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CENTRALE NANTES

MASTER OF SCIENCE, TECHNOLOGY AND HEALTH

CONTROL AND ROBOTICS

ADVANCED ROBOTICS

YEAR 1
SPRING SEMESTER

PROGRAMME SUPERVISORS:
GUY LEBRET, OLIVIER-HENRI ROUX

Établissement public sous tutelle du ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation

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PROJECT

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 SPRING SEMESTER

LEAD PROFESSOR: Guy Lebret, *guy.lebret@ec-nantes.fr*

Objectives

To contribute to solving a scientific, technological or theoretical problem proposed by any of the instructors of the master (professors, assistant professors, researchers etc.) or industrial partners.

Course contents

The students (individually or often a group of two) organize the project. Depending on the subject, a bibliography may be necessary, an original methodology or solution can be proposed or it can involve purely the application of techniques learned throughout the courses.

32 hours are set aside for the project in the timetable, but additional personal work will be required. Project assessment is based on a written report and an oral presentation.

Course material

Keywords

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	6	0 hrs	0 hrs	0 hrs	0 hrs	0 hrs

OPTIMIZATION TECHNIQUES

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 SPRING SEMESTER

LEAD PROFESSOR: Fouad Bennis, *fouad.bennis@ec-nantes.fr*

Objectives

The lecture presents different theoretical and computational aspects of a wide range of optimization methods for solving a variety of problems in mechanical engineering. The main objective of this course is to give the students the ability to formalise, select the appropriate method, implement the optimisation problem and then analyse the results in order to take the best decision regarding the objectives, variables and constraints.

Course contents

- Basic concepts of optimization,
- Gradient based methods,
- Evolutionary algorithms,
- Multi objective optimization methods,
- Robust optimization methods,
- Multidisciplinary optimization problems,
- Programming aspects,
- Use of optimization toolbox.

Practical Work: exercises and a project on the design optimisation of a mechanical product, manufacturing process or system.

The students will be able to understand different theoretical and computational aspects of a wide range of optimization methods.

Course material

R. Fletcher, Practical Methods of Optimization, Wiley, 2000.
Mitchell Melanie: An Introduction to Genetic Algorithms, MIT Press 1996

Keywords

Optimisation, gradient based approach, population-based approach, trajectory-based approach

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	16 hrs	0 hrs	16 hrs	0 hrs	2 hrs

MOBILE ROBOTS

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 SPRING SEMESTER

LEAD PROFESSOR: Gaëtan Garcia, *gaetan.garcia@ec-nantes.fr*

Objectives

The objective of the course is to provide students with the necessary tools to model, localize and control conventional wheeled mobile robots.

Course contents

The following subjects will be addressed:

- Modelling of wheeled Robots: Constraint equations, Classification of robots using degrees of mobility and steerability, Posture kinematic model, Configuration kinematic model, Motorisation of wheels.
- Localization: Relative localization using odometry, Absolute localisation, Localization sensors, Localization using extended Kalman filtering.
- Control: Controllability and stabilization, static and dynamic feedback linearization, non-linear control based on Lyapunov functions.

Practical Work: The students will study various control laws in simulation. They will also implement a Kalman filter-based localization algorithm using data recorded with a real robot.

Course material

- "Theory of robot control", Carlos Canudas de Wit, Bruno Siciliano, Georges Bastin, Springer Science & Business Media, 2012 - 392 pages.
- PDF documents provided by the teachers.

Keywords

Mobile robots, modelling, localization, control.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	20 hrs	0 hrs	12 hrs	0 hrs	2 hrs

DYNAMIC MODEL BASED CONTROL

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 SPRING SEMESTER

LEAD PROFESSOR: Sébastien Briot, Sebastien.Briot@ls2n.fr

Objectives

To show that using in a control law "a dynamic model" of a dynamical system can be the base of a fruitful control methodology. This course is an extension of two courses: Classical Linear Control and Modelling of Manipulators.
In the first part (16h), for linear multivariable systems, the model is used, first of all, to obtain observer-based controllers (state space approach of linear multivariable systems) as the feedback part of the control law, and secondly, in a possible feedforward part.
In the second part (16h), it is shown how the dynamic model of mechanisms or, more specifically, serial robots can be obtained, as this model is the basis of the so-called "computed torque control law". Different formalisms for the computation of the dynamic model will be explored (Newton-Euler, Lagrange equations).

