

# Weber's law based PSNR for perceptual image quality evaluation

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## Abstract

Conventional objective image quality evaluation considers little influence of human vision psychology. Weber's law claims that human's perception and response to the intensity fluctuation of visual signals varies with the background light intensity. This paper applies the well known perceptual law to the conventional image quality evaluation method peak signal-to-noise ratio (PSNR). Simulation results show that the proposed Weber's law based PSNR enhances the evaluation capability of PSNR regarding the perceptual meaningfulness.

## 1. Introduction

Image quality evaluation plays an important role in image processing research and development. Basically, current image quality evaluation methods can be classified into either subjective or object measure. An ideal image quality evaluation should be simple in computation, useful in analysis and meaningful in perception [1]. Peak signal-to-noise ratio (PSNR) is one of the reliable objective image quality evaluation methods, which is defined as Eq.1. The PSNR has been most commonly used thanks to its computational simplicity, analytic usefulness and somewhat perceptual meaningfulness.

$$PSNR = 10 \log_{10} \frac{(2^{bitDepth} - 1)^2}{\frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (x_{i,j} - \hat{x}_{i,j})^2} \quad \text{Eq. 1}$$

In Eq.1, M and N are image width and height in terms of pixel.  $x_{i,j}$  and  $\hat{x}_{i,j}$  is the original pixel value and the reconstructed pixel value, respectively. *bitDepth* represents the bit depth of the image under evaluation. For instance, the bit depth of eight has been widely used in current consumer applications. Noticed that the PSNR evaluates image quality via the mean square error (MSE), which is independent of the original pixel light intensity. However, from Weber's law, it is known that the noticeable light difference is proportional to the original pixel intensity. Therefore, inspired from the characteristic of human visual system, a Weber's law based PSNR is proposed in this paper for perceptually meaningful image quality evaluation.

The organization goes as follows. In Section 2, the Weber's law is briefly reviewed, followed by an explanation of the proposed Weber's law based PSNR. Section 3 analyzes the simulation results. The conclusion goes into Section 5.

## 2. Weber's law based PSNR

Weber's law was first described in 1834 by E.H. Weber, and was later formulated by Gustav Fechner [2]. Weber's law states that human's sensitivity to the light intensity change  $\Delta I$  is approximately proportional to the background intensity  $I$ . The Weber's law can be expressed as Eq.2,

where k is the Weber's fraction which is a constant.

$$\frac{\Delta I}{I} = k \quad \text{Eq. 2}$$

Based on the above observation, the Weber's law based PSNR is developed as illustrated in Eq.3, which attempts to considerate the influence of human vision psychology into the image quality evaluation regarding the perceptual capability.

$$PSNR = 10 \log_{10} \frac{(2^{bitDepth} - 1)^2}{\frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} w_{i,j}^2 (x_{i,j} - \hat{x}_{i,j})^2} \quad \text{Eq. 3}$$

$$w_{i,j} = 0.02 \times (2^{bitDepth} - x_{i,j}) \quad \text{Eq. 4}$$

Where a perceptual weight  $w_{i,j}$  is developed according to Weber's law,  $w_{i,j}$  is defined as Eq. 4, where the coefficient 0.02 is derived from the Weber fraction. From Eq.4, it can be seen that as the pixel intensity goes larger, the perceptual weight  $w_{i,j}$  goes smaller. While when the pixel intensity gets smaller, the weight  $w_{i,j}$  gets larger. With the perceptual weight, the Weber's law based PSNR brings larger weight to the distortion where the background intensity is smaller, while brings lighter weight to the distortion where the background intensity is larger. In this way, the proposed method evaluates image quality taking both MSE and original pixel intensity into consideration. Therefore, the evaluation capability of PSNR, regarding the perceptual meaningfulness, can be improved. Further analysis on the Weber's law based PSNR regarding both the subjective and objective quality evaluation is given in the next section.

