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Andrey Mastislavovich Korneev
doctor of technical sciences,
Lipetsk state technical University, Russia
weenrok@mail.ru
Yuliya Alexandrovna Glazkova
student,
Lipetsk state technical University, Russia
yuliya_glazkova2@inbox.ru
Galina Gennad'evna Boldyreva
student,
Lipetsk state technical University, Russia
galinashulenina@rambler.ru

SECTION 2. Applied mathematics. Mathematical modeling.

METHODS OF TIME SERIES ANALYSIS

Abstract: *Introduce methods of time series analysis, prediction methods for time series, described a method of implement individual function of the system, offered variants of use the result of the system.*

Key words: *time series, time series analysis, prediction for time series.*
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Time series accepted to represent as a graph, on one axis which instants of time divided into equal intervals, and on the other axis – the values if the time series at certain instants of time.

The purpose of time series analysis is the follows: /1/

1. Taken series and construct a simple mathematical model which describe the behavior this series in a compressed form;
2. An attempt is made explain the behavior of a series using various other variables and is determined the relationship between observations and some structural laws of behavior;
3. According to the results analysis of items 1 and 2 is predicted behavior of the series;
4. The ability to monitor the system:
    a. By making of linear warnings about possible adverse situations;
    b. By investigating what can happen when you change some parameters of the model;
5. Research of joint development several variables on time.

In a general view purpose of time series analysis can be reduced to the following – decomposition series of its components:

1. The trend (long-term movement);
2. More or less regular fluctuations relative to the trend;
3. The seasonal component;
4. The Remainder (not systematic random effect).

Series convenient to represent as the sum of these four components, and one of the purposes of the analysis is decomposition of a series into its component top for a separate study.

Upon further study of the time series can be seen that the trend and seasonality can’t be separated from each other. If you can deduct trend and seasonal component from the series, it remains fluctuating series.

Any time series can be investigated the following scheme:

1. Collection of information;
2. The assessment of accident on various criteria;
3. Selection of the trend and its exclusion;
4. Verification stationary series;
5. The assessment autocovariation and autocorrelation function;
6. Standard errors of autocorrelation. Determining the order of the moving average (SS) by the criterion Bartlett;
7. Partial autocorrelation function of autoregression (AR). Determining the order of the AR by the criterion Kenya;
8. The autocorrelation function of the ARSS(p,q) (AR is order p and SS is order q);
9. The parameters of the models AR and SS;
10. Model by the Kauden;
11. Exponential smoothing (ES).

A more advanced form given above schemes is considered further:

1. Collection of information – at this stage the value of the time series collected at regular intervals time(polling sensors, weather information and etc);
2. The assessment of chance on various criteria – the most widespread criteria of chance are:
    a. Slewing point;
    b. The length of the phase;
    c. A criterion based on the sign of the difference;
    d. A criterion based on rank correlation.

Choosing criteria depends on which hypotheses are tested (for example, in the case where data are meaning trend requires a criterion different from that needed in the time series analysis in the frequency).

3. The selection of the trend and its exclusion. The trend is smooth basic motion, no oscillatory type for a considerable period of time. Whether being verified by suitable the analyzed series under the definition.
4. Verification stationary series. Stationary series should be average value and variance.

The average value μ stochastic process can be estimated by the sample average of the time series

$$\bar{z} = \frac{1}{N}\sum_{t=1}^{N} z_t \qquad (1)$$

And dispesion σ2z stochastic process using the sample dispersion

$$\hat{\sigma}_z^2 = \frac{1}{N}\sum_{t=1}^{N}(z_t - \bar{z})^2 \qquad (2)$$

5. The assessment autocovariational and autocorrelation functions. Moving from the theoretical values of the autocorrelation function to the practical value, use the sampling estimations autocorrelation. Assessment of the autocorrelation function R_k is the expression:

$$r_k = \frac{c_k}{c_0} \qquad (3)$$

when

$$c_k = \frac{1}{N}\sum_{t=1}^{N-k}(z_t - \bar{z})(z_{t+k} - \bar{z}) \qquad (4)$$

6. Sample estimate autocovariances K_k, and $\bar{z}$ - the average value of the time series. Standard errors of autocorrelation. Determining the order of the moving average (SS) by the criterion Bartlett. For the dispersion the sample autocorrelations r_k delays k, larger than a certain value q, for which the theoretical autocorrelation function it can be assumed "damped" approximation by the Bartlett gives / 2 /

$$\mathrm{var}[r_k] \approx \frac{1}{N}\left\{1 + 2\sum_{v=1}^{q}\rho_v^2\right\}, k > q \qquad (5)$$

7. You can analyze the dynamics their change and build a model of order p autoregressive the time series [3].

$$\hat{K}_{\Sigma t} = a_t + \Phi_1 \hat{K}_{\Sigma t-1} + \Phi_2 \hat{K}_{\Sigma t-2} + ... + \Phi_p \hat{K}_{\Sigma t-p}, \qquad (6)$$

when $\Phi_1, \Phi_2, ..., \Phi_p$ - the final set of weight parameters,

$\hat{K}_{\Sigma t-i}$ - time-varying values of the investigated parameters.

