Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 201 (2017) 767–772

Procedia Engineering

www.elsevier.com/locate/procedia

3rd International Conference "Information Technology and Nanotechnology", ITNT-2017, 25-27 April 2017, Samara, Russia

The prediction algorithm of the technical state of an object by means of fuzzy logic inference models

Yu. E. Kuvayskova[a]*

[a]*Ulyanovsk state technical university, Ulyanovsk, 432027, Russia*

Abstract

The prediction algorithm of the technical state of an object was elaborated to predict emergencies at object functioning and to provide urgent steps required to control the object. The technical state is described by a set of indices represented by a system of time series. The adequate mathematical model is built by means of an adaptive regression modeling for the system of time series. The model is used to predict the object indices. The predicted values of indices are analyzed by means of fuzzy logic and predicted state of an object is deduced as a fuzzy term.

Peer-review under responsibility of the scientific committee of the 3rd International Conference "Information Technology and Nanotechnology".

Keywords: adaptive regression modeling; fuzzy logic; prediction; system of time series; technical object

1. Introduction

An object the technical state of which is described by a set of indices represented as a system of time series is considered. To prevent possible emergencies (failures, breakdowns etc.) it is necessary to know the technical state of an object at the moment and to foresee its future state. If the predicted values of the controlled indices are beyond critical limits, the process is distorted and the adequate decision should be taken, i. e. the load should be reduced or an object should stop functioning [1].

The effectiveness of an object functioning essentially depends on the accuracy of prediction of the set controlled indices [2]. To increase the accuracy of prediction of object indices the method of adaptive regression modeling [3,4]

* Kuvayskova Yu.E. Tel.: +7-902-245-0570.
E-mail address: u.kuvaiskova@mail.ru

1877-7058
Peer-review under responsibility of the scientific committee of the 3rd International Conference "Information Technology and Nanotechnology".
10.1016/j.proeng.2017.09.624

is suggested. Mathematical models built according to the methods of adaptive modeling are adequate in the real situation and allow us to get predictions with higher accuracy [4].

To describe the predicted technical state of an object in terms of qualitative estimates models of fuzzy logic [5,6,7] are suggested. The predicted indices of an object are analyzed by methods of fuzzy logic and the predicted state of an object is deduced as a fuzzy term.

2. The method of modeling and prediction of the system of time series

To build adequate mathematical models of the system of time series methods of adaptive regression modeling [3,4] is suggested. At each stage of the structural-parametric model identification checking of its residuals for adherence to the assumptions of regression analysis and application of adaption methods at its distortions is intended. It allows us to define the structure of a model more accurately and increase the accuracy of prediction [4].

The method of structural-parametric identification of a system of time series [8] is used to model a system interconnected time series. It allows us to apply the joint data analysis and approximate them more accurately.

To investigate predictive capabilities of initial data the methods of fractal and multifractal analysis [9,10] are used. They allow us to bind some important characteristics of random processes, such as regularity, trendresistance, quasi-periodic cycles, etc.

The results of fractal analysis allow des to find the preliminary structure of mathematical models of time series. In a general case the model of a time series contains several constituencies:

$$y(t) = f(t) + g(t) + \varphi(t) + \varepsilon(t)\,, \tag{1}$$

where $y(t)$ is the observed values of time series, $f(t)$ is function of the trend, $g(t)$ is harmonic constituent, $\varphi(t)$ is the random function with elements of regularity, $\varepsilon(t)$ is the random constituent.

In case of a strong regularity in the dynamics of the process observed the trend constituent $f(t)$ of the system of time series is singled out as paired dependencies of series on time [11].

A harmonic model $g(t)$ is built when quasi-periodic cycles are present, in case of stationarity of a series a joint harmonic constituent [8] is built, in case of non-stationarity of the process we use an autoregressive model on a cylinder [12].

After identification of a regular constituent the process is analyzed to use if autoregression and heteroscedasticity in residuals are present.

If autoregression in the residuals of the process under investigation is present, the function $\varphi(t)$ is described by the model of autoregressive moving-average [13,14], when the assumption about disperse consistency of the process (in case when heteroscedasticity exists) is violated the method of autoregressive conditional heteroscedasticity in residuals (ARCH) and its modifications (GARCH, ARCH-N, GARCH-N, ARCH-M, GARCH-M, etc.) is used [15,16].

In case of simultaneous violations of constancy of mathematical expectancy and process dispersion a model of autoregressive moving-average and an autoregressive model with conditional heteroscedasticity in residuals are built in succession.

These adequate complex mathematical models of a system of time series are used to predict the state of an object.

To estimate the prediction quality according to the models the original set of data is divided into two parts – a teaching part and a control one. A teaching set is used to build a model and a control one – to estimate the prediction quality.

As a criterion of the prediction estimate a mean square error calculated according to a control set is used:

$$\sigma_\Delta = \sqrt{\frac{1}{k}\sum_{i=1}^{k}\left(y(t_i) - \hat{y}(t_i)\right)^2}\,, \tag{2}$$

where k is the number of control set elements; $y(t_i)$ is the observed values of a time series at a control interval; $\hat{y}(t_i)$ is predictions calculated according to the model.