Course Title (in English) | Biomedical Imaging and Analytics
---|---
Course Title (in Russian) | Формирование и анализ биомедицинских изображений
Lead Instructor(s) | Dylov, Dmitry

Is this syllabus complete, or do you plan to edit it again before sending it to the Education Office? | The syllabus is a final draft waiting for form approval
Contact Person | Dmitry Dylov
Contact Person’s E-mail | d.dylov@skoltech.ru

1. Annotation

Course Description

This course is designed for Machine Learning and Data-Science students who would like to concentrate their research on the analysis of biomedical images. This cohort of specialists – especially early on in their careers – is known for dismissing both the physical mechanisms of image formation and the very biological rationale behind a given imaging modality. In this course, we will attempt to reunite the three disciplines in order to help students develop systematic analytical expertise and biological intuition.

The course is also aligned with the curriculum of the centers of life sciences and photonics and should be used for enriching those offerings with modern machine learning and image analytics skills.

Students will learn what forms the backbone of biomedical imaging, drawing from the mathematical, physical, chemical, and biological sciences, including the subjects of:

- Light microscopy (live cell imaging, deconvolution and superresolution microscopy, 3D microscopy, Optical Coherence Tomography);
- Medical imaging (X-ray, Computed Tomography, Magnetic Resonance Imaging, Ultrasound, Positron Emission Tomography);
- Image analytics (filtering and signal processing, machine learning and artificial neural networks, computer vision, image-based biological and physiological modeling).

The course is offered primarily for CDISE students who are assumed to know the basics of image processing and machine learning. In addition to the lectures, there will be 6 adapted seminars for those students who encounter the technical aspects of this course for the first time (e.g., Life Sciences students). The technical sessions will be shuffled with invited seminars by doctors/biologists with whom there is an ongoing collaboration.
Regardless of the educational track, all attendees should be familiar with basic calculus. Familiarity with Fourier Transform and Image Filtering is a plus but not required. One of the main goals of the course is to familiarize a computer scientist with math and physics of image formation, implying the students are anticipated to do ample reading.

2. Structure and Content

Course Academic Level

Master-level course suitable for PhD students

Number of ECTS credits

6

<table>
<thead>
<tr>
<th>Topic</th>
<th>Summary of Topic</th>
<th>Lectures (# of hours)</th>
<th>Seminars (# of hours)</th>
<th>Labs (# of hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Biomedical Modalities.</td>
<td>Biological rationale and case studies from healthcare. Tissue properties at different energies of electromagnetic radiation. Overview of imaging needs at different scales and recipes for choosing optimal modality.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapted Seminar on Imaging Mathematics (for Life Sciences students)</td>
<td>Understanding Fourier Transform and Image Processing.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical Microscopy</td>
<td>Visualization of image formation principles with living cells. Amplitude and phase contrast microscopy. Diffraction limit and super-resolution imaging. Fluorescence imaging and immunohistopathology. Multi-dimensional approaches.</td>
<td>3</td>
<td></td>
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</tr>
<tr>
<td>Ultrasound Imaging</td>
<td>Physical principles and systems engineering behind diagnostic ultrasound. Biological aspects of sound propagation in tissue. Ongoing research topics and state-of-art techniques.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapted Seminar on Image Analytics (for Life Sciences students)</td>
<td>Overview of programming-free approaches to modern image processing and machine learning toolsets using ImageJ and Weka platforms.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapted Seminar on How to work with clinical 3D data (for Life Sciences Students)</td>
<td>Introduction to DICOM format and associated software.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 3. Assignments

<table>
<thead>
<tr>
<th>Assignment Type</th>
<th>Assignment Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Set</td>
<td>Calculation/programming exercise on deconvolution microscopy.</td>
</tr>
<tr>
<td>Test/Quiz</td>
<td>In-class open book Midterm Exam on image formation principles.</td>
</tr>
<tr>
<td>Final Project</td>
<td>Computer Vision Project on a biomedical modality of student’s choice. The students who took this course along with Deep Learning (MA06057) are allowed to pass the final projects on both courses as a single presentation.</td>
</tr>
</tbody>
</table>

### 4. Grading

<table>
<thead>
<tr>
<th>Type of Assessment</th>
<th>Graded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Structure</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Activity weight, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework Assignments</td>
<td>20</td>
</tr>
<tr>
<td>Midterm Exam</td>
<td>30</td>
</tr>
<tr>
<td>Final Project</td>
<td>30</td>
</tr>
<tr>
<td>Attendance</td>
<td>20</td>
</tr>
</tbody>
</table>

| Grading Scale               | 86                  |
5. Basic Information

Maximum Number of Students

<table>
<thead>
<tr>
<th></th>
<th>Maximum Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall:</td>
<td>50</td>
</tr>
<tr>
<td>Per Group (for seminars and labs):</td>
<td>5</td>
</tr>
</tbody>
</table>

Course Stream

Science, Technology and Engineering (STE)

Course Term (in context of Academic Year)

Term 4

Course Delivery Frequency

Every year

Students of Which Programs do You Recommend to Consider this Course as an Elective?

<table>
<thead>
<tr>
<th>Masters Programs</th>
<th>PhD Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Science</td>
<td>Computational and Data Science and Engineering</td>
</tr>
<tr>
<td>Information Science and Technology</td>
<td></td>
</tr>
<tr>
<td>Life Sciences</td>
<td></td>
</tr>
<tr>
<td>Photonics and Quantum Materials</td>
<td></td>
</tr>
</tbody>
</table>

Course Tags

Math
Physics
Biotechnology
Programming

6. Textbooks and Internet Resources
### Required Textbooks

<table>
<thead>
<tr>
<th>ISBN-13 (or ISBN-10)</th>
<th>Title</th>
<th>Publisher</th>
<th>Year</th>
</tr>
</thead>
</table>

### Recommended Textbooks

<table>
<thead>
<tr>
<th>ISBN-13 (or ISBN-10)</th>
<th>Title</th>
<th>Publisher</th>
<th>Year</th>
</tr>
</thead>
</table>

### 7. Facilities

- Labs for Education
- Computer Lab

### 8. Learning Outcomes

#### Knowledge

Physics and image formation principles behind modern biomedical imaging modalities. Image acquisition and image processing approaches.

#### Skill

The acquired skillset will include mathematical approaches to biomedical imaging analytics. For novice image analysts, platforms like ImageJ and Weka will be learnt.
<table>
<thead>
<tr>
<th>Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work with state-of-art biological problems and clinical needs. Data scientist can develop biological intuition and correct feature perception skills, helpful in recognizing meaningful patterns in imaging data.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9. Assessment Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input or Upload Example(s) of Assignment 1:</strong></td>
</tr>
<tr>
<td><strong>Select Assignment 1 Type</strong></td>
</tr>
<tr>
<td><strong>Assessment Criteria for Assignment 1</strong></td>
</tr>
<tr>
<td>A functional program that gives correct answers to each question in the problem set.</td>
</tr>
</tbody>
</table>

| **Input or Upload Example(s) of Assignment 2:**                          |

| **Input or Upload Example(s) of Assignment 3:**                          |

| **Input or Upload Example(s) of Assignment 4:**                          |

| **Input or Upload Example(s) of Assignment 5:**                          |

<table>
<thead>
<tr>
<th>10. Additional Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Free Style Comments (if any)</strong></td>
</tr>
<tr>
<td>Students, who also take Deep Learning (MA06057) this term, are allowed to pass both courses using the same final presentation (to be held at a joint DL-BIA workshop).</td>
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</tbody>
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