SHAKE THE FUTURE.

CENTRALE NANTES

MASTER OF SCIENCE, TECHNOLOGY AND HEALTH

CONTROL AND ROBOTICS

EMBEDDED REAL TIME SYSTEMS

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

GROUPE CENTRALE

École Centrale de Nantes | 1 rue de la Noë | BP 92101 | F 44321 Nantes Cedex 3
T +33 (0)2 40 37 16 00 | F +33 (0)2 40 37 16 97 | www.ec-nantes.fr

SIGNAL PROCESSING

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
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 – EMBEDDED REAL TIME SYSTEMS
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 – EMBEDDED REAL TIME SYSTEMS
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

EMBEDDED ELECTRONICS

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 1 AUTUMN SEMESTER

LEAD PROFESSOR: Olivier H. Roux, *olivier-h.roux@ec-nantes.fr*

Objectives

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

- understand different synchronous or asynchronous architectures of embedded systems
- interface a microcontroller with a simple environment (LED, motor) and write a programme to control it;
- use VHDL to create the logic circuit used to configure a Complex Programmable Logic Device (CPLD).

Course contents

The first part of the course deals with interfacing a microcontroller:

- interfacing an Arduino with an environment composed of LED, buttons and a motor
- write programmes carrying out simple automatisms controlling this environment

The second part of the course introduces the configuration of a CPLD:

- VHDL Language
- use VHDL to create the logic circuit used to configure a Complex Programmable Logic Device
- control an environment with a Xilinx CoolRunner-II CPLD

Course material

- Philip Koopman, Better Embedded Software Systems, Drumnadrochit Education LLC, 2010
- Volnei A. Pedroni, Circuit Design and Simulation with VHDL, PH, 2011

Keywords

CPLD, Microcontroller, Arduino, VHDL

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	10 hrs	2 hrs	20 hrs	0 hrs	2 hrs

ADVANCED AND ROBOT PROGRAMMING

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
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

EMBEDDED COMPUTING

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 1 AUTUMN SEMESTER

LEAD PROFESSOR: Mikaël Briday, *mikael.briday@univ-nantes.fr*

Objectives

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

- understand the architecture of a microcontroller;
- design a low-level driver to access a peripheral of a microcontroller and deal with microcontroller interrupts;
- design a bare metal application.

Course contents

The first part of the course deals with the software environment for deeply embedded systems:

- cross compiler: bit operations, memory model, common C design rules, low level C and assembly specific attributes
- link script to declare the memory model to the application
- debugging with a JTAG probe (breakpoints, memory watch, etc)

The second part introduces hardware peripherals of a microcontroller to interact with the environment:

- standard GPIO
- timers
- serial communication peripherals
- interrupts

The third part of the module focuses on the design of a bare metal application, including concurrent execution of both software and hardware parts.

Course material

- Philip Koopman, Better Embedded Software Systems, Drumnadrochit Education LLC, 2010
- D. Patterson & J. Hennessy, Computer Organization and Design – ARM Edition, Morgan Kaufmann, 2017

Keywords

Microcontroller, low level C programming, bare metal application.

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

MODERN LANGUAGES - FRENCH

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
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 – Embedded Real Time Systems
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