Doc. Nr.	: RD6534
Subject	: Thesis 'Automatic contrast bolus front detection in an X-ray Angiographic Image Run'

Pie Medical Imaging designs and delivers software solutions in cardiovascular analysis that drive next-generation research and diagnostics. Backed by an extensive research and development department, Pie Medical Imaging uses its expertise in quantitative analysis software for cardiology and radiology to develop new state-of-the-art solutions for its customers. Pie Medical Imaging's customer file includes leading research centers and core labs around the world as well as major equipment manufacturers and local partners. Pie Medical Imaging is dedicated to the development and sales of quantitative analysis software to support medical professionals with the diagnostic process and applied treatment and to facilitate research to study the efficacy of modern interventions. The quantitative analysis software is intended for highly accurate and reproducible measurements of the dimensions of coronary arteries and other vessels as well as the analysis of left and right ventricular volumes.

The CAAS Workstation software package is able to visualize and analysis 2D coronary X-ray angiography images. During the X-ray angiographic image acquisition the contrast is injected and the contrast propagates through the vessels. In this way the vessels becomes clearly visible (see figure 1) and an obstruction within the vessel will can be identified. Due to the contrast in the vessel, the user is able to mark the vessel of interest, and luminal borders are automatically detected followed by calculation of analysis results (such as diameter and stenosis percentage).
To improve the user experience and extend the analysis methods, automatic contrast bolus front detection is desired.
Detection of the frame in which the first contrast agent arrival in the vessel is visible, enables the analysis algorithms to perform automatic image processing developed within Pie Medical Imaging.. Next to this, it is also of interest to detect the bolus front in successive frames, in this way the contrast bolus can be tracked during the cardiac cycle and this gives an indication of the local blood flow.

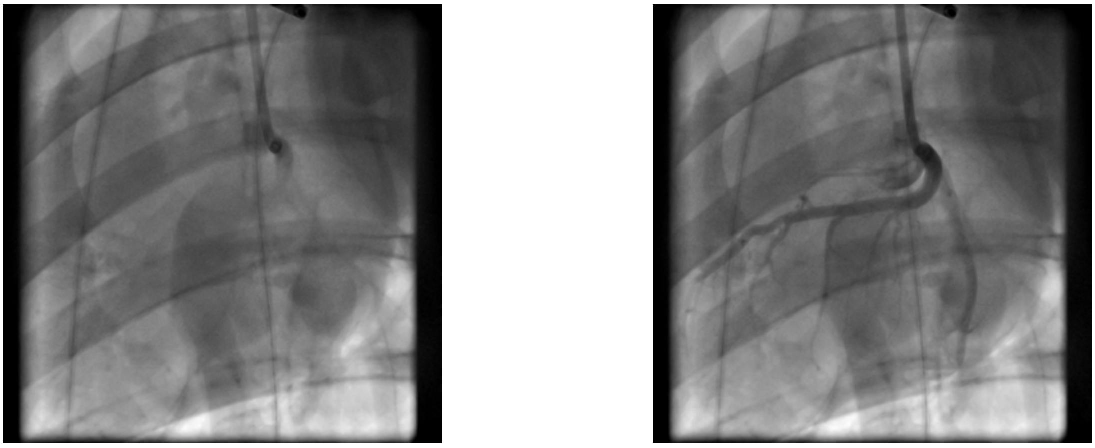


Figure 1, an example of two X-ray angiographic frames witin the image run. The frame on the left shows the first arrival of the contrast agent bolus. The frame on the right shows the propagation of the contrast agent into the vessels.

The aim of this thesis is to investigate, develop and apply image processing and signal analysis techniques to detect automatically the frame in which the first arrival of the contrast agent bolus accours within the X-ray angiography image run, and detect the contrast agent bolus front in successive frames. The developed method must be accurate, reproducible and fast. The used methodology must be documented and evaluated. The results will be presented to the research team within Pie Medical Imaging.

