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Forecast of Climatologically Events Using Improved Grey Model (Case Study: Qazvin Province Climatology)

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Abstract

The theory of grey system is used when sufficient information of the community under study is not in hand. The grey forecast model is proper when the information variety is fix and certain. Grey model can apply some additional computations to improve forecasting activities when data is insufficient. Through using improved grey model, the assessment error decreases significantly. This study made use of the mean maximum daily temperature data collected by Qazvin meteorological station, from August 2001 to August 2013. The findings revealed that the grey model metabolism method can reduce errors and improve the precision of forecasting the mean variable of maximum daily temperature.

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INTRODUCTION

All aspects of man's life are under the influence of climatic events and this influence is clearly visible in different domains including agriculture, economy, transportation & military technologies (Khalili et al., 2010). So many contemporary environmental pitfalls including floods, storms, drought, and augmented number of bugs and their immunity against pest killers and poisons and other pitfalls like this are rooted in the developments that are being made in the meteorological conditions of the globe and especially in the way the earth's climatic condition is changing. Considering the climatic changes, global warming, and recent droughts, forecast of maximum temperature as the most important climatic parameters to be considered, provides planners with a proper opportunity of planning and procurement. Study and analysis of maximum temperature is a climatic parameter significant to be considered for managing water and natural resources, agriculture, pest & disease control, floods and melting of snow, evaporation & transpiration, droughts, etc. weather forecast system is a nonlinear complicated system that does not follow mathematical rules; and since the system varies with the passing of time, ordinary prediction methods make the forecast impossible (Aliari Shourehdeli et al., 2004).

Most researchers encounter uncertain conditions, imperfect data and confusing information when are to deal with the task of forecasting. Assuming that the clear data of a system is displayed in white color and the unknown data is shown in black, then the data of most existing systems of nature is not purely white or black, rather, it is a mixture of both; it is grey. Such systems are called grey systems. The major specification of such data is their incompleteness (Mohammadi & Molaei, 2010). Grey model forecasting as the main core of grey system theory, has the privilege of creating a model using indefinite and insufficient data and is a tool proper to predict systems with complicated, unconfident and irregular structure (Deng, 1989). Compared with Box-Jenkins models and artificial intelligence techniques that require much time and effort in order to determine the parameters and make models of different stages, grey models of forecasting are more applicable and easier to use. Grey models make use of a differential equation in order to describe an uncertain system with insufficient data (Kazemi Alieh, et al., 2011). Ultimately, it can be deducted that compared with the statistics, probabilities, and fuzzy mathematics that deal with simple issues and uncertainties, the grey theory is ranked higher since it encounters semi-complicated issues and uncertainties. One of the most important privileges of this model is that it is precise even though the computations are quite simple (Malek et al., 2011).

In 2012, Wang and Liu, used the grey model (GM(1,1)) to predict people aged 60 and over in Shanghai, revealing that a minimum of 150000 retirees will be added to the society between 2010 to 2015. The findings were used to define pension policies (Wang & Liu, 2012).

In 2007, Tongyuan and Yue, used grey models to predict urban traffic accidents in China. Using the 4-variable statistics collected and via SPSS software, the statistical analyses of logistic regression and multivariable regression were simultanueously applied to determine the share of each parameter in the probability of traffic accident (Tongyuan & Yue, 2007). In 2014, Liu, et.al, predicted the number of tourists based on the improved grey model (GM(1,1)). The model has so many privileges such as simplicity and high precision. This study aims at developing of an optimized model in order to optimize the primary and background values. The numerical samples verified that the simulation and the short term forecast are improved (Liu et al., 2014). Javanmard and Faghidian (2014), applied the grey model to predict the price of raw oil price of OPEC. The results convey that in order to predict the price of raw oil in a short term period, data collected within two consecutive working weeks can bring better results compared with data collected within three consecutive working weeks. This proves the claims of grey model researchers who believe that grey models can provide a more precise prediction of oil price when data is insufficient (Javanmard & Faghidian, 2014).

