

Covid-19: Predicting third wave using Neural Network

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ABSTRACT

In this study, we predict three important parameters related to the pandemic Covid-19: total number of infected, deaths and vaccinated in different countries of the world where the Covid-19 cases are rising. We have used the neural network of Mathematica-12 to predict the above-said parameters. These parameters can help the Government of the respective countries to strategize their resources in such a way that the spread of the contagious disease can be controlled and treated clinically to reduce mortality. The citizens must be forced to follow the Covid-19 appropriate behaviour (CAB) so that they remain disease-free and healthy. The number of vaccination is being administered during the last 5 months is also taken into consideration and predicted for the next 30 to 45 days. The data shows that various countries have different rates of vaccinating their citizens against Covid-19. The prediction related vaccinations can help the Governments to efficiently manage the vaccination programmes by training health care workers, planning inventory of vaccination, motivating the population through awareness programmes and post-vaccination care arrangements.

1. Introduction :

Variability in transmission rate impairs infectious disease dynamics and control. The coronavirus spreads primarily through person-to-person contact via respiratory droplets produced by breathing, sneezing, coughing, and other activities, as well as contact with the infected [1]. Forecasting is the need of an hour that helps to devise a better strategy to tackle this crucial period across the globe because of this infectious disease [2]. For time-series predictions and forecasting, numerous Machine Learning models are implemented, specifically deep learning techniques such as Artificial Neural Networks [3], Recurrent Neural Networks (RNNs) have achieved great success over the years [4]. RNNs, especially those with hidden units that use Long Short-Term Memory (LSTM), are powerful and widely used models for learning from sequence data [5]. Particularly, LSTM has shown to perform better than other RNNs on the predictions involving long time lags [6]. The scientific community has taken up this pandemic as a challenge and worked in developing vaccination, testing clinically and managing logistics to deliver within a short interval of time. People were initially concerned about the negative effects of the vaccines, such as a disease-enhancing condition, because proper clinical trials of all phases are still ongoing [7]. The publicity of the efficacy and safety of the vaccination has a positive effect on the acceptance of vaccination.

All most all the countries of the world are over with the second phase of the Covid-19 pandemic as of July 2021. The infected and death cases have risen faster in the second wave as compared to the first wave and found to be devastating in several parts of the world [8]. In Maharashtra, researchers discovered a rare

combination of three mutations, implying that the SARS-CoV-2 virus is constantly mutating to escape the human immune response [9]. Thus, the virus is continuously changing and posing a new challenge in the efficacy of the vaccines already developed. This virus has been mutating more than 1-2 times per month [10]. We did our best efforts to find any research in major search engines related to the predictions of vaccinations using neural networks being administered to the population.

The study is divided into the following sections. In section 2, we introduce the deep learning method using a neural network to understand its integrities through model architecture. In section 3, the analysis and interpretation are done country-wise. Finally, conclusions are presented in section 4.

2. Model Architecture

Deep learning is a powerful set of neural network learning algorithms. Neural networks are biologically-inspired programming paradigm that allows a computer to learn from observational data. Many problems related to image identification, audio recognition, natural language processing [11], clinical medicine [3] and timeline predictions [12] are being solved successfully by implementing neural networks and deep learning.

Consider the architecture of a network given in *Fig.1*. The leftmost layer of this network is called the input layer, and hence the neurons within this layer are termed input neurons. The middle layer is called a hidden layer. The neurons in this layer are neither inputs nor outputs. This network has a single hidden layer, but many of the networks have multiple hidden layers. The rightmost or output layer contains a single or multiple output neurons.

We will be using the Predict command of Mathematica which implements many algorithms like linear regression, neural networks etc. Given a set of data, $\{x_i, y_i\}_{i=1}^N$ from an unknown function, $y=f(x)$, this package uses numerical algorithms to derive reasonable estimates of the function, $f(x)$. It is done basically in three basic steps: First, a neural network structure is chosen considering the type of data and underlying process to be modelled. Second, the neural network is trained by using a sufficiently representation set of data. Third, the trained network is tested with different data, from the same or related sources, to validate that the mapping is of acceptable quality [13].

