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Real-Time Resistor Color Code Recognition using Image Processing in Mobile Devices

Muhammed Fatih Demir
Department of Computer Engineering
KTO Karatay University
Konya, Turkey
m.f.demir@karatay.edu.tr

Aysenur Cankirli
Department of Computer Engineering
KTO Karatay University
Konya, Turkey
a.cankirli@karatay.edu.tr

Begum Karabatak
Turkcell
Nicosia, Cyprus
karabatak.begum@gmail.com

Amir Yavariabdi
Department of Mechatronics Engineering
KTO Karatay University
Konya, Turkey
amir.yavariabdi@gmail.com

Engin Mendi
Department of Computer Engineering
KTO Karatay University
Konya, Turkey
engin.mendi@karatay.edu.tr

Huseyin Kusetogullari
Department of Computer Science and Engineering
Blekinge Institute of Technology
Karlskrona, Sweden 37141
hku@bth.se

***Abstract*—This paper proposes a real-time video analysis algorithm to read the resistance value of a resistor using a color recognition technique. To achieve this, firstly, a nonlinear filtering is applied to input video frame to smooth intensity variations and remove impulse noises. After that, a photometric invariants technique is employed to transfer the video frame from RGB color space to Hue-Saturation-Value (HSV) color space, which decreases sensitivity of the proposed method to illumination changes. Next, a region of interest is defined to automatically detect resistor's colors and then an Euclidean distance based clustering strategy is employed to recognize the color bars. The proposed method provides a wide range of color classification which includes twelve colors. In addition, it utilizes relatively low computational time which makes it suitable for real-time mobile video applications. The experiments are performed on a variety of test videos and results show that the proposed method has low error rate compared to the other resistor color code recognition mobile applications.**

Keywords*—*Image and video processing, resistor classification, color recognition, decision making, android platform.

I. Introduction

Real-time image processing plays a significant role in many applications such as object and color recognition, motion detection, moving object tracking, feature extraction, image registration, shape modeling, and many others. In the last decade, there has been vast escalation in the development of color recognition techniques for the analysis of images. This escalation stems from the fact that there are many important real world applications in which color recognition can be applied, such as traffic light detection [1], video surveillance [2], vehicle color recognition [3] skin color detection [4], biometric identification [5], image segmentation [6], clothing color recognition [7], resistor color code recognition [8], and etc [9], [10]. Here, we propose a real-time color recognition method to automatically evaluate the resistance value of a resistor from video frames captured by an android phone.

Resistor is a passive electronic component used frequently in electronic circuits to limit the electric current. It is a tiny component which makes it difficult to print resistance values on it. To solve this issue, the resistor color coding system is used to indicate the resistive value and the tolerance. More specifically, the resistors generally contain four or five different color bands around them, which are printed on a carbon or metal film, to specify their resistive values and tolerances. Note that twelve different colors are used as codes and each color band indicates a decimal value associated with it. Fig. 1 shows the resistor color coding system. In the 4-band resistor example, the resistance value is 270 ohms $\pm 5\%$. The resistance value for this example is found by the following rule: the first and the second color bands (red and violet) together generate a two digit number (27), the third band (brown), which is a multiplier, is multiplied with the two digit number (27×10^1 ohms (Ω)) to obtain the resistance value of the resistor, and the fourth color band (gold) shows the tolerance ($\pm 5\%$). In the 5-band resistor, the four color bands on the left side (brown, black, black, orange, in this sequence) are grouped together to represent the resistance value of a resistor ($100 \times 10^3\ \Omega$) and the fifth color band (brown) on the right side indicates the tolerance of the resistor ($\pm 1\%$). It is obvious that reading

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Color	Value	Multiplier	Tolerance
Black	0	$x10^0$	± 20%
Brown	1	$x10^1$	± 1%
Red	2	$x10^2$	± 2%
Orange	3	$x10^3$	±3%
Yellow	4	$x10^4$	-0, +100%
Green	5	$x10^5$	±0.5%
Blue	6	$x10^6$	±0.25%
Violet	7	$x10^7$	±0.1%
Gray	8	$x10^8$	±0.05%
White	9	$x10^9$	±10%
Gold	—	$x10^{-1}$	± 5%
Silver	—	$x10^{-2}$	±10%
None	—	—	±20%

