HANDWRITTEN ELECTRONIC COMPONENTS RECOGNITION: AN APPROACH BASED ON HOG + SVM

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ABSTRACT

Recognition of hand drawn electronics components has application in academic and research in electronics engineering. In this paper, we propose an approach to recognize hand drawn electronic components using histogram of oriented gradient (HOG) features and subsequently Support Vector Machine (SVM) classifier is used to classify the components. The objective is to recognize the hand drawn electronics components. In order to achieve best recognition, we consider hand drawn scanned images and converted them to bi-level image then applied morphological operation to remove discontinuity. Further, the proposed method extracts features of intensity gradient and direction. We trained ten components with large data set each with 200 samples and tested with tenfold cross validation. To establish the efficacy of the proposed method, we have conducted experiment on large dataset of about 2000 images. From experiments it is revealed that the proposed method has yielded 96.9% recognition rate.

Key Words: Classifier, Circuits, Hand Written Components, HOG Descriptor

1. INTRODUCTION

In general sketch and character recognition has been focused from past many years. Recently, due to importance of electronic circuit analysis, many researchers are actively working towards developing algorithms to automatically analyze the circuit. In order to analyze the circuits, Components detection is very impotent, it helps to solve practical problem through analysis, design and implementation of circuit. There is a need for a system to generate circuit and detect the components automatically from hand written schematic. However, very few research works have been reported for hand written components recognition.

Recognition of electronics component from [1] hand written circuit schematic is preprocessed to remove noise and converted into a binary image. Each component is extracted from hand drawn circuit. Statistical features are captured from each component by considering some geometric properties like rectangular box, curvature, slope, width and number of intersects by Appyling conditional probabilities between consecutive features are applied to the Hidden Markov Model classifier. The confusion matrix shows that more misclassification between capacitor, DC battery and Variable battery [2] addresses the problem of circuit recognition from an online hand drawn circuit diagram. The sketch considered as a continuous time varying stroke stream. The Hidden Markov Model used to segment each stroke into regular straight lines from eight different directions. The Viterbi algorithms have been used to classify the connectors or components with recognition rate 83%. The method works only for online diagram and hence requires special devices to capture the circuit written online. [3] Address the problem of recognizing the circuits from the scanned image. In this method, the image is preprocessed and the circuits schematic consist of nodes, connection and components are recognized. Nodes and components are segmented using suitable threshold on a spatially varying object pixel density. The connection paths are traced using pixel stack. The nodes are classified using syntactic analysis and components are classified using a combination of movement, scalar pixel distribution features and vector relationship between straight lines in polygonal representation. However, this method achieved component recognition accuracy of 86%. The methods [2] and [3] do not handle the scale
and orientation changes in the images. To address the
problem of similarity transformation, [4] the
method which works for online hand drawn circuit
is recognized with scale, translation and rotation
invariant recognition. The system uses a structural
and topological relation matching for recognition.
[5] In this approach concentrated on circuit, text
and figure. Each component associated with
component label and value are recognized using
popular character recognition approach the
components are recognized by collection of
horizontal, vertical and diagonal lines are clustered
together based on production rule. After
recognizing each component and its label construct
the netlist of components and their connection. [6]
On the other hand the digital logic circuit diagram
comprises of AND, OR and NOT gates. All the
logic circuit symbols having one or more loop
structures the symbol recognition is carried out
under a decision-tree control strategy. However,
this method is capable of recognizing the
components and circuits it lags scalability with
complex circuits with various electronic
components. [7] Compare the performance of
different techniques such as template matching,
chain vector and Hough transform. The components
are classified using neural network. [8] Segments
the components using topology based technique
from circuit and features are extracted using the
Fourier descriptors and achieved an accuracy of
90%. [9] Address the recognition problem between
different component like DC power supply and
capacitor also similarity between roughly drawn
wire and resistor by considering length and slope of
stroke. [10] Address the recognition of analog and
digital components based on loop and non loop
symbols using syntax-based and statistical
classifier. [11] HMM model to segment the
component, it allows symbol hypothesis generation
using 2D dynamic programming and components
can be classified using neural network back
propagation algorithm [12][13] in this approach the
objects are recognized based on its physical
appearance by considering length breadth and
connecting leads of components. All the above
methods have complex and hybrid techniques in
feature extraction but HOG single method can give
best recognition and computationally less complex.
In the proposed work first importance given
towards hand written electronics components
recognition the input image is capture by scanning
paper document or by high resolution camera. The
gray level image converted to binary image then
preprocessed. We are not focused on segmentation,
individual component images are captured. We
proposed HOG feature extraction techniques and
classified using SVM classifier.

