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Image Quality Parameter Detection : A Study

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***Abstract*—Digital Image Processing applies efficient computer algorithms to process an image in digital computer. Different distortions occurred in image due to various reasons in image acquition, preprocessing, compression, reproduction can be removed by applying different methods like reducing noise, improving contrast etc. Image quality estimation is very widely used for many applications related to medical grounds, security related issues etc. Image quality can be measured either by Objective or Subjective methods. Mostly Peak Signal- to-Noise Ratio, Mean Squared Error, Structural Similarity Index Metric are used to estimate the quality of image using full reference objective method. Only in a few areas no reference and reduced reference are used to estimate image quality. Herein, different image quality parameters along with the image quality metrics have been reviewed. A fish bone model is proposed for expressing different estimating techniques of image quality parameters.**

Keywords— Image Quality; Image Quality Estimation; Image Quality Measures; Image Quality Parameters

I. INTRODUCTION

Image processing is widely popular in the field of modern technology. An image is a representation of a signal in a digital media. Image contains pixels. A digital image contains numbers indicating variations of red, green, and blue at a particular location on a grid of pixels. Image can be produced by human, camera, mirror, artist etc. It is a visual representation of something. Image quality assessment is an important problem due to the distortion introduced in a signal. Image quality measures the perceived image degradation. It is a characteristic of an image that compares the perceived image to an ideal image. In order to determine the best quality of two images, we must first perceive the differences between the two [1].

II. IMAGE QUALITY ESTIMATION

Image quality estimation is an important measure to find out the quality of images. As most of the images consist many distortions, so we need to process these distortions to find out the quality of the images. Quality of image can be measured using Objective and Subjective method [2].

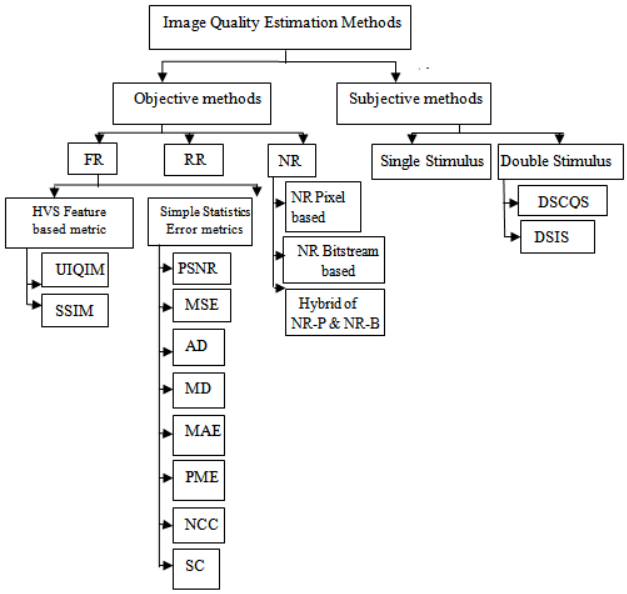

Fig.1. Image Quality Estimation Methods

TABLE I. Abbreviations used in Fig.1

Abbreviation	Full form
FR	Full Reference
RR	Reduced Reference
NR	No Reference
HVS	Human Visual System
UIQIM	Universal Image Quality Index Metric
SSIM	Structural Similarity Index metric
PSNR	Peak Signal-to-Noise Ratio
MSE	Mean Squared Error
AD	Average Difference

MD	Maximum Difference
MAE	Mean Absolute Error
PMS	Peak Mean Square
NCC	Normalized Cross Correlation
SC	Structural Content
DSCQS	Double Stimulus Continuous Quality Scale
DSIS	Double Stimulus Impairment Scale

A. Objective method:

The Objective method is a process of estimating image quality using computer based algorithm. It generates result of image quality automatically without the help of human observer [2].

Advantage:

- The method can automatically predict the perceived image quality [2].

Disadvantage:

- The image quality predicted through the objective method does not match with the image quality as perceived by human [2].

Existing Objective approaches are as follows:

(a) Full-reference (FR):
In this approach the quality of image is measured against a complete reference image. Again Full Reference method is further divided into two parts, namely Human Visual System Feature based metric and Simple Statistics Error metrics [2].

(i) Human Visual System Feature based metric (HVS feature based metric):
Image quality is better perceived by human than computer. Researchers assume that incorporating human visual system with objective quality metrics increase the level of accuracy of image quality [2].