In 2001, Zhang & He, formulated Grey prediction model of Markov Chain in order to predict the electrical requirements of agricultural sector in Shanghai (Zhang & He, 2001). In 2001, Tseng, et.al, presented a combined grey model to forecast seasonal time series. This essay assumes a method which combines grey prediction models (GM(1,1)) with the model of heterogeneous seasonal functions in order to predict time series based on the seasonal specifications (Tseng, et.al, 2001). In 2003, Hsu and Chen, presented the improved grey model of forecast in order to predict demand in Thaiwan (Hsu & Chen, 2003).

In 2004, Ping and Yang, used a combination of neural networks and grey model to predict productivity of telecommunication companies and argued that considering the complicated and unconfident atmosphere that prevail this industry, grey model of forcasting can predict the productivity of these companies far better (Ping & Yang, 2004).

In 2007, Li et al., suggested the triangular grey model method to predict demand for energy (Case Study China). In this essay, a triangular grey model of prediction is developed from combining the traditional grey model (GM(1,1)), with the triangular remnant improving method, in order to predict demand for energy and to improve the precision of prediction (Li et al., 2007).

In 2007, Huang, et.al, presented a grey Markov forecast model. In this research, the demand for energy until 2020 were predicted in China, using the energy consumption data collected between 1985 to 2001 (Huang et al., 2007). In 2010, Kumar & Jain, used grey Markov model to predict raw oil consumption in India (Kumar & Jain, 2010).

In 2010, Zhaozheng, et.al, presented a combined model of grey theory and neural network to predict demand for oil products. In this method, domestic oil products data are used and through an optimized combining of grey model forecasting (Gm (1,1)) and artificial neural network, a combined forecast model was developed. This model successfully assessed the demand for gasoline and gasoil in 2020, to be 101.52 million tons and 187.57 million tons respectively (Zhaozhang et al., 2010).

In 2011, Kazemi, et.al presented a model to predict transportation sector's demand for energy using grey Markov chain model. In this research, grey Markov chain model was used to predict the transportation sector's demand for energy by 2021. For the prediction, data collected from 1991 to 2007 were used. Furthermore, the results of the said model have been compared with the results obtained after execution of grey model and those of the regression model (Kazemi Alieh et al., 2011).

This essay aims at predicting the mean maximum temperature of August using grey model and improved grey model in order to decrease the assessment error without needing to deal with complicated computations and professional programming.

THEORETICAL CONCEPTS OF STUDY

Imagining the clear data of a white color system and the totally unknown data of a black color system, one can understand that the data of the most existing systems of nature are neither totally white, nor totally black, rather, are combination of the two, that is, grey. Such systems are called grey systems the primary feature of which is that the data they present is incomplete (Mohammadi & Molaei, 2010). Fig. 1, conveys the concept of a grey system.

GREY MODEL OF FORECAST

Traditional GM(1,1)

GM stands for Grey Model. Digit 1 represents a one-stage equation and the second digit 1 represents the existence of an independent variable. In this model, the series of numbers takes an accumulated form so that they increase with the passing of time. Approximate corresponding difference functions are formed to develop data. Below, you can find the process of developing and solving grey forecast model:

1)- In a grey model, the series of primary numbers are as follow:

$$x^{(0)}=(x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)) \qquad (1)$$

Where n represents the number of data

Furthermore, the accumulated data are produced as follows:

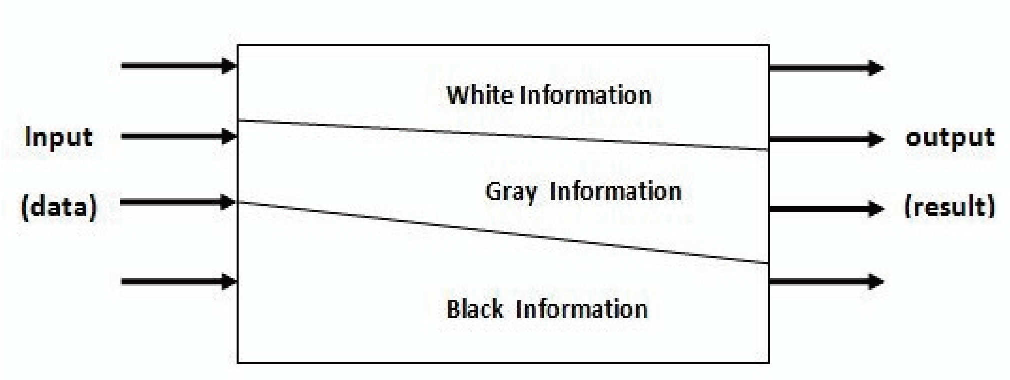

Fig. 1. Conceptual representation of the gray system

$x^{(1)}=(x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n))$ (2)

where:

$x^{(1)}(i)=\Sigma^{n}_{i=1} x^{(0)}(i), i=1,2, \ldots, n$ (3)

2) Gaussian uniformity test (p(i+1)= x(0)(i+1)/x(1)(i) is carried out for the accumulated data chain. P(i+1)<0.5 is desirable. Furthermore:

$$\sigma^{(1)}(i+1)=\frac{x^{(1)}(i+1)}{x^{(1)}(i)}=\frac{x^{(0)}(i+1)+x^{(1)}(i)}{x^{(1)}(i)} = 1+p(i+1) < 1.5$$

(4)

3) To achieve prediction equation coefficient, series w(1) should be calculated first:

$w^{(1)}= (w^{(1)}{}_{(1)}, w^{(1)}{}_{(2)}, \ldots, w^{(1)}{}_{(n)})$ (5)

Next we'll have:

$x^{(0)}{}_{(i)}+\alpha w^{(1)}{}_{(i)}=b$ (6)

4) Matrices B, Y & A, are formed to solve the equation as follow:

$$B=\begin{bmatrix} -w^{(1)}(2) & 1 \\ \vdots & \vdots \\ -w^{(1)}(n) & 1 \end{bmatrix}, Y=\begin{bmatrix} x^{(0)}(2) \\ \ldots \\ x^{(0)}(n) \end{bmatrix}, A=\begin{bmatrix} a \\ b \end{bmatrix}$$ and

Y=BA (7)

Ultimately we'll have:

$\hat{A}=(B^{T}B)^{-1}B^{T}Y$ (8)

And to assess the real values, we'll have:

$$\begin{cases} \widehat{x^{(1)}}(1) = x^{(0)}(1) \\ \widehat{x^{(1)}}(i+1) = \frac{\hat{b}}{\hat{a}} + e^{-\hat{a}i}\left(x^{(1)}(0) - \frac{\hat{b}}{\hat{a}}\right) \end{cases} \quad i \geq 1 \quad (9)$$

$$\begin{cases} \widehat{x^{(0)}}(1) = x^{(0)}(1) \\ \widehat{x^{(0)}}(i+1) = \widehat{x^{(1)}}(i+1) - \widehat{x^{(1)}}(i) \end{cases} \quad i \geq 1 \quad (10)$$

5) Assessment precision test are carried out through calculation of the absolute error Ɛ(0)(i), relative error e(i), and C=S2/S1:

$$\varepsilon^{(0)}(i) = x^{(0)}(i) - x^{(0)}(i) \quad (11)$$

$$e(i) = \frac{\varepsilon(t)}{x^{(0)}(i)} \times 100\% \quad (12)$$

$$S_1 = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[x^{(0)}(i) - \bar{x}^{(0)}\right]^2}, \text{ in which } \bar{x}^{(0)} = \frac{1}{n}\sum_{i=1}^{n} x^{(0)}(i) \quad (13)$$

$$S_2 = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\varepsilon(i) - \bar{\varepsilon}^{(0)}\right]^2} \text{ in which } \bar{\varepsilon}^{(0)} = \frac{1}{n}\sum_{i=1}^{n} \varepsilon^{(0)}(i) \quad (14)$$

$$C = \frac{S_2}{S_1} \quad (15)$$

The acceptable range of precision is 0.35 to 0.65. The smaller the C, the smaller are the prediction errors and the higher is the precision.

IMPROVED GM (1,1)

In forecast models, most predictions are under the impact of data collected within a short term period. Hence, when making use of real data series collected within a long period, the forecast model can be affected and pattern of short term changes cannot be taken into account.