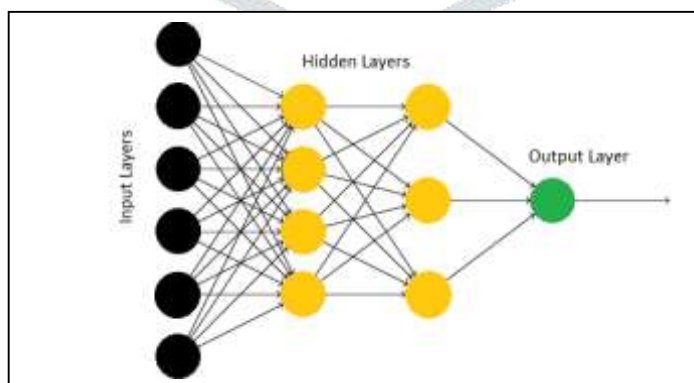


Fig1: A pictorial representation of a neural network

3. Data Preparation and Interpretation

We have made predictions for several countries: South Africa, United States, United Kingdom, Russia, Indonesia, Iran, Iraq, Bangladesh, Indonesia and India. Some of the countries were impacted heavily in the first wave of Covid-19 and now there is the onset of the third wave. The data post first wave is obtained from

[14] and predictions were made for the next 40 days. We have used Computer Algebra System: Mathematica-12 to analyse and predict the data.

The daily data of countries including new confirmed cases, new deaths, newly vaccinated is downloaded in real-time. The recovered cases are obtained by subtracting deaths from confirmed cases.

I. United States

The United States of America (US) is one the most severely impacted countries in the world by Covid-19 in both the first and second waves. The total population (in 2021) is 331 million and cumulative confirmed cases are 33.2 million (10% of the population). The total number of people vaccinated in the US accounts for 330.6 million, which is over 50% (two doses desired in most of the vaccinations) of the population (as of 5th July 2021) The average vaccination per hundred is 98.85. As of date, the daily deaths are around 500 while the total deaths due to Covid-19 so far are 0.6 million.

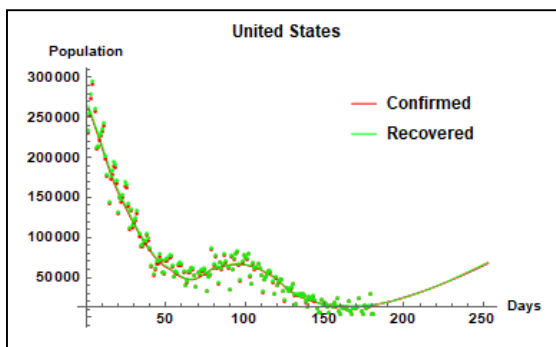


Fig. 2: Daily Confirmed and Recovered cases

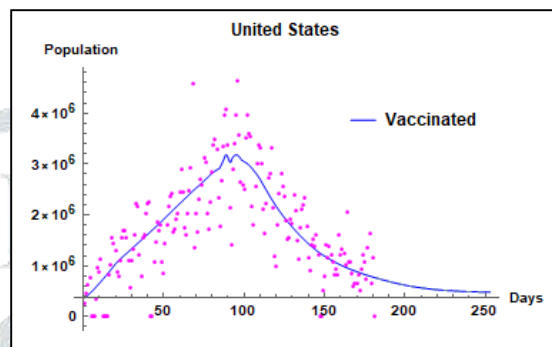


Fig. 3: Daily Vaccinated cases

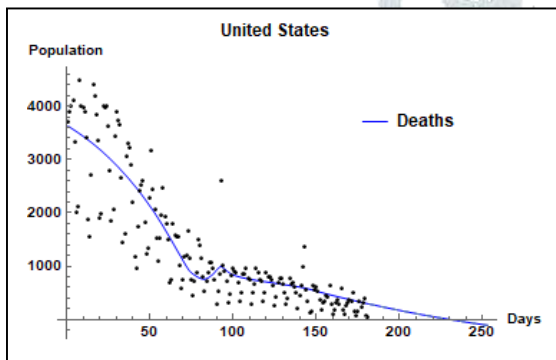


Fig. 4: Daily Death cases due to Covid

Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (*Fig.2-4*) with training: testing ratio as 60: 40. The training period is of 180 days (05/01/2021– 04/07/2021) and the testing period is 72 days (04/07/2021–14/09/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

II. United Kingdom

The United States of Kingdom (UK) was severely impacted by Covid-19 in both the first and second waves. The total population (in 2021) is 67.89 million and cumulative confirmed cases are 4.92 million (7.24% of the population). The total number of people vaccinated in the UK is 78.89 million, which accounts for over 50% of the population (as of 5th July 2021). The average vaccination per hundred (two doses required) is 116.21. As of date, the daily deaths are around 17 while total deaths due to Covid-19 so far are 0.13 million.

