Quality Estimation Model of Monochrome Still Picture Based on Distortion Factors and Texture Features

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Abstract

In this paper, we investigate the improvement of the estimation accuracy of the objective quality metric method named "the Picture Quality Scale (PQS)". To eliminate the dependence of the picture content of the PQS, we newly employ the texture features as the independent variance and combine with the distortion factors. For constructing new PQS, we apply the nonlinear combination model between the Mean Opinion Score (MOS) and factors, which is based on the logistic function.

Then, to discuss the improvement of the PQS, we carry out the subjective estimation experiment for 144 pictures and obtain the MOS. Finally, the proposed PQSnew closely approximate well the MOS, with a correlation coefficient of more than 0.98.

Introduction

The evaluation of picture quality is indispensable in picture coding. Subjective assessment tests are widely used to evaluate the picture quality of coded picture. However, careful subjective assessments are experimentally difficult and the results obtained may vary depending on the test conditions. Instead of subjective assessment tests, several estimation methods have been already proposed.¹⁻⁶ The PQS which has already proposed as the objective quality metric method, is widely used for comparing other evaluation methods.^{5,7,8}

In this paper, we investigate the improvement of the estimation accuracy of the PQS.^{1,2} For improving the performance of the approximation between the MOS and the obtained PQS, two key technology is employed here. At first, to eliminate the dependence of the picture content of the PQS, we newly employ the grobal texture features of image as some regression factors. Then, for constructing the new PQS, we apply the nonlinear combination model between the MOS and selected several factors, which is based on the logistic function.

Picture Quality Scale (PQS)

The block diagram of the conventional PQS applied for monochrome still picture, is shown in Fig. 1. The distortion factors are defined as the function of the error which calculates between original and decoded picture. Before calculating the distortion factors, the visual weighting characteristic is applied to the error. In this model, the PQS is directly calculated from the distortion factors, by using the principal component analysis and multiple regression analysis. As the distortion factors, we employ 5 kinds of factors.^{1,2}



Figure 1. Conventional PQS system.

ITU-R television noise weighting standard
 weighted mean square error for visual perception
 end of block disturbances

4. correlated errors

5. errors in the vicinity of high contrast image transitions

The value of the PQS is obtained by

$$PQS = b_0^* + \sum_{n=1}^J b_n^* Z_n.$$
 (1)

Construction of a PQSnew

Then, we investigate the improvement of the estimation accuracy of the PQS. To eliminate the dependency of the picture content of the PQS, we newly employ the global texture features as the independent variable and combine with the distortion factors. For constructing the new PQS, we apply the nonlinear combination model between the MOS and selected factors, which is based on the logistic function.

The block diagram of the new PQS (PQSnew) is shown in Fig. 2. The texture features used in this time are 11 kinds.⁹ There are

- 1. angular second moment,
- 2. contrast,
- 3. correlation,
- 4. variance,
- 5. inverse difference moment,
- 6. sum average,
- 7. sum variance,
- 8. sum entropy,
- 9. entropy,
- 10. difference variance,
- 11. difference entropy.

The PQSnew is defined as following equations,

$$PQSnew = \frac{4}{1 + \exp\{-\beta(PQS^* - 3)\}} + 1$$

$$PQS^* = b_0^* + \sum_{n=1}^J b_n^* Z_n + \sum_{m=1}^K b_{m+J}^* Y_m,$$
(2)

where Zn (n=1...J), Ym (m=1...K) denotes the principal component of the distortion factors and the texture features, respectively, bi* (i=0...K+J) shows the partial regression coefficients which is obtained from the least square estimation for the nonlinear parameters. β implies the gradient which PQSnew = PQS* = 3.

Visual Assessment Test

Then, to discuss the improvement of the PQS, we carry out the subjective visual assessment test for 144 pictures (including 24 original pictures) and obtain the MOS. The conditions and the MOS grading scale of the subjective assessment are shown in Table 1, 2, respectively.

The observers are asked to assign a subjective score A(i,k) to each decode picture, where A(i,k) is the score given by the i-th observer to picture k. For each assessed picture, the score are averaged to obtain the MOS value for a specific picture, where n denote the number of the observers.

$$MOS(k) = \frac{1}{n} \sum_{i=1}^{n} A(i,k)$$
 (3)



Figure 2. New PQS system (PQSnew).

