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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
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Revised Selected Papers

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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. Combing 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 be 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 106mm2, 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

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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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*stacom2019.cardiacatlas.org*

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