

# Forecasting Daily Covid-19 Deaths in Germany Using Artificial Neural Networks

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**Abstract** - In this research paper, the ANN approach was applied to analyze daily COVID-19 deaths in Germany. The employed daily data covers the period to 1 January 2020 to 31 December 2020 and the out-of-sample period ranges over the period to 1 January 2021 to 31 May 2021. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting daily COVID-19 cases in Germany. The applied ANN (12, 12, 1) model projections indicate that COVID-19 mortality in Germany will generally range between 29 and 1000 deaths per day over the out-of-sample period. Therefore the authorities in Germany are encouraged to continue applying WHO guidelines on prevention and control of COVID-19 including vaccination of its population in order to achieve herd immunity.

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

## I. INTRODUCTION

An artificial neural network is a mathematical model for the simulation of a network of biological neurons (Gallo, 2015). They are information processing structures providing the connection between input and output data (Honkela et al, 2011). ANNs are made up of processing elements called neurons (Gallo, 2015; Zhang, 2003; Kishan, 1997) combined according to different architectures (Gallo, 2015). There are many ANN frameworks but the commonly used one is the Multilayer Perceptron (MLP) (Nyoni et al, 2020; Zhao et al, 2020; Gallo, 2015; Zhang, 2003). The MLP is composed of an input layer, one or more hidden layers and an output layer. This ANN framework is a feed forward neural network type and utilizes the back propagation algorithm during the training process (Nyoni et al, 2020; Zhao et al, 2020; Arora et al, 2020; Yan et al, 2018; Kolter & Koltun, 2018; Kaushik & Sahi, 2018; Paswan et al, 2018; Ruder, 2017; Fojnica et al, 2016; Quazi et al, 2015; Raghupathi & Raghupathi, 2015; Schmidhuber, 2014; Gomes et al, 2011; Yan et al, 2006; Ozkan et al, 2003; Zhang, 2003; Kishan, 1997; Patterson, 1995). ANN applications can be divided into 3 categories 1) classification 2) function approximation and 3) time series forecasting (Weng et al, 2017). Time series forecasting is gaining popularity in public health surveillance. It is a useful surveillance tool to detect disease outbreaks, assess the impact of health intervention programs, facilitate planning and decision making and allocation of resources for health. In this paper we apply the ANN approach to model and forecast daily COVID-19 deaths in Germany. The results of the study are expected to reveal the future trends of COVID-19 mortality in Germany and help to assess the impact of COVID-19 prevention and control measures including the COVID-19 vaccination programme.

## II. METHODOLOGY

The study applies the Artificial Neural Network (ANN) approach which is usually celebrated for its capability to learn from any data-set and consequently describe the nonlinear and interaction effects with great accuracy. Arguably, explicit guidelines exist for the determination of the ANN structure hence the study applies the popular ANN (12, 12, 1) model based on the hyperbolic tangent activation function.

### Data Issues

This study is based on daily deaths of COVID-19 in Germany for the period 1 January – 31 December 2020. The out-of-sample forecast covers the period January 2021 – May 2021. All the data employed in this paper was gathered from the World Bank.

### III. FINDINGS OF THE STUDY

#### ANN Model Summary

Table 1: ANN model summary

Variable	K
Observations	354 (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	0.068530
MSE	1926.947614
MAE	30.223578

