

Fundamentals of Medical Imaging

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Information



Time: Monday & Wednesday, 3:00-4:40 pm, Week 1-16,

Location: 信息学院1B-110

Teacher: 郑锐

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Tel: 20684452

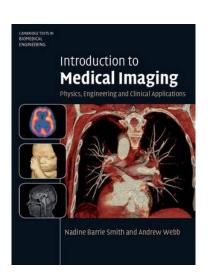
TA:刘安吉

Email: <u>liuaj@shanghaitech.edu.cn</u>

Platform: 互动教学平台

Textbook





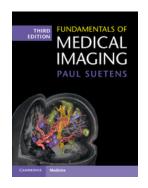
Introduction to Medical Imaging: Physics, Engineering and Clinical Applications

AUTHOR: Nadine Barrie Smith & Andrew Webb

PUBLISHER: Cambridge University Press (2010)

Reference book



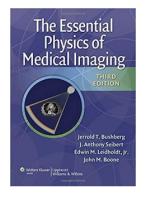


Fundamentals of Medical Imaging, 3rd Edition

AUTHOR: Paul Suetens

PUBLISHER: Cambridge University Press

(2017).



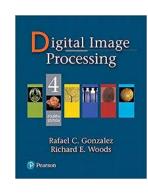
The Essential Physics of Medical Imaging, 3rd Edition

AUTHORS: Bushberg J. T., Seibert J. A.,

Leidholdt E. M. Jr., Boone J. M

PUBLISHER: Lippincott Williams & Wilkins

(2011)



Digital Image Processing, 4th edition

AUTHORS: Rafael C. Gonzalez &

Richard E. Woods

PUBLISHER: Pearson (2017)



医学影像成像理论 (第二版)

作者: 李月卿

出版社: 人民卫生出版社 (2010)

