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M2S1 Semester

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Master Complex Systems in Interaction (MSCI) : M2-S1 second trimester		
TIS	BMI	SMA
15 ECTS Every UE is 3 ECTS	15 ECTS Every UE is 3 ECTS	15 ECTS Every UE is 3 ECTS
• Advances in Statistical Machine Learning • Modeling and optimizing discrete systems • Estimation for robotic navigation • Control of autonomous robots in cooperation • Intelligent Interactive Systems • Algorithms and protocols for the interconnection of systems	• Engineering of biologic and bioartificial systems • Microfluidics and Microsystems for Biological and Health Applications • Modeling of the neuromuscular and musculoskeletal systems in interaction • Modeling osteoarticular and musculoskeletal systems in interaction • Nanotechnologies and Nanomechanics of Complex Biological Systems • Multiphysics modeling of the vascular system	• Model identification in mechanics • Compact and innovative actuators and sensors • Systems modeling and simulation • Robust design of mechanical and mechatronic systems • Multi-disciplinary Design Optimization • Smart materials • Embedded Systems: electric drives and actuators
Project workshop (6 ECTS)		

Modules shared between the 3 areas of specialization (common trunk)

SCI20 Advanced Data Analysis

Description

The aim of this course is to learn to students the techniques for characterizing and classifying data (times series) from complex system. In fact, for diagnostic purposes, the data variability can contain relevant information that allows the construction of discriminative vectors. These vectors permit the separation of data modalities by classification. For this purpose, several methods (nonlinear, statistical, functional) for extracting information to construct discriminative vectors will be described. Standard classifying methods based on statistical learning will also learned. Applications on computer will allow to students the quantification of efficiency of discriminative vector/classifying method combination. The studied methods will be tested on real data from technological plateforms.

Program

Analysis of the signal variability and discriminative vector conception :

- Energy, amplitude.
- Spectrum
- Stationnarity, randomness
- Shape, structures, time and amplitude dynamics
- Entropy, information
- Linearity, nonlinearity

Statistical learning

- SVM , regression, perceptron
- Neural networks
- Decision trees
- Extension from the binary case to the multi classes case

Applications of discriminative vector/classifying techniques combination and efficiency evaluation

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Sofiane Boudaoud

SCI21 Dependable system design

Description
The aim of this module is to introduce the main design techniques for dependable systems, particularly for the safety-critical systems

Program
The different methodological aspects concerning the design of dependable systems will be introduced:

- Hardware redundancy: 1ooN architectures, voters PooN
- Informational redundancy: errors detection and correction, coded processors, application to distributed systems
- Effects of uncertainty
- Robust design, reliability of structures
- Fault tolerance, fault removal
- Fail-safe and fail-operational systems

Duration
6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge
Walter Schön

SCI22 Modeling and propagation of uncertainties

Description

Uncertainties are present at all levels in the analysis and modeling of complex systems. In particular, one can distinguish between aleatory uncertainties, induced by the variability of studied phenomena, and epistemic uncertainties due to imperfectness of knowledge. The two classical formalisms for modeling uncertainties and propagating them in reasoning and computation mechanisms are Probability Theory and the set-membership approach (including Interval Analysis). More recently, the theory of belief functions, which extends these two approaches, has been developed. This course introduces the theoretical foundations of these three formalisms, as well as the main practical methods allowing for their application in complex system engineering.

Program

- Set-membership approach: introduction to interval analysis, constraint satisfaction problems, contractors.
- Probability theory: fundamental notions, Bayesian networks, maximum entropy principle, Monte-Carlo simulation, elements of Bayesian decision theory.
- Theory of belief functions; mathematical properties of belief functions on a finite set, main combination rules, extension and marginalization, propagation methods based on random sets, decision rules.

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Thierry Denoeux

SCI23 Optimization

Description

This course introduces different methods and tools used for optimization problems. It relies on multidisciplinary applications reflecting the activities of labex MS2T laboratories.

