SHAKE THE FUTURE.

CENTRALE NANTES

ENGINEERING PROGRAMME

SPECIALISATION

EMBEDDED CONTROL AND POWER GRIDS

AUTUMN SEMESTER

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

GROUPE CENTRALE

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EMBEDDED SYSTEMS SOFTWARE

EMBEDDED CONTROL AND POWER GRIDS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Pierre MOLINARO

Objectives

Embedded systems are subject to many constraints and interact closely with processes.
Some embedded systems such as in avionics and automotive systems are particularly critical and have significant real-time constraints.

To ensure compliance with requirements and facilitate exchanges with the environment, embedded micro-controller software often includes a real-time operating system (RTOS) which is a multitasking operating system for real-time applications.

Course contents

- Data Representation;
- Micro-controller card structure;
- Logic input/output; analogic input/output;
- Timer / counter programming; PWM;
- Interrupts;
- Architectural decomposition of embedded controllers;
- Software and operational architecture;
- Synchronous and asynchronous implementation: executive kernel services;
- Executive kernel structure;
- Synchronization primitives, time and task management primitives;
- Real-time applications.

Course material

Les systèmes d'exploitation temps réel - Techniques de l'Ingénieur R5080 et R5082 - J.P. Elloy Y. Trinquet.

Keywords

Logic/Analogic Input/Output, Interrupts, Executive kernel, Synchronization, Synchronous implementation, Asynchronous implementation.

Links with other programmes

Courses dealing with automatic control applications.

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	16 hrs	8 hrs	8 hrs	0 hrs

CONTROL METHODOLOGY OF LINEAR SYSTEMS

EMBEDDED CONTROL AND POWER GRIDS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Guy LEBRET

Objectives

To define a control methodology for linear multi input / multi ouput 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 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 the 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.

Keywords

Linear Systems, Controllability, Observability, State feedback, Estimated State Feedback, Pole Placement, The Standard Problem, LTR Technique.

Links with other programmes

From Measurement to Control, first year course
Other courses in this specialisation: Advanced control of non-linear systems, Analysis and Control of Power Systems, Synchronous automation and supervision.

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	20 hrs	2 hrs	8 hrs	0 hrs

SIMULATION OF DYNAMICAL SYSTEMS - RAPID PROTOTYPING

EMBEDDED CONTROL AND POWER GRIDS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: 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 in order to solve differential equations describing systems dynamics. Then, several software solutions (Matlab / Simulink , AMESIM , Labview) 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
+ Labview

Course material

Matlab documentation, The Mathworks
Labview documentation, National Instruments
Amesim documentation, LMS / Siemens

Keywords

Links with other programmes

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	12 hrs	0 hrs	20 hrs	0 hrs

ANALYSIS AND CONTROL OF POWER SYSTEMS

EMBEDDED CONTROL AND POWER GRIDS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: 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.

Keywords

analysis, control, power grids, transient/voltage/small signal stability

Links with other programmes

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	18 hrs	2 hrs	11 hrs	0 hrs

SYSTEMS IDENTIFICATION AND SIGNAL FILTERING

EMBEDDED CONTROL AND POWER GRIDS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Said MOUSSAOUI

Objectives

The aim of this course is to focus on:

- methods of linear filter synthesis and their application for the processing of real signals
- tools for dynamical system representation using linear models
- existing techniques for linear system identification

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 modeling and identification methodology
   - non-parameteric identification models and methods
   - review of linear models for system modeling (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] T. 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

Keywords

Dynamical system, system modeling, identification, signal filtering, filter synthesis

Links with other programmes

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	16 hrs	4 hrs	10 hrs	0 hrs

Modeling and verification of embedded systems

Embedded Control and Power Grids, Engineering programme specialisation
Autumn Semester

Professor: 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.

Keywords

Formal methods, model checking, verification, finite automata, Petri nets

Links with other programmes

Embedded Systems course

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	**3**	**20 hrs**	**2 hrs**	**8 hrs**	**0 hrs**

PROJECT 1

EMBEDDED CONTROL AND POWER GRIDS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Guy LEBRET

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.
- 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 Les Machines de LIles.
- 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

Keywords

Projects

Links with other programmes

All courses of the specialisation

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	1	0 hrs	0 hrs	0 hrs	32 hrs

ADVANCED CONTROL OF LINEAR SYSTEMS

EMBEDDED CONTROL AND POWER GRIDS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: 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

- Pontryagins 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.

Keywords

optimal control, predictive control, model reduction, generalized systems, LQG/H2/H∞; control

Links with other programmes

The state-space formalism presented in Control Methodology of linear systems is further developed end exploited here.

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	20 hrs	3 hrs	8 hrs	0 hrs

ADVANCED CONTROL OF NON-LINEAR SYSTEMS

EMBEDDED CONTROL AND POWER GRIDS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Alain GLUMINEAU

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 & 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

- Eduardo Aranda-Bricaire, Linéarisation par bouclage des systèmes non linéaires, Thèse de Doctorat, Ecole Centrale de Nantes / Université de Nantes, 10 June 1994.
- Gildas Besancon, Contributions à l'étude et à l'observation des systèmes non linéaires avec recours au calcul formel, Thèse de l'Institut national polytechnique de Grenoble, Grenoble, FRANCE
- Yvonne Choquet-Bruhat, Cecile DeWitt-Morette Professor, Analysis, Manifolds and Physics: Partie. 1 North Holland; Édition: 2 (1 May 1982), ISBN-10: 0444860177, ISBN-13: 978-0444860170
- Alain Glumineau : Solutions algébriques pour l'Analyse et le Contrôle des Systèmes Non Linéaires, Doctorat d'Etat, discipline Sciences, spécialité: Automatique, E.C.N./ Université de Nantes, novembre 1992, hal tel-01112114.
- Alain Glumineau, Introduction to Analysis and Control of Nonlinear Systems, Tempus Summer School, Bratislava, Slovak Technical University, 1997.
- Alberto Isidori, Nonlinear control systems: an introduction (2nd ed.), Springer-Verlag New York, Inc. New York, NY, USA , ISBN:0-387-50601-2, 1989.
- Riccardo Marino and Patrizio Tomei, Nonlinear control design. - London: Prentice Hall, ISBN 0-13-342-635-1,1995.
- Frank Plestan, PhD, Ecole Centrale de Nantes, Linéarisation par injection d'entrée-sortie généralisée et synthèse d'observateurs, 3 October 1995.
- Sliding Mode Control in Engineering, Marcel Dekker, W. Perruquetti & J.P. Barbot, 2002, ISBN: 0-8247-0671-4
- Constructive Nonlinear Control, R. Sepulchre, M. Jankovic, P.V. Kokotovic, 313 pages, Communications and Control Engineering, Springer edition, ISBN: 3540761276.

Keywords

Nonlinear System, Control, Observation, agebraic appoach, Robuste control, Sliding Mode Control, Backstepping Control

Links with other programmes

Methodology for linear control.

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	20 hrs	2 hrs	0 hrs	8 hrs