ISSN 2229-5518

# Image Quality using Attributes

Yusra Al-Najjar, Dr. Chen Soong Der

**Abstract -** Quality Assessment (QA) algorithms aim to assess the quality of images and videos automatically in a way that is consistent with human quality judgment. Many approaches have been followed in predicting image quality but up till now quality assessment algorithms are pointed toward specific type of images or distortion. In our approach we use contrast enhanced images trying to compute the quality depending on some attributes of the image such as naturalness, colorfulness and contrast. As well as discussing theoretical and practical implication of these attributes.

**Index Terms**— Naturalness, Colorfulness, Contrast, Image Quality Assessment

## 1 Introduction

IMAGE quality is not an attribute that could be measured for an image, quality takes into consideration many parameters. Human eye is the best judge for image quality, but what is meant by quality?

Quality means how natural, colorful, bright, clear, distortion free the image is, beside other attributes in which normal user sees it difficult to be found directly.

Image enhancement is the simplest and most common field in digital image processing techniques. The main idea of image enhancement is to increase the contrast of the image to get specific details.

RGB colour space, which is used by most of the conventional methods, could not be adjusted easily to Human Visual System (HVS) property because it does not express the colors as a combination of lightness and chromaticity. On the other hand, the CIELUV colour space is capable of performing colour quantization. The HVS is very sensitive to the colour that is considerably different from the surrounding colors, even if it occupies relatively smaller region of the image. Yet, this property may be ignored by the quantization method using Mean Squared Error (MSE).

## 2 Image Attribute

### 2.1 Naturalness

Naturalness is defined as the degree of consistency between visual representation of the image and the knowledge of reality as stored in memory [1]. It could also be considered by addressing e.g. how manipulated changes in attributes such as Sharpness or Chroma affect the perceived naturalness of an image [2].

Naturalness attributes also said to include some artifactual attributes (due to e.g. low-level quality), preferential attributes (e.g. colour balance, preferred colors), aesthetic attributes (e.g. lighting, perspective, cropping), and personal attributes (e.g. personal connection, familiarity) [2].


- *Yusra Al-Najjar Author is a PhD student in Universiti Tenaga Nasional, Malaysia (e-mail: yusra.najjar.2011@gmail.com).*
- *Chen Soong Der is with the College of IT, Universiti Tenaga Nasional, Putrajaya, Malaysia (e-mail: chensoong@uniten.edu.my).*


On the other hand, image quality has many overlapping attributes that could be classified differently into measureable attributes (e.g. contrast, colorfulness, noise. brightness) and hard to be measures attributes - since it depends on observers' point of view - (e.g. usefulness, balance, pleasantness, completeness), see Fig. 2.

Following is a discussion for some of these attributes:

### 2.2 Brightness

CIE defined by the as the attribute of a visual sensation according to light percentage emitted from the area. It measures the subjective sensation produced by a particular luminance, i.e., the brightness is the perceived luminance [3]. Stevens [4] proposed an expression for the apparent brightness that gives a suitable relationship between luminance and brightness for simple objects. In [5] Krawczyk et al. proposed an operator in order to get an accurate estimation of lightness in real world scenes by a theory called anchoring theory of lightness perception. This method is based on automatic decomposition of HDR (High Dynamic Range) image into framework (consistent areas), where lightness is then estimated by anchoring to the luminance level that is perceived as white, and then the global lightness is calculated.

### 2.3 Contrast

Image contrast could have more than one definition, but it is usually related to variations in image luminance, see Fig. 1.

Fig. 1: The simultaneous contrast effect: despite the two inner rectangles are of the same shade of gray, but the one to the left appears lighter than the one to the right.

Michelson's definition [6] for contrast is defined by Eq. (1):

$$C = \frac{L_{max}-L_{min}}{L_{max}+L_{min}} \quad (1)$$

where $L_{max}$ and $L_{min}$ are the maximum and minimum luminance values. Michelson's definition is sometimes used when measuring the global contrast of the image.

Using this method for global contrast is considered misleading, because it got affected by random, irrelevant pixels with extreme values. Peli in [6] proposed another definition of local contrast that is suitable for complex images; this method assigns a constant value to every point in the image as a function of the special frequency band where the constant is defined as the ratio of bandpass-filtered image at that frequency to low-pass image filtered on an octave below the same frequency. This method produces a multi-scale representation of the effective image contrast.