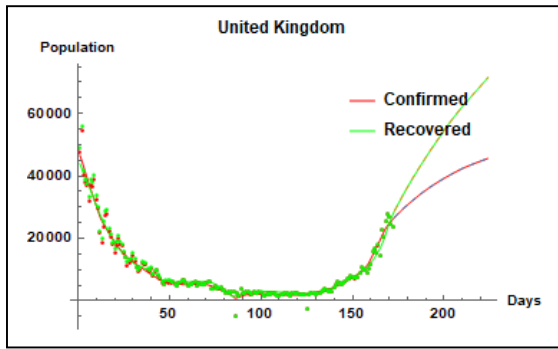


Fig. 5: Daily Confirmed and Recovered cases

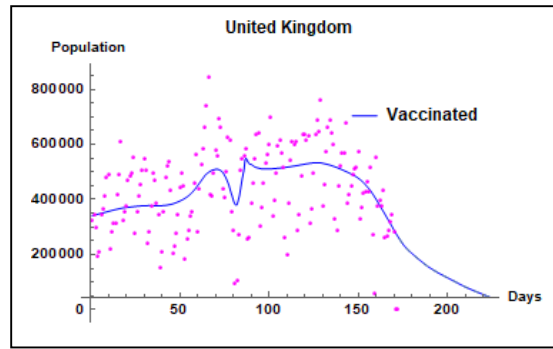


Fig. 6: Daily Vaccinated cases

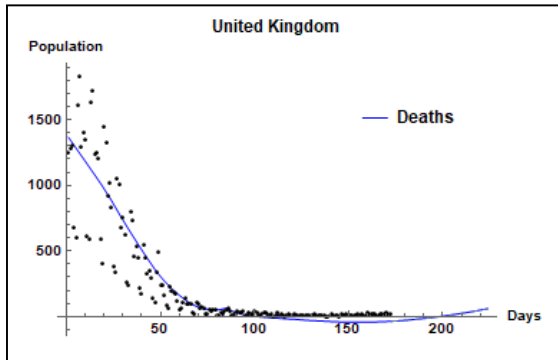


Fig.7: Daily Death cases due to Covid

Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (Fig.5-7) with training: testing ratio as 70: 30. The training period is of 171 days (14/01/2021–04/07/2021) and the testing period is 52 days (04/07/2021–25/08/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

III. Russia

Russia was also severely impacted by Covid-19 in both the first and second waves with infected cases in a day above 200,000 and above 500,000 in June 2020 and January 2021, respectively. The total population (in 2021) is 145.93 million and cumulative confirmed cases are 5.4 million (3.7% of the population). The total number of people vaccinated in Russia is 42.83 million, which is over 10% of the population (as of 5th July 2021). The average vaccination per hundred is 29.3. As of date, the daily deaths are around 652 while the total deaths due to Covid-19 so far are 0.13 million.

