Universidad de Alcalá

TEACHING GUIDE

Robotic Systems

Degree in
Industrial Electronics and Automatics Engineering

Universidad de Alcalá

Academic Year 2024/2025

4th Year - 1st Semester

Approved by the EPS School Board on June 14th, 2024

TEACHING GUIDE

Course Name:	**Robotic Systems**
Code:	**600023**
Degree in:	**Industrial Electronics and Automatics Engineering**
Department and area:	**Electrónica** **Electronic Technology**
Type:	**Compulsory**
ECTS Credits:	**6.0**
Year and semester:	**4th Year, 1st Semester**
Teachers:	Rafael Barea Navarro Elena López Guillén
Tutoring schedule:	Consultar al comienzo de la asignatura
Language:	Spanish/English Friendly

1. COURSE SUMMARY

This course deals with robotic systems in general, but focuses on the study of the morphology and sensorial systems of industrial robotic arms, the design of kinematic and dynamic controllers, and the programming of this type of robotic systems in industrial automation applications. The main concepts covered are the following: introduction to robotics; morphology, configurations and sensors for robotic arms; spatial representation methods; kinematic modelling and control; dynamic modelling and control; robot programming and implementation aspects for industrial robotic manipulators.

For better understanding of the course, it will be necessary to have prior knowledge of linear differential equations, spatial representation systems, fundamental laws of mechanics, analog and digital electronic circuits, basic mechanical systems, basic automation, modelling and simulation of systems and control techniques. As an advisable co-requisite, it is worth highlighting the knowledge of the MATLAB tool.

2. SKILLS

Basic, Generic and Cross Curricular Skills.

This course contributes to acquire the following generic skills, which are defined in the Section 3 of the Annex to the Orden CIN/351/2009:

en_TR2 - Knowledge in basic and technological subjects, which enables them to learn new methods and theories, and gives them versatility to adapt to new situations.

en_TR3 - Ability to solve problems with initiative, decision making, creativity, critical reasoning and to communicate and transmit knowledge, skills and abilities in the field of Industrial Engineering.

en_TR4 - Knowledge to carry out measurements, calculations, assessments, appraisals, appraisals, studies, reports, work plans and other similar works.

en_TR5 - Ability to handle specifications, regulations and mandatory standards.

en_TR9 - Ability to work in a multilingual and multidisciplinary environment.

en_TRU1 - Capacity of analysis and synthesis.

en_TRU2 - Oral and written competencies.

en_TRU3 - Ability to manage information.

en_TRU4 - Autonomous learning skills.

en_TRU5 - Team work.

Professional Skills

This course contributes to acquire the following professional skills, which are defined in the Section 5 of the Annex to the Orden CIN/351/2009:

en_CEI7 - Knowledge and capacity for modeling and simulation of systems.

en_CEI8 - Knowledge of automatic regulation and control techniques and their application to industrial automation.

en_CEI9 - Knowledge of principles and applications of robotic systems.

en_CEI11 - Ability to design control systems and industrial automation.

Learning Outcomes

After succeeding in this subject the students will be able to:

RASR18. Recognize the basic theoretical principles of robotic systems (structure, perception systems, control and programming).

RASR19. Solve problems of kinematic / dynamic control and industrial automation on robotic systems.

RASR20. Design a control system using a robot arm for an industrial automation application based on a given specification.

RASR21. Manage a professional robotic simulation environment and program industrial automation applications using robot arms, both in simulation environments and in real environments.

RASR22. Draft projects, reports and technical reports in the field of industrial engineering for the installation, assembly and operation of automation and control processes.

3. CONTENTS

Contents Blocks	Total number of hours
Chapter 1. Introduction to robotics. Definition of robot. Classification. Historical context: origin and development of robotics. Applications of industrial robots.	4 hours
Chapter 2. Morphology of a manipulator robot. Components of a robot. Mechanical structure Transmissions and reducers. Actuators Sensors Terminal elements.	4 hours
Chapter 3. Methods of spatial representation. Spatial location. Representation of position and orientation. Matrices of homogeneous transformation. Quaternios Comparison of methods. Introduction to the Matlab robotics toolbox.	4 hours
Chapter 4. Modeling and kinematic control. Direct kinematics of a robot arm: Denavit-Hartenberg procedure. Reverse kinematics of a robot arm: resolution by geometric methods, transformation matrices and kinematic decoupling. Differential model: Jacobian analytic and Jacobian geometric. Kinematic control: types of trajectories; generation, sampling and interpolation of trajectories. Exercises with Matlab.	14 hours
Chapter 5. Modeling and dynamic control. Dynamic model of the structure of a robot: Lagrange and Newton-Euler formulations. Dynamic model in variables of state and in the space of the task. Dynamic model of the actuators. Monoarticular and multiarticular dynamic control; adaptive control. Exercises with Matlab.	12 hours
Chapter 6. Robot programming. Robot programming methods. Requirements Programming of industrial robots. The RAPID programming language. Development of applications using ABB RobotStudio programming software.	16 hours
Chapter 7. Criteria for the implementation of an industrial robot. Design and control of a robotic cell. Characteristics to consider in the selection of a robot. Security. Robot market.	2 hours

