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A Full-Reference Enhanced Image Quality Index Based on Visual Image Attributes

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Abstract —*Past decades have witnessed a fast growth in developing objective image quality assessment (IQA) algorithms that measures image quality dependably with subjective evaluations. On the other hand, many new large scale image datasets have been released in the sake of evaluating FR IQA methods in recent years. Little of the approaches for IQA have been done in the field of image attributes.*
In this paper, we aim to fulfil this task by proposing an index that measures image quality using image attributes applied over a non-compressed database; and then conduct a comparison with other proposed image quality indices. Our evaluation results and the associated discussions will be very helpful for relevant researchers to have a clearer view.
Our research aims to develop a NR measurement index for TIF non-compressed images – to avoid any type of noise that might be caused by compression process. Image database used was selected from different databases such as LIVE [1], CSIQ [2], and DRIQ database [3]. A subjective experiment was conducted on this database. In our research we propose an index that measures the quality of the image depending on its naturalness, colourfulness, contrast and noise in the image, see Figure. 1. Furthermore, we present a computational Full-Reference (FR) index model for TIFF images. A subjective result – Mean opinion Score (MOS) **-** *is used for verifying the quality of this index, which achieved good quality prediction performance.*

Keywords-*Full-reference image quality index, Image Attributes, image enhancement, natural scene.*

I. INTRODUCTION

Rapid development of digital imaging and communication technologies has made the image quality assessment (IQA) a significant issue in various applications. So, we can see that the researchers' community has developed many automatic IQA methods in the past decades. According to the availability of a reference image, objective IQA indices can be classified as full reference (FR), no reference (NR) and reduced reference (RR) methods [4]. In this paper, our discussion is limited to FR methods.

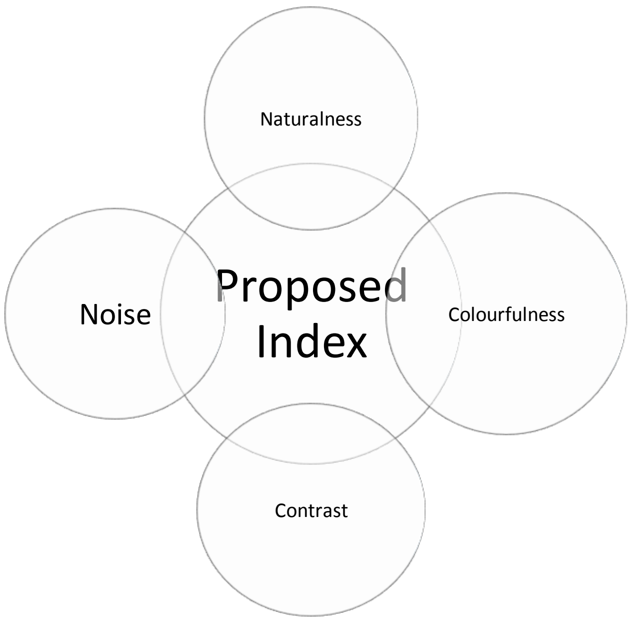

Figure 1: A diagram that shows items related to proposed index

It has been clearly notified that the traditional IQA indices, such as the peak signal-to-noise ratio (PSNR), that is applied directly on the intensity of the image, does not correlate well with the subjective fidelity ratings. Thus, many efforts have been made on designing sophisticated computational IQA models and great progress has been achieved in this area in the past decade. A great effort has been made in the field of objective image/video quality assessment that incorporate perceptual quality measures by considering characteristics.

