PhD PROJECT DETAIL
Year 2023/2024

Title of Proposed PhD Subject:
Study of fiber microstructures of the human heart using deep learning

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The human myocardium is composed of myocytes that are branched and are attached to each other by intercalated disks. These cardiac myocytes form elongated structures with a preferential local orientation which are regarded as fibers (or bundles of fibers) at coarse scales. The organization of these fibers (i.e. fiber structure) is fundamental in understanding the functioning of the heart and is a pertinent tissue characteristic of the human heart. However, for a long time, we do not have the possibility of accessing such information. It is even truer for the in vivo human heart. Nevertheless, diffusion magnetic resonance imaging (dMRI), which is by nature noninvasive, provides such possibility. In the past decade, dMRI has been intensively investigated to get insight into the fiber structure at a macroscopic scale of the human heart, such as fiber orientation. But, little has been devoted to microscopic fiber structure of the human heart, such as fiber diameter. The main reason of such situation is that such study requires acquiring a large number of diffusion-weighted (DW) images corresponding to a large number of diffusion gradient directions and so needs a very long acquisition time, which is particularly problematic for the in vivo human heart due to motions.

During the last years, we have succeeded in applying artificial intelligence (AI) to medical imaging. More precisely, we used various convolutional neural network (CNN) methods to segment and classify medical images [1-7]. In particular, our current studies showed that it is possible to accurately estimate diffusion tensors in in vivo cardiac diffusion tensor imaging (DTI) (which is a particular case of dMRI) by using a limited number of DW images [8]. That was achieved through using a generative adversarial network (GAN).

The goal of this PhD thesis is to extend our above approach to the estimation of orientation distribution functions (ODFs) in high angular resolution diffusion imaging (HARDI). The objectives are to accurately estimate ODFs using deep learning from a small number of acquired DW images and analyze subsequently fiber microstructures such as fiber diameter, fiber crossing, fiber bending, etc.

To reach these objectives, we need to overcome the following bottlenecks: i) Difficulty of acquiring high angular-resolution DW images corresponding a large number of diffusion gradient directions, ii) Signal loss due to cardiac and breathing motions.

To this end, the PhD student will be required to do the following research:

- Study of adaptive deep learning

  It concerns the study of neural architectures and adaptive learning strategy according to the particularity of DW image inputs and the intrinsic link between them via ODFs. A typical characteristic might be that they allow reconstructing or generating missing DW images in diffusion gradient directions that were not used in DW image acquisitions. A possible research direction would be to investigate different GANs.

- Generation of super angular-resolution DW images

  It is dealt with generating a large number of DW images from a small number of acquired DW images using the above proposed deep learning method. Several types of initial images may be considered for the generation of super angular-resolution images: i) Synthetic images, ii) Ex vivo cardiac DW images, iii) Realistic simulated in vivo cardiac DW images that could be obtained based on our preceding work [1], and iv) Real in vivo cardiac DW images. The higher the angular resolution (i.e. the higher the number of diffusion gradient directions), the larger the number of DW images.

- Investigation of influence of diverse factors on the CNN-generated DW images

  It concerns factors such as noise, angular resolution, angular sampling, spatial resolution, motions, etc. The ultimate objective would be that the resulting fiber microstructures are better brought out.

The present thesis will be co-supervised with Prof. L.H. Wang of Key Lab of Intelligent Medical Image Analysis and Precise Diagnosis of Guizhou Province, Guizhou University, Guiyang, China.

References

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