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COVID-19 Forecasting Using Deep Learning Models

Sahiti Cheguru[1], C.H. Prerana[2], K. Tejasree[3], Tarine Deepthi[4], and Dr. Y. Vijayalata[5]

[1]Student, B.Tech, Dept of CSE, Gokaraju Rangaraju Institute of Engineering and Technology, Bachupally, Telangana, India
[2,3,4]Student, B.Tech, Dept of CSE, Vidya Jyothi Institute of Technology, Aziz Nagar, Telangana, India
[5]Professor, Dept of CSE Gokaraju Rangaraju Institute of Engineering and Technology Bachupally, Telangana, India
E-mail: sahiticheguru2000@gmail.com; preranacheguru@gmail.com; tejasreekomati05@gmail.com; tarinedeepthi1998@gmail.com; vijaya@griet.ac.in

Abstract

COVID-19, responsible for infecting billions of people and the economy across the globe, requires a detailed study of the trend it follows to develop adequate short-term prediction models for forecasting the number of future cases. In this perspective, it is possible to develop strategic planning in the public health system to avoid deaths as well as managing patients. In this paper, forecast models comprising various artificial intelligence approaches such as support vector regression (SVR), long short term memory (LSTM), bidirectional long short term memory (Bi-LSTM) are assessed for time series prediction of confirmed cases, deaths, and recoveries in ten major countries affected due to COVID-19. The paper also reviewed a deep learning model to forecast the range of increase in COVID-19 infected cases in future days to present a novel method to compute multidimensional representations of multivariate time series and multivariate spatial time series data. The paper

enables the researchers to consider a large number of heterogeneous features, such as census data, intra-county mobility, inter-county mobility, social distancing data, past growth of the infection, among others, and learn complex interactions between these features. To fast-track further development and experimentation, the analyzed code could be used to implement the AI in an efficient way. The paper discusses existing theories and research that provide a better understanding of the spread pattern recognition which will help to tackle any future pandemic of similar intensity. We encourage others to further develop a novel modeling paradigm for infectious disease based on GNNs and high resolution mobility data.

Keywords: COVID 19, Artificial intelligence, Deep learning model, Time series data, Prediction model

4.1 Introduction

Corona viruses earn their name from the characteristic crown-like viral particles (virions) that dot their surface. This family of viruses infects a wide range of vertebrates, most notably mammals and birds, and are considered to be a major cause of viral respiratory infections worldwide [1]. With the recent detection of the 2019 novel corona virus (COVID-19), there are now a total of 7 corona viruses known to infect humans. Prior to the global outbreak of SARS-CoV in 2003, HCoV-229E and HCoV-OC43 were the only corona viruses known to infect humans. Following the SARS outbreak, 5 additional corona viruses have been discovered in humans, most recently the novel corona virus COVID-19, believed to have originated in Wuhan, Hubei Province, China. COVID-19 effect has highly noticeable in dense areas with elderly people and people with co-morbidities [2]. It is considered a multidisciplinary issue for the medical specialists, pharmaceutical industry, local government/health authorities, and epidemiological experts. This study is mainly focused on the review of forecasting and prediction of COVID-19 using various deep learning algorithms. A big challenge has been witnessed in various science domains globally to restrict the increasing COVID spread trends. Various modeling, forecasting, and analysis approaches are established to handle and insight this current pandemic. The evolution of confirmed COVID cases forecasting has been estimated by multiple mathematical models [3, 4].

This study is mainly focused on the review of forecasting and prediction of COVID-19 using various deep learning algorithms. A big challenge

has been witnessed in various science domains globally to restrict the increasing COVID spread trends. Various modeling, forecasting, and analysis approaches are established to handle and insight this current pandemic. The evolution of confirmed COVID cases forecasting has been estimated by multiple mathematical models. This study is aimed at deep learning models and a comparative study is made for forecasting COVID-19 cases. The deep learning models such as long short term memory LSTM, Bidirectional LSTM, Gated Recurrent unit- GRU, and Recurrent neural network- RNN have been analyzed. These models possess various advantages like distribution free learning models, managing temporal dependencies in time series data, and nonlinear features modeling of flexibility. Various datasets have been utilized in various studies like the John Hopkins dataset from starting to now COVID 19 status. The comparative study and challenges are exhibited in this study.