### 2.4 Colorfulness

The sensation of colour is considered to be an important aspect of the human visual system, and the correct reproduction of colors may help to increase the realistic appearance of the output image. One important feature of the human visual system is the ability to see the level of colors in a bright environment. This capability, measured as colour sensitivity, is reduced in dark environments, as the light sensitive rods take over for the colour-sensitive cone system.

As the luminance level is raised, the cone system becomes active and colors begin to be seen starting with the long wavelength reds and moving ahead toward the middle wavelength greens. Only at relatively high luminance, where short wavelength blue targets start to appear [7]. In colour reproduction, naturalness can be assessed by the mental recollection of the colors of familiar objects, i.e. memory colors. Colorfulness is often considered by the observers when evaluating overall image quality [2]. Correct reproduction of colors can make the output image more real. The success of a colour reproduction lies in how close the reproduced scene is to the original scene.

### 2.5 Usefulness

Usefulness is the accuracy of the visual representation of the image. It could also be defined by the presence of enough information required to identify a certain object in the image. It is how much we can benefit from the image regardless of how natural or good it is. In short words, image should serve a purpose [8].

### 2.6 Balance

This attribute is hard to be computed since it balances between different other attributes of the image depending on observers' point of view. A well balanced image should be bright, colored, clear and no distortion, and the main thing is to be acceptable by human eye.

In this paper we are mainly concerned with naturalness, colorfulness, and contrast attributes in order to find out an image quality index that is close to human perceptual judgment.

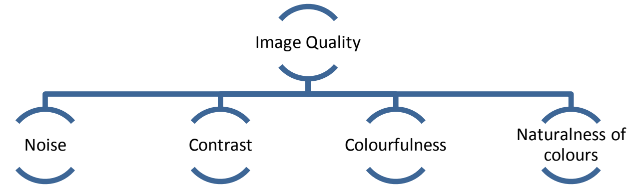


Fig. 2: The attributes that shares most in defining image quality

## 3 Attribute Relationship

Following scheme clarifies the relationship between image attributes and their effect over image quality. As seen Image Quality is affected by many attributes either positively or negatively, i.e. it strongly depends on the perceived brightness where bright scenes appear bright and dark scenes appear dim. Contrast should also be reproduced in order to make the resultant image natural. Details and visibility reproduction have their effect as well in image natural appearance.

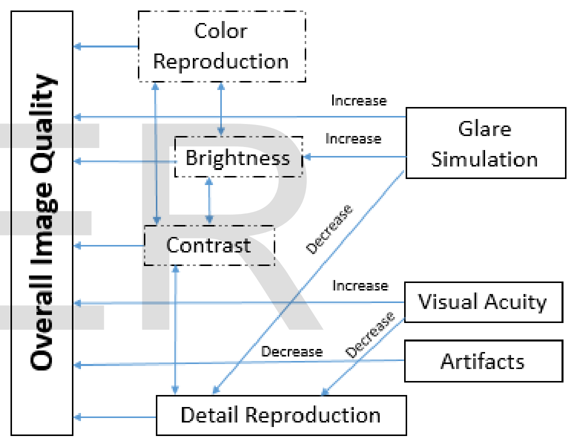


Fig. 3: The relations between image attributes **[7]**, dashed boxes are the attribute of our concern

## 4 Colour Spaces

The word 'Colour' maybe understood in different ways such as a certain kind of light, the effect of light on human eye, or the effect of this light on human mind. Colour is perceptual result of visible light that lies in the range of 380nm, and 750nm of spectrum wavelength, incident upon the retina [9] .

Colour space is a method by which colors are specified, created, and visualized [9]. They are usually specified by using three attributes or coordinate which represent its position within a specific colour space. These coordinates do not tell us what the colour looks like, only where it is located within particular colour space. Colour models are 3D coordinate systems, and a subspace within that system, where each colour is represented by a single point.

### 4.1 RGB Colour Space

This colour space is represented by the colors Red (R), Green

(G), and Blue (B) mainly and is an additive system. The additive system is specified by the chromaticity of its primaries and white point.

