Universidad de Alcalá

TEACHING GUIDE

Computer Vision Systems

Degree in
Information System Engineering (GISI)
Computer Engineering (GIC)
Computer Science Engineering (GII)

Universidad de Alcalá

Academic Year 2021/2022

4th Year - 1st Semester (GISI+GIC+GII)

Approved by the School Board on July 6, 2021

TEACHING GUIDE

Course Name:	**Computer Vision Systems**
Code:	**780029 (GISI+GIC+GII)**
Degree in:	**Information System Engineering (GISI)** **Computer Engineering (GIC)** **Computer Science Engineering (GII)**
Department and area:	**Electrónica** **Electronic Technology**
Type:	**Optional (Generic) (GISI+GIC+GII)**
ECTS Credits:	**6.0**
Year and semester:	**4th Year - 1st Semester (GISI+GIC+GII)**
Teachers:	Juan Manuel Miguel Jiménez
Tutoring schedule:	It will be communicated at the beginning of the course
Language:	English

1. COURSE SUMMARY

Computer Vision aims to introduce students to the study of computer vision and design of digital image processing algorithms. The theoretical concepts explained in the lectures are programmed later in the laboratory either in C/C++ with OpenCV or MATLAB.

Different alternatives for implementation of intelligent machine vision systems are detailed and analyzed. The main topics to be addressed include: fundamentals of digital image processing, image processing techniques in the spatial and frequency domains, image segmentation, recognition techniques and object tracking, 3D vision and its application in intelligent systems.

In order to make the most of the course, it is recommended (but not required) to have some knowledge about convolution, filtering, signal sampling, discrete Fourier transform, analog-to-digital and digital-to-analog conversions.

2. SKILLS

Basic, Generic and Cross Curricular Skills.

This course contributes to acquire the following basic, generic and cross curricular skills:

en_CG4 - Ability to define, evaluate and select hardware and software platforms for the development and execution of computer systems, services and applications, in accordance with the knowledge acquired as set out in section 5, annex 2, of resolution BOE-A-2009 -12977.

en_CG9 - Ability to solve problems with initiative, decision making, autonomy and creativity. Ability to know how to communicate and transmit the knowledge, skills and abilities of the profession of Computer Engineering Engineer.

en_CB1 - That students have demonstrated to possess and understand knowledge in an area of study that is based on general secondary education, and is usually found at a level that, although supported by advanced textbooks, also includes some aspects that involve knowledge from the forefront of their field of study.

en_CB2 - That the students know how to apply their knowledge to their work or vocation in a professional manner and possess the competencies that are usually demonstrated through the elaboration and defense of arguments and the resolution of problems within their area of study.

en_CB3 - That students have the ability to gather and interpret relevant data (usually within their area of study) to make judgments that include a reflection on relevant social, scientific or ethical issues.

en_CB4 - That students can transmit information, ideas, problems and solutions to both a specialized and non-specialized public.

en_CB5 - That the students have developed those learning skills necessary to undertake further studies with a high degree of autonomy.

en_TRU1 - Capacity of analysis and synthesis.

en_TRU2 - Oral and written competencies.

en_TRU3 - Ability to manage information.

en_TRU4 - Autonomous learning skills.

en_TRU5 - Team work.

Specific Skills

This course contributes to acquire the following specific skills:

en_CC3 - Ability to evaluate the computational complexity of a problem, know algorithmic strategies that can lead to its resolution and recommend, develop and implement the one that guarantees the best performance according to the established requirements.

en_CC4 - Ability to know the fundamentals, paradigms and techniques of intelligent systems and analyze, design and build systems, services and computer applications that use these techniques in any field of application.

en_CIC1 - Ability to design and build digital systems, including computers, microprocessor-based systems and communications systems.

en_CIC7 - Ability to analyze, evaluate, select and configure hardware platforms for the development and execution of computer applications and services.

Learning Outcomes

When the students finish this course successfully, they will be able to:

LO1: To know and understand the mathematical techniques that underlie digital image processing.

LO2: Apply the knowledge to digital processing techniques to solving specific problems with images..

LO3: Implement a machine vision application using a standard programming language and libraries for image processing.

3. CONTENTS

Content blocks	Total number of hours
Introduction.	1h
Fundamentals of computer vision. • Introduction to computer vision. • Lighting systems. • Optics. • Cameras. • Image capture and geometry. • Radiometry. • Photometry. • Digitalization. • Introduction to Color.	5h (2h T + 3h L)

