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Algorithms of Digital Processing and the Analysis of Underwater Sonar Images

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1. Introduction

At the present time in many countries the great attention is given to the problems of research of Ocean and development of underwater robotics. The vision system is one of the basic systems of "intellectual" autonomous unmanned underwater vehicle (AUV). Modern AUV vision systems can be equipped by various detectors including acoustic sensors, photo and video cameras. The side-scanning sonar or sector- scanning sonar is acoustic sensors. The given device is usually connected to a separate computer for the analysis, processing, recording and transmission of sonar images signals. The present chapter covers actual problems of computer processing and the analysis of the images received from a side-looking sonar (SSS).

At the beginning the main principles (Ageev et al., 2005) of sonar image signals creation are contemplated. The principle of scanning of a sea-bottom surface by narrow angle acoustic beam which is moved in the water environment by progressive motion of SSS antenna is assumed as basis of AUV action. The antenna has the harp diagram directivity, wide (up to 40-60 degrees) in a vertical plane and narrow (no more than 1-2 degrees) in horizontal. The parameter in horizontal plane determines angular resolution of SSS. An acoustic echo signal reflected from a sea-bottom surface, is formed with the help of two antennas located on the left and the right side of the underwater vehicle. During the presentation of information the sonar image is formed in such a manner that the distribution of probing pulses to space corresponds to the image deflection by lines. Thus in the process of device movement an echo signals of each probing cycle represent a separate line. As the result of *n* cycles of probing the image of a sea-bottom surface will be generated. During movement of AUV, an analog echo signal of every sonar image line will be transformed to the digital form and further can be exposed to preliminary processing, saved in the onboard computer memory and, also, can be transmitted by a communication channel.

The primary goals of preliminary processing of sonar images are the following: a filtration of signals from noise and time automatic gain control (TAGC).

Necessity of a signals filtration is caused by the fact that during the reception of hydro acoustic signals there is always noise on the background. Generally noise in the hydro acoustic channel can be divided into external and inherent (Olyshevsky, 1983). On the point of interaction the noise can be classified into additive and multiplicative. Additive noise

according to its structure can be fluctuation noise, pulse and harmonious noise. The most frequent noise is fluctuation, representing the infinite sum of radiations from different noise sources which are not connected to a useful signal. Impulsive noise includes such noise as single impulses originating, for example, during work of the radiating antenna. Noise action results in noise pollution of images and, hence, in impairment of its visual perception while solving analysis problems and recognition of underwater objects by the person - operator.

The peak signal-to-noise ratio (PSNR) is considered nowadays the most popular criterion of noisy images (Gonzalez & Woods, 2002). According to this criterion the normalized root-mean-square deviation of brightness coordinates of the test image pixels without noise and noisy images is calculated. Thus averaging is carried out at all square of the image. The ratio of the maximal value of brightness to a root-mean-square deviation in logarithmic scale defines PSNR value. Accordingly, if the closer the noisy image to the original, the bigger the PSNR value, the better its quality. However this and other similar metrics allow estimating only root-mean-square difference between images, therefore the best results from the metrics point of view is not always correspond to the best visual perception. For instance, the noisy image at which there are fine details with low contrast can have high PSNR value even in that case when the details are not visible on the noise background.

In the first part of the chapter the alternative criterion of the analysis of noisy sonar images in which properties of visual perception of fine details contrast are taken into account is offered. Results of the comparative analysis base algorithms of a filtration of images by objective criterion of an estimation of quality of reproduction of fine details and on peak PSNR value are resulted. The new filtration algorithm allowing effectively to filter a pulse noise and to keep at it image sharpness is offered.

Necessity of application time automatic gain control is caused by the following features (Ageev et al., 2005) of received an echo signals. The amplitude of acoustic echo signal depends on range of reception of a signal in each point of the antenna diagram. Thus the amplitude of the reflected signal in a distant zone of reception will be essentially lower, than in a near zone. Hence, alignment of sonar image contrast along a line needs automatic gain control of a signal depending on time (spatial) position of each pixel. Such control is usually carried out by TAGC device (Kravhenko, 2007). However at a finishing stage of computer processing, with the purpose of improvement of the image quality, manual contrast control of the image on its local segments usually is required.

The following actual task of digital processing of the underwater image is its compression. Compression algorithms are applied to more compact storage of the information on a hard disk or for transfer of the digital data on narrow-band communication channel. Use of compression algorithms with losses usually results in impairment of image quality. The traditional objective criterion of images quality considers root-mean-square criterion (MSE) or the PSNR. That they are integrated concerns to lacks of such criteria and not always correspond to the best visual perception of fine underwater details. In work (Sai, 2007) objective algorithms and criteria of the quality analysis of fine details reproduction of a photo and video images are described. In the second part of the chapter questions of the sonar images compression in real time are investigated. Results of the comparative analysis of compression efficiency and images quality on a basis of discrete cosine transformations, Haar transformations and wavelet transformations are resulted.

Now there are various variants of computer editors of sonar images. With the help of such editors the user can carry out: filtering of the image from noise; to change contrast and brightness of separate segments of the image; to scale the image; to measure and analyze

navigating parameters, etc. In the third part of the chapter the description of the developed computer editor of images is resulted. Its functions and features are described, examples of real images processing are resulted.

