Deep learning time series to forecast COVID-19 active cases in INDIA: a comparative study

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Abstract. In the present situation of “COVID-19 pandemic” which devastated worldwide socioeconomic implications that led by Indian government to initiate and to perform intense procedures to control the spread and impact by dispensing the capability to predict the outbreak, which hits the crest to decrease the impact of disease and guiding the government to update its policies as required for implementing protective steps needed for “Public Health System (PHS)”. These methodologies tend to be transforming among people for improvisation of vigor system. In this paper, we investigate thoroughly the precision of various “Time series” modeling techniques for detecting “corona virus outbreak” in topmost ten different states with the maximum number of “confirmed cases” as on 31 August 2020. We implemented six different deep learning approaches on time series for comparing the values associated in datasets that relates to the progression of the virus in each state based on the population as the attained results represent the scaling of time series methods accurately and predict various affected aspects in near future.

Keywords: COVID-19, coronavirus, machine learning, statistics, time-series

1. Introduction

The “Coronavirus disease” 2019 also called as “COVID-19” [1] instigated to be the innovative rigorous “acute respiratory syndrome coronavirus” 2 also called as “SARS-CoV-2” [2] which has been emerged into a worldwide virulent disease and is still in progress [2]. Initially it has been renowned in “December 2019 at Wuhan, China” [4] to be the enduring epidemic which has drastically effected almost every part of the world as on 31st August 2020. Whereas specifically in India more than 3.6 million medical cases have been identified in 7 union territories and 29 states resulting in more than 64,631 deaths and 2.7 million people have recovered [5].

In order to tackle the pandemic situation most of the states have put into practice procedures such as “self isolation”, “physical distancing”, “self quarantine” for preventing the auxiliary spread as it is therefore devastating the epidemic curve that leads to elude and being critical in sustainability of health services to the infected patients based on the severity of their health condition.

The methodology adopted in order to identify the spreading of disease the ability to identify leads us in crucial aspects for fight hostile to the pandemic situation by considering the certainty of expansion at a given specific instance in time span that has the possibility to help state and central governments in taking measures towards the public health and policy making for addressing the
consequences attained and to be obtained [6]. One of the probabilistic methods to implement is to accurately perform testing at a larger extent as in India it crossed 42 million samples are tested in various states and the testing ratio varies from state to state based on the severity is being 0.03%.

In this paper we use the deep learning statistical approach over the “Time series” methods that are anticipated to predict the proportion of “active cases” compared with respect to the total population of India in that particular state by using “Time series” approaches such as “ARIMA” [7], “Holt–Winters additive model (HWAAS)” [8], “TBAT” [9], “Facebook’s Prophet” [10], “DeepAR” [11] and “N-Beats” [12] are used for evaluating the metrics using the “Root Mean Squared Error (RMSE)” [32] is used to measure the functioning of each of the “time series model” and the results indicates that the approach predicts the active cases as the ARIMA and TBAT demonstrates greater performance in accessing.

2. Related work
Most of the researchers have done lot of research in this area and some of the predominant works includes:

In reference [13] comprises of ARIMA model that identifies the occurrence of repeating patterns in a cyclic manner that influences the seasonal aspects for performing “time series modeling” to forecast the future outbreaks and in reference [14] which comprises of a “time series prediction model (Tempel)” [22] which will mutate the forecast of influenza [23] a viruses which is based on the weekly time series implementation for flu related tweet counts that are performed over real-time evaluation in spreading of the influenza. In reference [15] consists of the construction process of SARIMA model specific to a region based on the query implementation over the internet searches being performed to predict an attribute of seasonal influenza epidemic and the time series modeling will perform investigation over the role of climate factors that leads to the epidemiology in transmission based on the climatic conditions.

