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Survey of Recent Applications of Artificial Intelligence for Detection and Analysis of COVID-19 and Other Infectious Diseases

Richard S. Segall
Arkansas State University - Jonesboro, rsegall@astate.edu

Vidhya Sankarasubbu
Arkansas State University - Jonesboro

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Survey of Recent Applications of Artificial Intelligence for Detection and Analysis of COVID-19 and Other Infectious Diseases

Richard S. Segall, Arkansas State University, USA*
https://orcid.org/0000-0001-7627-2609

Vidhya Sankarasubbu, Arkansas State University, USA

ABSTRACT

The purpose is to illustrate how artificial intelligence (AI) technologies have been used for detection and analysis of COVID-19 and other infectious diseases such as breast, lung, and skin cancers; heart disease; and others. 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 or other disease 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 or other disease 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 is also provided. An example is also shown for artificial intelligence (AI) and neural network (NN) applications using real-time COVID-19 data.

KEYWORDS

Artificial Intelligence (AI), Convolutional Neural Networks (CNN), COVID-19, Deep Neural Networks (DNN), Infectious Diseases, Machine Learning, Neural Networks

BACKGROUND

Infectious diseases are illnesses caused by harmful organisms (pathogens) that get into human body from the outside. The most common pathogens that causes infectious diseases are viruses, bacteria, fungi, and parasites. Humans can get infectious diseases from other people, bug bites and contaminated food, water or soil.

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 (World Health Organization, 2020).

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

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*Corresponding Author

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 (Chemical Abstract Service) COVID-19 antiviral candidate compounds dataset of nearly 50,000 chemical substances for use in applications including research, data mining, machine learning, and analytics. CAS is a division of American Chemical Society (ACS).

Artificial Intelligence (AI) has been used in medical imaging as decision-making support systems for lesion detection and segmentation as discussed by Calisto et al. (2022). AI techniques have been 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 article.

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 $\geq$ 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. 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 because COVID-19 is respiratory illness for which chest x-rays are used as a potential diagnostic method. Jain et al. (2021) published an article on deep learning-based detection and analysis of COVID-19 on chest x-ray images. Panahi et al. (2022) used Deep Residual Neural Networks using chest x-rays for COVID-19 detection.

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.

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).

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.

According to Brownlee (2017), Long Short-Term Memory (LSTM) 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 tasks such

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

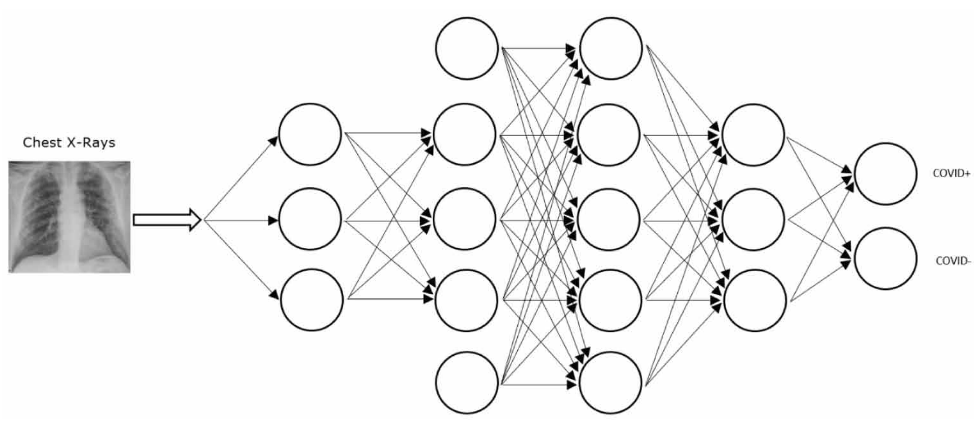
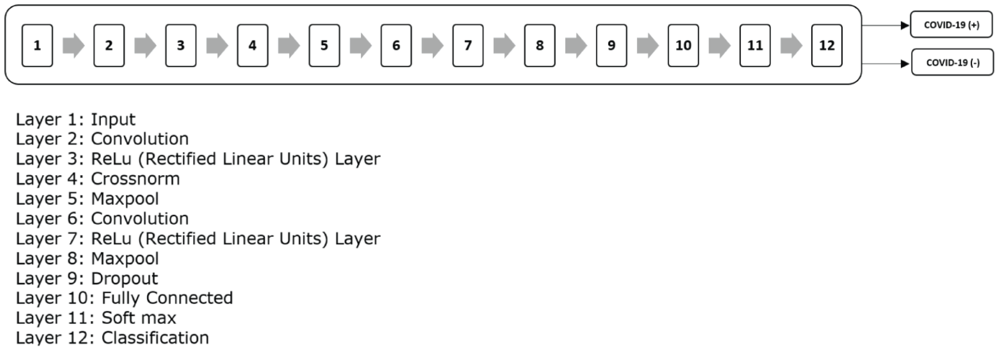


Figure 2. Example of Multi-layer Convolutional Neural Network (CNN) for COVID-19 detection



as unsegmented, connected handwriting 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). Figure 4 was constructed upon reading work of Wang et al. (2020) that includes a Step 3 for Pre-trained