The tasks within the internship project contain:

- Initial phase
  - Draw up a project plan.
- Research phase
  - Perform a literature research
- Development phase
  - Use of the CAAS application for image analysis.
  - Several tools can be used for data processing, such as Visual Studio (C++), MATLAB, and evaluation of the results e.g. Excel, SPSS.
  - Documentation of the results.
- Evaluation phase
  - Evaluation of the detection results.
  - Presentation of the results.

The ideal candidates are master students with strong technical background (biomedical engineering, computer science, electrical engineering, and the like). Interested candidates should send a curriculum vitae (complete with list of attended exams and obtained marks during their current Master study) and a letter of motivation:

Mr. Jean-Paul Aben, Director Research & Development at Pie Medical Imaging BV
Tel: +31(0)43 3281323
Email: jeanpaul.aben@pie.nl

PIE MEDICAL IMAGING

Doc. Nr.	: RD6122
Subject	: Thesis ‘segmentation of blackblood Late Gadolinium Enhancement CMR’

Pie Medical Imaging designs and delivers software solutions in cardiovascular analysis that drive next-generation research and diagnostics. Backed by an extensive research and development department, Pie Medical Imaging uses its expertise in quantitative analysis software for cardiology and radiology to develop new state-of-the-art solutions for its customers. Pie Medical Imaging’s customer file includes leading research centers and core labs around the world as well as major equipment manufacturers and local partners. Pie Medical Imaging is dedicated to the development and sales of quantitative analysis software to support medical professionals with the diagnostic process and applied treatment and to facilitate research to study the efficacy of modern interventions. The quantitative analysis software is intended for highly accurate and reproducible measurements of the dimensions of coronary arteries and other vessels as well as the analysis of left and right ventricular volumes.

The CAAS MRV software package is able to visualize and analysis multiple cardiac magnetic resonance acquisitions. To assess the extent of myocardium infarcts, Late Gadolinium Enhancement (LGE) cardic magnetic resonance (CMR) is performed in the clinical routine. These CMR images results in enhanced blood pool and enhancement of present myocardium infarcts, see figure 1 as an example.

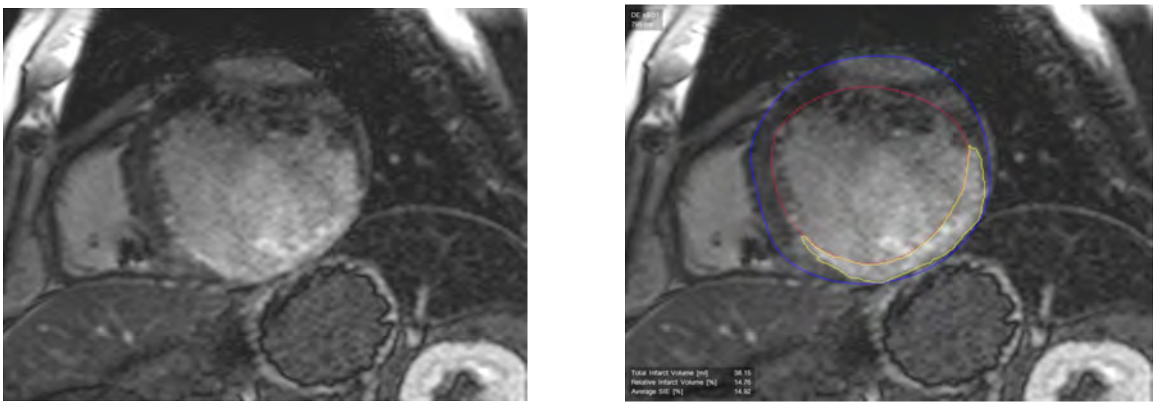
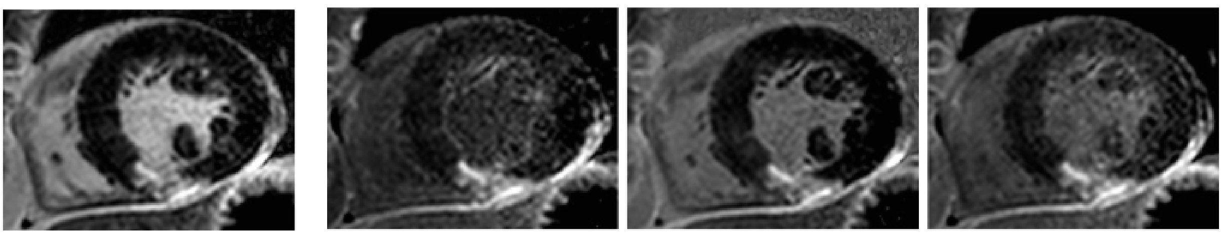