2. PROPOSED METHOD

The proposed method has following steps
as shown in figure 1 i.e. preprocessing, feature
extraction and classification. In preprocessing, the
scanned gray image has different writing styles
with various thicknesses these changes causes
challenges in recognition hence it requires to
change two level intensity and same thickness lines.
The gray level is converted into binary level by
adjusting threshold using Otsu’s approach [18]. For
effective recognition image should be noise free, to
remove salt and pepper noise we had take a
neighborhood of KxK and perform averaging of
KxK pixels and center pixel is replaced by average
value in the output image. The morphological
operation like opening and closing is used to
remove discontinuity and gaps between lines
caused due to binarization or filtering process.
Further the processed image is resized to a standard
size to ensure that the number of features remain
uniform. In this work we resize the image to
(64x72) with bilinear interpolation. Subsequently,
image is inverted then so that back ground becomes
black and objects into white using binary inversion
technique for operational convenience. Different
people write the components with different
thickness, and the recognition system is expected to
be width independent to make system to thickness
independent it is necessary to convert single pixel
level to perform this we had applied morphological
thinning operation as shown in figure 2. The
preprocessed images are applied to feature
extraction process
3. FEATURE EXTRACTION

Feature extraction is very important step in the recognition system and feature selection from image also important task to improve the classification accuracy. There are many feature extraction techniques are available. In this work, we have proposed Histogram of oriented gradient feature extraction technique.

3.1 Histogram of Oriented Gradients Features

The HOG features are used in object detection. This technique first introduced by Navneed Dalal and Bill Triggs [25]. The feature or descriptor can be describing the intensity gradient and direction. For histogram computation the image divided into small connected region called cell. The contrast and illumination can be normalized by selecting 2cells x 2cells connected regions called block. This block overlap all the cells horizontally and vertically, to generate cell histograms of each pixel gradient will be calculated with histogram channel called bin by selecting unsigned 0-180° square grid from each cell as shown in figure3.

3.2 Algorithm

The gradient values are computed using 1 dimensional discrete derivatives mask in X and Y direction with following filter

$$D_x = [-1 0 1] \text{ and } D_y = [-1 0 1]^T$$

We obtain the X and Y derivatives using a convolution operation: $I_x = I * D_x$ and $I_y = I * D_y$

The magnitude of the gradient $|G| = \sqrt{(I_x^2 + I_y^2)}$

The orientation of gradient is $\theta = \arctan I_x / I_y$

Feature vector per block are $f = (f_1, ..., f_9)$

In this work, we have considered image of size 64x72. The image is divided into 8 horizontal and 9 vertical cells with each cell of size 8x8 pixels. 16x16 sized block is created using 2x2 cells. The block is overlap across the image horizontally 7 times and vertically 8 times. Totally it takes 56 overlaps across the image with unsigned 9 histogram channel by 20° spacing called bin. The boundary details is retain from one block to another block by selecting 2cells x 2cells in the connected regions of the image. This block take 50% overlap all the cells horizontally and vertically, this normalized result is invariance to changes. It would generate 2016 feature values as shown in table1 in the proposed work, we have used linear Support vector machine (SVM) [17].
### Table 1: Feature description

