Clearance for Manipulators

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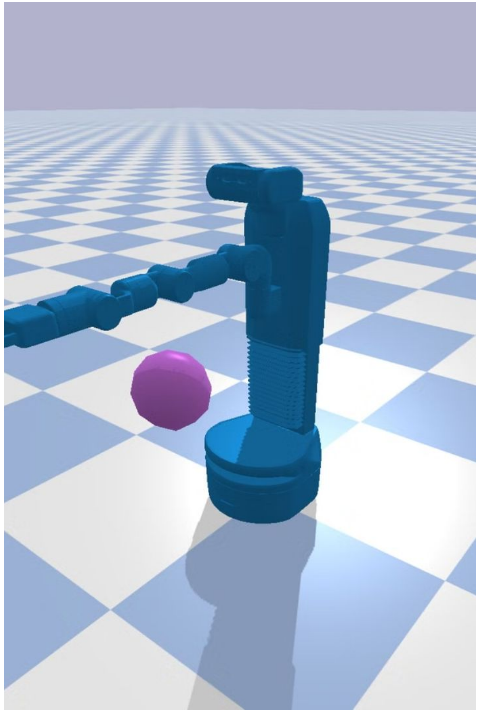
Problem Description

- Motion planning requires efficient distance computations to ensure safe navigation and collision avoidance
- Traditional planners like RRT* struggle with computational efficiency, especially for robots with many degrees of freedom (e.g., 8-DOF Fetch robot).
- Clearance calculations are slow, impacting real-time planning.

Objective

Leveraging learning-based methods to optimize distance calculations for asymptotically optimal planners like RRT*.

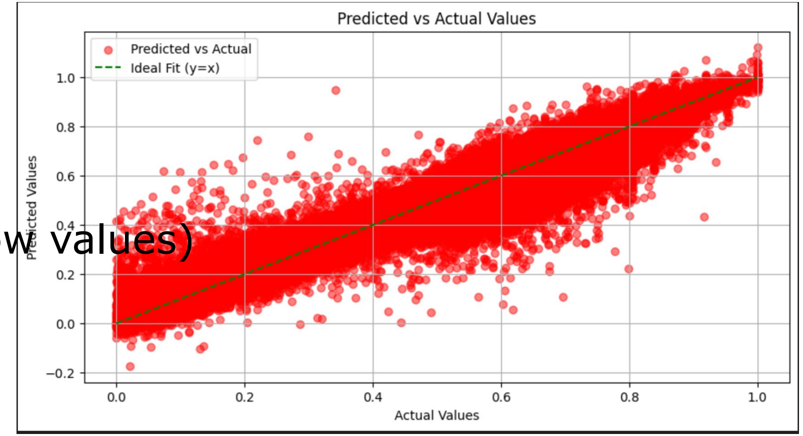


Dataset Collection

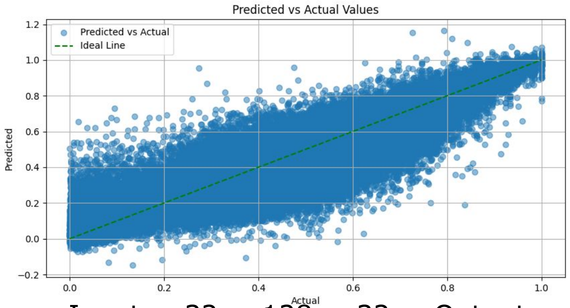
- Each sample includes **8** robot joint states and **6/12** obstacle parameters, with ground truth min distances calculated using PyBullet.
- Collected more than **15 million** samples using multiple WPI Turing Machines.

Neural Network Architecture (1 Obstacle)

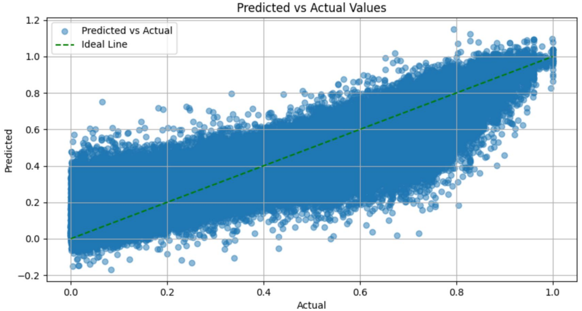
- **Input:** 8 Joint Values + 6 Obstacle Parameters
- **Hidden Layers:** 2 layers with 1400 neurons each, followed by *ReLU* activation and 1% *Dropout*
- **Output:** Single neuron to estimate minimum distance
- **Dataset Size:** 5 Million
- **Loss Function:** Weighted MSE Loss
  (Penalises more on wrong predictions for low values)
- **Learning Rate:** 1.7495e-04
- Test samples with relative error:
  - > 0.1 - 12.94%
  - > 0.2 - 5.32%



