Comparison of Machine Learning Algorithm's Performance Based on Decision making in Autonomous Car

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***Abstract*—This paper presents the performance comparison of popular supervised learning algorithms: SVM, MLP, CNN, DT, and RF. These algorithms are used for road images recognition. All images are collected by our model car. They are labeled with four different classes: left, right, forward and stop. We use 90% of them for training and use 10% for testing each model. The result shows that, CNN has the best accuracy about 83.45%.**

***Index Terms*—Autonomous car, Machine Learning, ML, Model prediction**

I. INTRODUCTION

Transportation plays an important role in our daily. We can travel to any places in quite short time. There are many options for traveling such as car, airplane, and ship. In Thailand most of people use a car for their traveling because of their convenience. Therefore, number of car in Thailand is increasing. This cause leads to an increase in traffic accident. Fig. 1 shows the number of road traffic accident in Thailand from 2012 to 2015.

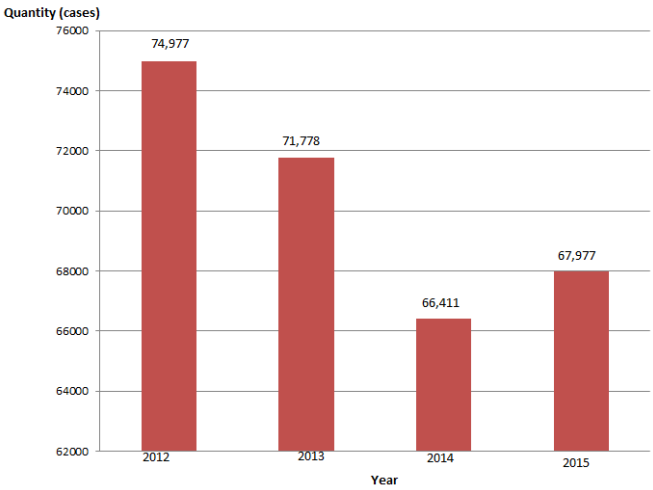

Fig. 1. Traffic accident statistic [1]

As you can see from Fig. 1, the number of accidents are decreasing but still at a high level. More over, drivers are the main cause of accident as shown in Fig. 2.

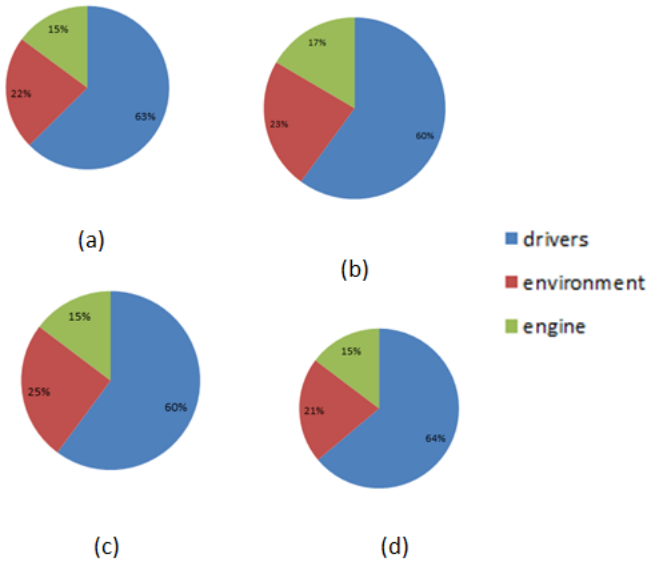

Fig. 2. The percentage of traffic accident causes [1]

Fig. 2 shows the percentage of traffic accident causes in Thailand from 2012 to 2015 respectively. As you can see from the figure, causes of accident are divided into three types: driver, environment and engine. The blue area is the percentage of causes from drivers. The percentage of causes from environment is shown in red area. The green area is the percentage of causes from engine. All of these are situation in Thailand. In 2014, Researchers in USA. Found that, there were 2.3 million dead from traffic accident. Most of causes are driver who violated traffic rule. For example, drivers who drink and drive. In addition, drivers who use phone while driving. Many studies found that, autonomous car can reduce

