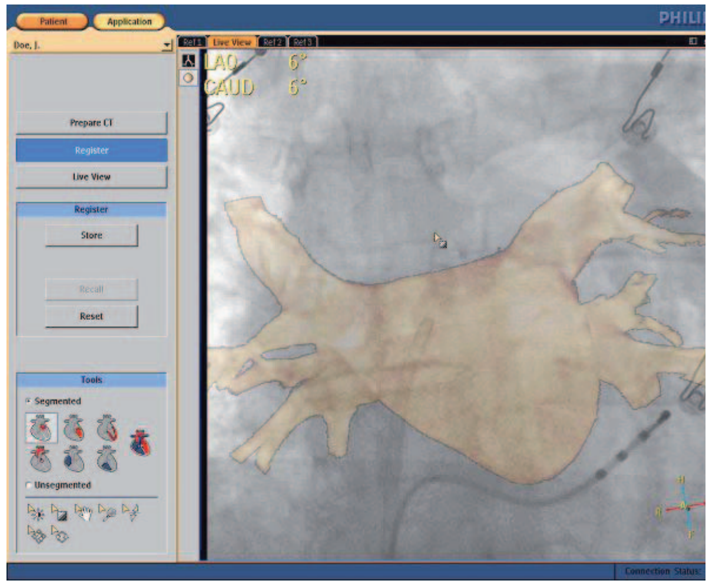
The Heart of the Matter

Modeling algorithms automatically improve cardiac care

Although recent innovations in medical imaging technology have provided physicians with a wealth of data on complex anatomical structures, it is often difficult to filter out the desired information. In a bid to provide clinicians with a tool for enabling efficient diagnosis and simplifying complex therapies, Philips has been researching algorithms which make use of existing anatomical knowledge. Researchers created a new automatic heart extraction model based on volumetric images. The algorithm for heart modeling is able to accurately detect the position of the heart and adapt an embedded cardiac reference model to a patient's images in a coarse-to-fine manner. While the algorithm has already been implemented in an application package for electrophysiological X-ray guided interventions, it also has the potential for use with computed tomography, magnetic resonance and ultrasound.

Model segmentation has been widely discussed but, owing to the individuality of each patient's cardiac anatomy, many believed the automatic adaptation of such a heart extraction model to be impossible. However, the new model-based segmentation software automatically detects the heart and



EP navigator shows the position of any catheter with respect to detailed 3D cardiac anatomy in real time.

even the very first adaptation of the model shows a mean error of only 5 mm, reduced to less than 1mm after iteration along the segmentation chain.

The new approach combines active shape models with deformable models. Parametric models are limited in terms of being able to approximate shapes, but are robust and fast, while deformable models ensure smoothness, offer high flexibility and can approximate any shape. With the new approach, a reference model is placed in the image and adapted according to the image structures, while deviations from the reference model are penalized. The algorithm first detects the organ's boundaries before reconfiguring mesh and finally updating the reference model. The model uses 15,000 triangles to adapt to the shapes of seven distinct anatomical regions, that is the four chambers of the heart, the myocardium, the pulmonary artery and the aorta.

Hidden information

Once the model has been applied and adapted, clinicians can measure the location of the heart in the image, its geometry, as well as volumes and functions. All annotations included in the model are transferred to the image and the cardiac landmarks encoded in the model are available after adaptation. The goal is to reveal previously hidden information, such as ventricular mass, ejection fraction or wall thickness, which ultimately makes diagnosis quicker and improves therapy planning.

"Many existing algorithms can already work out the left or right ventricle," explains Mr. Jürgen Weese, PhD, Principal Scientist at Philips Research Europe. "But even if they can adapt the model to the heart as a whole, they are unable to provide automatic segmentation. Manual or semiautomatic segmentation requires considerable effort and is very time-consuming for the physician, which is why we have concentrated on automatic segmentation." The whole segmentation chain runs in just 10 seconds and the new system has interactive tools for correcting data. Validation of the technology for ischemic disease has shown that in 97 % of cases, no corrections were needed, making the tool suitable for routine use in a large number of cases. "Many clinicians have been intrigued by the heart modeling algorithm," says Mr. Weese. "In one clinic, the physicians even printed the model of a patient's heart in 3D before they started a complex intervention."