To determine the order of model p use the partial autocorrelation function.

Let j coefficient autoregressive process of order k through Φ_{kj}, the latter the coefficient will be equal to Φ_{kk}. Φ_{kj} satisfies the system of equations:

$$R_j = \Phi_{k1}R_{j-1} + ... + \Phi_{k(k-1)}R_{j-k+1} + \Phi_{kk}R_{j-k}, j = 1,2,...,k, \qquad (7)$$

when R_j - autocorrelation coefficients.

Forming the Yule-Walker equations of the form:

$$\begin{pmatrix} 1 & R_1 & R_2 & \dots & R_{k-1} \\ R_1 & 1 & R_1 & \dots & R_{k-2} \\ \dots & \dots & \dots & \dots & \dots \\ R_{k-1} & R_{k-2} & R_{k-3} & \dots & 1 \end{pmatrix} \cdot \begin{pmatrix} \Phi_{k1} \\ \Phi_{k2} \\ \dots \\ \Phi_{kk} \end{pmatrix} = \begin{pmatrix} R_1 \\ R_2 \\ \dots \\ R_k \end{pmatrix}, \quad (8)$$

The value Φ_{kk}, considered as a function of delay k, is called particular autocorrelation function.

For the autoregressive process of order p particular autocorrelation function Φ_{kk} will be nonzero if $k \le p$ and zero for $k > p$. That is particular autocorrelation function of autoregressive process of p-th order break on the delay after the p.

Based on the claim of Kenya that selective particular autocorrelation of orders $(p+1)$ and above approximately independent and have dispersion:

$$\mathrm{var}\left[\hat{\Phi}_{kk}\right] \approx \frac{1}{n},\ k \ge (p+1), \quad (9)$$

where n – the length of investigating series .

Standard error (SE) particular autocorrelation $\hat{\Phi}_{kk}$ is:

$$CO[\hat{\Phi}_{kk}] = \hat{\sigma} = \frac{1}{\sqrt{n}},\ k \ge (p+1). \quad (10)$$

Autoregressive order p could be found using the formula

$$\Phi_{kk} < \frac{1}{\sqrt{n}}, \forall k > p. \quad (11)$$

For parameter's identification it may uses the Durbin recurrence formulas:

$$\hat{\Phi}_{p+1,j} = \hat{\Phi}_{p,j} - \hat{\Phi}_{p+1,p+1}\hat{\Phi}_{p,p-j+1},\ j = 1, 2, \dots, p. \quad (12)$$

$$\hat{\Phi}_{p+1,p+1} = \frac{r_{p+1} - \sum_{j=1}^{p} \hat{\Phi}_{p,j} r_{p+1-j}}{1 - \sum_{j=1}^{p} \hat{\Phi}_{p,j} r_j}, \quad (13)$$

where r_{p+1} - coefficient of autocorrelation function.

1. Combined autoregressive model — sliding average (APCC) represented in the form:

$$\tilde{z}_t = \phi_1 z_{t-1} + \dots + \phi_p z_{t-p} + a_t - \Theta_1 a_{t-1} - \dots - \Theta_q a_{t-q}$$

(14)

2. Parameters of model is AP and CC. The calculation of initial assesses of process APCC(p, q) is based on first p+q+1 autocovariation $c_j[j = 0,1,\dots,(p+q)]$ or $\omega_t = \nabla^d z_t$ and it's carried out in three stages.

A) Autoregressive parameters $\phi_1, \phi_2, \dots, \phi_p$ assessed by autocovariations $c_{q-p+1}, \dots, c_{q+1}, c_{q+2}, \dots, c_{q+p}$.

B) Based on the assesses $\hat{\phi}$, found in (A), calculation first q+1 autocovariations $c'_j\,(j = 0,1,\dots,q)$ founded series

$$\omega_t' = \omega_t - \hat{\phi}_1\omega_{t-1} - \dots - \hat{\phi}_p\omega_{t-p}$$

C) Finally, autocovariations $c_0', c_1', \dots, c_q'$ is using during iterative calculation of initial assesses of parameters CC $\Theta_1, \Theta_2, \dots, \Theta_q$ and residual dispersion σ_a^2 by two techniques:

- Linearly convergent process
- Quadratically convergent process

3. A model by Caudano. This model built using Caudano tables. IN this tables given weight for built time series. /1/

$$\sum_{-m}^{m}(z_t - a_0 - a_1 t - \dots - a_p t^p) \to \min \quad (15)$$

4. Exponential smoothing (ES). The method consists in finding the optimal value β and it may found the next values of series on the estimates made in previous moment.

