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Research Article

A Comparative Study On COVID-19 Prediction Using Deep Learning And Machine Learning Algorithms: A Case Study On Performance Analysis

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Abstract

COVID-19 disease has been the most important disease recently and has affected serious number of people in the world. There is not proven treatment method yet and early diagnosis of COVID-19 is crucial to prevent spread of the disease. Laboratory data can be easily accessed in about 15 minutes, and cheaper than the cost of other COVID-19 detection methods such as CT imaging and RT-PCR test. In this study, we perform a comparative study for COVID-19 prediction using machine learning and deep learning algorithms from laboratory findings. For this purpose, nine different machine learning algorithms including different structures as well as deep neural network classifier are evaluated and compared. Experimental results conduct that cosine k-nearest neighbor classifier achieves better accuracy with 89% among other machine learning algorithms. Furthermore, deep neural network classifier achieves an accuracy of 90.3% when one hidden layer including 60 neurons is used to detect COVID-19 disease from laboratory findings data.

Keywords: COVID-19 disease, SARS-CoV-2, laboratory data, machine learning, deep learning

1. Introduction

Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) belongs to a betacoronavirus family and has caused a disease known as COVID-19. COVID-19 has been announced as a worldwide pandemic and has caused many deaths worldwide. According to the World Health Organization (WHO) report published on March 9, 2021, the total number of patients who were positive in the diagnosis of COVID-19 is 119,450,269 and the number of patients who died from COVID-19 is 2,647,662. The common symptoms of the disease are tiredness, cough, fever, sore throat as well as problems in breathing and there is no proven treatment for COVID-19. Zoabi et al. [1] investigated importance of these symptoms and they reported that headache and sore throat were identified as the most important symptoms. Several studies have shown that people who have a chronic respiratory disease, older and male are more affected by COVID-19 disease. Furthermore, people with crucial medical diseases like cancer and cardiovascular illness are affected seriously from COVID-19.

This pandemic has led to an exponential increase in hospitalization demands. Furthermore, it continues to challenge the healthcare system due to shortages in medical equipment. It is important to forecast people who will be more likely to develop severe illness including death. The most common technique used in the diagnosis of COVID-19 is Reverse transcriptase polymerase chain reaction (RT-PCR); however, some countries have not enough RT-PCR tests, which causes infection rates to increase sharply. Another common technique to diagnose COVID-19 is to use computer tomography (CT) scans. However, they are unable to discriminate between COVID-19 and other illnesses like flu. Moreover, they are not effective in screening for SARS-CoV-2 in the general population. To overcome all these limitations and effectively use clinical decision-making equipment as well as healthcare resources, machine learning and deep learning aided systems have been developed, recently.

Machine leaning techniques are actively used in COVID-19 detection from genome sequences [2,3] and common symptoms of COVID-19 [4]. Furthermore, they are used to estimate the severity of COVID-19 infected into the patient [1]. Besides, deep learning techniques are efficiently used to predict COVID-

19 from medical imaging [5,6]. They are also efficiently used to interpret clinical findings from various types of cancers [7] and biomedical studies [8].

In this study, we provide a COVID-19 detection method by performing machine and deep learning techniques using laboratory findings of the patients. The rest of the paper is organized as follows. In Section 2, Explanatory information about the machine learning and deep learning techniques performed in this study is given. In Section 3, material and methods are given. In Section 4, the experimental results obtained as a result of using machine learning and deep learning methods are presented and interpreted. The last section presents important results that can be shown as a guide for future studies.

2. Related Work

In this section, we give machine and deep learning algorithms detecting COVID-19 positive cases from laboratory findings and symptoms rather than RT-PCR or CT imaging. Although these studies are limited in the literature, many state-of-the-art machine [9, 10] and deep learning algorithms [6] recently published to detect COVID-19 from medical images or genome sequences can be found in [11,12, 13, 14].

