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Camera-Based Colour Sensing System

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Abstract:- Repainting a small damaged area on a car panel may lead to repainting the whole panel if there was inaccurate colour match. This would be time-consuming and expensive. Therefore it is very important to achieve an accurate colour matching which will lead to a neat repainting job as well as cost-effective. Although the initial colour code of the car is usually provided by the car manufacturing company, it actually changes with time due to weather conditions and successive car washing with various detergents.

The paper describes the design and development of a camera-based colour sensing system for car repainting application. A camera will capture a picture for small undamaged part of the car panel. This picture will be passed to a program for analyzing and coding the actual colour to its basic colour percentages. Although the proposed system focuses on car repainting application, it may also be used in other industries such as in printing industry.

Key-Words:- Colour sensing, painting application

1 Introduction

Repainting a small damaged area on a car panel may lead to repainting the whole panel if there was inaccurate colour match. This would be time-consuming and expensive. Therefore it is very important to achieve an accurate colour matching which will lead to a neat repainting job as well as cost-effective. Although the initial colour code of the car is usually provided by the car manufacturing company, it actually changes with time due to weather conditions and successive car washing with various detergents. The aim of the research project is to provide the actual paint colour code and more important the mixing colour ratios to get that colour.

The project focuses on designing and developing a prototype unit for paint colour sensing. The unit will capture a picture for small undamaged part of the car panel. This picture will be passed to a program for analyzing and coding the actual colour to its basic colour percentages. Although the project focuses on car repainting application, it may also be used in other industries such as in printing industry.

The colour sensing system will convert the captured image into bitmap format in order to give the percentages of the primary colours for formats RGB and CMYK as shown in the simplified block diagram in figure 1.

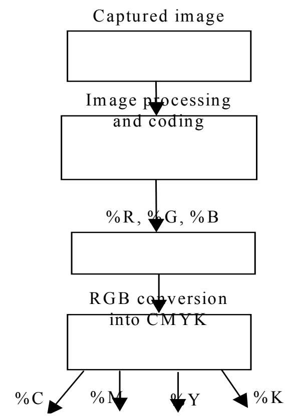

Figure 1: Simplified diagram for the colour sensing system

The three colours, Red (R), Green (G), and Blue (B) are combined to form colour monitors for TV and computer and called RGB format. RGB are the three primary colours of light. On the other hand, if you magnify 'colour print' with a magnifying glass, you will see Cyan(C), Magenta (M), Yellow (Y), and Black (K). The combination of these four colours forms 'colour print' and called CMYK format. CMY is subtractive mixture; in other words, CMY are the primary colours of paints. The black is a supplemental colour, because for printing (or painting) purposes, CMY colours are unable to produce 'Black'. Figure 2 below, shows the difference of the three colours.

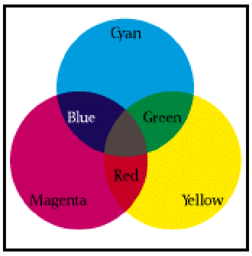

Figure 2: CMY colours

2 Theoretical Background

Colour is a perceived property by which we can tell different lights apart. These colours range from the reds through orange and yellow at the low frequency end to greens, blues and violet at the high end.

Like the retina of human eyes which consists of 3 types of colour receptors, in tri-stimulus theory, the colour is formed from 3 primary colours that are mixed to form the desired colour. Colour we perceive is the result of relative responses of the cones to red, green, blue light. This convenient to represent colour in terms of 3 primaries and describe colour in a 3D colour space [1].

A colour model chooses its own set of 3 descriptors (or primitive axes) to describe colours and for a given colour system produces its own colour gamut. A colour gamut is a range of colours that can be produced on a given colour system.

