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Survey of Applications of Neural Networks and Machine Learning to COVID-19 Predictions

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Chapter 2
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ABSTRACT

The purpose of this chapter is to illustrate how artificial intelligence (AI) technologies have been used for COVID-19 detection and analysis. Specifically, the use of neural networks (NN) and machine learning (ML) are described along with which countries are creating these techniques and how these are being used for COVID-19 diagnosis and detection. Illustrations of multi-layer convolutional neural networks (CNN), recurrent neural networks (RNN), and deep neural networks (DNN) are provided to show how these are used for COVID-19 detection and prediction. A summary of big data analytics for COVID-19 and some available COVID-19 open-source data sets and repositories and their characteristics for research and analysis are also provided. An example is also shown for artificial intelligence (AI) and neural network (NN) applications using real-time COVID-19 data.

BACKGROUND OF COVID-19

Corona Virus Disease 2019 (COVID-19) is a contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first case was identified in Wuhan, China, in December 2019. It has since spread worldwide, leading to an ongoing pandemic. (Wikipedia, 2021)

European Centre for Disease Prevention and Control (ECDC) (2021) has been posting weekly open-source COVID-19 related datasets for free download that includes data on hospital and ICI admission rates and current occupancy for COVID-19, and data on testing for COVID-19 by week and country.

The Office of Data Science Strategy (ODSS) of National Institute of Health (NIH) (2020) has made available open-access data and computational resources to address COVID-19 that includes CAS COVID-19 antiviral candidate compounds dataset of nearly 50,000 chemical substances for use in applications including research, data mining, machine learning, and analytics.

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Artificial Intelligence (AI) techniques used for diagnosis of COVID-19 include AI-empowered medical image acquisition, segmentation, diagnosis and follow-up. Many investigators have used different image segmentation methods in COVID-19 applications (Shi et al. (2020)).

Recent extensive studies have been presented in several books with detailed COVID-19 related studies of applications of artificial intelligence used for creating predictive models for decision making in this pandemic and include those of Abdelrahman (2020), Bandyopadhyay and Dutta (2020), Hassaniem et al. (2020), Santosh and Joshi (2021), Zhang (2020), Al-Turjan et al. (2021), Marques et al. (2021), and Raza (2021). Further discussions of these extensive studies are presented in this chapter.

MACHINE LEARNING AND COVID-19

Machine learning (ML) is based on the premise that an intelligent machine should be able to learn and adapt from its environment based on its experiences without being explicitly programmed. The availability of open-source data sets with COVID-19 data allows the experimentation of using machine learning techniques and deep neural networks for the prediction and diagnosis of COVID-19 using Computed Tomography (CT) scans and x-rays. CT scans show detailed images of any part of the body, including the bones, muscles, fat, organs and blood vessels.

Shuja et al. (2020) provided a comprehensive survey of open-source data sets that included categories of biomedical images, textual, and speech data. As COVID-19 test kits are in short supply, medical image-based diagnosis provides an alternative method of COVID-19 diagnosis. According to Shuja et al. (2020), the combination of artificial intelligence (AI) and open-source data sets practical solution for COVID-19 diagnosis that can be implemented in hospitals worldwide.

According to the World Health Organization (WHO) (2020) some of the leading hospitals across the world are utilizing artificial intelligence and machine learning algorithms to diagnose COVID-19 cases using Computed Tomography (CT) scans and X-ray images.

Rao and Vazuez (2020) showed that identification of COVID-19 can be quicker through artificial intelligence framework with use of machine learning algorithm when used with a mobile phone-based survey when cities and towns are under quarantine.

Bandyopadhyay and Dutta (2020) provided a validation of COVID-19 by Machine Learning approach using performance metrics of accuracy and Root-Mean Square-Error (RMSE) using a Recurrent Neural Network method.

Zoabi et al. (2021) created a model that predicted COVID-19 test results with high accuracy using only eight binary features: sex, age ^{3}60 years, known contact with an infected individual, and the appearance of five initial clinical symptoms. Zoabi et al. (2021) indicate that their framework of can be used, among other considerations, to prioritize testing for COVID-19 when testing resources are limited.

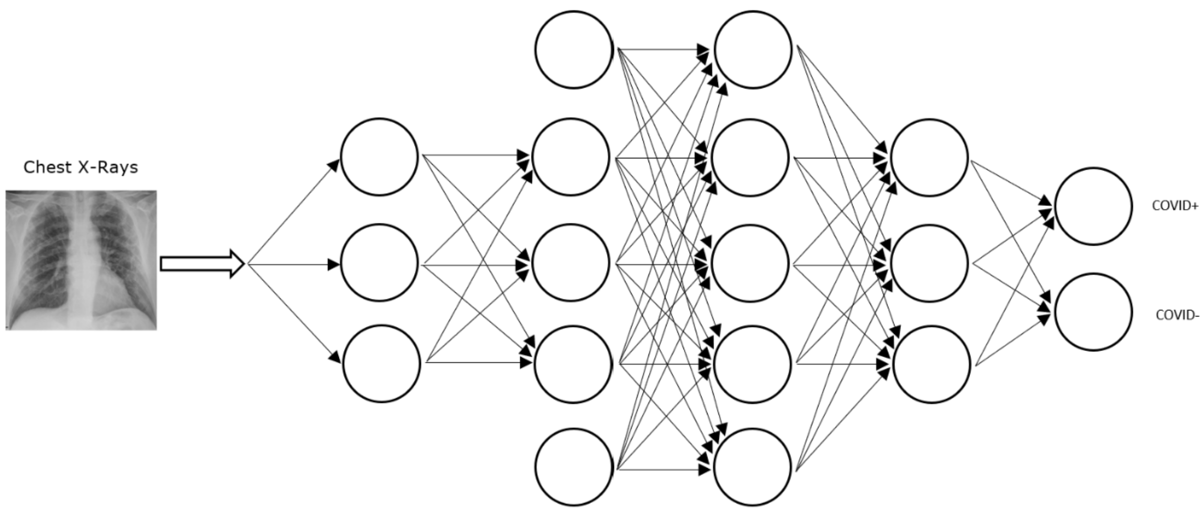
NEURAL NETWORKS AND COVID-19

Pham (2020) presented a comprehensive study on classification of COVID-19 on computed tomography with pretrained convolutional neural networks (CNN). Pham (2020) found that using certain parameter specification and training strategy for the networks, this study found very high performance of several of the 16 pretrained CNNs for COVID-19 diagnosis using CT scans.

