



# 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

Email: [zhengrui@shanghaitech.edu.cn](mailto:zhengrui@shanghaitech.edu.cn)

Office: 信息学院3号楼426

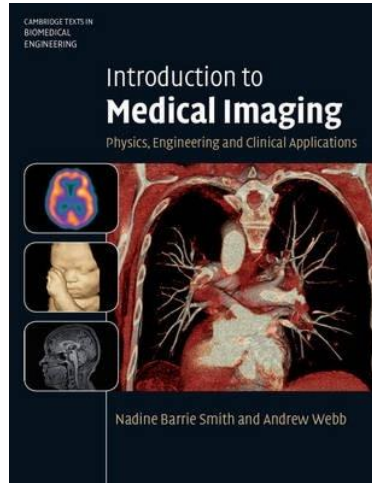
Tel: 20684452

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Platform: 互动教学平台

# Textbook

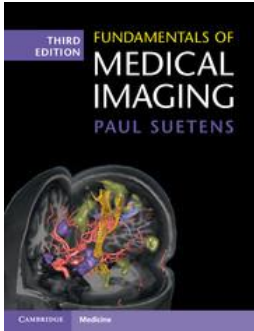


## Introduction to Medical Imaging: Physics, Engineering and Clinical Applications

AUTHOR: Nadine Barrie Smith & Andrew Webb

PUBLISHER: Cambridge University Press (2010)

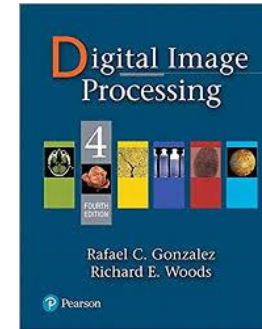
# Reference book



## Fundamentals of Medical Imaging, 3rd Edition

AUTHOR: Paul Suetens

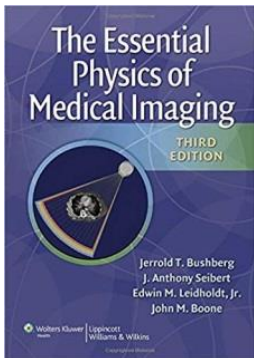
PUBLISHER: Cambridge University Press (2017).



## Digital Image Processing, 4th edition

AUTHORS: Rafael C. Gonzalez & Richard E. Woods

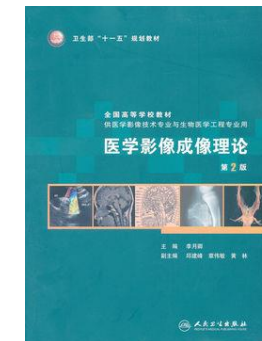
PUBLISHER: Pearson (2017)



## 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)



## 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5日	Introducton to Medical imaging		Due: 9/25
	9月7日	Image characteristics	CH1.1-1.9	
2	9月12日	Holiday		
	9月14日	Basics of Digital image processing	DIP CH2.4, CH2.6	
3	9月19日	X-ray physics, Radioactivity	CH2.1-2.5	Due: 10/16
	9月21日	Instrumentation and Characteristics of Radiography	CH2.6-2.8	
4	9月26日	X-ray Imaging application	CH2.9-2.11	
	9月28日	Image Reconstruction Algorithm	CH2.14, DIP CH5.11	
5	10月3日	Holiday		
	10月5日			
	10月8日	CT Instrumentation	CH2.12-2.13, 2.15	Due: 10/30
6	10月10日	Clinical application of CT	CH2.16-2.18	
	10月12日	Introduction to Nuclear Medicine	CH3.1-3.5	
7	10月17日	Test 1: Fundamentals, X-ray and CT		
	10月19日	Gamma Camera	CH3.6	Due: 11/20
8	10月24日	SPECT, Image characteristics	CH3.7-3.9	
	10月26日	PET/CT	CH3.13-3.21	
9	10月31日	Radiation Biology and protection		Due: 12/11
	11月2日	Ultrasound Physics	CH4.1-4.4	
10	11月7日	Ultrasound Instrumentation	CH4.5-4.7	
	11月9日	Ultrasound Image Characteristics	CH4.8-4.10	
11	11月14日	Applcation of Ultrasound	CH4.11	Due: 12/11
	11月16日	Magnetic resonance	CH5.1-5.4	
12	11月21日	Test 2: Neclear medicine & Ultrasound		
	11月23日	Relaxation time	CH5.5-5.7	
13	11月28日	MRI Image Acquistion	CH5.8-5.10	Due: 12/11
	11月30日	MRI sequence	CH5.11-5.13	
14	12月5日	MRI Instrumenation	CH5.14-5.16	
	12月7日	Image Characteristics and Applcation of MRI	CH5.17-5.23	
15	12月12日	Medical image computing & visualization	FMI CH7-8	
	12月14日	Test 3: MRI		
16	12月19日	Project presentation		
	12月21日			

