*Spécialité Robotique*

# Syllabus FISEA 3A

*Spécialité Robotique*

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| 3A UE2 | Sciences de base 1 | 9 ECTS | 1er semestre (S5) |
| 3A ECUE2.1 | **Mise à niveau en mathématiques**<br>Mathematics refresher | FISE<br>FISEA | 30h TD |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Compute a partial fraction decomposition in the context of integration
- Compute an integral using one of the following methods: classical form recognition,
- integration by parts, change of variable
- Give a basis and compute the dimension of a linear subspace
- Determine the kernel, the image and the matrix associated to a linear map between two
- linear spaces
- Solve a linear first or second order ordinary differential equation with constant coefficients
- Introduce some approaches to data analysis using these mathematical concepts

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- A homework on the mathematical bases of each topic is given before each small class in order to give the students the opportunity to study efficiently the course before the practical exercises.

**Summary description of the lessons - Description synthétique des enseignements**

- Complex, polynoms and rational fractions
- Integration
- Linear systems, vector spaces, basis, linear application
- Ordinary Differential Equations
- Introduction to serie
- Introduction to probability and statistics

**Prerequisites - Pré-requis**

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**Bibliographical references - Références bibliographiques**


- [1] J. Grifone. Algébre linéaire. Cépadués Editions, 2015.
- [2] K. Weltner, J. Grosjean, W. Weber. Mathématiques pour les physiciens et les ingénieurs. De Boeck, 2012
- [3] Daniel Duverney, Sylvain Heumez et Géry Huvent : Toutes les mathématiques MPSI-PCSI PTSI-TSI . Ellipses Marketing, 2004.
- [4] Walter Rudin. Principes d'analyse mathématique. Cours et exercices. Dunod, 2006.


**Keywords - Mots clés**

- Complex numbers, linear differential equation, integral calculus, generalized integral, series convergence, Fourier series, Laplace transform, vector calculus, matrix calculus

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| 3A UE2 | Sciences de base 1 | 9 ECTS | 1er semestre (S5) |
| 3A ECUE2.2 | **Informatique**<br>Algorithmic basics and programming | FISE<br>FISEA | 8h C, 10h TD, 16h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Analyse and decompose a problem to propose an algorithmic solution
- Select the appropriate data structures to model and represent the problem data
- Implement a solution in Python language and identify test situations to validate the developed programs or applications.

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Case studies

**Summary description of the lessons - Description synthétique des enseignements**

- Problem formulation and algorithm research
- Notions of spatial and temporal complexity related to algorithms
- Basic and compound data structures
- Expressions, Operators and Control structures
- Sub-programs
- Input-Output functions
- Algorithms/programs for sorting
- Algorithms/programs for compound data structures (for stacks, queues, trees, hash tables)
- Use of development environments
- Situation tables

**Prerequisites - Pré-requis**

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**Bibliographical references - Références bibliographiques**


- [1] J. Courtin, I. Kowarski. Initiation à l'algorithmique et aux structures de données, Tome I : programmation structurée et structures de données élémentaires. Editions Dunod.
- [2] T.H. Cormen. Algorithmes – Notions de base. Editions Dunod.
- [3] C. Froidevaux, M.C. Gaudel, M. Soria. Types de données et algorithmes. Ediscience.


**Keywords - Mots clés**

- Problem Analysis - Algorithmics – Complexity - Successive refining - Functional decomposition – Data Structures - Programming – Testing.

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| 3A UE2 | Sciences de base 1 | 9 ECTS | 1er semestre (S5) |
| 3A ECUE2.3 | **PROJET 1**<br>Project 1 | FISE<br>FISEA | 20h projet |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Analyze and decompose a complex task into sub-tasks
- Select the appropriate organization methods, algorithms, data structures and language to develop the software modules corresponding to each sub-task
- Implement, test, integrate and validate the developed modules to deliver a final software
- Encourage teamwork, internal and external communication and initiate students to the use of continuous integration tools

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Work on a cross-disciplinary project, based on Algorithmic basics and Imperative programming courses and related to the main topics of the training (interaction and robotics)
- Tackle the problem of project management in a group of 5 or 6 students interacting with a client (from the teacher team) through regular meetings, milestones, deliverables.
- Understand and comply with client requirements.

**Summary description of the lessons -** Description synthétique des enseignements

- Analysis of specifications given by the academic client (teacher team)
- Producing a specification report and a provisional schedule
- Develop the required components, think about generalization and reusability
- Deliver and present the final product

**Prerequisites - Pré-requis**

- Algorithmic basics and programming (Python)
- Imperative programming (Unix, C, shell)
- Project management (github, trello, …)

**Bibliographical references - Références bibliographiques**

- [1] J. Courtin, I. Kowarski. Initiation à l'algorithmique et aux structures de données, Tome I : programmation structurée et structures de données élémentaires. Editions Dunod.

**Keywords - Mots clés**

- Team work, client requirements, specifications, communication, planning, programming skills, integration issues.

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| 3A UE2 | Sciences de base 1 | 9 ECTS | 1er semestre (S5) |
| 3A ECUE2.4 | **Physique**<br>Physics | FISE<br>FISEA | 6h C, 28h TD |

**Electronique Numérique / Physics - Digital Electronics (6 h C, 12 h TD**)

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Synthesize simple combinatorial logical functions
- Identify and understand how the different scales work
- Analyze and describe the operation of simple sequential systems (counter, register)

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

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**Summary description of the lessons - Description synthétique des enseignements**

- Numeration: study of bases 2, 10 and 16, change of base.
- Representation of integers: pure binary, complement to 2.
- Boolean Algebra: theorems and axioms, algebraic simplifications. Karnaugh's paintings.
- Representation of combinatorial logical functions: truth table, algebraic form, logigram, chronogram
- Introduction to sequential logic
- RS, JK and D scales
- Asynchronous and synchronous systems
- Counters, Registers

**Prerequisites - Pré-requis**

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**Bibliographical references - Références bibliographiques**


- Claude Brie (2002), Logique combinatoire et séquentielle, éditions Ellipses, 320 pages, ISBN-13 :978-2729814250
- Jacques Jorda & Abdelaziz M'zoughi (2012), Mini-manuel d'architecture de l'ordinateur, éditionsDunod, ISBN-13 : 978-2-10-057411-7


**Keywords - Mots clés**

- Binary, Hexadecimal, Coding, Boolean Algebra, Karnaugh Tables, Combinatorial logic, Sequential logic, Toggle, Counter, Register, Logic Function, Digital Electronics

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**Mécanique / Physics - Mechanics (16 h TD)**

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Apply the fundamental principle of dynamics and statics to a point and a solid
- Understand the concept of hyperstatism for a system
- Be able to compute the hyperstatism degree for a system
- Know how to calculate the velocity and acceleration of a point

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

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**Summary description of the lessons - Description synthétique des enseignements**

- Part 1: static equilibrium, calculating the degree of hyperstatism of a system, definition of forces, Newton's laws
- Part 2: Vector manipulation, components, scalar product, vector product
- Part 3: point kinematics, Eulerian and Lagrangian point of view, velocity composition, acceleration,
- Part 4: Fundamental principle of dynamics for a point and a solid, momentum

**Prerequisites - Pré-requis**

- Use of vectors
- Notion of force
- Basic mathematics

**Bibliographical references - Références bibliographiques**

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**Keywords - Mots clés**

- statics, kinematics, dynamics

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| 3A UE2 | Sciences de base 1 | 9 ECTS | 1er semestre (S5) |
| 3A ECUE2.5 | **Outils mathématiques**<br>Mathematical tools for engineers | FISE<br>FISEA | 18 h C, 18 h TD |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Compute a partial fraction decomposition in the context of integration
- Compute an integral using one of the following methods: classical form recognition, integration by parts, change of variable
- Give a basis and compute the dimension of a linear subspace
- Solve a linear system using the Gauss elimination method
- Determine the kernel, the image and the matrix associated to a linear map between two linear spaces
- Solve a linear first or second order ordinary differential equation with constant coefficients

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

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**Summary description of the lessons - Description synthétique des enseignements**

- Complex, polynoms and rational fractions
- Integration
- Linear systems, vector spaces, basis, linear application
- Ordinary Differential Equations
- Introduction to series

**Prerequisites - Pré-requis**

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**Bibliographical references - Références bibliographiques**

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**Keywords - Mots clés**

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|---|---|---|---|
| 3A UE3 | Sciences de spécialité 1 | 12 ECTS | 1er semestre (S5) |
| 3A ECUE3.1 | **Introduction aux systèmes robotiques**<br>Introduction to robotic systems | FISE<br>FISEA | 6h C, 6h TD, 9h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand the problematic of robotics and its application fields
- Know the basic concepts and terminology
- Understand the problem of geometry in the joint space of robots

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP.

**Summary description of the lessons - Description synthétique des enseignements**

- Introduction to robotics (manipulator arm, mobile robot, cobot...)
- Description of robot mechanical structure (joints, links…)
- Joint space and operational space
- Basic tools (rotation matrices, homogeneous transformations...)
- Introduction to Forward Kinematics
- Application to industrial manipulator structures
- Practical lesson: getting started with industrial robots (Staubli, Kuka…) for tool calibration, pick & place task and input/output control. Security concepts.

**Prerequisites - Pré-requis**

- Basics of linear algebra.