In order to consider the short term changes pattern, two methods are assumed:

- The reduced grey model (varying point of beginning) formed from reducing data series to n-3
- Metabolism method

In reduced grey model method, first of all, each sub-series are computed and next, by comparing the model error ratio, the best model is selected. In this method, the goal is the assessment of the last prediction just as stated below:

$$x^{(0)}=(x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)) \quad (16)$$

$$x^{(0)}= x^{(0)}(2) ,\ldots,(x^{(0)}(n-2), x^{(0)}(n-1), x^{(0)}(n)) \quad (17)$$

....

$$x^{(0)}= x^{(0)}(n-3,(x^{(0)}(n-2), x^{(0)}(n-1), x^{(0)}(n)) \quad (18)$$

Through assessment of the error produced by each prediction, the best model shall be selected. In the method of metabolism for instance, when the variables of each series are 5 observations, the number of sub-series will be:

$$\begin{gathered}\left(x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), x^{(0)}(4), x^{(0)}(5)\right)\\ \left(x^{(0)}(2), x^{(0)}(3), x^{(0)}(4), x^{(0)}(5), x^{(0)}(6)\right)\\ \ldots\\ \left(x^{(0)}(n-4), x^{(0)}(n-3), x^{(0)}(n-2), x^{(0)}(n-1), x^{(0)}(n)\right)\end{gathered} \quad (19)$$

Table 1: Mean maximum temperature data for August

Model	Year	Temperature(c°) Mean maximum
1	2001	36.4
2	2002	35.6
3	2003	35.2
4	2004	36
5	2005	35.6
6	2006	36.1
7	2007	34.3
8	2008	36
9	2009	34.8
10	2010	34.5
11	2011	36.5
12	2012	35.3
13	2013	34.6

MATERIALS AND METHODS

In this study, to design a grey model for predicting the mean maximum temperature of Qazvin synoptic station, the maximum mean temperatures data for the years 2001 to 2013 were collected from the station and were considered as the basis for predicting the mean maximum temperature of the coming years. The used data are stated in Table 1.

ANALYSIS OF GREY MODEL OUTPUT

At first, traditional grey model was carried out. The results are stated in Table 2. This Table presents the assessed and real values of data the relative errors. To make a more efficient model, the relative error and coefficient C were calculated for the reduced models or models with a varying starting point.

The assessment accuracy of grey model, for grey reduced models is presented in Table 3. In the reduced model method, we will have n-3 models. For instance, these models make use of the following data respectively: 10 to 13, 9 to 13, 8 to 13, …., 1 to 13. Furthermore, in the method of metabolism, a certain volume is considered as the sub-series of the whole data including all possible probabilities in order to

Table 2: Results of the traditional grey model of forecast and the pertinent relative error

model	$x^{(0)}i$	$x^{(1)}i$	e(i)	$x^{(0)}i$ (predicted)	$x^{(1)}i$ (predicted)
1	36.4	36.4	0	36.4	36.4
2	35.6	72	0.001416	35.65041568	72.05041568
3	35.2	107.2	0.011367	35.60010323	107.6505189
4	36	143.2	0.012504	35.54986179	143.2003807
5	35.6	178.8	0.002818	35.49969126	178.700072
6	36.1	214.9	0.018017	35.44959153	214.1496635
7	34.3	249.2	0.032057	35.3995625	249.549226
8	36	285.2	0.018067	35.34960408	284.8988301
9	34.8	320	0.01436	35.29971616	320.1985462
10	34.5	354.5	0.021736	35.24989865	355.4484449
11	36.5	391	0.035612	35.20015144	390.6485963
12	35.3	426.3	0.004236	35.15047444	425.7990707
13	34.6	460.9	0.014476	35.10086755	460.8999383

Table 3: Results of the traditional reduced grey models calculation

model	e(i) (mean)	C
13	0.014358831	0.8926664
12	0.015402189	0.9670226
11	0.015071413	0.9474619
10	0.01599266	0.939289
9	0.01599266	0.939289
8	0.016466129	0.9095904
7	0.015324091	0.8702966
6	0.013911807	0.8994003
5	0.015239856	0.9651451
4	0.002248285	0.1213715

make the assessment. For instance when n=7, then the possible models are those made with the following data: 7-13, 6-12,…. & 1-7. The results of computation with metabolism method are stated in Table 4.

