Image Fidelity Assessment Using the Edge Histogram Descriptor of MPEG-7

Chee Sun Won

ABSTRACT—An image fidelity assessment using the edge histogram descriptor (EHD) of MPEG-7 is presented. Neither additional data nor fragile watermarking is needed, and there is no need to access the original image as a reference. Only the EHDs of the original image and the received image are required. The peak signal-to-noise ratio (PSNR) obtained by comparing the EHD extracted from the received image and that of the original image is used to assess the noise level of the received image. Experimental results show that the PSNRs calculated from the conventional pixel-to-pixel gray level and from the proposed bin-to-bin EHD maintain a proportional relationship. This implies that the EHD can be used instead of image data for the image fidelity assessments.

Keywords—MPEG-7, edge histogram descriptor, watermarking, image fidelity assessment.

I. Introduction

A fragile watermark can be embedded into an original image for image fidelity [1], [2]. The embedded watermark should be changed in accordance with the channel status so that the difference between the original watermark and the extracted one at the receiver can indicate the noise level in the transmission channel. Thus, the watermark extracted at the receiver can be used for the following multimedia communications [2]: control feedback to the sending user on the transmission quality of the link, detailed information to the operator for billing purposes, and diagnostic information to the operator on the channel status of the link. In previously proposed approaches, image quality assessment requires watermark embedding, which results in modification of the image data. This may deteriorate the quality of the original image. Also, the original image or watermark should be available at the receiver to be compared with the watermark extracted from the received image. This full-reference method is not applicable to most current multimedia communication scenarios. Instead, the concept of the quality-aware image [3] was recently proposed, in which certain features of the original image are embedded into the original image and are extracted at the receiver to measure the quality of the distorted image. The merits of this reduced-reference method are twofold. First, it does not require full access to the reference image, but only extracted features of the image. Second, the extracted features of the reference image are embedded into the image. No additional channel for the delivery of the extracted features is required. However, this approach is still in the realms of image watermarking.

In this paper, as in studies using the quality-aware image [3], we make use of the image features extracted from the original image for assessment. Here, we adopt the MPEG-7 descriptor [4], [5] as the extracted image features. Since the MPEG-7 visual descriptor is already attached to the image file as meta-data for image indexing and retrieval, neither data embedding nor an additional channel to send the extracted image features is required.

II. Image Fidelity Assessment

The EHD of the MPEG-7 visual descriptors represents the distribution of five edge types: vertical, horizontal, 45-degree diagonal, 135-degree diagonal, and non-edge. The distribution of the five edge types is represented by 16 local edge histograms. Each local histogram is generated from a sub-image, which is a non-overlapping 4×4 partition of the given image. Thus, the total number of bins in the EHD is 80, which equals 16 sub-images × 5 edge types. For more detail on the EHD, see [4] and [5].

Let us assign a number to each edge type: 1 for vertical, 2 for

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horizontal, 3 for 45-degree diagonal, 4 for 135-degree diagonal, and 5 for non-directional. Then, denote the EHD bin value of the k-th edge type of the sub-image at (i, j) as $E_{ij}(k)$, where $i, j \in \{0, 1, 2, 3\}$ and $k \in \{1, 2, 3, 4, 5\}$. Suppose that we have the two EHDs, $E_{ij}(k)$ of the original image and $E'_{ij}(k)$ of the received (possibly deteriorated) image. If the original image is changed or degraded, then the EHD of the original image will be different from that of the degraded image, yielding $E_{ij}(k) \neq E'_{ij}(k)$.

Since any change in the image data could distort the edge distribution in the image, the difference between the original EHD and the EHD extracted from the altered (or degraded) image can be used to measure the similarity between them. For example, the peak signal-to-noise ratio (PSNR) can be used as a measure of the similarity. Since the normalized EHD bin values are less than or equal to 1, we set the peak signal value as 1. Then, we can define the PSNR value P as

$$P = -10\log_{10}\left(\frac{1}{80}\sum_{i=0}^{3}\sum_{j=0}^{3}\sum_{k=1}^{5}\left(E_{ij}(k) - E'_{ij}(k)\right)^{2}\right). \qquad (1)$$

III. Experiments

To demonstrate the feasibility of the EHD for the measurement of image distortions, we compared the PSNRs obtained from the image-to-image matching (pixel-to-pixel gray level comparisons) with those obtained from the EHD-to-EHD (bin-to-bin histogram comparisons) matching. To include diverse image distortions and to guarantee the reproducibility of the experimental results, we used the Laboratory for Image and Video Engineering (LIVE) image database of the University of Texas at Austin [6].

There are five distortion types in the LIVE database. They are JPEG compressed images, JPEG 2000 compressed images, Gaussian-blurred images, white noisy images, and fast-fading Rayleigh channel noisy images. All 29 original images are distorted by the above distortion types with 4 to 6 different distortion parameters for each image. Note that, since the assessment method proposed in this paper is based on edge information, the distorted color images were converted into gray level images before we measured the PSNR.

Figures 1 to 5 show comparative graphs of the two PSNRs obtained by pixel-by-pixel gray level and bin-to-bin EHD comparisons. The results clearly demonstrate that the PSNR values obtained by the bin-to-bin EHD and those of the pixel-to-pixel gray level show proportional relationship. This implies that the proposed PSNR measurement with the EHD can be used as an alternative to the gray level PSNR obtained by image-to-image matching. However, the numerical comparisons in Table 1 show the different sensitivities of the two PSNRs for different

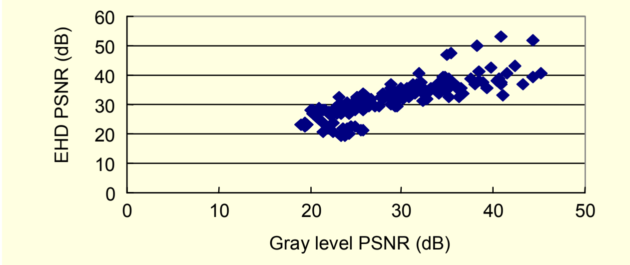

Fig. 1. EHD PSNR vs. gray level PSNR for JPEG distortions.

