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A Deep Learning Approach for Effective Predictor of COVID-19 and ICU Requirements

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Abstract
COVID-19 also known as Coronavirus is a global pandemic which has already affected millions of people around the world and is continuing to do so even now. Due to the high positivity rate among patients, the health and medical facilities faced lot of issues such as, lack of medical staff, beds, and intensive care units (ICUs). Therefore, it is important to identify and detect COVID-19 as earliest as possible. Over the years, a large number of methods were proposed for predicting covid-19, but the problem with those methods was that they were high complex and took huge time for training. In this paper, a bidirectional Long Short-Term memory (Bi-LSTM) based model is proposed that performs two classification tasks i.e. detection of COVID-19 and predicting the need for regular wards and ICU and semi-ICUs. The main objective of the proposed work is not only to decrease the complexity and training time of the model but also to enhance the accuracy of the system. For this, a publicly available dataset taken from the Kaggle.com is taken and pre-processing is applied to it, for making the data balanced and normalized. In addition to this, the complexity of the system is decreased by using the Eigenvector centrality feature selection (ECFS), in which only important and crucial features are selected. Furthermore, the effectiveness of the suggested system is enhanced by using the DL based classifier, named as, Bi-LSTM. Finally, the efficacy of the suggested approach is analyzed and compared with several traditional approaches in terms of various dependency factors like, accuracy, specificity, precision, recall and Fscore. The simulated outcomes determine the supremacy of the proposed approach over traditional approaches.
Keywords:COVID-19, ICU requirements, Disease detection, Predicting models, Artificial intelligence, etc.

Introduction

The year 2020 has proven to be a disaster for humanity. In the month of December 2019, a group of strange pneumonia cases was discovered in the Wuhan region of china, which subsequently spread to the rest of the globe. Corona-virus infection, also referred as COVID-19, is a respiration disorder that develops as a result of the acute respiratory disease (sars syndrome corona-virus-2 (abbreviated as SARS-COV-2) [1-2]. The disease spread rapidly over the globe, causing a pandemic and bring the medical systems of several countries to their knees. As India is the second populous country in the world and is one of the top five nations that got severely affected with COVID-19 [3]. The transfer of COVID-19 virus from one individual to another was quickly realized as an additional route of disease. According to recent research, it was discovered that COVID-19 transmission arises when humans are in close vicinity to each other and are infected with the virus. Folks and the general public with lower immune mechanism, like diabetes, heart disease, respiratory illness, leukemia, urinary, and liver failure are at a significantly greater chances for getting infected with COVID-19 infectious disease rather than kids that are less prone to infections or, if they do, have mild illness or even asymptomatic infection [4]. COVID-19 has a broad range of health symptoms, including asymptomatic and symptomatic types which include serious breathing issues requiring ventilatory and ICUs (intensive care unit) support, multi-organ failure and various other systemic manifestations such as septic shock, sepsis, and MODS or multiple organ dysfunction syndromes [5]. Illnesses with zero indications were also reported, although their origin is uncertain. Temperature, coughing, breathlessness, dry mouth, and other indications are very common in COVID19 positive patients. In addition to this, Pneumonia is also one of the serious symptoms found in COVID19 patients [6]. Headaches, sore throats, and rhinorrhea are some of the relatively prevalent symptoms. Other than this, various gastrointestinal indications like vomiting and diarrhea are also prevalent in some cases. The primary route of transmission are droplets that are disbursed during coughing or sneezing, and asymptomatic person-to-person encounters.

1.1 TRANSMISSION OF COVID-19

COVID-19 can be transmitted from one person to another in number of ways, some of the most common ways of transmitting the disease are explained below;

- The predominant route of transmission of SARS-CoV-2 is by close touch and potentially infectious respiratory secretions from pre-symptomatic, asymptomatic and symptomatic patients.

- Fomite transmission of COVID-19 results from the contaminated surfaces and it was also observed that the COVID-19 virus is more effective on plastic and stainless-steel materials rather than copper and paper items. Also, infection tends to be significantly greater in ICUs, with COVID-19 virus accumulated on rugs, computer mice, waste bins, and hospital bed railings, and also in atmosphere up to 4 meters from victims, implying the fomite spread.
- According to epidemiologic information from many investigations, individuals with covid-19 illness had flu virus in their feces, suggesting fecal-oral spread.
- A meta-analysis of 936 infants from COVID-19-positive moms found that vertical transmission can occur, but only in a small percentage of cases.

