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A Survey on SARS-COV-2 (COVID-19) using Machine Learning Techniques

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***Abstract*--SARS-CoV-2, widely known as (COVID-19), is a deadly contagious disease globally. The new suspicious virus is spreading quickly. Several studies have found that SARS and COVID-19 have comparable patterns of an inflammatory outbreak. The Coronavirus causes a severe respiratory disease that affects lung functions, and the transmission can occur through direct, close, or indirect contact from infected secretions or droplets. The typical symptom includes fever, persistent cough, cold, shortness of breath, pneumonia, decreased sense of smell, insomnia, brain fog, and many organ dysfunctions. Antibody tests and RT-PCR tests are used to diagnose fatal diseases. This literature review examines the occurrence and pathogenicity of COVID-19 infection along with radiological images, machine learning classifiers, feature extraction methods and disease prediction algorithms, and pattern recognition. This overview also summarizes the ML and DL algorithms and tools used for analysis.**

***Keywords*---COVID-19, SARS-CoV-2, Pneumonia, Medical Images, Deep Learning, Machine Learning.**

I. INTRODUCTION

As the largest family in the Nidovirales order, the first Coronavirus was discovered in 1960. Coronavirus-2019 began in Wuhan, China, and has since spread around the globe. Currently, the newly discovered virus has caused many deaths and seriously threatened public health. COVID-19 is a virus that creates critical breathing syndrome (SARS-CoV-2). Many cases of pneumonia caused by unknown causes have been recorded in Wuhan, China, since December 2019. Several immune deficiency viruses exist on earth, and some new viruses are predictable, but many are unpredictable. The Coronavirus is an infectious disease that causes mild upper respiratory infections, induces mild to severe respiratory syndromes, and causes severe viral pneumonia [1].

The Coronavirus encompasses two subfamilies: Orthocoronavirinae and Torovirinae. Orthocoronavirinae genetically categorized into four genera according to their genes: Alpha-coronavirus(α-CoV), Beta-coronavirus(β-CoV), γ-coronavirus(γ-CoV), and δ-coronavirus(δ-CoV)[2][3]. Alpha and Betacoronaviruses diffuse faster in animals and bats. Gammacoronaviruses infects avian and mammalian species. Deltacoronaviruses infects birds and mammals[4]. The CoV genome, the largest RNA viral, is a sense-single-stranded RNA with 26 KB to 32 KB. Mammals are infected by both α- and β-CoV, while birds are infected by both δ- and γ-CoV [5]. Fig 1 shows the MERS-CoV axial CT image pulmonary window.

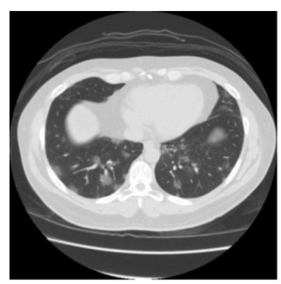

Fig.1. CT scan image of MERS CoV

Summary of the paper: Section 2 presents the basic concept of SARS-CoV-2. Section 3 provides a focused review on various ML and DL process from the existing literature. Section 4 describes the nuances of ML and DL algorithms. The results and discussions are narrated in Section 5 and Section 6.

II. COVID-19 TEST ANALYSIS AND TRANSMISSION ORIGIN

Three coronaviruses have formerly been diagnosed: They are known as Swine Acute Diarrhea Syndrome (SADS), Severe Acute Respiratory Syndrome

(SARS) and Middle East Respiratory Syndrome (MERS). The SARS and MERS viruses were identified in 2003 and 2012, while SADS was diagnosed in 2017. SARS virus was diagnosed first in Foshan, China, in November 2012 [6]. The World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) have a list of symptoms that disclose the infection of COVID-19 [7]. Table 1 shows the case fatality rate (CFR) of three zoonotic members that have evolved to infect humans and have a relatively high CFR [8].