In reference [16] an updated stacked autoencoder based on the deep learning model is implemented to predict the implementation of COVID-19 active cases as the autoencoder network comprises of four layers: “input, first latent layer, second latent layer and the output layer” with many numeral nodes that comprises of 9, 30, 5 and 2 with 8 key points in a input network that is fed into clustering algorithms for obtaining the singular value decomposition and the resultant errors in model are low when the confidence applied to attain the forecast is accurate.

In reference [17] the discrete time and stochastic agent based model is updated using the ACEMod (Australian Census based Epidemic Model) that models the COVID-19 cases incurred in Australia
over a specific time by considering the attributes such as “age, occupation, gender, susceptibility and immunity levels” to predict the virus and level of contact rates that include the interference strategies such as “social distancing, school closures, travel bans, and case isolation” that are estimated using the tuned model that is practiced.

In reference [18] proposed a process of detecting COVID-19 virus using the data attained through sensors available in Smartphone like “cameras, microphones, temperature and inertial sensors” for accessing the virus indications by comparing the previously obtained data that is utilized in medical Kits or CT scans taken and the temperature attained through finger print sensor as the fever level of prediction and the audio obtained through mobiles microphone used for identification of cough type.

In reference [18] proposed the “hybrid AI model” for predicting the COVID-19 virus spread rate by adding the “Epidemic Susceptible Infected (ESI)” model [28] and NLP as a deep learning tool [29]. As the “Susceptible Infected Recovered (SIR)” [29] model is the conventional epidemic model for performing modeling and predicting the life span of infectious using differential equations to characterize the relationship and proposed a NLP model that is used to obtain the semantic features that is related to current research area as the epidemic is currently influencing the measures to be taken by governments or individuals by the knowledge attained towards the prevention of virus using the “Long Short Term Memory (LSTM)” deep learning model that comprise of molecular impact on COVID-19 patients.

In reference [19] has proposed deliberately the machine learning models like “Generative Autoencoders (GANs)” [36], “Genetic Algorithms and Language Models (GALM)” [35] used for exploiting the molecular characterization in creation of optimizing reinforcement learning structures that synthesizes and evaluates the attained molecules by exploiting the maximum drugs that are similar to chemical space that extracts the knowledge from higher dimensional data for constructing the model.

3. Time series model description
The Time series forecasting [2] primarily focuses on performing the analysis on various observations made from the previously attained observations through a random variable model that is deployed in the pest practices by verifying the underlying relationship and its patterns that predicts the future values by using the following forecasting methods:

3.1. ARIMA model [1]:
Is the one of the most often used time series model that comprises of “Auto Regressive Integrated Moving Average (ARIMA)” [1] is a linear correlation model which is developed from the economics applications with the statistical properties implemented in known Box Jenkins methodology during the training process of the model as it comprises of the ability to implement various exponential smoothing models by exploiting the linear dependencies for extracting the local patterns by removing noise from data.

Some of the benefits by using ARIMA model are: Maximum level of implement ability based on the predictions and relationships between the independent variables in specific model and the reliant variables can be clearly understood and further illustrated which allows us to attain the gain of deep understanding of the relationship between current state and the previous states that influences the inputs [20]. The potential of ARIMA model is it can be implemented easily in an automated way for maximizing the prediction accuracy being made [21]. ARIMA models comprises of the ability to further accommodate the systems that are governed by dynamics that updates over a specific span by updating the model that is based on current events for predicting the expected state of system [22]. And the disadvantage with ARIMA model is it can’t cope up with nonlinear patterns as the estimation of complex real world problems [23].
3.2. The Holt Winters Additive Model (HWAAS) [2]:
This model “Holt Winters additive model” [2] is considered to be an expansion to the exponential smoothing process which is performed on the time series forecasting method over the univariate data which is enhanced by adding the regular interval factor for forecasting the model with the seasonal component or systematic trend which is dominant and widely used forecasting method that has the potential to cope up with the seasonal trend and is an alternate to the Box Jenkins ARIMA family model as it is not so accurate to obtain the average [24].