the number of accidents from illegal driver. In addition, autonomous car make travel more convenient for disabled people and aging people. It also reduces stress from driving too. [2-3]. Autonomous car has been studied from previous decade. Many studies in the 1980s were launched by PROMETHEUS project. VaMP cars, which were almost automatically driven, were built. The 98% of autonomous car was built by CMU NAVLAB at the same time. This car can drive across the USA [5]. In 2004, DARPA (Defense Advanced Research Projects Agency) held the autonomous car competition. There are many cars from many research projects in this event. In conclusion, Sandstorm a car from Carnegie Mellon University which drove the longest distance got the reward. The important issue that affect to user confidence is the safety. Autonomous cars have to reach their destination safely. They have to avoid obstacles around them. Decision making system in autonomous car acts like a brain which controls their movement. There are several stages in this system. First of all, the environment around the car is modeled by many sensors such as radar, Lidar, camera. In the last few years, computer vision is a popular technique used in this stage because of its ability in image recognition. Recently, Machine Learning (ML) is applied in image recognition because of its performance. ML may be classified as a branch of science which studies how computer thinks and acts like human. Basically, ML is using algorithms to extract information from raw data and represent it as a model. We use this model to predict other data [6]. This paper presents the performance comparison of popular ML algorithms such as Support Vector Machine (SVM), Convolutional Neuron Network (CNN), ANN Multi-layer Perceptron (ANN_MLP), Decision Tree (DT), and Random Forest (RF) for decision-making in autonomous car.

II. RELATED WORK

A. Autonomous car

The first autonomous car was built in the early 1980s by a research team led by Ernst Dickmanns. This 5 tons car has many sensors attached on it to control steering engine and brake. Control commands are derived from computers that work on the principles of computer vision and probability [7]. This car was tested by running on an unobstructed road. It can move on its own at a speed of 96 kilometers per hour. In 1987, EUREKA, a research organization in Europe, was awarded a scholarship to study and research automation in a project called Prometheus (Program for a European Traffic of Highest Efficiency and Unprecedented Safety). This project is responsible for the development of unmanned vehicles. In early stages, autonomous cars move automatically by embedding the cable in it. After that, this approach was replaced by computer vision principle, presented by Dickmanns. As a result, during the year. 1990 The project was able to develop autonomous car that drove on the highway at speeds of 80 kilometers per hour. This success has led to more technical research, such as tracking other cars, lane changing, taking over another car [8]. The development of this research has been re-launched in the year. 2004, when the first of DARPA Challenge, autonomous car competition was held. In this competition, each autonomous cars have to drive across the desert. The performance are evaluated by their driving distance. However, there are no teams complete in this event. But Sandstorm, a car developed by Carnegie Mellon University got $ 1 million prize because it has maximum distance 7.4 miles. In the following year, there were 5 teams that drove at 132 miles. The winner was Stanley, a car developed by Stanford University [9]. Generally, autonomous car consists of the following devices: RADAR: A device that detects objects around the car. It will alert before car crashes an obstacle. LANE GUIDANCE: The camera which is attached to the rearview mirror to detect the traffic lane. In addition, it can also tell the difference of surface level too. LIDAR: The sensor on the roof of the car consists of a laser point around it for detecting images around the car. INFARED CAMERA: A camera that allows the car see objects at night. STEREO VISION: The camera is installed to process a 3D image when it encounters animals or pedestrians. GPS: A device used for searching desire location and identifying current location of the car. The important issue for developing autonomous car is safety. Autonomous car have to avoid obstacles and reach their destination safely. In order to reach that requirement, they must have a good decision making system. Decision making system acts like a human's brain. It controls the movement of the car according to the plan. For example, it selects the best route for traveling. Moreover, it controls the car to stop when the stop signal is found. Generally, the decision-making system consists of four main components as shown in the figure 3. Route planning is the first step and it is important

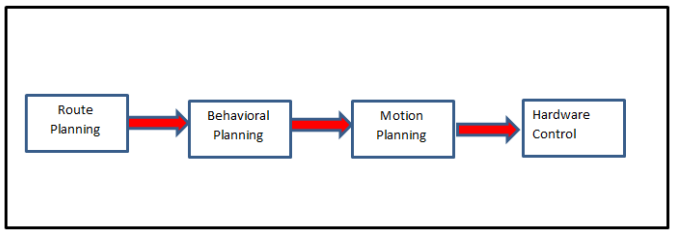

Fig. 3. Decision making components

for decision making. In this step, the best routes are selected and represented in graph. Then agents, obstacles, traffic sign are considered for behavioral planning. In motion planning car is selecting a suitable action and sending a command for movement controlling in the last step.

