

SH2314 Medical Imaging Signals and systems, spring term 2022

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:

Mats Persson

Assistant professor

KTH Department of Physics, Physics of Medical Imaging

mats.persson@mi.physics.kth.se

Phone: 0762742376

Note about PhD-level course

The PhD-level course FSH3220 is co-taught with SH2314. To pass FSH3220, you need to fulfill the requirements for SH2314 and pass an additional oral examination. In order to arrange this, please contact me.

Office hours

The course responsible is available for answering questions Thursdays 12.00-13.00 via Zoom:

<https://kth-se.zoom.us/j/61718745350>.

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: $A \geq 27 \text{ p} > B \geq 24 \text{ p} > C \geq 21 \text{ p} > D \geq 17 \text{ p} > E \geq 14 \text{ p}$

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 but 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 up to 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 in total for presentation and questions). If you attend the seminar and give a successful presentation you will get 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 virtual lab tour of a hospital radiology department with a quiz (We will not visit the hospital in person due to Corona.)
2. The X-ray imaging and CT lab. This laboratory exercise is made in groups of at most 3 persons, and each group should hand 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. You can choose to answer in English or Swedish on the exam and hand-in assignments.

Course website

<https://canvas.kth.se/courses/31310>

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

Classes will be held physically, but there will also be the possibility to join over Zoom if you are unable to join in person or have symptoms: <https://kth-se.zoom.us/j/61718745350>. If you can attend in person, it is highly recommended that you do so. If you have to attend remotely, please let me know.

Schedule

Class	Day	Time	Topic (preliminary)
1	Tue 2022-03-22	10.15-12.00	Introduction; signals and systems
2	Wed 2022-03-23	10.15-12.00	Fourier-space description of imaging systems
3	Tue 2022-03-29	10.15-12.00	Image noise; metrics of image quality
4	Wed 2022-03-30	10.15-12.00	Physics of radiation
	Thu 2022-03-31	23.59	Deadline homework 1
5	Tue 2022-04-05	10.15-12.00	Radiation detectors
6	Wed 2022-04-06	10.15-12.00	Projection radiography
	Thu 2022-04-07	23.59	Deadline homework 2
7	Tue 2022-04-12	10.15-12.00	X-ray computed tomography
8	Wed 2022-04-13	10.15-12.00	X-ray computed tomography (continued)
	Wed 2022-04-13	23.59	Deadline virtual study visit (Note the date!)
9	Tue 2022-04-26	10.15-12.00	Ultrasound imaging (guest lecture)
10	Wed 2022-04-27	10.15-12.00	Nuclear physics
	Thu 2022-04-28	23.59	Deadline homework 3
11	Tue 2022-05-03	10.15-12.00	Magnetic resonance imaging (guest lecture)

12	Wed 2022-05-04	10.15-12.00	Nuclear medicine imaging
	Thu 2022-05-05	23.59	Deadline homework 4
13	Tue 2022-05-10	10.15-12.00	Nuclear medicine imaging (Continued)
14	Wed 2022-05-11	10.15-12.00	Student presentations; Rehearsal and exercises if time.
	Thu 2022-05-12	23.59	Deadline homework 5
	Thu 2022-05-19	23.59	Deadline homework 6
	Tue 2022-05-31	08.00-13.00	Exam
	Tue 2022-06-14	23.59	Deadline lab report

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 book 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. However, having access to the above book is not necessary since an alternative, multi-textbook reading list with material available through the KTH library is provided below.

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

[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)

Topic	Prince and Links (PL)	Multi-textbook reading list
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. (skip 7.A3-4 and 7.C6). (Alternatively, you can read BKVM ch1.2 instead of CSP ch. 6) CSP ch. 8.C and 10.A-B CSP ch. 11A 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) CSP ch. 16.A-C. (Alternatively, you can choose to read Hsieh Ch. 3: 3.1-3.4.2 instead of CSP ch. 16.C. If so, read 3.4.2 briefly up to fig 3.25 and skip the rest of the section.) CSP 19.B 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)

Nadine Barrie Smith, Andrew Webb, “Introduction to Medical Imaging” (Cambridge University Press, 2010)