MAQUETTE 1A

				%	H	C	TD	TP	Projet
SEMESTRE 5	Sciences économiques, humaines et sociales, langues 1 (9 ECTS)	Langues - LV1 Anglais		33%	24		24		
		Economie et Gestion d'entreprise		33%	36	18	18		
		SHS		23%	18	8	10		
		EPS		11%	16		16		
	Sciences de base (9 ECTS)	Informatique		50%	34	8	10	16	
			PROJET SRI 1	*25%*					20
		Outils mathématiques		25%	36	18	18		
		Mises à niveau (Mathématiques et Informatique)		-	30		30		
		Physique		25%	34	6	28		
	Sciences de spécialité 1 (12 ECTS)	Systèmes automatisés et robotiques		25%					
			Introduction aux systèmes robotiques	*15%*	21	6	6	9	
			Modélisation des Systèmes à évènements discrets	*10%*	16	6	6	4	
		Ingénierie logicielle et système		25%	36	12	12	12	
		Outils de modélisation informatique		25%	36	12	18	6	
		Programmation impérative		25%	36		12	24	
		Total des heures S5			**373**	94	208	71	**20**

				%	H	C	TD	TP	Projet
SEMESTRE 6	Sciences économiques, humaines et sociales, langues 2 (9 ECTS)	Langues - LV1 + LV2 au choix		33%	36		36		
		SHS		23%	18	8	10		
		EPS		11%	16		16		
		Gestion de projets		33%	36	10	26		
		Stage 2 mois		-					
	Sciences et techniques de l'ingénieur (9 ECTS)	Informatique Industrielle		33%	35	10	10	15	
		Communication des systèmes		34%	36	12	12	12	
		Traitement du signal		33%	36	12	12	12	
	Sciences de spécialité 2 (12 ECTS)	Modélisation de systèmes robotiques		60%					
			Modélisation de systèmes continus	*15%*	20	6	6	8	
			Systèmes à Evénements discrets	*15%*	23	8	6	9	
			Modélisation robotique 1	*15%*	21	6	6	9	
			PROJET SRI 2	*15%*					20
		Programmation Orientée Objet		20%	36	12	12	12	
		Introduction aux systèmes interactifs		20%					
			Intro SI - Image et son	*14%*	28	8	10	10	
			Intro SI - IHM	*6%*	14	4	4	6	
		Total des heures S6			**355**	96	166	93	**20**
		1A : total des heures étudiant			**728**				**40**

UE	*SCIENCES DE BASE*	*9* ECTS	1er semestre
Matière	*Informatique* **Algorithmic basics and programming**	Organisation	Présentiel : 8 h C, 10 h TD, 16 h 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

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.

UE	*SCIENCES DE SPECIALITE 1*	*12* ECTS	1er semestre
Matière	*Introduction aux systèmes robotiques* **Introduction to robotic systems**	Organisation	Présentiel : 6 h C, 6 h TD, 9 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

Understand the problematic of robotics and its application fields
To know the definitions and basic concepts
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, mobile, cobot...)
Description of robot mechanical structure (joint, link…)
Joint space and operational space
Basic tools (rotation matrix...)
Homogeneous transformations
Direct Kinematic Model
DKM application to industrial manipulator structure

Practical lesson : getting start industrial robot (Staubli, Kuka…) for tool calibration, pick & place task and input/output control. Security concepts.

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 modelling

UE	*SCIENCES DE SPECIALITE 1*	*12* ECTS	1er semestre
Matière	*Modélisation des systèmes à événements discrets* **Modelling Discrete Event Systems**	Organisation	Présentiel : 6 h C, 6 h TD, 4 h 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

UE	*SCIENCES DE SPECIALITE 1*	*12* ECTS	1er semestre
Matière	Outils de modélisation informatique **Computer modeling tools**	Organisation	Présentiel : 12 h C, 18 h TD, 6 h 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

UE	*SCIENCES DE SPECIALITE 1*	*12* ECTS	1er semestre
Matière	Ingénierie logicielle et système *Software and system engineering*	Organisation	Présentiel : 12 h C, 12 h TD, 12 h 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

UE	*SCIENCES DE SPECIALITE 1*	*12* ECTS	1er semestre
Matière	*Programmation impérative* **Imperative programming**	Organisation	Présentiel : 12 h TD, 24 h 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

UE	*SCIENCES ET TECHNIQUES DE L'INGENIEUR*	*9* ECTS	2ème semestre
Matière	*Informatique industrielle* **Industrial Informatics**	Organisation	Présentiel : 10 h C, 10 h TD, 15 h 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

UE	*SCIENCES ET TECHNIQUES DE L'INGENIEUR*	*9* ECTS	2ème semestre
Matière	*Traitement du signal* **Signal processing**	Organisation	Présentiel : 12 h C, 12 h TD, 12 h 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.

UE	*SCIENCES DE SPECIALITE 2*	*12* ECTS	2ème semestre
Matière	*Modélisation de systèmes continus* **Modelling of continuous systems**	Organisation	Présentiel : 6 h C, 6 h TD, 8 h 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.

UE	*SCIENCES DE SPECIALITE 2*	*12* ECTS	2ème semestre
Matière	*Systèmes à événements discrets* **Discrete event systems**	Organisation	Présentiel : 8 h C, 6 h TD, 9 h 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

Modelling 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

UE	*SCIENCES DE SPECIALITE 2*	*12* ECTS	2ème semestre
Matière	*Modélisation robotique 1* **Robotic modelling 1**	Organisation	Présentiel : 6 h C, 6 h TD, 9 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

Understand the kinematics of robotic structures in joint space
Know how to generate joint trajectories
Know the technology 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

Differential kinematic model
Derivatives of a rotation matrix
Geometric Jacobian
Singularities
Analytical Jacobian
Jacobian of classical industrial manipulator robots
Joint space trajectory
Actuators, sensors and gear box

Practical lesson on industial robots (kuka, Staubli….) and simualtion (trajectory and jacobian)

Prerequisites - Pré-requis

UE Systèmes automatisés et robotiques (S5)

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, jacobian, joint trajectory

UE	*SCIENCES DE SPECIALITE 2*	*12* ECTS	2ème semestre
Matière	Programmation orientée objet **Object oriented programming**	Organisation	Présentiel : 12 h C, 12 h TD, 12 h 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.

UE	*SCIENCES DE SPECIALITE 2*	*12* ECTS	2ème semestre
Matière	*Introduction aux systèmes interactifs – Image et son* **Intro to SRI – Image and Audio**	Organisation	Présentiel : 8 h C, 10 h TD, 10 h 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

TPs 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.

UE	*SCIENCES DE SPECIALITE 2*	*12* ECTS	2ème semestre (S6)
Matière	*Introduction aux systèmes interactifs – IHM* **Intro to SRI – Human-Machine Interaction**	Organisation	Présentiel : 4 h C, 4 h TD, 6 h 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.

MAQUETTE FISE 2A

				%	H	C	TD	TP	Projet
SEMESTRE 7	Sciences économiques, humaines et sociales, langues 3 (12 ECTS)	Langues - LV1 Anglais		25%	36		36		
		Création d'entreprise		25%	34	18	16		
		SHS		13%	18	8	10		
		EPS		12%	16		16		
		Initiation à la recherche et TER 1		25%	14		14		25
	Sciences de spécialité 3 (9 ECTS)	IA - Méthodes de résolution de problèmes		33%	46	12	10	24	
		Modèles pour le parallélisme		33%	34	12	10	12	
		Programmation avancée		34%	36	10	10	16	
	Sciences de spécialité 4 (9 ECTS)	Robotique		75%					
			Optimisation	*25%*	30	10	10	10	
			Commande de systèmes robotiques	*25%*	34	12	10	12	
			Modélisation robotique 2	*25%*	30	10	8	12	
		Estimation et Localisation en robotique 1		15%	14	6	4	4	
		Introduction au middleware robotique (ROS)		10%	12			12	
		Total des heures S7			**354**	98	154	102	**25**

				%	H	C	TD	TP	Projet
SEMESTRE 8	Sciences économiques, humaines et sociales, langues 4 (6 ECTS)	Langues - LV1 + LV2 au choix		50%	36		36		
		Qualité		25%	12	6	6		
		EPS		25%	16		16		
	Sciences de spécialité 5 (9 ECTS)	Programmation multi-tâche et systèmes TR		33%	30	10	8	12	
		IA - Apprentissage Automatique et Apprentissage profond		33%	44	16	12	16	
		Initiation à la recherche et TER 2		34%	14		14		25
	Sciences de spécialité 6 (9 ECTS)	Navigation en robotique		50%					
			Perception 3D	*10%*	18	6	6	6	
			Navigation sous ROS	*20%*	20	2	2	16	10
			Estimation et Localisation en robotique 2	*10%*	18	6	6	6	
			Contrôle de robot mobile	*10%*	18	8	6	4	
		Traitement de la parole		25%	30	8	8	14	
		Traitement des images		25%	30	10	8	12	
	STAGE (6 ECTS)	Stage		100%					
		Total des heures S8			**286**	72	128	86	**35**
		2A : total des heures étudiant			**640**				**60**

UE	*SCIENCES ECONOMIQUES, HUMAINES ET SOCIALES, LANGUES 3*	*12* ECTS	1er semestre
Matière	*Initiation à la recherche et TER 1* **Initiation: How to conduct a scientific study and research work** **(Part 1 – State-of-the-art)**	Organisation	Présentiel : 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 SRI (S6), Communication (S5 and S6).

Keywords - Mots clés

Project Management, State of the art.

UE	*SCIENCES DE SPECIALITE 3*	*9* ECTS	1er semestre
Matière	*IA – Méthodes de résolution de problèmes* **AI and solving problem methods**	Organisation	Présentiel : 12 h C, 10 h TD, 24 h 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 optimisation 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, Modelling, Decision problem

UE	*SCIENCES DE SPECIALITE 3*	*9* ECTS	1er semestre
Matière	*Modèles pour le parallélisme* **Models for parallelism**	Organisation	Présentiel : 12 h C, 10 h TD, 12 h 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

UE	*SCIENCES DE SPECIALITE 3*	*9* ECTS	1er semestre
Matière	*Programmation avancée* **Advanced Programming**	Organisation	Présentiel : 10 h C, 10 h TD, 16 h 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.

UE	*SCIENCES DE SPECIALITE 4*	*9* ECTS	1er semestre
Matière	*Optimisation* **Optimization**	Organisation	Présentiel : 10 h C, 10 h TD, 10 h TP/Projet

Learning outcomes and skills - Objectifs d'apprentissages et compétences

Be able to model and apply 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
- Non-linear programming without constraints: optimality conditions, numerical methods
- Least-squares problems
- Linear programming (simplex method)
- Non-linear programming with constraints: optimality conditions, numerical methods
- Quadratic Programming

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

UE	*SCIENCES DE SPECIALITE 4*	*9* ECTS	2ème semestre
Matière	*Commande de systèmes robotiques* **Control of robotic systems**	Organisation	Présentiel : 12 h C, 10 h TD, 12 h 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

UE	*SCIENCES DE SPECIALITE 4*	*9* ECTS	1er semestre
Matière	*Modélisation robotique 2* **Robotic modelling 2**	Organisation	Présentiel : 10 h C, 8 h TD, 12 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

Understand the issues of defining an operational task

Know how to solve a 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

Task space definition

Inverse kinematics problem

Inverse differential kinematics

Jacobian properties (statics, redundancy, manipulability…)

Operational space trajectory

Dynamics model

Practical lessons : simulation tools (python) and industrial operational task with/without ROS tools (Yaskawa…)

Prerequisites - Pré-requis

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

Inverse robot model, dynamics, space trajectory

UE	*SCIENCES DE SPECIALITE 4*	*9* ECTS	1er semestre
Matière	*Estimation et Localisation en robotique 1* **Estimation and Localization in Robotics 1**	Organisation	Présentiel : 6 h C, 4 h TD, 4 h 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 (typically: the localization of a static robot from proprioceptive/exteroceptive sensor data)
- Analyze and synthesize a stochastic (static) estimation scheme, in a classical or Bayesian context
- Address related robotics 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
- Estimator analysis: bias, covariance, mean-square error, Cramér-Rao lower bound, etc.
- Synthesis of classical and Bayes estimators (maximum likelihood, minimum mean-square error, maximum a posteriori) with a focus on the linear Gaussian case

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.

Keywords - Mots clés

Stochastic models – Stochastic estimation

UE	*SCIENCES DE SPECIALITE 4*	*9* ECTS	1er semestre
Matière	*Introduction au middleware robotique (ROS)* **Introduction to robotics middleware (ROS)**	Organisation	Présentiel : 12 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

Understand the ROS basics

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
- 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

UE	*SCIENCES DE SPECIALITE 5*	*9* ECTS	2ème semestre
Matière	*Programmation multi-tâche et systèmes temps réel* **Multi-task programming and real-time systems**	Organisation	Présentiel : 10 h C, 8 h TD, 12 h 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 this UE 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

UE	*SCIENCES DE SPECIALITE 5*	*9* ECTS	2ème semestre
Matière	*IA – Apprentissage automatique et apprentissage profond* **Machine learning and deep learning**	Organisation	Présentiel : 16 h C, 12 h TD, 16 h 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, exercices (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.