B. Machine Learning (ML)

Machine Learning may be classified as a branch of artificial intelligence that allows computers create knowledge from raw data. ML is using algorithms to extract information from data and represent it in a model. This model is used for inferring unseen data. ML can be divided into 3 types: supervised learning, unsupervised learning and reinforcement learning. In present, ML is applied in many intelligent systems. For example, computer vision uses ML in image recognition. In

health care system, ML is used for disease forecasting [10]. Support Vector Machine (SVM) is a set of supervised learning. The method is modeled by labeled data. The objective of SVM is to find the hyperplane that divides the dataset. Although, it is a complex algorithm, but can provides high accuracy [11]. Multi-Layer Perceptron (MLP) may be classified as a class of feedforward artificial neuron network. Its structure consists of three layers. Each node is a neuron that uses backpropagation technique for training. Convolutional Neural Network (CNN) can be classified as a class of deep learning. It is most popular technique applied in image recognition. Decision Tree (DL) is a type of supervised learning algorithm. It is the most popular algorithm for classification task. It can easily deal with interaction between features. ID3, C4.5, C5.0 and CART are an example of famous algorithms. In addition, Decision Tree can handle many types of data such as text, numeric [12]. Although, Decision Tree is a high performance algorithm. However, dealing with multi- dimensional data is difficult. RF was developed to solve this problem. RF is a method that operates by training a number of decision trees. RF output is the class with the majority over all the trees. RF is fast, scalable and robust method [12]. In this paper, we studied supervised learning algorithms: SVM, MLP, CNN, Decision Tree, Random Forest, Linear regression for behavior classifying. Then their performances are compared by their accuracy.

III. METHODOLOGY

A. Data set

In this study, we modeled an autonomous car for collecting data. Our car consists of three subsystems: input unit, processing unit and car control unit. A Raspberry Pi board attached with pi camera module are used to collect input image. Two client programs run on Raspberry Pi for streaming color video. In order to achieve low latency video streaming, video is scaled down to 160×60 resolution. Processing unit is receiving data from Raspberry Pi, learning model to make decision and steering. After that, steering command will be sent to car control unit in order to control a car. There are 2,836 images of data set. Input images are road images with 4 different characteristics. Each image are labeled with 4 different classes too. Description of images characteristics and labels shown in table 1.

TABLE I
DETAIL OF ROAD IMAGES

No.	Image	Characteristic/Description	Class	Quantity
1		straight route	forward	1,906
2		junction	left	144
3		junction	right	32
4		Intersection	stop	754

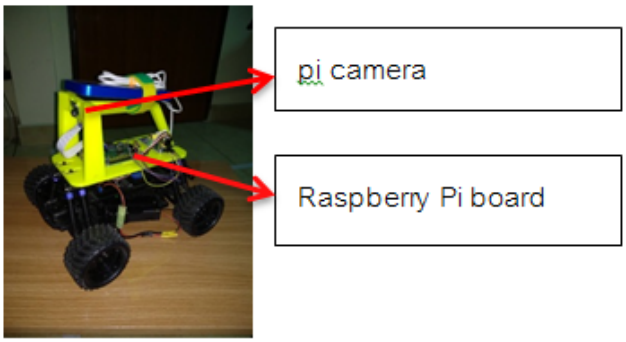

Fig. 4. Our model car

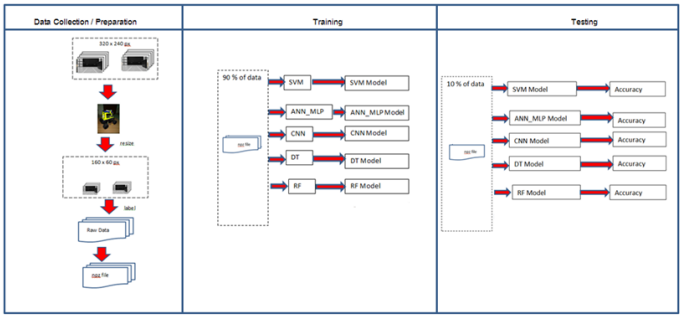

Fig. 5. Data evaluation model

B. Training data

In training process, first each frame is cropped and converted to a numpy array. Then the train image is paired with train label (human input). Finally, all paired image data and labels are saved into npz file. We labeled them with four different classes: left, right, forward and stop. We used 90% of images as a training data. Another 10% of data set are used for testing each algorithm.

