Classification of Hand-Drawn Circuit Components by Considering the Analysis of Current Methods

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***Abstract*— In this paper, at first, existing classification methods for classifying hand drawn circuits and circuit components are briefly introduced by examining advantages and disadvantages of each classification method. The handled methods are Support Vector Machine method (SVM), nearest neighbor method (KNN) and convolutional neural network method (CNN). Then, in the experimental part of the study, four different hand-drawn circuit components, which are diode, capacitor, resistor and ac voltage source, have been tried to be classified by using CNN method which is a highly recommended classification method in literature. The classification tables and graphics have been presented for the performed study. According to the obtained results and accuracy rate, it is concluded that CNN method can be used reliably to achieve high performance in the classification of hand-drawn circuit components.**

Keywords*— *circuit component, classification, CNN, SVM, KNN

I. INTRODUCTION

Recently, especially thanks to rapid advances in technology, researchers have made certain attempts to get computers to do what people can do. Performing the actions of walking, talking and thinking, which are human actions, on robots via computers has made an important breakthrough in engineering. One of the actions which people perform is distinguishing an object or an image from the others. In order to perform this action in computers or digital world, artificial intelligence, machine learning and deep learning are used generally. The number of people working on artificial intelligence and machine learning is increasing significantly due to the intense interest in this field. With new ideas and new approaches, computers have become capable of many things that people can do. Correspondingly, computers have achieved serious success in classifying images in different categories. There are several classification methods available for classifying hand drawn circuit images or circuit components. Many approaches have been developed to achieve the desired goals in this field day by day. These methods are Support Vector Machine method (SVM), nearest neighbor method (KNN), decision trees method and convolutional neural networks method (CNN).

Circuits have an important role in Electrical and Electronics Engineering. Electrical and Electronics engineers perform circuit drawing in two different ways. The first is manual drawing on paper, which is the basic method and oftenly used. The second is the digital drawing by using various simulation programs in computers.

Various methods have been studied before to determine the circuit type or circuit components through images of hand drawn circuits which are frequently used in Electrical and Electronics Engineering.

In the literature, circuit components found in hand drawn circuit diagrams were classified by using SVM method [1-4]. Also, KNN method was used to classify the components on a hand-drawn electrical circuit diagram [5]. In recent years, CNN method is used in the classification of electronic components on hand-drawn electronic circuits [6,7].

In this study, after giving a brief comparative analysis of mentioned classification methods, four hand-drawn circuit components are classified by using CNN method, and the success rate of the used method has been evaluated by considering obtained results.

II. IMAGE CLASSIFICATION METHODS

In this section, basic information is given about three classification methods widely used in the literature.

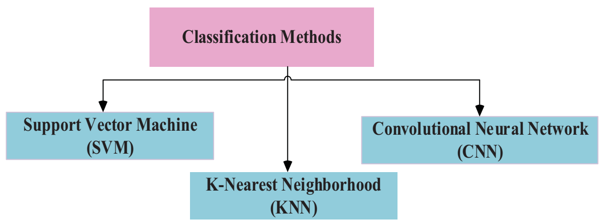

Figure 1. Image classification methods.

A. *Support Vector Machines (SVM)*

The support vector machine is a widely used method of classifying handwritten images. SVM, which is a linear method but can be also applied to nonlinear datasets, is a classification method that achieves high performance in classifications consisting of two categories [8]. SVM is a machine learning algorithm that was originally developed to

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be used only in the solution of two-class classification problems, however it became available in the solution of multi-class problems by time. The basis of classification with SVM is the process of finding a suitable hyperplane that can distinguish the two classes from each other [9]. As seen in Fig. 2, data with two classes can be distinguished by more than one hyperplane.