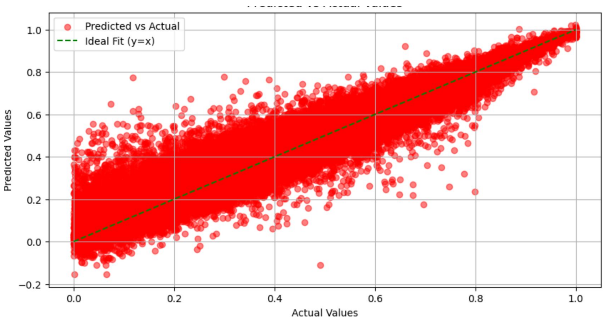
Other Tested Model Architectures



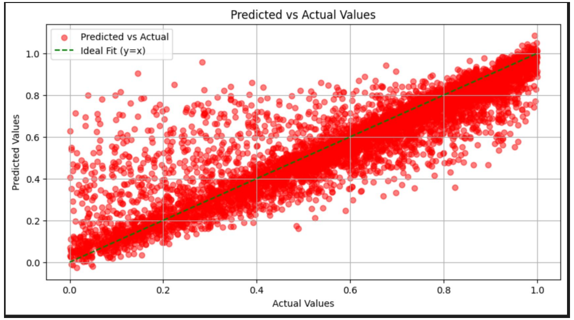
Input=>32=>128=>32=>Output
MSE Loss
LR: 3e-03



Input=>16=>64=>16=>Output
Weighted MSE Loss
LR: 1.7495e-04



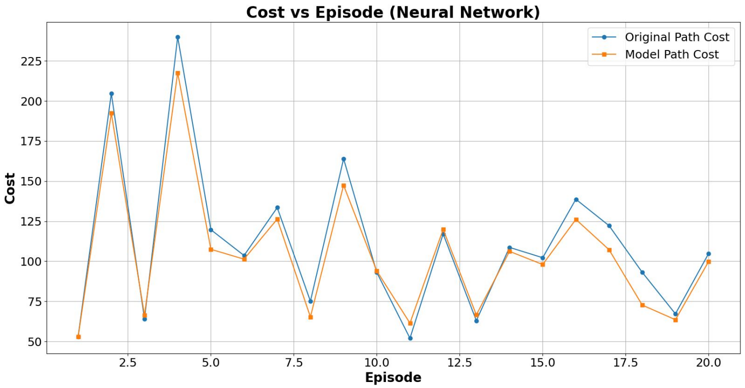
Input=>64=>128=>512=>128=>64=>
Output
MSE Loss
LR: 6e-05