Program

This course has three components:

- Combinatorial optimization: search-tree methods (successive and progressive process separations assessments - SES / SEP), introduction to complexity theory and model descriptions problems
- Evolutionary methods, metaheuristics, genetic algorithms
- Optimization in continuous variables: unconstrained problems solver, first and second order problems under constraints, optimality conditions, solution methods with/without Lagrangian approach

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Pierre Villon

Modules shared between 2 areas of specialization

SCI30 Method and Modeling of 3DMotion Capture

Description

For 3D motion capture of mobile systems (e.g.: human skeleton, robot, UVA…), the formalism and measure of the 3D displacements are the key stones for attitude estimation and system control. This course identifies and details the methods and tools for motion capture with and without markers. First, the mathematical formalism for spatial representation of systems will be recalled, followed by the presentation of optoelectronic systems, IMU and multi-cameras image processing. Finally examples will be given (e.g. gait analysis, vehicle and UAV attitude estimation) and lab mini project will be performed.

Program

- Mathematical formalism 1 (Euclidean space, Isomorphism, 2D/3D projection, scalar product, cross product) (2h)
- Mathematical formalism 2 (projective geometry 2D/3D, Robust estimation method, Fourier transform for image processing) (2h)
- Rotations and quaternions (2h)
- Geometrical and photometrical camera models and calibration (2h)
- Image based feature extraction and tracking (2h)
- Multi-Cameras 3D reconstruction, stereovision and structure-from-motion method
- Screw axis and dual numbers (2h)
- Inverse problem for Rotation / Screw axis determination (2h)
- Application - Gait analysis (2h)
- Application - Vehicle and UAV attitude estimation (2h)
- Lab/mini project 1: MoCap (3h)
- Lab/mini project 2: Calibration (3h)
- Lab/mini project 3: Animation (3h)
- Lab/mini project 4: 3D Reconstruction (3h)

Duration

6 weeks + 1 exam
16 h Lectures, 16 h Lab

Person in Charge

Frédéric Marin

SCI31 Modeling, control and observation of dynamical systems

Description

After having introduced the basic concepts of dynamic systems modeling, this course introduces the concepts of model-based control. Specific methods of control for systems of systems are then described. Finally, the course focuses on state observation methods and their use in various areas with different types of dynamical systems.

Program

- Unified representation, modeling examples.
- Analysis of the properties of systems: stability, controllability, observability, passivity.
- Linear and nonlinear control Techniques
    - State feedback
    - Global linearization
    - Optimal control
    - Robust control
- Introduction to the control for systems of systems
    - Distributed and networked control
    - Hierarchical control
    - Cooperative control
- Linear state observers
- Examples and case studies

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Ali Charara

SCI32 Multi-scale structure-mechanical behavior relationship in material science

Description

The structural complexity of materials that makes them versatile also presents a challenge to understand them. A multi-scale description of the structure as a description of the structure and the morphology at several length-scale is the most appropriate approach to smarter design. However prediction of their macroscopic properties using the current available models requires precise values of the relevant structural parameters at several length scales. During the semester we will focus on describing the microstructure of different materials and provide the appropriate experimental techniques to the corresponding length-scale. Multi-scale models will be also introduced. Indeed the experimental techniques will be introduced as a tool to provide input to either derive or improve the studied models.

Program

- Introduction to material science
- Length-scale sensitive experimental techniques
- Multi-scale modeling

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Fahmi BEDOUI

Area of Specialization TIS
Information Technology for Autonomous Systems in Cooperation

TIS01 Foundation of interconnection networks

Description
A System of System is composed by the relationship between entities, relying on an interconnection network. This course introduces the fundamental aspects of interconnection networks, from a structural and algorithmic point of view. No previous knowledge on communication protocol is required.

Interconnection networks, whatever is their implementation admit common characteristics and properties. The aim of this course is to give necessary information for their understanding, including modelling and algorithms, as well as recent advances.

Program
- Modeling interconnection networks: graphs and interconnection networks, particular networks, models of communication, routing, global communication
- Models for distributed computing: process and communication, synchronisation, causality, snapshot
- Protocols of communication: layered organization, alternated-bit and sliding window, distributed algorithms of broadcasting, waves and routing
- Fault-tolerance in networks: consensus, agreement, failure detectors, self-stabilization
- Specificities of dynamic networks: modeling, properties, protocols
- Resource sharing in networks: resource management, election, mutual exclusion, dinning philosophers, congestion in networks, fairness, introduction to mathematical tools.

Duration
6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge
Bertrand Ducourthial

TIS02 Advances in Statistical Machine Learning

Description

Large datasets are available today on the Web, for instance from user-generated content (collaborative content creation as on Wikipedia, sharing information as on Flickr, Facebook or Twitter) or navigation logs collected by Websites. The domain of statistical machine learning provides tools to exploit large datasets to build explanatory or predictive models. The recent advances in this field, which can deal with large-scale, heterogeneous and complex data are nowadays important tools in many application domains such as image processing, information retrieval or natural language processing. In this lecture, we will present the fundamental techniques of statistical machine learning, the recent approaches to deal with large amounts of complex data, as well as some practical applications.

