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Experiments with Fusion of Images with Use of Wavelet Transformation in Problems of the Text Information Analysis

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Abstract— An analysis of images is the powerful tool of research in various fields of knowledge. One of directions of application of such analysis is a computer processing of text information. There is defined a number of problems among existing variety of methods of image processing of a text, where a wavelet procedure of fusion of images is in the basis. There is carried out a number of experiments for the purpose of a substantiation of possibility and expediency of application of wavelet procedure of fusion of images for the computer processing and the analysis of text information. As a result of the carried out experiments, a complexity of a choice of a fusion method of investigated images and an estimation of quality of such fusion are shown. Necessity of use of adaptive procedures is proved at a choice of a fusion method of approximating and detailing coefficients of wavelet expansion.

Keywords— pattern recognition, Image, wavelet analysis, image fusion, approximating coefficients of wavelet expansion, detailing coefficients of wavelet expansion, computer analysis of text information.

1. INTRODUCTION

A computer processing and an analysis of text information is one of directions of the general theory of pattern recognition. A complexity of practical realization of such direction consists in necessity of the solution and the account of:

– traditional problem aspects which are inherent to the general problematics of the solution of problems by means of the pattern recognition theory [1, 2],

– specificity of recognition of text information which is connected, first of all, with specificity of concrete language representation of such information [3, 4].

Nevertheless, among such problem aspects it is possible to define the general problems which are necessary for solving in the course of computer processing and the analysis of text information. There are following problems:

– restoration of a fragment of the lost text,

– restoration of the text by means of fusion of several fragments,

– improvement of quality of perception of the text by computer system on the basis of removal of noise or increase of dearness of the analyzed text,

– identifications of the considered test on the basis of carrying out of the comparative analysis of the initial text with a database of various texts.

Thus as the tool which is used for the solution of the considered problems, it is possible to use separate procedures of wavelet analysis. Such choice is based on, that a wavelet analysis is a quite powerful device used in pattern recognition and processing of images. It is connected with that the use of procedures of wavelet analysis gives:

– possibility of the account for various aspects of investigated images from the point of view of a way of their representation,

– possibility of use of various approaches for underlining of any aspects of representation of visual images in the course of their the subsequent processing.

It, finally, defines the interest in a choice of a considered subject of research.

2. WAVELET TRANSFORMATION AS METHODOLOGY OF PROCESSING OF IMAGES

The wavelet transformation is an expansion of a signal on system of wavelets. Wavelets are made by shift and scaling of one function – a generating wavelet [5]. In this case a wavelet is a function which rapidly decreases on infinity and its average value is equal to zero. If the signal has a gap then high amplitudes will be present only in those wavelets which maximum appears next to a gap point. A gap is a sharp discontinuous transition during any process. Quantitatively it can be estimated in size of the first derivative

of such process. There, where the jumps take place, the first derivative is very great. If jump has a gap form, the first derivative aspires to infinity. However, the real processes which are measured by physically real devices cannot have ideal gaps. Actually, measured fractural transitions are characterized by final value of a derivative. The more sharply gap, the greater value of a derivative. Smooth transitions will have small values of a derivative. Because of this fact, it is possible to define presence of features of a signal as well as a point where it is shown.

Thus, the main idea of the wavelet transformation – time-and-frequency representation of a signal [5]. From the formalized point of view under a wavelet transformation (W) we understand expansion by means of functions, where each of them is the shifted and scaled copy of one function – a parent wavelet [5, 6].

Continuous wavelet transformation of function $f(t)$ is defined by expression:

$$W[f(t)] = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} f(t) \cdot \varphi\left(\frac{t-b}{a}\right) dt, \qquad (1)$$

where a – scale;

b – centre of time localization;

function $\varphi(t)$ is a parent wavelet and it satisfies to a condition:

$$\int_{-\infty}^{+\infty} \varphi(t) dt = 0. \qquad (2)$$

Function of continuous wavelet transformation is applicable for one-dimensional signals, and the image is a two-dimensional signal. Therefore the discrete wavelet transformation is applied to processing of images in the assumption, that [7]:

values a, b accept only discrete values,

accordingly integration is replaced with summation which is separately conducted for every line and every column of the analyzed image.

If we have some input image B which is presented in the form of a matrix $B(x, y) \in L_2(R)$ then its wavelet expansion at each level of decomposition can be presented in the form of the scheme [8] shown on figure(1) (sign $2\downarrow$ – image decimation, L – low-frequency filter, H – high-frequency filter).

x, y – current co-ordinates of the matrix of the values of image B which displays co-ordinates of a line and a column, and $B(x, y)$ – quantitative value of an element of the image with co-ordinates (x, y).

i ($i = 1,2,...j$, $N = 2^j$ N – a linear size of the initial analyzed image) is a level of wavelet expansion of the initial (input) image (the image which is exposed to wavelet expansion or decomposition in future).

vv – an input image in the form of the matrix $B(x, y)$. Target images are designated accordingly – $v1^{(i)}, v2^{(i)}, v3^{(i)}, v4^{(i)}$ where $v1^{(i)}$ – the reduced copy of the initial image, and, $v2^{(i)}, v3^{(i)}, v4^{(i)}$ – images of wavelet expansion of the initial image across, verticals and diagonals for the certain level of expansion i.

