COMILLAS
UNIVERSIDAD PONTIFICIA
ICAI ICADE CIHS

Syllabus
2024 - 2025

GENERAL INFORMATION

Data of the subject	
Subject name	Computer Vision I
Subject code	DEAC-IMAT-317
Mainprogram	Bachelor's Degree in Mathematical Engineering and Artificial Intelligence
Involved programs	Grado en Ingeniería Matemática e Inteligencia Artificial [Third year]
Level	Reglada Grado Europeo
Quarter	Semestral
Credits	3,0 ECTS
Type	Obligatoria (Grado)
Department	Department of Electronics, Control and Communications
Coordinator	Javier García López
Office hours	Arrange an appointment through email.

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Teacher	
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DESCRIPTION OF THE SUBJECT

Contextualization of the subject

Prerequisites

Contribution to the professional profile of the degree

Over the last two decades, the field of computer vision has experienced exponential growth. Cameras are now regarded as one of the most informative sensors and their use has spread to sectors as diverse as healthcare, the automotive industry, and manufacturing. However, extracting this information is not straightforward and often involves considerable computational effort.

This course covers some of the main classical image and video processing techniques. It starts with how images are captured with a camera and presents the most common algorithms to highlight areas of interest and remove noise or other unwanted effects. Afterward, students learn how to extract robust features to train machine learning models, culminating with some notions of motion detection and tracking in videos. By the end of the term, students should understand the fundamentals behinf the deep learning-based models currently in use, which are covered in detail in more advanced courses.

Prerequisites

Linear algebra and fundamentals of Python programming.

Course contents

Contents

Theory

Unit 1. Introduction

- What is computer vision?
- Applications

Unit 2. Image acquisition

- Camera models
- Calibration and distortion
- Color spaces and encoding

Unit 3. Image processing

- Filtering
- Morphological operators
- Edge detection

Unit 4. Feature extraction and matching

- Corner detection
- Line detection
- Point-feature detection: SIFT
- Region detection
- Feature matching
- Image stitching
- Visual bag-of-words
- Face detection: Viola-Jones algorithm

Unit 5. Motion detection and tracking

- Background subtraction
- Optical flow
- Kalman filter

Laboratory

Lab 1. Camera calibration

- A distortion correction method will be implemented on a set of images taken with a specific camera model.
- An extrinsic calibration method will be implemented and executed from initial data and a known calibration pattern.

Lab 2. Image processing

- The histogram of intensities of a dataset will be calculated and the impact of several preprocessing methods on the data will be analyzed.
- The effect of different types of filters (Gaussian, morphological, edge detection...) will be studied.
- For a set of images with some particularities, it will be necessary to determine the most appropriate preprocessing technique to normalize it.

Lab 3. Feature extraction and visual bag-of-words

- Point-features will be extracted from an image dataset.
- Afterward, a bag-of-words algorithm will be used to classify them.

Lab 4. Object tracking

- An algorithm to track objects in videos will be developed using different techniques such as background subtraction or Kalman filters.

Final project

Using a Raspberry Pi to which a camera will be connected, the students will implement a computer vision system using the techniques covered during the lab assignments. The system will include an initial automatic calibration method.

EVALUATION AND CRITERIA

Evaluation activities	Evaluation criteria	Weight
• Midterm • Final exam	• Understanding of the theoretical concepts. • Application of these concepts to problem-solving. • Critical analysis of the numerical results. • Written communication skills.	40
• Lab assignments	• Understanding of the theoretical concepts. • Application of these concepts to problem-solving. • Critical analysis of the experimental results. • Oral and written communication skills.	40 %
• Project	• Quality of the proposal. • Execution and quality of the final design. • Difficulty. • Working robustness. • Autonomy and problem-solving skills. • Oral and written communication skills.	20 %

Grading

Regular assessment

The weighting of each of the evaluation activities will be as follows:

- Theory (40%)
  - Midterm: 10%
  - Final exam: 30%
- Laboratory (60%)
  - Lab assignments: 40%
  - Project: 20%

The final grade will be computed according to these **restrictions**:

- If the marks of the final exam and the project are greater than or equal to 5, the course grade will be obtained as indicated in the percentages above. Otherwise, the final grade will be the lower of the two marks.

Retake

A new final exam will be taken. If the mark of the project is lower than 5, the student will also carry out an individual project, which will be defended publicly at the latest on the day of the retake exam. The marks of all those evaluation activities that do not have to be repeated will be preserved: midterm, lab assignments, and, if applicable, the project. The final grade will be computed as in the regular assessment period and according to the same restrictions.

Course rules

Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Académicas) of the ICAI School of Engineering. Not complying with this requirement may have the following consequences:

- Students who fail to attend more than 15% of the lectures may be denied the right to take the final exam during the regular assessment period.
- Regarding laboratory, absence from more than 15% of the sessions can result in losing the right to take the final exam of the regular assessment period and the retake. Anyway, unjustified absences to laboratory sessions will be penalized in the evaluation.

Students who commit an irregularity in any graded activity will receive a mark of zero in the activity and disciplinary procedures will follow (cf. Article 168 of the General Regulations (Reglamento General) of Comillas Pontifical University).

WORK PLAN AND SCHEDULE

Activities	Date of realization	Delivery date
Midterm	Week 7	
Final exam	Regular examination period	
Lab sessions	Weeks 3, 6, 9, and 11	
Self-study of the concepts covered in the lectures	After each lesson	
Problem solving	Every two weeks	
Lab report writing	After every lab assignment	One week after the end of each assignment
Project development	From the first lab assignment	Last week
Midterm preparation	One week before the test	
Final exam preparation	December	

BIBLIOGRAPHY AND RESOURCES

Basic References

- Slides and notes prepared by the instructors (available in Moodle).
- R. Szeliski, *Computer Vision: Algorithms and Applications*, 2nd Ed., Springer, 2021. ISBN-13: 978-3-030-34371-2
- OpenCV, [Online]. Available: https://opencv.org/
- P Sturm, S. Ramalingam, J.-P. Tardif, S. Gasparini, and J. Barreto, *Camera models and fundamental concepts used in geometric computer vision. Foundations and trends in computer graphics and vision*, vol. 6, no. 1-2, pp. 1-183, 2011 DOI: 10.1561/0600000023

- A. Ammar, H. B. Fredj, and C. Souani, *Accurate realtime motion estimation using optical flow on an embedded system,* Electronics, vol. 10, no. 17, 2164, 2021. DOI: 10.3390/electronics10172164
- E. F. I. Raj and M. Balaji, *Shape feature extraction techniques for computer vision applications,* in B. V. Kumar, P. Sivakumar, B. Surendiran, J. Ding (eds.) Smart Computer Vision, EAI/Springer Innovations in Communication and Computing, Springer, Cham, 2023. DOI: 10.1007/978-3-031-20541-5_4

Complementary bibliography

- S. Dey, *Hands-on Image Processing in Python: Expert techniques for advanced image analysis and effective interpretation of image data*, 1st Ed., Packt Publishing, 2018. ISBN-13: 978-1-789-34373-1
- E. Adil, M. Mikou, and A. Mouhsen, *Investigation of stereo camera calibration based on Python*, in Proc. 12th Int. Conf. Soft Computing and Pattern Recognition (SoCPaR 2020). Advances in Intelligent Systems and Computing, vol. 1383. Springer, Cham., 2021. DOI: 10.1007/978-3-030-73689-7_74
- P. Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB*, 2nd Ed., Springer International Publishing, 2017. ISBN-13: 978-3-319-54412-0