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Editorial

1. Functional imaging and modelling of the heart

Cardiac imaging is one of the most active fields of medical imaging, partly due to the importance of heart diseases being still one of the first factors of mortality in developed countries. It is difficult to imagine another field of medical imaging with so many different imaging modalities providing anatomical and functional information. The most widespread cardiac imaging techniques span from ultrasound (including intravascular) techniques, to cardiac magnetic resonance (including myocardial perfusion, coronary angiography delay enhancement, and tagging techniques as well as, more recently, efforts towards visualization of myocardial fibers through diffusion tensor imaging), nuclear cardiology (both SPECT and PET), computed tomography (including recent developments in dynamic multislice tomography,) and conventional and rotational X-ray angiography. In addition, new imaging modalities are out there to extend the information provided by classical imaging techniques: intravascular thermography allows measuring the heat generated by inflamed plaque, near-infrared spectroscopy provides information on the chemical and molecular structure of the myocardial tissue, optical coherence tomography measures reflected infrared light and visualizes the layers of intimae invaded by the plaque and the thickness of its fibrous cap, etc. The fast development of novel imaging modalities as well as the fact that most of them provide very complementary information of the heart triggered the interest amongst researchers of investigating approaches to develop comprehensive *in silico* models of the heart that integrate this wealth of experimental information. The promise is that *in silico* modeling of the heart may contribute to the understanding of cardiovascular diseases, to the diagnosis of cardiovascular pathologies, and to plan and simulate cardiac therapies.

Moreover, the research community devoted to understanding the heart and connected vessels is much wider than cardiac and coronary imaging investigators. Functional Imaging and Modelling of the Heart is a scientific initiative to bring together scientists from several complementary although often isolated scientific and clinical fields: cardiac imaging, signal and image processing, applied mathematics and physics, biomedical engineering and computer science, cardiology, radiology, biology and physiology. Working together in a multidisciplinary project, these disciplines will make possible to integrate cardiac imaging within multiscale modelling and simulation efforts in order to achieve a comprehensive mathematical cardiac model based upon detailed measurements of the cardiovascular system. In such a way we could analyze the heart behaviour and its function in order better understand cardiovascular diseases and to predict the results of cardiac interventions and pharmaceutical treatments. An excellent example for a such multidisciplinary endeavour is reflected in the Cardiome project (part of the bigger IUPS Physiome[1] initiative) where experts from physiology and biochemistry provide quantitative descriptions of ionic currents underlying the cardiac cell action potential, the contractile properties of the myofilaments, and other subcellular processes; a variety of anatomical measurements provide the geometry and fibrous-sheet structure of the heart, the extra-cellular collagen orientation and density, the structure of the coronary vasculature, and the specialized conducting system; experts from engineering continuum mechanics provide the physical conservation laws and the mathematical framework for formulating the equations of deformation mechanics coupled to electrical activation and fluid flow; and modern computational methods allow the efficient solution of these equations on parallel computing architectures while computer graphics provides the means of visualizing the complex interactions of the sophisticated computational heart model. Another excellent example is the Integrative Biology project,[2] a key part of which relates to the heart, aiming to develop a vision for computational physiology where knowledge and understanding at every length and temporal scale of the different organic systems of the human body can be integrated through solid computational models and simulation tools. Although this summary does not pretend to be neither complete nor exhaustive, we are certain that over the next years we will witness more and more the blooming of integrative and personalized modelling and simulation

[1] www.physiome.org.nz.
[2] www.integrativebiology.ac.uk.

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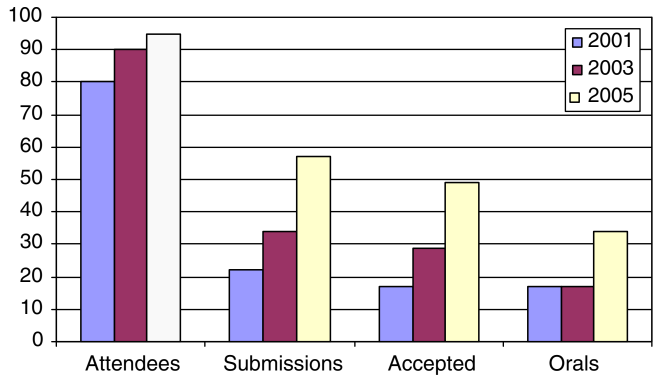

Fig. 1. Number of attendees and number of submitted, accepted and orally presented manuscripts in the first three editions of FIMH in Helsinki 2001, Lyon 2003 and Barcelona 2005.

initiatives some of which will be particularly targeted towards the cardiovascular system.

