Spécialité Robotique

Syllabus FISE 3A

Spécialité Robotique

3A UE2	Sciences de base 1	9 ECTS	1er semestre (S5)
3A ECUE2.1	**Mise à niveau en mathématiques** Mathematics refresher	FISE 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** Algorithmic basics and programming	FISE 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** Project 1	FISE 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** Physics	FISE 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

Spécialité Robotique

3A UE2	Sciences de base 1	9 ECTS	1er semestre (S5)
3A ECUE2.5	**Outils mathématiques** Mathematical tools for engineers	FISE 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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Spécialité Robotique

3A UE3	Sciences de spécialité 1	12 ECTS	1er semestre (S5)
3A ECUE3.1	**Introduction aux systèmes robotiques** Introduction to robotic systems	FISE 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

Spécialité Robotique

3A UE3	Sciences de spécialité 1	12 ECTS	1er semestre (S5)
3A ECUE3.2	**Modélisation des systèmes à événements discrets** Modeling of Discrete Event Systems	FISE 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

Spécialité Robotique

3A UE3	Sciences de spécialité 1	12 ECTS	1er semestre (S5)
3A ECUE3.3	**Ingénierie logicielle et système** Software and system engineering	FISE 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** Computer modeling tools	FISE 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** Imperative programming	FISE 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

Spécialité Robotique

3A UE5	Sciences et techniques de l'ingénieur	9 ECTS	2ème semestre (S6)
3A ECUE5.1	**Informatique industrielle** Industrial computing	FISE 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

Spécialité Robotique

3A UE5	Sciences et techniques de l'ingénieur	9 ECTS	2ème semestre (S6)
3A ECUE5.2	**Communication des systèmes** System Communication	FISE 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** Signal processing	FISE 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** Modeling of continuous-time systems	FISE 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** Discrete event systems	FISE 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** Robotic modeling 1	FISE 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,

Spécialité Robotique

3A UE6	Sciences de spécialité 2	12 ECTS	2ème semestre (S6)
3A ECUE6.4	**PROJET 2** Project 2	FISE 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.

Spécialité Robotique

3A UE6	Sciences de spécialité 2	12 ECTS	2ème semestre (S6)
3A ECUE6.5	**Programmation orientée objet** Object oriented programming	FISE 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.

Spécialité Robotique

3A UE6	Sciences de spécialité 2	12 ECTS	2ème semestre (S6)
3A ECUE6.6	**Introduction aux systèmes interactifs - Image et son** Introduction to interactive systems - Image and sound	FISE 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.

Spécialité Robotique

3A UE6	Sciences de spécialité 2	12 ECTS	2ème semestre (S6)
3A ECUE6.7	**Introduction aux systèmes interactifs - IHM** 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.

Spécialité Robotique

Syllabus FISE 4A

Spécialité Robotique

4A UE1	Sciences économiques, humaines et sociales, langues 3	12 ECTS	1er semestre (S7)
4A ECUE1.6	**Initiation à la recherche et TER 1** Initiation: How to conduct a scientific study and research work (Part 1 – State-of-the-art)	FISE	14 h TD, 25 h Projet

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Apply bibliographical research methods related to a given topic.
- Carry out a bibliographic study as part of a R&D project: searching for relevant documents and producing a synthesis of the scientific information collected. Citing and referencing related work, avoiding plagiarism.
- Answer academic or industrial specifications, identify the underlying problem, carry-out in-advance studies for the choice of equipment, tools and algorithms leading to innovative solutions.
- Communicate with the project client and identify his/her expectations and requirements.
- Be able to report on group work in written (report) and oral form (presentation and demonstration).

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

- Pedagogy by project: Develop or acquire new skills through transversal projects, in an academic or industrial context.

Summary description of the lessons - Description synthétique des enseignements

- **Bibliographical research**
  - Objectives of a state of the art,
  - Methods and tools to search for scientific information into scientific databases,
  - Synthesis of existing work.
- **Implementation of the TER**
  - Analysis of a specification,
  - Positioning of the work in relation to a state of the art.

Prerequisites - Pré-requis

- Project management (S5 and S6), Programming skills (S5, S6 and S7), Introduction to RI (S6), Communication (S5 and S6).

Keywords - Mots clés

- Project Management, State of the art.