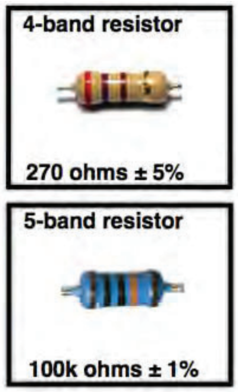


Fig. 1. Resistance color code chart with examples of 4- and 5-band resistors.

the resistance value of a resistor is not an easy task, especially for color blind people and non-professional person. Therefore, it is important to tackle this problem by taking advantage of image processing and computer vision algorithms.

Estimating the resistance value of a resistor using image processing and computer vision algorithms is a challenging research problem due to rotation, scaling, and illumination variations as well as resistors have highly specular reflective surface which strongly affects the color recognition accuracy. To tackle this problem, Chen et al. [8] proposes an automatic color classification approach, which is invariant to specular reflection and rotation of the resistor's body. To achieve this, firstly, an adjustable light source is used to decrease the effect of specular reflection in the extraction and identification of color bands. Next, an improved Niblack thresholding method [11] is proposed and applied to segment the resistor's body and the color bands. After that a median filter is used to remove noise artifacts from the obtained binary image. Then, the convex hull technique is utilized for horizontal alignment of the resistor's body so that, the resistor can be located at any orientation. Finally, K-Nearest Neighbor method is employed to train and classify the color bands. However, this framework cannot be adopted in the mobile application as its accuracy significantly depends on the external adjustable light source. Mitani et al. [12] proposes a semi-supervised method to classify resistors. The method consists of two steps: 1) color extraction and 2) color classification. In the firs step, a histogram thresholding method is combined with the K-means clustering to extract the resistor's body and colors. In the second step, the nearest neighbor algorithm is used to recognize colors. The main drawback of this method is that it uses only twenty training samples for each color so that the classification procedure can easily fail to correctly distinguish colors as natural variations in light and shadows can generate many shades of colors. Mallik et al. [13] proposes a histogram thresholding based approach to detect the resistor color bands. In this method, the resistor image is manually segmented and then different thresholds are fixed for each color band using histogram method. For each color band, the color combination is estimated and the color with maximum pixel is recognized as the color of the band. Even though this method is very swift which makes it suitable for real-time applications, there are two main drawbacks associated with it: 1) user must manually select the region of interest and 2) it is based on the RGB color space which makes it sensitive to illumination changes and specular reflection.

In this paper, a new real-time photometric invariants color recognition technique is proposed to automatically evaluate the resistance value of a resistor and its tolerance. To achieve this, the proposed method firstly applies a median filter to remove noise artifacts. After that a photometric invariants technique is used to convert the RGB video frame into the HSV color space. This is in contrast with the most of the existing methods as they only use the color value constancy assumption. This assumption makes them sensitive to illumination variations and specular reflection, which result in wrong color recognition. Next, a hard constrain is used to make the algorithm insensitive to the resistor's body orientation and scale. To this end, the resistor must align with an augmented horizontal line in the center of the video frame. More specially, the horizontal line has length of 75 pixels and it is also divided into four or five steps with the width of 5 pixels based on the resistor types (4- or 5-band). Note that the number of steps is selected by the user in the interface. Finally, at each step, five intensities are obtained and an Euclidean distance based clustering framework is used to classify the color of the band. The experimental results show that the proposed method is robust, effective, and suitable to mobile application as the error rate is low and the response time is high.

This paper is organized as follows. Section II describes the proposed color recognition method. Section III provides some experimental results of the proposed method and compared with two resistor color code recognition mobile applications. The paper is concluded in Section IV.

