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

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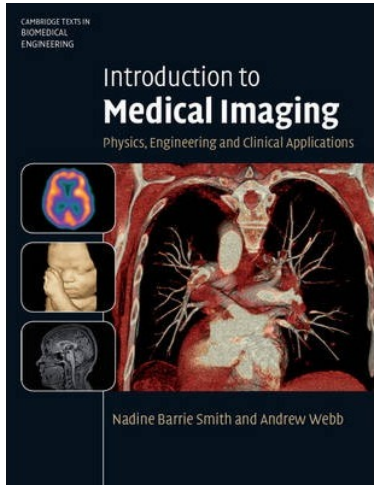
Platform: 互动教学平台

Textbook

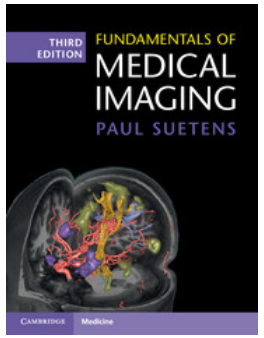


Introduction to Medical Imaging: Physics, Engineering and Clinical Applications

AUTHOR: Nadine Barrie Smith & Andrew Webb

PUBLISHER: Cambridge University Press (2010)

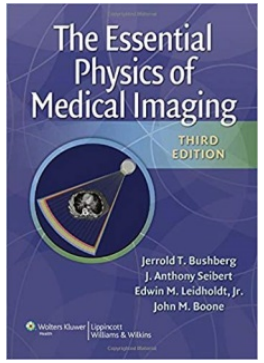
Reference book



Fundamentals of Medical Imaging, 3rd Edition

AUTHOR: Paul Suetens

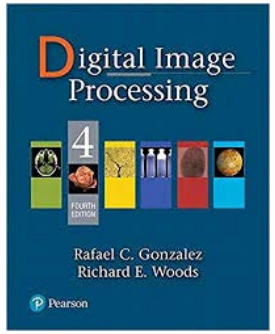
PUBLISHER: Cambridge University Press (2017).



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

Week	Date	Topic	Reading Material	Homework
1	9月13日	Introduciton to Medical imaging		Due: 9/26
	9月15日	Image characteristics	CH1.1-1.9	
2	9月20日	Basics of Digital image processing	DIP CH2.4, CH2.6	
	9月22日	X-ray physics, Radioactivity	CH2.1-2.5	
3	9月27日	Instrumentation and Characteristics of Radiography	CH2.6-2.8	Due: 10/17
	9月29日	X-ray Imaging application	CH2.9-2.11	
4	10月4日	Image Reconstruction Algorithm	CH2.14, DIP CH5.11	
	10月6日			
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		
	10月20日	Introduction to Nuclear Medicine	CH3.1-3.5	Due: 11/7
7	10月25日	Gamma Camera	CH3.6	
	10月27日	SPECT, Image characteristics	CH3.7-3.9	
8	11月1日	PET/CT	CH3.13-3.21	
	11月3日	Radiation Biology and protection		
9	11月8日	Ultrasound Physics	CH4.1-4.4	Due: 11/21
	11月10日	Ultrasound Instrumentation	CH4.5-4.7	
10	11月15日	Ultrasound Image Characteristics	CH4.8-4.10	
	11月17日	Apllication of Ultrasound	CH4.11	
11	11月22日	Test 2 / invited talk		
	11月24日	Magnetic resonance	CH5.1-5.4	Due: 12/19
12	11月29日	Relaxation time	CH5.5-5.7	
	12月1日	MRI Image Acquistion	CH5.8-5.10	
13	12月6日	MRI sequence	CH5.11-5.13	
	12月8日	MRI Instrumenation	CH5.14-5.16	
14	12月13日	Image Characteristics and Apllication of MRI	CH5.17-5.23	
	12月15日	Medical image computing & visualization	FMI CH7-8	
15	12月20日	Test 3 / invited talk		
	12月22日	TBD		
16	12月27日	Project presentation		
	12月29日			