The process of exponential smoothing will iteratively reverse the prediction model after considering the recent observations as the exponential value will further reduce the previous observations importance that predicts the reduction in weights and another criteria is that every predicted new value must be greater than that of the existing or older ones [25].

And the disadvantage of this model is it comprises of the choice of preliminary inputs where the understanding of abnormal procedures or outliers that comprises of the preference while performing the “smoothing” of parameters and when further normalizing the indices related to seasonal data [26].

3.3. TBAT [3]:
The acronym TBAT denotes four distinct basic components: “Trigonometric seasonal formulation” [24], “Box–Cox transformation” [25], “ARMA errors” [26] and the “Trend component” [27]. As this procedure clearly relies on “trigonometric” methods to model various floating point data based on the seasonal frequencies into normal shape by allowing certain level of nonlinearity that is illustrated by empirical studies for decomposing the complex seasonal time series data which enables the detection and extraction of elements based on the time series plotted values for better forecast [27][48].

3.4. Prophet [4]:
Prophet is an automatic “Time Series Forecasting model” [3] which is developed by “Facebook” [4] and was formerly deliberated to tackle business “time series problems” that are based on distinct techniques for predicting outcomes of business that share similar pool of features by using the decay “time series model” with three major components such as “trend, seasonality and holidays” by using the regression model with parameters that interpret the default values by choosing the components for effortlessly forecast [28].

To prophet model employs models that comprises of a drenched growth model and a phase wise linear model that are based on the nonlinear growth model that attains the saturation point with the carrying capacity as the prediction is that the saturating point will be never reached based on the phase wise model with the steady growth rate that grants efficient and useful results that are flexible and periodic as the process is based on the Fourier series transmission data related to predefined list of previous and future holidays that are independent and trivial [29].

3.5. DeepAR [5]:
DeepAR is the “Probabilistic Forecasting with Auto-Regressive Recurrent Networks” [5] which is a prediction method that is implemented on the “autoregressive recurrent neural networks” [26] for performing the “probabilistic forecasting” [27] as the problem incorporates the likelihood by combining with the nonlinear data for transforming the techniques by the “Deep Neural Networks” [30] by utilizing the “Long Short Term Memory (LSTM)” [30] based recurrent neural network architecture to address the probabilistic forecasting problem through additional complicated transformations that are preferred[45].

The benefits in DeepAR is that it reluctantly generates probabilistic predictions based on the “Monte Carlo samples” [28] for calculating the reliable approximation for all sub ranges in forecasting the scope and then it will not assume the Gaussian noise as it supports broad series of likelihood functions which allows an user for selecting top fits various statistical properties of data along with the complex dependencies of seasonal behaviors with very minimal human intervention [32].
3.6. N-Beats [6]:
The “Neural Basis Expansion Analysis for Interpretable Time Series Forecasting (N-Beats)” [6] is a profound “times series forecasting model” that uses a “Deep Neural Architecture” [12] with forward and backward enduring links with the deep load of totally associated layers as the model operates by traditionally decomposing the seasonality based trend level approach [32].

N-Beats architecture comprises of two stacks: the Trend Stack [7] and the Seasonality Stack [8], where both of them comprises of numerous connected blocks using residual connections that combines resultant data with the forecast or backcast principle over the trend component by eliminating the input window before passing it to seasonality stack as both of them are decoupled among one another while interpreting the model as the interpretability and accuracy benefits while implementing over many well known datasets due to which it trains the data very quickly by considering various target domains [33].

4. COVID-19 data set:
The data set of COVID-19 has been downloaded from the Indian official website (https://www.covid19india.org/) which is publicly available dataset and freely accessible as on August 31, 2020.

The data comprises of time series data related to progression of the virus in each state and union territory as our model extracts data and forecast the active cases of virus as a percentile of the total population during the phases such as training, evaluation and testing which allows us with more clearer picture for comparing the data with spread rate of the disease among various states and union territories of India.

