Testing a method for detection of synchronization between the low-frequency oscillations in the cardiovascular signals on the model dataset

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The autonomic control of circulation, attributed to the sympathetic and parasympathetic branches of the autonomic nervous systems, is important for maintaining homeostasis. Dysfunction of the autonomic control could lead to the development of various cardiovascular and other diseases, including myocardial infarction and arterial hypertension, therefore diagnostics of the autonomic control is important for prevention and therapy of cardiovascular diseases.

The ~0.1 Hz oscillations in the RR-intervalogram and photoplethysmogram are coupled and exhibit intervals of phase synchronization, which can last up to hundreds of seconds and alternate with the intervals of asynchronous behavior. Relative duration of the synchronous intervals is smaller in people with impaired autonomic control and is perspective for medical diagnostics and therapy of myocardial infarction and arterial hypertension.

We proposed mathematical models for the electrocardiogram and photoplethysmogram signals with functionality to preset the pattern of synchronization between the phases of the ~0.1 Hz oscillations. The simulated phase difference reproduce the statistical and spectral characteristics of the experimental data, including the alternating horizontal and sloped sections, corresponding to the intervals of synchronous and asynchronous behavior. The developed models were used to generate the testing dataset.

The previously proposed method for detection of phase synchronization between the abovementioned ~0.1 Hz oscillations was tested against the model dataset. The parameters of the method were refined to achieve better accuracy. The refined method reached the sensitivity of 0.69, specificity of 0.60, and AUC of 0.75. The performance improved, since the unmodified approach reached the sensitivity of 0.64, specificity of 0.63, and AUC of 0.71.

The results suggest that accuracy of the method is lower, than previously assumed, but we consider this estimation to be more credible, due to a more accurate simulation of the real data processing routine, including filtration of the broadband experimental signals and introduction of the phases using the Hilbert Transform.

Key words: cardiovascular system, medicine, mathematical modeling, phase coupling.

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