The major contribution of this study involves,

- To review the various deep learning models related to COVID-19 forecasting and time series prediction globally.
- To analyze the LSTM, Bi-LSTM, and GRU techniques applied in various medical images related to COVID-19 cases.
- To make a comparative study for the discussion related to COVID-19 prediction and forecasting.

The following Section 4.2 describes the deep learning models against covid-19 and their applications, Section 4.3 describes the population attributes of COVID-19, followed by Section 4.4 describes the various deep learning models and the involved COVID-19 dataset. Finally, the conclusion is presented in Section 4.5.

4.2 Deep Learning Against Covid-19

With the regular increase in the newly acquired and suspected COVID 19 cases, diagnosis of the disease is becoming a growing issue in most of the main hospitals because of the inadequate supply of detection systems in the corresponding epidemic area. Radiography and computed tomography hence originated as the integrative players in the pre-detection and diagnosis of COVID 19. But due to the aforementioned overwhelming patients, false positive rates leading to urgent requirements of computer automated diagnosis like deep learning that precisely confirm patientsscreen them thereby conducting viral surveillance. The following studies developed a deep learning process on the basis of CT diagnosis for the detection of COVID 19

patients that were able to automatically retrieve the radiographic characteristics of the novel virus, particularly the GGO (ground glass opacity) from the radiographic images.

This research [5] developed a DL framework for the automatic quantification and segmentation of the quantification of the infectious areas and the whole lung from the corresponding chest scans. The paper employed VB-Net NN (neural network) for the segmentation of COVID 19 infection areas in CT images. This setup has been trained with the utilization of two hundred and forty-nine COVID patients followed by the validation of three hundred patients. For accelerating the manual description of CT images to train the features, a HITL (human in the loop) has been adapted for assisting the physician in refining automatic annotation in every case. The assessment of the DL based performance system in accordance with Dice similarity coefficient, percentage of infection in between the manual and automatic segmentation outcomes on the validated images.

Moreover [6] the study provided a fully automated and rapid diagnosis of COVID 19 by adopting deep learning. The experimental assessment on 6524 X rays of various institutions described the efficiency of the suggested method with an average detection time of 2.5 seconds as well as with average accuracy of 0.97 [7]. Formulated the task of classifying viral pneumonia from the healthy controls and non-viral pneumonia into anomaly detection problems. Hence the study suggested a CAD model that consisted of shared feature extraction, prediction module, and detection module. The main benefit of the suggested method over the binary classification is preventing individual class explicitly followed by the complete treatment. This suggested model possesses greater efficiency of AUC 84% and a sensitivity of 72%.

Similarly [8] evaluated the longitudinal modifications of pneumonia in various COVID 19 clinical types at the baseline and follow-up imaging with the use of quantitative image parameters that has been automatically developed by deep learning systems from chest X rays. The major findings of the study are lung opacity burden, entire lung, and per lobe comparison. This system was able to assess quantitatively the percentage of lung pacification and the recent vision required for the radiologist supervision. The study yielded 8.7% of the cases for insufficient segmentation that ensures precise quantification.

4.2.1 Medical Image Processing

Medical image processing is a complex method and understanding of this process is the main cause in the patients who do not respond to the CRT.

The study [9] demonstrated the voltage dependent right ventricle capture by the misplaced right atrial lead. The study suggested that device interrogations with the 12 lead ECG and succeeding multimodality imaging must be regarded in accordance with the premature diagnosis of non-responder.

