Arima Approach For Forecasting Temperature In A Residential Premises

Part 2

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Abstract—**This paper presents the choice of a prediction model using ARIMA time series forecasting approaches. These approaches have been used as a tool to predict temperature changes in residential premises. Based on calculations using the software product IBM SPSS, the temperatures at six points in the residential premises are predicted. The software product MATLAB was used to construct the equations of the functions approximating the temperature in a formed cross section of six symmetrically located points in an interval of one hour, every ten minutes.**

Keyword-ARIMA model; prediction; temperature; residential premises.

I. Introduction

Smart home systems are becoming increasingly popular due to their advantages and promising capabilities for control and management of various electronic devices, which aims to minimize human involvement. This ensures greater reliability, comfort and security. The efficient use of electricity contributes to significant savings [5]. Research in this area is developing very actively, as it offers very powerful tools to facilitate everyday life. For this reason, an electronic system for managing energy flows in a residential premise has been developed. The study of the system aims the optimization of these energy flows [1, 2, 3].

The aim of the paper is to present the forecasting of the temperature in the living room, using ARIMA models of time series, as the forecasting is done on the basis of the geometric arrangement of six multifunctional modules in six points.

The main expectation is to reduce the level of used energy in residential premises.

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II. Theoretical Justification Of The Arima Approach To Forecasting Temperature In A Residential Premises

The ARIMA approach is a class of statistical models for analyzing and forecasting time series of data. It serves to a set of standard time series data structures and as such provides a simple but powerful technique for making complex time series forecasts [4, 5].

The software product IBM SPSS, which is specialized in statistical surveys and can utilize ARIMA models, as well as the software product MATLAB, were used to predict temperature fluctuations in a residential premise.

ARIMA (Auto Regressive Integrated Moving Average) models are presented as ARIMA (p, d, q) [4]. The autoregressive element p represents the influence of the data from p previous moments in the model. The integrated element d represents the trend in the data, and the element q shows how many terms are used to smooth out small fluctuations using the moving average. By default, interim data analysis is performed in the following three steps: identification, evaluation, and diagnosis [4, 6, 7].

A. Identification of the time series

The identification includes analysis of the data by calculating and plotting the autocorrelation functions (ACFs) and the partial autocorrelation functions (PACFs).

B. Building and evaluation of the model

When modelling time series of data, it is necessary to build a model and evaluate its parameters (test for their statistical significance).

C. *Validation of the model*

Validation of the model aims to examine differences between predicted (calculated) modelled values and the observed data.

III. Results of the ARIMA Approach for Forecasting Temperature in a Residential Premises

As already mentioned, a specialized statistical software product IBM SPSS is used for the needs of the research, which can utilize ARIMA models.

Two ARIMA models will be presented only for point 1, due to the uniform approach for each point.

In graphical form, MATLAB shows the predicted values in all six points in an interval of one hour, every ten minutes, and for each point at certain time the constructed linear functions describing the temperature in section will be presented, according to the coordinates of the room. Given the trend of temperature change, it is appropriate to look for models of the type: ARIMA (p, 1, q):

A. *ARIMA model 1*

Autocorrelation (ACF) and partial autocorrelation graphs (PACF).

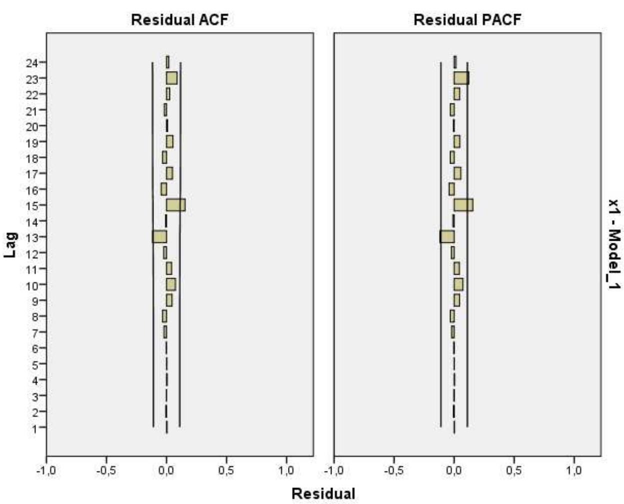

Figure 1. Errors and confidente intervals for the functions ACF and PACF for model ARIMA (6,1,2)

The choice of p and q values is done taking into account the autocorrelation (ACF) and partial autocorrelation (PACF) graphs.

