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Identifikacija sezonskih modelov temperatur zraka v področju glavnega mesta Sirije Damask

An Identification of Seasonal Models for Air Temperature in the Capital Zone Damascus in Syria

Kamal Skeiker

Ta prispevek predstavlja matematično predstavitev vremenskih parametrov v glavnem mestu Sirije Damask. Sezonski modeli, kot alternativa za uporabo urnih vremenskih vrednosti, so bili predlagani in uporabljeni za generiranje vremenskih podatkov za naslednje parametre:
- temperaturo suhega zraka,
- temperaturo vlažnega zraka,
- temperaturo rosišča.
Matematični modeli so bili izdelani za ogrevalno sezono (od novembra do aprila) in za sezono klimatizacije (od junija do septembra).

(Ključne besede: projektiranje stavb, analize toplotne, modeli matematični, temperature zraka)

This paper presents a mathematical representation of weather parameters in the city of Damascus in Syria. As an alternative to using hourly historical weather data, seasonal models were suggested and used to generate synthetic weather data for the following parameters:
- air dry-bulb temperature,
- air wet-bulb temperature,
- air dew-point temperature.
These mathematical models were derived for the heating season (November to April) and for the air-conditioning season (June to September).

(Keywords: building design, thermal analysis, mathematical models, air temperatures)

0 UVOD

Raba energije različnih panog v Siriji se deli na 42% za zgradbe in kmetijstvo, 41% za transport in 17% za industrijo [1]. Ker je največji del energije uporabljen v zgradbah, je smotrno nadaljevati raziskave na tem področju. Zato so raziskave usmerjene v: razvoj matematičnih modelov za preračune in simuliranje toplotnih sistemov, organizacijo in avtomatizacijo notranjih klimatizacijskih sistemov, oblikovanje pasivnih in aktivnih sončnih toplotnih sistemov, uporabo zunanjih površin za toplotno izolacijo in dvoslojnih oken.

V okviru razvoja matematičnih modelov za izračun in simuliranje toplotnih sistemov za stavbe je bil izdelan in preoblikovan računalniški program

0 INTRODUCTION

The energy consumption for the various sectors in Syria is as follows: 42% for buildings and agriculture, 41% for transportation and 17% for industry [1]. Since the greatest share of the energy consumption is accounted for by buildings, research in this field could prove to be useful, and so research has focused on the following areas: the development of mathematical models for thermal system calculations and simulations; the organization and automation of internal air-conditioning systems; the design of passive and active solar thermal systems; and the use of outer surfaces thermal insulation and double glazed windows.

As part of the development of mathematical models for the calculation and simulation of building thermal systems, the computer program LOS-A0 [2]

LOS-A0 [2]. Spremenjena verzija CLIMA lahko računa poljubna obdobja v letu. V računalniškem programu CLIMA je izračun neustaljenega prevoda toplote v zgradbi izdelan glede na matematični model z enournim časovnim korakom. Potrebuje urne meteorološke vrednosti za lokalno področje kot del vhodnih podatkov. Tako je računalniški program CLIMA izdelan z urnim testnim referenčnim letom (TRL - RMY Reference Meteorological Year) za glavno mesto Sirije. Podatki TRL bazirajo na dostopnih urnih meteoroloških vrednostih , ki so bili dobljeni na Oddelku za meteorologijo. Posneti so bili na posebno datoteko z vrednostjo 347000 bytov. Ti podatki so bili zbrani tudi v prejšnjih fazah dela [3].

Da bi zmanjšali celotni obseg računalniškega programa CLIMA in potrebne programske opreme, smo se odločili predstaviti TRL podatke v obliki matematične predstavitve vremenskih parametrov. V tem okviru so bili izdelani sezonski modeli za naslednje parametre:

- temperaturo suhega zraka;
- temperaturo vlažnega zraka;
- temperaturo rosišča.

Takšni matematični modeli so bili izdelani za ogrevalno sezono (od novembra do aprila) in za sezono klimatizacije (od junija do septembra) v Damasku. Potrebno je omeniti, da so številni avtorji uporabljali ta pristop za njihova specifična področja ([4] in [5]).

1 POSTOPEK IDENTIFIKACIJE MODELA

Ker je oblika grafičnega prikaza podatkovnih točk $M(x_i,y_i)$ v tej študiji več-polinomska, se bomo osredotočili na modele nelinearne regresije. Splošna oblika polinoma, ki ustreza podatkom je podana v naslednji obliki ([6] do [10]):

$$Y_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 + ... + \beta_m x_i^m + \varepsilon_i \quad (1).$$

Y_i je vrednost spremenljivke v i-*tem* poskusu in x_i je vrednost neodvisne spremenljivke v i-*tem* poskusu. Parametri modela so β_k (k=0,1,2,…m), in napaka je ε_i. Y_i predstavlja različne vremenske parametre opisane v tem prispevku kot so temperatura suhega zraka ϑ, temperatura vlažnega zraka ϑ_w in temperatura rosišča ϑ_d.

Tehnika, ki jo uporabljamo za določevanje krivulj z najboljšim prilagajanjem, se imenuje metoda najmanjših kvadratov. Naj bo a_k cenilec parametra β_k. V metodi najmanjših kvadratov so a-ji izbrani tako, da je vsota kvadratov ostankov najmanjša. Z drugimi besedami parameter a_k minimizira vrednost ([6] in [7]):

was modified and re-organized at an earlier stage of this work. The modified version of CLIMA can calculate optional period during the year. In the CLIMA computer program the calculation of non-stationary heat transfer in a building is conducted according to the adopted mathematical model by using a one-hour time increment, and it requires hourly meteorological data for the locality as a part of its input. Therefore, the CLIMA computer program was provided with an hourly Reference Meteorological Year RMY database for the capital zone in Syria. The RMY database was based on the available hourly meteorological data, which was measured by the Department of Meteorology. It was recorded in a separate file with a size of 347000 byte. This database was also organized in the previous stage of this work [3].

