Deep-LSTM ensemble framework to forecast Covid-19: an insight to the global pandemic

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Abstract The pandemic of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is spreading all over the world. Medical health care systems are in urgent need to diagnose this pandemic with the support of new emerging technologies like artificial intelligence (AI), internet of things (IoT) and Big Data System. In this dichotomy study, we divide our research in two ways—firstly, the review of literature is carried out on databases of Elsevier, Google Scholar, Scopus, PubMed and Wiley Online using keywords Coronavirus, Covid-19, artificial intelligence on Covid-19, Coronavirus 2019 and collected the latest information about Covid-19. Possible applications are identified from the same to enhance the future research. We have found various databases, websites and dashboards working on real time extraction of Covid-19 data. This will be conducive for future research to easily locate the available information. Secondly, we designed a nested ensemble model using deep learning methods based on long short term memory (LSTM). Proposed Deep-LSTM ensemble model is evaluated on intensive care Covid-19 confirmed and death cases of India with different classification metrics such as accuracy, precision, recall, f-measure and mean absolute percentage error. Medical healthcare facilities are boosted with the intervention of AI as it can mimic human intelligence. Contactless treatment is possible only with the help of AI assisted automated health care systems. Furthermore, remote location self treatment is one of the key benefits provided by AI based systems.

Keywords LSTM · Covid-19 · Deep learning · Artificial intelligence · Nested ensemble

1 Introduction and background

The coronavirus cases were firstly reported in 1960 and around 500 patients were identified with flu and out of them, 18 were infected by coronavirus. Until 2002, coronavirus was treated as a simple non fatal disease and from 2003 onwards various research reports were published about increasing cases of coronavirus in many countries. Severe acute respiratory syndrome (SARS) caused by coronavirus led to 1000 deaths in 2003 and about 8000 patients were infected with coronavirus. Moreover, 50 patients of severe acute respiratory syndrome (SARS) were also confirmed by a Hong Kong study report in which 30 patients were infected with coronavirus and correspondingly in 2004, World Health Organization (WHO) declared the state emergency in infected countries [1]. In 2012, Saudi Arabia also reported some confirmed cases and deaths [2, 3]. In late December 2019, few patients were identified with pneumonia symptoms in Wuhan city (capital city of Hubei Province in China). Out of them, few
patients worked at the local Huanan seafood wholesale market in which live animals were also on sale [4, 5]. At a very early stage of this pneumonia, severe acute respiratory infection occurred which led to acute respiratory system failure or acute respiratory distress syndrome (ARDS).

Coronaviruses belong to the subfamily of Coronaviridae and are single strand positive RNA viruses that can be subgrouped as alpha, beta, gamma and delta [6–8]. There are four common human coronaviruses namely (i) 229E (alpha coronavirus) (ii) NL63 (alpha coronavirus) (iii) OC43 (beta coronavirus) (iv) HKU1 (beta coronavirus). MERS-COV and SARS-COV are the beta coronaviruses that cause Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS) respectively. SARS-COV-2 is the novel coronavirus that results 2019-nCov, coronavirus disease 2019 or Covid-19 [9–11].

About 215 countries and regions were affected due to this pandemic [12, 13] and is a global threat to mankind on earth. The cause of the spread of Covid-19 pandemic is lack of AI assisted automated diagnostic systems. As the pandemic is spreading via human to human contact, there is an urgent need for contactless treatment to save lives. The purpose of this study is to inculcate knowledge about Covid-19 pandemic through various databases, websites and experiments done so far and to diagnose Covid-19 using proposed deep-LSTM ensemble model. To the best of our knowledge and experience from the literature review, all the information propagated through present research work along with proposed deep learning based experimentation was not done before. This can also help future research direction to use collective information. This paper focuses on the role of Artificial Intelligence to combat Covid-19 pandemic.

The remainder of this paper is arranged as follows: In Sect. 2, we discuss the applications of AI to detect and diagnose Covid-19. In Sect. 3, various Covid-19 datasets along with websites and current pandemic situations are discussed. In Sect. 4, there is research methodology discussed with data description, experiment and results. In Sect. 5, the author’s contribution to defeat Covid-19 pandemic is tabulated. In Sect. 6, the discussion and conclusion is elaborated.

2 Artificial intelligence in diagnosing Covid-19

Artificial intelligence (AI) will play a vital role in diagnosing the global pandemic presently known as COVID-19. The contribution and analytics of artificial intelligence in the fields of Medical Imaging, Natural Language Processing, Text Mining, Deep Learning, Machine Learning, Expert Systems, Data Analytics and Internet of Things are unprecedented and keen to be appreciable. As the time passes, AI is becoming more dominant in public health sectors. Some applications of AI in diagnosing Covid-19 are mentioned below.