# Assessment

## ➤ Homework (30%)

- 5 assignments (1<sup>st</sup>-4<sup>th</sup> : 5%, 5<sup>th</sup>: 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. 13th), Final package (Dec 25th, 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



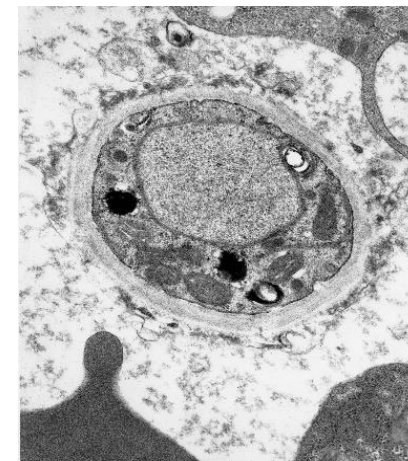
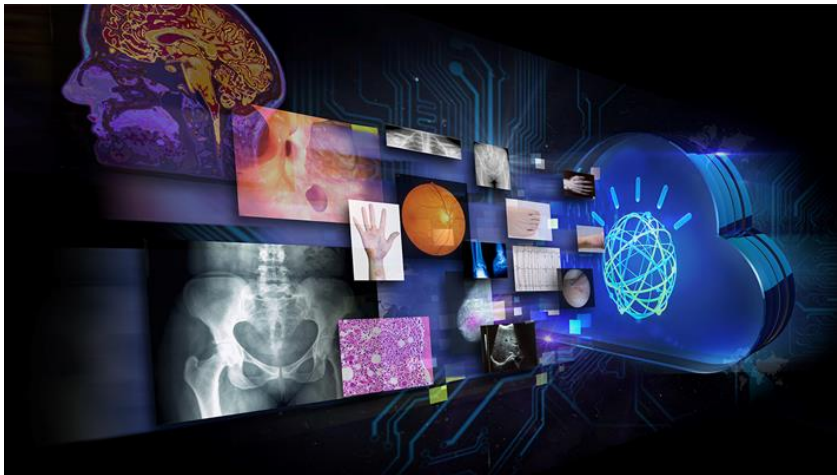
# What is Medical Imaging



