List of Topics for the 2016 Robotics exams

The exam questions will be related to the topics listed below, but they shall be considered only as indications to help students focalizing on important parts of the course program. Slides are not the only source of knowledge; students are encouraged to use also other learning materials. There is no guarantee that the exam questions will exactly reproduce or use the same words used in the slides.

**Slide 01 - Introduction**
- Definition of robotics
- Types with characteristics: Industrial robots, Humanoid robots, Biomimetic robots, Service robots, Unmanned autonomous vehicles, Exploration robots

**Slide 02 - Kinematics**
- Kinematic chains, links, arms
- degrees of motion, revolute/prismatic joints
- open/closed chains/ graphical representation 2D/3D
- end effectors, TCP
- task space/joint space, pose vector
- kinematic functions;
- degrees of freedom, redundancy, redundant robots, why used, human arm redundancy, redundancy in 2D and 3D
- robot types: cartesian, cylindrical polar/spherical, SCARA, articulated
- parallel robots
- wrists: spherical wrist, euler and RPY wrists

**Slide 03 - Kinematic functions**
- pose=position+orientation
- kinematic functions: direct position dpkf, inverse position ipkf, direct velocity dvkf, inverse velocity ivkf: their meaning, general formulation
- dpkf: Denavit-Hartenberg conventions: generalities and rules, parameters, DH homogeneous transformation HT (*exact formula NOT required*)
- procedure for computing dpkf
- how to extract pose from HT; from pose to HT and viceversa
- problems in orientation description (also related to Jacobians)
- ipkf: problems, relation with spherical wrists, possible solutions, recursive formulation of ipkf
- dvkf: general formula, Jacobians; what they are, how to compute them; geometric/analytic velocities, geometric/analytic Jacobians, their interpretation
- linear and angular Jacobians
- how to compute a geometric Jacobian when prismatic/revolute joint are present
- How to transform analytical Jacobian to geometrical Jacobian and viceversa (*exact formulas NOT required*)
- inverse velocity when Jacobians are not square
- ivkf: general formula, Jacobian singularities.
- singularity conditions for a3D articulated robot

**Slide 04 - Statics**
- generalized forces in task space and in joint space; their differences
- virtual work principle, static equilibrium, kineto-static duality with formula, equilibrating vs equivalent generalized forces
- range and kernel of Jacobian and Jacobian transpose: no formulas, only effects on task/joint velocities and task/joint forces.
- elasticity, where is located. **NO elastic forces slides 14-17**
Slide 05 - Dynamics

- The two approaches for modeling the robot dynamics; their characteristics pros and cons
- NO formulas of Newton approach
- general formulation of Lagrange approach (NO formulas slides 15-26)
- final equations slides 27-28
- physical interpretation slides 29-30, 45
- properties of LAG equations; dynamic calibration
- state equations:
  - numerical recursive method: generalities, NO formulas slides 41-44
  - conclusions

Slide 06 – Trajectory planning 1

- NO slides 1-5
- Planning and control, fixed vs mobile
- Path/trajectory, trajectory planning in task space and in joint space, constraints
- Point-to-point path/trajectory, convex combination, profile generator, coordinated motion
- 2-1-2/trapezoidal profile bang-bang profile, general considerations (NO formulas slides 24-27)
- Sampled data profile, generic considerations, practical problems
- Interpolation schemes NO formulas, effects of approximation of commutation instants NO formulas
- Joint point-to-point trajectory planning
- Technological constrains on actuators (only concepts, NO formulas)

Slide 07 – Trajectory planning 2

- Planning of the task space variables
- Task space planning: the position variables case 1/case 2 (only concepts, NO formulas)
- Orientation planning, three methods, their characteristics
- NO slides on actuators constraints
- Micro-macro interpolation

Slide 08 – Control 1

- Types of tasks, joint/task space control, motion control general characteristics
- Joint space control architectures
- Motor and gearbox model
- Control equations, only the main formulas (slide 17-18), effects on inertia etc.
- Matrix formulation (joint side), only formulas slide 29
- Decentralized joint control, Open loop vs Closed loop, only concepts NO formulas
- Practical Issues

Slide 09 – Control 2

- Centralized control, characteristics
- Inverse dynamics control, characteristics, exact linearization, inner loop/outer loop
- Practical aspects of exact linearization, approximate linearization
- PD control with gravity compensation, only concepts NO formulas, NO slides 36-39
- Independent joint control NO formulas, NO slides 41-42
- Computed Torque Method
- NO slides 46-50

Slide 10 – Control 3

- THESE SLIDES ARE NOT IN THE EXAM PROGRAM

Slide 11 – Control 4

- THESE SLIDES ARE NOT IN THE EXAM PROGRAM

Slide 12 – Mobile & Service robotics 1

- Environment types: structured/unstructured, known/unknown
- Locomotion types, biomimetic systems
- steering/non steering wheels, active/passive wheels, wheel types
- NO slides 26-32
Slide 13 – Mobile & Service robotics 2
- Fundamental problems in mobile robotics
- Instantaneous Curvature Center: what is; skid
- NO slides 8-11
- Differential drive robot and kinematics slide 20-22
- Euler approximation, Runge-Kutta approximation, exact integration with formula B)
- Path planning: general ideas NO slides 30-34
- Unicycle slide 35 only
- Bicycle slide 40 only
- Quadcopter concepts with equation slide 49
- Odometry: what is, and related problems. Visual odometry
- Mapping, localization, SLAM, path planning
- NO slides 55-65

Slide 14 – Mobile & Service robotics 3
- Control strategies: deliberative/model based vs reactive/behavior based; general concepts and characteristics
- Some examples of behaviors NO slides 19-21
- General ideas from slides 23-40

Slide 15 – Mobile & Service robotics 4
- Only general concepts, NO formulas

Slide 16 – Sensors 1
- Definitions, sensor types, sensor classification
- Sensor characteristics; accuracy and precision
- Noise; noise types (only list)

Slide 17 – Sensors 2
- Sensor types for mobile robots
- Encoders: working principle and types
- Resolvers: working principle
- Inertial sensors: working principle and types
- Compasses, inclinometers NO
- Gyrosopes: working principle
- IMUs: working principle, problems
- Beacons, GPS NO
- Distance sensors: principles and types, ultrasonic sensors

Slide 18 – Sensors 3
- Laser sensors: working principle. LIDARS
- Triangulation, infrared sensors, structured light, 3D sensors based on structured light

Slide 19 – Sensors 4
- Vision sensors: CCD CMOS, principles
- Camera model, thin lens camera, aberration, equations slide 14
- Camera projections, perspective projection equations slide 22
- Canonical projection matrix slide 25
- Camera parameters, intrinsic, extrinsic
- Lens distortion
- Depth from focus
- Stereo vision, correspondence, disparity, baseline, formula slide 42
- Epipolar lines
- ToF cameras, optical flow