**Bibliographical references - Références bibliographiques**


- [1] W. Khalil, E. Dombre. Modélisation, identification et commande des robots. Edition Hermès, 1999.
- [2] B. Siciliano & all. Robotics: modelling, planning and control. Springer, 2009.


**Keywords - Mots clés**

- Robot modeling

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| 3A UE3 | Sciences de spécialité 1 | 12 ECTS | 1er semestre (S5) |
| 3A ECUE3.2 | **Modélisation des systèmes à événements discrets**<br>Modeling of Discrete Event Systems | FISE<br>FISEA | 6h C, 6h TD, 4h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Master finite state machine models, tabular and algebraic representations of discrete event systems.

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Lectures, practical works, case studies

**Summary description of the lessons - Description synthétique des enseignements**

- Combinatorial logic functions
- Sequential logic
- Representation of sequential systems by finite state machine and algebraic description …

**Prerequisites - Pré-requis**

- Boolean algebra

**Bibliographical references - Références bibliographiques**


- [1] C. Brie. Logique combinatoire et séquentielle : méthodes, outils et réalisations. Ellipses, 2002.
- [2] Cassandras, C.G. et Lafortune, S., Introduction to Discrete Event Systems, Springer, 2008


**Keywords - Mots clés**

- Discrete event systems

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| 3A UE3 | Sciences de spécialité 1 | 12 ECTS | 1er semestre (S5) |
| 3A ECUE3.3 | **Ingénierie logicielle et système**<br>Software and system engineering | FISE<br>FISEA | 12h C, 12h TD, 12h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Perceive the necessity, importance and transversality of dependability for software and material systems, by apprehending basics concepts and terminology.
- Discover and learn about the methods and tools necessary and appropriate for the development of robust and reliable systems.

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy in courses, TD and TP

**Summary description of the lessons - Description synthétique des enseignements**

- Basic concepts, methods and vocabulary of dependability: causes of dysfunctions (threats), properties (attributes, such as reliability, safety), means to evaluate and/or achieve a given level of attributes (e.g.: tests, fault tolerance).
- System engineering: Basic concepts, processes, methodology.
- Software engineering:
  - Development stages (explanation and implementation): from specification stage to validation/release stage, with a particular focus on testing (unit and integration)
  - Adaptation of the process to standards/requirements
  - Some tools (examples): debuggers (gdb), dynamic analysis (Valgrind), version management (Git / Github)

**Prerequisites - Pré-requis**

- No prerequisite

**Bibliographical references - Références bibliographiques**


- [1] J.C. Laprie et al. Guide de la sûreté de fonctionnement (2ème édition). Cépaduès-Éditions, Toulouse, 1996.
- [2] Collectif AFIS, S. Fiorèse, JP. Meinadier. Découvrir et Comprendre l'Ingénierie Système. Cépaduès-Éditions, 2012.


**Keywords - Mots clés**

- Dependability (reliability, safety), system engineering, software development, tests

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| 3A UE3 | Sciences de spécialité 1 | 12 ECTS | 1er semestre (S5) |
| 3A ECUE3.4 | **Outils de modélisation informatique**<br>Computer modeling tools | FISE<br>FISEA | 12h C, 18h TD, 6h TP |

## Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Acquire fundamental notions concerning graphs, understand classical problems and master the algorithms to solve them:
  - Define and illustrate the fundamental concepts of graph theory (vertices, arcs, edges, connexity, trees, coloring, directed and undirected paths, flows),
  - Recognize and Represent a Problem in terms of graph theory,
  - Execute an appropriate algorithm for computing the connected components, minimum weight tree, shorter path in a graph, or for finding a solution for scheduling or maximum flow problems.
- Acquire the notion of object and handle UML diagrams:
  - Read a class diagram,
  - Describe a business context by class diagrams,
  - Identify inputs/outputs by system sequence diagrams for a previously identified case (described by a text),
  - Describe a case, previously specified by a system sequence diagram, by constructing the detailed sequence diagram and associated participating class diagram.

## Pedagogical methodology and specific aspects of teaching

- Quizz (during Graph and UML lessons), role games (during UML tutorials).

## Summary description of the lessons

- Informally, graph theory makes it possible to reason on schemas in which vertices and arcs appear. Operational research proposes rational methods for making better decisions in organizational problems. The topics covered in this course are at the confluence of graph theory and combinatorial optimization:
  - connexity, coloring,
  - trees, shortest paths; task scheduling, flow problems.
- In a second part this course deals with UML modeling:
  - the "object" concept,
  - UML diagrams.

## Prerequisites

- Algorithmic, Notions about Algorithmic Complexity, Notions about Set theory,

## Bibliographical references


- [1] BERGE Claude. « Graphes et Hypergraphes », Edition Dunod, Paris, 1969.
- [2] GONDRAN Michel, MINOUX Michel, « Graphes et Algorithmes », Edition Eyrolles, 1985.
- [3] LACOMME Philippe, PRINS Christian, SERVAUX Marc, « Algorithmes de graphes », Edition Eyrolles, 2003.
- [4] MULLER Pierre-Alain, GAERTNER Nathalie, « Modélisation objet avec UML », Edition Eyrolles, 2003.


## Keywords

- Graphs, vertices, arcs, directed and undirected path, coloring, trees, connected component, flows, scheduling, object, classes, UML diagrams

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| 3A UE3 | Sciences de spécialité 1 | 12 ECTS | 1er semestre (S5) |
| 3A ECUE3.5 | **Programmation impérative**<br>Imperative programming | FISE<br>FISEA | 12h TD, 24h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Acquire a structured and effective programming methodology to design program based a methodology of imperative programming
- Use a programming language (C) for the development of applications
- Modelling compound data structures to take into account a dynamic management of memory

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Case studies

**Summary description of the lessons - Description synthétique des enseignements**

- Methodology of imperative programming
- Expressions and Operators in C
- Control structures in C
- Sub-programs in C
- Memory management in C
- Input/output functions in C
- Use of development environments for imperative programming (including UNIX system)
- Programs in C for compound data structures

**Prerequisites - Pré-requis**

- Algorithmic notions

**Bibliographical references - Références bibliographiques**


- [1] J. Courtin, I. Kowarski. Initiation à l'algorithmique et aux structures de données, Tome I : programmation structurée et structures de données élémentaires. Editions Dunod.
- [2] T.H. Cormen. Algorithmes – Notions de base. Editions Dunod.
- [3] B. W. Kernighan, D. M. Ritchie. Le langage C. Editions Dunod.
- [4] C. Froidevaux, M.C. Gaudel, M. Soria. Types de données et algorithmes. Ediscience.


**Keywords - Mots clés**

- Imperative Programming – Compound data structures – Memory management

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| 3A UE5 | Sciences et techniques de l'ingénieur | 9 ECTS | 2ème semestre (S6) |
| 3A ECUE5.1 | **Informatique industrielle**<br>Industrial computing | FISE<br>FISEA | 10h C, 10h TD, 15h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understanding basic working of a processor and how it interacts with its peripherals
- Understanding how to navigate and use microcontroller documentation
- Low-level programming of microcontroller
- Developing a control system with a microcontroller, sensors and actuators

**Summary description of the lessons - Description synthétique des enseignements**

- Mastering a microcontroller for implementing a control system requires a good understanding of:
  - The general architecture of a computer
  - Techniques for encoding information in a computer
  - Operations of an arithmetic and logical unit
  - Operating principles of a processor (analysis of information transfers and instruction execution)
  - Its general architecture (processor, memory, peripherals)
  - Its functionalities (signal generation, time interval measurement), event management (external interruption)
  - Its programming
- Practical implementation including data acquisition, processing and process control

**Prerequisites - Pré-requis**

- Basics of computer programming
- C language
- Basics of combinatorial and sequential logic

**Bibliographical references - Références bibliographiques**


- [1] Tanenbaum, J.A. Hernandez, R. Joly. Architecture de l'ordinateur : Cours et exercices. Edition Dunod, 4ème édition, 2001
- [2] Kernighan, Brian; Ritchie, Dennis (1988). The C Programming Language (2 ed.). Prentice Hall.


**Keywords - Mots clés**

- Microcontroller, CPU, input/output, peripherals

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| 3A UE5 | Sciences et techniques de l'ingénieur | 9 ECTS | 2ème semestre (S6) |
| 3A ECUE5.2 | **Communication des systèmes**<br>System Communication | FISE<br>FISEA | 12h C, 12h TD, 12h TP |

## Learning outcomes and skills

- Understanding the need and importance of a multilayered generic model (OSI) of communication systems by apprehending basic concepts and terminology (layers, protocols, services)
- Choose a communication system for a distributed robotic system
- Configure an Internet communication stack
- Program a communication protocol adapted to real-time distributed control

## Pedagogical methodology and specific aspects of

- Classical pedagogy: courses, TD and TP.

## Summary description of the lessons - Description synthétique des enseignements

- Fundamental notions necessary for any network user: vocabulary and concepts (including in particular multilayer architecture).
- Functionalities of the lower layers of a network, essential to allow communications between a limited number of subscribers (local network).
- Impact of the network on the time constraints of the system using it.
- Upper layers required to extend the network in terms of distance and/or of number of subscribers
- Internet architecture and illustration of additional layers: network and transport level protocols, concepts of service quality.
- Specificities of embedded networks, example of the CAN network.
- Practical implementation work:
  - Configuration and manipulation of Internet protocols
  - Control (of an electric motor) distributed through a CAN network.

## Prerequisites

- Operating system (Unix), microcontroller (seen in S5 and S6) -Programming in C language (seen in S5).

