University of Macau
Department of Electromechanical Engineering
ELEC404 – Introduction to Robotics
Syllabus
1st Semester 2012/2013
Part A – Course Outline

Required elective course in Electromechanical Engineering

Course description:
Robot terminology; spatial descriptions and transformations; manipulator kinematics; Jacobians and static forces; trajectory generation; linear and nonlinear control of manipulators; application of various robots.

Prerequisite:
MECH205 – Electrical Engineering

Textbook:
- John. J. Craig, ***Introduction to Robotics: Mechanics and Control***, 3rd Edition, Person Education, 2005.

References:
- L. Sciavicco and B. Siciliano, Modelling and Control of Robot Manipulators, 2nd edition, Springer, 2000.
- Richard M. Murray, Zexiang Li, S. Shankar Sastry, A Mathematical Introduction to Robotic Manipulation, 1st edition, CRC Press, 1994.

Course objectives:
1. Learn robot terminology, classifications and applications in various fields. [c, k]
2. Introduce to students mathematical modeling of manipulator. [a, b, e]
3. Learn manipulator forward kinematics and inverse kinematics. [a, e]
4. Use Jacobians matrix to analyze velocity and static forces. [a, b]
5. Learn trajectory generation. [a, k]
6. Grasp linear control and nonlinear control techniques. [a, e]
7. Use force control for manipulators. [b, k]
8. Introduce to advanced robotic systems. [k]

Topics covered:
1. **Introduction –** Robot history; Classification of robots; Mechanics and control of manipulators; Notation in robotics.
2. **Spatial description and transformation –** Descriptions: position, orientation, and frames; Mappings; Operators; Transform equations; Transformation of free vectors; Computational considerations.
3. **Manipulator kinematics –** Link description; Convention of frames to links; Kinematics; Actuator, Joint, and Cartesian space.
4. **Inverse manipulator kinematics** – Solvability; Algebraic vs. Geometric solutions; Repeatability and accuracy.
5. **Jacobians: velocities and static forces –** Linear and rotational velocity of rigid bodies; Velocity "propagation; Singularities.
6. **Trajectory planning –** Path description and generation; Joint and Cartesian space schemes; Planning paths.
7. **Control of manipulator –** Feedback control; Control law partitioning; Trajectory-following control; Continuous Vs. Discrete time control; Industrial robot controller.

Class/practice schedule:

Timetabled work in hours per week			No of teaching weeks	Total hours	Total credits	No / Duration of exam papers
Lecture	Tutorial	Practice				

3	0	1	14	56	3.5	1 / 3 hours

Topic Outline:

Week No.	No. of hours	Topics
1	3	**Introduction** Review of Syllabus; Introduction to the history of robot; The Mechanics and Control of Mechanical Manipulators; Notation
1, 2	6	**Spatial description and transformation** Descriptions: Position, Orientation, and Frames; Mappings; Operators; Transform Equations; Representation of Orientation; Transformation of Free Vectors; Computational Considerations
3,4	6	**Manipulator kinematics** Link Description; Link-Connection Description; Convention for Affixing Frames to Links; Manipulator Kinematics; Actuator, Joint, and Cartesian space; Industrial Robot Examples; Frames with Standard Names; Computational Considerations.
5, 6, 7	9	**Inverse manipulator kinematics** Solvability; Manipulator Subspace Notation; Algebraic vs. Geometric Solutions; Examples of Inverse Manipulator Kinematics; The Standard Frames; Solving a Manipulator; Repeatability and Accuracy; Computational Considerations.
8, 9,10	9	**Jacobians: velocities and static forces** Notation for Time-varying Position and Orientation; Linear and Rotational Velocity of Rigid Bodies; Velocity Propagation; Jacobians; Singularities; Static Forces in Manipulators; Cartesian Transformation of Velocities and Static Forces.
11, 12	6	**Trajectory planning** Path description and generation; Joint and Cartesian Space Schemes; Geometric Problems with Cartesian Paths; Path Generation at Run Time; Planning Collision-free Paths.
13, 14	6	**Control of manipulator** Feedback Control; Control Law Partitioning; Trajectory-following Control; Continuous Vs. Discrete Time Control; Industrial Robot Controller.

Contribution of course to meet the professional component:

This course prepares students to work professionally in the area of **automation**.

Relationship to EME program objectives and outcomes:

This course primarily contributes to Electromechanical Engineering Program outcomes that develop student abilities to:
(a) an ability to apply knowledge of mathematics, science, and engineering.
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
(l) An ability to use the computer/IT tools relevant to the discipline along with an understanding of their processes and limitations.
The course secondarily contributes to Electromechanical Engineering program outcomes that develop student abilities to:
(b) an ability to design and conduct experiments, as well as to analyze and interpret data.
(e) an ability to identify, formulate, and solve engineering problems.
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Course content:

Maths	Basic Sciences	Engineering Science	Engineering Design and	Complementary Studies	Computer Studies	Total 100%

			Synthesis			
20	0	50	20	0	10	100

Persons who prepared this description:
Prof. Carlos Silvestre
____

Part B General Course Information and Policies

1st Semester 2012/2013

Instructor: Prof. Carlos Silvestre
Office Hour: By appointment
Email: cjs@isr.ist.utl.pt

Office: Block II – A408
Phone: (853) 8397-8550

Time/Venue:

Every Wednesday, 9:30 a.m. - 11:30 a.m., Room U106
Every Thursday, 11:30a.m. – 01:30p.m., Room U106

Assessment:

Final assessment will be determined on the basis of:
Homework: 15%
In-class Quizzes: 8%
Course Project: 7%
Mid-term: 30%
Final Exam (Comprehensive): 40%

Grading System:

The credit is earned by the achievement of a grade from 'A' to 'D'; 'F' carries zero credit.

