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RESEARCH ARTICLE

Handwritten Circuit Schematic Detection and Simulation using Computer Vision Approach

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Abstract*— *Hand-drawn sketch is a natural and direct way to express people's thought and meaning and is of common use in many different fields. Document image analysis is an active and challenging area of research in computer vision. Documents comprise of text and graphics. Machine recognition of hand-written text involves languages, mathematical symbols, digits, medical symbols etc. Machine recognition of hand-drawn graphical entities such as circuit diagrams, flow charts, tables, etc. will add another dimension to human computer interaction. In this work we propose a system of offline circuit recognition and simulation using digital image processing. The proposed model consists of all possible components of a diagram recognition system, such as segmentation, feature extraction, classification and redrawing and repositioning. Then we use this circuit for simulation purpose by substituting values for each component to generate output waveforms/characteristics graph.

Keywords*— *handwritten circuit schematics, circuit recognition, image processing, support vector machines, simulation

I. INTRODUCTION

Sketches are widely used in engineering and architecture fields, especially for the early design phases. This is mainly due to the fact that a sketch is a convenient tool to catch rough ideas, so that the designers can focus more on the critical issues rather than on the intricate details. The problem is that although it seems so quick and intuitive for humans to recognize sketches, it is really a great challenge for the computer. While handwritten text recognition is already widely addressed as a research topic much less effort has been devoted to hand-drawn sketch understanding. Support Vector Machine (SVM), Hidden Markov Model (HMM), Neural Networks (NN), Genetic Algorithms (GA), and many other pattern matching algorithms have been fostered by this challenging application and very promising results are obtained by combining these techniques.

This paper presents an application of image processing techniques to detection of hand-drawn circuit diagrams and simulation of circuit. The scanned image of a diagram is pre-processed to remove noise and converted to bi-level. Morphological operations are applied to obtain a clean, connected representation using thinned lines. The diagram comprises of nodes, connections and components. Nodes and components are segmented using appropriate thresholds on a spatially varying object pixel density. Connection paths are traced using a pixel-stack. Nodes are classified using syntactic simulation.

Components are classified using a combination of invariant moments, scalar pixel-distribution features, and vector relationships between straight lines in polygonal representations. Then we extract the features of each shape. Then we use classifier for the purpose of recognizing the shapes based on the extracted features. Here we use the Support Vector Machines (SVM) to classify the shapes. Finally shapes are redrawn in the same relative position and with the same drawn size to produce a professional diagram similar to that produced by structured graphics editors currently on the market. Then we use this circuit for simulation purpose by substituting values for each component to generate output waveforms/characteristics graph.

II. EXISTING SYSTEM

The existing detection methods are used to detect the documents comprise of text such as languages, mathematical symbols, digits, and medical symbols etc. while graphics detection has thus far generated less interest than text detection such as circuit diagrams, flowcharts, tables etc. In this work, we propose an application of digital image processing technique to detect and simulate the Hand-written circuit schematics using support vector machines classifier.

III. OVERVIEW OF THE PROPSED SYSTEM

This section discusses the block diagram of the proposed Simulation of Handwritten circuit schematics system. It consists of preprocessing, segmentation, feature extraction and SVM classification, detection and Simulation stages.

The scanned image is given as input to the preprocessing stage. The image should have a specific format such as JPEG, BMP etc. Pre-processing is generally used to enhance the image quality and to shrink down the data size of the handwritten circuit. In segmentation the circuit is breaking up into components and nodes by separating from connections using appropriate threshold ‘T’. In shape feature extraction stage every component is assigned a feature vector to identify it. This vector is used to distinguish the component from other component. Classification is the decision making part of detection system. The detected and redrawn circuit is used further for simulation purpose so as to get output characteristics graph/waveforms.

