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DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

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Thesis

of the student of the Department of Electrical and Computer Engineering of the School of Engineering of the University of Patras

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Subject

Robotic surgical tool manipulator - Recognition, control and manipulation of laparoscopic tools

Supervisor

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ΠΙΣΤΟΠΟΙΗΣΗ

Πιστοποιείται ότι η διπλωματική εργασία με θέμα

Robotic surgical tool manipulator - Recognition, control and manipulation of laparoscopic tools

του φοιτητή του Τμήματος Ηλεκτρολόγων Μηχανικών και Τεχνολογίας Υπολογιστών

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παρουσιάστηκε δημόσια και εξετάστηκε στο τμήμα Ηλεκτρολόγων Μηχανικών και Τεχνολογίας Υπολογιστών στις

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Ο Επιβλέπων — Ο Διευθυντής του Τομέα

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1 Kinematic Analysis

1.1 Forward Kinematics & DH parameters

i	θ_i (rad)	L_{i-1} (m)	d_i (m)	α_{i-1} (rad)
1	θ_1	0	0.36	0
2	θ_2	0	0	$-\pi/2$
3	θ_3	0	0.36	$\pi/2$
4	θ_4	0	0	$\pi/2$
5	θ_5	0	0.4	$-\pi/2$
6	θ_6	0	0	$-\pi/2$
7	θ_7	0	0	$\pi/2$

$$^{i-1}M_i = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & L_{i-1} \\ s\theta_i c a_{i-1} & c\theta_i c a_{i-1} & -s a_{i-1} & -s a_{i-1} d_i \\ s\theta_i s a_{i-1} & c\theta_i s a_{i-1} & c a_{i-1} & c a_{i-1} d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

1.2 Inverse Kinematics

1.2.1 Decoupling Technique

$$R_{target} = \begin{bmatrix} i_x & j_x & k_x \\ i_y & j_y & k_y \\ i_z & j_z & k_z \end{bmatrix} \quad {}^0\mathbf{p}_5 = {}^0M_4 {}^4\mathbf{p}_5 = \begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix}$$

$$\theta_6 = atan2\left(\pm\sqrt{1-k_y^2}, k_y\right)$$

$$\theta_7 = atan2\left(-j_y, i_y\right)$$

$$\theta_5 = atan2\left(-k_z, k_x\right)$$

$$\theta_2 = atan2\left(\sqrt{p_x^2+p_y^2}, {}^1p_{5z}\right) \pm \varphi$$

$$\varphi = acos\left(\frac{d_3^2 + \|{}^1p_5\|^2 - d_5^2}{2d_3\|{}^1p_5\|}\right)$$

$$\theta_4 = atan2\left(\pm\sqrt{1-c_4^2}, c_4\right) \quad , \quad c_4 = \frac{\|{}^1p_5\|^2 - d_3^2 - d_5^2}{2d_3d_5}$$

$$\theta_1 = atan2\left(\pm\frac{p_y}{\sqrt{p_x^2+p_y^2}}, \pm\frac{p_x}{\sqrt{p_x^2+p_y^2}}\right)$$

1.2.2 Workspace constraints & Singularity points

1.2.3 Numerical Solution

1.2.4 Quaternion Solution

1.2.5 Redundancy & Optimization Conditions

1.2.6 Comparison of Inverse Kinematics Techniques

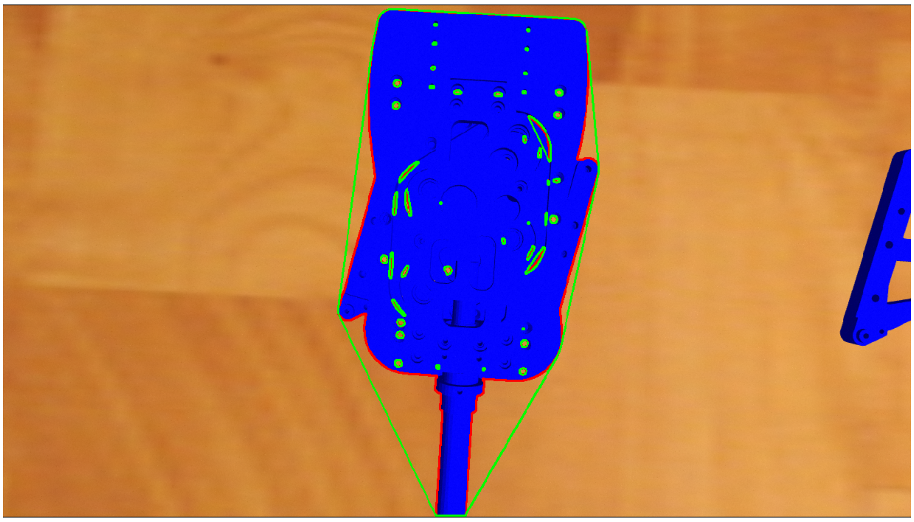
2 Dynamic Analysis

3 Control

3.1 Robotic Arm Controller

3.2 Gripper Controller

4 Laparoscopic tool recognition with Computer Vision



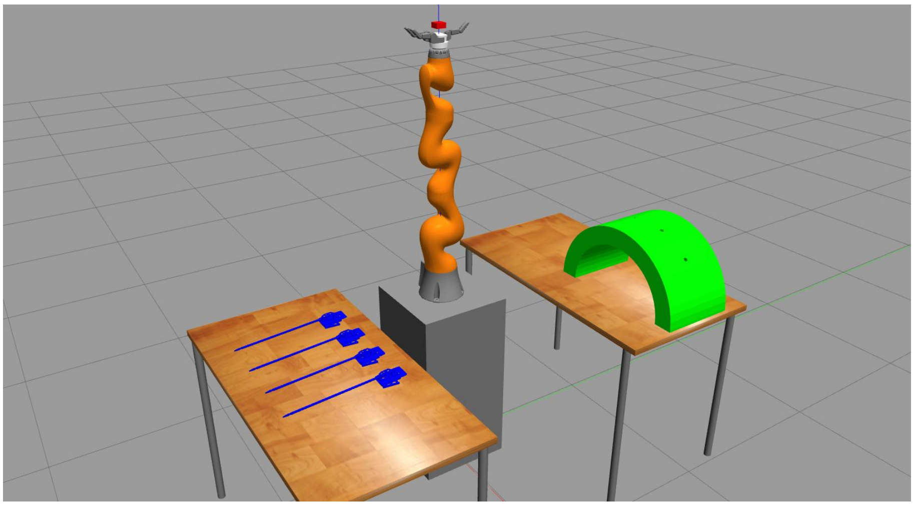
5 Path Planning

6 Trajectory Planning

6.1 Trajectory planning in cartesian coordinates

6.2 Trajectory planning in joint angles space

7 Simulation with the ROS framework



Nomenclature

${}^{i-1}\mathbf{p}_{iO}$ Position vector from the origin of the coordinate frame $\{i\}$ to the origin of the coordinate frame $\{i-1\}$

${}^{i-1}M_i$ Transformation matrix from coordinate frame $\{i\}$ to coordinate frame $\{i-1\}$

${}^{i-1}R_i$ Rotation matrix from coordinate frame $\{i\}$ to coordinate frame $\{i-1\}$

c_i Shorthand notation for $cos\theta_i$

$J^{\dagger}$ Geometric Jacobian or the Pseudoinverse of the Jacobian

s_i Shorthand notation for $sin\theta_i$

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