Unet beats CNN in topology optimization

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Final project: Deep Learning

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How to create lighter and safer structures ?

- How to create optimal designs:
  - ✓ As lightweight as possible
  - ✓ Strong enough to ensure safety

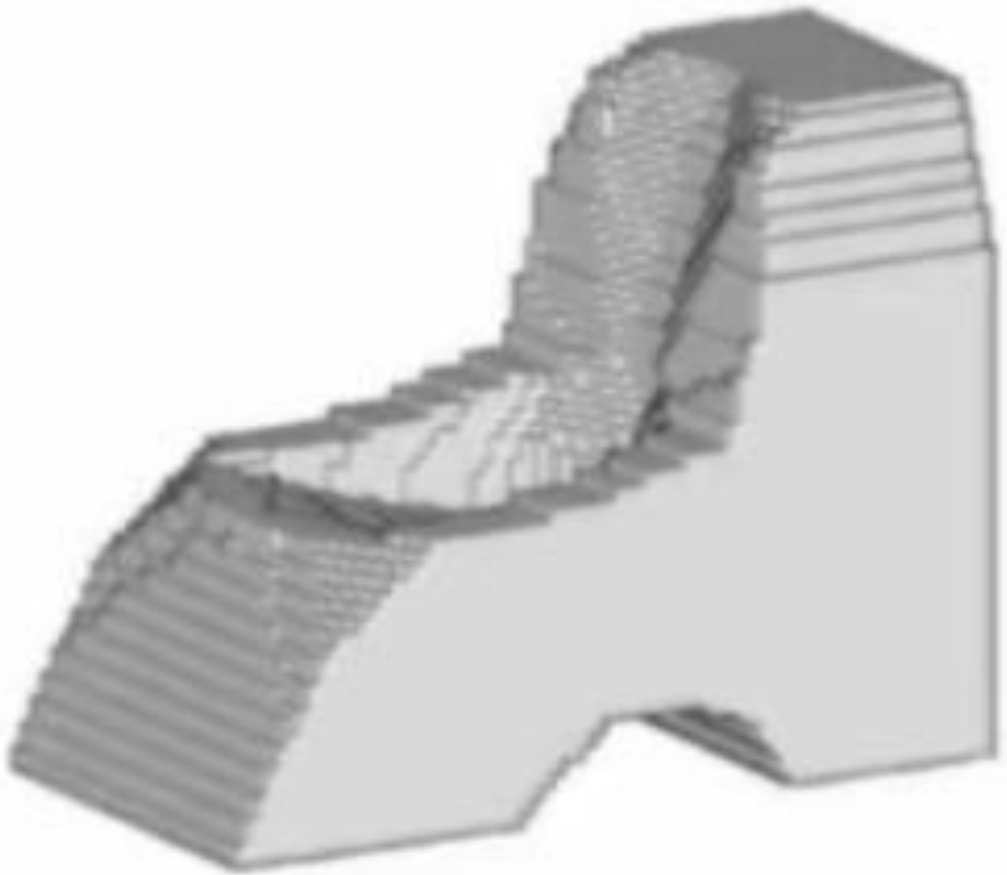