<table>
<thead>
<tr>
<th></th>
<th>Feature Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Image size</td>
</tr>
<tr>
<td>2</td>
<td>Cell size</td>
</tr>
</tbody>
</table>
| 3 | Total number of cell                      | Horizontally 8 cells
    |                                           | Vertically 9 cells |
| 4 | Block size                                | 16 X 16 pixels |
| 5 | Bin number/cell                           | 9 (unsigned 0-180° with 20° spacing) |
| 6 | Block overlapping                         | 7 horizontal & 9 vertical overlapping |
| 7 | Total block overlap                       | 56 blocks    |
| 8 | Total features                            | 56 block overlap X 4 cell per block X 9 bin per cell=2016 values |

4. EXPERIMENTATION

In this experiment we have considered around 2000 samples from 10 classes of components where each class has 200 images the Samples from each class were validated using ten fold cross validation method. The recognition accuracy is shown in the subsequent section.

4.1 Result analysis

In this work, we have present experimental result analysis using large data set for 10 components with 2000 samples, each component with 200 samples. Data set collected from various users hand written samples with different sizes. The algorithm is implemented in Matalab. The experimental classification accuracy and confession matrices of proposed method shown in table 2 & table3 also confusion matrix of existing system in table 4& table 5. In order to demonstrate the generalization and stability about the classifier, we also carried out the experimentation with varying number of training samples and its recognition response. The ROC curves from the above experimentation have been given in the Figure 5.
### Table 2: Classification Accuracy by Class

<table>
<thead>
<tr>
<th>Sl no</th>
<th>TP rate</th>
<th>FP rate</th>
<th>Precision</th>
<th>Recall</th>
<th>F-Measure</th>
<th>MCC</th>
<th>ROC Area</th>
<th>PRC Area</th>
<th>Class</th>
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<td>0.955</td>
<td>0.965</td>
<td>0.960</td>
<td>0.956</td>
<td>0.988</td>
<td>0.950</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0.980</td>
<td>0.006</td>
<td>0.951</td>
<td>0.980</td>
<td>0.966</td>
<td>0.962</td>
<td>0.997</td>
<td>0.969</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0.940</td>
<td>0.004</td>
<td>0.964</td>
<td>0.940</td>
<td>0.952</td>
<td>0.947</td>
<td>0.982</td>
<td>0.917</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
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<td>0.002</td>
<td>0.980</td>
<td>0.965</td>
<td>0.972</td>
<td>0.969</td>
<td>0.985</td>
<td>0.956</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>0.985</td>
<td>0.001</td>
<td>0.995</td>
<td>0.985</td>
<td>0.990</td>
<td>0.989</td>
<td>0.999</td>
<td>0.990</td>
<td>5</td>
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<tr>
<td>6</td>
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<td>0.990</td>
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<td>0.983</td>
<td>0.995</td>
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<td>0.970</td>
<td>0.980</td>
<td>0.975</td>
<td>0.972</td>
<td>0.994</td>
<td>0.958</td>
<td>7</td>
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<tr>
<td>8</td>
<td>0.960</td>
<td>0.003</td>
<td>0.975</td>
<td>0.960</td>
<td>0.967</td>
<td>0.964</td>
<td>0.993</td>
<td>0.950</td>
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<tr>
<td>9</td>
<td>0.950</td>
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<td>0.927</td>
<td>0.950</td>
<td>0.938</td>
<td>0.931</td>
<td>0.984</td>
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</tr>
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<td>0.970</td>
<td>0.001</td>
<td>0.990</td>
<td>0.970</td>
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<td>0.978</td>
<td>0.993</td>
<td>0.974</td>
<td>10</td>
</tr>
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</table>

| Weighted Avg | 0.969 | 0.003 | 0.969 | 0.969 | 0.969 | 0.965 | 0.991 | 0.954 |

### Table 3: Confusion matrix of proposed method

<table>
<thead>
<tr>
<th>Diode</th>
<th>Transistor</th>
<th>Resistor</th>
<th>capacitor</th>
<th>Inductor</th>
<th>DCsource</th>
<th>ACsource</th>
<th>ground</th>
<th>Zener</th>
<th>Amplifier</th>
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</thead>
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<td>96.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>0.5</td>
<td>97.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
<td>0</td>
<td>Transistor</td>
</tr>
<tr>
<td>2.5</td>
<td>1</td>
<td>94</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>1</td>
<td>Resistor</td>
</tr>
</tbody>
</table>

