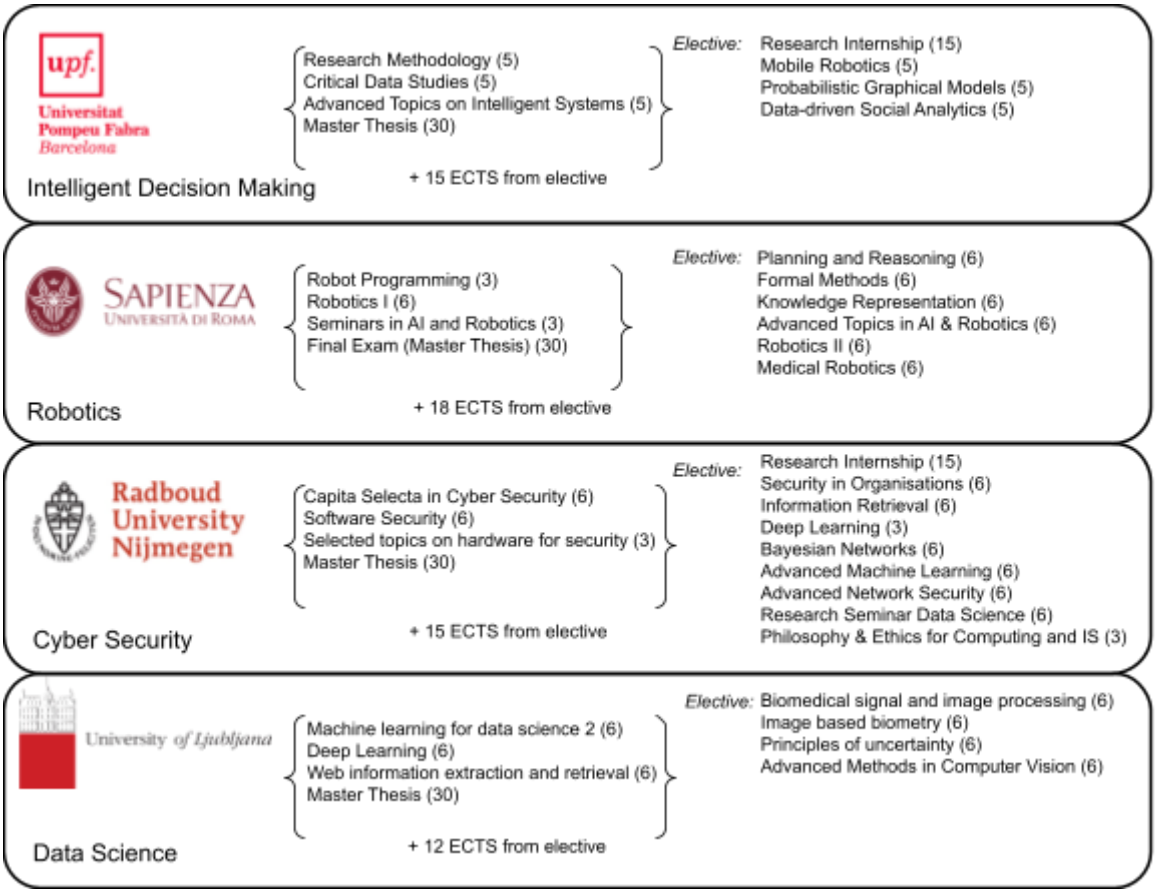
EMAI Study program (2nd year)



Research Internship (15 ECTS) *UPF (elective) AND RU (elective).* This course is offered by Radboud University at The Institute for Computing and Information Sciences (ICIS) at Radboud University and at the Department of Information and Communication Technology (DTIC) at University Pompeu Fabra.

The goal of the research internship is that the student gains experience in his/her future work field, in academia or in industry. It also gives the student the opportunity to find out about a prospective work environment, and some experience in carrying out a larger individual project as preparation for the Master thesis. Depending on the student interests and Master specialisation, the student can choose to do the research internship internally in one of the research groups of or externally at some company or organisation in industry or the public sector. The student can also do your research internship in an academic setting outside the ICS / DTIC, for instance in a research group in another faculty of UPF or RU, or at another university altogether. The research can be done abroad as well, in this case a special planning is required. Irrespective of the type of project, the student will always need a supervisor who is an ICIS / DTIC staff member (i.e. an assistant, associate, or full professor).