Figure 3. Illustration of Recurrent Neural Network (RNN)

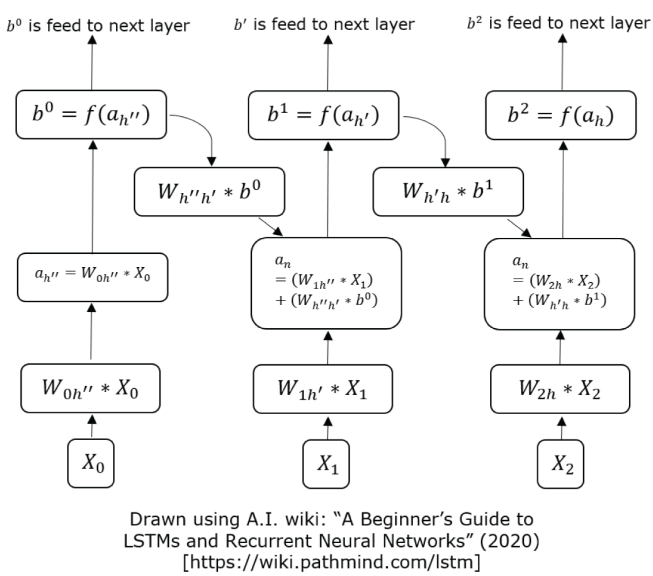
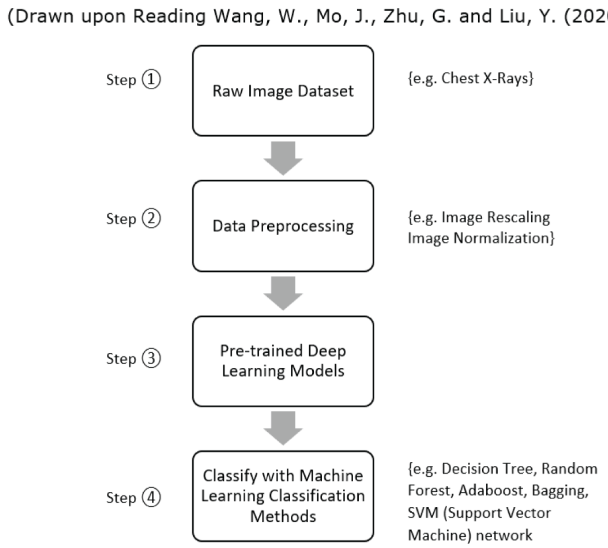


Figure 4. Flowchart of Deep Neural Networks (DNN) and Machine Learning (ML) for COVID-19 diagnosis



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 presents a 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 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.

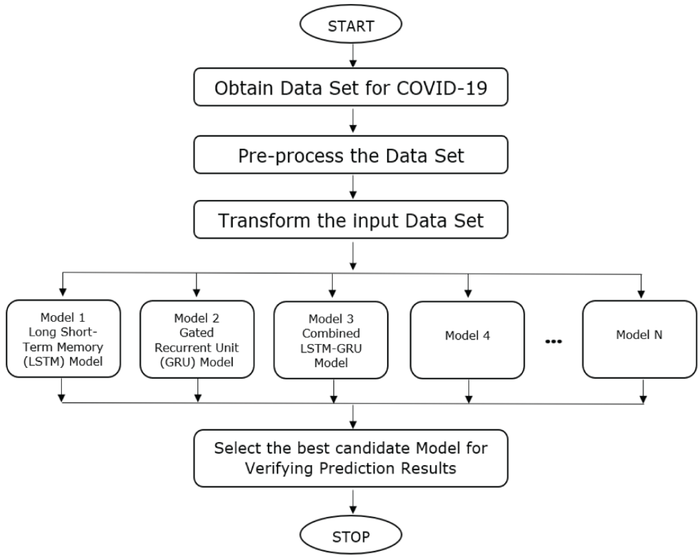
Long Short-Term Memory (LSTM) used as Model 1 in Figure 5 is a type of Recurrent Neural Network (RNN) capable of learning order dependence in sequence prediction problems as a behavior required in complex problem domains like machine translation, speech recognition, and more (Brownlee, 2017).

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 (Saxena, 2021).

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

Table 1 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 COVID-19 using Computer Tomography (CT) or X-ray images.

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

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

The applications of Artificial Intelligence to Big Data Analytics are important to be investigated because of the huge amount of data created by this world-wide pandemic.

APPLICATIONS OF ARTIFICIAL INTELLIGENCE (AI) TO COVID-19

Segall (2022a, 2022b, 2021a, 2021b, 2020) presented a representative summary of recent advances for using Artificial Intelligence to COVID-19. The below are some other investigators who used artificial intelligence for detection and prediction of COVID-19. Segall and Sankarasubbu (2022) discussed investigating COVID-19 using Big Data Analytics and visualization with artificial intelligence techniques.

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

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.

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.

