Universidad Zaragoza

Academic Year/course: 2022/23

69155 - Computational Imaging

Syllabus Information

Academic Year: 2022/23
Subject: 69155 - Computational Imaging
Faculty / School: 110 - Escuela de Ingeniería y Arquitectura
Degree: 615 - Master's in Robotics, Graphics and Computer Vision/ Robótica, Gráficos y Visión por Computador
ECTS: 6.0
Year: 1
Semester: Second semester
Subject Type: Compulsory
Module:

1. General information

1.1. Aims of the course

The course and its expected results respond to the following approaches and objectives:

With a strong applied character, upon successful completion of the module, each student should have achieved the following objectives:

- Multidisciplinary understanding of the scientific basis of the world of computer imaging and its industrial and scientific applications. Knowledge of its evolution, state-of-the-art and open problems.
- He/She will know how to transmit the knowledge acquired to an audience of any kind adapting himself to the peculiarities of that audience.
- He/She will be able to work both in an autonomous manner and in team, taking responsibilities.
- He/She will be able to carry out the projection, calculation and design of solutions to specific problems.
- He/She will be able to plan and work out R+D+I projects.
- He/She will know how to design hardware and software solutions.
- He/She will have knowledge of tools and methodologies.

These approaches and objectives are aligned with some of the Sustainable Development Goals, SDG, of the 2030 Agenda (https://www.un.org/sustainabledevelopment/es/) and certain specific goals, in such a way that the acquisition of the Learning outcomes of the subject provides training and competence to the student to contribute to a certain extent to their achievement:

- Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
    - Target 8.2 Achieve higher levels of economic productivity through diversification, technological modernization and innovation, including by focusing on high value-added and labor-intensive sectors
    - Target 8.3 Promote development-oriented policies that support productive activities, the creation of decent jobs, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro, small and medium-sized enterprises, including through access to financial services.
    - Target 8.6 By 2030, significantly reduce the proportion of young people who are not employed and do not study or receive training
- Objective 9: Industry, innovation and infrastructure
    - Target 9.5 Increase scientific research and improve the technological capacity of industrial sectors in all countries, particularly developing countries, including by fostering innovation and significantly increasing, by 2030, the number of people working in research and development

per million inhabitants and the spending of the public and private sectors in research and development

1.2. Context and importance of this course in the degree

The rationale for this course is to know the state-of-the-art in the field of computer Imaging, its industrial and scientific and technological applications as well as the open problems that exists nowadays.

1.3. Recommendations to take this course

There is no special requirement or recommendation to take this course.

2. Learning goals

2.1. Competences

BASIC AND GENERAL COMPETENCES:

- CB6 – To possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context.
- CB7 – Students are able to apply the knowledge acquired and their problem solving skills in new or unfamiliar environments with broader (or multidisciplinary) contexts related to their area of study.
- CB8 – Students are able to integrate knowledge and deal with the complexity of making judgements based on pieces of information which, while being incomplete or limited, includes reflections on social and ethical responsibilities linked to the application of their knowledge and judgement.
- CB9 – Students are able to communicate their conclusions and the underlying knowledge and ultimate reasons to specialist and non-specialist audiences in a clear and straightforward manner.
- CB10 – Students possess the learning skills to enable them to continue studying in a way which will be largely self-directed and autonomous.
- CG01 – Students will have acquired advanced knowledge and demonstrated, in a scientific and technological research or highly specialised context, a detailed and solid understanding of the theoretical and practical aspects and working methodology in the fields of Robotics, Graphics and/or Computer Vision, allowing them to be innovative in a context of research, development and innovation.
- CG02 - Ability to apply and integrate their knowledge and its understanding, their scientific basis and problem solving skills in new and undefined contexts, including highly specialised multidisciplinary research and professional contexts.
- CG03 – Ability to evaluate and select the appropriate scientific theory and precise methodology of their fields of study in order to make judges base don incomplete or limited information, including, when needed and relevant, a reflection on the social and ethical responsibility linked to the solution proposed in each case.
- CG04 – Ability to predict and control the evolution of complex situations by developing new, innovative working methodologies adapted to the specific, generally multidisciplinary, scientific/research, technological or professional scope in which the activity is being carried out.
- CG05 – Ability to transmit in English, orally and in writing, in a clear and straightforward manner, to both specialised and non-specialised audiences, results from scientific and technological research or from the most advanced innovation spheres, as well as the most relevant foundations in which they are based.
- CG06 - To have developed sufficient autonomy to take part in research projects and research or technological collaborations within his topic, in interdisciplinary contexts and, where appropriate, with a significant share of knowledge transfer.
- CG07 – Ability to take responsibility for one’s own professional development and specialisation in one or more fields of study.

- CG08 – To possess the aptitudes, skills and method necessary to carry out a multidisciplinary research and/or development work in the fields of Robotics, Graphics and/or Computer Vision.
- CG09 – Ability to use Engineering techniques, skills and tools necessary for problema solving in the fields of Robotics, Graphics and/or Computer Vision.
- CG10 – Ability to understand, relate to the estate-of-the-art and critically evaluate scientific Publications in the fields of Robotics, Graphics and/or Computer Vision..
- CG11 – Ability to manage and use bibliography, documents, databases, software and hardware specific to the fields of Robotics, Graphics and/or Computer Vision.
- CG12 – Ability to work in a multidisciplinary group and in a multilingual environment.

