

# Diagnostic Medical Image Processing

## Introduction

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# Diagnostic Medical Image Processing

- 1 Can we shift the time for the lecture?  
*No, but lectures will be recorded and the files (both slides and videos) can be downloaded from the web.*
- 2 Is *Diagnostic Medical Image Processing* required to attend part 2 (IMIP)?  
*Yes, but if you are highly motivated it should be no problem to follow IMIP without having attended DMIP.*
- 3 Do I need to know Matlab or Octave?  
*It is advantageous. We will provide a tutorial in the first hands-on-hardware session.*
- 4 Is there a book that covers the topics of the lecture?  
*Unfortunately not. It is in preparation.*



# Diagnostic Medical Image Processing

## 1 Introduction

- Topics of Diagnostic Medical Image Processing
  - Modalities for Medical Imaging
  - Morphologic Imaging
  - Molecular Imaging
  - Diagnostic Imaging
  - Interventional Imaging
  - Take Home Messages
  - Further Readings



# Diagnostic Medical Image Processing

Guidelines of the lectures on Diagnostic Medical Image Processing (DMIP):

- Be unique in its contents.
- Challenge, but do not overload students.
- Have tons of fun in learning and experimenting.
- Provide access to the cutting edge research in DMIP.
- Bring students closer to the lab and its research.



# Diagnostic Medical Image Processing

## Guidelines of the lectures on Diagnostic Medical Image Processing (DMIP):

- Introduce students to international, interdisciplinary and industry collaborations.
- Learn that the real hard problems, are real world problems.
- Find the right balance between algorithms, mathematics, physics and clinical applications.
- Do not only introduce theory and methods, but demonstrate the practical impact.
- Require students to read and to work through original research papers.



# Topics of Diagnostic Medical Image Processing

- A view into the human body is made possible by spies, like:
  - standard cameras
  - sound waves
  - attenuation
  - magnetism
- Medical Image Processing is a perfect (and sometimes difficult) combination of
  - physics,
  - mathematics,
  - computer science, and
  - engineeringstrongly tied to medicine and medical applications.

# Topics of Diagnostic Medical Image Processing



- All medical imaging approaches and systems heavily require physics for signal generation and detection.
- All modalities generate signals, and the signal processing and analysis is what all these share to a large extend.

**Note:** The lectures on Diagnostic Medical Image Processing focus on the algorithmic aspects the signal processing and analysis. The physics of medical imaging is not part of this course.

# Topics of Diagnostic Medical Image Processing



Diagnostic Medical Image Processing is mostly about methods and algorithms that are required for *diagnostic medical imaging*.

In detail we will discuss the following chapters that are the pillars of the whole course:

- 1 Different modalities in medical imaging
- 2 Acquisition specific image enhancement and pre-processing
- 3 Multiple images and reconstruction
- 4 Image registration and fusion



# Topics of Diagnostic Medical Image Processing



In addition to theory we offer to our students:

- 1 an insight in currently ongoing research projects at the LME
- 2 several exciting and highly motivating lectures given by leading physicians and collaborators of our local hospital
- 3 guided tour through several departments of our scientific partners in our university hospital:
  - Nuclear Medicine
  - Radiology
  - Eye Clinics
  - Imaging Science Institute (ISI) Erlangen
- 4 excursion to Siemens Medical Solutions



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SPECT  
PET

# Modalities for Medical Imaging



## Definition

In medical imaging we call any of the various types of scanners used to acquire images of the human body a **modality**. If we speak about modality in general terms, we just mean a medical image acquisition device.

## Definition

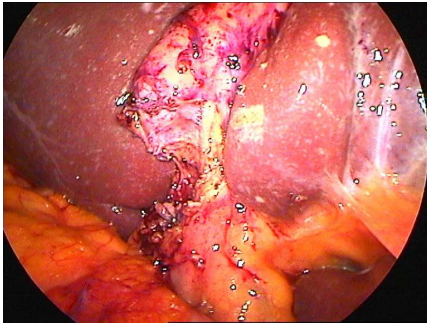
An image acquisition device that combines two or more modalities is called **hybrid scanner** or **hybrid system**.