Figure 1: *An example of the LGE CMR image. Left one slice at mioventricle, right same slice segmented; blue represents the epicardial border, red represents the endocardial border and yellow the infarct.*

Due to the enhancement of the blood pool within LGE, accurate automatic segmentation of myocardium/infarct region is difficult, due to the equal enhancement of blood pool and infarct. Recently a new CMR imaging method is been developed to assess the myocardium infarct, namely ’black-blood LGE’. Figure 2 shows several black blood LGE techniques related to the conventional LGE technique. These new imaging techniques allows accuate segmentation of the myocard incase myocardium infarcts are present.



(a) (b)

Figure 2: *Example of conventional LGE (a) compared to different blackblood LGE techniques (b)*

The aim of this thesis is the development of algorithm(s) to (semi-)automatic myocardium/infract detection using the different black blood LGE imaging techniques.

The tasks within the thesis include:

- Initial phase
  - Draw up a project plan.
- Research phase

    - Perform a literature research:
        - Which methods are available?
        - What are the pros/cons of each method in relation to the used application?
- Development phase
    - Several development tools can be used for prototyping, such as Matlab and/or Mathematica.
    - Documentation of the algorithm.
    - Implementation of the algorithm in Matlab/Mathematica
    - Implementation in C/C++
- Evaluation phase
    - Evaluation of the developed algorithm.
    - Presentation of the algorithm and results.

The ideal candidates are master students with strong technical background (biomedical engineering, computer science, electrical engineering, and the like). Interested candidates should send a curriculum vitae (complete with list of attended exams and obtained marks during their current Master study) and a letter of motivation:

Mr. Jean-Paul Aben, Director Research & Development at Pie Medical Imaging BV
Tel: +31(0)43 3281323
Email: jeanpaul.aben@pie.nl

Doc. Nr.	: RD6117
Subject	: Thesis ‘3D Liver Segmentation in CTA scans’

Pie Medical Imaging designs and delivers software solutions in cardiovascular analysis that drive next-generation research and diagnostics. Backed by an extensive research and development department, Pie Medical Imaging uses its expertise in quantitative analysis software for cardiology and radiology to develop new state-of-the-art solutions for its customers. Pie Medical Imaging’s customer file includes leading research centers and core labs around the world as well as major equipment manufacturers and local partners. Pie Medical Imaging is dedicated to the development and sales of quantitative analysis software to support medical professionals with the diagnostic process and applied treatment and to facilitate research to study the efficacy of modern interventions. The quantitative analysis software is intended for highly accurate and reproducible measurements of the dimensions of blood, vessels as well as the analysis of 3D volumes in various types of medical scans (X-ray, CT, MR, OCT, and ultrasound).

Recently, as a possible research side-development of a 3D vessel centerline segmentation algorithm designed by PMI and 3mensio Medical Imaging BV (Bilthoven, the Netherlands), promising preliminary results have been obtained using a similar algorithm for tracking the centerline of the vessel tree structure within the liver. One functionality that still needs to be added in order to complete the research is the 3D volumetric segmentation of the liver organ itself in the CTA scan. This would be facilitating both the algorithm design and the computational efficiency of the liver vessel centerline analysis software.