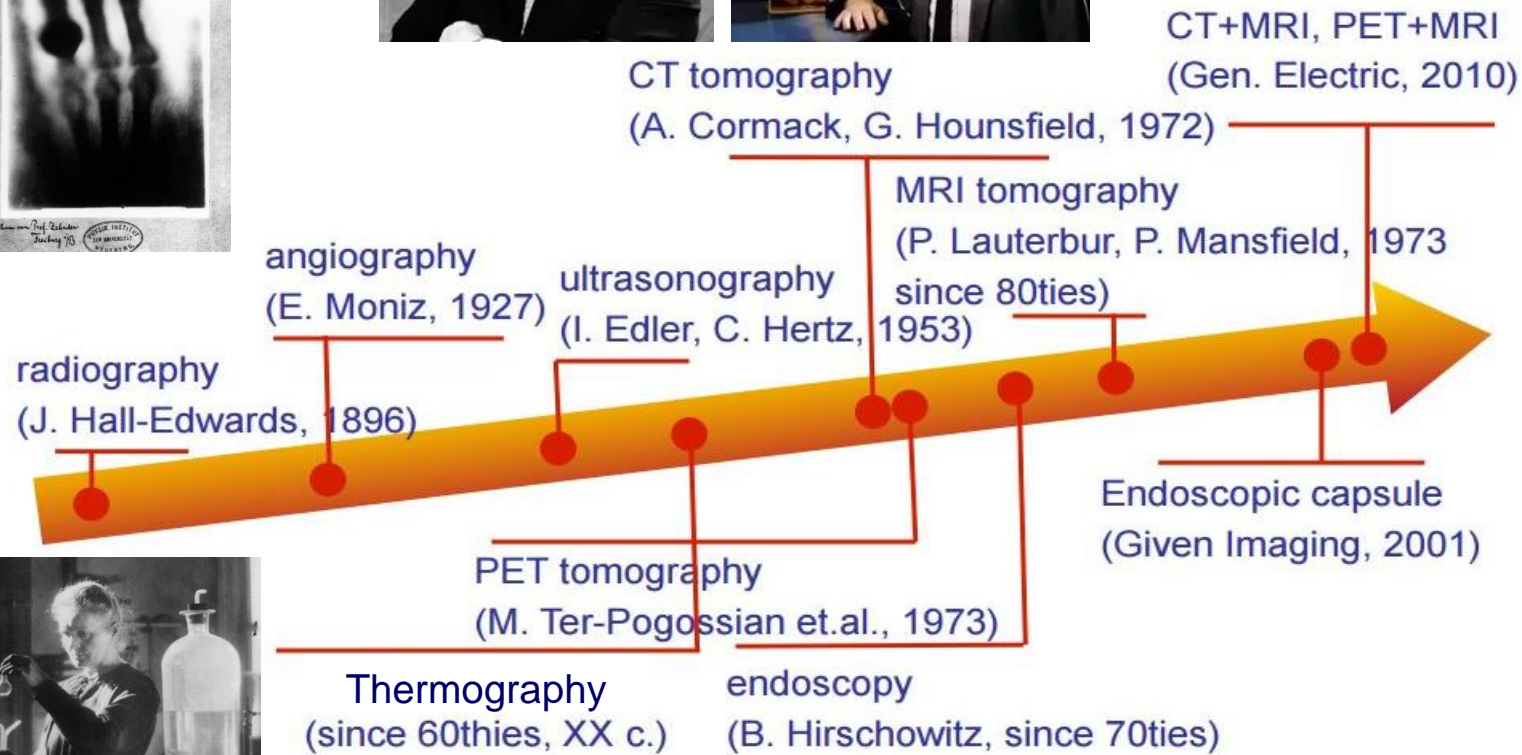
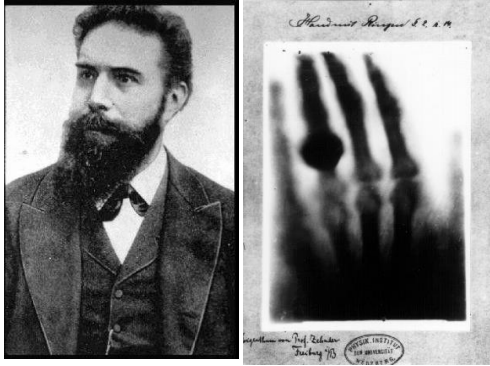


# Medical Imaging

- **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



# 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

- ✗ 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
- ✗ 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	<b>True positive</b> , Power	<b>False positive</b> , 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	<b>False negative</b> , Type II error	<b>True negative</b>	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) $= \frac{\text{LR+}}{\text{LR-}}$  $F_1 \text{ score} = \frac{1}{\frac{1}{\text{Recall}} + \frac{1}{\text{Precision}}}$
		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-) $= \frac{\text{FNR}}{\text{TNR}}$	