[10] The study aimed to offer burnout medical professions an opportunity by intelligent DL classification methods. The study detected an appropriate CNN model by an initial comparative analysis of various CNN frameworks. The study then optimized the selected VGG 19 model for image modeling for depicting that the model might be utilized for high demand and challenging datasets. The paper then highlighted the limitations in using the publicly available datasets for the development of useful DL models and the process of creating an adverse impact on training the complex system. The study also suggested an image pre-processing stage for creating a trustworthy dataset in order to develop and test the DL models. This robust method has been aimed to decrease the unwanted noise from the images thereby DL models could focus on identifying diseases with peculiar features from the extraction. The results represented that the US images offer an extraordinary detection rate when compared with the CT and X-ray scans. These experimental outcomes signified that with the presence of limited data, many deep networks suffer for training effectively and provide low consistency when compared with the three used image models. The selected model has been then widely tuned with the corresponding parameters and made to perform the COVID 19 detection over pneumonia or normal lungs for all the three lung models with the accuracy of 84% of CT, 100% of US, and 86% of X-ray.

Advanced AI methods [11] and deep learning techniques have depicted high efficiency in the detection of patterns like diseased tissue. This study examined the efficiency of the VGG 16 base DL model for the detection of COVID 19 and pneumonia with the employment of torso radiographs. The results depicted that a high level of sensitivity in the detection of COVID 19 associated with the high level of specificity represented that this model could effectively be used as the screening test. ROC and AUC Curves are higher than 0.9 for all the considered classes.

4.2.2 Forecasting COVID-19 Series

This article [12] employed six machine learning methods such as CUBIST, RIDGE, RF, SVR, and stack ensemble learning and ARIMA model for the cumulative confirmation of COVID 19 in the Ten Brazil States in accordance with the incidence. The study evaluated the stability of the efficiency and out

of sample errors by box plots. The study failed to adopt the DL approach in combination with ensemble learning. The study did not attempt couples function for dealing with data augmentation. Also, the study adapts hyper parameter tuning forecasting of the upcoming cases of COVID 19.

On the other hand [13] focused on two main problems which are as follows: One which generates real time forecast of the upcoming COVID 19 case for several countries and next is the assessment of the risk of novel COVID 19 for few more affected countries by a determination of several significant demographic features of the countries and its disease characteristics. To resolve the initial problem, the study presented a hybridized approach on the basis of an autoregressive integrated moving model and a wave-let based forecast model for generating short-term forecasts to determine future predictions of the outbreak. This study might be useful for the efficient allocation of medical professionals and also it acts as an early warning framework for the government policy makers. The next issue could be solved by the application of optimal regression of tree algorithms in order to determine the important causative variables which considerably affect the fatal rates for various countries. This analysis would necessarily 4offer deep insight for understanding the early risk of assessing 50 highly affected countries.

4.2.3 Deep Learning and IoT

Because of the global pandemic, there is an emergency requirement for the utilization of technology to its optimum potential. IoT is considered as one of the recent methods with great capability in performing against the COVID 19 outbreak. IoT comprises a limited network where IoT devices sense the surrounding environment and send useful data on the internet. This research [14] examined the present status of IoT applications in relation to novel viruses for the identification and deployment of their operational challenges and suggested the possible outcomes for further pandemic situations. Apart from that, the study performed statistical analysis for the implementation of IoT where the external and internal factors are being discussed.

Likewise [15] tested several number of COVID 19 diagnosis methods that depend on deep learning algorithms with the corresponding instances. The test results of the study depicted that DL models did not consider defensive frameworks against adverse probabilities that remain vulnerable to the corresponding attacks. At lasts the study presented in detail regarding the implementation of the attack model of the prevailing COVID 19 diagnostic applications. The study hoped that this process will generate awareness of

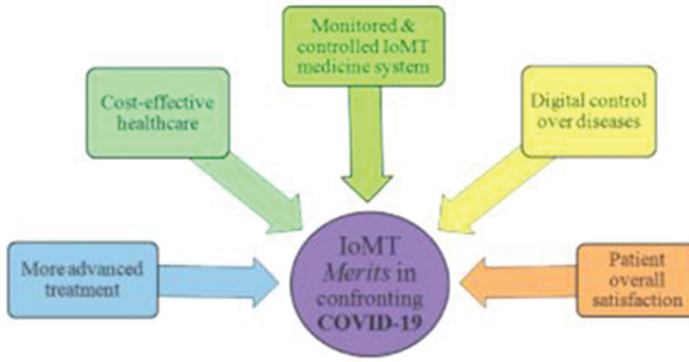

Figure 4.1 IoT merits towards COVID 19 [16].

the adversarial attacks thereby encouraging others to safeguard DL methods from the attack of the healthcare system.