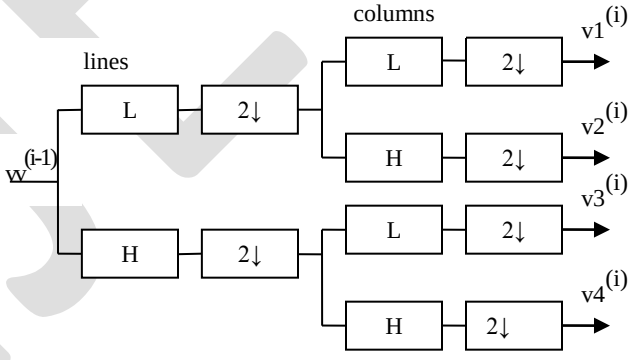

Figure (1): Two-dimensional discrete wavelet transformation

Thus, the result of consecutive wavelet expansion of some image is its multilevel representation in the form which is represented on figure (2). Figure (2) as an example shows schematic two-level wavelet expansion of the initial image B, where B2 – the reduced copy of the initial image B on the second level of expansion; H, V and D – accordingly images of wavelet expansion of the initial image across, verticals and diagonals for the certain level of expansion.

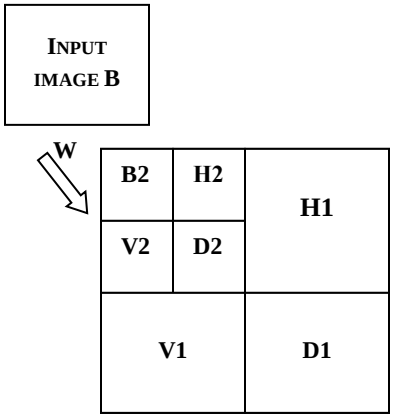

Figure (2): Schematic representation of wavelet expansion

Expansion of the initial image with the help of wavelet transformation, in particular, allows to compress the initial image for its subsequent transfer through communication channels and in the subsequent to restore, using the reverse wavelet transformation (W^{inf}) [9]. Thus, application of updating procedure which is used taking into account separate levels of wavelet expansion is possible before restoration of the compressed image. The essence of such updating consists in use of image fusion procedure for separate levels of expansion of initial images therefore the new and modified wavelet expansion of some investigated image has appeared. Figure (3) shows schematic representation of process of updating of some wavelet expansion of the initial image B by means of wavelet expansion of the auxiliary image C where in the result we'll get the modified image A [10].

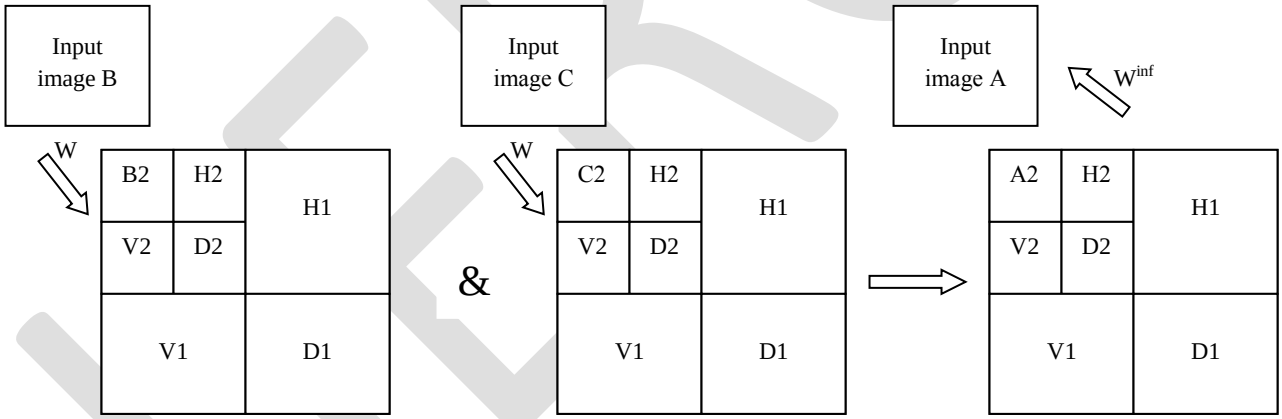

Figure (3): Schematic representation of the image updating by means of its wavelet expansion and the reverse wavelet transformation

Symbol & designates a way of fusion of the images which essence consists in application of certain procedure of fusion of approximating and detailing coefficients [9, 10] which are the result of wavelet transformation (expansion) of input images B and C [7, 8].

