

COLLABORATIVE WORKSHOP ON TRANSLATIONAL APPLICATIONS OF PATIENT-SPECIFIC CARDIOVASCULAR MODELS

1. Summary

A workshop on “Translational applications of patient-specific cardiovascular models”, funded by the French Embassy, was held on April 3-4, 2014 and brought together researchers from the Centre for Cardiovascular Imaging (UCL Institute of Cardiovascular Science & Great Ormond Street Hospital for Children, GOSH) and from the Institut National de Recherche en Informatique et en Automatique (mainly from the Asclepios Lab based in Sophia Antipolis, but also from the Reo team based in Paris). The workshop was held at the Wolfson Centre. This Anglo-French collaboration brought together complementary skills within a very specific research realm. INRIA has excellent expertise in software development and advanced biomedical image processing, whilst the UCL group has worked closely with clinicians, understanding the intricacies of clinical data and appreciating what may be required in moving some research from the bench to the bedside, both groups ultimately advancing the knowledge in the field of patient-specific modelling (in particular for cardiovascular applications). Refinement and validation of these models could lead to tailored solutions in the clinic, aiding in the decision-making process and providing virtual scenarios based on analysis of imaging data, and carrying additional value for the purpose of dissemination and education.

The main goals of the workshop were

- a) Identification of clinical problems: focusing on the cardiovascular problems currently being tackled with modelling methods, and what has been achieved and what is still lacking
- b) Discussion on the engineering techniques: focusing on the current state of our groups with regard to modelling anatomies, physiologies and devices, and debating what are the improvements needed in the near future

The workshop was attended by 19 people, including professors, lecturers, researchers and PhD students, of which 10 from the UK and 9 from France, providing a mix of different disciplines and backgrounds (clinical cardiology, medical imaging, fluid mechanics, computing).

All participants agreed that the workshop was very successful and productive, identifying a range of specific areas for future collaboration and specific projects that are currently being brought forward.



2. Workshop programme

Thursday, April 3

- 2:00 PM Arrival, welcome & coffee
- 2:30 PM Modelling hypoplastic left heart syndrome
- *Observations from wave intensity analysis* - G. Biglino (UCL)
 - *Shape analysis methodology* - K. McLeod (INRIA/Simula Lab)
 - *Results from 40 patients* - J. Bruse (UCL)
- 3:30 PM Modelling the ventricle
- *Normal anatomy, cardiomyopathies, tetralogy of Fallot* - A. Taylor (UCL)
 - *Globular shape of left ventricle in repaired TGA* - H. Ntsinjana (UCL)
 - *Statistical modeling of the cardiac fiber architecture* - H. Lombaert (INRIA)
- 4:30 PM Coffee break
- 5:00 PM *Can we model exercise physiology in Fontan patients?* - E. Cervi (GOSH)
- 5:30 PM *Learning from cardiac databases* - J. Margeta (INRIA)
- 6:00 PM *What do we need for an accurate analysis?* - I. Vignon-Clementel (INRIA)
- Uncertainty in image registration* - L. Folgoc (INRIA)
- 7:00 PM Wrap up & end of day 1
- 8:00 PM Dinner at Tom's Kitchen Somerset House

Friday, April 4

- 8:30 AM Coffee
- 9:00 AM *Difficulties in modelling cardiovascular devices* - C. Capelli & G. Bosi (UCL)
- 10:00 AM *Longitudinal morphometric analysis: from the brain to the heart?* - X. Pennec (INRIA)
- 11:00 AM Coffee break
- 11:30 AM *Electromechanical models for CRT and ablation* - M. Sermesant (INRIA)
- Cardiac ablation: can machine learning & images help?* - R. Cabrera-Lozoya (INRIA)
- 12:30 AM Summary & discussion - led by S. Schievano (UCL) & M. Sermesant (INRIA)
- 1:30 PM End of workshop



All participants at the end of the workshop, photographed in the Wolfson Centre

3. List of participants (alphabetical)

Dr Giovanni Biglino

Research Fellow (National Institute for Health Research, NIHR), UCL Institute of Cardiovascular Science

Core research: experimental modelling for cardiovascular applications, wave intensity analysis

Ms Giorgia Bosi

PhD Candidate, UCL Institute of Cardiovascular

Core research: modelling of transcatheter aortic valve replacement

Mr Jan Bruse

PhD Candidate, UCL Institute of Cardiovascular Engineering

Core research: growth modelling, single ventricle circulation

Ms Rocio Cabrera Lozoya

PhD Candidate, INRIA Asclepios Project

Core research: Machine learning, biophysical modelling, electrophysiology, ablation planning

Dr Claudio Capelli

Research Fellow (Heart Research UK), UCL Institute of Cardiovascular Science

Core research: modelling of cardiovascular devices, structural analysis

Dr Elena Cervi

Cardiology Registrar, Great Ormond Street Hospital for Children, London, UK

Core research: single ventricle circulation, exercise physiology

Dr Paolo Ciliberti

CMR Fellow, Great Ormond Street Hospital for Children, London, UK

Core research: cardiac magnetic resonance imaging, echocardiography, congenital lesions

Dr Jakob Hauser

Cardiologist & PhD student at UCL Institute of Cardiovascular Science

Core research: heart failure, biomarkers

Mr Loïc Le Folgoc

PhD Candidate, INRIA Asclepios Project

Core research: machine learning, statistical shape analysis, nonlinear dimensionality reduction, kernel methods, compressed sensing, image segmentation

Dr Hervé Lombaert

Post-doctoral researcher, INRIA Asclepios Project

Core research: statistical learning of anatomy and function

Mr Jan Margeta

PhD Candidate, INRIA Asclepios Project

Core research: Content based image retrieval, Cardiac MRI image processing, Segmentation

