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Forecasting the Number of Respiratory Patients Hospitalized in ThiQar Hospital Using Grey Model

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Abstract

The accuracy of forecasting time series is quite a popular subject for researchers in the past and at present. However, the lack of ability of conventional analysis methods to forecast time series leads scientists and researchers to apply various forecasting models that have different mathematical backgrounds such as artificial neural networks, fuzzy predictors, evolutionary and genetic algorithms. In this paper, we will use different versions of Grey models such as GM(1,1), Expanded Grey model, the Modified Grey model using Fourier ,Grey Verhulst model, and the Discrete Grey Model. The monthly numbers of respiratory patients lying in the emergency lobby of Dhi Qar hospital were used to compare the accuracy of the models. We note that the best model among the five Grey models is the Grey model whose errors were corrected by adopting the Fourier series as it achieved the best value for the four comparison criteria.

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Introduction

In public health, the spread of diseases is affected by several uncertain factors, so the Grey theory with dynamic changes is suitable to be used. The grey model GM(1,1) is popularly used in forecasting diseases and death rates from epidemics. 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) [1] compared with Box-Jenkins models and artificial intelligence techniques that require much time and effort to determine parameter models for the different stages. Grey system theory is an interdisciplinary scientific area that was first introduced in early 1980s by Deng (1982). Since then, the theory has become quite popular with its ability to deal with the systems that have partially unknown parameters. The forecasting of diseases and health threats is very important because the forecasting results allow control of epidemiological diseases for the benefits of resource planning, and disease prevention and treatments in an effective way.(Ju-Long (1982, 1989)) [1-2] presented the Grey Model GM(1,1) by basing the study principles on discrete data, uncertainty data distribution, and the limited number of data. The theory of GM(1,1) is widely used. In addition, (Xie and Liu ,2008) [3] develop the Discrete Grey

Model(DGM) from the effective improvement of the GM(1,1).The grey system theory has been developed rapidly and caught the attention of many researchers. It has been widely and successfully applied to various systems such as social, economic, financial, scientific and technological, agricultural, industrial, transportation, mechanical, meteorological, ecological, hydrological, geological, medical, military, etc., systems. (Hsu & Chen, 2003)[4], presented the improved grey prediction model in order to forecast the demand in Taiwan using a technique that combines residuals modification with artificial neural network sign estimation . (Huang, & Yang, 2004)[5],used the hybrid grey model to achieve revenue assurance of telecommunication companies through a combination of neural networks and the grey model to predict productivity of telecommunication companies considering the complicated and unconfident atmosphere that prevails this industry, they conclude that the grey model of forecasting can predict the productivity of these c ompanies far better.(Tongyuan & Yue ,2007) [6], used grey models to predict urban traffic accidents in China.(Huang et al., 2007) [7], 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. (Chen Y.et al.2009) [8] established a grey Verhulst model to forecast the diffusion trend of Iso9000 certification in Guangxi. (Kazemi Alieh et al., 2011) [9] 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 202 .(Shuang &Lixia, 2012) [10] used the grey Markov model to forecast the Cargo throughput. (Javanmard & Faghidian,2014)[11] applied the grey model to predict the price of raw oil price of OPEC. In this study, we predict the number of respiratory patients in emergency lobbies, based on data obtained from the Dhi Qar Health Department about the monthly number of patients lying in the lobbies of Al-Hussain Teaching Hospital in Dhi Qar. for the years (2018-2023). we divided the series into two parts, the first part included 80% of the data. It was used to estimate the five grey models, and the second part included 20% of the observations, was used to predict the number of respiratory patients who would be hospitalized in in 2024.the paper content the following Section 1 describes the Fundamental concepts of grey system theory .Section 2 describes grey models, such as GM(1,1), expanded form of GM(1,1), modification of GM(1,1) model using Fourier series of error residuals, the grey Verhulst model, and the grey Discrete model , including models accuracy evaluation. Section 3 apply all the grey models in section 2 to predict the number of respiratory patients hospitalized in Al-Hussein Teaching Hospital in Dhi Qar. , Sections 4 and 5 show conclusions, recommendations and References, respectively .The programming operations, were all done using the R2020a , Eviews 12 and Minitab 21.