The Master Thesis (30 ECTS)

At the end of the first year, students will be able to choose the topic of their Master thesis with the assistance of academic coordinators and write a first version of their Master thesis project proposal. Students will primarily devote the fourth semester to the Master thesis, working closely with the supervisor, either in an industrial or a HEI partner.
The master thesis project is a very important part of the master's degree, including 30 ECTS, which represents 25% of the total of 120 ECTS. Students will have to identify a research hypothesis to be validated or disproved, and address some important scientific challenge that will often require the development of a system. It is a mixture of practice in the design, construction and elaboration using scientifically sound methods and evaluation. The thesis work will be considered for submission to scientific conferences.

Courses at Universitat Pompeu Fabra (specialisation in Intelligent Decision Making)

Research Methodology (5 ECTS) *UPF (obligatory)*
Prof: Davinia Hernandez-Leo
This course covers the major considerations and tasks involved in conducting scientific research, with special emphasis in those aspects related to the context of Information and Communication Technologies. Students are expected to develop the following skills: formulation of research questions; ability to search and distinguish the types of information sources and their impact; selection of the techniques and methods that can be applied to different types of research work; communication skills in the context of research; understanding the context and role of professional researchers, including the tasks of writing and reviewing papers and projects.

Critical Data Studies (5 ECTS) *UPF (obligatory)*
Prof: Carlos Castillo
The course focuses on three key issues in data processing, addressed from an ethical, legal, and technological perspective: Personal data processing: privacy, confidentiality, surveillance, recourse, data collection, and power differentials: Data-driven decision support: biases and transparency in data processing, data-rich communication, and data visualisation: Automated decision making: conceptualizations of power and discrimination in scenarios with different degrees of automation.
We will spend about half of the course studying computing technologies for, e.g., anonymizing data, or detecting and mitigating algorithmic bias. The other half of the course we will study different conceptualizations of power around data processing pipelines, analyse bias and discrimination in computer systems from a moral philosophy perspective, and overview the relevant legal frameworks for data processing.

Advanced Topics on Intelligent Systems (5 ECTS) *UPF (obligatory)*
Prof. Vicenç Gómez
In this course, we will examine state-of-the-art methods for the design of intelligent systems, with an emphasis on problems that involve sequential decision making. The course will include seminars and lectures about the research area of intelligent decision making, an overview of the state-of-the-art and the current trends. Several research papers for each lecture will be presented and discussed by the students. During the last lecture of each section, there will be a presentation session where each student will present a paper, interacting with the audience about the paper contributions, methods, etc. The course also includes guest lectures from academia (invited researchers) as well as from the industry.

Data-Driven Social Analytics (5 ECTS) *UPF (elective)*
Prof: Andreas Kaltenbrunner
The aim of this course is to provide both the theoretical background as well as the practical tools to analyse, model and visualise the multiple facets of online social networks. Online social networks and social media play a central and growing role in our daily life. The course provides an overview about the state of the art in Social Network Analysis and how its metrics have been derived from theories in Sociology. Furthermore, it will provide knowledge about tools and methods to derive specific social media datasets and the way to visualise social networks that go beyond an ugly hair ball of nodes and edges. Finally, it will cover more advanced topics such as learning and inference, information diffusion, community structure and prediction.

Mobile Robotics (5 ECTS) *UPF (elective)*
Prof: Vladimir Estivill Castro
This is an introductory course to mobile robotics covering practical and theoretical aspects. The course will involve basic notions of robot locomotion, perception, localization, and action; robot architectures, and projects on real robots.

Probabilistic Graphical Models (5 ECTS) *UPF (elective)*
Prof: Vicenç Gómez
Probabilistic graphical models (PGMs) are powerful modelling tools for reasoning and decision making under uncertainty. PGMs have many application domains, including computer vision, natural language processing, efficient coding, and computational biology. PGMs connect graph theory and probability theory and provide a flexible framework for modelling large collections of random variables with complex interactions. This is an introductory course which focuses on two main principles: (1) emphasising the role of PGMs as a unifying language in machine learning that allows a natural specification of many problem domains with inherent uncertainty, and (2) providing a set of computational tools for probabilistic inference (making predictions that can be used to aid decision making), and learning (estimating the graph structure and their parameters from data).