The colour model for different graphics applications are:

→ RGB - good for colour represented on a video monitor;

→ CMY - good for printers/plotters;

2.1 RGB Colour Scheme

RGB colour scheme is an *additive colour system*. A colour C_{RGB} is expressed as a sum of certain amounts of RGB primaries. *E.g.* a colour in video monitor is produced by combining lights from 3 screen phosphors $C_{RGB} = RR + GG + BB$

Each component of (R G B) is in the range of [0,1]. RGB colour space is therefore confined to a unit cube, see Figure 3. A colour is specified by a 3-tuple (R,G,B), a point in the RGB cube. And out of the 4 sets of colours at diagonally opposite corners, 3 are complementary colour sets [2]. They mix up to form white colour. So, If $C_1 + C_2$ = white colour, then C_1 & C_2 are complementary colour pair.

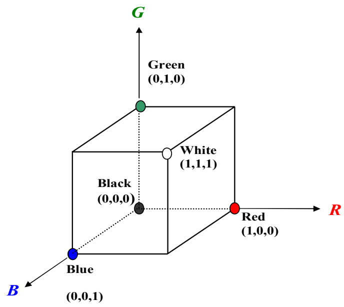

Figure 3: RGB colour space

2.2 CMY Colour Scheme

CMY colour model is a *subtractive colour system.* Its 3 primaries are cyan, magenta and yellow. It functions as a filter to subtract colour from white light through reflection [3]. A colour, C_{CMY} = (C,M,Y), is formed from white by subtracting amount C of the complement of cyan (i.e. red), amount M of the complement of magenta (i.e. green), and amount Y of the complement of yellow (i.e. blue). Thus CMY and RGB colour models are related as:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

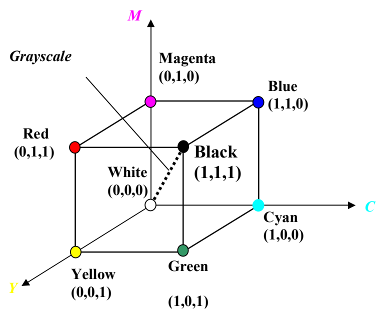

Figure 4: CMYcolour space

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Origin = white as no components of the incident white light is absorbed.
Point (1,1,1) = black as all components of incident light are absorbed and subtracted, see figure 4.

3 Colour Processing

RGB Intensities

Knowing that the RGB intensities range from 0 to 255, we can get the intensities percentages using the following methods:

- **Red:** (Red intensity)*100/255
- **Green:** (Green intensity)*100/255
- **Blue:** (Blue intensity)*100/255

CMY Intensities

Since CMY are known to be subtractive colours, to get the magenta for example we subtract the Red intensity from 255. The intensities percentages are given as follows:

- **Cyan:** 100-[(Red intensity)*100/255]
- **Magenta:**100-[(Green intensity)*100/255]
- **Yellow:** 100-[(Blue intensity)*100/255]

CMYK Intensities

Here we base our analysis on the CMY intensities. Therefore, the colour with the least intensity will be discarded and replaced by the black colour. The other colours intensities will be decreased by the lowest intensity. The process to get the intensities percentages goes as follows:

Cyan has lowest intensity.

- **Cyan**: 0
- **Magenta**:[100-(Green intensity)*100/255]-[100-(Red intensity)*100/255]
- **Yellow:** [100-(Blue intensity)*100/255]-[100-(Red intensity)*100/255]
- **Black:** 100-[(Red intensity)*100/255]

Magenta has lowest intensity:

- **Cyan**: [100-(Red intensity)*100/255]-[100-(Green intensity)*100/255]
- **Magenta**: 0
- **Yellow**: [100-(Blue intensity)*100/255]-[100-(Green intensity)*100/255]
- **Black**: 100-[(Green intensity)*100/255]

Yellow has the lowest intensity:

- **Cyan**: [100-(Red intensity)*100/255]-[100-(Blue intensity)*100/255]
- **Magenta**:[100-(Green intensity)*100/255]-[100-(Blue intensity)*100/255]
- **Yellow**: 0
- **Black**: 100-[(Blue intensity)*100/255]

RGB Percentages

To get the RGB composition percentages we get for example the Red colour intensity and we divide it by the sum of the RGB Colours Intensities. Consequently, we get the Red colour composition percentage. To get all the percentages we proceed as follows:

- **Red**: (Red Intensity)*100/(RGB Intensity Sum)
- **Green**: (Blue Intensity)*100/(RGB Intensity Sum)
- **Blue**: (Blue Intensity)*100/(RGB Intensity Sum)

CMY Percentages

Based on the subtractive property of the CMY colours we proceed as follows:

- **Cyan**: (255-(Red Intensity))*100/(CMY Intensity Sum)
- **Magenta**: (255-(Green Intensity))*100/(CMY Intensity Sum)
- **Yellow**:(255-(Blue Intensity))*100/(CMY Intensity Sum)
- **CMY Intensity Sum**: 255-(Red Intensity)+255-(Green Intensity)+255-(Blue Intensity)

CMYK Percentages

The process of calculating the CMYK percentages is somehow similar to the one used to calculate the CMYK Intensities. However, this time we will base our calculations on the results of the CMY percentages discussed above. Therefore we proceed as follows:

Cyan has lowest intensity.

- **Cyan**: 0
- **Magenta**: (Magenta Percentage)-(Cyan Initial Percentage)
- **Yellow**: (Yellow Percentage)-(Cyan Initial Percentage)
- **Black**: (Cyan Initial Percentage)

Magenta has lowest intensity:

- **Cyan**: (Cyan Percentage)-(Magenta Initial Percentage)
- **Magenta**: 0
- **Yellow**: (Yellow Percentage)-(Magenta Initial Percentage)

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- **Black**: (Magenta Initial Percentage)

Yellow has the lowest intensity:

- **Cyan**: (Cyan Percentage)-(Yellow Initial Percentage)
- **Magenta**: (Magenta Percentage)-(Yellow Initial Percentage)
- **Yellow**: 0
- **Black**: (Yellow Initial Percentage)

4 Implementation

The implementation of the system is based on an early work at AlAkhawayn University [4, 5] and further work at Massey University [6]. The language used in programming is Java.
The flowcharts in Figure 5 below are showing the stages involved in the colour detection system.