COVID-19 OPEN-SOURCE DATA REPOSITORIES

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

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% accuracy.	China
March 18, 2020	Zhao, H.	AI-based deep learning image analysis system based on CT chest scans.	Israel 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 with You Only Look Once (YOLO) real time object detection system.	Turkey United Kingdom 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
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	United States Namibia
2020	Gupta, D., Mahajan, A. & Gupta, S.	AI aid in facilitating social distancing	India

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 Big Query and includes 1TB of free Big Query processing each month that can be used to run queries on this public dataset.

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
January 2021	Kaiser, M.S. et al.	Healthcare Robots	Bangladesh United Kingdom
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

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 with 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.	COVID-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 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)	

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.

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 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	Alghamdi et al.	Convolutional Neural Networks (CNN) and other deep learning architectures.	Saudi Arabia
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 multi-layer 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

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 United Kingdom
September 29, 2020	Li, W. 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 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

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)).

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

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. Figure 6 shows the sample of the data that was used.

The clustered chart for COVID-19 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 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.

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

Date/Name and URL	Author(s)	Characteristics	Country
March 30, 2020 https://cloud.google.com/blog/products/data-analytics/free-public-datasets-for-covid19	Jennings & Glass	COVID-19 Public Dataset Program on Google Cloud	United States
March 30, 2020 https://healthitanalytics.com/	Health IT Analytics (owned by Google)	Google makes COVID-19 datasets freely available to researchers	United States
September 21, 2020 https://doi.org/10.1007/s10489-020-01862-6	Shuja et al.	A Comprehensive Survey of COVID-19 Open Source Data Sets	Pakistan 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)

Figure 6. Sample of COVID-19 Datasets used to create the visualizations from Figure 7 to Figure 11 (Github)

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

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.

In Figure 10, data is visualized using geographic bubble charts, which are overlayed on a map. These charts can provide much-needed context for data with spatial properties. Locations are specified

Figure 7. Centroid Chart Clustered Data using Rapid Miner Studio with COVID-19 Dataset

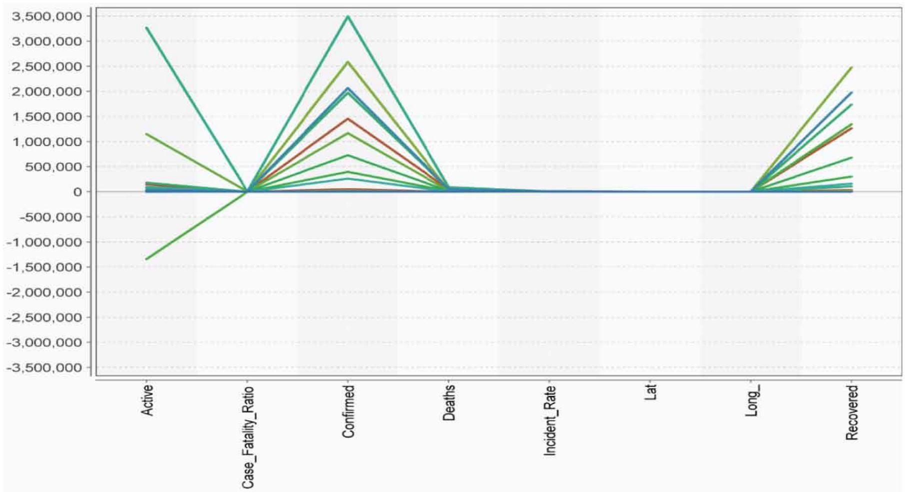
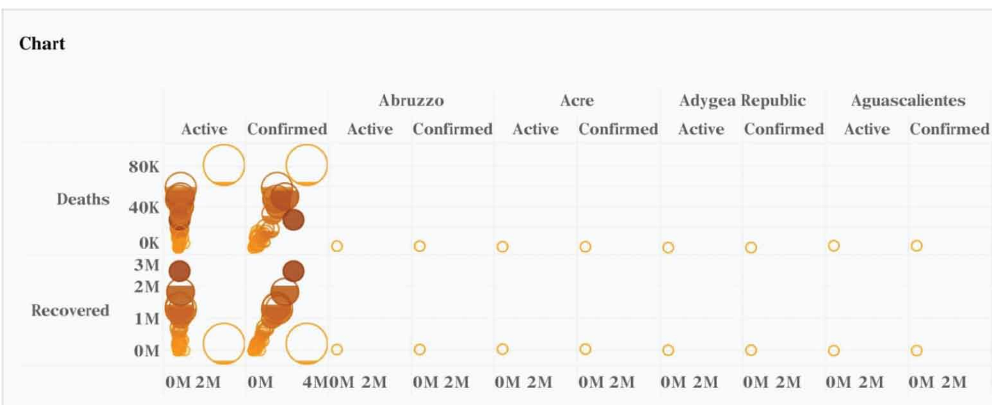


Figure 8. Sample Bubble Graph showing death rate and recovered rate from the active and confirmed cases of COVID-19 in each country region created using Rapid Miner



using the 'Latitude' and 'Longitude' columns, as well as the state/province columns. From June 30, 2021, to July 30, 2021, the graph is color coded to reflect the growth or decrease of cases on each day.