#### Residual Analysis for the Applied Model

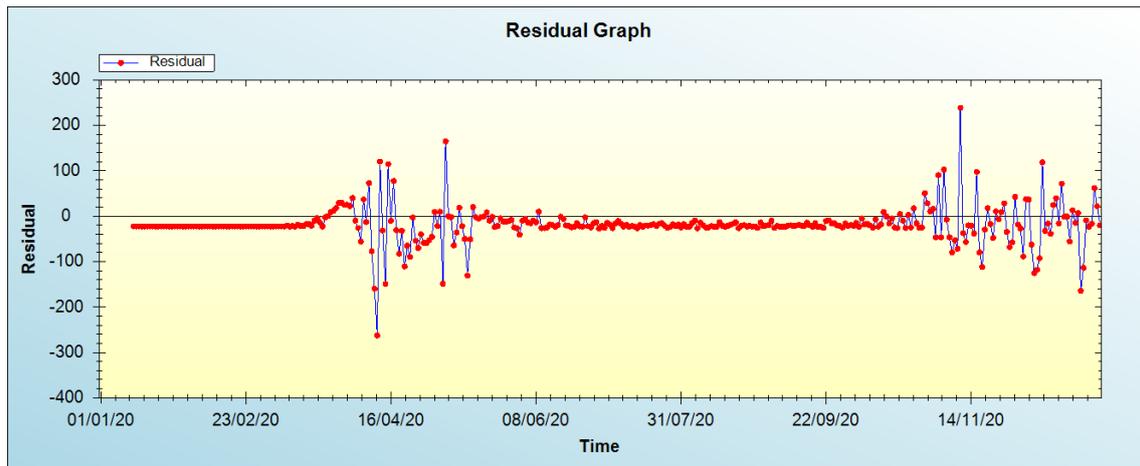


Figure 1: Residual analysis

#### In-sample Forecast for K

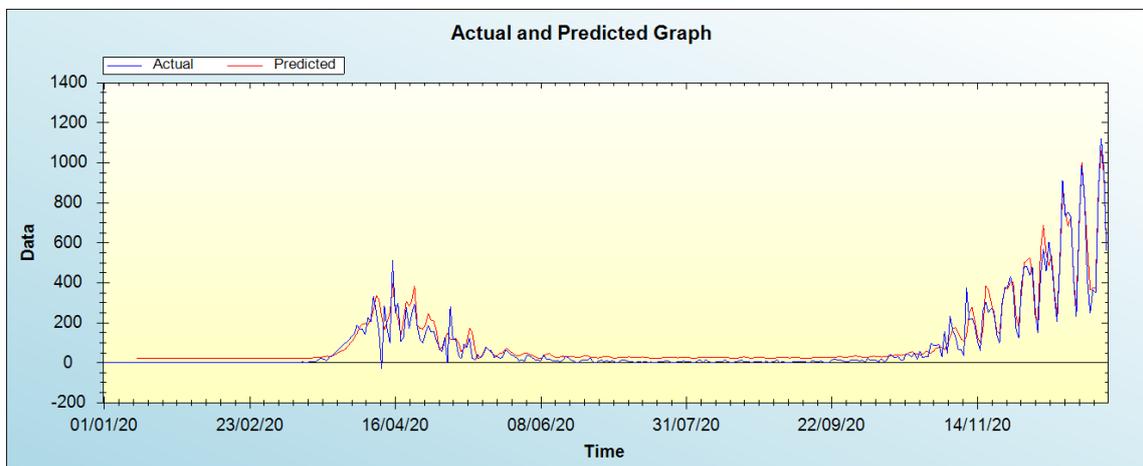


Figure 2: In-sample forecast for the K series

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

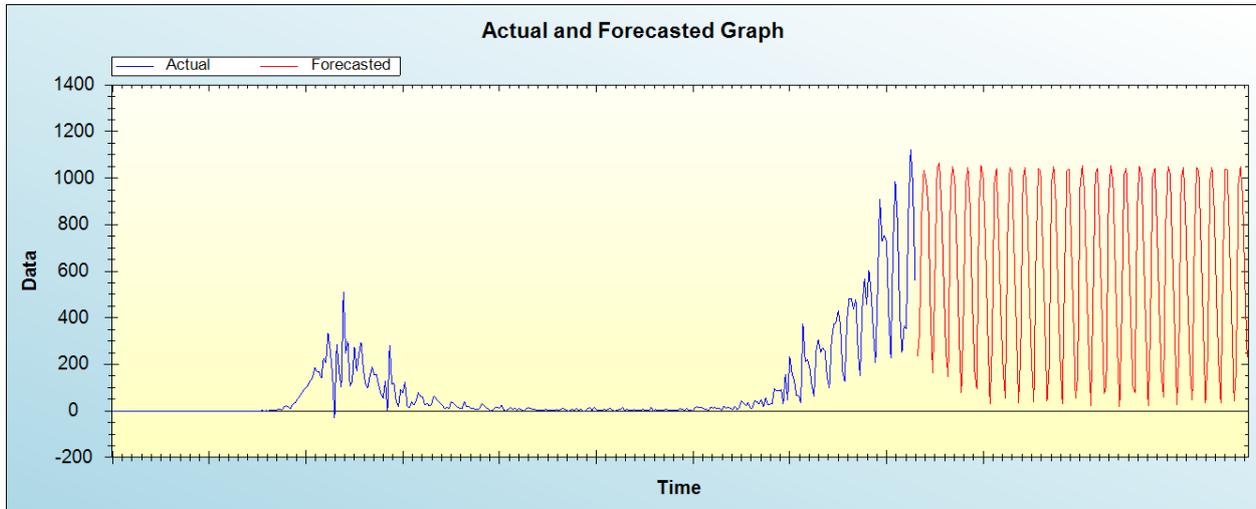


Figure 3: Out-of-sample forecast for K: actual and forecasted graph

Out-of-Sample Forecast for K: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Date	Forecasts
01/01/21	233.5842
02/01/21	335.8832
03/01/21	846.0791
04/01/21	1035.7746
05/01/21	989.9507
06/01/21	884.8523
07/01/21	398.9574
08/01/21	163.7671
09/01/21	573.1428
10/01/21	1041.6492
11/01/21	1066.2296
12/01/21	878.7030
13/01/21	541.7768
14/01/21	250.7865
15/01/21	145.4737
16/01/21	926.5515
17/01/21	1049.7331
18/01/21	991.3154
19/01/21	688.7256
20/01/21	311.4569
21/01/21	77.2661
22/01/21	438.7330
23/01/21	977.8839
24/01/21	1044.8608
25/01/21	880.2422
26/01/21	473.7468
27/01/21	169.6339
28/01/21	94.6194

29/01/21	880.2897
30/01/21	1054.1286
31/01/21	995.8225
01/02/21	720.1788
02/02/21	342.0528
03/02/21	31.0898
04/02/21	293.9053
05/02/21	980.1546
06/02/21	1040.1710
07/02/21	763.1308
08/02/21	424.5808
09/02/21	172.8838
10/02/21	56.6354
11/02/21	746.1333
12/02/21	1046.2742
13/02/21	1030.4252
14/02/21	697.9291
15/02/21	370.6161
16/02/21	33.4575
17/02/21	254.1198
18/02/21	999.0066
19/02/21	1044.5149
20/02/21	861.3700
21/02/21	492.1406
22/02/21	203.0340
23/02/21	38.7929
24/02/21	696.9845
25/02/21	1042.3151
26/02/21	1032.4881
27/02/21	721.0326
28/02/21	386.4871
01/03/21	41.1413
02/03/21	190.1710
03/03/21	978.9238
04/03/21	1049.2634
05/03/21	893.8225
06/03/21	520.0431
07/03/21	222.0208
08/03/21	29.2155
09/03/21	587.4882
10/03/21	1029.9480
11/03/21	1039.7110
12/03/21	724.5788
