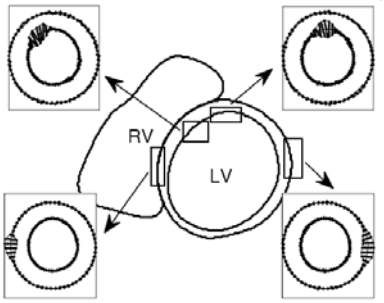
Section: Magnetic Resonance Imaging

Available masters project: Cardiac shape modeling for automated wall motion analysis

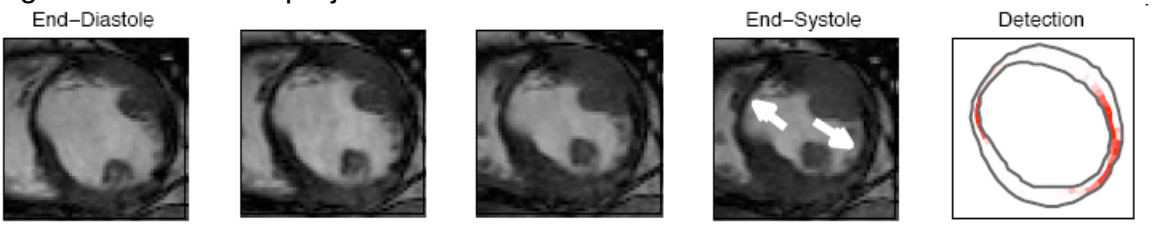
Overview

One of the most popular segmentation methods in medical imaging is the Active Shape Model or Active Appearance Model. With this approach, the segmentation is performed based on knowledge of a certain type of organs, e.g., brain, heart or bone. There are hundreds of research results have been produced with this approach, but do you know that there is something more interesting and challenging rather than a simple segmentation task with this statistical shape analysis?



Imagine a set of organ shapes that are trained from healthy subjects. Their statistical properties can be extracted to reveal normal shape variations. With this knowledge, we know how the shape of normal population is and we can bring forward this knowledge to detect abnormalities on a patient shape. This leads to an exciting area of computer-aided diagnosis (CAD) system.

Building a model of cardiac shape is a challenging task compared to other organs because of two reasons: (1) heart is dynamic, and (2) abnormal wall motion is regional. We have developed such a CAD system for detecting regional wall motion abnormality (RWMA) with independent component analysis (ICA). Local shape variations can be extracted (see figure above) and RWMA locations have been detected (see figure below). However, there are a lot of fascinating research topics that we need to investigate further in this project for master students.



Outline of the project:

1. Combining multiple slices of normokinetic shape models (apex, middle and base) into a full 3D cardiac shape model for detecting RWMA.
2. Building a novel method to increase temporal resolution of the normokinetic model to improve the automated RWMA detection method.
3. An investigation of how different automatic segmentation approaches affects the accuracy of the CAD system in terms of building the normokinetic model and detecting abnormality in a patient shape.

Further readings:

- Suinesiaputra, A., et. al., “Extraction of Myocardial Contractility Patterns from Short-Axes MR Images Using Independent Component Analysis”, LNCS 3117, 75—86, 2004.
- Suinesiaputra, A., et. al., “Automated Detection of Regional Wall Motion Abnormalities Based on a Statistical Model Applied to Multislice Short-Axis Cardiac MR Images,” IEEE Trans. on Medical Imaging, 28 (4), 595—607, 2009.

