PREDICTING COVID-19 CASES IN MOROCCO USING ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

The COVID-19 has had a profound global impact, characterized by calamitous situations throughout the entire world. Its rapid transmissibility has forced the whole world to adopt strict measures to contain its spread. Indeed, this pandemic has become a public health emergency of international concern. In this research paper, the ANN model was applied to forecast COVID-19 confirmed cases in Morocco. 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 applied model indicate that the model is stable and adequate in forecasting daily confirmed cases of COVID-19 in the country. The results of the study indicate that COVID-19 cases will initially continue to rise from 3661 on November 1, 2020 and by December 11, 2020; COVID-19 daily confirmed cases would have reached what we can term an equilibrium case volume, which shall be maintained throughout the out-of-sample period. This suggests that the COVID-19 epidemic will not end anytime soon in Morocco, unless there is an effective vaccine against the disease. We encourage Moroccan authorities to continue to implement preventive and control measures such as wearing of masks, banning of unnecessary travel, social distancing, and proper washing of hands and so on., in order to avoid a further increase or a possibility of a second wave of infections, which could be more disastrous.

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

INTRODUCTION

Since the COVID-19 case was recorded in Wuhan in China in the tail end of December 2019, the virus has quickly spread to the rest of the world, mostly facilitated by the global air travel to the major cities in Europe, the US and elsewhere (Huang *et al*., 2020; Zhang *et al*., 2020a & b). By September 4, 2020; there were 26331492 confirmed cases of COVID-19 and continuing to grow by the day and 869290 deaths have been reported worldwide with more than 185 countries being affected by the pandemic (Johns Hopkins University, 2020). At the moment (Varela-Santos & Melin, 2020), we only have preventive measures (Guner *et al*., 2020), and a few global initiative in developing a vaccine which are basically on the final stages of clinical trials (CDC, 2020).

Although governments around the world, including the Moroccan government; impose numerous containment and social distancing measures, the need for the healthcare systems has dramatically increased and the effective management of infected patients becomes a challenging problem for hospitals. Therefore, accurate forecasting of the number of new COVID-19 cases is crucial for optimizing the available resources and arresting or slowing down the progression of the pandemic (Zeroual *et al*., 2020). Since the appearance of the first case of COVID-19 in Morocco in Casablanca city, on March 2, 2020, the cumulative number of reported infectious cases continues to increase (Hammoumi & Qesmi, 2020). We attempt to model and forecast daily confirmed COVID-19 cases in the country over the period March 2, 2020 to October 31, 2020; with an out-of-sample period of November 2020 to April 2021.

LITERATURE REVIEW

Zine *et al*. (2020) proposed a delayed mathematical model to predict the epidemiological trend of COVI-19 in Morocco. Parameter estimation and sensitivity analysis of the proposed model were also examined rigorously. Numerical simulations were presented in order to test the effectiveness of the preventive measures and strategies that were imposed by the Moroccan authorities. The researchers generally found out that the transmission rate and the proportion of individuals with symptoms are the most sensitive parameters and have a high impact on the basic reproduction number. In another Moroccan study, Ifguis *et al*. (2020) used the SIR model to analyze COVID-19 case volumes and found that the start of acceleration of the epidemic is around 21 March 2020, and that the regular growth will begin on 8 April 2020, and that the end of the epidemic in Morocco would be around 26 April 2020, with a total of 1446 infected cases and 366 final number of susceptible cases. Unfortunately, reality has shown us that Ifguis *et al*. (2020)'s predictions missed the point, completely: what is even more appalling is that the epidemic did not end in late April, instead the cases increased exponentially. It happens, especially when modelling and forecasting epidemics. In yet another predictive modeling study, Layelmam *et al*. (2020) applied the TBATS model to forecast confirmed cases in Morocco. The study found out that the epidemic will continue to grow and that the peak of this epidemic is not yet identified. It is important to note that the model by Layelmam et al. (2020) has been consistent with reality unlike the one produced by Ifguis *et al*. (2020). This, probably suggests that; TBATS models perform better than SIR models when it comes to forecasting COVID-19 cases volumes. In this paper, we use a completely different model, the Artificial Neural Network (ANN) model, a deep learning technique; to analyze COVID-19 cases in Morocco.

METHOD

We apply the multi-layer perceptron neural network type of the ANN approach in order to predict daily new COVID-19 cases in Morocco. The paper particulary applies the ANN (12, 12, 1) model and selected the more efficient hyperbolic tangent function as the activation function.