4. TEACHING - LEARNING METHODOLOGIES. FORMATIVE ACTIVITIES.

4.1. Credits Distribution

Number of on-site hours:	58 hours (56 hours on-site +2 exams hours)
Number of hours of student work:	92
Total hours	150

4.2. Methodological strategies, teaching materials and resources

In the teaching-learning process the following training activities will be held in person:

- Lectures (theory classes) given in large groups based on presentations that allow the teacher to introduce the skills necessary for the proper development of the learning process. These classes will present essential contents, subject of a reasoned conceptual learning, subsequently used to develop broader skills.
- Practical classes taught in small groups based mainly on solving exercises and problems. The aim of these classes is to promote meaningful learning that will allow students to deepen the knowledge acquired, relate and apply it creatively in order to solve situations, as the course progresses, that will gradually become more similar to real-world engineering problems.
- Lab classes taught exclusively in small groups and based on solving practical problems in simulation as well working with real industrial robots and using simulation and programming software.
- Tutorship sessions: individual or group sessions.
- Student previous or subsequent work: essential part of the teaching-learning process that will be guided and described in detail in the student's notebook quoted above.
- Exams, including the different face-to-face assessment tests that will be carried out in the subject.

The following additional resources may also be used:

- Individual and group works, which could pose, in addition to its realization, the relevant public presentation to the rest of the class to stimulate discussion.
- Attendance at conferences, meetings or discussions related scientific field.

Throughout the learning process in the course, students will use different bibliographic and electronic resources, in order to become familiar with the environments of documentation they will use professionally in the future. In addition, teachers will provide own materials developed specifically for the course (theoretical papers, collections of exercises and problems, practice manuals, audiovisuals, etc.) so that students can meet the course objectives and achieve the competences described.

Students will be provided throughout the semester with tutorship in group (if requested by the students themselves) or individual. Whether individually or in small groups, this tutorship will resolve doubts and consolidate the knowledge acquired. Also it will help to make appropriate monitoring and assess the proper functioning of the mechanisms of teaching and learning.

Finally, the whole development of the subject will be detailed on the website of the course (see table at the beginning of the document). All resources developed for the subject, such as slides, exercise statements and solutions, statements of problems for practices, detailed schedules for each group and class, mid-term exams marks and any other information that teachers consider appropriate for the proper teaching and learning process will be available on the website.

5. ASSESSMENT: procedures, evaluation and grading criteria

Preferably, students will be offered a continuous assessment model that has characteristics of formative assessment in a way that serves as feedback in the teaching-learning process.

5.1. PROCEDURES

The evaluation must be inspired by the criteria of continuous evaluation (Learning Assesment Guidelines, LAG, art 3). However, in compliance with the regulations of the University of Alcalá, an alternative process of final evaluation is made available to the student in accordance with the Learning Assesment Guidelines as indicated in Article 10, students will have a period of fifteen days from the start of the course to request in writing to the Director of the Polytechnic School their intention to take the non-continuous evaluation model adducing the reasons that they deem convenient. The evaluation of the learning process of all students who do not apply for it or are denied it will be done, by default, according to the continuous assessment model. The student has two calls to pass the subject, one ordinary and one extraordinary.

In accordance with current regulations, and as the experimental laboratory part is considered essential for the acquisition of the subject's objective competences, passing the compulsory on-site practicals will be considered an essential element of the assessment, both in the ordinary and extraordinary call (regulations governing the learning assessment processes approved by the Governing Council on 24 March 2011, Article 6, paragraph 4). For this reason, laboratory practicals are common and essential in both types of assessment: continuous and non-continuous'.