To reduce the size of the CLIMA computer program and its relevant peripheral software we decided to represent the RMY database with a mathematical model of the weather. Therefore, a decision was made to identify seasonal models as an alternative to the use of hourly historical weather data and to generate synthetic weather data instead. Consequently, for this paper seasonal models were suggested for the following weather parameters:

- air dry-bulb temperature;
- air wet-bulb temperature;
- air dew-point temperature.

Such mathematical models were derived for the heating season (November to April) and for the air-conditioning season (June to September) in the Damascus zone. Several other authors have followed this approach for their specific localities ([4] and [5]).

1 METHOD OF MODEL IDENTIFICATION

Since the shape of the graphical outlay of the data points $M(x_i,y_i)$ for a particular parameter under consideration in the present study suggested a multi-polynomial representation as a strong candidate, it was considered to be worth focusing on the nonlinear regression models. The general form of the polynomial used to fit the data is given by the following relation ([6] to [10]):

Y_i denotes the value of the response variable in the *ith* trial, and x_i is the value of the explanatory variable in the *ith* trial. The parameters of the model are β_k (k=0,1,2,….m), and the error term is ε_i · Y_i represents the various weather parameters predicted in this study, such as the air dry-bulb temperature (ϑ), air wet-bulb temperature (ϑ_w) and air dew-point temperature (ϑ_d).

The technique used to determine the best-fitting curve was the least-squares method. If a_k denotes the estimators of the parameters β_k, in the least-squares method the values of the a's that make the sum of the squares of the residuals as small as possible are chosen. In other words, the parameter estimates a_k to minimize the quantity ([6] and [7]):

$$\sum_{i=1}^{n}(y_i - Y_i)^2 \quad (2).$$

Obrazec za najmanjše kvadrate je precej zapleten. Zato se bomo osredotočili na razumevanje načela in pustili programski opremi, da opravi izračune.

Da bi raziskali zmožnot regresijskega modela moramo vpeljati naslednje parametre:

- Standardna deviacija: Na splošno je standardna deviacija definirana kot ([6] do [8]):

The formula for the least-squares estimates is complicated. Therefore, we will be content to understand the principle on which they are based and to let the software do the computations.

To examine the aptness of the regression model for the data at hand, the following statistical parameters need to be determined:

- Standard Deviation: In general, the standard deviation is defined as ([6] to [8]):

$$\sigma(Y) = \sqrt{\frac{1}{n-p}\sum_{i=1}^{n}(y_i - Y_i)^2} \quad (3).$$

Vrednost n-p je prostostna stopnja povezana z σ^2 (Y). Stopnje prostosti so enake podatkom "n" minus "p=m+1", število β pa moramo oceniti, da ustreza modelu. Standardna deviacija je vedno pozitivna in ima enako enoto kot vrednosti, ki jih obravnavamo. Srednja standardna deviacija σ_m (Y) je definirana kot ([6] do [8]):

The quantity n-p is the degrees of freedom associated with σ^2(Y). The degrees of freedom equal the size of the data set "n" minus "p=m+1", the number of β's we must estimate to fit the model. The standard deviation is always positive and has the same units as the values under consideration. The standard deviation of the mean σ_m(Y)is defined as ([6] to [8]):

$$\sigma_m(Y) = \frac{1}{\sqrt{n}}\sigma(Y) \quad (4).$$

Ker so cenilke a_k znane funkcije Y, in ker so napake v Y znane, so lahko napake a_k določene z množenjem napak. Matrična algebra uporablja pravila varianc in ocenjuje, da je standardna deviacija cenilk a_k podana z naslednjo relacijo [8]:

Since the estimators a_k are known functions of Y, and the errors in Y are known, the errors in a_k may be determined by error propagation. Some matrix algebra using the rules of variances establishes that the standard deviations of the estimators a_k are given by the following relation [8]:

$$[\sigma(a)] = \sigma_m(Y)\sqrt{\left[[X]^T[X]\right]^{-1}} \quad (5).$$

$[\sigma(a)]$ predstavlja vektor standardnih deviacij cenilk z "m+1" elementi. [X] pa je matrika spremenljivk z "n" vrsticami in "m+1" kolonami. $[X]^T$in $[X]^{-1}$ sta transponirana in inverzna matrika matrike [X].

- t preizkus: Da bi pokazali ali je ničta hipoteza pravilna ali napačna in če potrebujemo polinom višjega reda, uporabimo test za β_k. Da testiramo ali drži trditev β_k=0 lahko uporabimo statistični test ([6] in [8]):

$[\sigma(a)]$ denotes the column vector of the standard deviations of the estimators with "m+1" elements, and [X] is the matrix of the explanatory variable with "n" rows and "m+1" columns. $[X]^T$ and $[X]^{-1}$ are the transpose and inverse of the matrix [X], respectively.

