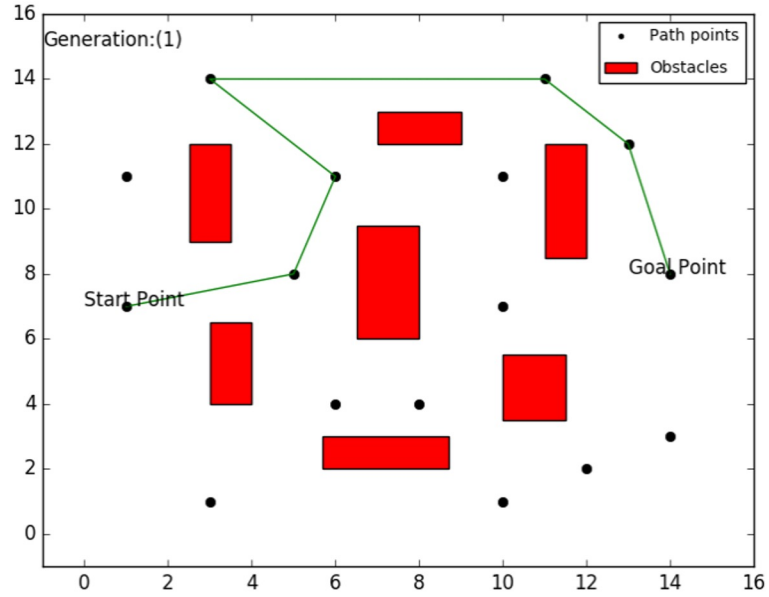
GAN based Heuristics for Sampling-based Path Planning

Author:
Alberto García Hernández

Background

Path planning

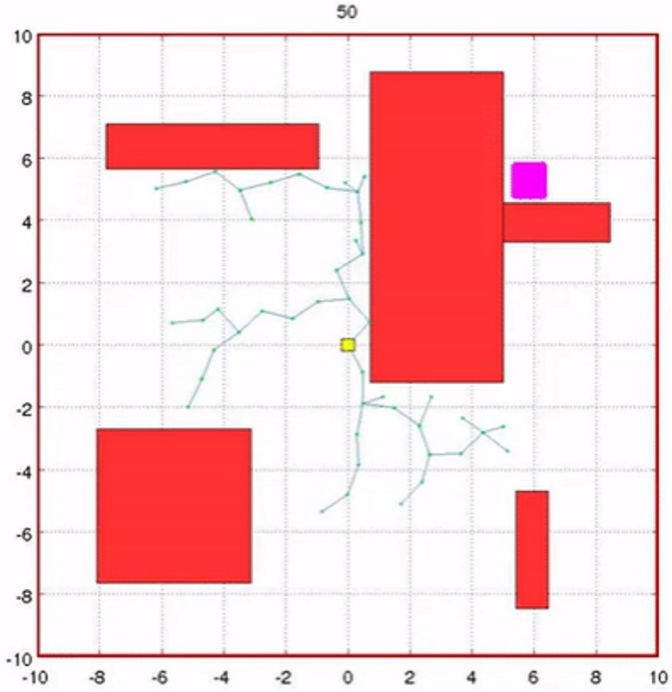
- Methodology to find a **feasible path** (**no collision)** to move a robot from source to destination
- Different approaches:
  - Gradient Based
  - Combinatorial / Exact Algorithms
  - Sampling Based