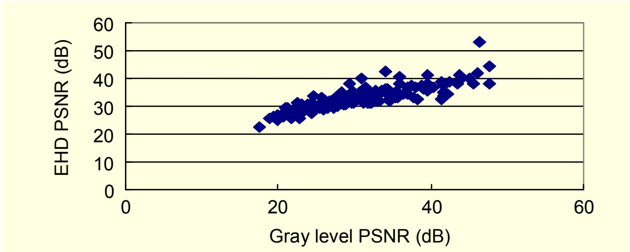

Fig. 2. EHD PSNR vs. gray level PSNR for JPEG 2000 distortions.

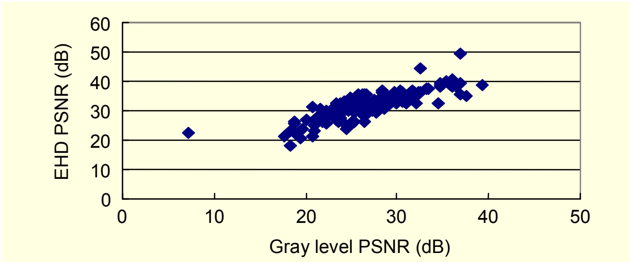

Fig. 3. EHD PSNR vs. gray level PSNR for blurring distortions.

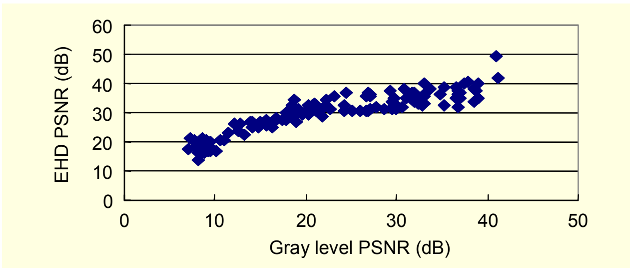

Fig. 4. EHD PSNR vs. gray level PSNR for white noise distortions.

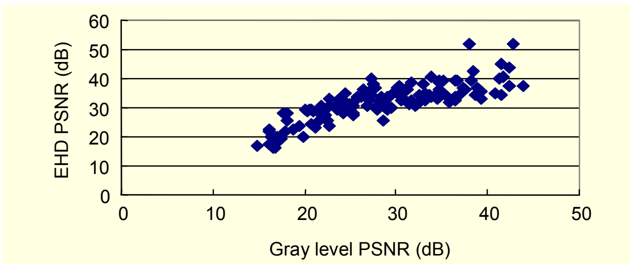

Fig. 5. EHD PSNR vs. gray level PSNR for fast fading distortions.

Table 1. Statistical data for the PSNR values.

Distortion types	Average gray-level PSNR (A)	Standard gray-level deviation	Average EHD PSNR (B)	Standard EHD deviation	Average of PSNR differences (A-B)	Standard deviation of PSNR differences	Number of test images
JPEG	28.93	6.18	31.63	6.16	-2.70	3.68	175
JPEG 2000	30.49	6.70	32.78	4.04	-2.29	4.00	169
Gaussian blur	26.88	4.88	31.74	4.73	-4.86	2.84	145
White noise	22.28	9.81	29.54	6.81	-7.26	4.74	143
Fast fading	28.20	7.12	31.39	6.14	-3.69	4.21	145

Fig. 6. White noise distorted images with the PSNR values of (a) 18 dB for gray level and 34 dB for EHD, and (b) 23 dB for gray level and 35 dB for EHD.

Fig. 7. JPEG distorted images with the PSNR values of (a) 23 dB for gray level and 21dB for EHD, and (b) 28 dB for gray level and 35 dB for EHD.

noise types. The EHD PSNRs consistently yield higher values than the gray level PSNRs, and the difference between the two PSNRs is maintained almost constantly. For white noise, the difference is the largest (7.26). Also, the standard deviation of the gray level PSNR (9.81) is higher than that of its EHD PSNR (6.81). This implies that the gray level PSNR is more sensitive than the EHD PSNR for white noise.

A particular example which clearly demonstrates this sensitivity issue can be found in Fig 6. In the figure, although the visual difference between the two images is substantial, the difference between the EHD PSNRs is only 1 dB, whereas the difference between the gray level PSNRs is about 5 dB. An opposite case can be also found in JPEG distortion. In Fig 7, for the clearly visible JPEG distortions, the gray level PSNRs yield only a 5 dB difference, while the EHD PSNRs have a 14 dB difference. In terms of the standard deviations of the differences, the white noise distortion yields the largest value (4.74), which implies that the largest disagreements between the two PSNRs are for the white noise distorted images. Recalling that the main goal of the experiments is to show a proportional relationship between the proposed EHD PSNR and a conventional image quality measure, namely, the gray level PSNR, further comparative studies between the EHD PSNR and the gray level PSNR for various noise models and image types, varying from highly-textured images to almost non-textured images, are beyond of the scope of this paper and will be the subject of future work.

IV. Conclusion

A novel use of the EHD of the MPEG-7 visual descriptors was presented. It has been shown that the EHD can be used for fidelity measurement of image data. The proposed scheme requires no additional data to be stored. No watermark needs to be embedded and transmitted to the receiver. The PSNRs obtained from the EHD-to-EHD matching show similar tendencies to those obtained from image-to-image matching.

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