13/03/21	399.2852
14/03/21	52.7182
15/03/21	146.9667
16/03/21	956.3143
17/03/21	1052.2495
18/03/21	943.5321
19/03/21	571.8646

20/03/21	248.6099
21/03/21	21.3768
22/03/21	492.9093
23/03/21	1019.3112
24/03/21	1042.1294
25/03/21	722.5949
26/03/21	403.5503
27/03/21	74.2856
28/03/21	107.7950
29/03/21	913.7775
30/03/21	1053.0904
31/03/21	979.3750
01/04/21	611.0216
02/04/21	278.6115
03/04/21	19.0841
04/04/21	407.8762
05/04/21	1011.2385
06/04/21	1043.1439
07/04/21	737.4922
08/04/21	413.3675
09/04/21	106.2056
10/04/21	79.5715
11/04/21	862.1560
12/04/21	1051.8566
13/04/21	1001.8612
14/04/21	642.7279
15/04/21	311.8999
16/04/21	20.6582
17/04/21	339.3682
18/04/21	1005.0622
19/04/21	1044.1129
20/04/21	774.0405
21/04/21	433.1196
22/04/21	143.8184
23/04/21	60.4917
24/04/21	806.7823
25/04/21	1049.5723
26/04/21	1016.5738
27/04/21	673.0175
28/04/21	343.8471
29/04/21	25.2296
30/04/21	279.9278
01/05/21	997.5063
02/05/21	1045.5756
03/05/21	818.4860
04/05/21	459.9774
05/05/21	177.9393
06/05/21	46.5619
07/05/21	738.6966
08/05/21	1045.4527

09/05/21	1027.7372
10/05/21	701.1589
11/05/21	371.6855
12/05/21	32.6334
13/05/21	225.2714
14/05/21	988.7104
15/05/21	1047.8216
16/05/21	865.3241
17/05/21	495.3834
18/05/21	206.1204
19/05/21	34.9481
20/05/21	653.5119
21/05/21	1037.8853
22/05/21	1035.8782
23/05/21	719.7416
24/05/21	391.4627
25/05/21	43.3763
26/05/21	175.5377
27/05/21	973.6666
28/05/21	1050.6781
29/05/21	913.5080
30/05/21	539.8513
31/05/21	230.9042

The main results of the study are shown in table 1. It is clear that the model is stable as confirmed by evaluation criterion as well as the residual plot of the model shown in figure 1. It is projected that COVID-19 mortality in Germany will generally range between 29 and 1000 deaths per day over the out-of-sample period.

