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# Statistical Atlases and Computational Models of the Heart

Multi-Sequence CMR Segmentation,  
CRT-EPiggy and LV Full Quantification Challenges

10th International Workshop, STACOM 2019  
Held in Conjunction with MICCAI 2019  
Shenzhen, China, October 13, 2019  
Revised Selected Papers

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ISSN 0302-9743

ISSN 1611-3349 (electronic)

Lecture Notes in Computer Science

ISBN 978-3-030-39073-0

ISBN 978-3-030-39074-7 (eBook)

<https://doi.org/10.1007/978-3-030-39074-7>

LNCS Sublibrary: SL6 – Image Processing, Computer Vision, Pattern Recognition, and Graphics

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# Preface

Integrative models of cardiac function are important for understanding disease, evaluating treatment, and planning intervention. In recent years, there has been considerable progress in cardiac image analysis techniques, cardiac atlases, and computational models, which can integrate data from large-scale databases of heart shape, function, and physiology. However, significant clinical translation of these tools is constrained by the lack of complete and rigorous technical and clinical validation, as well as benchmarking of the developed tools. For doing so, common and available ground-truth data capturing generic knowledge on the healthy and pathological heart is required. Several efforts have been established to provide web-accessible structural and functional atlases of the normal and pathological heart for clinical, research, and educational purposes. We believe that these approaches will only be effectively developed through collaboration across the full research scope of the cardiac imaging and modeling communities.

The 10th edition of the Statistical Atlases and Computational Modelling of the Heart workshop, STACOM 2019 (<http://stacom2019.cardiacatlas.org>), was held in conjunction with the MICCAI 2019 international conference (Shenzhen, China), following the past nine editions: STACOM 2010 (Beijing, China), STACOM 2011 (Toronto, Canada), STACOM 2012 (Nice, France), STACOM 2013 (Nagoya, Japan), STACOM 2014 (Boston, USA), STACOM 2015 (Munich, Germany), STACOM 2016 (Athens, Greece), STACOM 2017 (Quebec City, Canada), and STACOM 2018 (Granada, Spain). STACOM 2019 provided a forum to discuss the latest developments in various areas of computational imaging and modeling of the heart, as well as statistical cardiac atlases.

The topics of this 10th anniversary edition of the STACOM workshop included: cardiac imaging and image processing, machine learning applied to cardiac imaging and image analysis, atlas construction, statistical modeling of cardiac function across different patient populations, cardiac computational physiology, model customization, atlas based functional analysis, ontological schemata for data and results, integrated functional and structural analyzes, as well as the pre-clinical and clinical applicability of these methods. Besides regular contributing papers, additional efforts of the STACOM 2019 workshop were also focused on three challenges: Multi-Sequence Cardiac MR Segmentation Challenge; Cardiac Resynchronization Therapy CRT-EPiggy Electrophysiology Modelling Challenge; and Left Ventricle Full Quantification Challenge. These challenges are described more in detail below.

From an initial submission of 76 papers (regular and challenges), 44 papers were accepted for presentation at the workshop and 42 papers were invited for publication in this LNCS proceedings volume.

**MS-CMR Seg Challenge 2019 (Multi-Sequence Cardiac MR Segmentation Challenge):** Accurate computing, analysis, and modeling of the ventricle and myocardium from medical images is important, especially in the diagnosis and treatment

management for patients suffering from myocardial infarction (MI). Late gadolinium enhancement cardiac magnetic resonance (LGE CMR) image is an important means to visualize MI, appearing with distinctive brightness compared with the health tissues. It is widely used to study the presence, location, and extent of MI. Before the analysis of MI, accurate segmentation of myocardium is required. However, automating this segmentation remains challenging due to the indistinguishable boundaries, heterogeneous intensity, and complex enhancement patterns of pathological myocardium from LGE CMR. Combining the complementary information of multi-sequence CMR from the same patient can assist the myocardial segmentation.