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Section: Knowledge guided image processing

Available masters project: Atlas-Based Cryosection Mouse Segmentation

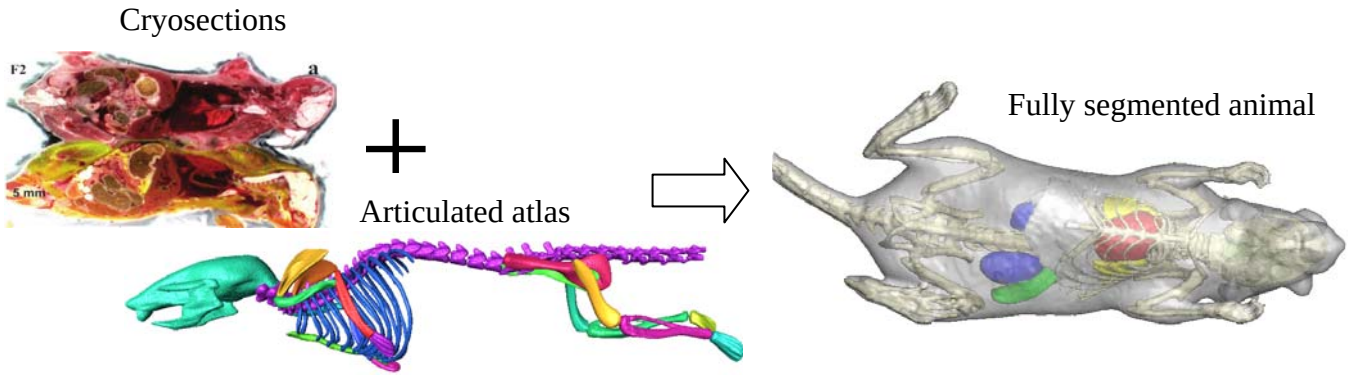
Project overview

Pre-clinical studies are conducted in order to collect information so that safe human testing can begin. Those are done usually in the fields of medical devices, drug testing (e.g.: for cancer treatment), gene therapy solutions and other product development.

Small animals like mice and rats are extensively used for drug testing on various stages of its development and one way to analyze and monitor the effects of a given drug is to sacrifice the animal on various time-points of the study and perform a traditional histological exam. In order to do that the animal is cryosectioned (sliced, while frozen) and the slices are analyzed under a microscope or on a computer monitor. The clinician then has the very tedious task to distinguish between all organs in order to find the regions of his interest (tumors, metastasis, and other cellular and molecular events).

What we propose, is to develop an algorithm that would allow, using a whole-body articulated mouse/rat atlas, to automatically segment all the organs present in the cryosections, in order to facilitate a very fast and easy browsing through the mouse data and to easily detect tumors or other abnormalities. In order to achieve this, various image processing techniques (like image registration, image segmentation, labeling, etc.) can be applied. See Figure, for a very simplistic illustration of the project.

If the student is interested, this project would involve a short practical part, where he/she would participate in the data acquisition process (cryo-sectioning).



References

[1]. *3D Cryo-Imaging: A Very High-Resolution View of the Whole Mouse.* Roy Debashish *et al.* ANAT. REC., 2009
[2]. *Cryo-Imaging of Fluorescently-Labeled Single Cells in a Mouse.* Grant J. Steyer *et al.* PROC. OF SPIE, 2009
[3]. *Enhanced Volume Rendering Techniques for High-Resolution Color Cryo-Imaging Data.* Gargesha *et al.* SPIE 2009
[4]. *Digimouse: a 3D whole body mouse atlas from CT and cryosection data.* Dogdas, B *et al.* PMB 2007
[5]. *The visible animal project: A three-dimensional, digital database for high quality three-dimensional reconstructions.* Bottcher, P. *et al.* VET. RADIOL. ULTRASOUN., 1999
[6]. *Atlas-based whole-body segmentation of mice from low-contrast Micro-CT data.* Baiker, M. *et al.* MEDIA 2010
[7]. *2D/3D registration of micro-CT data to multi-view photographs based on a 3D distance map.* Wildeman *et al.* ISBI 2009
[8]. *Integrated visualization of multi-angle bioluminescence imaging and micro CT.* Kok *et al.* SPIE 2007
[9]. *Atlas-based organ & bone approximation for ex-vivo μMRI mouse data: a pilot study.* Khmelinskii *et al.* ISBI 2010

