Academic Year/course: 2021/22

69153 - Modeling and Simulation of Appearance

Syllabus Information

Academic Year: 2021/22
Subject: 69153 - Modeling and Simulation of Appearance
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: First semester
Subject Type: Compulsory
Module:

1. General information

1.1. Aims of the course

The course targets computational techniques for simulating physically-based light transport, as well as modeling the appearance of the real world. The final goal is to be able to implement systems capable of generating photorealistic images. The course focuses on the physical and mathematical foundations of light transport and appearance, the definition of (virtual) appearance models, and the main computational techniques for generating synthetic imagery based on these physical models.

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

Computer graphics, and in particular the physical models defining real-world appearance are crucial for realistic synthetic images (with applications in entertaining, architecture, product design, or advertising). In addition, these physical models form the basis for computational photography, advanced image processing, or virtual and augmented reality (subsequent courses in the degree). Finally, forward appearance models are key to define inverse problems within computer vision and scene understanding.

1.3. Recommendations to take this course

Background on coding, and in particular on object oriented programming, is required. Previous knowledge on linear algebra and numerical calculus are also assumed.

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 - That students know how to apply the acquired knowledge and ability to solve problems in new or little-known settings within broader (or multidisciplinary) contexts related to their area of ??study.
- CB8 - That students are able to integrate knowledge and face the complexity of formulating judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
- CB9 - That students know how to communicate their conclusions and the latest knowledge and reasons that support them to specialized and non-specialized audiences in a clear and unambiguous way.
- CB10 - That students possess the learning skills that allow them to continue studying in a way that will have to be largely self-directed or autonomous.
- CG01 ? Acquisition of advanced and demonstrated knowledge, in a context of scientific and technological research or highly specialized, a detailed and well-founded understanding of the theoretical and practical aspects and of the 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, their understanding, their scientific foundation and their problem-solving abilities in new and imprecisely defined environments, including multidisciplinary contexts, as highly specialized researchers and professionals.
- CG03 - Ability to evaluate and select the appropriate scientific theory and the precise methodology of their fields of study to formulate judgments based on incomplete or limited information, including, when necessary and pertinent, considerations on social or ethical responsibility linked to the solution that is proposed in each case.
- CG04 - Ability to predict and control the evolution of complex situations by developing new and innovative work methodologies adapted to the specific scientific / research, technological or professional field, generally multidisciplinary, in which their activity is carried out.
- CG05 - Ability to transmit in English, orally and in writing, in a clear and unambiguous way, to a specialized audience or not, results from scientific and technological research or the most advanced field of innovation, as well as the most relevant foundations on which they are based.
- CG06 ? To have developed sufficient autonomy to participate in research projects and scientific or technological collaborations within their subject area, in interdisciplinary contexts and, where appropriate, with a high component of knowledge transfer.
- CG07 - Ability to take responsibility for your own professional development and specialization in one or more fields of study.
- CG08 ? To possess the aptitudes, skills and method necessary to carry out multidisciplinary research and / or development work in the fields of Robotics, Graphics and / or Computer Vision.
- CG09 - Ability to use the techniques, skills and tools of Engineering necessary for solving problems of the Robotics, Graphics and / or Computer Vision fields.
- CG10 - Ability to understand, relate to the state 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, documentation, 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.
- **CE03 -** Ability to understand light transport phenomena and apply them to the development of new computational imaging techniques.
- **CE05 -** Ability to conceive, design and develop software, products and systems in the field of Computer Graphics.
- **CE09 -** Ability to autonomously carry out a work of initiation to research and / or development in the field of Robotics, Graphics, or Computer Vision, in which the skills acquired in the degree are synthesized and integrated.
- **CE13 -** Ability to apply high performance computer systems or numerical or computational methods to Robotics, Graphics or Computer Vision problems.

2.2. Learning goals

The student must be able to:

- Understand the different types of physical processes of light transport.
- Understand the models that define the appearance and transport of light in media and surfaces.
- Understand, analyze and explain computational techniques to solve the models of appearance and light transport.
- Design and develop rendering systems based on Monte Carlo integration.
- Design and implement algorithms that solve material appearance models.
- Analyze the limitations and evaluate the benefits of different rendering algorithms.

2.3. Importance of learning goals

Within the field of Computer Graphics, the ability to model and simulate light transport is the basis for generating photorealistic synthetic images. This is critical in multiple applications, including entertainment, architecture, industrial design, advertising, computational manufacturing, and most recently in machine learning and computer vision techniques. Likewise, the physical models learned in the subject have application in other scientific-technical disciplines, including remote sensing, atmospheric sciences or medical imaging. This discipline is complex, it is the result of the combination of high performance computing, applied mathematics, and computational physics.

3. Assessment (1st and 2nd call)

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

Supervised work and final project (70%): A set of guided practices will be carried out throughout the course, with a total value of 20% of the grade, as well as a final project related to the theme of the subject, which will be 50 % of the final grade.

Presentations (20%): There will be a series of presentations, followed by turns of questions, throughout the course, focused on various related topics. Participation in the discussion of the round of questions will be positively valued.

Exam (10%): There will be an exam at the end of the course, in order to assess the theoretical knowledge acquired throughout the course.

To pass the course, there is a requirement of a 4/10 minimum in each part of the course, and a weighted average grade greater than 5/10. In the event that one of the parts does not pass the 4/10 mark, the grade will be the maximum between 4/10 and the weighted average.

In case of renouncing to continuous evaluation, the students will have to deliver at the end of the course the directed works and the final project (80%) and they will be subject to an exam for the remaining 20%.

4. Methodology, learning tasks, syllabus and resources

4.1. Methodological overview

The methodology is geared towards achieving the learning outcomes and skills described above. The teaching-learning process will be carried out through multiple activities: master classes and expert talks (oral presentations of content), problem solving classes (examples and practical cases with active participation of students), laboratory sessions (in small groups, with simulation tools or real systems) and the development of practical assignments and study work supervised by the faculty.

More details regarding the development of the subject will be specified on the first day of class.

4.2. Learning tasks

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

- Theoretical classes: The theoretical concepts of the subject will be explained and illustrative practical examples will be developed to support the theory when necessary. (30h)
- Practical classes: Problems and practical cases will be carried out as a complement to the theoretical concepts studied. (12h)
- Laboratory practices: There will be a series of guided work tutored by the teacher. (6h)
- Study and assimilation of the theory exposed in the master classes. (30h)
- Practical application or research work (60h).
- Personalized teacher-student tutoring (7h)
- Assessment tests (5h).

4.3. Syllabus

The program is designed to cover the necessary background for understanding modern rendering, including physical and mathematical background. In addition, it will cover most recent trends on rendering, both in industry and academia. In particular, it is roughly articulated as:

1. The physics of light transport
2. Ray tracing
3. Appearance models
4. Monte Carlo methods
5. Direct and global illumination
6. Light transport in participating media
7. Bidirectional methods
8. Denoising, distributed effects and post-processing
9. Production rendering
10. Differentiable rendering and inverse problems

4.4. Course planning and calendar

The calendar of the course will be defined by the the academic calendar. The detailed calendar of activities will be available in Moodle, and will be presented on the first day of class.

4.5. Bibliography and recommended resources

- Eric Veach. Robust Monte Carlo Methods for Light Transport Simulation. PhD Thesis, Stanford, 1997. - Libre distribución: https://graphics.stanford.edu/papers/veach_thesis/
- Matt Pharr, Wenzel Jakob, and Greg Humphreys. Physically Based Rendering: From Theory To Implementation.