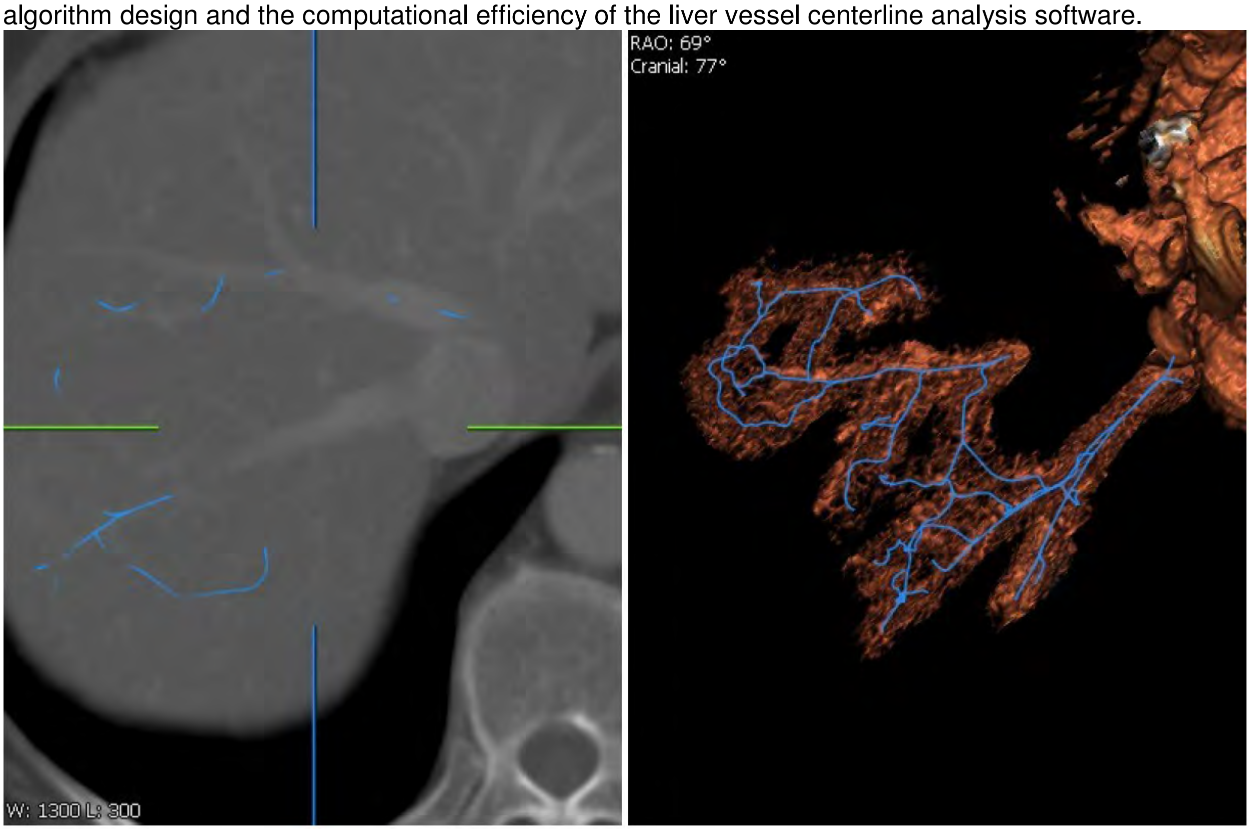


Figure 1. An example of our liver vessels centerline tracking in CTA scans.

The subject of this Master Thesis project is therefore to design and implement an algorithm to automatically segment the whole liver in 3D within the volumetric CTA scan. The prototyping and initial implementation of the method can be performed by using high-level interpreter languages such as Matlab and/or Mathematica. The final implementation in PMI/3mensio commercial software should be executed in C# and/or C++.

In detail the following tasks need to be performed:

- Planning of the activities.
- Literature research;
    - Which methods are available,
    - What are the pros/cons of each method.

- Algorithm design an implementation;
    - Prototyping (Matlab and/or Mathematica), and preliminary evaluation,
    - Documentation of the algorithm,
    - Implementation of the algorithm in C# and/or C++,
    - Validation of the algorithm.

