World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

Behavioral analysis of COVID-19 daily deaths in Sri Lanka

Hapu Arachchige Dulari Udayanthi Perera * and Rodrigo Dinushiya Shamalee

Department of Mathematics, University of Sri Jayewardenepura, Nugegoda, Sri Lanka.

World Journal of Advanced Research and Reviews, 2023, 18(01), 431–437

Publication history: Received on 20 February 2023; revised on 02 April 2023; accepted on 05 April 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.18.1.0524

Abstract

In December 2019, the world was unknowingly caught by coronavirus disease. Since it spread worldwide and the burden of this disease is very high, the whole world has tried to reduce the impact. Therefore, known scientific facts about future events are very useful for policymakers. Hence, this research contributes to a scientific and technological process to provide a method for controlling the movements of the general public by forecasting the future using Discrete Fourier Transform (DFT) technique. DFT technique can decompose a complex signal into simpler parts to facilitate the analysis. In this research, comparing the accuracy of the daily deaths and daily infected patient datasets, the daily deaths dataset was selected for the model. After that, the Sri Lankan COVID-19 daily deaths data subsequence was modelled as the DFT amplitude spectrum. Then by backward-transformation of significant harmonics predicts the near future of daily COVID-19 deaths. The results conclude that the proposed method can provide short-term forecasting of COVID-19 daily death data with sufficient accuracy. And these near-future predictions will help guide health planning and short-term policy changes.

Keywords: COVID-19; Discrete Fourier transform; Daily deaths; Short term forecasting

1. Introduction

COVID-19 is the most significant pandemic nearly reported. This disease is an infectious disease caused by the SARS-CoV-2 virus. The first corona patient to be infected with the coronavirus was reported from Wuhan City, China, and it quickly spread to other parts of the world. On 30th January 2020, the outbreak was recognized as a Public Health Emergency of International Concern. Moreover, on 11th March 2020, it was declared a pandemic [1]. This pandemic has caused various impacts on important areas such as health, economy, tourism, etc.

According to the epidemiology Unit of the Ministry of Health in Sri Lanka [2], the first case in Sri Lanka was a Chinese tourist who was detected with the illness on the 27th of January 2020 and admitted to the National Infection Disease Hospital. Then, on 28th March 2020, a 65-year-old diabetic man was reported as the first corona death in Sri Lanka. Since then, Sri Lanka has gone through three pandemic waves. And the 3rd wave did the most significant damage. In order to prevent the spread of COVID-19, the public is advised to adhere to good health practices and avoid close contact with anyone who has fever and cough. Also, the government strictly minimized public gatherings by imposing curfews in several areas and imposing island-wide lockdowns. To prevent the spread more precisely, scientifically knowing facts is very important. Because using those facts, policymakers can strengthen their policy to control the epidemic without harming the country's economy and other sectors.

In the COVID-19 dataset, two types of data can be identified for research purposes: daily deaths and daily infected cases. But in this research, only daily COVID-19 deaths were used to analyze the behavior of COVID-19. This is because the accuracy of the daily number of infected people is relatively poor. Since there is a possibility that unknowingly infected people and recently infected people may not be tested. However, the COVID-19 deaths are counted after checking by a

* Corresponding author: Hapu Arachchige Dulari Udayanthi Perera

medical team and PCR is done if there is any uncertainty. For this reason, it is relatively better to use the number of deaths rather than the number of infected people for monitoring a pandemic behavior.

2. Material and methods

2.1. Mathematical motivation

DFT technique can be used to convert the time domain discrete finite length signal into a frequency domain discrete spectrum. These obtained frequency domain spectrum properties are used to simply analyze the properties of a real-world problem. Normally real-world data are discrete, so DFT is very useful in data analysis. And practically, we need an efficient algorithm to deal with a large class of physical problems. Therefore Fast Fourier Transform (FFT) has been used to convert the time domain signal into the frequency domain. This FFT is not a new or different type of Fourier transform and is only an efficient algorithm for computing DFT. And the Inverse Discrete Fourier Transform (IDFT) performs the backward transform of DFT.