RGB values can be transformed into a CIE XYZ colour space by three-by-three matrix transform. The transform is done using the following matrix:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.412453 & 0.35758 & 0.180423 \\ 0.212671 & 0.71516 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (2)$$

However, RGB is not very efficient when dealing with real-world images. To generate any colour within the RGB colour cube, all three RGB components need to be of equal pixel depth and display resolution. Also, any modification of the image requires modification of all three planes [10].

Since white is normalized to unity, the middle row sums to unity. To recover the white point, the RGB is transformed into CIE XYZ, then x, y are computed.

### 4.2 CIE XYZ Colour Space

There are three types of cone receptors in the retina, and they are acceptable to describe the colour. The set of perceivable colors is only three-dimensional space. The convenient set used for colour measurement, is the CIE 1931 (X, Y, Z) – system adopted by the Commission International de l'Eclairage (CIE) [11]. Each point in the XYZ colour space represents a unique colour perception.

In XYZ colour space, colour components such as Hue and Chroma, can be represented with x and y chromaticity coordinates defined as

$$x = \frac{X}{X+Y+Z}, \quad y = \frac{Y}{X+Y+Z} \quad (3)$$

### 4.3 CIELUV Colour Space

Perceptual uniformity means that the distance between two points in the colour space makes the equal perceived colour difference. The XYZ, RGB, or even HSV colour spaces do not exhibit perceptual uniformity.

There are two other perceptually uniform colour spaces, the CIElab and the CIELuv. Considering the CIELuv, we find that the three variables $L^*$, $u^*$, and $v^*$ are defined as follows:

$$L^* = \begin{cases} 116\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16 & if \quad \frac{Y}{Y_n} > 0.008856 \\ 903.3\,\frac{Y}{Y_n} & otherwise \end{cases} \quad (4)$$

$$\begin{aligned} u^* &= 13L^*(u' - u'_n) \\ v^* &= 13L^*(v' - v'_n) \end{aligned}, \quad (5)$$

where $u'$, $v'$ are calculated from,

$$\begin{aligned} u' &= \frac{4X}{X+15Y+3Z}, & v' &= \frac{9X}{X+15Y+3Z} \\ u'_n &= \frac{4X_n}{X_n+15Y_n+3Z_n}, & v'_n &= \frac{4Y_n}{X_n+15Y_n+3Z_n} \end{aligned} \quad (6)$$

$X_n$, $Y_n$, and $Z_n$ values are the values of the illuminant, with $Y_n$ equals to 1.

Unlike the RGB colour space, each axis of the CIELuv colour space has different expression ranges. The range $L_{range}$ of the expression for $L^*$ component has the 101 steps ranging from 0 to 100, while the $u^*$ component has 355 steps ranging from 134 to 220, and the $v^*$ has 263 steps ranging from -140 to 122.

The colour difference between any two colors in the CIELuv colour space is calculated using the Euclidian distance as follows:

$$\Delta E^*_{uv} = [(\Delta L^*)^2 + (\Delta u^*)^2 + (\Delta v^*)^2]^{1/2}, \quad (7)$$

where $\Delta L^*$, $\Delta u^*$, and $\Delta v^*$ represent the difference between two colors in the $L^* - axis,\ u^* - axis, and\ v^* - axis$ [4].

## 5 Experiment

In our experiment we intend to measure the naturalness, colorfulness, and contrast of colored images in order to verify the quality of the image. Naturalness is the degree of conformity between human perception and reality world, and will be presented as Naturalness Index CNI; colorfulness on the other hand represents colour vividness degree, and will be presented by the Colorfulness Index CCI; while the Contrast Index is CoI.

Yendrikhovskij introduced a model for best colour regeneration of natural images which are based on the colour quality of natural images based on perceived naturalness and colorfulness of these images [12]. Hasler gives another precise metric for colorfulness, which will be considered in the algorithm we use [13].

