MASTER EN INTELLIGENCE ARTIFICIELLE – MASTER IN ARTIFICIAL INTELLIGENCE (AI)

Langue principale d'enseignement :
Français ○ Anglais ☑ Arabe ○

Campus où le programme est proposé : CST

OBJECTIVES

The Master in AI is part of a professional program to prepare specialists capable of developing intelligent software and systems to be implemented in different industries for the better of mankind.
It is a professional master program that meets the needs of the job market. Furthermore, the theoretical basis that this program provide allows students to pursue a doctoral thesis in this domain.

This Master program aims to train:
- High-level professionals capable of designing and implementing new AI tools for industrial use. The applications include and are not limited to the fields of healthcare, robotics, industry, economy, environment and self-driving cars;
- Scientific researchers in computer engineering, computer science, and optimization;
- Multidisciplinary consultants able to turn information into decision support tools within a company.

PROGRAM LEARNING OUTCOMES (COMPETENCIES)

1) Ability to apply knowledge of mathematics, and physics in problem solving.
2) Ability to design, conduct experiments, analyze, and interpret data.
3) Ability to design a system, component, or process that meets the needs and realistic constraints of economic, environmental, social, political and ethical considerations.
4) Ability to identify, formulate and solve an AI problem.
5) Ability to understand professional and ethical responsibilities.
6) Ability to understand the impact of AI in a global, economic, environmental and societal context.
7) Knowledge of contemporary subjects.
8) Ability to use the modern techniques, skills, and tools needed for AI.

ADMISSION REQUIREMENTS

Admission of students is based on their file and an interview might be required.

1- Admission to the first semester of the Master's program (S1)

To be authorized to submit application files, students must satisfy one of the following conditions:
- Hold a Bachelor in Computer and Communications Engineering, Computer Science, or Telecommunications;
- Hold an equivalent degree recognized by USJ.

2- Admission to the third semester of the Master's program (S3)

To be authorized to submit application files, students must satisfy one of the following conditions:
- Hold a Bachelor of Engineering in Computer and Communications Engineering or be a CCE student at ESIB and have earned at least 120 credits in the Engineering Cycle.
- Hold a Master's degree in Computer Science, Computer and Communicationss, or Informatics.
- Hold an equivalent degree recognized by USJ.

The documents required when submitting the application form are specified in the common admission file specific to the Saint Joseph University of Beirut.
The submitted files will be examined by the Scientific Committee of the Faculty of Engineering, which will subsequently establish the list of admitted candidates. For each application, the Scientific Committee will decide

the teaching units validated according to the program and the previously obtained results. Selected candidates may be interviewed before their final admission. The application file is downloadable from the Saint Joseph University of Beirut 's website and is to be submitted at the Faculty of Engineering (ESIB) at USJ.

COURSES/CREDITS GRANTED BY EQUIVALENCE

Engineers with degrees in computer engineering and/or communications, holders of a Master's degree in computer science or information technology, fifth-year CCE students at ESIB and holders of an equivalent diploma, can validate by equivalence a maximum of 60 credits of the program: upon approval from the Director of the Department of Doctoral Studies, the admission jury will decide for each student accepted directly in M3 the set of validated courses and modules based on their background and their results, and will define accordingly its path in the Master program, possibly including additional prerequisite courses. The validation of previously pursued programs is subject to approval by the USJ Equivalences Commission.

PROGRAM REQUIREMENTS

Required courses (120 credits)

AI Based Control Systems (6 Cr.). AI in Computer Vision (6 Cr.). AI in Cybersecurity (4 Cr.). AI in Financial Technology (4 Cr.). AI in Natural Language Processing (4 Cr.). AI in Robotics (4 Cr.). Big Data Frameworks (4 Cr.). Foundation of Artificial Intelligence (6 Cr.). Foundations of Decision Modeling (6 Cr.). Game Theory (4 Cr.). Graph Theory and Operational Research (6 Cr.). Industrial AI (4 Cr.). Legal, Policy and Ethical Considerations for AI (2 Cr.). Machine Learning and Deep Learning (6 Cr.). Master Thesis (30 Cr.). Mathematics for AI and Machine Learning (6 Cr.). Parallel Computing (6 Cr.). Programming for AI and Machine Learning (6 Cr.). Statistics for AI and Machine Learning (6 Cr.).

