Medical Images

Programme course

6 credits

Medicinska bilder

TSBB31

Valid from: 2021 Spring semester

Determined by
Board of Studies for Electrical Engineering, Physics and Mathematics

Date determined
2020-09-29

Main field of study
Electrical Engineering

Course level
First cycle

Advancement level
G2X

Course offered for
- Master of Science in Biomedical Engineering

Prerequisites
Continuous 1-D Fourier transform and its theorem for scaling, translation, derivation, convolution and multiplication. Basic knowledge of Matlab programming. Linear algebra: vector, matrix, determinant and scalar product. One- and multidimensional calculus.

Intended learning outcomes
After completing the course, the student will be able to:

- Describe the generalization from 1-D to 2-D continuous Fourier transform and related theorems, such as scaling, translation, derivation, convolution and multiplication.
- Explain the following concepts in 1-D and 2-D: sampling and reconstruction, DFT, the sampling theorem and aliasing, resampling and interpolation.
- Interpret the results of a 2-D Fourier transform of an image, such as understanding what a spatial frequency means. Describe simple convolution kernels and filters that perform differentiation, low-pass and high-pass filtering.
- Know of the most common types of medical images, what they show, their underlying physics and technique: ultrasound, x-ray, CT, MRI, gamma-camera, SPECT, PET.
- Have a deeper understanding the above techniques, with focus on signal- and image processing.

Course content
The course consists of two parts. The first part provides fundamental knowledge about 2D signal processing on images. In the second part, these skills are used in the study of various medical imaging techniques. The course aims to give a deeper

understanding of ultrasound, CT, MRI, SPECT and PET, with focus on signal- and image processing.

- The digital image: pixels/size/zoom, storage and quantization, grayscale/color, real/complex. Histogram and gray-scale transformations. Color Tables: grayscale, RGB true, pseudo.
- Repetition of 1-D Fourier transform. From 1-D to 2-D Fourier transform. Theorems for 1-D and 2-D Fourier transform, such as scaling, translation, derivation, convolution and multiplication. Theorems for the 2-D Fourier transform such as the rotation and projection theorem. Looking at images and their Fourier transforms and relating them to the theorems.
- The Dirac impulse. Sampling and reconstruction. Effects on the image during aliasing in the spatial or Fourier domain.
- 1-D and 2-D DFT and FFT. Discrete 1-D and 2-D convolution. Convolution kernels/filters in the spatial and Fourier domain: low-pass (gauss), high-pass (Laplace), derivative (Sobel). Edge detection using the magnitude of the gradient.
- Resampling and interpolation, especially up- and down-sampling. Ideal up-sampling by zero-padding.
- Some simple image analysis tools: threshholding, erosion, labelling.
- Important measurements on images such as: contrast, MTF, resolution, SNR.
- Ultrasound.
- Briefly on different imaging techniques: digital radiography, angiography, fluoroscopy, mammography.
- Briefly on the physics for plain radiography and CT: X-ray spectrum, physical interactions such as photoelectric effect, Compton and Rayleigh radiation, noise. The idea is to show how the physics influence the image quality.
- CT: the projection theorem, 2-D reconstruction using the direct Fourier method, 2-D reconstruction using filtered back projection, parallel beam and fanbeam, rebinning, briefly on 3-D reconstruction.
- PET and SPECT. CT-PET and CT-SPECT.
- Carefully about MRI basics. Overview of some MRI-variants, fMRI, EPI, diffusion.

The computer exercises:

- 1) The digital image: pixels/size/zoom, quantization and storage, grayscale/color, real/complex. Histogram and grayscale transformations. Color tables: grayscale, RGB true, pseudo. 2-D Fourier transform of the images: appearance, properties. Simple convolution kernels in the spatial domain. Linear filters in the Fourier domain.
- 2) Resampling and interpolation. Effects of sampling in the spatial and Fourier domain. Extra exercise on dowsampling and aliasing.
- 3) CT reconstruction: How do you do a CT image?
- 4) Basic MRI. Design of pulse sequences.
- 5) How do you do an ultrasound image? Rf-signal => envelope detection => downsampling => histogram transformation => scan conversion

(resampling) => ultrasound image
- 6) Measurement of noise. Some simple image analysis methods. Preparation for computer exercise 7.
- 7) Measurements on SPECT/CT-volumes. Example volumes form healthy and COPD patients.