Zoabi et al. [1] developed a machine learning algorithm to diagnose COVID-19. They designed their methods based on basic information and symptoms without using any medical equipment. The features of their dataset include information about cough, fever, sore throat, shortness of breath, headache as well as sex and age information. Their method achieves an auROC of 0.86. Cabitza et al. [15] evaluated five machine learning techniques on the data including blood tests. They performed logistic regression, naive bayes, random forest, SVM, and KNN methods. They achieve satisfactory results and concluded that machine learning techniques based on blood tests can detect COVID-19 cases fast compared to the RT-PCR tests. Unal and Dudak [16] implemented naive bayes, SVM, KNN, and decision tree methods on the dataset including 19 features which are sex, age, the state of pneumonia as well as the state of various types of diseases such as asthma, diabetes, kidney failure, and hypertension. They showed that SVM achieved an accuracy of 100%. Alakus and Turkoglu [5] compared deep learning approaches to diagnose COVID-19 using laboratory findings. Their methods achieve an accuracy of 68.6%. Jiang et al. [17] developed an artificial intelligence tool to predict patients at risk for COVID-19. They used the data containing 11 features which are blood count, hemoglobin, temperature, Na+, creatinine, K+, a liver enzyme, myalgias, gender, lymphocyte count, and age. They performed logistic regression, KNN, decision tree, and SVM classifiers. They concluded that myalgias, hemoglobin, and the liver enzyme are important features and the most predictive. Batista et al. [18] used SVM, random forest, neural network, gradient boosted trees and logistic regression to diagnose COVID-19 using laboratory findings. Their method achieved the best AUC score with 0.84 when SVM and random forest methods are used. Schwab et al. [19] evaluated predictive models using logistic regression, neural network, random forest, different SVM methods and gradient boosting using demographic, clinical and blood analysis data containing 111 features. They obtained the best performance with 66% AUC score when gradient boosting method is used. Göreke et al. [20] proposed a new architecture using deep neural networks for diagnosing COVID-19 from laboratory findings. Shaban [21] proposed a novel hybrid diagnosing system based on deep neural network and fuzzy inference engine.

3. Material and Methods

In this section, the data sets and methods used in the training of artificial intelligence algorithms proposed for the solution of the COVID-19 prediction problem will be explained.

3.1 Data Description

The main data set used for this study was obtained from routine blood test results performed on 600 patients on admission to the emergency room at San Raffaele Hospital (OSR) between 19 February 2020 and 31 May 2020 [22]. COVID-19 positivity for each case was determined according to the result of the SARS-CoV-2 molecular test performed with RT-PCR on nasopharyngeal swabs. All samples have eighteen features and given in Table 1.

Table 1 The features that are used.

Name	**Abbreviation**
Hematocrit	HTC
Hemoglobin	HGB
Platelets	Thrombocytes
Red blood Cells	RBC
Lymphocytes	L
Leukocytes	WBC
Basophils	
Eosinophils	EBM
Monocytes	-
Serum Glucose	-
Neutrophils	N
Urea	-
Proteina Creativa	PCR
Creatinine	CR
Potassium	K
Sodium	NA
Alanine transaminase	ALT
Aspartate transaminase	AST

3.2 COVID-19 Detection Using Machine Learning Algorithms

Machine learning teaches computers the natural learning ability of humans. It also achieves this through experiences. Machine learning algorithms learn data without depending on a predetermined equation. Machine learning uses three types of methods as shown in Figure 1:

1. Supervised learning that trains known data to predict future outputs,
2. Unsupervised learning detecting hidden patterns in input data,
3. Reinforcement learning helping you to take your decisions sequentially based on interacting with the environment.

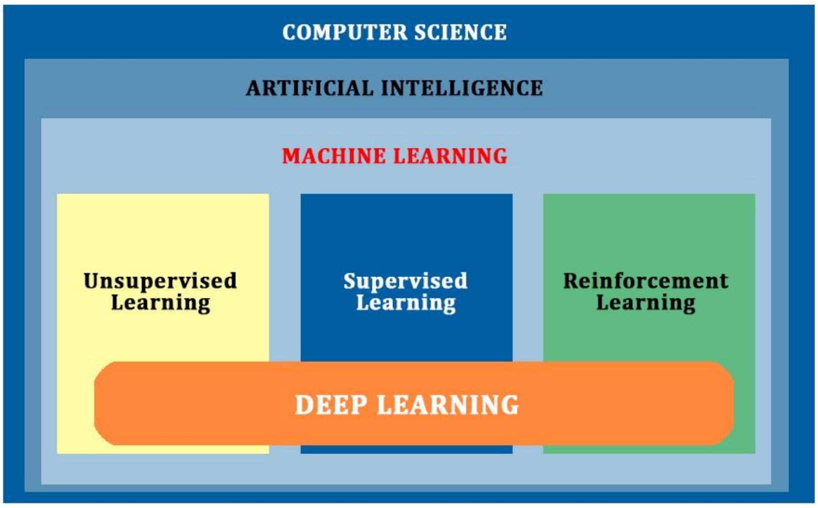

Figure 1 The Relationship between machine learning and deep learning in computer science [23]

The most well-known machine learning models in the field of artificial intelligence are given in Figure 2 [23].