In this article [16], the insight of DL tool application from the diverse view for empowering IoT applications in 4 major domains comprising smart home, smart health care, smart industry, and smart transportation is investigated. The main thrust has to be seamlessly coinciding with the two divisions of DL and IoT that resulted in an expensive range of new frameworks in the application of IoT like health monitoring, indoor localization, disease analysis, intelligent control, traffic monitoring, home robotics, autonomous driving, traffic prediction, and manufacture inspection. The study discussed the problems, future research, and challenges that use DL and for the motivation regarding further improvement in the promising area.

4.2.4 NLP and Deep Learning Tools

This study [17] utilized an automated extraction of the corona virus discussion from the social media and NLP method on the basis of topic modeling for uncovering several issues in accordance with the viral symptoms from public opinion. Further, the study also investigated the usage of LSTM RNN for the sentiment classification of COVID 19 comments. The findings of the present study focussed on the significance of the decision-making of COVID 19 issues.

Moreover [18] detected and analyzed sentiment emotions and polarity that has been described during the beginning of the initial stage of the pandemic lockdown period with employment of NLP and DL techniques on Twitter posts. LSTM models utilized for the estimation of emotions and

sentiment polarity from the tweets extracted were trained to obtain existing accuracy on the sentiment 140 dataset. This use of emotions depicted a novel and unique method of estimating and validating the supervised learning models on the tweets extracted from Twitter.

4.2.5 Deep Learning in Computational Biology and Medicine

Advances in technology in imaging and genomics led to the explosion of cellular and molecular profiling of the data from huge numbers of samples. This tremendous rise of the biological data acquisition and dimension rate is a complex and conventional analytical strategy. The modern ML methods like deep learning promise to handle huge datasets for the determination of the hidden structure within them thereby making precise predictions. The review discussed the application of novel breeds and approaches in cellular imaging and regulatory genomics. The study provided a background of the summary of deep learning and provided certain tips for the practical usage with possible pitfalls and challenges for guiding the computational biologists in the utilization of this methodology [19]. The study [20] briefly introduced the following manuscripts and discussed their overall contribution to the advancement of science and technology: transcriptomic, cancer informatics, visualization, and tools, computational algorithms, micro biome research, and deep learning.

4.3 Population Attributes – Covid-19

This study emphasized the impact of COVID-19 for the migrant workers who are affected immensely. The geographical assessment analysis has been focused and the key facts to control this epidemic have been stated. The population attributes are shown in Figure 4.2. The structural barriers have been addressed. The intervention focal points are recognized by built environments and social networks. The risky role of migrant workers in Singapore is thus identified by the network's protective roles [28] . The public health and world economy were highly affected due to the COVID-19 pandemic. This kind of issue has been controlled by non-pharmaceutical interventions and this study utilized the Susceptible Exposed Infected Recovered-SEIR for pandemic dynamics simulation utilizing the society following government, people, and business. With respect to social cooperation, the higher realistic implementation related to various social interventions followed. Further COVID ABS models have been developed in the Python language.

Table 4.1 Comparative Study of the Prevailing Literatures

S.No	Author	Description and Methodology	Comments on the Results
1.	[21]	The study introduced a novel DL framework (COVIDX-NET) for assisting the radiologists in the automatic detection of corona virus presence in X-Ray images. This suggested framework comprised 7 various architectures of deep CNN like VGG 19 and the Google MobileNet (second version)	The study described the useful implementation of DL models for the classification of COVID 19 in the COVIDNet processed X-Ray images and supported further research in deep learning for diagnosing COVID 19 with high accuracy.
2.	[22]	The study utilized the DL model for the automated identification of anomalies in chest CT of COVID 19 patients and compared the quantitative estimation with the radiological residents. A deep learning algorithm consisting of detection of lesions, segmentation, and location has been trained and validated in 14,435 patients with definite pathogenic inclusion.	The suggested algorithm depicted excellent efficiency in the detection of COVID 19 pneumonia on the chest CT when compared with the existing radiologists.
3.	[23]	The issue of automatic classification of pulmonary diseases, comprising the recently emerged COVID-19, from X-ray images has been focussed in the study. In specific the existing CNN known as the Mobile net has been employed and trained from the scratch for the investigation of the significance of the features extracted for the classification task.	The results suggested that training CNN from scratch revealed vital biomarkers but not constrained to the COVID-19 disease, whereas the top classification accuracy suggested further analysis of the X-ray imaging potential.
4.	[24]	The paper assessed the usefulness of the (ARIMA) model in the prediction of the dynamics of Covid-19 incidence at various stages of the epidemic, from the intial growth phaseto the maximum daily incidence, until the phase of the epidemic's extinction	The study recommended the ARIMA model for forecasting COVID 19 for countermeasures.