II. EXPERIMENT

The experiment was conducted using a collected dataset from different databases, contrast reduced, and then contrast enhanced to different levels. The dataset contained up to 92 images in TIF format to avoid disturbance caused by any compression as shown in Figure 2.
The experimental setup selected is a Single Stimulus Continuous Quality Scale (SSCQS) methodology according to the recommendations from the International Telecommunication Union (ITU) standard in their ITU-T Recommendation P.910 (09/99) report[5], single stimulus - is known Absolute Category Rating (ACR) - is a method where distorted images are displayed each at a time. The subject needs to rate the level of quality for each contrast enhanced image without any reference depending on image attributes that exist in the image and the amount of noise that appears.
The participants had a simple training session of total 5 images. The order of the stimuli was randomized to counterbalance order effects; the subjects were college students, they were asked to evaluate each image to a score between 1 and 100 (100 presents the best quality where 1 is the worst). The 30 scores of each image for a 92 image that made a 2760 score were averaged for a final Human Visual System (HVS) called Mean Opinion Score (MOS).
The main goal of this research is to develop a FR objective image quality index so it was nice to comprehend a comparison to see how other FR double stimuli algorithms correlate with the MOS values. The peak signal-to-noise ratio (PSNR) measure of quality works by first computing the mean squared error (MSE) and then dividing the maximum range of the data type by this MSE. This measure is simple but sometimes it doesn't align well with perceived quality by humans, even though it has been employed as a reference model to evaluate the effectiveness of other objective image/video quality assessment approaches [6].
On the other hand, The Structural Similarity (SSIM) Index measure of quality works by measuring the structural similarity that compares local patterns of pixel intensities that have been normalized for luminance and contrast. This quality metric is based on the principle that the human visual system is good for extracting information based on structure.

Figure 2: Some of the experimental test images

III. PROPOSED IMAGE QUALITY INDEX

Images used in the experiment were contrast reduced using *imadjust* in Matlab, and then each of these reduced contrast images was enhanced using the tool presented by Dr. Chen (SGHESE) in [7] with some little modifications to suit our research, Figure 3; the result of enhancing the image resulted in well enhanced images and unnatural images due to distortion caused by over enhancement giving unnatural results such as excessive brightness, noise artefacts, and brightness saturation [8].

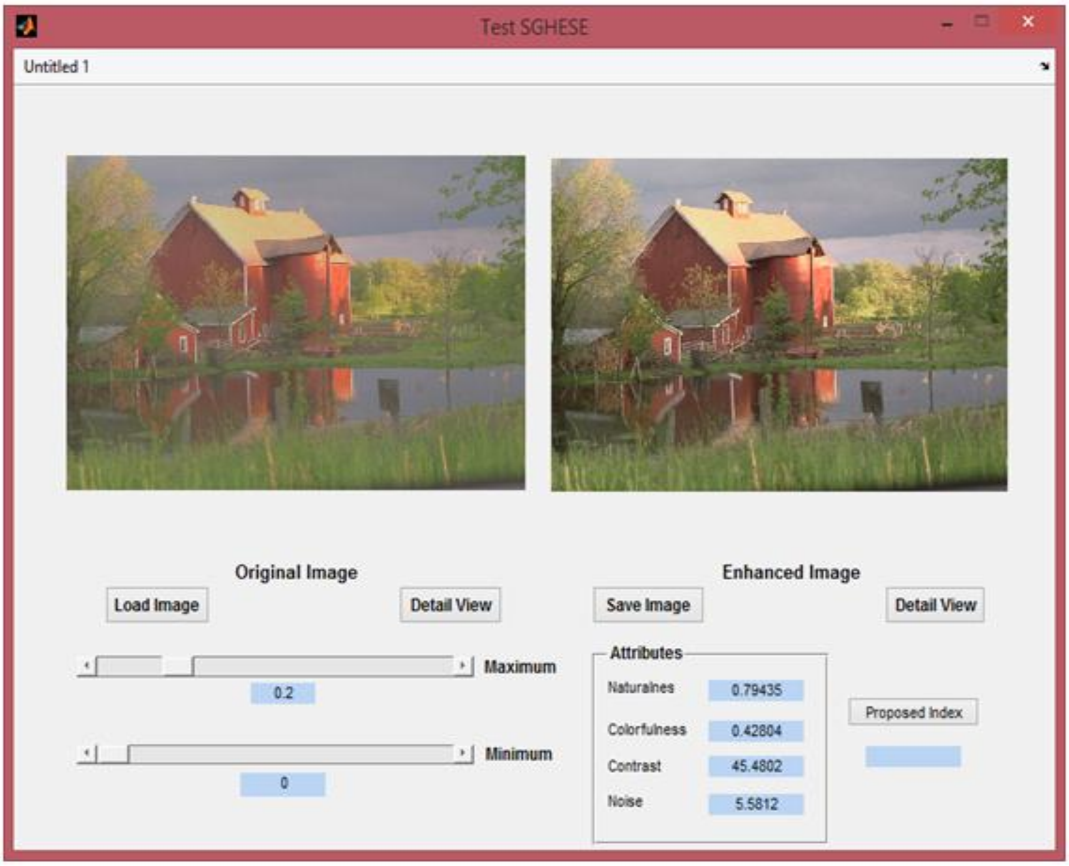

Figure 3: Tool used for image enhancement [7]

In designing naturalness index the following steps in the diagram in Figure 4 were followed.