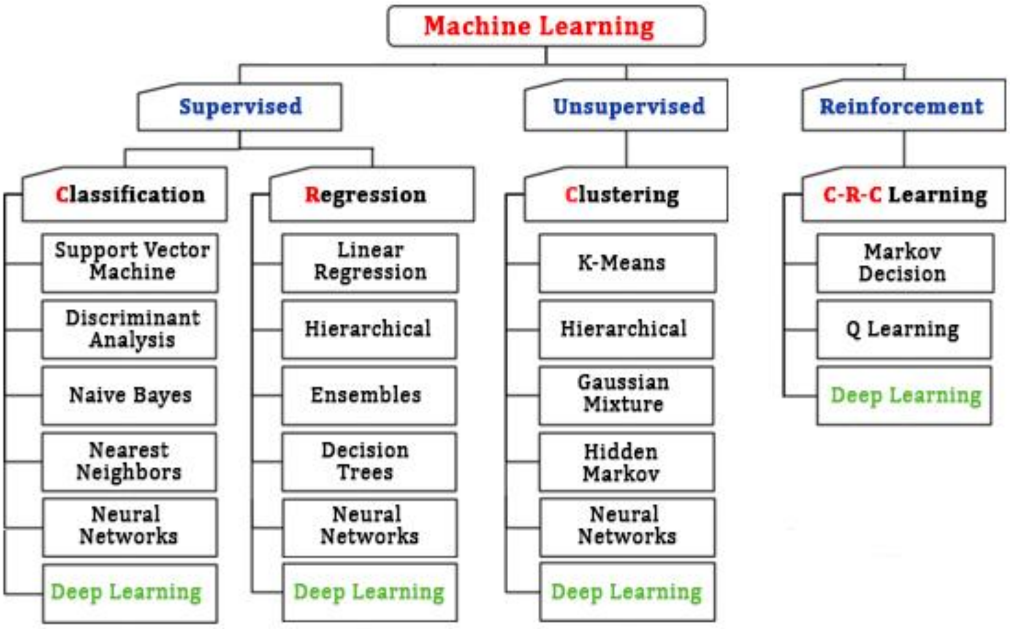

Figure 2 Machine learning models

Supervised machine learning enables the network to learn by making evidence-based predictions from the data. A supervised learning algorithm performs the training of the network by taking a known set of input data for examples and known output data as shown in Figure 3. It creates a mathematical model to generate reasonable estimates that fit the output data. Supervised learning using regression and classification techniques is used to develop predictive models.

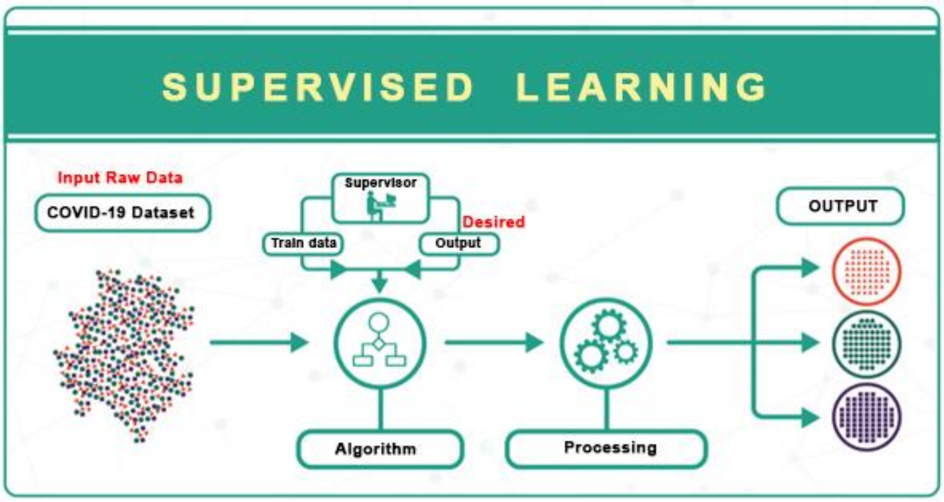

Figure 3 Supervised learning [23]

Unsupervised learning finds hidden patterns or intrinsic structures in data as shown in Figure 4. It performs the learning process by making inferences from data sets consisting of input data without labeled outputs. Clustering is the most common unsupervised learning technique. It is used to find meaningful relationships or groups hidden in data in exploratory data analysis processes. Market research, object recognition and gene sequence analysis are the most used research areas of clustering [23].