Program

- Elements of statistical learning theory
- Sequential models: conditional random fields, hidden Markov models
- Kernel methods for structured data
- Advances in neural networks: "deep learning", convolutional networks, …
- Large-scale learning

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Nicolas Usunier

TIS03 Modeling and optimizing discrete systems

Description

Several optimisation problems in transportation and logistics systems are discrete. One can cite the vehicle routing problem, planning problems and localization problems. They belong to combinatorial optimization, which is an active area of applied mathematics. This course presents the methodologies for solving them which combine logic, linear programming and algorithmic methods. After this course the student will be aware of the frontier between the problems that can be solved exactly and the ones that can only be solved approximately.

Program

This course is based on the complexity theory which is presented and illustrated by fundamental problems like the satisfiability problem, the traveling salesman problem and the partition problem. When someone has to solve a combinatorial problem, it is necessary to classify it. Some problems are easy in the sense that they can be solved by a polynomial algorithm, others are NP-hard. We will present polynomial algorithms solving scheduling problems. They are a building block for elaborated methods for NP-hard scheduling problems. It includes heuristic and exact methods. We will illustrate through examples the branch and bound methods and dynamic programming. We will also discuss on the guaranty that can be obtained by some heuristic by studying the bin-packing problem.

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Jacques Carlier

TIS04 Estimation for robotic navigation

Description

This course presents real-time estimation methods for autonomous navigation of mobile robots and intelligent vehicles. The canonical problems (localization, simultaneous localization and mapping, detection and tracking of moving objects) are covered with feature approaches and occupancy grids.
Finally, the course addresses issues of collaborative estimation for robotic systems interacting with each other when wireless communication means allow them to communicate.
The course leads to a practical study on real experimental data.

Program

- Description and formalization of canonical problems by feature or occupancy grids
- Multisensor Data Fusion and performance indicators: precision, accuracy, confidence, integrity, availability
- Optimal Linear Estimation, Dynamic State Observer by Kalman filter (KF), Extensions of KF to nonlinear systems and introduction to Particle Filtering
- Data Association, Multi-Hypothesis Tracking, Outliers rejection
- Set-membership State Observer, Set Inversion via Interval Analysis, Constraint Propagation, Set-robust inversion, a priori injection
- Cooperative Estimation by exchange of states or observations

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Philippe Bonnifait

TIS05 Control of autonomous robots in cooperation

Description

This course focuses on the modeling and control of autonomous robotic systems in real time from the perspective of non-linear control theory. It deals specifically with terrestrial and aerial mobile robots and their configuration in swarms to illustrate the concepts of systems of systems control.

Program

- Kinematic and dynamic models
- Stabilization and control:
    - global, input-output, feedback linearization
    - backstepping
    - bounded control using saturations (nested, separated)
- Reactive navigation (optical flow, obstacle avoidance, tentacles)
- Hierarchical and decentralized approaches for swarms of robots (cooperative control network)

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Isabelle Fantoni

TIS06 Intelligent Interactive Systems

Description

Interaction is central for the design of systems of systems. Three main types of interaction can be considered:

- Interaction between users and systems
- Interaction between autonomous systems (agents) interconnected on a network
- Integration of these aspects for interactive agents, search agents, personal assistants...

The goal of the course is to study these different types of interaction and the associated models, rules, standards and protocols, as well as the specific knowledge of the agents (in particular about the other agents - human beings or artificial - and their behavior). These models must allow the design, specification, validation and control of interactive systems particularly when they are based on cooperative and communicating agents.

Program

Human(s)-system(s) interaction

- Task models, interaction models, user models
- Adaptive systems
- Tactile, vocal, gestural interactions – Multimodality
- Mobile applications development

Interaction between systems

- State Machines
- UML Diagrams of interaction

Context sensitive systems

- Context servers
- Adaptation, learning, co-evolution

Multi Agents Systems

- Agents Models
- Interaction and communication between agents
- Standards and protocols (FIPA)
- Methods of development
- Multi-agents platforms

Duration

6 weeks + 1 week exam (32 h - 16 h lessons, 16h practical work)

Person in charge

Dominique Lenne

TIS07 Algorithms and protocols for the interconnection of systems

Description
This course presents algorithms, protocols, and communication technologies that are used in the design of systems of systems. It focuses on advanced topics in data communication in wired and wireless infrastructure (ad'hoc and wireless sensor networks) with the support of mobility, security, dynamism, real-time, and quality of service issues. All these concepts are fundamental in the design of several applications of systems of systems including Vehicular networks, Unmaned Area Vehicules (UAVs), Body-Area Networks, Smart Grids, Smart Cities, etc. where group communication constitutes a important building bloc of such systems.