MS-CMR Seg Challenge 2019 provided an open and fair competition for various research groups to test and validate their methods, particularly for the ventricle and myocardium segmentation. The aim of the challenge was not only to benchmark various segmentation algorithms, but also to cover the topic of general cardiac image segmentation, registration, and modeling, and to raise discussions for further technical development and clinical deployment. The challenge received great interest from participants all over the world and the proposed methods have achieved substantial methodological innovations and significant performance improvement. The organizers aim at keeping the MS-CMR Seg Challenge as a long-term event for participants who were not able to enter the competition, but are interested in further developments. Relevant information and challenge results can be found at: <https://zmiclab.github.io/mscmrseg19/>.

**CRT-EPiggy19 Challenge:** The spirit of the (not machine learning) CRT-EPiggy19 Challenge was to collectively review the current state of the art for computational cardiology models and their ability to predict pacing-based therapy outcomes, as well as the identification of the most critical phases and more promising solutions in the personalization modeling pipeline. More specifically, participants were asked to predict the electrical response of Cardiac Resynchronization Therapy (CRT) and to propose the optimal device configuration in a swine model of left bundle branch block, given fully controlled data. The unique multi-modal experimental data available in the challenge has helped to calibrate electrophysiological solvers based on different mathematical models. One key of the CRT-EPiggy19 Challenge has been to work in a collaborative way between the different participants, rather than competitively, fostering reproducible research and Open Science. Preliminary results from five international participant teams were presented during the STACOM 2019 workshop on the available data. Additionally, some lessons learned from the organization of a Biophysical Modelling Challenge and suggestions for joint initiatives between medical data science and physiological modeling communities were summarized. More information can be found here: <http://crt-epiggy19.surge.sh/>.

**The Left Ventricle Full Quantification Challenge (LVQuan19):** LVQuan19 aimed to promote effective machine learning models for efficiently assessing the heart's function. LVQuan19 provided original cardiac MRI data without preprocessing for training and testing phases, which is more clinical than the data providing by LVQuan18. In this challenge, the extraction of the LV's cavity and myocardium and subsequently the regression of regional wall thicknesses, LV dimensions and the classification of the phase of the cardiac cycle were to be performed. These are common and significant parameters to assess the LV function. However, in clinical

routine, these are time consuming and prone to error and inter-observer variability. Here, the four revised full workshop papers were carefully reviewed and selected from five submissions. In these submissions, state-of-the-art technologies including transfer learning, statistical models, incorporated 2D+3D, and multi-task learning were developed, and the performance achieved to 106mm<sup>2</sup>, 0.9920mm, and 0.9185mm of mean absolute error for area, dimension, and regional wall thickness, as well as 6.7% of error rate for phase classification. More information can be found here: <https://lvquan19.github.io/>

We hope that the results obtained by the challenges, along with the regular paper contributions will act to accelerate progress in the important areas of heart function and structure analysis. A total of 48 papers (i.e., regular papers and from the 3 challenges) were accepted for oral or poster presentations at STACOM 2019. The selected papers are published in this Springer *Lecture Notes in Computer Science* (LNCS) proceedings volume.

October 2019

Mihaela Pop  
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Alistair Young  
Tommaso Mansi  
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We would like to thank all organizers, reviewers, authors, and sponsors for their time, efforts, contributions, and support in making STACOM 2019 a successful event.

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### Multi-Sequence Cardiac MR Segmentation Challenge

|               |                                      |
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# Contents

