Medical Image Processing for Diagnostic Applications

Teaser – Course Introduction

Online Course – Unit 1

Andreas Maier, Joachim Hornegger, Markus Kowarschik, Frank Schebesch
Pattern Recognition Lab (CS 5)

virtuelle hochschule bayern

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Topics

Course Guidelines

Introduction

- Motivation for Medical Image Processing
- Topics of Medical Image Processing for Diagnostic Applications

Summary

- Take Home Messages
- Further Readings

Medical Image Processing for Diagnostic Applications

Guidelines of the course:

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

Medical Image Processing for Diagnostic Applications

Guidelines of the course:

- Introduce students to international, interdisciplinary, and industry collaborations.
- Learn that the really 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

Motivation for Medical Image Processing

- A view into the human body is made possible by “spies” like:
  - standard cameras,
  - sound waves,
  - radiation attenuation,
  - magnetism.
- Medical image processing is a perfect (and sometimes difficult) combination of
  - physics,
  - mathematics,
  - computer science, and
  - engineering,

  strongly tied to medicine and medical applications.

Motivation for Medical Image Processing

- All medical imaging approaches and systems require knowledge of physics for signal generation and detection.
- All modalities generate signals. Signal processing and analysis is a requirement what all of them share to a large extent.

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

Topics of Medical Image Processing for Diagnostic Applications

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

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

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

Topics

Take Home Messages

- This course is interdisciplinary and an excellent choice to learn about medical imaging.
- You will learn a lot and you will have tons of fun.

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 ed. London: Hodder Arnold, Apr. 2006. DOI: 10.1201/b13462-1
2. Arnulf Opelt, ed. *Imaging Systems for Medical Diagnostics: Fundamentals, Technical Solutions and Applications for Systems Applying Ionizing Radiation, Nuclear Magnetic Resonance and Ultrasound*. 2nd ed. Erlangen: Publicis, 2005

The mathematical details of medical imaging are described in:

Charles L. Epstein. *Mathematics of Medical Imaging*. Upper Saddle River, N.J.: Pearson Education/Prentice Hall, 2003

Medical Image Processing for Diagnostic Applications

Teaser – Modalities

Online Course – Unit 2

Andreas Maier, Joachim Hornegger, Markus Kowarschik, Frank Schebesch
Pattern Recognition Lab (CS 5)

virtuelle hochschule bayern

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Topics

Modalities for Medical Imaging

Definition

In medical imaging we call any of the various types of scanners used to acquire image signals of human organs 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***.

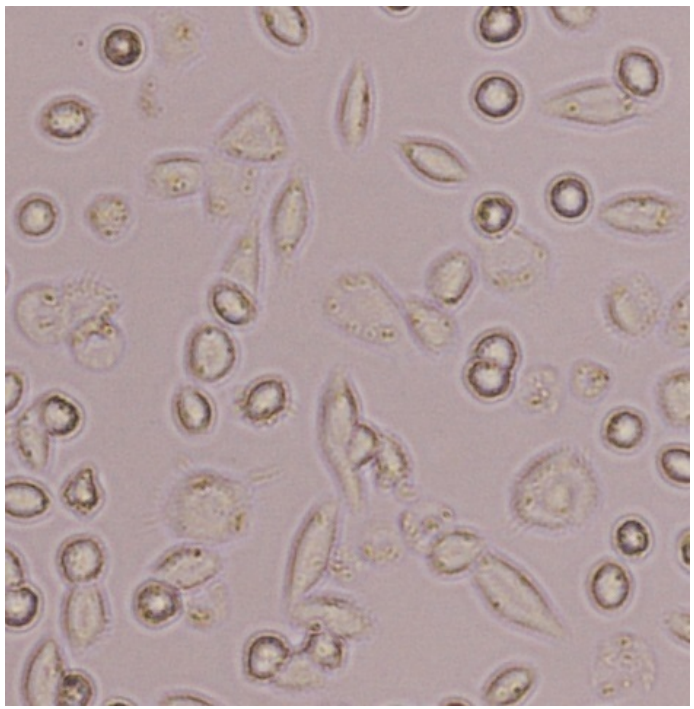
Modalities for Medical Imaging: Examples

The most commonly used modalities in medicine are:

- microscopes,
- endoscopes,
- cameras for retina imaging,
- optical coherence tomography (OCT),
- X-ray systems (X-ray),
- computed tomography (CT),
- magnetic resonance imaging (MRI),
- positron emission tomography (PET),
- single photon emission computed tomography (SPECT),
- ultrasound systems (US).

