Forecasting of Air Maximum Temperature on Monthly Basis Using Singular Spectrum Analysis and Linear Autoregressive Model

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Abstract. In this research, the singular spectrum analysis technique is combined with a linear autoregressive model for the purpose of prediction and forecasting of monthly maximum air temperature. The temperature time series is decomposed into three components and the trend component is subjected for modelling. The performance of modelling for both prediction and forecasting is evaluated via various model fitness function. The results show that the current method presents an excellent performance in expecting the maximum air temperature in future based on previous recordings.

Keywords: Autoregressive Model; Baghdad City; prediction model; temperature.

1. Introduction

The ecosystem has faced significant problems resulting from the variability of climate and global warming. These problems are likely to go worst depend on various climate change's scenarios (i.e., the temperature increased)[1, 2]. The natural disaster (e.g., volcanoes), industrialisation, and rapid increase of urbanisation led to Enormous greenhouse gases emission that in the last influence adversely climate change [3, 4]. It has set a considerable influence on the environment of residential areas in many places of the world [5-7]. These impacts differ in relation to the region, the type, and the importance.

The factors of climatic have directly and indirectly impacted both inhabitants and their residential environment along with short-, medium-, and long-terms [8]. Temperature is considered the most vital climatic variable that influences the growth, development and yield of crops [9]. In Addition, the system of houses is advanced in relation to factors of climatic [10, 11].

Different areas have faced a damaging impact of climate change that causes diminishing the quantity [12-16] and quality [17-22] of drinking water resources. High temperatures (i.e., dry days) lead to the growing urban water needed [23]. In addition, various studies presented that urban water needed was driven by maximum temperature [24-28].
Lately, a precise estimate of maximum temperature is a problem that has attracted the attention of researchers, since it has several various usages in the applications such as industry, agriculture or energy. Many approaches and methods are utilised in several fields [29-33], and research simulate the maximum temperature by different techniques [34-36]. The AR technique employed efficiently in several applications [37-39]. In this study, Auto-regressive (AR) approach will be applied to estimate the monthly maximum temperature.

2. Area of study and data set

Iraq is one of the Arab countries that lies in arid to the semi-arid area, and Baghdad is the capital of Iraq and locates in the centre of the country[40]. The weather is wet and cold in winter and dry and hot in summer (i.e., the temperature reaches 45 C). Iraq faced an acute climate change cased adversely impact the people, residential area, and freshwater sources[41-43]. The historical monthly data if maximum temperature along twelve years (2003-3014) used to build and assess the model.

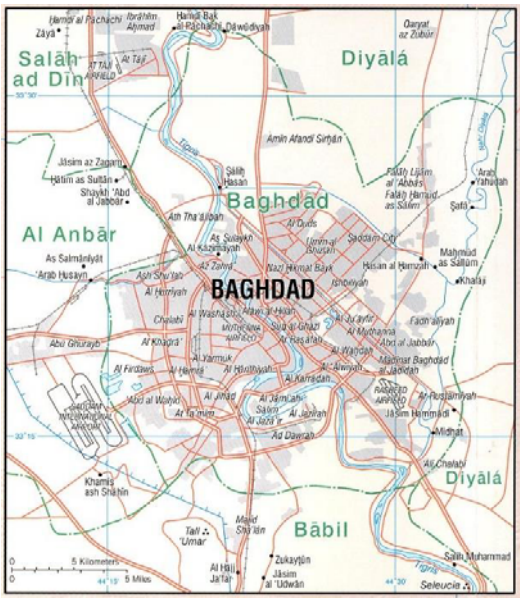

Figure 1. Location map of Baghdad city.

3. Methodology

The technique of this study divides into, data pre-processing, and auto-regressive approach.

