SHAKE THE FUTURE.

CENTRALE NANTES

MASTER OF SCIENCE, TECHNOLOGY AND HEALTH

CONTROL AND ROBOTICS

EMBEDDED REAL TIME SYSTEMS

YEAR 2
AUTUMN SEMESTER

PROGRAMME SUPERVISORS:
DIDIER LIME, OLIVIER-HENRI ROUX

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

GROUPE CENTRALE

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EMBEDDED SOFTWARE SYSTEMS

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 2 AUTUMN SEMESTER

LEAD PROFESSOR: Jean-Luc Béchennec, *jean-luc.bechennec@ls2n.fr*

Objectives

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

- Understand how an embedded operating system works
- Use advanced C programming
- Use formal methods in the design process

Course contents

Introduction to ESS

- Specificities of embedded software systems
- Embedded / Real-time operating systems

RTOS internals

- Processor modes
- System calls
- Interrupt handling
- Context switching

Advanced C programming

- Datatypes and memory mapping. Type casting
- Pointers, pointer arithmetics
- Mixing C and assembly language

Applied formal methods

- Software modelling
- Software / hardware modelling.

Course material

Keywords

Embedded software, RTOS, low level programming.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	12 hrs	9 hrs	9 hrs	0 hrs	2 hrs

EMBEDDED SYSTEMS DESIGN

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 2 AUTUMN SEMESTER

LEAD PROFESSOR: Audrey Queudet, *audrey.queudet@univ-nantes.fr*

Objectives

The main objective of the course is for students to become familiar with the typical problems and constraints that arise when designing and developing embedded systems.

The first part of the course aims at acquiring an understanding of the basic Linux operating system, highlighting areas of concern for embedded Linux systems development. We will address the testing, booting and configuring of embedded Linux systems including embedded cross-development and target board considerations.

The second part of the course focuses on embedded real-time systems which have energy limitations. The issue particularly concerns small electronic devices, such as wireless sensor nodes and cyber-physical objects. The objective is to present their special operational features, and accordingly demonstrating the necessity of implementing new techniques of real-time scheduling and power management.

Course contents

The course will be composed of the following parts:

- Introduction to embedded systems: Challenges of embedded systems, embedded system design process, Modelling of real-time embedded systems
- Linux operating system: strengths and weaknesses of Linux in embedded systems, Linux embedded market overview, Linux filesystem overview, configuring, (cross)compiling and booting a Linux kernel, toolchain generation tools, Linux tools for embedded systems (bootloaders, optimized libraries, Busybox)
- Setting a simple Buildroot-based embedded Linux: toolchain configuration, package selection, system configuration, kernel and bootloader configuration, building root filesystem image, customization.
- Real-time solutions for Linux: real-time patchs, Xenomai architecture.
- Designing autonomous embedded systems: hardware and software components of an autonomous system, harnessing ambient energy for embedded systems
- Classical approaches to minimize energy consumption in embedded systems: dynamic power management, DVFS (Dynamic Voltage Frequency Scaling)
- Real-time scheduling and power management in autonomous systems that rely on renewable energy harvesting

Course material

- Pierre Ficheux, Linux embarqué : Mise en place et développement, Eyrolles, 2017
- Maryline Chetto and Audrey Queudet, Energy autonomy of real-time systems, ISTE Press - Elsevier, 2016

Keywords

Embedded systems, embedded Linux, cross-development, autonomous systems, power management, energy harvesting

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	20 hrs	4 hrs	6 hrs	0 hrs	2 hrs

AUTOMATED PLANNING

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 2 AUTUMN SEMESTER

LEAD PROFESSOR: Loïg Jezequel, *loig.jezequel@univ-nantes.fr*

Objectives

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

- Describe a real-world planning problem in a language understandable by modern planners
- Understand best-first search planner advantages and limitations
- Choose a heuristic for solving a given planning problem
- Implement a simple planner from scratch

Course contents

Lectures will be organized into three parts:

Part 1 - Planning problems representation(s).
In this part we will focus on (propositional) languages for describing planning problems, such as STRIPS and PDDL. We will show how the state-space of a planning problem described in such a language can in fact be represented as a graph. This will bring some concerns as to the theoretical complexity for solving planning problems.