Modalities for Medical Imaging: Examples

Microscopes & endoscopes



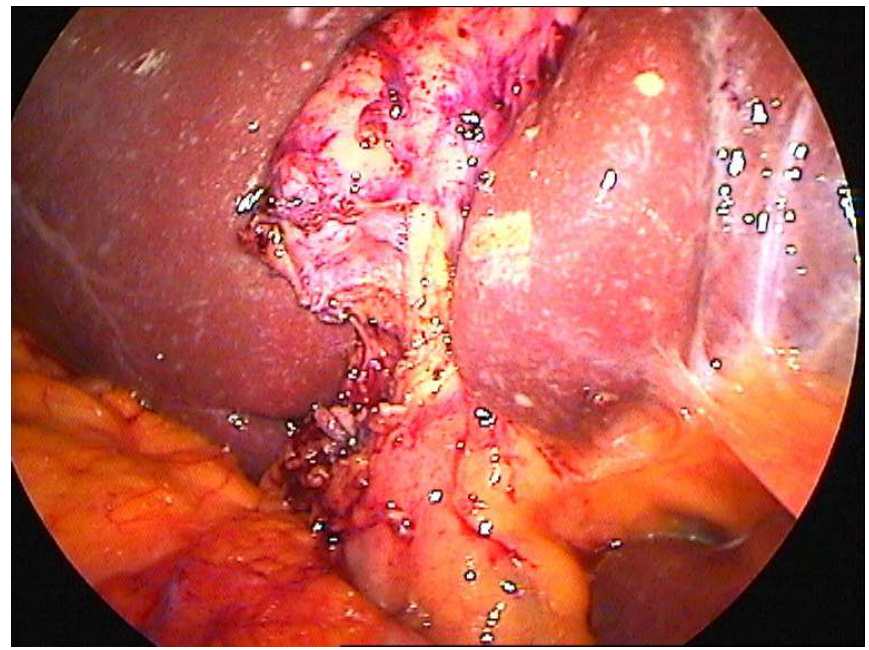


Figure 1: Microscopic and endoscopic images (Firas Mualla & Florian Vogt, Pattern Recognition Lab, FAU)

Modalities for Medical Imaging: Examples

Cameras for retina imaging & optical coherence tomography (OCT)

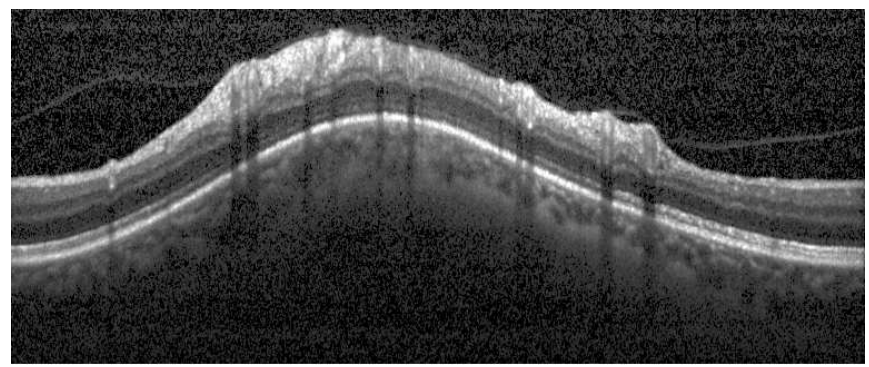


Figure 2: Retina images (Rüdiger Bock & Markus Mayer, Pattern Recognition Lab, FAU)