DFT and IDFT are defined as:

$$X[k] = \sum_{n=0}^{N-1} x[n] e^{-j(\frac{2\pi}{N})kn} \; ; \; k = 0, 1, 2, \dots, N-1$$

And

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] e^{j(\frac{2\pi}{N})kn} \; ; \; n = 0, 1, 2, \dots, N-1$$

Here, the time domain discrete finite length signal is defined as $x[n]$, $X[k]$ represents the sequence of DFT of the signal and the sample size defined by N [3, 4].

By Using Euler's formula DFT formula can be replaced as follows,

Euler's Formula, $e^{jx} = \cos x + j \sin x$

$$X[k] = \sum_{n=0}^{N-1} x[n] \left(\cos\left(\frac{2\pi kn}{N}\right) - j \sin\left(\frac{2\pi kn}{N}\right) \right); \; k = 0, 1, 2, \dots, N-1$$

Therefore the resulting each DFT coefficient is a complex number. So, by using real ($Real(X[k])$) and imaginary parts ($Imag(X[k])$) of the complex number we can calculate the amplitude and phase in each harmonic.

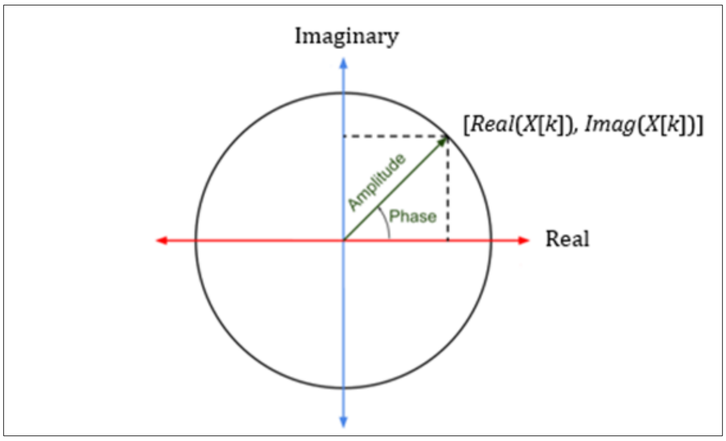

Figure 1 Representation X[k] in the complex plane

Suppose that we have a number of N sampled values. The magnitude for a given harmonic A_k is defined as,

$$A_k = \sqrt{(Real(X[k])^2 + (Imag(X[k])^2} \; ; \; k = 0, 1, \dots, N-1$$

And the phase for a given harmonic ϕ_k is defined as,

$$\phi_k = tan^{-1}\left(\frac{Imag(X[k]}{Real(X[k]}\right)\ ;\ k = 0, 1, \dots, N-1$$

The amplitude and phase spectrum can be obtained by plotting the magnitude, and phase of each DFT coefficient versus its frequency index, respectively.

2.2. Data Collection

Data on daily deaths in Sri Lanka are taken from the official website of the Epidemiology Unit of the Ministry of Health [2]. Moreover, the government policies related to Sri Lanka's COVID-19 are taken from the official news portal of the Department of Government Information Sri Lanka [5].

2.3. Fourier Forecasting Model

2.3.1. Pattern recognition of daily death data sequence

The daily deaths show the different patterns of trends, seasonal and cyclical, within the precise period of the data set. Therefore, in order to apply the forecasting techniques, the first step is to identify increasing and decreasing patterns ahead of the forecast period.

2.3.2. Forecasting Model

The discrete finite data sequences identified in Section 2.3.1 divide into two sets: a calibration data set which has N+1 data samples and a validation data set. Then calibration data were used as data in the forecasting model. However, the Fourier model does not provide good accuracy for series with trend data. Therefore generate the first difference sequence using the obtained data sequence. That means taking the difference between two daily deaths on consecutive days.

