ENGINEERING PROGRAMME

2021-2022

Year 2 / Year 3

Specialisation option

Embedded Control and Power Grids

OD C2SYST2E

PROGRAMME SUPERVISOR

Mohamed Assaad HAMIDA

Autumn Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 73 / 93	12	Core course	ACSEL INFEM METOD SSDYN	Analysis and control of power systems Embedded Systems Software Control methodology of linear systems Simulation of dynamical systems - rapid prototyping
UE 74 / 94	13	Core course	ANCOS CAVAN IDFIL MODEV P1C2SYS	Advanced control of non-linear systems Advanced control of linear systems Systems identification and signal filtering Modeling and verification of embedded systems Project 1

Spring Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 103 / 83	14	Core course	CONUM ETERE IMPDI P2C2SYS SYSIT	Digital design on FPGA Real-Time Operating Kernel Discrete time implementation of control laws Project 2 Interconnected systems

Analysis and control of power systems [ACSEL]

LEAD PROFESSOR(S): Bogdan MARINESCU

Objectives

Provide the basics on power grid dynamic behavior. The so-called model-based approach is used to analyse the interaction between several elements of a power grid.

After this class, the students should be able to:
- Understand and analyse the main dynamic phenomena of power systems
- Solve a control problem for a generator or another power grid element
- Use two professional software tools to analyse and simulate large-scale interconnected power-grids
- Be prepared for research (Master 2 or PhD) or engineering work in the field of power systems (for companies such as RTE, EDF or manufacturers such as Alstom, Siemens, ABB)

Course contents

Content:
-Basic notions of power systems (Kirchoff laws, load-flow computation)
-Dynamic models of the main elements of a power grid (generators, line, loads)
-The main dynamics: transient, small-signal and voltage stability
-The main regulations (voltage/frequency controls, damping of inter-area oscillations)
- grid connection specifications: industry lecture (RTE R&D)

Laboratory work:
-Load-flow; first-level regulations
-High-level regulations
-Modal analysis and damping of inter-area modes

Course material

P. Kundur, Power System Stability and Control, McGraw-Hill, 1994.
G. Rogers, Power System Oscillations, Kluwer Academic, 2000.
M. Ilic, J. Zaborsky, Dynamics and Control of Large Electric Power Systems, Wiley, 2000.
P.W. Sauer, M.A. Pai, Power Systems Dynamics and Stability, Prentice Hall, 1998.
J. Cladé, Electrotechnique, Eyrolles, 1989.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	18 hrs	2 hrs	11 hrs	0 hrs	1 hrs

Embedded Systems Software [INFEM]

LEAD PROFESSOR(S): Mikael BRIDAY

Objectives

Embedded systems are subject to many constraints and are in close interaction with processes. Some embedded systems, for example in avionics or the automotive sector, are particularly critical and with strong real-time constraints.
The objective of this course is to approach these embedded systems at 2 levels of abstraction:
- with a direct programming on embedded board (baremetal);
- using a real-time operating system (RTOS) that offers higher level services;

In the latter case, multi-tasking programming and synchronization mechanisms between tasks are addressed.

Course contents

Direct programming on embedded board:
- Representation of the information ;
- Structure of a micro-controller board;
- Programming of parallel, analog inputs/outputs;
- Programming of integrated counters, of a PWM ;
- Interruptions (with associated synchronization problems).

Use of a RTOS:
- Functional decomposition of embedded systems;
- Software architecture of a control system;
- Synchronous and asynchronous implementation: role of the executive;
- General structure of an executive;
- Primitives of synchronization, event and time management;
- Examples of Real Time applications.

Course material

- D. Patterson & J. Hennessy, Computer Organization and Design – ARM Edition, Morgan Kaufmann, 2017
- Les systèmes d'exploitation temps réel - Techniques de l'Ingénieur R5080 et R5082 - J.P. Elloy Y. Trinquet

Assessment

Collective assessment: EVC 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	4 hrs	12 hrs	0 hrs	0 hrs

Control methodology of linear systems [METOD]

LEAD PROFESSOR(S): Guy LEBRET

Objectives

To define a control methodology for linear multi-input multi-output systems based on the state approach, the concept of the standard problem.

Course contents

- Introduction to the concepts of the state space approach, controllability, observability, pole placement using state feedback or estimated state feedback.
- Specification of a control problem in terms of the standard problem
- Description of technical tools: RPIS (Regulator Problem with Internal Stability), robustness using Loop Transfer Recovery technique.
- Description of the methodology and application to the SISO case (choice of poles).