2.1 AI based mobile and web applications

Artificial Intelligence can easily chase the spread of this deadly virus and also assist to identify the high risk patients with coronavirus symptoms. Along with the extensive review in this paper, we also generalized the architecture of symptomatic analysis with AI and normal approach as shown in Fig. 1 where we differentiate between the therapy given by AI systems and normal human manual approach. AI systems don’t require taking multiple sample reports of Covid-19 patients manually whereas in Non-AI systems, the risk of health care workers to get infected is quite high [14]. As per the recent reports, 200 front line workers (including doctors and nurses) died on 3rd May 2020 in Black, Asian and Minority Ethnic (BAME) groups [15].

Artificial Intelligence can contribute to global health initiatives that are built across multiple tools such as to predict the healing time of the skin burn by using photographs on smart phones and tools which can accurately predict the pregnancy related complications discussed in [16, 17]. Similar kind of work is done by [18] and predicts the mortality rate of the patients using various machine learning algorithms with 93% accuracy. Authors in [19] also predicts the transmission dynamics of the coronavirus which leads to medical health strategy and policy making. To track, detect and predict the Covid-19 in real time, several data repository initiatives were taken at global level including a dashboard designed by Johns Hopkins Center for Systems Science and Engineering (CSSE) [20, 21]. Another dashboard is designed as HealthMap Covid-19 with participant institutions such as Oxford University is available at [22–24].

A web application is designed based on susceptible-infected-recovered (SIR) model with exposed individuals as additional category [25]. The application is available at [26] and the source code is also available at Github repository in [27]. An app was developed by University of Melbourne as Coronavirus 10-day forecast which updates daily data on Covid-19 based on country wise data collected by Johns Hopkins University and Ministry of Health and Family Welfare, Government of India datasets and is available at [28] and the code is also available at Github [29]. A web application is designed by [30] to track real time mutational status of Covid-19 and enable users to annotate their genomic sequences on Covid-19 globally. The web application is available at [31] and source code available at Github [32]. An Artificial Intelligence (AI) based mobile app AI4 VIVID-19 is designed to test Covid-19 symptoms with just a couple of cough recording
samples. This app distinguishes between Covid-19 and Non-Covid-19 patients with 90% accuracy [33]. COVID-MobileXpert is a lightweight mobile app designed by [34] using Deep Neural Networks and uses snapshots of chest X-ray for screening Covid-19.

2.2 AI based treatment using medical images

After detection and prediction of Covid-19 symptoms, there is a need to diagnose this severe disease using AI in a leading role. With an extensive literature review, we came to know various AI based algorithms which can detect as well as diagnose Covid-19 patients successfully. An overview is also given in Fig. 2 about how AI came into contact with the coronavirus pandemic. Study shows a positive correlation between coronavirus (Covid-19), mortality and morbidity rate, burden over radiologists and health care facilities [35].

It is nearly impossible in large countries like India and China to train a huge number of healthcare workers including nurses and doctors in the midst of pandemic. Its solution is to design intelligent AI machines that can mimic human intelligence. Transfer learning mechanism is being used in [36, 37] to design deep CNN based decompose, transfer, and compose (DeTraC) models with 95.12% accuracy. Niclosamide and promazine are two active drugs for SARS-CoV in [38] which designed two AI models by combining different datasets from approved drugs. Authors in [39] designed a model for mask wearing face detection using AI. Work in [40, 41] shows that AI can recognize breathing characteristics of a Covid-19 patient and distinguish it with non-Covid-19 person. Respiratory simulation model (RSM) is being used to simulate training and real world data and deep learning is being used to classify 6 clinical respiratory patterns. Authors in [42] proposed a Convolutional neural network based model viz. CoroNet which detects Covid-19 using x-ray images of the chest. Covid-19 gets confirmed by respiratory gene sequencing samples which is a key factor for reverse transcription polymerase chain reaction (RT-PCR) [40]. In [43, 44] authors make use of chest CT images and designed AI based automated systems for segmentation of all lung infections. Authors in [45] studies about MERS CoV and explored the features of chest CT and X-ray images which resemble pneumonia. CT scanning is an advanced version of X-ray machines which gives clearer image and softens the inner tissues and organs [46]. By combining AI with IoT, we can achieve contactless diagnosis and streaming of Covid-19 [47, 48]. This can be panacea for the front line workers as they are the first target during this pandemic. To make equilibrium between these two situations, cognitive internet of medical things (CIoMT) helps the doctors to
diagnose patients remotely via wearable IoT sensors [49, 50].