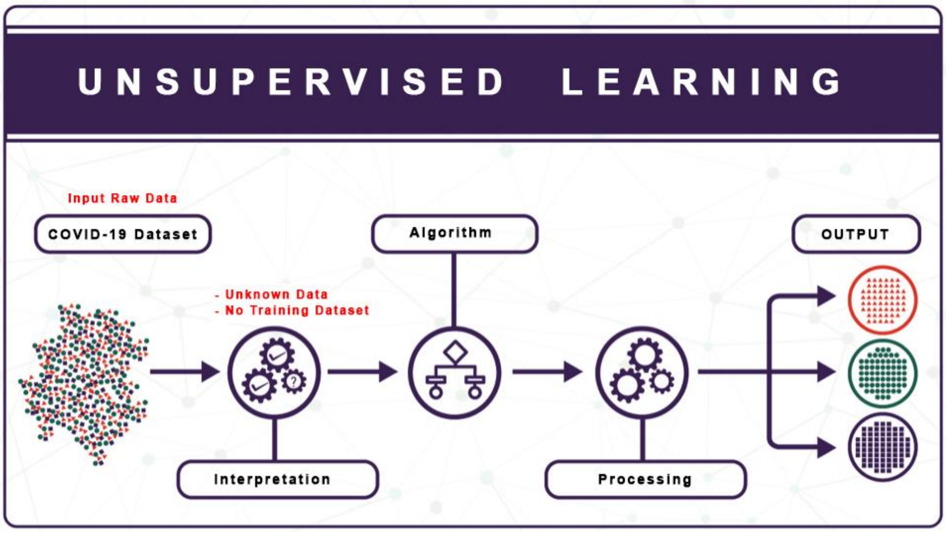

Figure 4 Unsupervised learning [23]

Reinforcement learning, unlike unsupervised learning, provides a high control area in the learning process as shown in Figure 5. Reinforcement learning is based on the concept of unsupervised learning and requires software agents to determine its ideal behavior in data. This structure has been created in a way that helps the performance of the machine to grow. In order to help the train the network, an operator is informed about the progress of the network with simple feedback [23].

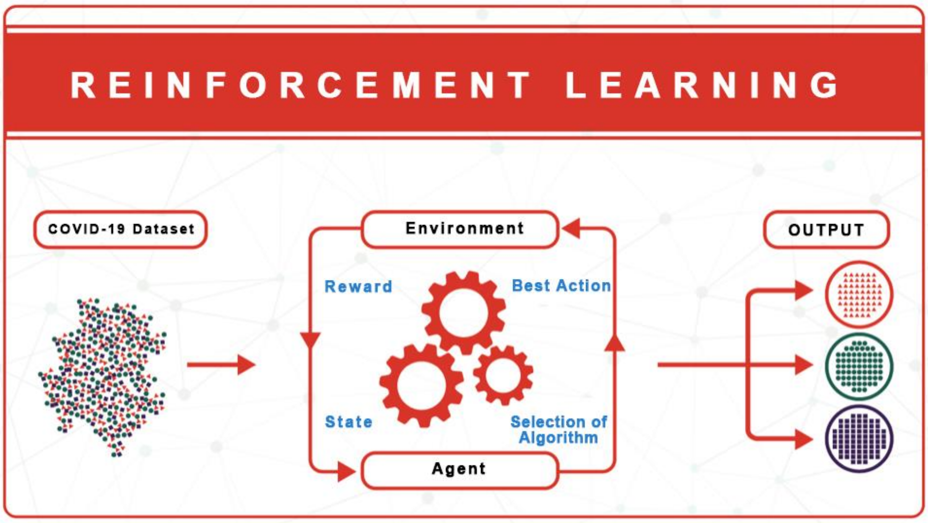

Figure 5 Reinforcement learning [23]

In this study, since the detection of COVID-19 is a classification problem, only classification methods were used among these 3 models. The most preferred deep learning techniques, machine learning and its derivatives were used for the detection process on Covid-19 data. These techniques are given in Table 2.