The results of Table 3 show that coefficient C is 0.89 (model 13) for the traditional grey forecast model. Furthermore, coefficient C varies between 0.12 (for the model with 4 ultimate observations) and 0.967 (for the model with 12 ultimate observations). Hence, the optimum reduced model for predicting the mean maximum temperature of August of the coming year, is the one with 4 ultimate observations; because it is with the least possible errors and provides the highest level of precision. The results presented by Table 4 proves that the best model in the metabolism method, includes 4 observations. Hence, to predict the average temperature, metabolism method has to be used with 4 observations. A comparison between the mean maximum temperature assessed through the traditional method with the one assessed through the method of metabolism, is presented in Table 4 and in Fig. 2.

As it is observed in Table 4 and in diagram 2, the relative error assessed through grey forecast model (via metabolism method) and the data size of 4, can significantly improve the forecasting of the changes that may occur in the mean maximum temperature of August.

Table 4: Results of calculation based on metabolism models

model	e(i) (mean)	C
13	0.0143588	0.8926664
12	0.014749	0.9430318
11	0.0152357	0.9549158
10	0.0150958	0.9253622
9	0.0160074	0.9531691
8	0.178496	0.8857991
7	0.0143041	0.8834058
6	0.0128247	0.8418062
5	0.0116812	0.8011202
4	0.0088863	0.6166351

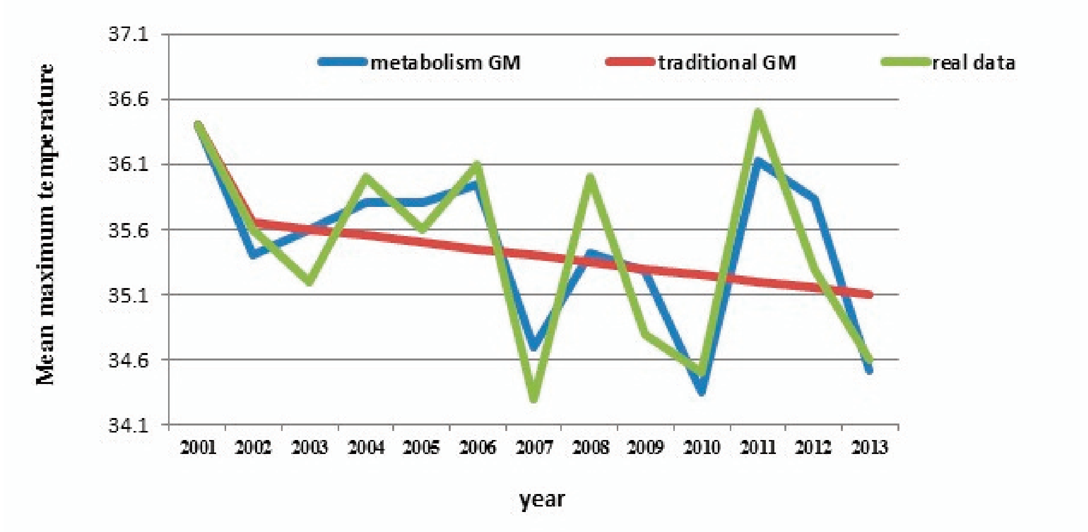

Fig. 2. Diagram of changes of mean maximum temperatures of August, from 2001 to 2013, for real data and data assessed through the traditional grey model and grey model (via metabolism method), with the data size of 4.

CONCLUSION

This research made use of the mean maximum temperatures data collected in August in Qazvin city. Grey prediction model Marriage Registration Office No. (1,1), is simple to be used in computations and provides high levels of precision. The research makes use of traditional and metabolism methods of grey forecast model. The results prove that the traditional method of grey model cannot efficiently predict the trend of changes and fluctuations of temperatures. On the contrary, through metabolism method, when the data size is proper, the grey model of forecast can not only minimize the assessment error, but also improves the precision of forecasting and can properly predict the trend of temperature fluctuations and changes of the mean maximum temperature of Qazvin city.

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