The ideal candidates are master students with strong technical background (biomedical engineering, computer science, electrical engineering, and the like). Interested candidates should send a curriculum vitae (complete with list of attended exams and obtained marks during their current Master study) and a letter of motivation:

Mr. Jean-Paul Aben, Director Research & Development at Pie Medical Imaging BV
Tel: +31(0)43 3281323
Email: jeanpaul.aben@pie.nl

Doc. Nr. : RD6023
Subject : Thesis “Tissue tracking and strain analysis on long axis cardiac cine MR images”

Pie Medical Imaging designs and delivers software solutions in cardiovascular analysis that drive next-generation research and diagnostics. Backed by an extensive research and development department, Pie Medical Imaging uses its expertise in quantitative analysis software for cardiology and radiology to develop new state-of-the-art solutions for its customers. Pie Medical Imaging’s customer file includes leading research centers and core labs around the world as well as major equipment manufacturers and local partners. Pie Medical Imaging is dedicated to the development and sales of quantitative analysis software to support medical professionals with the diagnostic process and applied treatment and to facilitate research to study the efficacy of modern interventions. The quantitative analysis software is intended for highly accurate and reproducible measurements of the dimensions of coronary arteries and other vessels as well as the analysis of left and right ventricular volumes.

Magnetic resonance imaging provides high accuracy and high reproducibility to assess the ventricular volumes and is considered as the reference standard in ventricular volume assessment. CAAS MRV software package includes a clinical validated left and right ventricle segmentation algorithm. Furthermore, CAAS MRV allows wall motion analysis by using the segmentation results from the left ventricle.

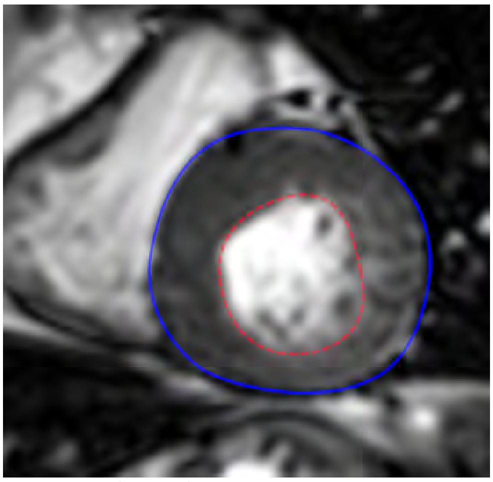


Figure 1: *frame from a short axis cine run.*

Recently, in cardiac magnetic resonance imaging, myocardial feature tracking on standard short-axis cine imaging has been proposed to assess the myocardium strain as an alternative to ultrasound speckle tracking or MRI tagging. Within PMI an algorithm is developed to assess strain in short axis myocardial cine images using tissue tracking. This algorithm is currently being evaluated. Figure 2 illustrates the displacement field of the tissue calculated by tissue tracking and strain calculated using the displacement field over time.

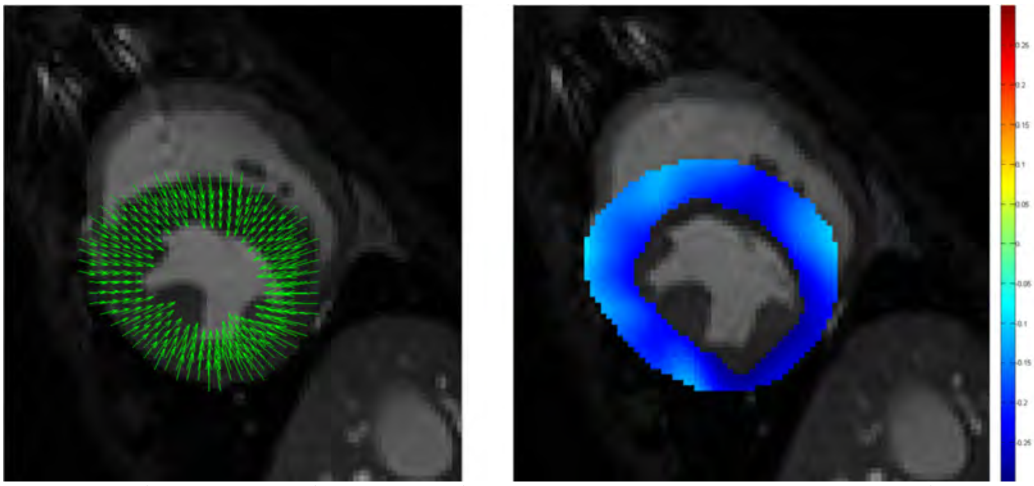


Figure 2: *Left displacement field between frames in a short axis cine run. Right circumferential strain calculated from displacement fields.*

Next step is to extend the algorithm with the possibility to perform tissue tracking in long axis cine images (figure 3). This tissue tracking can for example be used for strain analysis in long axes myocaldial cine images enabling longitudinal strain analysis (figure 4).

