A Vision System for the Inspection of Automobile Fuse Boxes

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1. INTRODUCTION

An automobile is composed of many parts. The parts that compose an automobile differ not only among different models, but also among supplementary options of automobiles; especially, the fuse and relay box mounted in an engine room has distinctive features and compartments according to automobiles' models and options. Due to their direct relations to automobile's safety, they have to be exclusively tested. However, manual inspection not only requires extraordinary dexterity of workers, but also cannot be fully granted the conviction of testing results. Not only for their extent diversity in kinds among automobiles, but also for many different kinds of fuses and relays they are composed of, fuses and relay boxes require uneasy quality control. In addition, these boxes changes as models of automobiles change and require different testing standards for different features, so implausibility of accurate examination is evident. This paper is about vision system that exhibits automatic examination of the conditions of fuses and relay boxes using a camera.

Proposed vision system is composed of three parts: image acquisition, vision algorithm, and user interface. The image acquisition part is composed of illumination and optics. The vision algorithm is the examining part, using the grabbed fuse box image. Lastly, user interface is divided into two parts, user interface for registering features of fuse box and user interface for examination operation.

2. IMAGE PROCESSING AND VISION ALGORITHM

We minimize the inspection error rate by combining color recognition and character recognition.

2.1. Color Recognition

Color recognition extracts color-rich part of a fuse through preprocessing by eliminating the converted part of a fuse caused by character area or illumination. After the location of a fuse is detected and the image of corresponding part of fuse is extracted, the operation eliminates the numbers, indicating the current rating of a fuse, and the white-or-black noise caused from irregular illumination and shades.

After preprocessing and the extraction of the image of distinct colors of a fuse, the operation recognizes the color. This paper uses a hue for color recognition. RGB color field is composed of addible three primary colors: red, green, and blue. RGB sample facilitates architecture of computer graphic design, but it is not ideal for all applications. Color components of red, green, and blue are heavily interrelated. On contrary to the facility of explicit depiction by RGB combination, RGB combination is highly sensible to illumination so it is very likely that it varies according to different working conditions. In order to overcome this problem, we consider three perceptive variables, which are hue, saturation, and brightness. We generally use hue to define color tone. Hue differentiates colors such as green and yellow. Hue is corresponding to the interaction of various wave lengths of colors we perceive. The most impactive color that has wave length between 430 nm and 480 nm is blue. Yellow lies within 570 nm and 600 nm, and anything above 610 nm is categorized in red. Gray, black, and white is understood to have colors, but they do not have cloe tone.

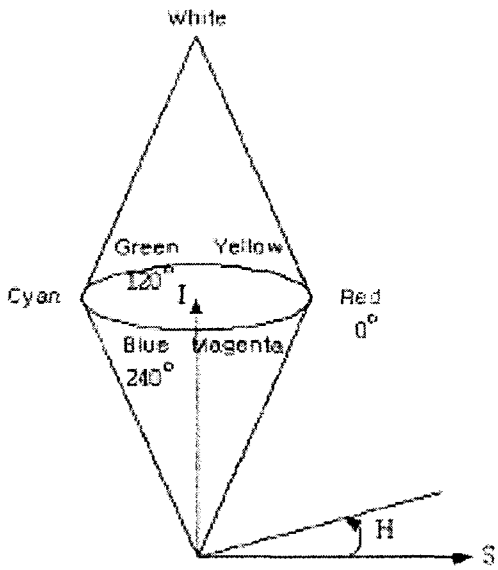
Saturation is the degree which differentiates color on the basis of the amount of white present. The more added into pure color, the more saturated that color is.

Saturation also commonly means the purity of a color. Weakly saturated color looks dim or vague, and strongly saturated one looks vivid and vigorous. Red has the highest saturation, while pink has the lowest saturation. Pure color has 100% saturation and is not mixed with white at all. Saturation varies from 0% to 100% according to the ratio of white and pure color mixed.

Brightness is the degree of light reflection, and it ranges all field from white to black. Therefore, we commonly call this range the gray level.

HSI color dimension is the color model that corresponds to three peculiarities, which are hue, saturation, and brightness. When using HSI dimension, it is unnecessary to identify the percentage of which color is required. Regardless of the illumination, hue(H) is a specific characteristic of a color, so this research have used a color-recognizing process through hue.