Part 2 - Best-first search algorithms and heuristics.
In this second and main part of the course, we will present the famous A* algorithm and explain how it evolved towards the current best-first search algorithms. These algorithms being heuristics based, we will present a few classes of heuristics (such as abstraction-based heuristics, or landmark-based heuristics).

Part 3 - Other approach to planning.
To complete this overview of planning, we will briefly discuss other (than A*) approaches to planning. In particular, we will focus on partial order techniques (mainly Graphplan), factored planning, and SMT based planning.

Exercises will be split into two parts:

Part 1 - Comparison of up-to-date planning tools.
In this part we will evaluate on a set of benchmarks a few state-of-the-art tools selected in the current literature on planning.

Part 2 - Implementation of a planner.
This part will be the most time-consuming. The objective will be to implement, from scratch, a best-first search-based planner.

Course material

- Judea Pearl. Heuristics: Intelligent Search Strategies for Computer Problem Solving. 1986.
- Blai Bonet and Hector Geffner. Planning as Heuristic Search. Artificial Intelligence, 2001.

- Malik Ghallab, Dana Nau, and Paolo Traverso. Automated Planning: Theory and Practice. Morgan Kaufmann, 2004.
- Malik Ghallab, Dana Nau, and Paolo Traverso. Automated Planning and acting. Cambrige, 2016.
- Stuart Russel and Peter Norvig. Artificial Intelligence: A Modern Approach, Third Edition. Pearson, 2016.

Keywords

Artificial Intelligence, automated planning, heuristic search

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	18 hrs	12 hrs	0 hrs	hrs	2 hrs

REAL TIME SCHEDULING

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 2 AUTUMN SEMESTER

LEAD PROFESSOR: Maryline Chetto, *maryline.chetto@univ-nantes.fr*

Objectives

The course deals with the problem of achieving timing correctness in real-time systems, which means guaranteeing that the system reacts within the timing requirements through an adequate real-time scheduler. The course describes the most common scheduling methods for periodic tasks and aperiodic tasks, resource access control protocols and overload handling approaches.

Course contents

The course will be composed of the following parts:

- Introduction: Concepts on real-time computing, Role of the scheduler in the Real-Time Operating System, Modelling of real-time tasks, Metrics for performance evaluation
- Scheduling periodic tasks: Fixed priority, Dynamic priority, Scheduling with precedence constraints, Schedulability testing, processor demand analysis
- Aperiodic task servicing: Background, Polling, Sporadic, Slack Stealing, Total Bandwidth
- Resource access control protocols: the priority inversion problem, Non-preemptive protocol, Highest Priority protocol, Priority Inheritance protocol, Stack Resource Policy, Schedulability analysis
- Overload management: Quality of Service, the Skip-Over model, the (m,k) firm model, the imprecise computation model, the Deadline Mechanism

Course material

- Maryline Chetto, Real-time Systems Scheduling 1: Fundamentals, Wiley, 2014
- Jane Liu, Real-time systems, Pearson, 2000

Keywords

Scheduling algorithm, periodic tasks, aperiodic task servicing, resource access control, overload management, timing fault tolerance.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	20 hrs	6 hrs	4 hrs	0 hrs	2 hrs

FORMAL MODELLING AND VERIFICATION

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 2 AUTUMN SEMESTER

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

Objectives

The aim of this course is to provide an understanding of the benefits and challenges of formal modelling and verification for complex systems, as well as the ability to use existing verification tools in practice.

