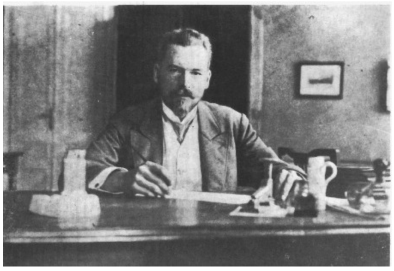

Contribution ID: **41** Type: **30 minute lecture**

On zero-delay synchronization in a network of timed automata modeling cardiac tissue

Friday, December 4, 2020 4:30 PM (30 minutes)

A network of timed automata (NTA), inspired by Greenberg-Hastings cellular automata, can efficiently and faithfully reflects the work of the real pacemaker [1]. In this system, each automaton cyclically switches between three states of a certain length of time: from F firing state of length f, to R refractory state of length r and then to A activity state of length a, what closely follows the phenomenologically known oscillations of myocytes. As a results of interactions between neighboring cells, the self-organization of the oscillating units to a common oscillation emerges which then leads to forming a signal of initiating a contraction of the whole heart. Thus NTA establishes an appropriate platform to model a natural human pacemaker, in which we gain insight into conditions and stages of the synchronization process [2].

The visible effect of synchronization in NTA is the excitation wave, i.e. the emergence of steady move of a cluster formed by automata staying in F state.
The synchronization can be of frequency locking type, when some automata force the neighboring automata to faster switch the state A to F than it is expected by intrinsic automaton's cycle, or of phase-locking type, when neighboring automata exhibit the common difference in oscillatory phase. Thus, the frequency-locking synchronizations result in the fast rhythms. The visible effect of such synchronization is a spiral origin of the excitation wave. The phase-locking synchronization occurs when neighboring automata are one step late in the advancement of the cyclic transitions of intrinsic time periods. A visible effect of such synchronization is propagation of the excitation wave with rhythm comparable to the period of oscillating automata.

The strength of synchronization is due to the reduction of uncorrelated degrees of freedom to a collective mode of operation, which then enables the long-term ordering and coordination of biological processes

The emergence of zero-delay phase-locking synchronization, the marching squad synchronization, has been observed in NTA when in response to the F state of neighbors, the length of the refractory phase r was increased [1].
On the other hand, in NTA system in which the vagal regulation was modeled as increase in the length a of the activity state in response to the vagal activity, such synchronization is also observed but only when the activity of vagal system often changes [2].
The mechanisms behind synchronizing without any delay in spatially distributed systems are not clear and debated. The presentation will be devoted to analyze possible mechanisms leading to the marching squad synchronization in the NTA system modeling the pacemaker.

[1] D. Makowiec "Pacemeaker rhythm through networks of pacemaker automata - a review" Acta Physica Polonica B Proceedings Supplement, 7(2014) 347
[2] D. Makowiec, W. Miklaszewski, J. Wdowczyk, A. Lawniczak "From cellular automata model of vagal control of human right atrium to heart beats patterns" Physica D, to appear, (2020)

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