This transmission can be reduced by following the guidelines issued by health experts, like, covering mouth while coughing and sneezing, washing hands regularly or using sanitizers, wear mask, maintain distance and avoid public gatherings. However, apart from enacting global health and disease prevention steps to avoid COVID-19 spread, the most important step is vaccination in societies. The vaccination results in producing neutralizing antibodies in the body against COVID-19 that empower the immunity in humans and reduce the probability of getting effected. India developed Covaxin, Spitnik V was developed by Russia and CoronaVAc was developed by China. These vaccines have already been used in different countries in order to prevent the transmission of COVID-19 further [7]. Due to the widespread number of persons getting infected of this deadly virus, several nations' hospitals and health-care systems are overburdened. As a result, early detection of these diseases is critical. In this regard, Machine learning and deep learning methods have been used for detecting the presence of COVID-19 diseases in humans by various researchers.

1.2 ROLE OF AI IN DETECTING COVID-19

Artificial Intelligence (AI), a rapidly emerging software tool in the field of medical image processing, has also aided in the fight against the new coronavirus [8-9] by quickly delivering superior detection rates while drastically decreasing or removing the need for human intervention. Over the years, different ML based algorithms which include, SVM, KNN, Naïve Bayes, Decision Tree etc. are used. However, the problem with the ML methods is that they cannot handle the large datasets generated by the medical field. Therefore, the researchers are moving towards the implementation of DL based methods. Deep learning (DL) approaches can handle enormous datasets, making them effective for detecting covid-19 that has a massive dataset. Numerous researchers trained their networks using publicly available datasets. The research in [10] found that by using the support vector machine (SVM) method, it was possible to correctly categorize COVID-19 individuals in 85 percent of instances. In this paper, an effective DL based approach is proposed that can efficiently predict Covid-19 as well as the need for regular wards and ICU/Semi-ICU requirements in the Hospitals.

2. LITERATURE REVIEW

In order to have a better understanding of the various ML and DL based COVID-19 detection methods, a significant number of existing techniques are studied and reviewed in this section. Over the years, various researchers proposed models by using different ML and DL classifiers in their work, some of them are discussed here; M. Sevi and İ. Aydin [11], proposed a covid-19 detection model in which data augmentation and classification though multi-class DL based methods was done. Similarly, S. Lafraxo and M. el Ansari, [12], suggested a DL based Covid-19 detection approach, named as, CoviNet in which adaptive median filter, histogram equalization was implemented. In addition to this, a CNN technique was used for classifying the disease. The results demonstrated that the suggested model achieved an accuracy of 98.62% and 95.77% for binary and multi-class classifications. Xiaoshuo Li et al. [13], suggested a DL based covid-19 approach that was based on the hybridization of stacked Generalization ensemble learning along with the VGG16 classifier so that a cascade classifier is developed. The suggested model was able to achieve a accuracy rate of 93.57% and a precision of 89.40%. L. Brunese et al. [14], proposed an effective mechanism for detecting the covid-19 in humans in which they utilized the supervised ML techniques and used a publicly available dataset containing a total of 85 chest x-ray of patients. Through extensive experimentation, the efficacy of the suggested scheme is depicted. SoumyajitPodder et al [15], proposed a Mask R-CNN based covid-19 detection approach that was trained on the publicly available dataset comprising of 668 x-ray frontal chest images. The results showcased that current approach was able to achieve an accuracy of 96.98% and a precision rate of 96.60% respectively. S. Sakib et al. [16], presented an appropriate and effective DL based Chest Radiograph Classification (DL-CRC) paradigm for separating covid-19 positive samples from the normal or pneumonic cases with an accuracy of 93.94%. A. Channa et al. [17], proposed an extremely effective method for detecting covid-19 by utilizing DeepNets to assemble images of patients. The suggested approach was able to yield an accuracy of 91.67% while as, the survival ratio of accuracy was attained to be 100%. E. F. Ohata et al. [18], proposed a covid-19 detection approach that was based on various structures of CNN that was trained on ImageNet. Moreover, the authors incorporated the CNN with traditional ML algorithms like KNN, NB, RF, MLP and SVM for identifying the best performing model. Sethy, P.K et al. [19], utilized a DL based technique, named as, ResNet-50 along with the ML SVM for identifying and classifying the covid-19 in x-ray images. The results showcased that the proposed strategy was able to achieve a classification accuracy rate of 95.38%. S K T Hwa et al. [20], proposed an effective and improved approach in which local morphological contrast enhancement and Canny edge detection techniques were merged for classifying pneumonia and covid-19 diseases was proposed.