3 AI working with Covid-19 data repository

Data is new fuel to modern world technologies like Artificial Intelligence, Data Science, Big Data, Blockchain and IoT. Without data these algorithms are of no use. AI algorithms required data to learn and analyze the sequences to give desired output. Author in [51] mentioned the importance of data for AI to train models for better prediction.

| S. no. | Reference | Dataset name | Country | Type(s) of data          |
|--------|-----------|--------------|---------|--------------------------|
| 1      | [52]      | Kinsa Smart Thermometer Weather Map | USA    | Temperature readings     |
| 2      | [53]      | RKI COVID19  | Germany | Infection cases          |
| 3      | [54]      | BSTI Covid-19 Imaging Database | UK     | CT scan                  |
| 4      | [55]      | COVID-19 DATABASE | Italy  | Radiological data        |
| 5      | [56]      | nCoV2019    | 7 countries | Epidemiological data     |
| 6      | [57]      | Data-Science-for-COVID-19 | Korea | Patient demographics     |
| 7      | [58]      | covid-19-data | USA   | Live data                |
| 8      | [59]      | covid-chestxray-dataset | Italy  | Patient demographics     |
| 9      | [60]      | RCSB Protein Data Bank | All countries | Genomic sequences |
| 10     | [61]      | COVID-CT-Dataset | All countries | Labeled chest CT scans |
| 11     | [62]      | Public Corona-virus Twitter Dataset | All countries | Twitter ID’s             |
| 12     | [63]      | COVID-19 Community Mobility Reports | 135 countries | Community Mobility Report |
| 13     | [64]      | Novel Corona-virus 2019 dataset | All countries | Patient demographics     |
| 14     | [65]      | COVID-19 Open Research Dataset Challenge (CORD-19) | All countries | Research articles dataset |
| 15     | [66, 67] | LitCovid     | All countries | Research articles dataset |
| 16     | [68]      | Coronavirus Source Data | All countries | Time series data         |
| 17     | [69]      | JHU CSSE COVID-19 Data | All countries | Mortality count, cured patient count, confirmed cases, location |
| 18     | [70]      | Coronavirus COVID19 Tweets | All countries | Tweet text, hashtags, location |
| 19     | [71]      | hCOV-19     | All countries | genomic epidemiology     |
| 20     | [72]      | CHIME       | All countries | Susceptible, infected and recovered patient count |
| 21     | [73]      | Global research on COVID-19 | All countries | Research articles dataset |

Table 3 Shows Covid-19 status of top 10 countries ordered in terms of confirmed, death, recovered and active cases. These countries are most affected due to the pandemic and
require automated systems and health care workers in abundance. Figure 3 Shows the graphical view of Covid-19 death cases globally [75]. Figure 4 shows Covid-19 death cases in WHO regions from 30th December 2019 to 1st September 2020 graphically which shows a clear upward trend as time passes [75].

### Table 2  Distinguished Covid-19 websites and community resources

| S. no. | Website Description |
|-------|---------------------|
| 1     | CSSE at JHU and Dashboard |
| 2     | MATLAB for Deep Learning |
| 3     | Partnership on AI |
| 4     | Global research database (WHO) |
| 5     | Telehealth Toolbox |
| 6     | Vector Institute |
| 7     | Montreal AI task force |
| 8     | LitCovid |
| 9     | Covid-19 Data Portal |
| 10    | CDC Library, USA |
| 11    | Amazon AWS |
| 12    | Semantic Scholar Covid-19 |
| 13    | Aitslab_Covid-19 NLP toolbox repository for Covid-19 research |
| 14    | AI against Covid-19 Information related to Genomics, Datasets, Research articles and NLP source data |
| 15    | HealthMap Covid-19 Visualization of Covid-19 with the help of global map |
| 16    | Worldometer Real-time online tracking system of Covid-19 cases |

### Table 3  Top 10 countries in cases on Covid-19 pandemic [12, 13]

| S. no. | Country | Confirmed cases | Recovered cases | Deaths | Active cases |
|--------|---------|-----------------|-----------------|--------|--------------|
| 1      | USA     | 5,746,534       | 2,473,186       | 177,438| 2,473,186    |
| 2      | Brazil  | 3,505,097       | 2,653,407       | 112,423| 739,267      |
| 3      | India   | 2,910,032       | 2,160,059       | 55,002 | 694,971      |
| 4      | Russia  | 946,976         | 761,330         | 16,189 | 169,457      |
| 5      | South Africa | 599,940   | 497,169         | 12,618 | 90,153       |
| 6      | Peru    | 567,059         | 380,730         | 27,034 | 159,295      |
| 7      | Mexico  | 543,806         | 371,638         | 59,106 | 113,062      |
| 8      | Colombia | 513,719      | 339,124         | 16,183 | 158,412      |
| 9      | Spain   | 404,229         | N/A             | 28,813 | N/A          |
| 10     | Chile   | 391,849         | 366,063         | 10,671 | 15,115       |