SUGGESTED STUDY PLAN

Semester 1

Code	Course Name	Credits
020IAGOM2	Graph Theory and Operational Research	6
020IAAIM1	Foundation of Artificial Intelligence	6
020IAMAM1	Mathematics for AI and Machine Learning	6
020IAOOM1	Programming for AI and Machine Learning	6
020IASTM1	Statistics for AI and Machine Learning	6
	Total	**30**

Semester 2

Code	Course Name	Credits
020IAGTM2	Game Theory	4
020IADMM1	Foundations of Decision Modeling	6
	Industrial AI	4
020IAMLM2	Machine Learning and Deep Learning	6
020IABDM2	Big Data Frameworks	4
020IAPCM2	Parallel Computing	6
	Total	**30**

Semester 3

Code	Course Name	Credits
020IARBM3	AI Based Control Systems	6
020IACVM3	AI in Computer Vision	6
020IACSM3	AI in Cybersecurity	4
020IAFIM3	AI in Financial Technology	4
020IANLM3	AI in Natural Language Processing	4
020IAROM3	AI in Robotics	4
020IALPM3	Legal, Policy and Ethical Considerations for AI	2
	Total	**30**

Semester 4

Code	Course Name	Credits
020IAINM4	Master Thesis	30
	Total	**30**

COURSE DESCRIPTION

Semester 1 (30 credits)

020IAAIM1 Foundations of Artificial Intelligence 6 Cr.

This course covers the study of intelligent agents, including problem-solving techniques, length and width search algorithms, game programming with algorithms such as minimax and expectimax, knowledge and reasoning, planning, learning, natural language processing, vision, and robotics. It also delves into inference mechanisms, Bayes networks and Markov processes, as well as reinforcement learning and its algorithms such as TD and Q-learning. The content includes:

- Reinforcement learning
- Intelligent agents
- Uncertainty, knowledge, and reasoning
- Learning: Knowledge bases
- Observational learning
- Game planning, search, and programming
- Problem-solving
- Decision-making

020IAGOM2 Graph Theory and Operational Research 6 Cr.

This course introduces students to graph theory and operational research as modeling and decision-making tools for engineers. By the end of the course, students will be able to:

- Make mathematical and computer representations of graphs
- Apply graph traversal algorithms
- Calculate the shortest path
- Maximize flow problems
- Apply graphs to project management
- Understand the Simplex algorithm and linear programming

020IAMAM1 Mathematics for AI and Machine Learning 6 Cr.

Artificial Intelligence has gained importance in the last decade with a lot depending on the development and integration of AI in our daily lives. The progress that AI has already made is astounding with the self-driving cars, medical diagnosis and even beating humans at strategy games like Go and Chess.

The future of AI holds tremendous promise, potentially leading to the creation of robotic companions. Consequently, many developers are now diving into AI and ML programming, recognizing its significance. However, mastering AI

and ML algorithms demands a strong understanding of mathematics.
Mathematics plays an important role as it builds the foundation for programming for these two streams. This course will help students master the mathematical foundation required for writing programs and algorithms for AI and ML.
It covers three main mathematical theories: Linear Algebra, Multivariate Calculus and Probability Theory.

- **Probability Theory** – The theories are used to make assumptions about the underlying data when we are designing these deep learning or AI algorithms. This part of the course delves into key probability distributions and topics such as Elements of Probability, Random Variables, Distributions, Variance and Expectation, and Special Random Variables.
- **Linear Algebra** – Linear algebra notation is used in Machine Learning to describe the parameters and structure of different machine learning algorithms. Understanding Linear Algebra is vital for understanding neural networks. The course covers Scalars, Vectors, Matrices, Tensors, Matrix Norms, Special Matrices and Vectors, Eigenvalues, and Eigenvectors.
- **Multivariate Calculus** – This is used to complement machine learning by facilitating learning from examples, parameter updates, and performance improvements. Topics include Derivatives, Integrals, Gradients, Differential Operators, and Convex Optimization.

020IAOOM1 Programming for AI and Machine Learning 6 Cr.