3. WAVELET IMAGE FUSION PROCEDURE AS A BASIS OF THE SOLUTION OF PROBLEMS OF COMPUTER PROCESSING AND THE ANALYSIS OF TEXT INFORMATION

The considered procedure of image fusion for their updating can be used both in problems of computer processing, and the analysis of text information. It is connected with that the wavelet image fusion procedure does not limit a spectrum of considered

initial images. The key moment in use of such procedure is the substantiation of the way of fusion of two images (&) depending on complexity of representation of the considered text, a context of a solved problem and various noise on images.

Thus it is necessary to notice, that questions of possible use of the wavelet image fusion procedure are considered in works of different authors:

in research of K. Amolins, Z. Yun, and D. Peter variety of different methods, ways and schemes of association of images in comparison with the wavelet image fusion procedure where achievement of the most desirable characteristics undertakes a basis of an estimation of quality of such fusion in the general image which are inherent in initial images [10] are in detail considered;

in research of W. Shi, C. Zhu, Y. Tian and J. Nichol at consideration of wavelet image fusion procedure, the emphasis is placed on an estimation of quality of the obtained image after fusion of initial images. Thus as such estimation it is offered to use coefficient of an average and standard deviation for the values of initial and processed images, and correlation coefficient between initial and processed images as a measure of distortion of the analyzed information [11];

P. R. Hill, C. N. Canagarajah and D. R. Bull investigate quality of fusion of images depending on wavelet functions which are applied to such procedure [12];

Z. Wang, D. Ziou, C. Armenakis, D. Li and Q. Li analyze productivity of different procedures of fusion, placing thus emphasis on a preliminary filtration of initial images for the purpose of reduction of influence of noise by fusion process at reception of the final image [13];

S. Li and B. Yang study possibility of combined use of different methods and approaches at image fusion [14].

Thus, there is a set of different researches where the analysis and research of existing procedures of image fusion is carried out. At the same time the estimation of quality of image fusion depends on its concrete application. In different applications various aspects of the account of quality of the image can be demanded. At the same time it is necessary to notice, that the main objective of image fusion, in particular at processing of text information, consists in increase of visibility of the initial text. It is necessary to have possibility to read and work with a text. Finally, it defines the objective of this research.

4. RESULTS AND DISCUSSION

For the purpose of realization of the object in view of research, there has been carried out the analysis of quality of wavelet image fusion procedure which assumes the solution of the following problem – restoration of the initial image on the basis of fusion of two images with loss of separate fragments of the text.

For this purpose it is considered:

The initial image (figure (4)) – the original of the text which has been lost,

Two images with partial loss of various fragments of the text (figure (5), figure (6)) which are used in fusion procedure.

Figure (4): The initial image of the text

Figure (5): The image 1 from the partial fragment loss

Figure (6): The image 2 with partial fragment loss

Thus, the experiment essence consists in fusion of the images presented on figure (5) and figure (6) and comparison of some image obtained at such fusion with the image which is presented on figure (4).

Each of the presented images is the binary image which characteristics are:

the general number of points of the image (N),

the number of points of the text (I) –they are marked with black color on figures,

the number of background points (F) –they are marked with white color on figures.

Characteristics of considered images are presented in table (1) according to figure (4), figure (5) and figure (6).

Table 1: Statistical characteristics of analyzed images

Images	Characteristics		
	N	I	F
Figure (4)	64616	13376	51240
Figure (5)	64616	10410	54206
Figure (6)	64616	10819	53797

As we can see from the table 1 for the image 1 (figure (5)) the loss of a fragment of points of the text makes 22,17 % from points of the original text or 4,6 % from the general number of points of the original image (figure (4)). For the image 2 (figure (6)) the loss of a fragment of points of the text makes 19,12 % from points of the original text or 3,96 % from the general number of points of the original image (figure (4)). Total loss of fragments of the text which are necessary for restoring makes 5523 points.

Wavelet fusion procedure of two images was carried out by means of wavelet Dobeshi-2 function and wavelet expansion on three levels. As a whole, the choice of concrete family of wavelets is dictated by applied problems and type of the initial information. Nevertheless, use of Dobeshi wavelets creates more smooth approximation of investigated input data, and it has formed a basis for its application in the given research, being based on work conclusions «Properties of wavelet coefficients of self-similar time series» [15]. The number of levels of expansion has been chosen based on the sizes of images and insignificant separately by each of parts of the lost fragments in relation to a total square of all original image.

Result of research was ascertainment of quality of fusion of two images (figure (5) and figure (6)) on the basis of use of various ways of fusion of two images (&).

