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COMMUNICATIONS

CORRECTION OF THE DIGITAL IMAGE SHIFT IN TWO–DIMENSIONAL PLANE

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The aim of this article is to present a problem caused by wrong synchronization of two digital images in a 2-D plane and a method of image adjustment based on quality criterion "average difference" AD.

K e y w o r d s: digital image, AD error, synchronization, criterion

1 INTRODUCTION

Dynamic development of digital images acquiring and processing techniques which has been observed in recent years has brought about the fact that digital image processing became very attractive from the science point of view. Digital image processing is used in many fields for example medicine, adaptive algorithms, neural network learning processes and so on. In many cases synchronization of images, especially those acquired by different sources, has a very important meaning.

Let us analyze it on an example of a recently popular criterion of digital images evaluation *Universal Image Quality Index* [1] called simply Q, described by formula (1).

$$Q = \frac{4\sigma_{y,y'}\overline{y}\,\overline{y'}}{\left(\sigma_y^2 + \sigma_{y'}^2\right)\left[(\overline{y})^2 + (\overline{y'})^2\right]} \tag{1}$$

where

$$y = \{y_i \mid i = 1, 2, \ldots, N\} \text{ – image no 1,}$$

$$y' = \{y'_i \mid i = 1, 2, \ldots, N\} \text{ – image no 2,}$$

$$\overline{y} = \frac{1}{N}\sum_{i=1}^{N} y_i\,,\ \overline{y'} = \frac{1}{N}\sum_{i=1}^{N} y'_i\,,$$

$$\sigma_y = \frac{1}{N-1}\sum_{i=1}^{N}\left(y_i - \overline{y}\right)^2,$$

$$\sigma_{y'} = \frac{1}{N-1}\sum_{i=1}^{N}\left(y'_i - \overline{y'}\right)^2,$$

$$\sigma_{y,y'} = \frac{1}{N-1}\sum_{i=1}^{N}\left(y_i - \overline{y}\right)\left(y'_i - \overline{y'}\right).$$

Criterion "Q" has enjoyed growing popularity recently because of combining advantages of subjective and objective evaluation. Apart from its advantages this criterion has a slight disadvantage, it is very sensitive for shifting images toward themselves. Looking at images presented in Fig. 1 it can be stated that they are the same images.

Fig. 1. Test images

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Fig. 2. Test images a) original b) shifted of plus one pixel in plane X

The value of criterion "Q" confirms it too $Q = 1$. It is true, because both images are the same. This means that objective evaluation matches the subjective evaluation.

Let us look now at the images in Fig. 2. Evaluating both images subjectively, we can state that they are the same. Indeed this is true, those are the same images shifted by plus one pixel in the direction of plane X (Fig. 3 presents differences between the images). However, this slight shift has dramatically affected the criterion "Q", which amounts now to $Q = 0.6243$ From the subjective evaluation point of view, shifting an image by a few pixels does not have a meaning, but it counts when it comes to criterion "Q".

Fig. 3. Difference between the images

This is one of the examples when inaccurate adjustment of digital image causes many errors and leads to wrong results interpretation.

Another example in which the lack of images synchronization leads to many errors are the learning processes of the neural network in order to generate an optimal filter mask FIR.