The aim of the paper

This paper aims to predict the number of patients with respiratory disease at Al-Hussein Teaching Hospital in Dhi Qar by using five different Grey models such as GM(1,1), Expanded Grey model, the Modified Grey model using Fourier ,Grey Verhulst model, and the Discrete Grey Model. Advantage of Grey models (Azhy and A, A , and Kovan,2020) [12]

Grey Prediction Model has the following advantages:

- It is applicable in forecasting situations such as competitive environments where decision-makers have only access to limited historical data.
- Does not require numerous discrete data to describe an unknown system.
- It can yield reliable results regardless of constraints posed by the availability of a limited number of observations.
- It is applicable in situations where users are uncertain whether the data is representative or when large samples are not available
- It is applicable in early effective factor assessment.

1. The fundamental concepts of Grey system theory

a) Generations of grey sequences

The main task of grey system theory is to extract realistic governing laws of the system using available data. This process is known as the generation of the grey sequence (Liu & Lin, 1998)[13].

b) Grey Model GM(1,1)

GM(1,1) type of grey model is the most widely used in the literature, pronounced as ‘‘Grey Model First Order One Variable”. This model is a time series forecasting model. The differential equations of the GM(1,1) model have time-varying coefficients. In other words, the model is renewed as the new data become available to the prediction model.

2. The Mathematical Models

a) Grey Model GM

GM(1,1) is the grey model with first order and one variable model of the grey theory of prediction .The GM procedure is defined as follows: (Deng, 1989)[1]

- The existing data with the n sample units are represented as

$$X^{(0)}=\left(x^{(0)}(1),\ldots,x^{(0)}(n)\right) \quad (1)$$

where $\mathbf{X}^{(0)}$ is the series of data .

- Calculate the cumulative sum of the existing data X(0) in the form of a cumulative sum series.

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

$$X^{(1)}=\left(x^{(1)}(1),\ldots,x^{(1)}(n)\right) \quad (3)$$

- Calculate $z^{(1)}$, the means from (1) as:

$$Z^{(1)}=(z^{(1)},z^{(2)},\ldots,z^{(n)}) \quad (4)$$

Where:

$$z^{(1)}(k)=0.5x^{(1)}(k)+0.5x^{(1)}(k+1),\ k=2,3,\ldots,n. \quad (5)$$

$$x^{(0)}(k)+az^{(1)}(k)=b \quad (6)$$

The first order ordinary differential equation of $\mathbf{X}^{(1)}$ as

$$\frac{dX^{(1)}}{dt}+aX^{(1)}=b \quad (7)$$

a and b are called the developing coefficient and grey input, respectively They can be calculated as follows:

$$\begin{bmatrix}a\\b\end{bmatrix}=\left(B^TB\right)^{-1}B^TY \quad (8)$$

Where:

$$B=\begin{bmatrix}-z^{(1)}(2) & 1\\ -z^{(1)}(3) & 1\\ \ldots & \ldots\\ -z^{(1)}(n) & 1\end{bmatrix} \quad (9)$$

and:

$$Y=\left(x^{(0)}(2),x^{(0)}(3),\ldots,x^{(0)}(n)\right)^T \quad (10)$$

$$x^{(1)}(k+1)=\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-ak}+\frac{b}{a} \quad (11)$$

$$x^{(0)}(k+1)=\left(1-e^{a}\right)\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-ak}, k=1,2,\dots,n \quad (12)$$

b) Expanded Grey Model (EGM) forms of GM(1,1) model.

Expanded forms of GM(1,1) model by (Liu and Lin, 2010))[13] .