Modalities for Medical Imaging: Examples

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

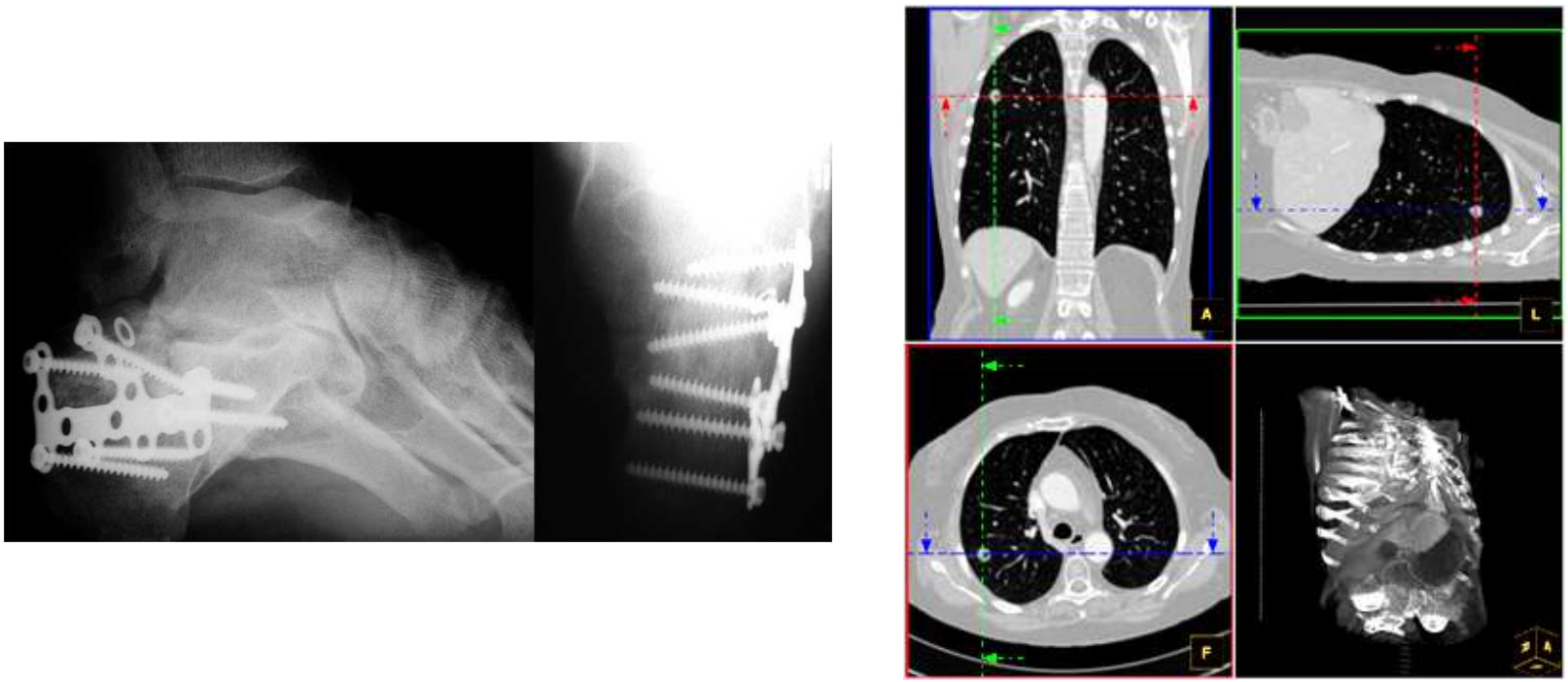
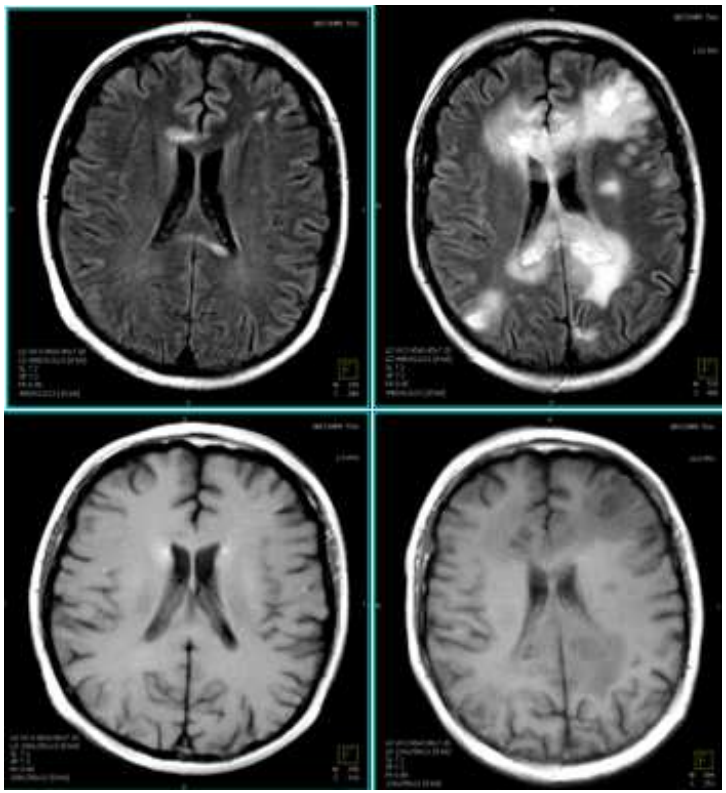