Schedule



1 9月13B Introduciton to Medical imaging 9月15B Image characteristics CH1.1-1.9 Due: 9/26	Week	Date	Topic	Reading Material	Homework	
2 9月20B Basics of Digital image processing DIP CH2.4, CH2.6 9月22B X-ray physics, Radioactivity CH2.1-2.5 3 9月27B Instrumentation and Characteristics of Radiography CH2.6-2.8 9月29B X-ray Imaging application CH2.9-2.11 4 10月4B Image Reconstruction Algorithm CH2.14, DIP CH5.11 5 10月1B CT Instrumentation CH2.12-2.13, 2.15 10月1B Test 1 / invited talk CH3.1-3.5 10月20B Introduction to Nuclear Medicine CH3.1-3.5 10月27B SPECT, Image characteristics CH3.7-3.9 Due: 11/7 8 11月1B PET/CT CH3.13-3.21 11月3B Radiation Biology and protection PET/CT CH4.1-4.4 11月10B Ultrasound Physics CH4.1-4.4 11月17B Apllication of Ultrasound CH4.11 11 11月22B Test 2 / invited talk Test 2 / invited talk 11月21B Magnetic resonance CH5.1-5.4 12 11月29B Relaxation time CH5.5-5.7 12月1B MRI Image Acquistion MRI Sequence CH5.11-5.13 12月6B MRI Instrumenation CH5.17-5.23 12月20B Test 3 / invited talk Test 2 / Invited talk Test 2 / Invited talk CH5.17-5.23 12月20B Test 3 / invited talk Test 2 / Invited talk	1	9月13日	Introduciton to Medical imaging			
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3			Basics of Digital image processing DIP CH2.4, CH2.6		Due. 9/20	
9月29B X-ray Imaging application CH2.9-2.11 10月4B Image Reconstruction Algorithm CH2.14, DIP CH5.11 10月1B CT Instrumentation CH2.12-2.13, 2.15 10月1B Clinical application of CT CH2.16-2.18 10月20B Introduction to Nuclear Medicine CH3.1-3.5 10月27B SPECT, Image characteristics CH3.7-3.9 Due: 11/7 10月27B SPECT, Image characteristics CH3.13-3.21 11月3B Radiation Biology and protection PET/CT CH3.13-3.21 11月3B Radiation Biology and protection PI1月3B Ultrasound Physics CH4.1-4.4 11月10B Ultrasound Instrumentation CH4.5-4.7 11月17B Application of Ultrasound CH4.11 11月182B Test 2 / invited talk CH4.11 11月29B Relaxation time CH5.1-5.4 12 11月29B Relaxation time CH5.5-5.7 12月1B MRI Image Acquisition CH5.14-5.16 14 12月13B Image Characteristics and Aplication of MRI CH5.17-5.23 12月28B MRI Instrumenation CH5.17-5.23 12月29B Test 3 / invited talk CH5.17-5.23 12月29B Project presentation Project presentat			X-ray physics, Radioactivity	CH2.1-2.5		
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10月6B		9月29日	X-ray Imaging application	CH2.9-2.11		
5 10月11日 CT Instrumentation CH2.12-2.13, 2.15 10月13日 Clinical application of CT CH2.16-2.18 6 10月18日 Test 1 / invited talk CH2.16-2.18 10月20日 Introduction to Nuclear Medicine CH3.1-3.5 7 10月25日 Gamma Camera CH3.6 10月27日 SPECT, Image characteristics CH3.7-3.9 Due: 11/7 8 11月1B PET/CT CH3.13-3.21 9 11月3B Radiation Biology and protection CH4.1-4.4 9 11月8B Ultrasound Physics CH4.1-4.4 11月10B Ultrasound Instrumentation CH4.5-4.7 10 11月15B Ultrasound Image Characteristics CH4.8-4.10 11月17B Apllication of Ultrasound CH4.11 11 11月24B Magnetic resonance CH5.1-5.4 12 11月24B Magnetic resonance CH5.5-5.7 12月1B MRI Image Acquistion CH5.8-5.10 Due: 12/19 13 12月6B MRI Instrumenation CH5.14-5.16 14	4		Image Reconstruction Algorithm CH2.14, DIP CH5.11		Due: 10/17	
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9 11月8日 Ultrasound Physics CH4.1-4.4 Lead of the project of project or project of project or	8	11月1日	PET/CT	CH3.13-3.21		
11月10日 Ultrasound Instrumentation CH4.5-4.7 10		11月3日	Radiation Biology and protection			
10	9	11月8日	Ultrasound Physics	CH4.1-4.4		
10		11月10日	Ultrasound Instrumentation	CH4.5-4.7	D 11/21	
11月17日 Apllication of Ultrasound CH4.11	10		Ultrasound Image Characteristics	CH4.8-4.10	Due: 11/21	
11月24日 Magnetic resonance CH5.1-5.4 12		11月17日		CH4.11		
12	11	11月22日	Test 2 / invited talk			
12月1日MRI Image AcquistionCH5.8-5.101312月6日MRI sequenceCH5.11-5.1312月8日MRI InstrumenationCH5.14-5.161412月13日Image Characteristics and Apllication of MRICH5.17-5.2312月15日Medical image computing & visualizationFMI CH7-81512月20日Test 3 / invited talkTest 3 / invited talk1612月27日Project presentation		11月24日	Magnetic resonance	CH5.1-5.4		
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12月22日 TBD 16 12月27日 Project presentation	15	12月20日				
16 12月27日 Project presentation			TBD			
12月29日 Project presentation	16	12月27日	Drainst presentation			
		12月29日	Project presentation			

Assessment



Homework (30%)