Course material

Ph. de Larminat, 'Automatique, Commande des Systèmes Linéaires', Hermés
Ph. de Larminat, 'Le Contrôle d'Etat Standard', Hermés.
K. Zhou, 'Essential on Robust Control', Prentice Hall.
G. Lebret, 'Méthodologie de la Commande', Polycopié Centrale de Nantes.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	2 hrs	8 hrs	0 hrs	2 hrs

ENGINEERING - OD C2SYST2E

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

Simulation of dynamical systems - rapid prototyping [SSDYN]

LEAD PROFESSOR(S): Franck PLESTAN

Objectives

The main objective of this course is to present problems and solutions related to the simulation of dynamical systems. First of all, it consists in presenting some integration algorithms which can be used to solve differential equations describing systems dynamics. Then, several software solutions (Matlab / Simulink , AMESIM) are presented and implemented. A significant part of this course is delivered by speakers from software companies.

Course contents

- Mathematical reminder of digital integration techniques
- Introduction to simulation software (through practical sessions)
 + Matlab / Simulink
 + AMESIM

Course material

+ Matlab documentation, The Mathworks
+ Amesim documentation, LMS / Siemens

Assessment

Collective assessment: EVC 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	12 hrs	0 hrs	20 hrs	0 hrs	0 hrs

Advanced control of non-linear systems [ANCOS]

LEAD PROFESSOR(S): Franck PLESTAN

Objectives

Real systems are often nonlinear, the objective of this lecture is to give a basic understanding of nonlinear control theory without approximation. This course takes a modern approach to analysis and control. Numerous applications (robots, electric actuators, etc.) are used throughout the course to illustrate the relevance of the course. An introduction to robust nonlinear control is made with Sliding Mode Control (order 1 et 2) and Backstepping Control.

Course contents

- Introduction to the algebraic approach for non-linear control theory and its tools.
- Structural analysis, relative degree, controllability and observability concepts. Nonlinear system inversion.
- Feedback Control: feedback linearization, noninteracting control.
- Nonlinear Observer design.
- Introduction to robust nonlinear control : Sliding Modes, Backstepping Control.

Course material

- "Nonlinear Control Systems-3rd edition", A. Isidori, Springer, New York, 1996.
- "Nonlinear systems", Hassan K. Khalil, Prentice Hall, New Jersey, 2002.
- "Sliding mode control and observation", Y. Shtessel, C. Edwards, L. Fridman, A. Levant, Springer, New York, 2016.

Assessment

Collective assessment: EVC 1 (coefficient 0.2)

Individual assessment: EVI 1 (coefficient 0.8)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	2 hrs	8 hrs	0 hrs	2 hrs

Advanced control of linear systems [CAVAN]

LEAD PROFESSOR(S): Bogdan MARINESCU

Objectives

The objective is to provide methods for analysis and control of complex systems which have several inputs/outputs and many state variables. Building on the fundamentals previously acquired on state-space formalism, this course presents more advanced techniques to ensure the performance and robustness required in industrial specifications: reference tracking, disturbance rejection, oscillations damping, compensation of the effect of data transmission delays.

Analysis techniques are also presented not only to facilitate control, but also for modeling and simulation purposes. The student will learn how to reduce large-scale dynamic models, to analyse the structure of a generalized system, e.g., to chose its inputs, and to distinguish several representations of the same dynamical system given in its most general form.

In addition to theoretical examples, two industrial cases are presented in detail in order to give a realistic view of the application of these methods in a real industrial context.

Course contents

Optimal control
- Pontryagin's maximum principle
- Linear quadratic (LQ) control
- H2, H∞; control
- predictive control

Analysis
- intrinsic representation of a dynamical system
- structure and inputs
- model reduction

Laboratory work and exercises.

Course material

Optimal control:

F.L. Lewis, V.L. Syrmos, Optimal Control, 2nd edition 1995 Wiley.
J.M. Dion, D. Popescu, Commande optimale - conceptions optimisées des systèmes, Diderot 1996

Predictive control:

P. Boucher, D. Dumur, La commande prédictive - avancées et perspectives, Hermes-Lavaoisier 2006
J. Richalet, Pratique de la commande prédictive standard, Hermes 1993.
H2, H∞, LQ, réduction de modèles
S. Skogestad, I. Postlethwaite, Multivariable Feedback Control - Analysis and Design, 2nd edition Wiley 2005.
K. Zhou, J.C. Doyle, K. Glover, Robust and Optimal Control, Prentice-Hall 1996.
K. Zhou, J.C. Doyle, Essential of Robust Control, Prentice Hall 1998.