2. Filtering of the sonar image

Algorithms of images filtering are well enough investigated and submitted in references (Pratt, 2001). Known filtering algorithms usually specialize on suppression of any particular kind of noise. Meanwhile there are no universal filters which could detect and suppress all kinds of noise. However many noise can be approached rather well model Gaussian noise, therefore the majority of algorithms is focused on suppression of this kind of noise. The basic problem at noise filtering consists in not spoiling sharpness of details borders of the image, and also do not lose fine details, comparability on amplitude with noise.

One more complexity is the rating of noise suppression quality. As a rule, quality is estimated as follows: on the original image artificial noise is imposed, then the received image is filtered with the help of the chosen algorithm and compared to the initial image with the help of the chosen metrics. More often for this purpose use PSNR metrics which for gray-scale images is determined by the formula:

$$PSNR = 20 log_{10} \frac{255}{\sqrt{\frac{1}{N} \sum_{i=1}^{N} \left(Y_i - \widetilde{Y}_i \right)^2}} \qquad (1)$$

where Y_i and $\widetilde{Y}_i$ is the brightness values of *i-th* pixels of two compared images, N is the common of pixels number in the image. Accordingly, the closer the filtered image to original, there is more value PSNR, and it is above considered that quality of the work of algorithm. As it has been marked above, value PSNR allows to estimate only root-mean-square difference between images, therefore the best results from the point of view of the metrics do not always correspond to the best visual perception.

An alternative analysis algorithm and criterion of noisy images in which properties of visual perception of fine details contrast are taken into account.

With the purpose of the analysis the following preliminary processing of the original image is carried out. At the first stage search of fragments of the image as blocks with a size 3×3 a pixel which contrast corresponds to the established limits is carried out. Thus contrast of each block is calculated in normalized equal color space (Sai, 2007) in which thresholds of visual perception of fine details on brightness index are taken into account.

$$\Delta K = \Delta W^* / \Delta W_{th}^*, \qquad (2)$$

where $\Delta W^* = 3(W_{max}^* - W_{min}^*)$ is the contrast of the original image block, determined by number of the minimum perceptible color difference (MPCD); ΔW_{th}^* is the threshold value of contrast at which fine details differ with an eye. Value of a brightness index of in equal color space (Wyszecki, 1975) for everyone *i-th* pixel it is calculated as $W_i^* = 25 \ Y_i^{1/3} - 17$.

Further for the analysis fragments with the contrast satisfying a condition ($1 \le \Delta K \le 4$) get out and recognition of the image blocks to the following attributes is carried out: «dot object», a «thin line», a «structure fragment». The recognition algorithm is submitted in work (Sai & Sorokin, 2008).

At the second stage, the noise adds in the test image where model of the noise at model Gaussian noise is chosen. Further the maximal brightness deviation of original and noisy image for everyone *k-th* the block is calculated:

$$\Delta_k = max_{i,j,k} \sqrt{\left(\frac{W_{i,j,k}^* - \widetilde{W}_{i,j,k}^*}{\Delta W_{th}^*} \right)^2} \tag{3}$$

and average value of brightness deviation for all fragments of the image:

$$\overline{\Delta_k} = \frac{1}{M} \sum_{k=1}^{M} \Delta_k , \tag{4}$$

where M is the amount of fragments with low contrast fine details.

Finally on deviation value ($\overline{\Delta_k}$) and, hence, on value of contrast reduction of fine details it is made a decision on a noisy degree of images. As criterion the rule is chosen simple: if contrast decrease does not exceed one normalized threshold

$$\overline{\Delta_k} \le 1 , \tag{5}$$

that is made a decision that fine details differ with an eye on a noise level and definition of noisy images essentially is not reduced.

With the purpose of research of noise influence on quality of reproduction of fine details of images, authors have developed the computer analyzer. The user interface of the analyzer is shown on Fig. 1.
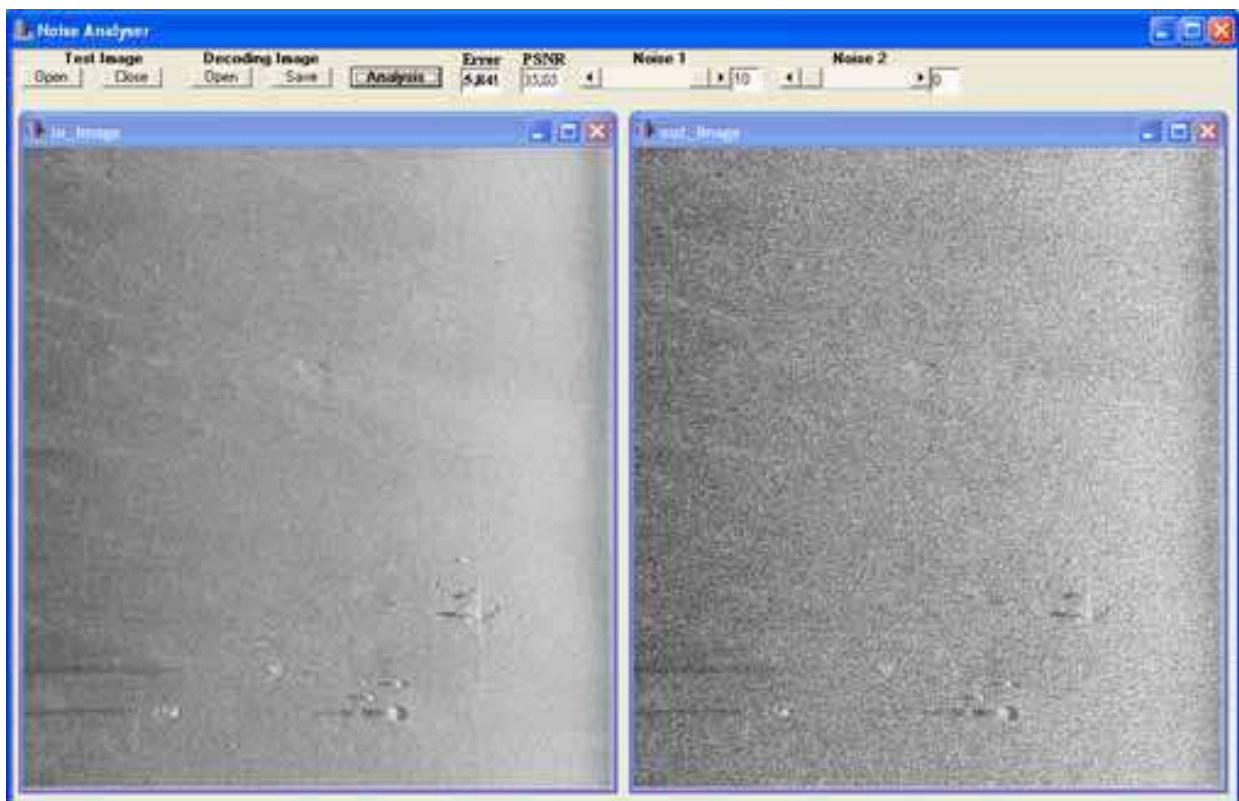