## Bibliographical references


- [1] G. Pujolle. Initiation aux réseaux (cours et exercices). Edition Eyrolles. ISBN-10: 2212091559
- [2] Tanenbaum. Réseaux. Edition Dunod. ISBN-10: 2744070017
- [3] R. Orfali, D. Harkey, J. Edwards. Clients/Serveurs : guide de survie. 3ème édition, édition Vuibert 1999.


## Keywords

- Principles, vocabulary and basic network technologies - OSI model - Protocols (Ethernet, CAN, IP).

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| 3A UE5 | Sciences et techniques de l'ingénieur | 9 ECTS | 2ème semestre (S6) |
| 3A ECUE5.3 | **Traitement du signal**<br>Signal processing | FISE<br>FISEA | 12h C, 12h TD, 12h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Know the time and frequency representation tools for analog and digital signals
- Analyze the input-output relationship of linear systems such as filters and amplitude modulation.
- Analyze a digital signal with FFT using the properties of windowing and zero-padding
- Design an analog or digital filter that meets a given specification

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, exercises and labs...

**Summary description of the lessons - Description synthétique des enseignements**

- Reminder on the frequency representations of time-continuous signals and systems.
- Signal digitization (sampling, Shannon theorem, quantification). Frequency representations of discrete time signals and systems (Z-Transform, Discrete Time Fourier Transform, Discrete Fourier Transform-DFT, FFT).
- Analog filtering (analysis and synthesis of an analog filter) and analog modulations.
- Digital filtering: filter characterization, synthesis of FIR digital filters, synthesis of IIR digital filters by digitizing analog filters.
- Spectral analysis by DFT: truncation effect and notion of resolution; effect of DFT calculation and frequency accuracy; windowing and zero padding effects; introduction to time-frequency analysis.
- **Example of practical sessions (using Matlab):** signal digitization, detection of the direction of arrival of a sound and denoising by synthesis and implementation of IIR digital filters, demodulation of a stereo signal by synthesis and implementation of FIR digital filters, spectral analysis and time-frequency analysis of signals by FFT.

**Prerequisites - Pré-requis**

- Mathematical tools for engineers.

**Bibliographical references - Références bibliographiques**


- [1] F. Auger. Introduction à la théorie du signal et de l'information, Cours et exercices. Editions Technip, 1999.
- [2] M. Kunt. Traitement numérique des signaux. Presses Polytechniques et Universitaires Romandes, 1996.
- [3] G. Blanchet, Charbit. Signaux et Images sous Matlab - Méthodes, Applications et Exercices Corrigés. Edition Hermès Science Publications, 2001.


**Keywords - Mots clés**

- Digital signal processing, Fourier analysis, Filtering, Amplitude modulation, Matlab.

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| 3A UE6 | Sciences de spécialité 2 | 12 ECTS | 2ème semestre (S6) |
| 3A ECUE6.1 | **Modélisation de systèmes continus**<br>Modeling of continuous-time systems | FISE<br>FISEA | 6h C, 6h TD, 8h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand the basics of dynamic system modeling
- Analyze a continuous-time linear time-invariant (LTI) system: stability, controllability, observability, etc.
- Determine and Simulate the time response of a LTI system

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogical methodology: Cours, TD, TP

**Summary description of the lessons - Description synthétique des enseignements**

- Basic notions on systems, models, and their properties through examples from robotics
- The state-space model: mathematical structure, basic definitions, properties, etc.
- The transfer function: mathematical structure, basic definitions, properties, etc.
- Time response: definition, impulse and step responses, time domain indexes of performance, relation with the system characteristics (poles, zeros, gain)
- TP/Project: Modeling and analysis of a dynamic system thanks to MATLAB software

**Prerequisites - Pré-requis**

- Mathématiques pour l'ingénieur (équations différentielles, transformée de Laplace, algèbre matricielle)

**Bibliographical references - Références bibliographiques**


- [1] Franklin, G., Powell, J., Emami-Naeini , A. «Feedback Control of Dynamic Systems», Pearson, 2019.
- [2] Ogata, K. « Modern Control Engineering », 5th edition, Pearson, 2009.


**Keywords - Mots clés**

- Dynamical systems, state-space model, transfer functions model, time response.

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| 3A UE6 | Sciences de spécialité 2 | 12 ECTS | 2ème semestre (S6) |
| 3A ECUE6.2 | **Systèmes à événements discrets**<br>Discrete event systems | FISE<br>FISEA | 8h C, 6h TD, 9h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Design finite state machine models
- Implement discrete-event control systems

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Lectures, practical works, case studies

**Summary description of the lessons - Description synthétique des enseignements**

- Modeling effective finite state machines that respect users' requirements
- Asynchronous/synchronous implementation of finite state machines
- Software and hardware implementation of finite state machines

**Prerequisites - Pré-requis**

- Boolean algebra

**Bibliographical references - Références bibliographiques**


- [1] C. Brie. Logique combinatoire et séquentielle : méthodes, outils et réalisations. Ellipses, 2002.
- [2] Cassandras, C.G. et Lafortune, S., Introduction to Discrete Event Systems, Springer, 2008
- [3] R. Airiau, J.-M. Bergé, V. Olive, J. Rouillard. VHDL, langage, modélisation, synthèse - Presses Polytechniques et Universitaires Romandes - 1998


**Keywords - Mots clés**

- Discrete event systems, Design of control systems

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| 3A UE6 | Sciences de spécialité 2 | 12 ECTS | 2ème semestre (S6) |
| 3A ECUE6.3 | **Modélisation robotique 1**<br>Robotic modeling 1 | FISE<br>FISEA | 6h C, 6h TD, 15h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand the kinematics of robotic structures in joint and operational spaces
- Know how to generate joint trajectories
- Know the technology of robots
- Introduce to robotic integration concepts

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP.
- Project design and development teams

**Summary description of the lessons - Description synthétique des enseignements**

- Complement of basic tools
- Forward kinematics
- Inverse kinematics
- Joint space trajectory
- Actuators, sensors and gearbox
- Implementation of robotic integration concepts (engineering design office) on industrial robots (Kuka, Staubli….) and simulation (trajectory)

**Prerequisites - Pré-requis**

- UE Sciences de spécialité 1 (S5) - Systèmes automatisés et robotiques

**Bibliographical references - Références bibliographiques**


- [1] W. Khalil, E. Dombre. Modélisation, identification et commande des robots. Edition Hermès, 1999.
- [2] B. Siciliano & all. Robotics : modelling, planning and control. Springer, 2009


**Keywords - Mots clés**

- Forward and Inverse kinematics, joint trajectory,

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| 3A UE6 | Sciences de spécialité 2 | 12 ECTS | 2ème semestre (S6) |
| 3A ECUE6.4 | **PROJET 2**<br>Project 2 | FISE<br>FISEA | 20h projet |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Analyze and decompose a complex task into sub-tasks
- Select the appropriate organization methods, algorithms, data structures, languages and sensors to develop the software modules corresponding to each sub-task
- Implement, test, integrate and validate the developed modules to deliver a final software
- Capitalize on the former semester project, carry on developing skills in project group management, teamwork, organizational methods and use of continuous integration tools.

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Work on a second cross-disciplinary project as an applicative context of skills (acquired/to be acquired)
- Push forward specific modules developed during the former project, to go from simulation to work with a real mobile robotic platform.
- Carry on to tackle the problem of project management in a group of 5 or 6 students interacting with a client (from the teacher team) through regular meetings, milestones, deliverables.
- Understand and comply with client requirements as well as the constraints imposed by the robotic platform used and the human-robot interaction modalities.

**Summary description of the lessons - Description synthétique des enseignements**

- Analysis of specifications given by the academic client (teacher team)
- Specify, organize, identify and develop the require components
- Deliver and present the final product (report, demonstration, video)

**Prerequisites - Pré-requis**

- Algorithmic, programming (imperative, oriented object, system)
- Computer modeling tools and prototyping methods
- Introduction to SRI (Human-Machine interaction, Image and Audio, Robotics Systems)
- Project management

**Bibliographical references - Références bibliographiques**

**Keywords - Mots clés**

- Team work, client requirements, specifications, communication, planning, programming skills, integration issues, mobile robotic platform, Human-Robot Interaction, audio and visual modalities.

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| 3A UE6 | Sciences de spécialité 2 | 12 ECTS | 2ème semestre (S6) |
| 3A ECUE6.5 | **Programmation orientée objet**<br>Object oriented programming | FISE<br>FISEA | 12h C, 12h TD, 12h TP |

## Learning outcomes and skills

- Define and explain the main paradigms of object programming.
- Recognize when it is appropriate to use exceptions and Implement exception.
- Implement a program from a given UML specifications (in the target language JAVA).

## Pedagogical methodology and specific aspects of teaching

- Flipped classroom, poling (wooclap), role-games, standard course with lectures/ tutorials / practical works.

## Summary description of the lessons

- Introduction to the concepts of object programming (objects, methods, attributes, classes, associations, inheritance, polymorphism - constrained or not -, etc.).
- Basics of object-oriented programming with the Java object language.
- Initiation to object-oriented design: starting from a text specifying the client needs, identify the use cases, specify the software inputs/outputs, detail the program specification; then implement it in Java.

## Prerequisites

- Algorithmic, basics of programming in at least one imperative language.