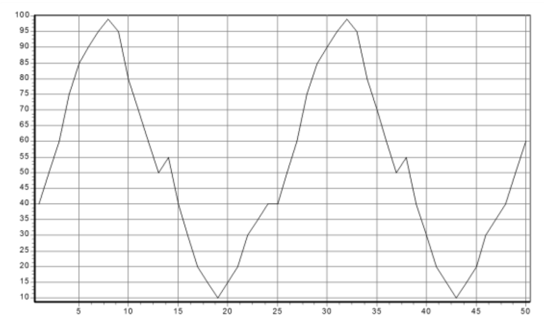
It's necessary to minimize by β the sum of sum squared errors:

$$\sum_{-\infty}^{t_0}\{z_t-(1-\beta)\sum_{j=1}^{\infty}\beta^j z_{t-j}\}^2 \to \min \qquad (16)$$

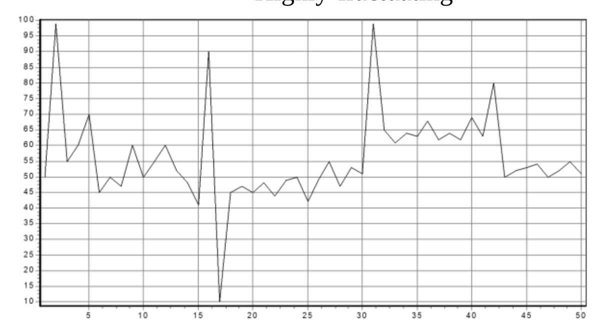
Founded models may be used for predict time series. Prediction can be short, medium and long.

As an example, considered the seasonal and fast-fluctuating time series, the results are presented in the figure.

Seasonal



Highly-fluctuating

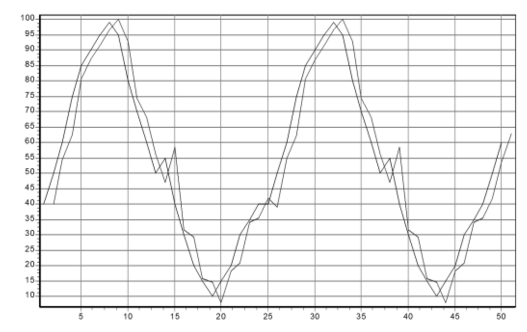


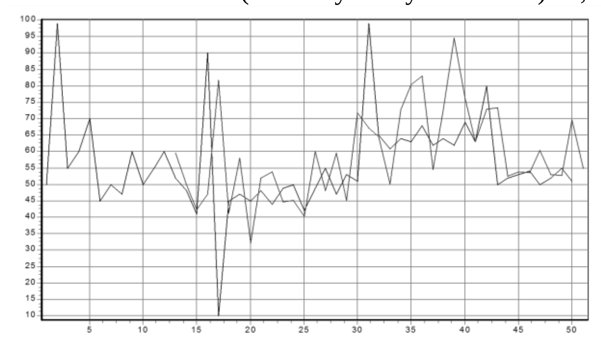
Initial series ES

The value of Beta -0,445

Initial series AP

The order of model AP (assess by Kenya meseaure) 12,000

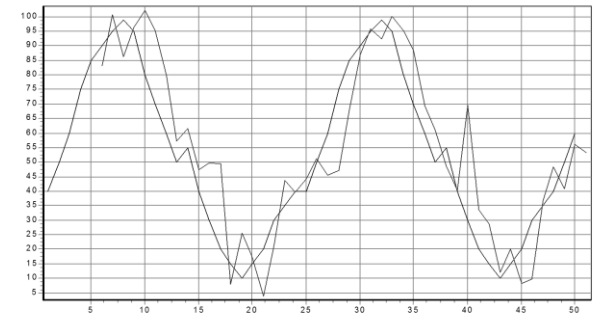




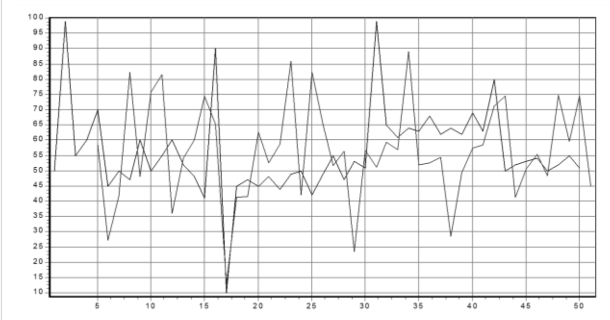
Initial series APCC

Quadratically convergent process

APCC(4, 5)



APCC(2, 4)



Picture 1 - Initial series.

When considering series of different length the same prediction technique will produce different results.

Analyzing prediction results by different techniques for different series, it's impossible to say which prediction technique is best, universal. The different techniques are best for different series. The different techniques may be best for different series even for fluctuating series consisted of 50 values and 1000 values.

This can be explained by the fact that the weight attributed to the observations that characterize their involvement in prediction One of the series was more sensitive for weight's changes and gave the best result, unlike other. The developed system allows to choose optimal model for any time series. Conducted researches have shown high efficiency of analysis time series techniques using in the system.

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