Courses at Sapienza University of Rome (specialisation in Robotics)

Robot Programming (3 ECTS) *Sapienza (obligatory)*
Prof: Giorgio Grisetti
This course aims at providing the students with essential background in developing programs for mobile robots. The course will provide some background on C++, which is used in the kernels of robot programs, as well as ROS: the robotic operating system. As practical applications we will address in detail the components of a mobile robot navigation system, and we will provide the necessary knowledge to complement such a system with additional functionalities.

Robotics I (6 ECTS) *Sapienza (obligatory)*
Prof: Alessandro De Luca
The student will be introduced to the basic tools for the kinematic analysis, trajectory planning, and programming of motion tasks for robot manipulators in industrial and service environments. Students will learn how actuation units and sensing components of robots operate, the basic methods for the kinematic modelling, analysis and control of robot manipulators, as well as the main algorithms for trajectory planning. Students who will take the Robotics II course will also understand the tools for the dynamic modelling of robot manipulators, the use of kinematic redundancy, the design of feedback control laws for free motion and interaction tasks, including visual servoing.

Seminars in AI and Robotics (3 ECTS) *Sapienza (obligatory)*
Prof: Cristian Napoli
This seminar series includes two consecutive, independent sections, plus two 3-days workshops. For each section, the first lectures will include a brief introduction by the teacher about the research area, with an overview of the state-of-the-art and the current trends. In the remaining lectures of each section, two or three research papers for each lecture will be presented and discussed by the students. During the last lecture of each section, there will be a poster session where each student will present a paper through a poster, interacting with the audience about the paper contributions, methods, etc… In the presentation of the paper, students should cover: Aims and objective of the paper; Some related work; The main contributions of the paper; Methods; Presented experiments. In the discussion of the paper students should critically focus on: Impact of the presented paper, i.e. relevance and applicability; Novelty (is it a new idea? is the approach novel?) Soundness (are the results convincing? Is the methodology sound?)
Main limitations. Each paper will be presented by a student and discussed by another student. Some questions will be asked by the teacher and possibly by the students during the presentation and/or the discussion.

Planning and Reasoning (6 ECTS) *Sapienza (elective)*
Prof: Paolo Liberatore
The students will gather an advanced knowledge of the main ideas of automated planning and mechanism for formal logic reasoning within the field of artificial intelligence. The aim is to prepare the student so that they can use the existing systems for automated planning and understand their inner workings, which is fundamental to adapt them to cope with issues arising from specific problems. Furthermore, the student will understand the theoretical bases of the uses of formal logics in artificial intelligence.

Formal Methods (6 ECTS) *Sapienza (elective)*
Prof: Giuseppe De Giacomo
Students will get a deep knowledge of how to ensure a fundamental quality of software, especially in robot systems: correctness. Such a study concerns both the static aspects (data) and the dynamic aspects (processes) of software, considering both how to conceptualise and model such aspects and how to verify them. The main tools used for such study are various forms of logic: first-order logic and description logics for the static aspects, Hoare Logic and dynamic and temporal logics of programs for the dynamic aspects. After a successful completion of the course, the student will have acquired techniques and methods to model and verify programs, both wrt data and processes.

Knowledge Representation (6 ECTS) *Sapienza (elective)*
Prof: Riccardo Rosati
Students will get introduced to the main languages of the current semantic technologies, in particular, the families of class-based and rule-based knowledge representation formalisms, and the main reasoning techniques for such formalisms. To know the standard semantic technologies based on the above knowledge representation formalisms, in particular the RDF language and the OWL language, with the goal of designing and managing an ontological knowledge base. Semantic technologies have an important role in robot software development as it improves the ability of the robot to reason about the

context it is inserted into.

Advanced Topics in AI and Robotics (6 ECTS) *Sapienza (elective)*
Prof: Giuseppe De Giacomo, prof. Luca Iocchi
This course covers every year different topics that are complementary to those studied in the different topics of AI and Robotics.