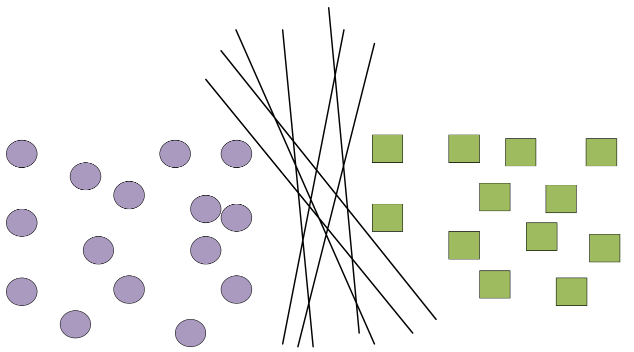


Figure 2. Linearly separable two-class classification problem.

SVM aims to find the optimum hyperplane which is the most suitable hyperplane among the drawn hyperplanes. In the two-class classification, the optimum hyperplane is the plane that maximizes the distance of both classes as seen in Fig. 3. The points that limit the width between two borders are called support vectors [10].

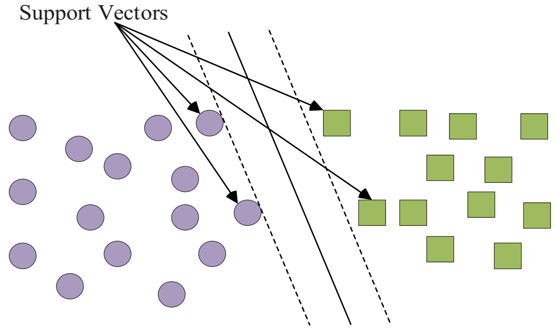


Figure 3. Optimal hyperplane and support vectors in a linearly separable two-class classification problem.

A decision function is used in support vector machines to be used to distinguish two classes of data that can be linearly separated. Classes are expressed with $\{-1,+1\}$ tags. Assuming that there are M samples, it is expressed as training data for i=1,…,M.

As can be seen in Fig. 4, the data in the training dataset can't always be linearly separated. In cases where the data can't be separated linearly, the most suitable curve must be found to distinguish the data.

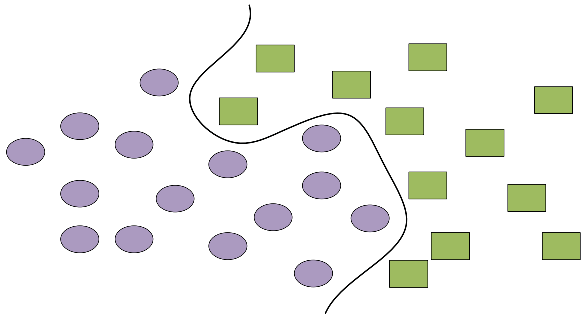


Figure 4. A two-class dataset that can't be separated linearly.

For this, data is transferred from the original input space to the higher dimensional feature space as seen in Fig. 5. In the process of classifying data that cannot be separated linearly, linear separation is enabled with the Kernel function [11].

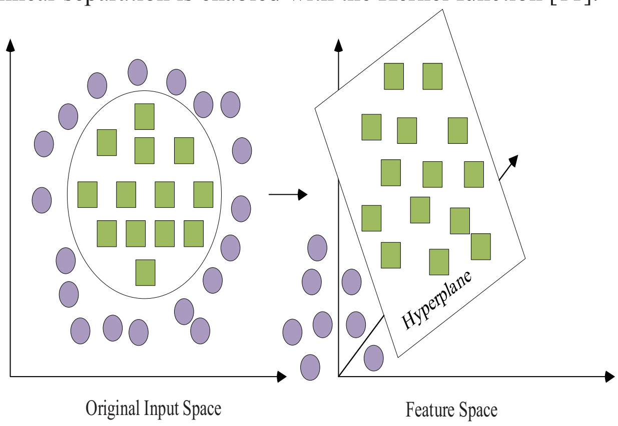


Figure 5. The transition of two classes of data that cannot be separated linearly to the property space.

