Abstract: The recent process of digitalizing archives has increased the importance of choosing the best compression method and evaluating the quality of the compressed materials. Our paper focuses on monochrome portrait photographs. We suggest using an image quality index partly based on Human Visual System. We think that, despite its simplicity, it equals with Mean Subjective Rank. In addition we intend to ascertain that (the index submitted by us) the index is very easy both to understand and to implement.

1. Introduction

The evaluation of digital photographs has an integral part in many relevant processes, especially so in the process of digitalizing of the archives materials, such as books, documents, photographs. Undoubtedly, the quality of these materials should be optimized according to preferences and expectations of the archives’ potential users. However fulfilling this criterion would generate in practice many obstacles [1]. One of them would be maintaining lighting quality. During the test, the group of archives users quickly become skillful in finding imperfections of the pictures. Another difficulty arises from the various subjects of photographs and the viewers’ different attitudes towards them, which in turn would make us deal with problematic random factor. Therefore, to avoid the aforementioned problems, it is reasonably regarded as more beneficial to apply an objective method of evaluation instead. The list of such methods, including their statistic
analysis is published in paper [2]. The most commonly used are MSE (mean squared error) and SNR (signal to noise ratio) [3, 4]. The evaluation of digital photographs quality made by these indexes is often different from human assessment [5].

Unfortunately, these propositions are not as simple and refined as the indexes based on Minkowski’s metric and its derivatives.

Our proposition does not aspire to an universal image quality index. On the contrary – it is designed as a specialist tool for comparison of the monochrome portrait quality. Another issue has also an integral part in the process of digitalizing of archives, that is a correction of scanned images, either as a part of the scanning process or as a separate procedure based on processing previously scanned materials in uncontrolled conditions. By correction we mean for instance eliminating printing raster, sharpening or contrast correction.

Our index is based on the one presented in paper [6]. That index has many excellent features – it reflects precisely the control group’s assessment of the images quality. However our careful researches led us to the conclusion that in case of analyzing monochrome low quality photographs with printing raster traces and with low contrast and noise, that index applies less successfully. In order to improve its efficiency we suggest accentuating focal point of every picture, and so deflecting the viewer’s attention from its imperfections. In case of portraits the focal point is always the face of the model. Therefore, any deformations in this area will particularly affect perception. The scheme of our procedure is as following: automatic selection of an area of a face (as an ellipse/circle ring) and then presentation of a criterion for determining the quality index.

2. Determining the main ellipse

The new index criterion will be determined in the subsequent paragraphs. First let us show the way of marking ellipse/ circle ring that encloses the model’s face. The circle ring will be area of our main interest, and the focal point of the photographs. The review article [7] presents a range of methods of determining human face or skin. Our researches is based on the monochrome photographs on particular subject. Hence, it seems reasonable to choose the method based on Hough Transform. Paper [8] delineates how the method may be encompass the ellipse. Whereas the paper [9] illustrates how to mark an ellipse on pictures of human face. The algorithm included in paper [10] would be an appropriate one as well.

We decided to adapt Hough Transform simplified. The following steps are taken: first the edges must be found (we use the easy gradient and thresholding, but every edges detection filter will be appropriate, see [11]) and using simple height and width parameter of the photograph the range of needed circle radius is determined. There is no need to be very precise, so radii in determined area can be transformed but including
rsteps > 1 stage. Next the centre of the circle is found for each of radius value. The
centre of the circle is some value (Hough Peaks). The average of these values is calcu-
lated and then the centre can be determined as an average of the circles’ centers that have
the Hough Peaks value bigger than their average. The average radius value is calculated
in the similar manner – after dismissing the values lower than the Hough Peaks average.

3. The quality index

The authors in paper [6] proposed:

\[
Q_j = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \frac{2 \bar{x} \bar{y}}{(\bar{x})^2(\bar{y})^2} \frac{2 \sigma_x \sigma_y}{\sigma_x + \sigma_y}
\]

(1)

Where:

\[
x = \frac{1}{N} \sum_{i=1}^{N} x_i; \quad \bar{y} = \frac{1}{N} \sum_{i=1}^{N} y_i;
\]

(2)

It is assumed that the original image is defined by \(x\) values, and the analysed image
is defined by \(y\) values:

\[
x = \{x_i | i = 1 \ldots N\}; \quad y = \{y_i | i = 1 \ldots N\};
\]

(3)

\[
\sigma_x^2 = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2
\]

