INSTITUTO POLITÉCNICO DE BRAGANÇA

Course Unit	Computational Biomechanics	Field of study	Biomechanics
Master in	Biomedical Technology - Biomechanics and Rehabilitation	School	School of Technology and Management
Academic Year	2019/2020	Year of study	1
Level	2-1	ECTS credits	6.0
Type	Semestral	Semester	2
Code	5025-421-1201-00-19		

Workload (hours)	162	Contact hours	T	-	TP	60	PL	-	TC	-	S	-	E	-	OT	-	O	-

T - Lectures; TP - Lectures and problem-solving; PL - Problem-solving, project or laboratory; TC - Fieldwork; S - Seminar; E - Placement; OT - Tutorial; O - Other

Name(s) of lecturer(s)	Luís Manuel Ribeiro Mesquita

Learning outcomes and competences

At the end of the course unit the learner is expected to be able to:
1. Using computational methods to modelling and simulate biomechanical systems.
2. Describe the relationship between physical, analytical and computational representations in biomechanical systems.
3. Interpret results and distinguish between validation and verification of computational models.
4. Formulate and identify a problem, create an approach model, identify the boundary conditions, choose a solution method to the problem and explain the solution limitations.
5. Describe the impact that the biomechanical simulation can have in the patient life quality and the clinical benefit at a long term, by applying the computational biomechanics methods.

Prerequisites

Before the course unit the learner is expected to be able to:
Apply the acquired knowledge and competences of matrix, integral and differential calculus.

Course contents

Finite elements using displacement method. Interpolation, shape functions and numerical integration. Virtual work principle. Hard and soft tissues, and other materials. Constitutive models: elastic, viscoelastic and non-linear elastic behaviour. 2D and 3D elasticity. Computational applications and potential injury assessment, structural components analysis, orthopaedic implants, prosthesis and equipment for mobility support. A commercial finite element code.

Course contents (extended version)

1. Modelling and analysis
   - The finite element method in Biomechanics.
   - Codes for modelling and analysis. Files format.
   - Basic structure of a finite element program.
   - Geometric modelling. Primitives. Booleans operations. Elements types.
   - Mesh generation. Control mesh. Symmetry and non-symmetries.
   - Format conversion.
   - Convergence requirements and solution error types.
   - Optimum points for results calculation.
2. Biological materials and continuum mechanics
   - Constitutive laws of solids. Displacements, strains and stresses.
   - Systems of equations.
   - Stress-strain relation. Anisotropic, isotropic, orthotropic and elastic relations.
   - Mechanical properties of cortical and trabecular bone, ligaments and others materials.
   - Mechanical bone properties as function of age, gender and density.
   - Exponential laws for elastic properties determination.
   - Bone remodelling.
3. Formulation methods: discrete and continuous models
   - Discrete model and direct formulation.
   - Stiffness method. Bar element.
   - Continuous models.
   - Energetic methods.
   - Minimum total potential energy formulation.
   - Virtual work principle.
4. Formulation of bar element
   - Bar element formulation.
   - Pre-processor, solution and postprocessor phases.
   - Stiffness matrix and global assembly. Equations systems.
   - Bar element implementation in Matlab code.
   - Space bar structures.
   - Computational application in human mobility support.
5. Formulation of beam, plane and solid elements
   - Global, local and natural coordinates.
   - Shape functions. Displacements interpolation.
   - Isoparametric formulation and numerical integration.
   - Finite beam element.
   - Finite elements in two and three dimensional elasticity.
   - Lagrangian and Serendipity elements.
   - Computational applications in elements with discontinuities: bone plates structure.
6. Applications in computational biomechanics
   - Structural (static, dynamic, instability) and thermal analysis with ANSYS.
   - Linear and non-linear analysis.
   - Loading, interface and boundary conditions.
   - Technical aids: walking frames, lifts aids, orthopaedic beds, and chairs.
   - Analysis of stresses in skeletal structures: femur, tibia, hip, foot structures and mandible.
   - Stresses in femoral prosthesis, screws and bone plates, cementless implants, dental implant.
   - Analysis of stress shielding effect in bone-implant structure.

Recommended reading

1. Moaveni, S. , Finite Element Analysis, Theory and Application with Ansys, 2nd Edition, Prentice Hall, 2003.
2. Cees Oomens, Marcel Brekelmans, Frank Baaijens; Biomechanics Concepts and Computation; Cambridge Texts in Biomedical Engineering, 2009, ISBN-13: 9780521875585.

Teaching and learning methods

Theoretical lessons and practical problems solution. Cases studies beyond the classes. Resources: Software in laboratory.

Assessment methods

- Alternative - (Regular, Student Worker) (Final, Supplementary, Special)
    - Practical Work - 100%

Language of instruction

Portuguese

Electronic validation

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06-03-2020	09-03-2020	10-03-2020	11-03-2020