Wang et al. (2020) used five pretrained convolutional neural networks (CNN) for COVID-19 diagnosis in chest x-ray images that achieved an overall accuracy of 95%.

Bassi and Attux (2020) showed that chest x-rays used together with Deep Neural Networks (DNN) and Layer-wise Relevance Propagation (LRP) to generate heatmaps can become a cheap and accurate method for COVID-19 diagnosis. Hanfi (2020) also discussed a neural network approach to, detect COVID-19 through chest x-ray. The below Figure 1 was created based upon reading these and other related works to show a representative Deep Neural Network approach to detect COVID-19 with chest x-rays.

Figure 1. Sample Deep Neural Network (DNN) framework to detect COVID-19 using chest x-rays [COVID+ (presence), COVID- (absence)]



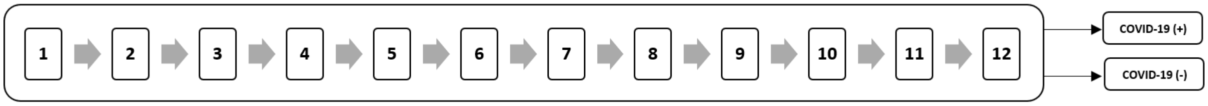
Wieczorek at al. (2020) created a neural network powered COVID-19 spread forecasting model with results in some cases reaches above 99% accuracy.

Abdulaal et al. (2020) made prognostic modeling as a point-of-admission mortality risk scoring system for COVID-19 using an adaptive Artificial Neural Network (ANN) for patient data in the United Kingdom (UK) that was predicted with 86.25% accuracy.

Irmak (2020) presented implementations of two powerful and robust convolutional neural networks (CNN) approaches for COVID-19 disease detection. The first is architecture is able to determine a given chest x-ray image of a patient contains COVID-19 with 98.92 average accuracy. The second architecture presented by Irmak (2020) is able to divide a given chest x-ray image of patient into three classes: COVID-19, normal, and pneumonia with 98.27% accuracy and used databases of over 1,500 images for each of these three categories.

The below Figure 2 presents an example of a Convolutional Neural Network (CNN) that consists of 12 layers for COVID-19 detected and was created after reading Irmak (2020).

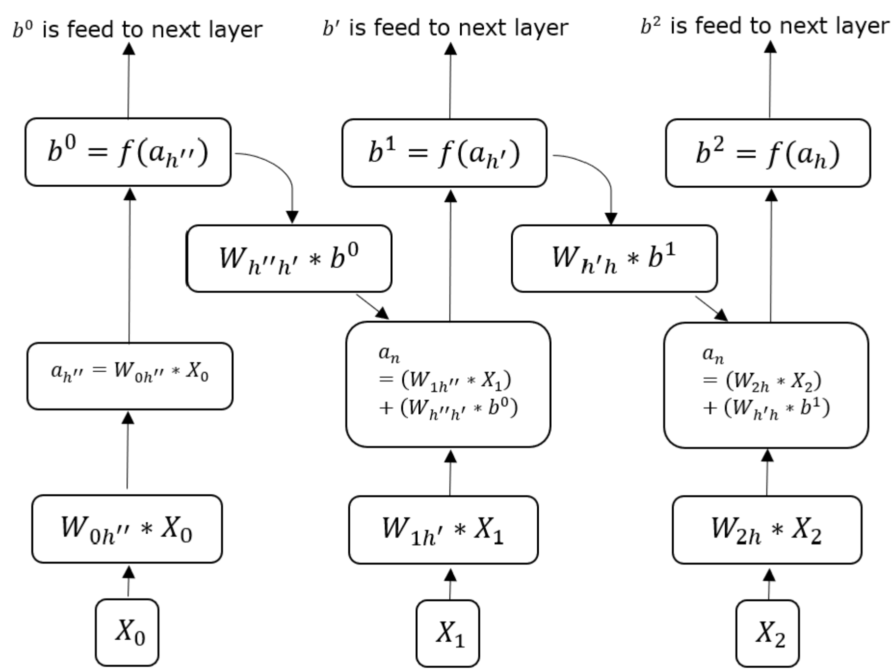
Figure 2. Example of Multi-layer Convolutional Neural Network (CNN) for COVID-19 detection



Layer 1: Input
Layer 2: Convolution
Layer 3: ReLu (Rectified Linear Units) Layer
Layer 4: Crossnorm
Layer 5: Maxpool
Layer 6: Convolution
Layer 7: ReLu (Rectified Linear Units) Layer
Layer 8: Maxpool
Layer 9: Dropout
Layer 10: Fully Connected
Layer 11: Soft max
Layer 12: Classification

Nicholson (2020) presented a beginner's guide to Long-Short Term Memory Units (LSTMs) and Recurrent Neural Networks (RNN). Nicholson (2020) explains that Recurrent Neural Networks (RNN) are a type of Artificial Neural Network (ANN) designed to recognize patterns in sequences of data, such as numerical times series data emanating from sensors, stock markets, and government data.

Figure 3. Illustration of Recurrent Neural Network (RNN)



Drawn using A.I. wiki: "A Beginner's Guide to LSTMs and Recurrent Neural Networks" (2020) [https://wiki.pathmind.com/lstm]

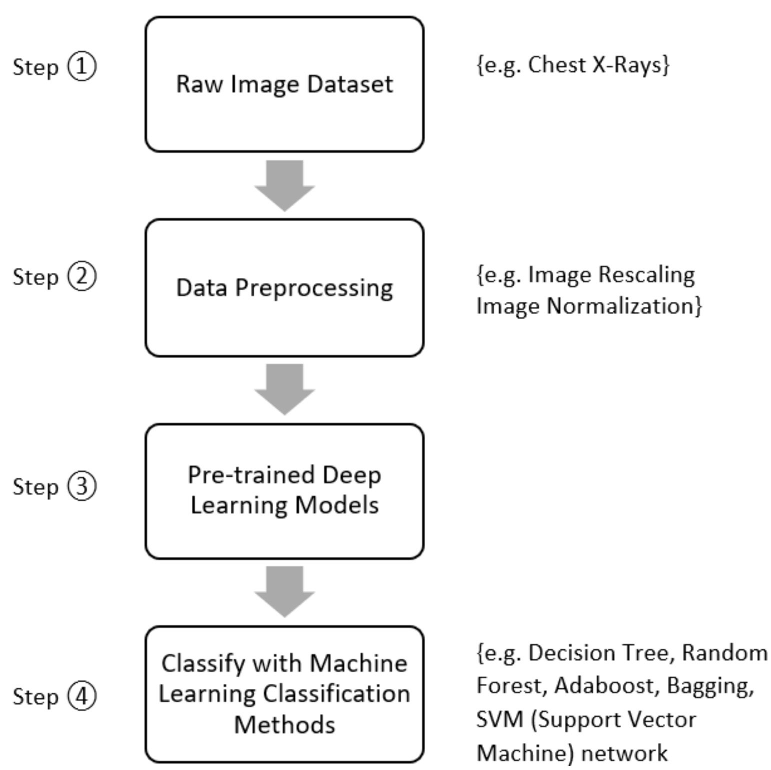
According to Wikipedia (2021b), Long Short-Term Memory (LSTM) has feedback connections and can not only process single data points (such as images), but also entire sequences of data (such as speech or video). For example, LSTM is applicable to tasks such as unsegmented, connected handwriting recognition, speech recognition, and anomaly detection in network traffic or IDSs (intrusion detection systems).