From the literature survey conducted, it is observed that over the years a significant number of AI based approaches were proposed by any researchers in order to identify and detect the COVID-19 disease effectively and efficiently in humans. Majority of the researchers have implemented the ML based algorithms in their work for predicting covid-19. Although, the ML based methods were providing god classification and quantification results, they undergo through some issues that degrade their overall performance considerably. One of the main issues faced in such approaches is that ML algorithms are not able to handle the large datasets which directly affect the efficiency of the detection system. Therefore, in order to combat this issue, a DL method are recommended. In addition to this, the complexity in current ML based systems was very high because not much work has been done on reducing the dimensionality of the datasets. Another drawback in these systems was that most of the ML algorithms used by researchers either get stuck in the local minima or have high computational cost. Moreover, feature selection is considered as one of the important factors in enhancing the accuracy of the systems, and no focus was given to it. Inspired from these findings, a new and improved model will be proposed that will not only enhance the accuracy of the system but will also reduce its intricacy and computational cost.

3. PROPOSED WORK

In order to overcome the limitations of traditional Covid-19 detection models, a new and enhanced detection model that is based on DL method is proposed in this research. The suggested method works for two classification phases, the first phase is intended for identifying covid-19 in patients and appropriately the necessity for ICU/semi-ICU requirement if predicted in the second phase. The main objective of the proposed DL method is to reduce the complexity of the system as well as enhance the accuracy of the system. To accomplish this task, firstly a dataset is needed upon which more advanced techniques will be applied to generate the final covid-19 and ICU requirement predictions. However, the problem with the available datasets is that they are unbalanced in nature and contain a lot of empty cells, null and NAN values, which enhances the complexity of the system. Therefore, it becomes necessary to apply pre-processing and other advanced techniques to it so that its complexity id reduced and only informative and useful data is present in it. Here, we propose an efficient and effective method where, Eigenvector centrality Feature Selection (ECFS) technique is applied along with the advanced version of LSTM, named as, Bi-LSTM (bi-directional Long Short-Term Memory). The main motive for using the Bi-LSTM is that it can handle large datasets effectively and also it remembers the information of the pasta as well as the future. Along with this, the feature selection technique used helps in reducing the dimensionality of the dataset which in return reduces the overall complexity and increases the accuracy of the system.

The dataset taken from the Israelita Albert Einstein hospital at Sao Paulo, Brazil is utilized in the proposed work, whose details are mentioned briefly in the methodology section. As previously stated, the used database is unbalanced and has a large number of empty and NAN entries which must be refilled or eliminated. To do so, an average Insertion Approach is applied on the selected dataset where a particular column is selected and analyzed so that the missing values are filled by calculating the average values and empty cells are removed from it. This helps in reducing the dimensionality of the dataset. In addition, Eigenvector Centrality Feature Selection (ECFS) approach is also implemented on the given dataset to ensure that only important and significant characteristics are chosen from it, thereby reducing the complexity of the system. Moreover, in conventional detection approaches ML classifiers were used that were not able to handle big datasets, therefore, an DL based Bi-LSTM model is used in the proposed work that handles the large datasets quite effectively and enhances the classification accuracy results. The Bi-LSTM classifier is used in the proposed work for predicting the covid-19 and the need for normal wards and ICU/Semi-ICU requirements. Another major reason for using the Bi-LSTM in the proposed work is that their prediction rate is quite higher than the regular LSTMs and doesn't get stuck in the local minima. Therefore, an effective and highly accurate model is developed by utilizing the ECFS and Bi-LSTM approaches that not only predicts the covid-19 but also predicts the requirement for ICUs. The step by step process of the proposed model is mentioned in the following section of this paper.