Continued

Table 4.1 *Continued*

S.No	Author	Description and Methodology	Comments on the Results
5.	[25]	The study developed a prototype of a decentralized IoT based biometric face detection framework for cities under lockdown during the COVID-19 pandemic. The study built a deep learning framework of multi-task cascading for the detection of the face.	The study proved that it has an edge over cloud computing architecture.
6.	[26]	The study built an automated tool known as COVID 19 sign sym that could extract symptoms with their eight factors (severity, body location, condition, uncertainty, temporal expression, negation subject, and course) from the clinical text.	The information extracted is also mapped to the standardized clinical concept in the general OHDSI model. The evaluations of the notes followed by the medical sayings describe promising outcomes.
7.	[19]	Explored the possibility of Zakat and Qardh-Al-Hasan as a financial method to handle the adverse impact of Corona virus on poor and SMEs. It resolved by proposing an Artificial Intelligence and NLP based Islamic FinTech Model integrated with Qardh- and Al-Hasan Zakat	The study revealed that Islamic finance has immense potential to overcome any kind of pandemic like COVID 19
8.	[27]	The study signified the difference and similarity in extensively utilized models in deep learning studies, by discussing their basic structures, and reviewing diverse disadvantages and applications	The study anticipated the work can serve as a meaningful perspective for future development of the suggested algorithm in computational medicine.
9.	[28]	The paper investigated the networks of non-work related activities in migrant workers to intimate the improvement of lockdown exit techniques and upcoming pandemic preparedness	The study recommended social and geospatial distance followed by avoiding mass gathering and it also encouraged the welfare of migrant workers.

Continued

Table 4.1 *Continued*

S.No	Author	Description and Methodology	Comments on the Results
		It was conducted with 509 migrant workers over the nation, and it evaluated dormitory attributes, mental health status and social ties, physical and COVID-19-related variables, and mobility patterns with the use of grid-based network questionnaires.	
10.	[29]	The study assisted the policy makers in taking required decisions in order to stop the pandemic spread; precise forecasting of the propagation of the disease is the paramount significance. The suggested method initially groups the countries possessing the same socioeconomic and demographic details as well the health sector indicators with the use of k means algorithm	The method obtained high accuracy in forecasting the daily cumulative viral cases.
11.	[30]	The study might be used to differentiate several respiratory patterns and the suggested device could be readily employed for practical utilization.	The suggested deep learning possesses the vital potential to be extended to large-scale applications like sleeping scenarios, public places, and office environments.

By modifying the input parameters this developed model can be extended to other populations/societies. For health and government authorities, this model is very helpful [31]. In Israel, 271 localities have been assessed during the outbreak of 3 months in which 90 percent of the population is urban. Higher infection rates were seen in political minority groups. On the urban political attributes, the density's influence and significant impact have been highly recorded. Among the environmental degradation and urban sprawl the contagious disease spread leads to new tensions in cities observed from assessment [32]. For population criteria, the weight assigned is performed by potential approaches which describe the COVID-19 spatial distribution and however the temporal variation has not been considered as a drawback. The uniform infection rates have not recorded the COVID-19 transmission