Simplified interventions

One of the first products to come out of the research project was the EP navigator, which was launched in 2007. The EP navigator provides an automatically segmented 3D CT image of the heart for navigation in atrial fibrillation ablation procedures (A fib). Combined with live fluoro data from a Philips Allura Xper cath lab system, this new tool shows the position of all catheters and the detailed atrial anatomy in real time on a single image. This information supports the electrophysiologist in performing complex EP procedures with greater confidence, in a more intuitive way, helping to reduce A-fib procedure time.

Dr. Gerhard Hindricks, Director of the Department of Electrophysiology at the University of Leipzig, Germany has been working in the field of electrophysiology for more than 20 years. One of the early adopters of this technology, he was quick to realize its value. "EP navigator tells you exactly where the pulmonary veins are, exactly where the roof of the left atrium is, and in addition, shows you where the position of your catheters are in relationship to these structures. This can only be accomplished by a technology that provides an integration of images into fluoro and EP navigator is the only technology that I'm aware of that has this ability."

Coping with data explosion

CT is becoming the preferred non-invasive method for imaging the heart. However, the data explosion is a challenge to the clinical staff in terms of workflow and diagnostics,

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Jürgen Weese, PhD, Principal Scientist at Philips Research Europe

and Philips is planning to integrate the new technology into its upcoming CT cardiac packages in order to further improve CT reconstruction. If motion fields are extracted from the data, reconstruction time can be shortened, the signal-to-noise ratio improved and dosage limited.

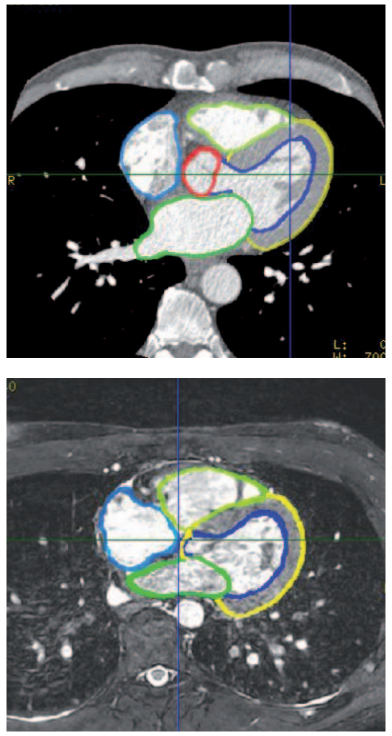
"It's not our intention to do the diagnostics and replace the physician, rather we want to provide physicians with relevant information quickly so that they can come up with a diagnosis," explains Mr. Weese.

Future applications

Philips Research and Philips Medical Systems have formed a multinational team based in Cleveland, Haifa, Aachen and Hamburg. Philips now holds several heart modeling patents and is researching other application areas.

EP protocols used with magnetic resonance are another potential application of the new technology. "We are looking at creating one algorithm using our experience with other modalities, for example MR and ultrasound," says Mr. Weese. Using essentially the same algorithm, gray-value normalization could enable fully automatic, full heart segmentation in MR images. The technology could also be applied to vascular structures or the segmentation of other organs. "In the long run, we will also research microstructures, for example the direction of fibers within a muscle."

Automatic segmentation could be used in databases and integrated into a PACS system, the algorithm could help shorten the time to first image. Costs can be reduced by improving efficiency, for example with Cardiac CT, while revenues can also be increased, for example in the cath lab, since more interventions can be carried out. In terms of imaging, scan planning will be more consistent and it will be possible to use a motion map to estimate the position of the coronary artery. Modeling may also help with integrating information from various modalities, such as scar tissue imaging in MR combined with CT or by combining information from PET and CT.



Axial slice of a 3D CT image (upper) and 3D MR image (lower) showing the result of model-based segmentation. The contours outline the structures included in the heart model with different colors.

"I envision the use of model segmentation in the simulation of operations or interventions," says Mr. Cristian Lorenz, PhD, Senior Scientist at Philips Research Europe. "This is still 10 to 15 years away. But ultimately, it may be just like the application of computer simulation in other areas. The first tests of a new car or plane will also be computer-based. Although medicine is a different area, I imagine that in future, physicians will also first simulate before they operate." <