Advantages of this method in image classification are i) Training takes a fast and short time, ii) At the classification stage, it achieves high accuracy, iii) It can be applied to other classification problems by expanding. And the disadvantages of this method in image classification are i) Slow running and long training in large datasets, ii) Good kernel function selection is not easy, iii) The need for large memory in computers in large datasets [12].

B. K-Nearest Neighbor (KNN)

It is a widely used algorithm for image classification in the literature. Considering that there are M numbers of training data belonging to S classes in the training dataset, M numbers of training data are labeled with the correct classes. When it is desired to find out which class a new sample belongs to, which is not included in the tagged train data, the sample whose class is unknown is included in the class to which it is close depending on the distance.

As seen in Fig.6, a new sample denoted by ”?” is included into a class which has closer distance to the sample according to K = 1.

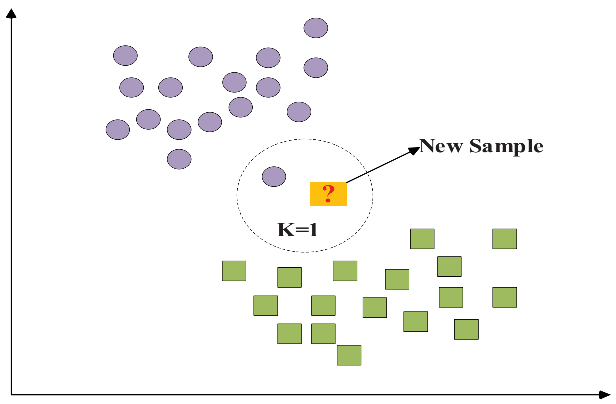


Figure 6. Determining the classification of a new untagged sample according to the k parameter.

In this classification method, the Euclidean distance method is widely used to determine the distance between two samples. When a new data that has not been labeled by the user is wanted to be included in the existing dataset, untagged data has K number of closest neighbors. The parameter K refers to the number of neighbors. Euclidean distance method is generally used to determine the distance between K number of neighbor data and new data. Advantages of this method in image classification are i) Understandable and easy to apply, ii) Training phase takes a short time, iii) Performs well in noisy training data. The disadvantages of this method are i) Calculation of distance for each data, ii) To memorize during the training phase, iii) Since the distance calculation is made for each data, it takes up much space in the memory of the computers used, iv) Requires large memory for large datasets [13].

C. *Convolutional Neural Networks (CNN)*

Convolutional neural networks are deep neural networks method that has achieved great success in image classification studies in recent years. The most important difference between deep neural networks and neural networks is that the number of hidden layers is more than two. The greater the number of hidden layers results in the deeper the network and more feature extraction. Deep neural networks do not require a specialist in feature extraction stages. Without a specialist, the feature extraction phase is successfully completed with the help of layers in the network. While creating CNN architecture, convolution layer, pooling layer, relu layer, fully connected layer and various activation functions are used. A general CNN architecture is shown as an example in Fig. 7 below.

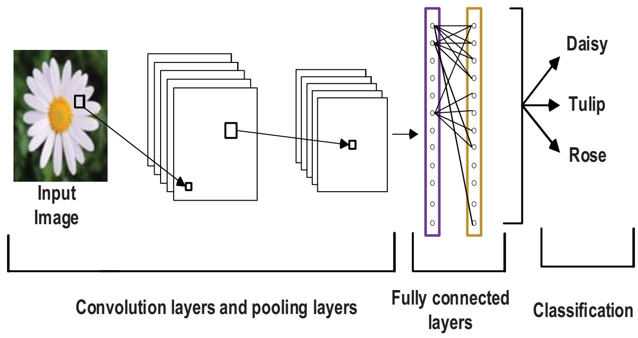


Figure 7. General structure of the convolutional neural network architecture

Each layer in CNN has a different task in architecture. In the convolution layer, the input image expressed in matrix form is subjected to the convolution process with a filter matrix to be selected. All numbers in the filter matrix are convoluted with all the pixels in the image, respectively. As a result of this convolution process, the property map is reached. The max pooling layer is usually added to the CNN architecture after each convolution layer. In the max pooling layer, the largest pixel value in each area covered by the filter is selected by moving an empty filter step by step over the image matrix. Consequently, the computational cost of the neural network and the processing density in memory decrease due to the decrease of the number of weights. In the fully connected layer, feature data in matrix format is converted to a flat vector format. And finally, the classification process is completed with the help of the selected classification function.