- t Test: In order to show whether the null hypothesis is true or false, and whether higher power is important, tests for β_k are set up in the usual fashion. To test whether or not β_k = 0 we may use the test statistic ([6] and [8]):

$$t^* = \frac{a_k}{\sigma(a_k)} \quad (6)$$

in pravilo odločitve:

and the decision rule:

$$\begin{aligned} |t^*| &\leq t(1-\alpha/2\,;\,n-p) \quad \Rightarrow \beta_k = 0 \\ |t^*| &> t(1-\alpha/2\,;\,n-p) \quad \Rightarrow \beta_k \neq 0 \end{aligned} \quad (7),$$

kjer člen (1-α/2) predstavlja koeficient zaupanja

- Koeficient večkratne določenosti in koeficient večkratne korelacije: Koeficient večkratne določenosti, ki ga označimo z R^2, je definiran na sledeč način ([6] do [10]):

where the term (1 - α/2) represents the confidence coefficient.

- Coefficient of multiple determination and coefficient of multiple correlation: The coefficient of multiple determination, denoted by R^2, is defined as follows ([6] to [10]):

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - Y_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (8).$$

Izraz $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ predstavlja aritmetično povprečje podatkov. R^2 meri proporcionalno zmanjševanje variacije spremenljivke Y v odvisnosti od spremenljivk x. Zavzema vrednosti:

The term $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ denotes the arithmetic mean of the data values y_i. R^2 measures the proportionate reduction of total variation in Y associated with the use of the set of x variables. It takes the values as:

$$0 \leq R^2 \leq 1$$

Večji je R^2 bolj je zmanjšano variiranje spremenljivke Y v odvisnosti od spremenljivke x. R^2 zavzema vrednost 1 ko točke padejo direktno na odvisnostno črto, to je, ko je Y_i=y_i za vse i-je. R^2 zavzema vrednost 0, ko so vsi a_k=0 (k=1,2,...m), to je, ko je $Y_i = \bar{y}$ za vse i-je. V praksi R^2 ni 0 in ne 1 ampak nekje med tema mejama.

Koeficient večkratne korelacije, označen z R, je pozitivni kvadratni koren iz R^2:

The larger R^2 is, the more the total reduction of variation in Y caused by introducing the explanatory variable x. R^2 takes on the value 1 when all data points fall directly on the fitted response curve, that is, when Y_i=y_i for all i. R^2 assumes the value 0 when all a_k=0 (k=1,2,…m), that is, when $Y_i = \bar{y}$ for all i. In practice, R^2 is not likely to be 0 or 1, but rather somewhere in between these limits.

The coefficient of multiple correlation, denoted by R, is the positive square root of R^2:

$$R = \sqrt{R^2} \qquad (9).$$

Vredno je omeniti, da je za vsak R^2, ki ni 0 ali 1, velja $R^2 <|R|$, tako da R daje vtis"večje" odvisnosti med x in Y kot kaže vrednost R^2.

- Relativni odklon: i-ti odklon je razlika med opazovano vrednostjo in napovedano vrednostjo Y_i. Relativni odkloni od napovedanimi vrednostmi so podani z naslednjo relacijo ([6] do [10]):

Since for any R^2 other than 0 or 1, $R^2 <|R|$, R may give the impression of a "closer" relationship between x and Y than does the corresponding R^2.

- **Relative Error**: The i*th* error is the difference between the observed value of the response variable y_i and the corresponding predicted value Y_i. The relative errors of the predicted values are given by the following relation ([6] to [10]):

$$e_i = \frac{y_i - Y_i}{y_i} \qquad (10).$$

Srednja relativna napaka je tudi merilo natančnosti in se lahko izračuna kot:

The mean relative error is also a fundamental measure of accuracy, and can be calculated as follows:

$$e_m = \frac{\sum |e_i|}{n} \qquad (11).$$

2 PREDLAGANI SEZONSKI MODELI

Za postavitev sezonskih modelov je bilo potrebno identificirati vremenske parametre, ki so bili omenjeni v uvodu. Opaziti je, da so značilnosti vremenskih parametrov spreminjajo od sezone do sezone in jih ne moremo predstaviti z enotni modelom skozi celo leto. Zato smo analizirali samo zimski (ogrevanje) in letni (klimatizacija) letni čas. Čas od 1 novembra do 30 aprila obravnavamo kot ogrevalno sezono, čas od 1 junija do 30 septembra pa kot sezono klimatizacije.

Podatki v tej analizi so vzeti iz urne TRL podatkovne baze za Damask. Podatki za merilno obdobje so podani v [3]. Čeprav so podatki v TRL podatkovni bazi dobljeni iz omejene okolice (mednarodno letališče v Damasku, zemljepisna širina 26°33' N in zemljepisna dolžina 32°36' E, nadmorska višina 608 m), predstavlja to velik del Damaska.

V začetku je bilo preizkušanih veliko modelov. Na koncu je prišel v poštev krivuljno-

2 SUGGESTED SEASONAL MODELS

The aim to set up seasonal models lead to the identification of the weather parameters mentioned in the introduction. It was noticed that the characteristics of the considered weather parameters differed from one season to the next, and can not be represented by single model throughout a particular year. Thus, only winter (heating) and summer (air-conditioning) seasons are analyzed in this paper. The period time from November 1 to April 30 is considered as the heating season, and the period from June 1 to September 30 is considered as the air-conditioning season for this analysis.

The data used in this analysis is extracted from the hourly RMY database for the Damascus zone. The recorded time of this data is given in [3]. Although the data considered in the RMY database had been derived from data collected over a limited area (Damascus International Airport, a latitude of 26° 33' N and a longitude of 32° 36' E, with an elevation of 608m above sea level), they represent a large area of Damascus.