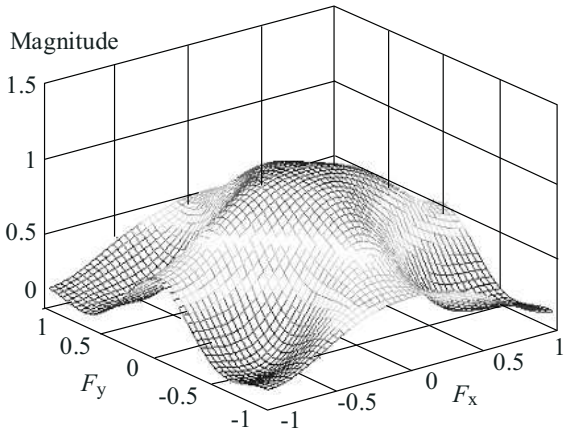

Fig. 4. Amplitude characteristic of the filter without shift

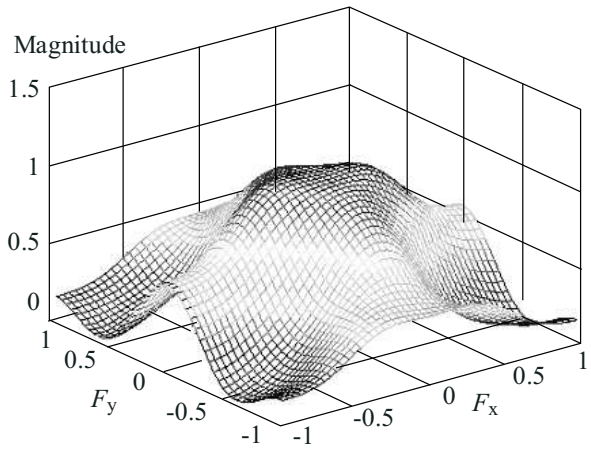

Fig. 5. Amplitude characteristic of the filter with a shift of one pixel

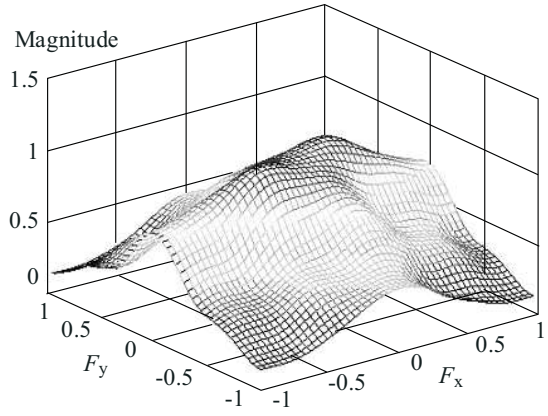

Fig. 6. Amplitude characteristic of the filter with a shift of two pixels

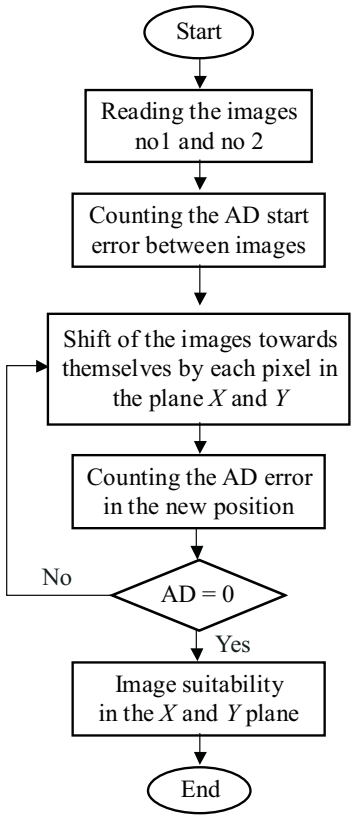

Fig. 7. Block diagram of the algorithm

3 EXPERIMENTAL RESEARCH RESULTS

Figures 4, 5 and 6 present the amplitude characteristics generated by a filter network for digital images which are equally disturbed toward the original and shifted by zero, one and two pixels in the direction of plane X. As it is shown, the shift significantly affects the filter characteristic and its mask ratios. Such a filter, apart from disruptions elimination, will try to correct the error caused by the shift between images.

In this article the authors will present an algorithm that adjusts digital images in plane X and Y that is based on testing an average difference AD error (formula no 2) between images.

$$AD = \frac{\sum_{x=1}^{N} \sum_{y=1}^{N} [y(x,y) - y'(x,y)]}{MN} \tag{2}$$

where
M, N — image size,
$y(x,y)$ — image no 1,
$y'(x,y)$ — image no 2.

2 PRINCIPLE OF OPERATION OF THE IMAGE SYNCHRONIZATION ALGORITHM

The principle of operation of the algorithm is presented in Fig. 7. Its operation, the algorithm begins from testing the AD error between two images (Fig. 8). This error is a start error and a reference point for further actions to synchronize images.

In the next step, we shift images toward themselves of one pixel in every direction X and Y (Fig. 9). In each new position we observe the changes in AD error indication between images all the time. If indication comes to 0 value, it means that the image is shifted in the right direction, if indication recedes from 0 value, it means image shifting direction needs to be changed.

The whole process ends when AD error indicates value equal 0. It means that both images are perfectly adjusted. Exemplar graph of AD terror decay is presented in Fig. 10.

Table 1. Experimental research results for pair no 1

Shift		**AD**	**Shift found**		**AD**
X	Y	**start**	X	Y	**end**
1	0	10.79	1	0	0.00
2	0	12.71	2	0	0.00
3	0	14.95	3	0	0.00
−1	0	−10.79	−1	0	0.00
−2	0	−12.71	−2	0	0.00
−3	0	−14.98	−3	0	0.00
−1	1	14.58	−1	1	0.00
−1	2	15.43	−1	2	0.00
−1	3	16.78	−1	3	0.00
−2	−1	−14.53	−2	−1	0.00
−2	−2	−18.28	−2	−2	0.00
−2	−3	−20.34	−2	−3	0.00

3 EXPERIMENTAL RESEARCH RESULTS

To confirm the operation efficiency of the algorithm experimental research was conducted.