The ARIMA model (6,1,2) was initially selected. The model is built on data of 312 values, and the last six values are left to validate the model.

The coefficient of determination is $R^2 = 0.339$ and is statistically significant (Sig. < 0.05).

Fig. 1 presents the errors of the autocorrelation function and of the partial autocorrelation function. Almost all values fall within the confidence interval, which shows that the model works well.

The real and approximated data, as well as the ones provided by the model are shown in Fig. 2. Fig. 3 presents a correlogram of real and approximate values. It is clear that the variance of the values depicts a line. Fig. 4 and Fig. 5 show the absolute and relative errors.

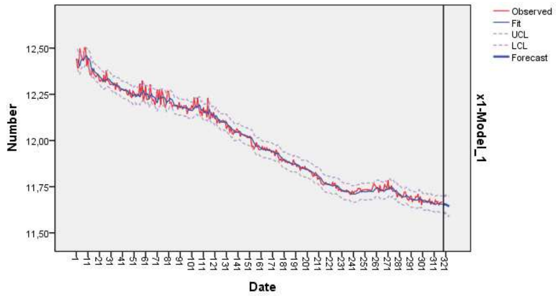

Figure 2. Real (in red), approximated (light blue) and predicted (dark Blue values for model ARIMA(6,1,2)

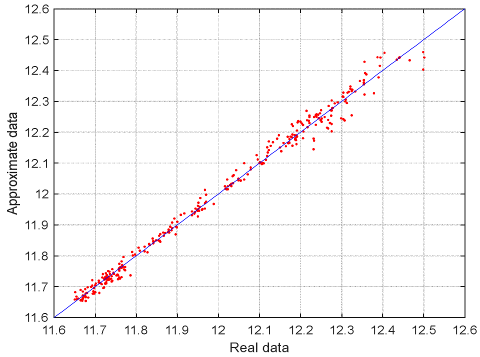

Figure 3. Correlogram for real (in blue), approximated (in red) for model ARIMA(6,1,2)

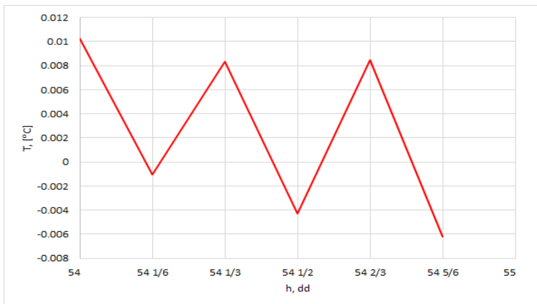

Figure 4. Absolute error for the model ARIMA (6,1,2)

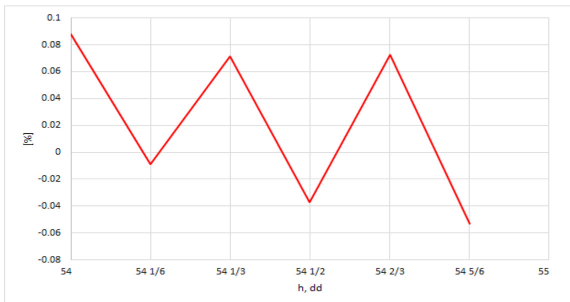

Figure 5. Relative error for the model ARIMA (6,1,2)

The obtained results show that the used model ARIMA (6,1,2) satisfactorily reflects the trend, but the predictions (relative error ± 0,1%). But a more precise model can be sought. After repeated playback of different ARIMA models (setting a different combination of *p* and *q* values) the second modified model is selected.