Bridge

www.usa.skanska.com

Aircraft wings

https://pilotinstitute.com/

Topology optimization



Topology optimization process

Topology optimization

Optimal design

https://www.jorislaarman.com/

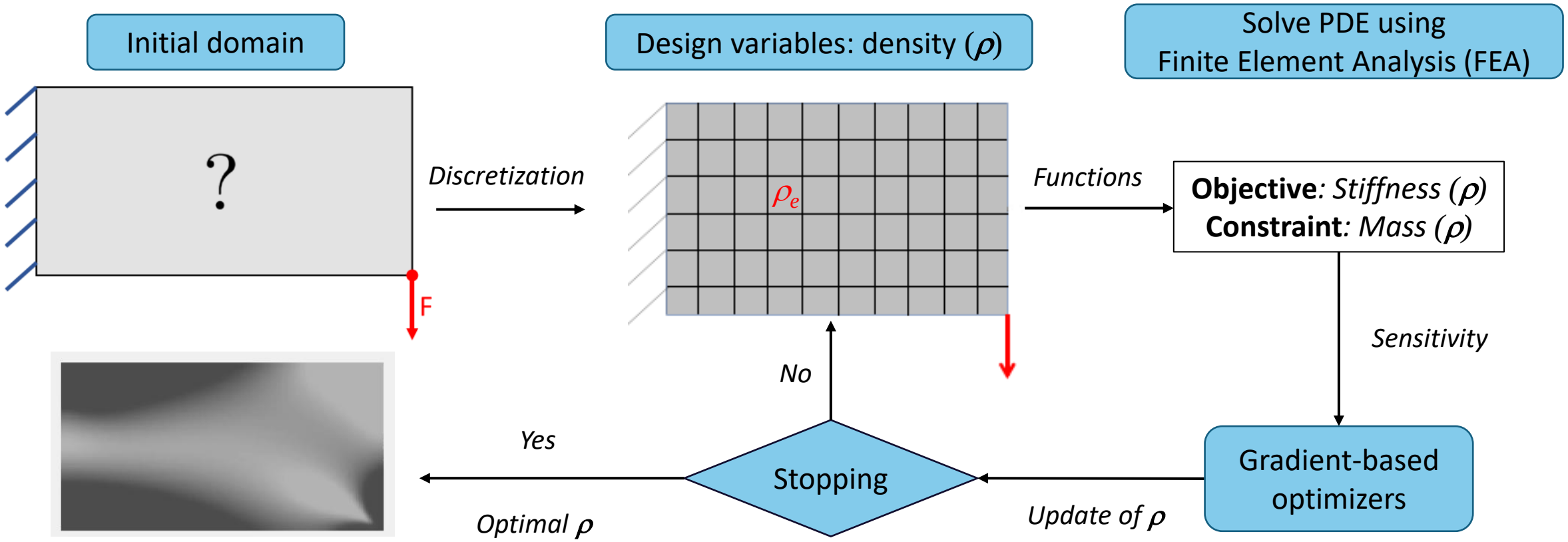
Applications of topology optimization

Optimal bridge design

Airbus use topology optimization in aircraft wings to save 1000 kg of weight