3.1 METHODOLOGY

The proposed bi-LSTM model undergoes through a series of steps like, data collection, pre-processing, feature selection and classification. At each stage the data is modified and refined so that effective results can be obtained at the end. The flowchart of the proposed system is shown in figure 1.2 and is explained below;

• Data acquisition: The first step opted in proposed model is of data collection. In this stage, the necessary information is collected from the available datasets. The dataset used in the proposed work is taken from the Kaggle.com and is utilized for performing two classification tasks (predicting covid-19 and ICU requirement) in the proposed work.

DATASET USED

The dataset used in this research is taken from the Kaggle.com, and it contains information about various patients at Israelita Albert Einstein hospital located in Sao Paulo, Brazil. A sum of 5644 patient samples are included in the collection, together with their 111 characteristics. The difficulty with the existing database, unfortunately, is that it is unbalanced because 90% of the information is for negative instances. Furthermore, the collection contains empty and missing NAN values, which must be eliminated.

•Data pre-processing: once the data is collected. The next step to eb followed is pre-processing. For this, an average insertion approach is used which removes the empty cells from the dataset and fills the missing and NAN values by calculating their average sum. The data is processed and normalized so that only informative and useful information is present in the system.

•Feature selection: In order to reduce the dimensionality and complexity of the dataset, an Eigenvector Centrality Feature Selection (ECFS) is applied to the processed data. The ECFS selects only those features that are important and crucial for predicting the cobid-19 and ICU requirements in proposed work. The two important parameters of ECFS are alpha and mean threshold whose values are given in table 1.1. The final dataset obtained is then divided into two categories for training and testing.

TABLE 1.1 DIFFERENT PARAMETERS OF PROPOSED MODEL

Sr. No.	Factors	Values
1	Alpha	0.85
2	Mean Threshold	0.7*W1 and W2
3	HiddenUnits	25
4	InputLayer (Type)	Sequential
5	Network Type	BILSTM
6	Epochs	100
7	InitialLearning Rate	0.045
8	GradientThreshold	0.02
9	BatchSize	10

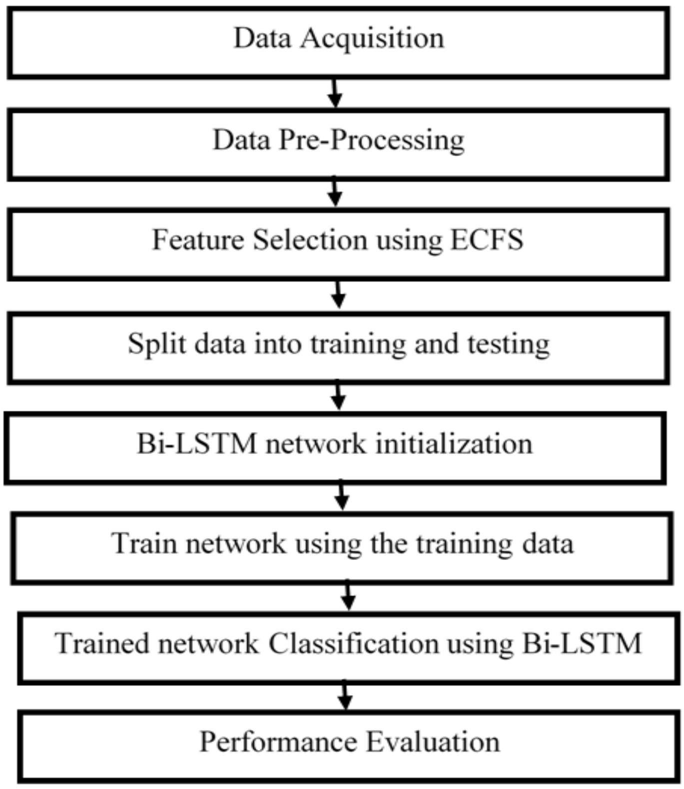

Fig.1.1Proposed Bi-LSTM model

- Network initialization: After this, the proposed Bi-LSTM network initialized wherein, a number of Bi-LSTM parameters are defined. Some of the parameters used in the proposed work are input layers, network type, hidden units and max epochs, whose values are mentioned in table 1.1.
- Training of model: Once the model is initialized, it starts training itself by passing the training data to it. The model trains itself as per this data.
- Classification: In the last phase, the performance of

the proposed model is analyzed by passing the testing data to it. The proposed Bi-LSTM model predicts the covid-19 and ICU requirements as per the training provided to it. On the basis of this classification, its performance is evaluated in terms of number of parameters like accuracy, precision, recall and Fscore that are mentioned briefly in next section.

