Multi-Goal Motion Planning for Steerable Surgical Needles

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Steerable needles allow minimally invasive yet precise surgical procedures by reducing the size of incisions and the disturbance of tissues during the operation. Bevel-tipped steerable needles naturally follow circular arcs when inserted into tissue. Rotating the needle at its base changes the direction of curvature as the needle is inserted, allowing the needle to be steered around obstacles such as bone or sensitive tissue. Due to the nature of its actuation, a steerable needle is not easily controlled by a human operator. However, an autonomous motion planner can produce a path from the insertion point that passes through all goal areas without colliding with obstacles. By considering multiple goals, the needle can be used for more complex surgical procedures and could reduce the number of incisions needed in an operation. This project presents a motion planner for a bevel-tipped needle based on a Rapidly-exploring Random Tree (RRT), and accounts for multiple goals. An RRT planner samples many random points, connects them to a tree, and when a point in the goal region is found, traces back through the tree to construct a path. The approach accounts for multiple goals by first deciding an order in which to reach the goals and then running the RRT planner to produce paths between them. The goal order is determined by passing approximate movement costs between goals to a Traveling Salesman Problem solver. The approach is implemented in Java. Experiments conducted in simulation show that the approach is able to produce consistently short paths in under one second, which would allow it to control a needle-steering robot in real-time.

Awards Won: