Semester 5 Modules: Specialization Artificial Intelligence (Intelligence Artificielle – IA -)

code	Title	type	Coefficients	ECTS	Total workload	Contact hours	Private study
AI.5.1	Multi-agent systems	Compulsory	2	2	50	30	20
AI.5.2	Non-Classical Logics	Compulsory	2	2	50	30	20
AI.5.3	Applied Deep Learning	Compulsory	2	2	50	30	20
AI.5.4	Natural Language Processing	Compulsory	2	2	50	30	20
AI.5.5	Robotics and soft computing	Compulsory	2	2	50	30	20
ISA.5.1	Big Data	Compulsory	2	2	50	30	20
ISA.5.3	Interactive Decision Support Systems	optional	2	2	50	30	20
ISA.5.2	Data mining	Compulsory	2	2	50	30	20
MAT.5.1	Combinatorial Optimization	optional	2	2	50	30	20
MAT.5.2	Category theory and functional programming	Compulsory	2	2	50	30	20
AI.5.6	Knowledge Representation & Reasoning	Compulsory	1	1	25	15	10
ISA.5.6	Text Mining	Compulsory	1	1	25	15	10
ISA.5.5	Recommender systems	optional	2	2	50	30	20
ISA.5.4	Business Intelligence	optional	2	2	50	30	20
AI.5.7	Deep Reinforcement Learning	optional	1	1	25	15	10
ISA.5.7	Distributed databases	optional	1	1	25	15	10
ISA.5.8	Advanced BI	optional	1	1	25	15	10
AI.5.10	Semantic web & Linked Data	optional	1	1	25	15	10
AI.5.8	Affective computing	optional	1	1	25	15	10
AI.5.9	Intelligent Transport Systems	optional	1	1	25	15	10
DOS.5.8	Introduction to Cloud computing	Compulsory	1	1	25	15	10
DOS.5.2	Blockchain	Compulsory	1	1	25	15	10
AI.5.11	AIOT	optional	1	1	25	15	10
	Complementary Module 1		2	2	50	30	20
	Complementary Module 2		2	2	50	30	20
	Complementary Module 3		2	2	50	30	20
	Complementary Module 4		1	1	25	15	10
	Complementary Module 5		1	1	25	15	10
	Complementary Module 6		1	1	25	15	10

AI.5.1 Multi-agent systems

Module designation	AI.5.1 MultiAgent Systems
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Narjès Bellamine Ben Saoud
Language	French/English
Relation to curriculum	Compulsory
Teaching methods	lesson, lab works, project, seminar.
Workload (incl. contact hours, self-study hours)	Total workload:50h Contact hours :30h Private study:20h
Credit points	2 ECTS
Required and recommended pre-requisites for joining the module	SE.3.1 Software Engineering AI.3.1
Module objectives/intended learning outcomes	- Master the concepts of agent and multi-agent systems - Study and apply a design methodology for a multi-agent system. - Learn the development of a multi-agent system - Explore complementary research questions Competencies: C1 and C7
Content	Chapter 1: Introduction to MAS Chapter 2: Intelligent Agents Chapter 3: Agents architectures Chapter 4: Methodologies for developing multi-agent systems Chapter 4: MAS Development environments & case study
Examination forms	35% Continues evaluation + 65% Written exam
Study and examination requirements	10/20
Reading list	Ferber, J. (1995). Les systèmes multi-agents. InterEditions. Wooldridge, M. (2002). An Introduction to MultiAgent Systems. Wiley. Russell, S., & Norvig, P. (2006). Intelligence Artificielle (2ème édition). Pearson Education France. (Chapter 2). Russell, S., & Norvig, P. (2020). Artificial Intelligence: A Modern Approach (4th ed.). Pearson.

AI.5.2 Non-Classical Logics

Module designation	AI.5.2 Non-Classical Logics
Semester(s) in which the module is taught	S5
Person responsible for the module	Leila Ben Ayed
Language	French
Relation to curriculum	Compulsory
Teaching methods	lesson, project (Prolog and Spin Tools)
Workload (incl. contact hours, self-study hours)	Total workload: 50h Contact hours: 30h (20h Lessons, 10h Exercises and Project) Private study: 20h
Credit points	2 ECTS
Required and recommended pre-requisites for joining the module	AI.1.1 Formal logic AP.2.3 Automata theory and formal Languages SE.4.1 Formal Development Methods
Module objectives/intended learning outcomes	The objective of this lesson is to introduce the temporal logic used to express and deduce system dynamic properties as well as fuzzy logic for approached reasoning. The practical aspect is implemented with Prolog and SPIN. ● Knowledge: - Formal systems and formal inference for decision - Theorem proving - Fuzzification, defuzzificaion and decision - Formal mapping rools Competencies: C1, C4, C5, C9
Content	Lesson I (06h). Introduction Theoretical aspects of Logic – Formal proof and logical deduction - Formal systems and deduction steps - Inference rools and theorem proving Lesson II (06h). Formal Systems for Temporal logics - Formal system for Modal logic - Formal system forTemporal logic Lesson III (09h) . PLTL logic, Buchi models, automata composition and semantic verification - Buchi automata - Modeling properties in Buchi - Automata composition for the verification Lesson III (09h) Fuzzy Logic- Fuzzification ans Defuzzification - Modelling in Fuzzy logic - Fuzzifcation Methods - Defuzzification Methods
Examination forms	35% Continues evaluation + 65% Written exam
Study and examination require-ments	10/20

Reading list	Manna, Z., & Pnueli, A. (1992). The Temporal Logic of Reactive and Concurrent Systems: Specification. Springer. Schnoebelen, Ph. (1999). Vérification de logiciels Techniques et outils du model-checking. Vuibert. Walper, P. (2001). Introduction à la Calculabilité. Dunod. Gacogne, L. (1997). Eléments de logique floue. Hermès-Lavoisier.

AI.5.3 Applied Deep Learning

Module designation	AI.5.3 Applied Deep learning
Semester(s) in which the module is taught	S5
Person responsible for the module (co-ordinator)	Nesrine Ben Yahia
Language	French/English
Relation to curriculum	Compulsory
Teaching methods	lesson, lab works, project, seminar.
Workload (incl. contact hours, self-study hours)	Total workload:50h Contact hours :30h Private study:20h
Credit points	2 ECTS
Required and recommended prerequi-sites for joining the module	MAT.1.1 Probability and Statistics MAT.4.1 Stochastic processes AI.3.1 AI & Machine learning
Module objectives/intended learning outcomes	- Students know the basics and the different types of deep learning - Students use and apply some supervised and unsupervised deep learning algorithms
Content	Chapter 0. Machine Learning Basics 1. Machine Learning types 2. Overfitting and Underfitting 3. Hyperparameters and Parameters 4. Estimators, Bias and Variance 5. Gradient-Based Learning 6. Stochastic Gradient Descent 7. Challenges Motivating Deep Learning Chapter 1. Introduction to deep learning 1. What is deep learning? 2. Machine learning VS deep learning? 3. Artificial neural networks (ANN) 4. Deep neural networks (DNN) 5. Back-Propagation Algorithms 6. Regularization for deep learning 7. Optimization for training deep models 8. Typology 9. Applications Chapter 2. Recurrent neural networks (RNN) 1. Definition 2. Algorithms 3. LSTM 4. GRU 5. Practical: LSTM with python Chapter 3. Feed-Forward Neural Network (FFNN) 1. Definition 2. Example: Learning XOR 3. Algorithms 4. MLP 5. CNN 6. Practical: CNN with python Chapter 4. Autoencoders (AE) 1. Definition

	2. Encoders & Decoders 3. Applications of Autoencoders 4. Practical: AE with python Chapter 5. Deep Generative Models 1. Restricted Boltzmann Machines 2. Deep Belief Networks 3. Deep Boltzmann Machines 4. Convolutional Boltzmann Machines Chapter 6. Introduction to Federated learning
Examination forms	35% Continues evaluation + 65% Written exam
Study and examination requirements	10/20
Reading list	Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press. Chollet, F. (2017). Deep Learning with Python. (384 pages).