Program
- Design of IP networks architectures and wireless communication
  - Fundamentals of Internet architectures
  - Wireless communication Technologies sans fil : 802.11p, Zigbee
  - Advanced IP architectures: Mobile IP, IPv6, Nemo.

- Ad'hoc and Dynamic network design
  - Ad'hoc network routing protocols
  - Algorithms and protocols for dynamic networks
  - Vehicular Ad'hoc Unmanned Area Vehicular (VANETs & UAVs)

- Wireless Sensor Network (WSN) Design
  - WSN routing protocols,
  - Data aggregation and energy saving in WSN
  - WSN for Heatlthcare

- Real-time and group communication
  - Real-time and quality of service communication architectures and protocols
  - Multicast communication protocols
  - Mobile multicast Communications

- Design of secure systems
  - Basics and security services
  - Key management protocols
  - Trust and secure routing protocols

Duration
6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge
Abdelmadjid Bouabdallah

Area of Specialization BMI
Biomechanics and bioengineering

BMI01 Mechanical Properties of Biological Systems

Description

The continuum mechanics, solid and fluid mechanics, as well as the fundamental laws of physics will be covered. They will be applied to describe and understand the mechanical behavior of biological materials and fluids.

Experimental methods and techniques will be described for in vivo and in vitro characterization of the mechanical and morphological properties at different scales (from ultrastructure to macrostructure: molecule, cell, tissue, organ) for different biological materials (musculoskeletal, osteoarticular and vascular systems).

Program

- Static elasticity (stress, strain), dynamic (wave propagation in solid and fluid media), the conservation equations of fluid mechanics (mass, momentum).
- Techniques of in vitro characterization (mechanical tests: biaxial, DMAperformed with BOSE equipments, ultrasound tests, nanoindentation, rheometer, etc. ...)
- Techniques of in vivo characterization (ultrasound, magnetic resonance elastography: MRE)
- Mechanical properties of materials for the osteoarticular and musculoskeletal systems
- Mechanical properties of materials and fluids for the vascular system

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Sabine Bensamoun

BMI02 Engineering of biologic and bioartificial systems

Description

This lecture will address the cell culture techniques fundamental for tissue engineering. The approach will be multi-scale:

- Traditional two dimensional cell cultures
- Three dimensional cultures (scaffolds, artificial organs, cellular interaction)
- Dynamical fluid movements in cell culture (bioreactors, systemic interactions)

The complexity of the biological systems will be addressed through specific examples such as the skin with the molecular and cellular deconstruction of the cell interactions in vivo prior to the reconstruction of stratified epithelium in 3D systems

Program

- In-vitro cell cultures
- Cytotoxicity
- Immunocytochemistry

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Christophe Egles

BMI03 Microfluidics and Microsystems for Biological and Health Applications

Description

Microfluidics has been booming for the last 15 years both in research and in high-tech applications (inkjet printers, implantable micropumps, biological analysis systems, microreactors ....). Economically, the market for microfluidic systems in chemical, medical, or metrology applications was estimated to be worth between 4 and 6.5 billion dollars in 2003. The integration of microfluidic systems is now a routine process in systems of everyday life (as for implantable micropumps, portable glucose analyzers, air bags, …). In this context of fast development and high competition, we offer PhD and Master MS2T students a course on the basic concepts of microfluidics and on the development techniques of microsystems designed for biological and health applications. The concept of system of systems is key in the manufacturing processes in particular and in interfacing and parallelization of microfluidic devices with the macroscopic world.