Study visit: The course includes a study visit to CMIV, where we will look at a CT-scanner and an MRI-camera. We will also listen to a lecture about how medical images are used today at the University Hospital in Linköping

Teaching and working methods

The course consists of lectures, tutorials and laboratory sessions based on Matlab.

Examination

LAB1	Laboratory work	2 credits	U, G
TEN1	Written examination	4 credits	U, 3, 4, 5

Grades

Four-grade scale, LiU, U, 3, 4, 5

Other information

Admission courses: Courses within the image profile.

About teaching and examination language

The teaching language is presented in the Overview tab for each course. The examination language relates to the teaching language as follows:

- If teaching language is Swedish, the course as a whole or in large parts, is taught in Swedish. Please note that although teaching language is Swedish, parts of the course could be given in English. Examination language is Swedish.
- If teaching language is Swedish/English, the course as a whole will be taught in English if students without prior knowledge of the Swedish language participate. Examination language is Swedish or English (depending on teaching language).
- If teaching language is English, the course as a whole is taught in English. Examination language is English.

Other

The course is conducted in a manner where both men's and women's experience and knowledge are made visible and developed.

The planning and implementation of a course should correspond to the course syllabus. The course evaluation should therefore be conducted with the course syllabus as a starting point.

Department

Institutionen för systemteknik

Director of Studies or equivalent

Lasse Alfredsson

Examiner

Maria Magnusson

Course website and other links

https://www.cvl.isy.liu.se/education/undergraduate/

Education components

Preliminary scheduled hours: 71 h
Recommended self-study hours: 89 h

Course literature

Books

Prince, J.L., Links, J.M., (2008) *Medical Imaging: Signals and Systems (Prince, J.L. and Links, J.M.; 2006) [Book Review]*

Compendia

Maria Magnusson, Grundläggande 1D och 2D signalbehandling för Bilder
(in Swedish)

Other

*) Lecture slides.
*) Lesson material.
*) Laboratory exercise material.
*) Formula collection.
*) Short extract from the PhD-thesis by Maria Magnusson.
*) Short extract from the PhD-thesis by Henrik Turbells.
*) Parts from the Master Thesis by Oscar Grandell.
*) Short on Poisson noise by Theo Fuchs.
*) Parts from the TBMI02 Compendium: "MRI, fMRI, Image Registration, Image Segmentation".

All material above are in pdf-format and are available from the course home page.

Common rules

Course syllabus

A syllabus must be established for each course. The syllabus specifies the aim and contents of the course, and the prior knowledge that a student must have in order to be able to benefit from the course.

Timetabling

Courses are timetabled after a decision has been made for this course concerning its assignment to a timetable module.

Interrupting a course

The vice-chancellor's decision concerning regulations for registration, deregistration and reporting results (Dnr LiU-2015-01241) states that interruptions in study are to be recorded in Ladok. Thus, all students who do not participate in a course for which they have registered must record the interruption, such that the registration on the course can be removed. Deregistration from a course is carried out using a web-based form: https://www.lith.liu.se/for-studenter/kurskomplettering?l=en.

Cancelled courses

Courses with few participants (fewer than 10) may be cancelled or organised in a manner that differs from that stated in the course syllabus. The Dean is to deliberate and decide whether a course is to be cancelled or changed from the course syllabus.

Guidelines relating to examinations and examiners

For details, see Guidelines for education and examination for first-cycle and second-cycle education at Linköping University, Dnr LiU-2019-00920 (http://styrdokument.liu.se/Regelsamling/VisaBeslut/917592).