TABLE 1. CASE FATALITY RATES (CFR)

Name of the virus	CFR %
SARS-CoV	CFR = 10%
SARS-CoV-2	CFR = 6%
MERS-CoV	CFR (approximately 35%)

RT-PCR test analysis

Coronavirus is diagnosed using a process of reverse transcription-polymerase chain reaction (RT-PCR). It is often referred to as nasopharyngeal swab tests, which help to identify negative cases of COVID-19 patients. Two types of tests are negative and positive RT-PCR. The negative criteria were negative, worsening of clinical symptoms and 2 weeks of isolation, while for positive, the first two tests were positive [9].

Blood test analysis

RT-PCR testing was performed with a nasopharyngeal swab to identify COVID-19 infection (positive swab test, negative swab test) in each patient. In other ways to detect the COVID-19, routine blood tests have been extracted based on the collected blood tests from each patient. Age, gender, leukocytes (WBC), platelets, C-reactive protein (CRP), transaminases (ALT), monocytes, eosinophils, basophils, lymphocytes, and neutrophils are all predictive characteristics of the parameters. The precise correlation of the features used for the variables arc-back, CRP, AST, and Lymphocytes [10].

Virus discovery from an x-ray image

A chest X-ray can detect and diagnose diseases such as infiltration, pleural thickening, effusion, mass, pneumonia, consolidation and hernia [11]. Radiologists can use advanced technologies and automated algorithms to diagnose diseases more rapidly and accurately.

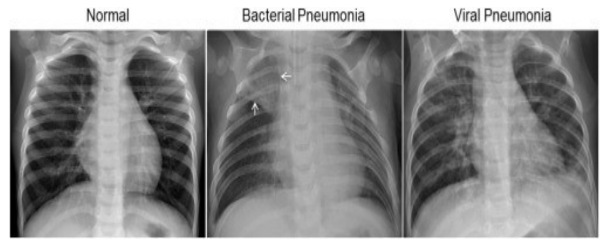

Fig. 2. Chest x-ray image

Figure 2 shows an X-ray with a usual symptom of COVID-19 and both bacterial pneumonia and viral pneumonia.

Chest CT-Scan image findings and features

The first findings of the COVID-19 chest CT image were published in January 2020, including bilateral lung damage and opacity of the glass mirror [12]. Detecting patterns on radiographic images of infected patients is challenging. However, it leads to false-negative and false-positive results. Collected chest CT images of infected patients were classified full as dose, ultra-low dose for prediction [13]. The CT Severity scores are classified as the following <8 - Mild, 9-15 - Moderate, >15–Severe and typical CT image features are: GCO, Consolidation, GCO+consolidation, Rounded morphology, Other morphology, Crazy paving pattern, Interstitial changes, Subpleural distribution, and Diffuse distribution. Using CT scan, it is possible to make early detection, early diagnosis, and improve prognostic evaluation.

Treatment for Coronavirus

In humans, symptoms of this virus can appear within 1 to 14 days of infection. Still, there is no proper antiviral treatment or vaccine against the novel Coronavirus [14]. The normal human body temperature is 37°C, but within two weeks, the infected person's temperature exceeds 38°C (93.2-102.2°F). To control the disease, the most common treatment is a combination of antiviral drugs, antibacterial drugs, and glucocorticoids (45/78, 57.7%) [15].

III. RELATED WORKS

This section describes the literature survey-related work on the following topics, the use of medical images for pneumonia detection, various machine learning and deep learning prediction methods, feature extraction methods, and performance analysis. Pereira et al. Proposed a classification schema for COVID-19 recognition. Multiple classifications and hierarchical classification approaches are examples of classification methods. Using a CNN model, this classification scheme extracts visual attributes from chest X-ray images. The evaluation method is RYDLS-20, which yields a multi-class macro average F1 score of 0.65 for each class [16]. To improve efficiency, Wei Tse Li et al. proposed an extreme Gradient Boosting (XGBoost) ensembling ML algorithm to classify COVID-19. 5-fold cross-validation was done with 70 booster iterations.,The ROC receiver operating characteristic curve and recall curve (PR) are helpful to evaluate XGBoost results[17].