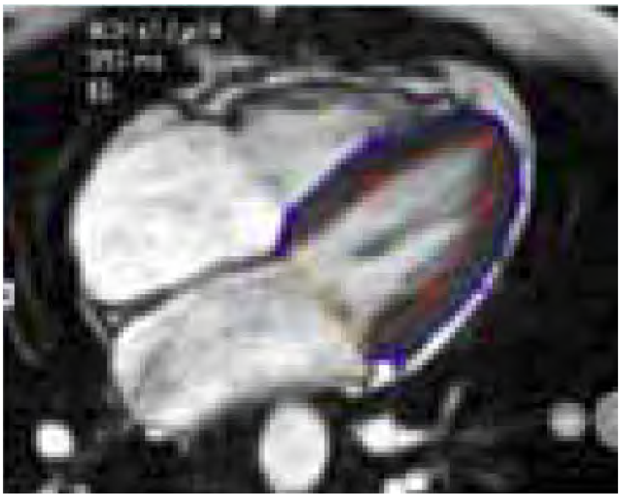


Figure 3: *Illustration of a long axis cine image*

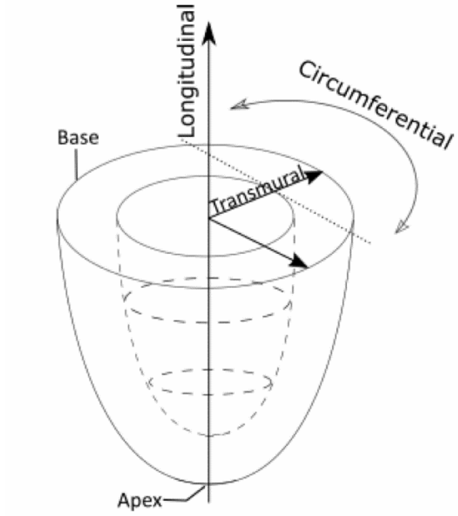


Figure 4: *Illustration directions of transmural (radial), circumferential and longitudinal strain directions*

The goal of the project consists of following parts:

1. extent the tissue tracking algorithm for long axis cine MR images;
2. Calculate longitudinal strain based on the displacement field of the tissue tracking.
3. Combine the short-axis strain and long-axis strain into a semi 3D strain analysis.

The tasks within the project are:

- Initial phase
  - Draw up a project plan.
- Research phase
  - Perform a literature research:
    - Which methods are available?
    - What are the pros/cons of each method in relation to the used application?
- Development phase
  - Several development tools can be used for prototyping, such as Mathematica and/or MATLAB.
  - Documentation of the algorithm.
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Mr. Jean-Paul Aben, Director Research & Development at Pie Medical Imaging BV
Tel: +31(0)43 3281323
Email: jeanpaul.aben@pie.nl

Doc. Nr.	: RD5745
Subject	: Thesis 'QCA4D non-rigid propagation'

Pie Medical Imaging designs and delivers software solutions in cardiovascular analysis that drive next-generation research and diagnostics. Backed by an extensive research and development department, Pie Medical Imaging uses its expertise in quantitative analysis software for cardiology and radiology to develop new state-of-the-art solutions for its customers. Pie Medical Imaging's customer file includes leading research centers and core labs around the world as well as major equipment manufacturers and local partners. Pie Medical Imaging is dedicated to the development and sales of quantitative analysis software to support medical professionals with the diagnostic process and applied treatment and to facilitate research to study the efficacy of modern interventions. The quantitative analysis software is intended for highly accurate and reproducible measurements of the dimensions of coronary arteries and other vessels as well as the analysis of left and right ventricular volumes.