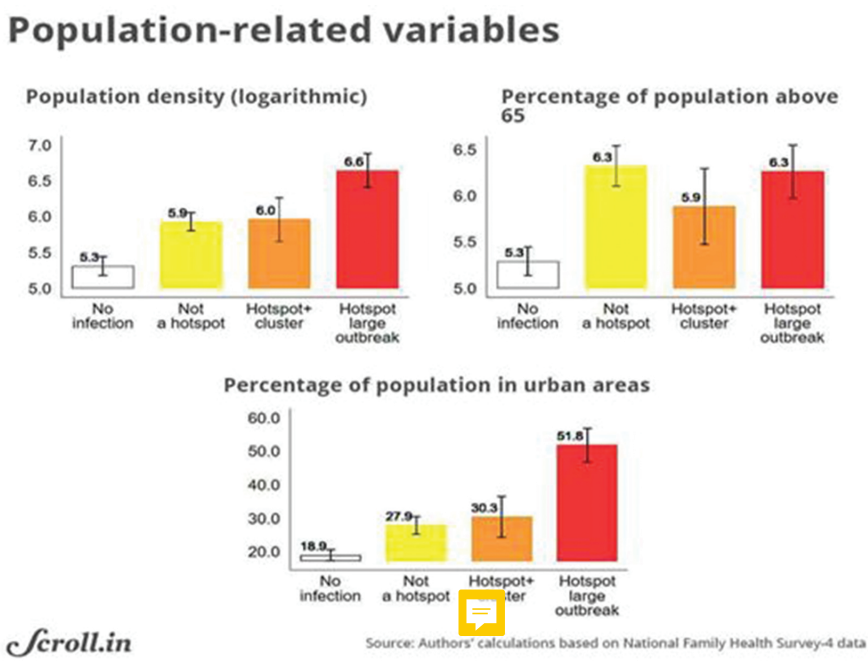

Figure 4.2 Population variables in India.

Source: (Scroll. in/National Family health survey data).

dynamics. The standard model SEIR has been used and does not measure the temporal variation. This study focused on the Brazilian health care system to take an account of the infected patients count. If the control strategies have been affected the infection rate of the long term due to the unclear findings [33]. This study major aim shows the infection or death rates have not been predicted before or disease evolution. At-risk populations have been highly focused and the non-hotspot district characteristics have been analyzed. However, from the below graphical representation, Fsig 4.1, shows that the districts with no infections are mostly the rural areas. For denser areas in India, the COVID-19 present burden is higher which the urban areas are usually. For this critical illness, the older people show a larger share of risks [34].

This study developed the contact tracing app in the Netherlands and the dynamics are not considered. The potential uptake alone is predicted from the contact tracing app. For this app promotion, the government and local health authorities put a lot of effort. Personal data sharing has increased

due to this app and the respondents may change in the future as the disease risks eased [35]. This study utilized the long term climatic records of population density (PD), air temperature (T), specific humidity (SH), rainfall (R), and wind speed (WS) with topographic altitude (E), actual Evapotranspiration (AET), and solar radiation (SR) at the regional level for the spatial relation association with COVID-19 infection count. With the number of infected cases in India of 36 provinces, the vicariate analysis shows failure in identifying the important relation. The higher importance has been identified by the partial least square technique. After the analysis of various parameters, the present study focused on India shows the COVID-19 infections are more prone to the hot and dry regions with below altitude [36]. The health population is highly infected by the asymptomatic, symptomatic, and pre-symptomatic persons. Another study depicted that the population of asymptomatic patients is higher compared with symptomatic patients. This study has been conducted in India and the improved SIERD model is utilized to predict both kinds of infectious persons. The asymptomatic infected population dynamics were evaluated and this study suggested by making these persons quarantined the number of symptomatic persons also reduced [37].

