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No-reference image quality assessment algorithms: A survey

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ABSTRACT

Evaluation of noise content or distortions present in an image is same as assessing the quality of an image. Measurement of such quality index is challenging in the absence of reference image. In this paper, a survey of existing algorithms for no-reference image quality assessment is presented. This survey includes type of noise and distortions covered, techniques and parameters used by these algorithms, databases on which the algorithms are validated and benchmarking of their performance with each other and also with human visual system.

1. Introduction

Estimation of noise content of a signal/image and its subsequent removal is a very important area of research. Till these years, human intelligence was considered to be the only tool for sensing noise in signal/image. However, a few developments in signal processing like transform based statistical tools have generated a ray of hope that noise sensing by machines may become possible. This paper presents a brief review of major published algorithms for no reference noise sensing in an image which is referred to as 'image quality assessment' (IQA). Finally we present a few parameters for image quality assessment.

Quality of an image represents the amount of visual degradations of all types present in an image. Degradations may occur due to presence of noise, blocking artifacts, blurring, fading etc. These degradations are introduced during image acquisition, compression, storage, transmission, decompression, display or even printing. Sensing the degradation at the time of image acquisition can be useful to take counter measure to reduce the degradation while storing the image as a file. In general, sensing quality of an image during various stages of operations may be helpful for appropriate reconstruction. It saves unnecessary application of denoising algorithms. It may also suggest appropriate denoising or processing algorithm to retrieve quality of degraded image. A noise-sensing or IQA algorithm can provide types of distortions present in the image along with levels of degradation which can be used while denoising as shown in Fig. 1.

Overall image quality cannot be evaluated by only a few parameters like brightness, contrast or sharpness which can be mathematically calculated from image pixels. A sharp image can have salt and pepper noise present in it thereby devaluating its quality. A standardized evaluation procedure is required to assess the quality of an image irrespective of the type of distortions present. This evaluation procedure and the results should confirm well with human perception of an image quality.

The simplest way to evaluate the quality of an image is to show it to an expert human observer. However, human perception may be different for each individual. One can tackle this problem by taking multiple views from different individuals and then statistically processing the results. This is called subjective image quality assessment. But it is a very lengthy and imprecise procedure for quality evaluation. Right from selection of observers, their knowledge, expertise, availability, seriousness bias, interpretations everything is subjective and qualitative. Thus an automated system for quantitative evaluation of images is required. The problem can thus be represented as "Quantitative Evaluation of Quality". Obviously this may require a high level of intelligence.

Automated evaluation of image quality by means of machine is referred to as 'Objective Image Quality Assessment'. Objective image quality assessment can be accomplished in three ways,

(a) Full reference image quality assessment (FR-IQA)
(b) Reduced reference image quality assessment (RR-IQA)
(c) No reference image quality assessment (NR-IQA)

Full reference image quality assessment (FR-IQA) refers to assessing the quality of distorted image by comparing with the

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0030-4026/

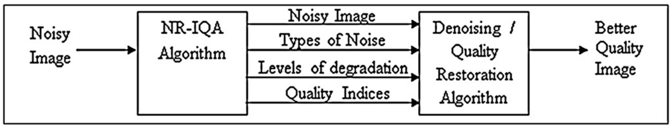

Fig. 1. Application of NR-IQA – image denoising.

original, believed to be undistorted version of same image. The extent of distortion is calculated by measuring the deviation of distorted image from the reference image. Simplest way to measure image quality is by calculating the peak signal to noise ratio (PSNR) however PSNR does not always correlate with human visual perception and image quality [1]. To tackle the limitation of PSNR metric, other parameters were proposed. Parameters which correlate well with human perception include structural similarity index (SSIM) [2], visual information fidelity (VIF) [3], Fast SSIM [4], information fidelity criteria (IFC) [5], Multi-scale Structural Similarity (M-SSIM) [6], four-component weighted structural similarity [7]. These parameters give the extent of deviation of a distorted image from the reference image. The need of reference image for quality evaluation limits the use of these parameters and subsequent quality evaluation algorithms.