NA not available

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### 4 Research methodology

#### 4.1 Data description

In this paper, Covid-19 confirmed and death cases of India are taken from World Health Organization [73] as on 1st September 2020. Data for experimentation is taken from the day when first case was taken into consideration in the country. Confirmed cases are taken from 29th January to
1st September 2020 and death cases are taken from 12th March to 1st September 2020.

4.2 Experiment

The experiments are carried out in Google Colaboratory using python 3.0 with open source libraries like

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Fig. 3 Covid-19 death cases worldwide as on 1st September 2020

Fig. 4 Covid-19 death cases in WHO region from 30th December to 1st September 2020

Fig. 5 Proposed deep-LSTM ensemble model

1st September 2020 and death cases are taken from 12th March to 1st September 2020.
Tensorflow, Pandas, Numpy, and keras. The experimental setup is based on working environment having Intel(R) Core (TM) i5-7400 CPU @ 3.00 GHz with 4 GB RAM under 64-bit Windows 10 pro Operating system. Various time series techniques can be used to forecast the data which includes long short term memory and exponential smoothing [74]. We have proposed a nested ensemble model using deep learning based long short term (LSTM) models as shown in Fig. 5. The deep-LSTM ensemble model using convolutional and bi-directional LSTM gives state-of-the-art results and designed the high accuracy model to forecast Covid-19. The dataset used for experimentation is divided into training and testing phases as 70% of data is used for training and 30% of it is used for testing purpose. The tuning of hyper-parameters is set after rigorous testing at each stage. MinMaxScaler is used to scale the data between (−1, 1) to make it fit for experimentation. Results are compared in terms of accuracy,

| S. no. | Country | Accuracy | Precision | Recall | F-measure | MAPE |
|-------|---------|----------|-----------|--------|-----------|------|
| 1     | India   | 97.59    | 100       | 97.14  | 0.98      | 2.40 |
| 2     |         | 98.88    | 98.73     | 100    | 0.99      | 1.11 |

Fig. 6 India Covid-19 confirmed cases prediction

Fig. 7 India Covid-19 death cases prediction
precision, recall and F-measure. The error in the model is calculated in terms of mean absolute percentage error (MAPE) as shown in Table 4. We forecasted the Covid-19 confirmed and death cases for one month ahead as is shown graphically in Figs. 6 and 7.

The forecasted Covid-19 confirmed cases of India shows significant upward trend for some more time in near future. The actual (blue line) and predicted (red line) data is visualized in Fig. 6 having some sudden jump (red dotted line) in the forecasted data also. Significant downward trend is shown after some time in Covid-19 predicted confirmed cases. Figure 7 shows Covid-19 actual (blue line) and predicted (red line) cases for one month ahead, showing a significant downward trend in death cases at the end of the month.

5 Author contributions using AI applications

This section summarizes working of Covid-19 datasets with AI assisted systems to diagnose this pandemic. Through extensive literature survey we came to know
various models and methods of different researchers on Covid-19 shown in Table 5.

6 Conclusion and future work

Artificial intelligence is the key concept for all diseases including coronavirus. It can monitor the health care services to easily detect, prevent and diagnose the Covid-19 pandemic. AI assisted intelligent medical imaging aimed at coronavirus is the key factor to diagnose this pandemic. In this paper, we take a deep insight to the pandemic in terms of sources of information and also designed an experimental study using proposed deep-LSTM ensemble model to diagnose Covid-19. We carry out our experimentation for Covid-19 confirmed and death cases of India. Various classification metrics are used to check efficiency of proposed model with error rate. For Covid-19 confirmed cases we achieved an accuracy of 97.59% and for death cases it is 98.88%. MAPE value for both the experiments aimed Covid-19 confirmed and death cases are 2.40 and 1.11 respectively.

In the future, we can forecast Covid-19 cases for different countries with comparative analysis. As the Covid-19 cases are increasing exponentially it is impossible to defeat this pandemic without the inception of Artificial Intelligence that can help in proper treatment, prevention and vaccine development. Therefore, we can compare the leading technologies and vaccines used or developed by various countries to recede Covid-19 impacts and enhance its future time line.

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Compliance with ethical standards

Conflict of interest None declared.

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