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ELECTRIC CIRCUIT DIAGRAM DETECTION, RECOGNITION AND SIMULATION

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Abstract - *In this paper, we propose a method for electric circuit diagram recognition and simulation. The method first detects and classifies the components present in the circuit. The morphological thinning and adaptive thresholding of the binarized image is used to separate the components from the circuit. The feature vector is obtained by combining Local Binary Pattern (LBP) feature and some statistical features of the separated components. The feature vector is already trained to the SVM classifier. The classified components are labeled to form a string. The string obtained is then fed to a FSM system for recognition of a particular circuit. The method can be used only when the circuit diagram is closed.*

Key Words: **Adaptive Thresholding, Component Detection, Circuit Recognition, Finite State Machine, Local Binary Pattern, Simulation.**

1. INTRODUCTION

Diagram or architecture is a natural and direct way to express ones thought and it is mainly used for fields such as engineering and architecture fields since, a sketch is an easiest and practical tool to grasp any person estimated ideas, so that the producer or an engineer can work more on the essential or crucial issues rather than on the tangled details. Recognition of electronic or electrical components and type of circuit from the circuit diagram is gaining importance. Electronic circuit diagram recognition has many applications like simulating the electronic characteristics of the circuit, layout planning for actual circuit design rendering, Human-computer interface for circuit analysis etc. Electronic circuit diagram recognition also has significant application in teaching and conducting electronics subject, where the students are asked to take picture of already printed circuit diagram and to simulate it's behaviors without actual circuit building.

The current work aims mainly for developing a tool to evaluate the electronics circuit lab exercise. Further it can be extended for recognition of handwritten electric circuit. This reduces the task of evaluating the correctness of circuit written by a student. The circuit can be fed to the model to check the correctness of circuit. Also it assists the user to simulate the circuit without physical design. While, handwritten text and symbol recognition is very well-established research area where many researchers attempted to build text recognition system to recognize the characters for various languages. Even though many works are done related to hand written electric circuit only a few works are reported for recognizing the circuit type. In the next section, we brief out the existing methods for recognizing the hand-drawn circuit diagram.

2. RELATED WORK

As the time changes, technology developed in hand drawn electric circuit recognition and there are several models for recognition, the recent models are as follows. One approach is symbol sequence model which utilizes the four HMMs per symbol class to perform classification and the segmentation of a symbol into its basic features is done by parsing the image of the symbol in a straight direction at a given orientation. They've used the orientation along which the set of foreground pixels of the symbol extends the most. For each class, four HMMs are trained to learn the distribution of the sequence of features in that class. The features that are proposed for the above model do a poor job to distinguish among the symbols. A larger training set may improve the classification rate to some extent. Second approach proposes the strategy of utilizing K-Nearest Neighbor (KNN) to read the electrical images directly from a hand-drawn circuit picture and also utilize it to perceive and differentiate the electrical characters from an electrical circuit picture. The KNN capability and image moments are used in order to recognize the electrical components present in the electrical circuit image.[1 2] In third approach, each segmented component in the electrical circuit is feature extracted by quantify the Histogram of Oriented Gradients (HOG) descriptor while classification is carried out by the method called Support Vector Machine (SVM). An accuracy of 87.7% and 92% in segmentation and classification respectively, demonstrates the effectiveness of the proposed technique. It fails to recognize the symbols, units and the textual content of the images. Using syntactic analysis and other features like scalar pixel distribution features, invariant moments and vector relationships between straight lines in polygonal representations respectively, all the nodes and components in the image are classified. [3 5] The circuit can be drawn using online or it can be a hand drawn. The circuit is