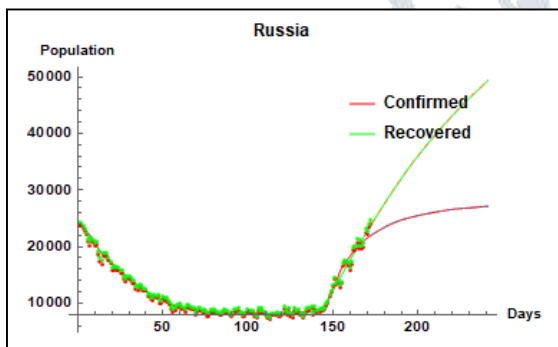


Fig. 8: Daily Confirmed and Recovered cases

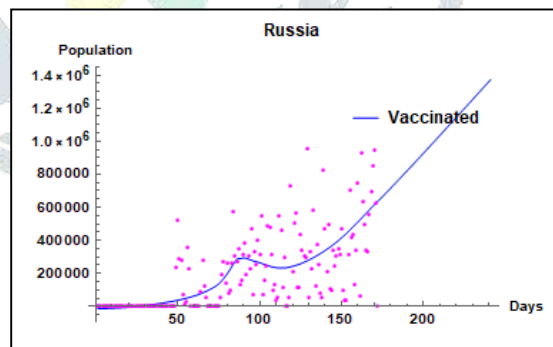


Fig. 9: Daily Vaccinated cases

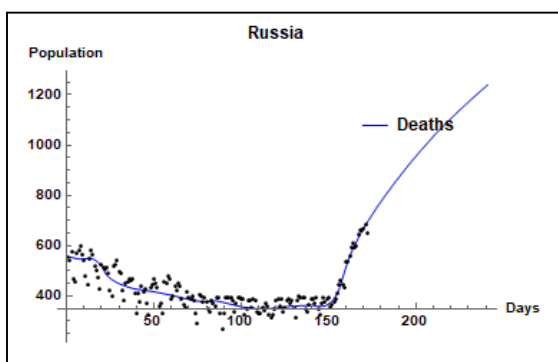
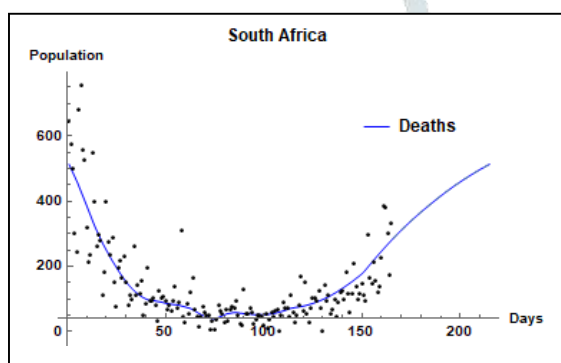
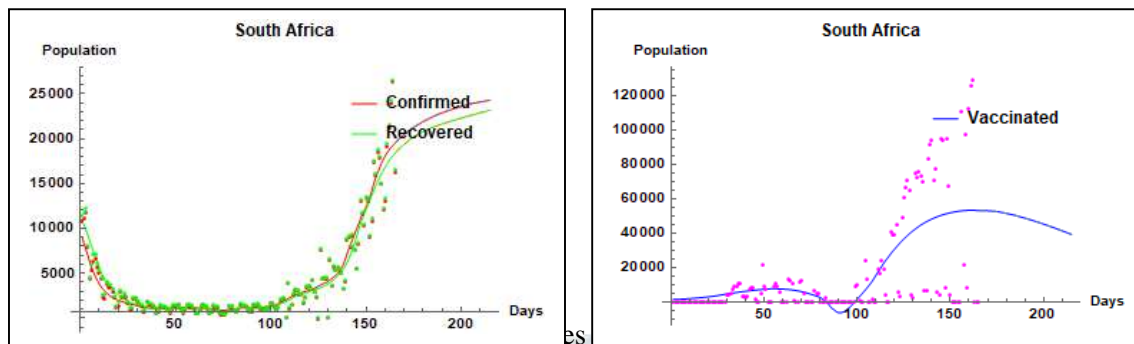


Fig.10: Daily Death cases due to Covid

Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (Fig.8-10) with training: testing ratio as 60: 40. The training period is of 171 days (14/01/2021–04/07/2021) and the testing period is 69 days (04/07/2021–11/09/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

IV. South Africa

The daily infected population had a peak in the first wave nearly less than 200,000 while in the second wave was over 200,000 in South Africa which was impacted severely by Covid-19. The total population (in 2021) is 59.31 million and cumulative confirmed cases are 2.06 million (4.3% of the population). The total number of people vaccinated in South Africa is 3.31 million, which accounts for nearly 5% of the population (as of 5th July 2021). The total vaccination per hundred is 5.59. As of date, the daily deaths are around 277 while the total deaths due to Covid-19 are 61840.



Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (Fig.11-13) with training: testing ratio as 70:30. The training period is of 164 days (21/01/2021–04/07/2021) and the testing period is 50 days (04/07/2021–23/08/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

Fig.13: Daily Death cases due to Covid

V. Indonesia

The first wave in Indonesia was a shorter one with approximately 65,000 daily infected cases while the second wave had 175,000 daily infected cases at its peak. The total population (in 2021) is 273.52 million and cumulative confirmed cases are 2.28 million (0.8% of the population). The total number of people vaccinated in Indonesia is 46.04 million, which is over 10% of the population (as of 5th July 2021). The average vaccination per hundred is 16.83. As of date, the daily deaths are around 492 while the total number of deaths due to Covid-19 is 60,582.