Initially, several models were attempted. Finally, one important type of curvilinear response model, the multilinearni model z imenom več polinomski reprezentančni model. Uporabljeni so bili polinomi z dvema spremenljivkama, parametri rezultata pa so definirali stopnjo polinoma, ki je najbolj ustrezal danim pogojem. Najvišji izbrani red polinoma je bil 7, ker nad tem redom nismo opazili pomembnih izboljšav.

Statistični način obdelave je bil predstavljen v prejšnjem poglavju. Z uporabo te metodologije je bil vsak set podatkov nekajkrat analiziran. To pomeni polinome od prvega do sedmega reda. V vsaki analizi smo izdelali naslednje izračune:

- cenilk a_k;
- standardne deviacije $\sigma(Y)$;
- srednje standardne deviacije $\sigma_m(Y)$;
- standardne deviacije cenilk $\sigma(a_k)$;
- t-test t*;
- koeficient večkratne določenosti R^2;
- srednje relativne napake e_m.

Ker delamo z velikim številom podatkov, je vrednost R^2 0,75 ali več primerna [11]. Še več, velika vrednost R^2 ni dovolj dobra razen, če je e_m dovolj majhen. Moderna programska oprema je bila uporabljena za te zahtevne izračune [12]. Ta oprema nam omogoča izračune ne da bi poznali vse podrobnosti. S korelacijo podatkov smo ugotovili tisti model, ki najbolje predstavlja podatke. Ta model je tudi izbran za objavo v tem prispevku.

Matematični modeli, ki predstavljajo v uvodu opisane vremenske parametre, so podani v naslednjih poglavjih. Dve spremenljivki sta t_1 in t_2. t_1 je čas v urah in zavzema vrednosti 1 (prva ura prvega dne v novembru) do 4344 (24 ura 30 dne aprila) za ogrevalno sezono. t_1 zavzema vrednost 1 (prva ura prvega dne v juniju) do 2928 (24 ura 30 dne v septembru) za sezono klimatizacije. Nadalje t_2 predstavlja uro v dnevu in zavzema vrednosti od 1 do 24.

polynomial representation model, was considered. Thus, polynomials with two explanatory variables were attempted and the statistical parameters of the results dictated the degree of the multi-polynomial that was best for the particular parameter under consideration. The highest degree of the multi-polynomial is taken as 7 since no appreciable improvements were noticed in the values computed by the resulting models when it was increased beyond this value.

The statistical approach used is outlined in the previous section. In applying the outlined methodology, each set of data was analyzed several times. This covers multi-polynomials in the order of one to seven. In each analysis the following computations were performed:

- the estimators a_k;
- the standard deviation σ (Y);
- the mean standard deviation σ_m (Y);
- the standard deviation of the estimators σ (a_k);
- the t-test t*;
- the coefficient of multiple determination R^2;
- the mean relative error e_m.

Since we deal with large sets of data, a value of 0.75 or more for R^2 is desirable [11]. Moreover, a high R^2 value is not good enough unless e_m is also small enough. Modern software was used for these rather complex calculations [12]. Such software allows us to perform these calculations without an intimate knowledge of all of the computational details. In correlating the data by following the procedure outlined above, one of the models stands out as the best representative of the data. Such a model was selected for inclusion in this paper.

The mathematical models representing the data of the weather parameters mentioned in the introduction are given in the following subsections, where the two explanatory variables are t_1 and t_2. t_1 denotes the time series in hours and takes the values 1 (the first hour of the first day in November) through 4344 (the 24^{th} hour of the 30^{th} day in April) for the heating season. It takes the values 1 (the first hour of the first day in June) through 2928 (the 24^{th} hour of the 30^{th} day in September) for the air-conditioning season. t_2 denotes the time in hours on the day under consideration, and takes the values 1 through 24.

2.1 Temperatura suhega zraka

Dobljeni so modeli za napoved temperature suhega zraka za poljubni čas med ogrevalno sezono in sezono klimatizacije. Ti modeli so izraženi z naslednjo glavno zvezo:

2.1 Air Dry-bulbTemperature

The adequate models for predicting air dry-bulb temperature for an optional time during the heating and air-conditioning seasons were obtained. These models are expressed by the following general relation:

$$\vartheta = a_0 + a_1 t_1 + a_2 t_1^2 + a_3 sin\left[\frac{\pi}{12}(t_2 - 10)\right] \qquad (12).$$

Cenilke a_k, koeficienti določenosti R^2, standardna deviacija $\sigma(\vartheta)$ in srednje vrednosti relativne napake e_m so predstavljene v preglednici 1.

Vzemimo čas ob 12 uri 21 decembra (t_1=1213, t_2=12) kot primer za primerjavo merjene in izračunane vrednosti. Izmerjena vrednost je 11,1°C, ki jo

The estimators a_k, the coefficient of determination R^2, the standard deviation $\sigma(\vartheta)$ and the mean of the relative error e_m of these models are listed in Table 1.

As an example, we took 12:00 on 21 December (t_1= 1213, t_2= 12) to compare the recorded value and the computed value. The recorded value was primerjamo z 10,8 °C izračunane z gornjo zvezo. Ugotovimo malenkostno napako 0,3°C. Vzemimo še čas ob 12 uri 21 julija (t_1=1213, t_2=12) kot naslednji primer. Izmerjena vrednost je 33.6°C v primerjavi z 32.6°C izračunana z zgornjo zvezo. Ocenjena napaka v tem primeru znaša 1°C.

