2021-05-05

SH2314 Medical Imaging Signals and systems, spring term 2021

Course description

The course treats the physical, mathematical, and technological aspects of medical imaging systems from a signals-and-systems perspective. Detailed learning goals are found in the course syllabus https://www.kth.se/student/kurser/kurs/SH2314.

Examiner and course responsible:

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Note about PhD-level course

This course is also given as a PhD-level course, FSH3220. To pass FSH3220, you need to fulfill the requirements for SH2314 and pass an additional oral examination. In order to arrange this, please talk to me or contact Mats Danielsson (md@mi.physics.kth.se, examiner for FSH3220) directly.

Office hours

The course responsible is available for answering questions Tuesdays 12.00-13.00 via the same Zoom link that is used for the class.

Examination

There are two mandatory moments:
Written exam (TEN1, 4.5 ECTS credits)
Laboratory assignment (LAB1, 3.0 ECTS credits)
The grade is set based on the score on the exam. The maximum score is 30 p, which can be increased with up to 7 bonus points for passed homework problems and a presentation.
Grades: A ≥ 27 p > B ≥ 24 p > C ≥ 21 p > D ≥ 17 p > E ≥ 14 p
13 p will give you Fx meaning that you have the right to complete a supplementary task in order to get an E. These preliminary grade limits may be adjusted downwards nut not upwards.
Allowed aids in the examination: calculator, dictionary, provided formula sheet and up to five pages of your own formula sheets (front- and backside counts as two pages).

Hand-in problems

Six sets of homework problems will be provided during the course. They are not mandatory, but each homework set gives one bonus point for the exam if correct solutions are handed in before the deadline. Solution to the homework should be handed in individually and of course no copying of others' solutions is allowed. But discussing with your fellow students is encouraged.

Optional presentation

If you want, you can study an advanced topic of your choice related to the course and give a seminar presentation to the class (10 min presentation + 5 min questions). If you attend the seminar and give a successful presentation gives one bonus point for the exam. If you want to give a presentation, ask the course responsible to approve of the topic in advance.

Laboratory assignment

In order to pass the laboratory part of the course you need to complete two things:

1. A lab tour of a hospital radiology department (replaced by a virtual tour and a quiz this year due to Corona!)
2. The X-ray CT laboratory exercise. The laboratory exercise is made in groups of at most 3 persons, and each group should in one lab report afterwards. Note that you need to complete some preparatory assignments in order to be allowed to do the lab!

Software tools

To solve the homework problems and laboratory exercise, you will need to use a numerical programming language (e.g. Matlab or numPy). You can use either of these languages, according to your preference. Make sure that you know how to use the necessary software ahead of time!

Language

The course is given in English. On exams and hand-in assignment, you can choose between answering in English or Swedish.

Course website

https://canvas.kth.se/courses/21976

Students with disabilities

Students with disabilities may receive compensatory support as decided by Funka, funka@kth.se. Please inform the course responsible about any need for compensatory support related to the course.

Corona adaptations

All activities take place via Zoom: https://kth-se.zoom.us/j/62915859020 Although unlikely, there may be changes if new directives are issued by KTH management. Please pay attention to any future changes, which will be posted in the course feed on canvas and announced in class!

Schedule

Class	Day	Time	Topic
1	Tue 2021-03-23	10.15-12.00	Introduction; signals and systems
2	Wed 2021-03-24	10.15-12.00	Fourier-space description of imaging systems
3	Tue 2021-03-30	10.15-12.00	Image noise; metrics of image quality
4	Wed 2021-03-31	10.15-12.00	Physics of radiation
	~~Thu 2021-04-08~~ Sun 2021-04-11	23.59	**Deadline homework 1**
5	Tue 2021-04-13	10.15-12.00	Radiation detectors
6	Wed 2021-04-14	10.15-12.00	Nuclear physics (guest lecture)
	Thu 2021-04-15	23.59	**Deadline homework 2**
7	Tue 2021-04-20	10.15-12.00	Projection radiography
8	Wed 2021-04-21	10.15-12.00	Ultrasound imaging (guest lecture)
	Thu 2021-04-22	23.59	**Deadline homework 3**
9	Tue 2021-04-27	10.15-12.00	X-ray computed tomography
	Thu 2021-04-29	23.59	**Deadline homework 4**
10	Tue 2021-05-04	10.15-12.00	Magnetic resonance imaging (guest lecture)