An examiner must be employed as a teacher at LiU according to the LiU Regulations for Appointments, Dnr LiU-2017-03931 (https://styrdokument.liu.se/Regelsamling/VisaBeslut/622784). For courses in second-cycle, the following teachers can be appointed as examiner: Professor (including Adjunct and Visiting Professor), Associate Professor (including Adjunct), Senior Lecturer (including Adjunct and Visiting Senior Lecturer), Research Fellow, or Postdoc. For courses in first-cycle, Assistant Lecturer (including Adjunct and Visiting Assistant Lecturer) can also be appointed as examiner in addition to those listed for second-cycle courses. In exceptional cases, a Part-time Lecturer can also be appointed as an examiner at both first- and second cycle, see Delegation of authority for the Board of Faculty of Science and Engineering.

Forms of examination

Principles for examination

Written and oral examinations and digital and computer-based examinations are held at least three times a year: once immediately after the end of the course, once in August, and once (usually) in one of the re-examination periods. Examinations held at other times are to follow a decision of the board of studies.

Principles for examination scheduling for courses that follow the study periods:

- courses given in VT1 are examined for the first time in March, with re-examination in June and August
- courses given in VT2 are examined for the first time in May, with re-examination in August and October
- courses given in HT1 are examined for the first time in October, with re-examination in January and August
- courses given in HT2 are examined for the first time in January, with re-examination in March and in August.

The examination schedule is based on the structure of timetable modules, but there may be deviations from this, mainly in the case of courses that are studied and examined for several programmes and in lower grades (i.e. 1 and 2).

Examinations for courses that the board of studies has decided are to be held in alternate years are held three times during the school year in which the course is given according to the principles stated above.

Examinations for courses that are cancelled or rescheduled such that they are not given in one or several years are held three times during the year that immediately follows the course, with examination scheduling that corresponds to the scheduling that was in force before the course was cancelled or rescheduled.

When a course is given for the last time, the regular examination and two re-examinations will be offered. Thereafter, examinations are phased out by offering three examinations during the following academic year at the same times as the examinations in any substitute course. If there is no substitute course, three examinations will be offered during re-examination periods during the following academic year. Other examination times are decided by the board of studies. In all cases above, the examination is also offered one more time during the academic year after the following, unless the board of studies decides otherwise.

If a course is given during several periods of the year (for programmes, or on different occasions for different programmes) the board or boards of studies determine together the scheduling and frequency of re-examination occasions.

Retakes of other forms of examination

Regulations concerning retakes of other forms of examination than written examinations and digital and computer-based examinations are given in the LiU guidelines for examinations and examiners, http://styrdokument.liu.se/Regelsamling/VisaBeslut/917592.

Registration for examination

Until January 31 2021, the following applies according to previous guidelines: In order to take an written, digital or computer-based examination student must register in advance at the Student Portal during the registration period, which opens 30 days before the date of the examination and closes 10 days before it. Candidates are informed of the location of the examination by email, four days in advance. Students who have not registered for an examination run the risk of being refused admittance to the examination, if space is not available.

From February 1 2021, new guidelines applies for registration for written, digital or computer-based examination, Dnr LiU-2020-02033 (https://styrdokument.liu.se/Regelsamling/VisaBeslut/622682).

Symbols used in the examination registration system:

** denotes that the examination is being given for the penultimate time.

* denotes that the examination is being given for the last time.

Code of conduct for students during examinations

Details are given in a decision in the university's rule book: http://styrdokument.liu.se/Regelsamling/VisaBeslut/622682.

Retakes for higher grade

Students at the Institute of Technology at LiU have the right to retake written examinations and digital and computer-based examinations in an attempt to achieve a higher grade. This is valid for all examination components with code "TEN", "DIT" and "DAT". The same right may not be exercised for other examination components, unless otherwise specified in the course syllabus.

A retake is not possible on courses that are included in an issued degree diploma.

Grades

The grades that are preferably to be used are Fail (U), Pass (3), Pass not without distinction (4) and Pass with distinction (5).