Clearly, the objective of the course is to present a unified methodology to obtain control laws. In this methodology, once the dynamic model has been obtained, then the non-linear coupled MIMO systems can be linearized and decoupled, and finally the linear methodology of the first part can be applied.

Course contents

Part 1 state space approach of linear multivariable systems:

- Time domain state response, modal decomposition of the response
- Controllability, observability
- Observer-based controllers
- Possible two degrees of freedom controllers.

Part 2, mechanisms or more specifically, serial robots:

- Recalls of classical mechanics
- Newton-Euler equations
- Euler-Lagrange equations
- Optimal computation of dynamic models for serial robots (recursive formalisms)

Skills: After completing this course the students will be able to

- Use all classical tools of the linear state space approach to analyse (mode, controllability, etc) and design observer-based controllers.
- Compute the dynamic model of open-loop mechanisms and robots
- Evaluate the benefit of the use of a dynamical model in a control law.

Course material

Recommended texts: Course notes will be provided by the lecturers.

Further reading:

- "Control system design", G.C. Goodwin, S.F. Graebe and M.E. Salgado, Prentice Hall, 2001.
- "Linear Multivariable Control, A Geometric Approach", W.M.Wonham. Springer Verlag, New York, 1985.
- "Linear Systems", T. Kailath, Prentice-Hall, New Jersey, 1980.
- "Modelling, Identification and Control of Robots" W. Khalil and E. Dombre, Hermes Penton, Ltd, 2002

Keywords

Model based control, dynamic model, linear control, robots

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	22 hrs	6 hrs	4 hrs	0 hrs	2 hrs

SOFTWARE ARCHITECTURE FOR ROBOTICS

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 SPRING SEMESTER

LEAD PROFESSOR: Gaëtan Garcia, *gaetan.garcia@ec-nantes.fr*

Objectives

The main objective of Software Architecture for Robotics is to provide students with methodological tools and practical information about how to design and develop complex software architecture for intelligent robots. Nowadays, robots can be considered as complex systems made up of modules and components whose behavior is complex in its own right. Given a specific scenario where a robot must operate autonomously and effectively, the problem of defining software architecture requires one to:

- define which sensory information is needed and how it must be processed;
- couple sensory information and internal representation structures, which must be appropriate in terms of efficiency, computational load and usability;
- design and develop algorithms to operate on such representation structures;
- embed those algorithms in software modules and components, which must be concurrently executed on (typically real-time) operating systems.

The course provides a principled treatment of current state-of-the-art design approaches, development frameworks, modelling tools and advanced research trends in this field, as well as a comprehensive discussion about typical scenarios, solutions and use cases. In terms of development framework, the objective is to obtain sufficient command of ROS (Robot Operating System – web: http://www.ros.org/) to implement moderately complex applications.

Course contents

The course covers the following aspects:

- Design patterns for robot software development,
- Component-based software engineering aspects,
- Typologies of software architecture for robots, and their use in real-world scenarios,
- Biologically-inspired approaches to robot software design,
- Real-time and non-real-time software components,
- Integration of robot perception, knowledge representation, reasoning, and action.
- Practical introduction to ROS in the labs.

Course material

Relevant material will be provided by the instructors during the course

Keywords

Design patterns, component-based software engineering, real-time systems, ROS.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	12 hrs	0 hrs	20 hrs	0 hrs	2 hrs

COMPUTER VISION

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 SPRING SEMESTER

LEAD PROFESSOR: Vincent Fremont, vincent.fremont@ec-nantes.fr

Objectives

- To acquire knowledge and skills in computer vision and image processing to understand and to master methods for artificial perception and scene understanding.
- To learn to implement current visual odometry pipelines used in mobile robots and to understand and how to tune Deep Learning algorithms for semantic segmentation.

Course contents

- Introduction
- Image Formation 1: perspective projection and camera models
- Image Formation 2: camera calibration algorithms
- Filtering and Edge detection
- Feature Point Detection
- Multiple-view Geometry and Robust Estimation
- Optical Flow and Feature Tracking
- Visual SLAM Frameworks
- Deep Learning and Semantic Segmentation

Practical Work: Sessions on low-level image processing, Structure-from-Motion and Semantic Segmentation will be proposed.

Course material

Recommended textbooks:

- Digital Image Processing, by Rafael C. Gonzalez and Richard E. Woods, 2018
- Computer Vision: Algorithms and Applications, by Richard Szeliski, 2009.
- Multiple view Geometry, by R. Hartley and A. Zisserman, 2003.
- An Invitation to 3D Vision, by Y. Ma, S. Soatto, J. Kosecka, S.S. Sastry, 2004.
- Robotics, Vision and Control: Fundamental Algorithms, by Peter Corke, 2011.

