Jakub PĘKSIŃSKI, Grzegorz MIKOŁAJCZAK

Zachodniopomorski Uniwersytet Technologiczny, Wydział Elektryczny

The preparation of input data in digital image processing

Streszczenie. *W artykule przedstawiono, wpływ odpowiedniego przygotowania danych wejściowych, w cyfrowym przetwarzaniu obrazów, na wyniki końcowe miary jakości obrazu tzw. kryterium Q (Universal Quality Index).W celu wyeliminowania braku synchronizacji między obrazem wejścia i wyjścia, zaproponowano algorytm dopasowania, oparty o dwuwymiarowy współczynnik korelacji. (**Przygotowanie danych wejściowych w cyfrowym przetwarzaniu obrazów**).*

Abstract. *The aim of the article is presenting what kind of influence an appropriate preparation of entry data in digital image processing has got upon the final results. The authors have presented it on the basis of lack of synchronization between entry data and its influence on the quality criterion Universal Image Quality Index "Q" as well as the process of neuron network learning. In the article an algorithm based on correlation has been proposed. Its function is to eliminate the lack of synchronization between entry images in such a way so that the final result is burdened by the smallest possible mistake, resulting from lack of adequate fitting.*

Słowa kluczowe: dopasowanie danych, korelacja, sieć neuronowa, miary jakości.
Keywords: data match, correlation, neural network, quality measure.

Introduction

The development of digital signals processing which was noted last few decades, needs using objective criteria of the evaluation of the quality of the implemented algorithms, so that it is possible to compare them by expected results. Because of that parallel to the search of more effective algorithms of the digital signal processing, the methods of their evaluation were being developed, because this is an ambiguous and often intensely subjective matter. Particularly, it is visible in evaluation of the algorithms of the image digital processing, where it is difficult to find an objective indicator reflecting quantitatively an impression which viewed image gives. It is possible that quality measure which is used indicates low level of distortion whereas subjective evaluation of an expert, who evaluates final processing result may be different. It is mainly caused by non-linear human perception sense, which is very sensitive on high frequency components of the graphic information, such as edges and tiny details. Those elements in the process of image processing can be significantly relegated, because many methods of signal digital processing have downband character. The most current and used quality measures are:

- MSE (Mean Square Error):

(1) $$MSE = \frac{1}{M \cdot N} \cdot \sum_{i=1}^{M} \sum_{j=1}^{N} [f(i,j) - f^{'}(i,j)]^2$$

- NMSE (Normalized Mean Square Error):

(2) $$NMSE = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} [(f(i,j) - f^{'}(i,j)]^2}{\sum_{i=1}^{M} \sum_{j=}^{N} [(f(i,j)]^2}$$

- MAE (Mean Absolute Error):

(3) $$MAE = \frac{1}{M \cdot N} \cdot \sum_{i=1}^{M} \sum_{j=1}^{N} \left| f(i,j) - f^{'}(i,j) \right|$$

- NMAE (Normalized Mean Absolute Error):

(4) $$NMAE = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} \left| (f(i,j) - f^{'}(i,j) \right|}{\sum_{i=1}^{M} \sum_{j=1}^{N} \left| (f(i,j) \right|}$$

- PMSE (Peak Mean Square error):

(5) $$PMSE = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} [(f(i,j) - f^{'}(i,j)]^2}{M \cdot N \cdot \left[\max\{[(f(i,j)\}\right]^2}$$

- AD (Mean Error):

(6) $$AD = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} [(f(i,j) - f^{'}(i,j)]}{M \cdot N}$$

where: *M, N*- image size; *f(i,j)* – reference image; *f'(i,j)*- image after processing.

Analyzing preceding correlations it can be observed that numerical values of the quality indexes depend on the content of test image. For example interferences evenly distributed, with mere amplitudes, influence strongly on Mean Absolute Error (MAE), whereas impulse interferences decide mainly about value of Mean Square Error (MSE).

The above mentioned criteria (1-6) belong to the group of so called objective quality measures videlicet they generate a number, which value reflects the quality of the evaluated algorithm or processed signal. Apart from this types of measures, subjective criteria of quality evaluation (observations) are used, which are conducted by a team of experts, who evaluate the result of processing due to fixed rules (for example note scale with literal description). Overview of these measures can be found in the study [2]. Because the user-interpreter of information is a man, the evaluation of objective measure should be compliant with the subjective estimation of this person. The usage of objective measures results from easiness of affiliation the optimization of processing with the quality of received results. As an example, measures based on Mean Square Error can be presented here, which are easy in use and in some degree correlate with graphic content. However, mere image spatial shift (for example by one pixel) causes articulate increase of this indicator while subjective evaluation does not practically give any differences. Similarly it is with the influence of particular algorithms CPS on processed signal. Example no 1 illustrates this.

Example 1

Bearing in mind that quality measures quoted earlier (1-6) do not always reflect reality, which means that their values do not correspond with subjective impression that comes from observation of the algorithm operation results.

