2021 International Conference on Information and Communication Technology for Sustainable Development (ICICT4SD) | 978-1-6654-1460-9/21/$31.00 ©2021 IEEE | DOI: 10.1109/ICICT4SD50815.2021.9396820

Predicting COVID-19 infections and deaths in Bangladesh using Machine Learning Algorithms

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***Abstract*—Since December 2019, the novel coronavirus(COVID-19) has caused over 700,000 deaths with more than 10 million people being infected. Bangladesh, the most densely populated country in the world, is now under community trans-mission of the COVID-19 outbreak. This has created huge health, social, and economic burdens. Till the 10th of February 2020, Bangladesh has reported over 500,000 infected cases and 8000 deaths. To prevent further detriment in our scenario, predicting future consequences are very important. Studies have shown that machine learning(ML) models work extremely well in providing precise information regarding COVID-19 to the authorities thus enabling them to make decisions accordingly. However, to the best of our knowledge, no ML models have been applied that can help in determining the pandemic circumstance for Bangladesh demographics. In this study, we explore different machine learning algorithms that can provide more accurate estimations for predicting future cases which includes infections and deaths due to COVID-19 for Bangladesh. Based on this the government and policymakers can make a decision about the lockdown, resource mobilization, etc. Our study shows that in predicting the pandemic situations, amidst many predicting models the Facebook Prophet Model provided the best accuracy. We believe that using this information the authorities can take decisions that will lead to the saving of countless lives of the people. Additionally, this will also help to reduce the immeasurable economic burden our country is facing due to the present status quo. Furthermore, this study will help analysts to construct predicting models for future explorations.**

***Index Terms*—COVID-19, Corona Virus, Machine Learning, Time-series Analysis, Data Analysis, Regression Models, Forecasting Models, Facebook Prophet Model, Predictive Models, Bangladesh**

I. Introduction

Corona Virus Disease 2019(COVID-19) is a respiratory illness, caused by the new coronavirus that has been the purpose behind a global pandemic in 2020. The virus first emerged in Wuhan, China on December, 2019 [1]. As of now (February, 2020) the virus has reportedly claimed over 2.3 million lives while over 107 million have been infected by it. The rate at which the number of cases is increasing is of huge concern. Bangladesh, ranking 8th for highest population and being the most densely populated in the world is under severe threat from the COVID-19. To restrict the spread of coronavirus, the government of Bangladesh has imposed lockdown on the whole country from 27th March, 2020 [2]. Due to poverty being high and a significant amount of the population depending on daily income, Bangladesh cannot afford to continue enforced lockdown for a long period. Hence, the country needs to predict and understand the situation to overcome this issue.

Only 7 types of coronaviruses can infect humans. The first was discovered by scientists in 1965 [3]. Symptoms were mild, limited a common cold. In 2002, the virus that caused Severe Acute Respiratory Syndrome(SARS) was discovered in China [4]. The virus quickly spread to 28 countries. In total, 8403 people were infected and 775 deaths were reported [5]. In 2012, the Middle East Respiratory Syndrome(MERS) was discovered in Saudi Arabia [6]. Although, this virus was only limited to the Middle East it was much deadlier than the SARS virus with a mortality rate of almost 30. However, compared to SARS and MERS, the SARS-COV-2 which is the virus that causes Covid-19 is a different beast altogether.

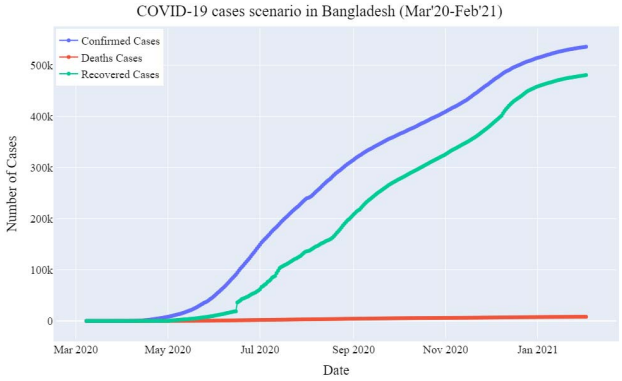

Fig. 1: Number of Confirmed cases, Deaths cases and Recoveries cases scenario in Bangladesh till 8th, February, 2021