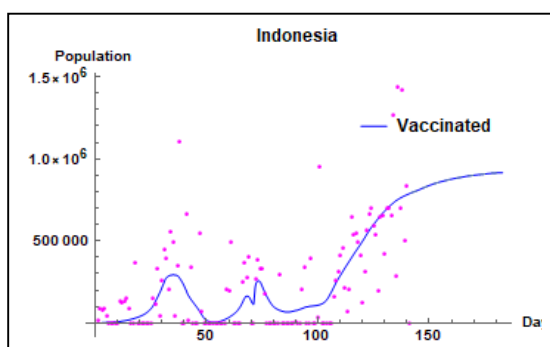
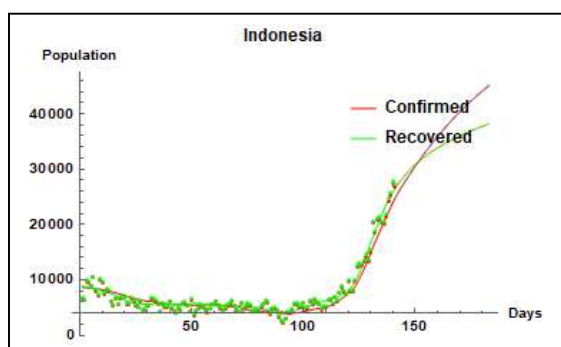


Fig. 14: Daily Confirmed and Recovered cases Fig. 15: Daily Vaccinated cases

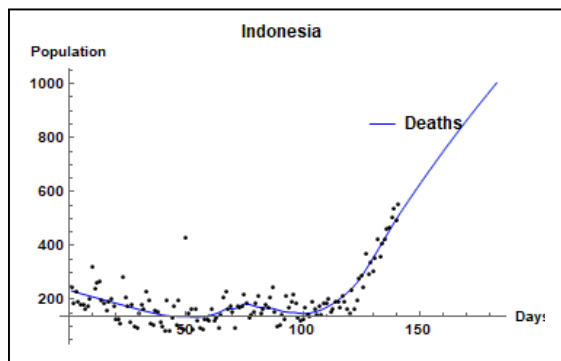


Fig.16: Daily Death cases due to Covid

Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (Fig.14-16) with training: testing ratio as 70:30. The training period is of 140 days (14/02/2021–04/07/2021) and the testing period is 42 days (04/07/2021–15/08/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

VI. Iran

The first wave in Iran began in August end with a peak of almost 14,000 while the second wave was shorter in duration with approximately 25,000 infected cases at its peak. The total population (in 2021) is 83.99 million and cumulative confirmed infected cases are 3.27 million (4% of the population). The total number of people vaccinated in Iran is 5.72 million, which is above 5% of the population (as of 5th July 2021). The average vaccination per hundred is 6.81. As of date, the daily deaths are around 135 while the total number of deaths due to Covid-19 is 84,792 so far.

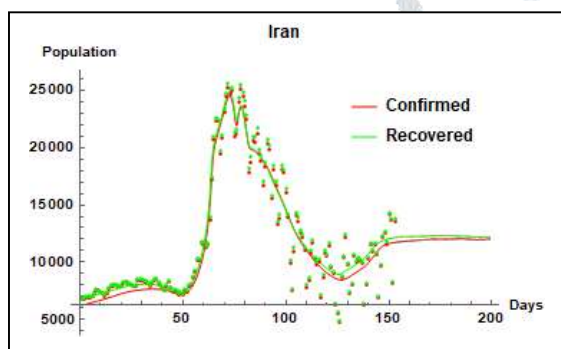


Fig. 17: Daily Confirmed and Recovered cases

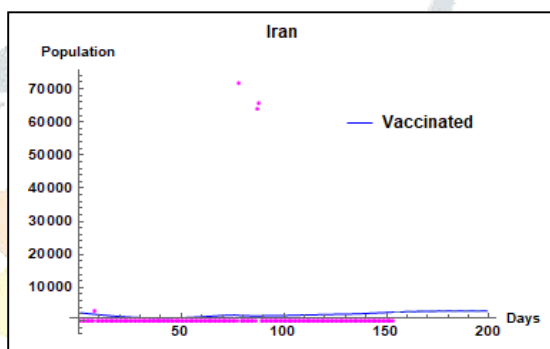


Fig. 18: Daily Vaccinated cases

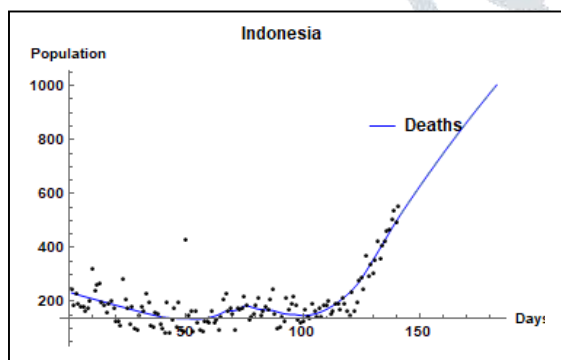


Fig.19: Daily Death cases due to Covid

Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (Fig.17-19) with training: testing ratio as 70:30. The training period is of 140 days (02/02/2021–04/07/2021) and the testing period is 31 days (04/07/2021–04/08/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

