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CENTRALE NANTES

MASTER OF SCIENCE, TECHNOLOGY AND HEALTH

CONTROL AND ROBOTICS

ADVANCED ROBOTICS

YEAR 1
AUTUMN 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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SIGNAL PROCESSING

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 AUTUMN SEMESTER

LEAD PROFESSOR: Eric Le Carpentier, *eric.le-carpentier@ec-nantes.fr*

Objectives

- To interpret the spectral representations of signals
- To understand the time sampling of signals (sample rate, anti-aliasing filter etc.)
- To model a system using the transfer functions language
- To model a system using the state space language
- To switch from one representation to the other
- To link the physical phenomena to the parameters of these representations (stability, response velocity etc.)
- To simulate these mathematical representations with adapted scientific software tools (Matlab, Simulink)

Course contents

- Analysis of continuous-time and discrete-time signals
    - Fourier, Laplace and z transforms
    - Sample, hold, quantization, Shannon theorem
- Modelling of continuous-time and discrete-time linear time invariant (LTI) systems
    - Transfer function, state space representation
    - Poles, zeros, stability
    - Time response, frequency response
    - Sampling
    - Simulation (Matlab Simulink)
    - First-order and second-order systems
- Design of an actual digital control implementation
    - Analog to Digital Converter, Digital to Analog converter
    - Sample and hold
    - Link with the previous mathematical representations
- Lab work
    - Music: from the sound signal to the score
    - Tide Periodicities
    - Spacecraft control simulation

Course material

- Modern Signals and Systems, H. Kwakernaak, R. Sivan, Prentice Hall.
- Signals and Systems, R. Baraniuk, http://www.eng.ucy.ac.cy/cpitris/courses/ece623/notes/SignalsAndSystems.pdf
- Signal processing. Introduction to signals and systems theory, E. Le Carpentier, https://hippocampus.ec-nantes.fr/mod/resource/view.php?id=9179

Keywords

Signal, System, Sampling, Filtering

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	5	14 hrs	0 hrs	18 hrs	0 hrs	2 hrs

CLASSICAL LINEAR CONTROL

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 AUTUMN SEMESTER

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

Objectives

Review the fundamentals of classical control for linear systems and provide a control methodology starting from the open loop analysis of the system to be controlled to the synthesis of a closed loop using classical PID type controllers (one degree of freedom controllers) which can be combined with a feedforward part (two degrees of freedom controllers).

Course contents

- Description of SISO linear systems through the transfer function
- Analysis of behaviour (poles/zeros, first/second/more general systems, time domain/frequency domain responses etc)
- Definition the Control objectives (stability/performance, tracking/regulation)
- Nominal/robust stability (Routh, Nyquist criteria, stability margins).
- Nominal/robust performance and the unavoidable trades off between stability and performance.
- Synthesis of PID type controllers, using frequency approach tunings, in a classical closed loop (one degree of freedom controller strategy).
- Possibility of introducing a feedforward contribution which tries to "invert" the first closed loop obtained (two degrees of freedom controllers).

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

- Analyse the dynamic behaviour of a SISO linear system
- Design a PID type controller as an example of a feedback controller
- Design a feedforward controller to increase tracking performance

Course material

Recommended texts: course notes will be provided by the lecturer.
Further reading:

- "Modern Control Systems", R.C. Dorf and R.H. Bishop, Prentice Hall, 2011.
- "Control Systems Engineering", N. S. Nise, John Wiley & Sons, 2011.
- "Control system design", G.C. Goodwin, S.F. Graebe and M.E. Salgado, Prentice Hall, 2001.
- "Multivariable Feedback Control Analysis and Design", D.S. Skogestad and I. Postlethwaite, Wiley, 2005.

Keywords

Classical control, SISO Linear Systems, two degree of freedom controllers, PID, lead lag controllers

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	5	22 hrs	6 hrs	4 hrs	0 hrs	2 hrs

ARTIFICIAL INTELLIGENCE

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 AUTUMN SEMESTER

LEAD PROFESSOR: Didier Lime, *didier.lime@ec-nantes.fr*

Objectives

The goal of this course is to present how a computerized agent can learn from its environment and find strategies to achieve well-defined goals.

