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# Quantifying the Defect Visibility in Digital Images by Proper Color Space Selection

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## ABSTRACT

**The selection of color space is one of the determinants of quantifying the visibility of the defects like scratches, spots, edge defects etc in glass sheets. We propose an evaluation system that assigns each color space a corresponding level according to the extent of visibility of the defect that objectively agrees with human visual perception. By "objective," we mean that the evaluation corresponds, on average, with the assessment of a group of inspectors. The basic idea is to use the human visual perception to evaluate defects. In the process, the Visibility–test is done to evaluate the level of defect visibility in terms of a five point Likert scale. The conversion time from RGB color space to the other is also considered to evaluate the maximum visibility of the defect in each color space used.**

*Keywords*: Color, Color space, visibility-test.

## 1. INTRODUCTION

Color is an important vision property of image. It is one of the perpetual features for the human to recognize an image. Quantitative description of color is a challenging problem. Another problem is that even under equal intensity, some colors appear visually brighter than others. Therefore different color representations are used which try to overcome these problems to different extent. The aim of the color spaces is to aid the process of describing color, either between people or machines or image processing algorithms.

A color space is a method by which we can specify, create and visualize color [1, 2]. The color spaces can be classified into two basic categories, namely device dependent and device independent color spaces.

### 1.1 Device Dependent Color Space

These are the color spaces that are tied to specific piece of the equipment and dictate the type of color space that can be used [3]. A *white point* is present in all color spaces, which is defined as the whitest white that can be produced in that color space. Different devices can have different white points [10]. All colors that a device can produce are relative to its white point. Therefore, a color management system must be able to map the white point of one color space into another and preserve the relative locations of all colors. It must also be able to map a color in one color space to its closest match in another color space regardless of the differences in the white points. For example: the appearance of RGB colors varies with display and scanner, CMYK colors vary with printer, ink and paper characteristics.

### 1.2 Device Independent Color Space

These are the color spaces which are equally valid on whatever device they are used [3]. A color space was created by CIE based on "imaginary" primary colors to meet the need for standard, device-independent color measurements. No actual device is expected to produce colors in this color space. It is used as a means of converting colors from one color space to another. The primary colors in this color space are the abstract colors X, Y, and Z which are called the tristimulus values. The 1931 CIEXYZ color space is widely used as the basis for color space conversion [11]. This is not a practical approach in open digital imaging systems that consist of many devices. For example: Standard predefined RGB color space i.e. sRGB.

Researchers randomly select one of the color spaces for color image processing applications. But there should be a way to select a suitable color space according to the purpose because the choice will directly affect final results of image processing [4]. The most commonly used color spaces are RGB, HSV, YCbCr, NTSC etc.

Five most commonly used color spaces are tested in this paper. The conversion of color images between RGB, HSV, YCbCr, NTSC, Gray is done. Their conversion efficiency is computed and their performance in quantifying the defect visibility is compared based on which the best color space can be chosen. The advantages of this color-space conversion algorithm are: 1) This algorithm is easy to implement; 2) no complexity; 3) higher conversion accuracy.

The rest of the paper is organized as follows: Section two discusses about the color spaces. Section three briefly introduces the visibility test algorithm used for testing the color spaces. Section four discusses the results and section five concludes the paper.

## 2. COLOR SPACES

### 2.1 RGB (Red, Green, blue)

In RGB color space, the colors red, green, and blue are mapped onto a 3-D Cartesian coordinate system which results is a 3-D cube . The vertices of cube are the primary colors (red, green, and blue) and the secondary colors (cyan, yellow, and magenta) of light. The origin of the coordinate system is black where the red, green, and blue (RGB) color components are all 0.0. The diagonally opposite corner of the cube is white, where the RGB color components are at their maximum value. It is the most commonly used color space in computer systems, televisions and videos.

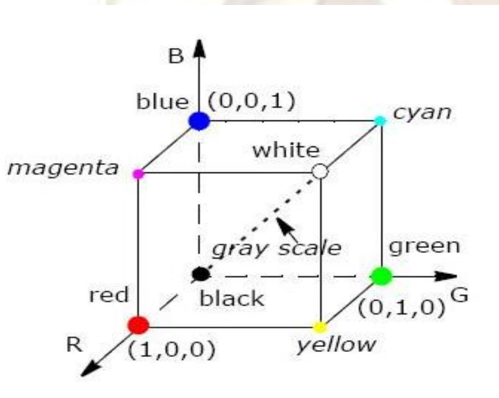


Figure 1 RGB Color Space

### 2.2 HSV

The HSV color model is a kind of method to define colors according to the three basic features of the color: Hue, Saturation and luminance [5].