In Bangladesh, the first coronavirus case was reported on 8th March, 2020 [7]. Since then it has infected over 500,000 people. Additionally, over 8000 lives were taken due to this virus. Figure 1 shows the growth of COVID-19 in Bangladesh. Almost 20% of the tests had positive results for infections and hence, the government had to enforce lockdown on the general population. This has resulted in an 80% reduction of the underprivileged people's income [8]. Furthermore, these lockdown has severely effected the food supply in Bangladesh [9]. Thus, the price of food and other necessities has increased, which is causing more issues for

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the underprivileged in Bangladesh. The ready-made garments (RMG) sector in itself is facing losses equivalent to $1.5 billion [10]. On top of this, Bangladesh being a tourist hotspot for foreigners is facing a significant loss in this sector due to travel being limited. Reports show that the tourism sector may face losses of upto 60 billion BDT from January to December [11]. Furthermore, the longer lockdown continues, the more it will affect the economy and the Growth Domestic Product(GDP) of Bangladesh. It is expected that Bangladesh will lose approximately 3 billion dollars in GDP [12].

To overcome this situation, information is required on how much of the population will be infected by the virus. These information will be key for the authorities to take decisions that will strike a balance between continuing lockdown and stabilizing the economy. The authorities can then decide how long lockdown needs to last, how much food needs to imported, how much budget to be used for medical services, etc. Previous studies have shown that machine learning(ML) models work well in predicting the number of COVID-19 cases [13]. Some of these ML models also work very well in predicting the number of deaths caused by COVID-19 [14]. Keeping all the above-mentioned points in mind, our objectives are as follows.

- Collecting time-series data of COVID-19 cases.
- Assess ML models to predict the total number of infections and the deaths due to COVID-19. Also, find out the best model for predicting cases for Bangladesh.
- Predict the number of people infected and the number of deaths for the upcoming month.

Utilizing the information given by this study, the policymakers will realize what choice to make a month ahead of time. Whenever used right, this planning will assist the government officials with striking a parity that will prompt negligible lives being lost and the most extreme usage of our assets to guarantee our economy remains stable. As of now, the nation is under desperate conditions and we firmly believe that our system will be the light at the end of the tunnel for Bangladesh.

The preprint for this paper is available at [15]

II. Background Study

Scientists all over the world have been trying to help in every possible way in humanities fight against COVID-19. In the computer science community, researchers are attempting to conjecture the potential cases in the coming days to help the administration planning for the most noticeably awful situations and act as needs be by assigning the perfect measure of assets. Studies have been conducted on data all over the world. In forecasting the COVID-19 scenario ML has had a huge impact. Shinde et al [16] described the importance of the forecasting model to predict the pandemic situation. They have presented some parameters which play a crucial rule in the pandemic situations. In their study, they have provided some recommendations for forecasting. They have suggested the most important parameters for predicting pandemic situations. In their study, they suggest some ML models like Logistic regression, Weibull equation, and the Hill equation to find infection rates. For the challenging part, they showed that tracking of people is a very difficult task, the longer incubation period is also challenging for forecasting models. Results indicated how a lack of proper data had a negative impact on forecasting. Rustam et al [17] have used SVM, Least Absolute Shrinkage and Selection Operator (LASSO), Linear Regression(LR), and Exponential Smoothing(ES) for forecasting COVID-19 confirmed cases, the number of death cases, and the number of recoveries for following 10 days. Gupta et al [18] worked on the growth rate of infected cases and found that lockdown event has negative effects on the number of infected cases. They used ES and Polynomial Regression (PR) models to predict the cases. Sujath et al [19] In their research used LR, Multilayer perceptron (MLP), and Vector Auto-Regressive (VAR) for forecasting COVID-19 cases in India. These studies have used the datasets from John Hopkins GitHub repository and Kaggle datasets in their studies [20].

Researchers from various nations have presented numerous techniques. To the best of our knowledge, no significant research has been found on Bangladeshi data.

