Written exams of Robotics 1

http://www.diag.uniroma1.it/~deluca/rob1_en.php

All materials are in English, unless indicated (oldies are in Italian)

Year	Date (mm.dd)	Number of exercises	Topics	Notes
2015	07.10	2	Analysis and displacement computation for an assigned bang-bang type profile of the snap (4th time derivative); Placing of the base of a planar 2R robot for executing a straight line in its workspace and joint velocity computation at a singular configuration	
2015	06.05	2	Path planning with an helix in 3D and minimum time rest-to-rest motion with cubic timing profile and bounded norm of Cartesian velocity; Placing of the base of an elbow-type 3R robot for executing a straight line in its workspace and joint velocity computation at a specific configuration	
2015	04.01	1	Minimum-time trajectory planning between two Cartesian points for a planar 2R robot under joint velocity and joint acceleration constraints	same as 2006.07.13 (in Italian), with modified data
2015	02.06	2	Complete inverse kinematics analysis in orientation for a 3-dof robot, including singular or regular numerical cases and an inverse differential problem; Planning a Cartesian trajectory on a circular path of given radius between two points, with trapezoidal speed and bounds on the norms of the velocity, of the acceleration, and of the normal acceleration.	solutions (also a longer version is available)
2015	01.09	3	Effect of incremental encoder resolution on the accuracy of end-effector position measure for a planar 2R robot*; Planning of a Cartesian straight line trajectory for a RP planar robot, to be executed in minimum time under joint range and joint velocity limits*; Kinematic control with prescribed Cartesian transient error for a 3R anthropomorphic robot*.	solutions; Matlab codes

2014	11.21	4 (test)	Reduction ratio and optimal inertia/acceleration of joint 2 of PUMA 560 robot; DH table of parameters from assigned frames of a PUMA 560 robot; Primary workspace of a generic planar 3R manipulator; Inverse kinematics in closed form of a 3P-3R spatial robot with spherical wrist	solutions
2014	10.27	2	Inverse representation problem and analysis of relation between angular velocity and derivative of Euler angles XYZ; Geometric Jacobian of SCARA-type robot and solution of a problem of inverse differential kinematics in a singularity	solutions
2014	09.22	1	DH frames and table for the Siemens Artis Zeego medical robot, having 7 dofs (one prismatic and six revolute joints)	---
2014	07.15	1	7R KUKA LWR robot, with frozen last three joints: direct kinematics of the tool center point and related Jacobian, solution to the inverse kinematics when one joint angle is assigned, singularity analysis	---
2014	06.10	1	DH frames assignment and table for the COMAU RACER 7-1.4 robot, and mapping by comparison with the one used by the robot manufacturer	solution
2014	04.02	3	Draw the DH frames of a 4R robot and the direct kinematics (position only), given the DH table; For the same robot, static torques balancing a desired force; Smooth minimum time rest-to-rest motion of a single joint under velocity and acceleration bounds	---
2014	02.06	3	Definition and use of the Jacobian transpose for force transformations; A 4-3-4 trajectory planning problem: formulation and solution*; Proof of Cartesian trajectory tracking using both the Jacobian transpose (feedback) and the Jacobian inverse (feedforward)	solutions; Matlab code
2014	01.09	3	PPR planar robot: DH frame assignment and table, primary and secondary workspace for bounded range of prismatic joints; Planning of rest-to-rest orientation trajectory using YZY Euler angles, with motion time satisfying a bound on the norm of angular velocity*; Joint velocity commands in a 6R robot with spherical wrist for planning or tracking (kinematic control) end-effector trajectories with zero desired angular velocity	solutions; Matlab code

2013	11.29	3 (test)	Optimal reduction ratio of a cascaded spur gear and harmonic drive transmission; K-1207 7-dof robot: DH frames and table of parameters; Planar RPR manipulator: inverse kinematics for planar pose, primary workspace for limited range of prismatic joint	solutions
2013	09.19	1	Planar RPPR manipulator: DH frames and table of parameters, analysis of maximum reach with limits on the prismatic joints	---
2013	07.15	1	Analysis of a joint velocity motion of trapezoidal type for a planar 2R arm, with evaluation of selected Cartesian quantities (displacement, velocity, acceleration)	---
2013	06.10	1	4R spatial manipulator: assignment of DH frames, Jacobian for the linear velocity, and analysis of feasible motion at a singularity	---
2013	04.10	1	Minimum time trajectory planning for planar 3R manipulator on a three-dimensional rest-to-rest task, with joint velocity and acceleration bounds*	solution; Matlab code
2013	02.06	2	DH assignment and geometric Jacobian of a 4-dof robotic finger; Trajectory interpolation with a class of trigonometric functions, with analysis of wandering*	solutions; Matlab code
2013	01.09	3	Definition of a minimal representation of orientation, and singularities of the associated differential relation; Singularities and minimum norm joint velocity solution for a planar 4R arm; Effect of encoder errors on the end-effector position estimate of a 3R anthropomorphic robot	solutions
2012	09.10	1	DH frame assignment to elbow-type 3R robot, with analysis of linear and angular velocities of the end-effector in a given configuration	solution
2012	07.05	1 (4 parts)	6-dof portal robot for aeronautical industry: pointing task; inverse kinematics; positioning task and its inverse kinematics; solution for numerical data*	solutions; Matlab code
2012	06.11	3	Derivative of a rotation matrix in fixed or rotated frame; Jacobian, singularities, and null/range spaces analysis of planar RPR arm; Resolution of incremental encoders for a Cartesian task of a 2R robot	solutions
2012	04.26	2	DH assignment and Jacobian expressed in camera frame of 3R articulated arm (symbolic Matlab code included); Rest-to-rest orientation planning with axis-angle method and cubic timing law*	solutions; Matlab code