AI.5.4 Natural Language Processing

Module designation	AI.5.4 Natural Language Processing (NLP)
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Chiraz Ben Othmane Zribi
Language	French
Relation to curriculum	Compulsory
Teaching methods	e.g. lecture, lab works, project
Workload (incl. contact hours, self-study hours)	Total workload:50h Contact hours : 30h (18h lecture + 6h exercise + 6h lab) Private study:20h
Credit points	2 ECTS
Required and recommended prerequisites for joining the module	AI.3.1 AI & Machine learning
Module objectives/intended learning outcomes	This course introduces the fundamental concepts and techniques of NLP by presenting the different levels of processing and giving a relatively broad overview of the the commonly used algorithms and tools. Objectives : Students will gain an in-depth understanding of the computational properties of natural languages and the commonly used algorithms for processing linguistic information. Learning Outcomes: The students will be able to: - Understand key concepts from NLP those are used to describe and analyze language - Understand POS tagging and context free grammar for Natural language - Understand semantic representation of Englisfh Natural language for processing - Apply Machine learning /deep learning methods to process texts Learning outcomes: C1, C8, C9 and C13

Content	1. Introduction - Overview of course content - Motivations and challenges of TAL - Examples of applications - Levels of analysis (oral and written) - Types of problems to solve - Approaches and techniques for NLP - Presentation of Python toolkit for NLP 2. Morphological analysis - Presentation of the morphology (flexion, derivation) - Representation of morphology by lexical lists - Representation of morphology by finite state automata - Representation of morphology by automata with transducers 3. Part-Of-Speech (POS) tagging - Definitions (POS labeling, tag set,...) - Rule-based taggers (Example: Brill's taggerà - Probabilistic taggers (NGrams, based on hidden Markov chains) 4. Syntactic analysis and formal grammars - General presentation of syntactic analysis - Formal grammar: definition and types - Context free grammar for NLP - Syntax analysis with a context free grammar - Common parsing algorithms (CYK, Earley) 5. Lexical semantics - General presentation of the semantics - Types of semantic relationships between words - Semantic similarity between words based on a thesaurus - Semantic similarity between words based on context - Semantic vectors and construction methods (LSA, Word2Vec) 6. Machine Learning (ML) and deep learning (DL) for NLP - Drawbacks of Statistics methods and linguistic methods - Why machine learning / deep learning for NLP ? - Construction of features - Word embeddings - Application 1: POS-tagging based en ML - Application 2: Text classification based en DL 7. Dialog systems and Chatbots - Rule based chatbots - Corpus based chatbots - Hybrid architectures - Frame based dialog agents - Voice XML - Evaluating Dialog systems 7. Named Entity recognition (NER) - Presentation of NER - Frame based dialog agents - Evaluating Dialog systems 8. Named Entity Recognition (NER) - General presentation of NER - Extraction of NE as sequence labelling based on supervised ML methods - Extraction of relations based on pattern methods - Extraction of relations based on semi-supervised methods - Evaluating NER and relation extraction
Examination forms	Project (35%) Final exam (75%)
Study and examination requirements	10/20

Reading list	Gunning, D. (2019). Natural Language Processing Fundamentals. Packt Publishing. Jurafsky, D., & Martin, J. (2020). Speech and Language Processing. Indurkhya, N., & Damerau, F. J. (Eds.). (2010). Handbook of Natural Language Processing. Gelbukh, A. (Ed.). (2008). Computational Linguistics and Intelligent Text Processing.

AI.5.5 Robotics and soft computing

Module designation	AI.5.5 Robotics & Soft Computing
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Moncef TAGINA
Language	French
Relation to curriculum	Compulsory
Teaching methods	Lesson, lab works.
Workload (incl. contact hours, self-study hours)	Total workload: 50h Contact hours:30h (18h lecture, 6h exercise, 6h lab) Self-study:20h
Credit points	2 ECTS
Required and recommended prerequisites for joining the module	MAT.1.1, MAT.1.2
Module objectives/intended learning outcomes	In terms of Knowledge: Soft computing is a set of so-called intelligent techniques that allow efficient control of automated systems and particularly autonomous mobile robots. The objective of this course is to present these techniques and make them accessible to students for implementation in practical cases. Competences: C2, C3, C5, C9

Content	I. Introduaction to Robotics and Soft computing (1.5 h) II. Classical commands in robotics (3 h) - Introduction and definitions - Position control - Speed control - Position and speed control - Limits of classical methods III. Fuzzy control (10.5 h) - Introduction and definitions - Fuzzy logic operator - Fuzzy rules - Inference - Fuzzy control process IV. Neural control (9h) - Introduction and definitions - Deterministic Perceptron - Probabilistic Perceptron - Multi Layer Perceptron and error backpropagation - Implementation of neural control V. Path optimization (6h) - Introduction and definitions - Genetic algorithm - Application in robotics
Examination forms	100% Final exam
Study and examination requirements	10/20
Reading list	1. Dieulot, J.-Y., Dubois, L., Borne, P., & Rozinoer, J. (1998). Introduction à la commande floue. Editions Technip. 2. Faure, A. (2006). Classification et commande par réseaux de neurones. Editions Hermès. 3. Santhosh, S. (2012). Soft-I-Robot: Soft Computing Techniques. LAP Lambert Academic Publishing.