B. ARIMA model 2

After repeated experiments with ARIMA models, the selected model is ARIMA (7,1,12).

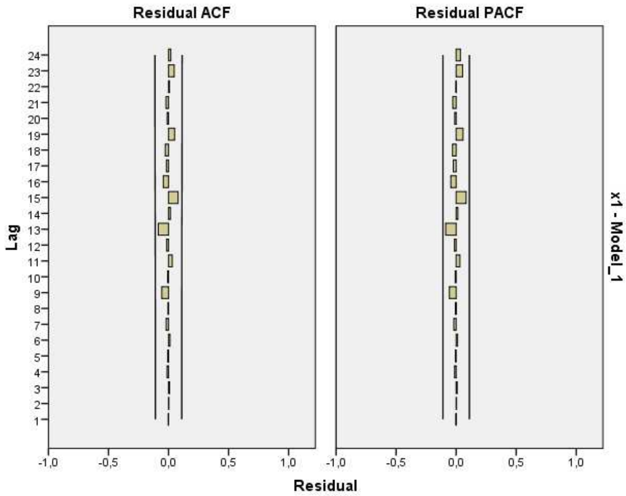

Figure 6. Errors and confidente intervals for the functions ACF and PACF for model ARIMA(7,1,12) for point 1

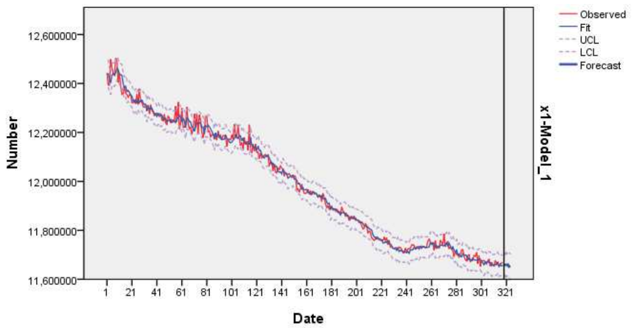

Figure 7. Real (in red), approximated (light blue) and predicted (dark Blue values for model ARIMA(7,1,12) for point 1

Fig. 6 shows the lag errors of the autocorrelation ACFs and the partial autocorrelation functions PACF. They all fall within the confidence interval unlike the first model.

Real and approximated data, as well as the predicted data from the model are presented in Fig. 7.

Fig. 8 presents a correlogram of the real and approximated values.

It is clear that the variance of the values depicts a line. Fig. 9 and Fig. 10 show the absolute and relative errors of the model.

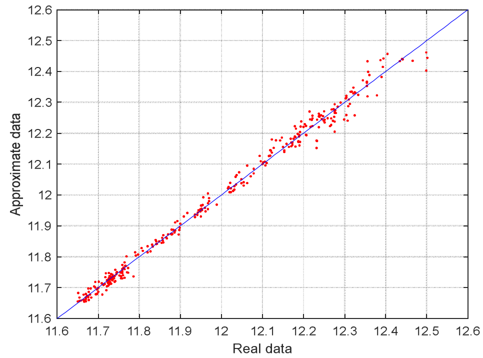

Figure 8. Correlogram for real (in blue), approximated (in red) for model ARIMA (7,1,12) for point 1