Figure 3: X-ray and CT images (Dieter Hahn, Pattern Recognition Lab, FAU)

Modalities for Medical Imaging: Examples

Magnetic resonance imaging (MRI)



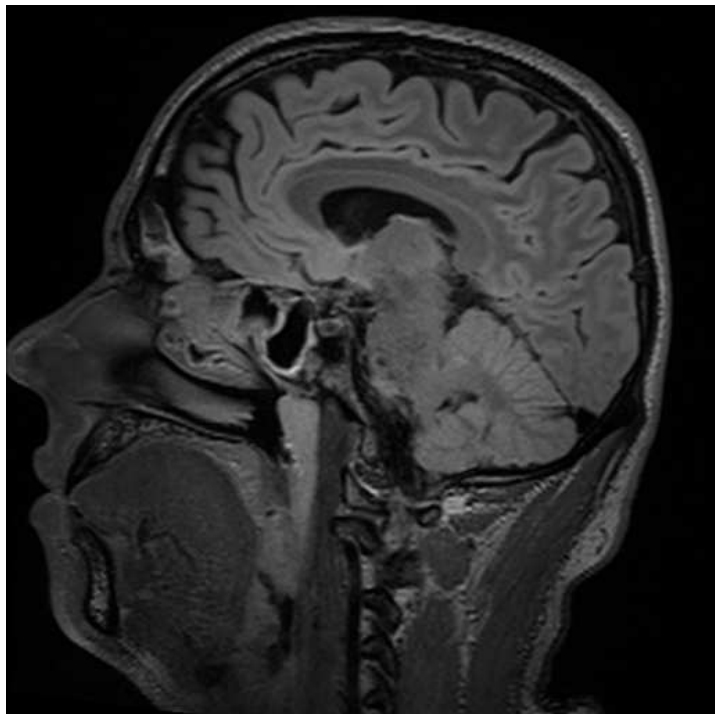


Figure 4: Brain MRIs (Links: Dieter Hahn & Florian Jäger, Pattern Recognition Lab, FAU)

Modalities for Medical Imaging: Examples

Single photon emission computed tomography (SPECT)
& positron emission tomography (PET)