Input=>64=>64=>Output
MSE Loss
LR: 2e-04

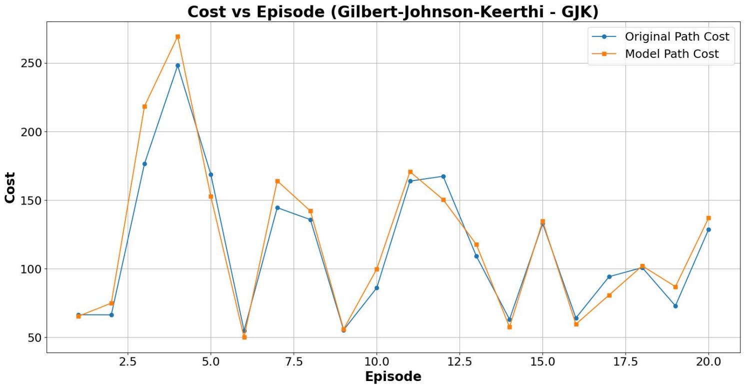
Results - RRT* with 1 obstacle

Avg Cost: 110.36

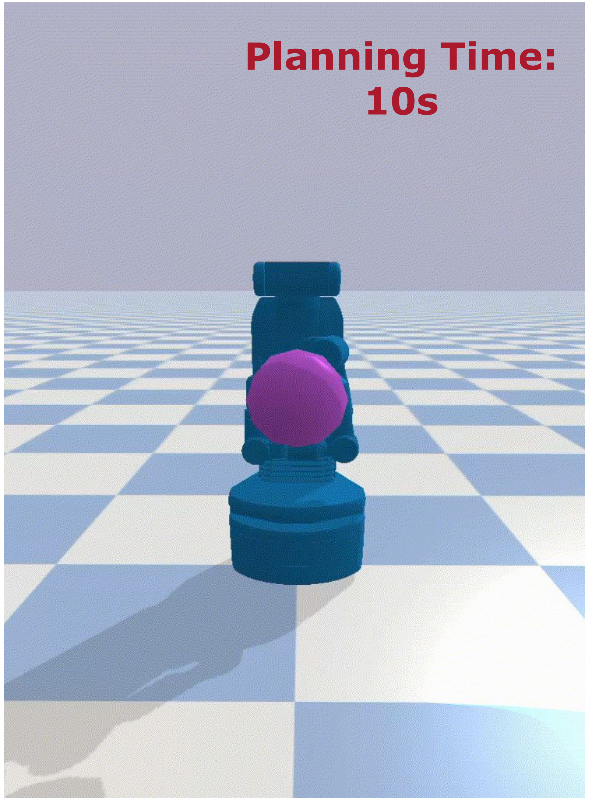


Number of States in Tree using NN: 202

Avg Cost: 114.98



Number of States in Tree using GJK: 160



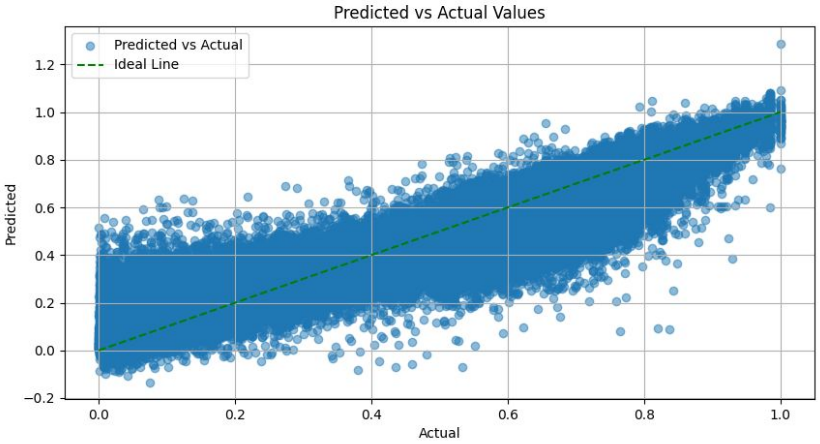
Neural Network Architecture (2 Obstacles)

- **Input:** 8 Joint Values + 12 Obstacle Parameters
- **Hidden Layers:** 2 layers with 1400 neurons each, followed by *ReLU* activation and 1% *Dropout*
- **Output:** Single neuron to estimate minimum distance

- **Dataset Size:** 10 Million

- **Loss Function:** Weighted MSE Loss
  (Penalises more on wrong predictions for lo