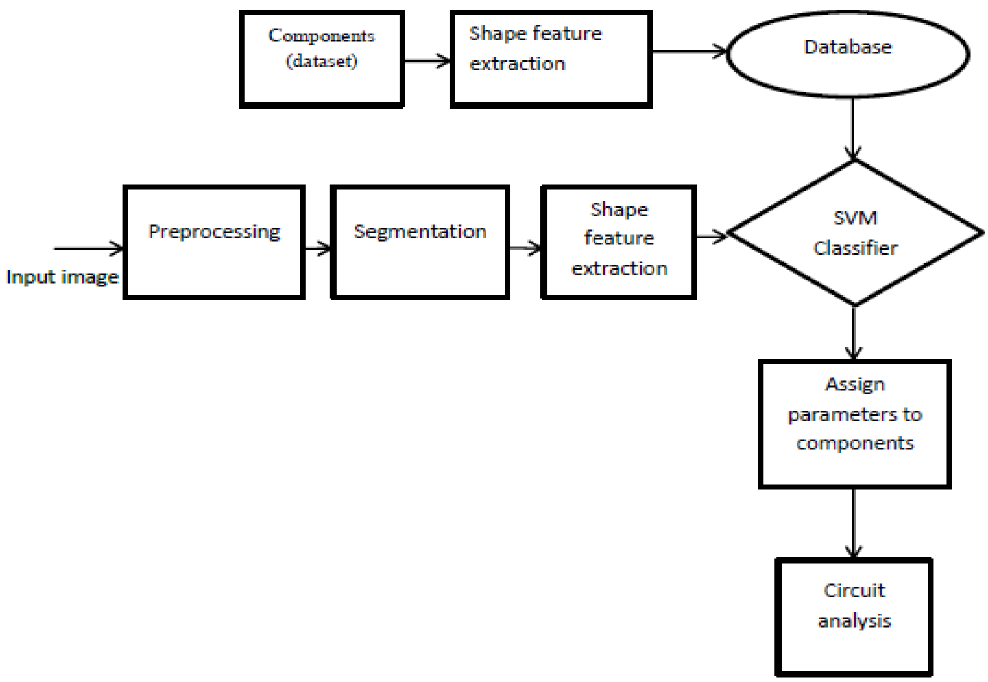


Fig.1 Block diagram of proposed system

The main objectives of this paper is the Simulation of handwritten circuit Schematics using digital image processing by using support vector machines. It involves,

- Detection of handwritten components,
- Detection of Handwritten circuit diagram and
- Simulation of circuit by assigning parameters to each component i.e. simulation involves the characteristics graph/output waveforms.

A. Image Acquisition

In Image acquisition, the detection system acquires a scanned image as an input image. The image should have a specific format such as JPEG, BMP etc. This image is acquired through a scanner, digital camera or any other suitable digital input device.

B. Pre-processing stage

The preprocessing is a series of operations performed on the scanned input image. It essentially enhances the image rendering to make it suitable for segmentation. The various tasks performed on the image in preprocessing are shown in fig 5.2. Initially color image is converted into gray scale (monochrome conversion). Binarization process converts a gray scale image into a binary image using threshold technique. Detection of edges in the binarized image, closing and thinning of the image and area based noise removal using appropriate threshold are the operations performed in the last two stages to produce the preprocessed image. Now the processed image is suitable for segmentation stage.

C. Segmentation

Segmentation is the process of breaking up the image into pieces that are small enough to be detected. For this application, segmentation is used to
(a) Separate the components and nodes, and
(b) Separate the connections, from the image.

Components, nodes and connections are all made up of lines of different lengths, orientations and curvature. Knowledge of the line structures is useful for segmentation as well as classification. Appropriate thresholds applied to the spatially varying object pixel density were used to separate components and nodes from connections and the rest of the image.

The image can be partitioned using the threshold technique 'T' called global threshold. The threshold 'T' is used to separate objects from the background. Depending on the gray level of scanned image is greater than or less than the threshold value 'T' the segmentation can be done.

D. Shape feature extraction

After preprocessing and segmentation on the image of circuit, features of each component are extracted. This step is heart of the system as this step has greater impact on detection rate. This step helps to classify the components based on their features. Feature extraction is the name given to a group of procedures for measuring the relevant shape information contained in a pattern so that the task of classifying the pattern is made easy by a formal procedure. The feature extraction stage analyses segmented component and selects a set of features that can be used to exclusively identify the component segment. The issue of choosing the features to be extracted should be guided by the following concerns:

- The features should carry sufficient information about the image and should not necessitate any domain-specific knowledge for their extraction.
- They should be easy to calculate in order for the approach to be feasible for a large image collection and rapid retrieval.
- They should be related well with the human perceptual characteristics because users will finally decide the correctness of the retrieved images.

