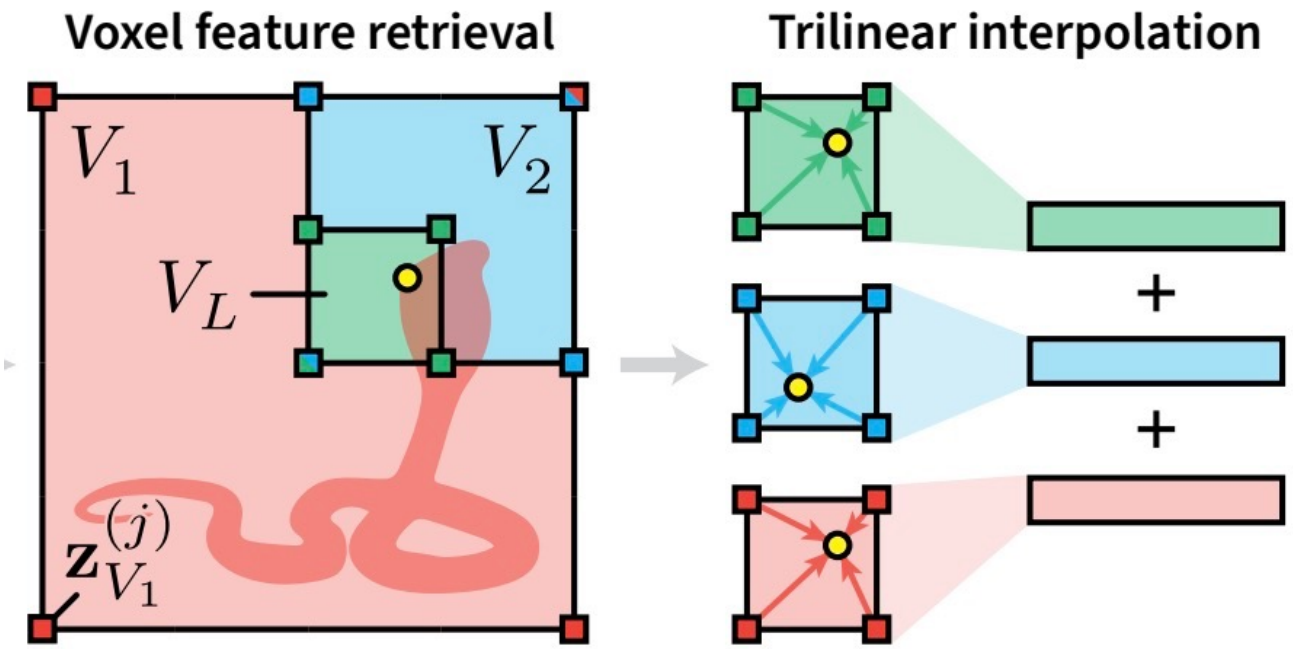
Occupancy fields

- More efficient hybrid representation
  - Hash encoding



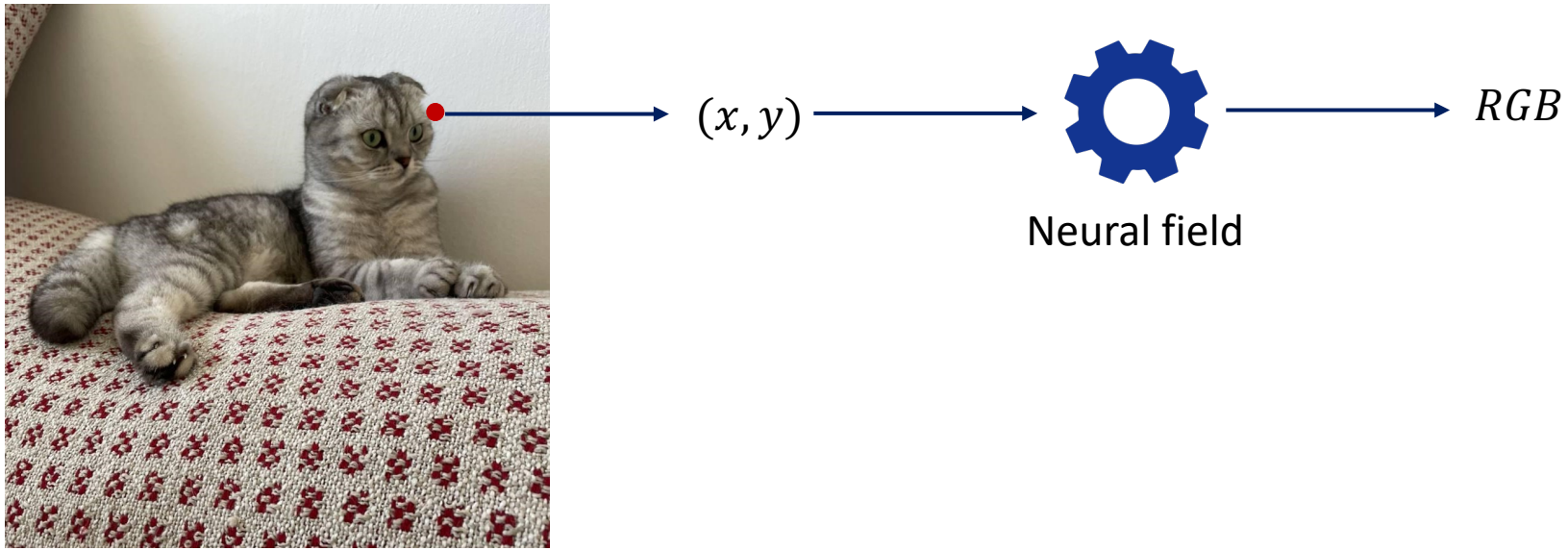
Occupancy fields

- Better grid representation
  - Multi-LoD representation



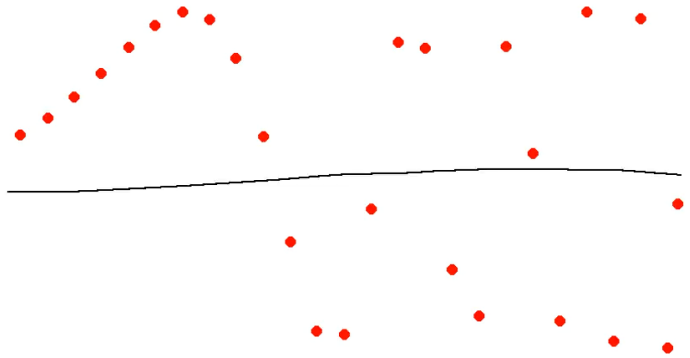
Demo

- RGB field (Image memorization)



Spectral bias in Neural fields

- MLPs are biased towards low frequency signals



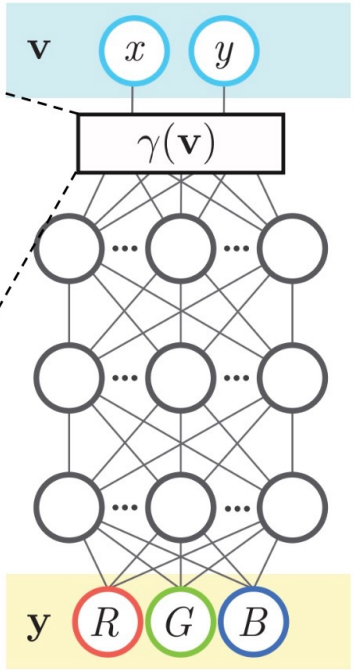
Spectral bias in Neural fields

- Positional encoding