11	Wed 2021-05-05	10.15-12.00	X-ray computed tomography (continued)
	Thu 2021-05-06		**Deadline virtual study visit**
12	Tue 2021-05-11	10.15-12.00	Nuclear medicine imaging
13	Wed 2021-05-12	10.15-12.00	Nuclear medicine imaging (Continued); student presentations
	Mon 2021-05-17		**Deadline homework 5** (note the day!)
	Thu 2021-05-27		**Deadline homework 6**
14	To be determined		Rehearsal and exercises
	2021-06-01	08.00-13.00	Exam

Course literature

The core content of the course will be covered by lecture notes, lab notes and homework problems. However, reading the literature is recommended in order to put the course material into context. There is no mandatory course book, but the following is recommended and will be followed in the lectures:

[PL] Jerry L. Prince, Jonathan M. Links, "Medical Imaging Signals and Systems", 1st Edition (2009) or 2nd Edition (2014) (Pearson Education)

This book can be hard to get hold of as a hardcopy, but a time-limited subscription can be purchased from the publisher. Having access to the book is not necessary for the course, as an alternative reading list with material available through the KTH library is provided below.

[HR] William R. Hendee, Russell Ritenour, Medical Imaging Physics, Fourth Edition (Wiley 2002)

[BKVM] Jacob Beutel, Harold L. Kundel, Richard L. Van Metter (eds.), Handbook of Medical Imaging – Volume 1: Physics and psychophysics (SPIE 2000)

[Hsieh] Jiang Hsieh, “Computed tomography: principles, design, artifacts, and recent advances”, Third edition (SPIE 2015)

[CSP] Simon Cherry, James Sorenson and Michael Phelps, “Physics in Nuclear Medicine”, Fourth edition (Elsevier Health Science 2012)

Topic	Prince and Links (PL)	Alternative course literature (Updates May 5 in yellow)
Overview	Ch. 1: All	CSP ch.1, HR ch.1
Signals and systems	Ch. 2: All except 2.7 Ch. 3: All	BKVM ch. 2: 2.1-2.5.5, 2.6.1
Physics of radiographic imaging	Ch. 4: All	CSP ch. 6, 7. (read ch. 7 briefly and skip 7.A.3 and 7.C.6). (Alternatively, you can read BKVM ch1.2) CSP10A-B BKVM ch. 1.1, 1.3 CSP ch. 22.A-C (skip 22.C6-7) ch. 23.A-B (Alternatively, you can read BKVM ch 1.4 instead)
Projection radiography	Ch. 5: All except 5.3.4. (Read 5.2.5-5.2.8 briefly)	HR Ch. 13 (skip the “x-ray film” part) CSP 9.A-D.

X-ray computed tomography	Ch. 6: All except 6.3.4 and 6.4.1. (Read 6.3.5-6.3.7 briefly. Read 6.4.2 briefly and study the interpretation of the final results for σ^2 and SNR)	Hsieh ch. 1 (read briefly), ch. 2 (you may skip parts of 2.1-2.2 that have already been covered) Ch. 3: 3.1-3.4.2. (Read 3.4.2 briefly up to fig 3.25 and skip the rest of the section.) (Alternatively, you can choose to read CSP ch. 16.A-B. instead of Hsieh ch. 3) CSP ch. 16.C. Hsieh ch. 6: get an overview of the different components, but there is no need to read everything. Hsieh ch. 7: Understand what causes aliasing, beam hardening, scatter and motion artifacts. No need to read everything.
Nuclear medicine	Ch. 7: All Ch. 8: All Ch. 9: All. (Read 9.2.3 briefly.)	CSP ch 2-5, all except 4D. (Read 4.A-C briefly). CSP ch. 13-18
Ultrasound	Ch. 10: 10.1-10.4 Ch. 11: 11.1-11.3, 11.5, 11.6.1 (Read 11.2 briefly)	HR ch. 19-21
MRI	Ch. 12:12.1-12.7, 12.9, 12.10 (Read 12.6 briefly. In 12.10 read briefly about P_D- T1-, and T2-weighted contrast) Ch. 13: 13.1-13.2.7, 13.3.1-13.3.2	BKVM ch. 6.1-6.3.5.2.3. (In 6.3.5.2.1-6.3.5.2.3, read briefly about spin-density-, T1-, and T2-weighted contrast) Also read about gradient echoes in Sec. 6.3.5.4 on p. 408-409.

Further reading materials, alternative presentations or more in-depth coverage:

Victor I. Mikla and Victor V. Mikla “Medical Imaging Technology” (Elsevier 2014)

Roger L. Easton Jr., “Fourier Methods in Imaging” (Wiley 2010)

Zhi-Pei Liang, Paul C. Lauterbur, “Principles of Magnetic Resonance Imaging: A Signal Processing Perspective”, Wiley-IEEE press 2000

Thomas L. Szabo “Diagnostic Ultrasound imaging: inside out” (Elsevier 2013)