11.1 °C compared to 10.8 °C computed from the above relation. Thus a negligible error of 0.3 °C is observed for the predicted value. For 12:00 on 21 July (t_1= 1213, t_2=12) the recorded value was 33.6 °C compared to 32.6 °C computed from the above relation, an error of about 1 °C is observed in the prediction of this value.

Preglednica 1. *Sezonski modeli cenilk in statističnih parametrov za temperaturo suhega zraka*
Table 1. *Estimators and statistical parameters for air dry-bulb temperature seasonal models*

Sezona Season	a_0	a_1	a_2	a_3	R^2	$\sigma(\vartheta)$ [°C]	e_m
Ogrevanje Heating	13,6280	-8,1386 10^{-3}	2,1844 10^{-6}	5,3841	0,91	1,65	0,120
Klimatizacija Air-conditioning	22,2633	6,1894 10^{-3}	-2,2553 10^{-6}	8,7402	0,96	1,30	0,048

2.2 Temperatura vlažnega zraka

Podobno kot sezonske modele za temperaturo suhega zraka imamo tudi modele za napoved temperature vlažnega zraka za poljubni čas. Ti modeli so podani z naslednjo glavno zvezo:

2.2 Air Wet-bulb Temperature

As with the seasonal models of the air dry-bulb temperature, the models for predicting air wet-bulb temperature for an optional time during the heating and air-conditioning seasons were obtained. These models are expressed by the following general relation:

$$\vartheta_w = a_0 + a_1 t_1 + a_2 t_1^2 + a_3 sin\left[\frac{\pi}{12}(t_2 - 10)\right] \quad (13).$$

Cenilke a_k in statistični parametri R^2, $\sigma(\vartheta)$ in e_m so podani v preglednici 2. Ker se oblika grafičnega izhoda podatkov razlikuje v posameznih korakih, samo en model vseh podatkov ne more popisati. Zato imamo dve skupini cenilk za ogrevalno sezono in tri skupine za sezono klimatizacije.

Izmerjena vrednost za čas ob 12 uri 21 decembra je 7,6°C v primerjavi z 6,9°C izračunano iz zgornje relacije. Odstopanje v tem primeru je 0,7°C. Nadalje je izmerjena vrednost za čas ob 12 uri 21 julija 18,9°C v primerjavi z 18,7°C izračunane z gornjo relacijo. Ocenjena napaka v tem primeru znaša 0,2°C.

The estimators a_k and the statistical parameters R^2, $\sigma(\vartheta)$ and e_m of these models are listed in Table 2. Since the shape of the graphical outlay of the data differed from one time interval to another, a single model throughout the season could not be used to represent them. Thus, two groups of estimators for the heating season and three groups for the air-conditioning season are listed.

The recorded value for 12:00 on 21 December is 7.6 °C compared to 6.9 °C computed from the above relation. Thus a negligible error of 0.7 °C is observed in the predicted value. The recorded value for 12:00 on 21 July is 18.9 °C compared to 18.7 °C computed from the above relation. Thus, the error in the prediction of this value is about 0.2 °C.

2.3 Temperatura rosišča

Statistični pristop, ki je bil uporabljen v prejšnjih podpoglavjih je bil uporabljen za napoved temperature rosišča zraka za poljubni čas med ogrevalno sezono in sezono klimatizacije. Ti modeli so podani v naslednji splošni odvisnosti:

2.3 Air Dew-point Temperature

The general statistical approach used in the previous two subsections was applied to obtain models for predicting air dew-point temperature for an optional time during the heating and air-conditioning seasons. These models are expressed by the following general relation:

$$\vartheta_d = A(\vartheta_{d1} + \vartheta_{d2}) \quad (14),$$

ϑ_{d1} in ϑ_{d2} so podani v naslednji odvisnosti:

ϑ_{d1} and ϑ_{d2} are given by the following relations:

$$\vartheta_{d1} = a_0 + a_1 t_1 + a_2 t_1^2 \quad (15),$$

$$\vartheta_{d2} = a_3 t_2 + a_4 t_2^2 + a_5 t_2^3 + a_6 t_2^4 + a_7 t_2^5 + a_8 t_2^6 + a_9 t_2^7 \quad (16).$$

Cenilke a_k teh modelov so podane v preglednici 3. Faktor množenja in statistični parametri

The estimators a_k of these models are listed in Table 3. The multiplication factor A and the sta-

R^2, $\sigma(\vartheta)$ in e_m so podani v preglednici 4. Pomembno je upoštevati, da je imamo za ogrevalno sezono tri skupine cenilk.

Izmerjena vrednost za čas ob 12 uri 21 decembra je 4,9°C v primerjavi z izračunano vrednostjo 4,6°C. Standardni odstopek je v tem primeru 0,3°C. Izmerjena vrednost za čas ob 12 uri 21 julija je 13,5°C v primerjavi z izračunano vrednostjo 13,3°C. Pričakovano odstopanje pri napovedi teh vrednosti znaša 0,2°C.

tistical parameters R^2, $\sigma(\vartheta)$ and e_m of these models are listed in Table 4. Three groups of estimators are listed for the heating season.

The recorded value for 12:00 on 21 December is 4.9 °C compared to 4.6 °C computed from the above relation. Thus a negligible error of 0.3 °C is observed in the predicted value. The recorded value for 12:00 on 21 July is 13.5 °C compared to 13.3 °C computed from the above relation. Thus, the error in the prediction of this value is about 0.2 °C.

