MASTER ISC : INGENIERIE DES SYSTEMES COMPLEXES

PARCOURS Robotique et Objets Connectés (ROC)

ECS MASTER: Engineering of Complex Systems

OPTION: Robotics and Connected Objects (RCO)

SYLLABUS

Semester 1

TU 12: Robotic modeling
- Modeling of mechanical systems
- Modeling of marine systems

TU 13: Linear systems and control
- Control theory of multi-variable linear systems (common course with VISTA)

TU 14: Learning
- Unsupervised learning
- Supervised learning
- Reinforcement learning

TU 15: Electronics & Telecommunication
- Analog signal processing
- Electronics for radiocommunication
- Embedded digital electronics

Semester 2

TU 22: Mechanical robotics
- Actuation and perception chain
- Biomechanics

TU 23: Optimal control
- Optimization techniques (common course with VISTA)
- Non linear control theory

TU 24: Statistical deep learning
- Vision-based deep learning
- Multimodal perception

TU 25: Embedded and connected systems
- Digital sensors and buses
- Networks and wireless communication
- Instrumentation and sensors

Semester 3

TU 32: Robotics and applied non linear control
- Underwater drones
- Parallel robotics
- Bio-inspired robotics
- Robotic control and planning
- Applied non linear control

TU 33: Applied artificial intelligence
- Simultaneous Localization and mapping
- Behavior, decision-making and prediction

TU 34: Internet of Things – Connected objects
- Real time systems and security
- Applications with connected objects

TU 12 : Modeling of mechanical systems

Lecture: 14h, tutorial work: 9h, practical work: 6h

ECTS: 3

Objectives

Know how to model the dynamical behavior of a manufacturing robot, characterize and mathematically model an actuated kinematic chain in terms of forces, velocities, and power.
Know the control principles for a robotic system.

Content

• classification of rigid kinematic chains.
• Introduction to homogeneous coordinates.
• Geometric and kinematic modeling of serial and parallel robots.
• Ellipsoids of power/constraints.
• Dynamical modeling (Lagrange, Newton/Euler, Hamilton formalisms. Quaternions) – duality between statics and kinematics.

Prerequisite

Solid mechanics (general theorems, Lagrange). Linear algebra. Matrix calculus.

TU 12 : Modeling of marine systems

Lecture: 8h, tutorial work: 7h, practical work: 8h

ECTS: 3

Objectives

Know how to model mobile underwater robots, for design, sizing and control purposes.
Know how to model the dynamical behavior of an underwater robot.
Know how to take into account the interactions of an underwater vehicle with the aquatic environment.
Know the control principles of an underwater robotic system.

Content

- refresher on fluid mechanics (hydrostatics, fluid flows).
- hydrodynamical parameters: physical phenomena and identification.
- Dynamical model of submerged vehicle. Models of boats/drones.
- Underwater sensors.
- Control law principles for navigation.

Prerequisite

Solid mechanics (general theorems, Lagrange). Linear algebra. Matrix calculus. Fluid mechanics.

TU 13 : Control theory of multivariable linear systems (common course)

Lecture: 21h, tutorial work: 15h, practical work: 15h

ECTS: 6

Objectives

The objective of this module is to present the theoretical basics and general concepts for the analysis and the control of multivariable dynamical systems that are linear or can be linearized around an operating point.

Content

- Continuous-time and discrete-time state-space representation,
- State-space representation vs Laplace formalism,
- Solution to the state-space equation – Transition matrix,
- Controllability and observability, Kalman criterion,
- Lyapunov stability,
- State feedback control,
- Linear quadratic regulator (LQR),
- Synthesis of observers (Luenberger, Kalman).

Prerequisite

Fundamentals of control theory and basics of analysis and control of linear discrete and continuous systems. Identification and control of systems. Linear algebra.