Differencing sequence of X_t are as follows; $t = 1, 2, 3, \dots, N$

$X_t = Y_t - Y_{t-1}$; Where Y_t − Death count at time t;

The amplitude of the first harmonic gives the average value of the sequence. It is obtained by calculating the absolute value of the first complex number of the array by dividing N, since there is no conjugated value associated with the first harmonic. The rest of other harmonics amplitude is derived by dividing N/2. Next, the significant harmonics which have the highest amplitude in the amplitude spectrum were selected. Then, a function for X_t using the significant harmonics amplitude and phase values was written. This function is created by selecting the correct number of significant harmonics with a repetitive process of getting one by one harmonics waveform (order of decreasing amplitude) and checking the minimum errors. After that, a function for the time domain data set using the Y_t, t and frequency between each harmonics(Δf) was written. Finally, the fitting and prediction data series was created by using Y_1 and changing the t value of the model.

3. Results and discussion

The analysis contains two main parts:

- Pattern recognition of daily deaths in Sri Lanka 3rd wave.
- Forecasting model.

Initially, pattern recognition of daily deaths in 3rd wave of Sri Lanka was examined. Then daily death data during the lockdown period and before the lockdown period were forecasted separately.

3.1. Pattern recognition of daily death data in Sri Lanka 3rd wave

Figure 2 shows the time domain plot of daily death in Sri Lanka from 10th April 2021 to 31st December 2021. There were two exponential growth and declining trend periods. The first growth period and declining trend period were observed from 26th April 2021 to 10th June 2021 and 13th June 2021 to 12th July 2021 respectively. Once again there was a huge growth for the period of 23rd July 2021 to 27th August 2021. Besides, a declining trend was observed from 28th August 2021 to 1st October 2021.

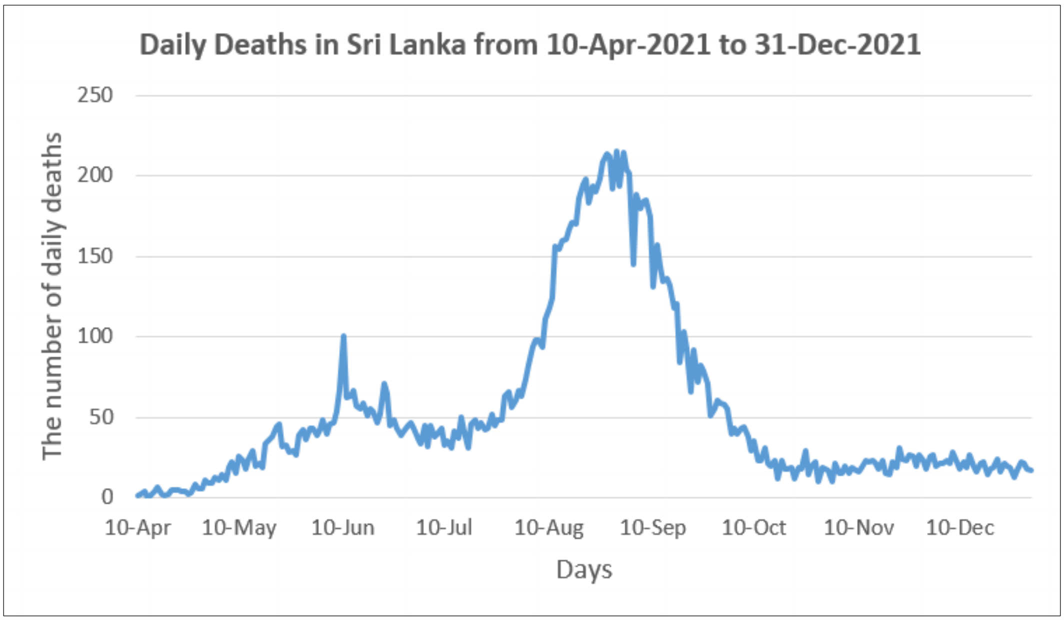

Figure 2 Daily Deaths in Sri Lanka from 10-Apr-2021 to 31-Dec-2021

By analyzing the records of SARS-CoV-2 variants over time in Sri Lanka [6], we can identify this 2nd rising trend from 23rd July 2021 to 20th August 2021 caused due to the delta variant. And then due to the 3rd lockdown in Sri Lanka from 20th August 2021 to 30th September 2021, a declining period has occurred.