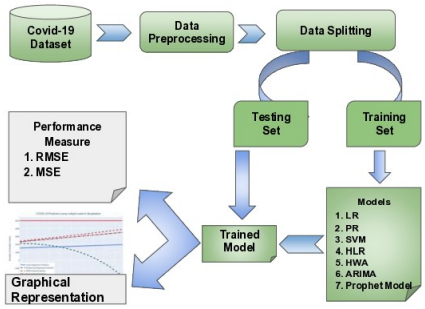

Fig. 2: Overview of System Architecture for COVID-19 analysis and prediction in Bangladesh

III. Methodology

In this section, methods are presented through which we can accurately predict the number of COVID-19 cases, and the number of deaths due to COVID-19. The overview of our system is shown in figure 2. For this research, we are using the Time Series dataset provided by John Hopkin University, USA [20]. Our first step was to break down the datasets into 3 parts, training, validation, and testing sets. Then using this dataset we tested several machine learning models(i.e, Linear Regression(LR), Polynomial Regression(PR), Support Vector Regression(SVR), Auto Regressive Model(AR), Moving Average Model(MA) Holt's Winter Additive Model (HWAM), Auto Regressive Integrated Moving Average Model(ARIMA), Facebook Prophet's Model(FPM) to find out which algorithms performed the best on the dataset. We used the Root Mean Square Error(RMSE) [21] to assess how well the algorithms worked. Details about the models we used are given below.

A. Preparing the Dataset

Data processing is a fundamental part of machine learning. We used the time-series data of the Center of System Science and Engineering (CSSE) [20]. CSSE collected data from

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different government published sources and other sources(e.g. WHO, ECDC, US CDC, BNO New). The data was preprocessed after assortment. We collected the data from their official repository[1]. The repository contained data from all the countries around the globe. From here, we extracted the data for Bangladesh. After extracting Bangladesh's data we determined the date of the first COVID-19 case confirmed in Bangladesh which was 8th March 2020. The dataset for CSSE contains data starting from 21st January. In our case data from 21st January to March 7th was removed and the data from 8th March to 8th February 2021 for our research.

B. Root Mean Square Error

Root Mean Square Error is a standard method to calculate the performance of a model in predicting values based on Time Series Data. Previous research has suggested that RMSE is a good indicator of how well a model performs [22]. It can found by using the formula 1.

$$RMSE = \text{root of}(\tfrac{1}{n}\Sigma_{i=1}^{n}\left(\tfrac{d_i - f_i}{\sigma_i}\right)^2) \tag{1}$$

C. Polynomial Regression

Polynomial Regression is a special kind of regression approach to finding the correlation between two variables is found using the nth degree polynomial of the dependent variable [23]. For our research, we used 6 degree polynomial.

D. Support Vector Regression

Support Vector Regression(SVR) is a concept of Support Vector Machines(SVM) [24]. Here the process of Kernalization [25] is used to find the similarity between two points. The objective of the SVR is to find the hyperplane between the support vectors close to the plane. This maximizes the difference between two separate classes thus making this algorithm very versatile. For our system, we are using the polynomial kernel since previous research has shown that it can be on par with other state-of-the-art kernels [26]. For our system, the epsilon value(acceptable error) is equivalent to 0.01.

E. Holt's Winter Model

The HWA [27] Model is a model for time series data analysis. It consists of 3 smoothing equations- the average value, slope, and seasonality(repeating patterns in a time series) and forecasting equations. The equations are given below.
The average is given by equation 2. Slope is give by equation 3. Seasonality is given by equation 4. The forecasting equation is given by equation 5. We used the additive method because this method is preferred when the seasonal variation is constant.

F. ARIMA Model

The ARIMA is a regression analysis based model used to visualize time series data and predict future movements from past data [28], [29]. The model consists of 2 parts: Auto Regressive(AR) and Moving Average(MA). The AR model uses data to make future predictions. Results from the previous step is used as input to compute the value of the next step. The equation for the AR model is given in equation 6. p is the order of the model. The MA model uses previous errors as input. The MA model compares how inaccurate the model was in the past to rectify it and get a better result in the future [30].

The forecasting equation for the ARIMA model can be given by equation 7, where p is the autoregressive term, d is the number of non-seasonal differences and q is the number of forecast errors. For our system, we initialized p and q at 0 and continued until they had a maximum value of 5.

$$A_t = \alpha(\tfrac{X_t}{I_{t-s}}) + (1-\alpha)(S_{t-1} + T_{t-1}) \tag{2}$$

$$T_t = \gamma(S_t - S_{t-1}) + (1-\gamma)(T_{t-1}) \tag{3}$$

$$I_t = \delta(\tfrac{X_t}{S_t}) + (1-\delta)(I_{t-1}) \tag{4}$$

$$\bar{X}_t(k) = (S_t + T_t k) I_{t-s+k} \tag{5}$$

$$y_t = c + \theta_1 y_{t-1} + \theta_2 y_{t-2} + ... + \theta_p y_{t-p} + \epsilon_t \tag{6}$$

$$\bar{y_t} = \mu + \alpha_1 y_{t-1} + ... + \alpha_p y_{t-p} - ... - \theta_q e_{t-q} \tag{7}$$

G. Facebook Prophet Model

The Facebook Prophet Model is a model used for predicting time series data [31]. This model is perfect to be used in data that contains seasonality and has an abundance of historic data. The biggest advantage is that this model is robust in handling missing values or changes in trends of the data [32]. Similar to HWA model, The Facebook Prophet Model consists of 3 main components- Trend, Seasonality and Holidays.