TU 14 : Unsupervised learning

Lecture: 10h, practical work: 9h

ECTS: 2

Objectives

Give basic skills in unsupervised learning techniques to solve problems of grouping, density estimation, classification and regression. The main objective relies in being capable of summarizing as closely as possible a large set of data, and of designing efficient generalization and prediction models.
At the end of this module, students must be capable of :
- creating and programming fast solution prototypes of learning optimal representation of complex time series data (marine)
- incorporate them into classification/self-indexing systems,
- understand data complexity and stream,
- extract value from data set, identify significant variables and build predictive tools.

Content

Algorithms and programming dedicated to Artificial Intelligence.
Closest neighbor and K-means.
Parzen Density estimator.
Model of mixing law and expectation-maximization algorithm.

Prerequisite

Algorithm fundamentals and programming background.

TU 14 : Supervised learning

Lecture: 12h, practical work: 12h

ECTS: 3

Objectives

Provide basic skills in supervised learning to solve problems of grouping, density estimation, classification and regression. The main objective relies in being capable of classifying a large set of data, and of designing efficient generalization and prediction models for temporal dimensions and series.

Content

Convexity and gradient.
Introduction to supervised learning.
Mixed cost functions.
Ultra-large sizes malediction.
Structural risk minimization and large-margin classifier: neural network, multilayer perceptron, convolutional neural network, long short-term memory.

Prerequisite

Unsupervised learning.

TU 14 : Reinforcement learning

Lecture: 6h, practical work: 4h

ECTS: 1

Objectives

Know how to make use of reinforcement learning, especially for the motion of autonomous robots. Reinforcement learning will be presented through the impressive and instructive 2016 demo of AlphaGo, a robot who won the Go championship. We will show how these algorithms can also be used in the case of autonomous car driving.

Content

Introduction to reinforcement learning.
Dynamic programming, Markov model, Monte-Carlo method.
Full and sub-optimal exploration of action policies.

Prerequisite

Unsupervised and supervised learning.

TU 15 : Analog signal processing

Lecture: 12h, tutorial work: 4h, practical work: 3h

ECTS: 2

Objectives

Master the electronic design of continuous-time systems for the implementation of embedded electronic systems.

Content

Analog electronics is the fundamentals of electronics. Although digital technology is today everywhere, in particular when it comes to use high sampling frequencies, the building of some functions is still more straightforward and simpler with analog technology.
First the fundamental equations of bipolar and MOS transistors will be presented. Secondly, the operation in small-signal and large-signal dynamical regime is introduced in the case of MOS polarization in saturated mode and in the case of bipolar direct active regime. The various small-signal elements that take into account the effect of the substrate and the parasites, high frequencies, will be carefully studied. The second part of the course will focus on the building of amplifiers – simple or of cascode type. The study will follow on large and small signal regime in low and medium frequencies. The third part of the course will introduce current mirrors (polarization and transfer of variable signals). Then the focus will be on the main differential structures (opamps) and their applications (quadratic filters -> Butterworth/Tchebychev filters, oscillators, phase locked loop, analog and digital frequency synthesizers).
Tutorial and practical classes will be the opportunity to implement the acquired knowledge, e.g. the implementation of an audio amplification system and a second order control filter.

Prerequisite

Linear Systems, Fourier transform, passive filters, complex variable functions, Bode diagram, stability theory (Nyquist), regulation, partial derivatives, electrical principle of linear systems, quadripole theory, principle of semi-conductor physics. Theoretical knowledge of DC and AC signal processing, how to build a small-signal electrical schematics diagram.

TU 15 : Electronics for radiocommunication

Lecture: 11h, tutorial work: 4h, practical work: 3h

ECTS: 2

Objectives

Know the general functioning of an homodyne or heterodyne radiofrequence communication chain (front-end RF: low noise amplifier – LNA, Mixer, PLL) ; understand the principles of analog modulation, frequency modulation, and different digital modulations (FSK, BPSK, QPSK, QAM).