We need to choose highly discriminate features like average height, inclination, features extracted from dots, Entropy etc. because these features give us higher detection rate. A number of features are extracted from each shape for the purpose of serving as inputs to the classifier.

E. Support Vector Machines Classifier

In the last years, Support Vector Machines have been massively used by machine learning and pattern detection communities. They have successfully been applied to several different areas ranging from face detection and verification, speaker verification, text categorization, prediction, image retrieval, and handwriting detection. A detailed description of SVM classifiers is as given below.

a. *History of SVM*

The SVM (Support Vector Machine) was introduced first by Vapnik and co-workers in 1992.Support Vector Machines are a group of supervised learning methods which can be applied to classification or regression. The SVM classifier accepts the set of input data and predicts to classify them in one of the only two distinct classes. Basically, SVM classifier is trained by a given set of training data and a model is prepared to classify test data. Depending on how all the samples can be classified in dissimilar classes with appropriate margin, different types of kernel in SVM classifier are used. Frequently used kernels are: Linear kernel, Polynomial kernel, Gaussian Radial Basis Function (RBF) and Sigmoid (hyperbolic tangent)

***b.** Mathematical model of SVM linear binary classifier*

SVM is the binary classification setting. We are given training data {x1,x2…..xn} that are vectors in some space XcRd. We are also given their labels {y1,y2,….yn}where yi ϵ {-1, 1}. In their simplest form, SVMs are hyper planes that separate the training data by maximal margin. All vectors lying on one side of the hyper plane are labeled as -1, and all vectors lying on the other side are labeled as 1.The training instances that lie closest to hyper plane are called support vectors. More generally, SVMs allow one to project the original training data in space X to a higher dimensional feature space F via a mercer kernel operator K.

Suppose we have n training data points $(x_i, y_i)_{1\leq i\leq n}$ where $x_i \epsilon R^d$ and $y_i=\{\pm 1\}$.We want to classify x among two classes. First, we consider the case of linear support vector machines to discriminate two classes (positive and negative classes), which are separated by a hyper plane.

$$y=sign((w.x)+b)$$

Where *w* is normal to the separating hyper plane, b is an offset and *(w. x)* is the scalar product between *w* and *x*, as shown in Figure.

Our target is to try to maximize the margin of the classification on the training data set. We consider the margin as the minimal distance between any training points to the decision boundary. For separable data belonging to respectively positive and negative classes, we have:

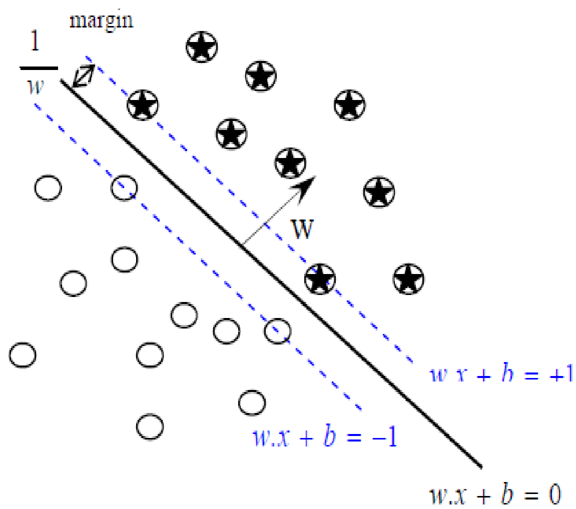


Fig 2: SVM linear binary classifier

$$\begin{cases} x_i.w+b \geq +1 & for\ y_i=+1 \\ x_i.w+b \leq -1 & for\ y_i=-1 \end{cases}$$

The goal of maximizing the margin can be formulated as a quadratic optimization problem:

$$min_{w,b} \frac{1}{2}\|w\|^2$$

Subject to $y_i(x_i.w+b)-1 \geq 0$

Thus, by solving this optimization problem we get the following non-linear function:

$$f(x) = sign(\sum_{i=1}^{n} a_i y_i .K(x_i .x_j) + b)$$

F. Detection and Simulation

The objective of detection is to interpret the circuit taken from the scanner. In detection same series of operations are carried out, comparing the features extracted with simulation of trained classifier the circuit is detected.