Advantages and disadvantages of using CNN in image classification is as follows [14]: Advantages are i) Realization of the feature extraction phase without the need for feature engineering, ii) The calculation cost is low, as the feature extraction phase takes place automatically with CNN, iii) Short duration of the test phase compared to SVM and KNN methods. And disadvantages are i) Training takes a long time in large datasets, ii) The need for large memory in computers in large datasets.

III. Experimental Study And Results

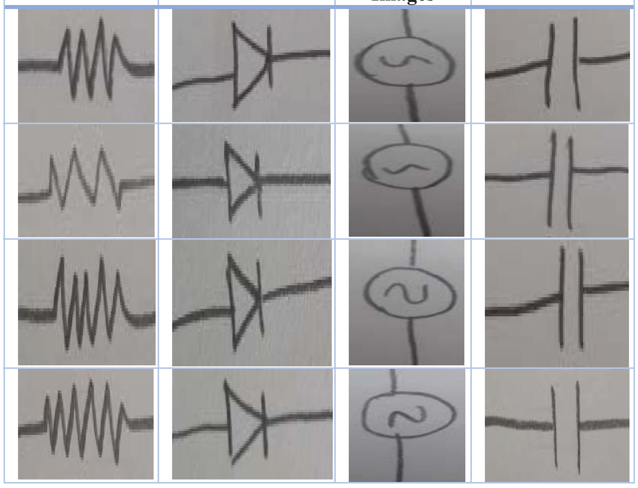
A dataset is created from hand-drawn images of AC voltage source, resistor, diode and capacitor, which are among the most frequently used circuit components and were drawn by the students of Munzur University. Then, a sequential CNN architecture of 12 layers is created by using the mentioned layers [7]. Table I shows the data numbers for each circuit component included in the dataset. Sample images of the circuit components used in the dataset are given in Table II.

TABLE I. DATA NUMBERS OF EACH COMPONENT IN THE DATASET

Component Class	Train Dataset	Test Dataset	Total
Resistor	130	20	150
Diode	130	20	150
AC Voltage Source	130	20	150
Capacitor	130	20	150

TABLE II. SAMPLE IMAGES OF HAND-DRAWN CIRCUIT COMPONENTS IN THE DATASET

Resistor Images	Diode Images	AC Voltage Source Images	Capacitor Images



As known, due to the used algorithm and the technical properties of the computer, the required time for obtaining the results can change. As a result of the training applied for 50 epochs, the accuracy graph is given in Fig. 8 and the loss graph is given in Fig. 9. When the graphics are examined, it is seen that the training performance is at a good level.

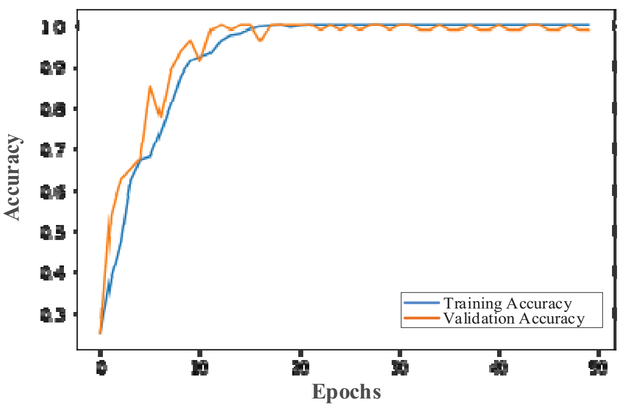


Figure 8. Accuracy graph for 50 epochs.

