Summary

The noninvasive technique of determining local stiffness of human arteries

Bezinwazyjna metoda wyznaczania lokalnej sztywności ludzkich tętnic

Keywords: cardiovascular, soft tissue, parameter estimation, stiffness estimation, Extended Kalman Filter, DEKF

Cardiovascular diseases are the major cause of death around the world. It is estimated that 20% of the population is affected by elevated arterial wall stiffness. Arterial stiffening is a pathophysiological marker for prediction and severity of cardiovascular diseases such as, myocardial infarction, heart failure, as well as stroke, dementia, atrial fibrillation, aneurysm rupture or renal disease.

The stiffness may be assessed by measuring Pulse Wave Velocity or Shear Wave Elastography. For the former method, length of the segment between two points of measurements is required, e.g. between femoral and carotid artery. This measurement is associated with large uncertainty and the resulting stiffness is an average value along the chosen segment. Shear Wave Elastography allows non-invasive and real-time measurement of the elasticity of soft tissues. Shear waves are generated by focused acoustic radiation force from a linear ultrasound probe. The velocity of the wave is related with Young's modulus of the investigated tissue.

The dissertation presents methodology for non-invasive arterial stiffness assessment by combining measurement of arterial wall displacement with ultrasound, applanation tonometry for pressure waveform measurement and solving inverse problem to estimate Young's modulus. The 3D Neo-Hookean and Linear Elastic model of the artery is solved by Finite Element Method open-source software FEBio.

For model validation and testing proposed methodology for inverse problem based on Dual Extended Kalman Filter, experiments on artificial artery with known mechanical properties were performed.

The proposed approach is then applied to medical data. The resulting estimation of Young's modulus falls into physiological range reported in literaturę.