Reducing Collision Checking for Sampling-Based Motion Planning Using Graph Neural Networks

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NEURAL INFORMATION PROCESSING SYSTEMS

ABSTRACT

We propose new learning-based methods for reducing collision checking to accelerate motion planning by training graph neural networks (GNNs) that perform path exploration and path smoothing.

- The framework consists of a path exploration component that iteratively predicts collision-free edges to prioritize their exploration, and a path smoothing component that optimizes paths obtained from the exploration stage.
- The approach significantly reduces collision checking and improve overall planning efficiency in challenging high-dimensional motion planning tasks.

PRELIMINARIES

Random Geometric Graphs

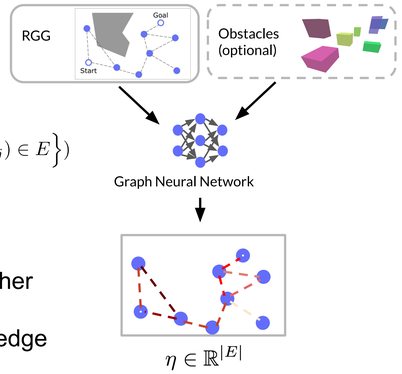
A graph where the nodes that are sampled from the free space, and the edges are connected by k nearest neighbor or r-disc.

Graph Neural Networks

A neural network that aggregates information from neighbors, such as:

$$c_i^{(k)} = \oplus^{(k)}(\{f(x_i^{(k)}, x_j^{(k)}, y_{i,j}^{(k)}) \mid (v_i, v_j) \in E\})$$

$$x_i^{(k+1)} = g(x_i^{(k)}, c_i^{(k)})$$

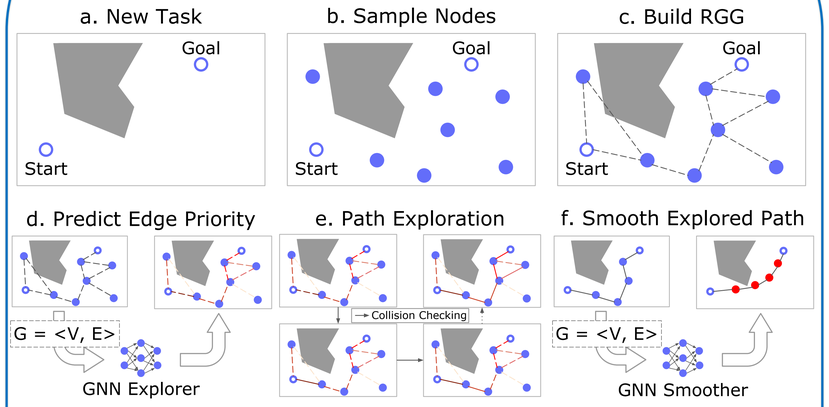


Collision Checking

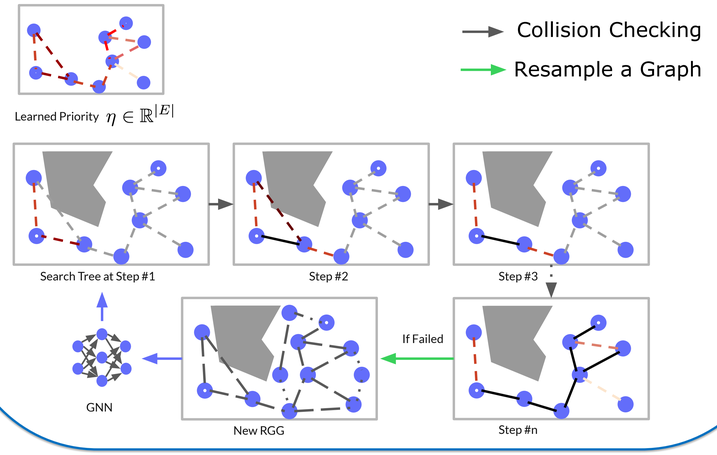
The procedure to check whether the robot collides with the obstacles w.r.t. a node or an edge in the configuration space

PROCEDURE

Overall Framework:

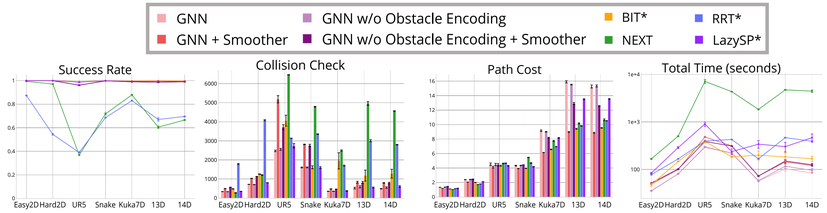


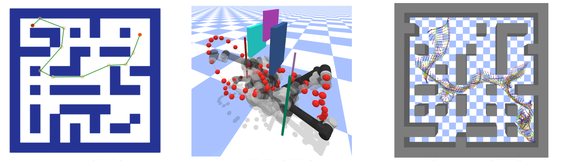
Path Exploration:

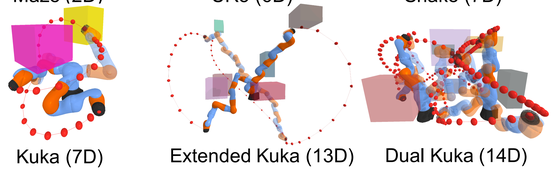


RESULTS

- We conduct the experiments on: (i) a 2D point-robot, (ii) a 6D UR5 robot, (iii) a 7D snake robot in 2D workspace, (iv) a 7D KUKA arm, (v) an extended 13D KUKA arm, (vi) and a pair of 7DoF KUKA arms.
- Our approaches significantly reduce collision checking while maintaining high success rate, low path cost, and fast overall planning. The performance scales well from low-dimensional to high-dimensional problems..







Project page available at