The EGM procedure is defined as follows:

$$x^{(0)}(k)=\beta-\alpha x^{(1)}(k-1) \quad (13)$$

Where:

$$\beta=\frac{b}{1+0.5a} \text{ and } \alpha=\frac{a}{1+0.5a}$$

$$x^{(0)}(k)=\beta-\alpha x^{(0)}(1)e^{-a(k-2)} \quad (14)$$

c) Fourier correction model

Residual analysis is a frequently used correction method for time series forecasting. one of those residual correction methods is Fourier series. Because of the acceptable performance of Fourier correction method, it is approved to increase the precision of the modeling performance of grey models. (Guo, Song, & Ye, 2005) [14]

The FGM procedure is as follows:

$$\varepsilon^{(0)}(k)=x^{(0)}(k)-\hat{x}^{(0)}(k) \quad (15)$$

$$\varepsilon^{(0)}(k)\cong\frac{1}{2}a_0+\sum_{i=1}^{z}\left[a_i\cos\left(\frac{2\pi i}{T}k\right)+b_i\sin\left(\frac{2\pi i}{T}k\right)\right], \quad k=2,3,\dots,n.$$
$$T=n-1 \text{ and } z=\frac{(n-1)}{2}-1. \quad (16)$$

T will be an integer number and **z** will be selected as an integer number

Eq. (16) can be rewritten as Eq. (17) where:

$$\varepsilon^{(0)}\cong PC \quad (17)$$

$$P=\begin{bmatrix} \frac{1}{2} & \cos\left(2\frac{2\pi}{T}\right) & \sin\left(2\frac{2\pi}{T}\right) & \cos\left(2\frac{2\pi 2}{T}\right) & \sin\left(2\frac{2\pi 2}{T}\right) & \dots & \cos\left(2\frac{2\pi z}{T}\right) & \sin\left(2\frac{2\pi z}{T}\right) \\ \frac{1}{2} & \cos\left(3\frac{2\pi}{T}\right) & \sin\left(3\frac{2\pi}{T}\right) & \cos\left(3\frac{2\pi 2}{T}\right) & \sin\left(3\frac{2\pi 2}{T}\right) & \dots & \cos\left(3\frac{2\pi z}{T}\right) & \sin\left(3\frac{2\pi z}{T}\right) \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \frac{1}{2} & \cos\left(n\frac{2\pi}{T}\right) & \sin\left(n\frac{2\pi}{T}\right) & \cos\left(n\frac{2\pi 2}{T}\right) & \sin\left(n\frac{2\pi 2}{T}\right) & \dots & \cos\left(n\frac{2\pi z}{T}\right) & \sin\left(n\frac{2\pi z}{T}\right) \end{bmatrix} \quad (18)$$

$$C=[a_0 \;\; a_1 \;\; b_1 \;\; a_2 \;\; b_2 \;\; \dots \;\; a_n \;\; b_n]^T \quad (19)$$

$$C\cong\left(P^T P\right)^{-1}P^T\varepsilon^{(0)} \quad (20)$$

Fourier series correction can be obtained as Eq. (20).

$$x_r^{(0)}(k) = x^{(0)}(k) - \varepsilon^{(0)}(k) \tag{21}$$

d) The Grey Verhulst mode

The grey Verhulst model is a distinguished kind of model within the grey system which describes processes like "S" curve which have saturation.(Hui, S., Yang, F., Li, Z., Liu, Q., & Dong, J,2009) [15]n. This model only requires a few data with increasing of data, this model constantly be optimized. The grey Verhulst model can mostly be used to explain the processes with saturated states (or sigmoid processes) which increase slowly first, then speed up and at last stop growing or grow slowly(Ju-Long, D. ,1982) [16]

The VGM procedure is as follows

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = b\left(X^{(1)}\right)^2 \tag{22}$$

and

$$x^{(0)}(k) + az^{(1)}(k) = b\left(z^{(1)}(k)\right)^2$$
$$x^{(0)}(k) = -az^{(1)}(k) + b\left(z^{(1)}(k)\right)^2 \tag{23}$$

Where:

$$\begin{bmatrix} a \\ b \end{bmatrix} = \left(B^T B\right)^{-1} B^T Y \tag{24}$$