UE	*SCIENCES DE SPECIALITE 5*	*9* ECTS	2ème semestre
Matière	*Initiation à la recherche et TER 2* **Initiation: How to conduct a scientific study and research work** **(Part 2 – Implementation)**	Organisation	Présentiel : 14 h TD, 25 h 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.

UE	*SCIENCES DE SPECIALITE 6*	*9* ECTS	2ème semestre
Matière	*Perception 3D* **3D perception**	Organisation	Présentiel : 6 h C, 4 h TD, 6 h 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 perception:

- 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 Estimation and Optimization (S7), UE Image Processing (S6)

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.

UE	*SCIENCES DE SPECIALITE 6*	*9* ECTS	2ème semestre
Matière	*Navigation sous ROS* **ROS Navigation**	Organisation	Présentiel : 2 h C, 2 h TD, 16 h TP, 10 h Projet

Learning outcomes and skills - Objectifs d'apprentissages et compétences

Understand the problem of autonomous navigation of a mobile robot

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 creation
Motion control
Location and movement planning
Implementation on the TIAGO mobile robot

Prerequisites - Pré-requis

Introduction to ROS robotics middleware

Bibliographical references - Références bibliographiques

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

Keywords - Mots clés

Navigation, ROS

UE	*SCIENCES DE SPECIALITE 6*	*9* ECTS	2ème semestre
Matière	*Estimation et localisation en robotique 2* **Estimation and Localization in Robotics 2**	Organisation	Présentiel : 6 h C, 6 h TD, 6 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Understand how to state into mathematical terms the estimation of a time-sequence of unknown parameters from a time-sequence of noisy observations (typically: the localization of a mobile robot from a sequence of proprioceptive/exteroceptive sensor data)
- Synthesize a solution based on the Kalman filter – Master is fundamental properties
- Get insights into the tuning of a Kalman filter
- Address related robotics problems

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

- Mathematical setting and equations of Kalman filtering (linear Gaussian case)
- Error statistics – Tuning – Implementation – Nonlinear extensions (EKF,UKF)
- Overview of some related robotics problems and their solutions: mobile robot localization; introduction to Simultaneous Localization and Mapping (SLAM)

Prerequisites - Pré-requis

Estimation and Localization in Robotics 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.

Keywords - Mots clés

Robot localization – Kalman filtering

UE	*SCIENCES DE SPECIALITE 6*	*9* ECTS	2ème semestre
Matière	*Contrôle de robot mobile* **Mobile robot control**	Organisation	Présentiel : 8 h C, 6 h TD, 4 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

Understand the problematic of wheeled robots

Understand a state feedback control scheme

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

Kinematic model of whelled robots (Nonholonomic constraints)

State space feedback

Motion control : tracking and path following

Odometry localization

Prerequisites - Pré-requis

Modélisation de systèmes continus

Modélisation robotique2

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, whelled robot, motion control

UE	*SCIENCES DE SPECIALITE 6*	*9* ECTS	2ème semestre
Matière	*Traitement de la parole* **Speech Processing**	Organisation	Présentiel : 8 h C, 8 h TD, 14 h 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

UE	*SCIENCES DE SPECIALITE 6*	*9* ECTS	2ème semestre
Matière	*Traitement des images* **Image processing**	Organisation	Présentiel : 10 h C, 8 h TD, 12 h 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