For ascertainment of quality of fusion of considered images, in particular, it was considered:

the opinion of seven experts which compared the restored image with the original one (figure (4)). Each of experts on five-grade scale (from 1 – the worst quality to 5 – the best quality) estimated quality of fusion of two images. As a result the average estimation has been obtained;

quantity of points of the text of the restored image in relation to quantity of points of the text of the original image.

Results of estimation of quality of fusion of images are presented in table (2) on the basis of opinion of experts.

Table 2: An expert estimation of quality of fusion of images

Experiment number	Way of fusion of coefficients		Average estimation of experts
	approximating	detailing	
1	max	mean	2,86
2	max	rand	2,43
3	max	linear-0,5	2,71
4	max	Up-down fusion-1	2,57
5	max	Down-up fusion-1	2,57
6	max	Left-right- fusion-1	2,71
7	max	Right-left fusion-1	1,86
8	max	img1	1,57
9	max	img2	1,57
10	mean	max	3,57
11	rand	max	3,29
12	linear-0,5	max	3,71
13	Up-down fusion-1	max	3,86
14	Down-up fusion-1	max	3,86
15	Left-right- fusion-1	max	4,00
16	Right-left fusion-1	max	3,57
17	img1	max	3,71
18	img2	max	3,71
19	mean	rand	3,86
20	min	max	4,71
21	mean	mean	4,43

22	max	max	3,57
23	linear-0,5	max	4,57
24	max	min	1,00
25	min	min	3,57

As we can see from the table (2) the restoration of the lost fragments of the text by means of procedure of fusion of images is quite challenge, from the point of view of achievement of quality of the total image. It allows to speak about necessity of a careful choice of a way of fusion of images by means of the wavelet analysis. A basis of such conclusion is the fact, that estimations of experts were based on a common view of fusion of images. Result of such common view of process of fusion is restoration of separate points of the lost fragments, however thus such points cannot be identified unequivocally as a point of a fragment of the text. In particular the given type of restoration concern:

the restored contour of the lost fragment,

points of the lost fragment which have numerical values in the matrix of the restored image distinct from the matrix of values of the original image.

The made remark proves to be true given table (3) where the corresponding estimation of quality is presented by percentage of quantity of the restored points of the lost fragments to number of such points in the original image.

When we compare data from table (2) and table (3) we can see some discrepancy in estimations of quality of fusion of images. The explanation of such discrepancy has been specified above.

Table 3: An estimation of quality of fusion of images on the basis of calculation of the restored points which have been lost

Experiment number	Way of fusion of coefficients		Percent of the restored points which have been lost, %
	approximating	detailing	
1	max	mean	23,54
2	max	rand	21,73
3	max	linear-0,5	22,63
4	max	Up-down fusion-1	19,92
5	max	Down-up fusion-1	20,82
6	max	Left-right- fusion-1	21,91
7	max	Right-left fusion-1	9,05
8	max	img1	12,67
9	max	img2	10,14
10	mean	max	63,37
11	rand	max	54,32
12	linear-0,5	max	66,99
13	Up-down fusion-1	max	65,18
14	Down-up fusion-1	max	61,56
15	Left-right- fusion-1	max	72,42
16	Right-left fusion-1	max	62,47
17	img1	max	61,56
18	img2	max	57,94
19	mean	rand	76,05
20	min	max	96,74
21	mean	mean	86,91
22	max	max	25,35
23	linear-0,5	max	83,29
24	max	min	0,00
25	min	min	74,24

Hence, at consideration the wavelet procedure of fusion of images it is necessary to consider, both a way of such fusion, and a way of estimation of quality of fusion of images. At the same time a necessary condition of improvement of quality of fusion of investigated images is application of adaptive procedures of a choice of a way of fusion of approximating and detailing coefficients of wavelet expansion of such images based on a context of a task. The given conclusion is based on possibility of use of different ways of

fusion of approximating and detailing coefficients of wavelet expansion of investigated images and ambiguity in an ascertainment of a total estimation of quality in the course of use of considered procedure of fusion of images.

5. CONCLUSION

Thus, the work considers the results of experiments on application of wavelet procedure of fusion of image for computer processing and the analysis of text information. Revealing of complexity of carrying out of wavelet procedure of fusion of image was the purpose of carrying out of such experiments and it consists of:

necessity of a choice and a substantiation of procedure of fusion of images on the basis of consideration of different variants of possible fusion of approximating and detailing coefficients of wavelet expansion of investigated images,

consideration of separate estimations of quality of fusion of images.

As a result of the carried out research different ways of fusion of approximating and detailing coefficients of wavelet expansion of investigated images are considered. The estimations of the obtained results of fusion are resulted.

The conclusion is drawn on necessity of use of adaptive procedures for a choice of a way of fusion of approximating and detailing coefficients of wavelet expansion. Nevertheless, the obtained results can be used for construction of the automated systems of the computer analysis of text information.

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