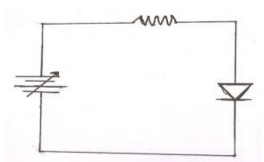
Then based on SVM classifier the components are detected and redrawn. Finally the redrawn circuit is used for simulation purpose by substituting values for each component to generate output waveforms/characteristics graph.

IV.RESULTS AND CONCLUSION

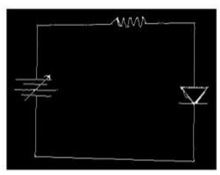
The snapshots of the results of Simulation of Handwritten Circuits are as follows:

Fig 3: Main menu

The figure 4 shows the snapshot of preprocessed stage of the circuit which includes the scanned input image, binarized image, segmented and node identified image, component traced image.

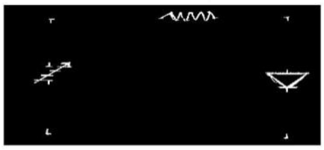


(a) Scanned input image



(b) Binary image

(c) Segmented and node identified image



(d) Component traced image

Fig4: Snapshot of preprocessed stage outputs of the scanned circuit

Figure 5 shows the snapshots Detection of Circuit components and redrawn circuit. Each component is detected by its equivalent printed circuit. That is the circuit is redrawn by connecting the nodes and components by using equivalent printed components from database and further processed for simulation purpose to get characteristics graph.

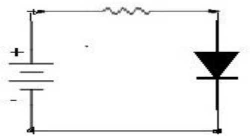


Fig 5.snapshots Detection of Circuit components and redrawn circuit

Figure 6 shows the snapshots of dialog box to enter the current (in mA) and voltage(in volts) values in order to get the output characteristic graph.

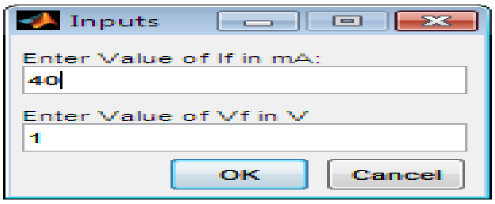


Fig 6: snapshots of dialog box to enter the current (in mA) and voltage (in volts)

Figure 6.8 shows the output or characteristics graph of the scanned circuit which shows the diode characteristics and Q-point.

We get the Q –point by Using the Equation of diode characteristics

$$E=IR+V$$

Where,

E=source voltage

R=value of resistor

V=voltage across diode

With R=100Ω.

We get the diode characteristics & Q-point at

I=40mA & V=1V

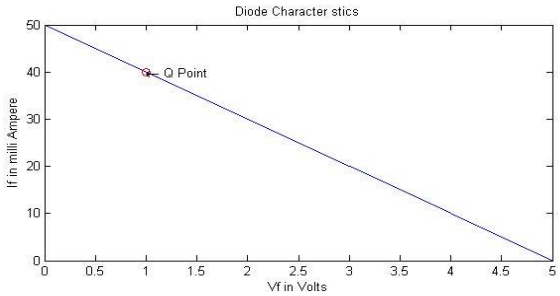


Fig 7: Snapshot of diode characteristics graph indicating Q-point

CONCLUSION

In this work a system Simulation of Handwritten circuit schematics using digital image processing. This Simulation starts with preprocessing the acquired image, feature extraction, classification and detection and simulation of circuit. A SVM classifier seems to be better than other techniques used for Simulation of Handwritten circuit schematics using digital image processing. The implemented system is found to be less complex and faster detection. The proposed system will find a large number of applications in wide range of areas.

- This detection can be used for layout "beautification" or to generate input code for circuit simulation and simulation packages.
- Automatic input of circuit diagrams for circuit simulation purposes.
- Human-computer interface for circuit input.

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