Course guide
295909 - GD - Geometry for Design

Last modified: 27/05/2024

Unit in charge: Barcelona East School of Engineering
Teaching unit: 749 - MAT - Department of Mathematics.

Degree: **Academic year:** 2024 **ECTS Credits:** 6.0
Languages: Catalan

LECTURER

Coordinating lecturer: Claverol Aguas, Mercè

Others: Claverol Aguas, Mercè

PRIOR SKILLS

Knowledge of basic techniques of calculus (in one and several variables) and algebra to operate with vectors and matrices.

REQUIREMENTS

Pre-requirements: Calculus (CAL) and Algebra and Multivariate Calculus (ACM).

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEB-01. Solve mathematical problems that may arise in engineering. Apply knowledge of linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and partial differential equations; numerical methods; numerical algorithms; statistics and optimisation.
CEB-05. Understand spatial vision and graphic representation techniques, whether using traditional metric and descriptive geometry methods or computer assisted design applications.
CEMEC-19. Understand and apply graphic engineering techniques.

Generical:
CG-03. (ENG) Conocimiento en materias básicas y tecnológicas, que les capacite para el aprendizaje de nuevos métodos y teorías y les dote de versatilidad para adaptarse a nuevas situaciones.

Transversal:
07 AAT N1. SELF-DIRECTED LEARNING - Level 1. Completing set tasks within established deadlines. Working with recommended information sources according to the guidelines set by lecturers.
07 AAT N2. SELF-DIRECTED LEARNING - Level 2: Completing set tasks based on the guidelines set by lecturers. Devoting the time needed to complete each task, including personal contributions and expanding on the recommended information sources.

TEACHING METHODOLOGY

In theory and problem classes, the teacher will use an expository methodology with illustrative examples. It will also guide students in the resolution of related exercises.
In the laboratory classes will be made graphic practices to deepen the concepts and techniques presented in the theoretical classes.

LEARNING OBJECTIVES OF THE SUBJECT

To know how to use coordinate systems changes to solve geometric problems.
To be able to construct orthonormal basis for geometric construction and parameteriztion of curves and surfaces.
To know the most used curves and surfaces in geometry, amb to know methods for generation of surfaces.
To become acquainted with affine geometric transforms in the plane, and how to use them.
To know and to be able to use affine geometric transforms in the space.
To know and to be able to design the most used curves in computer aided graphic design: Bézier curves, B-splines, rational Bézier curves and NURBS.
To know basic concepts of differential geometry of curves: curvature, torsion, osculating circle, Frenet trihedral, offset curves.
To know basic concepts of differential geometry of surfaces: tangent plane, normal vector, Dupin indicatrix.
To know how to deal with the problem of geometric continuity in curves and Bézier surfaces.
To know basic structures of computational geometry: Voronoi diagrams and Delaunay triangulations.

STUDY LOAD

Type	Hours	Percentage
Hours small group	30,0	20.00
Self study	90,0	60.00
Hours large group	30,0	20.00

Total learning time: 150 h

CONTENTS

Introduction: Rendering of basic geometric elements

Description:
Basic geometric element representation: points, vectors, matrices, lists, sequences, curves and surfaces. Description of bidimensional and three-dimensional curves: explicit, implicit and parametric form. Description of surfaces: explicit, implicit and parametric form.

Related activities:
Practice 1, Test 1

Full-or-part-time: 2h
Theory classes: 2h

Affine geometry. Barycentric coordinates

Description:
Description of affine geometry. Combinations of points and convex hull. Barycentric coordinates. Ratio of aligned points.

Related activities:
Practice 2, Test 1

Full-or-part-time: 2h
Theory classes: 2h

Plane Affine Geometric Transforms

Description:
Plane translations. Affine transformations in the plane. Matrix expression of affine transformations. Geometric construction problems solved with geometric affine transformations in the plane. Scalings in the plane. Plane rotations. Reflections about a point in the plane. Reflections to a line in the plane.

