PhD Subject
3D ultrasound coherence imaging using deep learning

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Context

The heart is a complex organ that performs the essential function of circulating blood in the human body. This function is crucial to life, and heart disease remains a fundamental cause of death in industrialised countries. The development of diagnostic tools or therapeutic methods requires a detailed understanding of the physiology of the heart: motion/deformation of the muscle, hemodynamics in the various cavities, electrical activation, etc. Moreover, since the heart consists of muscle fibres, it also looks pretty relevant to try to image the local fibrous structure of the tissue as finely as possible to establish a link between this local structure and heart function and, more generally, with the development of the various pathologies.

Based on MRI imaging of the free diffusion of water in tissue, CREATIS is one of the world leaders in cardiac fibre imaging. This imaging type is very complex, primarily because of the rapid and significant movement of the heart during MRI acquisition. In addition, thanks to the emergence of ultra-fast ultrasound imaging by plane-wave, the first technique for imaging tissue structure by ultrasound has recently been developed [1-2]. Ultrasound has many advantages over MRI, including its much lower cost, portability and, for our application, its high acquisition speed, particularly in ultra-fast imaging.

As part of the work in the laboratory [3], the technique was developed and validated in various experimental environments. The synchronisation of 4 Verasonics Vantage 256 devices is required to carry out the acquisitions. This procedure is very time-consuming to implement, synchronisation is inconsistent, and the handling time is significantly reduced due to the rare availability of the 4 Verasonics systems. To avoid this, a new multiplexed 3D ultrasonic probe (256, 512 or 1024 elements) was acquired, allowing some adaptations to implement the imaging technique we have proposed from a single or two Verasonics system. However, even with such improvement, the coherence technique did not perform as well as expected.

Objectives

To complete this PhD project, several aspects will have to be investigated:

1. Development of the learning network: The PhD student must propose a network adapted to the local extraction of anisotropy (or its absence). To do this, he will have to generate several simulation data sets based on the laboratory's synthetic model, derived from the work of previous studies, and enriched by previously acquired experimental data sets (or data sets to be acquired if too many parameters have changed). These numerous raw 3D signal data sets will have to be arranged before being used in the identified network to avoid generating too many different networks and optimise the total learning time.
2. Experimental acquisition: The acquisition sequence, although pre-existing, will have to be optimised to acquire various test data sets to enrich the learning base. In addition, once the network has been identified, tested and validated, it will have to be ported to the 3D system of the lab to carry out inference in real-time.
3. Clinical validation: It will be carried out in collaboration with the Creatis MRI team, with which

links already exist. Thanks to a clinical protocol already established, it will be possible to take part in various operations on pigs during open-heart surgery. It will be possible to measure the local orientation of the tissue using ultrasound and MRI. In addition, the team has expertise in ischaemia creation and reperfusion. The value of ultrasound measurement can therefore be assessed in the face of this clinical problem.

Maturity

Ultrasound is currently undergoing a veritable revolution. After ultrafast 2D imaging, which is starting to become standard in research laboratories, ultrafast 3D imaging is now emerging. In addition, the project will benefit from strong support from the PiLoT[1] laboratory's imaging platform for access to various 3D ultrasound scanners (Verasonics, dbSAS system under development) and the manufacture of tested *in vitro* and *in silico* media. In addition, the dbSAS system will be fully 3D (no multiplexing), and the proposed network could be directly installed in real-time acquisitions.

Concerning the database and network generation, given the work of the previous Master's trainee and PhD students, several promising avenues have been identified, and no significant difficulties in setting up the learning base and the network are imagined.

Profile/Skills

Student from a top engineering school (generalist or EEA profile), image and signal processing, ultrasound imaging, deep learning, mathematics, etc.

Application procedure

Please send a CV, cover letter and M1&M2 transcripts to

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References

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[2] C. Papadacci, V. Finel, J. Provost, O. Villemain, P. Bruneval, J.-L. Gennisson, M. Tanter, M. Fink and M. Pernot, "Imaging the dynamics of cardiac fiber orientation in vivo using 3D Ultrasound Backscatter Tensor Imaging", in Scientific Reports, 7, no. 830, 2017.
[3] E. Turquin, L. Petrusca, O. Bernard, M. Viallon, H. Liebgott, F. Varray, "Local Orientation Imaging for Tissue Structure Using Ultrasound Imaging", in Innovation and Research in BioMedical engineering (IRBM), vol. 38, no. 5, pp. 298-303, 2017.
[4] Z. Wang, F. Varray, P. Clarysse, and I.E. Magnin. "Towards a multi-scale virtual heart model", In 15th IEEE International Conference on Signal Processing, 2020.

[1] https://www.creatis.insa-lyon.fr/site7/en/PILoT