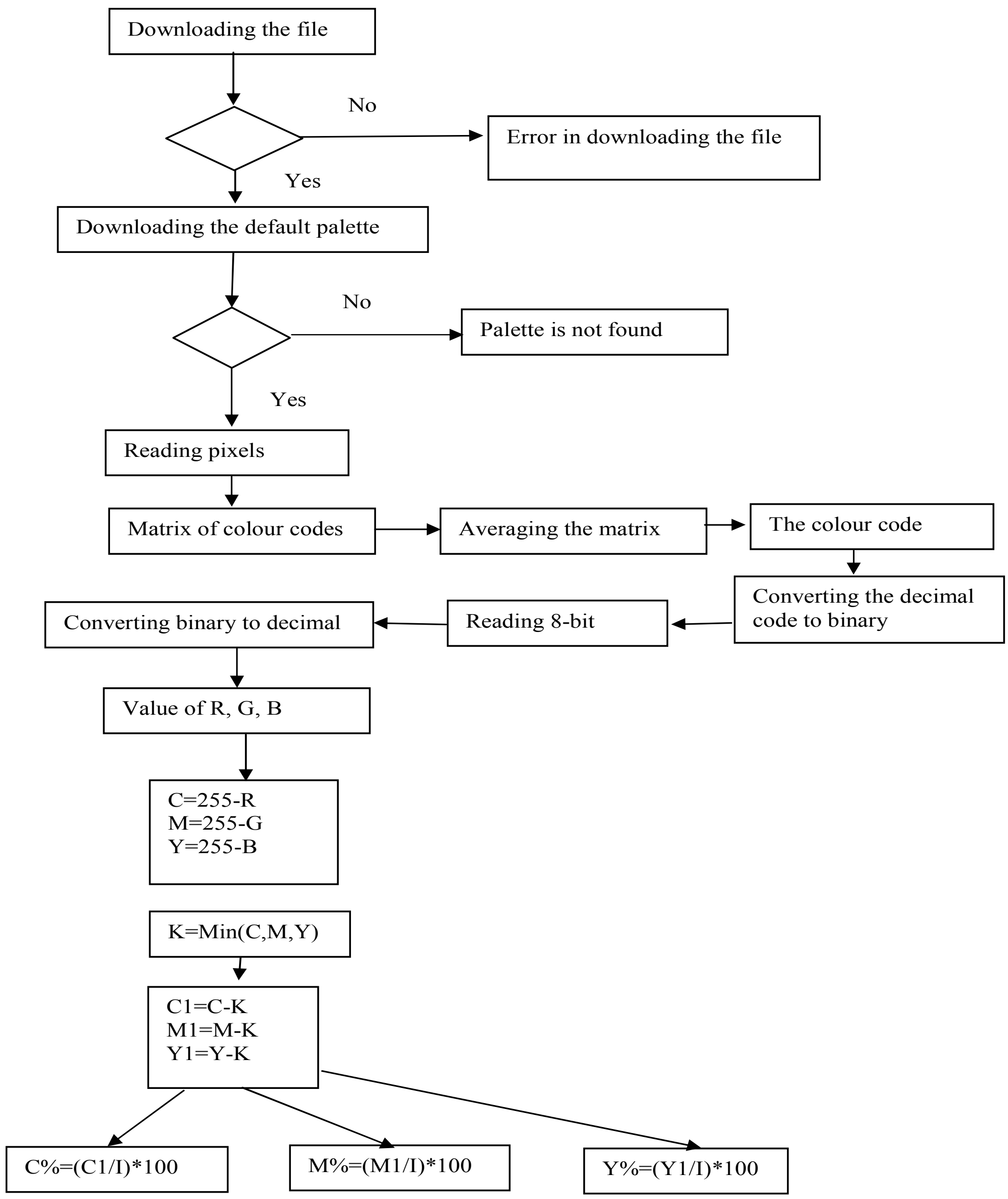

Figure 5: The stages involved in the colour detection system

5 Testing and Results

A simple representation showing the process that was followed is shown in figure 6 below:

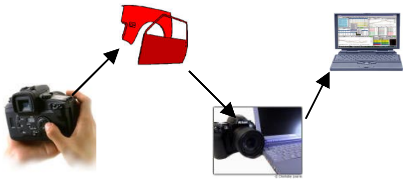

Figure 6: Simple representation of process undergone.

The process begins by using a digital camera to capture an image of the car panel. The picture is downloaded to a laptop hard drive, then the image is fed into the software and the processing begins. The software outputs the colour ratios detected and allows the viewing of the image and its further analysis.

Several shots of different angle and at varying distance were taken of the car door panel. The camera used was the Cannon Power shot Digital, an example of the resulting image is shown in figure 7.

Figure 7: Shot at 1m distance 90 degree angle.

The image depicted above was captured in an area where no direct sunlight faced the vehicle, so that it would not influence the results remarkably. Once an image downloaded onto the 'colour sensor' software, the colour percentages would be displayed on the left hand side as shown in figure 8.

To minimise the errors when analysing the colour percentages what was done is that a square sample of the panel was taken to a known width x length and applied to all the images hence each of the four corners of the sample were taken down as shown in table 1.

