PREDICTION OF COVID-19 CASES IN SAUDI ARABIA USING ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

Understanding the trend of COVID-19 is fundamental for purposes of formulating and implementing appropriate precautionary measures to mitigate the spread of the epidemic. In this study, the ANN approach was applied to analyze daily COVID-19 cases in Saudi Arabia. The employed data covers the period March 2, 2020 to October 31, 2020 and the out-of-sample period ranges over the period November 2020 to April 2021. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the model used in this study indicate that the model is stable in forecasting daily COVID-19 cases in the country. The results of the study imply that the pandemic is likely to reach an equilibrium level of approximately 126 cases per day, sometime around November 29, 2020 and this equilibrium level of case volumes is likely to be experienced for the rest of the out-of-sample period. The government of Saudi Arabia ought to continue to enforce adherence to the World Health Organization (WHO) sanitary rules and guidelines in order to suppress any further increase in the number of cases.

Keywords: - *ANN, COVID-19, Forecasting*

INTRODUCTION & BRIEF BACKGROUND

The first case of COVID-19 originated from Wuhan, China, after which the disease spread to the rest of the world (Alharbi *et al*., 2020). In Saudi Arabia, the first case of COVID-19 was confirmed on March 2, 2020; in a citizen arriving from Iran through Bahrain (Alsofayan *et al*., 2020). Since then, cases of infection and deaths continued to grow, exponentially, reaching more than 255000 cases of infection and at least 2500 deaths by late July 2020 (Worldometers Info, 2020). In response to COVID-19, the government of Saudi Arabia quickly implemented stringent non-pharmaceutical interventions to prevent the spread of the deadly scourge via human-to-human transmission (Ministry of Health, 2020). Patients with COVID-19 can develop mild to severe symptoms following infection, for instance; signs of fever, cough, dyspnea, myalgia, and fatigue can arise in patients mildly affected. The virus can also lead to severe pneumonia, acute respiratory distress syndrome (ARDS), or multi-organ failure in some patients (Huang *et al*., 2020; Zhou *et al*., 2020). The government actually commenced with implementing a partial lockdown, followed by a full lockdown and this led to a significant decline in the number of new cases and mortality cases per day in Saudi Arabia (Barry *et al*., 2020; Komies *et al*., 2020). By so doing, the main goal of the government of Saudi Arabia, just like other government around the

world was to reduce infection and mortality rates, as well as reducing the inevitable economic downturn (Ali *et al*., 2020). Few modeling and forecasting studies have been done for Saudi Arabia, for example; Elhassan & Gaafar (2020), Alharbi *et al*. (2020) and Alboaneen *et al*. (2020). Using ARIMA and logistic growth models, Elhassan & Gaafar (2020), predicted that there would be a gradual increase in total confirmed cases in the country. Employing modified SIR models, Alharbi *et al*. (2020), predicted that the cumulative number of infected cases would reach 359794 and that the pandemic would end by early September 2020. Based on both logistic growth and SIR models, Alboaneen *et al*. (2020), predicted that the outbreak will enter its final phase by end of June 2020. Reality has shown that the study by Alharbi *et al*. (2020) is questionable given that the pandemic is still wreaking havoc in Saudi Arabia. This could have been caused by a relatively limited data-set used by Alharbi *et al*. (2020). In order to improve the quality of the results of this study, we make use of a relatively larger data set, with 244 daily observations [over the period under study]. The main purpose of this paper is to forecast COVID-19 daily cases in Saudi Arabia in order to explain the future dynamic spread of the disease and to support the allocation of scarce COVID-19-related resources throughout the country.

METHODOLOGY

This paper applies the multi-layer perceptron neural network type of the ANN approach in order to predict daily new COVID-19 infections in Saudi Arabia. This paper particularly applies the ANN (12, 12, 1) model and chooses the more efficient hyperbolic tangent function as the activation function. This study is actually based on daily new Covid-19cases (referred to as SA series in this study) for all age groups in Saudi Arabia. The data covers the period 2 March 2020 to 31October 2020 while the out-of-sample forecast covers the period November 2020 to April 2021. All the data employed in this research paper was gathered from John Hopkins University (USA).

FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
1423.3	1165.0	0.00000	4919.0
Std. Dev.	C.V.	Skewness	Ex. kurtosis
1230.8	0.86478	0.86634	-0.20320
5% Perc.	95% Perc.	IQ range	Missing obs.
8.2500	3942.5	1817.3	0

ANN MODEL SUMMARY FOR COVID-19 DAILY CASES IN SAUDI ARABIA

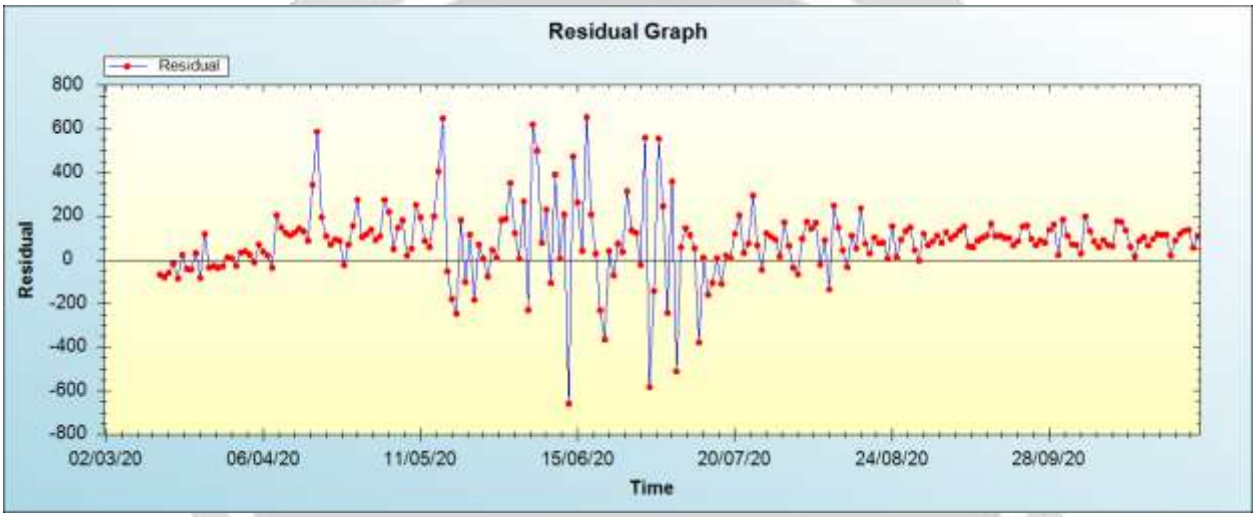
Table 2: ANN model summary

Variable	SA
Observations	232 (After Adjusting Endpoints)
Neural Network Architecture:	
Input Layer Neurons	12

Hidden Layer Neurons	12
Output Layer Neurons	1
Activation Function	Hyperbolic Tangent Function
Back Propagation Learning:	
Learning Rate	0.005
Momentum	0.05
Criteria:	
Error	0.067436
MSE	33962.295427
MAE	133.089310