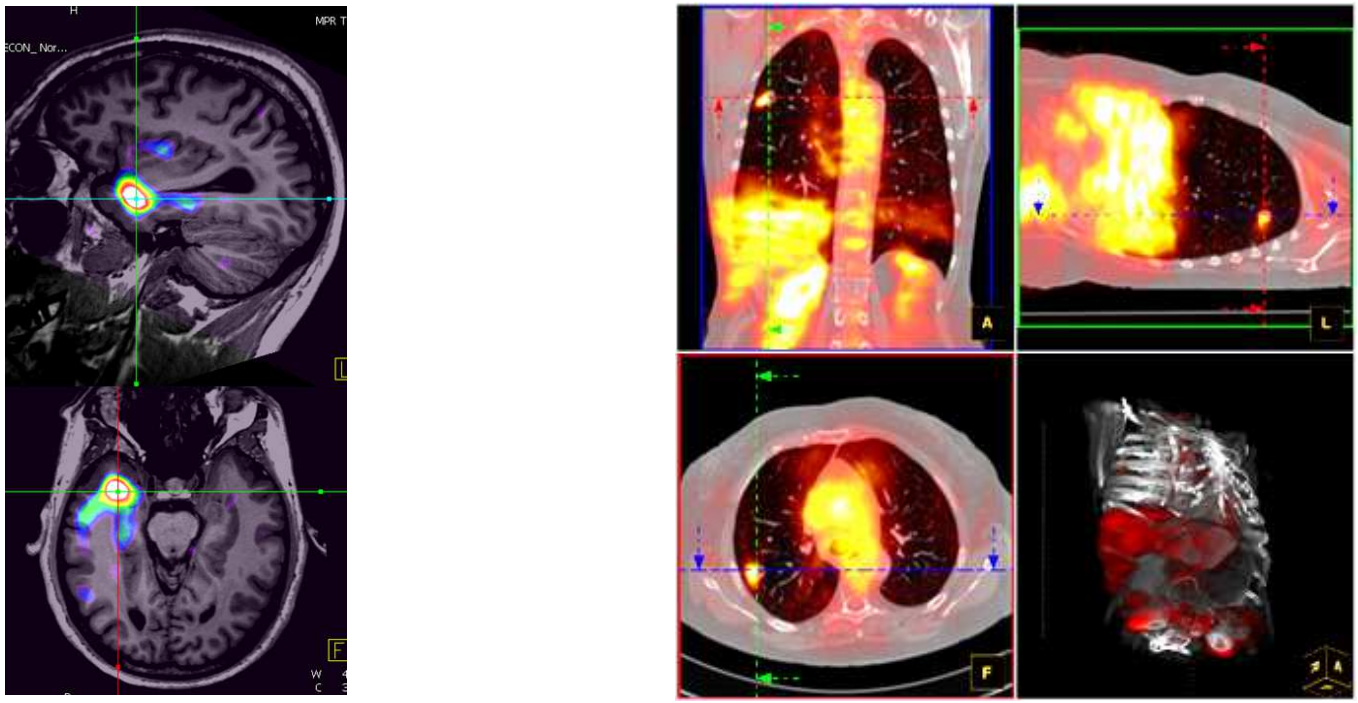
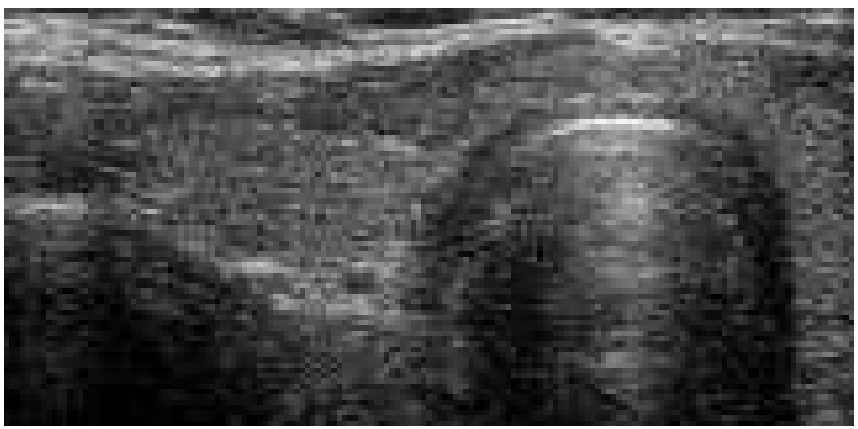


Figure 5: SPECT and PET overlays (James Sanders & Dieter Hahn, Pattern Recognition Lab, FAU)

Modalities for Medical Imaging: Examples

Ultrasound systems (US)