Specific objectives:
Practice 3, Test 1

Full-or-part-time: 2h
Theory classes: 2h

Three-dimensional Affine Geometric Transforms

Description:
Translations in space. Affine transformations of space. Matrix expression of an affine transformation of space. Affine geometric transforms to solve geometric problems in three-dimensional space. Three-dimensional scaling. Rotations in space: rotations about the coordinate axes, rotations about an arbitrary line. Reflections about a point. Reflections about a line. Reflections in an arbitrary plane.

Specific objectives:
Practice 3, Test 1

Full-or-part-time: 2h
Theory classes: 2h

Euclidean geometry. Metric Problems

Description:
Dot product and cross product. Orthonormal basis. Changes between orthonormal basis. Changes between rectangular cartesian coordinates. Construction of orthonormal basis. Application to contructions of curves and surfaces in general position. Orthogonal projection.

Related activities:
Practice 4. Test 1

Full-or-part-time: 2h
Theory classes: 2h

Bézier and B-splines curves

Description:
Bézier curves: definition, De Casteljau's Algorithm, properties, operations and geometric continuity. B-splines curves.

Related activities:
Practices 5 and 8. Test 1

Full-or-part-time: 5h
Theory classes: 5h

Differential geometry of curves

Description:
Regular parametritzacions. The Frenet trihedron. Curvature and torsion. Osculating Circle. Evolute. Offset Curve.

Related activities:
Practice 6, Test 2

Full-or-part-time: 4h
Theory classes: 4h

Rational Curves, NURBS

Description:
Projections. Conics. Rational Bézier curves. NURBS (Non-uniform rational basis spline).

Related activities:
Practices 7 and 8. Test 2

Full-or-part-time: 5h
Theory classes: 5h

Differential geometry of surfaces

Description:
Tangent plane. Normal curvatures, Dupin's indicatrix. Gaussian curvature and median curvature. Types of surfaces: minimal, ruled, of revolution, tabulated, offset. Bézier surfaces.

Related activities:
Practice 9, Test 2

Full-or-part-time: 4h
Theory classes: 4h

Computational Geometry: Voronoi diagrams and Delaunay triangulations

Description:
Introduction to basic structures in computational geometry with applications in engineering and design:
Voronoi diagram and Delaunay triangulation. Farthest Voronoi diagram. Higher-order Voronoi diagrams.

Related activities:
Practice 10, Test 2

Full-or-part-time: 2h
Theory classes: 2h

GRADING SYSTEM

The Grade is calculated through continuous assessment through the presentation of exercises, laboratory tasks and a realization of two tests.
Exercises: 30%, Laboratory tasks: 50%, Test: 20%

BIBLIOGRAPHY

Basic:
- Trias Pairó, Joan. Geometria per a la informàtica gràfica i CAD [on line]. Barcelona: Edicions UPC, 1999 [Consultation: 26/05/2020]. Available on: http://hdl.handle.net/2099.3/36243. ISBN 8483013541.
- Tortosa Grau, Leandro; Vicent Francés, José. Geometría moderna para ingeniería. Alicante: Editorial Club universitario, 2012. ISBN 9788499487083.
- Lengyel, Eric; Smith, Emi. Mathematics for 3D game programming and computer graphics [on line]. 3a ed. Boston: Cengage Learning, 2012 [Consultation: 26/05/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=3136454. ISBN 9781435458871.
- Farin, Gerald E; Hansford, Dianne. Practical linear algebra : a geometry toolbox. 3a ed. Boca Raton: CRC Press, Taylor & Francis, 2014. ISBN 9781466579569.
- Cordero Valle, Juan Manuel; Cortes Parejo, José. Curvas y superficies para modelado geométrico. Madrid: Ra-ma, cop. 2002. ISBN 8478975314.
- Piegl, Les; Tiller, Wayne. The NURBS book. 2nd ed. Berlin [etc]: Springer, 1997. ISBN 3540615458.

Complementary:
- Selig, J. M. Introductory robotics. New York, NY [etc.]: Prentice Hall, 1992. ISBN 0134888758.

RESOURCES

Other resources:
http://3d-xplormath.org/j/applets/en/index
http://www.mathcurve.com/courbes3d/courbes3d.shtml />http://www-history.mcs.st-andrews.ac.uk/Curves/Curves