Data Issues

This paper is based on newly confirmed daily COVID-19 cases for all age groups in Morocco (reffered to as the XM series in this study). The data covers the period March 2, 2020 to October 31, 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 the USA's Johns Hopkins University online database.

FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
897.89	223.50	0.0000	4320.0
Std. Dev.	C.V.	Skewness	Ex. kurtosis
1117.6	1.2447	1.2618	0.51604

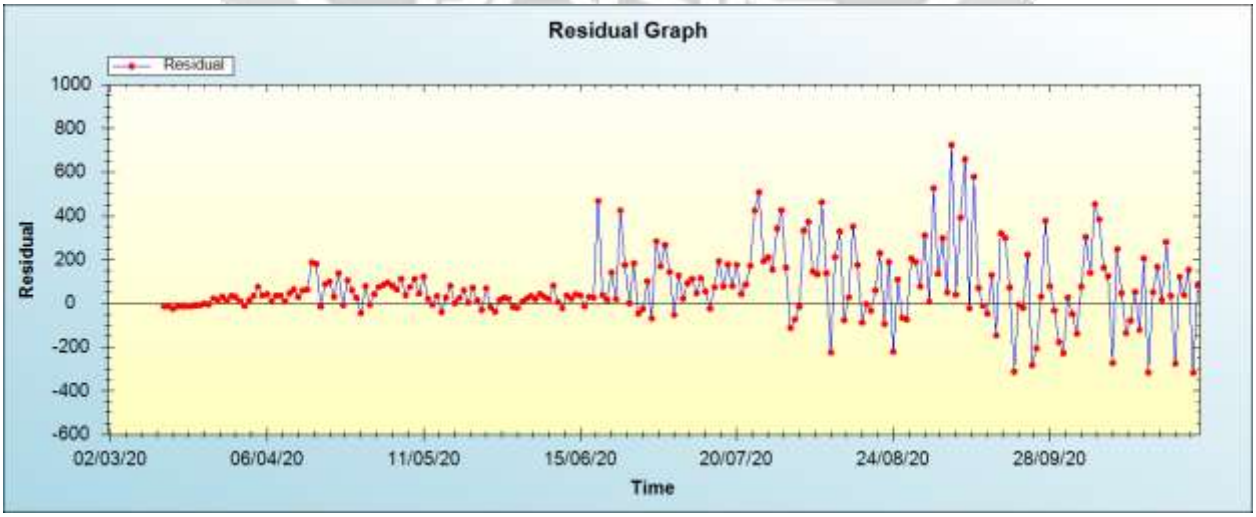
ANN MODEL SUMMARY FOR COVID-19 DAILY CASES IN MOROCCO

Table 2: ANN model summary

Variable	XM
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	0.073075
MSE	30758.263463
MAE	117.385530