Table 2 Different algorithms to detection of COVID-19.

Neural Network		**SVM**		**Trees**	
1	Narrow Neural Network	**15**	Linear SVM	**29**	Boosted Trees
2	Medium Neural Network	**16**	Quadratic SVM	**30**	Bagged Trees
3	Wide Neural Network	**17**	Cubic SVM	**31**	Subspace Discriminant
4	Bilayered Neural Network (FF)	**18**	Fine Gaussian SVM	**32**	RUSBoosted Trees
5	Trilayered Neural Network (FF)	**19**	Medium Gaussian SVM	**33**	Fine Tree
6	Probabilistic Neural Network	**20**	Coarse Gaussian SVM	**34**	Medium Tree
7	Learning Vector Quantization	**KNN**		**35**	Coarse Tree
8	Multilayer NN (1 Hidden Layer)	**21**	Fine KNN	**Deep Neural Network**	
9	Multilayer NN (2 Hidden Layer)	**22**	Medium KNN	**36**	Deep NN with CNN layer pre-layer (1 Hidden Layer)
10	Multilayer NN (3 Hidden Layer)	**23**	Coarse KNN		
Naive Bayes		**24**	Cosine KNN	**37**	Deep NN with CNN layer pre-layer (2 Hidden Layer)
11	Gaussian naive Bayes	**25**	Cubic KNN		
12	Kernel Naive Bayes	**26**	Weighted KNN	**38**	Deep NN with CNN layer pre-layer (3 Hidden Layer)
Discriminant		**27**	Subspace KNN		
13	Linear Discriminant	**Regression**		**Used to detection of COVID-19**	
14	Quadratic Discriminant	**28**	Logistic Regression		

The following systematic machine learning workflow shown in Figure 6 is used in this study. In this way, it helped to overcome machine learning challenges for detection of COVID-19.

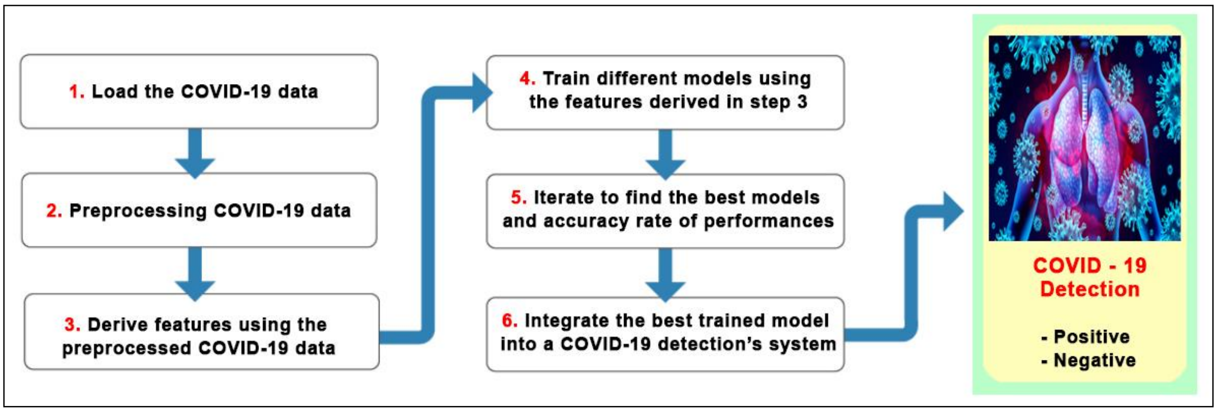

Figure 6 Operation steps of the COVID-19 model

3.3 COVID-19 Detection Using Deep Neural Network Algorithm

Deep learning is a class of machine learning that teaches computers the skills that they naturally learn through experiences. The most well-known deep learning method is convolutional neural network (CNN).