MAQUETTE FISE 3A

				%	H	C	TD	TP	Projet
SEMESTRE 9	Sciences économiques, humaines et sociales, langues 5 (6 ECTS)	Langues - LV1 + LV2 au choix		50%	36		36		
		Innovation et législation		50%	30	10	20		
	Sciences de spécialité 7 (9 ECTS)	Systèmes robotiques		40%					
			Perception 3D	*25%*	27	10	8	9	
			Coopération multi-robots + architecture	*15%*	16	6	4	6	
		Filtrage particulaire et SLAM		20%	20	6	6	8	
		Intégration de systèmes robotiques		40%					
			Projet intégration sous ROS	*25%*	25	3	2	20	
			Motion planning et robotique humanoïde	*15%*	18	6	4	8	
	Sciences de spécialité 8 (6 ECTS)	Mineure Interaction (choix)		60%					
			Agents conversationnels	*25%*	16	3	5	8	
			Intégration IA et Interaction	*35%*	20	6	8	6	
		Mineure Robotique (choix)		60%					
			Systèmes robotiques complexes	*20%*	12	4	4	4	
			Optimisation de trajectoires et commande ref vision	*40%*	24	8	8	8	
		Multithreading/Safety		40%	30	10	8	12	
	Sciences de spécialité 9 (9 ECTS)	Gestion de projet, Coaching PGE, Agilité, Logistique		40%	42	10	8	24	40
		Systèmes interactifs		60%					
			Vision et IA	*20%*	36	10	10	16	
			IA appliquée à l'interaction	*10%*	14	2	2	10	
			IHM multimodale	*10%*	18	4	2	12	
			IA et Dialogue oral	*10%*	18	4	4	10	
			Interactions distribuées	*10%*	14	4	2	8	
		Total des heures S9			**380**	94	129	157	**40**

			%	H	C	TD	TP	Projet
SEMESTRE 10	Sciences économiques, humaines et sociales, langues 6 (3 ECTS)	RE&D2	100%	20	20			
	Sciences de spécialité 10 (6 ECTS)	Professionnalisation et Qualification	100%					60
	STAGE (21 ECTS)	Stage	100%					
		Total des heures S10		**20**	20	0	0	**60**
		3A : total des heures étudiant		**400**				**100**

UE	*SCIENCES DE SPECIALITE 7*	*9* ECTS	1er semestre
Matière	*Perception 3D* **3D Perception**	Organisation	Présentiel : 10 h C, 8 h TD, 9 h 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 modelling 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 modelling, 3D recognition.

UE	*SCIENCES DE SPECIALITE 7*	*9* ECTS	1er semestre
Matière	*Supervision et Coopération multi-robots* **Multi-robot supervision and cooperation**	Organisation	Présentiel : 6 h C, 4 h TD, 6 h 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 (BE

Multi-robot Cooperation : Architectures and Paradigms

Prerequisites - Pré-requis

Software, Objet 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,

UE	*SCIENCES DE SPECIALITE 7*	*9* ECTS	1er semestre
Matière	*Filtrage particulaire et SLAM* **Particle filtering and SLAM**	Organisation	Présentiel : 6 h C, 6 h TD, 8 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Master prominent particle filtering techniques
- Know the main properties and solutions to the Simultaneous Localization and Mapping (SLAM) problem in Robotics

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

- Recursive exact equations of Bayesian filtering
- Approximate solution based on particle filters: sequential importance sampling, sequential importance resampling, Rao-Blackwellized filter
- Mathematical statement and properties of Simultaneous Localization and Mapping (SLAM)
- SLAM solutions based on Extended Kalman filtering and Rao-Blackwellized particle filtering
- Factor graph approach to SLAM and its solution based on sparse quadratic nonlinear optimization

Prerequisites - Pré-requis

Good knowledge on stochastic estimation and Kalman filtering

Bibliographical references - Références bibliographiques

[1] DOUCET A., DE FREITAS N., GORDON N., "Sequential Monte Carlo Methods in Practice", Springer, 2001.
[2] THRUN S., BURGARD W., FOX D., "Probabilistic Robotics", MIT Press, 2005.

Keywords - Mots clés

Sequential Monte Carlo methods – Probabilistic SLAM – Graph SLAM

UE	*SCIENCES DE SPECIALITE 7*	*9* ECTS	1er semestre
Matière	*Projet intégratif sous ROS* **ROS Integrative project**	Organisation	Présentiel : 3 h C, 2 h TD, 20 h 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 & motorman)
Test in real conditions

Prerequisites - Pré-requis

Introduction au middleware robotique ROS

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

UE	*SCIENCES DE SPECIALITE 7*	*9* ECTS	1er semestre
Matière	*Motion planning et robotique humanoïde* **Motion planning and humanoid robotics**	Organisation	Présentiel : 6 h C, 4 h TD, 8 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

Master the motion planning problem
Understand humanoid robotic

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

Humanoid robotics

- Modeling
- Control
- Planning

Practical lesson : planning legged robotics

Prerequisites - Pré-requis

Modélisation robotique 1 et 2

Bibliographical references - Références bibliographiques

[1] S. Lavalle. Planning Algorithms. Cambridge Univ. Press, 2006.