Fig. 1. Computer Noise Analyzer

Let's consider the basic functions of the analyzer. Before the beginning of the analysis the user opens in the first window original image ("Test Image" – "Open").

In the second window on the original image additive noise is imposed. As model of noise gets out fluctuation noise with Gaussian the law of distribution (Noise 1) or pulse noise (Noise 2). The noise level is set in percentage terms to the maximal amplitude of a signal.

By pressing button "Analysis" the program analyzes two images and carries out algorithm of calculation of value $\overline{\Delta_k}$ (4). Thus, the result appears in window "Error". Also, in window "PSNR" there is a calculated value of the peak signal–to–noise ratio (1). Thus, by results of the analysis of value ($\overline{\Delta_k}$) the user makes a decision about a degree of image noisy.

As an example in table 1. experimental dependences ($\overline{\Delta_k}$) and PSNR from root-mean-square value (σ) of the additive Gaussian noise in the brightness channel for a test fragment of sonar images are resulted.

σ %	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0
$\overline{\Delta_k}$	0,30	0,57	0,84	1,08	1,40	1,68	1,96	2,24	2,54	2,82
PSNR	47,8	44,9	43,3	42,0	41,0	40,3	39,6	39,0	38,5	38,1

Table 1. Dependences of $\overline{\Delta_k}$ and PSNR from root-mean-square deviation σ

On Fig. 2. fragments of sonar image with a various noise level are shown. The analysis of images quality shows that at value of noise in the brightness channel ($\sigma \leq 2\%$), the condition (5) is carried out. At performance of this condition, reduction of contrast of fine details invisibility for an eye and influence of noise does not reduce quality of visual perception of the image. Thus, the developed criterion, as against metrics PSNR, allows estimating objectively influence of noise on reduction in clearness of fine details of images.

It is obvious, that the computer analyzer also can be used for an estimation of the efficiency of filtration algorithms. In this case in the second window it is necessary to open the filtered image and to analyze.

From known filtration algorithms images it is possible to allocate the following base algorithms (Gonzalez & Woods, 2002) 1. Linear pixels averaging; 2. Median filtration; 3. Gaussian diffusion. The features of formation of sonar image concerns that in real time it is formed line-by-line. Hence, filtration algorithms should process pixels of the image also line-by-line.

The authors   research influence of base filtration algorithms into efficiency of noise suppression and into quality of reproduction of fine details of sonar image.

The elementary idea of a noise filtration consists in averaging values of pixels in a spatial vicinity. For each pixel the next pixels for it which settle down in a window at the left and to the right of this pixel are analyzed. Then the size of a window is more taken, the there is an averaging more strongly. The simplest variant of a filtration is when as new value of the central pixel average gets out arithmetic all pixels in a window.