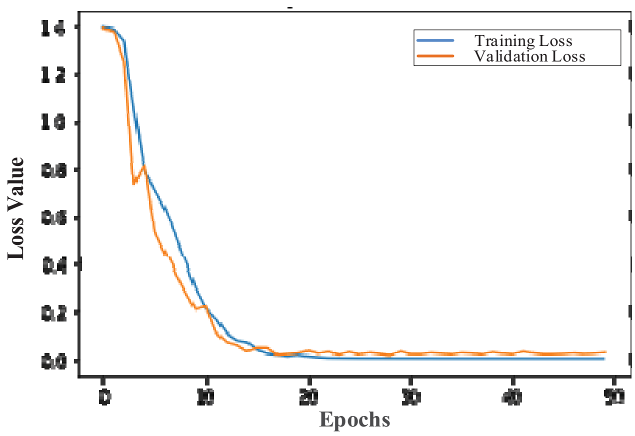


Figure 9. Loss value graph for 50 epochs.

The confusion matrix of the sequential CNN model used in the study is shown in Fig. 10. Accordingly, the classification performance of the sequential CNN architecture used is 93.75%. The ratios of classification success for AC voltage source, diode, resistor and capacitor are determined as 100%, 100%, 95.2% and 83.3%, respectively.

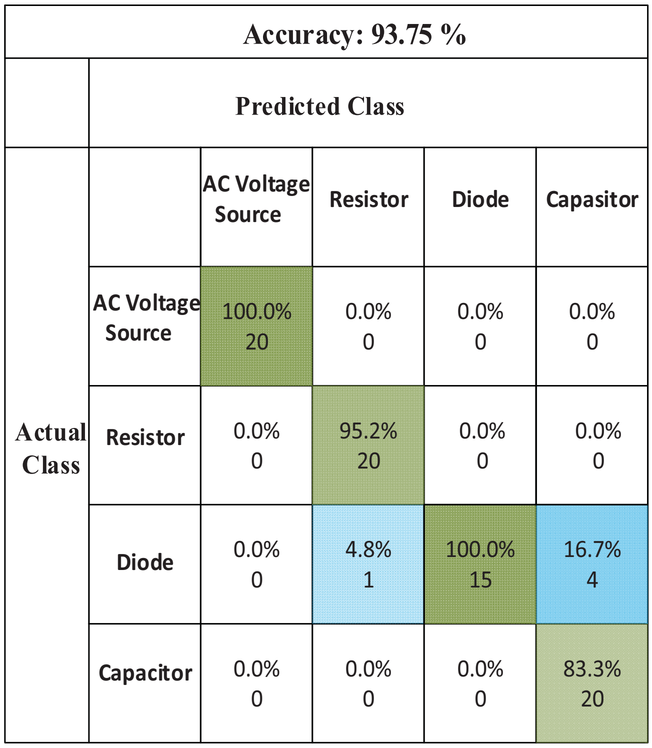


Figure 10. Confusion matrix for different circuit components.

IV. CONCLUSIONS

This paper presents an experimental study to classify hand-drawn electronic components of resistor, capacitor, diode and AC voltage source. The dataset was created by taking hand-drawn circuit components from different students in Munzur University. After a brief analysis of basic classification methods of SVM, KNN and CNN by introducing the positive sides and drawbacks, the experimental study was conducted by using CNN method which has yield good results in former studies. The reason why CNN is preferred is that feature extraction is done over layers, does not require feature engineering and has low computational cost. In classification with CNN, the increase in the number of data and the number of epochs for each of the circuit components in the dataset positively affects the training and classification performance. According to the obtained results, it is observed that accuracy rate in the classification of hand-drawn circuit components by CNN method was found quite high. So, it can be concluded that CNN method is reliable and successful to classify this type of circuit components.

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