Barstugan et al. proposed the following matrix as grey-level co-occurrence matrix (GLCM), discrete wavelet transform (DWT), gray run lengthy matrix (GLRLM), grayscale area matrix (GLSZM) and local pattern (LDP)to classify X-ray images. In performance evaluation, two-fold, five-fold, and ten-fold cross-validation methods achieve an accuracy of 99.68 percent [18]. Using the CNN classification model and Bayesian function, Xiaowei et al., COVID-19 infection risk was calculated using a predictive model. Images of suspected samples were taken from CT samples, including H1N1, H3N2, H5N1, H7N9 influenza virus pneumonia. The predictive model achieves a maximum precision of 86.7 percent [19].

Ucar et al. UsedX-ray scans to diagnose and used Bayesian optimization to help the SqueezeNet model [20]. Xu S et al. developed a model based on chest X-ray imaging to identify lung diseases using a convolutional neural network. CNN uses AlexNet, ResNet, and VGG16 templates to achieve high precision [21]. Wang S et al. investigated the CT image changes of infected patients. CT image features were extracted for diagnosis and used a deep learning-based prediction model of transfer learning technique followed by internal and external validation. By using this model, an accuracy of 85.2% achieved finally [22]. Akib Mohi et al. proposed the classical and ensemble techniques for feature extraction of coronaviruses. Logistic Regression and Polynomial Naive Bayes achieved a better result of 96.2% [23]. Afshar et al. proposed a model of capsule network to identify COVID-19. It has 95.7 percent accuracy, 90 percent sensitivity, 95.8 percent precision, and a 0.97 region under the curve (AUC) [24]. Hemdan et al.used a deep convolutional neural network model to diagnose positive or negative COVID-19 cases from X-ray imaging, such as the Modified Visual Geometry Group Network (VGG19) and the second edition Google MobileNet [25].

Khan et al. Used the Xception architecture in the ImageNet dataset to classify X-ray images of ordinary, bacterial and viral cases to detect COVID-19 infection. This model had an accuracy of 95% [26]. Alqudah et al. investigated how X-ray images are to be used to diagnose the novel disease called covid. The following algorithms like Random Forest (RF), softmax classifier, Support Vector Machine (SVM) and K-Neighbor (K-NN) are being used to filter and classify image features[27].

Chen et al. Proposed U-Net residual attention deep learning algorithms to extract spatial features from medical images to diagnose lung infections associated with COVID-19 pneumonia. U-Net connects the encoder function with the decoder [28]. Singh D et al., The chest computed tomography (CT) images of COVID-19 and non-COVID-19 infected patients were categorized using a CNN based on multi-objective differential evolution (MODE) [29].

IV.ALGORITHMS FOR MACHINE LEARNING AND DEEP LEARNING

Machine Learning (ML) technology has grown rapidly. It is the intersection between statistics and computer science. ML provides various predictive algorithms and pattern recognition in various fields, especially in the healthcare field. Machine learning is based on the assessment, prediction, and classification of characteristics. Machine learning approaches include different levels of learning such as supervised and unsupervised, evolutionary and reinforcement learnings [44]. There are also other algorithms used to classify the collected data such as Support Vector Machine (SVM), Recurrent Neural Network (RNN), K- Nearest Neighbor (KNN), Neural Network (NN), Decision Tree (DT), Convolutional Neural Network (CNN), Naive Bayes (NB), Logistic Regression (LR) and Random Forest Classifier (RF)[45].

Machine Learning Methodologies

Supervised Learning: Supervised learning uses labeled data to bind the current and previous dataset to predict the values [41].

Unsupervised Learning: When the training data set is unlabeled, unsupervised learning will be used [42].

Reinforcement Learning: Reinforcement learning techniques used to determine the ideal behaviour for improving performance [43].

