MSc project proposal 2022-23

Title of the MSc project:	Realistic simulation of ultrasound image sequences for deep-learning-based assessment of arterial wall deformation
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Laboratory:	CREATIS CNRS 5220, INSERM U1206 (head O. Beuf)
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Scientific field and context: Ultrasound (US) imaging is well suited for cardiovascular disease screening due to its spatio-temporal resolution. In particular, it can allow the observation of pathological changes in the arterial wall. Recently, it has been shown that cyclic deformations of the wall (during the heartbeat) might provide additional information on its biomechanical state, which in turn may improve early detection of at-risk individuals [1, 2]. These phenomena are difficult to quantify and the validation of methods published to date is subject to uncertainties related to the use of manual tracings as a reference. It is technically impossible to obtain manual references for deformation parameters such as wall compression or shear. Simulating very realistic image sequences with perfectly known geometry and deformation patterns might allow the assessment of the methods being developed in our team. Additionally, as these methods are based on deep learning, such simulated sequences also might be used as ground truth to train the implemented models, which is otherwise unavailable. Nevertheless, the current simulation methods either perfectly control the geometry of the simulated tissues, but strongly simplify the anatomic context and thus the realism of the resulting images is limited, or they mimic clinical images so that the appearance of the result is very realistic, but the knowledge of the underlying geometry and deformations are limited and so is the usability for our tasks of interest.

Objectives of the project: The main goal is to develop a "2 in 1" simulation method for US image sequences combining the main characteristics of the two existing approaches: very good control of geometry and deformations of the modelled arterial wall and high realism of the surrounding tissues mimicking clinical images. Depending on the candidate's interests and skills, optimization of the deep-learning-based method developed in the team for the wall segmentation in image sequences can be foreseen, to improve its ability to quantify the wall cyclic compression.

Scientific challenges: The main challenge is a seamless immersion of an *in-silico* artery model in the anatomic context from a real clinical image. Such a 2-in-1 method has never been developed in the vascular field. Nevertheless, a similar approach has been successfully developed in the team for the cardiac imaging [3], we also implemented a simulation pipeline to obtain realistic vascular images based on clinical ones, and the modelling of the artery may be inspired by the recent literature [4]. A remaining secondary challenge here can be to further improve the realistic appearance of the simulated images despite the unavailability of information on actual acquisition setting of the clinical images used as source.

Expected innovative contributions: Three contributions responding to the main challenge are expected. The first one will be the definition of the reflection coefficients associated with the scatterers in the artery model to achieve an overall consistency with the source clinical image. The second one will be the definition of deformation patterns consistent with clinical observations and continuous between the vessel model and the “background” representing the surrounding tissues (drawn from a clinical source image). The third one will be the definition of the changes in the scatterer map beyond the vessel model – from one frame to another – to simulate a realistic speckle decorrelation.

Research program and proposed scientific approach: After an appropriate bibliographic search and familiarization with the work already done in the team (methodology, code, data), the candidate will first work on simulating static images with an “insert” representing an artery model. Second, image sequences will be simulated with deformations of the artery model and with a fixed “background” scatterer map. Third, a solution will be sought to achieve speckle decorrelation in the background. At each step, the candidate will test on the images and sequences thus simulated, the segmentation and motion-tracking algorithms developed in the team. This work will be carried out in close collaboration with a PhD student (Nolann Lainé) with the aim to train and evaluate deep-learning models he is developing. Consequently, the candidate likely will contribute to the improvement of these models.

Expected candidate profile (prerequisite): understanding the physical processes underlying the ultrasound image acquisition, programming, image processing, deep learning, interest for biomedical field and biomechanical modeling for health sector.

Skills that will be developed during the project: US-image simulation, deepening skills in collaborative/versioned programming and image processing, applied deep learning, integrating simulation tools for deep model training. Ability to interact with the medical community.

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References:

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