VII. Bangladesh

In Bangladesh, the first wave began in April 2020 and touched above 4000 daily infected cases at its peak while the second wave began before the first wave finished. The third wave beginning at the end of February 2021 lasted mid-May, 2021 with 7000 daily infected cases with a cumulative 800,000 confirmed infected cases to date. Now, the fourth wave has already begun. The total population (in 2021) is 164.69 million. The total number of people vaccinated in Bangladesh is 10.1 million, which accounts for nearly 3.5% of the population (as of 5th July 2021). The total vaccination per hundred is less than 6.14. As of date, the daily deaths are around 128 while the total number of deaths due to Covid-19 is 15,065 so far.

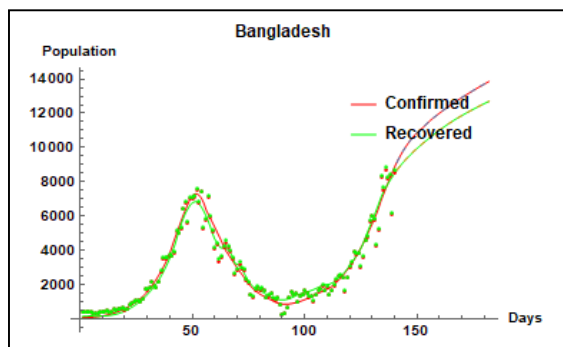


Fig. 20: Daily Confirmed and Recovered cases

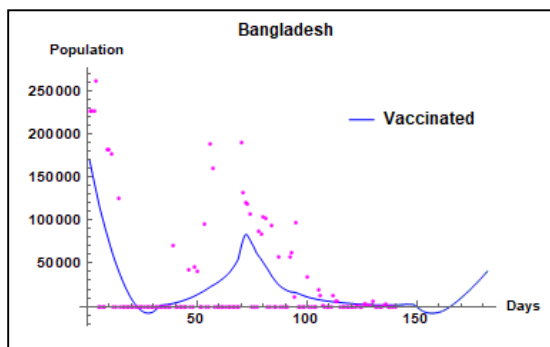


Fig. 21: Daily Vaccinated cases

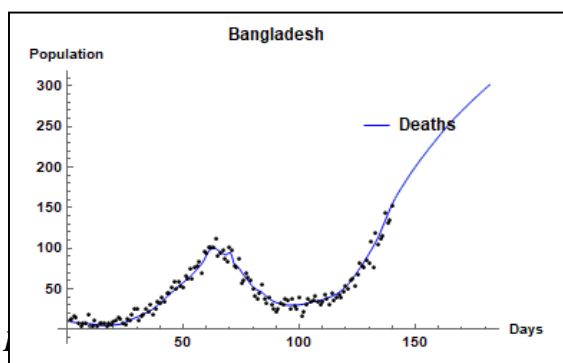


Fig.22: Daily Death cases due to Covid

Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (Fig.20-22) with training: testing ratio as 70:30. The training period is of 140 days (02/02/2021–04/07/2021) and the testing period is 31 days (04/07/2021–04/08/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

VIII. Iraq

The first wave in Iraq began at the end of April 2020 while the second wave at the end of January 2021. The first wave had a peak at 5000 infected cases in a day while in the second wave the active cases were almost doubled. The third wave has already begun. The total population (in 2021) is 40.22 million and cumulative confirmed cases are 1.3 million (3.23% of the population). The total number of people vaccinated in Iraq is 805,363, which accounts for over 1% of the population (as of 5th July 2021). The average vaccination per hundred is above 2. As of date, the daily deaths are around 32 while the total number of deaths due to Covid-19 is 17,316 so far.