Spécialité Robotique

4A UE2	Sciences de spécialité 3	9 ECTS	1er semestre (S7)
4A ECUE2.1	**IA – Méthodes de résolution de problèmes** AI and solving problem methods	FISE 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

Spécialité Robotique

4A UE2	Sciences de spécialité 3	9 ECTS	1er semestre (S7)
4A ECUE2.2	**Modèles pour le parallélisme** Models for parallelism	FISE 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

Spécialité Robotique

4A UE2	Sciences de spécialité 3	9 ECTS	1er semestre (S7)
4A ECUE2.3	**Programmation avancée** Advanced Programming	FISE 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.

Spécialité Robotique

4A UE3	Sciences de spécialité 4	9 ECTS	1er semestre (S7)
4A ECUE3.1	**Optimisation** Optimization	FISE 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

Spécialité Robotique

4A UE3	Sciences de spécialité 4	9 ECTS	1er semestre (S7)
4A ECUE3.2	**Commande de systèmes robotiques** Control of robotic systems	FISE	12h C, 10h TD, 12h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Synthesize prominent position and force feedback control strategies on a rigid serial manipulator robot

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

- Classical pedagogical methodology, with Labs on physical realistic small-size devices

Summary description of the lessons - Description synthétique des enseignements

- The problematics of feedback control of dynamic systems
- Overview of prominent feedback control strategies of Linear Time-Invariant (LTI) systems
- Robot joint space position control
  - Independent joint LTI feedback control
  - Feedforward strategies
  - Feedback computed-torque control (feedback linearization)
- Robot cartesian space position control
- Introduction to prominent force control strategies

Prerequisites - Pré-requis

- Modélisation robotique 2 (SRI2)
- Modélisation de systèmes continus (SRI1)

Bibliographical references - Références bibliographiques

- [1] F.L. Lewis, D.M. Dawson, C.T. Abdallah. Robot Manipulator Control – Theory & Practice. Dekker, 2007.
- [2] M.W. Spong, S. Hutchinson, M. Vidyasagar. Robot Modeling and Control. Wiley, 2020.

Keywords - Mots clés

- Robot control

Spécialité Robotique

4A UE3	Sciences de spécialité 4	9 ECTS	1er semestre (S7)
4A ECUE3.3	**Modélisation robotique 2** Robotic modeling 2	FISE 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

Spécialité Robotique

4A UE3	Sciences de spécialité 4	9 ECTS	1er semestre (S7)
4A ECUE3.4	**Estimation et Localisation en robotique 1** Estimation and Localization in Robotics 1	FISE 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

Spécialité Robotique

4A UE3	Sciences de spécialité 4	9 ECTS	1er semestre (S7)
4A ECUE3.5	**Introduction au middleware robotique (ROS)** Introduction to robotics middleware (ROS)	FISE 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

Spécialité Robotique

4A UE5	Sciences de spécialité 5	9 ECTS	2ème semestre (S8)
4A ECUE5.1	**Programmation multi-tâche et systèmes TR** Multi-task programming and real-time systems	FISE 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

Spécialité Robotique

4A UE5	Sciences de spécialité 5	9 ECTS	2ème semestre (S8)
4A ECUE5.2	**IA – Apprentissage automatique et apprentissage profond** AI - Machine learning and deep learning	FISE 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.

Spécialité Robotique

4A UE5	Sciences de spécialité 5	9 ECTS	2ème semestre (S8)
4A ECUE5.3	**Initiation à la recherche et TER 2** Initiation: How to conduct a scientific study and research work (Part 2 – Implementation)	FISE	14h TD, 25h Projet

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Answer academic or industrial specifications, identify the underlying problem, carry-out in-advance studies for the choice of equipment, tools and algorithms leading to innovative solutions.
- Organize and work as a team to design and develop an R&D application.
- Communicate with the project client and identify his/her expectations and requirements.
- Be able to report on group work in written (report) and oral form (presentation and demonstration).

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

- Pedagogy by project: Develop or acquire new skills through transversal projects, in an academic or industrial context.

Summary description of the lessons - Description synthétique des enseignements

Implementation of the TER

- Analysis of a specification
- Positioning of the work in relation to a state of the art
- Choice of hardware and software for the realization of a prototype or a POC
- Testing and evaluation of the performances of the application and/or device developed

Prerequisites - Pré-requis

- Project management (S5 and S6), Programming skills (S5, S6 and S7), Introduction to SRI (S6), Communication (S5 and S6), Initiation: How to conduct a scientific study and research work (Part 1 – State-of-the-art).

Keywords - Mots clés

- Proof of concept, Prototype, Validation and evaluation tests.