4.4 Various Deep Learning Model

Promising results obtained from the highly challenging state of art methods related to deep learning. The features interpretation and minimal neural architecture is the challenging one. Various deep learning models like CNN, R-CNN, adversarial models, generative and attention based models have been analyzed in this study. For image segmentation, various analyses and strong research directions have been estimated [38]. For COVID-19 infection prediction, the deep learning models were found to be the most appropriate ones, according to this study. The personal risk scores from lab assessment assigned for the scarce healthcare resources. From this study, the healthcare resource prioritization improved and patient care has been further informed [39]. For predicting the COVID-19 cases of positive this research proposed the deep learning models. State wise comparison has been made based on mild, moderate, and severe in COVID cases. In 32 states, the bi directional LSTM, deep LSTM, and convolutional LSTM have been used for an efficient prediction in which maximum accuracy and absolute error have been chosen. Bidirectional LSTM shows better results. For a short-term prediction, 1 to 3 days BI-LSTM shows better results and it is available publicly. For handling

the medical infrastructure these predictions are very helpful for the health authorities. This proposed model can be applied to all nations worldwide [40]. Based on chest X-ray images, three deep CNN approaches have been utilized for COVID-19 detection. With various kernel functions, deep CNN with SVM classifier has been associated. The results depicted asthis study outperformed the local existing approaches. Compared with deep feature extraction, fine-tuning and end to end training needs higher time. The cubic kernel function shows superior performance. Usually, the ResNet-50 model shows better results related to the CNN pre-trained model. Deep CNN performs better for the end to end training process. For the COVID-19 detection, more number of chest x-ray images can be evaluated in future and the various evolution stages can be analyzed to help the radiologists in prediction [41]. This research also utilized the chest radiography images for an efficient COVID-19 prediction by the deep learning approaches. New Coronet model was developed in this study is considered to be low cost and better results obtained. Higher sensitivity and accuracy resulted and thus this model is highly beneficial for the medical practitioners for proper understanding [42].

4.4.1 LSTM Model

In the public health system, strategic planning has been required to avoid deaths from COVID-19. The time series prediction of COVID-19 cases has been performed by LSTM, Bi-LSTM, autoregressive integrated moving average- ARIMA and support vector regression- SVR in 10 major COVID affected countries. This study was estimated by means of the root mean square error, r2-score indices, and absolute error. In this study, BI-LSTM outperforms the other algorithms and it obtains reduced RMSE and MAE values. For better planning and management Bi-LSTM has been considered as a better pandemic prediction algorithm [42]. This work utilized the Canadian health authority and John Hopkins university public datasets for the COVID-19 forecasting model based on deep learning models. For future COVID-19 cases forecasting, this study used the long short term memory-LSTM. The possible ending point of the COVID outbreak was predicted in this study as of June 2020 and compared it with USA, Italy, and Canada transmission rates [43]. Due to the rapid population growth, automatic disease detection is considered a challenging one. However automatic disease detection can support doctors in diagnostics. LSTM is combined with CNN in this study and utilizes the X-ray images to automatically detect COVID-19.