Median filtration is a standard way of pulse noise suppression. For each pixel in a window it is searched median value and it is given to this pixel. Definition median values: if a massive of pixels in a window to sort on their value, a median will be an average element of this massive.
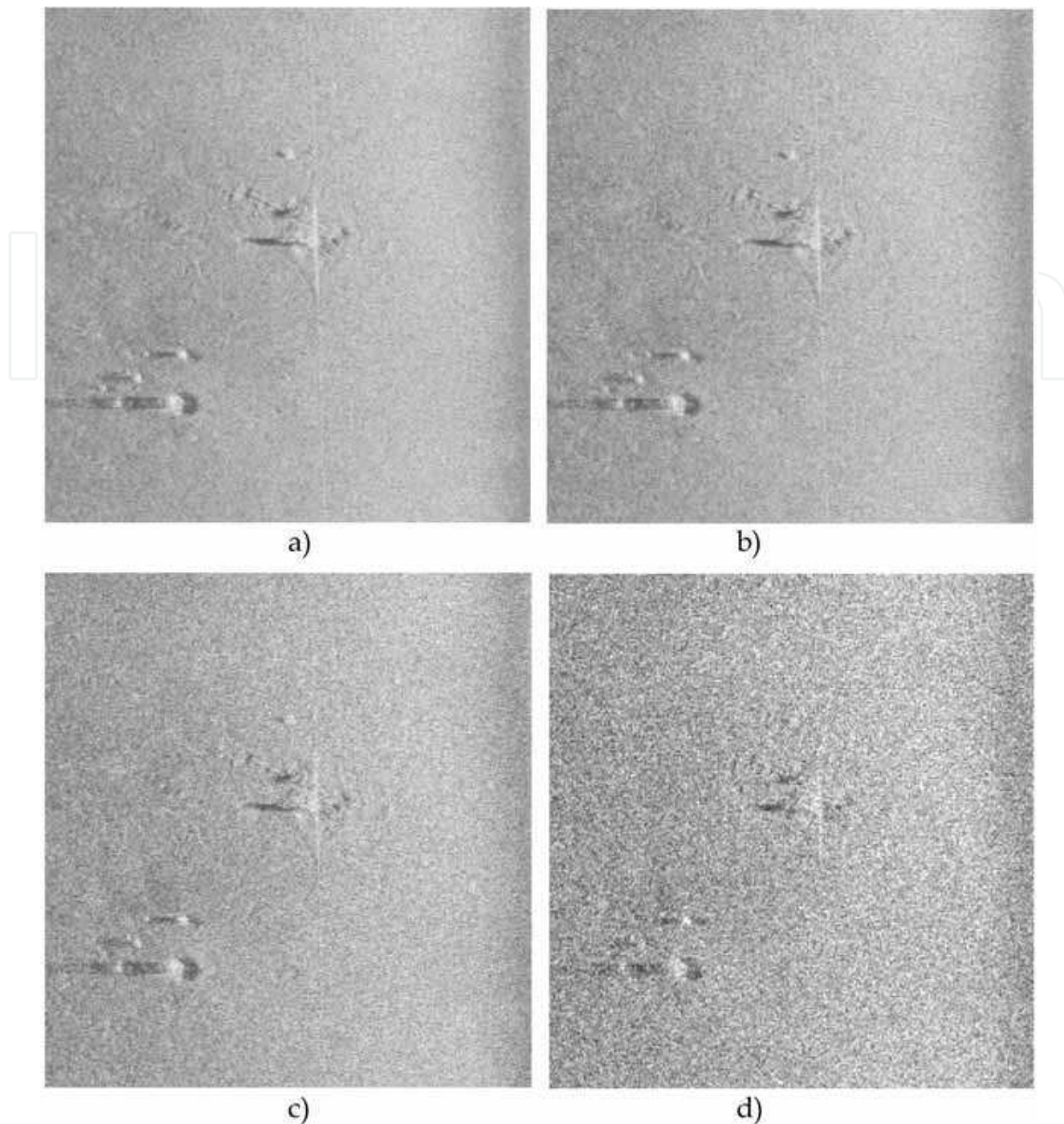
Fig. 2. Fragments of the test image:

a) σ =0%, $\overline{\Delta_k}$ =0 ; b) σ =2%, $\overline{\Delta_k}$ =1,08; c) σ =5%, $\overline{\Delta_k}$ =2,82; d) σ =10%, $\overline{\Delta_k}$ =5,85.

Gaussian diffusion is a convolution of the image with function $g(x) = A \cdot exp\left[-x^2/\delta^2\right]$, where the parameter ($\delta$) sets a diffusion degree, and parameter A provides normalization. Actually, this same averaging, only pixel mixes up with associates under the certain law set by Gaussian function.

With the purpose of the analysis of efficiency of noise suppression by base algorithms of a filtration we shall take advantage of the computer analyzer (Fig. 1). For this purpose at the first stage of processing it is execute two variants of noisy a test fragment of sonar images: fluctuation and pulse noise with the following parameters. For fluctuation noise it is installed σ =10%, thus an average deviation of fine details contrast equally $\overline{\Delta_k}$ =5,85 and value PSNR = 35,04 дБ. For pulse noise it is installed σ =80% and probability of its

appearance P = 0,2, thus an average deviation of fine details contrast equally $\overline{\Delta_k}$ =11,3 and value PSNR = 41,6 дБ.

At the second stage the filtration of noisy images is carried out and quality of noise suppression on value $\overline{\Delta_k}$ is estimated.

In table 2. results of the analysis of quality of noise suppression for three base algorithms where the size of a window of filters is set by three pixels are resulted.

Filter	**Average**	**Median**	**Gaussian**	Noise
$\overline{\Delta_k}$	3,25	3,74	3,02	Fluctuation
PSNR	36,94	36,35	37,26	
$\overline{\Delta_k}$	3,23	2,07	3,41	Impulse
PSNR	38,44	41,15	39,39	

Table 2. Dependences of $\overline{\Delta_k}$ and PSNR from type of Filter

The analysis of the received results allows doing the following conclusions.

1. The best characteristics at a filtration of fluctuation noise has Gaussian filter.
2. The best characteristics at a filtration of pulse noise has median filter.
3. For the set noise parameters in the brightness channel, the condition (5) after a filtration of images is not carried out. Hence, for improvement of quality of fine details reproduction it is required to increase the signal–to–noise ratio in the initial image or to use more optimum filtration method.

