Magnetic Needle Tracking for Medical Applications

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Research question: Can a needle tracking system be made by using permanent magnets and DC motor and loadcell feedback?

Overview

- **What?** Tracking a magnetically-steered needle for clinical applications
- **Purpose?** Treating tumors for targeted drug delivery or tissue ablation and to improve the tracking capabilities for needle steering
- **How?** A magnetic needle is steered by a permanent magnet attached to the end effector of a robotic arm. The needle is also attached to a Kevlar line that is attached to a DC motor just outside the workspace. The DC motor, paired with a loadcell, ensures that the needle moves at a constant velocity through the workspace.

Current Experimental Setup

- **Robotic Arm:** 6-DOF, DH-parameters
- **Magnet:** NS2 magnet, 2x1x0.5-in. Needle moves in the direction of the magnet. The magnet is located at end effector of robotic arm. End effector’s z-axis and position align with the needle’s path.
- **Workspace:** Agar, stiffness of 2.70 kPa.
- **DC Motor:** Slowly releases the needle at constant velocity. Sits on Plexiglass plate which can move slightly without friction. PID controlled.
- **Loadcell:** Reads forces in Kevlar. Pin is attached to plexi-plate; makes sure there is no slack in Kevlar line.
- **Workspace w/ needle inside:** DC motor & loadcell assembly

MATLAB & Simulink

- **EEff Orientation & Position:** Uses the desired needle position, Npos, and the needle’s previous predicted position, NposP as inputs to determine the end effector’s pose.
- **Npos – Input needle position:** the needle’s path consists of tightly spaced discretized points. Npos reads each needle point one step at a time from the workspace.
- **DC Motor:** uses Npos and NposP as inputs to determine the length that the needle has traveled between steps and tells the system when to move on to the next step in needle position; also reads loadcell values: if slack occurs the motor renews the Kevlar and the robotic arm remains stationary.
- **Needle Position Prediction:** Uses the position of the end effector and the length between steps to calculate the estimated needle position.
- **Simulation:** Plotted using Peter Corke’s Robotics Toolbox. Red cylinders represent joints. Zoomed in views of the needle path show that the needle travels along the end effector’s z-axis.

Preliminary Experiments

- **The DC motor PID control achieved minimal overshoot with a settling time of approximately 0.4 seconds.**
- **The loadcell values were also verified and tested alongside the rest of the loadcell/DC motor assembly.**
- **Changing loadcell values resulted in the DC motor changing direction to rewind the Kevlar, as desired.**
- **The needle, and the Kevlar tether attached to it, were successfully dragged through the gel with a single magnet by hand.**
- **From 2.5 inches away the needle was able to move in the direction of the magnet.**
- **When moving the magnet from side to side, while slowly releasing the tether, the needle was able to follow.**
- **Simulation:** each component of the Simulink code can work together to track the needle in theory.

Future Work

- **Magnet Configuration:** Want to have a magnetic configuration to move the needle from above or the side. This will improve the control of the needle / have more needle stability; create more accessible paths for the robotic arm, i.e. steering the needle cephalad while in the abdomen; be safer for the patient.
- **Robotic Arm Upgrade:** Have feedback from the arm to have a more accurate estimate of the end effector position.
- **Needle Design:** Create a needle that is more applicable for medical applications, i.e. without Kevlar string but with a non-elastic tube for drug delivery.
- **Experiments:** Perform experiments testing the entire system together.

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