This course equips students with the necessary tools for developing advanced-level programs in their programs. It focuses on fundamental building blocks essential for becoming an AI practitioner. Students will delve into programming skills and essential math required for building AI architectures, including neural networks and deep learning.
The course covers the following topics:

- Introduction to Python: Start coding with Python, drawing upon libraries and automation scripts to efficiently solve complex problems.
- Tools for working with data in Python: Learning how to use key tools for data manipulation in Python, including Jupyter Notebooks, NumPy, Anaconda, Pandas, and Matplotlib.
- Linear algebra essentials: Learning the foundational linear algebra concepts necessary for success in AI, such as vectors, linear transformations, matrices, and the linear algebra behind neural networks.
- Calculus essentials: Learning the foundations of calculus to grasp the training process of neural networks, covering plotting, derivatives, the chain rule, and more. Witnessing how these mathematical concepts visually come to life through a neural network example.
- Neural networks: Gaining a solid foundation in the hottest fields of AI: neural networks, deep learning, and PyTorch.

020IASTM1 Statistics for AI and Machine Learning 6 Cr.

This course offers a basic, high-level introduction to the mathematics and statistics that form the foundation of many modern machine learning and AI algorithms. It covers two main areas of statistics: inference and prediction.

- The inference part introduces common statistical concepts necessary for understanding populations and testing hypotheses, including conducting A/B tests and calculating and interpreting p-values.
- The prediction part starts with simple algorithms like linear regression and progresses to more advanced topics such as random forests and cross-validation.

Real-world examples from healthcare, genetics, marketing, and manufacturing will be used throughout the course.

Semester 2 (30 credits)

020AIFRM2 Big Data Frameworks 4 Cr.

This course is conceptually divided into two parts:

- The first part covers the fundamental concepts of MapReduce parallel computing, focusing on Hadoop, MrJob, and Spark. It delves deeply into Spark, data frames, Spark Shell, Spark Streaming, Spark SQL, and MLlib. Students use MapReduce for industrial applications and deployments across various fields, including advertising, finance, health, and search engines.
- The second part focuses on algorithmic design and development in parallel computing environments (Spark). It covers algorithm development (learning decision trees), graphics processing algorithms (such as PageRank and Shortest Path), Newton algorithms, and support vector machines.

020IADMM1 Foundation of Decision Modeling 6 Cr.

Preferences are present and pervasive in many situations involving human interaction and decisions. Preferences are expressed explicitly or implicitly in numerous applications and relevant decision should be made based on these preferences. This course aims at introducing preference models for multicriteria decisions. It covers concepts and methods for preference modeling and multicriteria decision-making, as well as the presentation of stochastic processes and estimators.

020IAGTM2 Game Theory 4 Cr.

This course will initially present the main principles concerning decision-making under uncertainty and the use of graphical models for such decisions. Secondly, it will cover the principles of game theory and demonstrate how this theory can model and analyze decisions in situations involving uncertain and strategic interactions.

020IAIAM2 Industrial AI 4 Cr.

This course equips students with a comprehensive understanding of industrial AI, enabling them to effectively apply AI techniques in real-world industrial settings. They acquire practical skills in MLOps, AI deployment, and XAI, making them valuable contributors to the rapidly evolving field of industrial artificial intelligence. In the final part of the course, students explore the emerging field of Explainable AI (XAI) and learn techniques to interpret and explain the decisions made by AI models, with an emphasis on their application in industrial scenarios.

020IAMLM2 Machine Learning and Deep Learning 6 Cr.

This course delves into machine learning, a scientific discipline that deals with the design and development of algorithms that enable computers to evolve their behaviors based on empirical data, such as databases or sensor data. The primary aim of machine learning research is to empower machines to recognize and learn complex patterns and make intelligent decisions based on captured data. However, describing the set of all possible behaviors considering all potential entries becomes exceedingly complex with traditional programming languages. Throughout the course, students delve into essential machine learning concepts, exploring the fundamental paradigms and methods that form the basis of modern machine learning. This involves the specific study of learning algorithms, and the empirical experimentation of algorithms. Furthermore, the course introduces deep learning, a branch of machine learning dedicated to the development and application of modern neural networks. Deep learning algorithms extract layered high-level representations of data, optimizing performance across various tasks. Topics covered span from basic neural networks, convolutional and recurrent network structures, deep unsupervised and reinforcement learning, LSTM, and applications to problem domains like speech recognition and computer vision.