  - Expand dimensionality of input
  - Include different frequency bands

$$\gamma(\mathbf{x}) = [\gamma_1(\mathbf{x}), \gamma_2(\mathbf{x}), \ldots, \gamma_m(\mathbf{x})]$$

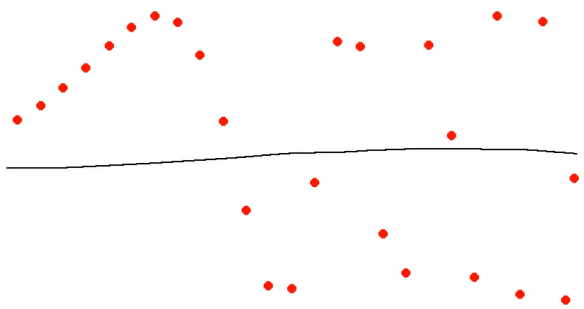
$$\gamma_{(2i)}(x) = sin(2^{i-1}\pi x),$$

$$\gamma_{(2i+1)}(x) = cos(2^{i-1}\pi x)$$

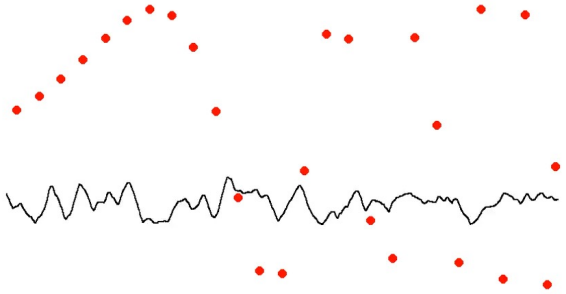


Spectral bias in Neural fields

- Positional encoding



No encoding



Positional encoding

Spectral bias in Neural fields

- Positional encoding