A Novel Technique for No-Reference Image Quality Assessment

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ABSTRACT

In this paper, a new measure for no-reference assessment of image quality based on the use of the structural properties of an image is proposed. As a measure, it is proposed to use the estimate of the Weibull distribution shape parameter, obtained by the set of image gradient magnitudes. This measure was previously successfully used to estimate the blurriness of the image. To test the effectiveness of the proposed measure, we used the data from the well-known TID2013 image database, which includes images of various types of distortions and corresponding mean opinion scores of the humans. The ability of the proposed measure is shown to distinguish the types of image distortions, which change the structural properties of an image.

Keywords

Gradient magnitude, Weibull distribution, shape parameter, database TID2013, Human Visual System.

1. INTRODUCTION

One of the main problems in the area of digital image processing is the development of effective measures for an objective assessment of image quality. In real-world applications, image processing techniques, as a rule, image distortions arise due to the influence of various factors, such as blurring, noise, contrast change, etc. At the same time, distortions can occur both in the process of an image acquisition and during its processing or transmission via communication channels. The human visual system (HVS) is able to distinguish images with high and low qualities, while quality assessment using technical means or computer processing is a rather complicated task.

Algorithms for an image quality assessment are divided into three categories:
1. Full use of standards (Full Reference),
2. Partial use of standards (Reduced Reference),
3. Lack of standards (No Reference).

With the full use of standards, it is assumed that the latter has an acceptably high quality, and the test image is compared with it by evaluating their differences. The need for such a comparison arises in cases where the original image is obtained after some processing, as a result of which it may have been distorted. This is a typical situation, long considered in the theory and technology of signal and image processing. Therefore, a number of such measures have been proposed in the literature, and in this paper we will limit ourselves to the references to [1–4], which are based on the use of various structural properties of the image. We also point out the review papers [5-7], in which numerous measures for assessing the quality of the image are classified and analyzed.

With the partial use of standards, i.e. at reduced reference they are based on certain properties or features that allow decisions to be made regarding the quality of the test image. This category of algorithms is not characterized by any general approach to quality assessment, and in each case it uses the specifics of the problem statement regarding the types and properties of distortions considered in this situation [8].

The most interesting and difficult category is represented by no reference algorithms that do not require specific informative information about the test image. The main difficulty in this case is related to the fact that there is a large number of types of distortions to which the image may be subjected, and often nothing is known about the absence or presence of distortion in the test image. Therefore, the development of algorithms that work equally well for all types (or at least for a large number of types) of distortions is quite a difficult task. Moreover, the degree of distortion also depends on the specific type of image. Apparently, this explains the fact that numerous works proposed in the scientific literature are mainly performed for certain types of distortions applied to certain databases. In this case, we confine ourselves to references to reviews devoted to the comparative analysis of no reference methods for assessing the quality of the image. We mention, for example, the papers [9-10].

Another difficulty in developing a no reference method of assessing image quality is that there is no universal criterion for evaluating the quality of the no reference method itself. Ultimately, we have to compare the result with verified data obtained by any reliable research. Note that currently several databases are described in the literature that contain many distorted by certain algorithms images, with corresponding estimates of visual quality. One of the most famous databases is described in [11].

In this paper, a technique for no-reference image quality estimation by using the Weibull model for the gradient magnitude is proposed. In [12–13], the Weibull model was successfully used in a number of problems due to some invariance of the proposed measures to the size and orientation of the image. In particular, in [12] it was proposed to use the estimate of the shape parameter of the Weibull distribution as a measure of image blur. In the same paper, an attempt was made to substantiate the thesis that this measure also characterizes “image structuredness”. Without going into the philosophical aspects of the concepts of "quality" and "structure" of the image, we note that the basis of the entire methodology for applying the properties of the gradient field of an image is that the human visual system (HVS) extracts mainly structural information from the image. Consequently, it can be expected that the proposed measure can respond to certain structural properties of the image, characterized by both a variety of details of the original scene and possible effects of the type of distortion applied.