Content

This course deals with the study of the main processes of analog modulation and demodulation, and of digital modulators and demodulators (introduction) used in communication systems. The student who completes the course with success will be able to easily apply the spectral analysis tools to the study of deterministic signals and linear systems that can be encountered in communication systems, be able to explain the operating principles of the different modulation and demodulation processes, and estimate their spectral characteristics (IM3, IIP3, THD%, S/N), be familiar with block-schematics and global characteristics of a modulation chain, and be capable of identifying the function and the characteristics of every part of the chain, and of evaluating the performances of the systems under study.

Prerequisite

Linear Systems, Fourier transform, passive filters, complex variable functions, Bode diagram, stability theory (Nyquist), regulation, partial derivatives, electrical principle of linear systems, quadripole theory, analog electronics (L3 level).

TU 15 : Embedded digital electronics

Lecture: 8h, tutorial work: 4h, practical work: 3h

ECTS: 1

Objectives

Master the electronic design of continuous-time systems for the implementation of embedded electronic systems.

Content

Digital electronics is widespread in today electronic systems that are based on processors.
First, the acquisition chain of a processor-based digital system will be examined, in particular focusing on the high-performance analog-digital conversion aspects.
Then, the discrete-time system theory based on the Z transform will be studied and applied to the case of digital filtering on embedded processors.
The third part will cope with the efficiency of digital processing through the fixed-point and floating-point computing units and the structures that implement them.
Finally, the low power aspects in relation with embedded systems will be examined.
Tutorial and practical classes will be the opportunity to implement the acquired knowledge, e.g. the implementation of a digital acquisition chain and a second order control filter.

Prerequisite

C language, functions and basic structures of digital electronics.

TU 22 : Actuation and perception chain

Lecture: 14h, tutorial work: 7h, practical work: 3h

ECTS: 3

Objectives

At the end of this course, the student will be able to specify the actuation and proprioceptive perception organs of a robot or a robotic system in interaction with the humans for design, piloting, and performance evaluation purposes, according to the technical specifications.

Content

- Actuation of robots (hydraulic, electrical or thermal driving power).
- Electrical motors for robotics (principles, models, sizing, control).
- Proprioceptive and exteroceptive perception (measurement chain).
- Movement sensors and force sensors.
- Actuation and proprioceptive perception chain.
- Sizing of electrical actuator.

Prerequisite

General mechanics and basics of electronics.

TU 22 : Biomechanics

Lecture: 7h, tutorial work: 9h, practical work: 8h

ECTS: 3

Objectives

Master tools for the modeling and analysis of human movements for robotic, biomechanical and biomedical applications thanks to embedded sensors.

Content

The understanding of mechanical specificities of biological systems is a prerequisite to the development of versatile artificial systems and to the skilled evaluation of motricity in sport or in case of impairment in the biomedical field using embedded sensors. Hence, the objective of this course will consist of presenting the biomechanical tools that are specific to the study and the simulation of human body locomotion, which can be modeled through multiple poly-articulated chains.

The lecture course and the tutorial classes will focus on the following items:

1. Link between robotics and biomechanics: reproduce and simulate the structuring of the movement of biological systems (bio-inspired approach)
2. Biomechanical modeling
• Modeling of human body, kinematics, geometrical and inertial parameters
• Mechanics for muscles
• Evaluation of non-measurable parameters to understand the efforts the human body is subject to (inverse kinematics, inverse dynamics, muscular efforts)
3. Measurement of human movement
4. Evaluation indices of robotics applied to biomechanics: manipulability and force polytopes
5. Application: postural balance, locomotion, gripping, handicap

Practical classes:

Movement analysis though musculoskeletal model: the objective of practical classes for the students consists of being able to master Opensim, the reference open source software in musculoskeletal modeling. We will focus on the scaling of a reference model using data issued from an optoelectronic system, on the evaluation of the inverse kinematics from measured data, and on the evaluation of muscular joint torques and forces resulting from optimization. The different aspects related to human body modeling will be examined. In a second part, evaluation indices issued from robotics will be analyzed to quantify the quality of a posture or a movement.

Prerequisite

Modeling of mechanical systems.