Reduced reference image quality assessment (RR-IQA) algorithms are those which use only limited features from reference image instead of complete image to evaluate the quality of distorted image. A training approach can also be used for RR-IQA. RR-IQA methods are mentioned in [8–10]. The limitation of FR-IQA still remains in RR-IQA, i.e., features extracted from reference image are necessary for quality evaluation. In spite of all its limitations, the RR-IQA techniques are widely used in satellite and remotely sensed image quality evaluation.

No reference image quality assessment (NR-IQA) algorithms provide quality of an image without the need of any reference image or its features. The problem of NR-IQA is much tougher than the above two problems. Due to absence of reference image, one needs to model the statistics of reference image, the nature of human visual system and effect of distortions on image statistics in an unsupervised way. It is also very difficult to evaluate the effectiveness of a quality measure with a specific distorted image in absence of a reference image.

This paper provides an extensive review of major NR-IQA algorithms developed so far. This review summarizes the methods used by algorithms, evaluation parameters, distortion types for which they are designed, image databases used for validation and benchmarking of the algorithms with human visual performance.

2. Benchmarking parameters

Different NR-IQA algorithms provide different quality score. So to compare the performance of different NR-IQA algorithms, a common benchmarking system is necessary. Few benchmarking parameters are mentioned as follows.

2.1. Pearson correlation coefficient (PCC)

It is used to measure the dependency between to variables. Its value lies between '−1' and '+1' where value close to '+1' indicates that the two variables have positive correlation and value close to '−1' indicates that the two variables have negative correlation. A very low or zero value implies that the two variables are not correlated. Pearson correlation coefficient (ρ) between two variables 'X' and 'Y', with standard deviation σ_X and σ_Y respectively is shown in (1).

$$\rho = \frac{convariance(X, Y)}{\sigma_X \sigma_Y} \tag{1}$$

The two variables 'X' and 'Y' are the output of NR-IQA algorithm and the actual quality score provided with the database.

2.2. Spearman correlation coefficient (SCC)

Spearman correlation provides the relation between two ranked variables. Its range is from '−1' to '+1' with same interpretation as that of Pearson's correlation coefficient. Spearman correlation coefficient is calculated as shown in (2).

$$\rho = 1 - \frac{6 * \sum d^2}{n(n^2 - 1)} \tag{2}$$

where 'd' is the difference in ranks of two variables 'X' and 'Y'.

2.3. Outlier's ratio (OR)

Outlier's ratio is defined as the percentage of algorithm's output which is beyond twice standard deviation of subjective scores. If there are 'I' images and 'S_i' is the subjective quality score of ith image then mean subjective score (S_m) is calculated as shown in (3).

$$S_m = \frac{1}{I}\sum_{i=1}^{I} S_i \tag{3}$$

The standard deviation of subjective scores (σ_s) is calculated as shown in (4).

$$\sigma_s = \left[\frac{1}{2}\sum_{i=1}^{I}(S_i - S_m)^2\right]^{1/2} \tag{4}$$

Suppose there are 'P' images with individual objective quality score (O_i) such that

$$|O_i - S_i| > 2 * \sigma_s \tag{5}$$

then the outlier's ratio is given by (6)

$$\text{Outlier's ratio} = \frac{P}{I} \tag{6}$$

Outlier's ratio increases if the output of NR-IQA algorithm is not at all in agreement with standard or subjective quality score.

2.4. Root mean square error (RMSE)

Root mean square error (RMSE) is used to measure the pixel wise deviation between two entities. If 'I' and 'I_N' are original and noisy images of size $M \times N$, then the RMSE between these two images is defined as

$$\text{RMSE} = \left[\sum_{n=1}^{N}\sum_{m=1}^{M}\frac{I(m, n) - I_N(m, n)}{MN}\right]^{1/2} \tag{7}$$

3. No-reference image quality assessment algorithms

The NR-IQA algorithms that are developed by researchers are discussed in this section. The algorithms are discussed in the order of their publication.

Marziliano et al. [11] proposed a perceptual blur and ringing metric for images corrupted by distortion caused by JPEG-2000 compression. The method is based on edge detection using Sobel