COURSE SYLLABUS
2015-2016

GENERAL INFORMATION

Course information	
Name	Computer Vision
Code	DEA-OPT-623
Degree	Máster en Ingeniería Industrial (MII), Máster en Ingeniería de Telecomunicación (MIT)
Year	2nd
Semester	2nd (Spring)
ECTS credits	3 ECTS
Type	Elective
Department	Electronics, Automation and Communications
Area	Automation
Coordinator	Jaime Boal Martín-Larrauri

Instructor	
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DETAILED INFORMATION

Contextualization of the course

Contribution to the professional profile of the degree

Over the past two decades, the field of computer vision has experienced a rapid growth, and cameras are currently regarded as the most informative sensory source for many industrial applications. However, extracting this information is not straightforward and often involves a lot of processing. Starting from the fundamentals, this course is conceived as an introductory walk through some of the most extensively used techniques in the field of computer vision, in which the student will be progressively exposed to a number of algorithms that permit to obtain meaningful data from images.

By the end of the course, students will understand the basic principles behind image acquisition and processing, will have experience with the most common feature extraction algorithms, and will have well-formed criteria to choose the most appropriate technique for a given application. As a result, they will be able to develop computer vision based systems for the health care, automotive, or manufacturing industries, to name a few, or join cutting-edge research groups in which a solid background in the topic is often requested.

Prerequisites

Students willing to take this course should be familiar with linear algebra, basic probability and statistics, machine learning, and undergraduate-level programming. Previous experience with MATLAB and an object-oriented programming language (especially C++) is also desired although not strictly required.

CONTENTS

Contents
Theory
Chapter 1. Introduction
1.1 What is computer vision? 1.2 Applications of computer vision
Chapter 2. Image formation
2.1 Camera models 2.2 Distortion and camera calibration 2.3 Color sensing and encoding
Chapter 3. Image processing
3.1 Filtering 3.2 Edge detection and segmentation
Chapter 4. Feature extraction and matching
4.1 Overview of the most common types of features 4.2 Vertical edges 4.3 Intensity and color histograms 4.4 Point features 4.5 Region detectors
Chapter 5. Movement detection and tracking
5.1 Background subtraction 5.2 Optical flow 5.3 Kalman filtering
Laboratory
Lab 1. Camera calibration and image processing
In this first lab session, students will become familiar with the most common preprocessing steps in a computer vision system: basic camera calibration and the application of filters to improve the captured images.
Lab 2. Visual place categorization: The “bag-of-words” approach
The objective of this practice is that students improve their understanding of feature detection and matching by applying them to a real problem. They will be asked to classify images of different places into known categories by extracting keypoints and using the “bag-of-words” algorithm.
Lab 3. Object tracking
In the third practice students will learn how to track moving objects in a video sequence. First, they will have to detect a single object (e.g., a rolling ball) and determine its position in every frame even if it becomes occluded. Afterwards, a more realistic sequence with two moving objects following different trajectories will be analyzed.
Final project
The final project may be: ▪ An original implementation of a new or already published idea. ▪ A detailed empirical evaluation of an existing implementation. ▪ A comparative study of two or more algorithms for a given application. ▪ A follow-up of the project developed in other subject that involves computer vision. A project proposal will have to be submitted and approved by the instructor.

Competences and learning outcomes

Competences[1]

General competences

CG4. Conduct research, development and innovation in products, processes and methods.
Realizar investigación, desarrollo e innovación en productos, procesos y métodos.

CG8. Apply the acquired knowledge and solve problems in new or unfamiliar environments within broader and multidisciplinary contexts.
Aplicar los conocimientos adquiridos y resolver problemas en entornos nuevos o poco conocidos dentro de contextos más amplios y multidisciplinares.

CG10. Be able to clearly and unambiguously communicate conclusions –and the knowledge and rationale that support them– to specialist and non-specialist audiences.
Saber comunicar las conclusiones –y los conocimientos y razones últimas que las sustentan– a públicos especializados y no especializados de un modo claro y sin ambigüedades.

CG11. Possess the learning skills that allow further study in a self-directed or autonomous manner.
Poseer las habilidades de aprendizaje que permitan continuar estudiando de un modo autodirigido o autónomo.

Learning outcomes

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

RA1. Enumerate several fields where computer vision is widely used nowadays or is bound to become relevant in the near future.