Targeted audience: PhD/Master students who are interesting in learning about the problems associated with microfluidics, microtechnology and microsystem integration in biology and health science. The course will be oriented towards the analysis of the governing physical phenomena and their orders of magnitude. The course will not involve any complicated mathematical developments

Program

The program includes basic courses on microfluidics and the governing physical phenomenon at stake, as well as experimental demonstrations:

- Physics of miniaturization, scaling laws
- Hydrodynamics of microfluidic systems (flows, artifacts of miniaturization …)
- Electrophoresis
- Electro-osmosis
- Capillarity
- Mass transfer and mixing in microfluidic systems
- Technological aspects (microfabrication, metrology, pumps, valves, etc…)
- Concept of lab-on-chip and system integration

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Eric Leclerc

BMI04 Modeling of the neuromuscular and musculoskeletal systems in interaction

Description

The neuromuscular and musculoskeletal systems are complex and interact for movement generation. It is composed of motor control by the nervous system, muscles, tendons, bones and joints. The modeling of such system is limited by the complex and heterogeneous associated data (biomechanical, cinematical, electrophysiological). Some models (neuromuscular and musculoskeletal) exist but deals partially with the complexity without considering the complete system. The aim of the proposed course, after presenting physiological and adaptation aspects of the system, is to describe modeling methods of the subsystems (joint movement, tendons, muscle activation, motor control, force, etc..) and their interaction for attempting a global realistic modeling. Practical courses will be yielded to aboard research in this field at UTC.

Program

Neuromuscular physiology
1/ the skeletal muscle, the force generator : structural/functional relationship
2/ biomechanical properties of the skeletal muscle
3/ Evaluation of the biomechanical characteristics of the skeletal muscle
4/ The muscle under control : proprioceptive receptors and muscle neurophysiology
5/Evaluation of neurophysiological caracterisitics
6/ Muscular plasticity

Neuromuscular modeling
1/Neural drive simulation
2/Surface EMG and force generation
3/ Surface EMG/Force relationship modeling
4/Musculotendinous interaction modelling

Joint motion-musculoskeletal motion modelling

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Sofiane Boudaoud

BMI05 Modeling osteoarticular and musculoskeletal systems in interaction

Description

Human body could be described as a system of biological systems in interaction. Methods of osteoarticular and musculoskeletal modeling and their interaction are addressed.
These models allowed a better comprehension and evaluation of deformities, degenerescence of osteoarticular and musculoskeletal systems. Subsequently a better planification of surgery or rehabilitation could be addressed. Examples of design and their efficiency of orthoses, prostheses on the osteoarticular and musculoskeletal systems will be discussed.

Program

- Advanced biomechanics modeling methods for subject, patient specific
- Geometrical, mesh, constitutive laws derived from medical imaging techniques
- Static and dynamic structural analyses (deformable and rigid bodies)

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Marie-Christine Ho Ba Tho

BMI06 Nanotechnologies and Nanomechanics of Complex Biological Systems

Description

The aim of this course is to describe the concepts, technologies and methods at the basis of nanotechnologies for Biology, to propose some examples of applications and to show the prospects of this emerging field in Biology and Health.

Objective : describe the bottom-up approach on which nanotechnologies are based. The state-of-the-art concerning the behavior and assembly of biomolecules on the nanometer scale will also be discussed. The risks associated with the use of nano-objects and the importance of regulation will be described as well. The mechanical properties of biological tissues on the nanometer scale will also be an important part of these courses.

Examples: Fabrication of bio-inspired nanoparticles, vectorization, nanostructuration, biofunctionalization, nanoindentation,…

Program

– Biological complex systems on the nanoscale
– Nanotoxicology
– Nanoparticles (synthesis, proprerties)
– Applications in Nanobiotechnologiques
– Atomic Force Microscopy
– Nanoindentation
– Principles of solid biomechanics

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Karim El Kirat

BMI07 Multiphysics modeling of the vascular system

Description

The course is dedicated to the study of vascular flows. We will study vascular dynamics in general and consider the strong coupling that exists between blood flow, vascular wall motion and deformation and mass transfer through the blood vessel wall. Interest will also be laid on associated pathologies and development of new therapeutic techniques.

After having developed the equations of the physical phenomena (fluid mechanics, solid mechanics, mass transfer) necessary to understand blood flows, we will focus on the modeling techniques. We will detail the different approaches that may be used for the study (experimental, numerical or analytical approach). We will study the complexity of multiphysics simulations based on strong coupling between different physical problems.

Pre-requisites: basic notions of continuum mechanics and of the physiology of the cardiovascular system. The course will be oriented towards the analysis of the governing physical phenomena and will not involve any complicated mathematical developments.