Basic techniques for image processing. • Spatial and frequential transformations. • Types of filters. • Geometric transformations on images. • Histogram. • Image enhancement. • Detecting edges and corners. • Morphological operators.	10h (4h T + 6h L)
Segmentation techniques. • Introduction to segmentation. • Fundamentals of segmentation techniques. • Region-based segmentation. • Edge-based segmentation. • Segmentation based on the histogram. • Segmentation based on probabilistic methods.	10h (4h T + 6h L)
Test 1	1h
Representation and image description. • Chain codes. • Signatures. • Basic descriptors. • Fourier descriptors. • Topological descriptors. • Moments. Invariant moments.	6h (2h T + 4h L)
Machine Learning techniques in Computer Vision. • Basic concepts of Machine Learning. • Region-based classifier (Neural Networks). • Euclidean distance classifier, Mahalanobis and K-NN. • Statistical classifier, Naïve/Normal Bayes. • Clustering by GMM-EM. • Decision trees. • SVM Classifier (Support Vector Machines).	8h (4h T + 4h L)
Camera Geometry. • Pinhole camera model. • Homogeneous coordinates. • 3D Euclidean transformation. • Euclidean transformation in homogeneous coordinates. • Projective transformation. • Perspective, affine and similarity projections. • Intrinsic and extrinsic parameters of a camera.	6h (3h T + 3h L)
Coursework	8h (L)

Examination (Presentation of the coursework + Test 2)	3h

4. TEACHING - LEARNING METHODOLOGIES. FORMATIVE ACTIVITIES.

4.1. Credits Distribution

Number of on-site hours:	58 hours (56 hours on-site +2 exams hours)
Number of hours of student work:	92
Total hours	150

4.2. Methodological strategies, teaching materials and resources

In the teaching and learning process, the following training activities will be undertaken:

- Theoretical Classes and example solving.
- Practical Classes: laboratory and exercise solving.
- Tutorials: individual and/or in groups.

The following complementary resources, among others, will also be available for use:

- Individual or group tasks: after completing a project, students can present it publically in front of the rest of their classmates in order to stimulate debate.
- Attendance at conferences, seminars or scientific discussions which are related to the module content.
- Watching videos about the content of this subject.

In the course of the year, both theoretical and practical activities and tasks will be proposed to the students. Different practical tasks will be undertaken at the same time as theoretical concepts are taught, so that students can experiment both individually and in groups, thus consolidating their knowledge of the concepts they have learned. *Gamification* concepts may be included in some practices, based on this potentially positive methodology to motivate students.

In order to complete these practical tasks, the students will have access to an area in the laboratory with a computer and the required software for digital image processing.

In the course of the module, the students must make use of different bibliographic resources, so that they familiarize with the type of documentation that they will use professionally in their future.

5. ASSESSMENT: procedures, evaluation and grading criteria

Preferably, students will be offered a continuous assessment model that has characteristics of formative assessment in a way that serves as feedback in the teaching-learning process.

5.1. PROCEDURES

The evaluation must be inspired by the criteria of continuous evaluation (Learning Assesment Guidelines, LAG, art 3). However, in compliance with the regulations of the University of Alcalá, an alternative process of final evaluation is made available to the student in accordance with the Learning Assesment Guidelines as indicated in Article 10, students will have a period of fifteen days from the start of the course to request in writing to the Director of the Polytechnic School their intention to take the non-continuous evaluation model adducing the reasons that they deem convenient. The evaluation of the learning process of all students who do not apply for it or are denied it will be done, by default, according to the continuous assessment model. The student has two calls to pass the subject, one ordinary and one extraordinary.

Ordinary Call

Continous Assessment:

The main assessment tools are the following:

1. **Assessment Tests** (TCB1 and TCB2), consisting of a set of questions covering the theoretical knowledge of the subject.
2. **Laboratory Practices** (PP.LL.). These practices cover the knowledge acquired in the theoretical part of the course and have guided content, with small sections that students must complete on their own.
3. **A coursework** (PF). Consisting of a program to solve a complete computer vision application, using all the knowledge acquired in the subject. A work report will be presented and an oral presentation will be made.

Assessment through final exam:

The main assessment tools are the following: one assessment test (TCB), laboratory practices (PP.LL.) and a coursework (PF).

Extraordinary Call

The procedure will be the same as that described for the assessment by means of a final exam in the ordinary call.

5.2. EVALUATION

EVALUATION CRITERIA

The assessment criteria measure the level in which the competences have been acquired by the student. For that purpose, the following are defined:

CE1. Students should be able to correctly solve mathematical problems related to computer vision.

CE2. Students have to integrate conceptual knowledge explained in the different theoretical classes to solve in a creative and original way the problems that could arise.

CE3. Students have to implement in practice digital image processing algorithms that provide solutions to the problems raised. It will be carried out by integrating the acquired knowledge about the operation of machine vision systems, using library resources and software tools at their availability.

CE4. Students should be able to make clear and accurate reports on the work done in the laboratory.

CE5. Students have to present and explain their proposals for resolving problems in a clear and reasonable way.

GRADING TOOLS

The work of the student is graded in terms of the assessment criteria above, through the following tools:

1. Ordinary call. Continuous assessment, with two assessment tests (TCB1,TCB2), laboratory practices (PP.LL.) and a coursework (PF).
2. Extraordinary call. One assessment test (TCB), laboratory practices (PP.LL.) and a coursework (PF).