3.1 Data Pre-processing

This technique has a significant effect on the precision of the prediction techniques. It can be separated here into two stages: normalisation and cleaning. Normalisation time series assistances to reduction the influence of outliers and makes the data to be normal or near-normal distribution [44, 45]. In this study, a natural logarithm is used for normalising the data due to its capability to reduction the influence of multicollinearity among predictor factors[28, 46].

3.2 Autoregressive Model (AR)

In autoregressive (AR) model, the output pertaining to a particular variable can be predicted from the past observations of that variable [47]. This model has a linear form. As such, the simplicity of this model coupled with its powerful prediction increases the popularity of this model in different disciplines in which time series data need to be analysed. In water demand forecasting, city engineers and water authorities are working collectively to maintain the balance between the demand and supply of drinking water to residents in their city. Hence, to achieve this goal, a sound statistical method should be used. Accordingly, there is a growing interest in applying autoregressive model in water demand forecasting. The outputs in this model are merely dependent on the previous observations of the same variable [37, 38].

To mathematically formulate autoregressive models, Eq. (1) is used to relate the current observation with the past ones in a linear relationship as illustrated [37, 38]:

$$X_t = \theta_0 + \sum_{i=1}^{p} k_i X_{t-1} + \varepsilon_t \quad (1)$$

Where; X_t and X_{t-1} are the observations in periods *t* and *t-1*, p is the order of the AR model considered, k_i is the autoregressive parameters, θ_0 is the constant term, and ε_t is the disturbance term for period *t.* A least-square algorithm using MATLAB is utilised to accurately predict the unknown coefficients in the AR model.

4. Results and discussion

Initially, the maximum temperature data are normalised and cleaned. Afterwards, the time series of maximum temperature was analysis. Figure 2 visualises the temperature time series components obtained from the singular spectrum analysis. The first component represents the trend component, which follows the same fluctuation of the original time series. It is clear that this component, i.e. trend component, has the greatest portion of the variance of the original time series.

The data of trend then categorised into training set (70%, 101 data points) and testing set (30%, 43 data points). The AR approach fitness criteria, i.e., R^2, MAE, MSE, and RMSE are shown in Table 1 for the training and testing stages. The table presents the model fitness at order 10 for both the prediction of the training sample and forecasting the testing sample. The comparison shows that the use of the combined technique outperforms the use of AR alone for both the prediction and forecasting processes. This can be clearly seen from the reduction in the MAE, MSE, and RMSE values when the SSA-AR is used.

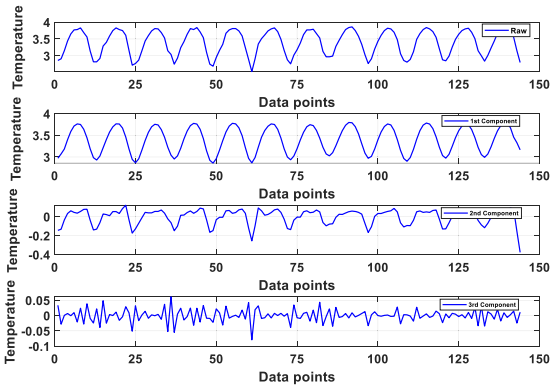

Figure 2. The normalised and the first three signals of maximum temperature time series.

Table 1: Model fitness for AR and SSA-AR methods

	Training sample				**Testing sample**			
	R^2	**MAE**	**MSE**	**RMSE**	**R^2**	**MAE**	**MSE**	**RMSE**
AR	0.92	7.67	1.03	1	0.94	2.92	0.3	0.55
SSA-AR	0.98	3.16	0.17	0.41	0.94	2.36	0.19	0.44

Additionally, Figure 3 represents the visual comparison between the measured and forecasted values of the testing sample. As it was mentioned earlier that the testing sample includes 44 recordings. It is clearly seen how precise the model forecasting is.

