

The project deals with the fundamental problems in robotics and artificial intelligence. The goal is to transfer the capabilities of humans and animals to the machines so the robots can perform real-world tasks. Industrial robots work in factories where the environment is determined and prepared in advance. If we'd like the robots of the future to work in the real world and help humans in daily activities they should operate in real environment. It means that the robots should be able to precisely measure the shape of the objects using of-the-shelves RGB-D sensors and neural-based algorithms. With an efficient map and motion constraints model the robot will be capable of efficiently planning its motion and interaction with the environment.

The robot perception primarily relies on the representation of geometric structures within the surroundings. Wheeled mobile robots, walking robots, and manipulators employ RGB cameras, depth sensors, and laser scanners to measure the configuration of obstacles in their environment. The most popular environment models are occupancy maps, raster maps, and voxel maps constructed to represent the occupied space and the configuration of obstacles. The map of the environment is used by a robot to plan a collision-free path that guarantees performing the given task.

In the traditional approach to robot perception, the environment is divided into equal blocks (cells, voxels) where the size of the block is connected to the accuracy of the system. High accuracy of the environment model is required when the robot performs precise operations and the distance between the robot and the obstacles is small. Decreasing the size of the blocks increases the accuracy of the map but, at the same time, increases the memory consumption and slows down the motion planning algorithms.

Recently, neural scene representations like NeRF or NeuS gained huge attention in computer vision and robotics. The original method shows that a simple Multi-layer Perceptron (MLP) can represent a scene with great accuracy when trained on RGB images only. In this project, we are going to bridge a gap between classical online-built maps and offline neural models that can significantly increase the accuracy of the environment map.

With such a perception system, the robots will be able to better plan their motion and interaction with the environment based on RGB-D measurements. This model will provide environmental constraints during the planning of the motion of the robot and avoid collisions with objects. We focus on neural modeling of kinematic motion constraints like self-collisions, kinematic limits of joints, and kinematic range of motion. The neural network can also take into account dynamic constraints that come from the dynamic model of the robot and stability constraints that are related to the configuration of the robot. We also aim for differentiable models that provide information about the constraints violation and also give the direction of motion that moves the robot out of these states to the closest region with an acceptable state.

Finally, we are going to obtain the neural model of the robot that can be efficiently used during motion planning. We will show the performance of the proposed method in two scenarios: (i) "peg in the hole" and (ii) path planning of a multi-DoF walking robot walking through a small hole. Both problems are challenging to classical path planning methods and are sensitive to the accuracy of the mapping methods.