Robotics II (6 ECTS) *Sapienza (elective)*
Prof: Alessandro De Luca
This course provides tools for: Advanced kinematics and dynamic analysis of robot manipulators; Design of feedback control laws for free motion and interaction tasks, including visual servoing. Contents: Advanced kinematics for robot manipulators (calibration, redundancy resolution). Derivation and use of the dynamic model of robots (Euler-Lagrange and Newton-Euler formulations). Identification of dynamic coefficients. Inclusion of joint transmission elasticity. Linear and nonlinear control schemes for set-point regulation (PD with gravity compensation, saturated PID, iterative learning) and for trajectory tracking (feedback linearization and decoupling, passive control, adaptive control) in free motion tasks, as well as for interaction tasks with the environment (admittance control, compliance control, impedance control, hybrid force/velocity control). Image- and position-based visual servoing (kinematic treatment). Special topics will be presented in a seminarial way: diagnosis of robot actuator faults; detection of collisions and safe reaction; human-robot coexistence and physical collaboration.

Medical Robotics (6 ECTS) *Sapienza (elective)*
Profs: Marco Ferro and Marilena Vendittelli
Introduction to the basic robotic technologies in the medical context, with particular emphasis on surgical robotics. Expected learning results: Knowledge of the main robotic surgical systems, of the challenges and methodologies of medical robot design and control. Expected competence in: critically reading a scientific paper describing medical robotics technologies; discussing in detail the state of the art of robotic applications in medicine; estimating potential benefits deriving from the introduction of robotic technologies in a medical procedure; arguing the development of a particular technology not yet available or experimentally validated; communicating and collaborating with people with different technical background; evaluating clinical, social and economical constraints in implementing a robotic technology in a medical context; design control scheme for teleoperation of medical robots and for shared execution of surgical tasks between humans and robots.

Courses at Radboud University (specialisation in CyberSecurity)

Capita Selecta in Cyber Security (6 ECTS) *RU (obligatory)*
Prof: Gunes Acar
The idea behind this capita selecta course is to treat a topic within the broad field of cyber security in-depth. The topic may vary over the years, but it will be a topic that is highly relevant and important and one that is an active area of research within the Digital Security group at ICIS. The current topic is 'Online Tracking and Privacy' and the following subtopics will be treated: stateful and stateless cross-site tracking on the web (e.g. cookies, super-cookies, browser fingerprinting, cookie syncing); microtargeting and behavioural advertising; intentional and unintentional exfiltration of personal data; countermeasures against password leaks; countermeasures against web tracking, at browser or network level; tracking on mobile platforms; IoT devices and privacy (e.g. data collection from smart home devices and by smart TV channels); online manipulation: microtargeting and dark patterns; practical analysis of online privacy practices for the web, mobile devices, and IoT, including building web crawlers for large scale measurements and using machine learning techniques for analysis; privacy-preserving analytics, telemetry, and advertising (e.g. RAPPOR, Local Differential Privacy, Mozilla Prio, Google FLoC).

Software Security (6 ECTS) *RU (obligatory)*
Prof: Erik Poll
Software is THE most important cause of computer security problems. This course is about the challenges in developing secure software and the technologies that can be used to improve software security, at the various stages in the software development life-cycle, and at various "levels", eg. specific

to an individual application or at the level of the programming language.

Selected Topics on Hardware for Security (3 ECTS) *RU (obligatory)*
Prof: Ileana Buhan
In this course we explore the role hardware plays in securing embedded systems.
We identify the typical components available in a wide range of Commercial off the shelf
(COTS) products such as gaming consoles, IP cameras, routers and diverse IoT devices, and explore the role of memories and interfacing.
Next we contrast the architecture for COTS products with that of high-end security devices and we zoom-in and examine components that are typically present in high-end security devices such as true random number generators, physically unclonable functions and dedicated crypto coprocessors. This is a course for students interested in hardware and software design in industry i.e. real-world security applications. The course is devoted to the state-of-art in cryptographic hardware and embedded systems.

Security in Organizations (6 ECTS) *RU (elective)*
Prof: Eric Verheul
Information security deals with the preservation of the confidentiality, integrity and availability of information. The leading standard on information security is ISO 27001 that defines the notion of a Information Security Management System (ISMS).
One of the difficulties of the information security process is its multidisciplinary nature: it needs to grasp security requirements from the organisation business processes (where the managers typically are not savvy on information security) and to translate them to security controls. These controls can be of various types, including ICT technical or cryptographic but also related to personnel security (e.g. screening) or physical security (e.g. ‘locks’). The multidisciplinary nature of information security is reflected in the different areas ISO 27001 refers to.
The course provides the basic information on information security required by the security officer of an organisation, by IT security auditors and by IT security consultants. As information security is still a rapidly evolving topic the course can also provide inspiration for further scientific research.
The course starts with introduction of security management based on ISO27001 and then follows the different areas of ISO 27001. In each class one of these areas is discussed in more detail, in many cases by practical experts from the field, e.g. on internet banking fraud, ‘lock-picking’, ‘hacking’ etc.