Table 1. Conditions of the subjective assessment.

Pictures	24 pictures (ITE Standard Pictures : 5 pictures, Barbara, Kodak Photo CD : 1	
	pictures)	
Coding method	JPEG coding (Q-scale : 0.5, 1, 2, 3, 4)	
Visual Distance	4H (H : picture height)	
Lighting	quasi-dark room	
Number of	-	
observers	12 persons (8 times for each picture),	
	expert observers.	
Time of		
observation	unlimited	
Scale	5 grading scale	

Table 2. MOS grading scale.

Number 5	Impairment Imperceptible
4	Perceptible, but not annoying
3	Slightly annoying
2	Annoying
1	Very annoying

Results

The assessment tests are obtained in a set of 24 pictures encoded with JPEG standard coder and for the entire range of quality. The average MOS score was computed for each decoded picture.

Principal Components of Distortion Factors

The distortion factors were defined so as to quantify specific types of impairments. Clearly, some of the local picture impairments will contribute to several or all factors, and the all factors will be correlated.

A principal component analysis is carried out to quantify this correlation between distortion factors. In this case, 3 kinds of principal components which the cumulative contribution rate is more than 99%, are obtained. The relation between the MOS and the principal components of the typical 6 pictures are shown in Fig. 3. These pictures, shown in Figure 3, include the ITE test pictures ¹⁰ "Ch : Church", "Da : Color matching chart", "Ha : Hairband", "Tu : Tulip" and "We : Weather", and the widely used "Ba : Barbara"pictures.

In Fig. 3(a), all plotted lines are the tendency with left up. It implies that Z1 express "the amount of error". The "Tu", "Ch" and "Ba" pictures contain with many edge parts and detail objects. On the other hand, the "Da", "Ha", "We" pictures consist of several objects and clear background. Hence, the gradient of this line increases in proportion with the complexity of picture content.

For the principal component 2 illustrated in Fig. 3(b), the curve are roughly categorized with 2 groups. The outline of one group is similar with a inverse logarithmic curve,. another is a quadratic function with upper convex shape. Especially, it is clear that the shape of convex is severe of the picture which contains the detail parts. So, Z2 implies "the structure of error based on the image content".

In Z3, there isn't any tendency for picture content and distortions. As the result, it seems that Z3 works as the corrective term of multiple regression between the MOS and the principal components.

Principal Components of Texture Features

Next, we analyze the principal components of texture features. From the result of the principal component analysis, the cumulative contribution rate achieves 99% by summing the 6th components. The relation between several principal components of texture features and the MOS are shown in Figure 4.

In Y1, the cross correlation between Y1 and "Sum entropy" of texture feature is 0.90 and well correlated. From this fact, this component may imply "the complexity of image (Entropy)". It is clear that the Y1 indicated the entropy of image is decreasing with quality degradation.

The relation between component Y1 and component Y2 are illustrated in Fig. 4(b). The component Y2 is good agreement with "Variance" of the texture features and the correlation is more than 0.84. When the picture consists of many contours, the value of the component Y2 is increasing. Moreover, from this Figure, we can obtain several clusters whose texture features are almost same.

The rest components are insufficient for discussing the dependence of the MOS and texture features.



(a) MOS - Principal Component 1 (Z1)



(b) MOS - Principal Component 2 (Z2)



(c) MOS - Principal Component 3 (Z3)

Figure 3. Relation between MOS and principal components.

Performance of PQSnew

In this paper, we construct several types of new PQS. All of them are based to the results of the principal component analysis.

- 1. PQS(3,0,NL) : Constitute PQS with 3 distortion factors only. (K=3, J=0)
- 2. PQS(4,6,NL) : Making up PQS with 4 distortion factors and 6 texture features. (K=4, J=6)
- 3. PQS(4,6,L) : Making up PQS with 4 distortion factors and 6 texture features. Then, apply the logistic function. (K=4, J=6)



(a) MOS - Principal Component 1 (Y1)



(b) MOS - Principal Component 1 (Y2)

Figure 4. Relation between MOS and principal component of texture features

The results is shown in Table 3. In order to describe the degree of approximation of several PQS and MOS quantitatively, the adjusted correlation coefficient R^* between several PQS and MOS is evaluated. The performance of these PQS are also shown in Figure 5 - 7.

