Course guide
270671 - A3DM - Advanced 3D Modeling

Last modified: 04/02/2025

Unit in charge: Barcelona School of Informatics
Teaching unit: 723 - CS - Department of Computer Science.

Degree: MASTER'S DEGREE IN INNOVATION AND RESEARCH IN INFORMATICS (Syllabus 2012). (Optional subject).

Academic year: 2024 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: CARLOS ANTONIO ANDUJAR GRAN

Others: Segon quadrimestre:
CARLOS ANTONIO ANDUJAR GRAN - 10
ALVARO VINACUA PLA - 10

PRIOR SKILLS

The course requires a basic linear algebra and 2D/3D geometry background.

Background on Computer Graphics (rendering pipeline, shaders, OpenGL) is strongly recommended.

Lab exercises will be implemented in Python and C++ languages, so students should have at least C/C++ programming skills.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEE1.1. Capability to understand and know how to apply current and future technologies for the design and evaluation of interactive graphic applications in three dimensions, either when priorizing image quality or when priorizing interactivity and speed, and to understand the associated commitments and the reasons that cause them.

Generical:
CG1. Capability to apply the scientific method to study and analyse of phenomena and systems in any area of Computer Science, and in the conception, design and implementation of innovative and original solutions.

Transversal:
CTR5. APPROPIATE ATTITUDE TOWARDS WORK: Capability to be motivated by professional achievement and to face new challenges, to have a broad vision of the possibilities of a career in the field of informatics engineering. Capability to be motivated by quality and continuous improvement, and to act strictly on professional development. Capability to adapt to technological or organizational changes. Capacity for working in absence of information and/or with time and/or resources constraints.
CTR6. REASONING: Capacity for critical, logical and mathematical reasoning. Capability to solve problems in their area of study. Capacity for abstraction: the capability to create and use models that reflect real situations. Capability to design and implement simple experiments, and analyze and interpret their results. Capacity for analysis, synthesis and evaluation.

TEACHING METHODOLOGY

The teaching methodology will be based based on weekly theory classes and lab classes. Course concepts will be introduced in the theory classes. Exercises will be used to consolidate these concepts, which will be further developed in the lab sessions.

The lab sessions basically involve the teacher presenting the guidelines for the practical work (split by sessions) and the concepts bearing on the software to be used. Students will complete the design and programming of the various applications bearing on the course contents. The exercises will be carried out individually.

LEARNING OBJECTIVES OF THE SUBJECT

1.Understand the foundations of geometric modeling systems
2.Understand and being able to implement the most relevant representation schemes for solids.
3.Understand the details of the Boundary Representation: main features, implementation, and basic queries/algorithms operating on BReps.
4.Understand the details of Space Decomposition Models (voxelizations, octrees). : main features, implementation, and basic queries/algorithms operating on these models.
5.Understand the details of Constructive Solid Modeling: main features, implementation, and basic queries/algorithms operating on CSGs
6.Being able to implement scripts (Python) and programs (C++) solving geometric modeling problems on different representation schemes for solids.
7.Understand Procedural Modeling techniques, including Fractals, L-systems and CGA grammars.
8.Understand implicit modeling techniques: scalar fields, surface extraction algorithms, metaballs and associated algorithms.

STUDY LOAD

Type	Hours	Percentage
Hours large group	40,8	27.20
Hours small group	13,2	8.80
Self study	96,0	64.00

Total learning time: 150 h

CONTENTS

Foundations of 3D modeling

Description:
Elements of a geometric modeling system. Solid models. Closed, bounded and regular sets of points. Two-manifold surfaces. Abstraction levels in geometric modeling.

Boundary representation (BRep)

Description:
Polyhedra. Cells, shells, faces, loops, edges and vertices. Genus of a surface. Euler equation for polyhedra. Incidence relationships. Creation of BRep models. Sweep. Boolean operations. Curves and Surfaces for Geometric Modeling

Subdivision surfaces

Description:
Subdivision surfaces. Interpolation and approximation. Update rule. Classification. Catmull-Clark subdivision.