Background: Sampling Based

Sampling Based

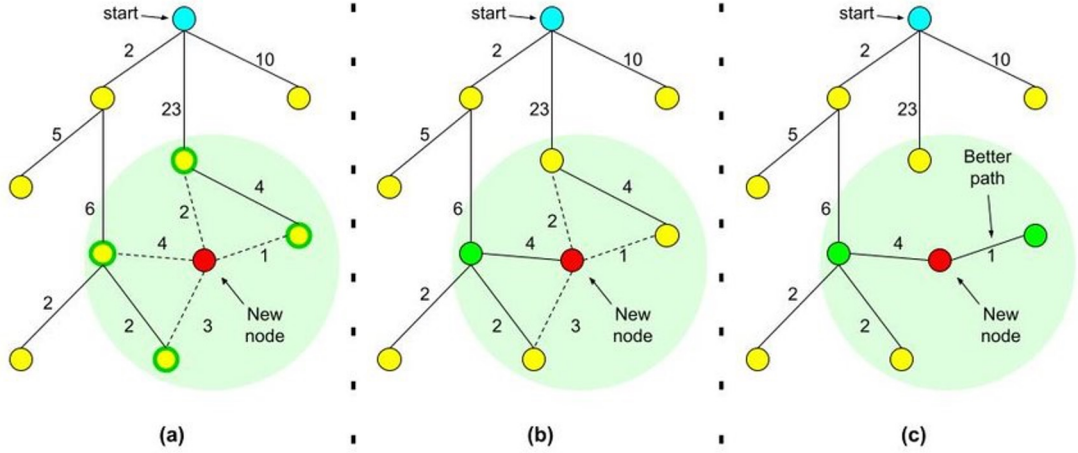
- RRT and RRT*
- Very **effective**
  - Find feasible path fast
- **(Most) Probabilistically complete**
- Finding **optimal path**
  - Computationally expensive
  - Not always realistic for some applications



RRT*

- One of the most widely used **sampling-based** algorithms for **asymptotically-optimal** motion planning.

- Based on **Near Neighbour** search and **Tree rewiring**.

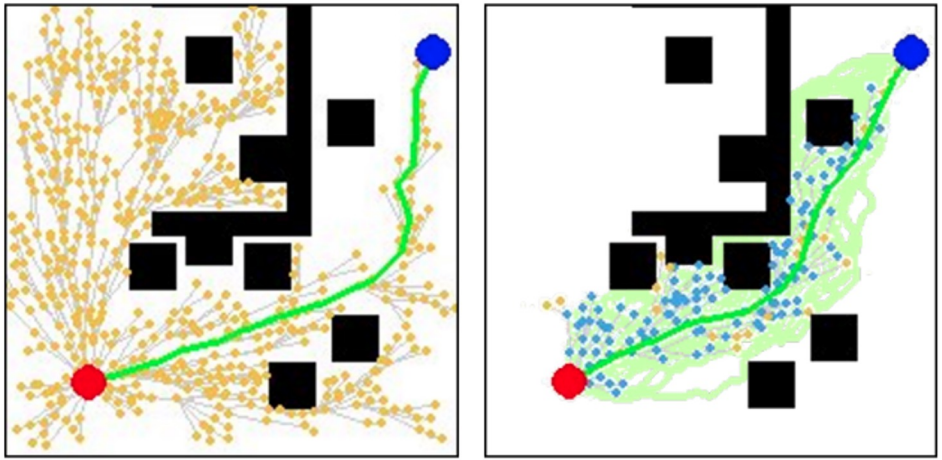


Motivation:
Can we make RRT* more efficient?

Heuristic Based RTT/RTT*

Generative Adversarial Network (GAN)

- Delimiting a Region of Interest (ROI).
- Sample ROI



(a) RRT*. (b) GAN-based heuristic RRT*.

X: state space
***X_goal**: goal state*
***X_init**: initial state*

Image Based Heuristic for RRT*

Algorithm 2: Comparison of RRT* and Heuristic RRT*

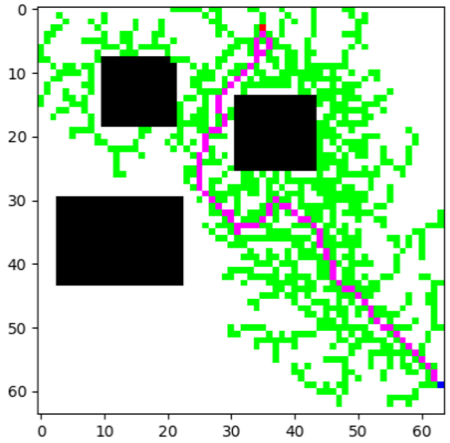
Input : x_{init}, $\mathcal{X}_{goal}$,$\mathcal{H}$, Map and $UseHeuristic$
Output: $G(V, E)$