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.

MACHINE LEARNING AND NEURAL NETWORKS FOR INFECTIOUS DISEASES

Artificial Intelligence (AI) in the form of machine learning has been used by many researchers and medical practitioners for the detection and prediction of chronic diseases such as heart disease, kidney disease, breast cancer, diabetes, Parkinson Disease (PD) and Alzheimer Disease. Table 9 summaries some characteristics of recent representative international research for these applications. Nayak et al. (2021) edited a book on advanced machine learning approaches in caner prognosis using a variety

Figure 9. The normalized magnitude and frequency graph and the time domain and amplitude for COVID-19 cases in 2021 using Deep Learning Toolbox of MATLAB

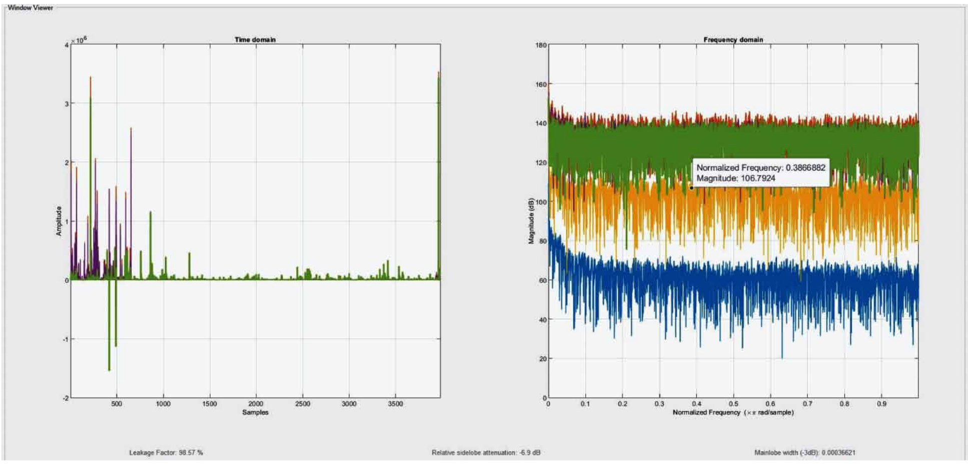
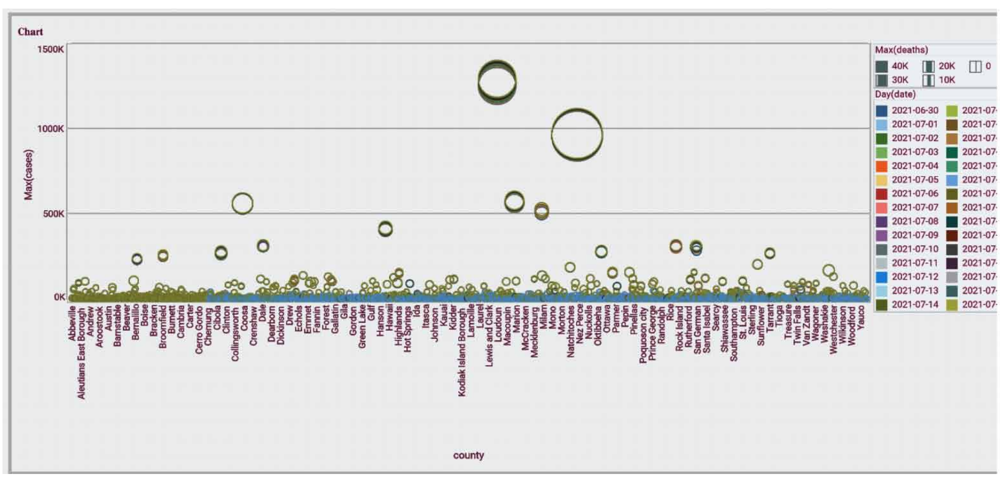


Figure 10. Bubble Graph showing maximum of active cases of COVID-19 in each country and their death rate in 2020 using Deep Learning Toolbox of MATLAB

