Segmentation of papillary muscles and trabeculae in cardiac MRI

Background: The quantitative values of left and right ventricular (LV & RV) volumes/masses are important parameters in the assessment of patients with suspected cardiovascular diseases. Cardiac Magnetic Resonance (CMR) is widely regarded as the non-invasive reference standard for measuring cardiac function due to its high spatial resolution and clear anatomical structures making it both accurate and reproducible.

To maximise the reproducibility and to allow comparison between the values from different hospitals, the Society for Cardiovascular Magnetic Resonance (SCMR) make recommendations for the standardised procedures that should be followed when making the segmentation of the ventricles and myocardium. However, there is still no consensus on how to deal with the trabecular tissue and the papillary muscles. The trabecular tissue is the complex network of muscular strands that line the inner surface of the heart, and the papillary muscles connect the ventricular walls to the atrioventricular valves and work to prevent the backflow of blood. Since both are muscular tissue, it is understood that they should be included in the calculation of myocardial mass and excluded from the ventricular volumes.

But, commonly, this is not done because they can be highly variable in their shape and location, making make it challenging to accurately segment them and they are difficult to distinguish from the surrounding tissue. Automated methods do not segment trabeculae/papillary muscles and it is too time-consuming to segment them manually. This is reflected in the clinical SCMR guidelines:

"As there is still discussion on the exact delineation of papillary muscles (e.g. versus trabeculation) and not all evaluation tools allow for their inclusion without manual drawing of contours, they are often included in the blood pool volume in clinical practice, which is acceptable."

The limitation of this is that in a normal left ventricle, the trabeculae account for ~10% of the myocardium mass and there are cardiovascular conditions that can cause this to be even larger. In particular, in the presence of a cardiomyopathy known as the *"excessive trabeculation cardiomyopathy"*, this value can exceed 35%. Csecs et al. have shown that the different volumes with and without trabeculae and papillary muscles can lead to a difference in computed ejection fraction of 10% (Csecs et al., 2018).

A comparison of the different strategies without and with papillary/trabecular muscle in the myocardium segmentation is shown in Figure 1 A and B, respectively.

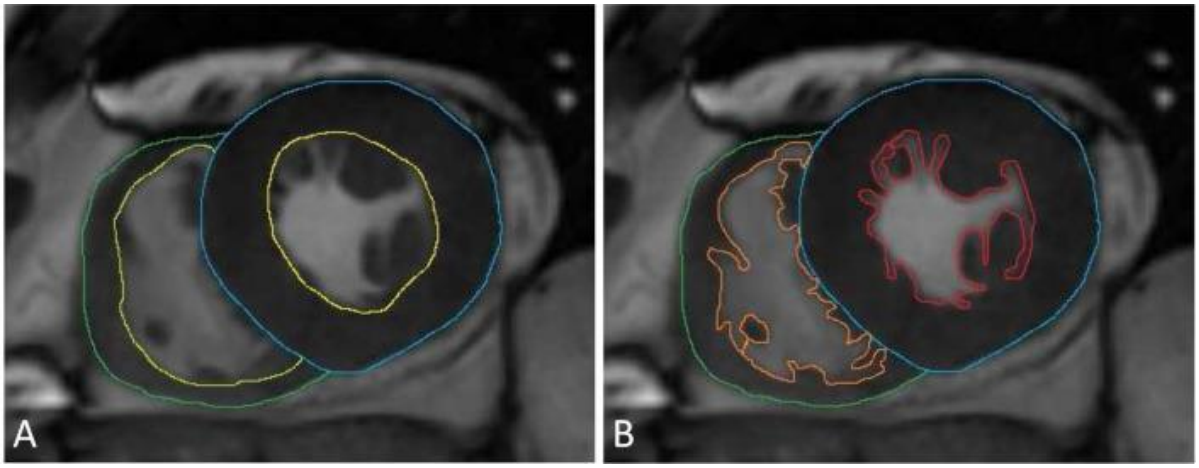

Figure 1

Aims: To develop an automated deep learning-based segmentation of cine CMR images that delineates the papillary muscles and trabecular tissue. In order to facilitate the development of such a model, training data will also be required. Since, as discussed, it is difficult to generate ground-truth segmentations for this application, the model will be trained with synthetic images that are also generated as part of this project. Previously synthetic images generated by segmentation conditional GANs, see Figure 2, have been shown to be useful for training segmentation models (Al Khalil et al., 2023). In this project we will be extending this previous work, that has generated images conditioned on simplified segmentation mask (Figure 3, left), to also include the papillary muscles and trabecular tissue (Figure 3, right).