Program

The program includes basic courses on biofluids and its coupling with solid biomechanics and mass transfer. We will apply all these governing equations to the study of vascular flows. Practical applications will be gained through problem session and a numerical project:

- Basic equations governing the blood flow (Navier-Stokes equations, Bernoulli equation) and the vessel deformation
- Applications to the study of vascular flows (pressure measurements, Poiseuille flow, Womersley flow, wall internal stresses, etc)
- Arterial blood flow and its characteristics; vascular pathologies
- 0D modeling of arterial flow by electrical analogy
- Experimental modeling of physiological flows
- Numerical modeling of physiological flows: computational fluid dynamics and simulation of the fluid-structure interactions
- Development of vascular medical devices

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Anne-Virginie Salsac

Area of Specialization SMA Mechatronic systems and advanced mechanics

SMA01 Advanced numerical modeling of mechanical structures

Description

Standard computational methods are not sufficient and face difficulties when dealing with the analysis of complex structures.
This course aims at presenting the limitations of standard computational methods and the advanced computational tools recently developed to circumvent those difficulties.
Based on the students' knowledge on computational tools and particularly on Finite Element methods, this course deals with the issue of the simulation of complex structures with particular concerns on their rupture.
The first part of the course focuses on the presentation of the tools dedicated to meshing/remeshing techniques (error estimators, field transfer operator, ...) in order to reach a better quality for the solution or to handle the propagation of discontinuities. The second part of the course is dedicated to the presentation of enrichment techniques allowing to tackle the difficulties inherent to the computation till rupture of structures.

Program

- Meshing / remeshing techniques
- Error estimators in Finite Element computations
- Field transfer, model transfer
- Extended Finite Element method (X-FEM)
- Strong discontinuity approach (SDA, EFEM)

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Delphine Brancherie

SMA02 Model identification in mechanics

Description

Model updating and material identification are addressed from the inverse approach point of view. The identification strategies should take into account the available information, while limiting the number of extra hypothesis. The taking into account of the data is addressed based on the relative confidence they can have. This can be performed through deterministic approaches, by the relaxation of the non-reliable information or through stochastic approaches where the knowledge on the data and the model is translated in terms of probability densities. The examples are taken from the fields of acoustic, structure dynamics, non destructive control and material characterization.

Program

- Inverse approaches in mechanics, ill-posed problem
- Various formulations: least-squares, constitutive relation error, equilibrium gap method,...
- The example of full-field measurements
- Tikhonov regularization
- Bayesian approach

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Pierre Feissel

SMA03 Compact and innovative actuators and sensors

Description

The objective of this course is to train students to design compact mechatronic systems having low energy consumption and high autonomy. This multidisciplinary course presents basics of microfabrication techniques that can be used at this scale as well as principles used in microactuators and microsensors compact systems. A focus will be done on the necessity to:
- integrate different functions of a system instead of only juxtapose them for compacity purpose and minimization of energy consumption,
- develop original concepts as well as microfactory in a system of systems approach.

Program

- Microfabrication techniques: silicon microfabrication, thin film coating, rapid prototyping at micro and mesoscales, laser machining
- Microactuation principles: magnetism, electrostatic, piezoelectricity, shape memory alloy, magnetostriction, electroactive polymer…
- Contactless micromeasurement techniques: optical, capacitive, hall effect…
- Exemples of innovative compact systems applied to microfactory concept, digital microactuation, wireless microactuation, long stroke and high resolution micro-conveyors. For each example, devices with several degrees of freedom will be described.

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Frédéric lamarque

SMA04 Systems modeling and simulation

Description

The main objective of this course is to propose some methods and applicative software to model and simulate systems. All these methods and applicative software are unavoidable to support systems engineering activities, which are system requirements management, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.
Specific applications will be set from the mechatronics systems field. To conduct such applications, mechanical, electronic, electrical and software modules have to be modeled and merged to create an integrated system.

Program

- Systems theory fundamentals,
- Requirements management,
- 0D and 1D numerical analysis,
- Multi-scale and multi-view systems modeling,
- BOMs management and systems configuration,
- Integration of systems engineering and numerical engineering approaches,
- Examples of mechatronic systems engineering, modeling and numerical analysis.

These activities will use several languages and applicative software such as: SysML, Modelica, AmeSIM, etc.