1) Trend: Trends are time-based functions which represent how a time series data will grow in the future steps [33]. This growth model can be found by using the equation 8. Time Series data may have sudden changes in their gradients known as changepoints(CP). FP detects these trends and adapts to them. The Prophet Model specifies potential CP positions distanced uniformly from one another at the start of the time series. The model checks for changes in trends at these locations. For our model, we used 25 CP. The trend flexibility was set at 0.05 to ensure overfitting and underfitting does not occur.

2) Seasonality: The trends calculated from above is summed up with weekly periods known as seasons. Seasonality is summed up with the Trend. For seasonality, repetitive patterns for a specific period is calculated. These periods are found using the Fourier Transform. Smoothing of the seasonal effects is completed afterward. The equation can be given by 9. In our case, the value of interval width is 0.95 and the value of changing range is 0.9 to fit seasonal patterns rapidly. Increasing it more made the model overfit.

$$g_t = \tfrac{C_t}{1+exp(-(k+(a(t))^T\delta)(t-(m+(a(t)^T\gamma)))} \tag{8}$$

$$s_t = \textstyle\sum_1^N (a_n cos(\tfrac{2\pi nt}{P}) + b_n sin(\tfrac{2\pi nt}{P})) \tag{9}$$

$$Z_t = [1(t \in D1), ..., 1(t \in DL)] \tag{10}$$

$$y_t = g_t + s_t + h_t + \epsilon_t \tag{11}$$

[1](https://github.com/CSSEGISandData/COVID-19)

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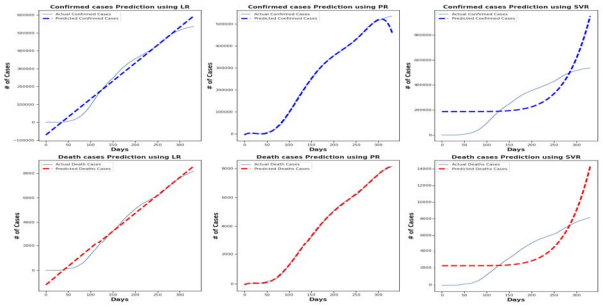
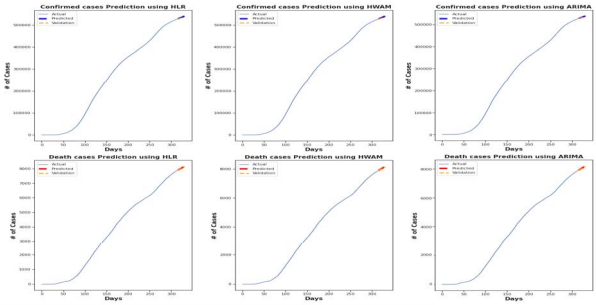


(a)



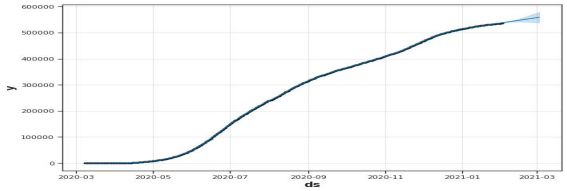
(b)

Fig. 3: Analysis of COVID-19 using Regression (Figure3a) and Time Series Models (Figure 3b). Confirmed(Top Row) and Death(Bottom Row) Cases, LR(Left), PR (Middle) and SVR (Right) models **(Figure 3a)**. Analysis of Confirmed(Top Row) and Death(Bottom Row) Cases using HLR (Left), HWA (Middle) and ARIMA (Right) models **(Figure 3b)** .