Course contents

The first part covers basic path-finding, which is further extended to account for non-determinism, probabilistic outcomes, partial observability, and the presence of other agents. The second part deals with the specific problems of supervised learning and reinforcement learning.

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

- use and implement graph-based strategy search, in particular using Markov decision processes
- use and implement decision tree and artificial neural network learning (including the basics of deep learning)
- use and implement several simple flavors of reinforcement learning.

Assessment: 100% final examination

Course material

S. Russel, P. Norvig. Artificial Intelligence: A Modern Approach (3rd ed). Pearson, 2009.

Keywords

Path-finding, Markov Decision Processes, games, Neural networks, decision trees, supervised learning, reinforcement learning.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	16 hrs	4 hrs	12 hrs	0 hrs	2 hrs

MODELLING OF MANIPULATORS

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 AUTUMN SEMESTER

LEAD PROFESSOR: Olivier Kermorgant, *olivier.kermorgant@ec-nantes.fr*

Objectives

This course introduces the modelling and basic control of serial robot arms. The topics include robot architecture and modeling conventions, forward and inverse kinematic model, differential kinematic modelling and the basics of trajectory planning and tracking.

At the end of the course, students will be able to:

- Have a clear view of 3D geometry, including rotation parametrization and velocity screws
- Define a table of modified Denavit-Hartenberg parameters to model a robot from a sketch
- Compute (manually or with software) the direct and differential kinematic models
- Derive the inverse kinematic model for standard manipulators (6R / 3P3R)
- Understand position and velocity control modes
- Know how to generate a trajectory from a sequence of 3D waypoints
- Know various symbolic or numeric software tools that can be used to model and control robots

Course contents

- Robot architecture, joint and operational spaces
- Homogeneous transformation matrices, 3D geometry, velocity screw
- Modified Denavit-Hartenberg parametrization and direct kinematics
- Definition and computation of the robot Jacobian
- Inverse kinematics in exact and iterative forms
- Trajectory generation
- Basic position and velocity control modes (trajectory / velocity tracking)

Exercises will involve modelling and simulating various serial manipulators.

Course material

- Slides and labs are available online.
- W. Khalil, and E. Dombre, Modeling, identification and control of robots, Hermes Penton, 2002.

Further reading:

- C. Canudas, B. Siciliano, G. Bastin (editors), Theory of Robot Control, Springer-Verlag, 1996
- J. Angeles, Fundamentals of Robotic Mechanical Systems, Springer-Verlag, New York, 2002.

Keywords

Serial robot, Denavit-Hartenberg, Jacobian, 3D geometry, trajectory generation

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

ADVANCED AND ROBOT PROGRAMMING

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 AUTUMN SEMESTER

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

Objectives

To provide students with the fundamentals of modern programming (with C++) and industrial robot manipulator programming with specialized robot languages.

After completing the course, students will be able to:

- Write a C++ programme from scratch or expand an existing project, using external libraries
- Create their own classes and know how to understand a class interface documentation
- Use tools such as Cmake, Qt Creator, a debugger and a profiler
- Use the STL when needed
- Analyze, program and test complex tasks on industrial robots in V+ language

In robot programming, the students will be able to:

- Analyze moderately complex robot tasks
- Implement the corresponding robot programmes
- Handle robotic tasks involving software interrupts and multiple programmes.

Course contents

C++

- Basic types, STL useful classes (string, vector, pair, map), struct
- Control blocks: if/then/else, for, while, switch
- Functions: argument passing, overloading
- Classes: attributes and methods, inheritance
- Templates, lambda-functions and STL algorithms
- Code organization
- Compilation with Cmake, using external libraries
- Debugger and profiler

Industrial manipulator programming

- The different levels of programming,
- Tools for teaching locations,
- Robots, sensors and flexibility,
- Synchronous vs asynchronous motions, guarded motions,
- Tool-level programming,
- Real-time aspects of robot programming,
- The V+ language, including its real-time aspects and sensor-handling capabilities.