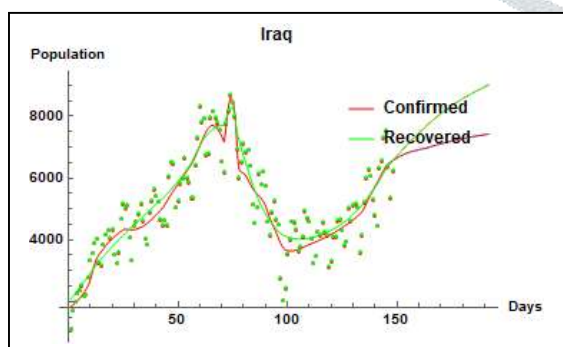


Fig. 23: Daily Confirmed and Recovered cases

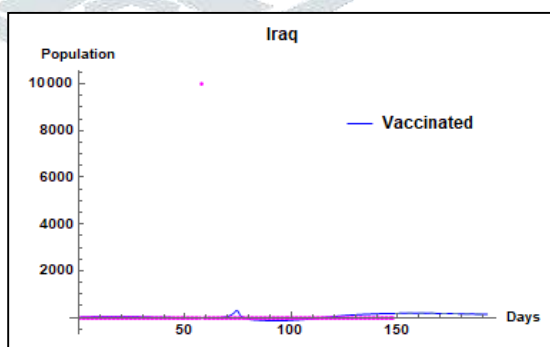


Fig.24: Daily Vaccinated cases

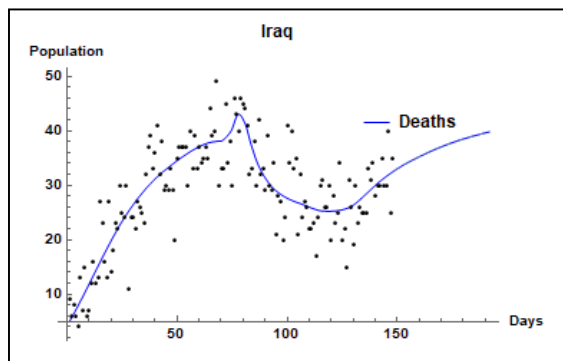


Fig.25: Daily Death cases due to Covid

Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (Fig.23-25) with training: testing ratio as 70:30. The training period is of 147 days (02/02/2021–04/07/2021) and the testing period is 44 days (04/07/2021–17/08/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

IX. India

The first wave in India began in the mid of February 2020 while the second wave at the end of February 2021. The first wave had a peak above 100,000 infected cases on a single day while in the second wave the active cases were quadrupled. The third wave is yet to begin. The total population (in 2021) is 1.38 billion and cumulative confirmed cases are 30.6 million (2.27% of the population). The total number of people vaccinated in India is 347.38 million, which is over 20% of the population (as of 5th July 2021). The average vaccination per hundred is 25.17. As of date, the daily deaths are around 856 while the total deaths due to Covid-19 are 402,728 so far.

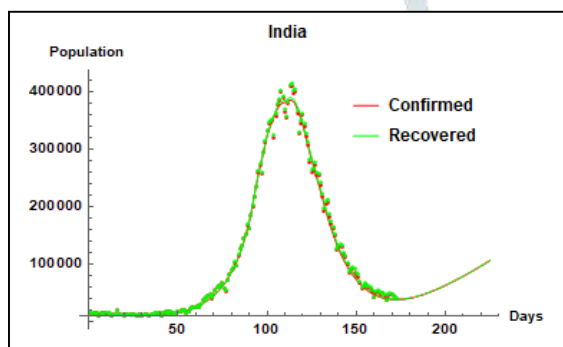


Fig. 26: Daily Confirmed and Recovered cases

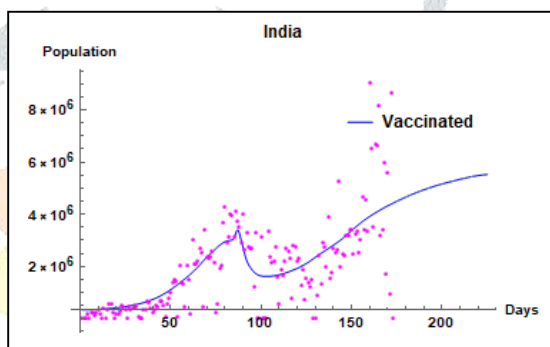


Fig. 27: Daily Vaccinated cases

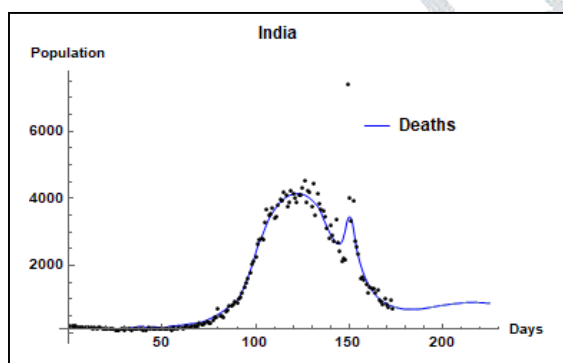


Fig.28: Daily Death cases due to Covid

Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (Fig.26-28) with training: testing ratio as 70:30. The training period is of 172 days (13/01/2021–04/07/2021) and the testing period is 52 days (04/07/2021–25/09/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