This special issue is a result of the 3rd International Conference on Functional Imaging and Modelling of the Heart[3] (FIMH'2005) in Barcelona, Spain. The 1st and 2nd International Conferences on Functional Imaging and Modelling of the Heart were held in Helsinki, Finland, in November 2001 and in Lyon, France, in June 2003. These meetings were born through a fruitful scientific collaboration between France and Finland that outreached to other groups and led to the start of the FIMH as a biennial event. The last conference, FIMH'2005 proved the growing interest in the area of imaging, modelling and simulating of the heart, receiving as a result 57 submissions, 47 of which were accepted to be published in *Lecture Notes of Computer Science* and 32 presented as oral. The conference papers were organized around several tracks: anatomical modelling of the heart, cardiac mechanics and function, cardiac motion estimation, etc. The conference was attended by nearly 100 researchers from 13 countries creating a very stimulating scientific environment by their active participation, high-quality scientific presentations, and enlightening multidisciplinary discussions. In Fig. 1 we show the evolution of several indexes over the last three editions of the conference which highlight a substantial increase in the interest awaken by this international event. Following the success of the previous three editions, FIMH will be consolidated as a biennial event. The next edition will take place on June 7–9th 2007 in Salt Lake City, Utah, USA.[4] We hope that this first edition held in the United States will facilitate the participation of the already growing number of North American delegates.

2. Background and contents of this special issue

Eight papers presented at FIMH2005 were selected by the conference programme committee to be submitted to this special issue of the Medical Image Analysis journal. From these, one was already submitted to the journal and was published in an earlier issue.[5] These manuscripts were reviewed by 3–4 independent referees following the regular procedure of the journal to guarantee the scientific quality and relevance. Finally four of them were accepted or made it to be reviewed in time for the scheduled publication date of this special issue.

The first paper presented by A. Wahle et al. study the relationship between plaque development, vessel geometry and wall shear stress distribution. In order to achieve automatic segmentation, a novel 3D graph-based method is presented that minimizes a knowledge-base cost function for segmenting intravascular ultrasound images. The authors show that the correlation between local curvature and circumferential plaque distribution is much higher than the correlation between plaque distribution and wall shear stress. As a result, they concluded that plaque tends to form at the inner curvature of the vessel wall, thus low wall shear stress is hypothesized to contribute to the initial formation of atherosclerotic plaque in the coronary arteries.

The paper presented by Ubbink et al. study in detail the relation between left ventricular shear strain and myofiber orientation. The authors investigate a previously published finite element model of cardiac contraction and compare how effective this method is in predicting cardiac contraction patterns as measured through magnetic resonance tagging. In addition, the authors study the extent in which the discrepancies between model and experiments depend on the model of orientation of myocardial fibers. The authors prove that the time course of circumferential-radial shear strain is very sensitive to the choice of the myofiber orientation (in particular, the choice of the transverse angle) and as a solution propose a technique to reduce this error by increasing significantly the transverse angle of the heart model.

Sermesant et al. present a generic myocardium model able to adapt to specific anatomy of a patient from magnetic resonance images, as well as a framework to automatically obtain mechanical parameters of the heart as local contractility. The authors propose a generic anatomical model of the ventricular myocardium integrating muscle fibre orientations and anatomical segments, develop techniques to fit the model to the patient anatomy and extensively discuss the biomechanical modelling of the myocardium as well as the data assimilation method to automatically adjust the parameters of the model from known displacements. The authors show that data assimilation make possible to quantify local contractility of the patient from the estimated image displacements.

The last paper by Lorenz et al. proposes a comprehensive geometric model of the human heart obtained by statistical analysis of 27 hearts imaged with multislice CT. As a result, the authors obtained a mean model of the

[3] www.cilab.upf.edu/fimh.

[4] www.cvrti.utah.edu/fimh/.

[5] van Assen, H.C., Danilouchkine, M.G., Frangi, A.F., Ordás, S., Westenberg, J.J.M., Reiber, J.H.C., Lelieveldt, B.P.F., 2006, SPASM: A 3D-ASM for segmentation of sparse and arbitrarily oriented cardiac MRI data. Medical Image Analysis 10(2), 286–303.

cardiac structures comprising the surfaces of the cardiac chambers and trunks of the connected vasculature, the coronary arteries and a set of different coronary landmarks. By applying just a similarity transformation to the model, cardiac surface location can be predicted with high accuracy. The constructed model opens several possibilities for its use in cardiac and coronary diagnostics: it can help in linking myocardial perfusion and coronary artery findings, in image-guided interventions with intravascular ultrasound images, and other coronary and cardiac interventional procedures.

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Guest Editors
Alejandro F. Frangi
Pompeu Fabra University, Department de Tecnologia,
Passeig de Circumval lacio 8, 08003 Barcelona, Spain
E-mail address: alejandro.frangi@upf.edu

Petia I. Radeva
Computer Vision Center, Barcelona, Spain

A. Santos
Universidad Politécnica de Madrid, Madrid, Spain

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