II. Proposed Method

This section consists of two parts, the first part discusses about the pre-processing steps that are used to decrease the influence of noise artifacts, the illumination changes, and the specular reflection in the resistor color classification process and provides details on color extraction. The second part provides solution for the resistor classification. The main objective of this work is to propose an online video processing framework to automatically calculate the resistance value and the tolerance of a resistor under regular room lighting condition via an android mobile application.

A. Resistor Color Band Extraction

1) Smoothing and Noise Reduction: Video frames capturing by a mobile phone camera can be corrupted by noises due to a low resolution camera. On the other hand, some mobile phones are equipped with a high quality camera and this includes redundant information in captured images. Consequently, both of these camera types can increase the complexity of the problem which can easily lead to erroneous classification of a resistor color bands. To solve this issue, each video frame, which is coming from the mobile phone camera, must firstly be smoothed. In practice, this results in decreasing intensity variations as well as removing impulse noises in the captured video frame. To achieve this, a nonlinear filtering method such as anisotropic diffusion [14] or median filter can be used to smooth the video frames while preserving edges (high frequencies). Here, the median filter is employed as it is considered as a low computational complexity algorithm.

Generally, the median filter substitutes a pixel by the median of all pixels in a neighborhood K:

$$X^n(h,w,t) = median\left\{Y^n(i,j,t),(i,j)\in K\right\} \tag{1}$$

where Y^n and X^n are the raw and filtered video frame at time t, respectively, with three spectral bands n, $w = 1,\cdots,W$, and $h = 1,\cdots,H$. Note that H and W are height and width of the of the video frame. Moreover, in this paper, K represents a 5×5 neighborhood, centered around location (h,w) in the video frame.

2) Color Space Transformation: In most of the video and image processing problems, the illumination of the scene is complex which is a serious problem in the color recognition context as a small change of the illumination can significantly affect the color recognition accuracy. In our problem, there are two main sources of illumination: 1) the sunlight coming through the windows and 2) the light bulb inside the room. Therefore, it is important to transform the RGB images into another color space that is independent of the effect of color illuminations of the scene. To achieve this, in this paper, a photometric color invariants technique based on the HSV color space is used. This is due to the fact that this color transformation proves to be insensitive to shadow, shading, and specular edges [15]. In other words, this photometric invariants technique allows to cope with shadow, shading, highlights, and specularities. Therefore, the HSV color space also makes the proposed method robust to the specular reflection.

The HSV color space represents each color in terms of Hue (H), Saturation (S) and Value (V). In general, this transformation can be formulated as

$$H(h,w,t) = \begin{cases} \frac{X^2(h,w,t)-X^3(h,w,t)}{M(h,w,t)-m(h,w,t)}\times 60^\circ & X^1 \geq X^2, X^3 \\ 2+\frac{X^3(h,w,t)-X^1(h,w,t)}{M(h,w,t)-m(h,w,t)}\times 60^\circ & X_i^2 \geq X_i^1, X_i^3 \\ 4+\frac{X^1(h,w,t)-X^2(h,w,t)}{M(h,w,t)-m(h,w,t)}\times 60^\circ & X_i^3 \geq X_i^1, X_i^2 \end{cases}$$

$$S(h,w,t) = \frac{M(h,w,t)-m(h,w,t)}{M(h,w,t)}$$

$$V(h,w,t) = M(h,w,t) \tag{2}$$

where $M = max\left(X^1(h,w,t),X^2(h,w,t),X^3(h,w,t)\right)$ and $m = min\left(X^1(h,w,t),X^2(h,w,t),X^3(h,w,t)\right)$. Note that the HSV color transformation generates a new image, I^n, which stores color information in three channels, just like Y^n, but the first two channels (H and S) convey color information and the third channel is devoted to brightness (V).