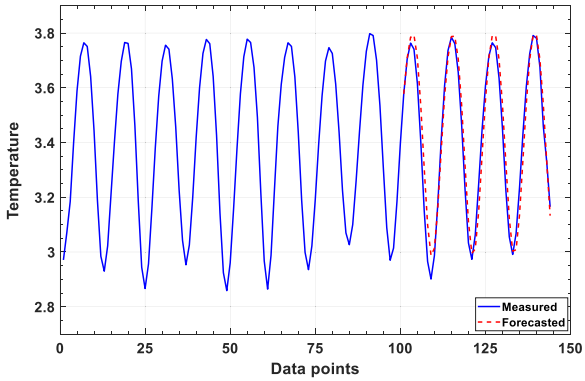

Figure 3. The comparison between measured and forecasted maximum temperature time series.

Moreover, Figure 4 illustrates the model forecasting error histogram. It can be seen that the absolute error value is 0.15 as a maximum while the majority of the errors range in between [-0.1 +0.1].

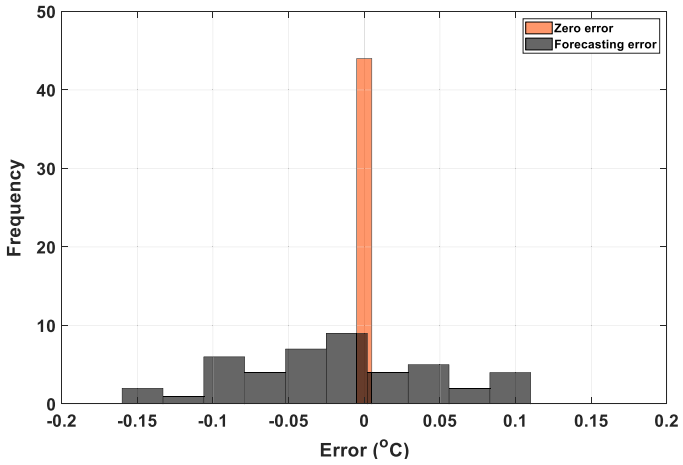

Figure 4. The error histogram of the suggested prediction model.

Based on the above statistical tests, the suggested methodology has the ability for simulating efficiently the monthly maximum temperature considering the pervious data.

5. Conclusions

Maximum temperature estimate is an important component in dynamic modern city planning and management because it helps to find suitable tools that utilised in building and industrials. In this research, the combined model includes the SSA and AR techniques employed for forecasting the monthly time series of temperature in Baghdad City over twelve years. The SSA used to denoise the time series of maximum temperature. The AR technique used to simulate the time series of maximum temperature. The outcomes reveal that the SSA is a suitable technique for noise removal. Also, the suggested methodology is effective to forecast the maximum temperature data in the testing stage (i.e., it is yield coefficient of determination 0.98 and 0.94 for training and testing stage, respectively). These results can be considered as an initial base of combined techniques for additional research in future.

6. References

[1] Zubaidi S L, Hashim K, Ethaib S, Al-Bdairi N S S, Al-Bugharbee H and Gharghan S K 2020 A novel methodology to predict monthly municipal water demand based on weather variables scenario *Journal of King Saud University - Engineering Sciences* 1-7

[2] Mohammed R and Scholz M 2019 Climate variability impact on the spatiotemporal characteristics of drought and Aridityin arid and semi-arid regions *Water Resources Management* **33** 5015-33

[3] Salman S A, Shahid S, Ismail T, Ahmed K and Wang X-J 2018 Selection of climate models for projection of spatiotemporal changes in temperature of Iraq with uncertainties *Atmospheric Research* **213** 509-22

[4] Zubaidi S L, Abdulkareem I H, Hashim K, Al-Bugharbee H, Ridha H M, Gharghan S K, Al-Qaim F F, Muradov M, Kot P and Al-Khaddar R 2020 Hybridised Artificial Neural Network Model

with Slime Mould Algorithm: A Novel Methodology for Prediction of Urban Stochastic Water Demand *Water* **12** 1-18