RA2. Determine the specific techniques that best suit a particular application.

RA3. Cite the physical principles involved in image formation.

RA4. Explain the fundamental methods employed to mitigate the influence of physical phenomena.

RA5. Describe image noise sources and the filters used to reduce it.

RA6. Know how to segment an image according to scene properties.

RA7. Enumerate the properties, advantages and disadvantages of the most common types of features.

RA8. Understand the steps required to obtain each of these features.

RA9. Know how to encode and compare the detected features.

RA10. Separate the dynamic foreground from the static background.

RA11. Track moving objects in a video sequence even if they become occluded.

RA12. Find, analyze, and understand computer vision literature.

RA13. Develop, implement, and test algorithms in an autonomous manner.

RA14. Provide evidence to assess the validity and performance of the proposed solution.

[1] Competences in English are a free translation of the Spanish version reproduced from the degree's Official Verification Report.

TEACHING METHODOLOGY

General methodological aspects	
The best way of gaining a full understanding of computer vision techniques is implementing them and facing real challenges. Consequently, all the proposed activities focus on providing students with the tools they require to be able to successfully develop a computer vision application by the end of the term.	
In-class activities	**Competences**
▪ **Lectures and problem-solving sessions (15 hours)**: The lecturer will introduce the fundamental concepts of each chapter, along with some practical recommendations, and will go through worked examples to support the explanation. Active participation will be encouraged by raising open questions to foster discussion and by proposing short application exercises to be solved in class either on paper or using a software package.	CG8, CG11
▪ **Lab sessions (12 hours):** Under the instructor's supervision, students, divided in small groups, will apply the concepts and techniques covered in the lectures to real problems and will become familiar with the most widespread software tools and libraries.	CG4, CG8, CG10, CG11
▪ **Tutoring** for groups or individual students will be organized upon request.	–
Out-of-class activities	**Competences**
▪ Personal study of the course material and resolution of the proposed exercises (24 hours).	CG8, CG11
▪ Lab session preparation to make the most of in-class time (3 hours).	CG8
▪ Lab results analysis and report writing (9 hours).	CG10, CG11
▪ Development of a final project in small groups during the last third of the course (24 hours).	CG4, CG8, CG10, CG11

ASSESSMENT AND GRADING CRITERIA

Assessment activities	Grading criteria	Weight
Mid-term exam	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem-solving. ▪ Critical analysis of numerical exercises' results.	10%
Final exam	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem-solving. ▪ Critical analysis of numerical exercises' results.	30%
Lab reports	▪ Application of theoretical concepts to real problem-solving. ▪ Ability to use and develop computer vision software. ▪ Written communication skills.	20%
Final project	▪ Problem analysis. ▪ Information search skills. ▪ Quality of the proposed solution. ▪ Teamwork. ▪ Oral presentation and written communication skills. ▪ There will be an intra-group evaluation method to differentiate among team members.	40%

GRADING AND COURSE RULES

Grading

Regular assessment

- **Theory** will account for 40%, of which:
  - Mid-term: 10%
  - Final exam: 30%
- **Lab** will account for the remaining 60%, of which:
  - Lab practices: 20%
  - Final project: 40%

In order to pass the course, the mark of the final exam must be greater or equal to 4 out of 10 points and the mark of the final project must be at least 5 out of 10 points. Otherwise, the final grade will be the lower of the two marks.

Retakes

Lab practice marks will be preserved, as well as that of the final project if it has a passing grade. Otherwise a new project will have to be developed and handed in. In addition, all students will take a final exam. The resulting grade will be computed as follows:

- Final exam: 40%
- Lab practices: 20%
- Final project: 40%

As in the regular assessment period, in order to pass the course, the mark of the final exam must be greater or equal to 4 out of 10 points and the mark of the final project must be at least 5 out of 10 points. Otherwise, the final grade will be the lower of the two marks.

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 to 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. Missed sessions must be made up for credit.
- Students who commit an irregularity in any graded activity will receive a mark of zero in the activity and disciplinary procedure will follow (cf. Article 168 of the General Regulations (Reglamento General) of Comillas Pontifical University).