The “Novel Corona Virus 2019 Dataset” [34] contains daily information that is related to 1) “The number of confirmed cases” 2) “The number of recovered cases” 3) “The death toll due to number of active cases” in top ten infected states for each day is intended by deducting both the “recovered patients” and total number of deaths incurred through “confirmed cases” and Figure 1 displays the distribution of total confirmed cases and Figure 2 denotes active cases using logarithmic scale.

![Figure 2. Dissemination of confirmed COVID-19 cases in top ten infected states of INDIA as on 31.08.2020](image)

![Figure 3. Day wise number of confirmed cases in ten most infected states of INDIA as on 31.08.2020](image)

By considering the statistics denoted in Figure 1 is related to the 10 major infected states with maximum number of “total confirmed cases” were kept based on the data acquired on 31st August 2020 in India and the states that are majorly affected by COVID 19 virus and almost certainly in later stages of the epidemic may be taken as a recommended point for newly impacted states and the percentile of “active cases” when compared with the total population per state is depicted in Figure 3 and Figure 4 comprises of confirmed cases and Figure 5 comprises of deceased cases.
5. Experiments and results
We implemented the execution process by using six different approaches: ARIMA [2,34], the “Holt–Winters additive model (HWAAS)” [3], “TBAT” [4], “Facebook’s Prophet” [5,35], “DeepAR” [6] and “N-Beats” [7,36] and attained results as illustrated below.

5.1. The modeling process
In this paper we compared the “time series methods” for performing prediction percentage of “active cases” with their population for the ten most infected states are selected to perform experiments and to obtain the comparisons using each of the time series models by training them and evaluating for performing the further testing as the time series data is in percentages of the active cases by considering more than 250 instances that were created on daily basis illustrating the data of top 10 most effected states with the active corona virus in India and the active cases where calculated by subtracting recovered number of cases and number of deaths per day from the active and confirmed cases from their respective states and in order to perform training and validation we used more than 150 instances from respective states were 75 of them are training set and leftover 25 are considered to be validation set by keeping seven days of windows space for evaluating the performance of predictive model to evaluate the metrics independently and the “Root Mean Squared Error (RMSE)” [12,37] is used to measure the prognostic ability of each deep learning approach[44][46].

5.2. The performance model:
The performance based results that are attained from each deep learning model from each state is denoted in Table-1 by representing in terms of “RMSE” [12,39] as no single method is appropriate for handling all the data hence we will perform prediction based on the percentage of active cases when compared them with total population of their respective states [38].

Table 1. The performance model implemented using RMSE [12,40] for the top ten infected states (confirmed cases) as on 31.08.2020 are:

|       | WB   | UP   | TG   | TN   | MH   |
|-------|------|------|------|------|------|
| “ARIMA” | **0.00772** | 0.08039 | **0.00593** | 0.00578 | 0.06112 |
| “Prophet” | 0.01418 | 0.06573 | 0.01952 | 0.00793 | 0.04478 |
| “HWAAS” | 0.17326 | 0.0318 | 0.00692 | 0.00467 | 0.01131 |
| “NBEATS” | 0.03726 | 0.05079 | 0.00895 | 0.03792 | **0.00452** |
"Gluonts" 0.04511 0.10914 0.04385 0.04643 0.01085
"TBAT" 0.01017 0.0296 0.00611 0.00461 0.0073

| KA | DL | BR | AS | AP |
|----|----|----|----|----|
| "ARIMA" 0.00673 | **0.00184** | 0.00474 | 0.00449 | 0.00293 |
| "Prophet" 0.03744 | 0.01498 | 0.0449 | 0.00958 | 0.01658 |
| "HWAAS" 0.00489 | 0.0026 | **0.00119** | 0.00602 | 0.00135 |

"NBEATS" 0.01349 0.02738 0.01857 0.01117 0.00405
"Gluonts" 0.05782 0.03478 0.09414 **0.00314** 0.00258
"TBAT" **0.00369** 0.00249 0.00225 0.00592 **0.00073**

**Figure 6.** Performance model implemented using RMSE [12] for the top ten effected states (confirmed cases) as on 31.08.2020 are:

**Figure 7.** Results attained using “friedman statistical test” ranking with the “significance level” of \( \alpha = 0.03 \).

