



National University of Engineering (UNI)
School of Computer Science
Syllabus 2027-I

1. COURSE

AI369. Robotics (Elective)

2. GENERAL INFORMATION

2.1 Course	: AI369. Robotics
2.2 Semester	: 9 th Semester.
2.3 Credits	: 3
2.4 Hours	: 2 HT; 2 HP;
2.5 Duration of the period	: 16 weeks
2.6 Type of course	: Elective
2.7 Learning modality	: Face to face
2.8 Prerequisites	: AI268. Computational Vision. (8 th Sem)

3. PROFESSORS

Meetings after coordination with the professor

4. INTRODUCTION TO THE COURSE

Robotics is the physical manifestation of Artificial Intelligence. This course introduces the fundamental concepts of robot design, including kinematics, perception, and control. Students will explore how robots interact with the physical world through sensors and actuators, and how they make autonomous decisions using probabilistic mapping and localization techniques. The course bridges the gap between abstract algorithms and physical execution.

5. GOALS

- Understand the mechanical and mathematical foundations of robot kinematics.
- Master sensor fusion techniques for robot perception.
- Implement navigation and path planning algorithms.
- Analyze the integration of machine learning in robotic control.
- Design and simulate autonomous agents for specific environments.

6. COMPETENCES

AG-C09) Design and Development of Solutions: Designs, implements, and evaluates solutions for complex computing problems. (Usage)

AG-C11) Use of Tools: Applies modern computing tools in problem solving. (Assessment)

7. TOPICS

Unit 1: Robotics (12 hours)	
Competences Expected: AG-C09,AG-C11	
Topics	Learning Outcomes
• Overview: problems and progress: – State-of-the-art robot systems, including their sensors and an overview of their sensor processing – Robot control architectures, e.g., deliberative vs reactive control and Braitenberg vehicles – World modeling and world models – Inherent uncertainty in sensing and in control • Sensors and effectors: – Sensors: e.g., LIDAR, sonar, vision, depth, stereoscopic, event cameras, microphones, haptics – Effectors: e.g., wheels, arms, grippers • Coordinate frames, translation, and rotation (2D and 3D) • Configuration space and environmental maps • Interpreting uncertain sensor data • Localization and mapping • Navigation and control • Forward and inverse kinematics • Motion path planning and trajectory optimization • Manipulation and grasping • Joint control and dynamics • Vision-based control • Multiple-robot coordination and collaboration • Human-robot interaction: – Shared workspaces – Human-robot teaming and physical HRI – Social assistive robots – Motion/task/goal prediction – Collaboration and communication (explicit vs implicit, verbal or symbolic vs non-verbal or visual) – Trust • Applications and Societal, Economic, and Ethical Issues: – Societal, economic, right-to-work implications – Ethical and privacy implications of robotic applications – Liability in autonomous robotics – Autonomous weapons and ethics – Human oversight and control	• List capabilities and limitations of today’s state-of-the-art robot systems, including their sensors and the crucial sensor processing that informs those systems [List] • Integrate sensors, actuators, and software into a robot designed to undertake a specific task [Apply] • Program a robot to accomplish simple tasks using deliberative, reactive, and/or hybrid control architectures [Apply] • Implement fundamental motion planning algorithms within a robot configuration space [Apply] • Characterize the uncertainties associated with common robot sensors and actuators; articulate strategies for mitigating these uncertainties [Characterize] • List the differences among robots’ representations of their external environment, including their strengths and shortcomings [List] • Compare and contrast at least three strategies for robot navigation within known and/or unknown environments, including their strengths and shortcomings [Compare] • Describe at least one approach for coordinating the actions and sensing of several robots to accomplish a single task [Describe] • Compare and contrast a multi-robot coordination and a human-robot collaboration approach and attribute their differences to differences between the problem settings [Compare] • Analyze the societal, economic, and ethical issues of a real-world robotics application [Analyze]