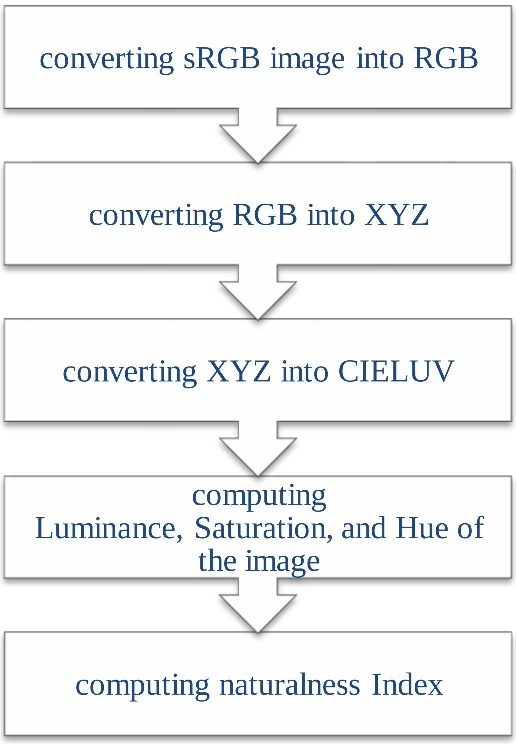

Figure 4: Steps followed in designing naturalness index

Figure 5 show images in different colour spaces.

Figure 5: From left to right: Original image (sRGB), image in RGB mode, Image in XYZ colour space, and image in CIELuv colour space for three images horse, beach, and forest

Converting the sRGB to RGB more intensive color is done using the following equation:

$$d(K) = \begin{cases} \left(\frac{K+0.055}{1.055}\right)^{2.4}, & \text{if } K > 0.04045 \\ \frac{K}{12.92} & \text{, otherwise} \end{cases} \quad (1)$$

While the following metrix was used to convert into XYZ color space:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \times \begin{bmatrix} d(R) \\ d(G) \\ d(B) \end{bmatrix}, \quad (2)$$

Next the image in XYZ colour space is converted into CIELuv colour space where luminance, hue, and saturation are computed as follows:

$$L^* = \begin{cases} 116\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16, & \text{if } \frac{Y}{Y_n} > 0.008856 \\ 9.03.3\left(\frac{Y}{Y_n}\right), & \text{otherwise,} \end{cases} \quad (3)$$

$$H_{uv}^* = \arctan(v^* / u^*), \quad (4)$$

$$S^*_{uv} = \frac{C^*_{uv}}{L^*} = \frac{\sqrt{(u^*)^2+(v^*)^2}}{L^*} \quad (5)$$

The second step was to compute image contrast index using the following equation[9]:

$$C_M = \frac{L_{max} - L_{min}}{L_{max} + L_{min}} \quad (6)$$

Next find image color index using the equation:

$$Cl_y = \sigma_{rgyb} + 0.3 * \mu_{rgyb} \quad (7)$$

Where the mean and the standard deviation are:

$$\sigma_{rgyb} = \sqrt{\sigma^2_{rg} + \sigma^2_{yb}} \quad (8)$$

$$\mu_{rgyb} = \sqrt{\mu^2_{rg} + \mu^2_{yb}} \quad (9)$$

And finally compute noise index according to the equation:

$$NR = \mu(\sigma(im(:))) \quad (10)$$

Now since we have all the indices we need, we combined then to form image quality index as in the following equation:

$$Q_i = (1 - w_q) * N_i + w_q * \left(\frac{Cl_i}{Cl_{max}}\right) + 0.5 * C - NR \quad (11)$$

Where w_q = 0.75. Constants used in the equation are experimental constants.

IV. RESULTS

Applying proposed index over the set of test images provided gave prediction results displayed in Figure. 6.