2012	02.09	3	Angular velocity of the COMAU NJ4 170 robot with non-spherical wrist; DH assignment, Jacobian, and singularities of RRP (polar) arm; Planning of straight Cartesian paths, singularity handling, and joint vs. Cartesian kinematic control for the RRP arm	solutions
2012	01.11	2 + bonus	Primary and secondary workspace of a planar 3R arm, singularities, and manipulability index H (bonus: write a Matlab* program plotting H); Rest-to-rest minimum time motion between two Cartesian poses, with bounds on joint velocity and acceleration	solutions; Matlab code
2011	09.12	1	Inverse differential kinematics for a SCARA-type robot for two 6-dimensional desired task velocities	solution
2011	07.04	1	Barrett 4-dof WAM: D-H frame check, direct kinematics, actuator transformation, linear velocity Jacobian*, singularity and joint limit check	solution; Matlab code
2011	06.17	1	Polytopes of feasible Cartesian velocity for a 2R planar robot with joint velocity bounds in different configurations*	solution; Matlab code
2011	02.25	1	Cyclic joint trajectory design, singularity crossing and time scaling for a 3R anthropomorphic robot*	solution; Matlab code
2011	02.03	1	Various Jacobians with their analysis and a joint acceleration synthesis for a 3R anthropomorphic robot	solution
2010	09.15	1	Trajectory definition with double symmetric bang-cost-bang jerk profile*	solution; Matlab code
2010	07.07	1	DH assignment for the 6R KUKA KR-30-3 robot and direct kinematics of the center of its spherical wrist	solution
2010	06.15	2	Singularities for a RP planar robot in a one-dimensional task and kinematic control at the joint acceleration level; Relation between angular velocity and derivative of Euler angles YXZ	solutions
2010	02.11	1	Path planning for a 2R planar robot among obstacles with singularity crossing*	solution; Matlab code
2010	01.12	2 (one in common, option A or B for other)	Cartesian trajectory planning on spiral path for position and orientation with velocity/acceleration constraints and trapezoidal speed profile*; (A) Input-output linearization control for front-wheel drive car-like; or (B) Geometric Jacobian for a cylindrical robot, singularities, and kinematic Cartesian control in acceleration	solutions A and B; Matlab code

2009	12.17	1 (test)	Geometric Jacobian for a 4R spatial robot, feasibility of a Cartesian linear/angular velocity, minimum norm joint velocity solution, and joint torque balancing a Cartesian force/torque*	solution; Matlab code
2009	11.10	2 (test)	Minimal representation of orientation around fixed YXZ axes; DH assignment for a spatial 3R arm pointing a head camera, direct kinematics for the orientation, and condition for an infinite number of inverse solutions	solutions
2009	09.10	1	Jacobian of mobile manipulator, with Nomad base (unicycle) and 3R anthropomorphic manipulator (Puma, with frozen wrist)	solution
2009	07.10	2	Inverse kinematics of a RP robot, workspace with limited joint range, and number and type of inverse solutions in the workspace; Planning of a coordinated roto-translation in the Cartesian space	solutions
2009	06.10	1 (3 parts)	DH assignment for a planar PRP robot; Singularities and linear subspaces associated to the Jacobian for a planar positioning task; Kinematic control in the task space (planar position and orientation) with two case studies of feasibility with respect to joint velocity bounds	solution
2009	02.09	2	Kinematic control in the Cartesian space in acceleration; Placing the base of a planar 2R robot so as to maximize manipulability and task velocity in a given direction **(in Italian)**	solutions **(in Italian)**
2009	01.08	2	Angular velocity for an axis/angle rotation: general proof and computation of a trajectory for end-effector orientation; Direct kinematics, Jacobian and singularity analysis for a 3R supporting leg of the SmartEE parallel platform **(in Italian)**	solutions **(in Italian)**
2008	09.11	1	Second-order kinematic model of a nonholonomic mobile manipulator, a car-like mobile base with a planar 2R arm (optional: singularity analysis) **(in Italian)**	solution **(in Italian)**
2008	07.02	2	Statics of a planar 2R robot with two force applied along the links; Nonholonomic constraints of a fire-truck mobile robot (optional: kinematic model) **(in Italian)**	solutions **(in Italian)**
2008	03.20	2	Optimal planning of a trajectory composed by three velocity pieces, with initial/final sinusoidal profiles and acceleration constraint; Differential kinematics of a spatial 3R robot with eye-in-hand camera **(in Italian)**	---
2008	01.07	2	Linear Cartesian motion of a planar 3R robot and singularities; Kinematic model of a WMR with two steering wheels **(in Italian)**	solutions **(in Italian)**