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Martin Baiker, MSc, m.baiker@lumc.nl, 071 – 562 1117
Boudewijn Lelieveldt, PhD, b.p.f.lelieveldt@lumc.nl, 071 – 562 1130

Section: Knowledge guided image processing

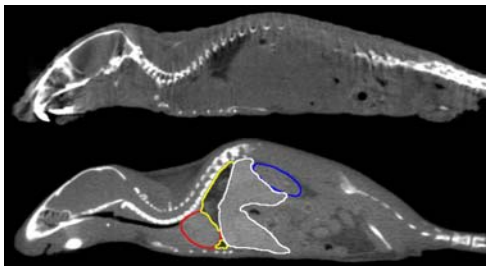
Available masters project: Whole-body segmentation of mice

Background

The development of whole-body small animal scanners (CT, MRI, PET, SPECT etc.) adds a new dimension to pre-clinical (animal) research since the classical cross-sectional studies (one time point, many subjects) can be extended to follow-up studies. This means that it is now possible to monitor e.g. disease progression or the effect of a particular drug application using the same subject at several points in time without sacrificing the animal. Especially powerful are the combinations of highly sensitive functional data and high-resolution anatomical data (image fusion), since complementary aspects of the same problem are brought together.

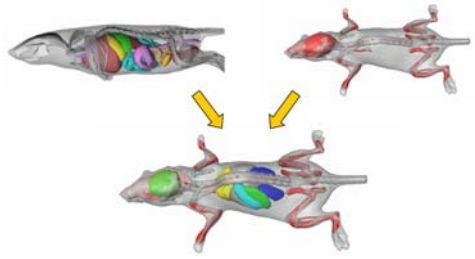
In our group we are working on combining bioluminescence imaging (BLI) data (functional modality) with MicroCT data (anatomical modality). The goal is to localize a light emitting cluster of cells in 3D inside a living subject using BLI by adding anatomical information of the same subject by means of MicroCT. To further facilitate this task, we aim on segmenting the entire animal body into individual bones and organs, based on MicroCT.

This segmentation task is complicated by the fact that the posture and shape of the animal in the scanner may vary significantly. The reason is that an animal body consists of many individual parts like bones and different organs and other soft tissues. Above that, non-contrast enhanced MicroCT data does only provide poor soft tissue contrast (see figure at the right).



MSc assignment

The goal of the MSc assignment is to provide a, possibly fully automated, method for whole-body segmentation of mice that builds on a method developed in our group (Baiker et al. 2007). In short, this method uses an anatomical mouse model (Segars et al. 2001) that is fitted to the data in two steps: First the parts that show high contrast in MicroCT data, thus skeleton, lungs and the skin, are taken from the atlas and fitted to the subject. Second, the remaining parts that show only little contrast are taken from the atlas and are interpolated (see figure at the left).



The method is highly robust and can handle large postural differences among animals. However, it has limited accuracy. The task of the student will be to review existing registration and segmentation methods and if necessary, develop a new method to perform a highly accurate segmentation of the animal. The particular challenge is the heterogeneous nature of the data i.e. rather stiff material (bones) next to soft material (organs). While the main focus is on non-contrast enhanced MicroCT data, the method should be generic enough to deal with contrast enhanced datasets as well, if available.

References

Baiker et al. 2007, Fully automated whole-body registration in mice using an articulated skeleton atlas, *ISBI*

Segars et al. 2004, Development of a 4D digital mouse phantom for molecular imaging research, *Mol Im Biol, 6*

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Section: Vascular and Molecular Imaging

Available masters project: Automatic Coronary Tree Labeling in CTA Dataset

Introduction

Coronary artery disease (CAD, Fig.1) is a leading cause of death in Europe and US. Cardiac computed tomography angiography (CTA), as a fast and non-invasive heart imaging modality, is widely used for diagnosis of CAD. It can provide not only anatomy of heart including heart chambers and coronary arteries (Fig.2), but also clinical information such as calcification, plaque composition and stenosis etc. Therefore, it allows developing computer-aided diagnosis systems to facilitate the early diagnosis of CAD. Automatic coronary artery extraction and labeling are important pre-requisite steps among these applications, thus have attracted more interests of researchers recently.