The CAAS QCA 3D (three-dimensional Quantitative Coronary Analysis software) offers 3D analysis of single and bifurcated coronary arteries. Multiple X-ray projections are used to calculate the true geometric shape in 3D space and create an interactive rendered 3D view of the artery of interest.

Figure 1: *An example of the CAAS QCA3D software in which a bifurcated coronary artery is reconstructed*

Recently we have been working on performing QCA3D through time (QCA4D) where multiple 3D modes are reconstructed for one heart beat. To create this 3D+t model, automatic propagation functionality is added to propagate from one time-instance to the next. The current algorithm is a non-rigid transformation of the 3D model and this method has its shortcommings, particularly when long vessels are reconstructed and when the heart has relatively large movements.

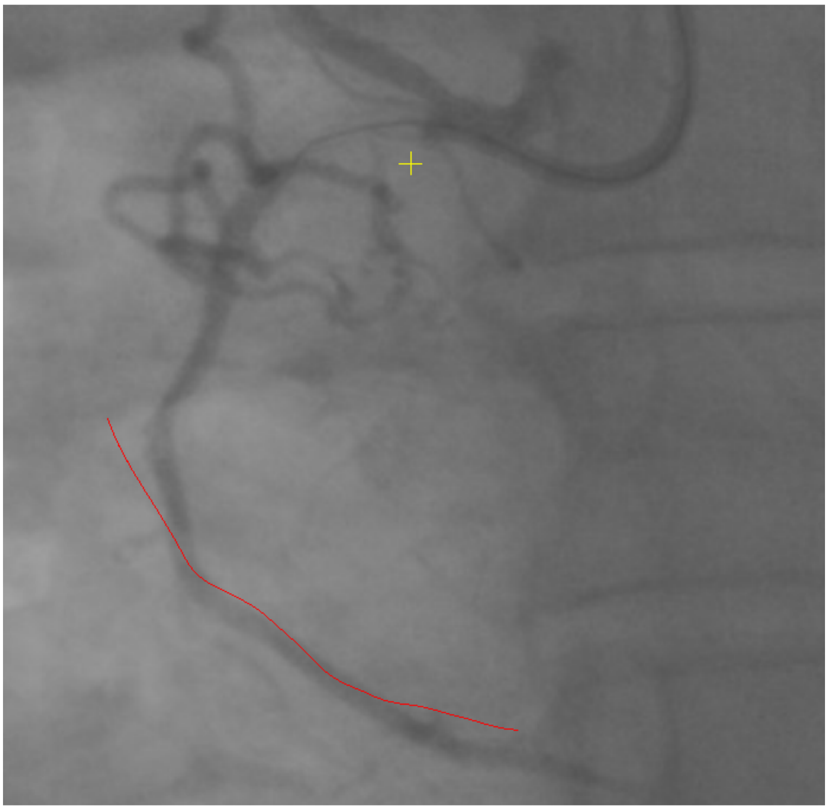

Figure 2: *An example of the propagation where non-rigid transformation is needed.*

There are two issues that need to be implemented to improve the current 3D-model propagation algorithm:

1. Determine a good initial 3D-displacement of the 3D-model in the next time-step with the guidance of two 2D DICOM images. For further optimization it is crusial that a point is found that is present in the 3D-model and in the images. This point can be used as starting point for the second part of the internship.
2. Make a non-rigid transformation of the 3D model so it fits the vessels in the DICOM images exactly. The current implementation has only rigid transformations, resulting in that the 3D+t model does not fit the vessels when they move non-rigid (see Figure 2). The reason that transformation is necessary is that reconstruction of vessels in different time moments can result in topological differences between the two models that can not happen due to the movement of the heart (e.g. bifurcation points of vessels that move).

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One of the imaging tools to quantify the functionality of cardiac is cardiac magnetic resonance (MR). By using the specific MR sequence, the MRI machine manages to capture the movement of the heart and hence its functionality. The cardiac MR images were taken at the heart short axis view and typically two long axis view, showing the 2- and 4-chamber view of the heart.