CSG models

Description:
Constructive Solid Geometry. CSG trees. Basic operations. Point-inside-CSG test.

Space decomposition models

Description:
Voxelizations. Octrees. Classic, Face and Extended octrees. Octree representation. Basic operations on octrees.

Implicit modeling

Description:
Scalar fields. Surface reconstruction from scalar fields. Blobby molecules, metaballs and soft objects.

Data structures for triangle meshes

Description:
Euler equation for triangle meshes. Face-based, Vertex-based and edge-based representations. The half-edge data structure. APIs for geometry processing.

Geometric tests and queries

Description:
Estimating normal and tangent planes at vertices of polygonal meshes. Discrete curvature at mesh vertices. Mesh quality. Non-selfintersection test.

Procedural modeling

Description:
Fractals. Lindenmayer systems (L-systems). Stochastic and parametric grammars. Shape grammars. Generative modeling.

Geometry acquisition

Description:
Pipeline for the acquisition of 3D models. Technologies. Registration and merge.

ACTIVITIES

Lectures

Description:
Material will be presented in lectures along the term. You are expected to conduct complementary readings and exercises will also be assigned on occasion, to be presented at a later date or turned in.

Specific objectives:
1, 2, 3, 4, 5, 7, 8

Related competencies :
CEE1.1. Capability to understand and know how to apply current and future technologies for the design and evaluation of interactive graphic applications in three dimensions, either when priorizing image quality or when priorizing interactivity and speed, and to understand the associated commitments and the reasons that cause them.
CG1. Capability to apply the scientific method to study and analyse of phenomena and systems in any area of Computer Science, and in the conception, design and implementation of innovative and original solutions.
CTR6. REASONING: Capacity for critical, logical and mathematical reasoning. Capability to solve problems in their area of study. Capacity for abstraction: the capability to create and use models that reflect real situations. Capability to design and implement simple experiments, and analyze and interpret their results. Capacity for analysis, synthesis and evaluation.
CTR5. APPROPIATE ATTITUDE TOWARDS WORK: Capability to be motivated by professional achievement and to face new challenges, to have a broad vision of the possibilities of a career in the field of informatics engineering. Capability to be motivated by quality and continuous improvement, and to act strictly on professional development. Capability to adapt to technological or organizational changes. Capacity for working in absence of information and/or with time and/or resources constraints.

Full-or-part-time: 63h
Self study: 40h
Theory classes: 23h

Implementation of selected algorithms

Description:
A selection of relevant algorithms will be assigned to implement in Lab sessions and on your own. You may be required to present your solution to the class. You must turn in fully functional source code that runs in the indicated platform. Usual languages are C++ and Python.

Specific objectives:
1, 2, 3, 4, 5, 6, 7, 8

Related competencies :
CEE1.1. Capability to understand and know how to apply current and future technologies for the design and evaluation of interactive graphic applications in three dimensions, either when priorizing image quality or when priorizing interactivity and speed, and to understand the associated commitments and the reasons that cause them.
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Full-or-part-time: 83h
Self study: 56h
Laboratory classes: 27h

Final exam

Description:
At the end of the term you will have a final exam, which may be a take-home.

Full-or-part-time: 2h
Guided activities: 2h

Partial exam

Description:
At the middle of the term you will have a partial exam, which may be a take-home.

Full-or-part-time: 2h
Guided activities: 2h

GRADING SYSTEM

Partial: mark based on the student's performance in the partial exam

Exam: mark based on the student's performance in the final exam

Lab: grade stem from the student's implementations of selected algorithms (including occasionally their presentation of their solution in a laboratory class)

The final grade for the course will be computed as:

Final Grade = 0.4 Exam + 0.3 Partial + 0.3 Lab

BIBLIOGRAPHY

Basic:
- Agoston, M.K. Computer graphics and geometric modeling. New York: Springer, 2004. ISBN 1852338180.

Complementary:
- Botsch, M. [et al.]. Polygon mesh processing. Natick, Mass.: A K Peters, 2010. ISBN 9781568814261.