3.2. Forecasting Model for Sri Lanka 3rd Wave Daily Deaths

Figure 3 shows an upward trend in daily mortality from 23rd July 2021 to 27th August 2021 with fluctuations due to the delta variant. And Figure 4 shows a declining trend of daily deaths from 28th August 2021 to 1st October 2021 with fluctuations due to the 3rd lockdown period in Sri Lanka.

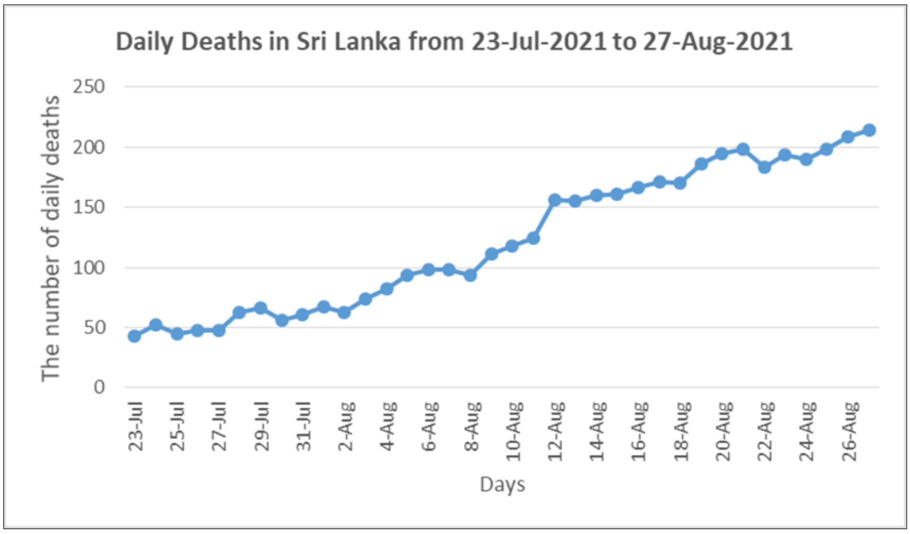

Figure 3 Daily deaths in Sri Lanka from 23-Jul-2021 to 27-Aug-2021

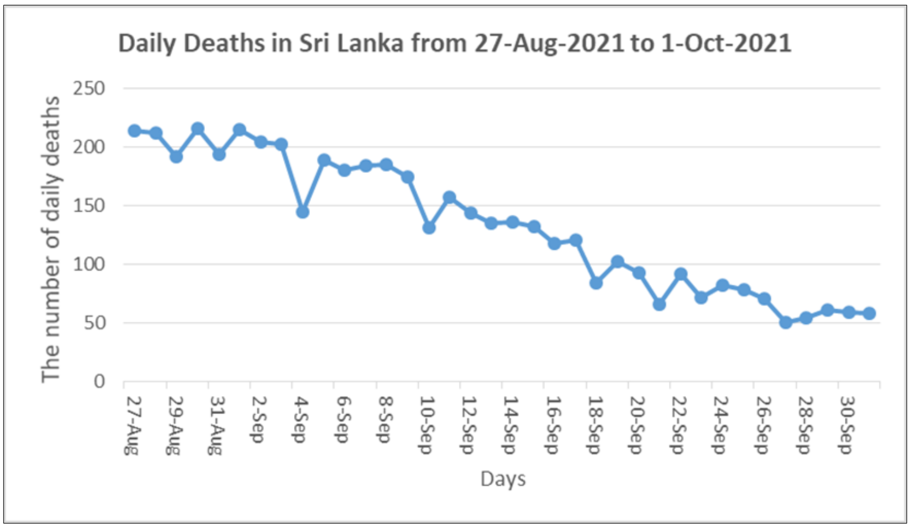

Figure 4 Daily deaths in Sri Lanka from 27-Aug-2021 to 1-Oct-2021

For calibration data set, the period 23-Jul-2021 to 20-Aug-2021 and 27-Aug-2021 to 24-Sep-2021 were selected. Besides the validation data set, the period 21-Aug-2021 to 28-Aug-2021 and 25-Sep-2021 to 01-Oct-2021 were chosen.