In the present work the original method of a filtration of pulse noise of sonar images, based on probability methods of detection and recognition of a pulse noise, and also on a method of a prediction is offered.

The essence of a method consists in the following.

At the first stage average value M and a root-mean-square deviation σ of a S signal in a line of the image are calculated:

$$M_s = \frac{1}{N}\sum_{n=1}^{N} S_n \; ; \; \sigma_s = \frac{1}{N}\sqrt{\sum_{n=1}^{N}(S_n - M_s)} \; , \qquad (6)$$

where N is the number of elements in line.

At the second stage, the condition is checked

$$\left| S_{n+2} - S_n \right| > a_1 \cdot \sigma_s \quad and \quad \left| S_{n+2} - M_s \right| > a_2 \cdot \sigma_s , \qquad (7)$$

where n = 1…(N-2); a_1 and a_2 is the constant factors.

If the condition (7) is carried out, we count, that the element of a image line the with number (n+2) is a noise pulse, and it is replaced with the help of the following equation:

$$S_{n+2} = (S_{n+1} + S_n)/2 . \qquad (8)$$

If the condition (7) is not carried out, the element of the image line S_{n+2} does not change. Factors a_1 and a_2 are picked up experimentally on the basis of the analysis of real signals of the sonar images.

On Fig. 3. fragments of noisy sonar images are shown: b) up to a filtration; c) after median filtrations; d) after a filtration a new method.

As have shown results of experiments, as against known filtration methods of the pulse noise (Mastin, 1985) , the offered method has such advantages as preservation of quality of fine structures reproduction of underwater images with a high degree of pulse noises suppression.
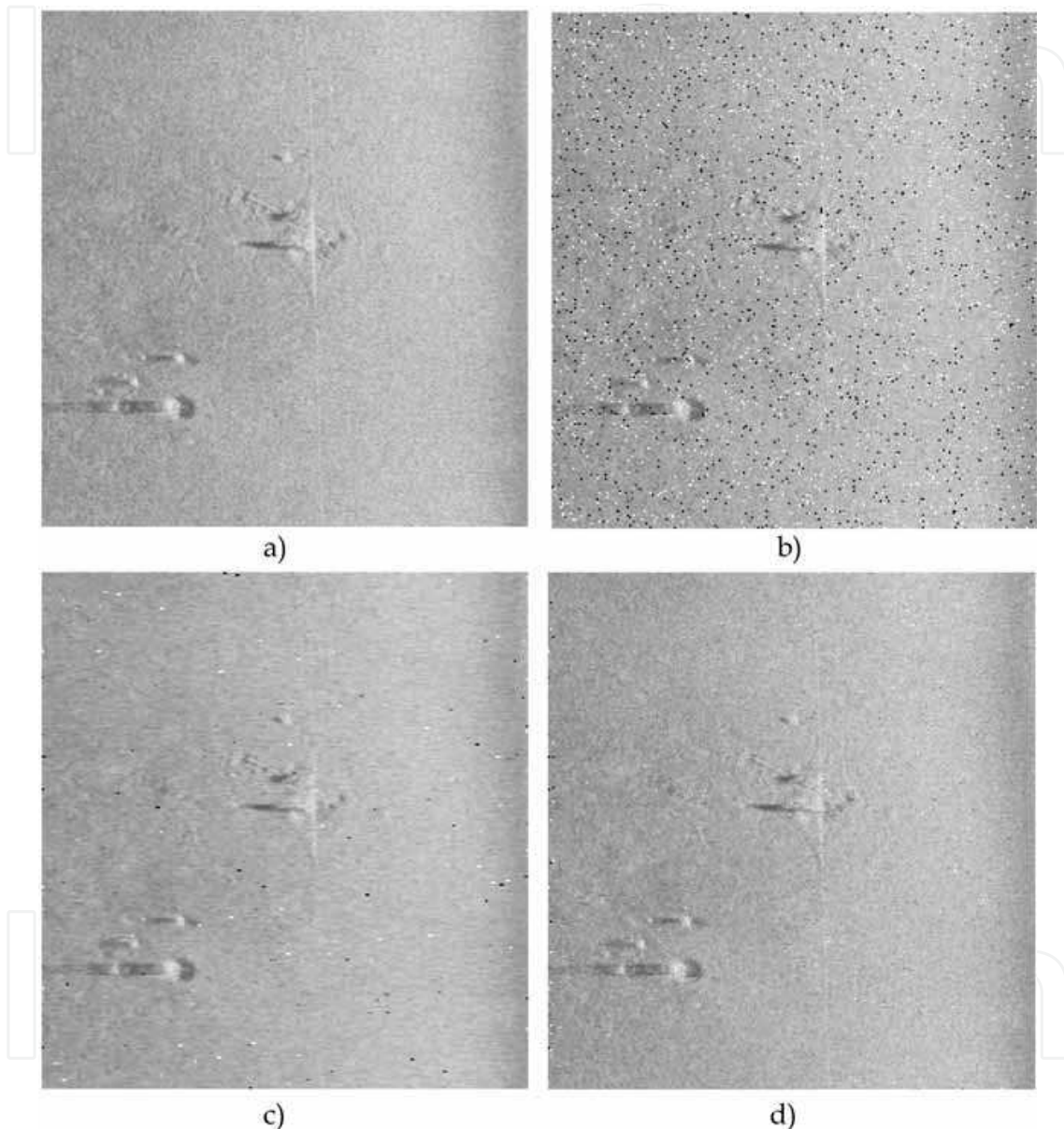

Fig. 3. Fragments of the test image:

a) Test image; b) σ =80%, $\overline{\Delta}_k$ =11,3; c) σ =80%, $\overline{\Delta}_k$ =2,07. d) σ =80%, $\overline{\Delta}_k$ =1,06.