Figure 3 is an illustration of Recurrent Neural Networks (RNN) that was created upon studying work of Nicholson (2020). Figure 3 shows the span of time where each "x" is an input example, "w" is the "weight" that filters inputs, "a" is the "activation" of the hidden layer (a combination of weighted input and the previous hidden state), and "b" is the "output of the hidden layer" after it has been transformed by the function "f".

MACHINE LEARNING AND NEURAL NETWORKS USED TOGETHER FOR COVID-19

Wang et al. (2020) presented an efficient mixture of deep and machine learning models for COVID-19 diagnosis in chest X-ray images using Deep Neural Networks (DNN) and Machine Learning (ML). The following Figure 4 was constructed upon reading work of Wang et al. (2020) that includes a Step 3 for Pre-trained Deep Learning Models using Deep Neural Networks (DNN) and a Step 4 that classifies the results of Step 3 using Machine Learning (ML) classification methods such as decision trees, random forest, AdaBoost, Bagging and SVM (Support Vector Method) Networks. Figure 4 below presents a flowchart of Deep Neural Networks (DNN) and Machine Learning (ML) for COVID-19 diagnosis.

Figure 4. Flowchart of Deep Neural Networks (DNN) and Machine Learning (ML) for COVID-19 diagnosis.



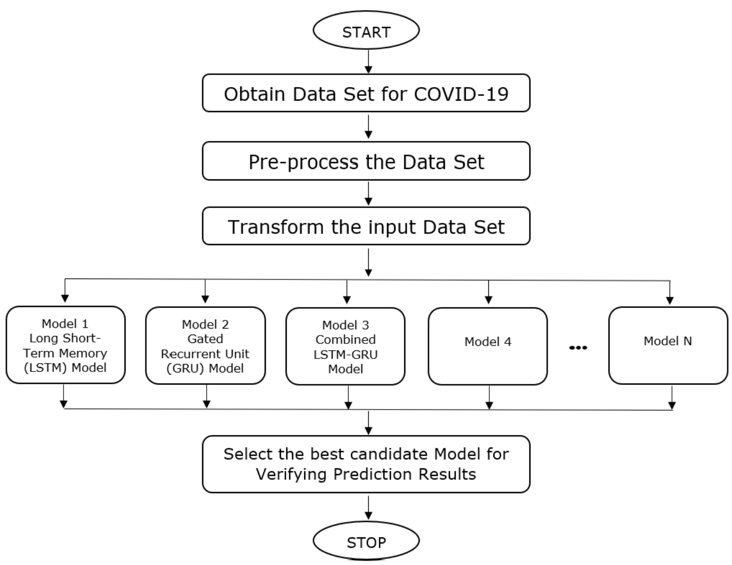
METHODOLOGY FOR SELECTING THE BEST MODEL FOR COVID-19 PREDICTION

Researchers are confronted with multi-criteria decision-making to select the best model or models for predictions of COVID-19. Figure 5 below created by author RS Segall shows a flowchart of steps for selecting the best candidate model for COVID-19 prediction results using multiple metrics based on accuracy, specificity, sensitivity and precision based on numerical values of True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN), and Room Mean Square Error (RMSE). The investigator needs to determine which of these Potential Metrics or other Metric is the most useful or suitable criteria for determining the best model for COVID-19 prediction.

Long Short-Term Memory (LSTM) used as Model 1 in Figure 5 is a type of Recurrent Neural Network (RNN) capable of learning order dependence in sequence prediction problems as a behavior required in complex problem domains like machine translation, speech recognition, and more. (Brownlee (2017))

Gated Recurrent Unit (GRU) used as Model 2 in Figure 5 is a gating mechanism in Recurrent Neural Networks, introduced in 2014 by Kyunghyun Cho et al. (2014). The GRU is like a long short-term memory with a forget gate, but has fewer parameters than LSTM, as it lacks an output gate. (Wikipedia, 2021a).

Figure 5. Flowchart of steps for selecting best candidate model for COVID-19 prediction results.



Potential Metrics

Metric 1: $Accuracy = \frac{TP+TN}{TP+TN+FP+FN}$

Metric 2: $Specificity = \frac{TN}{TN+FP}$

Metric 3: $Sensitivity = \frac{TP}{TP+FN}$

Metric 4: $Precision = \frac{TP}{TP+FP}$

Metric 5: RMSE (Rest Mean Square Error)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \hat{x}_i)^2}{N}}$$

Where in the above:
TP = True Positive
TN = True Negative
FP = False Positive
FN = False Negative
i = Data Value i
N = Number of Data Values
x_i = Actual Data
$\hat{x}_i$ = Estimated Data Value

BIG DATA ANALYTICS AND EMERGING ARTIFICIAL INTELLIGENCE TECHNOLOGIES FOR BATTLING COVID-19

Table 1 below shows some illustrations of Big Data Analytics for battling COVID-19. The work of Elghamrawy (2020) uses a Deep Learning model H2O based on Deep Learning Big Data analytics (DLBD-COV) for early diagnosis of COVID019 using Computer Tomography (CT) or X-ray images.