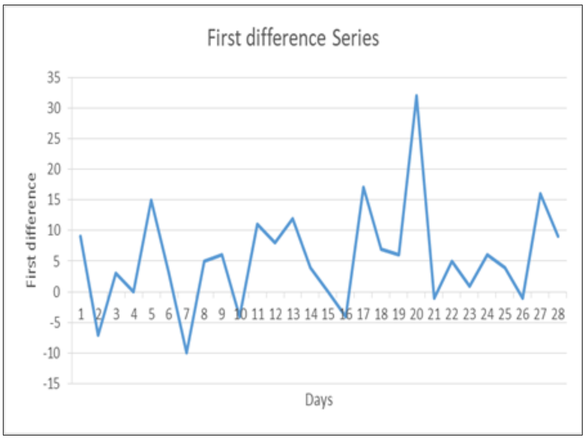

Figure 5 1st difference series before lockdown Period

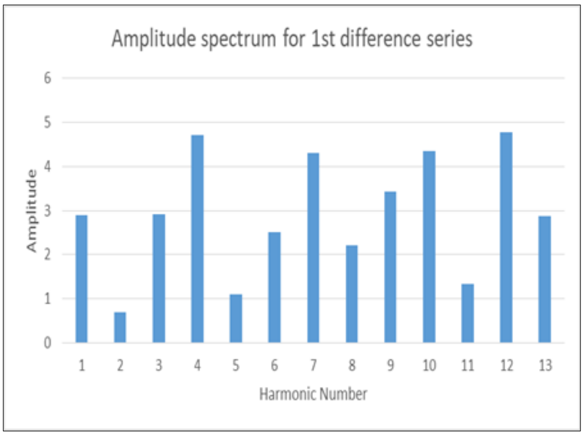

Figure 6 Amplitude spectrum before lockdown Period

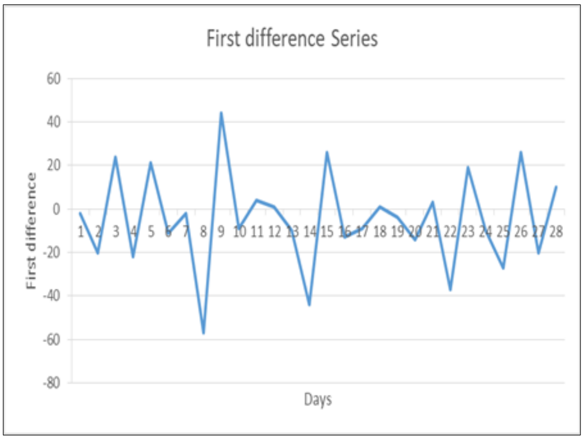

Figure 7 1st difference series in the lockdown Period

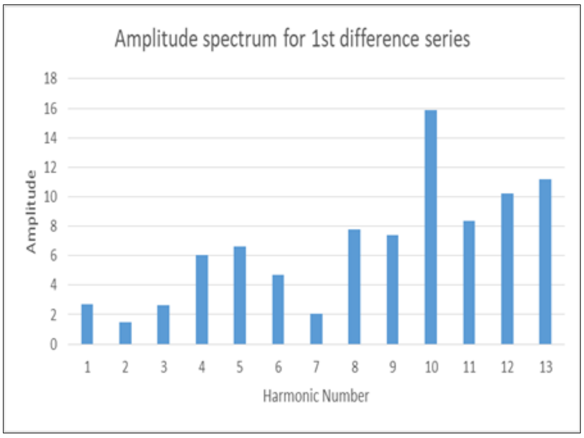

Figure 8 Amplitude spectrum in the lockdown Period

Figure 5 & 7 shows the plot of the first difference series of the daily deaths in Sri Lanka in the period 23-Jul-2021 to 20-Aug-2021 and 27-Aug-2021 to 24-Sep-2021 respectively. The periodic behavior of both figures confirms that the Fourier model should be chosen for both cases. Moreover, Figures 6 & 8 show the amplitude spectrum corresponding to the 1st difference series before the lockdown and the period of lockdown.