Spécialité Robotique

4A UE6	Sciences de spécialité 6	9 ECTS	2ème semestre (S8)
4A ECUE6.1	**Perception 3D** 3D perception	FISE 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.

Spécialité Robotique

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

4A UE6	Sciences de spécialité 6	9 ECTS	2ème semestre (S8)
4A ECUE6.3	**Estimation et localisation en robotique 2** Estimation and Localization in Robotics 2	FISE 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

Spécialité Robotique

4A UE6	Sciences de spécialité 6	9 ECTS	2ème semestre (S8)
4A ECUE6.4	**Commande de robot mobile** Mobile robot control	FISE	8h C, 6h TD, 4h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Understand a state feedback control scheme
- Understand the problematic of wheeled robots control
- Know how to implement a simple control on a mobile robot

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

- State space feedback
- Motion control (tracking, path following,..)
- Odometry localization

Prerequisites - Pré-requis

- Modélisation de systèmes continus
- Modélisation robotique 2

Bibliographical references - Références bibliographiques

- [1] J.P Laumond et all (Collectif). La robotique Mobile, Hermes, Traité IC2, 2000.
- [2] A. Kelly. Mobile Robotics, Cambridge University Press, 2013.
- [3] G. Franklin. Feedback Control of Dynamic Systems. Pearson. 2019

Keywords - Mots clés

- Feedback Control, wheeled robot, motion control

Spécialité Robotique

4A UE6	Sciences de spécialité 6	9 ECTS	2ème semestre (S8)
4A ECUE6.5	**Traitement de la parole** Speech Processing	FISE	8h C, 8h TD, 14h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Master the concepts related to speech modeling
- Understand the role of language models in the process of automatic speech recognition and understanding and be able to develop a voice command application.

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

- Modeling for Automatic Speech Recognition – Speech to text (STT)
  - Mixture of Gaussian laws,
  - Hidden Markov Models,
  - Deep Neural Networks.
- Learning problems
  - EM type algorithms (Viterbi, Baum-Welch),
  - MAP type adaptation.
- Language modeling and basics of speech understanding,
  - Rule-based models (grammars),
  - Statistical models (ngrams),
  - Word Embeddings (word2vect).
- Implementation of complete systems (speaker verification, keyword recognition, spoken command system etc.).

Prerequisites - Pré-requis

- UE Computer Sciences, 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] J.P. Haton, C. Cerisera, D. Fohr, Y. Laprie. Reconnaissance automatique de la parole. Edition Dunod, 2006.
- [3] D. Jurafsky, J.H. Martin. Speech and Language Processing: an Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition. Edition Pearson International (3ème édition – draft 2019) https://web.stanford.edu/~jurafsky/slp3/

Keywords - Mots clés

- Speech to text (STT), Pattern recognition, Speech understanding

Spécialité Robotique

4A UE6	Sciences de spécialité 6	9 ECTS	2ème semestre (S8)
4A ECUE6.6	**Traitement des images** Image processing	FISE 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

Spécialité Robotique

Syllabus FISE 5A

Spécialité Robotique

5A UE2	Sciences de spécialité 7	9 ECTS	1er semestre (S9)
5A ECUE2.1	**Perception 3D avancée** Advanced 3D perception	FISE 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.

Spécialité Robotique

5A UE2	Sciences de spécialité 7	9 ECTS	1er semestre (S9)
5A ECUE2.2	**Architecture de contrôle pour la robotique** Control architecture for robotics	FISE	6h C, 4h TD, 6h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Apply advanced software techniques for autonomous systems. Master robotic integration.

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

- **Robot software integration and architecture**
  - MiddleWare (ROS, ROS2, PocoLibs)
  - Emphasis on ROS/ROS2 MW and Tools (BE)
  - GenoM (BE)
- **Validation** and Verification of robotic systems
  - V&V of functional components/layer (BE)
  - Deployment of verification on the two running examples
- **Multi-robot Cooperation: Architectures and Paradigms**

Prerequisites - Pré-requis

- Software, Object programming

Bibliographical references - Références bibliographiques

- [1] M. Ghallab, D. Nau, and P. Traverso. Automated planning and acting. Cambridge University Press, 2016
- [2] F. Ingrand. Verification of Autonomous Robots: A Roboticist's Bottom-Up Approach. Software engineering for robotics, Springer, pp.219-248, 2021