Analysis of generalized systems:

H. Bourlès, B. Marinescu, Linear Time-Varying Systems, Algebraic-Analytic Approach, LNCIS Springer 2011

H. Bourles, Linear Systems, Wiley 2010.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	2 hrs	8 hrs	0 hrs	2 hrs

Systems identification and signal filtering [IDFIL]

LEAD PROFESSOR(S): Said MOUSSAOUI

Objectives

Signal filtering is a basic operation in signal processing which allows, for instance, undesired content to be deleted. The first part of this course deals with methods to design a linear filter and their application for the processing of real signals.

The second part of the course focuses on experimental signal modelling using linear models. It provides a detailed description of the signal identification chain from data acquisition to model validation.

Course contents

1. Linear filtering
- principles of linear filtering
- filter characterization in the frequency domain
- analog filter synthesis
- numerical filter synthesis (FIR, IIR)

2. System identification
- system modelling and identification methodology
- non-parameteric identification models and methods
- review of linear models for system modelling (ARX, ARMAX, OE)
- parameter estimation methods (least squares, instrumental variable, maximum likelihood)
- continuous-time identification methods

3. Applications
- audio signals filtering
- use of the system identification toolbox
- electromechanical system identification

Course material

[1] L. Ljung, System identification, Theory for the user, Prentice Hall, Englewood Cliffs, 1987
[2] . Soderstrom and P. Stoica, System identification, Prentice Hall, 1989
[3] H. Garnier and L. Wang, Identification of continuous-time models from sampled data, Springer, 2008
[4] H. Kwakernaak and R. Sivan, Modern signals and systems, Prentice Hall, Englewood Cliffs, 1991

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	4 hrs	10 hrs	0 hrs	2 hrs

ENGINEERING - OD C2SYST2E

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

Modeling and verification of embedded systems [MODEV]

LEAD PROFESSOR(S): Olivier Henri ROUX

Objectives

Embedded systems are subject to constraints and some interact closely with critical processes which have an impact on human life. The development of such systems must ensure proper function or repair under all circumstances.

Formal models and methods provide guarantees as to operational safety, hence offering increased confidence in these systems. Moreover, some embedded systems such as avionics and automotive systems are particularly critical with real time constraints.

This course presents the different formal models and formal verification methods (model checking) from discrete (such as finite automata) to timed models.

Course contents

1) Verification of discrete systems (finite automata, Petri nets)
2) Timed models: symbolic abstraction of the state space, model checking.
3) Parametric models: synthesis of parameters

Lab work: Use of UPPAAL and ROMEO model checkers

Course material

Claude Jard and Olivier H. Roux, editors. Communicating Embedded Systems - Software and Design. ISTE Publishing / John Wiley, October 2009. ISBN:978-1-8482-1143-8.

Claude Jard and Olivier H. Roux, editors. Approches formelles des systèmes embarqués communicants. Traité IC2. Hermes Lavoisier, 2008. ISBN: 978-2-7462-1942-7.

Assessment

Collective assessment: EVC 1 (coefficient 0.2)

Individual assessment: EVI 1 (coefficient 0.8)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	2 hrs	8 hrs	0 hrs	2 hrs

ENGINEERING - OD C2SYST2E

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

Project 1 [P1C2SYS]

LEAD PROFESSOR(S): Mohamed Assaad HAMIDA

Objectives

80 hours in total are set aside to project work within the specialisation. This is broken down as follows:

- 32 hours in the Autumn semester from the end of November to the end of January: Project 1.
- 48 hours in the Spring semester, beginning of February to the end of March: Project 2.

Each project is carried out in pairs and takes of the form of either a single 80-hour project with an interim evaluation after 32 hours (written report or oral presentation), or two separate projects of 32 and 48 hours respectively (priority is given to the single project). The final evaluation is a presentation.

Teachers and researchers, industrial engineers, students who have contact with companies after their internship, can propose project topics.

Course contents

Examples of past projects:
- Project proposed by students in collaboration with the association &guil;Les Machines de L'Iles&guil;.
- Project, partnership with the company QIVIVO (regulation of the temperature of a house).
- Project linked to a contract with the company STX: steering sails of a diesel-hybrid-sail ship.
- Projects linked to the RTE-Centrale Nantes Chair: Analysis of the dynamics of a electrical generator coupled to a power line.
- Control of a wheeled inverted pendulum (Segway type): application to the NXTway (lego Mindstorm), and Balanduino.
- Robust control of a 3DDL helicopter subject to wind gusts: application of a prototype of the IRCCyN Institute.
- Control of a "pico brewery"; with arduino micro controller.

Course material

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	1	0 hrs	0 hrs	0 hrs	32 hrs	0 hrs

Digital design on FPGA [CONUM]

LEAD PROFESSOR(S): Olivier Henri ROUX

Objectives

Objectives:
- Master the specificities and characteristics of synchronous approaches
- Be able to implement a synchronous system and program it with different languages including VHDL

Means :
- Study of synchronous vs asynchronous logic systems
- Study of hardware architecture and VHDL language.

