Course guide
295106 - 295II022 - Computer Vision

Last modified: 22/06/2026

Unit in charge: Barcelona East School of Engineering
Teaching unit: 707 - ESAII - Department of Automatic Control.
712 - EM - Department of Mechanical Engineering.
717 - DEGD - Department of Engineering Graphics and Design.

Degree: MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Compulsory subject).
ERASMUS MUNDUS MASTER IN SUSTAINABLE SYSTEMS ENGINEERING (EMSSE) (Syllabus 2024). (Optional subject).
MASTER'S DEGREE IN ADVANCED BIOMEDICAL TECHNOLOGIES (Syllabus 2025). (Optional subject).

Academic year: 2026 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: KEVIN IVAN BARRERA LLANGA

Others: KEVIN IVAN BARRERA LLANGA - Grup: T1
EDMUNDO GUERRA PARADAS - Grup: T1
JORDI TORNER RIBE - Grup: T1
CHRISTIAN MATA MIQUEL - Grup: T1
ROBERT EMBODAS NOGUERA - Grup: T1

PRIOR SKILLS

Programming. Basic statistics.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMUEII-10. Design and implement image analysis systems for the advanced characterization of complex systems in engineering.

Generical:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.

Transversal:
05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
06 URI. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

LEARNING RESULTS

Knowledges:
K5. Describe advanced knowledge of analysis and interpretation of biomedical signals.
K7. Infer advanced knowledge of digital biomarkers and artificial intelligence techniques in health technologies.
K1. Relate advanced knowledge of biomechanics, biomaterials, implants and prostheses to the design of medical devices.
K8. Demonstrate advanced knowledge of digital and mobile health applications (mHealth).

Skills:
S7. Design advanced computer vision and robotics applications in healthcare.
S01. Communicate effectively in oral, written and graphic form with others regarding learning, the development of ideas and decision making, and participate in discussions using interpersonal skills such as active listening and empathy, which foster teamwork.
S05. Apply pattern recognition, artificial intelligence and statistical data analysis techniques to make objective, quantitative and reproducible decisions in multidisciplinary problems.
S06. Use appropriate computational techniques to simulate engineering systems, and adapt and apply optimisation algorithms to engineering problems.

Competences:
C6. Integrate the values of sustainability and understand the complexity of systems, with the aim of undertaking or promoting actions that restore and maintain the health of ecosystems and improve justice, thereby generating visions of sustainable futures.
C2. Apply management methodologies to projects, teams and biomedical products and technologies that are appropriate to the type of project.
C3. Identify and analyse problems that require making autonomous, informed and reasoned decisions in order to act with social responsibility following ethical values and principles.

TEACHING METHODOLOGY

The course combines theory-practice sessions, laboratory activities, seminars and the development of applied projects. The classes are organized into three blocks: image processing, learning-based vision and three-dimensional vision.

In the theory-practice sessions, the concepts needed to understand each technique are presented and then applied through guided exercises using programming tools and working environments suitable for image analysis.

The laboratory activities allow students to implement processing methods, segmentation, feature extraction, classification models, convolutional networks, Vision Transformers, explainability techniques and 3D vision applications.

The course also includes block projects aimed at integrating the contents covered in class and solving practical computer vision problems. These projects make it possible to assess students' capacity for analysis, implementation, interpretation of results and technical presentation of solutions.

In addition, a seminar session linked to research projects is included, with the aim of presenting real applications of computer vision in scientific and technological contexts.

LEARNING OBJECTIVES OF THE SUBJECT

By the end of the course, students should be able to:

- Recognize different digital image modalities and identify their applications in engineering, science and technology problems.
- Manipulate digital images in different formats, applying basic operations for reading, visualization, transformation, filtering and enhancement.
- Apply image preprocessing techniques to prepare data before segmentation, analysis or classification.
- Implement automatic procedures for object segmentation and visual feature extraction.
- Develop classification and pattern recognition models in images using machine learning techniques.
- Understand the structure and operation of neural networks, convolutional networks and Vision Transformers applied to image analysis.
- Apply explainability techniques to interpret the behavior of computer vision models.
- Gain a general understanding of the development of interactive 3D environments with Unity, including VR, AR and XR concepts.
- Build basic three-dimensional vision applications and interactive environments using 3D modeling, programming and visualization tools.
- Design and implement suitable procedures for practical computer vision problems, considering the available data, the techniques used and the interpretation of the results.
- Prepare technical reports describing the development, evaluation, results obtained and conclusions of the work carried out.

STUDY LOAD

Type	Hours	Percentage
Hours large group	27,0	18.00
Self study	96,0	64.00
Hours small group	27,0	18.00

Total learning time: 150 h

CONTENTS

Image processing

Description:
- Basic handling of digital images: reading, visualization, file formats, color channels and matrix representation.
- Image preprocessing: intensity transformations, spatial filtering, statistical filtering and visual quality enhancement.
- Image segmentation: thresholding, Otsu method, watershed and morphological operations.
- Feature extraction: geometric descriptors, color descriptors and texture analysis.

Specific objectives:
Understand the workflow that transforms an original digital image into a quantitative representation for further analysis. Apply preprocessing, segmentation and feature extraction techniques to practical computer vision problems.

Related activities:
Session 1: Basic handling of digital images.
Session 2: Basic handling of digital images.
Session 3: Image preprocessing.
Session 4: Image preprocessing.
Session 5: Object segmentation.
Session 6: Object segmentation.
Session 7: Feature extraction.
Session 8: Feature extraction.
PA1: assessment of the image processing block.
BP1: project of the image processing block.