[5] Jasim I A, Farhan S L, Al-Maliki L A and AL-Mamoori S K 2021 Climatic Treatments for Housing in the Traditional Holy Cities: A Comparison between Najaf and Yazd Cities. In: *IOP Conference Series: Earth and Environmental Science*: IOP Publishing) pp 1-10

[6] Farhan S L and Nasar Z A 2020 Urban identity in the holy cities of Iraq: Analysis of architectural design trends in the city of Karbala *Journal of Urban Regeneration and Renewal* **14** 210-22

[7] Farhan S, Akef V, Antón D, Hashim K and Zubaidi S 2021 Factors influencing the transformation of Iraqi holy cities: the case of Al-Najaf *Przegląd Naukowy Inżynieria i Kształtowanie Środowiska* **30** 365-75

[8] Zubaidi S L, Kot P, Hashim K, Alkhaddar R, Abdellatif M and Muhsin Y R 2019 Using LARS – WG model for prediction of temperature in Columbia City, USA. In: *IOP Conference Series: Materials Science and Engineering,* (Najaf, Iraq: Materials Science and Engineering. IOP) pp 1-9

[9] Kadiyala M D, Nedumaran S, Singh P, S C, Irshad M A and Bantilan M C 2015 An integrated crop model and GIS decision support system for assisting agronomic decision making under climate change *Science of the Total Environment* **521-522** 123-34

[10] Farhan S L, Jasim I A and Al-Mamoori S K 2019 The Transformation of The City of Najaf, Iraq: Analysis, Reality and Future Prospects *Journal of Urban Regeneration and Renewal* **13** 1-12

[11] Farhan S, Akef V and Nasar Z 2020 The transformation of the inherited historical urban and architectural characteristics of Al-Najaf's Old City and possible preservation insights *Frontiers of Architectural Research* 1-17

[12] Mohammed R, Scholz M, Nanekely M, Mokhtari Y and assessment r 2018 Assessment of models predicting anthropogenic interventions and climate variability on surface runoff of the Lower Zab River *Stochastic Environmental Research and Risk Assessment* **32** 223-40

[13] Mohammed R and Scholz M 2018 Flow–duration curve integration into digital filtering algorithms for simulating climate variability based on river baseflow *Hydrological Sciences Journal* **63** 1558-73

[14] Hashim K S, Kot P, Zubaidi S L, Alwash R, Al Khaddar R, Shaw A, Al-Jumeily D and Aljefery M H 2020 Energy Efficient Electrocoagulation Using Baffle-Plates Electrodes for Efficient Escherichia Coli Removal from Wastewater *Journal of Water Process Engineering* **33** 1-7

[15] Hashim K S, Hussein A H, Zubaidi S L, Kot P, Kraidi L, Alkhaddar R, Shaw A and Alwash R 2019 Effect of Initial Ph Value on The Removal of Reactive Black Dye from Water by Electrocoagulation (EC) Method *Journal of Physics: Conference Series* **1294** 1-6

[16] Ethaib S and Zubaidi S L 2020 Removal of Methylene Blue Dye from Aqueous Solution Using Kaolin. In: *IOP Conference Series: Materials Science and Engineering,* (Nasiriyah, Iraq: IOP) pp 1-7

[17] Al-Marri S, AlQuzweeni S S, Hashim K S, AlKhaddar R, Kot P, AlKizwini R S, Zubaidi S L and Al-Khafaji Z S 2020 Ultrasonic-Electrocoagulation method for nitrate removal from water. In: *IOP Conference Series: Materials Science and Engineering,* (Najaf, Iraq: IOP) pp 1-9

[18] Alnaimi H, Idan I J, Al-Janabi A, Hashim K S, Gkantou M, Zubaidi S L, Kot P and Muradov M 2020 Ultrasonic-electrochemical treatment for effluents of concrete plants. In: *IOP Conference Series: Materials Science and Engineering,* (Najaf, Iraq: IOP) pp 1-10

