Image Quality Assessment using Bacterial Foraging Optimization Algorithm

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Abstract— In this paper, we present new approach to the objective image quality evaluation based on discrete wavelet transform (DWT) and bacterial foraging optimization algorithm (BFO). DWT is applied on the difference between the original and degraded image, which is decomposed into approximation and detail sub-bands. DWT coefficients are computed using Haar wavelet filter banks. The coefficients are used to compute new image quality measure that is defined as perceptual weighted difference between coefficients of original and degraded image. Weighting factors for wavelet sub-bands have been experimentally determined using BFO algorithm to achieve the best possible correlation with results of subjective (perceptual) image quality evaluation. Test case results demonstrate that the proposed technique has high correlation with results of subjective test and low computational time important for real-time applications. The test cases also show that this image quality assessment method has a better results than traditional method and it can accurately reflect the image visual perception of the human eye.

Keywords— Discrete Wavelet Transform, MSE, PSNR, UQI, VSNR, SSIM, MSSIM, Image Quality Measure,

I. Introduction

Discrete wavelet transform (DWT) can be used in various image processing applications, such as image compression and coding [1]. In this paper we examine how DWT can be used in the image quality evaluation, which has become crucial for the most image processing applications. Quality of image can be assessed using dissimilar measures. The best way to do this is by making visual experiment, under controlled situations, in which human observer's grade which image provides enhanced quality. Such experiments are time consuming and costly. Much easier approach is to use some objective measure that evaluates the numerical error between the original images and tested one. In real world, there is no perfect way for objective assessment of image quality [2]. However, there is no current standard and objective definition of image quality.

II. Simulation Database

For performance evaluation, we chose the Tampere Image Database (TID2013) [3]. TID2013 is intended for evaluation of full-reference image visual quality assessment metrics. TID2013 allows estimating how a given metric corresponds to mean human perception.

The TID2013 contains 25 reference images and 3000 distorted images (25 reference images × 24 types of distortions × 5 levels of distortions). All images are saved in database in Bitmap format without any compression. File names are organized in such a manner that they indicate a number of the reference image, then a number of distortion's type, and, finally, a number of distortion's level: "iXX_YY_Z.bmp".

For example, the name "i03_08_4.bmp" means the 3-rd reference image corrupted by the 8-th type of distortions with the 4-th level of this distortion. Similarly, the name "i12_10_1.bmp" means that this is the 12-th reference image corrupted by the 10-th type of distortion with the first level. "i17.bmp" means that this is non-distorted 17-th reference image.

The Mean Opinion Scores (MOS) for this database were [4] obtained from the results of 971 experiments carried out by observers from five countries: Finland, France, Italy, Ukraine and USA (116 experiments have been carried out in Finland, 72 in France, 80 in Italy, 602 in Ukraine, and 101 in USA). Higher value of MOS (0 - minimal, 9 - maximal) corresponds to higher visual quality of the image.

Some of the existing objective measures described in previous section did not take into account HVS in the sense that eye will see and grade image quality according to the type of an error, as well as location of an error in sub-band space. Because of that, our method calculates image quality using wavelet decomposition and grades quality depending on the wavelet sub-band in which error occurs. Experiments on image databases have shown that different types of image degradation produce different error distributions in wavelet sub-bands. For example, for JPEG and JPEG2000 compressed images errors will be placed in the higher wavelet sub-bands (HH sub-band, level 2 and higher) while images with G blur and Fast fading degradations will also have errors in lower sub-bands. White noise has equally distributed errors in all sub-bands.

III. Discreate Wavelet Transform

In our research work error image of luminance component (difference between original and degraded image) is firstly transformed using DWT. [5] we used Discreate wavelet filter because it gives best results on both image databases, has even lengths and linear phase, while 2D DWT is shown in Figure below.

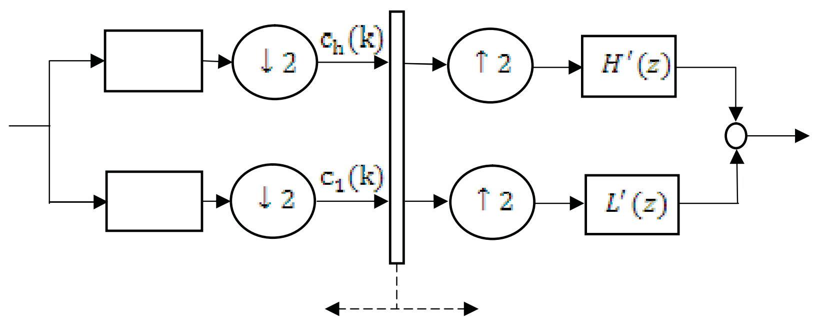


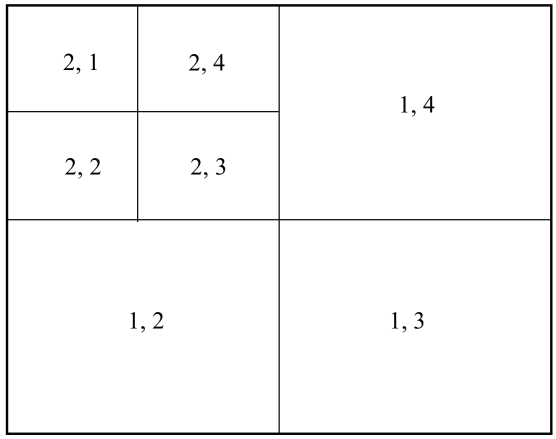
Figure 1. Discreate Wavelet Transform

After decomposing difference image into 2 level decomposition, error distance in each wave