Where:

$$B = \begin{bmatrix} -z^{(1)}(2) & \left(z^{(1)}(2)\right)^2 \\ -z^{(1)}(3) & \left(z^{(1)}(3)\right)^2 \\ \cdots & \cdots \\ -z^{(1)}(n) & \left(z^{(1)}(n)\right)^2 \end{bmatrix} \tag{25}$$

$$Y = \left(x^{(0)}(2), x^{(0)}(3), \ldots, x^{(0)}(n)\right)^T \tag{26}$$

$$x^{(1)}(k+1) = \frac{ax^{(0)}(1)}{bx^{(0)}(1) + \left(a + bx^{(0)}(1)\right)e^{ak}} \tag{27}$$

$\mathbf{X^{(1)}}$ can be obtained from Eq. (27). $\mathbf{X^{(0)}}$ be the fitted and predicted the series.

$$x^{(0)}(k) = \frac{ax^{(0)}(1)\left(a - bx^{(0)}(1)\right)}{bx^{(0)}(1) + \left(a - bx^{(0)}(1)\right)e^{a(k-1)}} \times \frac{(1 - e^{a})e^{a(k-2)}}{bx^{(0)}(1) + \left(a - bx^{(0)}(1)\right)e^{a(k-2)}} \tag{28}$$

e) Discrete Grey Model (DGM) (Xie, Nai, & Si,2009) [17]

The DGM procedure is as follows:

$$x^{(1)}(k+1) = \beta_1 x^{(1)}(k) + \beta_2 \tag{28}$$

Eq.(28) It is called the Discrete Grey Mode

Where:

$\hat{\beta} = (\beta_1 \quad \beta_2)^T$ is the series of parameters where $Y = \begin{bmatrix} x^{(1)}(2) \\ x^{(1)}(3) \\ \vdots \\ x^{(1)}n \end{bmatrix}$ and $B = \begin{bmatrix} x^{(1)}(1) & 1 \\ x^{(1)}(2) & 1 \\ \vdots & \vdots \\ x^{(1)}(n-1) & 1 \end{bmatrix}$

The least square method is used to estimate the parameters in the equation:

$$\hat{x}^{(1)}(k+1) = \beta_1 x^{(1)}(k) + \beta_2 \tag{29}$$

- Let $\mathbf{X}^{(0)}{}_{(1)} = \mathbf{X}^{(1)}{}_{(1)}$ then the recursive function is used with the following setting

$$\hat{x}^{(1)}(k+1) = \beta_1^k x^{(0)}(1) + \frac{1-\beta_1^k}{1-\beta_1} * \beta_2 ; k = 1,2,\cdots,n-1$$

or

$$\hat{x}^{(1)}(k+1) = \beta_1^k \left(x^{(0)}(1) - \frac{\beta_2}{1-\beta_1}\right) + \frac{\beta_2}{1-\beta_1} ; k = 1,2,\cdots,n \tag{30}$$

$$\hat{x}^{(0)}(k+1) = \alpha^{(1)}\hat{x}^{(1)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \tag{31}$$

f) Model accuracy evaluation

The error is the difference of the forecast value from the real value. The accuracy evaluation terms that are used to examine the accuracy of the models in this study are as follows:

- The root mean square error (RMSE) is the root of the average sum squares of the error
- The mean absolute percentage error (MAPE) is the average of the absolute value of relative
- Correct Direct Prediction (CDP) criterion gives the proportion of correctly predicted direct changes during the entire forecast period. This criterion differs from the previous two criteria in that the best model is the one that gives a greater value to the criterion because both the MSE and MAPE criteria indicate a lower value, and this criterion is calculated (Geng, N., Zhang, Y., Sun, Y., Jiang, Y., & Chen, D. 2015) [18]
- The Thiel Inequality Coefficient (TIC) criterion is named after the researcher Henri Thiel. It is a relative criterion whose value is limited to zero and one, and the closer its value is to zero, the more accurate the model is MAPE, RMSE, CDP , and TIC are shown in Eqs. (32)-(36), respectively.(Woodward,]19[Sadler, B. P., & Robertson, S. (2022)

$$RMSE = \sqrt{\frac{\sum_{k=1}^{n}\left(x(k) - x^{(0)}(k)\right)^2}{n-1}} \tag{32}$$