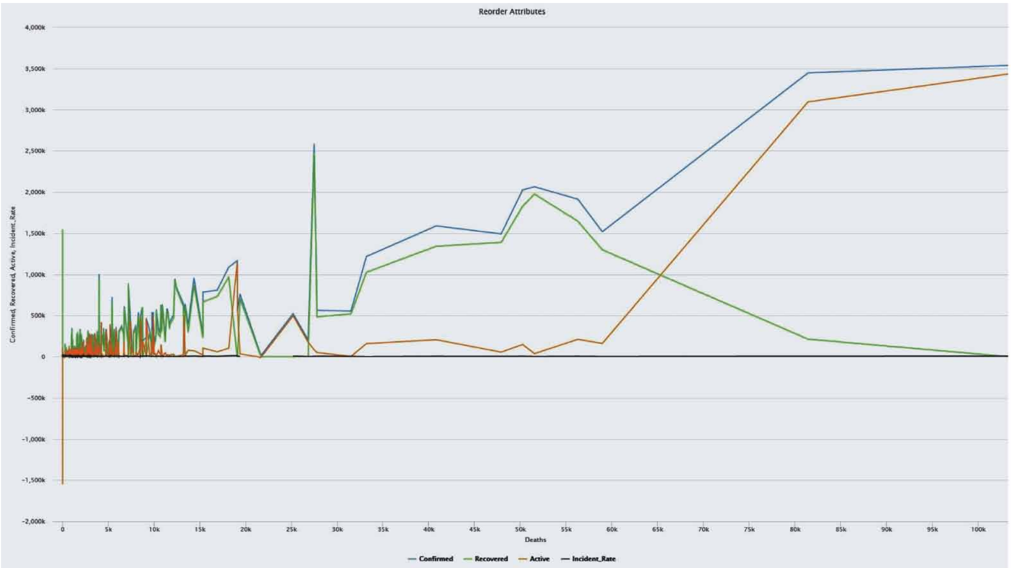


of neural networks, fuzzy logic and hybrid intelligence systems for supervised and unsupervised learning for the determination and diagnosis of cancer.

A new long-short-term-memory (LSTM) based deep fusion structure has been newly introduced as discussed by Naik et al. (2021) and Saihood et al. (2022), where, the texture features computed from lung nodules through new volumetric grey-level-co-occurrence-matrices (GLCM) computations are applied to classify the nodules into: benign, malignant and ambiguous.

Li, X., Yu, L. et al. (2020) discuss how to train a neural network to classify rare diseases that have little data. Li, X., Yu, L et al. (2020) present a difficulty-aware meta-learning method to address rare disease classifications and demonstrate its capability to classify skin cancer images. Their key approach is to first train and construct a meta-learning model from data of common diseases, then adapt the model to perform rare disease classification.

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



EXAMPLES OF ARTIFICIAL INTELLIGENCE APPLICATIONS TO BREAST, LUNG AND SKIN CANCERS AND HEART DISEASE

AI techniques play an important role in early cancer prognosis and detection by extracting and classifying disease features using machine and deep learning techniques with this research it was found that the majority of previous literature works used deep learning techniques, particularly Convolutional Neural Networks (CNN). Another significant finding in this is that the majority of previous studies have focused on breast cancer data. When deep learning models are applied to pre-processed and segmented medical images the research proved the early stages of cancer is predictable with sensitivity and accuracy.

Figure 12 was created using the MATLAB - machine learning toolbox and is an example of predicting Breast Cancer in its early stages. This image is created with the Kaggle dataset, depicts “malignant (cancerous)” or “benign (non-cancerous)” cells and their growth in a concave and compact mean.

Myriad CNN models were identified that can detect early-stage cancers on scan or biopsy images with high accuracy, and some of them had a proven impact on workflow triage. It is clear that combining multidimensional heterogeneous data with different techniques for selecting and classifying data can provide viable tools for implication in the cancer prediction.

Figure 13 is an example box plot of cancer data generated for prediction using CNN models and images of X-rays/MRI’s and is classifies based on Gender (G), type of cancer, Age of the patient and any other associated disease in the patient using Kaggle Datasets and RapidMiner. With this analysis it is predicted that Myopia and Skin cancer is correlated and is more likely to occur with young males. Glaucoma occurs in the early ages for females than males. Patients with glaucoma has more risk of cancer developing cells. Type 2 diabetes patients have an increased risk of liver, pancreatic and bladder cancer. Cancer treatments like radiation causes a risk of developing cataracts.

Table 9. Recent Research in Applications of Machine Learning for Infectious Diseases

Disease	Authors	Year	Characteristics	Country
Alzheimer	AlShamlan	2022	Hyprid SVM-based Classification Method	Saudi Arabia
Alzheimer	Dar et al.	2021	Deep Learning Models, Recurrent Neural Networks	India
Alzheimer	Chang et al.	2021	Convolutional Neural Networks (CNN)	Taiwan
Autoimmune	Kudari	2021	Case Studies using Data Analytics	India
Diabetes	Sharma & Shah	2021	Comprehensive study of Deep Neural Networks	India
General [e.g., heart and kidney disease, breast cancer, diabetes, Parkinson disease.]	Ahsan et al.	2022	Heart Disease, Kidney Disease, Breast Cancer, Diabetes, Parkinson Disease, COVID-19, Alzheimer Disease	USA, Bangladesh
General	Alanazi	2022	Convolutional Neural Network (CNN) & K-Nearest Neighbor (DNN)	Saudi Arabia
General	De et al.	2020	Disease Detection System (DDS) using Graphical User Interface (GUI)	India
General [e.g., cancer, diabetes, heart disease, skin and liver diseases.]	Kumar et al.	2022	Artificial Intelligence diagnosis of Alzheimer, cancer, diabetes, heart disease, tuberculosis, stroke, hypertension, skin & liver diseases.	India, South Korea
General	Nilashi et al.	2020	Systemic Literature Review by Data Mining Techniques	Malaysia, Iran, Saudi Arabia, Iraq
General [e.g., Lung, breast and prostate cancer]	Nayak et al.	2006	Neural Networks for Lung, Breast Prostate Cancer diagnosis and Brain Tumors classification	India, Russia, Australia
General	Sasubilli et al.	2020	Machine Learning Truth Maintenance System (TMS)	USA, India
General	Azeem et al.	2021	Convolutional Neural Network	Pakistan, China, Saudi Arabia
Heart	Bharti et al.	2021	Deep Learning Algorithms	India, Ethiopia
Heart	Kumar et al.	2022	Uses XGBoost to test alternative decision tree classification algorithms.	India, Bangladesh
Heart	Nashif et al.	2018	Machine Learning Algorithms with Real-Time Cardiovascular Health Monitoring System	Bangladesh
Heart	Nagavelli et al.	2022	Uses XGBoost to test alternative decision tree classification algorithms	India, Bangladesh
Influenza & Common Cold	Nadda et al.	2022	Long-Short Term Memory (LSTM)	Thailand
Multiple Sclerosis	Montolio et al.	2021	Algorithms implemented were from using Statistics and Machine Learning Toolbox and Deep Learning Toolbox in Matlab	Spain
Neuro-generative	Myszczynska et al.	2006	Patient stratification applied	United Kingdom, USA
Parkinson	Mei et al.	2021	Used 8 categories of algorithms for Machine Learning models	Canada
Skin	Rao et al.	2021	Convolutional Neural Network (CNN)	India
Skin	Elnar et al.	2021	Convolutional Neural Network (CNN)	Egypt India
Thyroid	Temurtas	2009	Multi-Layer Neural Network	Turkey