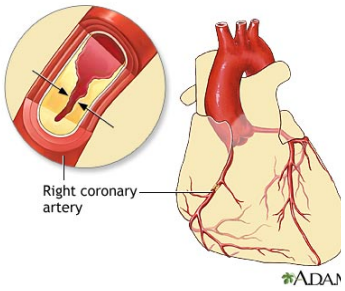

Fig. 1 Coronary artery disease

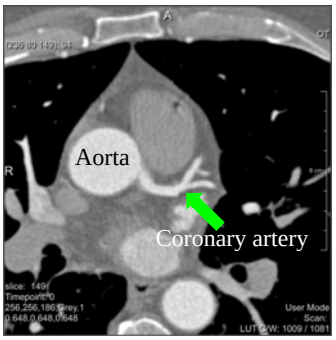

Fig. 2 CTA image

Problem description

In order to include the information of position of lesion, plaque burden and plaque composition into coronary arteries, the main segments of coronary tree extracted from CTA images (Fig.3) should be labeled according to its nomenclature. Thus, we are looking for an automatic method to perform coronary tree labeling. Because of the anatomical variation of coronary tree in the population, this method should adapt to 3 different structure types, i.e. right-, left- and co-dominant type. Finally, it can generate a hierarchical tree structure (Fig.4) with labeling anatomical names (Fig.5) for most of main branches.

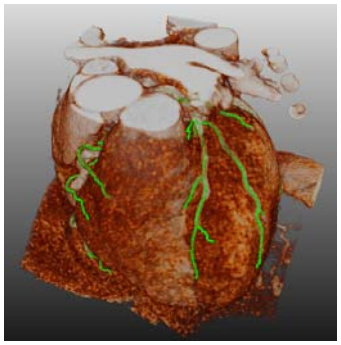
Fig.3 Extracted coronary centerlines

Project description

We are looking for a student (Technical Informatics, Technical Mathematics, Electrical Engineering, or Applied Physics) who is specializing in one or more of the following topics: image processing and/or computer graphics. The graduate project will cover the following topics:

- literature research (matching and clinical papers)
- writing algorithm in MevisLab environment (C++ and/or Python)
- performing a validation study and writing an article / graduate thesis about the project.

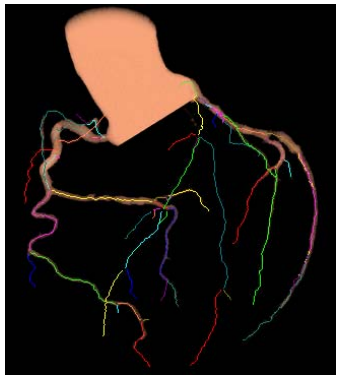
Fig.4 Hierarchical tree structure of extracted coronary arteries

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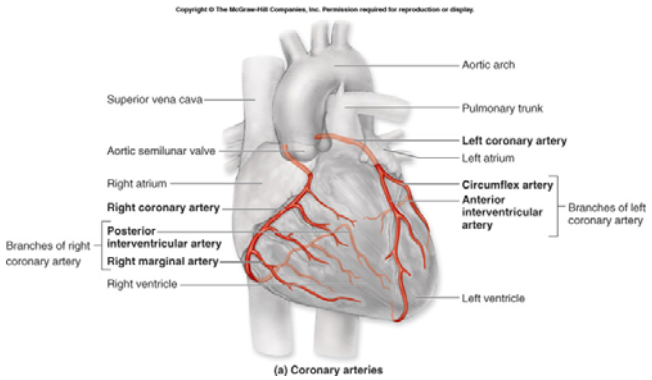

Fig.5 Segment definitions of coronary arteries

Section: Vascular and Molecular Imaging

Available masters project: Matching 3D Coronary Centerlines on 2D X-ray Images

Introduction

The coronary arteries provide the human hearth with oxygen rich blood. Diseases arteries can obstruct the flow of blood which causes heart attacks. The common treatment of the narrowing of diseased arteries is the placement of a stent (a small wire frame) inside the artery (Figure 1). The stent can be expanded to open the vessel re-enabling the flow of blood.