Residual Analysis for the ANN model

Figure 1: Residual analysis



In-sample Forecast for XM

Figure 2: In-sample forecast for the XM series

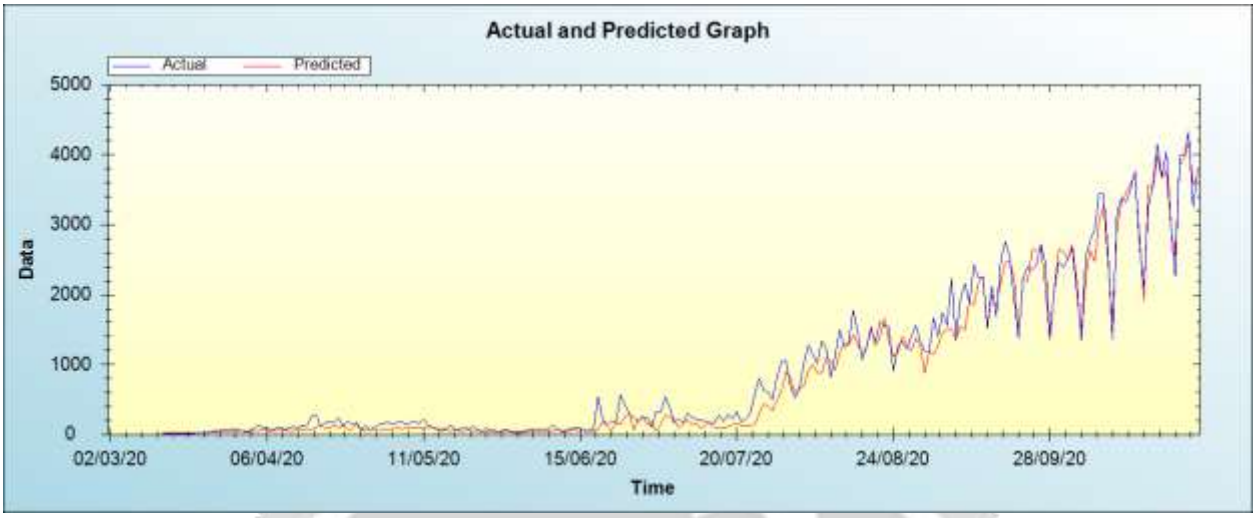
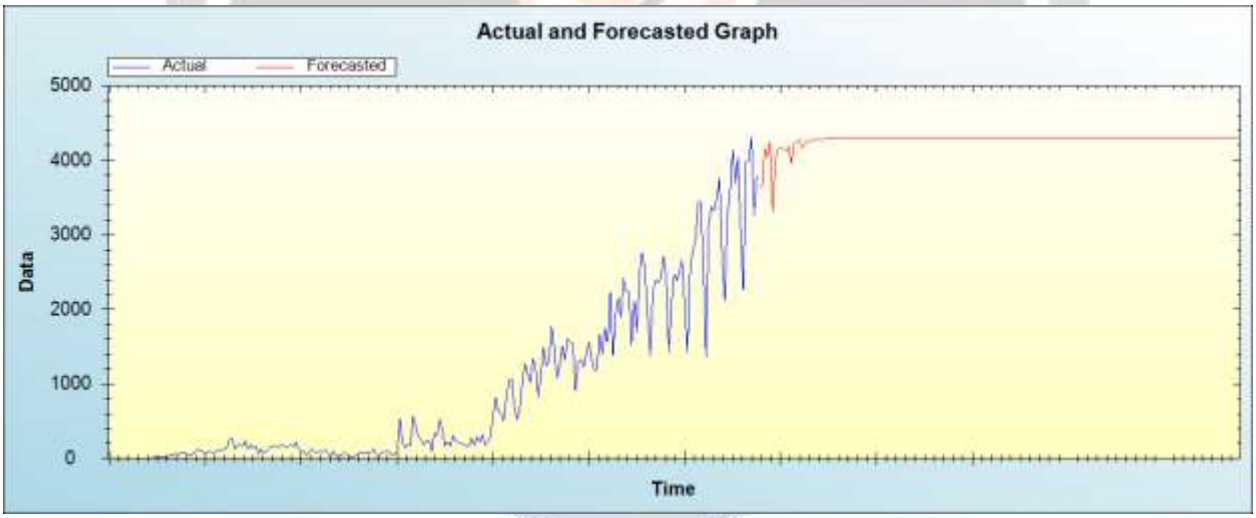


Figure 3 shows the in-sample forecast for XM series.

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

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



Out-of-Sample Forecast for XM: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Day/Month/Year	Forecasts
01/11/20	3660.6577
02/11/20	3649.3337
03/11/20	4152.1478

04/11/20	4058.7374
05/11/20	4245.6708
06/11/20	3306.1561
07/11/20	4010.9577
08/11/20	4146.6042
09/11/20	4157.3313
10/11/20	4154.7909
11/11/20	4112.5533
12/11/20	4188.0857
13/11/20	3964.4972
14/11/20	4226.1719
15/11/20	4244.5050
16/11/20	4284.7150
17/11/20	4161.9109
18/11/20	4222.4934
19/11/20	4263.7398
20/11/20	4242.6638
21/11/20	4284.3320
22/11/20	4277.6459
23/11/20	4294.7594
24/11/20	4259.5674
25/11/20	4286.7588
26/11/20	4292.2302
27/11/20	4297.4500
28/11/20	4295.6703
29/11/20	4296.4402

30/11/20	4300.9251
01/12/20	4295.7827
02/12/20	4301.7217
03/12/20	4301.5668
04/12/20	4304.2871
05/12/20	4302.0621
06/12/20	4303.4089
07/12/20	4303.8733
08/12/20	4303.8136
09/12/20	4304.5192
10/12/20	4304.4761
11/12/20	4305.1493
12/12/20	4304.5900
13/12/20	4305.0540
14/12/20	4305.0091
15/12/20	4305.2281
16/12/20	4305.2018
17/12/20	4305.2708
18/12/20	4305.3647
19/12/20	4305.2993
20/12/20	4305.3934
21/12/20	4305.3719
22/12/20	4305.4480
23/12/20	4305.4149
24/12/20	4305.4508
25/12/20	4305.4527