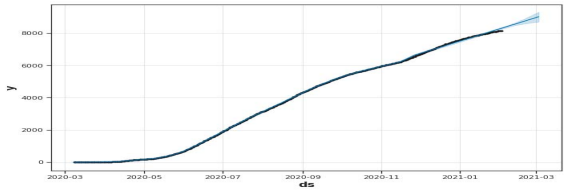
3) Holiday: Holidays are events at a specific time which significantly alter the way a time series progresses [34]. Holidays are not periodic and so they need to be given as input. For our case, we used the dates at which the country was under lockdown(26 March-30 May 2020) as the Holiday period. The Holiday effect can be calculated using the equation 10. Holidays influence the days surrounding those dates which were given as input [35]. All these 3 are summed up to find the forecasting equation given by equation 11. It is assumed that the error is normally distributed [31].

IV. Results

This section describes the results achieved by running these ML models. First, we assessed the results by calculating the RMSE of all the models. Using these values we found the 4 best models in predicting the number of cases and deaths due to COVID-19. The results generated by the Regression, Time Series models and FP models are given in Figure 3 and 4 respectively. From the figures 3 and 4 we can see how the models performed on the test sets. Using these results we can find the RMSE for each of the models. Table I shows the comparison of the models with respect to their RMSE scores.



(a) Confirmed Cases analysis and prediction



(b) Death Cases analysis and prediction

Fig. 4: Prediction of Confirmed Cases (Left) and Death Cases (Right) using Facebook Prophet's Model

TABLE I: Average RMSE Comparison for Number of Confirmed cases and Deaths cases prediction

Model Used	**Predicted Cases**	
	Confirmed Cases	***Death Cases***
Linear Regression	52627	372
Polynomial Regression	50430	112
Support Vector Regression	275176	4902
Holt's Linear Model	1521	13
Holt's Winter Additive Model	1911	11
Auto Regressive Model	1884	14
Moving Average Model	2026	18
ARIMA Model	1250	16
Facebook Prophet's Model	518	32

FP has the least average error when predicting confirmed cases followed by the ARIMA and HWA model.

TABLE II: Prediction of confirmed cases for upcoming 1 month

Date	**Predicted Cases**			
	PR	***HWA***	***ARIMA***	***Prophet***
2020-02-10	435939	542471	542028	541360
2020-02-12	419688	543681	543224	542580
2020-02-14	401632	544892	544426	543800
2020-02-16	38165	546102	545636	545020
2020-02-18	359645	547312	546853	546240
2020-02-20	335473	548523	548077	547460
2020-02-22	309014	549733	549308	548679
2020-02-24	280136	550944	550546	549899
2020-02-26	248700	552154	551791	551119
2020-02-28	214564	553364	553043	552339
2020-03-02	177579	554575	554302	553559
2020-03-04	137593	555785	555568	554779
2020-03-06	94446	556996	556841	557218
2020-03-08	47973	558206	558121	557828

V. Discussion

As mentioned above the results show that PR, HWA, ARIMA, FPM provide very good results with low RMSE scores. Historically, it has also been shown that PR works well

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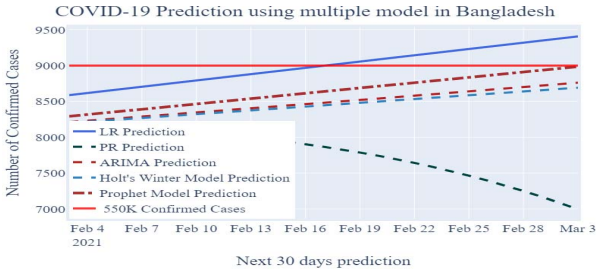
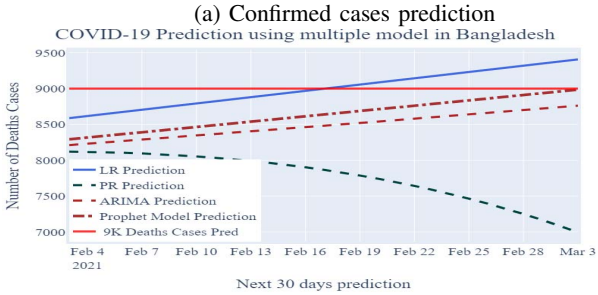


(a) Confirmed cases prediction



(b) Death cases prediction

Fig. 5: 8th Feb to 8th March Prediction of Confirmed(Top) and Death(Bottom) Cases using ML Models