020IAPCM2 Parallel Computing 6 Cr.

In parallel computing, where multiple processors work together to solve a given problem. We're witnessing an exciting era in parallel computing, with the largest parallel machines boasting over a hundred thousand processors. It's believed that machines with over ten thousand processors will become common by the end of the decade. Moreover, as most chip manufacturers transition to multicore processors, most machines will soon become parallel machines. Therefore, mastering the effective use of parallel machines is crucial.
Learning Objectives:

- Define terminology commonly used in parallel computing, such as efficiency and speedup.
- Describe different parallel architectures, inter-connect networks, programming models, and algorithms for common operations such as matrix-vector multiplication.
- Given a problem, develop an efficient parallel algorithm to solve it.
- Given a parallel algorithm, analyze its time complexity as a function of the problem size and number of processors.
- Given a parallel algorithm, an input to it, and the number of processors, show the steps performed by that algorithm on that input.
- Given a parallel algorithm, implement it using MPI, OpenMP, pthreads, or a combination of MPI and OpenMP.
- Given a parallel code, analyze its performance, determine computational bottlenecks, and optimize the performance of the code.
- Given a parallel code, debug it and fix the errors.
- Given a problem, implement an efficient and correct code to solve it, analyze its performance, and give convincing written and oral presentations explaining your achievements.
- Understand CUDA and using GPU

Semester 3 (30 credits)

020IARBM3 AI Based Control Systems 6 Cr.

This course introduces two intelligent data processing techniques derived from complex and imprecise environments. Fuzzy Logic theory is rooted in the empirical aspect of human reasoning and is used in handling imperfect, imprecise, or approximate knowledge. It has allowed the modeling and processing of highly complex systems, incorporating human factors, for over fifty years. Its applications span across various fields, including artificial intelligence, dynamic systems identification and control, complex system automatic decision-making, and industrial process fault diagnosis. On the other hand, Artificial Neural Networks are based on the biological aspect of the human brain. They are currently widely applied across sectors such as telecommunication systems, automation, robotics, image processing and recognition, artificial intelligence, medicine, and economics.

020IACVM3 AI in Computer Vision 6 Cr.

This course provides an overview of trends, modern methods, and applications of computer vision technologies in various visual computing problems, including visual analytics, object recognition, 3D scene modeling from multiple views, and cross-training of multimodal data. Additionally, it presents an overview of trends relevant to the automatic interpretation of medical imaging from computer-aided solutions. The course discusses the entire chain of problems in mid and high-level interpretation, addressing key issues in the field such as detection, segmentation, and registration, alongside the most advanced AI-driven technologies for computer-aided diagnosis.

020IACSM3 AI in Cybersecurity 4 Cr.

This course covers the use of popular AI techniques, including machine learning and deep learning methods, alongside concepts such as natural language processing, knowledge representation and reasoning, and knowledge or rule-based expert systems modeling, to intelligently address various cybersecurity issues. Students learn about data preparation for machine learning, common machine learning techniques and tools, and their applications in cybersecurity, such as anomaly detection, detecting known attack types like injections, clustering user activities, adversarial learning, etc. The course delves into main AI disciplines and demonstrates how they can be applied to resolve critical security challenges, including handling large-scale and high-speed data in threat response. Additionally, students explore strategies for effectively implementing AI-driven security within organizations.

020IAFIM3 AI in Financial Technology (Fintech) 4 Cr.

