BMDE-512: Finite-element modelling in biomedical engineering

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Zoom link: https://mcgill.zoom.us/j/82095820697

Classes

- Mondays & Wednesdays, 10:05 – 11:25

- 2022 Aug 31 – Dec 5

- Zoom

  – attendance required

  – classes recorded in part

  – cameras on if possible

- Check e-mail regularly

Prerequisites

- Differential equations (MATH 271 or equivalent) or permission of instructor

Calendar course description

General principles of quantitative modelling; types of models; principles of the finite-element method, primarily as applied to mechanical systems; introduction to the use of finite-element software; model generation from imaging data; modelling various material types, mainly biological; model validation.

Course objective

- Goal is to make students aware of the finite-element method and of issues involved in using it in biomedical engineering

    - accessible to undergraduate and graduate students who may not have a background in solid mechanics

- Goal is **not** to prepare students to use the finite-element method independently: also need

    - course on finite-element method with more theoretical emphasis

    - course(s) in application area (e.g., solid mechanics)

Course content

- Approaches to modelling mechanical structures

  – not only finite-element method

- Introduction to the finite-element method

  – mostly by using software

- Issues specific to biomedical engineering

  – image-based modelling

  – modelling of biological materials

  – uncertainty, variability, validation …

Course content

- Finite-element software

    – free/open-source

    – some locally developed

- Types of shape data used in creating models

- Mechanics, energy dissipation

- Biological materials

- Philosophy of modelling, types of models

- Model validation, parameter estimation

Instructional methods

- Lectures
  - few or none
- Tasks
  - out-of-class and in-class
- Assignments
  - readings, student presentations
  - questions, discussion
- Project
  - model creation & simulation, written report

Tasks

- Using open-source software
  - image segmentation, f-e model creation
  - f-e pre-processing, simulation & post-processing
- **Essential practice for the project**

Assignments

- Reading
  - course material
  - journal articles
  - software manuals

- Preparing written and/or oral reports
  - individual or groups

- Class discussions
  - if you can't attend class …
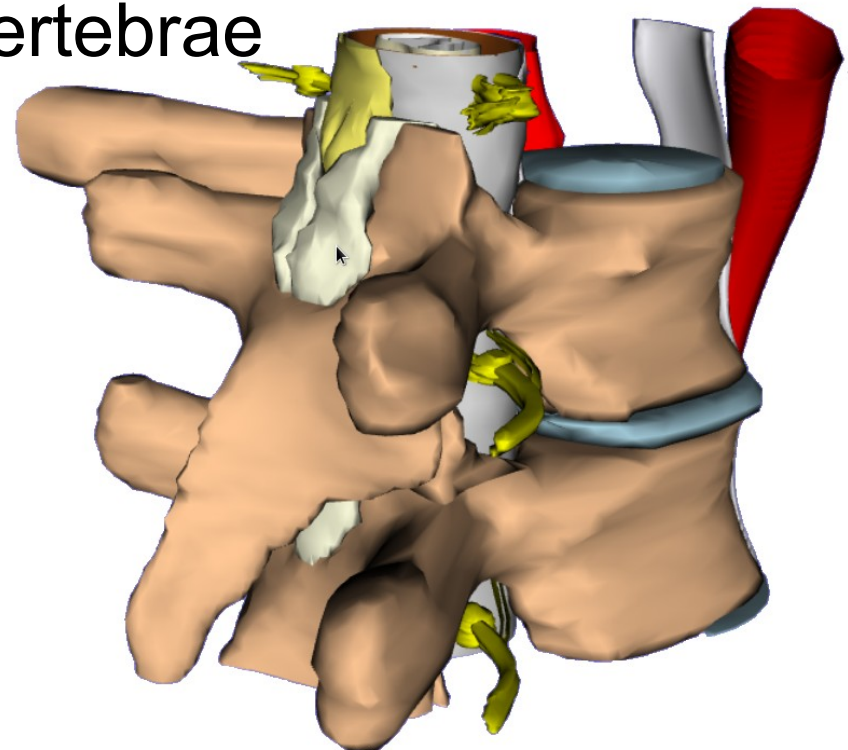
Project

- Create 3-D finite-element model of a biological structure and run some simulations

    – source of image data

    – choice of structure

    – features to be included

    – report on results, discussion of modelling issues

Project

- Images from Visible Korean Human project

- Each student will have own set of images

  - One complete vertebra

  - Parts of neighbouring vertebrae

  - Two discs

Project

Visible Korean Human

Project

- Model of
  - parts of 2 vertebrae
  - 1 disc

Singular: vertebra
Plural: vertebrae

- Shared surfaces between vertebrae & disc

- Simulation of the disc

  - arbitrary material properties, boundary conditions and load

  - visible deformation

Project

Report

- Brief Introduction
- Very brief Methods section
- Presentation of the modelling and simulation results
- **Discussion of modelling issues**