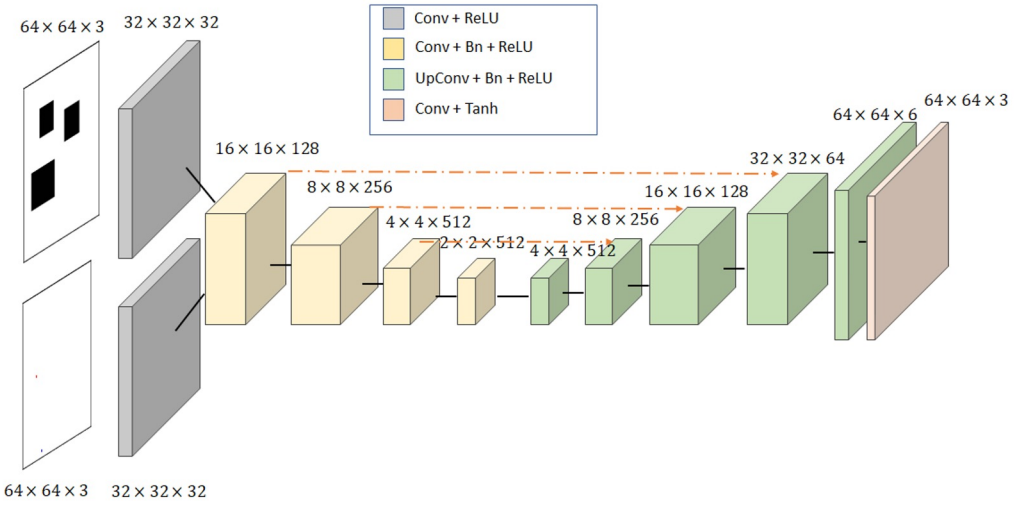
$V = x_{init}, E = \emptyset$;
for $i = 1 \cdots N$ **do**
  if $UseHeuristic = True$ **then**
    if $Rand() > \mu$ **then**
      $x_{rand} \leftarrow$ Non-uniformSample($\mathcal{X}_H$);
    else
      $x_{rand} \leftarrow$ UniformSample();
  else
    $x_{rand} \leftarrow$ UniformSample();
  $x_{nearest} \leftarrow$ Nearest(G, x_{rand});
  $x_{new} \leftarrow$ Steer($x_{nearest}, x_{rand}$);
  if *ObstacleFree*($x_{nearest}, x_{rand}$) **then**
    Extend(G, x_{new});
    Rewire();
    if $x_{new} \in \mathcal{X}_{goal}$ **then**
      Return $G(V, E)$;
  Return $failure$;

- Samples are randomly chosen from
  - non-uniform sampling
  - GAN heuristic
- **Trade-off** between:
  - **Efficiency**
  - **Still guarantee probabilistic completeness**

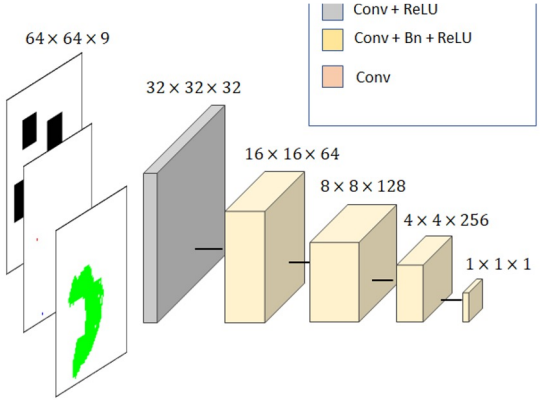
GAN based heuristic

- **Architecture based on Pix2Pix**
- **Generator:** input 64×64 map + (x_init, x_goal)
- **Discriminator:** input 64×64 map + (x_init, x_goal) + ROI



