Perception, control and path planning of robotic laparoscopic surgical system

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Table of Contents

Outline

Surgical Robotics Procedure

Advantages & Disadvantages of Surgical robotics

Biblography overview

Thesis goals

Outline

Forward Kinematics

Inverse Kinematics - Decoupling Technique

Singularity points

RCM constraint

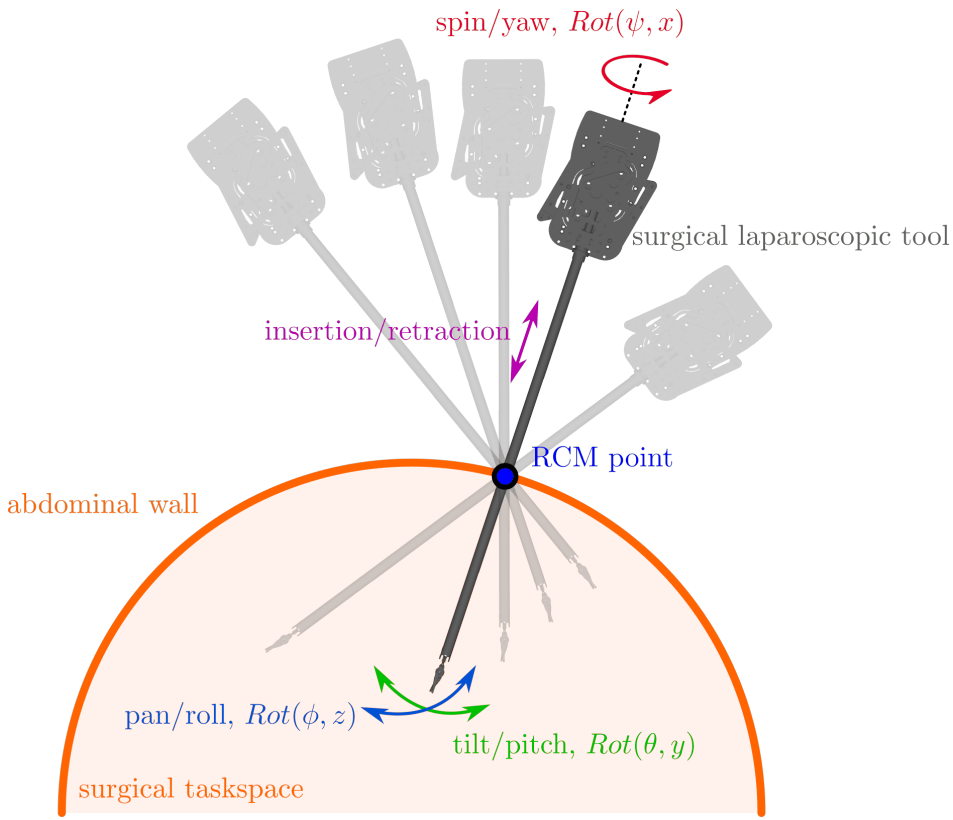

Figure: Illustration of pivoting motion of surgical laparoscopic tool around RCM point (also known as fulcrum or trocar point). Due to the RCM constraint, the tool has only 4 degrees of freedom.