recognized through online drawing on a software. The components are recognized based on the number of strokes. For some components, the strokes must follow a Vertical-Horizontal Horizontal-Vertical alignment or Horizontal-Vertical Vertical-Horizontal alignment before they can be recognized. Special devices like stylus and tablet are required in the above method. The users using this should be right-handed. It recognizes hand drawn electronic components using HOG features and subsequently SVM classifier is used to classify the components. The morphological operation is used to for our further convenience. [4 10] There are different effective methods for recognition of segmented components, in that one of the methods is Artificial Neural Network (ANN), which is used to understand and distinguish between the electrical characters from a hand-drawn circuit image using image's moments. Image moments are used in order to point out the properties of a simple electrical image which also includes intensity. It uses moments to an input image i.e., in a matrix form which shows the image in gray level. It uses Otsu's method to convert the gray level image to a bit-level image. In this the software part can only perform well any one operation either the speed or accuracy operation. It is based on the Artificial Intelligence (AI) algorithms can also introduced so as to increase the number of user's ideas or thoughts to draw circuit components. Scale-space based algorithm is used to segment the given pen stroke data into simplified fragments. Algorithm based on computer vision used for to shape contexts is also used to group the similar stroke fragments to digital logic gates. The system response is dependent mainly on the length of the input stroke and not on the complexity of the scene. It can be used only for digital circuits. [7 8] There are two types of recognition for which the characters, numbers and symbols alone are stored in a separate image in order to use it for optical character recognition. The components in the circuit are recognized on the basis of units. It is centered only on RLC circuit simulation. In this method the Pre-processing use the image independent thresholds and such usage of extensive thresholds will limit the functionality. The symbol recognition has two stages: primitive and combine. The strokes that are grouped into one cluster will construct a primitive symbol. It is used to transform the pre-processed strokes to strings, i.e. using a feature strings to describe the sketch symbols. The system recognizes a symbol by classification not by search. The system is not generalized to other domains without modification. [9 11] There are different systems used for the specific function. In that system one of it is DCSR which is completely based on sketch-based system which supports user to draw sketches in freehand drawing and Boolean algebra computations. Digital Circuit Sketch Recognition (DCSR) is a method used to combine the advantage like flexibility of this method with a computer's evaluation which as capabilities through a web-based interface. It based on a 2D Dynamic Programming technique by allowing symbol hypothesis generation, which currently locates the symbols even when they are drawn temporarily and overlapped with each other. A neural network classifier, which is embedded in the 2D-DP, is used to label each hypothesis. There are three different levels, i.e. sketch level variance, symbol-level variance and stroke-level variance. They are used in this method to train the classifier. NN Classifier are used to examine the connectivity according to the label given by the classifier. The multi-symbol strokes and the multi stroke symbols are used as samples. As the samples are drawn on the paper, modification is not allowed. If there are any mistakes, redrawing is necessary. [6 12] The system is based on structure and topology mechanism which is used for scale, translation recognition. The main goal of recognition technique is to find the symbols of our domain based on spatial and structure arrangement. We use hierarchical matching where recognition is based on simpler to complex components. The attempts have been made to detect electrical symbol using structure and topology mechanisms. Initially the system detects the primitive components and understands the nature of it. It offers the flexibility of the system over the rigid techniques designed. [13]

The image analysis is used for converting scanned electronic circuits into netlist of particular components. In pre-processing stage, the component label and values are removed. Then the image is moved to make lines, circles and arrows. The software can recognize minimum based components and not wide based components. The final stage forms a netlist of components with their connections. The work is needed to add component values to netlist and to extend component recognition. [14]

The summary or comparison of some of the above mentioned methods are shown in the Table1.

Table -1: Comparison table for different methods

Methods	Recognition Accuracy	Classification Accuracy
KNN	Recognition accuracy is 90%	Identification accuracy is 90%
SVM	Segmentation accuracy is 87.7%	Classification rate is 92%
Image Analysis	Node recognition accuracy is 92%	Component recognition accuracy is 86%
HMM	Recognition Accuracy is 93.06%	Classification accuracy is 93.06%

From the above Table No.1, the HMM method is considered to be having the highest accuracy rate of 93.06% when compared to the different methods. The accuracy rate of the SVM Classifier can be significantly increased when it is used along with the FSM Model.

3. PROPOSED METHODOLOGY

Figure 1 shows the proposed methodology for the hand drawn electrical circuit recognition which is classified into three stages. The Stage 1 mainly consists of two phases i.e., Training phase and testing phase, where in each phase there

are respective functions to be performed before the recognition. It is mainly based on finite state machine algorithm.