Keywords - Mots clés

- Robotics software architecture

Spécialité Robotique

5A UE2	Sciences de spécialité 7	9 ECTS	1er semestre (S9)
5A ECUE2.3	**Estimation et localisation en robotique 3** Estimation and Localization in Robotics 3	FISE	5h C, 5h TD, 6h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Investigate the theoretical foundations underlying the estimation problems and solutions overviewed in the UE Estimation and Localization in Robotics 1 & 2 so as to make their mathematical treatments self-contained
- Study advanced particle filtering strategies
- Investigate more in depth the properties and emblematic solutions to SLAM (among which advanced particle filter based solutions)

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

- Reminder on the mathematical statement of a stochastic estimation problem
- Estimator analysis in the classical and Bayes contexts: bias, covariance, mean-square error, Cramér-Rao lower bound, etc.
- Mathematical statement and proofs of the synthesis of the prominent estimators in the static and dynamic cases
- Further insights in Bayesian filtering: exact recursive equations; complements on Kalman filtering (error properties; residual monitoring; tuning; implementation…); complements on particle filtering (optimal recursive strategy; Rao-Blackwellized filter)
- Complements on the SLAM problem: advanced properties; FastSLAM (Rao-Blackwellized particle filter based solution); incremental Smoothing And Mapping

Prerequisites - Pré-requis

- Estimation and Localization in Robotics 1&2

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.
- [4] DOUCET A., DE FREITAS N., GORDON N., "Sequential Monte Carlo Methods in Practice", Springer, 2001.

Keywords - Mots clés

- Stochastic models, estimation and filtering – Advanced approaches to SLAM

Spécialité Robotique

5A UE2	Sciences de spécialité 7	9 ECTS	1er semestre (S9)
5A ECUE2.4	**Intégration de systèmes robotiques** Integration of robotic systems	FISE *(FISEA - 5A ECUE2.2)*	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

Spécialité Robotique

5A UE2	Sciences de spécialité 7	9 ECTS	1er semestre (S9)
5A ECUE2.5	**Planification et redondance** Planning and redundancy	FISE *(FISEA - 5A ECUE2.3)*	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

5A UE3	Sciences de spécialité 8	6 ECTS	1er semestre (S9)
5A ECUE3.1	**Mineure Interaction (choix)** Interaction Minor (Elective)	FISE	9h C, 13h TD, 14h TP

Agents conversationnels / Conversational Agents (3h C, 5h TD, 8h TP)

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Master new technologies (methods, concepts, tools) for developing conversational agents (chatbot/voicebot)
- Understand and apply advanced speech understanding principles based on word embeddings to interpret user's utterances
- Understand and apply advanced dialog management methods based on machine learning and deep learning to predict the next action of the system
- Train and test the chatbot components to evaluate their performances
- Design interactive applications for people with special needs considering human factors or accessibility

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

- Chatbot/Voicebot Architecture
- Speaker's intent detection
- History and Dialog state tracking
- Current approaches for conversational dialogue management.
- Metrics and Evaluation methods of interactive systems

Prerequisites - Pré-requis

- Python programming (S5, S7) – AI: Machine learning and deep learning (S8) - Introduction to Speech and Language Processing (S8) – AI: Decision Method under Uncertainty (S9) AI: Spoken Dialog system (S9)

Bibliographical references - Références bibliographiques

- [1] D. Jurafsky, J.H. Martin. Speech and Language Processing: an Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition. Edition Pearson International (3ème édition – draft 2021) https://web.stanford.edu/~jurafsky/slp3/
- [2] Kat Holmes, Mitmatch – How inclusion Shapes Design, MIT Press, ISBN 978-0-262-03888-1

Keywords - Mots clés

- Chatbot/Voicebot, conversational applications, vocal interaction.

Spécialité Robotique

Intégration IA et Interaction / AI interaction and integration (6h C, 8h TD, 6h TP)

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Collaborative work in a project group, choice of the application framework (target audiences, communication modalities, accessibility constraints, communication with existing web services or databases through corresponding API).
- Specification, design and development of the conversational agent (voicebot).
- Adaptation of the different models based on artificial Intelligence method (machine learning, deep learning) to the conversational context (intentions, named entities, actions).
- Integration and performance evaluation of the different components.

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

- Pedagogy based on project

Summary description of the lessons - Description synthétique des enseignements

- Large-scale implementation
- Mobilization of transversal (project management, collaborative work) and specialized skills (multimodal interaction, oral dialogue, conversational agents, distributed computing, …)
- Confrontation with integration issues…

Prerequisites - Pré-requis

- Spoken dialogue Systems (S9), Multimodal Interaction (S9), Distributed computing (S9), Artificial Intelligence (S8 & S9), Conversational agents (S9), Project Management (S7, S9).