Table 1 Model Summary of before the 3rd lockdown period in Sri Lanka

	Model Fitting		Model Verification	
$Y_t = Y_{t-1} + 5.4286 + 4.7835\cos(24\pi\Delta ft + 5.923) + 4.7216\cos(8\pi\Delta ft + 2.345) + 4.3515\cos(20\pi\Delta ft + 2.0301) + 4.301\cos(14\pi\Delta ft + 0.9505)$ $(\Delta f = 0.036)$	MAE	12.3496	MAE	15.1691
	MAPE	0.1513	MAPE	0.07647
	RMSE	15.5764	RMSE	16.4411
	RAE	0.1333	RAE	0.0829

Table 2 Model Summary of the 3rd lockdown period in Sri Lanka

	Model Fitting		Model Verification	
$Y_t = Y_{t-1} - 4.71 + 15.905\cos(20\pi\Delta ft + 0.412) + 11.173\cos(26\pi\Delta ft + 2.006) + 10.228\cos(24\pi\Delta ft + 2.385) + 8.3856\cos(22\pi\Delta ft + 1.8531)$ $(\Delta f = 0.036)$	MAE	11.5060	MAE	7.0348
	MAPE	0.08046	MAPE	0.1240
	RMSE	14.2433	RMSE	9.5953
	RAE	0.0915	RAE	0.1532

The measurements of errors in both tables are very low under the fitting and verifications. Figures 9 and 11 confirmed the patterns of actuals and fits of Forecasting model are similar in both periods. And figure 10 & 12 shows that the pattern of the forecast data set is also very similar to the actual data series and deviation were less. Therefore, both increasing and decreasing periods satisfy the least measurements of error, and show similar patterns of the actual, fits and forecast.