TU 23 : Optimization techniques
Lecture: 12h, practical work: 12h
ECTS: 3

Objectives

How to formulate a numerical optimization problem (identify parameters, define cost function, describe constraints)
How to characterize the problem (linear or nonlinear, with or without constraints)
How to select the optimization method that is adapted to the problem.

Content

1. Refresher in mathematics
Positivity, convexity, optimum
Differentiability, Gradient and Hessian
Existence conditions of optimum point
2. Optimization without constraints
Formulation of optimization problem
Gradient method
Conjugate direction method
Methods of Newton and Levenberg-Marquardt
3. Optimization with constraints
Method of simplex (Nelder-Mead)
Interior point method
Lagrange multipliers
Conditions of Karush-Kuhn-Tucker

Prerequisite

Mathematics: numerical analysis, differentiability, continuity.
Scientific programming: master scientific programming tools.

TU 23 : Nonlinear control theory

Lecture: 23h, tutorial work: 6h

ECTS: 4

Objectives

This course is very important for teaching unit 3 since it provides the essential methods of advanced control. At the end of this course, the student must know how to analyze a system that is characterized with a nonlinear dynamical model, how to control it and how to estimate the state of the system.

Content

The course starts with the refreshing of several basics of differential geometry (Lie derivatives, vector field distribution). Then it deals with local and global stability: Lyapunov functions, LaSalle invariance principle.
Several control methods will be examined:
• nonlinear control: linearization though feedback of mechanical systems, geometric control, stabilization with Lyapunov method, predictive control;
• Pontryagin maximum principle, optimal synthesis, direct and indirect methods;
• Sliding modes, variable-structure control;
• Model-free control.
In this course, methods are mainly based on state-feedback control, but this lecture course will also focus on high-gain observers, in particular the extended Kalman filter in its high-gain version.

Prerequisite

Matrix calculus,
Linear control theory (filtering and control),
Optimization.

TU 24 : Deep learning in images or time-frequency planes

Lecture: 12h, practical work: 12h

ECTS: 3

Objectives

Provide elementary skills in modeling and distinguishing sonar, image and multimodal data, through 'deep learning' approaches from their projection in the 2D space. In particular the course will focus on the learning methods of dense representation, which are specific to the coding in low power systems.

Content

Non-supervised and supervised models for 2-dimensional classification: spectrograms, scalograms.

Prerequisite

Basics in coding and in non-supervised and supervised deep learning in n-dimensional spaces. Basics in searching methods for subspaces, principal component analysis (PCA), linear discriminant analysis (LDA).

TU 24 : Multimodal perception

Lecture: 12h, practical work: 12h

ECTS: 3

Objectives

Provide elementary skills in modeling and distinguishing acoustic, sonar, image, spectral, and multimodal data, through 'deep learning' approaches (deep networks).

Content

Manipulate, compress, index, sort, generalize heterogeneous data: audiovisual, acoustic: represent and analyze them to make decisions of perception/action for an autonomous system. Reinforcement of the perception-action loop by incorporating the joint analysis of audio and visual information or multisensorial information. Joint localization and identification system of submarine acoustic sources and others through ‘deep learning’ and recurrent networks.
Students will be quickly confronted to practical cases related to real robotic situations: surface and submarine systems with embedded intelligent software aimed to detect and track targets. Links with industrial partners will be possible, in particular with SeaProven, Osean, DCNS in the context of mini projects.

Prerequisite

Learning methods for joint fusion and learning, combined object functions.

TU 25 : Digital sensors and buses

Lecture: 8h, tutorial work: 6h, practical work: 3h

ECTS: 2

Objectives

Master sensor interfaces and advanced signal processing for the implementation of embedded electronic systems.

Content

Existing sensors incorporate more and more advanced functionalities that enable autonomous operation and bring novel features to the embedded system, which are different from the mere measurement of a physical value. That is why they cannot be interfaced in a strictly analog way but require the implementation of communication buses that are adapted to their usage.

