Course guide
295459 - 295TM111 - Biomechanics Modelling

Last modified: 08/08/2024

Unit in charge: Barcelona East School of Engineering
Teaching unit: 712 - EM - Department of Mechanical Engineering.

Degree: MASTER'S DEGREE IN MECHANICAL TECHNOLOGIES (Syllabus 2024). (Optional subject).

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

LECTURER

Coordinating lecturer: GIL SERRANCOLÍ MASFERRER

Others: Primer quadrimestre:
DANIEL RODRÍGUEZ RIUS - Grup: T11, Grup: T12
ANTONIO JOSÉ SÁNCHEZ EGEA - Grup: T11, Grup: T12
DAVID SÁNCHEZ MOLINA - Grup: T11, Grup: T12
GIL SERRANCOLÍ MASFERRER - Grup: T11, Grup: T12

PRIOR SKILLS

- Use basic analytical mechanical methods to calculate forces and moments of a mechanical system.
- Solve differential equations.
- Use pressure/deformation calculation methods by finite elements of a simple system.
- Analyze basic signals.

TEACHING METHODOLOGY

This subject will combine theory sessions and one practical session per chapter. In theory sessions, the student will acquire the contents of each chapter, and in the practical sessions, he/she will be able to develop his/her skills using real biomechanical data.

LEARNING OBJECTIVES OF THE SUBJECT

- Understand the procedure to perform an inverse kinematics analysis from inertial sensor units.
- Learn the basic methods to calculate joint forces and moments of a biomechanical system during movement (macroscale analysis).
- Learn the most used constitutive models to model human tissues.
- Identify the boundary conditions of a microscale analysis (obtained from the macroscale analysis), mainly calculation of pressures and deformations using finite element methods. Familiarize with the main parameters of a constitutive tissue model.

STUDY LOAD

Type	Hours	Percentage
Hours large group	21,0	14.00
Guided activities	6,0	4.00
Self study	102,0	68.00
Hours small group	21,0	14.00

Total learning time: 150 h

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CONTENTS

Chapter 1. Introduction

Description:
- Introduction to the subject (macroscale to microscale)
- Review of the macro and microscale modelling of human body

Specific objectives:
• Identify active and passive structures of the human body responsible of the movement to create the biomechanics system model.
• Identify the current motion capture systems that can be used to capture the human body movement.

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

Chapter 2. Human body kinematics

Description:
2.1. Reminder of kinematics analysis
2.2. Human kinematics analysis with wearable devices
2.3. Case study: calculation of joint angles from IMUs (inertial measurement units)

Specific objectives:
• Calculate the joint angles by motion capture systems: optical cameras and inertial measurement units. Comprehend their differences, pros and cons.
• Learn how to perform an inverse kinematics analysis to a human movement.
• Learn to process data from an inertial measurement unit and extract the most relevant data.

Full-or-part-time: 24h
Theory classes: 4h
Laboratory classes: 3h
Self study : 17h

Chapter 3. Human body dynamics

Description:
3.1. Reminder Dynamics analysis.
3.2. Case study: calculation of dynamic joint moments.
3.3. Modelling of muscle forces.
3.4. Introduction to OpenSim (Inverse Kinematics, Inverse Dynamics, Static Optimization to estimate muscle forces).
3.5. Case study with OpenSim (analyze the difference in joint contact forces, depending on muscle-force sharing strategy).
3.6. Motion capture.

Specific objectives:
• The student will learn how to model the human body from a macro-scale point of view.
• Describe and perform inverse kinematics and dynamics analyses using the biomechanics open-source software OpenSim.
• Estimate muscle forces for a given movement.

Related activities:
Practical session 2. Motion capture and inverse kinematics and dynamics analyses.

Full-or-part-time: 48h
Theory classes: 11h
Laboratory classes: 3h
Self study : 34h

Chapter 4. Tissue Characterization and constitutive Models

Description:
4.1. Reminder of continuum mechanics
4.2. Kinematics of deformation and strain tensors
4.3. Forces in continuum mechanics and stress tensors
4.4. Equations of motion for deformable solids
4.5. Constitutive theory: examples of materials
4.6. Materials without memory: Linear and non-elasticity
4.7. Materials with memory: viscoelasticity and plasticity
4.8. Materials with memory: damage and degeneration parameters
4.9. Models for biological tissues (I): hard tissues
4.10. Models for biological tissues (II): soft tissues

Specific objectives:
• Comprehend how to apply the mechanical theories of continuous medium to develop a constitutive model for biological tissues.
• Learn the main phenomena of mechanical behaviour of tissues: anisotropy, viscoelasticity, fibres degeneration, etc.
• Learn how to design a set of specific experiments to adjust and calibrate parameter values of a specific constitutive model.

Related activities:
Practical session 4. Analysis of a flexion test with animal tissue.

Full-or-part-time: 48h
Theory classes: 11h
Laboratory classes: 3h
Self study : 34h

Chapter 5. FEM applied to biomechanics

Description:
5.1. Specificities of FEM applied to Biomechanics
5.2. Geometry and boundary conditions
5.3. FEM solver requirements for Biomechanical applications
5.4. Case study – Use of FEBio

Specific objectives:
Describe and perform a simulation by FEM of a hard tissue

Related activities:
Practical session 5 (use of FEBio in Biomechanics)

Full-or-part-time: 24h
Theory classes: 4h
Laboratory classes: 3h
Self study : 17h

GRADING SYSTEM

Lab session reports (25%)
Group projects (25%)
Individual assignments (30%)
Final exam of the subject (20%)

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BIBLIOGRAPHY

Basic:

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- Uchida, Thomas K. Biomechanics of movement : the science of sports, robotics, and rehabilitation. Cambridge, MA: The MIT Press, 2021. ISBN 9780262044202.

RESOURCES

Computer material:

- OpenSim. Biomechanics software OpenSim. Link: https://simtk.org/frs/?group_id=91- FEBio. Biomechanics software of finite elements applied to biomechanics. Link: https://febio.org/