Dr Kristin McLeod

Researcher, Simula Lab, Oslo, Norway & INRIA Asclepios Project

Core research: statistical cardiac modelling and reduced order modelling

Dr Hopewell Ntsinjana

Cardiologist & PhD student at UCL Institute of Cardiovascular Science

Core research: transposition of the great arteries, magnetic resonance imaging, computed tomography imaging

Dr Xavier Pennec

Research Scientist, INRIA Asclepios Project

Core research: medical image processing, computational anatomy, mathematics

Mr Marc-Michel Rohe

PhD Candidate, INRIA Asclepios Project

Core research: Medical image processing and simulation

Dr Silvia Schievano

Senior Lecturer in Biomedical Engineering, UCL Institute of Cardiovascular Science

Core research: modelling of cardiovascular devices, patient-specific cardiovascular modelling

Dr Maxime Sermesant

Research Scientist, INRIA Asclepios Project

Core research: Digital organs and medical image processing

Prof Andrew M. Taylor

Head, Cardiorespiratory Division, Great Ormond Street Hospital for Children

Director, Centre for Cardiovascular Imaging, UCL Institute of Cardiovascular Science

Professor of Cardiovascular Imaging

Core research: cardiovascular magnetic resonance imaging, congenital heart disease, translational research

Dr Irène Vignon-Clementel

Permanent research scientist (Chargée de recherche), INRIA Rocquencourt, Paris

Core research: multiscale and multiphysics modelling for cardiac and oncology applications

4. Discussion and on-going projects

All participants felt the workshop was extremely beneficial and productive. Presentations were very detailed, and some highly technical, leading to in-depth discussions. On the other hand, the final session of the workshop, led by Dr Schievano and Dr Sermesant, generated more general discussion on the differences between theoretical research vs. applied research, and the ways in which a combination of these may positively affect the clinical workflow. Prof Taylor, as a final remark, stressed the complementary nature of the research carried out at the different institutions participating to this workshop.

More specific points have been discussed, all involving collaborations between some of the participants, including:

- statistical shape analysis in patients with aortic coarctation, looking at whether patients with coarctation have an elevated blood pressure, i.e. no residual coarctation is observed but patients might still present with elevated BP, so shape of the ventricle might inform about the impedance
- methodological discussions have been carried out (led by Dr Pennec) especially with regard to shape analysis
- discussions on potential automatic area data extraction from MRI flow sequences and also possibility of automatic 3d volume segmentation
- work is on-going with regard to modelling of the left ventricle using different computational techniques in different congenital scenarios, especially tetralogy of Fallot
- exercise physiology has been also discussed, following a presentation from Dr Cervi; points that have been raised include: how to adjust heart rate effectively? And should lumped parameter models be used?
- acquisition of diffusion tensor imaging (DTI) data at GOSH to be investigated, as a possible tool for validation of heart failure model
- discussion about motion and number of slices and signal-to-noise ratio (SNR) affecting segmentation, data already acquired at GOSH and sent to INRIA for analysis

5. Collaborations and conferences

Interactions between the two groups are currently on-going regarding specific projects, including ventricular modelling and image analysis.

Conference abstracts have been presented at important conferences, including the *7th World Congress of Biomechanics* (Boston, July 2014) and the *4th International Conference on Engineering Frontiers in Paediatrics and Congenital Heart Disease* (Paris, May 2014). At the latter, one of the abstracts resulting from the collaboration between the groups (“Shape Atlas of the Surgically Reconstructed Aortic Arch in Patients with Hypoplastic Left Heart Syndrome”) was commended and its author, Mr Jan Bruse (PhD candidate at UCL), received the Young Investigator Award.

At least one journal paper is currently being discussed and prepared and it is expected that more will be produced in the near future, thanks to this collaboration.

Both groups (UCL and INRIA) are involved in a major European grant, namely MD-PAEDIGREE (“Model-Driven Paediatric European Digital Repository”). This represents a clinically-driven and strongly VPH-rooted project, where 7 world-renowned clinical centres of excellence strive to develop a set of multi-scale models for more predictive, individualised, effective and safer paediatric healthcare.

6. Finance

The funds we received allowed us to pay for travel and hotel (1 night) expenses of all French colleagues. Furthermore, funds also covered expenses for lunch and refreshments for all participants during the workshop. A dinner was organised for all participants at Tom’s Kitchen in the Somerset House at the end of Day 1 and this was a great chance for social interaction and discussing ideas in a more informal context.

If needed, a more detailed break-down of the expenses can be provided.

7. Additional remarks

The UCL and INRIA groups have recognised the complementary nature of their respective approaches to cardiovascular modelling. While on the one side day-to-day interaction between clinicians and engineers at GOSH/UCL leads to more translational research, on the other hand INRIA is a leading institution worldwide for image processing and mathematics. Discussions between the two groups have been very fruitful. While some of the discussed topics have been rather technical, more general points have also been debated, as in a talk by Dr Vignon-Clementel discussing what is needed for accurate analyses taking into account the uncertainty of clinical data.

The synergies between the participating groups are currently being fostered through more general collaborations (e.g. MD-PAEDIGREE grant) but also by means of smaller research projects that have emerged thank to the workshop. It is expected that several publications will be produced as a tangible outcome of the workshop.

All participants expressed interest in organising a follow-up meeting, perhaps in France (at INRIA Sophia Antipolis). This meeting ideally would take place at the end of 2014/beginning of 2015 and potential funding opportunities are currently being explored.

The author of the report, on behalf of all participants, would like to thank the French Embassy for providing the funds for the workshop, which was indeed very successful.