On the one hand, a review and a classification of field buses will be introduced and coupled with the description of their communication protocols. On the other hand, the common digital sensors (accelerometers, gyroscopes, magnetometers, electrocardiogram, external high-performance analog-to-digital converters...) that are used in embedded systems, and their interface (SPI I2C, CAN in particular) will be presented.
Filters that are specific to some of the sensors (e.g. Kalman) – taken either alone or in combination with others -, will be also developed in the framework of this course.
Tutorial and practical classes will be the opportunity to implement the acquired knowledge, e.g. the implementation of a positioning system using an inertial measurement unit with Kalman filtering.

Prerequisite

Embedded digital electronics. Electronics for radiocommunication.

TU 25 : Networks and wireless communication

Lecture: 8h, practical work: 6h

ECTS: 1

Objectives

Get a clear view of distributed-data exchange solutions in the field of IoT.

Content

Connected objects make use of communication networks for data exchange between acquisition systems and for data transmission to remote servers.
The expertise in sensor networks behind this data exchange is a key challenge of IoT (Internet of Things). The typology of sensor networks according to the IEEE 802.15.1 and IEEE 802.15.4 norms will be presented first, with use cases for each kind of network. The PAN (Personal Area Network) and MESH networks will be particularly detailed.
Emerging networks will be also studied to give students the useful tools that enable a critical analysis to select appropriate technological solutions according to the needed specifications, and to foster creativity to start novel research development in this field.

Prerequisite

Embedded digital electronics. Electronics for radiocommunication.

TU 25 : Instrumentation and sensors

Lecture: 12h, tutorial work: 3h

ECTS: 2

Objectives

Implement electronic functions to deal with time-continuous electrical signal processing issued from sensor. Understand the operating of an instrumentation chain.

Content

First the metrological characteristics of sensors such as sensitivity, linearity, swiftness, accuracy will be presented. Then some electronic circuits – also named « conditioner » will be studied (Wheatstone bridges, amplifiers, substractors, converters …). The implementation constraints that are due to noise sources and the presence of offset voltages and currents will be presented. Calibration issues and principles will also be described. The lecture course and the tutorial classes will include use cases up to the study of a complete system with the calculation of the instrumentation amplifier with low common-mode rejection ratio and the design of analog-to-digital and digital-to-analog converters.

Prerequisite

Linear electrical systems and associated differential equations, complex variable functions.
Analog and digital electronics, Fourier transform, Taylor series, basics in analog and digital signal processing.

TU 32 : Underwater drones

Lecture: 11h, tutorial work: 10h

ECTS: 3

Objectives

The objective of this course is to provide useful basics in the framework of the optimized design of robotized underwater systems. The engineering concepts that will be developed will lead to a design project of a vehicle thanks to sizing tools based on provided matlab and excel design modules. The project will consist of designing (design office style) and sizing an autonomous underwater vehicle in an optimal way. This project will be conducted on a team basis, following the rules of a project management from specifications to the release of a commercial and technical bid.
(visit of Ifremer to be planned for students outside class, preferably in the evening)

Content

System typology and markets
- manned systems, teleoperated and towed systems, autonomous systems, hybrid systems, markets, system of systems
Key technologies
Environment constraints
Modeling and sizing of a mobile underwater robot
Conventions
Dynamical equations,
Usual inertia matrix,
Hydrodynamics forces and moments
- Inertia and added masses, lift and drag, damping, umbilical impact on remotely-handled vehicle, coupling between telemanipulator and vehicle
Mobility - main actuators
- mobile surfaces, thrusters, inertial actuators, magneto-hydrodynamic propulsion, wheels, caterpillar and other archimedean screws
Power sources
- Teleoperated cable-driven vehicles
- Free vehicles
-- Energy converters, batteries, accumulators, fuel cells, summary on energy sources
Underwater positioning systems
- Position estimation, attitude measurement,
- Velocity measurement: mechanical and electromagnetic logs, acoustic logs
- Immersion sensors
- Inertia
- Acoustic positioning: long, short, ultra-short baseline systems
- basics of underwater communication
- Summary: integrated navigation
Calculation of bottom hull and shell

Basics of design optimization
Implementation of modeling in a project framework (Autonomous Underwater Vehicle – AUV, Remotely Operated Vehicle - ROV), in groups of 3 or 4 students.