ISA.5.1 Big Data

Module designation	ISA.5.1 Big Data
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Raoudha Chebil
Language	French
Relation to curriculum	Compulsory
Teaching methods	lesson, lab works, presentations.
Workload (incl. contact hours, self-study hours)	Total workload: 50 hours Contact hours: 30 hours (20 hours lessons + 10 hours lab works) Private study]: 20 hours
Credit points	2 ECTS
Required and recommended pre-requisites for joining the module	DAT.1.1 Database and DBMS
Module objectives/intended learning outcomes	Knowledge: Students: -Master the basic building blocks of the Hadoop platform, namely HDFS and MapReduce, and have an idea of the components of its ecosystem; -Master the MapReduce approach for problem solving; -Understand the limits of the relational model and know the different models of NOSQL databases. Competences: C4, C7, C8

Content	Chapter I – Introduction to Big Data 1. Motivations 2. Definition 3. The 3Vs and the additional Vs 4. Benefits and challenges 5. Application examples 6. Stages of a Big Data project 7. New professions 8. Related fields Chapter II – Hadoop: Building Blocks 1. Hadoop presentation 2. Hadoop history 3. Hadoop ecosystem 4. HDFS 5. MapReduce V1 6. MapReduce V2 7. Design Patterns MapReduce Chapter III - Advanced Processing Tools 1. Data processing types 2. MapReduce review 3. Abstraction languages a. Pig b. Hive 4. Apache Spark Chapter IV – NOSQL Databases 1. DBMS strengths 2. DBMS limits 3. BD NOSQL 4. BDR vs BD NOSQL 5. Study of BD NOSQL instances a. Cassandra b. MongoDB Chapter V – Big Data Architectures 1. Motivations 2. Lambda architecture 3. Kappa architecture 4. Other architectures 5. Case study Practical Works 1. Installation and testing of the working environment 2. HDFS 3. MapReduce 4. Pig and Hive 5. Spark 6. HBase
Examination forms	35% continuous evaluation (Lab works, presentations) ; 65% written exam
Study and examination requirements	10/20

Reading list	Mooc – "Fundamentals for Big Data", Télécom ParisTech – "Introduction to Hadoop and MapReduce", University Nice Sophia Antipolis Books Bruchez, R. (2015). NoSQL Databases and Big Data: Understanding and Implementing. Editions Eyrolles. Marr, B. (2015). Big Data: Using SMART Big Data, Analytics and Metrics to Make Better Decisions and Improve Performance. John Wiley & Sons. Zikopoulos, P., Eaton, C., et al. (2011). Understanding Big Data: Analytics for Enterprise Class Hadoop and Streaming Data. McGraw-Hill Osborne Media.Classes Nerzic, P. (2016). Hadoop Tools for Big Data. Lecture presented at Rennes1 University, France.

ISA.5.3 Interactive Decision Support Systems

Module designation	ISA.5.3 Interactive Decision support systems (SIAD)
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Imen BOUKHRIS
Language	French
Relation to curriculum	optional
Teaching methods	lesson, lab works.
Workload (incl. contact hours, self-study hours)	Total workload:50h Contact hours :30h Private study:20h
Credit points	2 ECTS
Required and recommended prerequisites for joining the module	MAT.1.1, M.1.2, DAT 2.1
Module objectives/intended learning outcomes	In terms of Knowledge: This course exposes students to the knowledge and skills needed to use computer software to solve business problems, particularly to support decision making. It involves the formalization of a decision problem and its resolution in order to assist decision-makers in their decision-making process in semi-structured tasks. The decision process is defined by the involvement of several variables which makes it very complicated and difficult to manage. The objective of this module is to understand the decision-making process and investigate the different components of a decision support system as well as the different models (e.g., multi-criteria, under risk or uncertainty) in order to be able to apply them according to a given situation (e.g., (individual, group, conflictual decision) as well as to the personality of the decision maker (e.g., optimistic, pessimistic). Competences: C1, C2, C4, C9
Content	. I Introduction to decision theory (3 h) II. What are decision support systems ? (3 h) - DSS vs Information system - Decision systems classifications - Group decision making - DSS Structures - DSS Architectures III. Multi-criteria decision making (6h) - Pareto-optimality - Analytical Hierarchical Process (AHP) - Analytical Network Process (ANP) IV. Decision making under uncertainty (9 h) - Introduction and definitions - Objective vs subjective probability - Lottery and Utility - Maximax, Wald, Hurwicz, Laplace, Savage criteria V. Decision making under risk (9h) - Introduction and definitions - Raiffa Decision trees - Influence diagrams
Examination forms	100% Final exam

Study and examination requirements	10/20
Reading list	1. Alter, S. (1977). A taxonomy of decision support systems. Sloan Management Review (pre-1986), 19(1), 39. 2. Sprague Jr, R. H. (1980). A framework for the development of decision support systems. MIS quarterly, 1-26. 3. Marakas, G. M. (2003). Decision Support Systems in the 21st Century (Vol. 134). Upper Saddle River: Prentice Hall. 4. Marchau, V. A., Walker, W. E., Bloemen, P. J., & Popper, S. W. (2019). Decision Making Under Deep Uncertainty: From Theory to Practice (p. 405). Springer Nature.

ISA.5.2 Data mining

Module designation	ISA.5.2 Data Mining
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Aroua Hedhili
Language	French
Relation to curriculum	Compulsory
Teaching methods	Lesson, lab works, project.
Workload (incl. contact hours, self-study hours)	Total workload: 50h Contact hours :30h (20h lessons 10h labs) Private study: 20h
Credit points	2 ECTS
Required and recommended prerequisites for joining the module	MAT.1.1: Probability and Statistics AI .3.1.: IA & Machine Learning Students must be competent in python.
Module objectives/intended learning outcomes	Key question: what learning outcomes should students attain in the module? E.g. in terms of: - Knowledge: Knowing standard data mining methods and techniques such as association rules, data clustering and classification. - Skills: Students are able to how apply standard and new techniques on datasets of realistic sizes using modern data analysis frameworks. - Competences: Students know new and advanced techniques for emerging applications (e.g. social network analysis, stream data mining). Competencies: C1, C2, C3, C4, C5

Content	Chapter 1: Introduction and Motivation 1. Why Data Mining? 2. What is Data Mining? 3. What is NOT Data Mining 4. What kind of data can be mined? 5. What kind of knowledge can be extracted? 6. When to use data mining? 7. Data Mining applications 8. Overview of data mining workflow 9. Data mining Project Methodology Chapter 2: Data Understanding 1. Data Types 2. Numeric Attributes 3. Categorical Attributes 4. Data exploration 5. Data exploration tools 6. Statistical Measures 7. Basic Graphs Chapter 3: Data cleaning 1. Goal of data cleaning 2. Common data problems 3. Data problems detection 4. Data cleaning methods Chapter 4: Feature Engineering 1. Basic concepts 2. Common features transformation 3. Transformation for numeric variables 4. Transformation for categoric variables 5. Python functions and classes Chapter 5: Feature Selection 1. Basic concepts 2. Features selection approaches 3. Dimensionality Reduction with PCA 4. Dimensionality Reduction with T-SNE 5. Python functions and classes Chapter 6: Clustering 1. Introduction 2. Partitioning methods 3. Hierarchical methods 4. Density-based methods 5. Grid-based methods Chapter 6: Learning Algorithms 1. Related concepts 2. Linear Regression 3. Decision Tree 4. Probabilistic approach 5. KNN Algorithm
Examination forms	35% in-class evaluation (project, labs) ; 65% written exam
Study and examination requirements	10/20

Reading list	Han, J., Pei, J., & Kambe, M. (2012). Data Mining: Concepts and Techniques (3rd ed.). Elsevier. ISBN 978-0-12-381479-1. Zaki, M. J., & Meira Jr, W. (2020). Data Mining and Machine Learning: Fundamental Concepts and Algorithms (2nd ed.). Cambridge University Press. ISBN: 978-1108473989. Cornuéjols, A., Miclet, L., & Barra, V. (2021). Apprentissage Artificiel, Concepts et Algorithmes - De Bayes et Hume au Deep Learning. Collection Algorithmes.