Unit 2: Perception and Computer Vision (12 hours)	
Competences Expected: AG-C09,AG-C11	
Topics	Learning Outcomes
• Computer vision: – Image acquisition, representation, processing, and properties – Shape representation, object recognition, and segmentation – Motion analysis – Generative models • Audio and speech recognition • Touch and proprioception • Other modalities (e.g., olfaction) • Modularity in recognition • Approaches to pattern recognition: – Classification algorithms and measures of classification quality – Statistical techniques – Deep learning techniques	• Summarize the importance of image and object recognition in AI and indicate several significant applications of this technology [Summarize] • List at least three image-segmentation approaches, such as thresholding, edge-based and region-based algorithms, along with their defining characteristics, strengths, and weaknesses [List] • Implement 2d object recognition based on contour-based and/or region-based shape representations [Apply] • Distinguish the goals of sound-recognition, speech-recognition, and speaker-recognition and identify how the raw audio signal will be handled differently in each of these cases [Distinguish] • Provide at least two examples of a transformation of a data source from one sensory domain to another, e.g., tactile data interpreted as single-band 2d images [Generate] • Implement a feature-extraction algorithm on real data, e.g., an edge or corner detector for images or vectors of Fourier coefficients describing a short slice of audio signal [Apply] • Implement an algorithm combining features into higher-level percepts, e.g., a contour or polygon from visual primitives or phoneme hypotheses from an audio signal [Apply] • Implement a classification algorithm that segments input percepts into output categories and quantitatively evaluates the resulting classification [Apply] • Evaluate the performance of the underlying feature-extraction, relative to at least one alternative possible approach (whether implemented or not) in its contribution to the classification task (8), above [Evaluate] • Describe at least three classification approaches, their prerequisites for applicability, their strengths, and their shortcomings [Describe] • Implement and evaluate a deep learning solution to problems in computer vision, such as object or scene recognition [Apply]
Readings : [Thrun2005], [Siegwart2011]	

Unit 3: Robotics (24 hours)	
Competences Expected: AG-C09,AG-C11	
Topics	Learning Outcomes
• Overview: problems and progress: – State-of-the-art robot systems, including their sensors and an overview of their sensor processing – Robot control architectures, e.g., deliberative vs reactive control and Braitenberg vehicles – World modeling and world models – Inherent uncertainty in sensing and in control • Sensors and effectors: – Sensors: e.g., LIDAR, sonar, vision, depth, stereoscopic, event cameras, microphones, haptics – Effectors: e.g., wheels, arms, grippers • Coordinate frames, translation, and rotation (2D and 3D) • Configuration space and environmental maps • Interpreting uncertain sensor data • Localization and mapping • Navigation and control • Forward and inverse kinematics • Motion path planning and trajectory optimization • Manipulation and grasping • Joint control and dynamics • Vision-based control • Multiple-robot coordination and collaboration • Human-robot interaction: – Shared workspaces – Human-robot teaming and physical HRI – Social assistive robots – Motion/task/goal prediction – Collaboration and communication (explicit vs implicit, verbal or symbolic vs non-verbal or visual) – Trust • Applications and Societal, Economic, and Ethical Issues: – Societal, economic, right-to-work implications – Ethical and privacy implications of robotic applications – Liability in autonomous robotics – Autonomous weapons and ethics – Human oversight and control	• List capabilities and limitations of today’s state-of-the-art robot systems, including their sensors and the crucial sensor processing that informs those systems [List] • Integrate sensors, actuators, and software into a robot designed to undertake a specific task [Apply] • Program a robot to accomplish simple tasks using deliberative, reactive, and/or hybrid control architectures [Apply] • Implement fundamental motion planning algorithms within a robot configuration space [Apply] • Characterize the uncertainties associated with common robot sensors and actuators; articulate strategies for mitigating these uncertainties [Characterize] • List the differences among robots’ representations of their external environment, including their strengths and shortcomings [List] • Compare and contrast at least three strategies for robot navigation within known and/or unknown environments, including their strengths and shortcomings [Compare] • Describe at least one approach for coordinating the actions and sensing of several robots to accomplish a single task [Describe] • Compare and contrast a multi-robot coordination and a human-robot collaboration approach and attribute their differences to differences between the problem settings [Compare] • Analyze the societal, economic, and ethical issues of a real-world robotics application [Analyze]

8. WORKPLAN

8.1 Methodology

Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

8.2 Theory Sessions

The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

8.3 Practical Sessions

The practical sessions are held in class where a series of exercises and/or practical concepts are developed through problem solving, problem solving, specific exercises and/or in application contexts.

9. EVALUATION SYSTEM

Theory Sessions:

The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

Lab Sessions:

In order to verify their competences, several activities including active learning and roleplay will be developed during lab sessions.

Oral Presentations:

Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

Reading:

Throughout the course different readings are provided, which are evaluated. The average of the notes in the readings is considered as the mark of a qualified practice. The use of our virtual campus allows each student to access the course information, and interact outside the classroom with the teacher and with the other students.

The final grade NF depends on the following grades:

- PE : Partial Exam.
- FE : Final Exam.
- P : Permanent Evaluation (Average of practical work and graded assignments).

The final grade NF is calculated as follows:

$$NF = \frac{PE + FE + P}{3}$$

10. BASIC BIBLIOGRAPHY