To show that, test image called “Lena” was put under median filtration. In this experiment standard median filters 2-D of element masks 3x3, 5x5, 7x7, 9x9 were used. Het results are presented in the table 1.

Table 1. Values of particular test image quality measures, after median filtration

Quality measure	Median filter of mask			
	3x3	5x5	7x7	9x9
MSE	2866	2652	3370	3166
NMSE	0,086	0,079	0,101	0,095
MAE	20,5	23,9	30,4	31,2
NMAE	0,124	0,145	0,184	0,189
PMSE	0,044	0,041	0,052	0,049
AD	-2,62	-6,02	-5,37	-7,45

Comparing the results received in table 1 with Fig. 1 from a to b, which show the result of standard median filter operation, it can be stated that with the increase of mask size, degradation of image is bigger, but particular indicators do not reflect that in a distinct way.

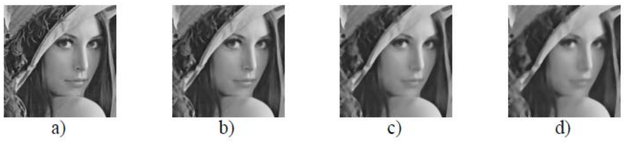

Fig.1. Test image after median filtration: a) 3x3 mask, b) 5x5, c) 7x7, d) 9x9 mask

Gaining good correlation between subjective and objective methods by evaluation of processed image quality is difficult. Due to that researches over construction of objective measure compliant with subjective estimation are being conducted. Example of that type of measures are criteria based on so-called HVS model, among which Hosak’s graph and Eskiciogl’s measure can be listed [2]. However, degree of their complexity and computational costs are much bigger than in case of objective methods, which have also advantages because they allow evaluation of interferences suppression degree and are independent from subjective estimation of individual receiver.

It occurs that a criterion, which combines advantages of subjective methods is a criterion proposed in the study [1] called “Universal Image Quality Index”:

$$(7) \qquad Q = \frac{\sigma_{f,f'}}{\sigma_f \cdot \sigma_{f'}} \cdot \frac{2 \cdot \overline{f} \cdot \overline{f'}}{(\overline{f})^2 + (\overline{f'})^2} \cdot \frac{2 \cdot \sigma_f \cdot \sigma_{f'}}{\sigma_f^2 + \sigma_{f'}^2}$$

where: *f* - orginal image; *f'*- result image, $\bar{f} = \frac{1}{N} \cdot \sum_{i=1}^{N} f_i$;

$\bar{f}' = \frac{1}{N} \cdot \sum_{i=1}^{N} f'_i$; $\sigma_f = \frac{1}{(N-1)} \cdot \sum_{i=1}^{N} (f_i - \bar{f})^2$;

$\sigma_{f'} = \frac{1}{(N-1)} \cdot \sum_{i=1}^{N} (f_i - \bar{f}')^2$; $\sigma_{f\,f'} = \frac{1}{(N-1)} \cdot \sum_{i=1}^{N} (f_i - \bar{f}) \cdot (f_i - \bar{f}')$

Its construction bases on arithmetic product of three independent factors: correlation, brightness and contrast. The first factor form (7) measures the degree of correlation between result image and original image. The second one informs about the change of mean brightness level. And the third one presents information about contrast differences. What was presented in [1], the value of this index corresponds with subjective estimation of observers, although value of MSE error in all kinds of interferences that occurred during image evaluation was equal. It occurs that, indeed an easy in use and objective quality index of image digital processing algorithms, which was used in quality evaluation in studies [1, 2] was developed. However, it should be pointed out that there is some shortcoming in this criterion, and this is a strong dependence on mere spatial shift of the pixels in the result image. It is illustrated by following example presented below.

Example 2

On the Fig. 2 exemplary image shifted towards itself of about a few pixels in the plane X and Y is presented.

The subjective impression resulted from the comparison of both images is very well, due to the fact that those images are identical, they have only been shifted towards themselves of about 4 pixels in the vertical and 3 in the horizontal. However, this kind of shift has a drastic influence on the Q criterion. Its value is: Q= 0.2838. It demonstrates a significant difference between researched images. In the table 2 exemplary results of the research of the Q criterion behavior on the shifts of images towards themselves in the plane X and Y are presented.

Fig.2. Image a) original image, b) shifted, c) the difference between original and shifted images

The images were subject to the objective and the subjective evaluation in relation to the reference image in the same way as in example 1. The results of the measurements are shown in table 2.

From the above mentioned results placed in the table 2 we can come to a conclusion that images shift of about 1 pixel has an intensive influence on the value of the quality evaluation criterion defined with the pattern (7) what causes, that this index in some circumstances can become non-objective.