4. RESULTS AND DISCUSSION

The results of the suggested Bi-LSTM framework are analyzed and explained in this section. Because the findings were acquired for two classification tasks, they were also analyzed separately for the two categorization groups. The suggested Bi-LSTM model is simulated using the MATLAB software. the results were obtained in terms of various dependency factors and is alter on compared with traditional methods to evaluate its supremacy.

4.1 PERFORMANCE EVALUATION FOR COVID-19 PREDICTION

The performance of the proposed Bi-LSTM model is analyzed and compared with various state of art approaches in terms of accuracy, precision, specificity, recall and Fscore. In addition to this, the learning rate of the proposed Bi-LSTM model is 0.0450 throughout all iterations. Moreover, the min. batch loss is also reduced from 0.6920 to 0.1916 and training accuracy is enhanced from 93.896 to 95.250% in proposed Bi-LSTM model. To validate the effectiveness of the suggested approach, its performance is compared with the traditional RF, MLP, LGBM, NB, ETC, S1-RF-XGB-LR, S2-NB-LGBM-LR, V1-ET-RF-LGBM-Hard, V1-RF-LR-SVM-Soft, V2-MLP-NB-LGBM- hard and V2-MLP-NB-LGBM-Soft approaches in terms of their accuracy value. The graph obtained for the same is represented in figure 1.2. The x-axis and the y-axis of the given graph calibrate the different approaches and tehri accuracy values respectively. After examining the graph closely, it is observed that the value of accuracy was lowest achieved in conventional MLP model with 90.55%, followed up by NB with 91.95, followed up by V2-MLP-NB-LGBM-hard, V2-MLP-NB-LGBM-Soft, V1-RF-LR-SVM-Soft, ETC, LGBM and RF with 91.95%, 91.65%, 91.56%, 91.56%, 91.29% and 91.1% respectively. while, as the accuracy values is considerably enhanced by other traditional models like, S1-RF-XGB-LR, S2-NB-LGBM-LR and V1-ET-RF-LGBM-Hard whose accuracy rate was mounted at 94.39%, 92.78% and 92.47% respectively. On the other hand, when the value of accuracy is analyzed for the proposed Bi-LSTM model, it is significantly higher than all the traditional models with value of 95.26129%. This means that the proposed Bi-LSTM model is able to predict Covid-19 and ICU requirement more accurately and effectively, when compared with traditional ML based methods.

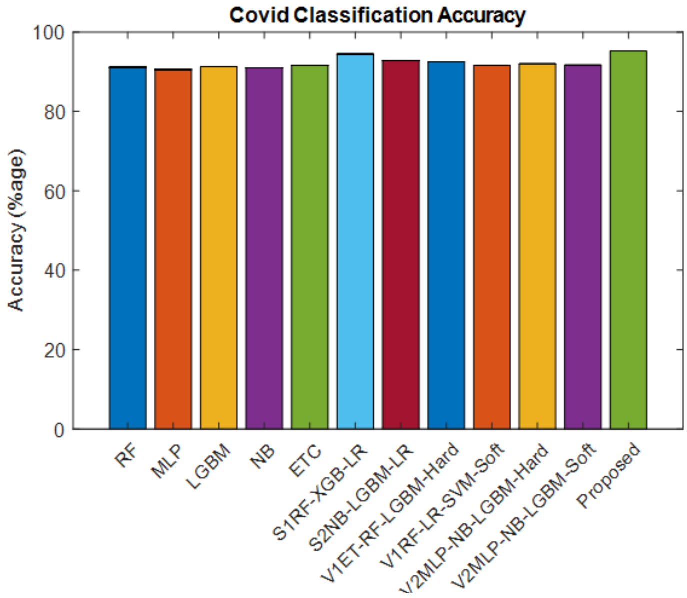

Fig.1.2Comparison graph for Accuracy (COVID)

In addition to the accuracy, the performance of the suggested Bi-LSTM model is evaluated in terms of precision, specificity, recall and Fscore as well. The values attained for each parameter in proposed Bi-LSTM model and traditional models is given in table 1.2.