MAT.5.1 Combinatorial Optimization

Module designation	MAT.5.1 Combinatorial optimization
Semester(s) in which the module is taught	S5
Person responsible for the module	Olfa BELKAHLA DRISS
Language	French
Relation to curriculum	Optional
Teaching methods	lecture, lesson, lab works, project, exercises
Workload (incl. contact hours, self-study hours)	Total workload:50h Contact hours :30h (20h lecture, 10h exercices) Private study:20h
Credit points	2 ECTS
Required and recommended prerequisites for joining the module	AP.1.2 Algorithms and data structure MAT.2.1 Graph theory
Module objectives/intended learning outcomes	- Students know that combinatorial optimization consists in solving many complex problems and finding an optimal solution in a large but finite search space. - Students know that combinatorial optimization is concerned with the study of efficient algorithms to solve these problems by efficiently exploring the space of solutions. - Students know categorizing problems into complexity classes. - Students are able to model and solve not only polynomial problems, but also NP-complete and NP-hard problems. - Students are able to apply exact methods, such as Branch and Bound, as well as approximate methods such as TS, RS, ACO, GA, etc. in order to solve many practical problems to avoid the combinatorial explosion and overcome the complexity and find solutions in a reasonable time. - Student are able to implement algorithms and perform experimentations on benchmark instances. Competencies: C1, C4, C9, C13

Content	Chapter 1: Introduction to combinatorial optimization (4H) 1. Definitions 2. Applications 3. Problem Modeling 4. Examples of combinatorial optimization problems 5. Problem Complexity Chapter 2: Resolution methods (4H) 1. Categories of resolution methods of CO problems 2. Exact Methods 3. Overview on Branch & Bound 4. Approximate methods: heuristics and metaheuristics Chapter 3: Constructive methods (4H) 1. Constructive approaches: Greedy algorithms 2. Greedy heuristics on the Knapsack problem 3. Greedy heuristics on scheduling problems 4. Greedy heuristics on the TSP 5. Greedy heuristics on the Bin Packing Problem 6. Advantages and disadvantages of constructive methods 7. Evaluation of the performance of heuristics Chapter 4: Local search based methods (6H) 1. Scientific history: Development of heuristics 2. Introduction to local search: Fable of the hikers 3. Gradient descent 4. Neighborhoods 5. Simulated Annealing 6. Taboo Search Chapter 5: Evolutionary approaches (6H) 1. Definitions 2. Choice of a metaheuristic 3. Ant Colony Optimization 4. Genetic algorithms Chapter 6 : Hybrid approaches (3H) 1. Advantages of hybridization 2. Examples of hybrid approaches Chapter 7 : Multi-objective optimization (3H) 1. Problem Modeling with MOO 2. Dominance relationship 3. Pareto optimality 4. NSGA-II 5. Quality measures 6. Multi-objective optimization frameworks
Examination forms	35% continuous assessment + 65% written exam
Study and examination requirements	10/20

Reading list	Martello, Silvano; Toth, Paolo (1990), "Bin-packing problem", Knapsack Problems: Algorithms and Computer Implementations, Chichester, UK: John Wiley and Sons, ISBN 0471924202 Bernhard Korte, Jens Vygen, Jean Fonlupt, Alexandre Skoda « Optimisation combinatoire Theorie et algorithmes », Collection IRIS, Springer, 2010. Alexander Schrijver « Combinatorial Optimization Polyhedra and Efficiency », Collection Algorithms and Combinatorics, 2003 Jerry Swan, Steven Adriaensen, Alexander E.I. Brownlee, Kevin Hammond, Colin G. Johnson, Ahmed Kheiri, Faustyna Krawiec, J.J. Merelo, Leandro L. Minku, Ender Özcan, Gisele L. Pappa, Pablo García-Sánchez, Kenneth Sörensen, Stefan Voß, Markus Wagner, David R. White, “Metaheuristics “In the Large””, European Journal of Operational Research, Volume 297, Issue 2, 2022, Pages 393-406, ISSN 0377-2217, https://doi.org/10.1016/j.ejor.2021.05.042. https://www.sciencedirect.com/science/article/pii/S0377221721004707 El-Ghazali Talbi, “Metaheuristics: From Design to Implementation”, Wiley, ISBN: 978-0-470-27858-1 June 2009.

MAT.5.2 Category theory and functional programming

Module designation	MAT.5.2 Category theory and functional programming
Semester(s) in which the module is taught	S5
Person responsible for the module	Fethi Kadhi
Language	French
Relation to curriculum	Compulsory
Teaching methods	Lessons, Lab, Projects.
Workload (incl. contact hours, self-study hours)	Total workload:50h Contact hours :30h Private study:20h
Credit points	2 ECTS
Required and recommended prerequi-sites for joining the module	
Module objectives/intended learning outcomes	The objectives of this modules are: - The Introduction of the category theory - Application of the category theory to functional programming - The study of Haskell as a pure functional language programming Competencies: C1, C9
Content	1. Categories 1.1 Definition 1.2 Examples 2. Functors and natural transformations 2.1 Definition 2.2 Examples 3. Yoneda lemma. 3.1 Representable functors 3.2 Yoneda lemma 4. Functional programming 4.1 Imperative programming 4.2 Functional programming 5. Hask category 5.1 Hask types 5.2 Hask functions 5.3 Hask functors 6. Hask Monads 6.1 Maybe monad 6.2 List monad
Examination forms	100% Written final exam
Study and examination requirements	10/20;
Reading list	Leinster, T. (2014). Basic Category Theory. Cambridge Studies in Advanced Mathematics. Cambridge Press. Serrano Mena, A. (2022). Practical Haskell. Apress.

AI.5.6 Knowledge Representation & Reasoning

Module designation	AI.5.6 Knowledge representation and Reasoning

Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Anja Habacha
Language	French
Relation to curriculum	Compulsory
Teaching methods	lesson, lab works, projects.
Workload (incl. contact hours, self-study hours)	Total workload: 25h Contact hours: 15h (9h lessons, 6h lab works) Private study in hours: 10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	IA.1.1 Formol Logic SE.3.2 Object Oriented Analysis & Design
Module objectives/intended learning outcomes	In terms of Knowledge: One of the objectives of artificial intelligence is to endow computer systems with intellectual capacities comparable to those of humans to produce "thinking" machines capable of reasoning. It is a question of dealing with problems requiring knowledge in a very specific field. This course exposes the diverse nature of the knowledge acquired, the problems of their representation in an incomplete, uncertain context, etc., the existing formalisms of representation and the means of interpretation allowing the implementation of the reasoning. Competencies: C1, C2, C4, C9
Content	Chapter 1: Introduction (3h) - History - AI approaches - AI Definitions - Knowledge Definition - Knowledge type and nature Chapter 2: Relational representations (6h) - Classical logic - Non-classical logic - Production rules Chapter 3: Object representations (6h) - Semantic networks - Frames - Ontologies - Practical case of biomedical domain
Examination forms	35% continuous assessment + 65% written exam
Study and examination requirements	10/20
Reading list	Russell, S., & Norvig, P. (2022). Artificial Intelligence: A Modern Approach (4th USA edition). Barr, A., & Feigenbaum, E. A. (1986). Le manuel de l'Intelligence Artificielle. Tome I. Eyrolles. Laurière, J.-L. (1988). Intelligence Artificielle - Représentation des Connaissances. Tome II. Eyrolles..