Students are offered, and recommended to follow, a continuous assessment procedure that has characteristics of formative assessment, in order to serve as a valuable feedback in the teaching process.

ASSESSMENT PROCEDURES

Students have two methods of assessment: continuous or final assessment. To optimize the teaching-learning process, teachers of the subject urge students to choose the continuous model but respecting the regulations of the University of Alcalá, an alternative final-exam assessment process is offered. Observing these rules, students will have a period of fifteen days from the start of the course to apply their intention to invoke the final assessment model providing relevant reasons. Written applications must be addressed to Polytechnic University School Director. The evaluation of the learning process for those students who do not request non-continuous assessment or whose application is refused will be done, by default, according to the model of continuous assessment, described in following paragraphs.

Next, assesment procedures corresponding to the ordinary and extraordinary calls are detailed:

1. Ordinary exam: Evaluation in the ordinary exam should be based on continuous assessment criteria (Regulatory Standards of teaching and learning processes, NRPEA, Article 3), consistent with the acquisition of the competences specified in the subject. However, there may:

   a. Continuous Assessment

   b. Final Assessment

2. Extraordinary exam: There are two situations:

   a. Students who followed, during the course, a continuous assessment procedure will be able to keep the mark of the passed parts making a theoretical/practical exam for the parts they did not pass.

   b. The remaining students will comply with the final assessment considerations.

According to current regulations and because the experimental lab skills are considered essential for the acquisition of the objectives of the course, attendance at all laboratory sessions and overcoming the mandatory practices is considered an essential element of the assessment, in both continuous and final modalities (regulations governing the evaluation processes learning models approved by the Governing Council of 24 March 2011, Article 6, paragraph 4). For this reason, the laboratory exercises are common and essential in both types of evaluation: continuous and final. In the same way, for the case of continuous evaluation, attendance is required for at least a 90% of the rest of classes.

5.2. EVALUATION

EVALUATION CRITERIA

The evaluation process aims at assessing the extent and depth of the student's acquisition of skills raised in the subject. Consequently, the evaluation criteria to be applied in the various tests that are part of the process, ensure that the student has the appropriate level in the following knowledge and skills:

- CE1: The student understands and knows the basic theoretical principles of robotic systems (structure, perception systems, control and programming).
- CE2: The student demonstrates ability to solve problems of kinematic/dynamic control systems and industrial automation with initiative, critical reasoning and making use of creative and innovative ideas based on the theoretical contents taught in the subject.
- CE3: The student is able to design a control system using an industrial robot manipulator for an industrial automation task, making use of the bibliographic resources and computer tools (simulation and programming software).
- CE4: The student demonstrates the ability to manage a professional robotic simulation software and to program industrial automation applications using robot manipulators, both in simulation and in real environments.
- CE5: The student is able to write projects, reports and technical reports in the field of industrial engineering for the installation, assembly and operation of automation processes based on robotic systems.

GRADING TOOLS - ASSESMENT TOOLS

The following assessment tools will be used:

1. Mid-term exam **(MT)**: This test consist of a number of questions (analysis and/or synthesis) on specific aspects of chapter 1-4.
2. Development of exercises **(EX)** on kinematics/dynamics of robot manipulators (chapter 4 and 5) using Matlab's robotics toolbox. The student must present a justifying report with the developments carried out and the results obtained.
3. **LP:** Lab projects covering robot manipulator programming using RAPID and ROBOTSTUDIO ABB software, both in simulation and real. Compulsory attendance.
4. **FE:** A final exam that consists of a number of questions (analysis and/or synthesis) on specific aspects of the whole course (theory and lab).

GRADING CRITERIA - MARKING INSTRUMENTS

Ordinary exam - Continuous assessment

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CEI8-9,TR2,TRU1-4	RASR18-19	CE1-CE2	MT	20%
CEI7-9,TR3-4,TRU1-5	RASR18-20	CE1-CE3, CE5	EX	15%
CEI7-9,CEI11, TR3-5,TR9,TRU1-5	RASR20-22	CE3-CE5	LAB	25%
CEI7-9,CEI11, TR3-5,TR9,TRU1-4	RASR18-22	CE1-CE5	FE	40%

A student will successfully pass the course following the continuous assessment model if he or she shows that has acquired the theoretical and practical skills, which means:

- The student has done **both mid-term exam (MT) and final exam (FE)**, obtaining a mark equal or greater than 50% of the maximum possible total mark in the theory-tests carried out (MT+FE) (hence successfully passing the evaluation of the skills and competences related to theory tests).
- The student has attended (**compulsory attendance**) and performed **all laboratory projects (LAB)**, and has successfully passed the evaluation of the lab skills and competences. A student is considered to have successfully reached these skills if he or she has attended and completed all the lab practicals and has obtained a mark equal or greater than the 50% of the maximum possible total mark in the projects carried out.
- The student has made and performed the exercices related to robotic manipulators kinematics and dynamics (EX).
- The student must obtain a final global mark equal to or greater than 5 (out of 10) calculated as a weighted average with the percentages detailed above.