The paper proposes a procedure for no-reference image quality estimation based on the use of the shape parameter of Weibull distribution. An experimental study of the effectiveness of the procedure was carried out using images that were distorted by various methods, including those that distort the structure of the image. At the same time, we proceed from the need to use well-known in the literature database of images containing information about the degree of conformity of their quality with the perception of HVS. At this stage, it suffices to use the base image TID2013 [11].

2. METHOD AND RESULTS

Mathematical model. Following [3], we take for the image gradient magnitude a model based on the Weibull distribution, the density of which is given by the formula as follows

$$f(x;\lambda,\eta)=\frac{\eta}{\lambda}\left(\frac{x}{\lambda}\right)^{\eta-1}\exp\left[-\left(\frac{x}{\lambda}\right)^{\eta}\right],\ x\geq 0, \qquad (1)$$

where $\eta > 0$ - shape parameter, $\lambda > 0$ - scale parameter. In this case, the gradient magnitudes are estimated using the Sobel operator, and the parameters of the distribution (1) are estimated from the aggregate of all the magnitudes. Details of the procedure can be found in [13].

We take the parameter η value as a measure characterizing the image quality (the smaller the measure value, the higher the quality).

Using the image base TID2013. The base contains 3000 images obtained from 25 originals, distorted by 24 different types with five levels each. Next, an extensive experiment was conducted on the visual assessment of quality by the point system by a large number of people in different countries. As a result of the processing of this data, each of the 3,000 images was assigned a numerical quality score of HVS (Mean Opinion Score - MOS).

Using the base TID2013 allows assessing the quality of any procedure used in the task of assessing the quality of full reference images and no reference images as well. In the latter case, the values of the HVS estimates obtained from the base data are taken as a basis, and the decision on the quality of the procedure itself is made according to the degree of correlation of the estimates of the procedure with the MOS estimates. However, the study of the dependence of the measure on the level of distortion for individual types of distortion allows us to draw a number of additional conclusions regarding their properties.

2.1. Results of experiments

Experiment 1. For all 3000 images, Weibull distribution shape parameter estimates were obtained, which are then grouped into 25 images and 24 types of distortions (descriptions, references and other details on the types of distortions are given in [11]).

The question of interest is: how the values of the proposed measure and the MOS scores are correlated. A high degree of correlation means that no-reference image quality estimation process can be carried out by applying the proposed measure instead of MOS.

In this experiment, calculations were performed for each of the 25 images separately. The Spearman’s correlation coefficients (SKK) are calculated for each of five items separately, and then their values are averaged over all 25 images for each of the 24 groups. In cases when small or negative SKK values appear in the calculations, additional analysis is performed to determine the reasons. Results for groups with the highest SKK values are shown in Table 1.

Table 1. Average values of SKK for selected types of distortions.

№	SKK	№	SKK	№	SKK
1	0.984	5	0.972	17	0.882
2	0.936	6	0.972	19	0.983
3	1.000	7	0.818	20	0.928
4	0.938	13	0.928	21	0.976

Consider the results of Table 1 in more detailed.

1. Taking into account the small amount of data when calculating the SKK, it should be borne in mind that even the minimum number of discrepancies in the ranks of the rows compared with this leads to a significant decrease in the SKK value. Detailed analysis shows that in some cases there are similar discrepancies, the cause of which is a non-monotonic change in either the measure used or the MOC values given in [11]. In this case, it often turns out that the values of the members of the variation series, due to which the indicated discrepancies occur, are very close and differ within the limits of experimental errors.

2. For other types of distortions, very significant, and even alternating, fluctuations of the values of the proposed measure are observed at different levels of image distortion. Therefore, the averaging of data in this case does not make sense. This circumstance allows investigating each of the suspicious distortions in more detail. In particular, based on the assumption that the proposed measure is intended for estimating structural changes in an image, a visual analysis of its gradient field was carried out at various levels of distortion.