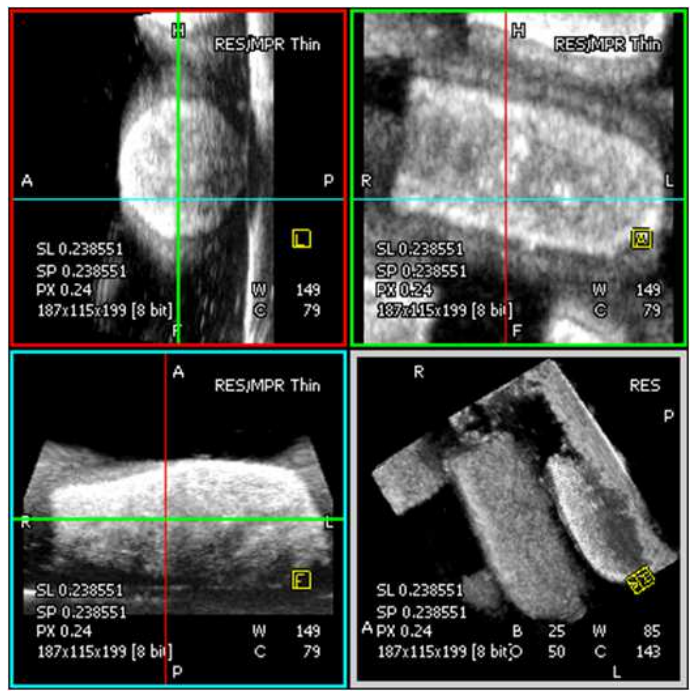


Figure 6: Ultrasound images (Eva Kollorz, Pattern Recognition Lab, FAU)

Hybrid Scanners for Medical Imaging

- 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.

Figure 7: First European installation of a SPECT/CT-Scanner (Image courtesy of Prof. Kuwert, Nuclear Medicine, FAU)

Hybrid Scanners for Medical Imaging

Commercially available hybrids are:

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

Figure 7: First European installation of a SPECT/CT-Scanner (Image courtesy of Prof. Kuwert, Nuclear Medicine, FAU)

Topics

Take Home Messages

- We heard about the concepts of different imaging modalities.
- We also learned that there are hybrid scanners which combine different modalities to benefit from their all their imaging characteristics.

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 ed. London: Hodder Arnold, Apr. 2006. DOI: 10.1201/b13462-1
2. Arnulf Opelt, ed. *Imaging Systems for Medical Diagnostics: Fundamentals, Technical Solutions and Applications for Systems Applying Ionizing Radiation, Nuclear Magnetic Resonance and Ultrasound*. 2nd ed. Erlangen: Publicis, 2005

The mathematical details of medical imaging are described in:

Charles L. Epstein. *Mathematics of Medical Imaging*. Upper Saddle River, N.J.: Pearson Education/Prentice Hall, 2003

Medical Image Processing for Diagnostic Applications

Types of Medical Imaging

Online Course – Unit 3

Andreas Maier, Joachim Hornegger, Markus Kowarschik, Frank Schebesch
Pattern Recognition Lab (CS 5)

virtuelle hochschule bayern

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Topics

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 1: 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.

Molecular Imaging

Definition

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

Major modalities used for molecular imaging are:

- positron emission tomography (PET),
- single photon 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!

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.

Interventional Imaging

Definition

In a ***medical intervention*** we act and apply methods in a way 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.

Topics

Take Home Messages

- You now know the different categories or dimensions of imaging:
  - morphologic imaging,
  - molecular imaging,
  - diagnostic imaging,
  - interventional imaging.
- We introduced the respective fields of application as well as technical and health implications.

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 ed. London: Hodder Arnold, Apr. 2006. DOI: 10.1201/b13462-1
2. Arnulf Opelt, ed. *Imaging Systems for Medical Diagnostics: Fundamentals, Technical Solutions and Applications for Systems Applying Ionizing Radiation, Nuclear Magnetic Resonance and Ultrasound*. 2nd ed. Erlangen: Publicis, 2005

The mathematical details of medical imaging are described in:

Charles L. Epstein. *Mathematics of Medical Imaging*. Upper Saddle River, N.J.: Pearson Education/Prentice Hall, 2003