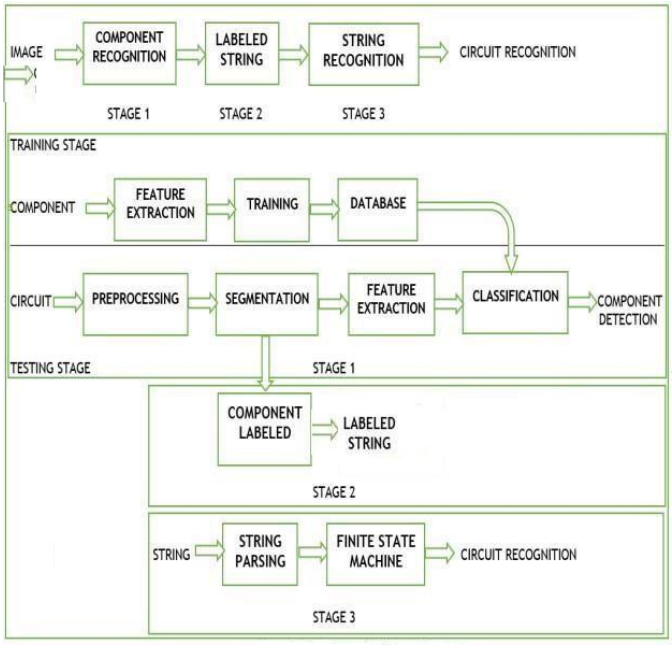


Fig -1: Block Diagram of the proposed method

The proposed methodology has three major stages:

(i) Component Detection Stage.
(ii) Labeled String Stage.
(iii) String Recognition Stage.

3.1 Component Detection Stage

In the training stage, we train all possible components that need to be recognized using SVM classifier, whereas the testing stage deals with assigning component class label for each component images posed as an input. It consists of the following two phases:

Training Phase:
This phase is given as an input to the system and also, used to train the model with respect to the feature extraction. It uses the database for the storage of feature extraction information of each circuit, which is used later in the recognition of the circuit.

Let us consider 36 electronic components representation for training the classifier. These component images are gathered from different classes. Each class consists of 6 images. It uses feature descriptor derived by Local Binary Pattern (LBP) and five statistical features derived using pixel density statistics in order to represent the training images in terms of its feature value. We have considered 4843 features for training the classifier. The image is resized into 54x54 pixels and it is divided into equal 6x6 sub images and LBP features are extracted from each block. The LBP features of all blocks are then combined to form 4838 features. SVM is the method used for recognition or classification of components in an image, which is also discriminative classifier method which is formally defined by a separating hyper plane.

The colored image converted into gray image and the salt and pepper noise are removed by averaging M × M neighborhood pixel and replaced with Centre pixel which is in the output of the image. The morphology operation like dilation and erosion is applied to remove the discontinuity and gaps between lines and thereafter applied for LBP feature extraction. The statistical features like eccentricity, Euler number, orientation, and extent are extracted from binary image.

Testing Phase:
Once the SVM classifier is trained, we need to test it on a set of component images. The electric circuit diagram is connected by components, line and line connected edges and is pre-processed using noise filters such as median filter. The preprocessed image is thinned using morphological operation for single pixel level. The components are then segmented from the circuit diagram using adaptive thresholding based on first order statistics. The components segmented are feature extracted and classified as a component by the classifier. The components are tested on 27 images which are already trained and 9 untrained images.

3.2 Labeled String Stage

The recognition sequence of the segmented components is recorded to have complete information about the circuit. They are labelled in the same sequential order i.e. Σ = {C1, C2, C3 ...Cn} where C1=component1, C2=component2 and Cn= nth component. This forms a string.

3.3 String Recognition Stage

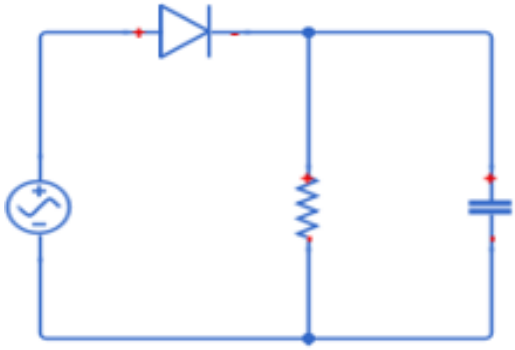
The system uses the syntactic analysis to detect the circuit based on grammar and string matching. A string is formed from sequence outcome of component generated by classifier and automata describes the string pattern for each circuit. Based on the string pattern the finite state machine recognizes the circuit. A finite state machine is a mathematical model of computation. It is an abstract machine that can be in exactly one of finite number of states at any given time. The circuit is further simulated to observe the characteristics.