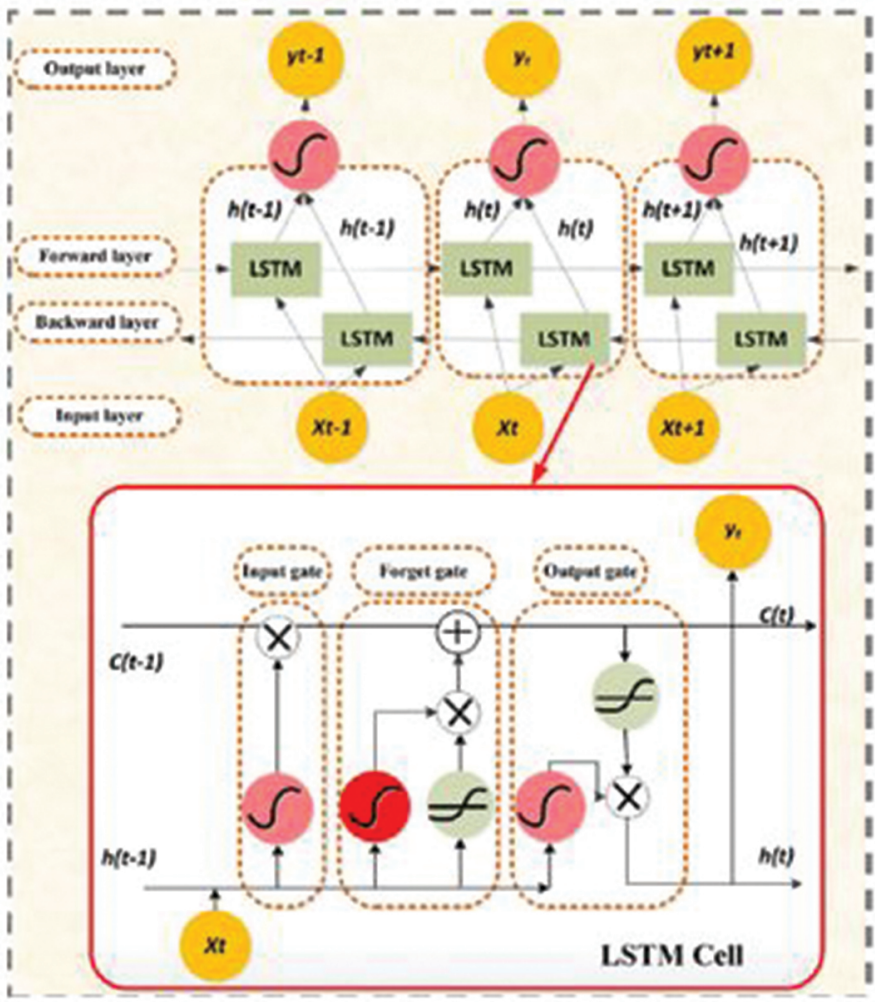

Figure 4.3 LSTM and Bi-LSTM architecture [42].

Better accuracy, sensitivity, specificity have resulted from this proposed system. Rapid diagnosis by doctors has been made from this study [44].

The time series prediction contains the data that is iteratively obtained by the LSTM model. More accurate outputs have been predicted and a number of positive cases have been reported by LSTM. Apart from Google trends data, other data sources can be combined like mass media, screening registers, social media information, environmental and climate factors.

Global prediction is necessary for terms of time series assessment [45]. For a variety of disease prediction, SEIR models have been applied and however, over fitting occurs since a lot of predictor variables have been used. In this study, several combinations of techniques have been executed based on LSTM, XGBoost, and K-means to forecast the short-term COVID-19 cases in the USA. Among the past days and forecasting, the similarity is evaluated in this study using the k means algorithm with the XGBoost technique. K-means with LSTM show larger accuracy as result [46].

4.4.2 Bidirectional LSTM

With the intention of forecasting the cluster data based on the COVID-19 Bi-LSTM model is established in this study. The prediction performance has improved which includes the lockdown information also [29]. The hospitalization estimation for the coming week compared with the present week has been inferred by the four recurrent neural networks. Higher accuracy resulted in predicting the hospitalization in which every patient must receive suitable treatment. The hospitalization requirement has been predicted before and it has the potential to send warning messages to the medical providers [47]. Various tweets have been found worldwide regarding COVID-19 and these kinds of tweets carry valuable information. It is highly challenging to process this information. To analyze the informative tweets, Bi-LSTM and other machine learning approaches are utilized for classification [48]. Various lockdown policies impact with respect to COVID-19 are evaluated and predicted in this study using deep learning techniques. Various scenarios are evaluated related to lockdown policies and their effects are assessed while predicting COVID cases. The lifting of the lockdown especially for schools resulted in increases in infected cases simultaneously [49]. This research provided an appropriate understanding of the statistical growth rate of COVID cases in India. Most affected cases have been predicted using deep learning models [50].

4.5 Conclusion

COVID-19 is the major reason for infecting billions of people and affecting the economy worldwide. This study presented a detailed view of prediction and forecasting the COVID-19 cases worldwide. The forecasting models comprised of various deep learning models such as support vector regression (SVR), long shot term memory (LSTM), bidirectional long short term memory (Bi-LSTM) are assessed for time series prediction of confirmed

cases, deaths, and recoveries in ten major countries affected due to COVID-19. The paper also reviewed a deep learning model to forecast the range of increase in COVID19 infected cases in future days. A comparative study was also performed regarding the discussed deep learning models for COVID-19 prediction. This study provided the guidelines to the various other researchers who focused on the deep learning models in COVID-19 forecasting and prediction.

4.6 Acknowledgement

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4.7 Figures and Tables Caption List

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