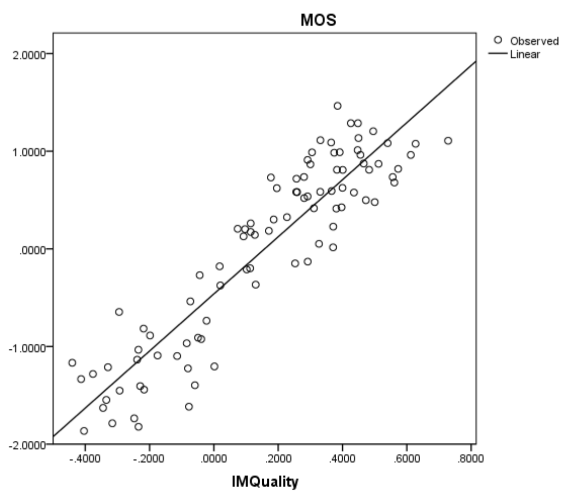

Figure6: Model prediction resulted from proposed image quality index IMQuality vs. MOS

Comparing proposed index with available image quality algorithms, see Table 1, gave the results listed in the table, Whereas Figure 7 shows results in columns.

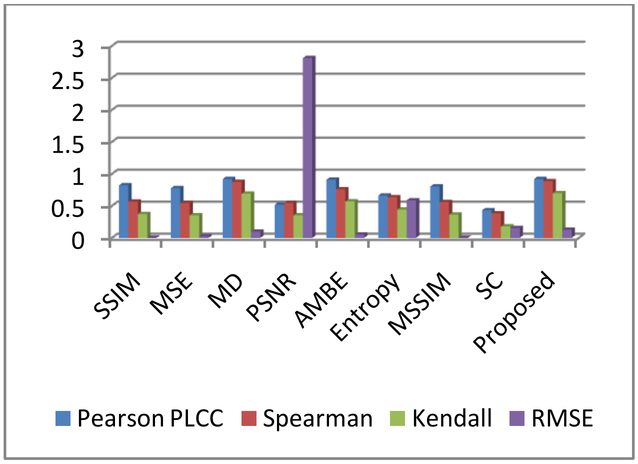

Figure 7: correlation coefficient for different types of image quality matrices.

Table 1: Correlation coefficient for the proposed index versus other quality metrices

Matric	Pearson PLCC	Spearman SROCC	Kendall KROCC	RMSE	Kurtosis
Structural Similarity (SSIM)	0.8219	0.5681	0.3727	0.003108	3.4187
Mean Square Error (MSE)	0.7758	0.5434	0.3521	0.02519	2.3624
Maximum Difference (MD)	0.9201	0.8760	0.6906	0.09686	2.3377
Peak Signal-to-Noise Ratio (PSNR)	0.5169	0.5434	0.3521	2.81	3.8709
AMBE	0.9093	0.7572	0.5695	0.05009	1.5675
Entropy	0.6620	0.6358	0.4424	0.587	1.6006
Mean SSIM (MSSIM)	0.8029	0.5595	0.3641	0.003911	2.7612
Structural Content (SC)	0.4321	0.3825	0.1782	0.1531	1.7971
Proposed IMQuality	0.9191	0.8857	0.6995	0.1266	2.0365

V. DISCUSSION

It is clear from Table. 1 and the chart in Figure 7 that proposed index gave a better Pearson and Spearman correlation results with less Root Mean Square error (RMSE) compared to the others, while PSNR gave the worst correlation.

Structural similarity SSIM and mean structural similarity MSSIM gave good results, that is because they take into consideration human perception item in estimating image quality. Maximum difference and ambe done well despite they have a different view in estimating image quality.

Based on the evaluation results, we can say that IQA indices that are designed to get a quality prediction to be consistent with human perceptions are capable of giving a better performance than IQA indices that are designed to work with pixels difference. Another thing is that the objective scores predicted by the proposed index are highly consistent with the subjective evaluations.

VI. CONCLUSIONS

In this paper, we have tested proposed index in comparison with other available indices on selected image dataset. Their prediction performance was reported.

We demonstrated a novel FR perceptual quality assessment index scheme for TIF non-compressed images. Subjective experiment was conducted to evaluate the quality of the TIF images. The attributes described in the paper (naturalness, contrast, colour, and noise) are the most noticeable attributes used in evaluating any image and the non-linear (curve-fitting-tool) gave a good agreement with MOS scores.

The proposed index is computationally efficient since indices were computed in their proper colour spaces. The basic methodology of the proposed index can be used to develop other FR quality indices for compressed images.
The implementation for the proposed index was done using Matlab.

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