# Sensitivity and Specificity

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

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

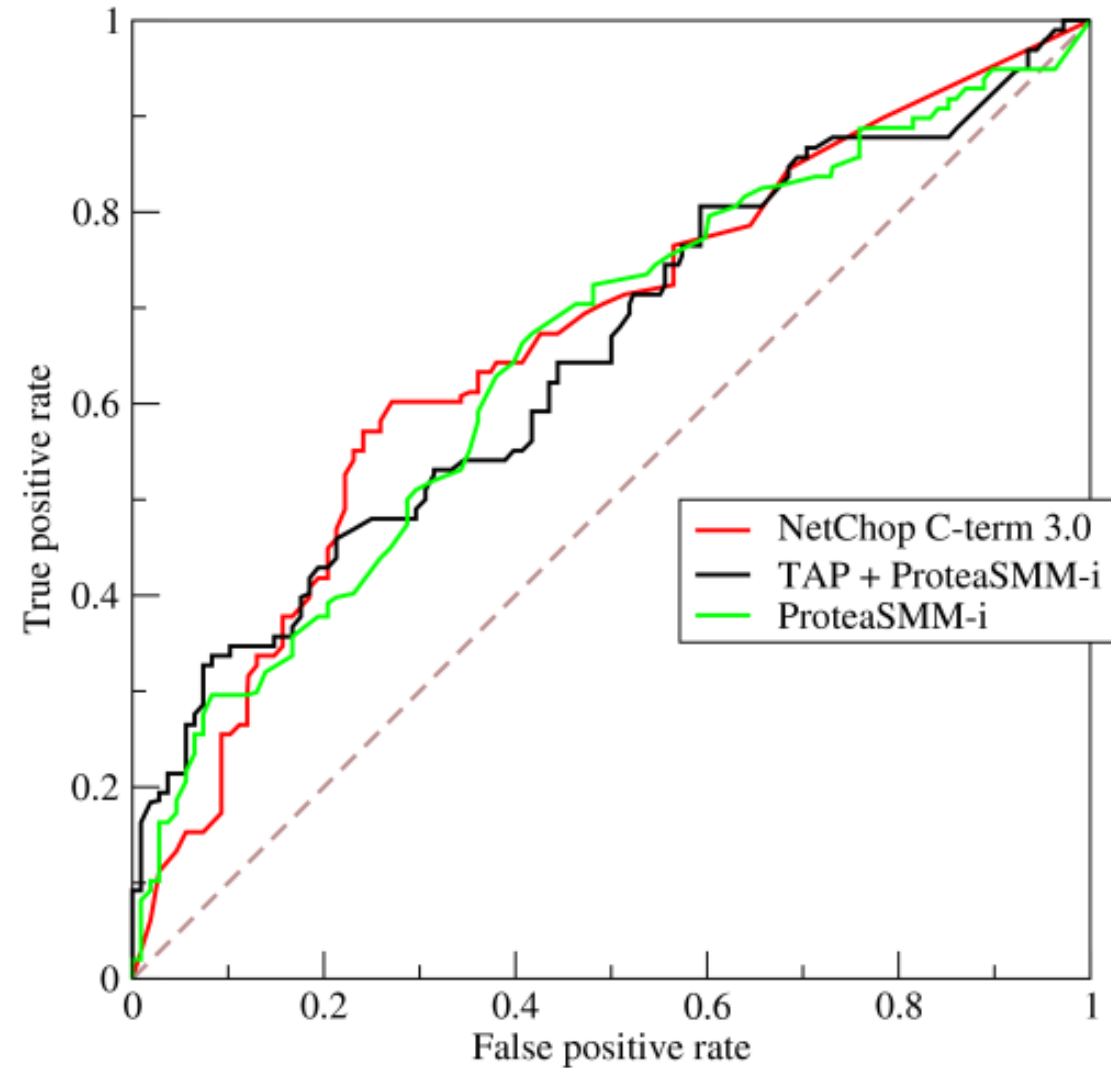
- **Specificity (特异性) or True Negative Rate**

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

# ROC Curve

## Receiver Operating Characteristic (ROC) Curve

(受试者操作特性  
曲线)



# Anatomical Planes