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Benoît Eynard

SMA05 Robust design of mechanical and mechatronic systems

Description

This course addresses the different tools for robust design in the particular case of mechanical or mechatronic systems.
On the one hand, the first part of this course introduce the methods of experimentation and the associated statistical data analysis methods to guide the choice of design parameters with a goal of controlling the variability (the robustness of a system is that its performance is not affected by the variability induced by the process of development or the conditions of use).
On the other hand, a second part focuses on the construction of predictive models, whether physical, statistical or hybrid and their validation. Particular attention will be given to methods of experimental design for the optimization runs (experiments real or simulation) during the construction of these models. A challenge is then the propagation of uncertainties in the models. This is an opportunity for physical models to address the calculation of non-deterministic structure. Finally, a section is devoted to methods of exploration of the solution space in the context of multi-criteria optimization by incorporating criteria related to robustness.

Program

Design of Experiments Methodology : Introduction

- Classical Design Of Experiments (DOE): factorial DOE
- Statistical Analysis Methods
- Taguchi approach: static and dynamic strength

Advanced Experimental Design of Experiments

- Criteria for the definition of experimental designs
- Response Surface Model Designs
- Orthogonal Array (OA) Designs
- Latin Hypercube (LH) Designs
- Low discrepancy Designs

Statistical modeling

- Response Surface Models
- Models with spatial correlation
- Models with Multilayer perceptrons
- Models with Radial Basis Function

Robust Multi-criteria optimization
Uncertainty propagation in models

Duration

6 weeks (30 hours Course/tutorials) + 1 week exam+Project

Person in charge

Nassim Boudaoud

SMA06 Multi-disciplinary Design Optimization

Description

For the optimization of mechanical systems, it is necessary to use simulations representing different fields of physics and using specific domain dependent tools. In this context, one has to consider the optimization procedures differently, to enable a dialogue between the different physical fields help and meet various criteria.

Program

- Strategies for collaborative optimization
- Design of digital experiences and response surfaces
- Metamodels and Reduced Order Modeling (ROM)
- Optimization of multiparameter form
- Uncertainty quantification for robust design
- Reliability based optimized design

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Piotr Breitkopf

SMA07 Smart materials

Description

Smart materials can change significantly their structure when subjected to external stimuli (magnetic, electrical, thermal or mechanical…). These changes result from several physical phenomena and involve several scales of the material microstructure. The aim of this teaching is to introduce the physical couplings associated with these behaviors, and the multi-physical models that can be used to describe them.

Program

– - Thermodynamic frame and multi-physical modeling
– - Shape memory alloys
– - Piezo-electrical materials
– - Magnetostrictive and magnetorheological materials
– - Smart polymers

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Nicolas Buiron

SMA08 Embedded Systems: electric drives and actuators

Description

Electric drives and actuators are key components of most of embedded systems (such as automotive, aerospatial, railway, naval, or bionics systems). They become more and more present and therefore important in new embedded systems.

This course consists in the presentation and the application of methods to be applied for the management of Design and Control studies of embedded electrical energy systems. The course will be based on a description of the main components (source, power converter, and actuator) and their interactions.

The presented methodology will be based on both physical and behavioral models.

Program

- Architecture of embedded electrical energy systems: focus on specificities and technological barriers;
- Methodology for the design and the optimization of electric actuators;
- Electrical power sources : storage components and power converters;
- Control strategies and their implementation;
- Implementation, using Matlab, of the different previous aspects in order to facilitate the assimilation.

Duration

6 weeks + 1 exam (Supervised 32 hours - 16 lessons, 16 TD)

Person in charge

Christophe FORGEZ

Other modules

SCI24 Seminars

Description

After having followed research seminars of the Labex laboratory, a student can ask for the validation of two ECTS.
He has then to review some papers of one seminar speaker and do an oral presentation during which he has to summarize the studied problem, the state of the art and the contribution.

Duration

2 hours per week reserved for the seminars during 14 weeks

Person in charge

Philippe Bonnifait

SCI25 Project workshop

Description

In this course, multi-skills groups composed of 4 to 6 students will work on a project linked to the three Master specializations. The objective is to apply the previously studied concepts, methods and tools on a project while encouraging interactions with the other students in the group which have skills in other domains. In this workshop, the students will also be trained to multidisciplinary engineering by taking into account the specific constraints to each field.
Each project will be supervised by a project leader (academic or industrial) and a teaching staff composed of researchers from different fields with skills in relation with the project.
The workshop integrates several aspects as systems design, modeling/simulation or development and characterization of experimental devices.

Duration

14 weeks
3h per week reserved for the project workshop

Person in charge

Laurent Petit