[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.

UE	*SCIENCES DE SPECIALITE 8*	*6* ECTS	1er semestre
Matière	*Agents conversationnels* **Conversational Agents**	Organisation	Présentiel : 3 h C, 5 h TD, 8 h 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.

UE	*SCIENCES ET TECHNIQUES 8*	*6* ECTS	1er semestre
Matière	*Intégration IA et Interaction* **AI and interaction: integration project**	Organisation	Présentiel : 6 h C, 8 h TD, 6 h 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).

UE	*SCIENCES DE SPECIALITE 8*	*6* ECTS	1er semestre
Matière	*Systèmes robotiques complexes* **Complex robotic systems**	Organisation	Présentiel : 4 h C, 4 h TD, 4 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

Understand and solve the redundancy robot's problem
Understand the principle of modern algorithms toolbox
Know closed-chain problem
Identification 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

Redundancy robots (jacobian null space, stack of tasks...)
Algorithms for dynamic robot modelling (RNEA…)
Closed-chain robots
Identification concepts

Prerequisites - Pré-requis

Modélisation robotique 1 et 2

Bibliographical references - Références bibliographiques

[1] R. Featherstone, Rigid Body Dynamics Algorithms. Springer, 2008.
[2] Y. Nakamura. Advanced robotics : redundancy and optimization. Addison-Wesley, 1991.
[3] K. Lynch, F. Parck. Modern robotics : mechanics, planning and control. Cambridge University Press, 2017.

Keywords - Mots clés

Redundancy, dynamic robot, complex robot

UE	*SCIENCES DE SPECIALITE 8*	*6* ECTS	1er semestre
Matière	*Optimisation de trajectoires et commande référencée vision* **Trajectory optimization and vision-based control**	Organisation	Présentiel : 8 h C, 8 h TD, 8 h TP

Learning outcomes and skills - Objectifs d'apprentissages et compétences

- Understand the principles of vision-based control
- Synthesize a vision-based control

Summary description of the lessons - Description synthétique des enseignements

Visual servoing

- Position-based and image-based visual servoing
- Basic tools & notions for visual servoing
- Design of a vision-based controller using the inverse Jacobian matrix
- Redundancy in vision-based control
- Labs: design of a vision-based positioning task

Optimization and Control

- Trajectory optimization by numerical methods of open-loop optimal control
- Introduction to Model Predictive Control

Prerequisites - Pré-requis

Modélisation robotique 1 et 2, Modélisation des systèmes complexes

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] Rossiter, J.A., « Model-based Predictive Control – A Practical Approach », CRC Press LLC, 2004.

Keywords - Mots clés

Vision-based control, position-based visual servoing, image-based visual servoing.

UE	*SCIENCES DE SPECIALITE 8*	*6* ECTS	1er semestre
Matière	**Multithreading/Safety**	Organisation	Présentiel : 10 h C, 8 h TD, 12 h 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.

UE	*SCIENCES DE SPECIALITE 9*	*9* ECTS	1er semestre
Matière	*Vision et IA* **Vision and AI**	Organisation	Présentiel : 10 h C, 10 h TD, 16 h 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

UE	*SCIENCES DE SPECIALITE 9*	*9* ECTS	1er semestre
Matière	IA appliquée à l'interaction **AI: Decision Method under Uncertainty**	Organisation	Présentiel : 2 h C, 2 h TD, 10 h 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.

UE	*SCIENCES DE SPECIALITE 9*	*9* ECTS	1er semestre
Matière	*IHM multimodale* **Multimodal interaction**	Organisation	Présentiel : 4 h C, 2 h TD, 12 h 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

UE	*SCIENCES ET TECHNIQUES 9*	*9* ECTS	1er semestre
Matière	*IA et dialogue oral* **AI and spoken dialogue systems**	Organisation	Présentiel : 4 h C, 4 h TD, 10 h 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.

UE	*SCIENCES DE SPECIALITE 9*	*9* ECTS	1er semestre
Matière	*Interaction distribuée* **Distributed Interaction**	Organisation	Présentiel : 4 h C, 2 h TD, 8 h 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

Keywords - Mots clés

Networks, high-level protocols