WORK PLAN AND SCHEDULE[2]

In and out-of-class activities	Date/Periodicity	Deadline
Mid-term exam	Week 9	
Final exam	May	
Lab sessions	Weeks 5, 8 and 11	
Review and self-study of the concepts covered in the lectures	After each lesson	–
Problem-solving	Weekly	–
Lab preparation	Before every session	–
Lab report writing	–	One week after the end of each session
Final project	During the last third of the course	Last week
Final exam preparation	May	–

STUDENT WORK-TIME SUMMARY			
IN-CLASS HOURS			
Lectures	**Problem-solving**	**Lab sessions**	**Assessment**
12	3	12	3
OUT-OF-CLASS HOURS			
Self-study	**Lab preparation**	**Lab report writing**	**Final project**
24	3	9	24
		ECTS credits:	**3 (90 hours)**

BIBLIOGRAPHY

Basic bibliography

- Notes prepared by the lecturer (available in Moodle).
- R. Szeliski, *Computer Vision: Algorithms and Applications*, 1st Ed., Springer, 2011. ISBN-13: 978-1-84882-934-3
- D. A. Forsyth and J. Ponce, *Computer Vision: A Modern Approach*, 2nd Ed., Prentice Hall, 2011. ISBN-13: 978-0-13-608592-8
- MATLAB Computer Vision System Toolbox, [Online]. Available: http://mathworks.com/products/computer-vision/

Complementary bibliography

- R. C. González and R. E. Woods, *Digital Image Processing*, 3rd Ed., Prentice Hall, 2008. ISBN-13: 978-0-13-168728-8
- R. C. González, R. E. Woods, and S. L. Eddins, *Digital Image Processing Using MATLAB*, 2nd Ed., Gatesmark Publishing, 2009. ISBN-13: 978-0-9820854-0-0
- P. Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB*, 1st Ed., Springer-Verlag Berlin Heidelberg, 2011. ISBN-13: 978-3-642-20143-1
- OpenCV (Open Source Computer Vision library), [Online]. Available: http://opencv.org/

[2] A detailed work plan of the subject can be found in the course summary sheet (see following page). Nevertheless, this schedule is tentative and may vary to accommodate the rhythm of the class.

	In-class activities				Out-of-class activities				Learning outcomes
Week	**Time [h]**	**Lecture & Problem-solving**	**Laboratory**	**Assessment**	**Time [h]**	**Self-study**	**Lab preparation and report writing**	**Other activities**	**Code**
1	**2**	Course presentation and introduction (1h) Applications of computer vision (1h)			**1**	Review and self-study (1h)			RA1, RA2
2	**2**	Camera models (2h)			**3**	Review, self-study and problem-solving (3h)			RA3
3	**2**	Distortion and camera calibration (1h) Color sensing and encoding (1h)			**3**	Review, self-study and problem-solving (3h)			RA3, RA4
4	**2**	Filtering (1h) Edge detection and segmentation (1h)			**3**	Review, self-study and problem-solving (3h)			RA5, RA6
5	**2**		Lab 1 (2h)		**4**		Lab preparation (1h) Report writing (3h)		RA3, RA4, RA5, RA6
6	**2**	Feature overview and vertical edges (1h) Intensity and color histograms (1h)			**1.5**	Review, self-study and problem-solving (1.5h)			RA7, RA8, RA9
7	**2**	Point features (1.5h) Region detectors (0.5h)			**2**	Review, self-study and problem-solving (2h)			RA7, RA8, RA9
8	**2**		Lab 2 (2h)		**4**		Lab preparation (1h) Report writing (3h)		RA7, RA8, RA9, RA13, RA14
9	**2**			Mid-term exam (1h)	**6**	Test preparation (6h)			RA1 – RA9
		Background subtraction (1h)			**1.5**	Review and self-study (1.5h)			RA10
10	**2**	Optical flow (1h) Kalman filtering (1h)			**4**	Review, self-study and problem-solving (3h)		Final project proposal (1h)	RA11
11	**2**		Lab 3 (2h)		**4**		Lab preparation (1h) Report writing (3h)		RA10, RA11, RA13, RA14
12	**2**		Final project (2h)		**6**			Final project development (6h)	RA2, RA12, RA13, RA14
13	**2**		Final project (2h)		**6**			Final project development (6h)	RA2, RA12, RA13, RA14
14	**2**		Final project (2h)		**6**			Final project development (6h)	RA2, RA12, RA13, RA14
15	**2**			Final project presentations (2h)	**5**			Final project paper and presentation preparation (5h)	RA1, RA14