Algorithms for Machines

Support Vector Machine: SVM stands for Support Vector Machine and is a discriminative technique for solving convex optimization problems. SVM was launched in 1992 by Boser, Guyon, and Vapnik. The SVM group various functions, which are called maximum margin classifiers.SVM is a non-parametric regression method for a set of mathematical functions, and SVM uses linear functions to solve regression problems [30].

Decision Trees (DT): The algorithm is simple to train and is highly interpretable. The attributes are grouped by value. It is mainly used for classification. Each tree is composed of nodes and branches. Nodes represent attributes, and the branches represent values [31].

Logistic Regression: The algorithm predicts numerical variables based on the relationship with the label. Statistician David Cox developed the model. It is the most commonly used regression models in statistics and scientific studies. This is used to correlate the relationship between two different variables using a logical function[46].

Linear Regression: To estimate the value of the coefficient, a linear regression model is used. It is directly related to the dependent variable and one independent variable[32].

Naive Bayes (NB): The algorithm calculates the probability of a text by using the Bayes rule. Naive Bayes is mainly used for text classification but also clustering and classification purpose. It creates a tree based on its probability. These trees are also called Bayesian Networks.

Techniques for Deep level Learning

CNN, known as Convolutional Neural Network, is an artificial feed-forward neural network that recognizes patterns in pixel images by combining feature extraction and classification. Convolutional, activation, grouping, and dense layers are the four different forms of CNN layers. A convolutional layer captures the input signal's complex properties. The Pooling layer is used to sub-sample the previous layer by summarizing the subset values after the dense layer is the activation layer, which produces the classification results [33].

ResNet50, ResNet101, ResNet18and SqueezeNetare used to classify CT image layers into binary categories[34]. A 224x224x3 input image is required for the ResNet18 model, which has 71 layers [35]. ResNet50 has 177 layers and includes an input image of 224x224x3. ResNet101 is a 347-level dynamic residual model. Requires input image size 224x224x3 [36]. The SqeezeNet model evaluates the efficiency of binary classification for chest CT images. It has 68 layers and requires an input image size of 227x227x3 [37].

V. RESULT AND DISCUSSIONS

Comparative analysis methods

The performance analysis is compared. The process of feature extraction and the initial data set is used for this analysis. The combination of various methods produces high accuracy.

TABLE 2:PREDICTION METHOD ANALYSIS

S.No	Method / Classifier	Accuracy
1.	GLCM, LDP, GLRLM, GLSZM, DWT,SVM	99.68%
2.	Inception V3, Inception-ResNetV2, ResNEt 50,CNN	98%
3.	Logistic Regression and Polynomial Naive Bayes	96.2%
4.	Capsule networks, CNN	95.7%
5.	Xception – CNN	95%

Model Evaluation

The performance of the ML and DL models will be assessed using several parameters. The evaluation parameters are accuracy, precision, recall, sensitivity, specificity, and F1. The real and predicted values are True Negative (TN), False Positive (FP), True Positive (TP) and False Negative (FN).

- *The following is the accuracy equation:*

$$\text{Accuracy} = \frac{tp+tn}{tp+tn+fp+fn} \quad (1)$$

- *The sensitivity equation is as follows:*

$$\text{Sensitivity} = \frac{tp}{tp+fn} \quad (2)$$

- *The following is the formula for the specificity equation:*

$$\text{Specificity} = \frac{tp}{tn+fp} \quad (3)$$

VI. CONCLUSION

Early forecasting is essential to prevent the spread of deadly diseases. This research presents several ML and DL algorithms that use various parameter values to assess disease accuracy at an early stage. The performance comparison results show that SVM with the CNN pre-training model provides the best accuracy in this study.

COVID-19 Negative report Analysis

Test report collected from 46 years male patient. The patient went with fever * 7 days, moderate grade, associated with chills. Blood Culture: no growth, Widal, Weil Felix – negative.