(ii) Simple Statistics Error:
This type of full reference method includes calculating error in signal of image or differences of signal between reference image and perceived image. These involve mathematical calculations.

(b) Reduced-reference (RR):
In this approach the perceived image is compared against a partially available image of the reference image to estimate the quality of the image [2].

(c) No-reference (NR):
This is a Blind Image quality estimation approach. Here the perceived image quality is estimated without any reference image [2]. Again Reibman et al. [3] classify NR methods into No Reference Pixel based method (NR-P) and No Reference Bitstream based method (NR-B). In NR-P based method the features of image are derived from pixel and in NP-B, the features are computed directly from the coded bitstream. The NR-B-based method is easy to compute as compared to NR-P method. But quality measurement performance is better in case of NR-P based method. The composition of both NR-P and NR-B based methods is called hybrid method. This method inherits the computational simplicity of NR-B-based methods, and depends on NR-P-related data to gain further robustness [4].

B. Subjective method:

The process of estimating image quality using human observer is known as subjective method of image quality estimation [2].

Advantage:

- This method is accurate in estimating the visual quality of an image because they are carried out by human subjects [2].

Disadvantage:

- It involves a costly process which requires a large number of observers. It also takes more time [2].

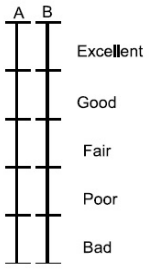

Fig.2. Sample linear 5-segments grading scale used by DSCQS [5], [6]

In subjective quality estimation method the human observer is asked to give grade in the 5-segments grading scale to represent the impression of image "A" and "B". Either "A" or "B" is the reference image while the other is the perceived image. Subjective methods are divided into single stimulus and double stimulus depending on the availability of reference image. In double-stimulus methodology, subject is presented with the source and test images before evaluating their qualities on a linear quality scale as in Fig. 2[7]. In single-stimulus methodology, the subject evaluates the quality of the test images on a linear quality scale without the source as reference [7]. Based on how the source image is presented to the subject, double – stimuli has several methodologies [5]. They are Double-Stimulus Continuous Quality Scale (DSCQS) and Double-Stimulus impairment scale (DSIS) [5].

III. ISSUES IN IMAGE QUALITY ESTIMATION

Most objective image quality metrics like Peak Signal to Noise ratio, Mean Square Error are widely used to estimate quality but they are criticized as well, for not correlating

well with perceived quality measurement. And subjective quality estimation need a number of human observer to estimate quality which it very time consuming and costly, and also human observer cannot differentiate quality in a scene with illusion. It is a big issue in estimating image quality. So Researchers try to develop techniques incorporating both objective metric and human observer.

IV. NEED OF IMAGE QUALITY ESTIMATION

The various aspects of image quality have gained more importance in the fast developing multimedia system of our time. Hence an optimized design of multimedia applications for complete control of the quality of images is necessary. Any inference we make about the world through vision may be incorrect because human vision cannot judge the absolute difference in a scene. We can only guess the relative reflectivity of a scene [8]. Therefore we need computers to process an image so that we can find out the properties of an image accurately. Computer takes image as input and produces knowledge about the object. It removes noise, blur and other distortions from an image.

V. IMAGE QUALITY PARAMETER

Quality of an image is greatly affected by many parameters. A few of the most common parameters deal with the quality of image are described below-