This course explores the increasing dominance of technology in the financial services industry, altering how existing players operate and create new ways to deliver core services like savings, investments, borrowing, and transactions. Focusing on AI and Blockchain, it provides an overview of the pivotal technological advancements reshaping the industry. Analysis is conducted on how these technologies create value in the financial industry by lowering frictions, from unit processing costs, through asymmetric information, and network effects. The course integrates a high-level discussion on competitive dynamics and market opportunities for new players, alongside an in-depth understanding of technology and its applications. By focusing on three key areas – (I) Lending, (II) Clearing, and (III) Trading – students gain insights into examples and developments within (1) marketplace lending, (2) blockchain and distributed ledgers, and (3) quantitative trading and its use of non-standard data analytics. The course begins with an analysis of the marketplace, incumbents, and strategies of emerging technology-based entrants, followed by an understanding of relevant technological applications in each area using real-world data.
Course Learning Outcomes:

- What is fintech?
- Market place lending, lending club: business model, loan data visualization
- Credit models
- Random Forest applied to LC data and MPL from investors' perspective
- Cryptography
- Blockchain — network and incentives
- Blockchain — finance applications
- Quantitative trading
- Crowdsourced trading
- Machine learning in trading
- Unstructured data and natural language processing

020IANLM3 AI in Natural Language Processing 4 Cr.

This course delves into advanced machine learning techniques, shifting focus from data collection to scaling machine learning algorithms for processing petabytes of both structured and unstructured data, enabling the creation of sophisticated predictive models. Conceptually, it is divided into two parts.

The first part deals with deep learning and key network architectures, such as convolutional neural networks, autoencoders, recurrent neural networks, and short-term long-term memory networks (LSTM). Additionally, it covers stochastic networks, conditional random fields, Boltzmann machines, stochastic and mixed deterministic models, and deep reinforcement learning.

The second part focuses on natural language processing (NLP), a field of artificial intelligence dedicated to automating linguistic data manipulation. Immediate applications include developing more natural textual interfaces, automatic document translation, spam detection, information retrieval, question-answering systems, among others. This part introduces students to various topics, including the problem of NLP and its applications, natural language ambiguity, linguistic theories, speech analysis and synthesis, morphological analysis (dictionary structure and suffix analysis), syntax analysis (ATN parser, unification grammars and representation of the semantics of natural language: formal logic and frameworks), semantic interpretation, knowledge of the world and speech context, and applications.

020IAROM3 AI in Robotics 4 Cr.

This course explores the integration of artificial intelligence techniques into robotics, enabling robots to perceive, reason, plan and interact with the environment intelligently. It covers fundamental concepts, methodologies and applications in the field, with an emphasis on real-world implementation.

020IALPM3 Legal, Policy and Ethical Considerations for Data Scientists and AI 2 Cr.

This course introduces ethics, politics, and the ethical implications of AI and data. It examines the legal, political, and ethical issues that arise throughout the entire lifecycle of the science of data collection, storage, processing, analysis, and use, including, privacy, surveillance, security, classification and discrimination. Case studies will be used to explore these issues in areas such as criminal justice, national security, health, marketing, politics, education, automotive, employment, athletics, and development.

Semester 4 (30 crédits)

020IAINM4 Master's Thesis 30 Cr.

During the 4th semester, students must complete a professional project in a company or research work in a laboratory for 4 months on an AI-related topic.

- They have the choice between:
  - A professional project in a company lasting 3 to 4 months, in a company on a theme related to AI, concluded by writing and defending a professional report.
  - A research topic lasting 3 to 4 months in a laboratory recognized by the scientific committee, concluded by writing and defending a research paper.
- The projects will take place in companies in Lebanon or abroad. The scientific responsibility for the project is provided jointly by the company and an instructor from USJ or a partner university. This project, of a minimum of one semester, aims to develop all the skills necessary for an AI specialist:
  - Bibliographic search.
  - Study of the state of the art.
  - Proposal and implementation of solutions.
- The research takes place in a laboratory either in Lebanon or in an external institution. Scientific responsibility for this research is provided by the research professor(s) who supervise them. This work, of a minimum duration of one semester, aims to develop the necessary skills to carry out research work:
  - Bibliographic search.
  - Critical analysis of the state of the art.
  - Proposals and implementations of solutions.
  - Proposals and outlets for thesis work.

- The project or research work is the subject of a report or a written dissertation and a public defense. Students who have validated the theoretical modules of semesters 1, 2, and 3 are authorized to submit the project report and possibly the research paper.
  The thesis or report includes a bibliographic part and a technical part. The evaluation of the project or research work considers three elements:
  - Evaluation of the trainee's scientific initiative.
  - Evaluation of the written brief or report.
  - Evaluation of the oral defense.