Table 1. Big Data Analytics for COVID-19

DATE	AUTHOR(S)	Big Data Contribution	COUNTRY
July 24, 2020	Agbehali et al. (2020)	Review of Big Data Analytics and AI Computing Models	South Africa
March 30, 2020	Kent, J. (2020b)	Google makes COVID-19 Datasets freely available to Researchers	United States
September 21, 2020	Kent, J. (2020c)	Big Data Analytics shows COVID-19 spread by Region.	United States
December 24, 2020	Kent, J. (2020d)	Intersection of Big Data Analytics, COVID-19 Top Focus of 2020.	United States
2020	Elghamrawy (2020)	H20 Deep Learning-Inspired Model on Big Data Analytics	Egypt

APPLICATIONS OF ARTIFICIAL INTELLIGENCE (AI) TO COVID-19

Unnithan et al. (2021) discussed use of both forecasting models and dynamic models in modeling COVID-19 data in Canada, and AI-based solutions for public health surveillance for informing public health strategies in Australia and Canada.

Arora and Soni (2021) presented a pre-screening approach for COVID-19 testing based on Belief Rule-Based Expert System (BRBES)to predict the likelihood of the person to be tested for COVID-19.

Srikusan and Karunamoorthy (2021) used Anomaly Detection (AD) to detect COVID-19 like disease outbreaks by comparing expected or forecasted results from past data that mimics the region-specific seasonal infection disease patterns.

Bhapkar et al. (2021) used Rough Set theory that is used for imperfect information in the AI province in the context of COVID-19 to predict symptomatic cases.

Kaiser et al. (2021) discussed the use of healthcare robotics to combat COVID-19 such as supporting patient care at the hospital and home, disinfecting places, collecting the sample from a patient for screening.

Chawki (2021) discussed Smart Screening for High Body Temperature, Surveillance, monitoring treatment, multi-purpose AI or IoT (Internet of Things) platforms that can be used to monitor people that are in compulsory COVID-19 quarantine. Chawki also discussed cross-population train/test models so that the model can be utilized to detect COVID-19 in a different country from a model trained in Wuhan, China.

Arya and Devi (2021) discussed the known AI-models that were earlier trained for different systems as being re-trained using COVID-19 data to assist in predicting and identifying those potentially infected with COVID-19.

Table 2 below shows some applications of Artificial Intelligence (AI) for COVID-19 detection and analysis for year 2020 and Table 3 for year 2021.

Table 2. Year 2020: Artificial Intelligence techniques used for COVID-19 detection and analysis

DATE	AUHTOR(S)	ARTIFICAL INTELLIGENCE (AI) TECHNIQUES	COUNTRY
February 21, 2020	So, D.	New AI algorithm that can diagnose suspected cases in 20 seconds with 96 percent accuracy.	China
March 18, 2020	Zhao, H.	AI-based deep learning image analysis system based on CT chest scans	Israel and United States
April 2, 2020	Cai, F.	GSInquire, a generative synthesis based explain-ability method for critical factors of DarwinAI	Canada
April 28, 2020	Ozturk, T. et al.	DarkNet model used as a classifier if the You Only Look Once (YOLO) real time object detection system.	Turkey, UK, Singapore, Taiwan.
May 7, 2020	Leong, B. & Jordan, S.	Focus on apps directed to health care professionals that leverage audio-visual data, text analysis, chatbots, and sensors.	United States
June 2020	Lalmuanawma, S. et al.	Digital contact tracing process using Bluetooth, Global Positioning System (GPS), Social graph, network-based API, & mobile tracking data.	India United Kingdom (UK)
August 25, 2020	Abdulaah et al.	Artificial Neural Networks (ANN)	United Kingdom
November 10, 2020	Chen, Y. et al.	AI-based imaging analysis methods including chest-imaging techniques.	China
November 2020	Bullock, J. et al.	Molecular, clinical and societal applications at different scales: including medical imaging and risk assessment	United States, United Kingdom, Switzerland
2020	Dalip, D.	AI merged with Global Positioning System (GPS)to prevent spread of COVID-19	India
2020	Jat, D.S. & Singh, C.	Robotic drone applications	Namibia and USA
2020	Gupta, D., Mahajan, A. & Gupta, S.	AI aid in facilitating social distancing	India

Table 3. Year 2021: Artificial Intelligence techniques used for COVID-19 detection and analysis

DATE	AUHTOR(S)	ARTIFICAL INTELLIGENCE (AI) TECHNIQUES	COUNTRY
January 2021	Unnithan, C. et al.	Blue tooth technology used in contact tracing apps, AI methods in predictive modeling.	Australia, Canada
January 2021	Arora, T. & Soni, R.	Belief Rule-Based Expert System (BRBES)	India
January 2021	Srikusan, R. & Karaunamoorthy, M.	Anomaly Detection (AD)	India
January 2021	Bhapkar, H.R. et al.	Rough set theory in COVID-19 to predict symptomatic cases.	India, Denmark, United Kingdom (UK)
January 2021	Kaiser, M.S. et al.	Heathcare Robots	Bangladesh, United Kingdom (UK)
January 2021	Chawki, M.	Smart Screening, Surveillance, Cross-Population Train/Test AI-Driven models	France
January 2021	Arya, M.S. & Devi, S.P.	Retraining of AI models for COVID data	India
January 2021	Agarwal, M. et al.	9 AI Models on cognitive systems in Next Generation Network (NGN).	India Italy
February 2021	Al-Turjman, F.	Cognitive Systems in Next Generation Networks (NGN)	Spain
February 2021	Nawaz, M.S. et al.	Sequential pattern mining (SPM), sequence prediction models, genome analysis.	China United States Japan
March 2021	Lv, D. et al.	Cascade Squeeze-Excitation and Moment Exchange (Cascade-SEME) framework	China United States United Kingdom
April 2021	Verde, L. & et.	Speech and Voice Analysis	Italy Saudi Arabia Egypt
April 2021	Huang, S., Yang, J., Fong, S. & Zhao, Q.	Literature review of challenges & perspectives of AI diagnosis of COVID-19	China
May 2021	Tali, S.H.S. et al.	Sensor and biosensor devices, including diagnostic imaging devices	Canada
May 2021	Ahmed, S. et al.	High-Resolution Network (HRNet) for feature extraction embedding with the UNet for segmentation purposes	Japan Bangladesh

APPLICATIONS OF NEURAL NETWORKS (NN) TO COVID-19

Table 4 shows some applications in year 2020 of neural networks for COVID-19 detection and analysis, and Table 5 for year 2021.