TABLE 3: REAL-TIME PCR ANALYSIS FOR POSITIVE TO MODERATE

Test Name	Result
Rapid Antigen Test	Positive
Blood Culture	No growth, Widal, Weil Felix - Negative
RT-PCR for SARS CoV2	Positive

TABLE 4: REAL-TIME PCR ANALYSIS FOR NEGATIVE TEST

Name of the test	Result
SARS-CoV-2, Nasopharyngeal / Orpharyngeal Swabs	
SARS-CoV-2 E Gene	Negative
SARS-CoV-19 RdRp Gene	Negative
The Interpretation for this patient is	**Negative for SARS-CoV2**
Positive	Indicates the presence of Coronavirus in the given specimen
Negative	Indicates the absence of Coronavirus in the given specimen

COVID-19 Positive report Analysis

SARS-COV-2-Negative-"RT-PCR Test report collected from 27 years, male patient". Specimen: Nasopharyngeal / Orpharyngeal Swabs.

A novel coronavirus (COVID-19) must be classified quickly to be diagnosed. Various ML and DL methods will be used to extract features, and different classification algorithms will be used to measure performance.

REFERENCES

[1] Lei C-C, Shih T-P, Ko W-C, Tang H-J, Hsueh P-R, "Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and co- rona virus disease-2019 (COVID-19): the epidemic and the chal- lenges", Int J Antimicrob Agents, vol.55, no.3, pp.105924, 2020.

[2] Yang D, Leibowitz JL, "The structure and functions of Coronavirus genomic 3′ and 5′ ends, Virus Res. vol.206, pp.120–133. doi: 10.1016/j.virusres.2015.02.025, 2015.

[3] Banerjee A, Kulcsar K, Misra V, Frieman M, Mossman K. Bats and coronaviruses. Viruses,doi: 10.3390/v11010041. pii: E41, 2019.

[4] Ashour, H. M., Elkhatib, W. F., Rahman, M., Elshabrawy, H. A. & others, "Insights into the recent 2019 novel coronavirus (SARS-CoV-2) in light of past human coronavirus outbreaks", Pathogens, vol.9, no.3, 2019.

[5] Song Z, Xu Y, Bao L, Zhang L, Yu P, Qu Y, "From SARS to MERS, thrusting coronaviruses into the spotlight", Viruses, 2019. doi: 10.3390/v11010059. pii: E59.

[6] Fan, Y., Zhao, K., Shi, Z.-L. & Zhou, P, "Bat coronaviruses in China", Viruses, vol.11, no.3, 2019.

[7] Bhattacharya, S., Maddikunta, P. K. R., Pham, Q.-V., Gadekallu, T. R., Chowdhary, C. L., Alazab, M., … others, "Deep learning and medical image processing for coronavirus (COVID-19) pandemic: A survey", Sustainable Cities and Society, 2019.

[8] Mostafa, A., Kandeil, A., Shehata, M., Shesheny, R. E., Samy, A. M., Kayali, G. & Ali, M. A, "Middle east respiratory syndrome coronavirus (mers-cov)", State of the science Microorganisms, vol.8, no.7, 2020.

[9] Cai, Q., Du, S.-Y., Gao, S., Huang, G.-L., Zhang, Z., Li, S, "A model based on CT radiomic features for predicting RT-PCR becoming negative in coronavirus disease 2019 (COVID-19) patients", BMC Medical Imaging, vol.20, no.1, pp.1–10, 2020.

[10] Brinati, D., Campagner, A., Ferrari, D., Locatelli, M., Banfi, G. & Cabitza, F, "Detection of COVID-19 Infection from Routine Blood Exams with Machine Learning: a Feasibility Study. medRxiv, 2020.

[11] S.Usha Kiruthika, S. Kanaga Suba Raja, V. Balaji, C.J.Raman, S. S. L. Durai Arumugam, "Detection of Tuberculosis in Chest X-rays using U-Net Architecture", International Journal of Innovative Technology and Exploring Engineering, vol. 9, no.1, pp. 2514-2519, 2019

[12] Huang C, Wang Y, Li X, "Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China", Lancet, pp.497–506, 2020.