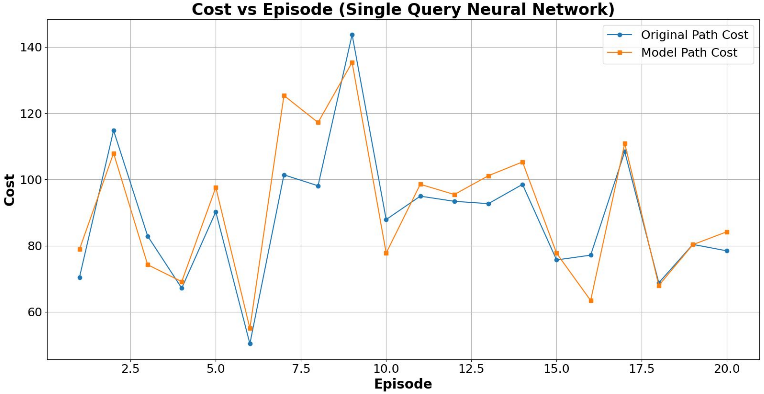
- **Learning Rate:** 1.7495e-04



- Test samples with relative error:
  - > 0.1 - 16.88%
  - > 0.2 - 10.78%

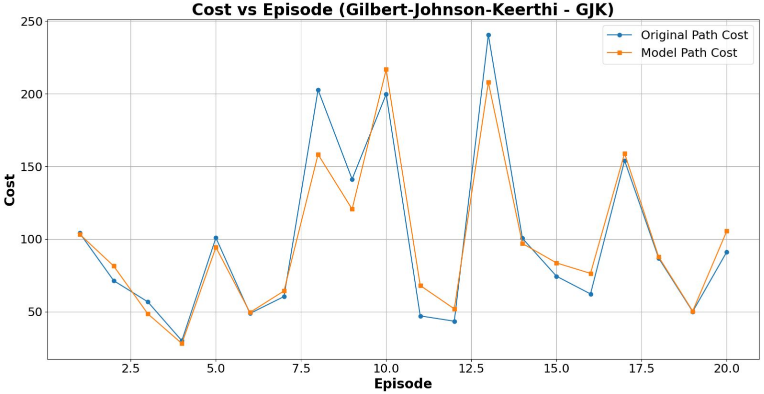
Results - RRT* with 2 obstacles - Single Call

Avg Cost: 88.78

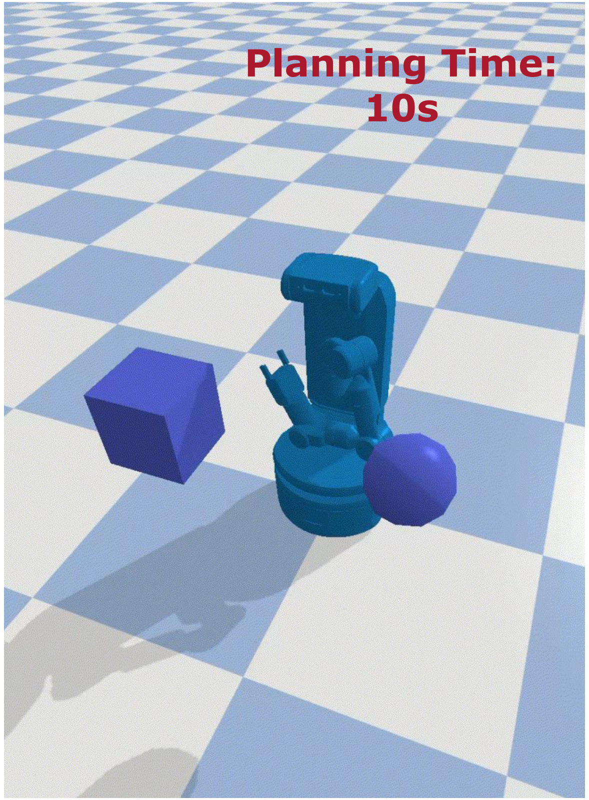


Number of States in Tree using NN: 203

Avg Cost: 98.33



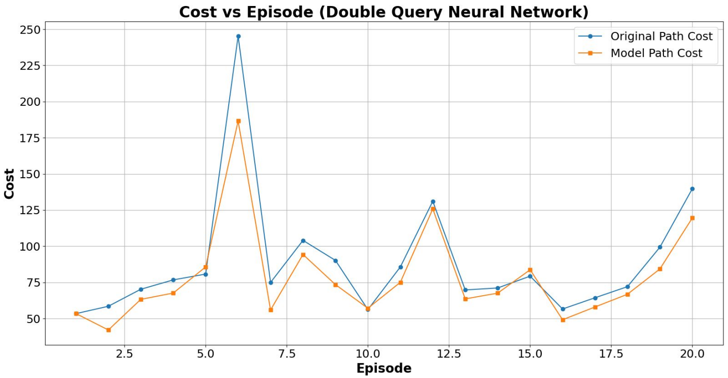
Number of States in Tree using GJK: 129



***Limitation:** Our model struggles to predict small values correctly.

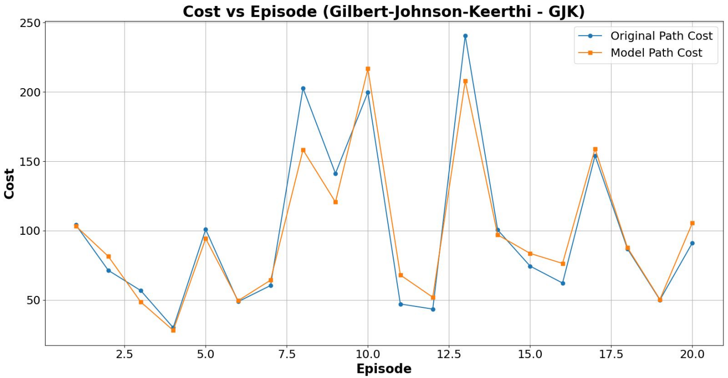
Results - RRT* with 2 obstacles - Multi Call

