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An automated microemboli detection and classification system using backscatter RF signals and differential evolution

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Abstract Embolic phenomena, whether air or particulate emboli, can induce immediate damages like heart attack or ischemic stroke. Embolus composition (gaseous or particulate matter) is vital in predicting clinically significant complications. 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. Sonovue micro bubbles are exploited to mimic the acoustic behavior of gaseous emboli. They are injected at two different concentrations (0.025 and 0.05 µl/ml) 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. We propose in this experimental study to exploit discrete wavelet transform and a dimensionality reduction algorithm based on differential evolution technique in the analysis and the characterization of the backscattered RF ultrasound signals from the emboli. Several features are evaluated from the detail coefficients. It should be noted that the features used in this study are the same used in the paper by Aydin et al. These all features are used as inputs to the classification models without using feature selection method. Then we perform feature selection using differential evolution algorithm with support vector machines classifier. The experimental results show clearly that our proposed method achieves better average classification rates compared to the results obtained in a previous study using also the same backscatter RF signals.

Keywords Microemboli · Gaseous embolus · Solid embolus · Radio frequency signals · Ultrasound · Differential evolution

Introduction

Embolism is intravascular migration of an insoluble body such as gas bubble, a fat globule, a blood clot, an atheromatous plaque, or a piece of thrombus. Embolus formation inside the body could be attributed due to different physiological, physical, and intervention mechanisms [1]. It can travel to any part of the body, accounting for many serious (and sometimes life-threatening) disorders thus the importance of an automatic classification system.

Transcranial Doppler (TCD) [1] is a non-invasive ultrasound approach employed to assess blood flow velocity in the major basal intracranial arteries on a real time basis. In order to evaluate the ability of TCD to detect and classify intracranial emboli, several experimental studies have been carried since the early 1960s. One of the approaches relies on detecting the appearance of abrupt changes (known as

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