26/12/20	4305.4601
27/12/20	4305.4695
28/12/20	4305.4700
29/12/20	4305.4852
30/12/20	4305.4779
31/12/20	4305.4879
01/01/21	4305.4854
02/01/21	4305.4913
03/01/21	4305.4904
04/01/21	4305.4927
05/01/21	4305.4944
06/01/21	4305.4941
07/01/21	4305.4959
08/01/21	4305.4954
09/01/21	4305.4970
10/01/21	4305.4965
11/01/21	4305.4974
12/01/21	4305.4974
13/01/21	4305.4977
14/01/21	4305.4979
15/01/21	4305.4979
16/01/21	4305.4982
17/01/21	4305.4981
18/01/21	4305.4984
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29/04/21	4305.4987
30/04/21	4305.4987

As shown by table 1, the average daily number of COVID-19 cases over the period under study is 898 cases, characterised by a maximum of 4320. The summary of the applied model is shown in table 2. The model is stable and indicated by the residual analysis in figure 1. In-sample predictions are shown in figure 2. Figure 3 and table 3 are out-of-sample forecasts. Interesting to note is that COVID-19 cases will continue to rise from November 1, 2020 [3661 cases] to around December 11, 2020 [4305] after which the cases will maintain an equilibrium daily case volume throughout the out-of-sample period. Our results are generally consistent with Layelmam *et al*. (2020).

CONCLUSION & RECOMMENDATIONS

Since the recent challenge that humanity is facing against COVID-19, several initiatives have been put forward with the goal of creating measures to help control the spread of the pandemic (Varela-Santos & Melin, 2020). This piece of work is a scientific initiative whose goal is to forecast COVID-19 daily confirmed cases in Morocco in order to inform policy. The applied model has been shown to be stable and adequate. The forecasts of the model are consistent with previous studies and are in line with reality. Basically, we establish that the daily confirmed cases will reach an equilibrium case volume of approximately 4305 somewhere around December 11, 2020 and oscillate around this level throughout the out-of-sample period. Since, there is no known, effective vaccine or drug against this epidemic, we encourage Moroccan authorities to continue to implement preventive and control measures such as wearing of masks, banning of unnecessary travel, social distancing, and proper washing of hands and so on.

REFERENCES

[1] CDC (2020). 2019-Novel Coronavirus (2019-nCoV) Real-Time RT-PCR Diagnostic Panel, *CDC*, New York.

[2] COVID-19 Repository By the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.

[3] Dong, E., *et al*. (2020). An Interactive Web-based Dashboard to Track COVID-19 in Real Time, *Lancet Infectious Diseases*, 20 (5): 533 – 534.

[4] Guner, R., *et al*. (2020). COVI-19: Prevention and Control Measures in Community, *Turkish Journal of Medical Sciences*, 50 (3): 571 – 577.

[5] Hammoumi, A., & Qesmi, R. (2020). Impact Assessment of Containment Measure Against COVID-19 Spread in Morocco, *Chaos, Solitons and Fractals*, 140 (2020): 1 – 8.

[6] Huang, C., *et al*. (2020). Clinical Features of Patients Infected With 2019 Novel Coronavirus in Wuhan, China, *Lancet*, 395 (10223): 497 – 506.

[7] Ifguis, O., *et al*. (2020). Simulation of the Final Size of the Evolution Curve of Coronavirus Epidemic in Morocco Using the SIR Model, *Journal of Environmental and Public Health*, pp: 1 – 5.

[8] Johns Hopkins University (2020). Coronavirus, *Coronavirus Research Center*, Johns Hopkins University.

[9] Layelmam, M., *et al*. (2020). Forecasting COVID-19 in Morocco, *Journal of Clinical and Experimental Investigations*, 11 (1): 1 – 8.

[10] Varela-Santos, S., & Melin, P. (2020). A New Approach for Classifying Coronavirus COVID-19 Based on its Manifestation on Chest X-rays Using Texture Features and Neural Networks, *Information Sciences*, 545 (2021): 403 – 414.

[11] Zeroual, A., *et al*. (2020). Deep Learning Methods for Forecasting COVID-19 Time Series Data: A Comparative Study, *Chaos, Solitons and Fractals*, 140 (2020): 1 – 12.

[12] Zhang, C., *et al*. (2020a). Measuring Imported Case Risk of COVID-19 From Inbound International Flights – A Case Study on China, *University of International Business and Economics*, China.

[13] Zhang, C., *et al*. (2020b). Exploring the Roles of High-speed Train, Air and Couch Services in the Spread of COVID-19 in China, *Transport Politics*, 94: 34 – 42.

[14] Zine, H., *et al*. (2020). Modeling the Spread of COVID-19 Pandemic in Morocco, *medRxiv*, pp: 1 – 18.