The convolutional neural network is a type of feed-forward artificial neural network whose connection between neurons is inspired by the visual cortex of animals. CNN is among the most popular deep learning algorithms and it learns to perform the classification process directly from image, video, text, or audio files. CNN is quite similar to ordinary ANNs, and it consists of neurons with learnable weight and bias values just like ordinary ANNs [24-27]. The biggest difference of CNN from ordinary ANNs is that by nature it assumes its inputs as two- or three-dimensional images. This situation causes a significant reduction in the number of network parameters, and at the same time, it prevents overfitting in problems with a high number of features and a low amount of data, thereby increasing efficiency. The main reason for using the CNN architecture in this study is that it automatically extracts features while learning as shown Figure 7. With this aspect, it provides more advantageous and successful results than ordinary machine learning algorithms.

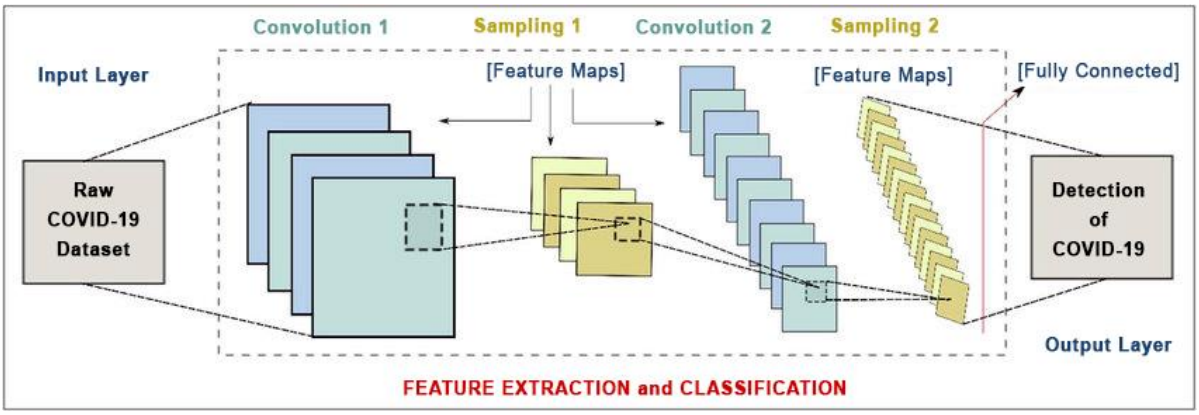

Figure 7 Classical deep learning with CNN structure

The details of the proposed deep NN model are given in Table 3.

Table 3 The sturucture of deep NN

Layers	Numerical Value
1. Input Layer (Raw Data)	18x600
2. Convolution Layer	4x4x600 (filter)
3. Sampling Layer	2X2X600 (filter)
4. Fully-Connected Layer	1X600

In our study, a hybrid CNN pre-layer deep artificial neural network is used. For this purpose, one convolution layer and two classifiers are used for the CNN structure to detect COVID-19.

A typical convolutional neural network has three types of layers that are repeated in different numbers and combinations between the input layer and the fully connected layer. These layers are the convolution layer, the ReLU layer, and the Pooling layer, respectively. While creating a CNN, these three types of layers are repeated over and over to adjust the depth of the network.

A CNN with appropriate parameter values (weights and bias) will correctly assign a given input to one of the classes it has in its output. The purpose of CNN training is to find the most appropriate CNN parameters to perform the correct classification process for a classification problem. At the start of the CNN training, the values of weights and biases are assigned random values or the process may be started using the parameter values of a different neural network performing similar tasks, which is a method that we call transfer learning.

After the initial values of parameter values are determined, each sample in the training set is fed as input to the CNN to calculate class scores generated for each class in its output. By applying these generated class scores to a cost function, whether the CNN produces appropriate results with the existing parameters or not is determined. If our parameter values are not suitable in terms of intuitiveness, our cost function will generate relatively high values. In essence, training a CNN is the process of finding CNN parameters that minimize the cost function [28].

For a single class NN classifier with a single neuron at its output layer, the cost function calculates the cost of each sample in the training set at the NN output. For a multi-class NN classifier with multiple neurons at its output layer, the cost function calculates the cost for all classes at the NN output for each sample in the training set. Cost values for each sample are generated based on the output class they belong.

NN training is the finding of network parameters that minimize the cost function for the training set. The backpropagation algorithm used in the training of NNs is an algorithm that minimizes the cost function. The partial derivatives obtained in the backpropagation algorithm are used together with the gradient descent [29] or a more advanced optimization algorithm to find network parameters that minimize the cost function. In this study, the gradient descent algorithm was preferred as the cost function.