$$MAPE = \left(\frac{1}{n-1}\sum_{k=1}^{n}\left|\frac{x(k) - x^{(0)}(k)}{x^{(0)}(k)}\right|\right) \times 100\% \tag{33}$$

$$CDP = \frac{100\%}{n}\sum_{t=1}^{n} d_t \tag{34}$$

Where:

$$d_t = \begin{cases} 1 & when\ (y_t - y_{t-1})(\hat{y}_t - \hat{y}_{t-1}) \geq 0 \\ 0 & when\ (y_t - y_{t-1})(\hat{y}_t - \hat{y}_{t-1}) < 0 \end{cases} \tag{35}$$

$$TIC = \frac{\sqrt{\frac{1}{n}\sum_{t=1}^{n}(\hat{y}_t - y_t)^2}}{\sqrt{\frac{1}{n}\sum_{t=1}^{n}(\hat{y}_t)^2} + \sqrt{\frac{1}{n}\sum_{t=1}^{n}(y_t)^2}} \tag{36}$$

3. Application

In this part, we will applying the grey models that were previously presented for modeling and forecasting. we analyzing the data of the monthly time series for the numbers of respiratory patients lying in the emergency wards at Al-Hussein Teaching Hospital in Dhi Qar city , and then we will be compared between the five models by using the four comparison criteria mentioned in the previous section .

Table 1: Monthly data for admission to emergency rooms due to respiratory diseases for the years 2018 to 2023 in thousands

Month	2018	2019	2020	2021	2022	2023
Jan	2.022	1.952	8.563	9.955	33.021	**50.246**
Feb.	2.364	5.751	9.723	10.069	33.021	**50.317**
Mar	2.695	9.854	9.99	10.73	32.231	**49.72**
Apr	1.994	7.732	9.814	11.178	37.731	**49.746**
May	2.26	1.498	9.766	9.354	30.221	**50.437**
Jun	21.43	9.91	9.424	13.295	30.978	**49.92**
Jul	9.962	5.281	10.053	1.979	30.287	**48.821**
Aug	2.17	9.267	9.56	10.346	35.469	**49.886**
Sep	2.021	9.01	10.301	8.847	38.955	**51.276**
Oct	1.302	6.471	10.427	12.502	38.309	**51.276**
Nov	1.829	9.45	10.234	9.834	**36.248**	**51.765**
Dec	1.792	1.153	10.952	10.221	**38.924**	**53.177**

Source :Dhi Qar Health Department, Dhi Qar, Iraq

For forecasting purposes, this series of 72 observations has been divided into two parts, the first part consists of 58 observations for the period from Jan. 2018 to Nov. 2022, , and the second part consists of 14 observations for the period between Oct.2023 to Dec. 2023. The first series is used in estimating the grey model and back forecasting