3. Sonar image compression

The basic complexity in design of vision system of AUV in real time is restriction of a pass band of a communication channel. In particular (Ageev et al., 2005), speed of transfer of the information on existing hydro acoustic communication channels can not exceed 3 … 4 KBit/s.

As an example we shall consider the following characteristics of sonar images signals. We believe, that the period of probing pulses is equal 0,5 seconds and digitization frequency of the analog signals received from antenna of left and right board of AUV is equal 3,2 KHz. In this case we have on 1600 pixels for every line transmitted image. Believing, that each pixel has byte structure, we shall receive, that digital stream speed of the entrance data is equal 3,2 Kb\ss. Thus, for signals transmission on a hydro acoustic channel it is necessary to provide compression of a digital stream approximately in 8 … 10 times and thus to keep enough high quality of the image.

Now standards JPEG and JPEG 2000, based on discrete cosine transformation (DCT) and on wavelet transformation (DWT) are considered as the most effective methods of compression of photo images. It is known, that in comparison with other types of orthogonal transformations, DCT and DWT have the best results of images coding on value of an root-mean-square (MSR) or on value PSNR, i.e. on global quality measures. Therefore, other types of transformations practically are not used for compression of images. In work (Sai & Gerasimenko, 2007) for compression of images as an alternative variant Haar transformation (DHT) is investigated. Results of the comparative analysis of coding efficiency of sonar image signals for three types of transformations below are resulted — DCT, DHT and DWT.

Let's consider algorithm of sonar images compression on basis DCT and DHT in real time.

During AUV movement digital image signals go line by line on an input of the coding block where its record in a buffer memory (RAM) in 16 lines capacity. After record of first eight lines, block process of transformation is beginning, where the size of the block is equal 8×8 pixels. During same time the data consistently record in second half RAM.

Realization of DCT or DHT is realized with the help of sequence matrix multiplying. Direct discrete cosine transformation or Haar transformation are described by the following expressions

$$P_{DCT} = M_{DCT} * P * M_{DCT}^{T};$$
$$P_{DHT} = M_{DHT} * P * M_{DHT}^{T},$$

where P – the block in the size 8×8 pixels; P_{DCT} and P_{DHT} is the blocks of factors DCT or DHT; M is the direct transformation matrix; M^{T} is the transposed matrix.

After transformation, factors of transformation, which value less than threshold Q size, are nulled. Further, for each block compression by the modified method RLE is carried out. It is obvious, that efficiency of compression and image quality in the big degree depends on Q size.

Let's consider of wavelet-transformation algorithm in real time.

As against two-dimensional block transformation one-dimensional transformation of a line sonar images here is used. Thus, capacity RAM is equal to two lines of the image.

For the first iteration of wavelet-transformation of a line of the image it is calculated (Mallat, 1999):

$$H_{j}^{(i)} = \sum_{k \in Z} X_{2j+k}^{(i+1)} h_{k}; \quad G_{j}^{(i)} = \sum_{k \in Z} X_{2j+k}^{(i+1)} g_{k},$$

where $H_{j}^{(i)}$ is the low-frequency wavelet-factors, $G_{j}^{(i)}$ is the high-frequency wavelet-factors, X_{j} is the pixels entrance sequence, h_{k} and g_{k} is the low-frequency and high-frequency components of wavelet parent.

Further the wavelet-factors calculated on the previous step of transformation, are compared to values of threshold factors. If the value of wavelet-factors appears smaller value of corresponding threshold factors their values transform in a zero.

After threshold quantization the received values of wavelet-factors are kept in out massive of transformation, and massive of LF components, which size twice less initial, is an entrance signal for the following iteration of wavelet-transformation

$$H_j^{(i)} = \sum_{k \in Z} H_{2j+k}^{(i+1)} h_k; \quad G_j^{(i)} = \sum_{k \in Z} H_{2j+k}^{(i+1)} g_k .$$

The quantity of transformation iterations can be varied, from one and up to such quantity that after last iteration the number of wavelet-factors and LF components of a signal will be less size of a window of the synthesizing filter. Optimum number of wavelet-transformation iterations – from 3 up to 5. After performance of transformation the line of wavelet-factors was coded by modified RLE method.

Factors of threshold quantization for each iteration of transformation were selected by practical consideration, by criterion of achievement of the best quality of the restored image at the maximal factor of compression. We shall note, that the velum of threshold factors decreases in process of increase in a level of wavelet-transformation, i.e. in process of increase in their influence at result of reconstruction of the image.

In work (Sai & Gerasimenko, 2007) influence on efficiency of compression of the following types parent wavelet – Daubechies (2, 4, 6, 8, 10, 12, 20) (Mertins A., 1999) is investigated. As a result of experiments it is received, that the optimum circuit for sonar images compression with sufficient quality is the circuit, realizable by four iterations of filter Daubechies 4.