4. Results

In this section, we evaluate and compare machine learning and deep learning results based on the classification accuracy to detection of COVID-19. For this purpose, dataset containing the laboratory findings of the patients retrieved from the Israelita Albert Einstein Hospital (Sao Paulo, Brazil) is used [22]. The performance of machine learning algorithms was evaluated with k-fold cross validation method (k = 5), one of the data enhancement methods. We applied nine different kinds of classification algorithms and the classification accuracies are presented in Table 4. All numerical results are obtained by using MATLAB application on a core intel processor under Windows 10 operating system.

First we evaluate results of decision tree classifier. Three different kinds of decision tree algorithms (fine tree, medium tree, and coarse tree) are applied for performance comparison, and coarse tree achieves the best accuracy with 86% among them. Second, we applied two different discriminant analysis algorithm (linear and quadratic discriminant) and the better result is obtained when linear discriminant method achieving an accuracy of 87.5% is used. Next, we look at the results of logistic regression classifier, it achieves 88.2% accuracy. We performed 2 different types of Naive-Bayes (NB) classifier (Kernel NB and Gaussian NB). The results of Naive Bayes classifier are close to the results of decision tree classifier and Kernel Naive Bayes method achieves better accuracy with 86.3%. We applied 6 different types of SVM methods (linear, quadratic, cubic, coarse gaussian, medium gaussian, and fine gaussian SVM), and the better result is obtained when medium gaussian achieving an accuracy of 88.8% is used. Next we evaluate results of the KNN classifier. We applied 6 different kinds of the KNN classifier (cubic, coarse, fine, medium, weighted and cosine KNN). Cosine KNN method achieves the best accuracy of 89.0%. We applied five types of ensemble classifiers (bagged trees, boosted trees, subspace discriminant, RUSBoosted tree, and subspace KNN). Bagged trees method achieves better results with an accuracy of 87.8%. Next we look at results of classical neural network classifiers (narrow, medium, wide, bilayered, trilayered neural networks). All types of neural networks give close results and better accuracy (85.5%) is achieved when wide neural network method is used. Finally, we look at the results of multilayer perceptron.

In this study, 36 different artificial intelligence methods were classified on COVID-19 data to detection. When all methods are compared, the highest performance has been obtained by synthesizing the deep neural network model CNN proposed as a hybrid model. Table 4 shows that the other models perform approximately the same. This is because the features given to the models are automatically selected with the CNN structure. It is seen that the feature extraction layer in this CNN structure improves accuracy performance on COVID-19 dataset.

Table 4 Accuracy results of machine and deep learning methods

Method		**Accuracy (%)**
Decision Trees	Coarse Structure	86.0
	Fine Structure	85.3
	Medium Structure	85.3
Discriminant Analysis	Linear Disc. Structure	87.5
	Quadratic Disc. Structure	85.3
Logistic Regression Classifier	Logistic Regression Structure	88.2
Naïve Bayes	Kernel Structure	86.3
	Gaussian Structure	85.0
SVM	Medium Gaussian Structure	88.8
	Linear Structure	87.0
	Fine Gaussian Structure	86.7
	Coarse Gaussian Structure	86.7
	Quadratic Structure	84.2
	Cubic Structure	83.0

KNN	Cosine Structure Cubic Structure Weighted Structure Medium Structure Fine Structure Coarse Structure	**89.0** 88.2 87.7 87.7 84.8 86.7
Ensemble Classifiers	Bagged Trees Structure Subspace Discriminant Structure Subspace KNN Structure Boosted Trees Structure RUSBoosted Trees Structure	87.8 86.5 86.3 84.8 80.7
Neural Network Classifiers	Wide NN Structure Medium NN Structure Narrow NN Structure Bilayered NN Structure Trilayered NN Structure	85.5 85.2 84.7 84.5 84.2
Multilayer Perceptron	Two Hidden-Layers Structure Three Hidden-Layers Structure One Hidden-Layer Structure	88.7 87.4 86.3
Our recommendation: Deep Neural Network with CNN Structure	One Hidden-Layer Structure Two Hidden-Layers Structure Three Hidden-Layers Structure	**90.3** 89.2 86.4

Now we evaluate accuracy results of deep neural network classifier. In the proposed model, it was observed how different hidden layer neuron numbers affect the performance and is given in Figure 8. As seen in Figure 8, it is understood that the excessive increase in the number of hidden layers negatively affects the performance of the network. It is understood that this is due to the increase in the mathematical computational burden of the model.