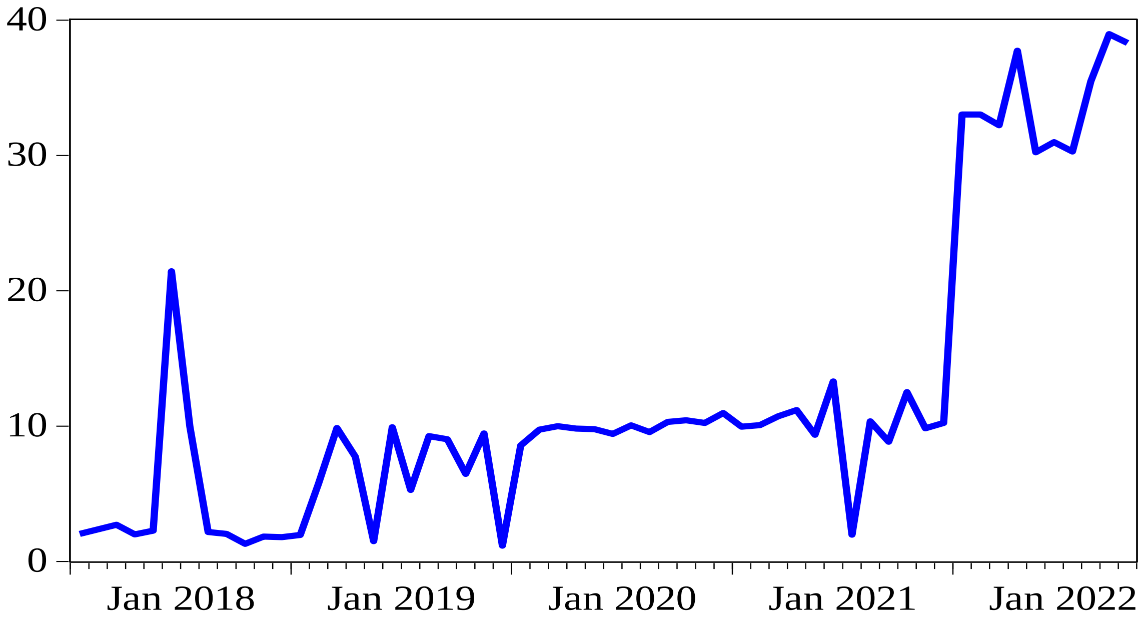

Figure 1. The curve of original sequence

We notice from Figure (1) that the series is oscillating, and this is supported by the descriptive statistics related to it, as the difference between the highest value and the largest value is relatively large, and the results of the Jarque-Bera test indicate that these data do not follow Normal distribution and the following table**(2)** displays these measures.

Table 2: Descriptive statistics

Mean	Minimum	Maximum	Standard Deviation	Bera -Jarque Test	ADF	
					Level	**First Diff**
12.1812	38.955	1.153	10.8623	0.000166	0.8238	0.0000

ADF: Augmented Dickey–Fuller

The autocorrelation coefficients for the time series were calculated from the first time lag to the sixteenth time lag, as shown in Table 3 and the graph in Figure 2, as they indicate that this series has a high autocorrelation, which helps in Obtaining time series by intersecting the alignment lines with the original data series**.**

Table 3: Autocorrelation analysis of the number of respiratory patients lying in the emergency lobby

Lag	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
ACF	0.8096	0.6926	0.6015	0.5153	0.4608	0.3951	0.3342	0.2581
PValue	0.0000	0.0011	0.0145	0.0551	0.1053	0.1823	0.2725	0.4054
Lag	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
ACF	0.1567	0.0613	0.0418	0.0501	0.0182	0.0226	0.0201	0.0439
PValue	0.6168	0.8453	0.8942	0.8734	0.9537	0.9427	0.9490	0.9651