## Regular Papers

|                                                                                                                                                                                                                                             |    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Co-registered Cardiac <i>ex vivo</i> DT Images and Histological Images for Fibrosis Quantification . . . . .                                                                                                                                | 3  |
| <i>Peter Lin, Anne Martel, Susan Camilleri, and Mihaela Pop</i>                                                                                                                                                                             |    |
| Manufacturing of Ultrasound- and MRI-Compatible Aortic Valves Using 3D Printing for Analysis and Simulation. . . . .                                                                                                                        | 12 |
| <i>Shu Wang, Harminder Gill, Weifeng Wan, Helen Tricker, Joao Filipe Fernandes, Yohan Noh, Sergio Uribe, Jesus Urbina, Julio Sotelo, Ronak Rajani, Pablo Lamata, and Kawal Rhode</i>                                                        |    |
| Assessing the Impact of Blood Pressure on Cardiac Function Using Interpretable Biomarkers and Variational Autoencoders . . . . .                                                                                                            | 22 |
| <i>Esther Puyol-Antón, Bram Ruijsink, James R. Clough, Ilkay Oksuz, Daniel Rueckert, Reza Razavi, and Andrew P. King</i>                                                                                                                    |    |
| Ultra-DenseNet for Low-Dose X-Ray Image Denoising in Cardiac Catheter-Based Procedures . . . . .                                                                                                                                            | 31 |
| <i>Yimin Luo, Daniel Toth, Kui Jiang, Kuberan Pushparajah, and Kawal Rhode</i>                                                                                                                                                              |    |
| A Cascade Regression Model for Anatomical Landmark Detection . . . . .                                                                                                                                                                      | 43 |
| <i>Zimeng Tan, Yongjie Duan, Ziyi Wu, Jianjiang Feng, and Jie Zhou</i>                                                                                                                                                                      |    |
| Comparison of 2D Echocardiography and Cardiac Cine MRI in the Assessment of Regional Left Ventricular Wall Thickness . . . . .                                                                                                              | 52 |
| <i>Vera H. J. van Hal, Debbie Zhao, Kathleen Gilbert, Thiranja P. Babarenda Gamage, Charlene Mauger, Robert N. Doughty, Malcolm E. Legget, Jichao Zhao, Aaqel Nalar, Oscar Camara, Alistair A. Young, Vicky Y. Wang, and Martyn P. Nash</i> |    |
| Fully Automatic 3D Bi-Atria Segmentation from Late Gadolinium-Enhanced MRIs Using Double Convolutional Neural Networks. . . . .                                                                                                             | 63 |
| <i>Zhaohan Xiong, Aaqel Nalar, Kevin Jamart, Martin K. Stiles, Vadim V. Fedorov, and Jichao Zhao</i>                                                                                                                                        |    |
| 4D CNN for Semantic Segmentation of Cardiac Volumetric Sequences . . . . .                                                                                                                                                                  | 72 |
| <i>Andriy Myronenko, Dong Yang, Varun Buch, Daguang Xu, Alvin Ihsani, Sean Doyle, Mark Michalski, Neil Tenenholtz, and Holger Roth</i>                                                                                                      |    |

|                                                                                                                                                          |     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Two-Stage 2D CNN for Automatic Atrial Segmentation from LGE-MRIs . . .                                                                                   | 81  |
| <i>Kevin Jamart, Zhaohan Xiong, Gonzalo Maso Talou, Martin K. Stiles, and Jichao Zhao</i>                                                                |     |
| 3D Left Ventricular Segmentation from 2D Cardiac MR Images<br>Using Spatial Context . . . . .                                                            | 90  |
| <i>Sofie Tilborghs, Tom Dresseleers, Piet Claus, Jan Bogaert, and Frederik Maes</i>                                                                      |     |
| Towards Hyper-Reduction of Cardiac Models Using<br>Poly-affine Transformations . . . . .                                                                 | 100 |
| <i>Gaëtan Desrues, Hervé Delingette, and Maxime Sermesant</i>                                                                                            |     |
| Conditional Generative Adversarial Networks for the Prediction<br>of Cardiac Contraction from Individual Frames. . . . .                                 | 109 |
| <i>Julius Ossenberger-Engels and Vicente Grau</i>                                                                                                        |     |
| Learning Interactions Between Cardiac Shape and Deformation:<br>Application to Pulmonary Hypertension. . . . .                                           | 119 |
| <i>Maxime Di Folco, Patrick Clarysse, Pamela Moceri, and Nicolas Duchateau</i>                                                                           |     |
| Multimodal Cardiac Segmentation Using Disentangled<br>Representation Learning. . . . .                                                                   | 128 |
| <i>Agisilaos Chartsias, Giorgos Papanastasiou, Chengjia Wang, Colin Stirrat, Scott Semple, David Newby, Rohan Dharmakumar, and Sotirios A. Tsaftaris</i> |     |
| DeepLA: Automated Segmentation of Left Atrium from Interventional<br>3D Rotational Angiography Using CNN . . . . .                                       | 138 |
| <i>Kobe Bamps, Stijn De Buck, Jeroen Bertels, Rik Willems, Christophe Garweg, Peter Haemers, and Joris Ector</i>                                         |     |
| Non-invasive Pressure Estimation in Patients with Pulmonary Arterial<br>Hypertension: Data-Driven or Model-Based? . . . . .                              | 147 |
| <i>Yingyu Yang, Stephane Gillon, Jaume Banus, Pamela Moceri, and Maxime Sermesant</i>                                                                    |     |
| Deep Learning Surrogate of Computational Fluid Dynamics for Thrombus<br>Formation Risk in the Left Atrial Appendage . . . . .                            | 157 |
| <i>Xabier Morales, Jordi Mill, Kristine A. Juhl, Andy Olivares, Guillermo Jimenez-Perez, Rasmus R. Paulsen, and Oscar Camara</i>                         |     |
| End-to-end Cardiac Ultrasound Simulation for a Better Understanding<br>of Image Quality. . . . .                                                         | 167 |
| <i>Alexandre Legay, Thomas Tiennot, Jean-François Gelly, Maxime Sermesant, and Jean Bulté</i>                                                            |     |