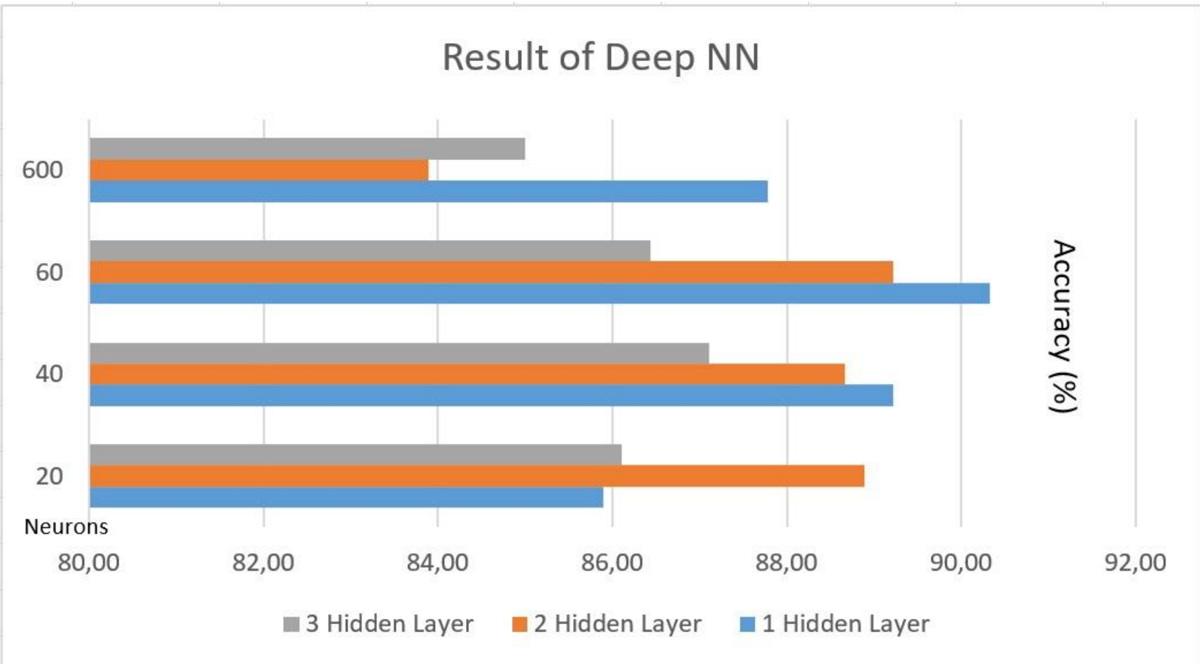

Figure 8. Result of Deep NN on COVID-19's detection

As a result, when the results obtained are examined, it is understood that the artificial intelligence methods mentioned above have an acceptable success for the detection of COVID-19. Accuracy performance can be expected to increase by increasing the number of samples in the dataset. In addition, performance can be increased with different hybrid models. However, it is seen that working with this current situation is successful.

5. Conclusion

COVID-19 disease has caused severe and deadly complications and fast and accurate detection of COVID-19 is important to prevent spreading from one person to another. This paper presents a comparative study for COVID-19 detection using various types of machine and deep learning methods from laboratory finding data. As the conclusion, the following results can be summarized:

- Nine different types of machine learning methods with different variants are performed and classification accuracy changes from 80.7 % to 89 %.
- Classification accuracies of decision tree, naive bayes, and neural network classifiers are close to each other.
- Cosine KNN method achieves the best accuracy with 89.0 % among other machine learning methods.
- Ensemble classifier achieves an accuracy of 87.8 %.
- In the deep neural network classifier, the number of neurons at a hidden layer is changed from 20 neurons to 600 neurons and the number of the hidden layer is changed from 1 to 3. The best classification accuracy is obtained when one hidden layer including 60 neurons is obtained.
- Accuracies of deep neural network classifier change from 83.9 % to 90.3 %.
- Performance of machine learning and deep learning method is close to each other and deep neural network method achieves the best result.

In future studies, we will combine supervised and unsupervised techniques to increase overall accuracy.

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