#### IV. CONCLUSION & RECOMMENDATIONS

Europe continues to battle rising cases of COVID-19 and the continent has witnessed one of the strictest lockdowns amid spiraling corona virus infections associated with high morbidity and mortality. The study was carried out to forecast COVID-19 mortality in Germany in order to understand the likely future trends of daily fatalities as a results of the deadly virus. The results of the study indicate that Germany is likely to record between 29 and 1000 COVID-19 deaths per day from January 1, 2021 to 31 May, 2021. The government is encouraged to speed up COVID-19 vaccination amongst other control measures.

#### REFERENCES

- [1] Bai, S., Kolter, J.Z & Koltun, V. (2018). An Empirical Evaluation of Generic Convolutional and Recurrent Networks for Sequence Modeling. Cornell University Library, arXiv.org, ISSN: 2331-8422, arXiv: 1409.0473.
- [2] Crescenzo Gallo (2015). Artificial neural networks tutorial, Encyclopedia of information science and Technology, 3rd Edition, pp 2-13.
- [3] Dan W. Patterson (1995) Artificial Neural networks Theory and Applications. Singapore; New York: Prentice Hall.
- [4] Fojnica, A., Osmanoviae & Badnjeviae A (2016). Dynamic model of tuberculosis-multiple strain prediction based on artificial neural network. In proceedings of the 2016 5th Mediterranean conference on embedded computing pp290-293.
- [5] Gomes, G. S. S., et al. (2011). Comparison of New Activation Functions in Neural Network for Forecasting Financial Time Series, Neural Computing & Applications, 20: 417 – 439.
- [6] Kaushik AC & Sahi. S (2018). Artificial neural network-based model for orphan GPCRs. Neural.Comput.Appl. 29,985-992.
- [7] KishanMehrotra., Chilukuri K., Mohan, & Sanjay Ranka (1997) Elements of artificial neural networks. Cambridge, Mass.: MIT Press.
- [8] Smartson P Nyoni., Thabani Nyoni & Tatenda A Chihoho (2020) Prediction of new Covid-19 cases in Spain using artificial neural networks. IJARIE Vol-6 Issue-6 2395-4396.

- [9] Smartson P Nyoni., Thabani Nyoni & Tatenda A Chihoho (2020) Prediction of new Covid-19 cases in Ghana using artificial neural networks. IJARIE Vol-6 Issue-6 2395-4396.
- [10] Smartson. P. Nyoni., Thabani Nyoni & Tatenda A. Chihoho (2020). Forecasting COVID-19 cases in Zimbabwe using artificial neural networks, IJARIE, 6, 6, 2395-4396.
- [11] Smartson. P. Nyoni., Thabani Nyoni & Tatenda A. Chihoho (2020). Forecasting COVID-19 cases in Ethiopia using artificial neural networks, IJARIE, 6, 6, 2395-4396.
- [12] Smartson. P. Nyoni., Thabani Nyoni., Tatenda. A. Chihoho (2020) Prediction of daily new Covid-19 cases in Egypt using artificial neural networks. IJARIE- Vol-6 Issue-6 2395-4396.
- [13] Weng SF., Reys J., Kai J., Garibaldi JM & Qureshi N (2017) Can machine-learning improve cardiovascular risk prediction using routine clinical data? PLOS ONE 12(4): e0174944. <https://doi.org/10.1371/journal.pone.0174944>
- [14] Yan, H., Jiang, J., Zheng, J., Peng, C & Li, Q. (2006) A multilayer perceptron based medical decision support system for heart disease diagnosis. Expert Syst. Appl. 2006, 30, 272–281.
- [15] Zhang G P (2003). “Time series forecasting using a hybrid ARIMA and neural network model”, Neurocomputing 50: 159–175.

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