After analyzing the above table (see table 1.2), it is observed that the proposed Bi-LSTM approach is outperforming the conventional RF, MLP, LGBM, NB, ETC, S1-RF-XGB-LR, S2-NB-LGBM-LR, V1-ET-RF-LGBM-Hard, V1-RF-LR-SVM-Soft, V2-MLP-NB-LGBM- hard and V2-MLP-NB-LGBM-Soft methods in terms of precision, recall, specificity and FScore as well. The precision value in proposed Bi-LSTM model is 100% while as, it was only 90% in RF, MLP, ETC, V1-ET-RF-LGBM-Hard, V1-RF-LR-SVM-Soft and V2-MLP-NB-LGBM-Soft models and 91% in LGBM, NB, S1-RF-XGB-LR, S2-NB-LGBM-LR and V2-MLP-NB-LGBM- hard. Similarly, the values achieved for Recall, specificity and Fscore in proposed Bi-LSTM model came out to be 95.26129%, 95.26129318% and 97.57315 respectively. From the given graph and table, it is proved that the proposed Bi-LSTM scheme for predicting covid-19 is more effective and efficient.

4.2 PERFORMANCE EVALUATION FOR ICU REQUIREMENT

As previously done for the first classification phase, the performance of the proposed Bi-LSTM model is also analyzed and compared with several conventional methods in terms of their accuracy. Figure 1.3 represents the comparison graph of the proposed Bi-LSTM model with traditional models.

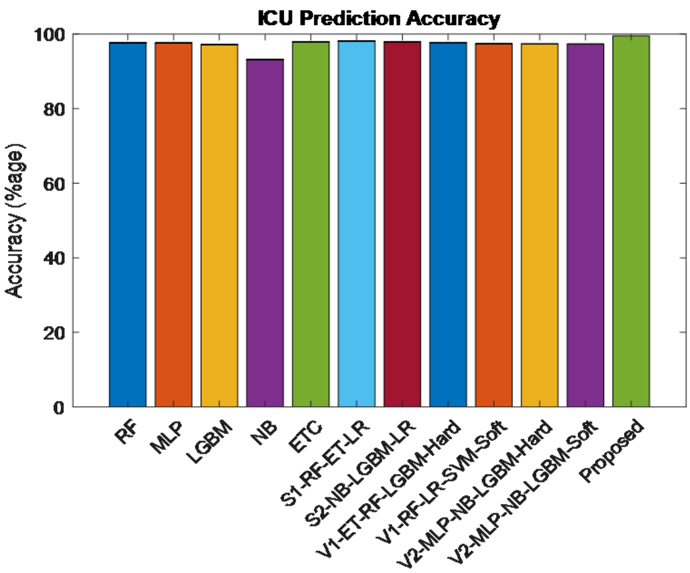

Fig.1.3Comparison graph for accuracy (ICU)

Figure 1.3 illustrates the comparison graph of the suggested Bi-LSTM model along with the traditional RF, MLP, LGBM, NB, ETC, S1-RF-XGB-LR, S2-NB-LGBM-LR, V1-ET-RF-LGBM-Hard, V1-RF-LR-SVM-Soft, V2-MLP-NB-LGBM- hard and V2-MLP-NB-LGBM-Soft methods in terms of their accuracy. The accuracy reached in standard RF, MLP, LGBM, NB, and ETC approaches was only 97.66%, 97.59%, 97.18%, 93.16%, and 97.94%, correspondingly, as shown in the graph. Meanwhile, hybrid approaches such as S1-RF-ET-LR, S2-NB-LGBM-LR, V1-ET-RF-LGBM-Hard, V1-RF-LR-SVM-Soft, V2-MLP-NB-LGBM-Hard, and V2-MLP-NB-LGBM-Soft enhance accuracy by a little percentage with 98.13%, 97.95%, 97.71%, 97.41% and 97.39% respectively. The accuracy achieved in the suggested Bi-LSTM framework, on the other hand, is about 99.555%, which is significantly higher than traditional models, therefore, demonstrating its usefulness and efficacy. Moreover, the efficiency of the proposed Bi-LSTM model is depicted in terms of other performance factors like Precision, recall and fscore, whose exact values are given in table 1.3.