When we consider the statistical testing that is performed using the “Friedman non-parametric multiple group test” [22,41] using the “significance level” of \( \alpha = 0.03 \) which is applied to attain the related rankings generated between various algorithms as denoted in table 2:

**Table 2.** Denoting “friedman statistical test ranking” with the “significance level” of \( \alpha = 0.03 \).

| Rank | Algorithm |
|------|-----------|
| 1.70200 | “TBAT” |
| 2.90300 | “ARIMA” |
| 2.90400 | “HWAAS” |
| 4.10200 | “NBEATS” |
| 4.60550 | “Prophet” |
| 4.80002 | “Gluonts” |

[42] As illustrated earlier both the RMSE which is measured and the performance is depicted in table 1 and further in table 2 the statistical ranking as the approaches such as “ARIMA”, “TBAT and HWAAS” outperforms various deep learning methods such as “N-BEATS and DeepAR (GluonTS)” which is possibly the yield of the non-availability of high volumes of data that “deep-learning algorithms” required to prosper as its significance is nothing but “Facebook Prophet” did not attain the greater performance in any of the states as the technique is basically created to deal with business issues[43][47].
Primarily “TBAT” and secondly “ARIMA” seems to be the outperforming technique that provides overall terms of RMSE as one of the best predictions that combines all the seven states to achieve the second best result for dealing with the specific ARIMA model that bestow the better performance in terms of “RMSE” as shown in figure 5 because TBAT achieves the best results in Andhra Pradesh and Assam by using “significance level” of α=0.03.

Table 3. comparison of all methods adopted using “holm’s post-hoc statistical analysis” which is applied and tested on using the “friedman test using the significance level” of α=0.03.

| Comparison         | Statistic | Adjusted p-Value | Result     |
|--------------------|-----------|------------------|------------|
| “TBAT vs Gluonts”  | 3.71542   | 0.00108          | “H₀ rejected” |
| “TBAT vs Prophet”  | 3.45627   | 0.00215          | “H₀ rejected” |
| “TBAT vs NBEATS”   | 2.85898   | 0.01233          | “H₀ rejected” |
| “TBAT vs ARIMA”    | 1.44436   | 0.30287          | “H₀ accepted” |
| “TBAT vs HWAAS”    | 1.44448   | 0.30324          | “H₀ accepted” |

5.3. Cross state comparison
It is typical to represent and illustrate the precise causes for distinct algorithms to perform improvised measure in one state but not in others and some of the factors that should be renowned are:

- Geographical characteristics and State specific calamities.
- Different types of population associated and their attributes such as density of population in distinct states.
- Inconsistencies while testing and measuring various events and performing data collection over different states.
- Different forms of quarantine procedures and imparting of social distancing measures in the different states are based on timing or duration and severity of such actions considered and implemented.

6. Conclusions
The knowledge attained from the percentage of “COVID 19 infected population in India” and therefore due to epidemic comprises of the potential that considerably decrease the influence of the pandemic situation it would enable social and health related policies. In this paper we have implemented six different statistical and deep learning algorithms inspired by time series methods and we estimate the percentage of active cases in top ten most impacted states with respect to the total population till 30.08.2020. and based on the TBAT proposed model it is predicted that every day there is a hike of 0.15% of cases increase as per the population rate of top ten states that are considered.

We used “Root Mean Square error (RMSE)” to assess the performance of each time series to model this work using distinct approaches that indicate results using traditional statistical methods such as “ARIMA and TBAT” due to lack of large amounts of data and further we analyzed that two approaches that produce the best overall performance using the predictive power by analyzing the friedman test which was applied to generate the relative ranking of the algorithm and by using the “Holm’s post hoc statistical analysis” method using significance level of α=0.03.

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