ISA.5.6 Text Mining

Module designation	ISA.5.6 Text Mining
Semester(s) in which the module is taught	S5
Person responsible for the module (co-ordinator)	Imtiez FLISS
Language	French/English
Relation to curriculum	Compulsory
Teaching methods	lectures, lab works and project.
Workload (incl. contact hours, self-study hours)	Total workload: 25h Contact hours : 15h Private study: 10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	ISA.5.2 Data Mining
Module objectives/intended learning outcomes	Key question: what learning outcomes should students attain in the module? At the end of this module, students should: – Understand the need for Text Mining – Know the definition of Text Mining – Know the difference between Text Mining and data mining – Know the different fields of application and the challenges of Text Mining – Understand the process of Text Mining applications – Design and develop a Text Mining application Learning outcomes: C1, C2, C3, C4, C5
Content	Chapter 1: Introduction 1. Definition and importance of Text Mining 2. Applications of Text Mining 3. Text mining pipeline 4. Challenges Chapter 2: Text Pre-processing and text feature extraction 1. Importance of Text Data Preprocessing 2. Text Cleaning and Pre-processing techniques 3. Text Cleaning and Pre-processing using Python 4. Feature extraction a) Feature extraction models (Bag of words, TFIDF, Word2vec, GloVe, FastText, BERT) b) Feature extraction models using Python c) Advantages and Limitations of Feature extraction Models Chapter 3: Text classification 1. Text Classification definition 2. Applications of Text classification 3. Different levels of scope 4. Text Classification Pipeline a) Dataset Preparation b) Feature extraction c) Feature Selection

	d) Classification Techniques e) Evaluation of Text Classifiers 5. Text classification using Python Chapter 4: Sentiment analysis 1. Sentiment Analysis definition 2. Sentiment analysis applications 3. Different Levels of Sentiment Analysis 4. Supervised Sentiment analysis pipeline 5. Unsupervised Sentiment analysis pipeline 6. Sentiment Analysis Challenges 7. Sentiment analysis using Python Chapter 5: Topic identification 1. Topic Modelling definition 2. Applications of Topic Modelling 3. Topic modelling algorithms (Latent Dirichlet Allocation, Non-Negative Matrix Factorization) 4. Topic modelling algorithms using Python 5. Topic modelling evaluation 6. Topic modelling evaluation using Python
Examination forms	100% Lab works and project
Study and examination requirements	10/20
Reading list	Konchady, M., & Sanger, J. (2006). Text Mining Application Programming. Boston: Charles River Media. Srivastava, A. N., & Sahami, M. (Eds.). (2009). Text Mining: Classification, Clustering, and Applications. CRC Press. Aggarwal, C. C., & Zhai, C. (Eds.). (2012). Mining Text Data. Springer Science & Business Media. Berry, M. W., & Kogan, J. (2010). Text Mining: Applications and Theory. West Sussex, PO19 8SQ, UK: John Wiley & Sons. Bengfort, B., Bilbro, R., & Ojeda, T. (2018). Applied Text Analysis with Python: Enabling Language-Aware Data Products with Machine Learning. O'Reilly Media, Inc. Sarkar, D. (2019). Text Analytics with Python: A Practitioner's Guide to Natural Language Processing. Apress. Silahtaroğlu, G. (2019). Concepts of Text Mining with Python and Real-Life Exercises. Žižka, J., Dařena, F., & Svoboda, A. (2019). Text Mining with Machine Learning: Principles and Techniques. CRC Press.

ISA.5.5 Recommender systems

Module designation	ISA.5.5 Recommender Systems
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Sonia Ben Ticha
Language	French
Relation to curriculum	Optional
Teaching methods	lesson, lab works, projects
Workload (incl. contact hours, self-study hours)	Total workload: 50h Contact hours: 30h (16h lessons, 14h lab works) Private study: 20h
Credit points	2 ECTS
Required and recommended prerequisites for joining the module	MAT.1.1, M.1.2, Linear algebra Algorithmics and data structures python
Module objectives/intended learning outcomes	In terms of Knowledge: This course introduces the foundations of the recommender systems with a focus on personalised recommender systems. Students Have a general overview of - Personalized user modelling - Collaborative recommender systems - Content-based recommender systems - Evaluation of a recommender systems - Implementing a collaborative filtering recommender system in python Competencies: C1, C2, C4, C9
Examination forms	35% continuous assessment + 65% written exam
Study and examination requirements	10/20
Reading list	Chevalier, M., Julien, C., & Soulé-Dupuy, C. (2009). Collaborative and Social Information Retrieval and Access: Techniques for Improved User Modeling. Information Science Reference. Ricci, F., Rokach, L., Shapira, B., & Kantor, P. B. (Eds.). (2011). Recommender Systems Handbook. Springer US. e-ISBN 978-0-387-85820-3.

ISA.5.4 Business Intelligence

Module designation	ISA.5.4 Business intelligence
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Manel BenSassi
Language	French
Relation to curriculum	Optional
Teaching methods	lesson, lab works.
Workload (incl. contact hours, self-study hours)	Total workload: 50h Contact hours:30h (21h lesson, 9h Lab works). Self study: 20h
Credit points	2 ECTS
Required and recommended prerequisites for joining the module	DAT.1.1 Database and DBMS
Module objectives/intended learning outcomes	This course refers to technologies, applications and practices of heterogeneous data integration, storage, multidimensional analysis, and visualization to support business decision making. Thus, the student will be able to propose concrete conceptual and technological architecture for the integration od heterogenous data in the professional environment as he will acquire many competencies such as: - Become able to evaluate the technologies that make up BI (data Warehousing, OLAP) - Become able to plan the implementation of a BI architecture. Learning outcomes: C1, C2, C3, C4, C8, C9
Content	Chapter 1 : Understanding Business intelligence - The challenge of decision making - What is business intelligence - The BI value chain and value Chapter 2: Data Integration - Data integration motivation - ETL Process - ETL techniques Chapter 3: Data Storage: Data Warehousing - What is data warehousing? - Data Marts and analytical Data - Organization of DataWarehouse - Data access Chapter 4: Multi dimensional Analysis with OLAP - Definitions - OLAP vs OLTP - Operational data stores - Multi-Dimensions techniques - OLAP architecture Chapter 5 : MDX Language - Problem presentation - MDX Syntax and Request
Examination forms	35% Continues evaluation + 65% Written exam
Study and examination requirements	10/20

Reading list	Fernandez, A. (2013). Les nouveaux tableaux de bord des managers: le projet Business Intelligence clés en main (6ème édition). Eyrolles. Fernandez, A. (2013). L'essentiel du tableau de bord: Concevoir le tableau de bord de pilotage avec Microsoft Excel (4ème édition). Galzy, C., Girona, P., Martin, B., Nicoloso, C., & Vandermoere, J. (May 2010). La Business Intelligence, Livre Blanc.