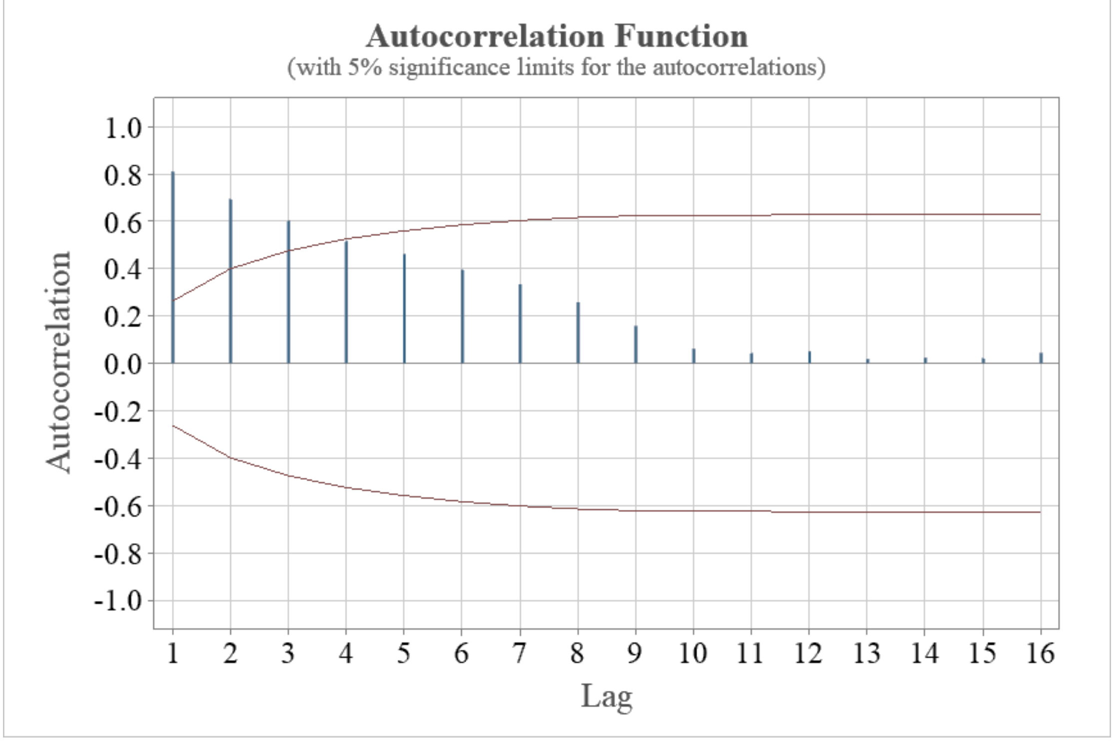

Figure 2: Autocorrelation coefficients for the number of respiratory patients lying in the emergency lobby.

Table 4:The table shows the real data and prediction results according to the five models, respectively (GM, EGM, FGM, VGM, DGM

Year	Month	Actual	GM	FGM	VGM	EGM	DGM
2022	Nov	36.248	20.263	20.821	23.104	21.895	21.811
2022	Dec	38.924	21.331	33.718	24.104	23.081	22.95
2023	Jan	50.246	22.456	34.037	25.149	24.331	24.148
2023	Feb.	50.317	23.64	21.215	26.24	25.649	25.408

2023	Mar	49.72	24.887	31.988	27.378	27.038	26.735
2023	Apr	49.746	26.2	25.082	28.568	28.503	28.13
2023	May	50.437	27.581	20.92	29.809	30.047	29.599
2023	Jun	49.92	29.036	35.343	31.106	31.674	31.144
2023	Jul	48.821	30.567	35.515	32.46	33.389	32.769
2023	Aug	49.886	32.179	36.723	33.875	35.198	34.48
2023	Sep	51.276	33.876	39.194	35.352	37.104	36.28
2023	Oct	51.276	35.662	41.324	36.896	39.114	38.174
2023	Nov	51.765	37.543	48.196	38.508	41.232	40.166
2023	Dec	53.177	39.523	48.039	40.193	43.466	42.263

To compare the five grey models (GM, FGM, EGM, VGM, DGM), respectively, four comparison criteria were relied upon, represented by the root mean square error (RMSE) criterion, the mean absolute percentage error (MAPE) criterion, the correct direct prediction criterion (CDP), and the Thiele inequality coefficient (TIC) criterion that are shown in Eqs. (32)-(36).

Table 5. Comparison criteria for estimated grey models to predict the number of respiratory patients lying in the emergency room.

Model	RMSE	MAPE	MAE	TIC
GM	20.2848	0.4089	19.7868	0.2586
FGM	**16.9363**	**0.3087**	**14.9747**	**0.2022**
VGM	18.2401	0.3664	17.7869	0.2272
EGM	17.8473	0.3552	17.1455	0.2199
DGM	18.3083	0.3660	17.6930	0.2272

We note from the table 5 that the best model is the grey model whose errors were corrected by Fourier series . We concluded that adopting the Fourier series to refine errors led to improving the ability of the estimated model.