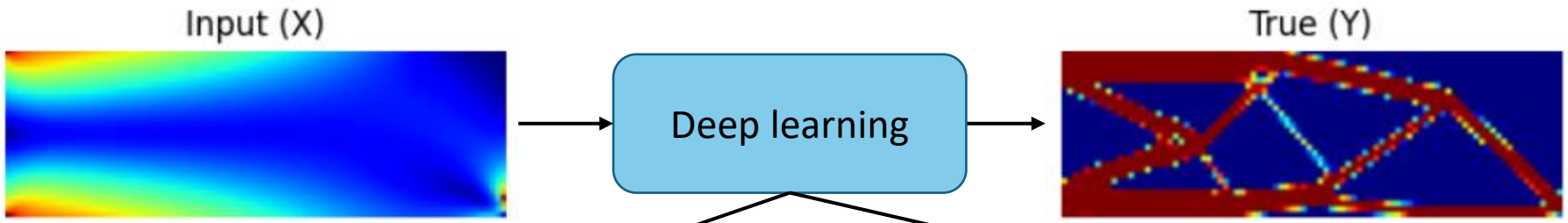
Javier et al. 2019

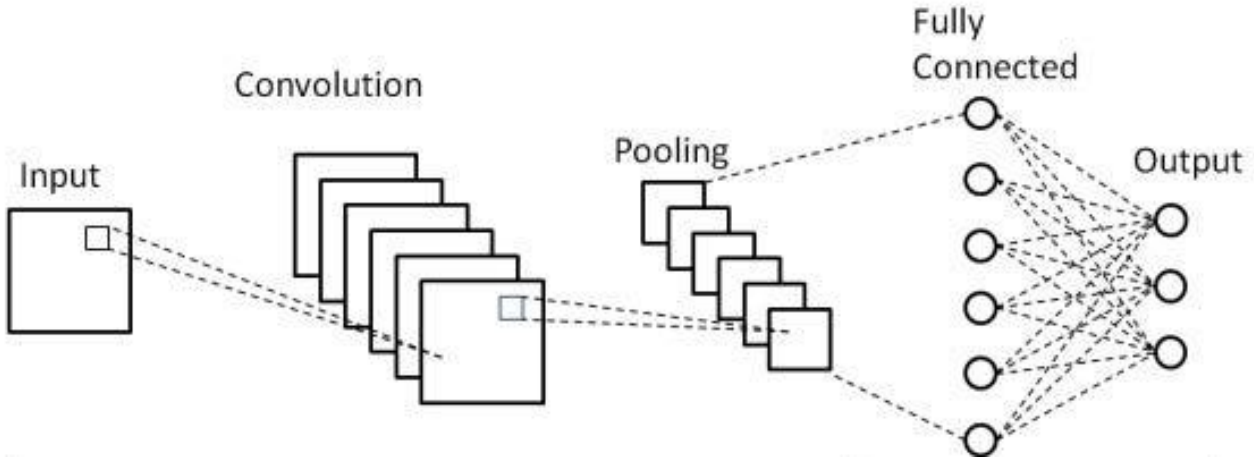
Challenges in Topology Optimization



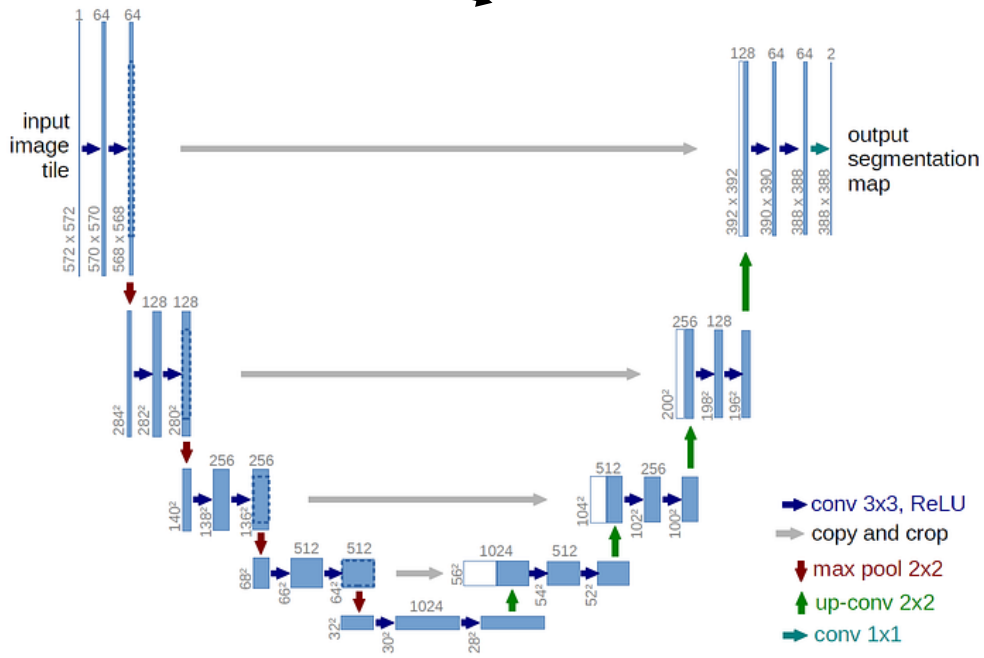
- 03 main challenges in Topology Optimization (TO)
  - *Solving PDE: Expensive*
  - *Gradients: Error prones + Time consuming*
  - *Iterative process: Expensive*