- 5 assignments (1st-4th: 5%, 5th: 10%);
- Handwriting or Hard copy;
- Only half score is counted if not submitting before due date; No score if not submitting at all.
- ➤ Quiz (5%): missing twice -2%; missing more than twice : -5%
- > **Test (30%):** 3 times, 10% for each;
- Project (35%)
 - Content: Literature review on a specific subject related to medical imaging;
 - Group of maximum 3 persons
 - Group presentation: PPT in English, present in Chinese or English.
 - Group project report (English): in the format of IEEE transaction, minimum 5000 words and 50 references.
 - Score requirement (以100分计)
 - ✓ Presentation (30分): 思路清晰, 重点明确, 按时完成;
 - ✔ Q&A (10分): 正确回答问题, 条理清楚;
 - ✔ Report (60分): 问题阐述明确, 内容完整, 逻辑通顺, 格式正确;
 - ✓ Submission package: PPT and Report;
 - ✓ 截止时间: Abstract (Before Nov. 21st), Final package (Jan 2, 2022)。无特殊情况逾期,24小时内扣20%分,24小时以外扣除50%分,未交则该project计0分。



Lecture 1 - Introduction

This lecture will cover:

- What is Medical Imaging?
- History of Medical Imaging
- Medical Imaging Modalities
- Contents of the course
- Fundamentals of medical diagnosis



What is Medical Imaging



Medical Imaging

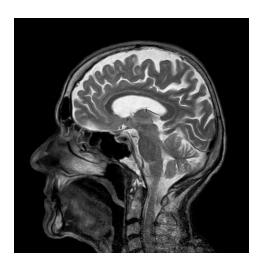


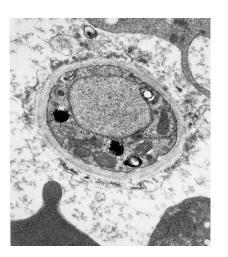
- Medical visual representation of human in multi-modality and multi-dimension
 - Revealing internal structures of a body (anatomy)
 - Visual representation of the function of some organs or tissues (physiology).

> Goals

- Clinical analysis (Diagnosis)
- Medical intervention (Treatment)
- Establishing a database of normal anatomy and physiology to make it possible to identify abnormalities.







History





radiography





CT+MRI, PET+MRI (Gen. Electric, 2010)

Endoscopic capsule

(Given Imaging, 2001)

(A. Cormack, G. Hounsfield, 1972) MRI tomography (P. Lauterbur, P. Mansfield, 1973 angiography ultrasonography since 80ties) (E. Moniz, 1927) (I. Edler, C. Hertz, 1953) (J. Hall-Edwards, 1896)

CT tomography

PET tomography

(M. Ter-Pogossian et.al., 1973)

endoscopy Thermography (since 60thies, XX c.) (B. Hirschowitz, since 70ties)











Categories



Imaging content

- **➤** Biomedical micro-imaging
 - ✓ Scanning Electron Microscope (SEM)
 - ✓ Optical microscope

➤ Medical imaging

- ✓ Radioactive: X ray, CT, Nuclear medicine, PET, SPECT
- ✓ Non-radioactive: MRI, Ultrasound, Thermography, Photoacoustic

Functional and Anatomical





Imaging modalities	2D	3D	Other technology
X-ray	Planar radiography	СТ	Angiography, fluoroscopy,
Nuclear medicine	Gamma camera	SPECT, PET/TOF PET	
MRI		MRI	fMRI
Ultrasound	B-mode, M-mode,	Multi-dimension arrays	Doppler ultrasound

Content



What we will learn?

- ✓ Imaging physics and theory
- ✓ Imaging instrumentation
- ✓ Imaging characteristics
- ✓ Application of different image modalities

What we won't learn

- x Electronic signal acquisition --- 电路基础,模拟数字电路
- × Signal processing --- 信号与系统,数字信号处理
- × Image analysis --- 数字图像处理、计算机图形学、计算机视觉、机器学习、深度学习
- X Medical diagnosis

Knowledge & Requirement



Involved knowledge

- Physics
- Mathematics
- System and signals analysis
- Anatomy and Physiology

Learning outcome

- Understanding the principles of various medical imaging techniques.
- Computing parameters for each imaging modality such as resolution, signal to noise ratio.
- Evaluating data sets from different devices
- Evaluating and analyzing image properties
- Discussing how a specific imaging modality can relate to an imaging scenario in the body.
- Quality control and Health protection