Project

Report discussion

- Problems that arose

- Rationale for the general approach taken to creating finite-element models, as discussed in class

- Strengths and weaknesses of the specific software tools used

- Alternative approaches and tools and their advantages and disadvantages

Evaluation

- Assignments & tasks (60%)

  - assignments every week or two

  - 5% deducted for each day (or fraction of day) late

- Final project (30%)

  - 10% deducted for each day (or fraction of day) late

- Participation (10%)

<p align="center">Possible scheme for grading presentations
2023 Jun 2</p>

- Content
  - relevant content at appropriate level
    - gives a good overview of the internship experience
  - well organized, coherent, flows logically
- Visual aids
  - clear and effective, not too dense
  - well synchronized with what is spoken
- Oral delivery
  - good timing, not rushed, not obviously reading
  - clear, appropriate loudness
- Answering questions
  - accurate
  - comfortable

Each of 4 categories graded out of 5:

- 5.0: Perfect, can't think of any criticisms
- 4.5: Excellent, with some minor criticisms
- 4.0: Very good, with one or two substantial criticisms
- 3.5: Acceptable, with major criticisms
- 3.0: Unacceptable
- 0 to 2.5: various levels of terrible

Course materials

- *Mechanics and modelling for the middle ear*

  – tutorial: audilab.bme.mcgill.ca/mammie/

- *Modeling of middle-ear mechanics*

  – book chapter (in myCourses)

- Software and documentation

  – FEBio Studio: audilab.bme.mcgill.ca/sw/febio.html

  – Slicer: audilab.bme.mcgill.ca/sw/slicer.html

  – Fie/Tr3/Thrup'ny/Fad: audilab.bme.mcgill.ca/sw/

Tentative schedule for BMDE-512, 2022

Week	Date	Class activities	Assignments
1			
	Aug 31	Introduction to course	T1: Download VirtualBox, Linux, Fie etc., start installing
2	Sep 5	*Labour Day*	
	Sep 7	Install VirtualBox, Linux, Fie etc. Work on Fie tutorial	T2: Install FEBio Studio, work on FEBio exercise
3	Sep 12	Do FEBio exercise	T3: Install Slicer, work on Slicer exercise A1: Sources of shape data
	Sep 14	Do Slicer exercise Presentation about presentations	
4	Sep 19	Work on Fie tutorial	
	Sep 21	Presentations about sources of shape data	
5	Sep 26	Presentations about sources of shape data	A2: Image segmentation
	Sep 28	Presentations about sources of shape data	
6	Oct 3	*Québec election*	
	Oct 5	Presentations about image segmentation	A3: Mechanics
7	Oct 10	*Thanksgiving*	
	Oct 13 **Thursday**	Presentations about image segmentation	
8	Oct 17	Presentations about image segmentation	
	Oct 19	Work on Fie tutorial	
9	Oct 24	Presentations about mechanics	A4: Dissipation
	Oct 26	Presentations about mechanics	
10	Oct 31	Presentations about mechanics Work on Fie tutorial	
	Nov 2	Work on Fie tutorial	
11	Nov 7	Presentations about dissipation	A5: Types, V&V
	Nov 9	Presentations about dissipation	
12	Nov 14	Presentations about dissipation Work on Fie tutorial	
	Nov 16	Circuit models; f-e mesh convergence Work on Fie tutorial & project	
13	Nov 21	Presentations on types, V&V	
	Nov 23	Presentations on types, V&V	
14	Nov 28	Presentation on types, V&V Work on project	
	Nov 30	Work on project	
15	Dec 5	Work on project; *Last day of classes, projects due*	

Use of computers

- Bring computers to class
  - reasonably powerful (not Chromebook)
  - adapter for using projector

- Linux / MS Windows / Mac OS

- VirtualBox

  - audilab.bme.mcgill.ca/~funnell/swil/swil_vbox.html
  - alternatives
    - Windows: QEMU, VMWare Workstation Player
    - Mac: Boot Camp, Parallels, VMWare Fusion

Policy statements

'In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded.'

'Conformément à la Charte des droits de l'étudiant de l'Université McGill, chaque étudiant a le droit de soumettre en français ou en anglais tout travail écrit devant être noté.'

Policy statements

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www.mcgill.ca/students/srr/honest/

Task

- Download and start installing VirtualBox, etc.
- Due on Wednesday, Sep 7