$$E = \sum_i \sum_j |e_{i,j}| \ldots\ldots\ldots\ldots\ldots (1)$$

In equation $e_{i,j}$, are coefficients from difference image in the same sub band. Weighting factors for level 2 decomposition have been experimentally [6] determined using BFO optimization algorithm [7] and subjective scores from TID2013 database. Results of BFO optimization algorithm are weighting factors determined to give the best possible correlation results between subjective scores and IQM. They are presented in Table below.

Table 1: Best Possible Correlation



Final measure IQM is then calculated as:

$$Fitness\ Funtion = @(x, y)\quad sum\big(sum(x - y)\big)$$

We used (normalization) so that final IQM measure won't have high values and they don't influence on the correlation results very much. From above Table, it can be seen that all sub-bands have to be included in IQM measure, some have to be calculated using negative weighting factor (experimentally they give better results). Also, [8] higher decomposition levels made our measure over fitted to TID2013 database so it gave somewhat worse results on our subjective database (and only slightly better results on TID2013 database). Weighting factors for 2 level decomposition have been experimentally determined using BFO algorithm which gives the best possible correlation results. They are presented in Table below.

Table 2. Weighting factors for 2 level decomposition

Orientation (θ)	**Level (λ)**	
	1	**2**
1	**-**	**1**
2	**-0.211**	**-0.921**
3	**-4.6**	**1.7**
4	**-0.211**	**-0.921**

The Weighting factors, W_{lo} are multiplied with the corresponding Error Distances, E_{lo} obtained from the previous block, and the resultant variables are transferred to the final block for quality score assessment.

The Fitness Function Range, $\{rMin, rMax\}$ which is specified according to the subband level whose weighting factor we need to find. The corresponding range values, $\{rMin, rMax\}$, per subband level can be found experimentally by finding the minimum and the maximum difference between the pixels of the current subband of the original and all the degraded images present in the database used for simulation purpose.

IV. Final Score

The Final score is calculated using the following formulae,

$$\text{Image Quality Score} = \frac{1}{dim_1 * dim_2} \sum_l \sum_o W_{lo} * E_{lo} \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where,

W_{lo} → weighting factors,

E_{lo} → Error distances,

dim_1 → Original Image width,

dim_2 → Original Image height,

l → Sub band level, $l \in \{1, 2\}$,

o → Sub band orientation, $\in \{1, 2, 3, 4\}$.

The score obtained using the above formulae is in numeric format and is directly proportional to the quality of the image. More the score, better is the image quality.

V. Results

The graphic user interface (GUI) developed using Matlab 2013a. To calculate the image quality metrics using – PSO, SNR, PSNR, SSIM, UQI. The scores obtained are shown in the table corresponding to each metric and query image respectively. Also the image quality score per query image is calculated using BFO and the obtained results in the text boxes adjacent to "Query Image #1" and "Query Image #2" labels, respectively, in the "Our Algorithm" panel. As a test case we have considered 4th reference image from the TID2013 database as the original reference image. Query Image #1 is of "Additive Gaussian noise" type distortion (distortion number 1) and distortion level is 1. [9] Query Image #2 is of "Multiplicative Gaussian noise" type distortion (distortion number 19) and distortion level is 1. MOS of Query Image #1 is 5.76190. MOS of Query Image #2 is 5.45238. Thus, Query Image #1 is of better quality than Query Image #2. In this case we can say that BFO gives accurate scores than SNR, PSNR, SSIM and UQI.

As a test case we have considered 4th reference image from the TID2013 database as the original reference image. Query Image #1 is of "Sparse sampling and reconstruction" type distortion (distortion number 24) and distortion level is 3. Query Image #2 is of "JPEG compression" type distortion (distortion number 10) and distortion level is 5. MOS of Query Image #1 is 2.58587. MOS of Query Image #2 is 2.19048. Thus, Query Image #1 is of better quality than Query Image #2. In this case we can say that BFO gives accurate scores than PSO.

VI. Average Time

Average time required to calculate each of the objective measures described before is given in table below. [10] Total time required for each image quality assessment metric was calculated over entire TID2013 database and then averaged.

Table 3. Total time required for each image quality assessment

Measure	Time (in Sec.)
IQA_BFO	0.0355973616
SNR	0.0033380656
PSNR	0.0018976249
SSIM	0.0666972003
UQI	0.0692296434
IQA_PSO	0.0355063346

As seen from the above results IQA_BFO computes the score faster than SSIM and UQI, in almost half the time

VII. Conclusion

In this thesis we presented a technique to assess the quality of an image using Bacterial Foraging Optimization algorithm. We proposed a new image quality measure based on DWT in different wavelet sub-bands and BFO. Our image quality measures takes into account properties of human visual system and provide better results than some other quality measures. It also works well with image databases like TID2013. Proposed measure can also be considered as a good starting point for evaluation and fair comparison of different types of image degradation, especially in applications where image quality evaluation should be performed in real-time.

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