Practical work on FPGA target for the control of a non-simulated operative part

Course contents

1) Synchronous hardware architectures
2) VHDL and FPGA

Course material

https://en.wikipedia.org/wiki/VHDL

Assessment

Collective assessment: EVC 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	8 hrs	4 hrs	20 hrs	0 hrs	0 hrs

ENGINEERING - OD C2SYST2E

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

Real-Time Operating Kernel [ETERE]

LEAD PROFESSOR(S): Jean-Luc BECHENNEC

Objectives

The goal of the course is to provide an understanding of the real-time operating systems (RTOS) compatible with OSEK-VDX and AUTOSAR standards. These two standards are used to design embedded electronic control units in automobiles. The knowledge acquired during lectures will be applied to embedded devices via the development of small applications designed to explore all facets of the operating system.

Course contents

Lectures on the RTOS compatible with OSEK-VDX and AUTOCAR and implementation:

- Task management
- Event management
- Alarms and periodic tasks
- Mutual exclusion and PCP protocol
- inter-task communication
- schedule tables

Course material

OSEK-VDX Specification: http://www.osek-vdx.org
AUTOSAR Spécification: http://www.autosar.org

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	8 hrs	22 hrs	0 hrs	0 hrs	2 hrs

Discrete time implementation of control laws [IMPDI]

LEAD PROFESSOR(S): Guy LEBRET

Objectives

During the synthesis of analog, continuous control laws, no account is taken of sampling and reconstruction of signals, among other points. The aim of this course is to describe the specificities of numerical control laws and consequently the technical change to introduce in the synthesis and implementation of digital control laws. Lab work will provide the opportunity to put this into practice with classical numerical PID.

Course contents

- Sampling and reconstruction of signals - Analog-Digital and Digital-Analog devices. Choice of sampling period.
- The z transform and the transfer functions of discrete linear systems.
- From analog systems to the digital control loop.
- Digitalisation of analog control laws.
- Direct synthesis of control laws for discrete systems.
- Lab work on classical numerical PID.

Course material

Roland Longchamp, Commande Numérique des systèmes dynamiques - méthode de base (tome1)', Presse polytechnique et universitaires Romandes. 2010 (3e édition).

Assessment

Collective assessment: EVC 1 (coefficient 0.6)

Individual assessment: EVI 1 (coefficient 0.4)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	15 hrs	0 hrs	16 hrs	0 hrs	1 hrs

Project 2 [P2C2SYS]

LEAD PROFESSOR(S): Mohamed Assaad HAMIDA

Objectives

80 hours in total are dedicated to project work within the specialisation. This is broken down as follows:

- 32 hours in the Autumn semester from the end of November to the end of January: Project 1.
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Each project is carried out in pairs and takes of the form of either a single 80-hour project with an interim evaluation after 32 hours (written report or oral presentation), or two separate projects of 32 and 48 hours respectively (priority is given to the single project). The final evaluation is a presentation.

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Course contents

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- Projects linked to the RTE-Centrale Nantes Chair: Analysis of the dynamics of a electrical generator coupled to a power line.
- Control of a wheeled inverted pendulum (Segway type): application to the NXTway (lego Mindstorm), and Balanduino.
- Robust control of a 3DDL helicopter subject to wind gusts: application of a prototype of the IRCCyN Institute.
- Control of a &guil;pico brewery&guil; with arduino micro controller.

Course material

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	2	0 hrs	0 hrs	0 hrs	48 hrs	0 hrs

Interconnected systems [SYSIT]

LEAD PROFESSOR(S): Mikael BRIDAY

Objectives

Understand how to perform data exchange between microcontrollers: asynchronous serial link, I2C bus, SPI and CAN, Ethernet, Wifi, radio link.

The course and TP are based on Adafruit Feather M0 Wifi and Teensy 3.6 boards, programmed via the Arduino IDE.

Course contents

Arduino-type systems
Universal Asynchronous Receiver Transmitter
I2C bus
SPI bus
Transmission line
CRC (Cyclic Redundancy Checksum)
CAN (Controller Area Network) network
TCP / IP protocol stack
Wifi link
Radio link

Course material

SPI : https://en.wikipedia.org/wiki/Serial_Peripheral_Interface
I2C : https://en.wikipedia.org/wiki/I2C
CAN : https://en.wikipedia.org/wiki/CAN_bus
UART : https://en.wikipedia.org/wiki/UART
Ethernet : https://en.wikipedia.org/wiki/Ethernet
Wifi : https://en.wikipedia.org/wiki/Wi-Fi

Assessment

Collective assessment: EVC 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	0 hrs	22 hrs	0 hrs	0 hrs