# Modalities for Medical Imaging: Examples

The most commonly used modalities in medicine are:

- microscopes
- endoscopes



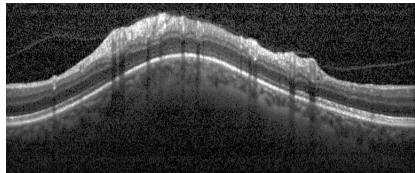
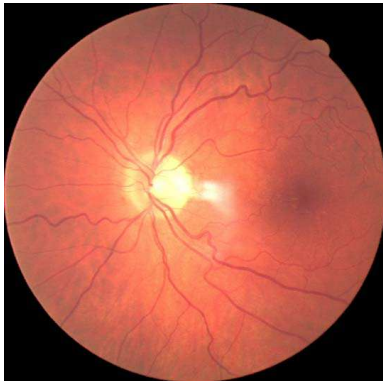
**Figure:** Endoscopic images (Florian Vogt, LME)



# Modalities for Medical Imaging: Examples

The most commonly used modalities in medicine are:

- cameras for retina imaging
- optical coherence tomography (OCT)



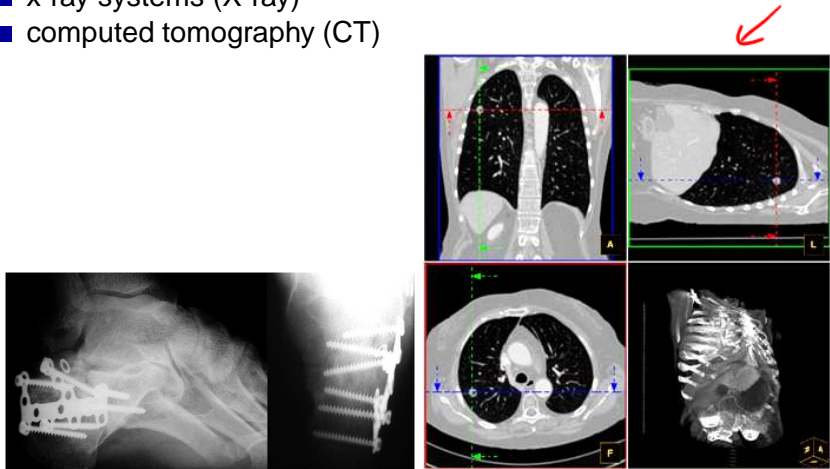
**Figure:** Retina images (Rüdiger Bock & Markus Mayer, LME)



# Modalities for Medical Imaging: Examples

The most commonly used modalities in medicine are:

- x-ray systems (X-ray)
- computed tomography (CT)



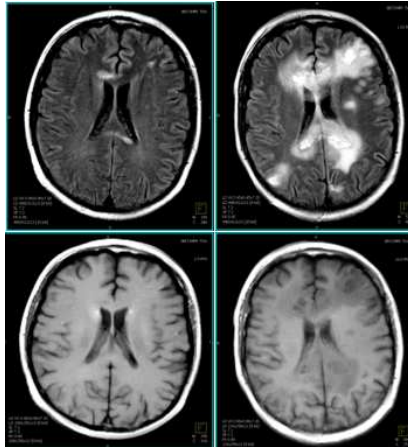
**Figure:** Images (Dieter Hahn, LME)



# Modalities for Medical Imaging: Examples

The most commonly used modalities in medicine are:

- magnetic resonance imaging (MRI)



**Figure:** Images (Dieter Hahn & Florian Jäger, LME)





# Modalities for Medical Imaging: Examples

The most commonly used modalities in medicine are:

- ultrasound systems (US)

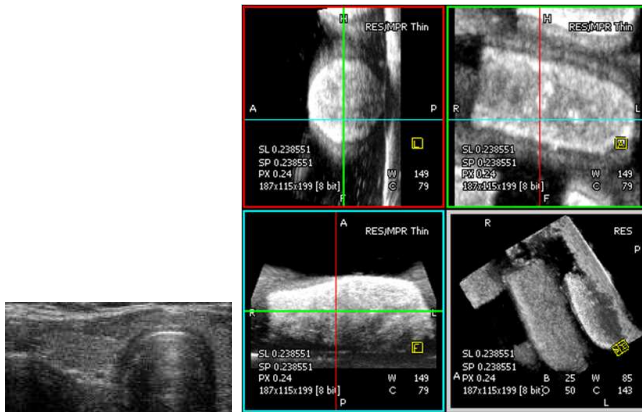


Figure: Images (Eva Kollorz, LME)

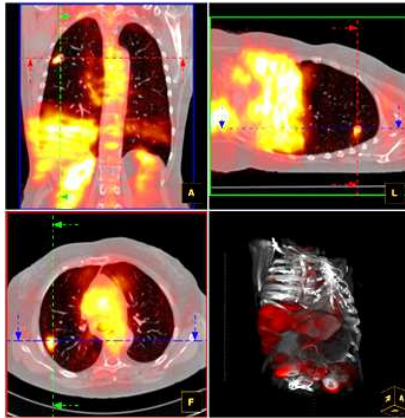




# Modalities for Medical Imaging: Examples

The most commonly used modalities in medicine are:

- single photon emission computed tomography (SPECT)
- positron emission tomography (PET)



nuclear medicine  
 ↗  
 nuclear med.  
 PET/CT  
 SPECT/CT

Figure: Images (Dieter Hahn, LME)



# Hybrid Scanners for Medical Imaging: Examples

The number of hybrid scanners on the market and in hospitals is increasing continuously. Themed to *get the best of everything*, modalities like PET-Scanners are no longer required as standalone systems but only in combination with morphologic imaging modalities, like CT.