Figure 1 Stent

Stent placement is done under x-ray image guidance. Special contrast fluid is injected into the arteries to image the lumen (blood filled area inside the artery) (Figure 2). The x-ray projection provides a 2D representation of the arteries which suffers from a number of shortcomings like foreshortening and projection overlap (Figure 3).

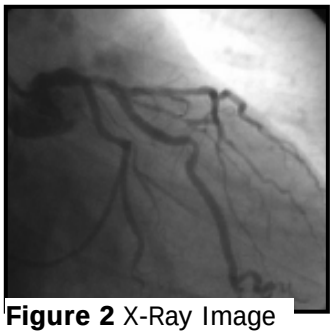

Figure 2 X-Ray Image

Another imaging technique to look at the coronary arteries is computed tomography angiography (CTA). CTA provides a 3D data set of the hearth and the coronary arteries (Figure 4).

Problem description

Both in the 2D x-ray and the 3D CTA datasets the coronary arteries can be segmented and centerline curve can be extracted representing the course of the artery. We are looking for a method to match the extracted 3D and 2D centerlines. This would allow for information from the 3D CTA domain to be mapped to the 2D image (and vice versa). For instance, during stent placement this would allow for more accurate length measurements since the 3D information can be used from the CT scan (which is acquired separately).

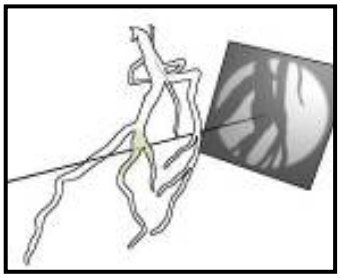

Figure 3 X-ray overlap

Project description

We are looking for a student (Technical Informatics, Technical Mathematics, Electrical Engineering, or Applied Physics) who is specializing in one or more of the following topics: image processing, signal processing and/or computer graphics.

The graduate project will cover the following topics:

- literature research (matching, registration and clinical papers)
- Writing software in the MeVisLab environment (C++ and/or Python)
- Performing a validation study / write an article / graduate thesis about the project.

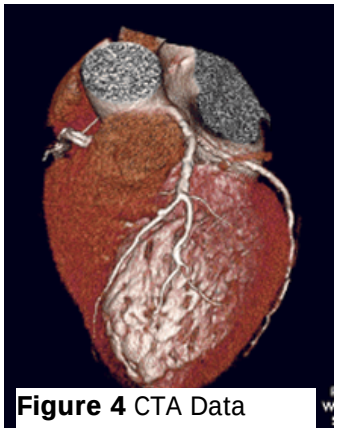

Figure 4 CTA Data

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Section: Vascular and Molecular Imaging

Available masters project: Automatic detection of anatomical landmarks in intravascular ultrasound images

Introduction

Intravascular ultrasound (IVUS) is an imaging modality using a catheter with an ultrasound probe, which allows monitoring from inside a vessel. Monitoring is important for instance to quantify atherosclerosis: thickening of the artery wall as the result of a build-up of fatty materials. Different landmarks can be found within an IVUS image as shown in Figure 1. Thickening is measured as the area between the lumen (red contour) with the blood and the vessel wall (green contour) of the artery. A longitudinal cross-section of multiple images (Figure 2) shows the location of the different anatomical landmarks within the vessel.