Prerequisite

Robotic techniques. Modeling and control. System engineering, mechanics, electronics, physics, basics in hydrodynamics and structure calculation, basics in acoustics and signal processing.

TU 32 : Parallel robotics

Lecture: 7h, tutorial work: 8h

ECTS: 2

Objectives

The objectives of this lecture course consist of laying the foundations from the specifications of a complex system to set up the equations in a generic way using different approaches (geometric, static, ...), and then analyze the properties of the obtained equations system (generic cases, singularities, redundancy, ...) in order to implement robust resolution methods, taking into account the set of all possible solutions. The impact of model uncertainties on the modeling results will be studied. The global educational objective aims to illustrate the implementation of a coherent and faultless modeling process on a complex system. This course is intended to be interactive: theory is detailed at the beginning, and is immediately followed by a practical implementation by the students.

Content

Keywords: modeling, system analysis, uncertainties

Lecture course sections:

1. mathematics basics (vectors, linear algebra, equation systems), formal manipulation
2. geometric modeling
3. static modeling
4. model analysis
5. model uncertainties
6. extension of modeling

Prerequisite

- basics in solid mechanics
- vector spaces, geometry, numerical analysis and linear algebra
- basics in the use of a formal-calculation system (Maple, Mathematica, ...)

TU 32 : Bio-inspired robotics

Lecture: 7h, tutorial work: 8h

ECTS: 2

Objectives

The objective of this course is to learn about the bio-inspired approach to designing an optical sensor that can be used for robotic navigation. The aim here will be to use knowledge from living organisms (insect vision, studies of ant behaviour) to propose a model and implementation of a celestial compass inspired by the desert ant.
The work will be done in pairs and will be evaluated on the basis of the students' ability to explain their approach and on the performance of the final compass. Arduino-compatible electronic boards will be provided and simple mechanical parts based on 3D printers and laser cutting will have to be produced.

Content

3D CAD 3D printer and laser cutting course.
Visual perception course in insects and modeling.
Mini project: realization of a celestial compass.
Development of fusion algorithm for heading estimation.

Prerequisite

Robotic techniques. Modeling and control.

TU 32 : Robotic control and motion planning

Lecture: 20h, tutorial work: 10h

ECTS: 4

Objectives

Be able to understand the current challenges in control theory at research level, know how to collect a bibliography and be capable of reading/understanding articles related to control theory and its applications.

Content

Vector fields, flows; commutativity of flows, Lie groups, definition of Lie algebra of vector fields;
Non-linear control systems, controllability : Chow theorem, systems with drift; Small-time local controllability.
Nilpotent systems, nilpotent approximation, chained systems.
Trajectory planning: admissible and non-admissible trajectories, non-holonomic constraints and degree of non-holonomy; sinusoidal controls, piecewise constant controls.
Flat systems, trajectory planning for flat systems.

Prerequisite

Differential equations, controllability
Analytic mechanics, Lagrangian and Hamiltonian formalisms,
Differential geometry, vector fields;
Parametrized curve, curve re-parameterization.

TU 32 : Applied nonlinear control

practical work: 24h

ECTS: 3

Objectives

Master all the techniques allowing to develop a robotic application, from trajectory planning up to trajectory tracking. Be capable of controlling a robot using its sensors, actuators and the real time system available onboard.

Content

This module is organized as a practical class, where students will work on practical cases on several robotic platforms. Hereafter is a list of some cases that can be developed on existing robots that are already available at the University of Toulon, with (between brackets) the concepts that are especially studied for these applications, from a theoretical point of view and an applied point of view:

- Geolocalization of an underwater robot (adaptive extended Kalman filter, asynchronous sensors, Robotics Operating System);
- Stabilization of an aerial drone nacelle (LQG control, image processing);
- Stabilization of a « unicopter » (model-free control)
- Control of a mobile robot and visual trajectory tracking (nonlinear control, camera calibration, image processing, network programming and micro-programming);
- Ball and beam and inverted pendulum (closed loop identification, feedback linearization, microprogramming).