## Bibliographical references - Références bibliographiques


- [1] Hugues Bersini, La programmation orientée objet - Cours et exercices en UML2, Python, PHP, C#, C++ et Java (y compris Android), 2017.
- [2] https://openclassrooms.com/fr/courses/6173501-apprenez-a-programmer-en-java Partie I - Partie 2 (points 1-2).


## Keywords

- Objects, methods, attributes, classes, associations, inheritance, polymorphism – oriented object programming, java, UML diagram.

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| 3A UE6 | Sciences de spécialité 2 | 12 ECTS | 2ème semestre (S6) |
| 3A ECUE6.6 | **Introduction aux systèmes interactifs - Image et son**<br>Introduction to interactive systems - Image and sound | FISE<br>FISEA | 8h C, 10h TD, 10h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Master the main principles related to industrial vision systems as well as the concepts of industrial image processing.
- Master the main principles of sound acquisition and acoustic parametrization.

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP.

**Summary description of the lessons - Description synthétique des enseignements**

**Audio analysis**

- Presentation of sound: frequency, intensity, etc.
- Speech production and auditory perception.
- Sound digitization process: transition from analog audio to digital audio
- Description of sound units: phonemes (speech), notes (music), etc.

**Image analysis**

- Image formation and implementation of industrial vision systems.
- Application to industrial image processing
- Practical works: specific to the two parts, illustrating their complementarity for Robotics and Interaction.

**Prerequisites - Pré-requis**

- None

**Bibliographical references - Références bibliographiques**


- [1] J.P. Haton, J.P., C. Cerisara, D. Fohr, et al. Reconnaissance automatique de la parole : Du Signal à son Interprétation. Dunod, 2006.
- [2] C. Demant, B. Streicher-Abel, P. Waszkewitz. Industrial image processing. Springer, 1999.


**Keywords - Mots clés**

- Industrial image processing, Audio processing.

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| 3A UE6 | Sciences de spécialité 2 | 12 ECTS | 2ème semestre (S6) |
| 3A ECUE6.7 | **Introduction aux systèmes interactifs - IHM**<br>Introduction to interactive systems - HMI | | 4h C, 4h TD, 6h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand the concepts of user-centered design methods
- Know how to conduct a participatory design session
- Be able to develop low and high-fidelity prototypes

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Participatory design sessions, prototyping of interactive applications

**Summary description of the lessons - Description synthétique des enseignements**

**Introduction to Human-machine interaction**

- Interaction foundations and areas of application
- Definition of the HMI, issues and Human Factors
- Interaction styles and techniques, introduction to gestural and tangible interaction
- The triptyc: design / prototype / evaluate
- HMI methods and tools
- Rapid prototyping tools

**Prerequisites - Pré-requis**

- None

**Bibliographical references - Références bibliographiques**


- [1] Donald A. Norman. The Design of Everyday Things. MIT Press, 2001.
- [2] Saul Greenberg and al. User Experiences: The Workbook. Sketching, Morgan Kaufmann, 2012.


**Keywords - Mots clés**

- Design process, Rapid prototyping.

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# Syllabus FISEA 4A

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| 4A UE1 | Sciences économiques, humaines et sociales, langues 3 | 12 ECTS | 1er semestre (S7) |
| 4A ECUE1.5 | **Alternance**<br>Work-study placement | FISEA | |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Acquire and reinforce the sets of skills along an interdisciplinary approach, in a professional environment

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Hands-on experience, under the guidance of the industrial tutor in connection with the academic tutor

**Summary description of the lessons - Description synthétique des enseignements**

- The scientific skills will be acquired along and in accordance with the chronology of the corresponding theoretical courses
- Besides, the work-study placement will enable the acquisition of specific complementary knowledge:
    - business environment: socio-productive organization of a company, legislative texts, security rules, ethical and environmental issues...
    - strengthening and improvement of self-regulation in a company: physical, emotional, mental and social
    - workplace culture, collaboration and team dynamics: autonomy, responsibility, accountability, trust, communication...
    - strategic relevance of a project w.r.t. company's long-term goals and competitive positioning: market analysis, feasibility and profitability studies, risk assessment, stakeholder analysis…
    - project organization and governance: structure, roles and responsibilities, decision-making, project leadership, and execution framework

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| 4A UE2 | Sciences de spécialité 3 | 9 ECTS | 1er semestre (S7) |
| 4A ECUE2.1 | **IA – Méthodes de résolution de problèmes**<br>AI and solving problem methods | FISE<br>FISEA | 12h C, 10h TD, 24h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Characterize and analyze a decision problem as a combinatorial problem
- Represent a combinatorial problem using Graphs, Logics or Equations and Inequations
- Solve a combinatorial problem by search and/or heuristics

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy in courses, TD and TP. Main concepts will be mastered thanks to a big dedicated project realized in TP.

**Summary description of the lessons - Description synthétique des enseignements**

- Different modes of representation and reasoning for decision-making systems.
- Examples of AI systems illustrating some of the most common problem classes (satisfaction problems, partitioning, scheduling, etc.).
- Study of the principles implemented in the field of operational research (complete and local methods for finding solutions in graphs, application to a classic AI problem).
- Modeling a decision problem with constraints and study of resolution methods (CSP programming).
- Modeling a decision problem with linear optimization methods (integer linear programming - ILP)

**Prerequisites - Pré-requis**

- UE "Scientific tools for engineers" including "Computer modelling tools" and "Mathematics".

**Bibliographical references - Références bibliographiques**


- [1] D. Crevier. A la recherche de l'intelligence artificielle. Editions Champs Flammarion (Poche).
- [2] J-M. Alliot, T. Schiex. Intelligence artificielle et informatique théorique. Editions Cepadues.
- [3] H. Farreny. Recherche heuristiquement ordonnée. Editions Masson.
- [4] S. Russel, P. Norvig. Artificial Intelligence, a modern approach. Editions Prentice Hall.


**Keywords - Mots clés**

- Problem Representation, Modeling, Decision problem

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| 4A UE2 | Sciences de spécialité 3 | 9 ECTS | 1er semestre (S7) |
| 4A ECUE2.2 | **Modèles pour le parallélisme**<br>Models for parallelism | FISE<br>FISEA | 12h C, 10h TD, 12h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Model, analyze and control of discrete event systems with parallel evolutions

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Lectures, practical works, case studies

**Summary description of the lessons - Description synthétique des enseignements**

- Limitations of state machine models.
- Models with parallel evolutions: Statecharts, Grafcet and Petri Nets.
- Models' properties analysis.
- Hardware and software implementation techniques

**Prerequisites - Pré-requis**

- Boolean algebra, State machines.

**Bibliographical references - Références bibliographiques**


- [1] Doron Drusinsky: Modeling and verification using UML statecharts - a working guide to reactive system design, runtime monitoring and execution-based model checking. Elsevier 2006: I-XII, 1-306
- [2] Reeb Bernard, "Développement des Grafcets, Automatismes, Niveau B, 2ème édition", Technosup, éditions Ellipses, 192 pages, 2011.
- [3] David R., Alla H. Du grafcet aux réseaux de Petri Hermes.1997.


**Keywords - Mots clés**

- Statecharts, Grafcet, Petri Nets

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| 4A UE2 | Sciences de spécialité 3 | 9 ECTS | 1er semestre (S7) |
| 4A ECUE2.3 | **Programmation avancée**<br>Advanced Programming | FISE<br>FISEA | 10h C, 10h TD, 16h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Deepen programming skills by mastering new high-level languages (C++ and Python).
- Be aware of the performance/expressiveness trade-off by comparing the two languages.
- Master basic technical knowledge in order to correctly program in the C++ & Python languages.
- Know how to code operators and implement polymorphism notion in the C++ & Python languages
- Master basics of scientific computing in Python

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP. These two programming languages are used in other practical sessions or projects during the second and third year

**Summary description of the lessons - Description synthétique des enseignements**

- **C++, object-oriented language and related concepts:**
  - Abstract types: class, operator overload, generic types.
  - Dynamic allocation: memory management, tables, memory leaks, intelligent pointers.
  - Dynamic polymorphism: inheritance, abstract classes, interfaces, ...
  - STL libraries and algorithms, generic class
- **Python language and related concepts:**
  - Object-oriented programming in Python
  - Functional programming, iterators, generators, decorators.
  - Scientific computing in python, vectorized computation

**Prerequisites - Pré-requis**

- UE Computer Science and C language (S5); UE Object Oriented Programming (S5) and UE Object Oriented Design in java (S6).

**Bibliographical references - Références bibliographiques**


- [1] C. Delannoy. Programmer en C++ moderne. Eyrolles, 2019 (lisible sous ScholarVox).
- [2] A. Martelli. Python en concentré. http://www.amazon.fr/dp/284177452X.


**Keywords - Mots clés**

- Object programming, classes, methods, inheritance, scientific computing.

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| 4A UE3 | Sciences de spécialité 4 | 9 ECTS | 1er semestre (S7) |
| 4A ECUE3.1 | **Optimisation**<br>Optimization | FISE<br>FISEA | 10h C, 10h TD, 10h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Model optimization techniques on robotic engineering problems,

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP/project-based learning

**Summary description of the lessons - Description synthétique des enseignements**

- Fundamental concepts
- Modeling
- Unconstrained nonlinear programming: optimality conditions, numerical methods
- Least-squares problems
- Linear programming (simplex method)
- Constrained nonlinear programming: optimality conditions, numerical methods
- Quadratic Programming
- Practical lessons: using toolbox (scipy, numpy,...) and programming in Python

**Prerequisites - Pré-requis**

- Mathematical tools for the engineer

**Bibliographical references - Références bibliographiques**


- [1] M. Bierlaire. « Introduction à l'optimisation différentiable ». PPUR presses polytechniques, 2006.
- [2] J. Nocedal S.J. Wright, « Numerical Optimization », Springer, 2006.