Fundamentals



- ➤ Diagnostic Test (Reference: CH1.2)
 - Binary Classification
 - Sensitivity and Specificity
 - ROC Curve
- Anatomical Planes





		True Condition (真实值)		
		Positive (阳性)	Negative (阴性)	
Predicted	Positive	True Positive (TP)	False Positive (FP)	
Condition	(阳性)	真阳性	伪阳性	
(预测值)	Negative	False Negative (FN)	True Negative (TN)	
	(阴性)	伪阴性	真阴性	

Contingency Table (列联表)



		True cor				
	Total population	Condition positive	Condition negative	Prevalence = $\frac{\Sigma \text{ Condition positive}}{\Sigma \text{ Total population}}$	Accuracy (A Σ True positive + Σ Σ Total popu	True negative
Predicted condition	Predicted condition positive	True positive, Power	False positive, Type I error	Positive predictive value (PPV), Precision = Σ True positive Σ Predicted condition positive	False discovery rate (FDR) = Σ False positive Σ Predicted condition positive	
	Predicted condition negative	False negative, Type II error	True negative	False omission rate (FOR) = $\frac{\Sigma \text{ False negative}}{\Sigma \text{ Predicted condition negative}}$	Negative predictive value (NPV) = Σ True negative Σ Predicted condition negative	
		True positive rate (TPR), Recall, Sensitivity, probability of detection $= \frac{\Sigma \text{ True positive}}{\Sigma \text{ Condition positive}}$	False positive rate (FPR), Fall-out, probability of false alarm $= \frac{\sum False\ positive}{\sum Condition\ negative}$	Positive likelihood ratio (LR+) = TPR FPR	Diagnostic odds ratio (DOR)	F ₁ score =
		False negative rate (FNR), Miss rate $= \frac{\Sigma \text{ False negative}}{\Sigma \text{ Condition positive}}$	Specificity (SPC), Selectivity, True negative rate (TNR) $= \frac{\Sigma \text{ True negative}}{\Sigma \text{ Condition negative}}$	Negative likelihood ratio (LR-) = FNR TNR	$= \frac{LR+}{LR-}$	1 + 1 Recall + Precision 2





• Sensitivity (敏感性) or True Positive Rate

Sensitivity =
$$\frac{TP}{TP + FN}$$

• Specificity (特异性) or True Negative Rate

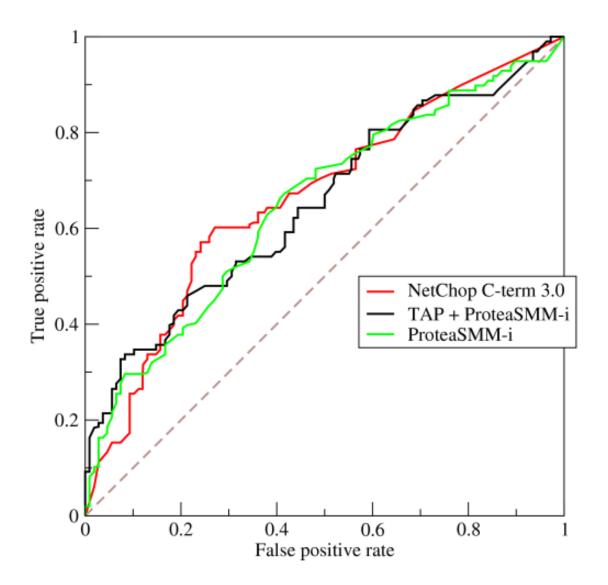
Specificity =
$$\frac{TN}{TN + FP}$$

ROC Curve



Receiver
Operating
Characteristic
(ROC) Curve

(受试者操作特性 曲线)



Anatomical Planes