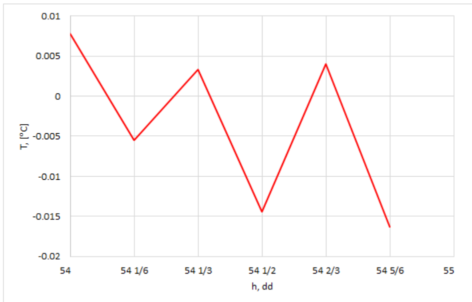

Figure 9. Absolute error for the model ARIMA (7,1,12) for point 1

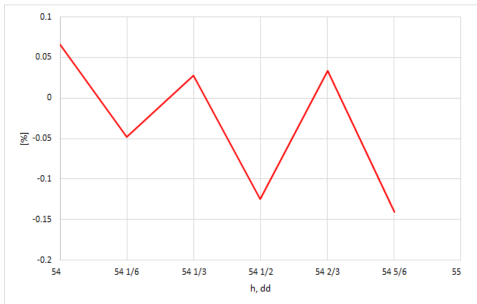

Figure 10. Relative error for the model ARIMA (7,1,12) for point 1

C. Predicted values in all six points in an interval of one hour, every ten minutes

After obtaining the predicted values at all six points in ten minutes, a linear function describing the cross-sectional temperature relative to the coordinates of the six multifunction modules measuring the temperature was constructed for each time discrete. Fig. 11 to Fig. 16 show the approximate cross-sectional temperatures within one hour, every ten minutes. In the three-dimensional coordinate system, the units of the *X* and *Y* axes are in meters, and the *Z* axis represents the measured room temperature.

In order to obtain the cross section, a linear regression model is proposed, giving the temperature at each point of the cross section, depending on *x* and *y* coordinates. Since time is a major factor, it is included as a variable:

$$T = \alpha_0(t) + \alpha_1(t)x + \alpha_2(t)y \qquad (1)$$

where: $\alpha_0(t), \alpha_1(t), \alpha_2(t)$ are functions dependent of the time of the measurement.

The functions $\alpha_0(t), \alpha_1(t)$ and $\alpha_2(t)$ are pseudo periodic, with a period one day, as the object of the analysis is a winter period with less temperature variations. It is for this reason that Fourier-type functions are used to construct the section.

The graphs present that the warmer colors (yellow and orange) show increased values of the room temperature near the ceiling. The turquoise color shows the temperature in the middle of the room, and the dark blue shows that the value of the floor temperature is the lowest.

Equations for the function approximating the temperature in the cross section for the next hour in interval of 10 minutes are:

$$f(x, y) = \alpha_0(t_i) + \alpha_1(t_i)x + \alpha_2(t_i)y, \ i = 1 \div 6 \qquad (2)$$

where: coefficients α_0, α_1 and α_2 are calculated for every discrete time t_i (t_i - 10min, t_i - 20min….. t_i - 60min).

The values of the coefficients α_0, α_1 and α_2 of the function with significance level of probability α = 1 – γ = 0.05 are presented in Table 1.

TABLE I. VALUES FOR COEFFICIENTS α_0, α_1 AND α_2

t_i, min	α_0	α_1	α_2
10	11.55	0.02862	-0.152
20	11.55	0.02944	-0.1527
30	11.55	0.02773	-0.1502
40	11.55	0.02805	-0.1527
50	11.54	0.02893	-0.1515