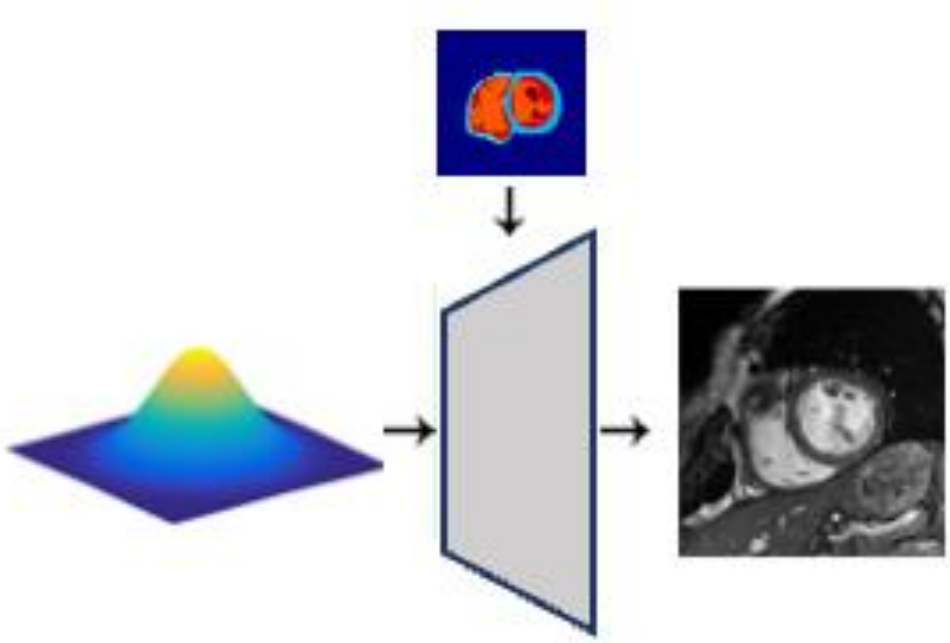

Figure 2

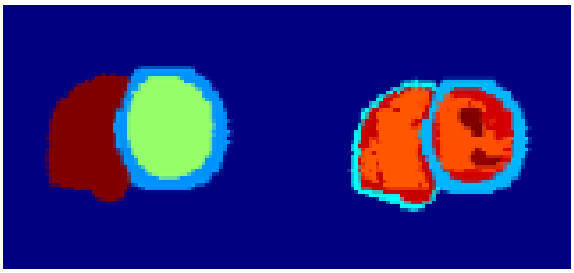

Figure 3

Outcomes: The outcome of this project may result in a scientific conference or journal paper, co-authored by the student.

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Further information: This project will be conducted with our clinical collaborators at King's College London and, if interested, the student could arrange to visit their hospital as part of the project.

Expected skills and experience

- Programming in Python, other languages (e.g. course BMB502417)
- Machine learning / deep learning (e.g. courses 8DM40, 8DM00, 8DM20)
- Medical image analysis (e.g. courses 8DC00, 2DMM10)
- Experimental study design (course 8DM20)
- Written and oral communication in English

References:

Al Khalil, Y., Amirrajab, S., Lorenz, C., Weese, J., Pluim, J., & Breeuwer, M. (2023). On the usability of synthetic data for improving the robustness of deep learning-based segmentation of cardiac magnetic resonance images. *Medical Image Analysis*, *84*, 102688. https://doi.org/10.1016/J.MEDIA.2022.102688

Csecs, I., Czimbalmos, C., Suhai, F. I., Mikle, R., Mirzahosseini, A., Dohy, Z., Szűcs, A., Kiss, A. R., Simor, T., Tóth, A., Merkely, B., & Vágó, H. (2018). Left and right ventricular parameters corrected with threshold-based quantification method in a normal cohort analyzed by three independent observers with various training-degree. *International Journal of Cardiovascular Imaging*, *34*(7), 1127–1133. https://doi.org/10.1007/S10554-018-1322-4/TABLES/3