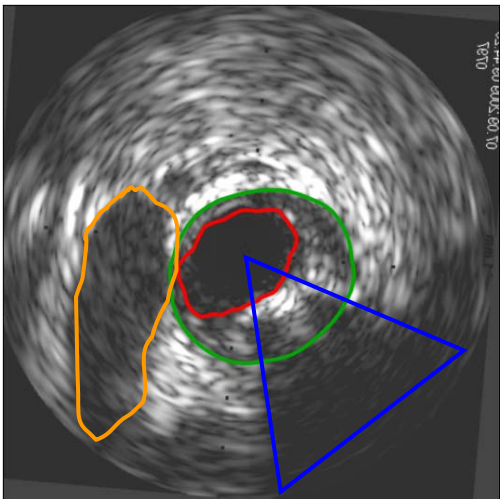

Figure 5: IVUS image with lumen (green) and vessel wall (red) contours including a calcified part (blue) and a sidebranch (orange)

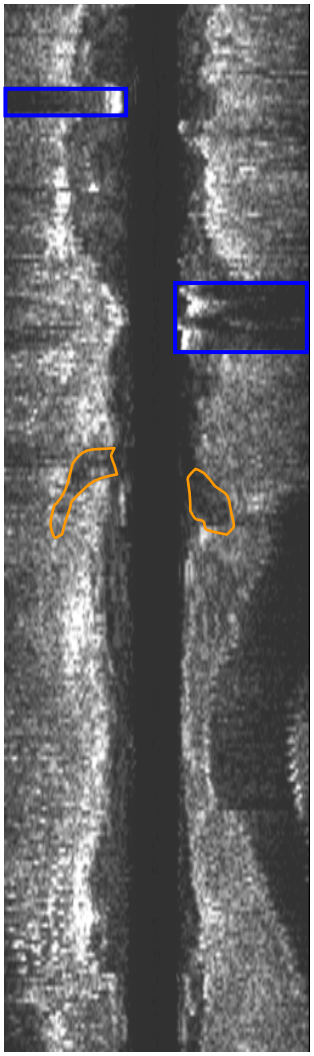

Figure 2: longitudinal cross-section of a series of IVUS images

Problem description

Anatomical landmarks like calcifications in the artery wall including the occluded regions behind these spots (blue contours) and side-branches of other arteries (orange contours) influence detection of lumen and vessel wall contours. In addition, the presence of a guide wire influences the automatic detection. Therefore, automatic methods are needed to detect these landmarks and use this knowledge to improve automatic contour detection.

Project description

We are looking for a student (Technical Informatics, Technical Mathematics, Electrical Engineering, or Applied Physics) who is specializing in one or more of the following topics: image processing or computer graphics.

The graduate project will cover the following topics:

- literature research
- learning characteristics of the IVUS data and the software environment (C++, Python, MeVisLab)
- develop a method for automatic detection of anatomical landmarks
- validation study
- write an article / graduate thesis about the project

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Section: Vascular and Molecular Imaging

Available masters project: Image based cardiac motion correction in intravascular ultrasound images

Introduction

Intravascular ultrasound (IVUS) is an imaging modality using a catheter with an ultrasound probe, which allows monitoring from inside a vessel. Monitoring is important for instance to quantify atherosclerosis: thickening of the artery wall as the result of a build-up of fatty materials. IVUS images are obtained by inserting a catheter into a vessel (Figure 1). The catheter is pulled back while capturing ultrasound images (Figure 2). In these images, the lumen (red contour) and vessel wall (green contour) are automatically detected to quantify the area in between them.

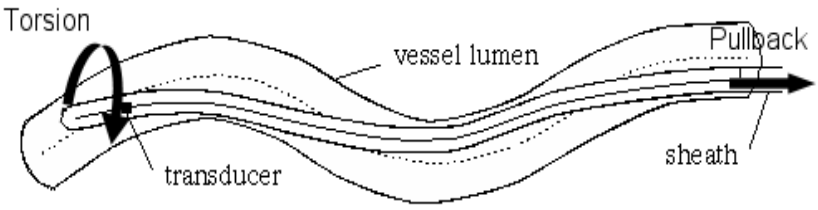

Figure 1: The IVUS catheter trajectory in a vessel. The pullback-induced torsion causes the transducer to rotate.