X. Malaysia

The first wave in Malaysia was very mild with hardly 300 active cases at its peak. The second wave began in mid-September 2020 and before its end, the third wave began in April 2021. The second wave had a peak of approximately 50,000 active cases a day while the third wave had a peak of 90,000 cases a day in the first week of June 2021. The third wave revived in the first week of June 2021 with a peak of 67,000 infected cases a day. The total population (in 2021) is 32.37 million. The total number of people vaccinated in Malaysia is 9.01 million, which is over 10% of the population (as of 5th July 2021). The average vaccination per hundred

is 27.83. As of date, the daily deaths are around 79 while the total number of deaths due to Covid-19 is 5,497 so far.

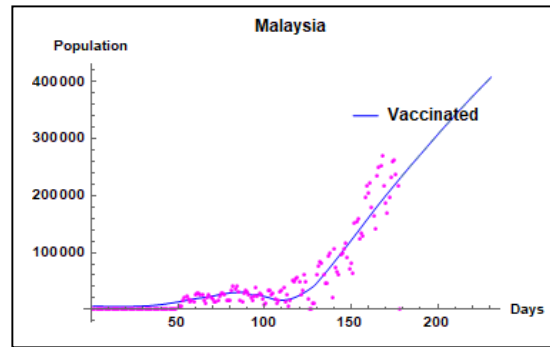
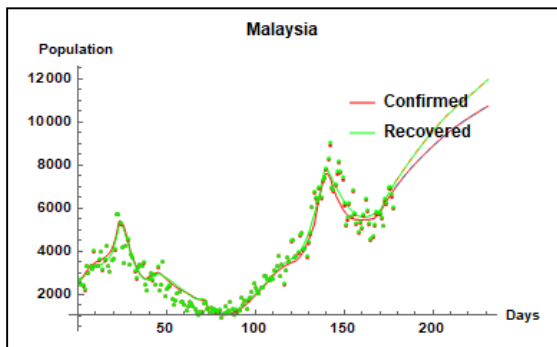


Fig. 29: Daily Confirmed and Recovered cases **Fig. 30:** Daily Vaccinated cases

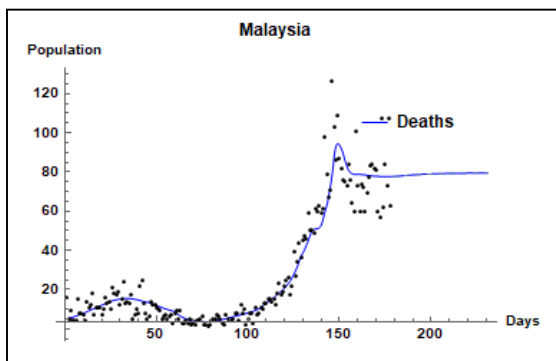


Fig.31: Daily Death cases due to Covid

Daily infected, recovered cases, daily vaccinated cases and daily deaths are plotted (**Fig.29-31**) with training: testing ratio as 70:30. The training period is of 172 days (13/01/2021–04/07/2021) and the testing period is 52 days (04/07/2021–25/09/2021). Here, the loss and standard deviation are in the confidence interval of 95%.

4. Conclusions

In this paper, we have used the neural network model architecture of deep learning for modelling and predicting the time series (with training: testing ratio as 60:40 or 70:30) for Covid-19 daily infected, recovered, deaths and vaccinated cases for 10 different countries namely: the United States, the United Kingdom, Russia, South Africa, Indonesia, Malaysia, Bangladesh, Iran, Iraq and India using the time-series data [14]. The trends are visible in the predicted graphs. It has been found that the deaths are on the rise where ever there is the onset of the third wave. The third wave in India is yet to come and may become severe in the next 50 days. Many countries except the United States have not vaccinated 30% of the population. This study will help in understanding the trends of the spread of the disease, mortality and vaccinations per day. These statistics will help the Government and citizens in formulating the Covid-19 related behaviour and policies to curb its spread.

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