Table 4. Year 2020: Neural Networks used for COVID-19 detection and analysis

DATE	AUTHOR(S)	NEURAL NETWORK TECHNIQUES	COUNTRY
March 16, 2020	Rosebrock, A.	X-ray images wih Keras, TensorFlow, and Deep Learning	Canada
March 22, 2020	Wang, L & Wong, A.	Introduced COVID-Net, a deep convolutional neural network design tailored for the detection of COVID-19 cases from chest X-ray (CXR) images that is open-source and available to the general public.	Canada
March 30, 2020	Zhao,J. et al.	COVIDE-CT-Dataset used with deep learning methods which predicts COVID-19 by analyzing CT scans.	United States
April 2020	Khan, A.I., Shah, J.L. & Bhar, M.	CoroNet: A deep neural network for detection and diagnosis of COVID-19 from chest x-ray images	India
April 24, 2020	Pal, R. et al.	Long Short-Term Memory (LSTM) based neural network to predict the risk category of a country.	Norway and India
April 27, 2020	Singh, D. et al.	Chest CT images using multi-objective differential evolution (MODE) based convolutional neural networks.	India
June 12, 2020	Mollalo, et al.	Multilayer perceptron (MLP) Neural Network	United States
August 15, 2020	Wieczorek et al.	Recurrent Neural Network (RNN)	Poland
October 9, 2020	Pham, T.D.	Pretrained Convolutional Neural Networks (CNN)	Saudi Arabia
October 22, 2020	Irmak, E.	Convolutional Neural Networks (CNN)	Turkey
December 11, 2020	Bassi & Attux	Deep Convolutional Neural Networks (CNN) with Layer-wise Relevance Propagation (LPR)	Brazil
December 13, 2020	Hanfi, S.A.	6-Layer Convolutional Neural Network (CNN)	

Table 5. Year 2021: Neural Networks used for COVID-19 detection and analysis

DATE	AUTHOR(S)	NEURAL NETWORK TECHNIQUES	COUNTRY
2021	Marques et al.	Long Short-Term Memory (LSTM) Networks	Brazil and Macao
2021	Hamadneh et al.	Multi-Layer Perception Neural Network (MLPNN)	Saudi Arabia, Vietnam, Jordan
2021	Bahrami & Sadeddin	Convolutional Neural Network (CNN) identifying COVID-19 coughs and the MIT AI model detecting asymptomatic COVID-19 infections using cough recordings	United States
2021	Colak	Prediction of Infection and Death Ratio of COVID-19 Virus in Turkey by Using Artificial Neural Network (ANN)	Turkey
2021	Kaliyar et al.	MCNNet: Generalizing Fake News Detection with a Multichannel Convolutional Neural Network using a Novel COVID-19 Dataset	India
March 2021	Alsaade, F.W., Al-Adhaileh, T.H. & Al-Adhaileh, M.H.	Developing a Recognition System for Classifying COVID-19 Using a Convolutional Neural Network Algorithm	Saudi Arabia
March 2021	Rahimzadeh, M., Attar, A., & Sakhaei, S.M.	A fully automated deep learning-based network for detecting COVID-19 from a new and large lung CT scan dataset	Iran
April 2021	Taresh, M.M., Zhu, N., Ali, T.A., Hameed, A.S. & Mutar, M.L.	Transfer Learning to Detect COVID-19 Automatically from X-Ray Images Using Convolutional Neural Networks (CNN)	China Iraq Malaysia
May 2021	DeGrave, A.J., Janizek, J.D., & Lee, S-I.	Convolutional Neural Network (CNN) for radiographic COVID-19 detection.	United States
May 2021	Eron, G., Janizek, J.D., Sturmfels, P. et al.	Improving performance of deep learning models with axiomatic attribution priors and expected gradients.	United States
May 2021	Mukherjee, H., Ghosh, S., Dhar, A. et al.	Deep neural network to detect COVID-19: one architecture for both CT scans and Chest X-rays.	India United States
May 2021	Narin, A., Kaya, C. & Pamuk, Z.	Automatic detection of coronavirus disease (COVID-19) using X-ray images and deep Convolutional Neural Networks (CNN)	Turkey
June 2021	Fouladi, S., Ebadi, M. J., Safaei, A. A., Bajuri, M. Y., & Ahmadian, A.	Convolutional Neural Network (CNN), Convolutional Auto-Encoder Neural Network (CAENN), and machine learning (ML) methods are proposed for classifying Chest CT Images of COVID-19.	Iran Malaysia
July 2021	N. N. Hamadneh, W. A. Khan, W. Ashraf, S. H. Atawneh, I. Khan et al.,	Multilayer perceptron neural network (MLPNN) is used in this study together with prey-predator algorithm (PPA). The proposed model is called the MLPNN–PPA.	Saudi Arabia

APPLICATIONS OF MACHINE LEARNING (ML) TO COVID-19

Table 6 presents some applications of machine learning to COVID-19 detection and analysis for year 2020 and Table 7 for year 2021.

Table 6. Year 2020: Machine Learning (ML) techniques used for COVID-19 detection and analysis

DATE	AUTHOR(S)	MACHINE LEARNING (ML) TECHNIQUES	COUNTRY
April 16, 2020	Gallagher, M.B.	Machine learning algorithm combines data on the disease's spread with a neural network, to help predict when infections will slow down on each country.	United States
June 25, 2020	Lalmuanawma et al.	Survey Paper of many methods	India and United Kingdom
September 29, 2020	Li et al.	eXtreme Gradient Boosting algorithm (XGBoost)	United States
October 30, 2020	An et al.	Least Absolute Shrinkage and Selection Operator (LASSO), Random Forest learning method	Korea
November 17, 2020	Wang et al.	Machine Learning Classification methods combined with Pre-trained deep learning models	China
2021	Marques et al.	H_2O AutoML	Brazil and Macao

Table 7. Year 2021: Machine Learning (ML) techniques used for COVID-19 detection and analysis

DATE	AUTHOR(S)	MACHINE LEARNING (ML) TECHNIQUES	COUNTRY
2021	Fernandes, F.T., et al.	Trained five machine learning algorithms: (artificial neural networks, extra trees, random forests, catboost, and extreme gradient boosting).	Brazil
2021	Miliard, M.	Gradient boosted decision trees, or XGBoost	United States
January 4, 2021	Zoabi et al.	Gradient-Boosting machine model with decision-tree base-learners.	Israel
February 15, 2021	Ackerman, D. MIT News Release	Used algorithms that infer causality in interacting systems to turn their undirected network into a causal network.	United States
March 2021	Roberts, D. et al.	Review of machine learning-based models for 2020 using standard-of-care chest x-rays (CXR) or chest computed tomography (CT) images.	United Kingdom
May 2021	Halasz, G. et al.	Developed a machine learning–based score—the Piacenza score—for 30-day mortality prediction in patients with COVID-19 pneumonia.	Italy Switzerland
June 2021	Argyris, Y.A. et al.	Multi-method approach that includes supervised classification algorithm for categorizing tweets.	Canada United States
June 2021	Peng, Y. et al.	Real-time Prediction of the Daily Incidence of COVID-19 in 215 Countries and Territories Using Machine Learning; Model Development & Validation	China

COVID-19 OPEN-SOURCE DATA REPOSITORIES

The below Table 8 provides COVID-19 Open-Source Data Sets for Research & Analysis that includes authors, characteristics and country.