C. Testing data

Each model is written on Raspberry Pi to detect and classify road images. Test data is about 10% of road images. In test process, we got an image with label and its probability.

D. Algorithms

Supervised learning algorithms are applied in this work. In training process, prediction models are created from these algorithms. Description of each algorithm is shown below. Multi-layer Perceptron (ANN_MLP) is one of methods that we applied to this study. The default behavior of the Multi-layer perceptron is the feed forward method, but we can define a parameter for change to the back-propagation algorithm that consists of three layers. The Input layer receives data and sends it to the hidden layer and passes to the output layer, respectively. The activate function is a function for summary the weight $(W_{i1}, W_{i2}, ..., W_{iN})$ of each neuron $(X_1, X_2, ..., X_N)$

and plus the bias value (W_{i0}) that implements the standard activate function, f(u) (Default is sigmoid function).

$$u_i = \sum_{i=1}^{n} x_i w_i + bias \tag{1}$$

$$y_i = f(u_i) \tag{2}$$

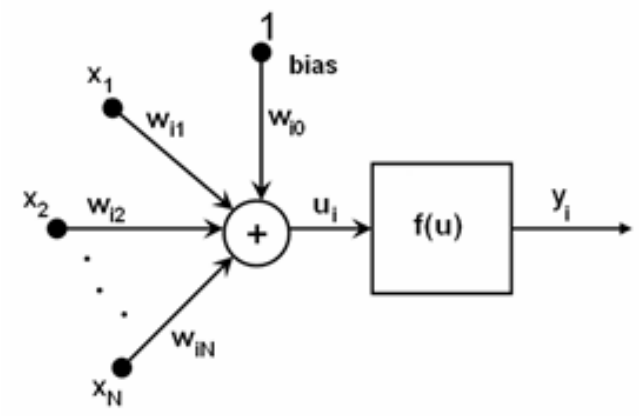

Fig. 6. Activate function

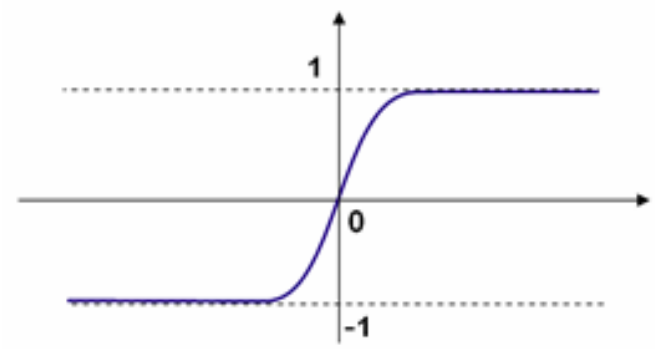

Fig. 7. Sigmoid function

The standard sigmoid activate function is

$$\beta = 1, \alpha = 1 \tag{3}$$

In MLP, all the neurons have the same activation function, with the same free parameters (β, α) that are specified by user and are not altered by the training algorithms. Process of data evaluation with ANN_MLP is shown in fig 8. Support Vector Machine (SVM) It is a class of supervised learning algorithms for pattern analysis that useful for non-linear hyper-plane that use the decision function is below:

$$sgn(\sum_{i=1}^{n} y_i \alpha_i K(x_i, x) + p) \tag{4}$$

$K(xi, x)$ is the kernel. Process of data evaluation with SVM is shown in fig 9.