HSI color sample can be geometrically represented by cone-shaped coordinates. Figure 1 shows HSI color sample represented by two cones adhering their bases. As shown in the figure, hue is represented by angle H that ranges from 0° to 360°. Adjustment of hue varies according to the angle, which is red at 0°, green at 120°, blue at 240°, and back to red at 360°. Saturation corresponds to the radius that ranges between 0 and 1, in other words, the distance between the color vector and I-axis. As the saturation gets higher, the color changes to white, gray, and black according to its brightness. Brightness corresponds to I on z-axis, and it is black when 0 and white when 1. Black, which has I of 0, is not defined by H. By controling I, color can be brighter or darker. If S is constant at 1, the density of that color can vary with the management of I.



Picture 1. Double-Cone-Shaped HSI color Model

The following equation explains the conversion from image value represented by RGB field to that represented by HIS field. H represents hue, S for saturation, and I for intensity.

$$H = \cos^{-1}\left(\frac{[(R-G)+(R-B)]}{2[(R-G)^2+(R-B)(G-B)]}\right) \quad (1)$$

if $B/I > G/I$ than, $H = 2\pi\text{-}H$

$$S = 1 - \frac{3}{R+G+B}[\min(R,G,B)] \quad (2)$$

$$I = \frac{1}{3}(R+G+B) \quad (3)$$

Color recognition uses hue, saturation, and intensity resulted from the equation above resulted from RGB values from preprocessing.

Table 1. Fuse color corresponding to volume

Part No.	Rated Current	Housing Color
1210	10	Red
1215	15	Blue
1220	20	Yellow
1225	25	Natural (White)
1230	30	Green

Color recognition uses hue, saturation, and intensity resulted from the equation above resulted from RGB values from preprocessing.

2.2. Character Recognition Using Neural Network

Character recognition uses partial images of a fuse, not the entire image, as it did in preprocessing of color recognition. Preprocessing of character recognition extracts characters from the image of a fuse. First, a histogram is made from the values of intensity of designated partial images of a fuse. This intensity histogram facilitates the fuse part for it contains bimodal distribution. Once the critical values are calculated from the histogram, the image is put in a binary scale, and numbers required for character recognition is normalized. This normalized number image is character-recognized through a neural network. This paper uses counter-propagation network in recognition. Since the variation of 1~2 pixels can critically influence the recognition, we use sample patterns for learning which are modified images of ± 1 pixels of difference from the original pattern along x- and y-axis. The structure of network is composed of 300 neurons on Kohonen network and 6 neurons on Grossberg network.

3. EXPERIMENT

270 fuses for each current rating, 270 fuses of combined current rating, hence, total 1,620 fuse samples have been tested on this developed vision system. Considering the effect of illumination, the presences of natural lighting has been differentiated, and as in figure 1, a box sample of 27 fuses of same rating and another box sample of various fuses were tested every hour 10 times from sunrise to sunset, and the corresponding sample images were acquired.

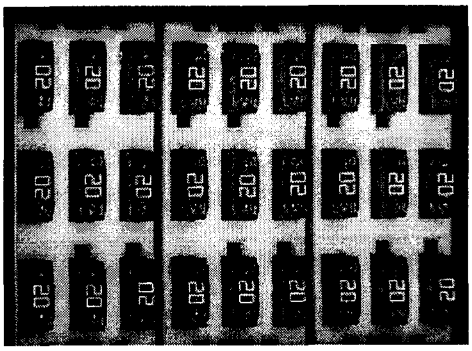
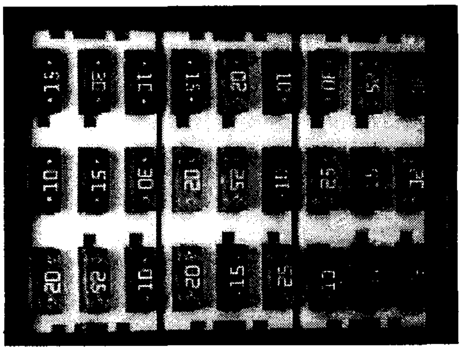
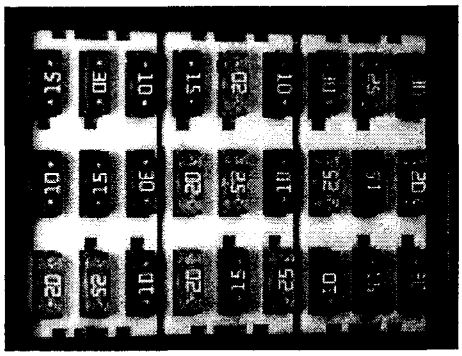


Fig. 1. Fuse box sample of same rating

For color recognition, partial image is extracted from preprocessing, and vivid image of a fuse is extracted by eliminating distorted image from numbers or illumination. Figure 2 shows the result of the location search of a fuse.