The COVID-19 data repository by Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE) is provided to the public by GitHub and cloud service BigQuery and includes 1TB of free Big Query processing each month that can be used to run queries on this public dataset.

Other COVID-19 open-source data sets provided in Table 8 include that of Machine Learning Repository of University of California at Irvine (UCI), Open Data for Deep Learning of Pathmind, Inc., Allen Institute of Artificial Intelligence, Coronavirus World Data, The Office of Data Science Strategy (ODSS) of National Institutes of Health (NIH), The National Center for Advancing Translational Science (NCATS) of National Institutes of Health (NIH), and Big Queries Public Datasets Program.

Reactome is fast-tracking the annotation of Human Coronavirus infection pathways in collaboration with the COVID-19 Disease Map group. Reactome release 74 features the SARS-CoV-2 (COVID-19) infection pathway. (Reactome (2020)).

Below is Table 8 of Open-Source data sets that is available in the public domain for no charge to users for research and analysis.

Table 8. COVID-19 Open-Source Data Sets for Research & Analysis

DATE/NAME & URL	AUTHOR(S)	CHARACTERISTICS	COUNTRY
March 30, 2020	Jennings & Glass	COVID-19 Public Dataset Program on Google Cloud	United States
March 30, 2020	Health IT Analytics (owned by Google)	Google makes COVID-19 datasets freely available to researchers	United States
September 21, 2020	Shuja et al.	A Comprehensive Survey of COVID-19 Open Source Data Sets	Pakistan and Saudi Arabia
Machine Learning Repository https://archive.ics.uci.edu/ml/index.php	UCI (University of California at Irvine)	Widely used by students, educators, and researchers all over the world as primary source of machine learning data sets.	United States
Open Data for Deep Learning https://wiki.pathmind.com/	Pathmind, Inc.	Maintained by a model deployment platform called Skymind	United States (San Francisco, CA)
COVID-19 Open Research Dataset (CORD-19) https://www.semanticscholar.org/cord19	Allen Institute for AI https://allenai.org/	Contains over 44,000 scholarly articles about COVID-10	United States (Seattle, WA)
Johns Hopkins University COVID-19 data https://github.com/CSSEGISandData/COVID-19	JHU CSSE (Johns Hopkins University Center for Systems Science and Engineering)	Data repository for the COVID-19 Dashboard aggregated from many sources including WHO, CDC, WorldoMeters, etc.	United States
Coronavirus World Data https://worlddata.ai/coronavirus	World Data AI (https://worlddata.ai)	World's Largest Data Platform (3.3 Billion Datasets)	United States (Houston, TX)
National Institutes of Health (NIH) https://datascience.nih.gov/covid-19-open-access-resources	The Office of Data Science Strategy (ODSS)	Open-Access Data & Computational Resources to Address COVID-19	United States
National Institutes of Health (NIH) https://opendata.ncats.nih.gov/covid19/index.html	National Center for Advancing Translational Science (NCATS)	Open Data for COVID-19	United States
https://console.cloud.google.com/marketplace/product/bigquery-public-datasets/covid19-open-data	Big Query Public Datasets Program	Daily time-series data related to COVID-19 globally	United States & European Union (EU)

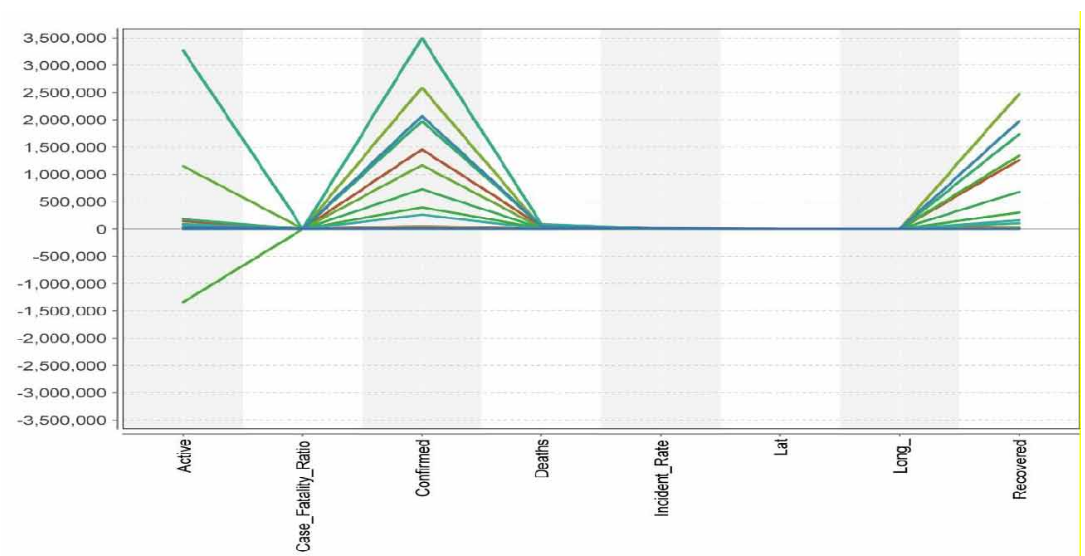
Example AI and NN Applications Using Real-Time COVID -19 Data

Using COVID-19 datasets from GitHub, the following images/visualizations were created. Rapid Miner, Tensor Flow, and the Deep Learning Toolbox of MATLAB were used to construct the following Figures: Figure 6 to Figure 11. The images show some of the AI and NN applications that can be used with real-time COVID-19 data. The data was aggregated and automated into figures that provide a full explanation of the death rate, recovery rate, active cases, case fatality ratio, confirmed cases, state where it is less and more, and time range where the cases are still much lower. The figures have been color-coded to make it easy to see when the cases were high and to see if there was a pattern. The figure 6 shows the sample of the data that was used.

Figure 6. Sample of Covid-19 Datasets used to create the visualizations shown in Figure 7 to Figure 11 (Github)
[Created by student Vidha Sankarasubbu and used with written permission.]