Elbow-up constraint

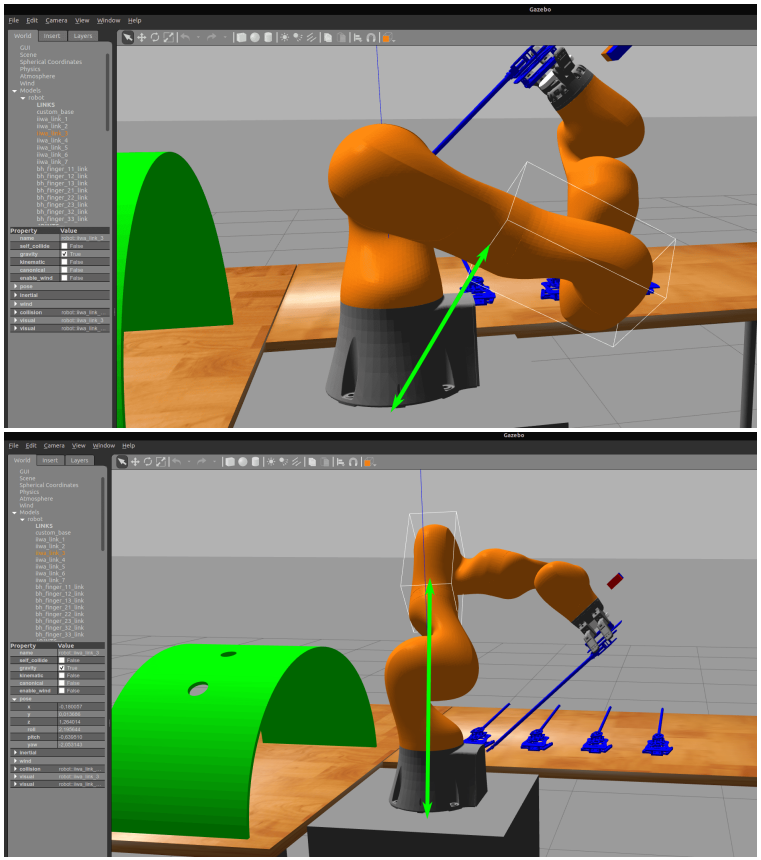

Figure: Top: elbow-down solution, bottom: elbow-up solution

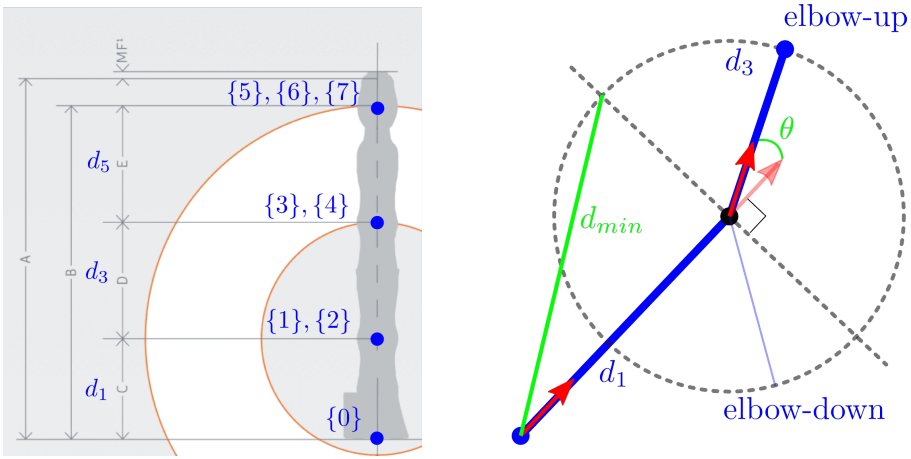

Figure: Elbow-up constraint description with relative distance or angle between links with lengths d_1 and d_3

$d_{\text{min}} \leq d \leq d_{\text{max}}$, where

$d_{\text{min}} = \sqrt{d_1^2 + d_3^2} = 553\text{mm}$ and

$d_{\text{max}} = d_1 + d_3 = 780\text{mm}$.