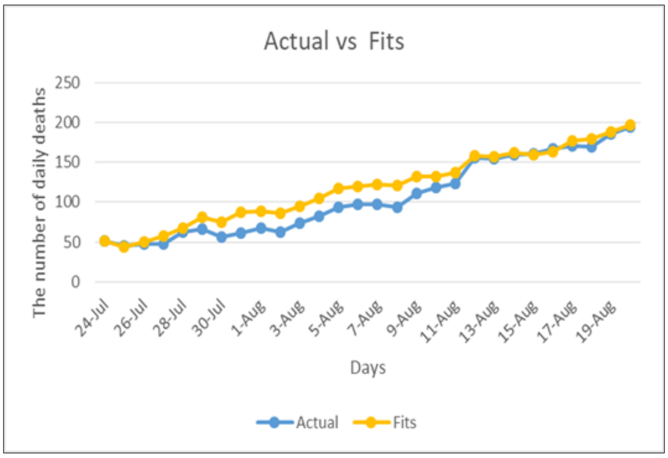

Figure 9 Actual vs. Fits before lockdown Period

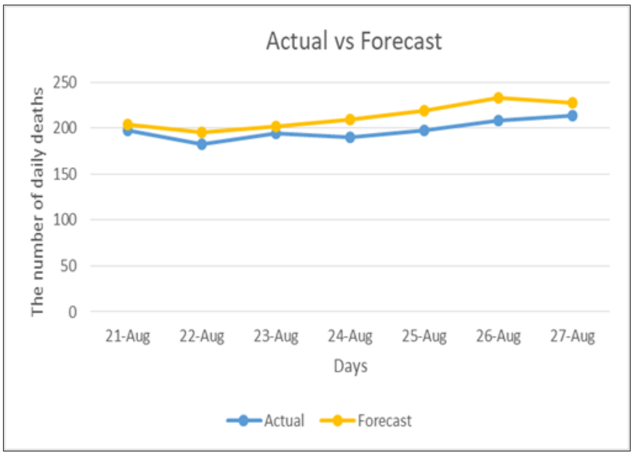

Figure 10 Actual vs. Forecast before lockdown Period

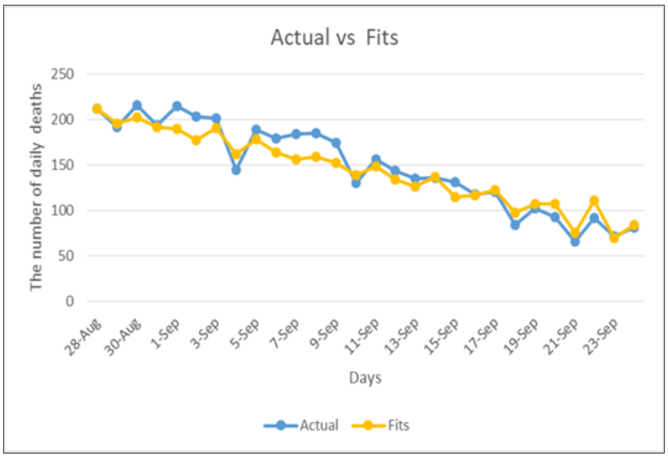

Figure 11 Actual vs. Fits in the lockdown Period

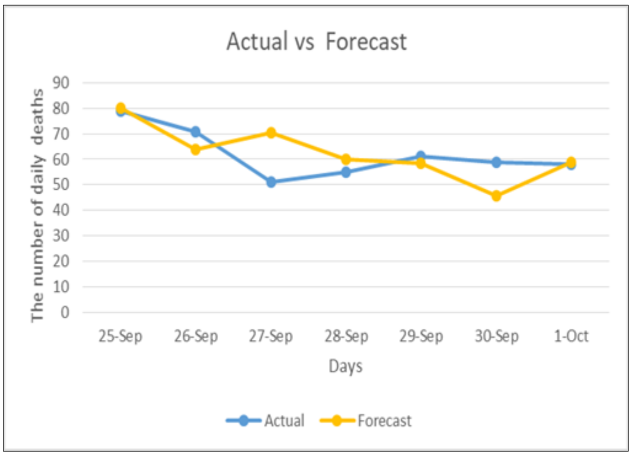

Figure 12 Actual vs. Forecast in the lockdown Period

4. Conclusion

The results show that the Fourier forecast model pattern is very similar to the actual series. Moreover, the deviations between actual vs. fits and actual vs. forecast were very less. Therefore, the fits and forecasts confirmed that the Fourier model is a suitable model for forecasting daily deaths in both increasing and decreasing periods in Sri Lanka. It can predict the coronavirus mortality rate in near future with good accuracy if the data are reliable and there are no second transmissions. The short-term forecasts will be helpful in making future plans and taking some short-term decisions like whether or not to increase the lockdown or how strict the lockdown should be depending on the trend.

Compliance with ethical standards

Acknowledgments

The authors are grateful to the Epidemiology Unit, Ministry of Health, Sri Lanka for facilitating data collection.

Disclosure of conflict of interest

There is no conflict of interest regarding the publication of this article.

References

[1] Amaratunga D, Fernando N, Haigh R, Jayasinghe N. The COVID-19 outbreak in Sri Lanka: A synoptic analysis focusing on trends, impacts, risks and science-policy interaction processes. Progress in Disaster Science. 2020;8.

[2] COVID-19 Situation Report [Internet]. Epidemiology Unit Ministry of Health Sri Lanka. Available from: https://www.epid.gov.lk/web/index.php?option=com_content&view=article&id=238&Itemid=519&lang=en

[3] Press WH, Teukolsky SA, Vetterling WT, Flannery BP. Numerical Recipes in C. 2nd ed. Cambridge University Press;1992.

[4] Tantrigoda DA, Rodrigo DS. Numerical implementation of Fourier transforms and associated problems. International Journal of Multidisciplinary Studies. 2014; 1(1):1.

[5] COVID-19 Latest Update [Internet]. News.lk The Government Official News Portal of Sri Lanka. Available from: https://news.lk/news/COVID-19

[6] Whole genomic sequencing of the SARS-CoV-2 variants in Sri Lanka [Internet]. University of Sri Jayewardenepura. 2021. Available from: https://www.sjp.ac.lk/news/whole-genomic-sequencing-of-the-sars-cov-2-variants-in-sri-lanka-issued-by-dept-of-immunology-and-molecular-medicine-usj/