- Grades U, 3, 4, 5 are to be awarded for courses that have written or digital examinations.
- Grades Fail (U) and Pass (G) may be awarded for courses with a large degree of practical components such as laboratory work, project work and group work.
- Grades Fail (U) and Pass (G) are to be used for degree projects and other independent work.

Examination components

The following examination components and associated module codes are used at the Faculty of Science and Engineering:

- Grades U, 3, 4, 5 are to be awarded for written examinations (TEN) and

digital examinations (DIT).
- Examination components for which the grades Fail (U) and Pass (G) may be awarded are laboratory work (LAB), project work (PRA), preparatory written examination (KTR), digital preparatory written examination (DIK), oral examination (MUN), computer-based examination (DAT), home assignment (HEM), and assignment (UPG).
- Students receive grades either Fail (U) or Pass (G) for other examination components in which the examination criteria are satisfied principally through active attendance such as tutorial group (BAS) or examination item (MOM).
- Grades Fail (U) and Pass (G) are to be used for the examination components Opposition (OPPO) and Attendance at thesis presentation (AUSK) (i.e. part of the degree project).

In general, the following applies:

- Mandatory course components must be scored and given a module code.
- Examination components that are not scored, cannot be mandatory. Hence, it is voluntary to participate in these examinations, and the voluntariness must be clearly stated. Additionally, if there are any associated conditions to the examination component, these must be clearly stated as well.
- For courses with more than one examination component with grades U,3,4,5, it shall be clearly stated how the final grade is weighted.

For mandatory components, the following applies: If special circumstances prevail, and if it is possible with consideration of the nature of the compulsory component, the examiner may decide to replace the compulsory component with another equivalent component. (In accordance with the LiU Guidelines for education and examination for first-cycle and second-cycle education at Linköping University, http://styrdokument.liu.se/Regelsamling/VisaBeslut/917592).

For written examinations, the following applies: If the LiU coordinator for students with disabilities has granted a student the right to an adapted examination for a written examination in an examination hall, the student has the right to it. If the coordinator has instead recommended for the student an adapted examination or alternative form of examination, the examiner may grant this if the examiner assesses that it is possible, based on consideration of the course objectives. (In accordance with the LiU Guidelines for education and examination for first-cycle and second-cycle education at Linköping University, http://styrdokument.liu.se/Regelsamling/VisaBeslut/917592).

Reporting of examination results

The examination results for a student are reported at the relevant department.

Plagiarism

For examinations that involve the writing of reports, in cases in which it can be assumed that the student has had access to other sources (such as during project work, writing essays, etc.), the material submitted must be prepared in accordance

with principles for acceptable practice when referring to sources (references or quotations for which the source is specified) when the text, images, ideas, data, etc. of other people are used. It is also to be made clear whether the author has reused his or her own text, images, ideas, data, etc. from previous examinations, such as degree projects, project reports, etc. (this is sometimes known as "self-plagiarism").

A failure to specify such sources may be regarded as attempted deception during examination.

Attempts to cheat

In the event of a suspected attempt by a student to cheat during an examination, or when study performance is to be assessed as specified in Chapter 10 of the Higher Education Ordinance, the examiner is to report this to the disciplinary board of the university. Possible consequences for the student are suspension from study and a formal warning. More information is available at https://www.student.liu.se/studenttjanster/lagar-regler-rattigheter?l=en.

Regulations (apply to LiU in its entirety)

The university is a government agency whose operations are regulated by legislation and ordinances, which include the Higher Education Act and the Higher Education Ordinance. In addition to legislation and ordinances, operations are subject to several policy documents. The Linköping University rule book collects currently valid decisions of a regulatory nature taken by the university board, the vice-chancellor and faculty/department boards.

LiU's rule book for education at first-cycle and second-cycle levels is available at http://styrdokument.liu.se/Regelsamling/Innehall/Utbildning_pa_grund-_och_avancerad_niva.