GRADING CRITERIA

In the ordinary call-continuous assessment the relationship among the skills, learning outcomes, evaluation criteria and grading tools are as follows.

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Weight in the final grade
en_CC3, en_CC4, en_CG4, en_CG9, CIC7	LO1, LO2	CE1, CE2	TCB1	15%
			TCB2	15%
	LO1-LO3	CE1-CE4	PP.LL.	50%
CIC1, CG4, CG9	LO1-LO3	CE1-CE5	PF	20%

To consider the continuous assessment passed, (demonstrating the acquisition of competencies) students must meet the following conditions:

- Students must complete all laboratory practices (PP.LL.) and the two partial evaluation tests (TCB1 and TCB2).
- Students have proved capable of solving problems, by integrating the acquired knowledge about the functioning of the computer vision systems, using library resources and software tools at their disposal. Students have to present and explain their reports in a clear and reasonable way. It is understood that students have gained these skills if they get more than 4 out of 10 in the laboratory practices (PP.LL. and PF).
- Obtain a weighted overall score equal to or greater than 5 (out of 10) among all the continuous assessment instruments.

Within the continuous assessment model, students who do not participate in the evaluation process will be given an "**Absent Fail**" for the ordinary call. A student is considered not to have participated in the continuous evaluation process if they do not attend the two evaluation tests (TCB).

In the ordinary call-final evaluation, the relationship among the skills, learning outcomes, evaluation criteria and grading tools are as follows.

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Weight in the final grade
en_CC3, en_CC4, en_CG4, en_CG9, CIC7	LO1, LO2	CE1, CE2	TCB	30%
	LO1-LO3	CE1-CE4	PP.LL.	50%
CIC1, CG4, CG9	LO1-LO3	CE1-CE5	PF	20%

With this model, students must obtain at least five out of ten points on average among all the assessment tools.

Extraordinary call

1) According to the continuous assessment model: Students who, having participated in the process of continuous assessment do not get a final grade higher than 5 out of 10 in the ordinary call, may take the extraordinary session in July. This call will consist of three parts, each of which may be recognized if the student has already passed the equivalent part in the ordinary call:

- Assessment Test (**TCB**), consisting of a set of questions covering the theoretical knowledge of the subject.
- Laboratory Practices (**PP.LL.**). These practices cover the knowledge acquired in the theoretical part of the course and have guided content, with small sections that students must complete on their own.
- A coursework (**PF**). consisting of a program to solve a complete computer vision application, using all the knowledge acquired in the subject. A work report will be presented and an oral presentation will be made.

In this case, the relationship among the skills, learning outcomes, evaluation criteria and grading tools are the same as those in the ordinary call-final evaluation.

2) According to the final assessment model: The grading procedure and criteria with this type of assessment will be identical to the final assessment model of the ordinary examination session.

6. BIBLIOGRAPHY

6.1. Basic Bibliography

- Documentation specifically prepared by the subject's teaching staff, which will be supplied directly to the students, or will be published on the subject's webpage.

- Video-classes covering the theoretical knowledge of this subject.

- David A. Forsyth and Jean Ponce. ***Computer vision: A Modern Approach***. Prentice Hall. Pearson Education International.

- Richard Szeliski. ***Computer Vision: Algorithms and Applications*** Draft c 2010 Springer.

6.2. Additional Bibliography

Books:

- Rafael C. Gonzalez and Richard E. Woods. Digital Image Processing. Prentice Hall.
- William K. Pratt. Digital Image Processing. Wiley Interscience.
- Richard Hartley and Andrew Zisserman. Multiple View Geometry in Computer Vision. Cambridge University Press
- Linda G. Shapiro, George C. Stockman. Computer Vision. Prentice Hall.
- Oliver Faugeras and Quang-Tuan Loung. The geometry of multiple Images. The MIT press.
- Kenneth R. Castleman. Digital Image Processing. Prentice Hall.
- Dona H. Ballard and Christopher M. Brown. Computer Vision. Prentice Hall
- Oliver Faugeras. Three- Dimensional Computer Vision. A geometric View point. The MIT press.
- Andrew Balke and Alan Yuille. Active Vision, The MIT Press.
- Robert M. Haralick and Shapiro. Computer and Robot Visison (vol I y II).
- Robert Laganière. OpenCV 2 Computer Vision Application Programming Cookbook. PACKT Publising. 2011
- MATLAB Image Processing Toolbox. (http://www.mathworks.es/products/image)

Web pages:

- The computer vision home page (http://www.cs.cmu.edu/~cil/vision.html)
- IEEE Xplore (http://ieeexplore.ieee.org)

Disclosure Note

The University of Alcalá guarantees to its students that, if due to health requirements the competent authorities do not allow the total or partial attendance of the teaching activities, the teaching plans will achieve their objectives through a teaching-learning and evaluation methodology in online format, which will return to the face-to-face mode as soon as these impediments cease.