2007	12.03	3	Inverse kinematics of a planar 2R robot with test on the joint range feasibility*; Angular resolution of a servo-drive with incremental encoder and sizing of the motion reduction element; Optimal trajectory planning with velocity/acceleration constraints and continuity up to acceleration* **(in Italian)**	solutions **(in Italian)**; Matlab code
2007	09.13	1 (2 parts)	DH assignment for a spatial 3R robot and computation of the end-effector linear and angular velocity; Pseudo-code of an algorithm for numerical inverse kinematics **(in Italian)**	---
2007	06.28	2	Geometric Jacobian for the wrist frame of a KUKA KR6 Sixx robot with last three joints frozen; Planning of a piecewise polynomial trajectory through four point with boundary conditions up to the jerk and continuity in acceleration **(in Italian)**	---
2007	03.23	1	DH assignment for the KUKA KR150K robot and relationship with the "zero" configuration from the industrial robot data sheet **(in Italian)**	---
2007	01.08	3	Singularity analysis and analytical inverse kinematics for a planar RRP robot; Use of kinematic redundancy for handling joint range limits; Pros and cons of the use of vision in robot motion control **(in Italian)**	solutions **(in Italian)**
2006	12.04	2	DH assignment, direct kinematics, and workspace of a spatial RRPR robot; Optimal planning of Cartesian straight line trajectory for a planar RP robot with velocity/acceleration constraints and use of uniform time scaling to satisfy maximum joint velocity bounds **(in Italian)**	solutions **(in Italian)**
2006	09.11	1 (3 parts)	DH assignment for a planar 3R robot; Jacobian and its singularities; Planning of a trajectory between two Cartesian points where the robot is in a singularity, with acceleration continuity **(in Italian)**	---
2006	07.13	1	Minimum-time trajectory planning between two Cartesian points for a planar 2R robot under joint velocity and joint acceleration constraints **(in Italian)**	---
2006	06.30	1	DH assignment for the DLR LWR-III 7R robot **(in Italian)**	---
2006	04.03	1 (2 parts)	Robot-excavator: Direct kinematics; Inverse kinematics, statics, placement of robot base in the workspace (choose one) **(in Italian)**	solution **(in Italian)**
2006	01.09	1 (3 parts)	Mobile base moving in circle with a planar 2R manipulator on board: Inverse kinematics; Differential kinematics; Singularity analysis **(in Italian)**	solution **(in Italian)**
2005	12.16	1 (3 parts)	"Painting" RPPR robot: DH assignment; Direct kinematics; Minimum-time cyclic Cartesian trajectory under joint velocity constraints **(in Italian)**	solution **(in Italian)**

2005	09.22	1	DH assignment for the Comau Smart Six robot **(in Italian)**	---
2005	04.05	2	Statics and computation of joint accelerations for a constrained planar 3R robot; Computing wheel velocities so as to assign a given linear velocity to a point on the chassis of the SuperMario mobile robot **(in Italian)**	solutions **(in Italian)**
2005	01.12	2	Direct and differential kinematics, singularity analysis and control of a mobile manipulator --unicycle base with spatial 3R robot; Minimum-time trajectory planning between two Cartesian points under acceleration and, possibly, velocity constraints for a planar 2P robot (multiple solution paths) **(in Italian)**	solutions **(in Italian)**
2004	12.16	2	DH assignment, direct kinematics, singularity analysis, trajectory planning without singularities, and workspace for a spatial RPR robot; Path planning in the joint space, with given initial and final Cartesian tangents and an obstacle to be avoided* **(in Italian)**	solutions **(in Italian)**; Matlab code
2004	04.06	1	Planning of a cyclic joint trajectory passing through three Cartesian points for a planar 2R robot **(in Italian)**	solution **(in Italian)**
2004	03.25	2	Odometry computation and minimum-time motion for the SuperMario wheeled mobile robot; Singularities, workspace, and manipulability for a planar 4R robot **(in Italian)**	solutions **(in Italian)**
2004	01.08	2	DH assignment, direct kinematics, statics, and minimum norm joint velocity computation for a (redundant) planar RRP robot; Planning of an orientation trajectory using the axis/angle method or with the YZY Euler angles* **(in Italian)**	solutions **(in Italian)**; Matlab code
2003	12.11	2	DH assignment for a 3R pointing structure and its direct kinematics; Trajectory planning for a planar RP robot under bounds on the Cartesian acceleration norm and on the joint velocities* **(in Italian)**	solutions **(in Italian)**; Matlab code

Note: For these* problems, Matlab codes for computing solutions and/or for graphics are either embedded in the solution text or available upon request (contact deluca@diag.uniroma1.it).