AI.5.7 Deep Reinforcement Learning

Module designation	AI.5.7 Deep Reinforcement Learning
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Wided Chaari
Teaching team	Sabrine Krichen (Instadeep)
Language	English
Relation to curriculum	Optional
Teaching methods	Lessons + lab works + project
Workload (incl. contact hours, self-study hours)	Total workload: 25h Contact hours: 15h (10h lessons, 5h lab session) Private study: 10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	MAT.1.1 Probability and Statistics MAT.4.1 Stochastic processes AI.3.1 AI & Machine Learning AI.5.3 Applied Deep Learning
Module objectives/intended learning outcomes	Students have a good understanding of Reinforcement Learning. Students know the difference between the different deep reinforcement learning algorithms. Students are able to implement a deep reinforcement learning algorithm on an open ai gym environment. Competencies: C1, C2, C4, C9
Content	Introduction to reinforcement learning. Value based methods in reinforcement learning. Policy based methods in reinforcement learning. Reinforcement learning tips and tricks.
Examination forms	Deep reinforcement project on GitHub + mini report. Questions answering session.
Study and examination requirements	Implement a converging deep reinforcement learning algorithm on an Open AI gym environment. Have a good understanding of the implemented work. Have an organized GitHub repo of the project. Write a very clear mini report.
Reading list	Sutton, R., & Barto, A. Reinforcement Learning: An Introduction. Lapan, M. Reinforcement Learning Hands-On: A Book with Tutorials.

ISA.5.7 Distributed databases

Module designation	ISA.5.7 Distributed Databases
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Raoudha KHCHERIF
Language	French
Relation to curriculum	Optional
Teaching methods	lecture, lesson, assignment, labs
Workload (incl. contact hours, self-study hours)	Total workload: 25 h Contact hours: 15 h Private study: 10h
Credit points	1 ECTS
Required and recommended pre-requisites for joining the module	DAT.2.1, DAT.2.2, NET3.1, NET3.2, NET4.1
Module objectives/intended learning outcomes	This course will deal with the fundamental issues in large distributed database systems which are motivated by the computer networking and distribution of processors, and control. The theory, design, specification, implementation, and performance of large systems will be discussed. Competencies:C1, C2, C8, C13
Content	I INTRODUCTION II. BDR DESIGN AND IMPLEMENTATION II. TRANSACTION AND COMPETITOR ACCESS IV. OPTIMIZATION OF DISTRIBUTED QUERIES
Examination forms	100% written Exam
Study and examination requirements	10/20
Reading list	Özsu, M. T., & Valduriez, P. (2011). Principles of Distributed Database Systems. Springer. Rahimi, S. K. (2010). Distributed Database Management Systems. John Wiley & Sons Inc.

ISA.5.8 Advanced BI

Module designation	ISA.5.8 Advanced Business intelligence
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Manel BenSassi
Language	French
Relation to curriculum	Optional
Teaching methods	lesson, lab works.
Workload (incl. contact hours, self-study hours)	Total workload: 25h Contact hours: 15h (9h lesson, 6h Lab works). Self study: 10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	ISA.5.4 Business intelligence
Module objectives/intended learning outcomes	This course refers to new technologies, applications and practices of Big and heterogeneous data integration, storage, multidimensional analysis, and visualization to support business decision making in a distributed environment. Thus, the student will be able to propose concrete conceptual and technological architecture for the integration of big data in the professional environment as he will acquire many competencies such as: - Become able to evaluate the technologies that adapt BI concept to new data challenges (datalake, real time datawarehousing, ect) - Become able to plan the implementation of a Big data based BI architecture. Learning outcomes: C1, C2, C3, C4, C8, C9
Content	Chapter 1: Understanding Business intelligence - The challenge of Business Intelligence Chapter 2: Data Storage: DataLake and NoSQL datawarehousing - Limits of classical storage - Data lake and data Acess - NoSQL DataBase: document, key-value, column and graph database Chapter 3: Data integration and analysis - ETL vs ELT - ELT Process and techniques - OLAP in NoSQL dataBase Chapter 4: Graph analytics techniques - Presentation of Neo4j Chapter 5 : Introduction to recommender system with graph - Concept presentation - Evaluation and metrics
Examination forms	30% Continues evaluation + 70% Written exam
Study and examination requirements	10/20
Reading list	• Fernandez, A. (2013). Les nouveaux tableaux de bord des managers: le projet Business Intelligence clés en main (6ème édition). Eyrolles.

	• Bruchez, R. (02/12/2021). Les bases de données NoSQL: Comprendre et mettre en œuvre (3ème édition). • Snowflake & Talend. Construire un Data Lake dans le Cloud: Livre blanc.

AI.5.10 Semantic web & Linked Data

Module designation	AI.5.10 Semantic Web & Linked Data
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Anja Hbacha
Language	French
Relation to curriculum	Optional
Teaching methods	lesson, lab works, projects.
Workload (incl. contact hours, self-study hours)	Total workload: 25h Contact hours: 15h Private study: 10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	AI.3.1 AI & Machine Learning
Module objectives/intended learning outcomes	This course aims to: represent the standards of the Web of data and the Semantic Web. represent and publish linked data on the Web (RDF); to interrogate and select data remotely and through the Web (SPARQL); Students are able to semantically link relationships between Web resources, real world resources, and concepts through the use of Linked Data enabled by Resource Description Framework (RDF). Learning outcomes: C1, C2, C3, C4, C5
Content	Chapter1: Introduction to Semantic Web & Linked Data 1. Brief history of the web 2. Architectural Principles 3. Standards and deployment 4. Linked Data Principles 7. The Standardization Stack Chapter2: RDF data model 1. Resources 2. Model of triples and graphs 3. Serialization Syntaxes 4. Values, types and languages Chapter3: SPARQL query language 1. RDF graph matching 2. Filters, constraints and functions 3. Different forms of requests 4. Modification of RDF databases Chapter4: Supporting RDFS ontologies and schemas 1. Introduction to ontologies 2. Schemas for and by RDF 3. Class hierarchies 4. Property Hierarchies 5. Property signatures 6. Schema Documentation Chapter4: Formalization in OWL

	1. Class relations 2. Characterization of properties 3. Equivalences and alignments 4. Restriction of properties 5. Manage schemas 6. OWL Profiles
Examination forms	50% Continues evaluation + 50% Final project
Study and examination requirements	10/20
Reading list	Hitzler, P., Krötzsch, M., & Rudolph, S. (2009). Foundations of Semantic Web Technologies. Chapman & Hall/CRC. Patel, A., Debnath, N. C., & Bhushan, B. (2022). Semantic Web Technologies: Research and Applications. CRC Press.