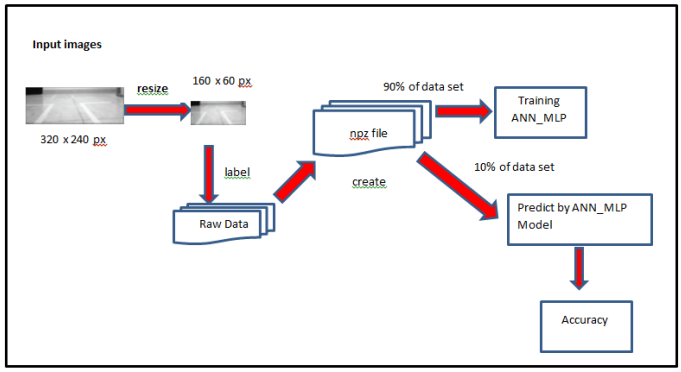

Fig. 8. Data evaluation with ANN_MLP

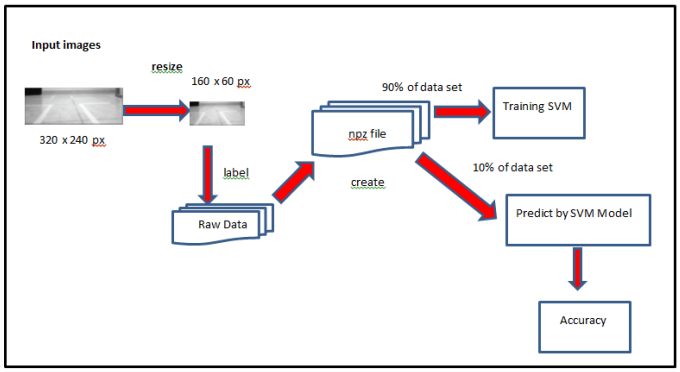

Fig. 9. Data evaluation with SVM

Convolutional Neural Networks (CNNs) are multi-layer neural networks with many hidden layers. The first hidden layers might only learn local edge patterns. Then, each subsequent layer (of filter) learns more complex representations. Finally, the last layer can classify the image as a direction of autonomous car. Dropout is an effective technique to reduce the over fitting in the complex neuron networks. Flatten is an operation to convert the output of the convolutional part into a single long feature vector. Dense is the fully connected layer that the final classification with produce abstract contents as we want. Process of data evaluation with CNNs is shown in fig 10. In fig 11, shows an example ConvNet Architecture. The initial volume stores the raw image pixel (left hand seide) and the last volume stores the class scores (right hand side). Each volume of activations along the processing path is sshown as a column. Decision Tree (DT) is a non-parametric supervised learning method used for classification. The goal creates a model that predicts the value of a target variable by learning simple decision rules inferred from the data features. They have many advantages. That is simple to understand and to interpret and to visualize. The cost of using the tree is logarithmic to train the tree. Process of data evaluation with DT is shown in fig 12. Random Forest (RF) A

random forest use a decision tree classifiers for fitting that on various sub-samples of the dataset and manage the predictive accuracy and control over-fitting by using average value to improve them. This method has many important parameters such as n_estimators define the number of trees in the forest, random_state tells the method to get the random number generator used by np.random, etc. Process of data evaluation with RF is shown in fig 13.