4. RESULTS OBTAINED

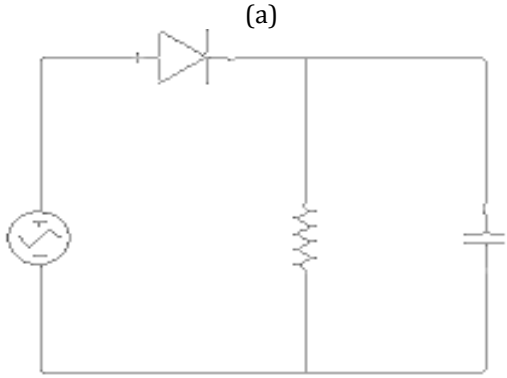
The results obtained for our method are shown in Fig 2. The segmented components are obtained from the circuit using morphological thinning and adaptive thresholding as shown in Figure 2 (c). After segmentation features are extracted from segmented regions and given to the SVM for classification. The classified outputs and labeled string are shown in Figure2 (d). Also the circuit recognition from FSM

model is shown. Finally, the circuit is simulated based on the name of the circuit as shown in Figure 2 (e).

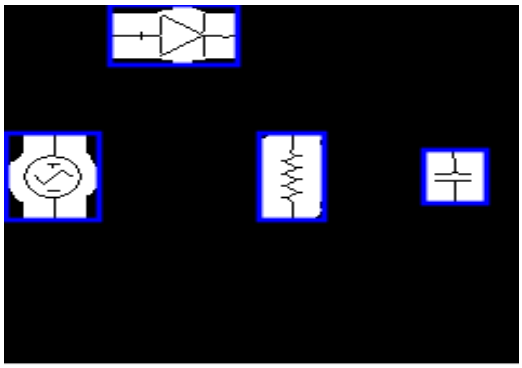
Table 2 and Table 3 tells us about the confusion matrix and classification accuracy respectively. Only single image of class ac source and dc source are misclassified. We can see that TP Rate and Recall has 94.3% accuracy. Since the dataset is small only single image misclassified leads to decrease in accuracy rate. However, the accuracy rate can be increased if larger dataset is used.



(a)



(b)



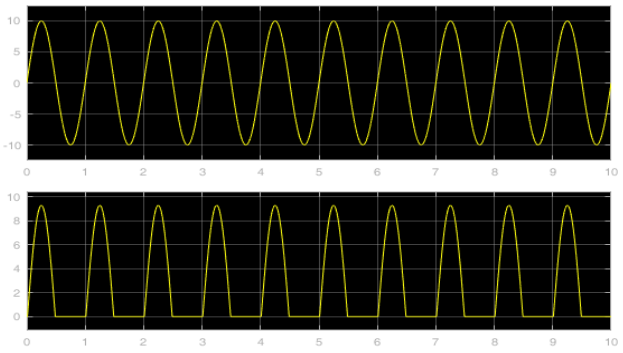
(c)

```
'Source(dc)'    'Diode'    'Resistor'    'Capacitor'

'S'    'D'    'R'    'C'

Half Wave Rectifier
```

(d)



(e)

Figure - 2: Recognition and simulation of a circuit (a) Original Image (b) Gray Image (c) Segmented Image (d) Labeled string and circuit recognized (e) Circuit Simulation

Table -2: Confusion Matrix of Different Components

	C	D	G	R	S(ac)	S(dc)
C	6	0	0	0	0	0
D	0	6	0	0	0	0
G	0	0	6	0	0	0
R	0	0	0	6	0	0
S(ac)	0	0	0	0	5	1
S(dc)	0	0	0	0	1	5

Table -3: Classification accuracy of the proposed method

Sl.No	TP Rate	FP Rate	Recall	Class
1	1	0	1	C
2	1	0	1	D
3	1	0	1	G
4	1	0	1	R
5	.833	.167	.833	S(ac)
6	.833	.167	.833	S(dc)
Weighted Average	.943	.055	.943	

5. APPLICATIONS

- Simulating the electronic characteristics of the circuit.
- Layout planning for actual circuit design rendering.
- Human-computer interface for circuit analysis.
- Teaching and conducting electronics subject.
- For developing a tool to evaluate the electronics circuit lab exercise.

6. CONCLUSIONS

The recognition of electric circuit diagrams is carried out using the proposed method. The method uses LBP features to train the SVM. The components are segmented from the

circuit using morphological thinning and adaptive thresholding. The SVM classifies the segmented components. The string is fed to a FSM model which recognizes the circuit. Further the circuit can be simulated. The results show that the components are detected very accurately and hence useful in real time application. The disadvantage is that the method can be used only on circuit images which are closed.

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