COMILLAS
UNIVERSIDAD PONTIFICIA
ICAI ICADE CIHS

COURSE SYLLABUS
2020-2021

GENERAL INFORMATION

Course information	
Name	Digital Manufacturing
Code	DIM-MIC-524
Degree	Máster Universitario en Ingeniería Industrial + Máster en Industria Conectada [2nd year]
Semester	2nd (Spring)
ECTS credits	3.0
Type	Compulsory
Department	Mechanical Engineering
Coordinator	Mariano Jiménez Calzado

Instructor	
Name	Silvia Fernández Villamarín
Department	Mechanical Engineering
Area	Design and Manufacturing
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DETAILED INFORMATION

Contextualization of the course

Contribution to the professional profile of the degree

Digital Manufacturing (DM) is the fastest and easiest way to transform a concept into a reality. DM belongs to a much larger trend known as the Fourth Industrial Revolution, which combines CAD design, digital manufacturing, robotics, sensors & data and analytics to redefine industrial production.

Consumption is changing and production with it. Traditional manufacturing does not satisfy the needs of today's consumers. DM enables perpetual feedback, from every actor, at every step, because small production runs fast and inexpensive, products continuously evolve and adapt. Loyalty of clients demands an adaptative product. DM helps go faster, invest less money and reduce the cost of trial and error: fast production, high performing prototypes, real-time inventory monitoring, cost reduction, close-to-reality testing, market success predictability…

This subject concentrates on providing the fundamental theoretical and practical knowledge to understand the additive manufacturing concept, a range of technologies that are capable of joining materials to make objects from 3D model data, usually layer upon layer, in a quick and easy process. The additive, freeform nature of the technology, coupled with improvements in materials, processing speed, accuracy and surface finish, open up an array of manufacturing options that before were impossible with conventional technologies.

An overview of conception and development of products will be provided while special focus will be put on computer aided design for additive manufacturing, validation and optimization of printable models using simulation, and finally on the scope and connection between reverse engineering and additive manufacturing processes.

At the end of the season, students will be able to transform product ideas into viable products: hand sketching; fundamental engineering design principles and procedures; design, analysis and optimization of parts using CADCAMCAE technologies; implementation of additive manufacturing; and reverse engineering complete processes.

Prerequisites

Fundamentals of engineering drawing and basic 3D modeling.

CONTENTS

Contents
Theory
Unit 1. Conception and development of products
Design processes and methods. CAD/CAM/CAE technologies and product lifecycle management (PLM). Concepts generation and embodiment. Expression of product design ideas using 2D sketches.
Unit 2. Computer Aided Design (CAD)
3D modeling. Parametric design. Assembly modeling. Render the appearance of a product. CAD and additive manufacturing.
Unit 3. Computer Aided Engineering (CAE)
Finite Element Analysis (FEA) to validate functional performance: general stages of the process, solid and FEA models, materials definition, loading (loads, displacements constraints…), post-processing, results and verifications. Topology optimization in additive manufacturing.
Unit 4. Reverse engineering
General methodology: point clouds, meshes (.stl), NURBS surface models and parametric CAD models. Digitizing methods and main technologies: applications and selection of reverse engineering systems. Hardware and software involved. Reverse engineering and additive manufacturing.
Unit 5. Additive manufacturing
General methodology, stages and components of the process. Main technologies, principles and applications. Strengths, weaknesses, challenges, and limitations of additive manufacturing technologies. Main brands and suppliers available. Design for Additive Manufacturing (DFAM). Design for functionality and 3D printability. Planning and slicing additive manufacturing software.
Laboratory
Each theoretical unit has at least one associated lab practice (2 hours). 1. 2D sketching of product design ideas. 2. 3D modelling and assembling. 3. 3D rendering products. 4. Optimization of parts and assemblies. 5. Use of 3D digitalization scanners. 6. Use of point clouds/meshes editing software. 7. Preparation of 3D CAD models and use of planning/slicing additive manufacturing software. 8. Use of FDM, SLA, DLP and SLS machines to produce 3D physical models.