Hue is the color type which ranges from 0 to 360.It is expressed as a color hexagon, using the red axis as the reference (0˚) axis.

Saturation, the vibrancy of color ranges from 0 to 100% and is also called as the 'purity'. It is measured as the distance from the V axis.

Value is basically the brightness of the color that ranges from 0 to 100%. It is measured along the axis of the cone.

This color model is the non-linear transformation of RGB color space and is closer to the way in which humans experience and describe color sensations [6]. To convert the image from RGB to HSV (assuming normalized RGB values), find the maximum and minimum values from the RGB triplet. Here are the conversions as given by Travis [7]

Saturation, S: S = (max - min)/max

Value, V: V = max

The Hue, H, is then calculated as follows. First calculate R'G'B':

R′= (max-R)/max-min

G′= (max-G)/max-min

B′= (max-B)/max-min

If saturation, S, is 0 (zero) then hue is undefined (i.e. the color has no hue therefore,

If R = max and G = min H = 5 + B′

Else if R = max and G 6= min H = 1 − G′

Else if G = max and B = min H = R′+ 1

Else if G = max and B 6= min H = 3 − B′

Else if R = max H = 3 + G′

Otherwise H = 5 − R′

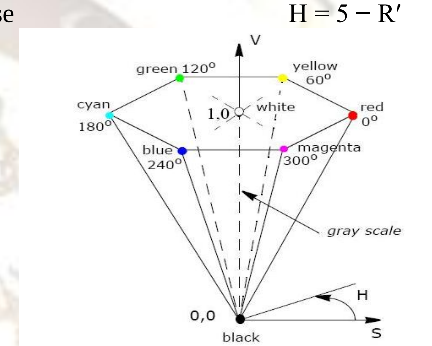


Figure 2 HSV Color Space

### 2.3 YCbCr

It is a model in which Y is the intensity component. Cb refers to blue color component and Cr refers to the red color component [8]. This color model is basically used in digital videos. The transformation used for RGB to YCbCr [9]:

Y = 16 + 65.481*R + 128.553*G + 24.966*B

Cb = 128 – 37.797*R – 74.203*G + 112*B

Cr = 128 + 112*R – 93.786*G – 18.214*B

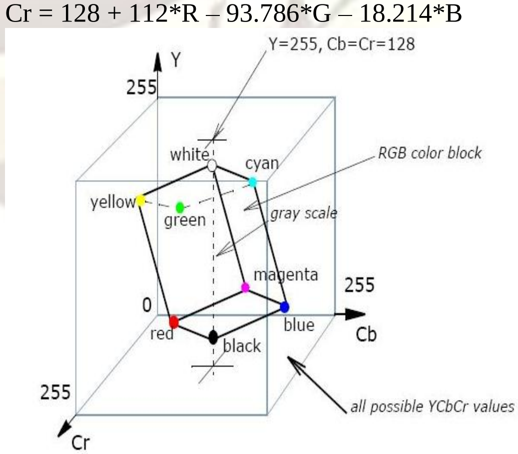


Figure 3 YCbCr Color Space

### 2.4 NTSC

In this type of color format, image data consist of three components: luminance (Y), hue (I) and saturation (Q), where the choice of letters YIQ is conventional [9]. The luminance component carries the g ray-scale information and the other two components carry the color information. It is the linear transformation of the RGB color space. This color model is used in analog television. The YIQ components [9] are obtained as:

Y = 0.299*R + 0.587*G + 0.114*B
I = 0.596*R – 0.274*G – 0.322*B
Q = 0.211*R – 0.523*G + 0.312*B

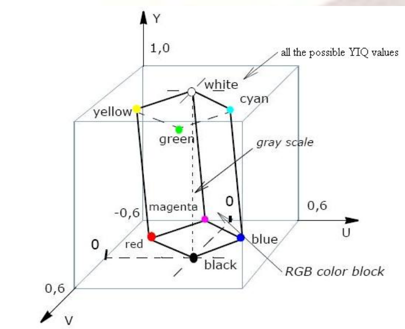


Figure 4 NTSC Color Space

### 2.5 Gray Scale

In photography and computing, a grayscale digital image is an image in which the value of each pixel is a single sample, that is, it carries only intensity information. Images of this sort, also known as black-and-white, are composed exclusively of shades of gray, varying from black at the weakest intensity to white at the strongest. To convert a gray intensity value to RGB, simply set all the three primary color components red, green and blue to the gray value.