Full-or-part-time: 12h
Theory classes: 8h
Laboratory classes: 4h

Learning-based vision

Description:
- Formulation of automatic segmentation problems and limitations of classical approaches.
- Automatic segmentation models: clustering, data-based methods and machine learning approaches.
- Multilayer neural networks: structure, learning process, activation functions and backpropagation.
- Convolutional neural networks: principles, architecture and applications in image analysis.
- Vision Transformers and comparison with convolutional models.
- Explainability techniques to interpret computer vision models.

Specific objectives:
Understand the foundations of learning-based and deep learning models for computer vision. Formulate image analysis problems, select suitable models according to the available data, implement classification or segmentation procedures and interpret the results obtained.

Related activities:
Session 1: Automatic segmentation: problem formulation and limitations of classical approaches.
Session 2: Automatic segmentation models: clustering and learning-based approaches.
Session 3: Multilayer neural networks: structure and learning process.
Session 4: Activation functions and backpropagation.
Session 5: Convolutional neural networks: principles and architecture.
Session 6: Applications of convolutional neural networks in image analysis.
Session 7: Vision Transformers and comparison with convolutional models.
Session 8: Model explainability techniques.
Seminar: research projects in computer vision.
PA2: assessment of the learning-based vision block.
BP2: project of the learning-based vision block.

Full-or-part-time: 16h
Theory classes: 10h
Laboratory classes: 6h

Three-dimensional vision

Description:
- Introduction to immersive visual environments: virtual reality, augmented reality and extended reality.
- Vision-based interaction: hand tracking, gestures, display devices and immersive environments.
- Spatial modeling and geometry creation in Unity: 3D structures, terrains and virtual scene organization.
- Appearance modeling: materials, textures, particle systems and scene creation.
- Implementation of interactive 3D environments in Unity: illumination, camera control and interaction with the environment.
- C# scripting for interactive 3D environments: GameObjects, prefabs, transforms, physics, events and audio.
- Development of interactive 3D vision applications.

Specific objectives:
Understand the basic concepts of immersive visual environments and three-dimensional vision. Develop interactive scenes and applications in Unity, integrating 3D modeling, materials, illumination, cameras, interaction and C# scripting. Apply this knowledge to the development of 3D vision prototypes.

Related activities:
Session 1: Introduction to immersive visual environments and vision-based interaction.
Session 2: Spatial modeling and geometry creation in Unity.
Session 3: Appearance modeling: materials, textures and particle systems.
Session 4: Implementation of interactive 3D environments in Unity.
Session 5: C# scripting for interactive 3D environments.
Session 6: Development of interactive 3D vision applications.
BP3: project of the three-dimensional vision block.

Full-or-part-time: 12h
Theory classes: 4h
Laboratory classes: 8h

GRADING SYSTEM

Any academic fraud, plagiarism or use or possession of unauthorised means in an assessment activity leads to a mark of zero (0) for the affected test or assignment. Furthermore, in accordance with the University's regulations, if disciplinary proceedings are initiated the subject is recorded as "Pending Assessment" until a decision is reached. These incidents are managed in accordance with the **Action Framework for Academic Integrity in Assessment at the UPC**.

The course follows a continuous assessment system, based on partial assessments and block projects. For this reason, no reassessment exam is scheduled.

Partial assessments: 45%

- PA1: image processing block assessment: 20%
- PA2: learning-based vision block assessment: 25%

Block projects: 55%

- BP1: image processing project: 15%
- BP2: learning-based vision project: 20%
- BP3: three-dimensional vision project: 20%

The final grade for the course is calculated from the partial assessments and the block projects, according to the weighting indicated above.

EXAMINATION RULES.

Assessment activities will take place on the dates, times and conditions established in the course schedule. Students must follow the instructions given by the teaching staff responsible for each assessment and may only use the materials, resources or tools that have been authorized.

Any irregular conduct during an assessment or submission, including copying, plagiarism, unauthorized use of devices, communication with other people or impersonation, will be handled according to the current academic and assessment regulations of UPC and EEBE.

The assessments are part of the continuous assessment system of the course and take place within the time slots assigned in the course calendar. In the event of timetable incompatibilities with other courses or academic activities, students must manage the situation through the channels established by the school.

BIBLIOGRAPHY

Basic:
- González, Rafael C.; Woods, Richard E. Digital image processing. 3rd ed., international ed. Upper Saddle River: Pearson Education Internacional, cop. 2010. ISBN 9780132345637.
- Webb, Andrew R. Introduction to biomedical imaging. Hoboken (N.J.): Wiley, cop. 2003. ISBN 0471237663.
- James, Gareth. An introduction to statistical learning : with applications in R. New York: Springer, 2013. ISBN 9781461471370.
- Géron, Aurélien. Hands-on machine learning with Scikit-Learn and TensorFlow : concepts, tools, and techniques to build intelligent systems [on line]. Sebastopol, CA: O'Reilly Media, 2017 [Consultation: 21/04/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=4822582. ISBN 9781491962299.
- Raschka, Sebastian; Mirjalili, Vahid. Python machine learning : machine learning and deep learning with Python, scikit-learn, and TensorFlow [on line]. 2nd ed. Birmingham, UK: Packt Publishing, 2017Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=5050960. ISBN 9781787126022|.

RESOURCES

Other resources:
Contents and software uploaded to Atenea