**Keywords - Mots clés**

- Nonlinear mathematical programming

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| 4A UE3 | Sciences de spécialité 4 | 9 ECTS | 1er semestre (S7) |
| 4A ECUE3.2 | **CAO et simulation en robotique**<br>Robotics CAD and simulation | FISEA | 8h C, 8h TD, 14h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

Master computer-aided design and simulation concepts and related softwares. Be able to

- select and dimension appropriate actuator and sensor technologies
- select and dimension suitable processing units
- take into account hardware, power, machining and manufacturing constraints

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Teaching will take the form of an integrated project (active teaching), with C-TD sessions being integrated as the project progresses.

**Summary description of the lessons - Description synthétique des enseignements**

- CAD and simulation
- Dimensioning
- Choosing sensors/motors
- Selecting a controller and hardware for its implementation
- Implementation in the form of practical work/project on the design and construction of a robotic system (work in teams).

**Prerequisites - Pré-requis**

- UE Sciences de spécialité 2 (S6) - Modélisation de systèmes robotiques 1
- UE Sciences et techniques de l'ingénieur (S6)

**Bibliographical references - Références bibliographiques**


- [1] I. Rolf. Mechatronic Systems: Fundamentals. London: Springer Nature, 2007.
- [2] L. Birglen. Mécatronique. Dunod, 2021.


**Keywords - Mots clés**

- Mechatronic Systems, CAD, simulation

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| 4A UE3 | Sciences de spécialité 4 | 9 ECTS | 1er semestre (S7) |
| 4A ECUE3.3 | **Modélisation robotique 2**<br>Robotic modeling 2 | FISE<br>FISEA | 10h C, 8h TD, 12h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand the issues of defining an operational task
- Know how to solve a standard and non-standard operational task

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP.

**Summary description of the lessons - Description synthétique des enseignements**

- Reminder on kinematics
- Geometrical and analytical Jacobian
- Forward and Inverse Differential Kinematics
- Jacobian properties (singularities, statics, redundancy, manipulability…)
- Operational space trajectory
- Introduction to Forward and Inverse Dynamics
- Kinematics of wheeled robots (nonholonomic constraints)
- Practical lessons: simulation tools (Python) and industrial operational tasks with/without ROS tools (Yaskawa…)

**Prerequisites - Pré-requis**

- UE Sciences de spécialité 2 (S6) - Modélisation robotique 1

**Bibliographical references - Références bibliographiques**


- [1] W. Khalil, E. Dombre. Modélisation, identification et commande des robots. Edition Hermès, 1999.
- [2] B. Siciliano & all. Robotics: modelling, planning and control. Springer, 2009.


**Keywords - Mots clés**

- Differential kinematics, dynamics, operational space trajectory

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| 4A UE3 | Sciences de spécialité 4 | 9 ECTS | 1er semestre (S7) |
| 4A ECUE3.4 | **Estimation et Localisation en robotique 1**<br>Estimation and Localization in Robotics 1 | FISE<br>FISEA | 6h C, 6h TD, 6h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand how to describe and handle uncertainties in a probabilistic (stochastic) setting
- Understand how to state into mathematical terms the estimation of: a vector of unknown constant parameters from noisy observations ("static case", e.g., the localization of a static robot from a vector of proprioceptive/exteroceptive sensor data); a time-sequence of unknown parameters from a time-sequence of noisy observations ("dynamic case", e.g., the localization of a moving robot from a sequence of proprioceptive/exteroceptive sensor data)
- Synthesize a stochastic estimator, in the static and dynamic cases
- Understand the probability distribution of the estimation error and its practical implications
- Address related robotic problems

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: lectures, seminars, labs – Polls using clickers – Flipped classroom

**Summary description of the lessons - Description synthétique des enseignements**

- Fundamentals of stochastic models and stochastic estimation – Robotics case studies
- Statement of a stochastic estimation problem: classical vs Bayes case; static vs dynamic case
- Synthesis of estimators in the linear Gaussian static case: maximum likelihood estimator, minimum mean-square error estimator, maximum a posteriori estimator
- Synthesis of estimators in the linear Gaussian dynamic case: Kalman filtering
- Overview of the theoretical probability distribution of estimation error – Practical implications
- Application to robot localization and other related problems

**Prerequisites - Pré-requis**

- Matrix computations, differential calculus, probabilities

**Bibliographical references - Références bibliographiques**


- [1] PAPOULIS Athanasios, "Probability, Random Variables and Stochastic Processes", Int'l Edition, 2002
- [2] KAY Steven M., "Fundamentals of Statistical Signal Processing: Estimation Theory", Prentice Hall, 1993
- [3] THRUN S., BURGARD W., FOX D., "Probabilistic Robotics", MIT Press, 2005.
- [4] SÄRKKÄ S., "Bayesian Filtering and Smoothing", Cambridge University Press, 2013.


**Keywords - Mots clés**

- Stochastic models – Stochastic estimators – Kalman filtering – Robot Localization

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| 4A UE3 | Sciences de spécialité 4 | 9 ECTS | 1er semestre (S7) |
| 4A ECUE3.5 | **Introduction au middleware robotique (ROS)**<br>Introduction to robotics middleware (ROS) | FISE<br>FISEA | 12h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand basics of the Robot Operating System (ROS) middleware

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Practical lessons

**Summary description of the lessons - Description synthétique des enseignements**

- Software concepts
- ROS ecosystem
- Basic tools
- Nodes, topics and services
- Package concept
- Modelling a simple robot
- Visualization tools
- Simulation in Gazebo

**Prerequisites - Pré-requis**

- Objet programming, Python

**Bibliographical references - Références bibliographiques**

- [1] https://homepages.laas.fr/ostasse/Teaching/ROS/poly-rosintro.pdf

**Keywords - Mots clés**

- ROS

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| 4A UE4 | Sciences économiques, humaines et sociales, langues 4 | 6 ECTS | 2ème semestre (S8) |
| 4A ECUE4.4 | **Alternance**<br>Work-study placement | FISEA | |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Acquire and reinforce the sets of skills along an interdisciplinary approach, in a professional environment

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Hands-on experience, under the guidance of the industrial tutor in connection with the academic tutor

**Summary description of the lessons - Description synthétique des enseignements**

- The scientific skills will be acquired along and in accordance with the chronology of the corresponding theoretical courses
- Besides, the work-study placement will enable the acquisition of specific complementary knowledge:
  - business environment: socio-productive organization of a company, legislative texts, security rules, ethical and environmental issues...
  - strengthening and improvement of self-regulation in a company: physical, emotional, mental and social
  - workplace culture, collaboration and team dynamics: autonomy, responsibility, accountability, trust, communication...
  - strategic relevance of a project w.r.t. company's long-term goals and competitive positioning: market analysis, feasibility and profitability studies, risk assessment, stakeholder analysis…
  - project organization and governance: structure, roles and responsibilities, decision-making, project leadership, and execution framework

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| 4A UE5 | Sciences de spécialité 5 | 9 ECTS | 2ème semestre (S8) |
| 4A ECUE5.1 | **Programmation multi-tâche et systèmes TR**<br>Multi-task programming and real-time systems | FISE<br>FISEA | 10h C, 8h TD, 12h TP |

## Learning outcomes and skills

- Understand problems associated with parallel execution of processes
- Learn to synchronize parallel processes using the semaphore concept
- Understand basic principles and concepts of real-time systems,
- Identify and take into account real-time constraints inherent to critical systems
- Understand real time scheduling to manage real time constraints
- Understand the role of real-time scheduling in managing real-time constraints and know how to calculate maximum response times and execution times for real-time tasks

## Pedagogical methodology and specific aspects of teaching

- Classical pedagogy: courses, TD and TP. Second and third year projects will enable the implementation of real time and multitask system

## Summary description of the lessons – Description synthétique des enseignements

- Introduction to parallelism (processes and resources).
- Programming and synchronization of processes under UNIX (processes, semaphores).
- Basics of real-time systems.
- Mechanisms of multi-tasking systems (communication, synchronization, etc.).
- Specificities and functionalities of a real-time executive.
- Operation of a real time kernel.
- Applicable to embedded systems.
- **Practical implementation**: UNIX parallel programming, data acquisition, real-time process processing and control. Transversal Projects based on these skills.

## Prerequisites

- Good knowledge of sequential programming in C language; Use of UNIX system (UE Computer Science S5).

## Bibliographical references


- [1] M. Ben-Ari. Processus concurrents. Introduction à la programmation parallèle. Edition Masson.
- [2] G. Padiou, A. Sayah. Techniques de synchronisation pour les Applications Parallèles. Edition Cepadues.
- [3] A. Tanenbaum, J.A. Hernandez, R. Joly. Systèmes d'exploitation : Cours et exercices. Edition Pearson Education – 2éme Édition, 2003.