## 3. Analysis of experimental results

For evaluating the performance of the proposed method, experiments have been done on images with different contents and picture size. Tab. 1 and Tab. 2 illustrate the numerical values obtained from the proposed method and the conventional objective image quality evaluation method, which are denoted as PSNR\_w and PSNR\_o, respectively. Correspondingly, Fig. 1 and Fig. 2 present the subjective image quality comparison which includes the original images and images with degraded quality.

	PSNR_o	PSNR_w
Bus_CIF	25.284	14.4734
Flower_CIF	25.262	18.1789

Tab. 1 Objective image quality comparison with the original PSNR and the Weber's law based PSNR evaluation method. "bus" and "flower" sequence at CIF format

	PSNR_o	PSNR_w
Staples_4CIF	32.751	19.8448
Harbor_4CIF	32.79	25.2466

Tab. 2 Objective image quality comparison with the original PSNR and the Weber's law based PSNR evaluation method. "staples" and "harbor" sequence at 4CIF format

Basically, with the proposed method, the distortion between the degraded image and the original image is scaled with its corresponding weight coefficient according to the background intensity. Therefore, the dynamic range of PSNR\_w becomes wider than that of the conventional PSNR\_o. From Tab. 1 and Tab. 2, it can be seen that images with a similar conventional PSNR present different objective quality with the proposed method. An observation on the subjective image from Fig. 1 and Fig. 2 shows that, generally, the "bus" and "staples" image are darker than the "flower" and "harbor" image. This is also reported from Fig. 1(e) and (f), where the histogram of the "bus" and "flower" image are illustrated, respectively.

From the subjective quality evaluation on Fig. 1(c) and (d), it can be seen that the "flower" image presents better subjective quality in comparison with the "bus" image where most of the degraded image quality, especially the leaves part, can be apparently noticed and become annoying. With conventional PSNR\_o, a similar PSNR is reported for both images. However, the Weber's law based PSNR\_w reports a higher PSNR for the "flower" image while a lower PSNR for the "bus" image. Therefore, the proposed PSNR\_w method works better than the conventional PSNR in sense of the meaningfulness of the perceptual image quality evaluation.

A similar performance of the proposed method can be observed from Tab. 2 and Fig. 2, where the "staples" and "harbor" images are employed for the image quality evaluation. From the observation, it can be seen that when a similar distortion in terms of the MSE is reported by the conventional PSNR\_o, while a different quality degradation is actually perceived from the subjective image, the proposed method PSNR\_w reports different image quality evaluation. Regarding the brighter image, say, the "harbor" image, where the noticeable distortion threshold is larger than that for the darker image, for instance, the "staples" image, the proposed method reports a higher PSNR for the image with a higher background intensity than that for the image with a lower background intensity. From the experimental results, it shows that the Weber's law based PSNR reflects image quality much closer to the human perceived image quality than the conventional method.

#### 4. Conclusion

This paper developed a Weber's law based PSNR for

perceptual image quality evaluation. The proposed method takes the influence of human vision psychology into consideration during the design of the evaluation method. Results of the experiments show that the developed method enhances the evaluation capability of PSNR in sense of perceptual meaningfulness.