Figure 12. Breast Cancer Prediction using Artificial Intelligence

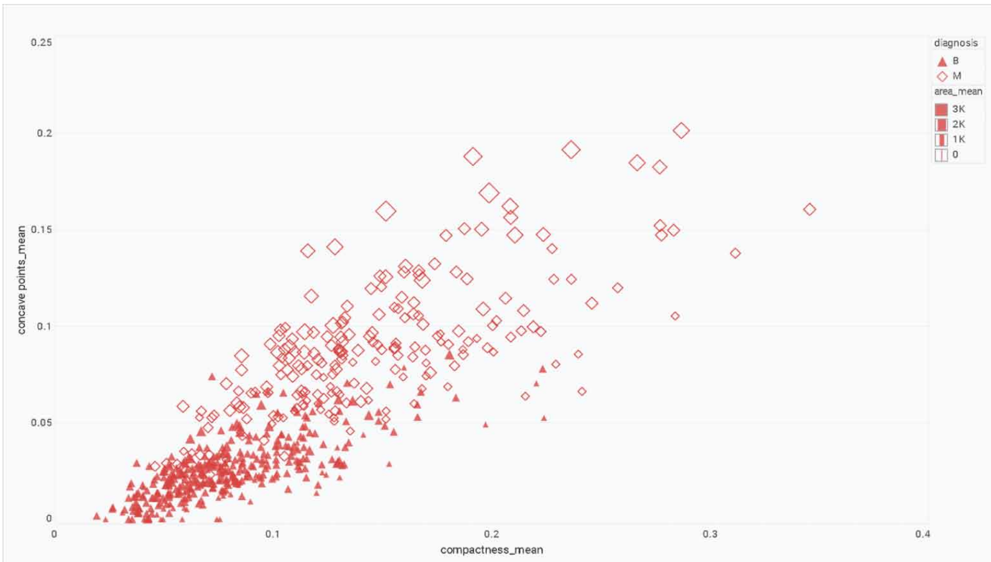
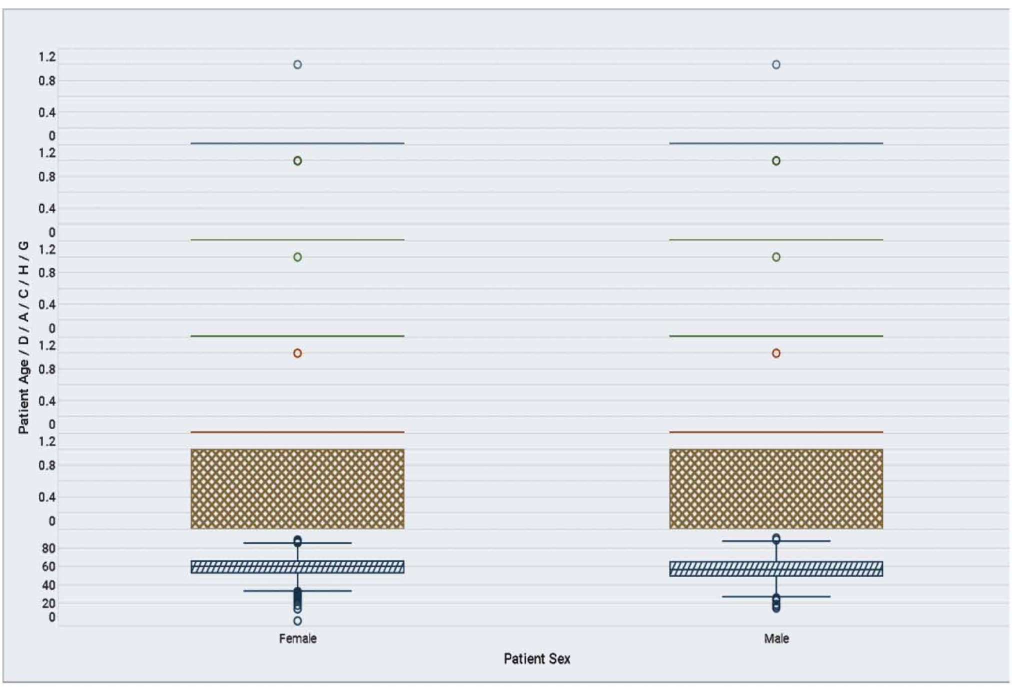