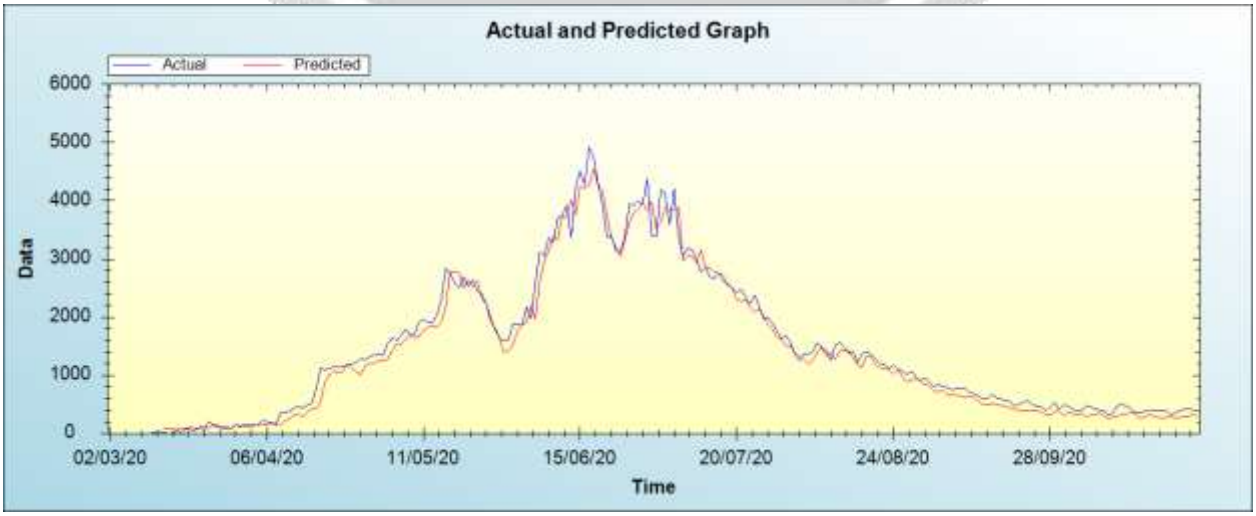
Residual Analysis for the ANN model

Figure 1: Residual analysis



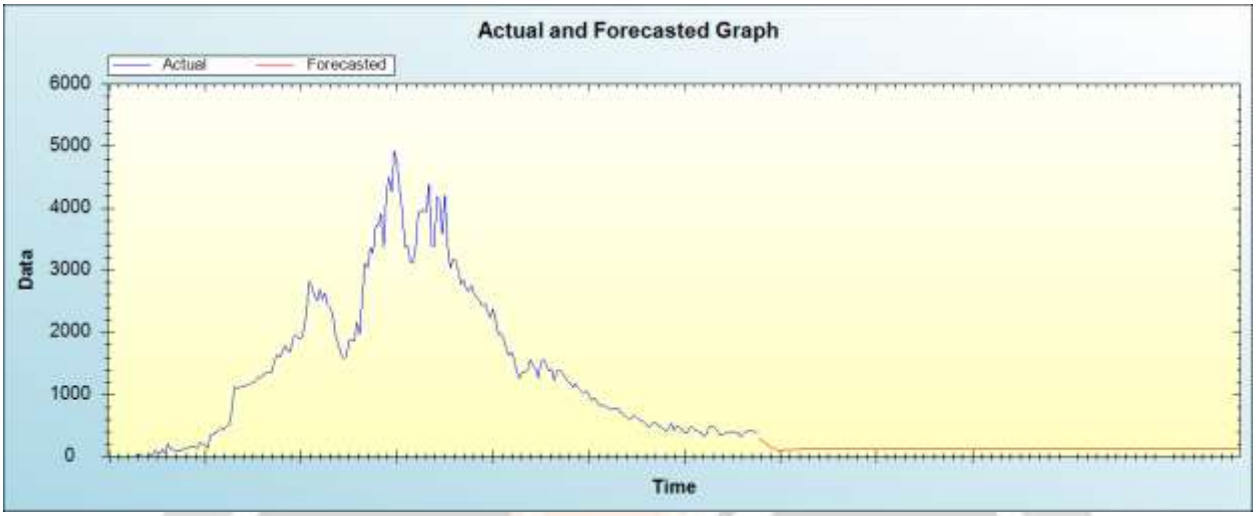
In-sample Forecast for SA

Figure 2: In-sample forecast for the SA series



Out-of-Sample Forecast for SA: Actual and Forecasted Graph

Figure 3: Out-of-sample forecast for SA: actual and forecasted graph



Out-of-Sample Forecast for SA: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Day/Month/Year	Forecasts
01/11/20	298.2872
02/11/20	248.9948
03/11/20	223.8548
04/11/20	198.9223
05/11/20	147.2302
06/11/20	146.2286
07/11/20	121.9553
08/11/20	102.0953
09/11/20	96.1333
10/11/20	107.0822
11/11/20	107.3631
12/11/20	102.7392

13/11/20	106.9868
14/11/20	112.7764
15/11/20	111.0572
16/11/20	114.6732
17/11/20	124.7346
18/11/20	124.3236
19/11/20	122.7306
20/11/20	125.8386
21/11/20	128.1302
22/11/20	126.4635
23/11/20	127.6162
24/11/20	129.4413
25/11/20	128.2881
26/11/20	126.1587
27/11/20	127.0745
28/11/20	127.6036
29/11/20	126.1985
30/11/20	126.0334
01/12/20	126.7259
02/12/20	125.8510
03/12/20	125.0482
04/12/20	125.7168
05/12/20	125.9511
06/12/20	125.3716
07/12/20	125.3802
08/12/20	125.7950