Preglednica 2. *Cenilke in statistični parametri za sezonske modele temperature vlažnega zraka*
Table 2. *Estimators and statistical parameters for air wet-bulb temperature seasonal models*

Sezona Season	a_0	a_1	a_2	a_3	R^2	$\sigma(\vartheta_w)$ [°C]	e_m
Ogrevanje Heating							
t_1 =1-3912	9,7880	-6,1693 10^{-3}	1,6346 10^{-6}	3,1158			
t_1 =3913-4344	469,373	-225,941 10^{-3}	27,7682 10^{-6}	2,9816	0,93	0,83	0,109
Klimatizacija Air-conditioning							
t_1 =1-1008	13,5879	5,7522 10^{-3}	-2,5753 10^{-6}	2,1476			
t_1 =1009-2136	15,3478	3,2647 10^{-3}	-1,0701 10^{-6}	1,3868			
t_1 =2137-2928	17,1440	2,6868 10^{-3}	-1,2859 10^{-6}	2,4088	0,89	0,66	0,033

Preglednica 3. *Cenilke za sezonske modele temperature rosišča zraka*
Table 3. *Estimators for air dew-point temperature seasonal models*

Časovno obdobje t_1 Period of time t_1	Ogrevalna sezona Heating season									
	a_0	a_1 10^3	a_2 10^6	a_3	a_4	a_5	a_6 10^2	a_7 10^3	a_8 10^5	a_9 10^6
t_1=1-768	7,3399	-6,8723	2,0226	2,7926	-1,8822	0,3698	-3,0136	1,0925	-1,4633	-
t_1=769-3912	5,0994	-3,6960	1,0883	1,9023	-1,2328	0,2315	-1,8167	0,6369	0,8263	-
t_1=3913-4346	651,433	-311,23	37,4567	0,0909	-0,5833	0,1614	-1,5657	0,6387	-0,9369	-
	Klimatizacijska sezona Air-conditioning season									
t_1=1-2928	9,7798	14,9859	-3,7733	6,2585	-5,1452	1,3678	-16,697	10,2364	-30,726	3,6015

Preglednica 4. *Faktor množenja in statistični parametri za sezonske modele temperature rosišča zraka*
Table 4. *Multiplication factor and statistical parameters for air dew-point temperature seasonal models*

Sezona Season	A	R^2	$\sigma(\vartheta_d)$ [°C]	e_m
Ogrevanje Heating	1	0,87	0,89	0,144
Klimatizacija Air-conditioning	$e^{-0,000178t_1}$	0,94	0,98	0,080

3 VIZUALNA PRIMERJAVA REZULTATOV IN NAPOVEDANIH VREDNOSTI

V nadaljevanju obravnave rezultatov so bili izračunani in izmerjeni rezultati izrisani na istem diagramu, da smo lahko obravnavali vizualno primerjavo.

Napovedane in izmerjene vrednosti so bile izrisane za 21 december in 21 julij. Slika 1 prikazuje

3 VISUAL COMPARISON OF THE DATA AND THE PREDICTED VALUES

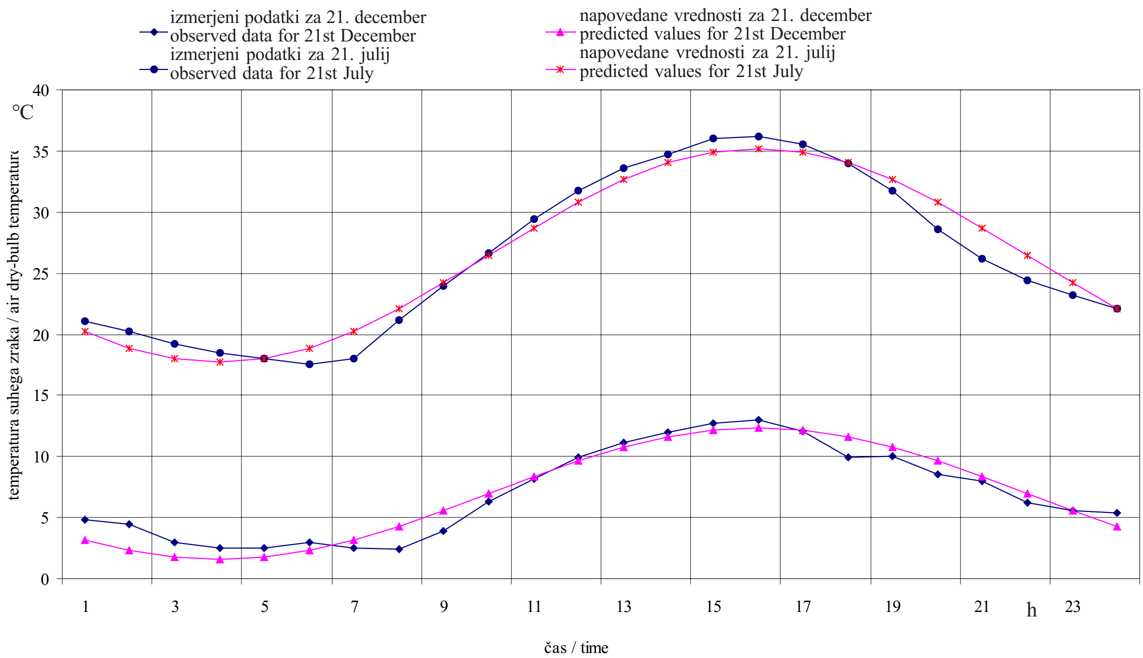
In a further study of the results, the predicted values along with the recorded data were plotted on the same scale for a visual comparison between them.