Practical Work: C++ labs are essentially oriented towards developing small to large games and problem-solvers. A number of the exercises will not be covered during the labs but solutions will be given.

As for industrial robot programming, the students will be able to practice with a setup of two Stäubli industrial robots, a Puma 560 and a RX 90 programmable in V+. The robots are equipped with a belt conveyor, and a number of sensors.

Course material

- C. Blume, W. Jakob, Programming Languages for Industrial Robots, Springer Verlag.
- Stäubli: RX Robots Technical Documentation, 2001.
- Bruce Eckel, Thinking in C++, volumes 1 and 2, 2007.

Keywords

C++, V+

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	8 hrs	0 hrs	24 hrs	0 hrs	2 hrs

MECHANICAL DESIGN METHODS IN ROBOTICS

CONTROL AND ROBOTICS – ADVANCED ROBOTICS
YEAR 1 AUTUMN SEMESTER

LEAD PROFESSOR: Stéphane CARO, *stephane.caro@ls2n.fr*

Objectives

This course presents an overview of the robot design process: (i) specifications, (ii) conceptual design, (iii) embodiment design and (iv) detailed design. Particular attention will be paid to the conceptual design phase as it is a distinct phase of the design process and 75% of total product life-cycle cost is committed at that stage. The conceptual design deals with the type-synthesis and evaluation of robot architecture. A focus will be placed on the design of serial and parallel robots.

Course contents

Design is an engineering activity that affects almost all areas of human life, using the laws and insights of science, building upon special experience, and providing the prerequisite for the physical realisation of solution ideas.
This course will deal with all the phases of the design process of a product, namely: task definition, conceptual design, embodiment, detailed design.
Particular attention will be paid to the conceptual design phase as stated above.

The following subjects will be discussed:

- Conceptual design: concept generation, concept evaluation.
- Product design: documentation, product generation, evaluation for function and performance, evaluation for cost, ease of assembly and other measures.
- Computer aided design, use of CAD software.
- The design of robotic production cells.
- Fundamentals of integrated design of control and drive systems taking into account measurement, gearing and transmission systems.

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

- Design serial and parallel robotic manipulators.
- Correctly formulate the information required for conceptual design (requirements),
- Use CAD systems on the basic level for the design of a typical mechanism (serial arm),
- Elaborate the design on general level without consideration of material, drive systems and actuators,
- Generate manufacturing drawings.

The course is evaluated with a final exam and a final project that is conducted by groups of two students. Projects are suggested by the instructor.

Course material

- French, M. J. Conceptual Design for Engineers, 3rd ed., 1999 (Springer)

- Pahl, G. and Beitz, W. Engineering Design: A Systematic Approach, 2nd ed. Wallace, K.M. (editor); Blessing, L., Bauert, F. and Wallace, K.M. (translators), 1996 (Springer-Verlag, London)
- Suh, N.P. The Principles of Design, 1990 (Oxford University Press, Oxford)
- Suh, N.P. Axiomatic Design. Advances and Applications, 2001 (Oxford University Press, Oxford)
- Kong X. and Gosselin, C., Type Synthesis of Parallel Mechanisms, Springer Tracts in Advanced Robotics, 2007.

Keywords

Robot design, conceptual design, CAD modelling, Serial manipulators, Parallel Manipulators

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 - AUTUMN 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. Giving 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 - AUTUMN SEMESTER

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

Objectives

Introduction to Cultural and Communicational English:

- Understand the general concepts of communication English (different levels of language, etc.)
- Build a communicational project
- Develop strategies for enhanced interaction
- Organize, lead and participate in discussions, interviews and meetings
- Behavioral skills in an inter-cultural environment:
- Strengthen engagement and level of conviction
- Develop a capacity to explain and argue
- Acquire notions of corporate culture and values
- Enhance team work

Course contents

Cultural and Communicational English: exercises to explore in practice the areas of culture and communication
Inter-cultural project (for example, documentary project, publishing project: construct a work of fiction or of educational value and experience the complete publishing process)

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