Table 3. Performance for various PQS.

Туре	Correlation R*	Average of error	Maximum
PQS(3,0,NL)	0.937	0.35	1.05
PQS(4,6,NL)	0.961	0.26	0.92
PQS(4,6,L)	0.980	0.18	0.68



Figure 5. MOS - PQS(3,0,NL).



Figure 6. MOS - PQS(4,6,NL).



Figure 7. MOS - PQS(4,6,L)

From Figure 5, the conventional PQS [PQS(3,0,NL)] is good agreement with MOS. Hence, the defined distortion factors are very valid to evaluate the picture quality. Nevertheless, the some plotted data are out of the range of the defined scale.

By considering the texture features which depend on the picture contents, the performance of PQS(4,6,NL) is improved than PQS(3,0,NL).

A fairly good agreement between MOS and PQS(4,6,L) is achieved, as shown in Figure 7. As the result, PQS(4,6,L) is the best performance under the conditions described in this paper. So, we define PQS(4,6,L) as PQSnew.

Conclusions

We have proposed a improvement method for conventional quality metric named PQS (Picture Quality Scale) for monochrome still pictures. In addition to the typical distortion factors, by take into account the texture features for picture, the performance of PQS affected from the picture content is improved. Moreover, instead of linear combination between MOS and several principal components, we newly employ the non-linear combination model with the logistic function. The resulting PQSnew closely approximates the MOS. We have also discussed the role of principal components which was elected after principal component analysis. Finally, it is clear that PQSnew proposed here is useful under the condition of the trained picture data set.

References

- M. Miyahara, K. Kotani, V. R. Algazi, "Objective Picture Quality Scale (PQS) for Image Coding", *IEEE Trans. Comm*, COM-46, No.9, pp.1215-1226, (1998).
- M. Miyahara, K. Kotani, Y. Horita, T. Fujimoto, "Objective picture quality scale (PQS) - consideration of local feature and universality", *IEICE Trans.*, J73-B-I, No.3, pp.208-218, (in Japanese) (1990).
- S. Daly, "The visible differences predictor : a algorithm for the assessment of image fidelity", SPIE Human Vision, Visual Processing, and Digital Display III, 1666, pp.2-15 (1992).
- 4. S. A. Karunasekera, N. G. Kingsbury, "A distortion measure for blocking artifacts in image based on human visual sensitivity", *IEEE Trans. IP*, IP-4, No.6, pp.713-724, (1995).
- 5. H. Hamada, S. Namba, "A study on objective picture quality scale for pictures digitally encoded for broadcast", *IEICE Trans. Comm.*, E77-B, pp.1480-1487 (1994).
- A. M. Eskicioglu, P.S.Fisher, "Image quality measures and their performance", *IEEE Trans. Comm.*, COM-43, No.12, pp.2959-2965 (1995).
- N. Avadhanam, V.R. Algazi, "Prediction and measurement of high quality in still image coding", *SPIE Very High Resolution* and Quality Imaging, 2663, pp.100-109 (1996).
- 8. P. Franti, "Blockwise distortion measure for statistical and structural errors in digital images", *Signal Processing: Image Communication*, **13**, pp.89-98, (1998).
- R.M.Haraclick, K.Shanmugam, I.Dinstein, "Textural features for image classification", *IEEE Trans.* SMC, SMC-3, No.6, pp.610-621, (1973).
- 10. ITE, "ITE television system chart (version II)", tech. rep., Digital Standard Picture, ITE (1987).

Appendix

ITE television system chart (version II). These pictures consist of 256 * 256 pixels (8 bit/pixel).



A-1. Picture "Ch : Church"



A-2. Picture "Da : Color matching chart"



A-3. Picture "Ha : A girl with hairband"



A-4. Picture "Tu : Tulip"



A-5. Picture "We : Weather forecast"