Rapid Motion Planning for Intracerebral Hemorrhage Evacuation using a Tubular Aspiration Robot

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Abstract— **Intracerebral hemorrhage evacuation using a tubular aspiration robot enables minimally-invasive surgery. To suction out blood from within, a 3D motion plan has to be determined prior to evacuation as well as intraoperatively based on CT images. In this paper, our previously proposed 3D motion planner is extended by a new objective, such that it allows for minimization of traveled distance in configuration space or traveled Cartesian distance of the tubular aspiration robot.**

I. Motivation and Problem Definition

Intracerebral hemorrhages appear, when a blood vessel ruptures within the brain and blood accumulates. They are life-threatening as they induce pressure onto surrounding brain structures. A surgical removal requires the opening of the skull (craniotomy) and is often not beneficial for the patient, as additional disruption of healthy brain tissue during the procedure cannot be prevented in order to gain access to the hemorrhage [1].

II. Related Work

To reduce the invasiveness, researchers proposed robotic surgery using a tendon driven continuum robot [2] or a tubular aspiration robot [3] to perform intracerebral hemorrhage evacuation. The tubular aspiration robot performs the evacuation in a minimally-invasive manner autonomously. We previously introduced a 3D motion planner [4] which maximizes coverage while minimizing traveled distance in configuration space.

III. Own Approach and Contribution

In this paper, we extend our algorithm by a new objective: traveled Cartesian distance and evaluate the results by comparing the overall traveled distance in Cartesian and configuration space for 3 patient datasets.

The tubular aspiration robot (Fig. 1 top) is composed of two tubes: the outer being straight to reach the hemorrhage on a straight path and the inner being precurved, which articulates within the hemorrhage to suction out the blood. Configuration parameters are the translation of both tubes β_1, β_2 and the rotation of the inner tube α. Our 3D motion planner starts at the center of the volume and considers spherical intervals s around it, moving from one interval to another, while moving with least cost within these intervals.

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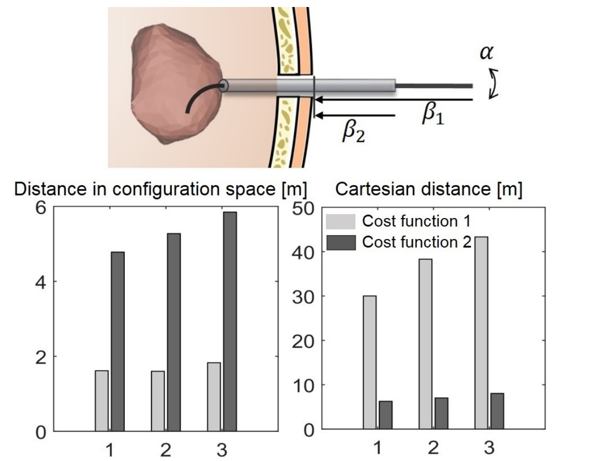

Fig. 1. Tubular aspiration robot (top) and mean traveled distance in configuration and Cartesian space for 3 patient datasets (bottom).

We defined the cost for traveling from one configuration to another by considering the least change in configuration parameters (cost function 1). Here, we propose a new cost function, where the robot travels with least Cartesian distance from one end-effector position to the next (cost function 2). For evaluation, we computed the 3D motion plan for 3 example patient hemorrhages using a randomly chosen entry path into each hemorrhage volume and computed the overall distance traveled in configuration and Cartesian space.

IV. Results

We ran the algorithm on an Intel Core i7-4790 3.60 GHz implemented in C++. The mean computation time for one patient dataset was 0.42 s. The interval size was chosen empirically as 2 mm. Fig. 1 (botttom) illustrates, that each cost function successfully resulted in either low traveled distance in configuration space or Cartesian distance for each patient case. In future work, we will experimentally validate the effectiveness of both cost functions.

References

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