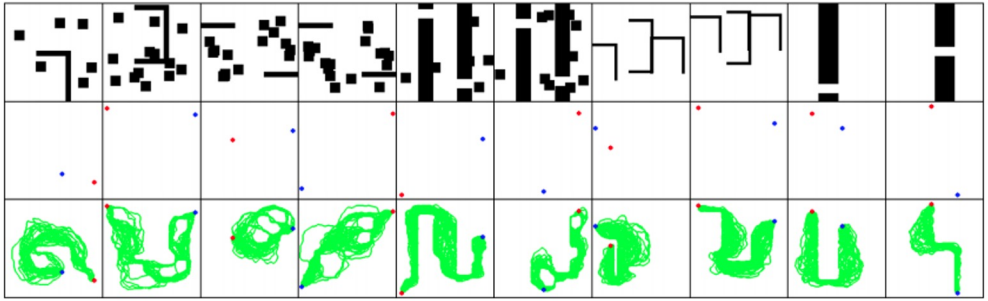


Generator

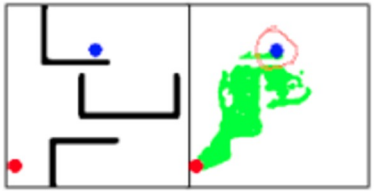


Discriminator

GAN based heuristic



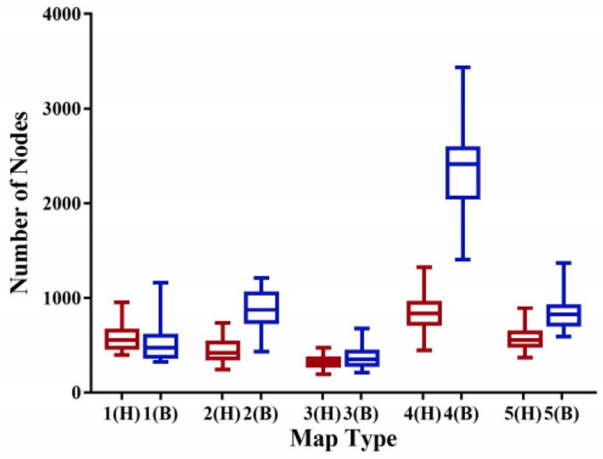
- **Dataset:**
  - 10.000 samples of different environment maps.
  - Ground truth obtained running RRT* multiple times.
  - 20 starting points -> sampled uniformly
- **Connectivity:**
  - Cases where the generator fails to provide a good mapping for a given input

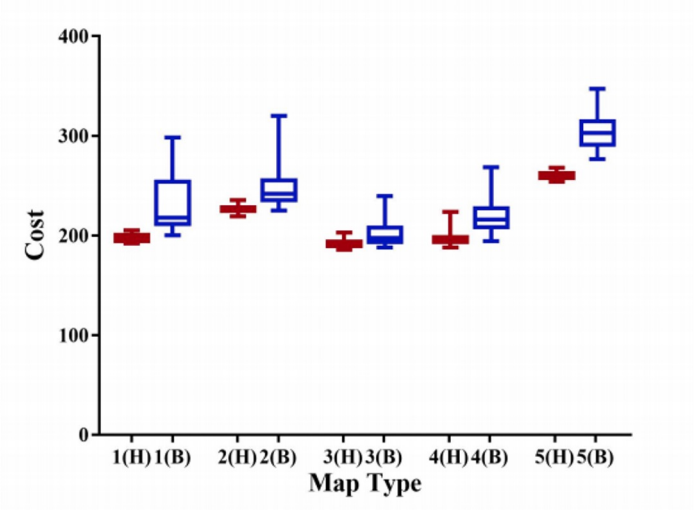


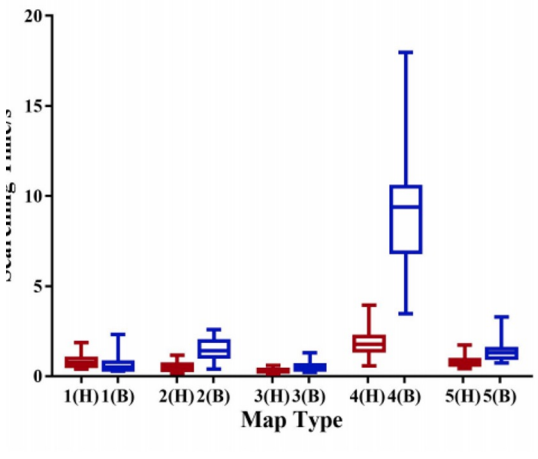
- **Generalization:**
  - Shows good **adaptability** on unseen environments.
  - Success rate of **81.9%** on a different dataset

Evaluation

- We test on **5 maps**, **10 runs** per experiment using **random start, goal** positions
- Metrics:
  - Cost(Euclidean distance)
  - Time
  - Nodes expanded







Limitations

- Possible **connectivity issues** -> forces the path planner to use traditional RRT*.

- Input map must follow the **same distribution** as training data.

- Need for s**pecialized hardwar**e to run **inference** on the real robot
  - (Nvidia Jetson, Google Coral)

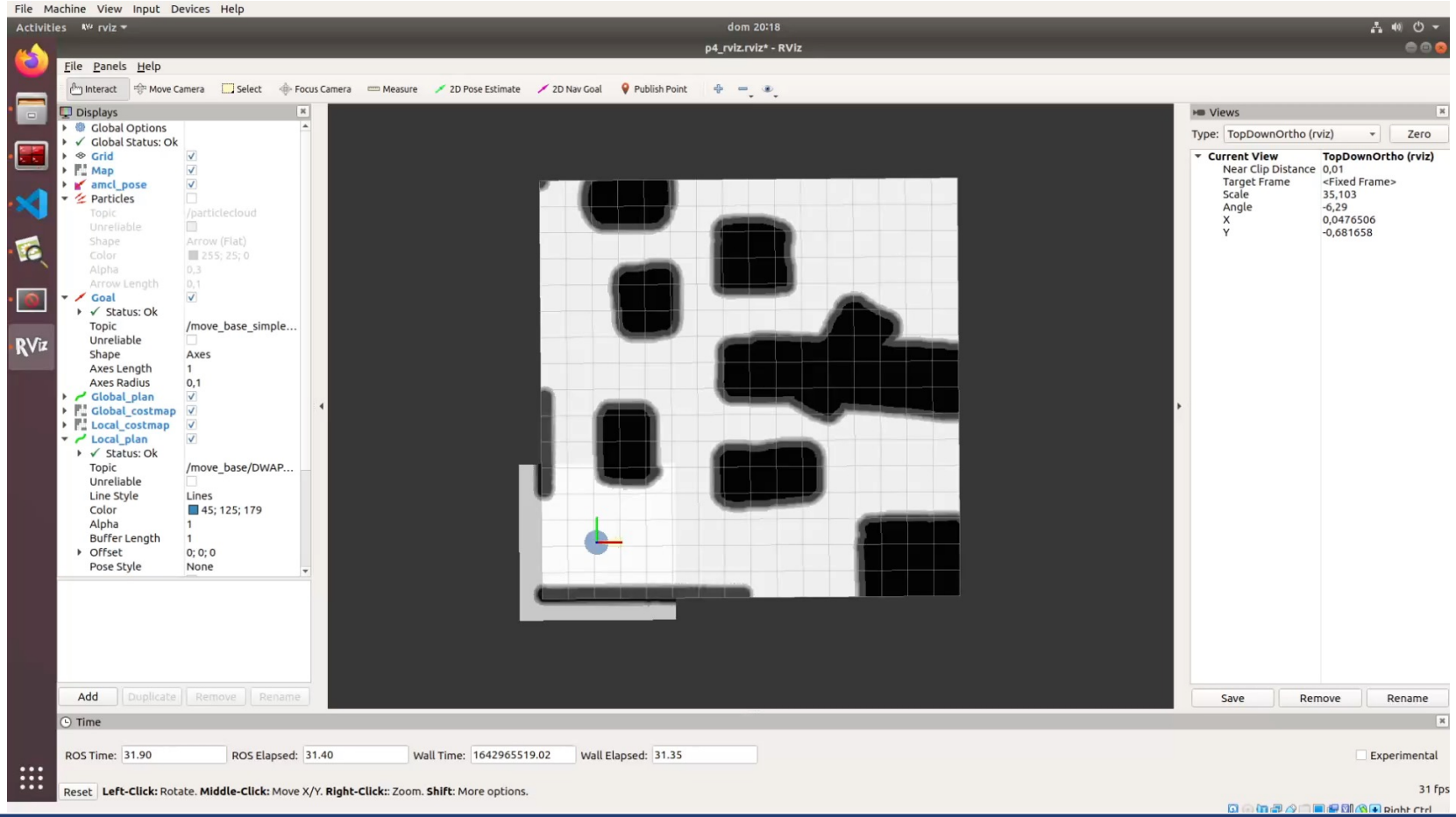
- **Decreased performance** when generating regions that cross **long distances**.
  - long-distance paths account for a small ratio in the randomly-generated dataset.

Conclusions

- Image-based heuristic to guide path planning algorithms shows **significant improvement**:
  - The **quality** of paths
  - **Accelerates** the **convergence** speed to the optimum.