Bibliographical references - Références bibliographiques

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Keywords - Mots clés

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Spécialité Robotique

5A UE3	Sciences de spécialité 8	6 ECTS	1er semestre (S9)
5A ECUE3.2	**Mineure Robotique (choix)** Robotics minor (elective)	FISE	12h C, 10h TD, 14h TP

Robotique humanoide et cobotique / Humanoid robotics and cobotics (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
- Cobotics (4h)
  - Advantages and disadvantages of cobotics
  - Cobotics technologies and safety standards
- Practical lesson: realization of a cobotics/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, Cobotics

Spécialité Robotique

Optimisation de trajectoires / Trajectory optimization (4h C, 4h TD, 6h TP)

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Review all the theoretical background on dynamical systems analysis and control necessary to address Model Predictive Control
- Introduce basic Model Predictive Control strategies

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

- Reminder on modeling, analysis and control of Linear Time Invariant systems – Introduction to nonlinear systems
- Lyapunov stability analysis
- Continuous-time and Discrete-time Linear Quadratic (LQ, DLQ) and Linear Quadratic Regulator (LQR, DLQR) control
- Introduction to optimal control – Optimality principle – Solution of discrete-time optimal control problems by Dynamic Programming
- Introduction to Model Predictive Control

Prerequisites - Pré-requis

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

Bibliographical references - Références bibliographiques

- [1] Khalil, H.K., "Nonlinear Systems", Prentice Hall, 2002
- [2] Rossiter, J.A., "Model-based Predictive Control – A Practical Approach", CRC Press LLC, 2004.

Keywords - Mots clés

- Stability analysis – Optimal control – Model Predictive Control

Spécialité Robotique

5A UE3	Sciences de spécialité 8	6 ECTS	1er semestre (S9)
5A ECUE3.3	**Multithreading/Safety** Multithreading/Safety	FISE 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.

Spécialité Robotique

5A UE4	Sciences de spécialité 9	9 ECTS	1er semestre (S9)
5A ECUE4.1	**Gestion de projet, Agilité, Logistique** Project management, Agility, Logistics	FISE	10h C

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

- Logistics: the concept of a supply chain
- Supply chain management (SCM)
- Information systems and SCM
- Industry of the Future - Industry 4.0 and 5.0
- Technological pillars
- Robotics and production scheduling
- Robotics and inventory management
- Robotics and just-in-time production
- Robotics and (Capacited) Vehicle Routing

Prerequisites - Pré-requis

- Combinatorial optimization
- Graph Theory

Bibliographical references - Références bibliographiques

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Keywords - Mots clés

- Production management, scheduling, inventory routing

Spécialité Robotique

5A UE4	Sciences de spécialité 9	9 ECTS	1er semestre (S9)
5A ECUE4.2	**Professionnalisation - PGE** Professionalization - PGE	FISE	8h TD, 24h TP, 40h projet

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Understand the challenges and steps of an industrial project
- Analyze and understand the needs of an industrial customer
- Break down, structure and plan the realization of an industrial project
- Manage the realization of an industrial project
- Organize and manage a project team

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

- Work on a cross-disciplinary project related to the main topics of the training (robotics and interaction)
- Carry out a project as part of a large team (about 18 members)
- Project team self-management

Summary description of the lessons - Description synthétique des enseignements

- Analysis of the needs given by an industrial customer
- Produce a schedule, a development plan (team organization, Product Breakdown Structure, Working Breakdown Structure) and a quality report
- Choose a team organization, a process and methods adapted to the realization of a complex industrial project
- Manage internal and external communication (with the industrial customer and the teaching team)
- Organize and lead reviews to present the work carried out
- Assistance of a team of experts to advise the project team on technical and technological choices
- Coaching at each phase of the project by the educational team to help the project team understand what is expected

Prerequisites - Pré-requis

- System and software engineering (process, methodology, development stages)
- Programming, robotics, vision, interaction (depending of the project)
- Project management (PBS, WBS, organization, scheduling, follow-up)

Bibliographical references - Références bibliographiques

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Keywords - Mots clés

- Team work, customer needs, specifications, communication, scheduling, organization

Spécialité Robotique

5A UE4	Sciences de spécialité 9	9 ECTS	1er semestre (S9)
5A ECUE4.3	**Vision et IA** Vision and AI	FISE *(FISEA - 5A ECUE4.2)*	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

Spécialité Robotique

5A UE4	Sciences de spécialité 9	9 ECTS	1er semestre (S9)
5A ECUE4.4	**IA appliquée à l'interaction** AI applied to interaction	FISE	2h C, 2h TD, 10h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Address a reasoning/decision problem under uncertain knowledge:
  - Identify the appropriate formal framework,
  - Modeling,
  - Select the relevant tools, implement and test the solution

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

- The basics of the studied models will be briefly presented in the course / TD, and developed and put into practice more deeply on case studies, during practical sessions.