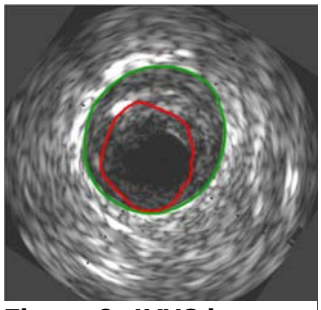

Figure 2: IVUS image with lumen (green) and vessel wall (red)

Problem description

The resulting sequential images are not well aligned to each other due to movements of the heart during acquisition as can be seen in Figure 3. A method is needed for the automatic correction of the translational and rotational displacement and movement along the vessel. For instance, this can be done by modeling the movements of the probe using the electrocardiography (ECG) signal.

Figure 3: longitudinal cross-section of a series of IVUS images

Project description

We are looking for a student (Technical Informatics, Technical Mathematics, Electrical Engineering, or Applied Physics) who is specializing in one or more of the following topics: image processing or computer graphics.

The graduate project will cover the following topics:

- literature research
- learning characteristics of the IVUS data and the software environment (C++, Python, MeVisLab)
- develop a method for automatic cardiac motion correction
- validation study
- write an article / graduate thesis about the project

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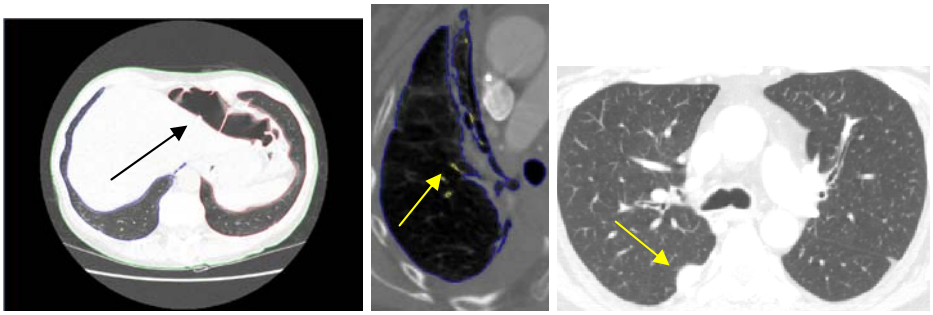
Section: Lung Diseases

Available masters project: Automatic Detection of the Lung Boundary from Computed Tomography Images

Background
The lung is a fragile organ, often a target of disease, such as the family of diseases Chronic Obstructive Pulmonary Disease (COPD), Asthma, Interstitial Lung Disease (ILD), or cancer. The increased role of imaging in modern medicine, especially Computed Tomography (CT) scans, necessitates the automated analysis of the lungs to aid the physician. The first step in such an analysis is the automated segmentation of the lung in these images.

Research Objectives
The current LKEB algorithms, based on seeded region growing, take advantage of the high contrast between lung and other tissue, which works quite well in normal and emphysematous patients. In order to apply these methods to other lung diseases, however, improvements are required, which is the core objective of this graduation project. Examples of issues are: leakage into the abdomen (image 1), lungs containing high intensity tissue (image 2), nodules and other irregularities at the lung boundary (image 3), and many others.



In addition to improving the standard algorithm, automatic detection of its failure would enable switching to a more advanced, but also more time-consuming, method based on image registration, for the difficult cases.

Project description:
We are looking for a student in a technical science (Technical Informatics, Technical Mathematics, Electrical Engineering, Applied Physics, or similar).

- An analysis of the current limitations should be made.
- Develop a method improving the lung segmentation (based on literature study as well as research).
- Develop a method for automatic detection of its failure.
- Validation study.
- Write an article / graduate thesis about the project.

The development of algorithms and software require some programming skills.

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