Course contents

In this course, we study how complex dynamic systems and the properties they should satisfy can be modelled using mathematically-grounded formalisms. Using finite state machines and temporal logics we investigate algorithms that perform automatic verification (model-checking) and, to some extent, synthesis on those systems. We study, in particular, the case of timed systems, in which the occurrence of discrete events is subject to timing constraints. The corresponding formalisms are very useful to assert the soundness of real-time embedded systems. The theoretical aspects of the course will be illustrated in practice, using the model-checker software tool Uppaal.

Course material

Chistel Baier and Joost-Pieter Katoen. Principles of Model Checking. MIT Press. 2008

Keywords

Modelling of complex systems, Model-checking, Synthesis, Temporal Logics

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	16 hrs	6 hrs	8 hrs	0 hrs	2 hrs

PETRI NETS

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 2 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:

- Model a reactive and concurrent system with a Petri Net
- Verify the boundedness, the reachability of a state and the coverability of Petri Nets
- Model a real time system with a Time Petri Net (TPN)
- Compute the state space of the TPN
- Model a property with an observer
- Express and verify a timed property with the logic TCTL (Timed Computation tree logic)
- Manipulate a Petri Net model checker

Course contents

Part 1: A Petri net, also known as a place/transition (PT) net, is one of several mathematical modelling languages for the description of distributed and embedded systems. It is a class of discrete event dynamic system. This course provides an introduction to Petri Nets. Firstly, after a set of basic definitions, a classification of Petri nets is proposed. Then, properties are exhibited whether they are dependant of the initial marking or not. A general algorithm is then stated to compute a set of properties. The last section covers the implementation of theoretical concepts, established above, in a functional language.

Part 2: In real-time and embedded systems, the correctness depends on the output and also on the time in which this output is produced. Therefore, the verification of such systems requires the determination of quantitative temporal properties, besides qualitative properties associated with its logical correctness. Time Petri Net (TPN) models have been widely used for the specification and verification of real-time and embedded systems. Semantics, expressiveness and properties of TPN are exhibited. The last section addresses reachability analysis for Time Petri Nets based on the state space computation.

Course material

- Wolfgang Reisig, Understanding Petri Nets - Modeling Techniques, Analysis Methods, Case Studies, Springer-Verlag, 2013
- Louchka Popova-Zeugmann, Time and Petri Nets, Springer-Verlag, 2013

Keywords

Modelling of concurrent systems, Model-checking

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	16 hrs	6 hrs	8 hrs	0 hrs	2 hrs

PROJECT

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 2 AUTUMN SEMESTER

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

Objectives

The purpose of this project is for the student to apply the theories and techniques studied during the courses, according to his/her career plan. It is, therefore, either a technical project for an industrial application, or an introduction to research to consider a research profession.

Course contents

This project can be either a technical project or an initiation to research: latest developments, proposals, experiments, analysis and prospects etc.
It is an extended individual project (including scientific support, bibliography, scientific study)

Course material

Keywords

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

MODERN LANGUAGES - FRENCH

CONTROL AND ROBOTICS – EMBEDDED REAL TIME SYSTEMS
YEAR 2 - 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. Those who already completed the first year of the French course will be prepared for working in a French business environment.

Course contents

Two different tracks are proposed: track 1 for students newly arrived at Centrale Nantes and track 2 for students who have completed the first year of the French course.

Track 1:
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

Track 2:
This track follows on directly from the first-year French course, developing and completing the concepts studied thus far. The main themes are: housing, health and work. These topics will help prepare students for their future work environment. For example, housing is explored in the form of a search for accommodation upon arrival in a new city.

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, business vocabulary

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 2 - AUTUMN SEMESTER

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

Objectives

Team-building and Communicational English:

- Understand the general concepts of team-building
- Build a team-building project
- Understand and nurture the creative process
- Enhance self-belief and self-empowerment

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

Field-related or inter-cultural project (for example, construct content for inter-cultural team-building activities; example WIOBOX website 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).

Keywords

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

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	14 hrs	16 hrs	0 hrs	0 hrs	2 hrs