MSc project proposal 2020

Title of the MSc project:	**Structural and kinematic analysis of the arterial wall in ultrasound image sequences using deep learning**
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Keywords:	ultrasound images, segmentation, motion estimation, simulation, convolutional neural networks

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Scientific field and context: Ultrasound (US) imaging is very well suited for cardiovascular disease screening due to its spatio-temporal resolution. In particular, it allows the observation of thickening and pathological changes in the radial movement of the arterial wall. Recently, it has been shown that variations in wall thickness and longitudinal wall motion provide additional information on the biomechanical state of the wall, which may improve early detection of at-risk individuals [1, 2]. These phenomena are much more 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. We have numerous sequences of 2D US images (more than a thousand) acquired in different centers, on different devices and representing the carotid artery over several cardiac cycles. In a significant number of these images, the wall contours have been drawn by hand and can be used for learning and/or evaluation. On the other hand, movement references are very limited: we have at most the trajectory of a point selected by an expert and traced along the sequence. It is technically impossible to obtain manual references for more complex motion parameters, such as shear or elongation, which may nevertheless be of great interest to evaluate the biomechanical state of the artery wall.

Key words: segmentation, motion estimation, simulation, convolutional neural networks

Objectives of the project: The main goal is to develop segmentation and motion estimation methods capable of delineating the arterial wall and finding all the components of its displacement, throughout sequences of ultrasound images representing an artery, typically a carotid artery. To do so, simulating realistic US-image sequences with all the movements of interest will be necessary to train the models and create perfectly controlled references for validation purposes.

Scientific challenges: In ultrasound images, speckle patterns strongly disturb the contours, making segmentation difficult (Fig. 1). Nevertheless, the estimation of variations in parietal thickness requires a high degree of segmentation accuracy, since the amplitude of these variations does not exceed two pixels in clinical images. The same speckle patterns are, however, the only visual cues for estimating longitudinal movement. The visual appearance of these patterns varies during their motion due to the phenomenon of decorrelation. The latter is particularly noticeable when the movement has an out-of-plane component, which is difficult to avoid. Current methods

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focus on tracking a very limited number (often only one) of these patterns, usually selected manually. This results in a high dependency on the operator and therefore limited reproducibility. In addition, it has been shown that the movement of speckle patterns does not fully reflect the movements of the scatterers present in the tissue.

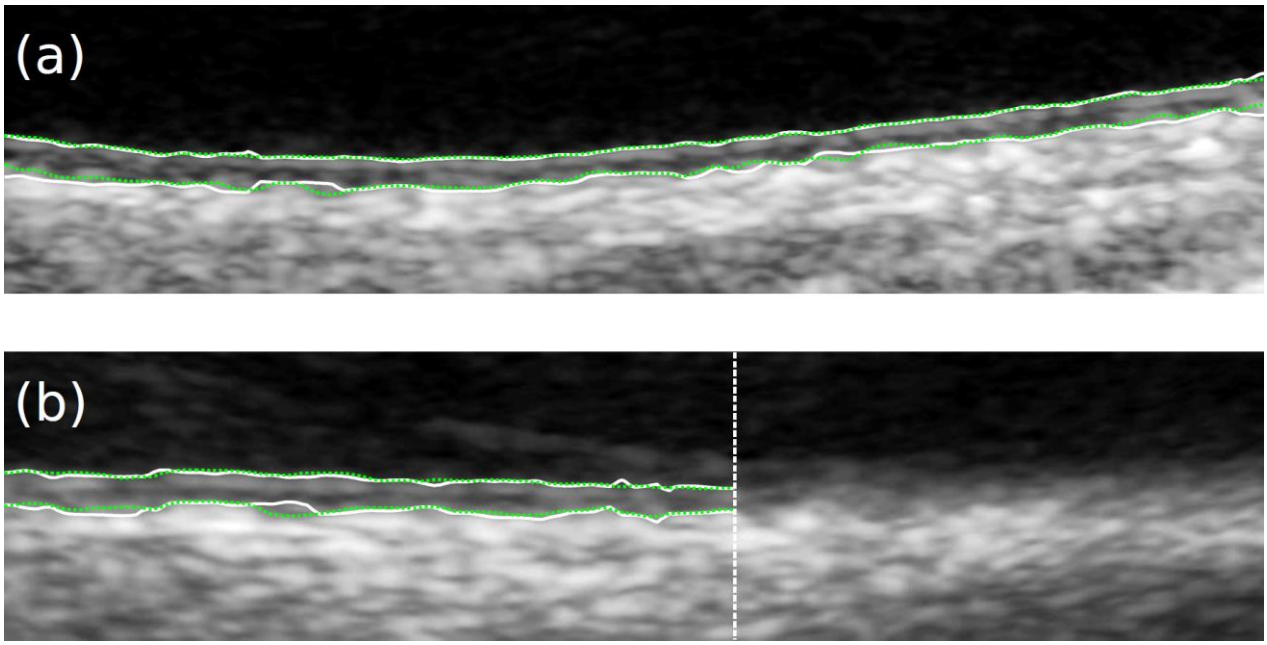

Figure 1. Examples of segmentation results in carotid-artery US images: manually drawn reference (green) and contours of the intima-media complex exctracted with an automatic method [1]. Irregularities due to speckle are noticeable despite of the relatively good quality of the images.

Expected innovative contributions: The main contribution will be a motion estimation method capable of finding not only global displacements, but also local tissue deformations. In order to do this, the disruptive idea is to consider the speckle pattern changes as a strong help for motion tracking (instead of "struggling" with its visual appearance changes) by incorporating it into a neural network trained for motion estimation.

Research program and proposed scientific approach: As a first step, evaluate the potential of deep-learning wall-segmentation methods, by choosing the most appropriate architecture. Secondly, develop a realistic deformation model, incorporating radial, longitudinal, and out-of-plane movements, shear, compression/elongation, as well as their variations along the artery. Then, incorporate this model into a realistic ultrasound image simulator to modify the spatial distribution of the scatterers from one image to the next in the sequence. In the next step, define the network architecture for deep learning of these deformations and train it on simulated and real sequences. Finally, evaluate the performance of the motion estimation performed by the trained network.

Expected candidate profile (prerequisite): image processing, machine learning, programming. Interest for biomedical field and biomechanical modeling for health sector.

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

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References:

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[2] G. Zahnd, S. Balocco, A. Sérusclat, P. Moulin, M. Orkisz, and D. Vray, "Progressive attenuation of the longitudinal kinetics in the common carotid artery: preliminary in vivo assessment", Ultrasound in Medicine & Biology, 41:1, 339–345, 01/2015 DOI: 10.1016/j.ultrasmedbio.2014.07.019.