AI.5.8 Affective computing

Module designation	AI.5.8 Affective computing
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Imtiez Fliss
Language	French
Relation to curriculum	Optional
Teaching methods	lesson, lab works, projects.
Workload (incl. contact hours, self-study hours)	Total workload: 25h Contact hours: 15h Private study:10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	AI.3.1 AI & Machine Learning
Module objectives/intended learning outcomes	This course aims to: 1. master the basic concepts of emotion and affective computing; 2. be able to design an emotion recognition system 3. have knowledge of some computational models of emotions for a robot and for a virtual character; 4. learn about the presentation of scientific work. Learning outcomes: C1, C2, C3, C4, C5
Content	Chapter 1: Introduction Section I: Importance of emotions Section2: Emotional Intelligence Section 3: Affective Computing Chapter II: Emotions Introduction Section I: Emotion Definitions Section II: Types of emotion Section III: Components of an emotion

	Section IV: Theories of emotions Section V: Representation of emotions Chapter III: Automatic Emotion Recognition Introduction Section I: Recognition of emotions by facial expressions Section II: Recognition of emotions by voice analysis Section III: Recognition of emotions by gesture analysis Section IV: Recognition of emotions from physiological signals Section V: Multimodal Recognition of Emotions Chapter IV: Computer Modeling of Emotions Introduction Section I: Computational models of emotions Section II: Computational modeling of specific emotions for virtual agents Section III: Examples of expressive virtual agents Section IV: Modeling emotions in robotics Section V: Examples of Expressive Companion Robots
Examination forms	35% Continues evaluation + 65% Written exam
Study and examination requirements	10/20
Reading list	Picard, R. (1997). Affective Computing. MIT Press. Salovey, P., Bedell, B., Detweiler, J., & Mayer, J. (2000). Current directions in emotional intelligence research. In M. Lewis & J. Haviland-Jones (Eds.), Handbook of Emotions (pp. 504–520). Guilford Press. Gratch, J., & Marsella, S. (2007). Computational models of emotion: Designs and evaluation. Tutorial ACII'2007. Baggia, P., Burkhardt, F., Pelachaud, C., Peter, C., & Zovato, E. (2011). Emotion Markup Language. Poria, S., Cambria, E., Bajpai, R., & Hussain, A. (2017). A review of affective computing: From unimodal analysis to multimodal fusion. Information Fusion, 37, 98-125.

AI.5.9 Intelligent transport Systems

Module designation	AI.5.9 Intelligent Transport Systems
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Walid Chaker
Language	French
Relation to curriculum	Optional
Teaching methods	lesson, lab works, projects.
Workload (incl. contact hours, self-study hours)	Total workload: 25h Contact hours: 15h Private study:10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	AI.3.1 AI & Machine Learning
Module objectives/intended learning outcomes	The objective of the course is to offer students a panorama of modern methodologies and technologies for Intelligent Transport Systems (ITS) through the study of real projects organized by theme. Following the course, the student will be able to: - Propose an ITS project using the knowledge acquired in the other training modules - Estimate the technological and budgetary resources to be deployed in an ITS project - Get an idea of recent trends and national and international ITS programs Learning outcomes: C2, C3, C4, C5
Content	Chapter I: Introduction to ITS − Brief history − Objectives of ITS, architecture and orientations Chapter II: Examples of projects (one or more examples for each of the following headings) − ATIS (Advanced Traveler Information Systems) − ATMS (Advanced Transportation Management Systems) − APTS (Advanced Public Transportation Systems) − Connected Vehicles and Autonomous Vehicles − ITS in crisis and emergency management Chapter III: ITS in Tunisia − Strategy of the Ministry of Transport in the field of ITS − Examples of completed projects − Presentation of student initiatives
Examination forms	50% Continues evaluation + 50% Final project
Study and examination requirements	10/20
Reading list	Pagano, P. (2016). Intelligent Transportation Systems: From Good Practices to Standards (1st ed.). CRC Press.

DOS.5.8 Introduction to Cloud computing

Module designation	DOS.5.8 Introduction to cloud computing
emester(s) in which the module is taught	5
Person responsible for the module (coordinator)	Dr. Mehrez Essafi
Teaching team	-
Language	French
Relation to curriculum	Compulsory
Teaching methods	• Lesson • Lab work
Workload (incl. contact hours, self-study hours)	Total workload: 25h Contact hours: 15 (12h lessons, 3h lab work) Private study: 10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	OS.2.1 Introduction to Operating systems and Unix environment NET.3.1 Local Networks NET.4.1 Computer Networks SE.4.2 Software Architecture SEC.4.1 Cybersecurity & cryptography
Module objectives/intended learning outcomes	• Introduce cloud computing as the provision of computing resources. • Expose modern systems architectures and software development kits that, together, provide cloud-computing frameworks. • Learn about different aspects of the design, development, provisioning and management of cloud-based applications. • Gain a sound understanding of cloud-based computing and the opportunities that it provides for a diverse range of computing applications. • Make a special attention to security of cloud-based applications and the different strategies that are available in these deployments. By the end of the course, students are expected to be able to: • Apply services and architectures offered by virtualisation and cloud platforms • Explain how cloud platforms can be used by organisations to achieve efficiencies in developing, operating and scaling modern applications • Propose new ways of modifying, extending or combining existing methodologies and implementation techniques • Apply international standards documents and application programming interface documentation • Examine the potential for, and practicality of, developing cloud computing architectures for specific applications Competencies: C2, C4, C5, C6, C7, C9, C10.

Content	Unit 1 – Cloud Computing: main concepts • General introduction • Historical overview • Cloud characteristics • Business model • Advantages and limits Unit 2 – Data-centres • Definitions • Main components • Green Computing • Security • High Availability Unit 3 – Cloud Services and deployment models • IaaS (Infrastructure as a Service) • PaaS (Platform as a Service) • SaaS (Software as a Service) • FaaS (Function as a Service) • Other services • Public Cloud • Private Cloud • Hybrid Cloud • Community Cloud • DevOps approach Unit 4 – Virtualization • Definitions • Architectures • Solutions • Servers virtualization • Containers • Storage virtualization Unit 5 – AI and Cloud Computing • Machine learning cloud services • Cloud AI platforms
Examination forms	• 20% labs • 80% written examination
Study and examination requirements	Student must achieve an overall minimum module mark of 10/20
Reading list	Mell, P., & Grance, T. (2011). The NIST Definition of Cloud Computing (800-145). National Institute of Standards and Technology (NIST). Duncan, C. H. (2017). Cloud Computing Gateway, Cloud Computing Hypervisor, and Methods. International Conference on Cloud Computing. Hennion, R., Tournier, H., & Bourgeois, E. (2014). Cloud Computing: Décider - Concevoir - Piloter – Améliorer. Plouin, G. (2014). Cloud Computing: Sécurité, Stratégie d'Entreprise et Panorama du Marché. Collection InfoPro, Dunod. Rapport Cigref. (2013). Fondamentaux du Cloud Computing: Le Point de Vue des Grandes Entreprises. Moyer, C. M. (2011). Building Applications in the Cloud: Concepts, Patterns, and Projects. Addison-Wesley. Marks, E. A., & Lozano, B. (2010). Executive's Guide to Cloud Computing. Wiley. Kshirsgar, P. (2021). Green Computing in Cloud Technology. Linguistica Antverpiensia. Hwang, K. (2017). Cloud Computing for Machine Learning and Cognitive Applications. The MIT Press.