1. *Color accuracy*: Color is the appearance of an image as a result of the way it reflects light. Color accuracy is an ambiguous image quality factor [9].
2. *Tone reproduction*: The relationship between luminance of a scene and the reproduced image brightness is called tone reproduction [10].
3. *Artifacts:* When operations are performed during RAW conversion, software can cause significant visual artifacts like data compression and transmission losses, low-contrast detail, noise [10].
4. *Lens (optical) distortion:* Lens (optical) distortion causes straight lines to curve near the edges of images. For architectural photography and photogrammetry, lens distortion can be a problem [9].
5. *Sharpness:* Sharpness determines the amount of change an image can do. It is affected by lens, sensor, signal processing, camera shake, focus accuracy, atmospheric disturbances [10].
6. *Veiling glare (lens flare):* Veiling glare is stray light in lenses and optical systems caused by reflections between lens elements and the inside barrel of the lens. It predicts the severity of lens flare [9].
7. *Color moiré:* Color moiré is artificial color banding that can appear in images with repetitive patterns of high spatial frequencies, like fabrics or picket fences. It is the result of aliasing in image sensors that employ Bayer color filter arrays [10].
8. *Noise:* Noise is a random variation of image density. It arises from the effects of the photon nature of light and the thermal energy of heat inside image sensors and amplifiers [10].
9. *Spatial resolution:* The transfer function can be calculated either from the point spread function or edge spread function [10].
10. *Contrast Sensitivity*: Contrast is used to make an object more distinguishable in an image. Contrast sensitivity is a characteristic of an imaging system that establishes the relationship between image contrast and object contrast [10].
11. *Light falloff (vignetting):* The process of darkening images near the corner is called Light falloff (vignetting). It can be particularly strong with wide angle lenses. Light falloff often improves when lenses are stopped down [9].
12. *Blemishes:* The visible spots or marks in an image are called Blemishes. It occurs due to sensor defects or dust in front of the sensor. They are extremely important in manufacturing [9].
13. *Exposure accuracy and ISO Sensitivity:* Exposure accuracy can be easily determined in manually-adjustable cameras. With fully automatic cameras and with video cameras that offer little opportunity for post-exposure tonal adjustment, it can be an issue [9].
14. *Lateral chromatic aberration (LCA):* Lateral chromatic aberration (LCA) causes colors to focus at different distances from the image centre. It is most visible near corners of images. LCA is worst with asymmetrical lenses, including ultrawides, true telephotos and zooms [9].
15. *Variance:* Variance is used to find how each pixel varies from neighboring pixels. It can be used to identify sharp details like edge [11].
16. *Entropy:* It is a quantity which is used to describe the amount of information which must be coded for by a compression algorithm [12].
17. *Image Gradient:* It is a directional change in the intensity or color in an image [13].
18. *Kurtosis:* It measures how data are presented to a normal distribution. Datasets with high kurtosis have distinct peak near the mean and datasets with low kurtosis have a flat top near the mean [14].

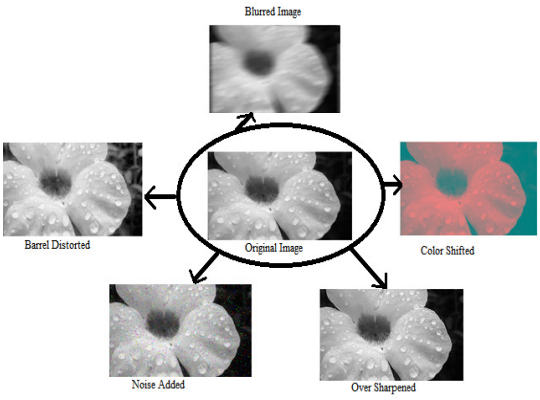

Fig.3. Effect of some parameters on an image

In Fig. 3, some of the effects of parameters on image are shown to understand the fact that different parameters affect on the same image differently. And in image acquition process, the image may have many distortions, which are needed to be identified and removed to estimate quality of image.

VI. LEVEL OF QUALITY ESTIMATION

In Fig. 4, a fish bone method is proposed to understand the different parameters of image and their corresponding techniques for assessment. Noise, Vignetting, Sharpness, Spatial Resolution, Exposure Accuracy, Color moiré are the parameters and Median Filter, Uniformity, Modulation Transfer Function, Exposure Compensation, Log Frequency are the corresponding techniques.

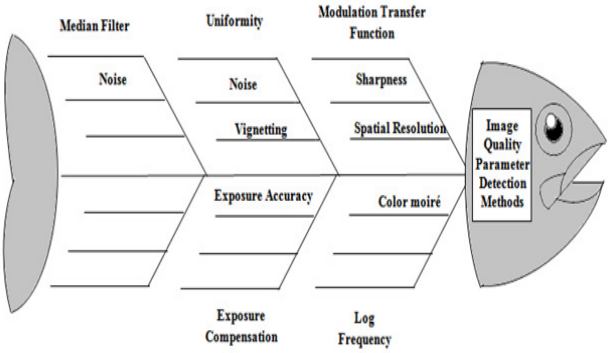

Fig .4. Fish Bone model of techniques estimating different parameters of an image.

In TABLE II, the description of techniques for estimating different parameters of image is given.