|                                                                                                                      |     |
|----------------------------------------------------------------------------------------------------------------------|-----|
| Probabilistic Motion Modeling from Medical Image Sequences:<br>Application to Cardiac Cine-MRI . . . . .             | 176 |
| <i>Julian Krebs, Tommaso Mansi, Nicholas Ayache, and Hervé Delingette</i>                                            |     |
| Deep Learning for Cardiac Motion Estimation:<br>Supervised vs. Unsupervised Training . . . . .                       | 186 |
| <i>Huaqi Qiu, Chen Qin, Loic Le Folgoc, Benjamin Hou, Jo Schlemper,<br/>and Daniel Rueckert</i>                      |     |
| <b>Multi-Sequence Cardiac MR Segmentation Challenge</b>                                                              |     |
| Style Data Augmentation for Robust Segmentation<br>of Multi-modality Cardiac MRI. . . . .                            | 197 |
| <i>Buntheng Ly, Hubert Cochet, and Maxime Sermesant</i>                                                              |     |
| Unsupervised Multi-modal Style Transfer for Cardiac MR Segmentation . . . .                                          | 209 |
| <i>Chen Chen, Cheng Ouyang, Giacomo Tarroni, Jo Schlemper,<br/>Huaqi Qiu, Wenjia Bai, and Daniel Rueckert</i>        |     |
| An Automatic Cardiac Segmentation Framework Based<br>on Multi-sequence MR Image. . . . .                             | 220 |
| <i>Yashu Liu, Wei Wang, Kuanquan Wang, Chengqin Ye,<br/>and Gongning Luo</i>                                         |     |
| Cardiac Segmentation of LGE MRI with Noisy Labels . . . . .                                                          | 228 |
| <i>Holger Roth, Wentao Zhu, Dong Yang, Ziyue Xu, and Daguang Xu</i>                                                  |     |
| Pseudo-3D Network for Multi-sequence Cardiac MR Segmentation. . . . .                                                | 237 |
| <i>Tao Liu, Yun Tian, Shifeng Zhao, XiaoYing Huang, Yang Xu,<br/>Gaoyuan Jiang, and Qingjun Wang</i>                 |     |
| SK-Unet: An Improved U-Net Model with Selective Kernel<br>for the Segmentation of Multi-sequence Cardiac MR. . . . . | 246 |
| <i>Xiyue Wang, Sen Yang, Mingxuan Tang, Yunpeng Wei, Xiao Han,<br/>Ling He, and Jing Zhang</i>                       |     |
| Multi-sequence Cardiac MR Segmentation with Adversarial Domain<br>Adaptation Network . . . . .                       | 254 |
| <i>Jiexiang Wang, Hongyu Huang, Chaoqi Chen, Wenao Ma, Yue Huang,<br/>and Xinghao Ding</i>                           |     |
| Deep Learning Based Multi-modal Cardiac MR Image Segmentation. . . . .                                               | 263 |
| <i>Rencheng Zheng, Xingzhong Zhao, Xingming Zhao, and He Wang</i>                                                    |     |
| Segmentation of Multimodal Myocardial Images<br>Using Shape-Transfer GAN . . . . .                                   | 271 |
| <i>Xumin Tao, Hongrong Wei, Wufeng Xue, and Dong Ni</i>                                                              |     |