Figure 13. Cancer Prediction using Artificial Intelligence



Key Legends for Figure 4:

G – Glaucoma
D- Diabetes
C- Cataract
A- Age related issue
H- Hypertension
M- Myopia
O – Other common/general disease
N- Normal

It has realized the use of AI medical image analysis to help doctors screen for esophageal cancer, lung nodules, diabetic retinopathy, colorectal tumors, breast cancer, and other diseases, as well as the use of an AI assisted diagnosis engine to help doctors identify and predict the risk of over 700 diseases. We can use computer vision and deep learning technology to assist doctors in reading through artificial intelligence medical image analysis capabilities, accurately locate tiny lung nodules larger than 3mm, and determine the sensitivity of their benign and malignant characteristics. It reaches 85%, with a specificity of up to 90% (Edubirdie, 2022).

Figure 14 is a radar plot for data from Males/Females, transsexual, hermaphrodite, other unknown genders and Black/Whites and Unknown Race/Other Race that shows the number of cases for all the cancer cases by gender and race. Despite the advancements in detection and treatment cancer remains the second leading cause of death in United States especially with communities with social and economic disadvantages. According to this analysis, black females are more likely to die out of breast cancer than white females, bisexual females are 70% more likely to get a cancer diagnosis compared to heterosexual females.

Figure 15 is created using datasets from Kaggle and is used in rapid miner to predict heart disease and cholesterol level in male and female. This application is based on the heart disease dataset, which includes patient data such as age, gender, alcohol, treetops, and many more. This analysis is for detecting the presence of heart disease using python. The graph shows that male generally develop

Figure 14. Lung Cancer Prediction using Artificial Intelligence

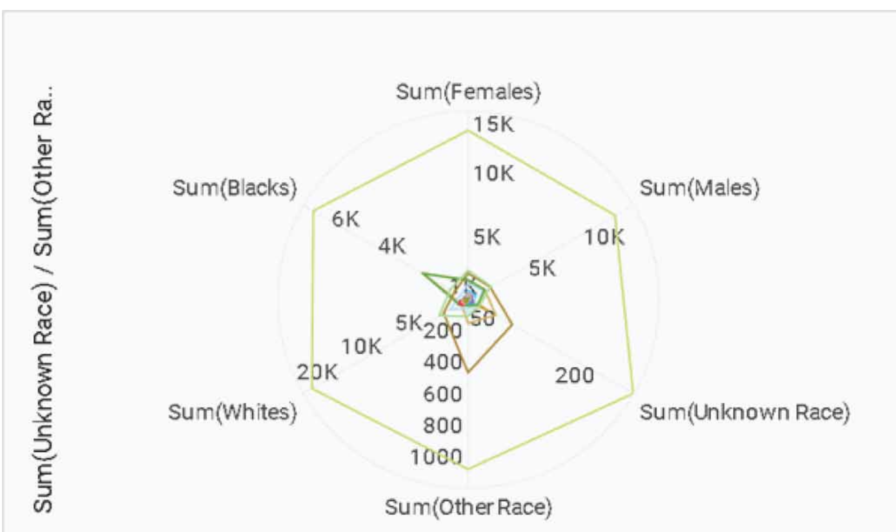
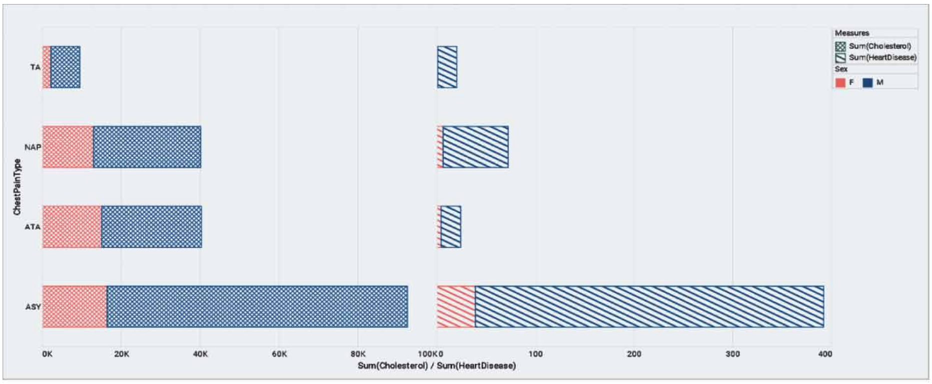


