University of Basel

Department of Biomedical Engineering

Path Planning for a Hyper Redundant Robot Inside the Human Knee

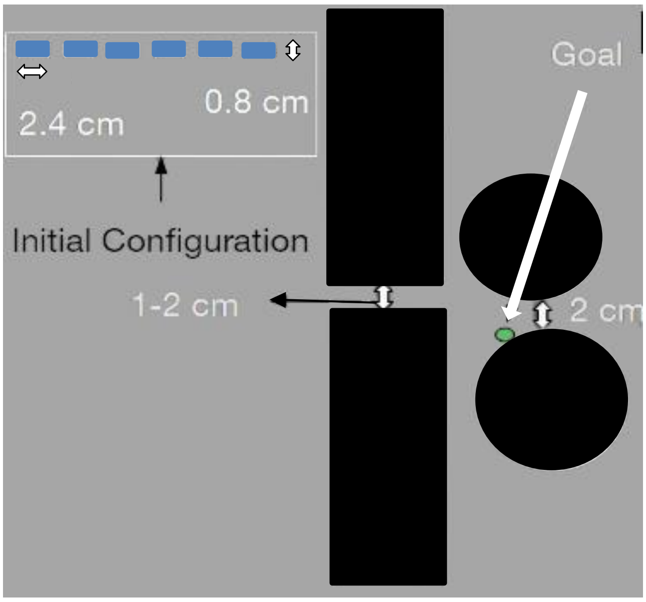

Figure 1: A map approximating 2D human knee anatomy with two spheres as joints and an entry portal between two rectangular obstacles. The goal is to find a path for the 6-DOF robotic endoscope from an initial configuration to the goal (green circle).

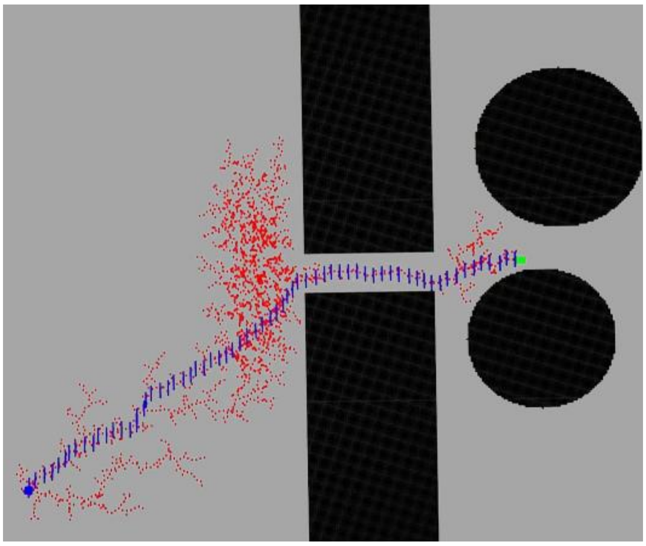

Figure 2: A biased sampling method improves the RRT sampling algorithm to expand the search tree towards the goal (red samples). The shortest 2D end-effector solution path is generated using Breadth first search algorithm (blue samples).

Internship Thesis by Shubham Mittal (IIT Kanpur, India) at the BIROMED-Lab.

The objective of this project is to develop a path-planning framework that enables a robotic endoscope to navigate through the intricate structures of a human knee in a minimally invasive way. The major challenges are posed by the narrow passages in the human knee, where the robot has to pass without hitting any anatomical structures. Sampling-based solutions have low likelihood of finding robot configurations (samples) that do not hit the obstacles. Consequently, they fail to find a complete solution within the allotted time, and it adversely impacts the overall success rate of the framework.

Acknowledging the absence of an exhaustive solution to this challenge (also for real-time applications), we address a simplified 2D version of the problem. Our proposed solution consists of a two-step process. First, we determine an end-effector trajectory using an improved and novel sampling method. Instead of relying solely on random sampling, we strategically guide the samples to increase the likelihood of capturing relevant points in the narrow passage. This is achieved by integrating the sampling-based strategy with the potential fields generated on the provided 2D map. Subsequently, in the second step, we find the joint configuration space solution by directing all the robot links to follow the previously found end-effector trajectory using a follow-the-leader approach. All the experiments were conducted on the Gazebo simulator within the Robot Operating System framework.

The algorithm was evaluated keeping the robotic endoscope's width fixed to 0.8 cm. The success rates achieved with the varying portal diameters i.e. the space between two rectangular obstacles, are as follows: 1 cm - 25%, 2 cm - 98%, and 3 cm - 100%.

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