In this paper, the CNI will be computed as follows:

1. Converting the RGB image into CIELuv colour space where it is easier to compute the factors needed for calculating image naturalness such as Chrome, Hue, Saturation, and Luminance. Conversion process passes through XYZ colour space which acts as an intermediate step [14] .
2. Computing the Luminance (L), Hue (H), and Saturation (S) correspondingly. L* should scale from 0 to 100 for luminance $(Y/Yn)$ scaling 0 to 1. There are three meaningful polar parameters that closely match human visual experience: Chroma, C*, Hue, $h_{uv}$, and saturation $S_{uv}$, as follows:

$$C^* = (u^{*2} + v^{*2})^{0.5} \quad (8)$$

$$h_{uv} = \arctan\left(\frac{v^*}{u^*}\right) \quad (9)$$

$$S_{uv} = \frac{C^*}{L^*} \quad (10)$$

3. Thresholding L and S components so that L values that are between 20 and 80 are kept and S values over 0.1 are kept.
4. Defining three kinds of pixels according to hue values: 25-70 is called "skin" pixels (pixels that represent skin colour), 95-135 is called "grass" pixels (pixels that represent green colour), and 185-260 is

called "sky" pixels (pixels that represent the blue colour)

5. Calculating averaged saturation values for the "skin" as Saverage_skin, for the "grass" Saverage_grass, and for the "sky" Saverage_sky, and number of "skin" pixels as nskin, "grass" pixels as ngrass, and "sky" pixels as nsky.
6. Calculating local naturalness index CNI values for the "skin", the "grass", and the "sky" pixels as follows:

$$N_{skin} = \exp\left(-0.5 * \left(\frac{S_{averag-skin} - 0.76}{0.52}\right)^2\right), \quad (11)$$

$$N_{grass} = \exp\left(-0.5 * \left(\frac{S_{averag-grass} - 0.81}{0.53}\right)^2\right), \quad (12)$$

$$N_{sky} = \exp\left(-0.5 * \left(\frac{S_{averag-sky} - 0.43}{0.22}\right)^2\right), \quad (13)$$

7. Calculating global colorfulness index CCI values:

$$N_{image} = \frac{n_{skin} * N_{skin} + n_{grass} * N_{grass} + n_{sky} * N_{sky}}{(n_{skin} + n_{grass} + n_{sky})} \quad (14)$$

$N_{image}$ varies from 0 (the most unnatural image) to 1 (the most natural image)

8. Computing the colorfulness index $CCI$ as in the (15):

$$CCI = ((0.2 * S_k) + \sigma_k), \quad (15)$$

where Sk is the average saturation of image k, $\sigma_k$ is standard deviation, and the value 0.2 is determined experimentally. $CCI$ varies from 0 (achromatic image) to $CCI$max (most colorful image).

9. Compute the contrast of the image according to Peli [6] as the standard deviation of pixels intensities

$$CoI = \frac{1}{MN} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} (I_{ij} - \bar{I})^2, \quad (16)$$

Where intensities $I_{ij}$ are the $i-th$, $j-th$ elements of a two dimensional image of size M by N, and $\bar{I}$ is the average intensity of all pixel values in the image.

Computing image quality IQ as a combination of naturalness, colorfulness, in addition to contrast with different ratios as in (17):

$$CIQ = (1-w) * CNI + w * \frac{CCI}{\max(CCI)} + CoI, \quad (17)$$

Where $w$ equals 0.75, experimentally determined.

Fig. 4 shows some of the images used in our experiment.

A group of 30 subjective have been selected to evaluate 42 natural scene images' quality. A simple training has been done. The experiment took place in a dark room, where each pair of the original and test images have been displayed in front of the subjective.

Each from the 42 contrast-reduced images was processed using SGHESE [15] with different parameters' values to generate one stimulus for each of the following categories. Forty two pairs of images, thirty subjective made 1260 judgments.

The categories generates five-point intervals ranging from 1 to 100, see Table 1. The observers rated image quality difference between two images, the original with low contrast image, and the enhanced image in pairs displayed sequentially on a wide screen. Each pair is displayed at a time to be quality judged.

Fig. 4: Sample of images used in the experiment

TABLE 1

CATEGORY INTERVALS FOR IMAGE QUALITY

| Category | Definition |
|---|---|
| 81-100 | Best Quality |
| 61-80 | Better Quality |
| 41-60 | Good Quality |
| 21-40 | Acceptable Quality |
| 1-20 | Bad Quality |

## 6 RESULTS

Table 2 displays the results of applying several methods including the proposed one.