(a) Fuse Box Image



(b) Result of Location Search

Fig. 2. Location Search of Fuses

Figure 2 is the image after elimination of interference in color recognition.

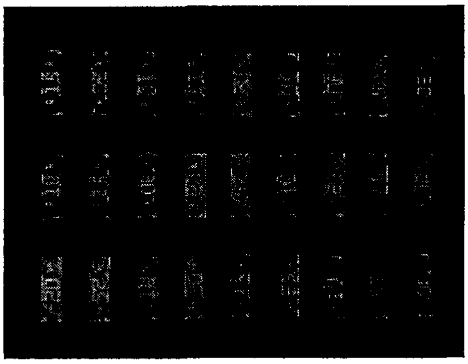
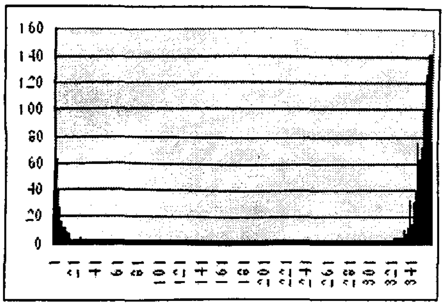
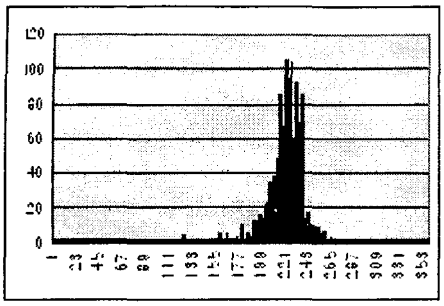


Fig. 3. Image after Interference Elimination

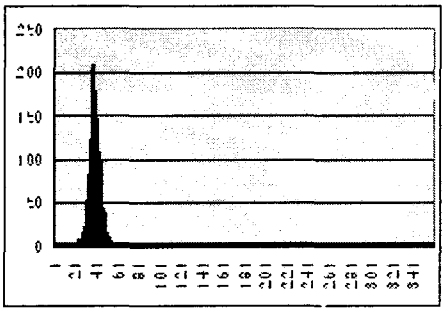
Figure 4 is a histogram according to fuse and hue. 10, 15, 30A fuses of red, blue, and green can be color-recognized only by the values of hue. Color is recognized if pixels of the hue value ranges from -40°~20° for 10A fuse, 200°~290° for 15A fuse, and 60°~200° for 30A fuse. 20A and 25A fuses are dependent of their saturation value if pixels of the hue value ranging 10°~80°is present more than some number. Figure 5 shows a saturation histogram of 20A and 25A fuses with similar hue value.