Prerequisite

Linear and non-linear control theory, programming skills, sensors and actuators in robotics.

TU 33 : Simultaneous Localization and mapping

Lecture: 11h, practical work: 9h

ECTS: 3

Objectives

Provide skills in the programming of autonomous systems, which, according to the state, are capable to self-localize, plan and predict the environment.
Neuro-inspired models.

Content

Presentation of Simultaneous Localization and Mapping issue (self-localization),
Instantiation on visual, electromagnetic and sonar modality.

Prerequisite

Robotic techniques for localization. Sensor.

TU 33 : Behavior, decision-making and prediction

Lecture: 12h, practical work: 15h

ECTS: 3

Objectives

Provide skills in the programming of autonomous systems, capable, according to the state, to self-localize, plan and predict the environment.

Content

Modeling of adaptive behavior in robotics.
Prediction of time acoustic, audiovisual sequences of the environment in general.
Prediction of the environment in very short time delay to optimize decision making.
Long term projection of operation and selection cost.

Prerequisite

Reinforcement learning, unsupervised and supervised learning: integration and information models of 1st year – M1 (statistical deep learning).

TU 34 : Real time systems and security

Lecture: 12h, practical work: 5h

ECTS: 2

Objectives

How to implement a real time operating system, be deeply aware of security challenges in embedded systems with limited resources which are used in the IoT field.

Content

Connected objects make use of communication networks for data exchange between acquisition systems and for data transmission to remote servers. They include signal processing units with limited capacities, but they can accumulate data issued from a lot of sensors.
The management of tasks with their priorities is therefore a strong challenge for the implementation of real time embedded systems: the use of real time operating systems (OS) is very suitable in the IoT field. The prime objective of this lecture course will consist of describing how these OS operate and their implementation on microcontrollers through selected examples such as Free RTOS.
Data transfer security over wireless communication networks is a also strong challenge, especially in sensitive applications related to safety or health. These aspects will be studied in a second part.

Prerequisite

Embedded digital electronics. Electronics for radiocommunication.

TU 34 : Applications with connected objects

Lecture: 18h, practical work: 16h

ECTS: 4

Objectives

Understand the different steps of implementation of small communicating and connected autonomous objects in the framework of research or industrial applications. Inform about design tools through practical classes or the use of demonstrators.

Content

A connected object is a small physical module with communication capabilities and energy autonomy, which can transmit and sometimes receive data (information issued from sensors in general).
The network connexion of these objects, namely IoT (Internet of Things), and the transmission of information to centralized remote servers significantly increases the potential of these modules.
The objective of this course is to present in an interactive and practical way several applications that use autonomous connected objects. Several application fields will be studied, such as health, environment monitoring, intelligent measurement (smart metering) or people/object tracking in an indoor environment.
For this purpose, specific technologies will be presented in each of the listed fields:

- Regarding tracking: systems relying on active beacons (using ultra-broadband technologies, RFID, ultrasonic or optic) will be presented. They have been recently developed in the framework of research/industrial cooperation programs.
- Regarding environmental monitoring: intelligent ultra low-power warning systems that enable the significant increase of embedded systems lifetime thanks to the capability to be woken up only when necessary, will be described.
- Regarding health: the application field of connected objects especially deals with the evaluation of human locomotion quality using significant parameters. In this framework, the objective consists of focusing on techniques that enable the evaluation of the locomotion quality or the postural balance thanks to inertial sensors, and on their applications in the clinical field as well as in health prevention trough sports or the study of sport performance.
- Regarding intelligent measurement, the systems used in Smart Grid technologies will be presented.

Prerequisite

M1 – Design of analog, digital and mixed electrical circuits and embedded systems, analog modulation, digital modulation principle, digital signal processing, embedded systems, electronics for radiocommunications.