TABLE III: Prediction of deaths for upcoming 1 month

Date	Predicted Deaths			
	PR	***HWA***	***ARIMA***	***Prophet***
2020-02-10	7944	8277	8270	8413
2020-02-12	7892	8307	5622	8456
2020-02-14	7830	8338	8353	8500
2020-02-16	7756	8369	8387	8550
2020-02-18	7668	8400	8421	8596
2020-02-20	7567	8431	8455	8637
2020-02-22	7451	8462	8489	8683
2020-02-24	7320	8492	8524	8733
2020-02-26	7171	8523	8558	8775
2020-02-28	7005	8585	8593	8820
2020-03-02	6820	8585	8628	8870
2020-03-04	6615	8616	8663	8916
2020-03-06	9667	6092	6235	8956
2020-03-08	6140	8677	8734	9002

in smoothing time series curves [36]. The COVID-19 growth curve is yet to start smoothing and so the PR model could not fit well with the data. The HWA model, on the other hand, worked best in the past for forecasting sales [37]. However, recent studies [38] showed that the ARIMA models did much better than the HWA for forecasting and hence, it has been one of the more popular. In 2018, Taylor et al proposed a model for predicting time series [31], the FP Model. Compared to the ARIMA model FP works very well with large outliers [39]. The FP is also more robust to missing values and changes in trends [40]. Added to this, it fits very quickly to the data [41]. Further studies have reinforced the fact that the FP works best in forecasting sales [35] and other time series analysis.

Applying the FPM, ARIMA, HWA, and PR models predictions were made for the coming one month(February - March 2021). Figure 5 shows us the prediction for the total number of COVID-19 confirmed and death cases till the month of September. From table I we have demonstrated that the Facebook Prophet Model gives the best outcomes. Hence, we will only concern ourselves with the FPM in this section. Table II and III gives us a tabular version of the results we get using our predictions. From the results, it can be observed that Bangladesh is projected to hit 550,000 cases by 24th February 2021 and 9000 death cases reached by 9th March 2021. Prior reports proposed that 2% of the cases might be deadly [42]. With under 1200 Intensive Care Units(ICU) in the entire nation, [43], the numbers suggest that the current facilities will not be enough to take of the severe cases of COVID-19. The circumstance appears to be much more terrible when it is considered that only 1769 ventilators [44] can be provided when lung diseases will be at its pinnacle. Taking all this into account, the Facebook Prophet model predicts that by the end of this month the death toll will exceed 8800. Be that as it may, numbers can deteriorate if the patients can't be treated because of the limited treatment facilities. With community transmission occurring right now, COVID-19 has spread to the majority of the districts [45]. The issues talked about above proposes that the authorities must intervene right away. Firstly, they will need to take the necessary actions to install more ICU's and ventilators and increase treatment facilities. Research in India who are in a comparative stance to Bangladesh have shown that lockdown helps in drastically cutting down the number of infections due to COVID-19 [46]. The government must enforce lockdown on the people again to ensure that the infection doesn't spread more, particularly to the region of Cox's Bazar where the Rohingya camps are found. Social attention to the threats of COVID-19 should likewise be promoted and it must be guaranteed that the individuals maintain social distancing and personal hygiene. Added to this, the government also needs to allocate sufficient funds to conduct research on COVID-19 to try and develop vaccines that will help us to treat our patients until a cure is developed.

VI. Conclusion

The severe acute respiratory syndrome caused by the novel coronavirus has already taken over 2.3 million lives. The global pandemic caused by this virus has influenced the lives of almost everyone in the year 2020 and is the primary target everyone is combating to dispose of. The current situation is one of the most crucial phases of Bangladesh's battle against COVID-19. The country has been hit hard throughout the last 5 months. Machine Learning can provide very accurate information on how the pandemic situation will affect us. Using the valuable forecasted information provided by our system, the authorities will know what decision to make a month in advance. When used right, this preparation will assist the policymakers to strike a balance that will lead to minimal loss of lives. Furthermore, it will ensure the maximum utilization of our resources to ensure our economy is still booming. This paper additionally provides a backbone for future researchers who are willing to create better ML models for better gauging of data.
However, for future studies, the system can be improved in

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numerous ways. The models designed in this study were not used to predict the mortality rate which provides significant insights into assessing how a region is being influenced by the virus. Although the lockdown period was taken under consideration when using the Facebook Prophet Model, it was neglected while using the other models. This may have resulted in them giving not as good prediction results. The results of the models could have been further improved if data for all regions in the country were accessible distinctly.

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