Proposed deep learning





CNN

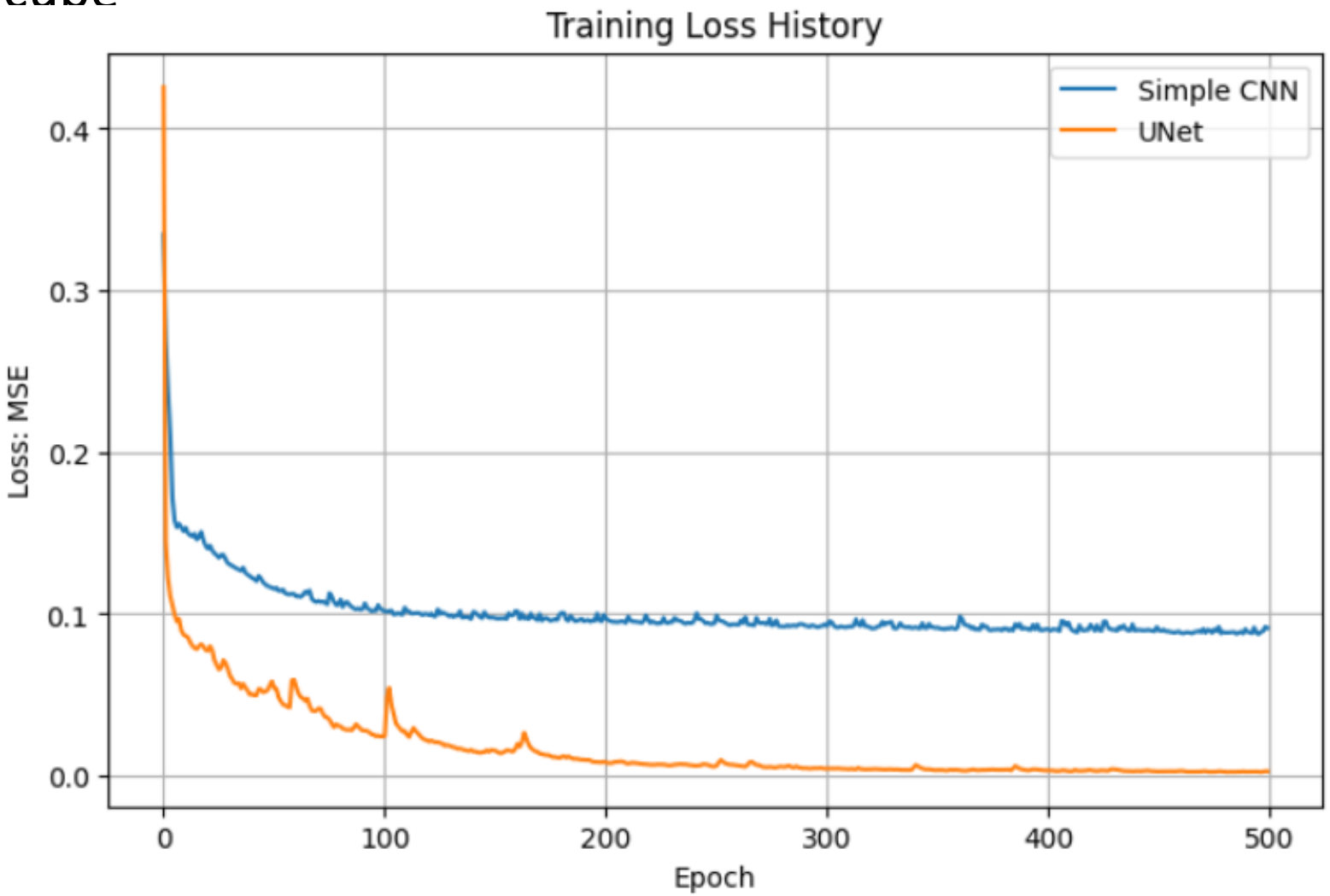


Unet

https://medium.com/

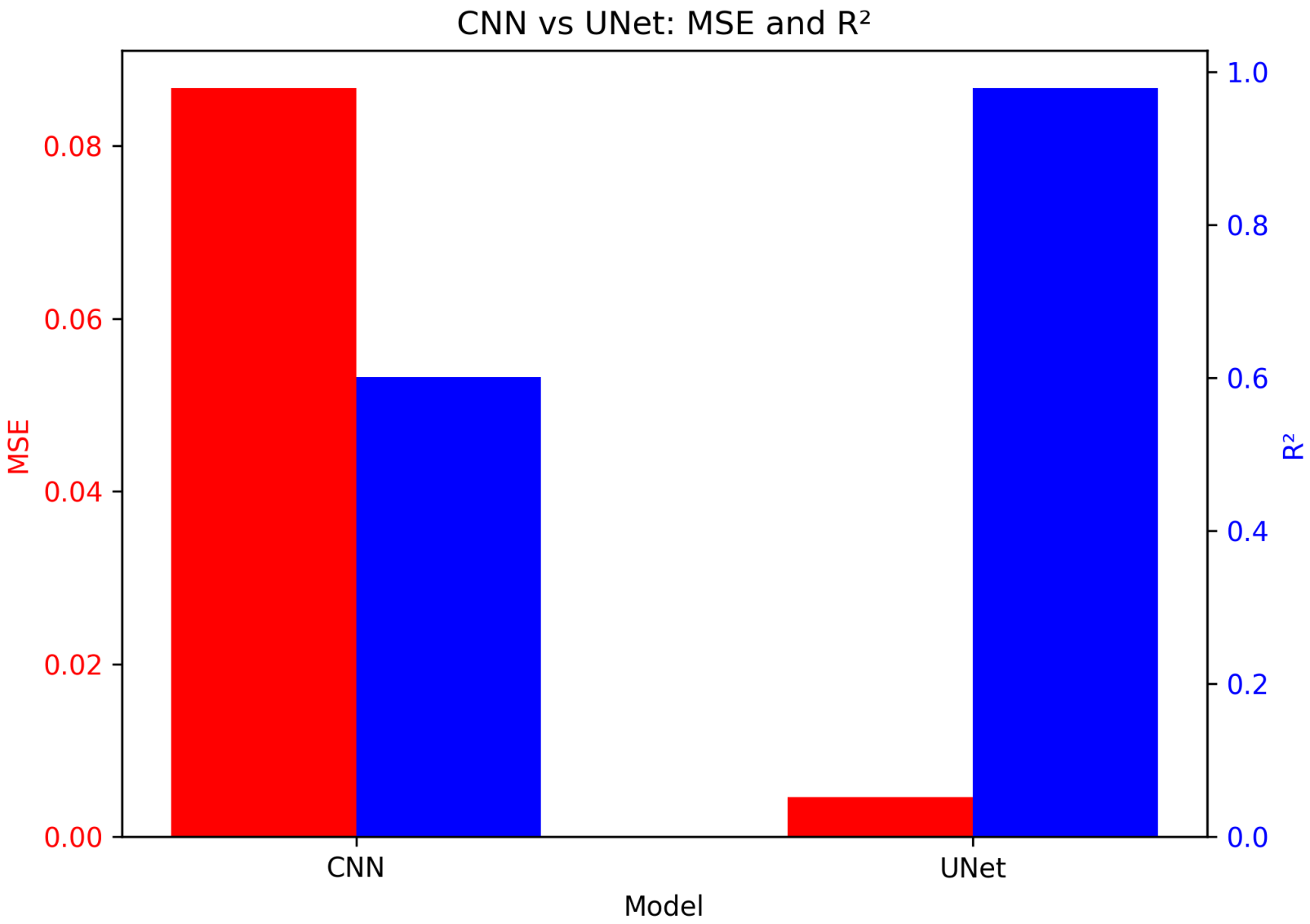
Dataset and Training

- 200 training: Latin Hypercube
- Input: 01 channel
- Output: 01 channel
- Parameters:
  - ✓ Stride = 1
  - ✓ Padding = 1
  - ✓ Learning rate = 1e-3
- Loss function: MSE
- Training time
  - ✓ CNN = 120s
  - ✓ Unet = 945s