[19] Alyafei A, AlKizwini R S, Hashim K S, Yeboah D, Gkantou M, Al Khaddar R, Al-Faluji D and Zubaidi S L 2020 Treatment of effluents of construction industry using a combined filtration-electrocoagulation method. In: *IOP Conference Series: Materials Science and Engineering,* (Najaf, Iraq: IOP) pp 1-8

[20] Ethaib S, Omar R, Kamal S M M, Awang Biak D R and Zubaidi S L 2020 Microwave-Assisted Pyrolysis of Biomass Waste: A Mini Review *Processes* **8**

[21] Ethaib S, Omar R, Kamal S M M, Awang Biak D R and Zubaidi S L 2020 Toward Sustainable Processes of Pretreatment Technologies of Lignocellulosic Biomass for Enzymatic Production of Biofuels and Chemicals: A Review *BioResources* **15** 10063-88

[22] Hashim K S, Ewadh H M, Muhsin A A, Zubaidi S L, Kot P, Muradov M, Aljefery M and Al-Khaddar R 2020 Phosphate removal from water using bottom ash: Adsorption performance, coexisting anions and modelling studies *Water Science and Technology* **3** 1-17

[23] Zubaidi S L, Ortega-Martorell S, Kot P, Alkhaddar R M, Abdellatif M, Gharghan S K, Ahmed M S and Hashim K 2020 A Method for Predicting Long-Term Municipal Water Demands Under Climate Change *Water Resources Management* **34** 1265-79

[24] Adamowski J, Fung Chan H, Prasher S O, Ozga-Zielinski B and Sliusarieva A 2012 Comparison of multiple linear and nonlinear regression, autoregressive integrated moving average, artificial neural network, and wavelet artificial neural network methods for urban water demand forecasting in Montreal, Canada *Water Resources Research* **48** 1-14

[25] Zubaidi S L, Dooley J, Alkhaddar R M, Abdellatif M, Al-Bugharbee H and Ortega-Martorell S 2018 A Novel approach for predicting monthly water demand by combining singular spectrum analysis with neural networks *Journal of Hydrology* **561** 136-45

[26] Zubaidi S L, Gharghan S K, Dooley J, Alkhaddar R M and Abdellatif M 2018 Short-Term Urban Water Demand Prediction Considering Weather Factors *Water Resources Management* **32** 4527-42

[27] Rasifaghihi N, Li S S and Haghighat F 2020 Forecast of urban water consumption under the impact of climate change *Sustainable Cities and Society* **52**

[28] Zubaidi S L, Ortega-Martorell S, Al-Bugharbee H, Olier I, Hashim K S, Gharghan S K, Kot P and Alkhaddar R M 2020 Urban Water Demand Prediction for a City That Suffers from Climate Change and Population Growth: Gauteng Province Case Study *Water* **12** 1-17

[29] Aljaaf A J, Van Tonder L, Mallucci C, Al-Jumeily D, Hussain A and Alloghani M 2019 Patients Attitude to Technology *Journal of medical systems* **43** 1-7

[30] Aljaaf A J, Mohsin T M, Al-Jumeily D and Alloghani M 2021 A fusion of data science and feed-forward neural network-based modelling of COVID-19 outbreak forecasting in IRAQ *Journal of Biomedical Informatics* **118** 1-8

[31] Al-Bugharbee H, Abolfathi A and Trendafilova I 2018 Vibration-Based Damage Detection of Structural Joints in Presence of Uncertainty *MATEC Web of Conferences* **148** 1-6

[32] Bugharbee H A and Trendafilova I 2018 A New Methodology for Fault Detection in Rolling Element Bearings Using Singular Spectrum Analysis *MATEC Web of Conferences* **148** 1-5

[33] Garcia D, Trendafilova I and Al-Bugharbee H 2014 Vibration-based health monitoring approach for composite structures using multivariate statistical analysis. In: *EWSHM-7th European workshop on structural health monitoring,* (France, Nantes: hal-01022019) pp 1743-50

