Simulation and synthesis of myocardial perfusion MRI

Background

Recent work has shown that it is possible to generate realistic synthetic cardiac MRI data using both physics-based simulations (Amirrajab et al., 2023) and deep learning-based image synthesis (Amirrajab et al., 2022). It has also been demonstrated that including such synthetic data in the training of further deep learning models, e.g. for image segmentation, can improve performance and robustness (Al Khalil et al., 2023).

Both approaches to generating data have some benefits. Simulation allows tight control of the generation process and details related to the scanning parameters or tissue characteristics can be explicitly changed, but it is difficult to simulate realistic textures and features. On the other hand, deep learning-based synthesis generates realistic appearances, as the texture and features can be learned from the real training examples, but it is not possible to exactly control this appearance.

The deep learning-based approach to image synthesis is currently receiving significant attention as the realistic appearance is thought to be critical to the usability of the synthetic images. However, the current literature has been heavily focused on generating static images from anatomical cine scans, conditioned on segmentation masks.

Dynamic contrast-enhanced MRI is another common type of cardiac magnetic resonance scan to assess perfusion and identify coronary artery disease. In this acquisition, videos are taken after an injection of a gadolinium-based contrast agent and the passage of the contrast through the heart is visualised. Examples of three of these phases of the contrast agent passage are shown in Figure 1, bottom and the signal intensity curves from different anatomical locations are shown in Figure 1, top.

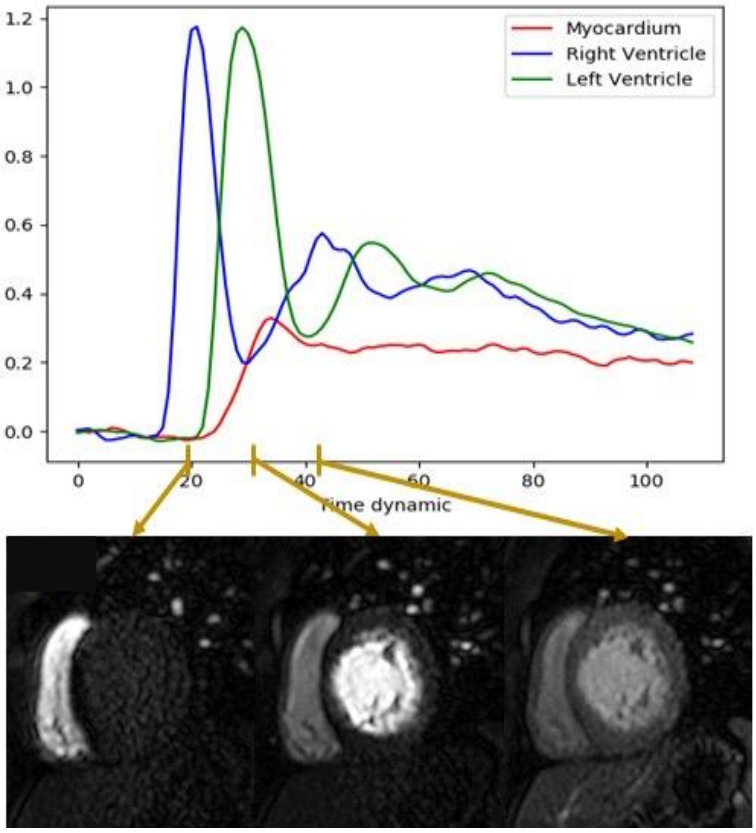

Figure 1

Aim

The aim of this project is to extend the current methods for generating synthetic cine cardiac MRI images to allow the generation of dynamic perfusion images. To achieve this, it is envisaged that it will be necessary to combine the benefits of deep learning synthesis with physics-based simulation to generate realistic images while constraining the contrast to fit the expected model of kinetics. Different approaches can be investigated such as first simulating the physics and using a deep learning model to add a realistic appearance to the simulated images or alternatively embedding the physics directly in the deep learning generation, as illustrated in Figure 2. Certain imperfections in MRI data, known as artifacts, are particularly common in perfusion images (dark-rim artifacts) and if time allows in the project, these artifacts will also be included in the simulated images.

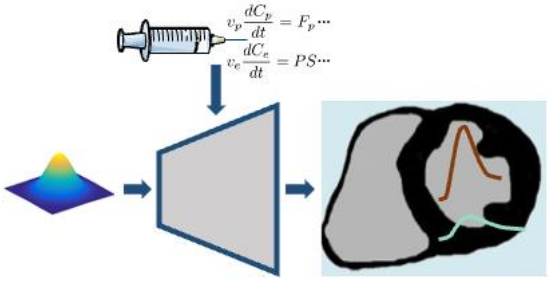

Figure 2

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

Amirrajab, S., Al Khalil, Y., Lorenz, C., Weese, J., Pluim, J., & Breeuwer, M. (2022). Label-informed cardiac magnetic resonance image synthesis through conditional generative adversarial networks. *Computerized Medical Imaging and Graphics*, *101*, 102123. https://doi.org/10.1016/J.COMPMEDIMAG.2022.102123

Amirrajab, S., Khalil, Y. Al, Lorenz, C., Weese, J., Pluim, J., & Breeuwer, M. (2023). A Framework for Simulating Cardiac MR Images with Varying Anatomy and Contrast. *IEEE Transactions on Medical Imaging*, *42*(3), 726–738. https://doi.org/10.1109/TMI.2022.3215798