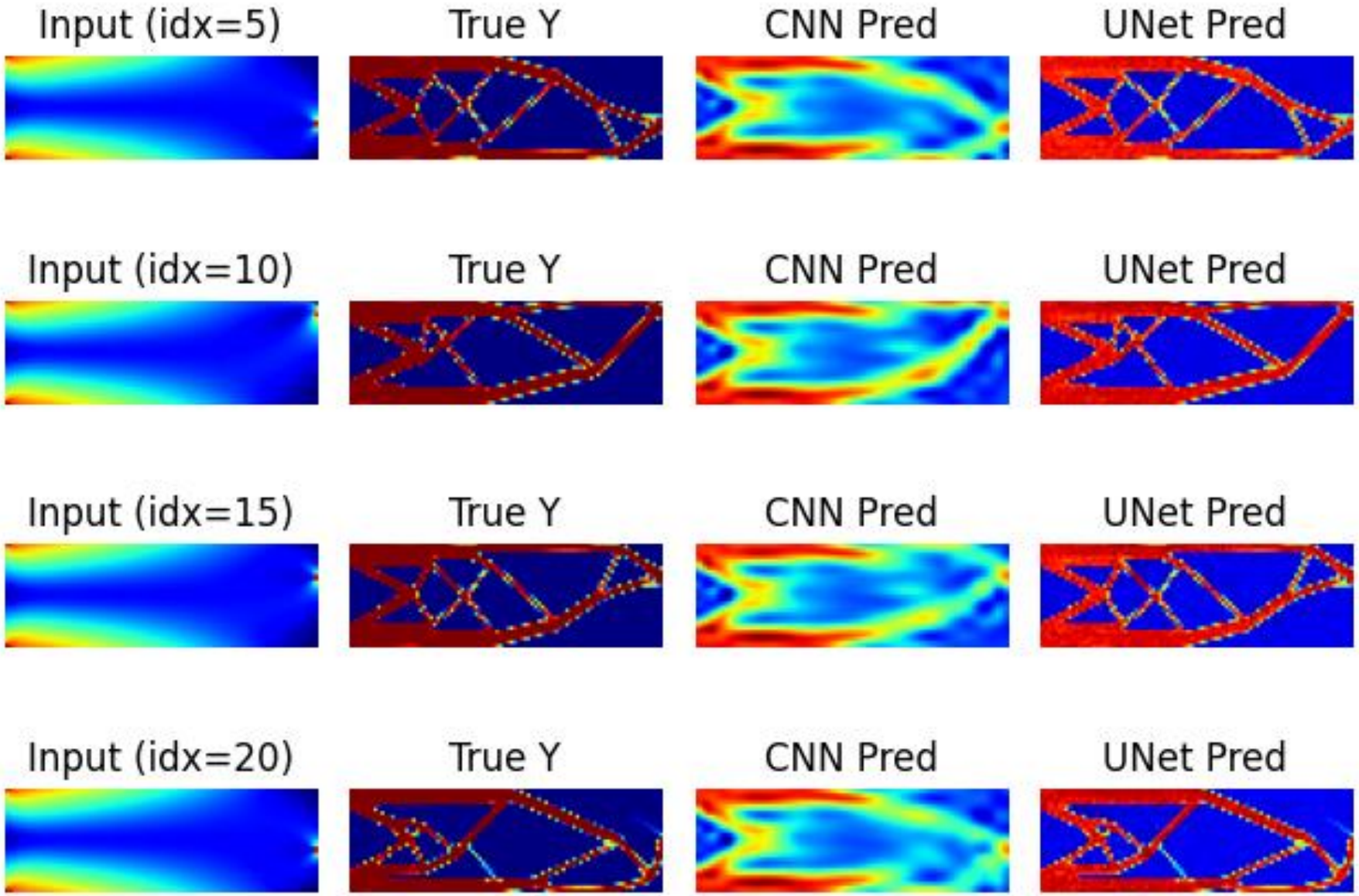
Testing data

- 50 for testing



Prediction

- Times:
  - ✓ TO = 137 s
  - ✓ CNN = 0.005 s
  - ✓ Unet = 0.001 s



Conclusion and future works

- Hyperparameter tunning
- Dataset
  - Increase number of dataset
  - 3D models
- Data augmentation: noise, rotation
- Different models:
  - Diffusions
  - Transformers