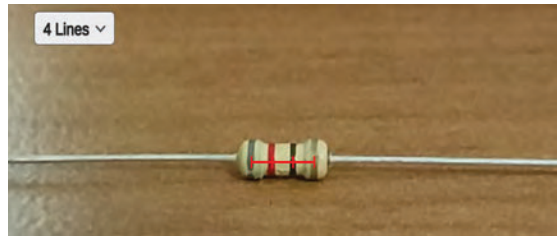


Fig. 2. Mobile application user interface with augmented horizontal line.

3) Color Extraction: After converting the RGB video frame into the HSV color space, the color bands must be extracted from the resistor's body. One way to achieve this is to firstly segment the repository's body, and then automatically estimates its orientation and localize the color bands. However, this strategy may not be applicable to mobile application because of complexity and speed. Therefore, in this paper, a new color extraction framework, which is swift and invariants to the resistor's body orientation and scale, is developed. To achieve this, firstly, a horizontal line with four or five steps is superimposed into the centre of video frame and the resistor color bands must align with the steps for further processing (See Fig. 2). Note that the number of steps in the horizontal line is selected by the user based on the resistor types. The horizontal line has the length of 75 pixels and each step has the width of 5 pixels. In this manner, at each horizontal line step, 5 pixel values from each channel of I are extracted.

$$D^n(h,w,t) = \delta(h,w)\times I^n(h,w,t) \tag{3}$$

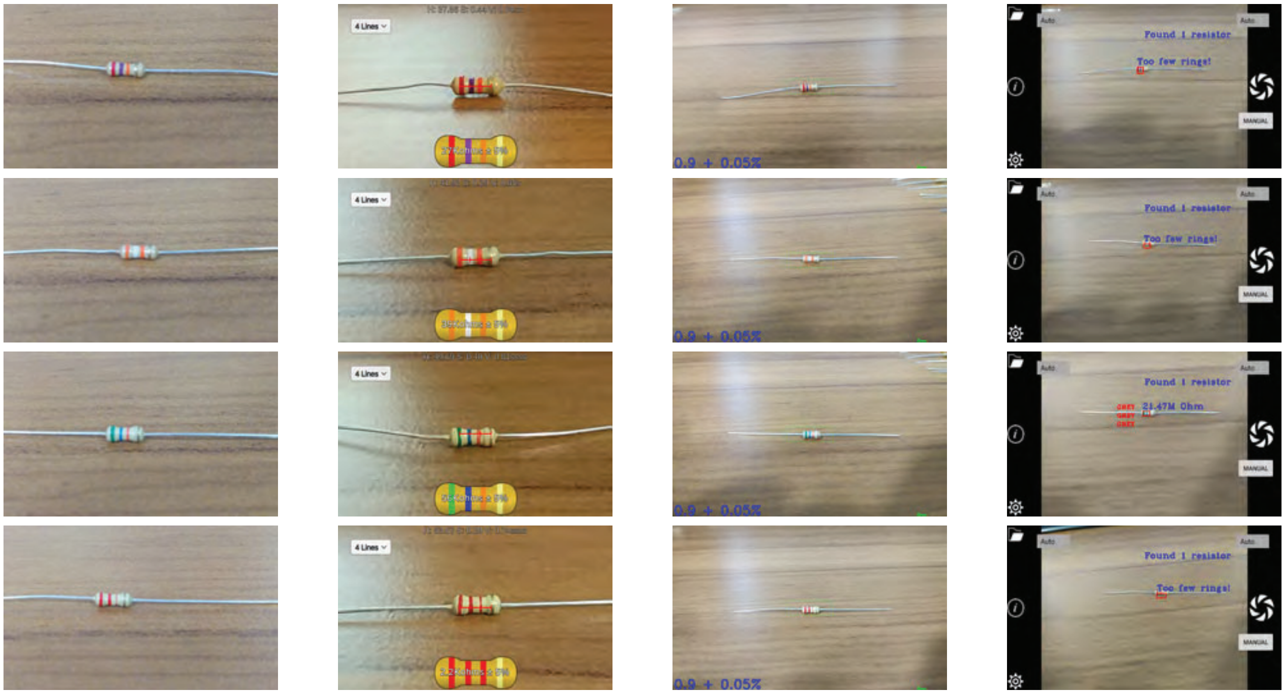
where δ is an index function, with $\delta : \Omega \rightarrow \{0,1\}$, Ω is the image domain and $\delta(h,w) = 1$ if (h,w) be in the steps' locations and 0 otherwise. Finally, in each HSV color channel, the mean of the five intensity values are calculated to obtain single intensity value for each color band. The mean intensities are collected in a dictionary, denoted by f^n.