[13] Shiri, I., Akhavanallaf, A., Sanaat, A., Salimi, Y., Askari, D., Mansouri, Z. "Ultra-low-dose chest CT imaging of COVID-19 patients using a deep residual neural network", European Radiology, pp.1–12, 2020.

[14] Yadav, M., Perumal, M. & Srinivas, M, "Analysis of novel coronavirus (COVID-19) using machine learning methods", Chaos, Solitons \& Fractals, M vol.139, pp.110-050, 2020.

[15] Liu, W., Tao, Z.-W., Wang, L., Yuan, M.-L., Liu, K., Zhou, L., "Analysis of factors associated with disease outcomes in hospitalized patients with 2019 novel coronavirus disease", Chinese Medical Journal, 2020.

[16] R. M. Pereira, D. Bertolini, L. O. Teixeira, C. N. Silla, and Y. M. Costa, "Covid-19 identification in chest x-ray images on flat and hierarchical classification scenarios", Computer Methods and Programs Biomedicine, pp.105-532, 2020.

[17] Wei Tse Li, "Using machine learning of clinical data to diagnose COVID-19: a systematic review and meta-analysis", BMC Medical Informatics and Decision Making,2020, https://doi.org/10.1186/s12911-020-01266-z.

[18] Barstugan M, Ozkaya U, & Ozturk S, "Coronavirus (COVID-19) Classification using CT Images by Machine Learning Methods", arXiv:2003.09424, 2020.

[19] Xiaowei Xu, "Deep Learning System to Screen Coronavirus Disease 2019 Pneumonia", 2019.

[20] Ucar F, and Korkmaz D, "COVIDiagnosis-Net: Deep Bayes-SqueezeNet based diagnosis of the coronavirus disease 2019 (COVID-19) from X-ray images", Medical Hypotheses, vol.140, pp.109-761, 2020.

[21] Xu S, Wu H, Bie R, "CXNet-m1: anomaly detection on chest X-rays with image-based deep learning", IEEE Access, vol.7, pp.4466–77, 2018.

[22] Wang S, Kang B, Ma J, Zeng X, Xiao M, Guo J, Cai M, Yang J, Li Y, Meng X, Xu B, "A deep learning algorithm using CT images to screen for coronavirus disease (COVID-19)", medRxiv preprint. https://doi.org/10.1101/2020.02.14.20023028, pp.1–26, 2020

[23] Akib Mohi "Machine learning-based approaches for detecting COVID-19 using clinical text data", https://doi.org/10.1007/s41870-020-00495-9, 2020.

[24] Afshar P, Heidarian S, Naderkhani F, Oikonomou A, Plataniotis KN, & Mohammadi A, "COVID-CAPS: A Capsule Network-based Framework for Identification of COVID-19 cases from X-ray Images", arXiv:2004.02696v2, 2020.

[25] Hemdan EED, Shouman MA, and Karar ME, "COVIDX-Net: A Framework of Deep Learning Classifiers to Diagnose COVID-19 in X-Ray Images", arXiv:2003.11055, 2020.

[26] Khan AI, Shah JL, and Bhat MM, "Coronet: A deep neural network for detection and diagnosis of COVID-19 from chest x-ray images", Computer Methods and Programs in Biomedicine, vol.196, no.105-581, 2020.

[27] Alqudah AM, Qazan S, and Alqudah A, "Automated Systems for Detection of COVID-19 Using Chest X-ray Images and Lightweight Convolutional Neural Networks", https://doi.org/10.21203/rs.3.rs-24305/v1, 2020.

[28] Chen X, Yao L, and Zhang Y, "Residual Attention U-Net for Automated Multi-Class Segmentation of COVID-19 Chest CT Images", arXiv:2004.05645v1, 2020.

[29] Singh D, Kumar V, and Kaur M, "Classification of COVID-19 patients from chest CT images using multi-objective differential evolution-based convolutional neural networks", European Journal of Clinical Microbiology Infectious Diseases, 39:1379-1389, https://doi.org/10.1007/s10096-020-03901-z, 2020.