Commercially available (or upcoming) hybrids are:

- 2-D/3-D endoscopy
- SPECT/CT scanner
- PET/CT scanner
- PET/MR scanner



**Figure:** First European installation of the SPECT/CT-Scanner in Erlangen (Image courtesy of Nuclear Medicine, Univ. Erlangen, Prof. Kuwert)



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# Morphologic Imaging

## Definition

***Morphologic imaging*** is about the imaging of the physical appearance of the inner human body like shape, structure or density.

Major modalities for morphologic imaging are:

- endoscopy
- X-ray
- computed tomography (CT)
- magnetic resonance (MR)
- ultrasound (US)



**Figure:** CT data set visualized with different volume rendering parameters (Image courtesy of Dr. Fishman, Baltimore)



# Morphologic Imaging

## Morphologic imaging

- ... requires to further increase spatial and contrast resolution.
- ... requires the minimization of artifacts caused, for instance, by respiratory motion.
- ... requires the development of new algorithms and methods for the reconstruction of moving objects like the heart or the thorax while breathing.

**Morphological imaging is still a highly demanding, innovative and challenging research field.**



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# Molecular Imaging



## Definition

Molecular imaging is about the imaging and visualization of processes and changes in the organism on the molecular level.

Major modalities used for molecular imaging are:

- positron emission tomography (PET)
- single ~~positron~~<sup>photon</sup> emission computed tomography (SPECT)
- functional magnetic resonance imaging (fMRI)



# Molecular Imaging

## Molecular imaging

- ... relies on concurrent advances in molecular medicine, nuclear medicine, chemistry, computer science, imaging science and engineering.
- ... allows for the imaging of cellular and molecular processes in vivo.
- ... is expected to serve as the connecting link between radiology and molecular medicine.

**Molecular imaging is considered as the initialization of the next revolution in medical imaging. Things in research and industry are a clear proof!**





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# Diagnostic Imaging



## Definition

The process of analyzing a disease by its symptoms and from the results of various measurements and images is called ***diagnosis***.

## Definition

***Diagnostic imaging*** includes the visualization of morphological structures or molecular processes of organs or tissues for the particular diagnostic evaluation.

# Diagnostic Imaging



## In diagnostic imaging

- ... the image acquisition is usually done by a technician and not by the treating physician.
- ... system parameters can be adjusted without high time pressure.
- ... short acquisition time is important but not crucial.
- ... a system crash is (usually) not life threatening.



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# Interventional Imaging

## Definition

In a ***medical intervention*** we apply methods to modify a health outcome.

## Definition

***Interventional imaging*** provides real-time imaging guidance to the physician to allow for an effective treatment.



# Interventional Imaging

## In interventional imaging

- ... the image acquisition is done while the patient gets treated.
- ... the image acquisition is usually done by the treating physician.
- ... the focus is on the patient, not on the system and its user interface.
- ... we have high demands on reliability, i.e. the loss of image information can be life threatening.
- ... real time image acquisition and processing is required that gets to the limit of current hardware performance.
- ... usually requires proprietary hardware accelerators.



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# Take Home Messages

- DMIP is an excellent choice and interdisciplinary
- you will learn a lot and you will have tons of fun.
- concept of imaging modality and hybrid scanners
- different categories resp. dimensions of imaging:
  - morphologic imaging
  - molecular imaging
  - diagnostic imaging
  - interventional imaging





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# Further Readings

- An introduction to the physics for medical imaging is given by the following books:
  - 1 David J. Dowsett, Patrick A. Kenny, and R. Eugene Johnston: The Physics of Diagnostic Imaging, 2nd edition, Hodder Arnold, London, 2006.
  - 2 Arnulf Opelt (Editor): Imaging Systems for Medical Diagnostics: Fundamentals, Technical Solutions and Applications for Systems Applying Ionizing Radiation, Nuclear Magnetic Resonance and Ultrasound, 2nd edition, Publicis, Erlangen, 2005.
- The mathematical details of medical imaging are described in:
  - 1 Charles L. Epstein: Mathematics of Medical Imaging, Prentice Hall, New York, 2003  
(<http://www.math.upenn.edu/~cle/notes/lec1-25.pdf>).