B. Resistor Color Band Classification

The resistor color code consists of 12 different colors which they can be used to calculate the resistance value of a resistor as well as the tolerance and reliability of the resistor. To classify the colors in each resistor band, we use the following strategy. Firstly, 200 images from 50 different resistors with various room lighting condition are captured. In this manner, for each HSV color channel, 12 different color clusters with 50 samples in each particular group are obtained. Then, the centroid of each cluster is computed. After that, the Euclidean distance between the mean intensities in the dictionary f^n and the centroids are calculated and the minimum distance assigns each mean intensity to one of the 12 color clusters. Finally, to classify the resistor, a lookup table is utilized to automatically estimate the resistance value of the resistor and its tolerance.

III. Results and Discussion

In order to quantitatively and qualitatively understand and analyse the effectiveness and robustness of the proposed method, fifty resistors with different resistance values are used. In our experimental setup, the resistors are located on a brown



(a): Input Frame (b): Proposed Method (c): Method [16] (d): Method [17]

Fig. 3. Qualitative results for four different resistors.

TABLE I
QUANTITATIVE RESULTS FOR 50 RESISTORS. THE PROPOSED METHOD PROVIDES THE LEAST ERROR RATE.

	Correct Detection	False Detection	Error Rate (%)
Proposed Method	46	4	8
Method [16]	0	50	100
Method [17]	0	50	100

table and the videos are captured under regular room lighting condition. The proposed method is compared with two existing resistor color code recognition mobile applications [16], [17]. The proposed method is implemented using Java and all the algorithms are installed on a Xiaomi Mi5 Android mobile phone. Moreover, for quantitative comparison purposes, the following error measurement is used:

$$P_E = \frac{N - T}{N} \times 100\% \tag{4}$$

where $N = 50$ is the total number of resistors and T is the total number of correct estimates.

The quantitative results are tabulated in Table I. The results show that the proposed method is robust to existence of artifacts (i.e. impulse noise, illumination changes, and specular reflection) and provides the highest accuracy rate as it correctly finds resistance values and their tolerances for 46 test images.Consequently, the error rate for the proposed method is 8%. Moreover, the other two mobile applications totally fail to correctly calculate the resistance values of the resistors.

Fig. 3 illustrates the qualitative results of the resistor color code recognition methods. Fig. 3 (a) shows four different resistors with resistance values of $27 \times 10^3\Omega$, $39 \times 10^3\Omega$, $56 \times 10^3\Omega$, and $2.2 \times 10^3\Omega$, respectively. The second column shows that the proposed method provides very promising results. However, the last two columns illustrates that the existing methods fail to correctly find the resistance value. The main issue with these methods is that they are trying to automatically detect the resistor location and then process the region of interest to recognize the color codes. However, due to simplicity of the segmentation algorithms, the resistors can only be segmented in far distances. This significantly increases the complexity of color recognition which results in erroneous classification.

IV. CONCLUSION

In this paper, a resistor color code recognition method is proposed to automatically estimate the resistance value of the resistor via an Android application. Our algorithm consists of two main steps. Firstly, a preprocessing method is applied to the input video frame to make the proposed method invariants to noise and illumination artifacts. Moreover, to easily extract color bands and make the proposed method invariants to scale and object orientation, a line scanner strategy is used. Secondly, the Euclidean distance based clustering strategy is combined with the lookup table to read the resistance value of the resistor. The proposed method is compared with two resistor scanner mobile applications and the results show that the proposed method is robust and effective.

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