(4)

\[
\sigma_y^2 = \frac{1}{N-1} \sum_{i=1}^{N} (y_i - \bar{y})^2
\]

(5)

\[
\sigma_{xy} = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})
\]

(6)

The particular elements of the first equation are interpreted in the following way: the
first element is the correlation coefficient between \(x\) and \(y\), which measures the degree
of linear correlation between \(x\) and \(y\). The second element measures how close the mean
illumination is between \(x\) and \(y\). The third product element measures how similar the
contrasts of the image are. The first product element is from the range \([-1,1]\), the other
ones are from the range \([0,1]\). The value 1 is the highest value that is accepted in case of
the identical images.

The technique of the value \(Q\) determining is following (that is described in paper
[6]): we calculate the value \(Q_j\) (from the first equation) for the value BxB squared (in
our paper we assumed B=4) starting from the left image top and move our square pixel by pixel to the right and bottom until we reach the right bottom corner. We get M steps and the final result is calculated from:

\[ Q = \frac{1}{M} \sum_{j=1}^{M} Q_j \]  

(7)

where \( Q_j \) is the index value for the chosen square.

Many test were carried out in paper [6]. These test showed very high correlation between index results and control group assessments for wide range of photographs. The introduced index is a special case of SSIM [12], for which parameters \( c_1 = c_2 = 0 \)

\[ SSIM = \frac{(2\sigma_x\sigma_y + c_1)(2\sigma_{xy} + c_2)}{(\sigma_x^2 + \sigma_y^2 + c_1)(\sigma_{xy}^2 + c_2)} \]  

(8)

If we determine index Q for the photo that was operated with many destructive methods then in some circumstances the values we get will be different from the index based on addressee opinion (MSR). It happens especially in case of situations when the correction/deformation is realized only on the photo’s fragment. It is also possible in case of the particular interest of the central photo’s element (in our case it is the model face).

Let us calculate the index by taking into consideration the particular area determined by specified ellipse/circle before.

Now index Q will be calculated:

\[ Q = \sum_{j=1}^{M} P_j Q_j \]  

(9)

The norm that is to sensitize our index to important photo’s fragments should meet two conditions:

\[ P_j \geq 0 \]  

(10)

\[ \sum_{j=1}^{M} P_j = 1 \]  

(11)

Let us introduce the new designations: where \( Se \) is the number of pixels included in ellipse that was specified in the first step, \( SI \) is the whole number of photo’s pixels. Let us introduce the norm:
\[
P_j = \begin{cases} 
P_c = \frac{1}{s_jX} & \text{When the middle of the square, that we determine } Q_j \text{ for, is in the ellipse} \\
Q_c = \frac{1}{s_jA} & \text{In the other cases} 
\end{cases}
\]

(12)

Where X is a real number that controls the sensitivity of our norm to the ellipse points. Coefficient A:

\[
A = \frac{(s_I - s_e)s_I X}{s_I^2 X - s_e}
\]

(13)

The numerator of the above expression is always positive and number X has to meet the condition number (9):

\[
X > \frac{s_e}{s_I^2}
\]

It can be checked by direct calculating that there is an ideal norm for our photo that equals (1) as the original norm. Let us calculate it for an ideal image (for each \(i.e_i = y_i\)).

\[
Q = \sum_{j=1}^{M} Q_j = \sum_{\text{ellipse's points}} P_j + \sum_{\text{points outside the ellipse}} P_j = s_e \frac{1}{s_I^2 X} + (s_I - s_e) \frac{1}{s_I A}
\]

(14)

We have \(Q = 1\) by simplifying the formula.

The value of parameter X may be related directly to the ratio: \(\frac{P_c}{Q_c}\). The choice is arbitrary and will be discussed in the next part.

4. Findings

400 archives photographs that were scanned to digital recording were tested. The photographs were divided on four groups depending on the pixels amount ratio contained in the ellipse (described in the paragraph 2) to the whole pixels amount. The first group includes photographs which ellipse is 0-10% of the whole pixels, the second one is between 10 and 20%, the third one between 20 and 30% and the fourth one is between 40-50%.