SPECIFIC COMPETENCES:

- CE01 – Ability to apply mathematical and artificial intelligence methods to model, design and develop Robotics, Graphics and/or Computer Vision systems and applications.
- CE02 – Ability to design and develop new methods and algorithms applicable to autonomous or virtual and augmented reality Systems..
- CE03 – Ability to understand light transport phenomena and apply them to the development of new computer imaging techniques.
- CE05 – Ability to devise, design and develop software, products and systems in the sphere of computer graphics.
- CE07 – Ability to develop and evaluate software for problems for Robotics, Graphics and/or Computer Vision, which may use general and/or specific purpose architectures
- CE09 – Ability to develop in an autonomous manner an initiation to research and/or development assignment in the field of robotics, Graphics or computer vision, in which the competences acquired in the degree are synthesized and integrated.
- CE13 – Ability to apply high performance computing systems or numerical or computational methods to Robotics, Graphics and/or Computer Vision problems.
- CE14 – Ability to apply mathematical methods, optics and high performance computing to model, design and develop computer imaging systems and applications.

2.2. Learning goals

The student must be able to:

1. Know the hardware elements involved in computer imaging systems.
2. Understand the main algorithms and techniques used in computer imaging..
3. Know the main applications of computer imaging.
4. Design and develop computer imaging systems for different applications.
5. Propose and evaluate the performance of new computer imaging techniques that address unsolved problems.

2.3. Importance of learning goals

Computer imaging is a field of great technological strength and a strong growth in its industrial applications of many different kinds. This course covers a very wide breadth of this topic, including:

a. the state-of-the-art in the field;

b. existing tools;

c. industrial and scientific applications;

d. open problems and relating possible future.

3. Assessment (1st and 2nd call)

3.1. Assessment tasks (description of tasks, marking system and assessment criteria)

Continuous evaluation

Evaluation system	Weight
E01 – Written/laboratory test (learning outcomes 1, 2, 3)	40%
E02 - Supervised assignments (learning outcomes 1, 2, 4, 5)	45%
E03 – Oral presentations and discussions (learning outcomes 1, 2, 3, 4, 5)	15%

Global evaluation

Students who do not opt for the evaluation procedure described above, does not pass such tests during the teaching period or wants to improve the mark/grade obtained, will be entitled to take a global evaluation that will have a weight of 100% of the course grade.

4. Methodology, learning tasks, syllabus and resources

4.1. Methodological overview

The learning process designed for this course is based on the following:

- Learning of concepts and techniques through master classes in which student participation will be encouraged.
- Personal study of the course by the student, and participation in the resolution of the exercises proposed in class.
- Accomplishment of practical assignments which develop the theoretical knowledge.

It should be noted that the course has both a theoretical and practical orientation

Teaching and learning activities are based on:

1. **Master class.** Exposition of contents by means of presentation or explanation by a lecturer (possibly including demonstrations).
2. **Practical classes**. Practical activities carried out with computers.
3. **Tutoring**. A period of instruction conducted by a tutor with the aim of reviewing and discussing the materials and topics presented in class.
4. **Evaluation**. Set of written, oral and practical tests, projects, assignments, etc. used in the evaluation of student progress.
5. **Tutorized assignments.** Projects which are larger than the practical classes, which will have to be orally presented.
6. **Theoretical study.** Self-study of the contents presented, including any study activity which has not be computed in the previous section (studying exams, library work, complementary reading, doing problems and exercises, etc.)

4.2. Learning tasks

Student work

The course consists of 6 ECTS credits that correspond to 150 estimated hours of student work, distributed as follows:

Learning activity	Nº Hours

A01 – Master class	30
A02 – Problem solving and cases	6
A03 – Laboratory sessions	12
A04 – Special practical sessions	0
A05 – Practical application or research works	31.8
A06 – Personalised teacher-student tutoring	0.2
A07 - Study	60
A08 – Evaluation tests	5

4.3. Syllabus

The course syllabus will include at least the following topics and its contents:

1. Introduction. Human and animal visual systems
2. Digital photography (camera pipeline, camera optics, ...)
3. Mathematical foundations (Fourier, compressed sensing, geometric optics matrix, ...)
4. Plenoptic imaging. Computational photography
5. High dynamic range imaging
6. Hyperspectral capture and polarization
7. 3D capture (focal stack/ light fields / panoramas)
8. Computational illumination and light transport capture
9. Transient imaging, non-line-of-sight imaging, multi-path interference
10. Computational displays

4.4. Course planning and calendar

Teaching organization is planned as:

- Master classes and problem solving and cases
- Practical sessions and assignments Prácticas y trabajos

Timetable of all lectures and dates of practical sessions will be announced well in advance on the center and course websites.

The calendar of lectures, practical sessions and presentations, as well as deadlines for practical papers and assignents will be announced well in advance.

4.5. Bibliography and recommended resources

1. Introduction to Fourier Optics, Joseph W. Goodman
2. Foundations of 3D Computer Graphics, by Steven Gortler.
3. Computer Vision: Algorithms and Applications, by Richard Szeliski. http://szeliski.org/Book/
4. Photography, by Barbara London and John Upton.
5. The computational approach to biological vision. Frisby, John and Stone, James. Seeing: 2nd Edition. MIT Press. 2010.