The predicted values along with the recorded data for 21st December and 21st July were plotizris napovedanih in izmerjenih vrednosti za temperaturo suhega zraka. Podobni izrisi so dobljeni za temperaturo vlažnega zraka in temperaturo rosišča.

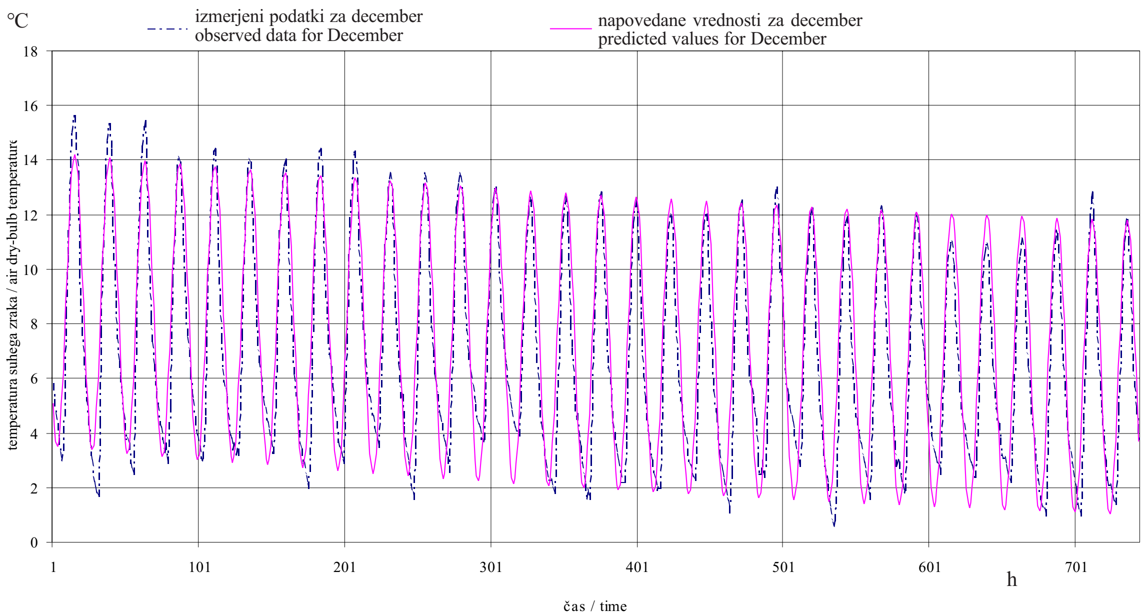
Na slikah 2 in 3 so predstavljene vrednosti za temperaturo suhega zraka za december in julij. Podobni izrisi so dobljeni za ostala dva parametra na slikah 2 in 3.

ted for a visual comparison of the data and their predicted values. Figure 1 shows a plot of the predicted and recorded data values for the air dry-bulb temperature. Similar plots for air wet-bulb temperature and air dew-point temperature were also obtained.

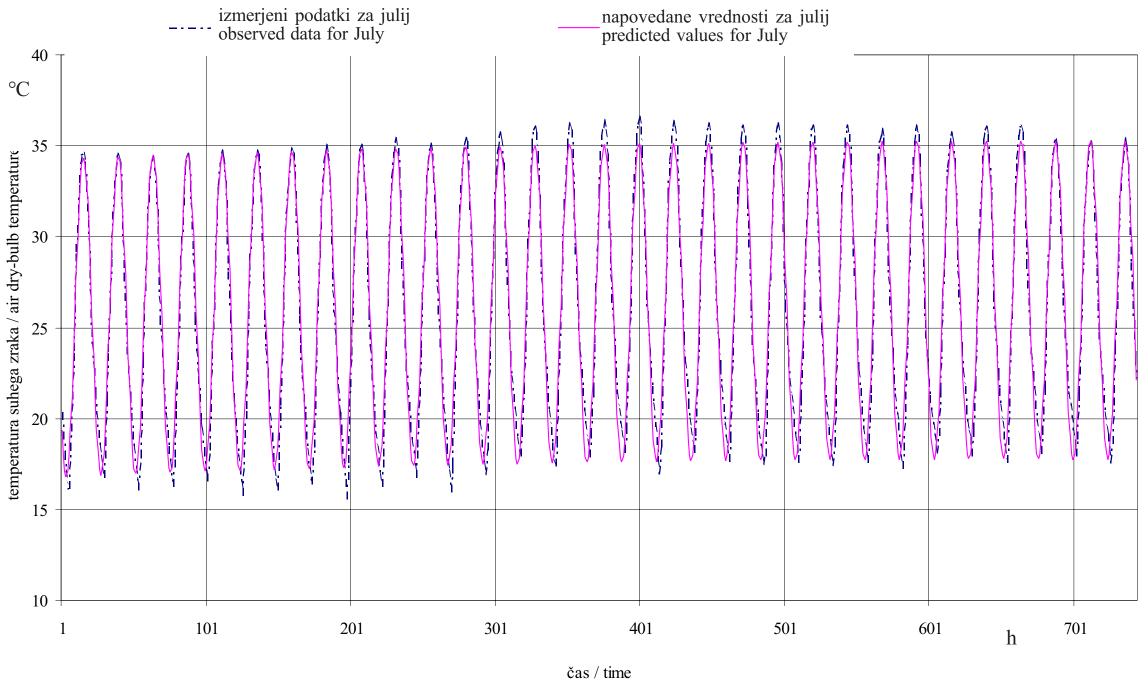
In figures 2 and 3, the predicted values along with recorded data are presented for the air dry-bulb temperature of December and July, respectively. Plots for the remaining two weather parameters are similar to those in figures 2 and 3.