DOS.5.2 Blockchain

Module designation	DOS.5.2 Blockchain
Semester(s) in which the module is taught	S5
Person responsible for the module	Hanen Idoudi
Teachers team	Hanen Idoudi, Mohamed Houcine Hdhili,
Language	French
Relation to curriculum	Compulsory
Teaching methods	Lesson, Lab works
Workload (incl. contact hours, self-study hours)	Total workload:25h Contact: 15h (9 lesson, 6h lab works) Private study: 10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	SEC.4.1 Cybersecurity and Cryptography
Module objectives/intended learning outcomes	Knowledge: After completing this course, students should be able to: • Explain blockchain and how it is applied across industries. • Describe key principles of blockchain technology and the benefits and value that they bring to enterprises. • Explain the role of a shared ledger. • Explain fundamental concepts in Hyperledger Fabric. • Describe the elements of a business network, the role of channels, and how the world state is maintained. • Develop, test, debug, and deploy chaincode with IBM Blockchain Platform Extension for Visual Studio Code • Apply concepts of blockchain security, identity and access control, and data privacy to blockchain solutions. • Write applications that interact with a blockchain network. • Describe patterns, best practices, and reference architectures for integration from enterprise applications to blockchain networks. Competencies: C6, C13
Content	Unit 1. Blockchain overview Unit 2. Introduction to chaincode development Unit 3. Chaincode query methods Unit 4. Best practices for writing, testing, and debugging chaincode Unit 5. Identity and access control Unit 6. Data privacy Unit 7. Basics of application development Unit 8. Blockchain integration and advanced application development
Examination forms	100% Continuous evaluation
Study and examination requirements	10/20
Reading list	IBM Blockchain Developer – Official course material

AI.5.11 Articial Intelligence of Things (AIoT)

Module designation	AI.5.11 AIoT
Semester(s) in which the module is taught	S5
Person responsible for the module (coordinator)	Pr Wided Chaari
Teaching team	Dr Mansour Saber
Language	French
Relation to curriculum	Optional
Teaching methods	lecture, lesson, project, presentation
Workload (incl. contact hours, self-study hours)	Total workload: 25h Contact hours: 15h (lessons) Private study: 10h
Credit points	1 ECTS
Required and recommended prerequisites for joining the module	AI.3.1 AI & Machine learning DAT.1.1 Databases and DBMS
Module objectives/intended learning outcomes	Key question: what learning outcomes should students attain in the module? E.g. in terms of: - Knowledge: familiarity with the IoT domain and relatives technologies (protocols, requirements...) Skills: Able to design an IoT solution linked to the field and able to use the data to provide added services using AI. - Competences: Students master the concepts of IoT and are able to develop systems using the IA and the capabilities of IoT (sensors and actuators) Competencies: C1, C2, C3, C4, C5, C6
Content	1- Presentation of the IoT domain: History, evolution and perspectives 2- Impact and Challenges of installing IoT systems to the classic Information systems (opening, external data, privacy…) 3- IoT and AI what is it and for which added value services 4- AIoT real live examples: Smart Building and Smart Cities as domain example 5- Deep Learning algorithm examples applied to IoT systems in Energy Management solution 6- A step by step design system solution for Verticla IoT solution (from hardware to API and data retreivement).
Examination forms	Mini Project of AiOT solution presented by pair of students
Study and examination requirements	Identify a real life issue to resolve using IoT solution. Define the different Design Systems Components of the solution. Prensents in details a machine learning algorithm that answer a required service.
Reading list	Springer. (2021). Intelligence of Things: AI-IoT Based Critical-Applications and Innovations (AIoT Innovation) (1st ed.).

AI.5.17 Quantum Artificial Intelligence

Module designation	*AI.5.17*
Semester(s) in which the module is taught	*S5*
Person responsible for the module	*Nesrine Ben Yahia*
Language	*English*
Relation to curriculum	*Optional*
Teaching methods	*lesson, seminar, projects, workshops*
Workload (incl. contact hours, self-study hours)	*(Estimated) Total workload: 30h* *Contact hours: 15h (10h lessons, 5h labs)* *Private study including examination preparation, specified in hours[1]:* *15h*
Credit points	*1.5*
Required and recommended prerequisites for joining the module	*Python* *AI.1.1 Formal logic* *AI.3.1 Artificial Intelligence & Machine learning* *AI.5.3 Applied deep learning*
Module objectives/intended learning outcomes	*Students have a general overview of quantum computing and its key concepts* *Students identify opportunities in machine learning for using quantum advantages and resources.* *Students implement quantum enhanced machine and deep learning models in Python* *Students are able to:* *C1. To master in depth the basic sciences, in particular computer science and mathematics, essential for the design and production of computer applications.* *C8. Master good practices in terms of software development as well as applicable standards and regulations.* *C9. Make complex decisions based on incomplete or limited information.* *C13. Become aware of the need to constantly update your knowledge and, if necessary, to undertake additional studies.*

[1] When calculating contact time, each contact hour is counted as a full hour because the organisation of the schedule, moving from room to room, and individual questions to lecturers after the class, all mean that about 60 minutes should be counted.

Content	***CHAPTER 1: INTRODUCTION TO QUANTUM COMPUTING*** *1. What is Quantum computing (QC) and why?* *2. QC principles* *2.1 Superposition* *2.2 Entanglement* *2.3 Decoherence* *3. Quantum computing fundamentals?* *3.1 Qubit* *3.2 Quantum sates* *3.3 Quantum gates* *3.4 Quantum algorithms* *4. QC in industry* *5. Practical Hands-on experiments for quantum circuits using Cirq* ***CHAPTER 2: QUANTUM MACHINE LEARNING (QML)*** *1. Quantum data & models* *2. Hybrid quantum-classical models : Parameterized quantum gates, variational quantum algorithm* *3. Quantum ML approches* *4. Supervised learning with quantum classifiers* *5. Unsuprevisedlearning using quantum resources* *5. Parametrized Quantum Circuits for Reinforcement Learning* ***CHAPTER 3: QUANTUM MACHINE LEARNING (QML) TOOLS*** *1. GOOGLE Quantum AI* *2. IBM Quantum* *3. Amazon Braket* *4. Microsoft Azure Quantum* *5. Practical Hands-on session* ***CHAPTER 4: QUANTUM NEURAL NETWORKS*** *1. Quntum deep learning* *2. Quantum CNN* *3. Quantum generative adversarial networks* *4. Practical Hands-on session using TensorFlow Quantum (TFQ)*
Examination forms	*100% continuous assessment (project)*
Study and examination requirements	*10/20*
Reading list	*Rietsche, R., Dremel, C., Bosch, S. et al. Quantum computing. Electron Markets 32, 2525–2536 (2022). https://doi.org/10.1007/s12525-022-00570-y* *Biamonte, J., Wittek, P., Pancotti, N. et al. Quantum machine learning. Nature 549, 195–202 (2017). https://doi.org/10.1038/nature23474* *Schuld, M., Sinayskiy, I., Petruccione, F. An introduction to quantum machine learning, Contemporary Physics, 56:2, 172-185, (2015) DOI: 10.1080/00107514.2014.964942*