The student will be mark as **NO PRESENTED** if the mid-term exam is not done.

Ordinary exam - Final assessments.

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CEI7-9,TR3-4,TRU1-5	RASR18-20	CE1-CE3, CE5	EX	15%
CEI7-9,CEI11, TR3-5,TR9,TRU1-5	RASR20-22	CE3-CE5	LAB	25%
CEI7-9,CEI11, TR3-5,TR9,TRU1-4	RASR18-22	CE1-CE5	GFE(FE+test)	60%

In order to pass the course in final assessment (ordinary exam), similar criteria apply in this case:

- The student has done a **final exam (GFE)**, which includes the FE made in continuous assessment and a test including several questions or test related to theoretical skills. A mark equal or greater than 50% of the maximum possible total mark is mandatory.
- The student has performed **all laboratory projects** (LAB), and has successfully passed the evaluation of the lab skills and competences, obtaining a mark equal or greater than the 50% of the maximum possible total mark.
- The student has made and performed the exercices related to robotic manipulators kinematics and dynamics (EX).

- The student must obtain a final global mark equal to or greater than 5 (out of 10) calculated as a weighted average with the percentages detailed above.

Extraordinary exam - Final assessment

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CEI7-9,CEI11, TR3-5,TR9,TRU1-5	RASR20-22	CE3-CE5	LAB	25%
CEI7-9,CEI11, TR3-5,TR9,TRU1-4	RASR18-22	CE1-CE5	FE	75%

As for the other two modalities, to successfully pass the course the student must show that he/she has successfully acquired theoretical and practical skills:

- The student has done a **final exam (FE)** which includes questions and problems test related to theoretical skills. obtaining a mark equal or greater than the 50% of the maximum possible total mark.
- A practical project (LAB) similar to those made in ordinary exam.
- The student must obtain a final global mark equal to or greater than 5 (out of 10) calculated as a weighted average with the percentages detailed above.

Students who has participated in ordinary exams may keep the passed parts marks and prepare only for the failed in the extraordinary exam.

6. BIBLIOGRAPHY

6.1. Basic Bibliography

- Course notes specifically prepared by teachers which will be provided to students directly through the website of the course (including slides, notes, data sheets and collections of exercises).

- Barrientos, Luis F. Peñín, C. Balaguer, R. Aracil. “Fundamentos de robótica”. McGraw Hill. Segunda edición 2007. ISBN: 978-84-481-5636-7.

  This book is the main reference for the subject. It covers nearly all the topics

- P. Corke. “Robotics,Vision and Control Fundamental algorithms in MATLAB”. Springer. Novena edición2011. ISBN: 978-3642201431,

- ABB Website (http://www.abb.es/)

6.2. Additional Bibliography

- Ollero. “Robótica, manipuladores y robots móviles”.Marcombo.Primera edición 2007.

- John J. Craig. “Introduction to robotics, mechatronics and control”, Prentice-Hall, Third edition.2005.
- F. Torres, J. Pomares, P. Gil, S. Puente, R. Aracil. “Robots y sistemas sensoriales”. Prentice Hall. 2002.
- M.W. Spong, S. Hutchinson, M. Vidyasagar. “Robot Modeling and Control”. Wiley. 2005.
- H. Choset, K.M. Lynch, S. Hutchinson, G.A. Kantor, W. Burgard, L.E. Kavraki, S. Thrun “Principles of Robot Motion: Theory, Algorithms, and Implementations (Intelligent Robotics and Autonomous Agents series)”. The MIT Press. 2005.

Disclosure Note

During the evaluation tests, the guidelines set out in the Regulations establishing the Rules of Coexistence of the University of Alcalá must be followed, as well as the possible implications of the irregularities committed during said tests, including the consequences for committing academic fraud according to the Regulation of Disciplinary Regime of the Students of the University of Alcalá.