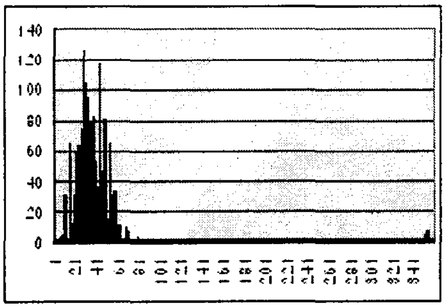
(a) 10A



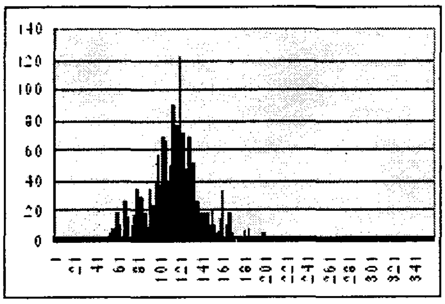
(b) 15A



(c) 20A



(d) 25A



(e) 30A

Fig. 4. Hue Histogram

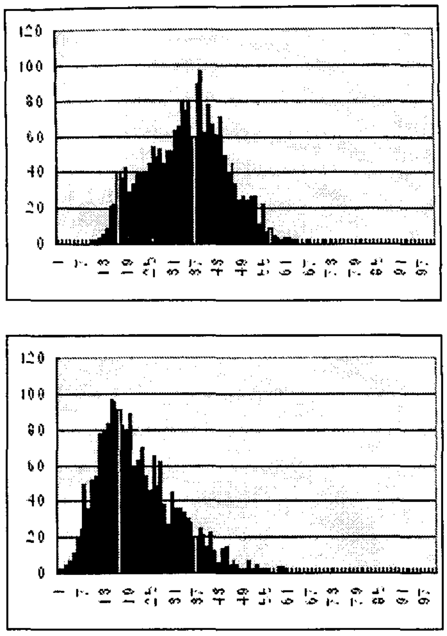


Fig. 5. Saturation Histogram

Character recognition algorithm uses counter-propagation network. Figure 6 shows pattern images used for learning.

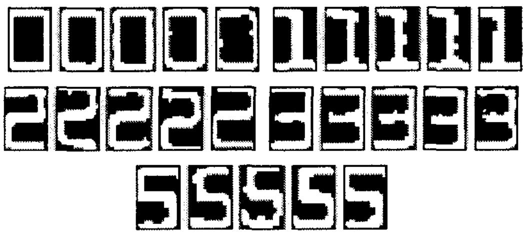


Fig. 6. Sample patterns for Learning.

The following table 1 shows the error rate of results from implementation of color and character recognition algorithm while recognition testing. **ALL** represents simultaneous color and character error for single fuse, **color** is when only color error is occurred, and **character** is when there is only a character error. They show that when character and color examinations for prototype are simultaneously tested,the error rate becomes 0

Table 1. Experiment Result

time	error rate with presence of natural light [%]				
		ALL	**color**	**character**	**note**
9	**10A**	0	0	0	
	15A	0	0	0	
	20A	0	0	0	
	25A	0	0	0	
	30A	0	0	0	
	random	0	0	0	mixed

time	error rate with absence of natural light [%]				
		ALL	color	character	note
2	10A	0	0	0	
	15A	0	0	0	
	20A	0	0	0.1	
	25A	0	0	0.9	
	30A	0	0	0.7	
	random	0	0	0	mixed

Figure 7 and 8 show the user interface and the prototype of vision system respectively.

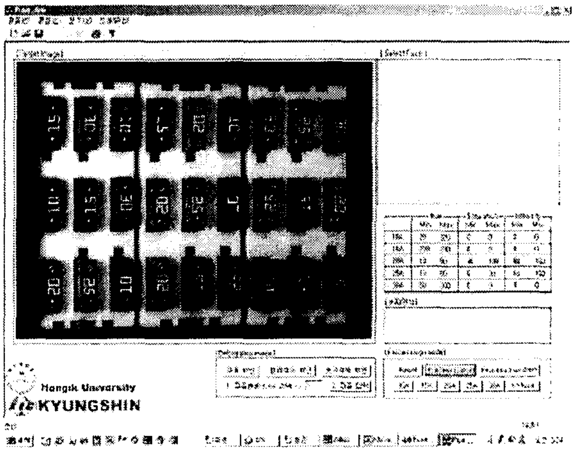


Fig 7. User Interface

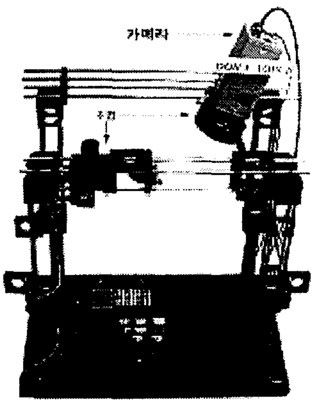


Fig. 8. Vision System prototype

Today, many different kinds of automobile are produced in the world, so harness-producing companies supply different harnesses according to their fitting kind of automobiles. Different wires, junction terminal, housing, fuse, and relay are used in automobile harness ccording to its model. Especially, a fuse and a relay box that go in an engine room and interior have different features for every kind of automobile, and mounting places. Fuse and relay varies in kinds and locations.

The automatic inspection system of this research is a tool for final examination of fuses that are in automobile's fuses and relay boxes. This tool can be practically used in production line by some adjustments after implementing in a testing production operation.

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