Avg Cost: 88.95



Number of States in Tree using NN: 153

Avg Cost: 98.33



Number of States in Tree using GJK: 129

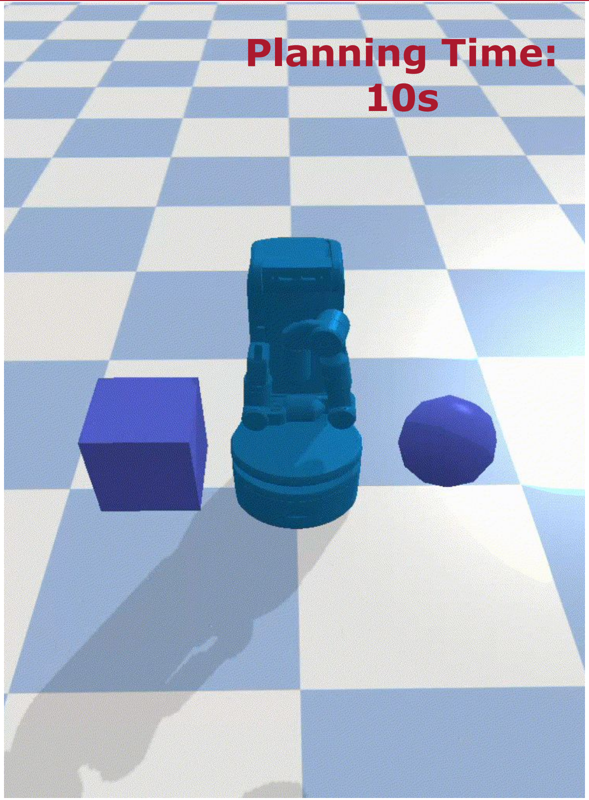
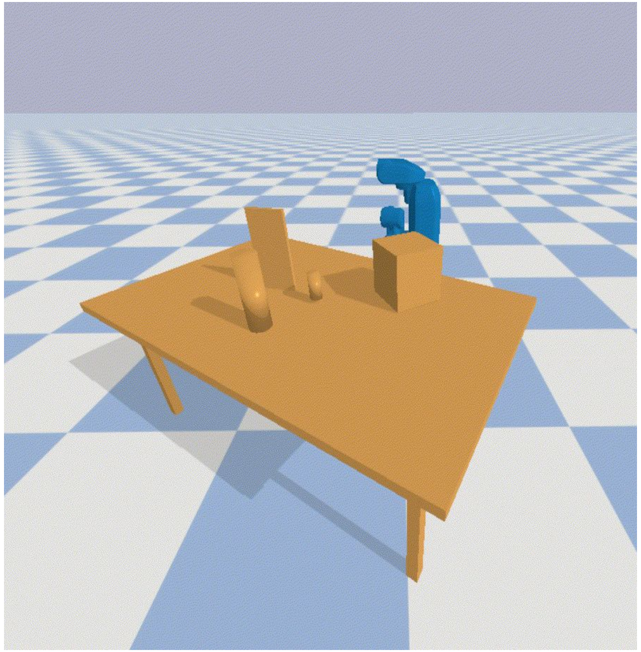
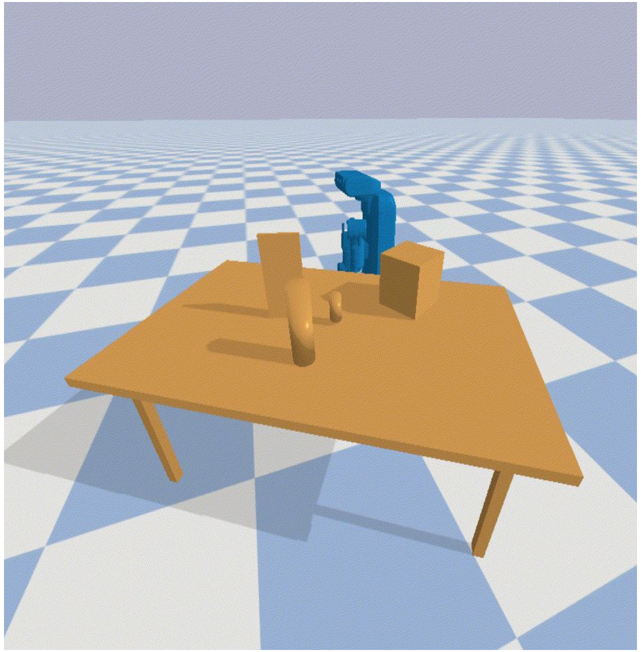


Table Scene





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References

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Thank You!

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