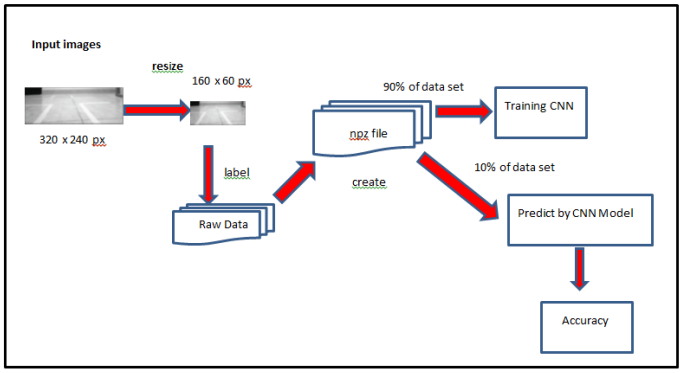

Fig. 10. Data evaluation with CNNs

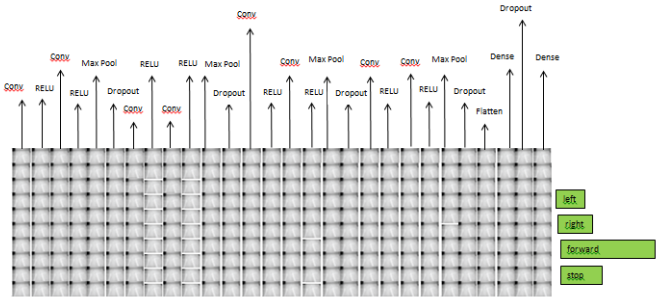

Fig. 11. The activation of an example ConvNet Architecture

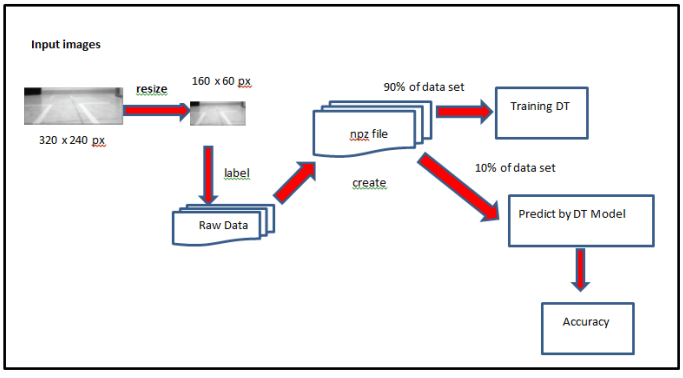

Fig. 12. Data evaluation with DT

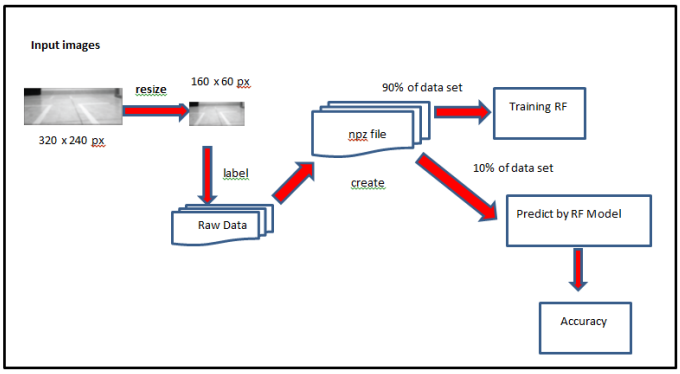

Fig. 13. Data evaluation with RF

IV. EXPERIMENTAL AND RESULT

There are 2,836 road images in this study. Images are labeled with four different classes: left (144 images), right (32 images), forward (1,906 images) and stop (754 images). Junction images are labeled for left or right and other images are labeled for forward and stop. Each algorithm is trained by 90% of data set and tested by 10% of data set. Accuracy of each algorithm are shown in table 2. Fig 14 and Fig 15 are an example of road images prediction. In Fig 14, the maximum probability is 0.80 which drop in forward. In Fig 15, the maximum probability is 1.00 which drop in stop.

TABLE II
ACCURACY OF EACH ALGORITHM

Algorithms	Accuracy
ANN_MLP	67.81%
SVM	70.78%
CNN	83.45%
DT	68.31%
RF	69.72%

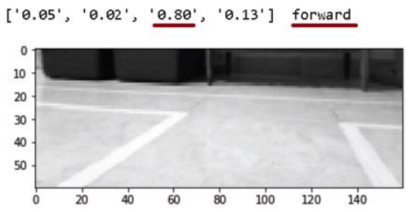

Fig. 14. An example of forward image

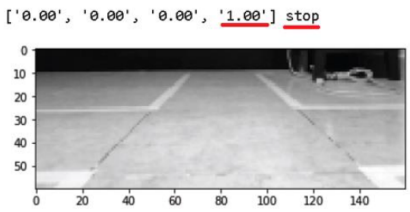

Fig. 15. An example of stop image

V. CONCLUSION

This paper presents a comparison of machine learning algorithm. There are five supervised learning algorithms are compared in this study. Data set in this research is road images which are collected by our model car. There are 2,836 road images in this study. In data collection and preparation, we use our model car to collect road images. Once images are collected, they are resized to 160 x60 resolution. After that, we labeled them with four different classes: left, right, forward and stop. This labeled data are used for making npz file. In training step, we use 90% of data set for training each algorithm. Finally, 10% of dataset are evaluated by each model. The result shows that, CNN has the best accuracy about 83.45%.

VI. DISCUSSION

The results of this research show that the Convolutional Neuron Network (CNN) method is the best. That's because the CNN method works by selecting the representatives of each layer and repeating them around. However, using this method will use a lot of computing power. In this experiment, researchers use the GPU to process for this study. The CNN has been successful in [12] that has many classes for prediction that means this experimenting with images processing which is similar to [12]. The Rectifier Linear Units (ReLU) activation function is used in CNN that is an important key in this study. The activation function in neural network aims to produce a decision boundary by combination of the weight of each neuron and bias value. Dropout technique is useful to prevent the over-fitting in deep learning. Dropout is an approach to regularization in neural networks which helps reducing interdependent learning amongst the neurons.

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