## Keywords

- Real time system, parallelism, process synchronization, embedded systems

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| 4A UE5 | Sciences de spécialité 5 | 9 ECTS | 2ème semestre (S8) |
| 4A ECUE5.2 | **IA – Apprentissage automatique et apprentissage profond**<br>AI - Machine learning and deep learning | FISE<br>FISEA | 16h C, 12h TD, 16h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Identifying the appropriate type of machine learning to apply to a given decision problem
- Implementing/using standard algorithms on classification, clustering, or reinforcement learning problems
- Understanding and applying typical Deep Learning architectures
- Understanding risks and limitations of machine learning approaches

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, exercises (TD) and practicals (TP). Main concepts will be mastered thanks to dedicated projects.

**Summary description of the lessons - Description synthétique des enseignements**

- **Basics of learning approaches:**
  - Reminder of the statistical tools for data processing (statistics, notion of distance, data preparation).
  - Problems of artificial learning (typology of methods and problems, space of hypotheses, inductive principles).
  - Formalization of artificial learning (PAC model, VC-dim, bias-variance compromise).
- **Learning from digital and categorical data:**
  - supervised: K nearest neighbors, decision trees, SVM, perceptron
  - Unsupervised learning/clustering
- **Reinforcement learning:**
  - statistical properties of Markov Decision Problems, Q-learning,
  - practical applications
- **Deep learning:**
  - basics of neural network, common architectures for speech and image processing: CNN, RNN
  - limitations of machine learning approaches

**Prerequisites - Pré-requis**

- Basics of artificial intelligence and problem-solving methods (operational research – S8).
- Statistics and Probability basics, Programming

**Bibliographical references - Références bibliographiques**


- [1] X. Cornuéjols, L. Miclet, Y. Kodratoff. Apprentissage Artificiel : Concepts et algorithmes. Editions Eyrolles, 3e edition 2018.
- [2] Ian Goodfellow, Yoshua Bengio and Aaron Courville. Deep Learning, MIT Press, 2016. https://www.deeplearningbook.org/
- [3] R. Sutton & A.G. Barto, Reinforcement Learning: An Introduction, Bradford Books, 2018. https://web.stanford.edu/class/psych209/Readings/SuttonBartoIPRLBook2ndEd.pdf


**Keywords - Mots clés**

- Artificial Intelligence, Machine Learning, Classification, Supervised and Unsupervised Methods, Deep Neural Network architecture.

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| 4A UE5 | Sciences de spécialité 5 | 9 ECTS | 2ème semestre (S8) |
| 4A ECUE5.3 | **Alternance**<br>Work-study placement | FISEA | |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Acquire and reinforce the sets of skills along an interdisciplinary approach, in a professional environment

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Hands-on experience, under the guidance of the industrial tutor in connection with the academic tutor

**Summary description of the lessons - Description synthétique des enseignements**

- The scientific skills will be acquired along and in accordance with the chronology of the corresponding theoretical courses
- Besides, the work-study placement will enable the acquisition of specific complementary knowledge:
    - business environment: socio-productive organization of a company, legislative texts, security rules, ethical and environmental issues...
    - strengthening and improvement of self-regulation in a company: physical, emotional, mental and social
    - workplace culture, collaboration and team dynamics: autonomy, responsibility, accountability, trust, communication...
    - strategic relevance of a project w.r.t. company's long-term goals and competitive positioning: market analysis, feasibility and profitability studies, risk assessment, stakeholder analysis…
    - project organization and governance: structure, roles and responsibilities, decision-making, project leadership, and execution framework

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| 4A UE6 | Sciences de spécialité 6 | 9 ECTS | 2ème semestre (S8) |
| 4A ECUE6.1 | **Perception 3D**<br>3D perception | FISE<br>FISEA | 6h C, 6h TD, 6h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Master the specificities of 3D sensors in robotics and 3D calibration and reconstruction methods.

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP.

**Summary description of the lessons - Description synthétique des enseignements**

- 3D sensors for robotics: passive/active sensors, camera model, associated 3D calibration.
- Acquisition and reconstruction of 3D scenes; applications to mobile robotics.

**Prerequisites - Pré-requis**

- UE Sciences de spécialité 2 (S6) - Intro SI - Image et son
- UE Sciences de spécialité 4 (S7) - Optimisation
- UE Sciences de spécialité 4 (S7) - Estimation et localisation en robotique 1

**Bibliographical references - Références bibliographiques**


- [1] M. Dhome. Perception visuelle par imagerie vidéo. Hermès et Lavoisier, 2003.
- [2] R. Horaud, O. Monga. Vision par Ordinateur, outils fondamentaux. Hermès, 1993.
- [3] O. Faugeras. Three Dimensional Computer Vision. A Geometric Viewpoint. MIT Press, 1993.


**Keywords - Mots clés**

- 3D active and passive sensors and their calibration, 3D perception for scene reconstruction, applications to mobile robotics.

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| 4A UE6 | Sciences de spécialité 6 | 9 ECTS | 2ème semestre (S8) |
| 4A ECUE6.2 | **Navigation sous ROS**<br>ROS Navigation | FISE<br>FISEA | 2h C, 2h TD, 16h TP,<br>10h Projet |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand autonomous mobile robot navigation

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Pedagogy by project and case studies.

**Summary description of the lessons - Description synthétique des enseignements**

- Complement on ROS
- Perception of the environment
- Map building
- Motion control
- Localization and Motion planning
- Implementation on real mobile robot (Tiago/Pal Robotics)

**Prerequisites - Pré-requis**

- Introduction to ROS robotics middleware

**Bibliographical references - Références bibliographiques**

- [1] O. STASSE, Robot Operating System: Introduction.

**Keywords - Mots clés**

- Navigation, ROS

*Spécialité Robotique*

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| 4A UE6 | Sciences de spécialité 6 | 9 ECTS | 2ème semestre (S8) |
| 4A ECUE6.3 | **Estimation et localisation en robotique 2**<br>Estimation and Localization in Robotics 2 | FISE<br>FISEA | 6h C, 6h TD, 6h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Overview some nonlinear extensions of the Kalman filter
- Synthesize elementary particle filters
- Address the Simultaneous Localization and Mapping (SLAM) problem in Robotics: basic statement, EKF solution, introduction to the graphSLAM solution

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: lectures, seminars, labs – Polls using clickers

**Summary description of the lessons - Description synthétique des enseignements**

- Overview of nonlinear Kalman filters (EKF, UKF)
- Approximate Bayes filtering based on particle filters: sequential importance sampling, sequential importance resampling
- SLAM: mathematical statement and basic properties; EKF solution; introduction to the factor graph approach and its solution based on sparse quadratic nonlinear optimization

**Prerequisites - Pré-requis**

- UE Sciences de spécialité 4 (S7) - Estimation et localisation en robotique 1

**Bibliographical references - Références bibliographiques**


- [1] THRUN S., BURGARD W., FOX D., "Probabilistic Robotics", MIT Press, 2005.
- [2] SÄRKKÄ S., "Bayesian Filtering and Smoothing", Cambridge University Press, 2013.
- [3] DOUCET A., DE FREITAS N., GORDON N., "Sequential Monte Carlo Methods in Practice", Springer, 2001.


**Keywords - Mots clés**

- Nonlinear filtering – Sequential Monte Carlo methods – SLAM

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| 4A UE6 | Sciences de spécialité 6 | 9 ECTS | 2ème semestre (S8) |
| 4A ECUE6.4 | **Capteurs innovants**<br>Innovative sensors | FISEA | 8h C, 8h TD, 14h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Master the physics of robotic proprioceptive and exteroceptive sensors, their associated specifications and limits in terms of data processing.
- Master the principles of data acquisition with such sensors as well as data transmission and preprocessing / cleaning for further interpretation.
- Illustrate sensor data fusion strategies on prominent robotic problems.
- Study reliable geolocalization as a case study.

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP. Main concepts will be mastered thanks to dedicated practices.

**Summary description of the lessons - Description synthétique des enseignements**

- Extero/Proprio-ceptive sensors for robotics in terms of:
  - Sensor physics: LIDAR, cameras, radar, IMU, odometry, etc.
  - Parameters, specifications.
  - Limitations, operating range.
  - Global Navigation Satellite Systems (GNSS) based positioning.
- Data handling
  - Sensor control, data acquisition and formats.
  - Data transmission: volumetry, compression, etc.
  - Quality of services.
  - Data preprocessing and cleaning.
- Prominent strategies for sensor data fusion and their application to robotics
  - Description of the main strategies.
  - Homogeneous vs heterogeneous fusion of sensor data.
  - Loose, tight and ultra-tight coupling of GNSS based positional measurements with proprioceptive and/or exteroceptive data

**Prerequisites - Pré-requis**

- UE Sciences de base (S5) - Outils mathématiques /Mathematica tools
- UE Sciences de spécialité 2 (S6) - Introduction aux systèmes interactifs
- UE Sciences de spécialité 4 (S7) - Estimation et localisation en robotique 1
- UE Sciences de spécialité 6 (S8) - Estimation et localisation en robotique 2
- UE Sciences de spécialité 6 (S8) - Perception 3D

**Bibliographical references - Références bibliographiques**


- [1] C. Demant, B. Streicher-Abel, P. Waszkewitz. Industrial image processing. Springer, 1999.
- [2] Handbook of Global Navigation Satellite Systems. P.J.G. Teunissen, O.Montenbruck Eds. Springer, 2017


**Keywords - Mots clés**

- Extero/Proprio-ceptive sensors for Robotics, sensor specifications, data analysis, sensor data fusion.