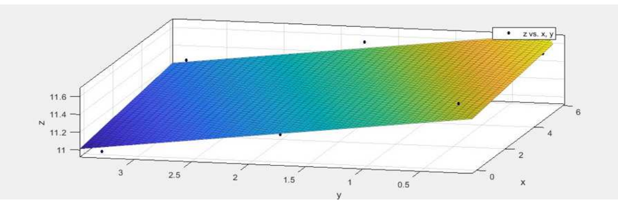

Figure 11. Predicted temperature values for the 10-th minute

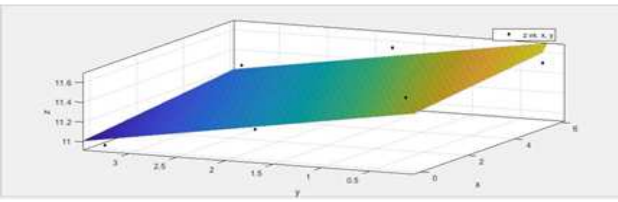

Figure 12. Predicted temperature values for the 20-th minute

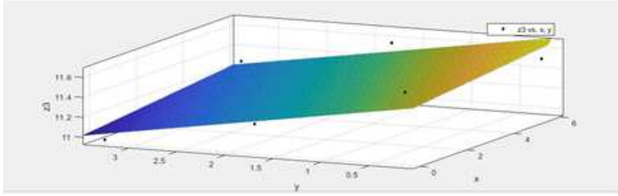

Figure 13. Predicted temperature values for the 30-th minute

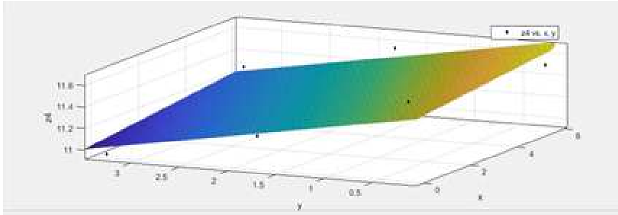

Figure 14. Predicted temperature values for the 40-th minute

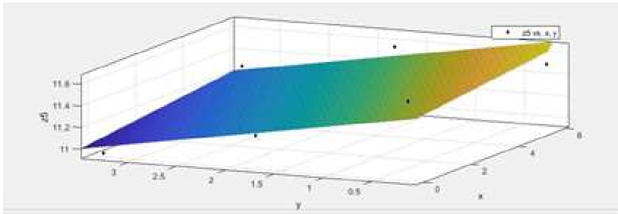

Figure 15. Predicted temperature values for the 50-th minute

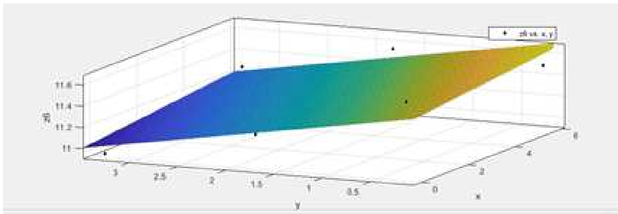

Figure 16. Predicted temperature values for the 60-th minute

Fig. 17 shows that all coefficients of determination are above 0.77, which means that the presented models describe the predicted temperature changes at any point over time well.

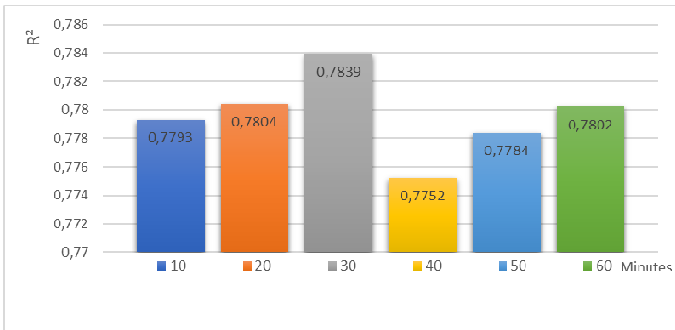

Figure 17. Coefficient of determination of the equations of the function approximating the temperature in the cross section in 10 minutes interval

IV. CONCLUSION

For more efficient use of energy resources of a residential premises, an electronic system for managing energy flows in a home has been developed.

The presented ARIMA approach for forecasting time series predicts the temperature changes in a residential premise. The choice of a specific model from different models is done on the basis of the results of correlation and autocorrelation errors (ACF, PACF), as well as the coefficient of determination (R^2), validated with temperature values measured by the electronic system (test values).

The ARIMA approaches were constructed using the software product IBM SPSS, predicting temperatures at six points in a living room.

The equations of the functions approximating the temperature in a formed cross section of six symmetrically located points in an interval of one hour, every ten minutes are constructed using the software product MATLAB.

Based on the obtained results, the temperature in time is predicted, through which the moment of switching on the heating unit can be optimized in order to achieve the desired comfort temperature at minimal energy costs.

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