Information Retrieval (6 ECTS) *RU (elective)*
Prof: Faegheh Hasibi
While the rise of the internet has helped strengthen the field of Information Retrieval (IR), the area stretches far beyond plain web search, as a discipline situated between information science and computer science. In 1968, Gerard Salton defined information retrieval as "a field concerned with the structure, analysis, organisation, storage, searching, and retrieval of information". Even though the area has seen many changes since that time and made a tremendous impact (who has never used a search engine?!), that definition is still accurate.
IR takes the notion of "relevance" as its core concept. As the scope of IR is limited to those cases where computers try to identify the relevance of information objects given a user's information need (as opposed to humans doing that, the common scenario in information science), perhaps "Computational Relevance" would have been a better term for the research in this area.
In this course, we cover the following aspects of Information Retrieval: How do people search for information, and how can this be formalised? How can we take advantage of term statistics, structure and annotations to capture the meaning of texts? How can these elements be combined in order to find "relevant" information? What techniques are necessary to scale to large text collections?

Deep Learning (3 ECTS) *RU (elective)*
Prof: Twan van Laarhoven
Deep Learning is a flavour of machine learning that uses deep artificial neural networks, meaning networks with many layers and often millions of parameters. Over the last couple of years Deep Learning has shown huge successes in different applications such as image and speech recognition, game playing agents, image synthesis, computational biology, etc. In this course you will learn both how to apply Deep Learning to solve problems, as well as how these deep neural networks are implemented and how they work. We will treat many different architectures, and show which ones are appropriate in which situations. Because this is a very broad field that is continuously developing, we will not be focusing on
any specific application, but rather lay the groundwork on which all deep learning techniques are built.

Bayesian Networks (6 ECTS) *RU (elective)*
Prof: Johannes Textor
Bayesian networks are powerful, yet intuitive tools for knowledge representation, reasoning under uncertainty, inference, prediction, and classification. The history of Bayesian Networks dates back to the groundbreaking work of Judea Pearl and others in the late 1980s, for which Pearl was given the Turing

Award in 2012.
Bayesian networks are used in many application domains, notably medicine and molecular biology. This course will cover the necessary theory to understand, build, and work with Bayesian networks. It will also introduce how Bayesian networks provide a much needed foundation for causal inference, giving rise to what is sometimes called the "causal revolution".

Advanced Machine Learning (6 ECTS) *RU (elective)*
Prof: Bert Kappen
The course provides advanced topics in machine learning. The aim of the course is to provide the student with advanced concepts of modern machine learning at the international research level. The student will become familiar with modern literature by presenting recent research papers on various topics. The student will implement these methods in computer code and apply them to real learning problems.

Advanced Network Security (6 ECTS) *RU (elective)*
Prof: Katharina Kohls
The course covers the following topics: *(i)* A brief overview of distributed systems, how to model them, and some basic distributed algorithms like leader election and mutual exclusion. *(ii)* A selection of fault-tolerant distributed algorithms (from byzantine agreement to self-stabilisation) as an alternative approach to availability. *(iii)* A discussion on several widely used Internet protocols, focusing on the security they provide (e.g. IEEE 802.11 and BGP). *(iv)* An overview of some of the current threats on the Internet and motivations behind these (e.g. botnets). *(v)* A discussion of possible solutions to current security issues in the Internet.

Research Seminar Data Science (6 ECTS) *RU (elective)*
Prof: Elena Marchiori
The Research Seminar Data Science is intended to provide students with the opportunity to develop the skill of critically reading and evaluating research papers in the broad area of data science. The course is a required component of the Data Science specialisation. Attendance is compulsory. Every student in the class will present and/or review two papers. The paper to be presented is a recent paper published in a top data science conference or journal. The paper to review has been submitted to some top conference and may have major impact in the future.

