BMDE-512: Finite-element modelling in biomedical engineering

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Duff room 302, local 6739
myCourses
Duff room 321
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

• Shared surfaces between vertebrae & disc

• Simulation of the disc
  - arbitrary material properties, boundary conditions and load
  - visible deformation

Singular: vertebra
Plural: vertebrae
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%)
Possible scheme for grading presentations  
2023 Jun 2

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

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‘McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures.’

‘L’université McGill attache une haute importance à l’honnêteté académique. Il incombe par conséquent à tous les étudiants de comprendre ce que l’on entend par tricherie, plagiat et autres infractions académiques, ainsi que les conséquences que peuvent avoir de telles actions, selon le Code de conduite de l’étudiant et des procédures disciplinaires.’

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

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