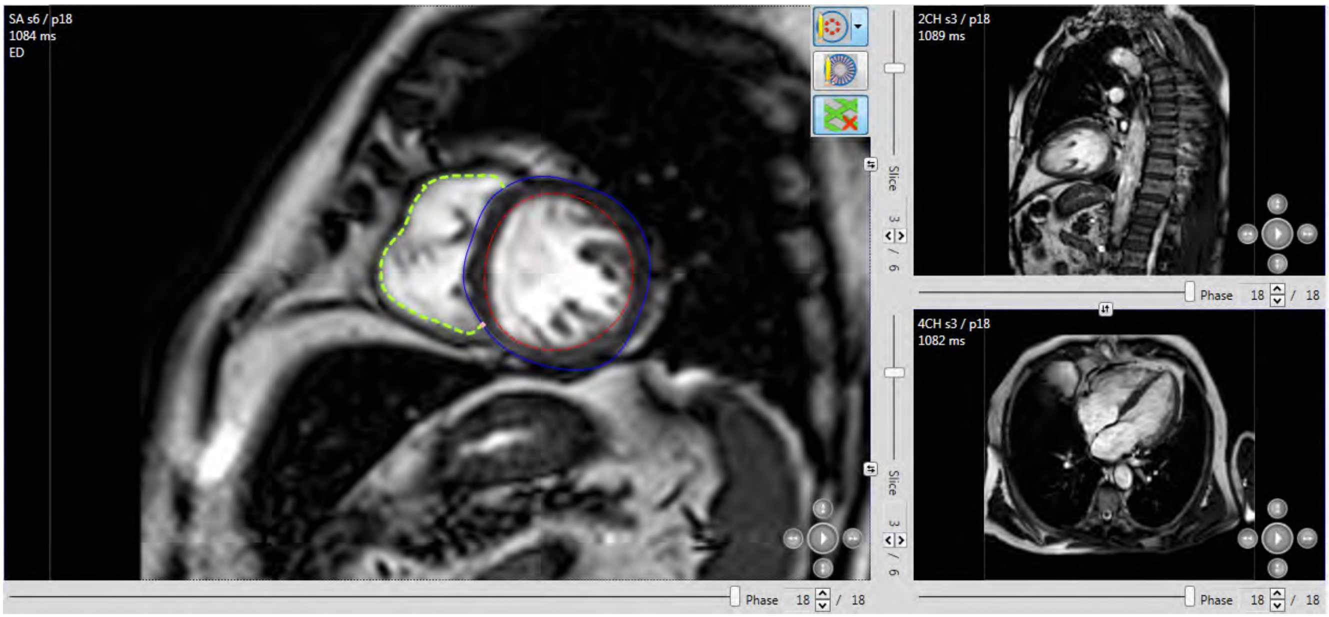

Figure 1. Cardiac MR taken at short-axis, 2-chamber, and 4-chamber view.

The CAAS MRV software package has been widely used in medical and research community to perform analysis on these cardiac MR images. With its sophisticated and accurate detection technology, CAAS MRV manages to perform a reliable (semi) automatic segmentation of the heart which in turn support the clinical workup as well as research purpose.
Recently, there is a new development on cardiac MR technology, which make a higher and isotropic cardiac MR images available. The images are taken at the normal axial view, taking virtually the whole volumetric data of the heart. (Thus, by-passing the need to take the scans in short-axis and long axes view and the limitations there-of). This fact brings a whole new opportunity to the way analyze cardiac MR images, and also new challenges to provide the tools to support the new work up.

Figure 2. Cardiac MR taken at axial view at higher and isotropic resolution.

The aim of this thesis project is to develop of an (semi) automatic algorithm to segment left (and/or right) ventricle on the new cardiac MR images dataset; axial MR Imaging.
The tasks within the thesis contain:

- Initial phase
  - Draw up a project plan.
- Research phase
  - Perform a literature research:
    - Which methods are available?
    - What are the pros/cons of each method in relation to the used application?
- Development phase
  - Several development tools can be used for prototyping, such as Mathematica and/or MATLAB.
  - Documentation of the algorithm.
  - Implementation of the algorithm in C/C++ into development environment.
- Evaluation phase
  - Evaluation of the developed algorithm.
  - Presentation of the algorithm and results.

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