Competences and learning outcomes

Competences[1]

General competences

CG1.	Have acquired advanced knowledge and demonstrated, in a research and technological or highly specialized context, a detailed and well-founded understanding of the theoretical and practical aspects, as well as of the work methodology in one or more fields of study. *Haber adquirido conocimientos avanzados y demostrado, en un contexto de investigación científica y tecnológica o altamente especializado, una comprensión detallada y fundamentada de los aspectos teóricos y prácticos y de la metodología de trabajo en uno o más campos de estudio.*
CG2.	Know how to apply and integrate their knowledge, understanding, scientific rationale, and problem-solving skills to new and imprecisely defined environments, including highly specialized multidisciplinary research and professional contexts. *Saber aplicar e integrar sus conocimientos, la comprensión de estos, su fundamentación científica y sus capacidades de resolución de problemas en entornos nuevos y definidos de forma imprecisa, incluyendo contextos de carácter multidisciplinar tanto investigadores como profesionales altamente especializados.*
CG5.	Be able to transmit in a clear and unambiguous manner, to specialist and non-specialist audiences, results from scientific and technological research or state-of-the-art innovation, as well as the most relevant foundations that support them. *Saber transmitir de un modo claro y sin ambigüedades, a un público especializado o no, resultados procedentes de la investigación científica y tecnológica o del ámbito de la innovación más avanzada, así como los fundamentos más relevantes sobre los que se sustentan.*
CG6.	Have developed sufficient autonomy to participate in research projects and scientific or technological collaborations within their thematic area, in interdisciplinary contexts and, where appropriate, with a high knowledge transfer component. *Haber desarrollado la autonomía suficiente para participar en proyectos de investigación y colaboraciones científicas o tecnológicas dentro de su ámbito temático, en contextos interdisciplinares y, en su caso, con una alta componente de transferencia del conocimiento.*
CG7.	Being able to take responsibility for their own professional development and their specialization in one or more fields of study. *Ser capaces de asumir la responsabilidad de su propio desarrollo profesional y de su especialización en uno o más campos de estudio.*

Specific competences

CE7.	Know the new manufacturing technologies, as well as its potential industrial application. *Conocer las nuevas tecnologías de fabricación, así como su potencial de aplicación en la industria.*

[1] Competences in English are a free translation of the official Spanish version.

Learning outcomes

By the end of the course students should be familiar with:

RA1. Design processes and methods.

RA2. CAD/CAM/CAE technologies and product lifecycle management (PLM).

RA3. Concepts generation and embodiment.

RA4. Expression of product design ideas using 2D sketches.

RA5. 3D modeling, parametric design and assembly modeling.

RA6. Rendering the appearance of a product.

RA7. CAD and additive manufacturing.

RA8. Finite Element Analysis (FEA) to validate functional performance.

RA9. General stages of the process, solid and FEA models, materials definition, loading (loads, displacements constraints…), post-processing, results and verifications.

RA10. Topology optimization in additive manufacturing.

RA11. General methodology: point clouds, meshes (.stl), NURBS surface models and parametric CAD models.

RA12. Digitizing methods and main technologies: applications and selection of reverse engineering systems.

RA13. Hardware and software involved in reverse engineering processes.

RA14. The relationship between reverse engineering and additive manufacturing.

RA15. General methodology, stages and components of the additive manufacturing process.

RA16. Main additive manufacturing technologies, principles and applications.

RA17. Strengths, weaknesses, challenges and limitations of additive manufacturing technologies.

RA18. Main additive manufacturing brands and suppliers available.

RA19. Design for Additive Manufacturing (DFAM).

RA20. Design for functionality and 3D printability.

RA21. Planning and slicing additive manufacturing software.

TEACHING METHODOLOGY

General methodological aspects	
Inspired by the "learn by doing" paradigm, this course is designed to provide students with the tools they require to develop digital-additive manufacturing process by the end of the term. In every unit, after the initial explanation of each concept, the instructor will propose individual or group activities (some of which will be graded) to test students' understanding.	
In-class activities	**Competences**
▪ **Lectures:** The lecturer will introduce the fundamental concepts of each unit, along with some practical recommendations, and will go through worked examples to support the explanation.	CG1, CG7, CE7
▪ **Lab sessions:** Under the instructor's supervision, students will apply the concepts and techniques covered in the lectures using computer software, machines and equipment. Students will later analyze and report lab results.	CG1, CG2, CG5, CG6, CG7, CE7
▪ **Tutoring** for groups or individual students will be organized upon request.	–
Out-of-class activities	**Competences**
▪ Personal study of the course material and resolution of the proposed exercises.	CG1, CG7, CE7
▪ Lab session preparation.	CG1
▪ Lab results analysis and report writing.	CG2, CG5, CE7
▪ Final project.	CG1, CG2, CG5, CG6, CG7, CE7