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| 4A UE6 | Sciences de spécialité 6 | 9 ECTS | 2ème semestre (S8) |
| 4A ECUE6.5 | **Traitement du son**<br>Audio Processing | FISEA | 4h C, 4h TD, 8h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Master the main principles related to feature extraction.
- Understand the concepts related to audio modeling

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP. Main concepts will be mastered thanks to dedicated projects.

**Summary description of the lessons - Description synthétique des enseignements**

- Audio feature extraction
  - Temporal analysis,
  - Frequential analysis,
  - Hybrid representation.
- Audio modeling
  - Mixture of Gaussian laws,
  - Hidden Markov Models,
  - Deep Neural Networks.

**Prerequisites - Pré-requis**

- Mathematical tools for engineers (S5), Signal processing, Introduction to SRI – Image and audio (S6), Python Programming (S7) and Machine learning and deep learning (S8).

**Bibliographical references - Références bibliographiques**


- [1] JP. Tubach. La parole et son traitement automatique. Edition Masson, 1989.
- [2] Ben Gold, Nelson Morgan, and Dan Ellis. 2011. Speech and Audio Signal Processing: Processing and Perception of Speech and Music (2nd. ed.). Wiley-Interscience, USA.


**Keywords - Mots clés**

- Audio processing, Feature extraction, Acoustic modeling.

*Spécialité Robotique*

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| 4A UE6 | Sciences de spécialité 6 | 9 ECTS | 2ème semestre (S8) |
| 4A ECUE6.6 | **Traitement des images**<br>Image processing | FISE<br>FISEA | 10h C, 8h TD, 12h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Using different filters to improve the visual content of an image before applyingng more complex process
- Estimating an intensity gradient by different means to detect contours in an image
- Producing regional segmentation, supervised or not, to locate objects in images
- Applying morphomathematic operators to refine the shape of automatically identified regions

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD, TP

**Summary description of the lessons - Description synthétique des enseignements**

- Linear and non-linear filtering of images.
- Improved rendering.
- Gradient estimation and segmentation into regions.
- Mathematical morphology.

**Prerequisites - Pré-requis**

- Notions of signal processing and set theory. Proficiency in linear algebra calculations.

**Bibliographical references - Références bibliographiques**

- [1] Rafael C. Gonzalez, Richard E. Woods. Digital Image Processing. Pearson, 4ème edition, 2018.

**Keywords - Mots clés**

- Image filtering, image segmentation

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# Syllabus FISEA 5A

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| 5A UE1 | Sciences économiques, humaines et sociales, langues 5 | 6 ECTS | 1er semestre (S9) |
| 5A ECUE1.3 | **Alternance**<br>Work-study placement | FISEA | |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Acquire and reinforce the sets of skills along an interdisciplinary approach, in a professional environment

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Hands-on experience, under the guidance of the industrial tutor in connection with the academic tutor

**Summary description of the lessons - Description synthétique des enseignements**

- The scientific skills will be acquired along and in accordance with the chronology of the corresponding theoretical courses
- During this second year of work-study placement, new specific knowledge will be built in addition to the one acquired during semesters S7 and S8 (i.e., besides business environment, self-regulation, workplace culture/collaboration/dynamics, strategic relevance of a project, project organization and governance):
    - project execution and operational management: in-depth preliminary study, task breakdown and scheduling, documentation and training, preventive maintenance planning, team coordination, client validation and qualification, financial tracking
    - project review and strategic assessment: positioning w.r.t. future initiatives; detailed evaluation of technical results costs, and timelines

*Spécialité Robotique*

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| 5A UE2 | Sciences de spécialité 7 | 9 ECTS | 1er semestre (S9) |
| 5A ECUE2.1 | **Perception 3D avancée**<br>Advanced 3D perception | FISE<br>FISEA | 10h C, 8h TD, 9h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Master the 3D perception techniques of camera self-calibration, 3D structure from motion, 3D localization and recognition from exteroceptive sensors.

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP.

**Summary description of the lessons - Description synthétique des enseignements**

- **3D perception functions given exteroceptive sensors of robotics:**
  - Camera self-calibration
  - Structure from motion
  - Incremental modeling of 3D scene
  - 3D localization and recognition
  - Applications by examples

**Prerequisites - Pré-requis**

- UE Image processing (S8), UE 3D Perception (S8).

**Bibliographical references - Références bibliographiques**


- [1] M. Dhome. Perception visuelle par imagerie vidéo. Hermès et Lavoisier, 2003.
- [2] F. Goulette. Modélisation 3D automatique, outils de géométrie différentielle. Presses des Mines, 1999.
- [3] O. Faugeras. Three Dimensional Computer Vision. A Geometric Viewpoint. MIT Press, 1993.


**Keywords - Mots clés**

- Camera self-calibration, structure from motion, 3D modeling, 3D recognition.

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| 5A UE2 | Sciences de spécialité 7 | 9 ECTS | 1er semestre (S9) |
| 5A ECUE2.2 | **Intégration de systèmes robotiques**<br>Integration of robotic systems | *(FISE - 5A ECUE2.4)*<br>FISEA | 3h C, 2h TD, 20h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Apply ROS basics concepts to a real use case (robot, sensor, decision)

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Practical sessions / use case study

**Summary description of the lessons - Description synthétique des enseignements**

- Presentation of the objectives
- Basic functionalities (motion planning, sensor acquisition)
- Identification of the expected contribution
- Node development and integration
- Test in simulation (Yaskawa & Motoman)
- Test in real conditions

**Prerequisites - Pré-requis**

- Introduction to ROS robotics middleware

**Bibliographical references - Références bibliographiques**


- [1] https://www.motoman.com/en-us/about/y-blog/ros-enabled-ready-to-go
- [2] http://wiki.ros.org/motoman


**Keywords - Mots clés**

- ROS/ROS-industrial, robotic integration

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| 5A UE2 | Sciences de spécialité 7 | 9 ECTS | 1er semestre (S9) |
| 5A ECUE2.3 | **Planification et redondance**<br>Planning and redundancy | *(FISE - 5A ECUE2.5)*<br>FISEA | 6h C, 4h TD, 8h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Know how to use motion planning tools
- Understand and solve the redundancy robots problem

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP.

**Summary description of the lessons - Description synthétique des enseignements**

- Motion planning
  - Limitation of deterministic methods
  - Probabilistic methods and algorithms
  - Industrial applications within and outside robotics
- Redundancy robots
  - Limitation and advantage of redundant robot
  - Jacobian and null-space methods
  - Industrial applications within and outside robotics arms
- Practical lesson: implementation of motion planning on a redundant robot.

**Prerequisites - Pré-requis**

- Robotique 1 et Robotique 2, Optimisation

**Bibliographical references - Références bibliographiques**


- [1] Y. Nakamura. Advanced robotics: redundancy and optimization. Addison-Wesley, 1991
- [2] S. Lavalle. Planning Algorithms. Cambridge Univ. Press, 2006
- [3] K. Lynch, F. Parck. Modern robotics: mechanics, planning and control. Cambridge University Press, 2017.


**Keywords - Mots clés**

- Redundancy, motion planning

*Spécialité Robotique*

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| 5A UE2 | Sciences de spécialité 7 | 9 ECTS | 1er semestre (S9) |
| 5A ECUE2.4 | **Alternance**<br>Work-study placement | FISEA | |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Acquire and reinforce the sets of skills along an interdisciplinary approach, in a professional environment

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Hands-on experience, under the guidance of the industrial tutor in connection with the academic tutor

**Summary description of the lessons - Description synthétique des enseignements**

- The scientific skills will be acquired along and in accordance with the chronology of the corresponding theoretical courses
- During this second year of work-study placement, new specific knowledge will be built in addition to the one acquired during semesters S7 and S8 (i.e., besides business environment, self-regulation, workplace culture/collaboration/dynamics, strategic relevance of a project, project organization and governance):
    - project execution and operational management: in-depth preliminary study, task breakdown and scheduling, documentation and training, preventive maintenance planning, team coordination, client validation and qualification, financial tracking
    - project review and strategic assessment: positioning w.r.t. future initiatives; detailed evaluation of technical results costs, and timelines

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| 5A UE3 | Sciences de spécialité 8 | 6 ECTS | 1er semestre (S9) |
| 5A ECUE3.1 | **Robotique humanoide et cobotique**<br>Humanoid robotics and cobotics | FISEA | 8h C, 6h TD, 8h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand the humanoid robot complexity
- How to apply visual enhancement
- Understand the challenges of cobotics in industrial applications

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses, TD and TP.

**Summary description of the lessons - Description synthétique des enseignements**

- Humanoid robotics (6h)
  - Modeling
  - Control
  - Motion Planning
- Visual servoing(4h)
  - Position-based and image-based visual servoing
  - Basic tools & notions for visual servoing
  - Designing a vision-based controller using the jacobian inverse
- Cobotic (4h)
  - Advantages and disadvantages of cobotics
  - Cobotic technologies and safety standards
- Practical lesson: realization of a cobotic/positioning visual servoing task.