.Country_Re...	Last_Update	Lat	Long_	Confirmed	Deaths	Recovered	Active	Combined_...	Incident_R...	Case_Fatali...
Categorical	Datetime	Number	Number	Number	Number	Number	Number	Text	Number	Number
Country_Re...	Last_Update	Lat	Long_	Confirmed	Deaths	Recovered	Active	Combined_...	Incident_Ra...	Case_Fatalit...
Afghanistan	2/15/2021 ...	33.93911	67.709953	55492	2427	48395	4670	Afghanistan	142.5491007	4.373603402
Albania	2/15/2021 ...	41.1533	20.1683	93075	1555	56764	34756	Albania	3234.241434	1.670695676
Algeria	2/15/2021 ...	28.0339	1.6596	110711	2939	75999	31773	Algeria	252.4706197	2.654659429
Andorra	2/15/2021 ...	42.5063	1.5218	10503	107	9911	485	Andorra	13593.47699	1.018756546
Angola	2/15/2021 ...	-11.2027	17.8739	20366	492	18795	1079	Angola	61.96626888	2.415791024
Antigua an...	2/15/2021 ...	17.0608	-61.7964	427	9	199	219	Antigua an...	436.0346377	2.107728337

Figure 7. Centroid Chart Clustered Data using Rapid Miner Studio with COVID-19 Dataset
[Created by student Vidha Sankarasubbu and used with written permission.]



Figures 6 to 11 below were created by student Vidhya Sankarasubbu under the supervision of author of this chapter as faculty mentor, and who was awarded a 2021 Summer Internship Research Award for a research proposal for support in writing this book as funded by Arkansas Biosciences Institute (ABI) located on the campus of Arkansas State University (A-STATE) in Jonesboro. Figures 6 to 11 are shown upon written permission of student Vidha Sankarasubbu.

The clustered chart for COVID datasets is shown in Figure 7. Based on the population rate, latitude, and longitude, the graph depicts the number of active cases as well as the number of deaths. The graph also shows the number of recovered cases, as well as the case fatality ratio and incident rate.

Figure 8. Sample Bubble Graph showing death rate and recovered rate from the active and confirmed cases of COVID-19 in each country region created using Rapid Miner
[Created by student Vidha Sankarasubbu and used with written permission.]

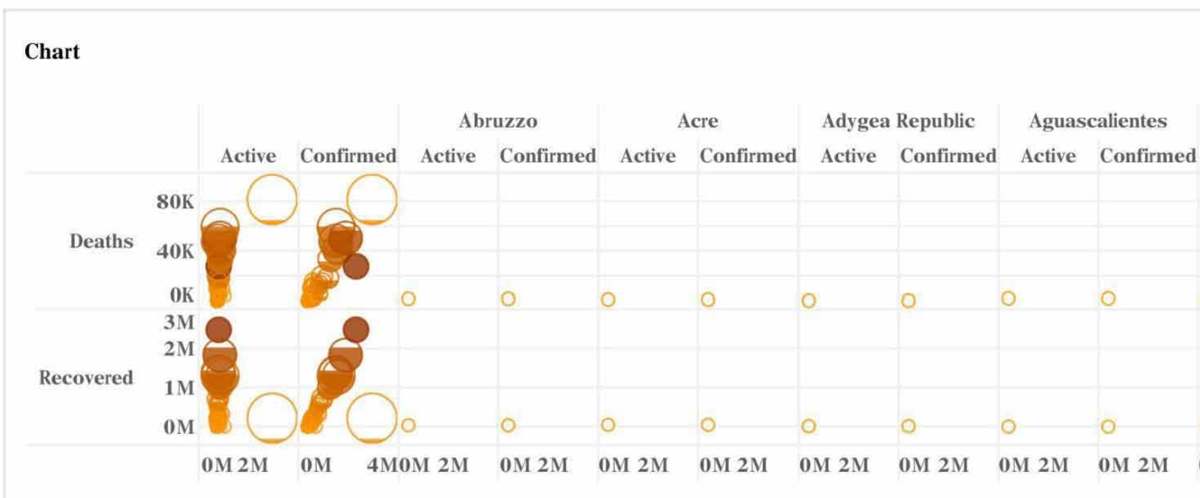
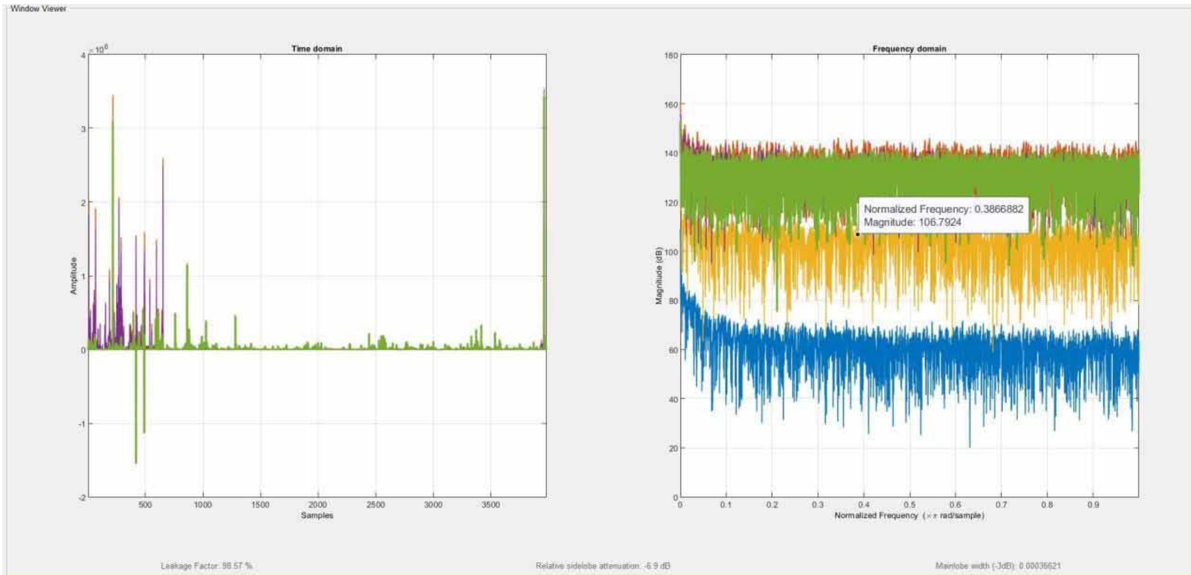


Figure 8 depicts a portion of the whole bubble graph that explains the death rate and current cases by geographic region. Because the data is multivariable, a bubble graph is employed. It is used to compare the number of deaths and the rate of survival in active cases based on geography.