Online courses:

- Course by Davide Scaramuzza: http://rpg.ifi.uzh.ch/teaching.html
- Course by James Hays at Brown University: https://www.cc.gatech.edu/~hays/
- Course by Andrea Vedaldi: http://www.robots.ox.ac.uk/~vedaldi/teach.html

Further reading: will be provided by lecturer

Keywords

Image Processing, Feature detection and Tracking, Multiple-view Geometry, Visual SLAM, Deep Learning for Semantic Segmentation.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	20 hrs	0 hrs	12 hrs	0 hrs	2 hrs

MODERN LANGUAGES - FRENCH

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 - SPRING SEMESTER

LEAD PROFESSOR: Silvia Ertl – *silvia.ertl@ec-nantes.fr*

Objectives

The objective is to familiarize the learner with the French language and French culture through an entertaining task-based communicative language teaching, focused on speaking combined with:

- Phonetics
- Self-correcting exercises on our learning platform
- Learning Lab activities
- Project work
- Tutoring

Course objectives include the acquisition and reinforcement of vocabulary, syntax, and pronunciation by both traditional means and through the use of digital resources. Students will learn general French, develop language skills of oral and written comprehension and expression.

After completing this course (32 hours + personal work), the students will be able to communicate in spoken and written French, in a simple, but clear manner, on familiar topics in the context of study, hobbies etc. Another important goal of this course is to introduce the student to French culture. At the end of the course (2 semesters), complete beginners can achieve an A1 level and some aspects of the A2 of The Common European Framework of Reference for Languages. More advanced students may aim for B1/B2 levels.

Course contents

Full range of practical communication language exercises: reading comprehension, listening comprehension, written expression, oral expression.

Learners will be able to use the foreign language in a simple way for the following purposes:

1. Gving and obtaining factual information:
    - personal information (e.g. name, address, place of origin, date of birth, education, occupation)
    - non-personal information (e.g. about places and how to get there, time of day, various facilities and services, rules and regulations, opening hours, where and what to eat, etc.)

2. Establishing and maintaining social and professional contacts, particularly:
    - meeting people and making acquaintances
    - extending invitations and reacting to being invited
    - proposing/arranging a course of action
    - exchanging information, views, feelings, wishes, concerning matters of common interest, particularly those relating to personal life and circumstances, living conditions and

environment, educational/occupational activities and interests, leisure activities and social life

3. Carrying out certain transactions:
   - making arrangements (planning, tickets, reservations, etc.) for travel, accommodation, appointments, leisure activities
   - making purchases
   - ordering food and drink

Course material

Course material: Preparation manuals, our own tailor-made documents, written and televised press, internet, general civilization documents, digital tools, our own educational materials on Hippocampus (Moodle).

Keywords

reception (listening and reading), production (spoken and written), interaction (spoken and written), knowledge, skills, linguistic competence, sociolinguistic competence, pragmatic competence, register, cultural differences, non-verbal communication

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
French	4	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

MODERN LANGUAGES - CULTURAL AND COMMUNICATIONAL ENGLISH

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 - SPRING SEMESTER

LEAD PROFESSOR: Spencer Hawkridge- *spencer.hawkridge@ec-nantes.fr*

Objectives

Interview techniques and communicational English:

- Understand the general concepts of interactive communication
- Build a media project
- Acquire interview techniques
- Understand the process of sourcing and checking facts and figures
- Understand issues related to plagiarism
- Create a bibliography
- Behavioral skills in an inter-cultural environment:
- Strengthen self-confidence and capacity for interaction
- Develop active listening and reformulation skills
- Develop networking skills

Course contents

Cultural and Communicational English: exercises to explore in practice the areas of culture and communication.
Media project (for example: prepare, conduct and promote interviews for a radio programme: *L'Heure Centralienne* (http://www.euradionantes.eu/emission/l-heure-centralienne), with the contribution of professors, PhD students, industrial partners, industry players at fairs, etc.

Course material

Written and televised press, information and digital tools, general documents business environment and company strategies.
Internet conferences (Ted Talks, etc.), our own educational materials on Hippocampus (Moodle).
Our own eZoomBook template for the Intercultural project.

Keywords

Culture and communication, inter-cultural environment, team-building, digital tools, etc.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	0 hrs	30 hrs	0 hrs	0 hrs	2 hrs