Table 2. The impact of shift on the criterion of the "Q"

Image	***Shift***	**Q**
Lena	x=-1 y=0	0.6243
	x=-2 y=0	0.3359
	x=-3 y=0	0.2411
	x=-1 y=1	0.5416
	x=-2 y=2	0.3557
	x=-3 y=3	0.2663
Pentagram	x=-1 y=0	0.6875
	x=-2 y=0	0.3282
	x=-3 y=0	0.1958
	x=-1 y=1	0.5300
	x=-2 y=2	0.2426
	x=-3 y=3	0.1167
Airplane	x=-1 y=0	0.6343
	x=-2 y=0	0.3311
	x=-3 y=0	0.2146
	x=-1 y=1	0.5395
	x=-2 y=2	0.2891
	x=-3 y=3	0.1873

Therefore, it is suggested that before the determination of the Q criterion value (7) there should be made an adjustment of both images in the X and Y plane according to the below mentioned algorithm, which leads to making real the received values of the quality index.

Algorithm of the adjustment of the images in X and Y plane

As a criterion of the adjustment of both images, authors suggest using the algorithm which is based on the mutual correlation (8) between images.

(8) $$r=\frac{\sum_i\sum_j(f_{i,j}-\bar{f})\cdot(f'_{i,j}-\bar{f}')}{\sqrt{\left(\sum_i\sum_j(f_{i,j}-\bar{f})^2\right)\cdot\left(\sum_i\sum_j(f'_{i,j}-\bar{f}')^2\right)}}$$

where: f - original image; f'- result image; $\bar{f}$, $\bar{f}'$ - mean value

The operation works according to strictly specified order, which describes block diagram on the figure no 3.

Fig.3. Block diagram of the algorithm of the both images adjustment image

Algorithm operation begins from the study of initial synchronization between images. To calculate the initial synchronization, a fragment of an image placed near the center is taken into account. The window of 20x20 pixels was used (Fig. 4 a),b)).

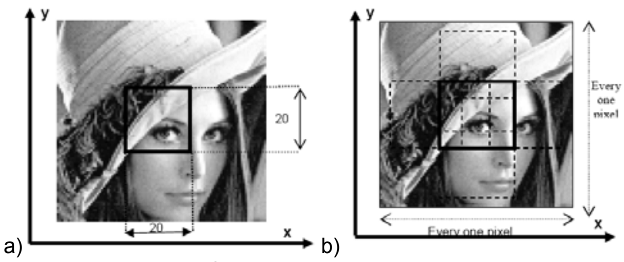

Fig.4. a) calculating of the initial synchronization, b) calculating of the synchronization in four dimensions.

In every location of this kind, mutual correlation between images windows is calculated. Where the correlation achieves a maximum value, both images will be the most adjusted towards themselves.

Conclusions

Results of conducted tests are placed in table 3. Received values present, that suggested method of making real the value of the *Q* criterion, described by the pattern (7) enables a better evaluation of the processed image, because it makes it independent from spatial shift of compared images, which has an influence on its value (8). It seems that agitated issue is important, due to the fact that it approaches us to the development of the objective quality criterion, which contains simplicity of calculations and correlates with picture content allowing an avoidance of subjective evaluation of processed signals.

Even though the paper features the problem of lack of synchronization of images exclusively on the basis of its effect on the values of the quality criteria, the problem is also encountered in other scientific fields (e.g. in the neural network learning processes [6]).

Table 3. The impact of shift on the criterion of the "Q"

Image	Shift	Initial correlation	Final correlation	Q before	Q after
Lena	x=-1 y=0	0.9710	1	0.6243	1
	x=-2 y=0	0.9268	1	0.3359	1
	x=-3 y=0	0.8893	1	0.2411	1
	x=-1 y=1	0.8893	1	0.5416	1
	x=-2 y=2	0.9160	1	0.3557	1
	x=-3 y=3	0.8765	1	0.2663	1
Pentagram	x=-1 y=0	0.8905	1	0.6875	1
	x=-2 y=0	0.7371	1	0.3282	1
	x=-3 y=0	0.6502	1	0.1958	1
	x=-1 y=1	0.8302	1	0.5300	1
	x=-2 y=2	0.6767	1	0.2426	1
	x=-3 y=3	0.5738	1	0.1167	1
Airplane	x=-1 y=0	0.9341	1	0.6343	1
	x=-2 y=0	0.8945	1	0.3311	1
	x=-3 y=0	0.8372	1	0.2146	1
	x=-1 y=1	0.8125	1	0.5395	1
	x=-2 y=2	0.7345	1	0.2891	1
	x=-3 y=3	0.7145	1	0.1873	1

Using this adjusting algorithm before issues of digital image processing, many errors caused by this can be eliminated.

Therefore, the algorithm elaborated by the author has a practical value, because due to its simplicity and high efficiency, it can be applied in all fields requiring synchronization of the images.

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Autorzy: *dr inż. Jakub Pęksiński, Zachodniopomorski Uniwersytet Technologiczny, Katedra Telekomunikacji i Fotoniki, ul. 26 Kwietnia 10, 71-126 Szczecin, E-mail: jpeksinski@zut.edu.pl; dr inż. Grzegorz Mikołajczak, Zachodniopomorski Uniwersytet Technologiczny, Katedra Przetwarzania Sygnałów i Inżynierii Multimedialnej, ul. 26 Kwietnia 10, 71-126 Szczecin, E-mail: grzegorz.mikolajczak@zut.edu.pl.*