[34] Cobaner M, Citakoglu H, Kisi O and Haktanir T 2014 Estimation of mean monthly air temperatures in Turkey *Computers and Electronics in Agriculture* **109** 71-9

[35] Appelhans T, Mwangomo E, Hardy D R, Hemp A and Nauss T 2015 Evaluating machine learning approaches for the interpolation of monthly air temperature at Mt. Kilimanjaro, Tanzania *Spatial Statistics* **14** 91-113

[36] Salcedo-Sanz S, Deo R C, Carro-Calvo L and Saavedra-Moreno B 2015 Monthly prediction of air temperature in Australia and New Zealand with machine learning algorithms *Theoretical and Applied Climatology* **125** 13-25

[37] Al-Bugharbee H and Trendafilova I 2015 Autoregressive Modelling for Rolling Element Bearing Fault Diagnosis *Journal of Physics: Conference Series* **628** 1-8

[38] Al-Bugharbee H and Trendafilova I 2016 A Fault Diagnosis Methodology for Rolling Element Bearings Based on Advanced Signal Pretreatment And Autoregressive Modelling *Journal of Sound and Vibration* **369** 246-65

[39] Zubaidi S L, Kot P, Alkhaddar R M, Abdellatif M and Al-Bugharbee H 2018 Short-Term Water Demand Prediction in Residential Complexes: Case Study in Columbia City, USA. In: *11th International Conference on Developments in eSystems Engineering (DeSE),* (Cambridge, United Kingdom: 11th International Conference on Developments in eSystems Engineering (DeSE). IEEE) pp 31-5

[40] Zubaidi S L, Al-Bugharbee H, Muhsen Y R, Hashim K, Alkhaddar R M and Hmeesh W H 2019 The Prediction of Municipal Water Demand in Iraq: A Case Study of Baghdad Governorate. In:

12th International Conference on Developments in eSystems Engineering (DeSE), (Kazan, Russia: 12th International Conference on Developments in eSystems Engineering (DeSE). IEEE) pp 274-7

[41] Farhan S L, Hashim I A J and Naji A A 2019 The Sustainable House: Comparative Analysis of Houses in Al Kut Neighborhoods-Iraq. In: *2019 12th International Conference on Developments in eSystems Engineering (DeSE),* (Kazan, Russia: IEEE) pp 1031-6

[42] Al-Maliki L A, Farhan S L, Jasim I A, Al-Mamoori S K and Al-Ansari N 2021 Perceptions about water pollution among university students: A case study from Iraq *Cogent Engineering* **8** 1895473

[43] Zubaidi S L, Al-Bugharbee H, Muhsin Y R, Hashim K and Alkhaddar R 2020 Forecasting of monthly stochastic signal of urban water demand: Baghdad as a case study. In: *IOP Conference Series: Materials Science and Engineering,* (Najaf, Iraq: IOP) pp 1-7

[44] Tabachnick B G and Fidell L S 2013 *Using Multivariate Statistics* vol sixth ed (United States of America: Pearson Education, Inc)

[45] Pallant J 2016 *SPSS Survival Manual: A step by step guide to data analysis using IBM SPSS*: Open University Press/McGraw-Hill)

[46] Zubaidi S L, Al-Bugharbee H, Ortega-Martorell S, Gharghan S K, Olier I, Hashim K S, Al-Bdairi N S S and Kot P 2020 A Novel Methodology for Prediction Urban Water Demand by Wavelet Denoising and Adaptive Neuro-Fuzzy Inference System Approach *Water* **12** 1-17

[47] Al-Bugharbee H and Trendafilova I 2014 Fault diagnosis in roller element bearings by using a linear autoregressive model. In: *the 26th International Conference on Noise and Vibration Engineering,* (Belgium, Leuven: Katholieke Universiteit Leuven) pp 2765-76