Sl. 1. *Potek temperature suhega zraka za 21. december in 21. julij*
Fig. 1. *Behaviour of air dry-bulb temperature for 21st December and 21st July*



Sl. 2. *Potek temperature suhega zraka za december*
Fig. 2. *Behaviour of air dry-bulb temperature for December*



Sl. 3. *Potek temperature suhega zraka za julij*
Fig. 3. *Behaviour of air dry-bulb temperature for July*

4 SKLEP

Razvoj zelo zmogljivih osebnih računalnikov je eden izmed razlogov za razvoj simulacije sistemov. Numerične simulacije toplotnih sistemov zgradb potrebujejo kot vhodni podatek vremenske parametre.

Tehnika, ki je bila uporabljena za določitev najbolj odgovarjajoče krivulje, je metoda najmanjših kvadratov. Uporabljen pristop je nadrobno opisan.

Grafična oblika podatkov je narekovala uporabo večpolinomskega modela. Z uporabo polinomov so bili izdelani sezonski modli za naslednje vremenske parametre:
- temperaturo suhega zraka;
- temperaturo vlažnega zraka;
- temperaturo rosišča.

Ti matematični modeli so bili izdelani za ogrevalno sezono in za sezono klimatizacije v Damasku. Razviti so bili na podatkih dolgega časovnega obdobja.

Izbira najboljšega modela je temeljila na treh statističnih parametrih: koeficientu določenosti R^2, srednji relativni napaki e_m in t testu. Ker delamo z velikim številom podatkov (4344/ali 2928 točk za ogrevalno/ali klimatizacijsko sezono), lahko predlagani modeli ustrezajo zgornjim parametrom z zadovoljivim R^2 in e_m. Vizualno je bilo ugotovljeno, da obstaja dobra skladnost med napovedanimi in izmerjenimi vrednostmi.

Predlagane matematične modele lahko uporabimo v CLIMA programu kot alternativo urnim vremenskim podatkom.

4 CONCLUSION

The proliferation of high-power personal computers has helped in the advancement of the science of system simulation. The numerical simulation of building thermal systems calls for the input of local weather parameters.

The technique used in determining the best-fitting curve is the least-squares method. The approach used in the analysis is outlined.

The shape of the graphical outlay of the data for the particular parameter under consideration suggested that a multi-polynomial representation was a strong candidate. By making use of a polynomial representation, mathematical seasonal models were suggested for the following weather parameters:
- air dry-bulb temperature;
- air wet-bulb temperature;
- air dew-point temperature.

Mathematical models were derived for the heating season and for the air-conditioning season in the Damascus zone. They were developed based on long-term data records.

The choice of the best model was based on three statistical parameters: the coefficient of determination R^2, the mean relative error e_m and the t-test. Since we deal with large sets of data (4344 or 2928 data points for the heating or air-conditioning season), the suggested models can estimate the above-mentioned parameters with acceptable R^2 and e_m. It is clear that good agreements between the predicted and the observed data values were obtained.

The suggested mathematical models can be used in the CLIMA computer program as an alternative to using hourly historical weather data.

Ta pristop moremo uporabiti za druge kraje in z uporabo dolgočasovnih nizov podatkov tudi za ostale vremenske parametre.

Such an approach needs to be followed for the other sites, and to be applied using long-term data sets of the remaining relevant weather parameters.

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5 OZNAČBE
5 NOMENCLATURE

faktor množenja	A	multiplication factor
cenilka parametra β	a	estimator of parameter β
relativna napaka	e	relative error
niz podatkov	M	set of data points
stopnja modela	m	model degree
obseg podatkov	n	size of the data set
število parametrov v modelu	p	number of model parameters
koeficient večkratne korelacije	R	coefficient of multiple correlation
koeficient večkratne določenosti	R^2	coefficient of multiple determination
t test	t	t-test
matrika spremenljivk	[X]	matrix of explanatory variable
transponirana matrika [X]	$[X]^T$	transpose of matrix [X]
inverzna matrika [X]	$[X]^{-1}$	inverse of matrix [X]
neodvisna spremenljivka	x	explanatory variable
spremenljivka za napoved odgovora	Y	predicted response variable
matematični model krivulje podatkov	Y=F(x)	mathematical model of the curve fitted to the data
opazovana spremenljivka	y	observed response variable
aritmetično povprečje podatkov spremenljivke y_i	$\bar{y}$	arithmetic mean of data value y_i
funkcijska predstavitev točk s podatki	y=f(x)	functional representation of data points
testno referenčno leto	TRL/RMY	reference meteorological year
stopnja zaupanja	α	level of significance
modelski parameter	β	model parameter
izraz za napako	ε	error term
temperatura	ϑ	temperature
Ludolfovo število 3,141593	π	Ludolphos number 3.141593
standardna deviacija	σ	standard deviation
vektor standardnih deviacij cenilk	[σ(a)]	vector of the standard deviations of estimators

Indeksi	**Subscripts**	
točka rosišča	d	dew-point
i-ti poskus	i	i*th* trial
k-ti	k	k*th*
srednji	m	mean
vlažni	w	wet-bulb

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6 REFERENCES

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