ASSESSMENT AND GRADING CRITERIA

Assessment activities	Grading criteria	Weight
Homework	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem-solving. ▪ Critical analysis of numerical exercises' results.	10%
Lab reports	▪ Application of theoretical concepts to real problem-solving. ▪ Ability to use and develop robotics software. ▪ Written communication skills.	30%
Final project	▪ Problem analysis. ▪ Quality of the proposed solution. ▪ Teamwork.	10%
End-of-term exam	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem-solving. ▪ Critical analysis of numerical exercises' results.	50%

GRADING AND COURSE RULES

Grading
Regular assessment
▪ Lab reports (including practical and theoretical sessions): 30% ▪ Homework: 10% ▪ Final project: 10% ▪ End-of-term exam (paper + computer): 50% In order to pass the course, the weighted average mark must be greater or equal to 5 out of 10 points.
Retake
▪ Lab reports (including practical and theoretical sessions): 30% ▪ Retake exam (paper + computer): 70% As in the regular assessment period, in order to pass the course, the weighted average mark must be greater or equal to 5 out of 10 points.
Course rules
▪ Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Académicas) of the ICAI School of Engineering. Not complying with this requirement may have the following consequences: - Students who fail to attend more than 15% of the lectures may be denied the right to take the final exam during the regular assessment period. ▪ Students who commit an irregularity in any graded activity will receive a mark of zero in the activity and disciplinary procedure will follow (cf. Article 168 of the General Regulations (Reglamento General) of Comillas Pontifical University).

WORK PLAN AND SCHEDULE[2]

In and out-of-class activities	Date/Periodicity	Deadline
Final exam	After the lecture period	–
Lab sessions	Weeks 1 to 6	–
Review and self-study of the concepts covered in the lectures	After each lesson	–
Lab preparation	Before every lab session	–
Lab report writing	During every lab session	At the end of every lab session
Final project	From week 4	Last week

[2] A detailed work plan of the subject can be found in the course summary sheet (see last page). Nevertheless, this schedule is tentative and may vary to accommodate the rhythm of the class.

STUDENT WORK-TIME SUMMARY			
IN-CLASS HOURS			
Lectures		Lab sessions and problems solving	
10		20	
OUT-OF-CLASS HOURS			
Self-study	Lab preparation	Homework	Final project
25	5	20	10
		ECTS credits:	3 (90 hours)

BIBLIOGRAPHY

Basic bibliography

- Slides prepared by the lecturer (available in Moodlerooms).
- K. T. Ulrich and S. D. Eppinger, *Product Design and Development*, 6th Ed., McGraw-Hill Education, 2015. ISBN-13: 978-0-078-02906-6
- Parametric Technology Corporation (PTC), *Simulation using Creo Parametric user guides*.
- V. Raja and K. J. Fernandes (eds.), *Reverse Engineering. An Industrial Perspective*, 1st Ed., Springer-Verlag London, 2008. ISBN-13: 978-1-849-96660-3
- N. Hopkinson, R. J. M. Hague and P. M. Dickens (eds.), *Rapid Manufacturing: An Industrial Revolution for the Digital Age*, 1st Ed., John Wiley & Sons, 2005. ISBN-13: 978-0-470-01613-8

Complementary bibliography

- K. Otto and K. Wood, *Product Design: Techniques in Reverse Engineering and New Product Development*, 1st Ed., Prentice Hall, 2000. ISBN-13: 978-0-130-21271-9
- Z. Zhou, S. Xie, and D. Chen, *Fundamentals of Digital Manufacturing Science*, 1st Ed., Springer-Verlag London, 2012. ISBN-13: 978-1-447-12714-7
- I. Gibson, D. W. Rosen, and B. Stucker, *Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing*. Springer-Verlag Boston, 2010. ISBN-13: 978-1-441-91119-3
- C. K. Chua, K. F. Leong, and C. S. Lim, *Rapid Prototyping: Principles and Applications*, 3rd Ed., World Scientific, 2010. ISBN-13: 978-9-812-77898-7

Week	Time [h]	Lecture
1	2	Unit 1 (I)
	2	Unit 1 (II)
2	2	Unit 1 (III)
	2	Unit 1 (IV)
3	2	Unit 2 (I)
	2	Unit 2 (II)
4	2	Unit 2 (III)
	2	Unit 2 (IV)
5	2	Unit 2 (V)
	2	Final Project – Design Case
6	2	Unit 3 (I)
	2	Unit 4 (I)
7	2	Unit 4 (II) & Unit 5 (I)
	2	Unit 5 (II)