TABLE II. Description of techniques used to estimate Image Quality Parameters

Technique	Description
Modular Transfer Function [15]	It measures how the lens reproduces detail from the object to the image produced by the lens. MTF=(mI – minI)/(mI + minI) mI= maximum intensity minI=minimum intensity
Median Filter [16]	It is a nonlinear digital filtering technique. It is used to remove noise from image.
Log Frequency [17]	It measures the contrast of narrow bar that increase logarithmically in spatial frequency. When the image is sinusoidal, contrast is equivalent to MTF.
Uniformity [9]	It measures the drop off in illumination at edges of image, sensor nonuniformities.
Exposure Compensation [9]	It is used to alter exposure from the value selected by the camera for making photos brighter or darker.
Mean Square Error[18]	The MSE is the cumulative squared error between the compressed and the original image, it is calculated by – $MSE=\frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y)-I'(x,y)]^2$ Where I(x, y) is the original image, I'(x, y) is the approximated version (decompressed image) and M, N are the dimensions of the images. A lower value for MSE means lesser error, so a compressed image having a lower MSE is better.
Peak-to-noise ratio [18]	PSNR is used to measure the quality of reconstruction of lossy compression codes such as image compression. PSNR = 20 * log10 (255 / sqrt (MSE)) A compressed image having a higher value of PSNR is better.
Gray level co-occurrence matrix [19]	Dhanashree Gadkari introduced the use of co-occurrence probabilities using GLCM for extracting various texture features. GLCM is defined as a two dimensional histogram of gray levels for a pair of pixels, which are separated by a fixed spatial relationship.

In digital image processing, a scene is analyzed for better quality assessment. Human and computer interpret an image in different ways. In all the field of medial, archeology, geography, biology, physics digital image processing gives an immense improvement for different quality analysis. We can analyze image through image processing and recognition, interpretation of image is done automatically by the developed application.

The following are the steps of processing an image to analyze different aspect of image:

(i) Image Acquisition:

Here an image as problem domain is captured using sensor. While capturing image through camera, the lens distortions may arise due to the adjustment of the camera lens. Also, in this step using digitizer, the image signals are digitized from analog-to-digital [20].

(ii) Preprocessing:

In this step, the obtained image is manipulated so that the resulting image is more suitable than the captured image for the successful execution of specific applications. So here image enhancement techniques are used to improve

the captured image. Here contrast of image is enhanced, noise is removed and likewise many other distortions occurred in the image acquition process are removed [20].

(iii) Segmentation:

Here the manipulated image is divided into some parts so that we can process the image parts successfully as an autonomous segmentation is a difficult task to perform successfully [20].

(iv) Representation and Description:

The output of segmentation is raw pixel data, constituting either boundary or complete region of image. Boundary representation focuses on external shape like corners and inflection whereas Region representation focuses on internal shape like texture. The representation is only a part of solution for transforming for transforming raw data into a form of suitable for subsequent computer processing [20]. Description of data is needed in order to highlight the features of interest. It deals with extracting features that result in some quantitative information of interest [20].

(v) Recognition and Interpretation:

Recognition is the process that assigns label to an object based on the information provided by its descriptors. And interpretation attempts to assign meaning for set of labeled entities [20].

(vi) Knowledge base:

It controls interaction between different modules of image processing. The knowledge about a specific problem domain is coded in the knowledge base [20].

Modulation transfer function, exposure accuracy, uniformity, log frequency etc. are the techniques to estimate the image quality parameter. All these methods are used in the processing step of Image processing. In general, processing an image defines removing distortions and makes the image ready to be used by other processing methods to estimate quality.

VII. RELATED WORK ON IMAGE QUALITY ESTIMATION

Image quality estimation plays a very important role in the fast developing technology world. As security is major concern for today's world. We need to find the good quality image for identifying an object. It plays a vital role in various image processing applications. Following are some works done in the field of Image quality estimation:

Hartwig Fronthaler, et al. [21], [2006]. In this paper the authors developed a reduced reference method to detect fingerprint image quality distortions like noise, lack of structure, blur. They used adaptive monomodal multi-algorithm fusion strategies. The developed method analyzes the orientation tensor of fingerprint images with a set of symmetry descriptors. They showed how a prior knowledge of fingerprints can be encoded for quality estimation. The introduced method behaves closest to human opinion on fingerprint quality.

C.Sasi Varnan, et al. [2], [2011]. In this paper the authors compare Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE) and Structural Similarity Index Metric (SSIM) for predicting image quality. The experimenting results show that MSE and PSNR have low computational complexities. They are simple and easy to implement. But MSE and PSNR are acceptable for image similarity measure only when the images differ by simply increasing distortion of a certain type. But they fail to capture image quality when they are used to measure across distortion types. But SSIM works accurately and can measure better image quality across distortion types as compared to MSE and PSNR, but fails in case of highly blurred image.