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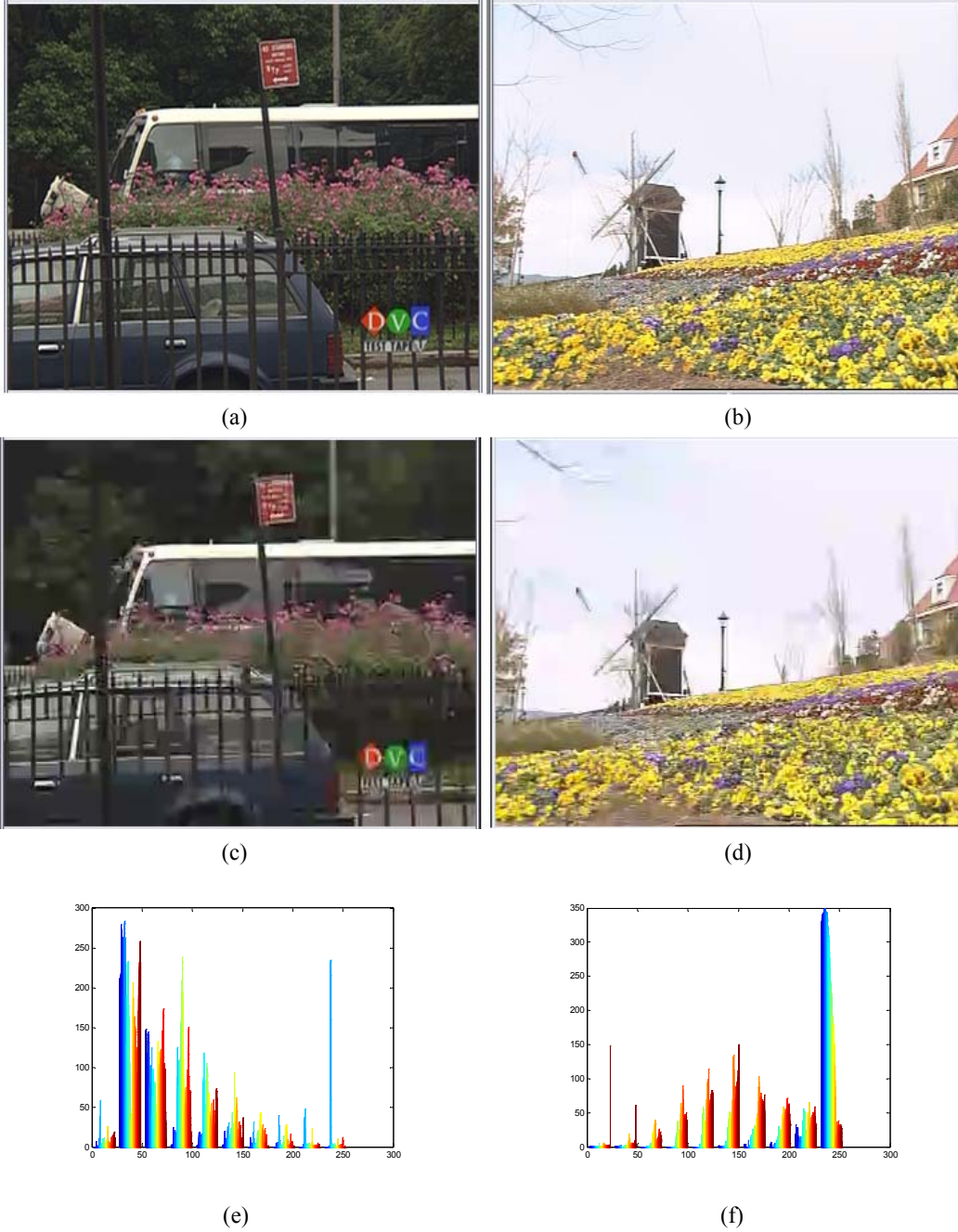
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#### Biography

**Jie Jia** received the B.S. and M.Eng. degrees in communication engineering from Xidian University, Xi'an, China, in 2000 and 2003, respectively. Since then, she has been working toward the Ph.D. degree in communication engineering at Xidian University, Xi'an China. She had been a researcher at Sejong University, Seoul, Korea from 2005 to 2007. Since 2007, she has been working toward the Ph.D. degree in computer science, Sejong University, Seoul, Korea. Her current research interests include video compression, scalable video coding, and error- and packet-loss resilient video coding.

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**Fig. 1** Subjective image quality comparison for “bus” and “flower” sequence (a) original “bus” image (b) original “flower” image (c) degraded “bus” image (d) degraded “flower” image (e) histogram analysis for “bus” image (f) histogram analysis for “flower” image



(a)



(b)



(c)



(d)

**Fig. 2** subjective image quality comparison for “staples” and “harbor” sequence (a) original “staples” image (b)original “staples” image (c) degraded “harbor” image (d) degraded “harbor” image