|                                                                                                                                                |     |
|------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Knowledge-Based Multi-sequence MR Segmentation via Deep Learning<br>with a Hybrid U-Net++ Model . . . . .                                      | 280 |
| <i>Jinchang Ren, He Sun, Yumin Huang, and Hao Gao</i>                                                                                          |     |
| Combining Multi-Sequence and Synthetic Images for Improved<br>Segmentation of Late Gadolinium Enhancement Cardiac MRI . . . . .                | 290 |
| <i>Victor M. Campello, Carlos Martín-Isla, Cristian Izquierdo,<br/>Steffen E. Petersen, Miguel A. González Ballester, and Karim Lekadir</i>    |     |
| Automated Multi-sequence Cardiac MRI Segmentation Using Supervised<br>Domain Adaptation . . . . .                                              | 300 |
| <i>Sulaiman Vesal, Nishant Ravikumar, and Andreas Maier</i>                                                                                    |     |
| A Two-Stage Fully Automatic Segmentation Scheme Using Both 2D<br>and 3D U-Net for Multi-sequence Cardiac MR . . . . .                          | 309 |
| <i>Haohao Xu, Zhuangwei Xu, Wenting Gu, and Qi Zhang</i>                                                                                       |     |
| Adversarial Convolutional Networks with Weak Domain-Transfer<br>for Multi-sequence Cardiac MR Images Segmentation . . . . .                    | 317 |
| <i>Jingkun Chen, Hongwei Li, Jianguo Zhang, and Bjoern Menze</i>                                                                               |     |
| <b>CRT-EPiggy19 Challenge</b>                                                                                                                  |     |
| Best (and Worst) Practices for Organizing a Challenge on Cardiac<br>Biophysical Models During AI Summer: The CRT-EPiggy19 Challenge . . . .    | 329 |
| <i>Oscar Camara</i>                                                                                                                            |     |
| Prediction of CRT Activation Sequence by Personalization of Biventricular<br>Models from Electroanatomical Maps . . . . .                      | 342 |
| <i>Juan Francisco Gomez, Beatriz Trenor, and Rafael Sebastian</i>                                                                              |     |
| Prediction of CRT Response on Personalized Computer Models . . . . .                                                                           | 352 |
| <i>Svyatoslav Khamzin, Arsenii Dokuchaev, and Olga Solovyova</i>                                                                               |     |
| Eikonal Model Personalisation Using Invasive Data to Predict Cardiac<br>Resynchronisation Therapy Electrophysiological Response . . . . .      | 364 |
| <i>Nicolas Cedilnik and Maxime Sermesant</i>                                                                                                   |     |
| <b>LV-Full Quantification Challenge</b>                                                                                                        |     |
| Left Ventricle Quantification Using Direct Regression with Segmentation<br>Regularization and Ensembles of Pretrained 2D and 3D CNNs . . . . . | 375 |
| <i>Nils Gessert and Alexander Schlaefer</i>                                                                                                    |     |

|                                                                                                                                              |            |
|----------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Left Ventricle Quantification with Cardiac MRI: Deep Learning Meets<br>Statistical Models of Deformation . . . . .                           | 384        |
| <i>Jorge Corral Acero, Hao Xu, Ernesto Zacur, Jurgen E. Schneider,<br/>Pablo Lamata, Alfonso Bueno-Orovio, and Vicente Grau</i>              |            |
| Left Ventricular Parameter Regression from Deep Feature Maps of a Jointly<br>Trained Segmentation CNN . . . . .                              | 395        |
| <i>Sofie Tilborghs and Frederik Maes</i>                                                                                                     |            |
| A Two-Stage Temporal-Like Fully Convolutional Network Framework<br>for Left Ventricle Segmentation and Quantification on MR Images . . . . . | 405        |
| <i>Zhou Zhao, Nicolas Boutry, Élodie Puybareau, and Thierry Géraud</i>                                                                       |            |
| <b>Author Index . . . . .</b>                                                                                                                | <b>415</b> |