

## Methods of nonlinear dynamics for analyzing historical processes

**Jan Awrejcewicz, Tatyana Y. Yaroshenko, Maxim V. Zhigalov, Igor I. Shulga, Ivan A. Bulatov, Vadim A. Krysko**

*Abstract:* The development of a state in a certain period of time is investigated by a set of nonlinear dynamics methods including the wavelet analysis, changes of the sign of the spectrum of the Lyapunov exponents, Fourier analysis, and the value of Kolmogorov entropy. The main components method is used for preliminary processing of time series. With the help of continuous and discrete wavelets, the energy characteristics of the development of historical processes in time are obtained. Fourier analysis allows you to identify the dominant frequency of the time series. According to the values of the Lyapunov indicator spectrum, it is possible to obtain information on the nonlinear state of the process (regular or chaotic). The Wolf, Rosenstein, Kantz, Sano-Sawada and neural networks are used for the computation of the Largest Lyapunov exponents. In order to identify trends in the development of crisis states both of the state as a whole and its individual structures, the time variation of the values of the first Lyapunov indicator according to the Wolf method is investigated. In particular, the authors explore the development of Russia since 1914 till 2018. To do this, based on a study of real historical events, time series are compiled, reflecting the development of such key government areas as education, economics, and the dynamics of demographic changes.

- 
- <sup>1)</sup> Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), awrejcew@p.lodz.pl.
  - <sup>2)</sup> Tatyana Y. Yaroshenko, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tyaroshenko@gmail.com.
  - <sup>3)</sup> Maxim V. Zhigalov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), zhigalovm@ya.ru.
  - <sup>4)</sup> Igor I. Shulga, Associate Professor: Department of History of the Fatherland and Culture, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), igorshulga@yandex.ru.
  - <sup>5)</sup> Ivan A. Bulatov, Associate Professor: Department of History of the Fatherland and Culture, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), kicum-333@yandex.ru.
  - <sup>6)</sup> Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.