Zhou Wang et al. [22], [2003]. They proposed a multi-scale structural similarity method. They developed an image synthesis method to calibrate the parameters that define the relative importance of different scales. It provides flexibility in incorporating the variations of image resolution and viewing conditions.

Mohammed Hassan and Chakravarthy Bhagvati [23],[2012]. They developed a color image quality measurement technique. Here an improvement to the Multi-Scale Structural Similarity index (MSSIM) is done by adding a color comparison to the criteria of the grayscale MSSIM. The new image quality estimation method uses the color information of the referenced image for the estimation of color.

V. RAMADEVI and S. POONGODI [24], [2015].

Here watermarking of video image is done using the AVI file format video file. Singular value decomposition (SVD) technique is applied in the transmitter section and receiver section. MSE, PSNR values are calculated for the watermarked images for different file format under noisy environment.

Anjali Krishna and Shanavaz K T [25],[2016]. In this paper the authors developed a scheme that helps to access the quality of an image. They use a tree structure based watermarking method without accessing the cover image. The watermarking coefficients are embedded in the selected trees of the decomposed image. Comparing the original watermark and the extracted watermark will indicate the quality degradation of the original cover image. The proposed scheme has good computational efficiency to estimate the image/video quality.

Peng Ye, et al. [26], [2013]. In this paper they proposed a supervised filter learning based algorithm for general-purpose No Reference Image Quality Assessment. The proposed method is very fast in operating the raw image patches using small set of supervised filters. This method is based on supervised feature learning. They conclude that a compact set of learned filters can achieve the same accuracy as by using a large number of unsupervised filters while reducing the computation time significantly.

Lukáš KRASULA, et al.[27],[2011]. Here the authors develop MATLAB-based applications useful for both image processing and image quality assessment. The Image Quality Assessment Application contains objective full reference quality metrics that can be used for image quality assessment. The Image Quality Evaluation Applications represent an easy way to compare subjectively the quality of distorted images with reference image.

Garrett M. Johnson and Mark D. Fairchild [1]. They represent a details a modular framework for a color image difference metric, based upon CIE color difference formulas. They develop an equation to predict differences of complex stimuli, such as color images. Using such an equation, it should be possible to link perceived differences between images with perceived quality of those images.

VIII. APPLICATION OF IMAGE QUALITY PARAMETER ESTIMATION

Image Quality Parameter Estimation plays an important role in Digital Imaging system. It is very useful in different areas of fast developing world. These areas need good quality image to perform image analysis accurately.

For easier interpretation of medical images need of image quality estimation arises. In physics image enhancement is done in electron microscopy. To study pollution pattern from aerial and satellite imagery in geography image processing is needed.

A few of the applications that rely on image quality parameter estimation is listed in TABLE III.

Table III. A few application areas of Image Quality Estimation

Application	Author/Description
Medical Purpose	M.A. Periard and P. Chaloner [28]. Here quality assurance for x-ray is done and this helps in medical diagnose.
HRSI	Mattia Crespi and Laura De Vendictis [29]. Here Image quality estimation can be used to estimate quality of data generated from High Resolution Satellite Imagery (HRSI) in the test period.
Biometric Detection	Shruti Ghorpade et al. [30]. Here a technique is developed to detect fake biometrics.
Realistic Image Synthesis	Robert Herzog et al. [31]. Here various non-trivial artifacts such as noise, clamping bias are detected.
Digital Radiology	Uwe EWERT et al. [32]. Here Computed Radiography (CR) and Digital Detector Arrays (DDA) in comparison to digitized film radiographs are done.
Multi-Score OMR	Dan Ringwalt and Roger B. Dannenberg [33]. Here features which predict the quality of a given score, allowing to select the highest-quality score to use for OMR is estimated.

IX. CONCLUSION AND FUTURE WORK

Image quality parameter detection and image quality estimation are the most important topics that enhance the effective use of computer technology in all the vital fields of our day-to-day life. In recent years, authors develop objective image quality estimation method. Basically full reference image quality is presented in most of the developed methods. In a few worked area, no reference and reduce reference image quality is included. This reference gives an insight view of image quality assessment techniques which helps in future to estimate image quality in various grounds like medical, security, astronomy.

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