## 3. VISIBILITY TEST

Glass defects are a major reason for poor quality and of embarrassment for manufacturers. It is a tedious process to manually inspect very large size glasses. The manual inspection process is slow, time-consuming and prone to human error. Automatic inspection systems using image processing can overcome many of these disadvantages and offer manufacturers an opportunity to significantly improve quality and reduce costs. But before the image is processed for detecting the defect, it is important that the defect be visible to the highest degree. Therefore it is necessary to select a color space which best shows the defect thereby reducing the further complexities during its detection.

This test converts each input image containing a defect into four other color spaces namely: HSV, Ntsc, Gray and YCbCr. Once the conversion is done each color space is assigned a level from 1 to 5 according to the degree of visibility of defects in the input image in each color space that objectively agrees with human visual perception. This type of scale is known as Likert scale. According to this scale, the color space with highest degree of visibility of the defect is marked 5, with a lower degree as 4 as so on and the one with least degree of visibility is assigned as 1. Thus, evaluation corresponds, on average, with the assessment of a group of inspectors. The basic idea is to use the human visual perception to evaluate defects. The conversion time of each image from RGB color space to other color spaces is also calculated. The test has been conducted on 77 images whose results have been discussed in the next section. The results of visibility test are as shown in the figure 5 below:

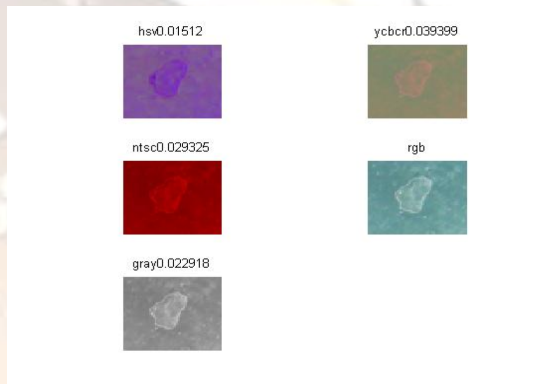


Figure 5 Visibility Test Result

The overall procedure is summarized as:


Figure 6 Flow Chart of the algorithm

## 4. RESULTS AND DISCUSSION

The proposed system has been applied to enhance the visibility of defects in large number of colored digital images taken before their detection for performance evaluation and comparison for each color space. The test has been conducted on 77 images whose results have been discussed in this section. Some typical results and discussion are given below. The input image is converted to four color spaces specified above. Two factors taken into account for analysis are:

- Five-Point Likert scaling
- Conversion Time

According to the Likert scale, level from 1 to 5 is assigned to each color space and the analysis below shows that RGB color space gives the best results with level 5 being assigned for all the images of the database. The second best color space according to human perception of degree of defect visibility is Gray color space and then Ntsc, HSV and last comes the YCbCr color space.

From time analysis graph shown below minimum time for conversion is taken by RGB-HSV color space while the order of time taken for conversion from minimum to maximum is Gray, NTSC and YCbCr color space.

So combining both the results, it can be concluded that the defects are best visible in RGB color space and RGB – Gray color space conversion would give the best results when these defects are detected during further processing in manufacturing industries like glass industries.

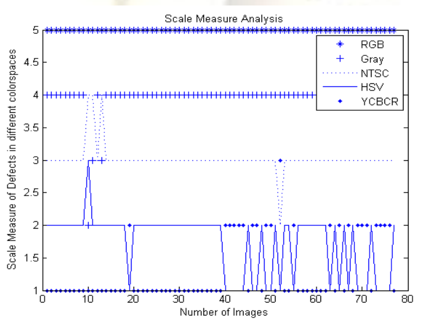


Figure 7 Five Point Likert Scale Analyses

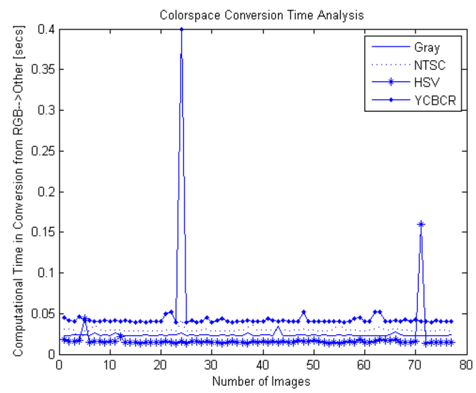


Figure 8 Conversion Time Analyses

## 5. CONCUSION

In this paper various color spaces have been analyzed and compared for their performance in quantifying the visibility of defects in digital images. On the above reported theory and results the RGB color space is recommended if one needs to view and process various defects like scratches, spots, edge defects etc in images. If any color space conversions are required the best choice is RGB to Gray color space conversion which makes the defect visible to largest extent.

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