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

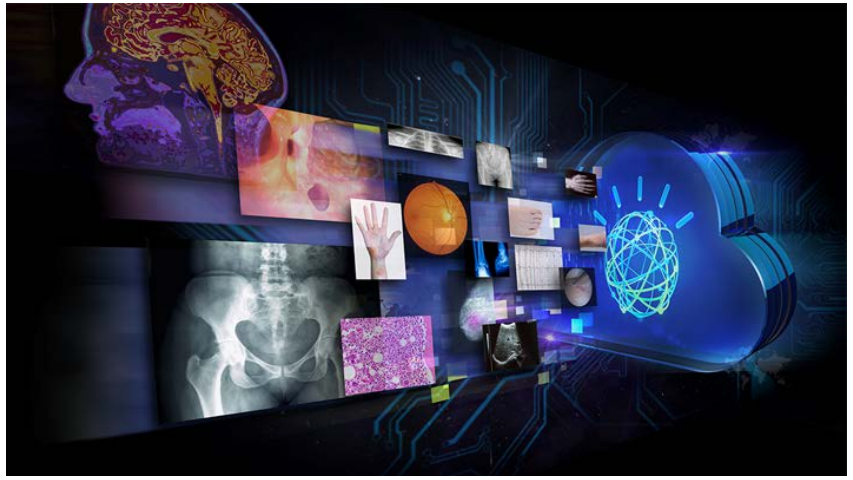
This lecture will cover:

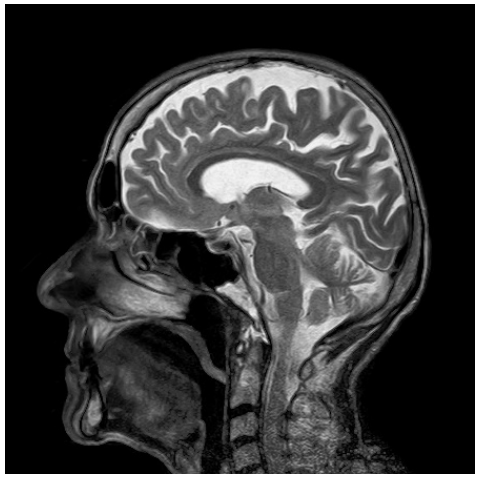
- What is Medical Imaging?
- History of Medical Imaging
- Medical Imaging Modalities
- Contents of the course
- Fundamentals of medical diagnosis

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

CT tomography
(A. Cormack, G. Hounsfield, 1972)

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

MRI tomography
(P. Lauterbur, P. Mansfield, 1973
since 80ties)

angiography
(E. Moniz, 1927)

ultrasonography
(I. Edler, C. Hertz, 1953)

radiography
(J. Hall-Edwards, 1896)

Endoscopic capsule
(Given Imaging, 2001)

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

Thermography
(since 60thies, XX c.)

endoscopy
(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**

Comparison of Imaging modalities

Imaging modalities	2D	3D	Other technology
X-ray	Planar radiography	CT	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
- x Signal processing --- 信号与系统，数字信号处理
- x 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**

Binary Classification (二元分类)

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

Contingency Table (列联表)

		True condition				
	Total population	Condition positive	Condition negative	Prevalence = $\frac{\Sigma \text{ Condition positive}}{\Sigma \text{ Total population}}$	Accuracy (ACC) = $\frac{\Sigma \text{ True positive} + \Sigma \text{ True negative}}{\Sigma \text{ Total population}}$	
Predicted condition	Predicted condition positive	**True positive**, Power	**False positive**, Type I error	Positive predictive value (PPV), Precision = $\frac{\Sigma \text{ True positive}}{\Sigma \text{ Predicted condition positive}}$	False discovery rate (FDR) = $\frac{\Sigma \text{ False positive}}{\Sigma \text{ Predicted condition positive}}$	
	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) = $\frac{\Sigma \text{ True negative}}{\Sigma \text{ Predicted condition negative}}$	
		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 = $\frac{\Sigma \text{ False positive}}{\Sigma \text{ Condition negative}}$	Positive likelihood ratio (LR+) = $\frac{\text{TPR}}{\text{FPR}}$	Diagnostic odds ratio (DOR) = $\frac{\text{LR+}}{\text{LR−}}$	F_1 score = $\frac{1}{\frac{1}{\text{Recall}} + \frac{1}{\text{Precision}}}{2}$
		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−) = $\frac{\text{FNR}}{\text{TNR}}$		

https://en.wikipedia.org/wiki/Receiver_operating_characteristic#Curves_in_ROC_space