Summary description of the lessons - Description synthétique des enseignements

- Representation of uncertainty:
  - Bayesian and non-Bayesian probabilistic models,
  - Belief functions,
  - Possibility theory.
- Decision under uncertainty:
  - Expected utility,
  - Choquet integral,
  - Non-expected utility and credal models,
  - Qualitative pessimistic utility
- Sequential decision under uncertainty:
  - Decision trees,
  - Markov Decision Processes.

Prerequisites - Pré-requis

- Probability theory, Constraint programming and/or mixed integer linear programming

Bibliographical references - Références bibliographiques

- Denis Bouyssou, Didier Dubois, Henri Prade, Pirlot (Edts) Decision Making Processes; Wisley. 2009.

Keywords - Mots clés

- Probability Theory, Imprecise Probabilities, Decision Theory, Decision under Uncertainty, Expected Utility, Multi Prior Model, Non-Expected Utility, Markov Decision Processes.

Spécialité Robotique

5A UE4	Sciences de spécialité 9	9 ECTS	1er semestre (S9)
5A ECUE4.5	**IHM multimodale** Multimodal interaction	FISE	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

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

5A UE4	Sciences de spécialité 9	9 ECTS	1er semestre (S9)
5A ECUE4.6	**IA et dialogue oral** AI and spoken dialogue systems	FISE	4h C, 4h TD, 10h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Understand the architecture of a task-driven spoken dialogue system to develop simple human robot interaction applications
- Use basic approaches to implement a frame-based speech understanding component
- Use basic approaches to implement a dialog management component
- Chose the appropriate interaction strategy to guide the flow of the dialogue depending on the user profile

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

- Case study

Summary description of the lessons - Description synthétique des enseignements

- Spoken dialog system architecture and components
- Concepts and Models dedicated to speech understanding and dialogue management
- Concepts related to user profiles and interaction strategy (directive or flexible)

Prerequisites - Pré-requis

- Advanced Programming (S7) – Introduction to Speech and Language Processing (S8)

Bibliographical references - Références bibliographiques

- [1] D. Jurafsky, J.H. Martin. Speech and Language Processing: an Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition. Edition Pearson International (3ème édition – draft 2021) https://web.stanford.edu/~jurafsky/slp3/

Keywords - Mots clés

- Spoken dialog system, Human-Machine Interaction, task-oriented systems.

Spécialité Robotique

5A UE4	Sciences de spécialité 9	9 ECTS	1er semestre (S9)
5A ECUE4.7	**Interaction distribuée** Distributed Interaction	FISE *(FISEA - 5A ECUE4.4)*	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

5A UE6	Sciences de spécialité 10	6 ECTS	2ème semestre (S10)
5A ECUE6.1	**Professionnalisation - PGE** Professionalization - PGE	FISE	60h Projet

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Understand the challenges and steps of an industrial project
- Analyze and understand the needs of an industrial customer
- Breakdown, structure and plan the realization of an industrial project
- Realize an industrial project
- Follow the realization of a project and adapt scheduling

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

- Work on a cross-disciplinary project related to the main topics of the training (robotics and interaction)
- Carry out a project as part of a large team (about 18 members)
- Project team self-management

Summary description of the lessons - Description synthétique des enseignements

- Design, implement, integrate and validate the product
- Evolve team organization and process to adapt to project hazards
- Manage internal and external communication (with the industrial customer and the teaching team)
- Organize and lead reviews to present the work carried out
- Deliver the final product and organize a public presentation to share the work carried out
- Assistance of a team of experts to advise the project team on technical and technological choices
- Coaching at each phase of the project by the educational team to help the project team understand what is expected

Prerequisites - Pré-requis

- System and software engineering (process, methodology, development stages)
- Programming, robotics, vision, interaction (depending of the project)
- Project management (PBS, WBS, organization, scheduling, follow-up)
- Communication

Bibliographical references - Références bibliographiques

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Keywords - Mots clés

- Team work, customer needs, specifications, communication, scheduling, organization, agility, SCRUM, communication