**Prerequisites - Pré-requis**

- Robotique 1 et Robotique 2, Optimisation

**Bibliographical references - Références bibliographiques**


- [1] F. Chaumette, S. Hutchinson, «Visual servo control. I. Basic approaches », IEEE Robotics & Automation Magazine 13(4):82 – 90, January 2007
- [2] S. Kajita, S. Sakka, H. Hirukawa, K. Harada, K. Yokoi. Introduction à la commande des robots humanoïdes : De la modélisation à la génération du mouvement. Springer 2005


**Keywords - Mots clés**

- Visual Servoing, Humanoïd robots, Cobotic

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| 5A UE3 | Sciences de spécialité 8 | 6 ECTS | 1er semestre (S9) |
| 5A ECUE3.2 | **Mise en œuvre de commande de robots**<br>Robot Control Implementation | FISEA | 10h C, 8h TD, 12h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Implement prominent state feedback control strategies for manipulator and mobile robots
- Implement output feedback controller on robots, involving state observers or stochastic filters
- Incorporate security requirements

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: lectures, seminars, labs – Polls using clickers – Flipped classroom

**Summary description of the lessons - Description synthétique des enseignements**

- Prominent strategies for motion feedback control of manipulator robots
- Prominent strategies for motion and force feedback control of manipulator robots
- Prominent strategies for motion feedback control of mobile robots
- Incorporation of a state observer or stochastic filter into an output feedback
- Security

**Prerequisites - Pré-requis**

- UE Modeling of Robotic Systems, UE Robotics 1, UE Robotics 2

**Bibliographical references - Références bibliographiques**


- [1] F.L. Lewis, D.M. Dawson, C.T. Abdallah. Robot Manipulator Control – Theory & Practice. CRC Press 2003.
- [2] M.W. Spong, S. Hutchinson, M. Vidyasagar. Robot Modeling and Control. Wiley, 2005.
- [3] J.P Laumond et all (Collectif). La robotique Mobile, Hermes, Traité IC2, 2000.
- [4] A. Kelly. Mobile Robotics, Cambridge University Press, 2013.


**Keywords - Mots clés**

- Motion and force feedback control, manipulator robots, mobile robots

*Spécialité Robotique*

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| 5A UE3 | Sciences de spécialité 8 | 6 ECTS | 1er semestre (S9) |
| 5A ECUE3.3 | **Multithreading/Safety**<br>Multithreading/Safety | FISE<br>FISEA | 10h C, 8h TD, 12h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Develop safe multithreaded application based on POSIX standard
- Understand the means of dependability dedicated to critical systems based on generic concepts of fault tolerance mechanisms
- Implement fault tolerance mechanisms based on parallel programming concepts such as multithreading

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy: courses and labs
- Pedagogy by projects to improve the student's skills in the context of robotic integration project.

**Summary description of the lessons - Description synthétique des enseignements**

- Operational safety: failure, error, faults.
- Means for Operational Safety: forecasting, prevention, elimination.
- Fault tolerance: error detection, error recovery.
- POSIX threads: life cycle management, mutexes, conditional variables

**Prerequisites - Pré-requis**

- Dependability, C language + UNIX, parallel programming

**Bibliographical references - Références bibliographiques**


- [1] Algirdas Avizienis, Fellow, IEEE, Jean-Claude Laprie, Brian Randell, and Carl Landweh. Basic Concepts and Taxonomy of Dependable and Secure Computing. IEEE TRANSACTIONS ON DEPENDABLE AND SECURE COMPUTING, VOL. 1, NO. 1, JANUARY-MARCH 2004.
- [2] Michael Kerrisk. The Linux Programming Interface: A Linux and UNIX System Programming Handbook. No Starch Press; 1st edition (October 28, 2010).


**Keywords - Mots clés**

- Critical systems, dependability, parallel programming, fault tolerance, integration project.

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| 5A UE4 | Sciences de spécialité 9 | 9 ECTS | 1er semestre (S9) |
| 5A ECUE4.1 | **Gestion de projet et intégration logicielle**<br>Project management and software integration | FISEA | 8h C, 8h TD, 8h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand the concept of supply chain network and its related management problematics
- Identify the links between robotization and logistics
- Illustrate the decision problems that robotization entails (task scheduling, vehicle touting, inventory routing)
- Introduce the Industry 4.0 and 5.0 paradigms

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Illustration of the various notions through real industrial uses-cases

**Summary description of the lessons - Description synthétique des enseignements**

- **Project management**
  - Logistics: the concept of a supply chain
  - Supply chain management (SCM) and Information systems
  - Industry of the Future - Industry 4.0 and 5.0
  - Robotics and production/management
- **Software integration**
  - Advanced use of Git
  - Continuous development and software integration
  - Docker container

**Prerequisites - Pré-requis**

- Operating system, Graph Theory, Software development

**Bibliographical references - Références bibliographiques**


- Continuous Integration: Improving Software Quality and Reducing Risk, Paul M. Duvall, Steve Matyas, Andrew Glover. Addison-Wesley Professional, 2007
- Continuous Integration, Delivery, and Deployment, S. Rosel, Packt Publishing, 2017


**Keywords - Mots clés**

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| 5A UE4 | Sciences de spécialité 9 | 9 ECTS | 1er semestre (S9) |
| 5A ECUE4.2 | **Vision et IA**<br>Vision and AI | *(FISE - 5A ECUE4.3)*<br>FISEA | 10h C, 10h TD, 16h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Know how to extract the different characteristics of an image and apply the most appropriate recognition method
- Master the architecture of image analysis systems based on deep neural networks

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Classical pedagogy in courses and TD

**Summary description of the lessons - Description synthétique des enseignements**

- Image characterization (texture, shape, color, local singularities)
- Image and features regularization before recognition
- Recognition methods
  - based on mathematical transforms
  - based on discriminant analysis
  - based on decision trees
  - based Deep learning

**Prerequisites - Pré-requis**

- Introduction to SRI (S6), Machine learning (S7), Image processing (S8).

**Bibliographical references - Références bibliographiques**


- [1] Convolutional Neural Networks in Visual Computing: A Concise Guide, R. Venkatesan, B. Li, CRC Press, 2017
- [2] Computer Vision: Algorithms and Applications, R. Szelinski, Springer, 2022


**Keywords - Mots clés**

- Pattern recognition, image understanding

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| 5A UE4 | Sciences de spécialité 9 | 9 ECTS | 1er semestre (S9) |
| 5A ECUE4.3 | **IHM et robotique**<br>HMI and robotics | FISEA | 4h C, 2h TD, 12h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand and experiment with the advantages and limitations of voice and gesture interaction modalities
- Know how to design and implement a multimodal fusion engine
- Know how to design and implement a multimodal fission engine

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Study program, practical work

**Summary description of the lessons - Description synthétique des enseignements**

**Multimodal HMI**

- Interactive System Engineering
- vocal and gestural interaction.
- Design of multimodal systems
- Application to human-robot interface

**Prerequisites - Pré-requis**

- Introduction to SRI (S6)

**Bibliographical references - Références bibliographiques**


- R. Bolt, "Put-That-There": Voice and Gesture at the Graphics Interface, SIGGRAPH 1980
- Sh. Oviatt, Ten Myths on Multimodal Interaction, Communication of the ACM, volume 42, Issue 11, November 1999


**Keywords - Mots clés**

- Multimodal system

*Spécialité Robotique*

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| 5A UE4 | Sciences de spécialité 9 | 9 ECTS | 1er semestre (S9) |
| 5A ECUE4.4 | **Interaction distribuée**<br>Distributed Interaction | *(FISE - 5A ECUE4.7)*<br>FISEA | 4h C, 2h TD, 8h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- know different programming approaches using communication networks
- be able to design, organize and implement systems composed of several sensors displayed into networks, make them interact, merge and visualize information

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Pedagogy by project dedicated to the integration of different sensors providing information through different protocols in the context of interactive system projects.

**Summary description of the lessons - Description synthétique des enseignements**

- sockets programming
- remote object programming
- event-driven bus programming
- API REST programming
- non-IP protocols

**Prerequisites - Pré-requis**

- Be familiar with basic network concepts

**Bibliographical references - Références bibliographiques**

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**Keywords - Mots clés**

- Networks, high-level protocols

*Spécialité Robotique*

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|---|---|---|---|
| 5A UE6 | Sciences de spécialité 10 | 6 ECTS | 2ème semestre (S10) |
| 5A ECUE6.2 | **Architecture communicante et cybersécurité**<br>Communicating architecture and cybersecurity | FISEA | 8h C, 8h TD, 14h TP |

**Learning outcomes and skills - Objectifs d'apprentissages et compétences**

- Understand how to choose a wireless communication system according to the objectives being pursued
- Understand why cybersecurity is important in the development of robotic applications, and how to implement the basic rules.

**Pedagogical methodology and specific aspects of teaching - Méthodologie pédagogique et particularités de l'enseignement**

- Introductory course, in-depth study of some concepts in tutorials, implementation in practical work.

**Summary description of the lessons - Description synthétique des enseignements**

- Wireless communication architecture
  - Introduction to wireless transmission
  - LPWAN (Low Power Wide Area Network) networks: example of LoRa
  - Wireless Local Area Networks (WLAN)
  - Architecture and services in 5G and industrial 5G networks
- Cybersecurity
  - Introduction to cybersecurity
  - Network and communications security
  - Security in embedded software
  - Example of the ETSI EN 303 645 standard on cybersecurity for the IoT
- Practical works, with the problems
  - connecting heterogeneous wireless systems
  - practice in developing secure software for robots.

**Prerequisites - Pré-requis**

- Sciences et techniques de l'ingénieur (S6) - Communication des systèmes

**Bibliographical references - Références bibliographiques**

- ETSI EN 303 645: Cyber Security for Consumer Internet of Things: Baseline Requirements

**Keywords - Mots clés**

- Modulation, LPWAN, WLAN, 5G, Cybersecurity, Attacks, Security, Supervision