09/12/20	125.5421
10/12/20	125.3217
11/12/20	125.7092
12/12/20	125.8631
13/12/20	125.5679
14/12/20	125.6149
15/12/20	125.8405
16/12/20	125.7272
17/12/20	125.6336
18/12/20	125.8082
19/12/20	125.8394
20/12/20	125.6880
21/12/20	125.7105
22/12/20	125.8113
23/12/20	125.7501
24/12/20	125.6967
25/12/20	125.7705
26/12/20	125.7756
27/12/20	125.7021
28/12/20	125.7190
29/12/20	125.7678
30/12/20	125.7345
31/12/20	125.7104
01/01/21	125.7459
02/01/21	125.7477
03/01/21	125.7159

04/01/21	125.7274
05/01/21	125.7502
06/01/21	125.7334
07/01/21	125.7227
08/01/21	125.7405
09/01/21	125.7413
10/01/21	125.7268
11/01/21	125.7331
12/01/21	125.7432
13/01/21	125.7343
14/01/21	125.7297
15/01/21	125.7384
16/01/21	125.7384
17/01/21	125.7315
18/01/21	125.7346
19/01/21	125.7390
20/01/21	125.7345
21/01/21	125.7326
22/01/21	125.7369
23/01/21	125.7366
24/01/21	125.7333
25/01/21	125.7349
26/01/21	125.7369
27/01/21	125.7347
28/01/21	125.7340
29/01/21	125.7361

30/01/21	125.7358
31/01/21	125.7343
01/02/21	125.7351
02/02/21	125.7360
03/02/21	125.7349
04/02/21	125.7347
05/02/21	125.7357
06/02/21	125.7355
07/02/21	125.7348
08/02/21	125.7352
09/02/21	125.7356
10/02/21	125.7351
11/02/21	125.7350
12/02/21	125.7354
13/02/21	125.7353
14/02/21	125.7350
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27/04/21	125.7352
28/04/21	125.7352
29/04/21	125.7352
30/04/21	125.7352

Table 1 shows that the maximum number of daily cases over the study period is 4919 cases while the average number of daily confirmed cases was 1423 cases per day. The applied model is summarized in table 2 while its residual diagnostics are presented in figure 1; indeed, the model is stable and acceptable for forecasting COVID-19 cases in the country. In-sample forecasts are presented in figure 2 while figure 3 and table 3 present out-of-sample predictions. As clearly show in our out-of-sample forecasts, COVID-19 cases will continue to decline from the estimated 298 cases on November 1, 2020 until an equilibrium level of 126 cases per day is reached sometime around November 29, 2020. Given the current restrictions, this level could be maintained throughout the out-of-sample period. These results are generally consistent with previous studies such as Elhassan & Gaafar (2020) and Alboaneen *et al*. (2020). The equilibrium level of around 126 cases per day is largely in line with the "final-phase" of the pandemic, initially identified by Alboaneen *et al*. (2020).

CONCLUSION & RECOMMENDATIONS

The COVID-19 outbreak continues to spread rapidly across the world and Saudi Arabia is among the countries that have been affected by the deadly disease. In this research endeavor, we applied the ANN (12, 12, 1) model to forecast daily COVID-19 daily cases in the country. The results of the study indicate that the pandemic is likely to reach an equilibrium level of approximately 126 cases per day, sometime around November 29, 2020 and this equilibrium level of case volumes is likely to be experienced in the remaining part of the out-of-sample period. The government of Saudi Arabia should continue to enforce adherence to the WHO sanitary rules and guidelines in order to suppress any further increase in the number of cases. These results can be used by relevant authorities in the country for resource allocation purposes, for example, acquiring

hospital beds and putting additional equipments in intensive care units and hiring more healthcare workers; to prepare in advance for the predicted trend of the pandemic. While this paper clearly suggests that the pandemic is far from ending in Saudi Arabia, it is important to note that the results confirm the fact that the pandemic is so far under reasonable control and therefore there is no need to panic or fear anymore.

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