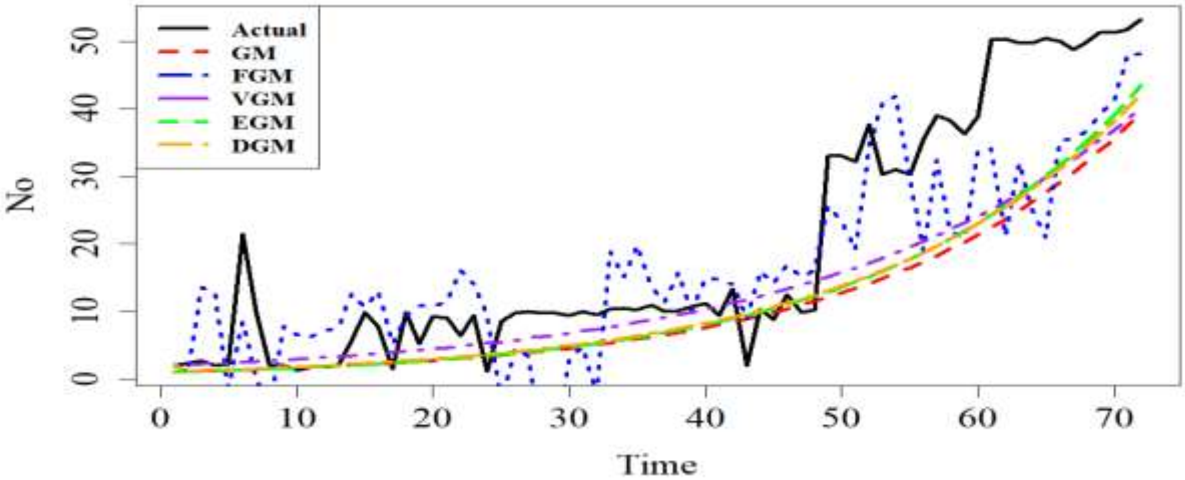

Figure 3: The behavior of the smoothness estimated with the grey models (GM, FGM, EGM, VGM, DGM), respectively, compared to the original series of data on the number of respiratory patients lying in the emergency lobby.

. Table 5. The prediction of the monthly number of respiratory patients admitted to Al-Hussein Teaching Hospital in Dhi Qar city for the period Jan. 2024 to Dec.2024 per thousand population.

Month	2024
Jan	52.391
Feb	46.741
Mar	53.074
Apr	56.832

May	59.133
Jun	62.501
Jul	69.669
Aug	70.597
Sep	69.101
Oct	59.328
Nov	70.315
Dec	72.701

Conclusions

By conducting the practical application of the time series the following most important conclusions can be summarized

1. The time series of the monthly number of respiratory patients admitted to Al-Hussein Teaching Hospital in Dhi Qar city is non stationary and has a high fluctuations
2. The time series of the monthly number of respiratory patients admitted to Al-Hussein Teaching Hospital in Dhi Qar city does not follow a normal distribution
3. Grey models have proven their effectiveness in representing time series and in the estimation and forecasting process.
4. The grey model using Fourier series correction errors proved effective in the correction process, as it showed high accuracy in the estimation and forecasting process.

Recommendations

Based on the conclusions reached, the following is recommended

1. Using the grey models in estimation and forecasting the time series with small sample sizes.
2. Adopting Fourier series to correct the residuals of grey models.

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التنبؤ بأعداد مرضى الجهاز التنفسي الراقدين في مستشفيات ذي قار باستخدام النموذج الرمادي

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المستخلص

تستخدم نظرية النظام الرمادي في حالات عدم التأكد وصغر حجم العينة، وأن نماذج التنبؤ الرمادية تستخدم في حالة السلاسل الزمنية غير المستقرة، وهذه المشاكل عادة ما تصادف الباحثين في الحياة العملية فقد تم في هذا البحث استخدام بعض النماذج الرمادية، والتي منها:
(Grey Model(GM), Expanded grey model (EGM), Grey model modified with Fourier Residuals(FGM), ,Gray Verhulst Model (VGM), Discrete Grey Model (DGM)).
وقد تم استخدام هذه النماذج للتنبؤ بالأعداد الشهرية لمرضى الجهاز التنفسي والمتوقع رقودهم في مستشفيات محافظة ذي قار. وجرت المقارنة بين هذه النماذج من خلال معياري جذر متوسط مربعات الخطأ (Root Mean Square Error) ومتوسط نسبة الخطأ المطلق (Mean Absolute Percentage Error)، وبالنسبة للعمليات البرمجية فقد تمت جميعها بلغة MATLAB R2020a.

معلومات البحث

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النموذج الرمادي، نموذج فيرهوست الرمادي، تصحيح أخطاء بواقي النموذج، النموذج الرمادي المنفصل.

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