Figure 15. Heart Disease prediction using Artificial Intelligence

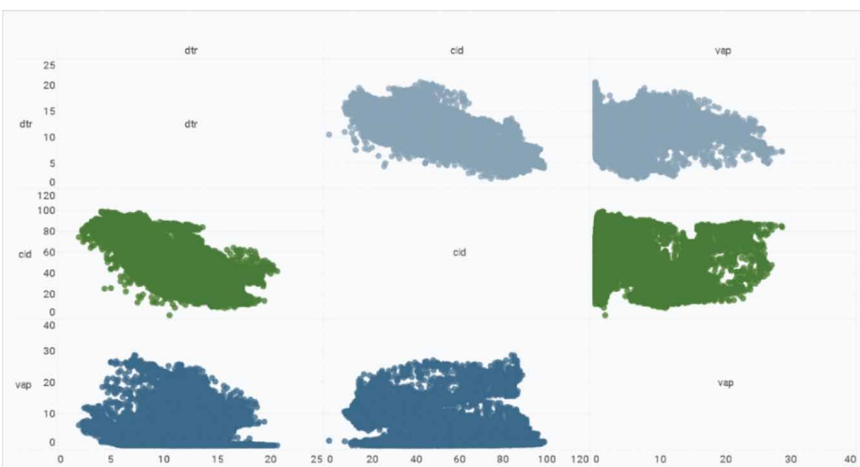


heart disease in younger age than female, however female is at higher risk of stroke even if it occurs at old age (Chang, et.al., 2022).

Based on research conducted between 2000 and 2015 to determine the geographical and temporal spread of Lumpy Skin Disease Virus (LSDV), infection outbreaks and forecast potential outbreaks in Ethiopia. The incidence varied by region, with hot dry lowlands having the lowest incidence and wet moist highlands having the highest. They discovered that outbreaks were seasonal, with the majority of them occurring in the months following a long rainy season. Molla et al. (2017). Based on some geospatial and meteorological parameters, machine learning algorithms such as ANN could potentially be used to accurately forecast the occurrence of LSDV infection. In areas where LSDV infection is a high risk, using this approach could be extremely beneficial for implementing monitoring and awareness programs, as well as preventive measures such as vaccine campaigns.

Statistical methods that are intended to infer relationships between variables rather than make predictions. Machine learning algorithms, on the other hand, aim to forecast unobserved outcomes (Bzdok et al., 2018), which is what was used in the current study. Disparities in the results of similar studies could be caused by the use of different independent variables (risk factors) and different study locations, in addition to the different methods used.

Figure 16. Lumpy skin disease using Artificial Intelligence



CONCLUSION AND RECOMMENDATIONS FOR FUTURE DIRECTIONS

The goal of this article is to provide future researchers with a quick reference to the Artificial Intelligence, Machine Learning, and Deep Learning applications that are currently being used to analyze and predict diseases, as well as to act as a catalyst for further research in these and other related fields.

This research has presented a survey of many current applications of artificial intelligence, neural networks and machine learning to the pandemic COVID-19 and other infectious diseases such as such as heart disease, kidney disease, breast cancer, diabetes, Parkinson Disease (PD) and Alzheimer Disease.

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 other infectious diseases and the international community is actively pursuing these applications.

The future directions of this research are to investigate new applications of Artificial Intelligence for detection and analysis of these and other infectious diseases. The recommendation for the future researchers is to apply this article's applications that are currently in use for analysis of COVID-19 and other infectious diseases that requires AI, Machine Learning and Deep Learning.

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CONFLICT OF INTEREST

The authors of this publication declare there is no conflict of interest.

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Richard S. Segall is Professor of Information Systems & Business Analytics in Neil Griffin College of Business at Arkansas State University. He holds BS/MS in mathematics, MS in operations research and statistics from Rensselaer Polytechnic Institute in Troy, New York, and PhD in operations research form University of Massachusetts at Amherst. He has served on faculty of Texas Tech University, University of Louisville, University of New Hampshire, University of Massachusetts-Lowell, and West Virginia University. His research interests include data mining, Big Data, text mining, web mining, database management, and mathematical modeling. His funded research includes that by U.S. Air Force, National Aeronautical & Space Administration (NASA), Arkansas Biosciences Institute (ABI), and Arkansas Science & Technology Authority (ASTA). He was member of the Arkansas Center for Plant-Powered-Production (P3) from 2008-2016 and is a member of Center for No-Boundary Thinking (CNBT), Editorial Board of International Journal of Data Mining, Modelling and Management (IJDMMM), and International Journal of Data Science (IJDS). He is a co-editor of 5 books: (1) Handbook of Big Data Storage and Visualization Techniques; (2) Research and Applications in Global Supercomputing; (3) Visual Analytics of Interactive Technologies: Applications to Data, Text & Web Mining; (4) Open Source Software for Statistical Analysis of Big Data: Emerging Research and Opportunities; and (5) Biomedical and Business Applications Using Artificial Neural Networks and Machine Learning; all published by IGI Global.

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