| 1     | 0.5        | 1.5      | 96.5      | 0        | 0.5      | 0         | 0      | 0     | capacitor |
| 0     | 0          | 0.5      | 98.5      | 0.5      | 0        | 0         | 0      | 0     | Inductor  |
| 0     | 0          | 0        | 0.5       | 99       | 0.5      | 0         | 0      | 0     | DCSource  |
| 0     | 0          | 0        | 0         | 1        | 97       | 0.5       | 0.5    | 0     | ACSource  |
| 0     | 1          | 0        | 0         | 0        | 1.5      | 96.5      | 3      | 0     | Ground    |
| 0     | 0.5        | 1.5      | 0         | 0        | 0        | 0         | 2      | 95    | Zener     |
| 0     | 0          | 0        | 0         | 0        | 0.5      | 0         | 2.5    | 97.5  | Amplifier |
Table 4: Confusion matrix of Chandan and Edward method

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>C</th>
<th>L</th>
<th>D</th>
<th>Grd</th>
<th>Vdc</th>
<th>Vac</th>
<th>NPN</th>
<th>PNP</th>
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<tr>
<td>R</td>
<td>100%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>C</td>
<td>53.8%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>46.2%</td>
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<tr>
<td>L</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>10%</td>
<td>90%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grd</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Vdc</td>
<td>0</td>
<td>22.2%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>77.8%</td>
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<tr>
<td>Vac</td>
<td>0</td>
<td>9.1%</td>
<td>9.1%</td>
<td>0</td>
<td>0</td>
<td>81.8%</td>
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<tr>
<td>NPN</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>17.6%</td>
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<tr>
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<td>0</td>
<td>0</td>
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Table 5: Confusion matrix of Palo salo method

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Vdc</th>
<th>C</th>
<th>L</th>
<th>D</th>
<th>grd</th>
<th>jump</th>
<th>R</th>
<th>T</th>
<th>V-C</th>
<th>Z</th>
<th>S</th>
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<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>Vdc</td>
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<td>85</td>
<td>6.6</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>C</td>
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<td>0</td>
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</tr>
<tr>
<td>L</td>
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<td>0</td>
<td>98.3</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
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<td>0</td>
<td>96.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.3</td>
<td>0</td>
<td>6.66</td>
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<tr>
<td>Grd</td>
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<td>0</td>
<td>0</td>
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<td>Jump</td>
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<td>0</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
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<td>0</td>
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<tr>
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<td>0</td>
<td>1.66</td>
<td>91.6</td>
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</tr>
</tbody>
</table>
5. DISCUSSION

The proposed method has been evaluated for its efficacy on the large number of images from 10 classes. The experimental results are tabulated in the table 4. For the purposes of establishing superiority of the proposed method we are compared the results of the proposed method with the existing method [1][3]. The results of the existing method from the above tables 5 & 6, it is observed that from the proposed method little better than the existing method an average case. It is also observed from table some of the existing method performs little better than proposed method. However we can take all classes the proposed method reduces consistency across classes. From this study it is evident that the proposed method is consistent, efficient and outperforms the existing method. However, to improve the overall accuracy of the proposed method, we are in the process of refining the method by adding more number of features and tuning the classifier this, will be the our future work.

6. CONCLUSION

In this paper, we are proposed the method to classify electronics components based on the features represented by histogram of oriented gradient and classifying with support
vector machine. The efficacy of the proposed method is established with extensive experiment on relatively large dataset. From the experiment it is evident that the proposed method has produced desirable results. Also, in order to establish the superiority of the proposed method with existing contemporary algorithm we compared the results of the proposed method with that of existing methods. From the comparative analysis it is evident that the proposed method is more consistent and produced better accuracy across the classes. This demonstrate that the proposed method outperforms existing contemporary method.

REFERENCES:

[8] Yachi Liu, Yao Xiao “Circuit Sketch Recognition” Stanford University, Stanford