Sensitivity and Specificity

- **Sensitivity (敏感性) or True Positive Rate**

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

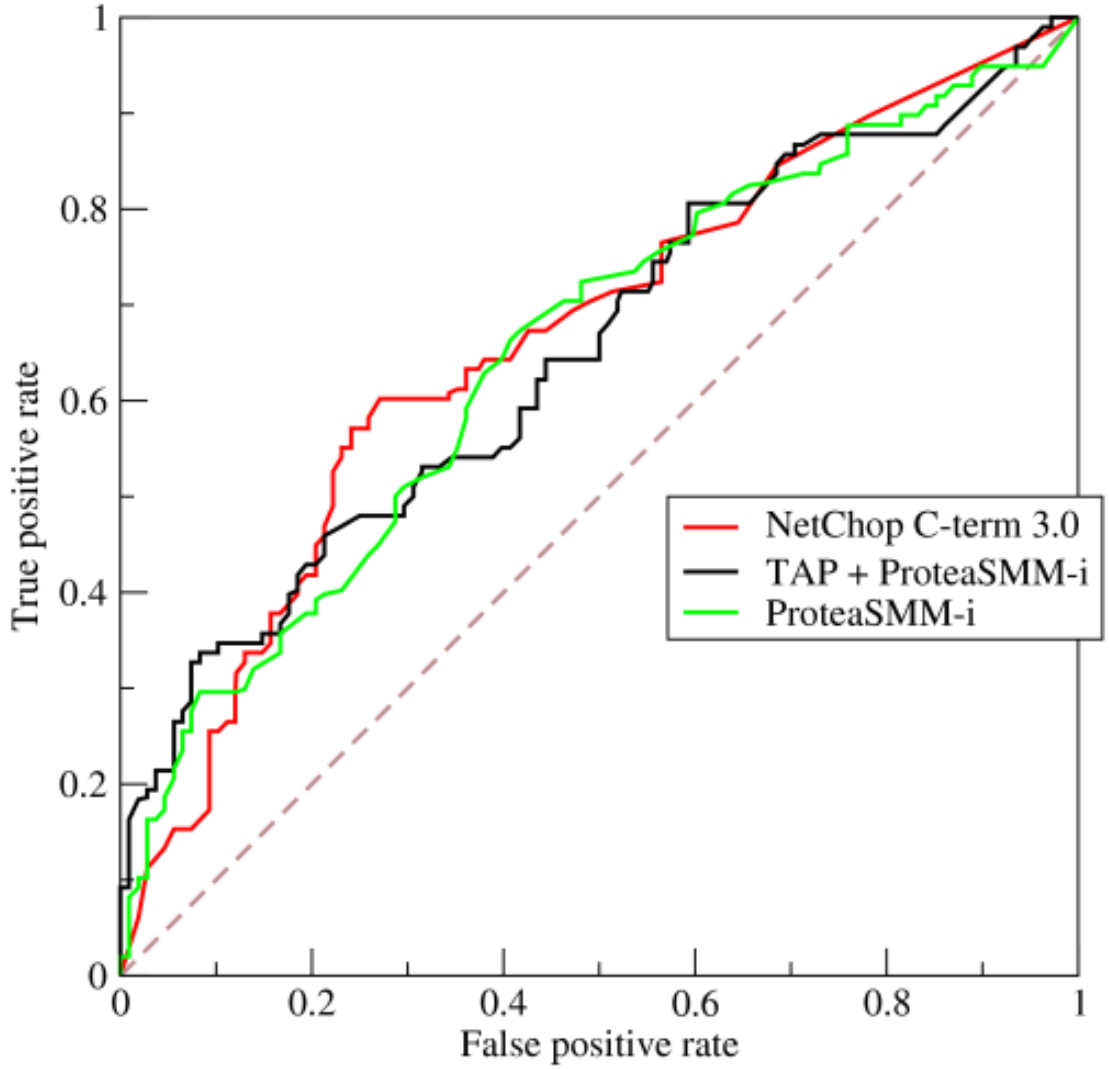
- **Specificity (特异性) or True Negative Rate**

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

ROC Curve

Receiver Operating Characteristic (ROC) Curve

(受试者操作特性曲线)



Anatomical Planes