Experiment 2. Table 2 shows the calculation results for the image I6 of the TID2013 base. The cipher contains the number of the type of distortion, and the vertical values of the measure correspond to the five levels of distortion. The first column of the table shows that the measure is monotonously increasing, i.e., the image quality decreases accordingly when the level of type 1 distortion increases.

Table 2. Measure values for some distorted TID2013 base images.

Distortion level	Image cipher by TID2013			
	I6-1	I6-8	I6-17	I6-18
1	1.0367	0.9604	0.9641	0.9845
2	1.0737	0.9478	1.0141	0.9845
3	1.1344	0.9199	0.9412	0.9837
4	1.2290	0.8573	1.0476	0.9833
5	1.3696	0.7876	0.9191	0.9837

The column with the cipher I6-8 corresponds to distortion of type 8, and we notice that the measure monotonously decreases! In this situation, the conclusion is that with an increase in the level of this type of distortion, there is no deterioration in quality, as indicated by MOS, but a change in the structural properties of the image. The column with the cipher I6-17 illustrates the randomness of changing the measure, which means the unpredictability of image quality with this type of distortion of its content. Finally, the column with the cipher I6-18 shows that this type of distortion has little effect on the structure of the image.

The validity of the comments made is supported by examples of the visualization of the gradient field of these images, shown in Fig. 1. For clarity, the selected images corresponding to the highest level of distortion. Note that these observations also take place for many other images of the base in question.

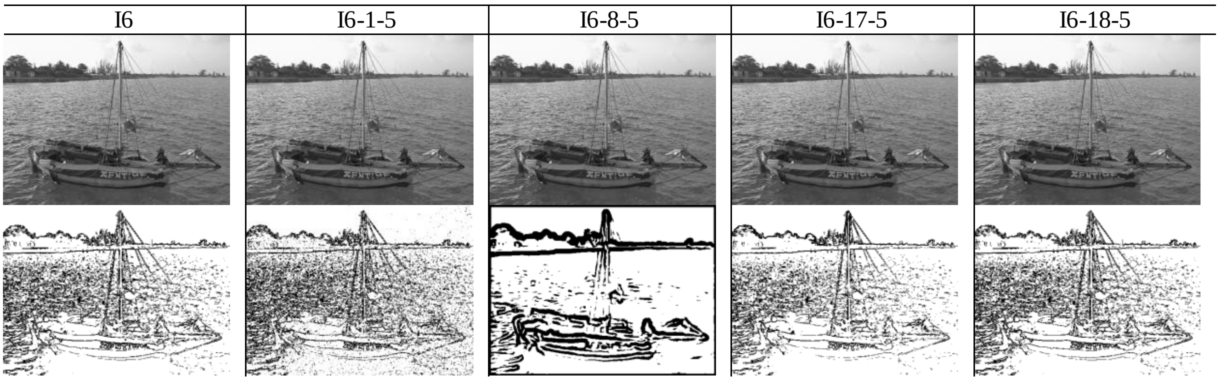

Figure 1. Image of cipher I6 and its distorted patterns (second row), visualized magnitude of the gradient of distorted images (third row).

Thus, the proposed no-reference measure of image quality can be effectively applied in cases where there is a reason to believe that possible distortions can lead to structural changes in the image. At the same time, the ability of one type or another of the effect distortion on the structural properties of an image can be checked experimentally using the research methodology developed in this paper.

3. CONCLUSIONS

The paper proposes a new measure for no-reference image quality assessment based on the use of the structural properties of the image. It uses the approach previously developed by the author, in which the Weibull distribution model for the magnitude of the image gradient is adopted. In this case, as a measure of quality, it is proposed to use a statistical estimate of the shape parameter of the Weibull distribution obtained by empirical distribution of gradient magnitudes. Using the example of the TID2013 database through a correlation analysis, a conclusion was drawn about the effectiveness of the proposed approach, which manifests itself in accordance with the obtained results as perceived by the human visual system. The conclusion about the ability of this measure to assess the degree of impact of a particular type of distortion on the structural properties of the image is substantiated.

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