Figure 9. The normalized magnitude and frequency graph and the time domain and amplitude for COVID-19 cases in 2021 using Deeplearning Toolbox of MATLAB.
[Created by student Vidha Sankarasubbu and used with written permission.]



A Bode plot, or graph of magnitude (in dB) vs frequency, is shown in Figure 9. This is used to determine the frequency of death and the rate of recovery in COVID-19 patients. This method has the advantage of demonstrating how circuit parts influence frequency response. In the design of frequency-selective circuits, this is very significant.

Figure 10. Bubble Graph showing maximum of active cases of COVID-19 in each country and their death rate in 2020 using Deeplearning Toolbox of MATLAB
[Created by student Vidha Sankarasubbu and used with written permission.]

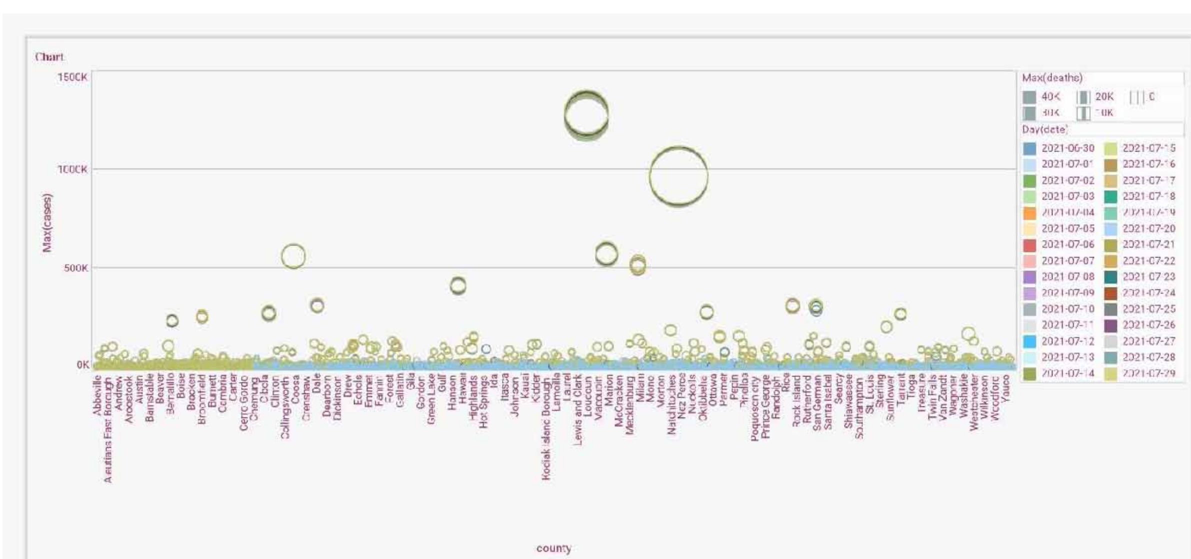


Figure 11. Line Graph of Reorder Attributes using Rapid Miner to show the number of deaths in a particular population rate and time range of recovery.
[Created by student Vidha Sankarasubbu and used with written permission.]

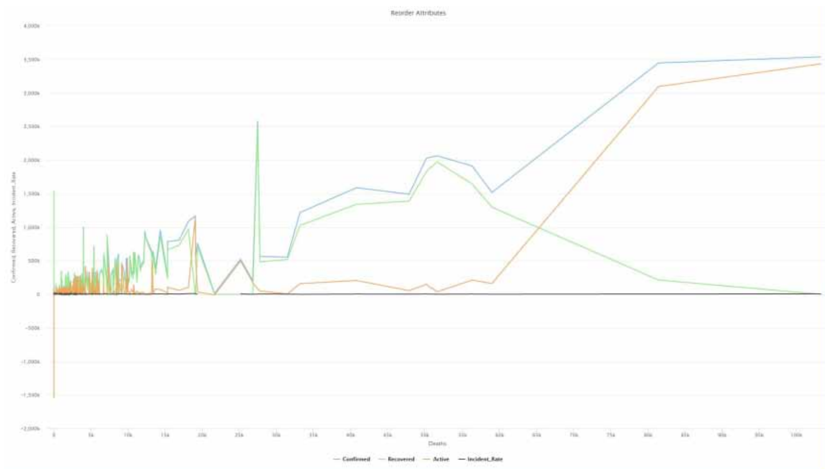


Figure 11 shows how to use chart sorting to reorder the data set's properties and create a line graph. The population and time range are arranged in this graph, which illustrates the pattern of the cases

CONCLUSION

This chapter has presented a survey of many current applications of artificial intelligence, neural networks and machine learning to the pandemic COVID-19 as attempts to search for solutions to this world-wide pandemic. It appears that the continuation of applications of these techniques will be used as valuable insights to COVID-19 and other diseases. Machine learning, neural networks and other artificial intelligence techniques can be combined together to obtain even more powerful insights into this COVID-19 pandemic and the international community is actively pursuing these applications.

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KEY TERMS AND DEFINITIONS

Convolutional Neural Networks (CNN): In deep learning, a convolutional neural network (CNN, or ConvNet) is a class of deep neural networks, most commonly applied to analyzing visual imagery.

COVID-19: Coronavirus disease 2019 (COVID-19) is a contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first case was identified in Wuhan, China, in December 2019.

Deep Neural Networks: Deep learning is a class of machine learning algorithms that uses multiple layers to progressively extract higher-level features from the raw input.

H_2O AutoML: Learning algorithm within H_2O open-source distributed machine learning platform that overlooks the process of finding candidate models using large datasets (Marques et al., 2021).

Keras: Keras is an open-source software library that provides a Python interface for artificial neural networks. It is a High-level Python neural network library that runs on the top layer of TensorFlow (Hanfi, 2020).

Long Short-Term Memory (LSTM): A type of Recurrent Neural Network (RNN) capable of learning order dependence in sequence prediction problems as a behavior required in complex problem domains like machine translation, speech recognition, and more (Brownlee, 2017).

Recurrent Neural Networks (RNN): Class of Artificial Neural Networks (ANN) also called Feedback Neural Networks (FNN) where connections between nodes form a directed graph along a temporal sequence (Wikipedia, 2020).

TensorFlow: Open-source software library originally developed by Google Brian Team for numerical computation using data flow graphs. TensorFlow is a free and open-source software library for machine learning. It can be used across a range of tasks but has a particular focus on training and inference of deep neural networks (Wikipedia, 2021c).