Experimental research was conducted on 5 pairs of test images which were artificially shifted between themselves

Table 2. Experimental research results for pair no 2

Shift		AD	Shift found		AD
X	Y	start	X	Y	end
1	0	20.51	1	0	0.00
2	0	22.32	2	0	0.00
3	0	24.18	3	0	0.00
−1	0	−20.51	−1	0	0.00
−2	0	−22.32	−2	0	0.00
−3	0	−24.18	−3	0	0.00
−1	1	24.49	−1	1	0.00
−1	2	25.23	−1	2	0.00
−1	3	26.56	−1	3	0.00
−2	−1	−24.53	−2	−1	0.00
−2	−2	−28.28	−2	−2	0.00
−2	−3	−30.87	−2	−3	0.00

Table 3. Experimental research results for pair no 3

Shift		AD	Shift found		AD
X	Y	start	X	Y	end
1	0	17.22	1	0	0.00
2	0	19.32	2	0	0.00
3	0	21.78	3	0	0.00
−1	0	−17.22	−1	0	0.00
−2	0	−19.32	−2	0	0.00
−3	0	−21.78	−3	0	0.00
−1	1	20.29	−1	1	0.00
−1	2	22.28	−1	2	0.00
−1	3	23.99	−1	3	0.00
−2	−1	−22.43	−2	−1	0.00
−2	−2	−24.32	−2	−2	0.00
−2	−3	−25.89	−2	−3	0.00

Table 4. Experimental research results for pair no 4

Shift		AD	Shift found		AD
X	Y	start	X	Y	end
1	0	37.42	1	0	0.00
2	0	39.62	2	0	0.00
3	0	31.98	3	0	0.00
−1	0	37.42	−1	0	0.00
−2	0	39.62	−2	0	0.00
−3	0	31.98	−3	0	0.00
−1	1	30.29	−1	1	0.00
−1	2	32.28	−1	2	0.00
−1	3	33.99	−1	3	0.00
−2	−1	32.43	−2	−1	0.00
−2	−2	34.32	−2	−2	0.00
−2	−3	35.89	−2	3	0.00

Table 5. Experimental research results for pair no 5

Shift		AD	Shift found		AD
X	Y	start	X	Y	end
1	0	8.32	1	0	0.00
2	0	9.27	2	0	0.00
3	0	11.78	3	0	0.00
−1	0	−8.32	−1	0	0.00
−2	0	−9.27	−2	0	0.00
−3	0	−11.78	−3	0	0.00
−1	1	12.11	−1	1	0.00
−1	2	14.267	−1	2	0.00
−1	3	16.29	−1	3	0.00
−2	−1	−12.28	−2	−1	0.00
−2	−2	−14.78	−2	−2	0.00
−2	−3	−15.49	−2	−3	0.00

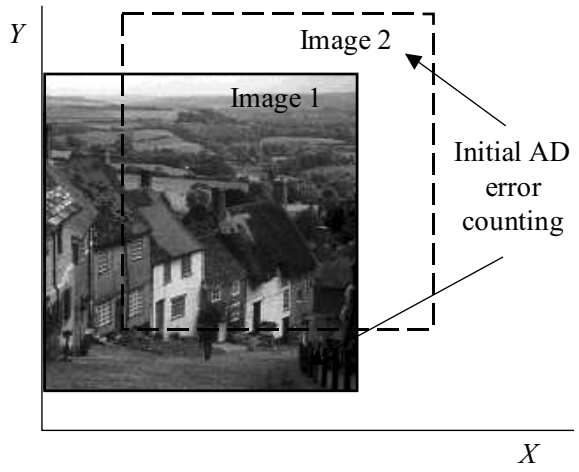

Fig. 8. Initial AD error counting

Fig. 9. Shifting and counting the AD error

by 1 to 3 pixels both in the direction of plane X and plane Y. The results of experimental research are presented in tables 1 to 5.

4 CONCLUSIONS

After analyzing the results presented in tables 1 to 5 it can be stated that the algorithm synchronizing images in

planes X and Y proposed by the authors is characterized by 100 percent precision. Owing to this algorithm, the error of subjective evaluation criterion Q, presented in the example, amounted to 1. This means that the value of criterion matches subjective evaluation of the observer. Using this adjusting algorithm before issues of digital image processing, many errors caused by this can be eliminated.

Simplicity and easiness of implementation belong to the advantages of this solution. Owing to that even a person with little experience in programming can, without a problem, write programs for synchronization of images in plane X and Y with the usage of the above described algorithm.

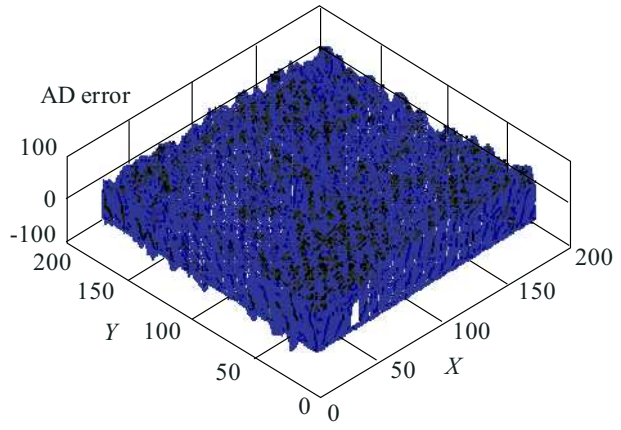

Fig. 10. AD error decay on the X and Y

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