Outline

Gripper & Forward Kinematics

Gripper Inverse Kinematics

Outline

Laparoscopic tool detection

Calculation of tool position and orientation

Calculation of grasping points

Outline

Path Planning - Sampling methods

Pick and place algorithm

Task space analysis

Outline

Tool pose & the Fulcrum Effect

Circular trajectory of tool tip

Circular arc trajectory of tool tip

Line segment trajectory of tool tip

Cubic Spline trajectory of tool tip

B-Spline trajectory of tool tip

Polynomials of 5th order

Planning with velocity profiles

Outline

Firm grasping algorithm & Force control

Position based visual servoing

Image based visual servoing

Outline

Gazebo simulation environment

Visualization with RViz

Motion Planning with Moveit

Tools, Packages and Libraries

Outline

Robot Planner 1: Simple MoveIt planning

Robot Planner 2: Simulation layout and reachability experiments

Robot Planner 3a: Circular and Circular arc trajectories in task space

Robot Planner 3b: Line segment trajectories in task space

Robot Planner 3c: Cubic Spline trajectories in task spac

Robot Planner 3d: B-Spline trajectories in task space

Robot Planner 3e: Polynomial trajectories in joint space

Robot Planner 3f: Trajectories in joint space with trapezoidal velocity profile

Robot Planner 3g: Trajectories in joint space with s-curve velocity profile

Robot Planner 4: Simple cube pick-and-place experiment

Robot Planner 5: Visual servoing

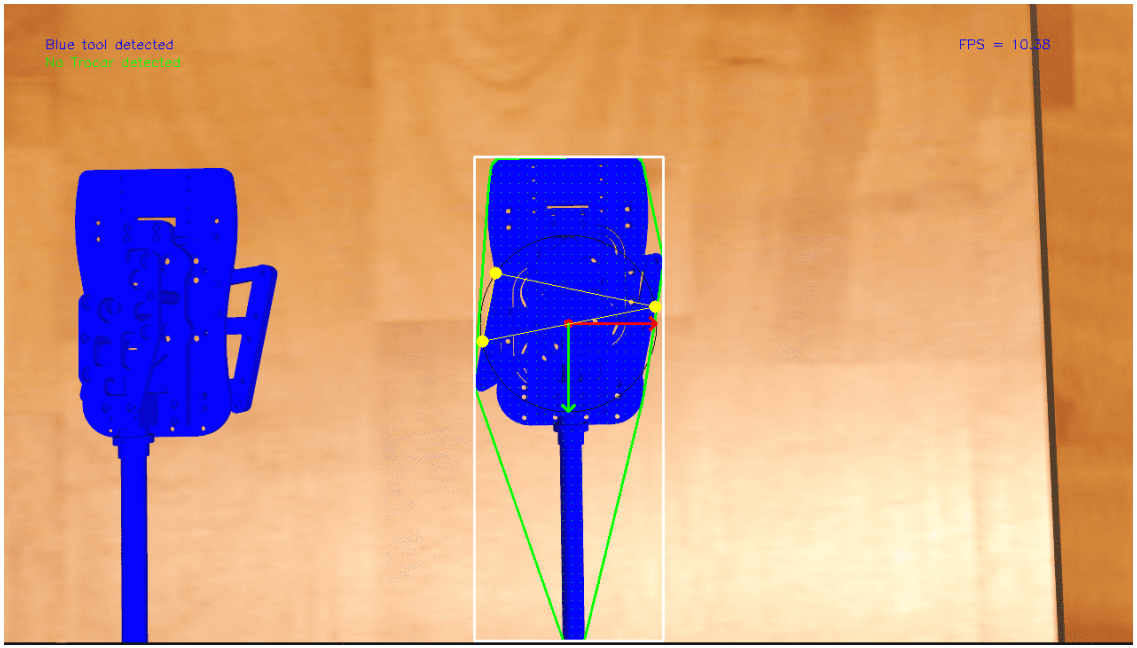

Figure: Image based visual servoing and calculation of grasp points. The yellow points are the grasp points and the thin black circumscribed circle is the growing circle that was used to calculate them.

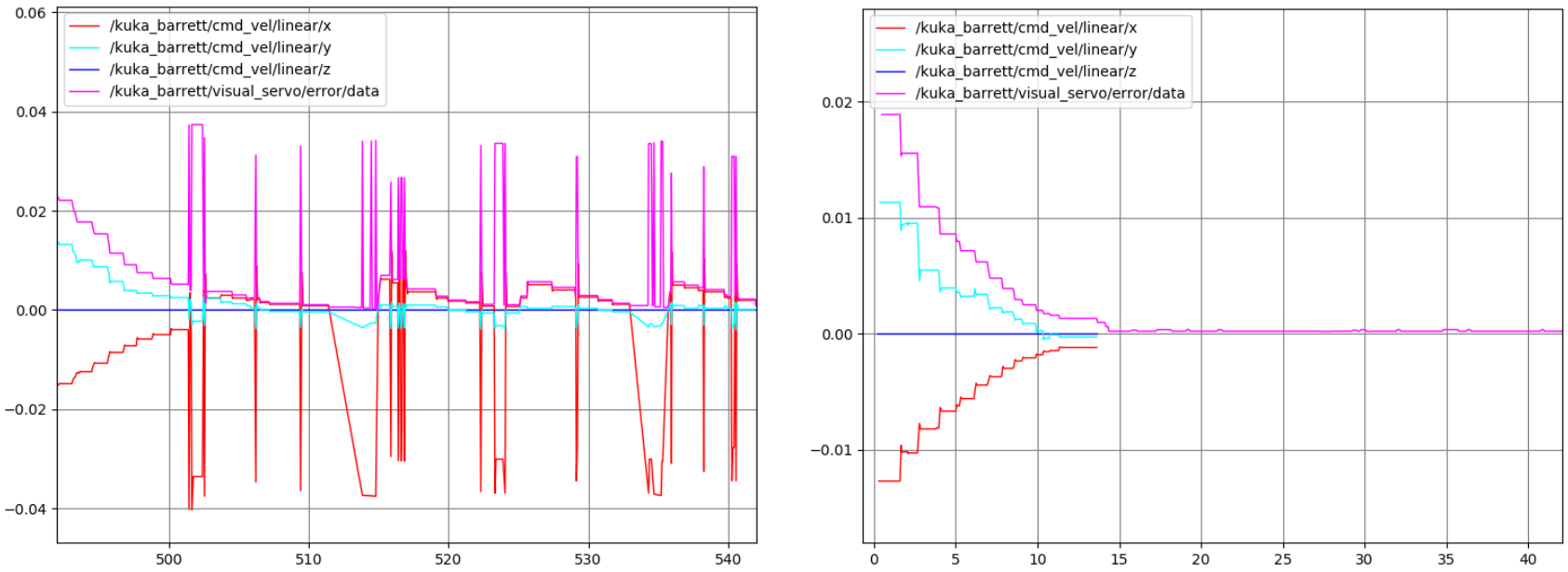

Figure: Visual servo controller error diagrams. On the left image in the error graphs appear some spikes. These spikes occur from the sudden temporary detection of a nearby surgical tool. On the right image, these spikes are filtered out, and only the error graphs of the visual servoing of one tool are shown. The controller parameters are $K_p = 0.9, K_d = 0.2$

Outline

Conclusions & Comparison with similar projects

Future Work