[30] Rustam, F., Reshi, A. A., Mehmood, A., Ullah, S., On, B., Aslam, W. & Choi, G. S., "COVID-19 Future Forecasting Using Supervised Machine Learning Models". IEEE Access, 2020.

[31] Cole, M. A., Elliott, R. J. & Liu, B, "The impact of the Wuhan Covid-19 lockdown on air pollution and health: a machine learning and augmented synthetic control approach", Environmental and Resource Economics, vol.76, no.4, pp.553–580, 2020.

[32] Manne, R., & Kantheti, S. C. (2021). Application of Artificial Intelligence in Healthcare: Chances and Challenges. Current Journal of Applied Science and Technology, 40(6), 78-89. https://doi.org/10.9734/cjast/2021/v40i631320

[33] Anthimopoulos, M., Christodoulidis, S., Ebner, L., Christe, A. & Mougiakakou, S, "Lung pattern classification for interstitial lung diseases using a deep convolutional neural network. IEEE Transactions on Medical Imaging, vol.35, no.5, pp.1207–1216, 2016.

[34] Ahuja, S., Panigrahi, B. K., Dey, N., Rajinikanth, V. & Gandhi, T. K, "Deep transfer learning-based automated detection of COVID-19 from lung CT scan slices", 2020

[35] Li D, Cong A, Guo S, "Sewer damage detection from imbalanced cctv inspection data using deep convolutional neural networks with hierarchical classification", Autom Constr, vol.101, pp.199-208. https://doi.org/https://doi.org/10.1016/j.autcon.2019.01.017, 2019.

[36] He K, Zhang X, Ren S, Sun J, "Deep residual learning for image recognition", IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp.770-778, 2016.

[37] Iandola FN, HanS, Moskewicz MW, Ashraf K, DallyWJ, Keutzer K, "Squeezenet: Alexnet-level accuracy with 50x fewer parameters and ¡0.5mb model size, 2016.

[38] Figure 1MERS CoV image source https://github.com/ieee8023/covid-chestxray-dataset/blob/master/images/1-s2.0 S0378603X1500248X-gr2a.jpg

[39] Figure 2 chest x-ray image source https://www.kaggle.com/paultimothymooney/chest-xray-pneumonia

[40] https://towardsdatascience.com/various-ways-to-evaluate-a-machine-learning-models-performance-230449055f15

[41] Mathkunti NM, Rangaswamy S, "Machine learning techniques to identify dementia", SN Comput Sci., https://doi.org/10.1007/s42979-020-0099-4, 2020.

[42] Subramaniyan, M., Sampathkumar, A., Jain, D. K., Ramachandran, M., Patan, R., & Kumar, A., "Deep Learning Approach Using 3D-ImpCNN Classification for Coronavirus Disease", Artificial Intelligence and Machine Learning for COVID-19, pp.141-152, 2021.

[43] Muhammad LJ, Islam MM, Usman SS, "Predictive data mining models for novel coronavirus (COVID-19) infected patients' recovery", Springer Nat Comput Sci., https://doi.org/10.1007/s42979-020-00216-w, 2020

[44] Dianbo L, Leonardo C, Canelle P, "A machine learning methodology for real-time forecasting of the 2019–2020 COVID-19 outbreak using Internet searches, news alerts, and estimates from mechanistic models, https://arxiv.org/abs/2004.04019, 2020.

[45] Edison O, Mei UW, Anthony H, "COVID-19 coronavirus vaccine design using reverse vaccinology and machine learning. bioRxiv preprint", doi: https://doi.org/https://doi.org/10.1101/2020.03.20.000141.

[46] Gurjit SR, Soltysiak MPM, El Roz H, de Souza CPE, Hill KA, Kari L, "Machine learning using intrinsic genomic signatures for rapid classification of novel pathogens: COVID-19 case study", bioRxiv 2020.02.03.932350;2020.