ISSN 2229-5518

TABLE 2

**COMPARISON OF DIFFERENT IMAGE QUALITY INDICES FOR THE 42 IMAGES USED IN THE EXPERIMENT**

| Index | Pearson | Spearman | RMSE |
|---|---|---|---|
| PSNR | 0.6906 | 0.6422 | 4.2512 |
| MSSIM | 0.5948 | 0.6271 | 4.6009 |
| AMBE | 0.5712 | 0.5192 | 4.7037 |
| ENTROPY | 0.4731 | 0.3715 | 5.0679 |
| CIQ | 0.8019 | 0.7874 | 3.4197 |

The performance of the proposed method CIQ has been assessed and compared with other methods for the forty two colored images used in the experiment. For the comparative study, we use Pearson, Spearman, and RMSE indices as illustrated in.

## 7 CONCLUSION

There are so many image quality evaluating metrics used for gray images, but still we lack image quality metrics IQM to be implemented over colored images in order to get the quality of the image. In our experiment we gathered three attributes of the image: naturalness, colorfulness, and contrast to compute image quality index. We believe that image depends on more than one factor in order to measure its quality.

## REFERENCES


[1] T. a. B. F. Janssen, "Predicting the usefulness and naturalness of color reproductions," *J. Imaging Sci. Technol.*, vol. 44, pp. 93-104, 2000.

[2] S. W. P. O. Raisa Halonen, "Naturalness and interestingness of test images for visual quality evaluation," *Proc. SPIE7867, Image Quality and System Performance VIII*, 24 January 2011.

[3] E. Adelson, "Lightness Perception and Lightness Illusion," *The New Cognitive Neuroscience*, vol. 2, pp. 339-351, 2000.

[4] M. D. Faichild, Color Appearance Models, vol. 2nd Ed., Chichester: Wiley-IS&T, 2005.

[5] M. K. a. S. H. P. Krawczyk G., "Computational model of lightness perception in high dynamic range imaging," *Human Vision and Electronics Imaging XI*, 2006.

[6] E. Peli., "Contrast in Complex Images," *Journal of the Optical Society of America*, pp. 2032 - 2040, 10 1990.

[7] M. Cadik and P. Slavik, "The Naturalness of Reproduced Hight DynamicRange Images," in *Proceedings of the Ninth International Conference on Information Visualisation (IV'05), IEEE*, 2005.

[8] T. J. W. M. J. a. F. J. J. Blommaert, "Image Quality Semantics," *Journal of Imaging Science and Technology*, vol. 41, no. 5, pp. 555-560, September/October 1997.

[9] A. R. Adrian Ford, "Colour Space Conversion," 11 August 1998.

[10] C. Models, "http://software.intel.com/sites/products/documentation/hpc/ipp/ippi/ippi_ch6/ch6_color_models.html," [Online].

[11] G. W. a. W. S. Stiles, Color science: concepts and methods, quantitive data and formulas, vol. 2, New York: John Wiley and Sons, 1982.

[12] F. B. a. H. d. R. S. Yendrikhovskij, "Perceptually optimal color reproduction," in *Proc. SPIE: Hum. Vision Electron. Imag. III 3299*, 1998.

[13] a. S. S. S. Hasler, "Measuring colorfulness in real images," in *Proc. SPIE Electron. Imag.: Hum. Vision Electron. Image.*, 2003.

[14] Q. W. a. Z.-Y. W. Kai-Qi Huang, "Natural color image enhancement and evaluation algorithm based on human visual system," *Computer Vision and Image Understanding*, vol. 1, p. 52–63, July 2006.

[15] S.-D. C. a. A. b. Suleiman, "Scalable global histogram equalization with selective enhancement for photo processing," in *Proceeding of the 4th International Conference on Information Technology and Multimedia*, Malaysia, 2008.

ISSN 2229-5518

**Yusra A. Y. Al-Najjar** was born on January 12, 1965 in Zarqa, Jordan. She received her B.E. degree in Computer Science from Kuwait University at 1986, M. Sc. in Computer Science from Al-Balqa'a Applied University at 2008. She is a LECTURER in KSA King Faisal University. Here research interest includes image enhancement, noise reduction, and Networks.

**Soong Der Chen** (M'2002) was born in October 6, 1973 in Kuala Lumpur, Malaysia. He received his B.E. in Electronics/Computer (1997), M.Sc (2000) and Ph.D (2008) from the Dept. of Comp. and Comm. Engineering in Universiti Putra Malaysia (UPM), Malaysia. Currently he is a senior lecturer in the Dept. of Graphics and Multimedia, College of IT, Universiti Tenaga Nasional (UNITEN). His research interest includes image quality assessment, image enhancement, computer vision and image compression.