TABLE 1.2
Performance Values attained by traditional and Proposed model (COVID Prediction)

Techniques	Precision	Recall	Specificity	Fscore	Accuracy
RF	90	89	95.9677	89	91.1
MLP	90	91	86.2903	91	90.55
LGBM	91	90	93.5484	90	91.29
NB	91	90	95.9677	90	90.95
ETC	90	89	95.9677	89	91.56
S1-RF-ET-LR	91	92	95.1613	91	94.39
S2-NB-LGBM-LR	91	91	95.1613	91	92.78
V1-ET-RF-LGBM-Hard	90	90	95.9677	89	92.47
V1-RF-LR-SVM-Soft	90	89	94.3548	89	91.56
V2-MLP-NB-LGBM-Hard	91	90	95.1613	90	91.95
V2-MLP-NB-LGBM-Soft	90	90	94.3548	90	91.65
Proposed	100	95.26129	95.26129318	97.57315	95.26129

TABLE 1.3
Comparison table for predicting ICU requirements

Techniques	Precision	Recall	Fscore	Accuracy
RF	98	98	98	97.66
MLP	97	98	97	97.59
LGBM	98	98	98	97.18
NB	98	94	96	93.16
ETC	98	97	98	97.94
S1-RF-ET-LR	99	99	98	98.13
S2-NB-LGBM-LR	98	99	98	97.95
V1-ET-RF-LGBM-Hard	98	98	98	97.71
V1-RF-LR-SVM-Soft	98	97	96	97.41
V2-MLP-NB-LGBM-Hard	98	98	98	97.39
V2-MLP-NB-LGBM-Soft	97	98	97	97.34
Proposed	100	99.11426	99.11426	99.55516

After analyzing the table 1.3, it is observed that the value of precision is highest among all in proposed Bi-LSTM model with 100% results. While as, the precision values were lowest among all in traditional MLP and V2-MLP-NB-LGBM-Soft models with just 97% value, 98% in conventional RF, LGBM, NB, ETC, S2-NB-LGBM-LR, V1-ET-RF-LGBM-Hard, V1-RF-LR-SVM-Soft and V2-MLP-NB-LGBM-Hard models and 99% in standard S1-RF-ET-LR model. In addition to this, the performance was evaluated in terms of recall and Fscore as well, whose values were mounted at 99.11426% for each. These values are enough to prove the superiority of the proposed Bi-LSTM model over traditional models in all factors including, accuracy, precision, recall and Fscore.

5. CONCLUSIONS

In this paper, an effective and efficient Bi-LSTM based approach is proposed for predicting the covid-19 and ICU requirement in hospitals. Through extensive simulations in the MATLAB software, the efficacy and accuracy of the proposed Bi-LSTM system is analyzed in terms of accuracy, precision, recall and Fscore. After examining the results, it is observed that the value of accuracy in proposed Bi-LSTM model for predicting covid-19 were mounted at 95.26129% while as for predicting the ICU requirement the accuracy value was 99.55516% respectively. However, when the accuracy values were analyzed for traditional models, it came out to be 91.1% in RF, 90.55% in MLP, 91.29% in LGBM, 90.95% in NB, 91.56% in ETC, 94.39% in S1-RF-XGB-LR, 92.78% in S2-NB-LGBM-LR, 92.47% and 91.56% in V1-ET-RF-LGBM-Hard and V1RF-LR-SVM-Soft, 91.95% in V2-MLP-NB-LGBM- hard and 91.65% in V2-MLP-NB-LGBM-Soft approaches for predicting covid-19. On the other hand, the value of accuracy for predicting ICU requirement in traditional approaches were 97.66%, 97.59%, 97.18%, 93.16%, and 97.94% in RF, MLP, LGBM, NB, and ETC and 98.13%, 97.95%, 97.71%, 97.41% and 97.39% in S1-RF-ET-LR, S2-NB-LGBM-LR, V1-ET-RF-LGBM-Hard, V1-RF-LR-SVM-Soft, V2-MLP-NB-LGBM-Hard, and V2-MLP-NB-LGBM-Soft approaches. In addition to this, the values were attained in terms of precision, recall and fscore whose values came out to be 100%, 95.26129% and 97.57315 for predicting covid-19 and 100%, 99.11426% and 99.11426% for predicting ICU requirements. From these results, it is concluded that the proposed Bi-LSTM model for predicting Covid-19 and ICU requirements is more accurate and precise with low complexity

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