Particle characterization by ultrasound using artificial intelligence methods

Karim FERROUDJI

Soutenue en: 2017

Abstract: This thesis presents a study on how microemboli problems can be detected and characterized. It investigates a novel approach to the detection and classification of microemboli using a combination of data mining techniques, signal processing methods, and Radio Frequency information extracted from gaseous and solid emboli instead of the traditionally used Doppler signals processing. Embolic phenomena, whether air or particulate emboli which are particles larger than blood cells, could occlude blood vessels and consequently prevent the normal blood flow to vital organs and surrounding tissue. As a result, it can induce immediate damages like heart attack or ischemic stroke. It is believed that detecting the emboli in early stage could prevent or reduce the associated risks of embolism. Embolus composition (gaseous or particulate matter) is vital in predicting clinically significant complications. Unfortunately, embolus detection using Doppler methods have shown their limits to differentiate solid and gaseous embolus. Radio Frequency (RF) ultrasound signals backscattered by the emboli contain additional information on the embolus in comparison to the traditionally used Doppler signals. Gaseous bubbles show a nonlinear behavior under specific conditions of the ultrasound excitation wave, this nonlinear behavior is exploited to differentiate solid from gaseous microemboli. In order to verify the usefulness of RF ultrasound signal processing in the detection and classification of microemboli, an in vitro set-up is developed at the University of François Rabelais Tours, France in the INSERM U930 laboratory under the direction of Professor A. Bouakaz. Sonovue micro bubbles are exploited to mimic the acoustic behavior of gaseous emboli. They are injected in a nonrecirculating flow phantom containing a tube of 0.8 mm in diameter. The tissue mimicking material surrounding the tube is chosen to imitate the acoustic behavior of solid emboli. Both gaseous and solid emboli are imaged using an Anthares ultrasound scanner with a probe emitting at a transmit frequency of 1.82 MHz and at two mechanical indices (MI) 0.2 and 0.6. Therefore, we acquire four datasets, each dataset consists of 102 samples (51 gaseous emboli and 51 solid emboli). This dataset is exploited to create a number of discriminative features used for the detection and classification of circulating microemboli.First, we employ Fast Fourier Transform approach based on neural network analysis using fundamental and second harmonic components information contained in the RF signal backscattered by an embolus. The proposed approach allows the classification of microemboli with a discrimination rate of 92.85%.Second, we exploit a discrete wavelet transform approach using three dimensionality reduction algorithms; Differential Evolution technique, Fisher Score method, and Principal Component Analysis based on Support Vector Machines in the analysis and the characterization of the backscattered RF ultrasound signals from the emboli. Furthermore, we propose a strategy to select the suitable wavelet filter among 59 mother wavelet functions. The experimental results, based on the selected wavelet function and differential evolution algorithm, show clearly that discrete wavelet transform method achieves better average classification rates (96.42%) compared to the results obtained in the previous method using FFT based approach. The obtained results demonstrated that Radio Frequency ultrasound signals bring real opportunities for microemboli detection and characterization.

Keywords : Microemboli, classification, Radio Frequency Ultrasound Signals