Philosophy & Ethics for Computing and IS (6 ECTS) *RU (elective)*
Prof: Luca Consoli
The course Philosophy and Ethics for Computing & Information Science explores cultural and social issues that have been made possible by the development of information technology
Starting from the concepts of privacy and the relationship between informatics and political decision-making processes, we will move on to examine the changes in our way to look at the world caused by the progresses of information technology. We will analyse among others the cultural meaning of hackerism, the role different ethical frameworks play in discussing technological advances, and the social/ethical/cultural implications of artificial intelligence (AI).

Courses at University of Ljubljana (specialisation in Data Science)

Machine Learning for Data Science 2 (6 ECTS) *UL (obligatory)*
Profs: *Blaž Zupan, Erik Štrumbelj*
This course focuses on advanced machine learning techniques and latest developments in machine learning methodology and research. Each student has three assignments - to fully reproduce a recent machine learning paper (the course participates in a reproducibility challenge), to study and assigned advanced topic and give a lecture, and to attend lectures by other students. As such, the course is different each year and evolves together with machine learning.

Deep Learning (6 ECTS) *UL (obligatory)*
Prof: Danijel Skočaj
Convolutional neural networks and related deep learning approaches have proven to be a very efficient way of finding the representations and building a classifier in a unified framework that yields excellent results in tasks in computer vision, natural language processing and other fields.
The main goal of this course is to introduce the students into the field of deep learning, to develop a good understanding of deep-learning principles, and master the deep learning-related techniques for practical applications and get acquainted with the state-of-the-art approaches. The course will briefly cover the fundamentals such as feedforward neural networks, stochastic gradient descent, auto-differentiation,

regularisation, and normalisation, and proceed with different architectures and paradigms, such as convolutional neural networks, recurrent neural networks, long short-term memory models, transformers, autoencoders, generative adversarial networks, and deep reinforcement learning. Most of these will be introduced through practical examples from computer vision, speech recognition, and natural language processing.

Web Information Extraction and Retrieval (6 ECTS) *UL (obligatory)*
prof: Marko Bajec
The Web is almost an unlimited source of information. Using search engines such as Google, Bing and similar we can easily find web pages with possibly relevant information. The number of returned pages would usually however be very large which does not allow for manual processing. The solution to this are computer programs that are able to find and extract relevant information from a possibly very large number of non-structured or semi-structured documents and return results in structured form.
The main objective of this course is to teach students about how to develop programs for web search (including surface web and deep web search) and for extraction of structural data from both, static and dynamic web pages. Beside basic concepts of web search and retrieval, students will learn about relevant techniques and approaches. After the course, if successful, students will be able to develop programs for automatic web search and structured data extraction from web pages (including search and extraction from on-line social media).

Biomedical Signal and Image Processing (6 ECTS) *UL (elective)*
prof. Franc Jager
The course introduces techniques and procedures for analysis of biomedical signals and images like: cardiology signals (electrocardiogram - ECG), neurophysiology signals (electromyogram - EMG, electroencephalogram - EEG), medical images (computed tomography – CT images) with the emphasis on problems of biomedical research.

Image Based Biometry (6 ECTS) *UL (elective)*
Prof. Peter Peer
The course relies mostly on computer vision as most biometrics technologies are based on it. The intended audience for this course are students interested in cutting edge technology, much of which is still in a research stage. We will cover biometry basics, biometric modalities, the structure of a typical biometric system, recognition/verification/identification metrics, conditions for valid comparisons of systems. The majority of the content is expected to evolve and adapt to latest developments in the field.

Principles of Uncertainty (6 ECTS) *UL (elective)*
Prof. Erik Štrumbelj
Probability is the language of modern quantitative data analysis and statistics, the key tool for modelling data. This course aims to be the second course in probability and statistics for the aspiring data scientist, but with extra effort can also serve as the first course. Probability and statistics are covered at a deeper level. We provide a measure theoretic perspective on probability spaces, random variables, and expectations. We introduce different types of convergence and different representations of random variables. The most common approaches to inference are also covered: nonparametric bootstrap, maximum likelihood estimation, null hypothesis testing, and Bayesian inference.

Advances Topics in Computer Vision (6 ECTS) *UL (elective)*
Prof. Matej Kristan
The course will include selected advanced topics in motion perception using computer vision. Concrete topics will change each year according to trends in this fast developing field in computer science and industry. Tentatively the course shall include: Low-level motion estimation techniques; Tracking regions by generative models; Tracking regions by discriminative models; Bayesian recursive filtering; Deep-learning-based trackers; Long-term tracking; and Visual tracking performance evaluation.