Let's execute the comparative analysis of efficiency of signals sonar images coding on basis DCT, DHT or DWT. With this purpose we shall take advantage of the computer analyzer shown on Fig. 1. In the second window of the analyzer interface it is opened the decoded image after chosen transformations. Further it is carried out calculations (1-4) and the estimation of images quality on value ($\overline{\varDelta}_k$) is put.

In table 3 experimental dependences of compression factor Cf test sonar images from threshold factors for three transformations are shown. For the analysis the test fragment of the image of a sea-bottom in the size 1600×500 pixels has been chosen. Here, values ($\overline{\varDelta}_k$) and PSNR are resulted. On Fig. 4. examples of fragments (260×280) of the test image before compression and after decoding for approximately identical values of quality parameter ($\overline{\varDelta}_k \approx 2,1$) are shown. In the table the given line of parameters is allocated by grey color.

DCT				DHT				DWT			
Q	Cf	$\overline{\varDelta}_k$	PSNR	Q	Cf	$\overline{\varDelta}_k$	PSNR	Q	Cf	$\overline{\varDelta}_k$	PSNR
1	3,44	1,69	40,89	1	3,49	1,72	40,79	6-3-2-1	3,06	1,39	40,80
2	6,14	1,98	40,23	2	6,31	2,02	40,14	12-6-4-1	5,17	1,84	39,87
3	9,16	2,14	39,92	3	9,51	2,16	39,84	18-9-6-1	6,89	2,06	39,50
4	12,22	2,23	39,73	4	12,73	2,27	39,66	24-12-8-1	8,00	2,31	39,17
5	15,04	2,29	39,61	5	15,71	2,32	39,55	30-15-10-1	8,17	2,42	38,99

Table 3. Test image compression factors from Q

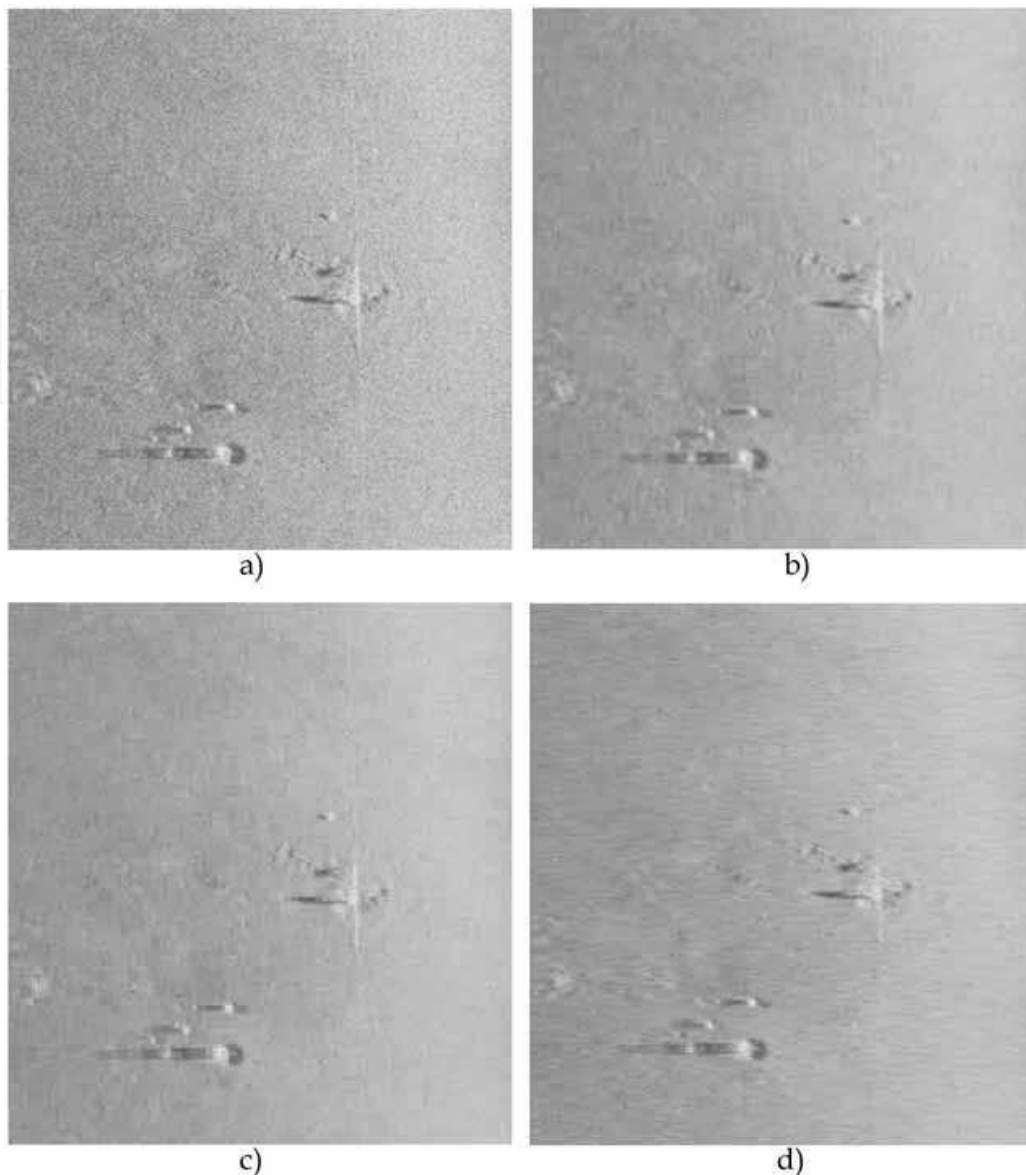Fig. 4. Fragments of the test image:

a) Test image; b) **DCT**, *Cf* = 9,16; c) **DHT**, *Cf* = 9,51; d) **DWT**, *Cf* = 6,8.