The each photograph was destructed in the same way: the strong JPG compression was applied on, the filter blur was applied on the whole photograph, the filter blur was applied on the area containing the face, the noise Gauss was added, the effect of the median filter outside the head, the effect of the median filter on the head area, the effect of the median filter on the whole photograph.
Fig. 1 The original photograph  
Fig. 2 The photograph with strong JPG compression  
Fig. 3 The photograph with blur filter on the whole area  

Fig. 4 Blur filter applied on the face area  
Fig. 5 The photograph with the Gauss noise  
Fig. 6 Median filter applied on the area outside the head  

Fig. 7 Median filter applied on the head area  
Fig. 8 Median filter applied on the whole area  
Fig. 9 The head area marked with the algorithm described in the text
The control group was asked to assess the photograph with regard to the original one (assigning values 0 to 1). For each photograph in the group was calculated: the index Q (formula 7), the proposed index (formula 9) and SIMM (formula 8). The proposed index (formula 9) is depended on parameter X. Few values of the ratio were taken into consideration: $\frac{P_e}{P_{oc}} = 3.5; \frac{P_e}{P_{oc}} = 13; \frac{P_e}{P_{oc}} = 58; \frac{P_e}{P_{oc}} = 218$.

The graphs show the two extreme groups. The graph below shows reflects the group between 40% and 50%. The monotone changes in groups were our basic criterion of the quality index verification (in accordance with subjective people assessment). Reading the graph from left to right each point on the graph situated more on the right side presents the photograph with the higher assessment of people. If the indexes reflected the control group opinion we should have the rising line. In this case the criterion is fulfilled for our index and the ratio $\frac{P_e}{P_{oc}} \geq 13$.

Graph 1 The graph shows the average results for photographs where the head was between 40 and 50% of the area. Parameters describing the ratio: $\frac{P_e}{P_{oc}}$ above-mentioned are on the vertical axis. MSR (from the worst to the best one) is on the horizontal axis, so the index which is the rising function reflects the viewers’ likes and dislikes best. This is the line for pairs = 13, 58, 128 in this case.

The similar graph is presented for group 0-10%. In this case the criterion is fulfilled for $\frac{P_e}{P_{oc}} \geq 58$. Basing on the behaviour analysis of the proposed index we propose to determine the value X from the formula 15 and assume the value of the parameter $\frac{P_e}{P_{oc}}$ as 58.

The typical results for the monochrome photo of a man will be showed. The photo is low quality and has the distinct scanning defects (Fig. 1) and it was exposed to above mentioned destructive actions. picture.
Graph 2 The graph shows the average results for photographs where the head was between 0 and 10% of the area. The quality indexes (the Basic one from the paper [6], SSIM and the proposal described in his paper with the several parameters describing the ratio: Pe/Poc above-mentioned) are on the vertical axis. MSR (from the worst to the best one) is on the horizontal axis, so the index which is the rising function reflects the viewers’ likes and dislikes best. This is the line for pairs = 58, 128 in this case.

<table>
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<th>our proposition equation (9)</th>
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Tab. 1 The comparison of results of Q coefficient calculating for one photograph distorted in different ways. The ways of distortions are described in the paper. The number of photograph is in the first column, the index from the paper [6] is the second column, our proposition is in the third column, the control group assessment is in the fourth column. The figure 1 is the original photograph with the evaluation 1.

We determined the index value at the original photo and compared with the test group evaluation. The test group was 45 people and they were asked to order the photos from the best one to the worst one. The table shows the result – sorted in ascending order by our new index.

The similar results we get for the other monochrome photos.
5. Conclusions

The index we proposed is an easy in use extension of the universal quality images measure. If we compare it and MSR in use for the monochrome photos it is very advantageous. It is much more advantageous than index Q. We are conscious of the fact that the method we propose is not universal. But in the particular situations using our algorithm brings extreme benefits and it can be used with success in the automatic quality evaluation systems.

References

Współczynnik oceny jakości kompresji monochromatycznych archiwalnych zdjęć portretowych

Streszczenie

Wybór metod kompresji i ocena jakości obrazów archiwalnych w ostatnich czasach nabiera znaczenia, zwłaszcza w kontekście cyfryzacji archiwów. Nasza praca koncentruje się na archiwalnych fotografiach czarno-białych portretów ludzkich i ocenie jakości kompresji takich zdjęć. Celem pracy jest zaproponowanie indeksu pozwalającego automatycznie porównywać jakość kompresowanych obrazów, przy założeniu, że ocena grupy kontrolnej jest oceną najlepszą z możliwych. Zaproponowany indeks wykazuje doskonałą zbieżność z tą oceną, ponadto jest prosty koncepcyjnie i w implementacji.