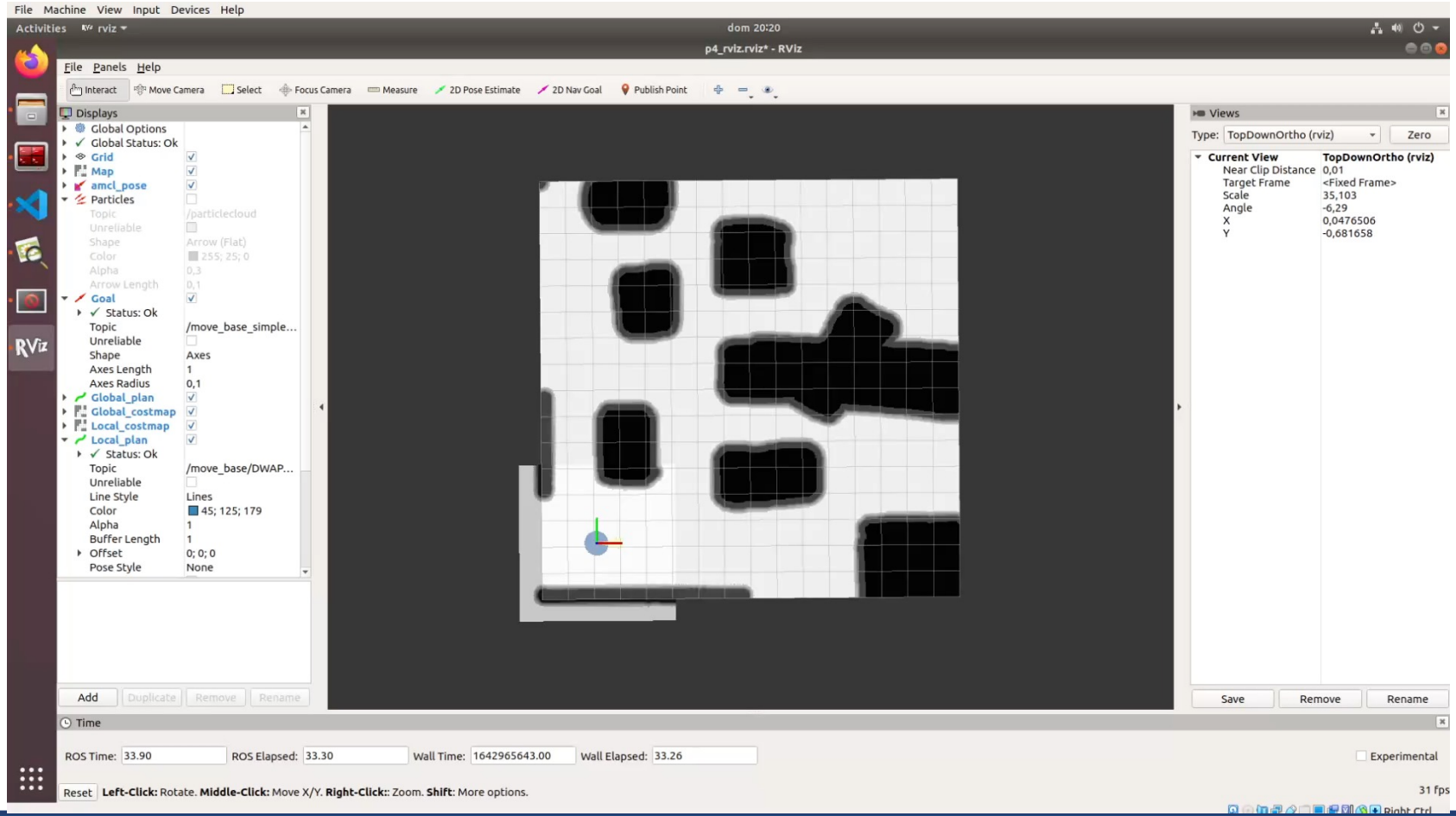
- **Modifications** can be done to improve our implementation:
  - Apply the model to **dynamic environments**
  - **Fine-tune** the model for **long distance paths**
  - Explore more **lightweight architectures**

Demo: RRT* GAN



*Videos available in drive

Demo: RRT*



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