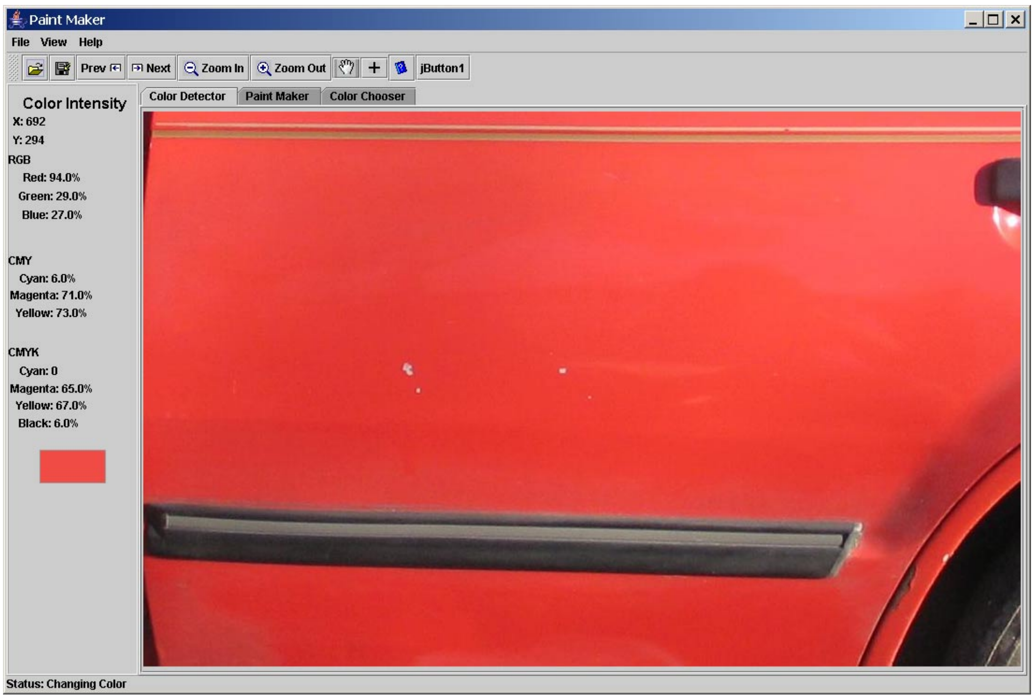

Figure 8: Image uploaded in software.

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	Top Left	Top Right	Bottom Left	Bottom Right	Average
R	93%	100%	87%	90%	93%
G	23%	28%	23%	25%	24.75%
B	22%	25%	19%	19%	21%
C	0%	0%	0%	0%	0%
Y	70%	72%	64%	65%	68%
M	71%	75%	68%	71%	71%
K	7%	0%	13%	10%	8%

Table 1: Table showing the four corner averages

As indicated that different angles and distances were considered when taking shots of the panel. The different distances were; 1 meter, 1 meter 45 degree right and left, 2meter, 2meter right and left. These different average ranges of proportions were noted in figure 9.

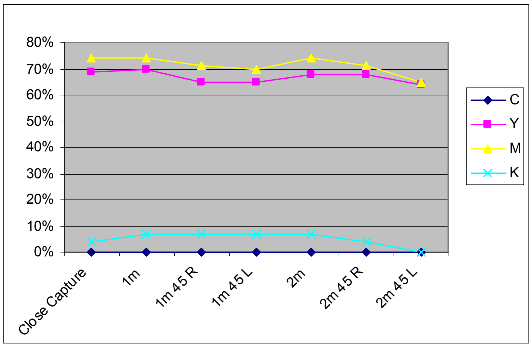

Figure 9: CYMK percentage proportions.

The above graph shows the percentages for CYMK which are consistent with some slight deviation. It must be mentioned that the testing and results so far revealed the consistency of the system. However to work out the accuracy a further testing is required. It must also be noted that there some factors would influence the results. These factors include lighting condition, temperature, and cleanness of the panel surface. So, optimum conditions for image capturing could be established for better accuracy. Colour recognition under varying illumination has generally been addressed as a colour constancy problem, where the goal is to match object colours under varying illumination without knowing the spectral composition of the incident light or surface reflectance [7, 8]. This approach would be useful for our application as long as maintaining the illumination conditions.

6 Conclusion

The paper described the design and development of a camera-based colour sensing system for car repainting. The system captures a picture of a small undamaged part of the car panel. This picture then passed to a program for analyzing and coding the actual colour to its basic colour percentages. Although the project focused on car repainting application, it may also be used in other industries such as in printing industry.

The colour sensing system converted the captured image into bitmap format in order to give the percentages of the primary colours for formats RGB and CMYK. The programming language used in the development is Java and a friendly user interface has been developed for the system. The test results have revealed a consistency over a range of distances. However some factors need to be taken into account for optimum results.

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