Grades are awarded according to the following system:

Letter Grades	Grade Points	Percentage
A	4.0 (Excellent)	93-100
A-	3.7 (Very good)	88-92
B+	3.3	83-87
B	3.0 (Good)	78-82
B-	2.7	73-77
C+	2.3	68-72
C	2.0 (Average)	63-67
C-	1.7	58-62
D+	1.3	53-57
D	1.0 (Pass)	50-52
F	0 (Fail)	Below 50

Comment:

The objectives of the lectures are to explain and to supplement the text material. Students are responsible for the assigned material whether or not it is covered in the lecture. Students who wish to succeed in this course should read the assignments prior to the lecture and should work all homework and lab assignments. You are encouraged to look at other sources (other texts, etc.) to complement the lectures and text.

Homework Policy:

The completion and correction of homework is a powerful learning experience; therefore:

- There will be approximately 8 homework assignments.
- Homework is due one week after assignment unless otherwise noted, no late homework is accepted.
- Possible revision of homework grades may be discussed with the grader within one week from the return of the marked homework
- The course grade will be based on the average of the homework grades.

Quizzes/Mid-terms Exams:

One mid-term exam will be held during the semester. There will be two 30-miniutes quizzes in class before and after the midterm exam. Course project reports should be submitted within 1 week of submission date.

Note:

- Recitation session is important part of this course and attendance is strongly recommended.
- Check UMMoodle (webcourse.umac.mo) for announcement, homework and lectures. Report any mistake on your grades within one week after posting.
- No make-up exam is give except for CLEAR medical proof.
- No exam is given if you are 15 minutes late in the midterm exams and 30 minutes late in the final exam. Even if you are late in the exam, you must turn in at the due time.
- Cheating is absolutely prohibited by the university.

Appendix - Rubric for Program Outcomes

Rubric for (a)	5 (Excellent)	3 (Average)	1 (Poor)
Understand the theoretic background	Students understand theoretic background and the limitations of the respective applications.	Students have some confusion on some background or do not understand theoretic background completely	Students do not understand the background or do not study at all
Use a correct model and formulation correctly	Students choose a model correctly and properly apply correct techniques	Students choose a wrong model sometime, use a wrong formula, or a different technique	Students use a wrong model and wrong formula, or do not know how to model
Compute the problem correctly	Students use correct techniques, analyze the problems, and compute them correctly	Students sometime solve problem mistakenly using wrong techniques	Students do not know how to solve problems or use wrong techniques completely

Rubric for (b)	5 (Excellent)	3 (Average)	1 (Poor)
Conduct experiments	Student successfully completes the experiment, records the data, analyzes the experiment's main topics, and explains the experiment concisely and well.	Student successfully completes the experiment, records the data, and analyzes the experiment's main topics.	Student either does not complete the experiment successfully, or completes it successfully but does not record the correct data.
Design experiments	Student understands what needs to be tested and designs an appropriate experiment that takes into account the limitations of the equipment and measurement accuracy.	Student understands what needs to be tested and designs an appropriate experiment, but may not fully understand the limitations of the measurements.	Student does not understand what needs to be tested and/or does not design an appropriate experiment.

Rubric for (c)	5 (Excellent)	3 (Average)	1 (Poor)
Design capability and design constraints	Student understands very clearly what needs to be designed and the realistic design constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	Student understands what needs to be designed and the design constraints, but may not fully understand the limitations of the design constraints	Student does not understand what needs to be designed and the design constraints.
Process to meet desired needs	Student understands very clearly the process of the design	Student understands what the needs of the process design, but may not fully understand the limitations of the design constraints	Student does not understand the process.

Rubric for (e)	5 (Excellent)	3 (Average)	1 (Poor)
Identify applications in engineering systems	Students understand problem and can identify fundamental formulation	Students understand problem but cannot apply formulation.	Students cannot identify correct terms for engineering applications
Modeling, problem formulation and problem solving	Students choose and properly apply the correct techniques	Students model correctly but cannot select proper technique or model incorrectly but solve correctly accordingly	Students at loss as to how to solve a problem

Rubric for (k)	5 (Excellent)	3 (Average)	1 (Poor)
Use modern hardware tools in engineering practice	Student uses the hardware to measure and/or build engineering systems/designs correctly, and understands the limitations of the hardware.	Student uses the hardware to measure and/or build engineering systems/designs correctly.	Student does not use the hardware correctly.

Rubric for (l)	5 (Excellent)	3 (Average)	1 (Poor)
Use modern computer and software tools in engineering practice	Student uses the computer and software to correctly analyze engineering problems and/or create engineering designs, and understands the limitations of the software.	Student uses the computer and software to correctly analyze engineering problems and/or create engineering designs.	Student does not use the computer and software to correctly create engineering designs and/or does not correctly interpret the results.