The analysis of the received results allows doing the following conclusions.

Factors of compression of the sonar images after processing DCT or DHT are approximately identical. Visual comparison of images quality also gives approximately identical result. Wavelet-transformation concedes both on efficiency, and on visual quality of images that explain speaks first of all application of one-dimensional transformation and the feature of sonar images in which granular structures prevail and practically there are no brightness smooth fluctuations.

Thus, Haar transformation is competitive DCT and is more preferable at processing of sonar images signals, both on compression efficiency, and on images quality.

4. The computer editor of the sonar images

At the present time there are different variants of computer editors of underwater sonar images. With the help of such editors the user can carry out various functions of processing

and the analysis of the hydro location information. The description of the computer editor of the sonar images has been developed in a research laboratory at the Institute of Marine Technology Problems FEB RAS and at the Pacific National University which is shown below.

The program of the sonar editor works with the files with expansion *.gbo, where echo signals of sonar images (digitized and compressed up to word length 8 bit) are registered, and with the additional files with expansion *.idx where the auxiliary information (time, signals from navigating gauges, etc.) is registered. The program is realized in language C ++ in application C ++ Builder 6.

Sonar files are formed in the process of AUV movement and are recorded on a hard disk of an onboard computer. For towed fastened AUV the mode line transfers sonar information through the modem on a conducting rope is provide with the purpose of sonar images supervision in a real time.

User interface

The program represents itself as a multiwindows viewer (Fig. 5), it is allows to open some files (the quantity is limited to computer memory) and to place them on the screen as convenient for the analysis (the cascade, vertically, horizontal). The tools panel and a condition line can be disconnected.

Fig. 5. User interface

In the top part of each window with the image there is the information about the file name with the indication of folders where it is.

In a mode "Editing", the user can allocate a rectangular fragment of the image with the purpose of its more detailed viewing.

To save of the processed file with the purpose of prevention of deleting of the initial information there is the option « Save As … ». In this case the user with the help of the mouse allocates completely or a rectangular fragment (the size of lines does not change) and in a window there is a table with the counted navigating parameters about a tack (the description is shown below). Further by pressing button "OK " the processed file can be saved with an arbitrary name.

Scaling

Scale (the panel of tools: "View" - "Scale") can be chosen arbitrarily up to 100 % on width and height without saving of proportions.

In the window "Scale" the user can choose the following types of scaling: "On width of the screen", "Proportionally", "Without of proportions", "On all screens".

The type of scaling "Proportionally" allows viewing images with a real ratio of the sizes on width and height, for the decimation pixels across with the purpose of alignment of spatial inter elements intervals along a line and between lines of probing.

Application of a preliminary low-frequency filtration of the image lines concerns to features of scaling in a case reduction of its size. Thus, the size of a window averaged the filter is chosen as a quantity of the ratio of the initial image size to the size of its reduced copy.

Modes of the image processing

Images processing is submitted by the following known methods (Shoberg, 2007):
• Inversion;
• Adjustment of brightness – linear increasing and reduction, automatic adjustment under the image and separately on the left and right board;
• Change of a palette on grayscale and on color "Sepia";
• Median filtration (on lines and on column with the any odd of a window sizes);
• Low-frequency filtration (one-dimensional, two-dimensional, Gaussian filtration).

In additional with well- known methods, in the program the new method of a pulse noise filtration is realized. Its description is shown in the second part of the chapter. The panel of tools: "Image" - "Filters" – "New Filter".

In the program the original method of time automatic gain control (TAGC) of sonar images signals is realized. Fig. 6 illustrates the example of TAGC window which is called through the tools panel ("Image" - "TAGC").

Fig. 6. TAGC window

At initialization diagrams of signal amplitudes distribution along lines for each side are appeared. Each point on the diagram is submitted as average value of brightness of all lines.

In "windows" for the left and right side the brightness and contrast in percentage terms to half of maximal amplitude of signal are shown.

After initialization of TAGC mode, the user can operate the following functions:

1. To install brightness and contrast of the image separately on each board. After installation of values the user can press "Convert" and look result. If the result does not settle the user should press the "Reset" button, thus reset of all options is carried out and the image is restored to an initial kind. Further it is possible to install the new parameters.

2. To adjust contrast on the chosen sites of the image with the help of construction of TAGC diagram. By pressing "Spline" button the horizontal axes of TAGC diagram are appeared. By pressing of the mouse button in any point of the left or right panel the third point of TAGC diagram is appeared, by the following pressing the fourth, etc. (up to 100 points). The diagram is drawn on a cubic spline. After diagram construction, "Convert" button is pressed and for everyone *n-th* pixel of a line for left or for the right board the following transformation is carried out

$$\widetilde{S}(n) = SPF(n) \cdot S(n) \cdot K_C + K_Y \,,$$

where $SPF(n)$ is the spline - function; K_C and K_Y is the established factors of contrast and brightness.
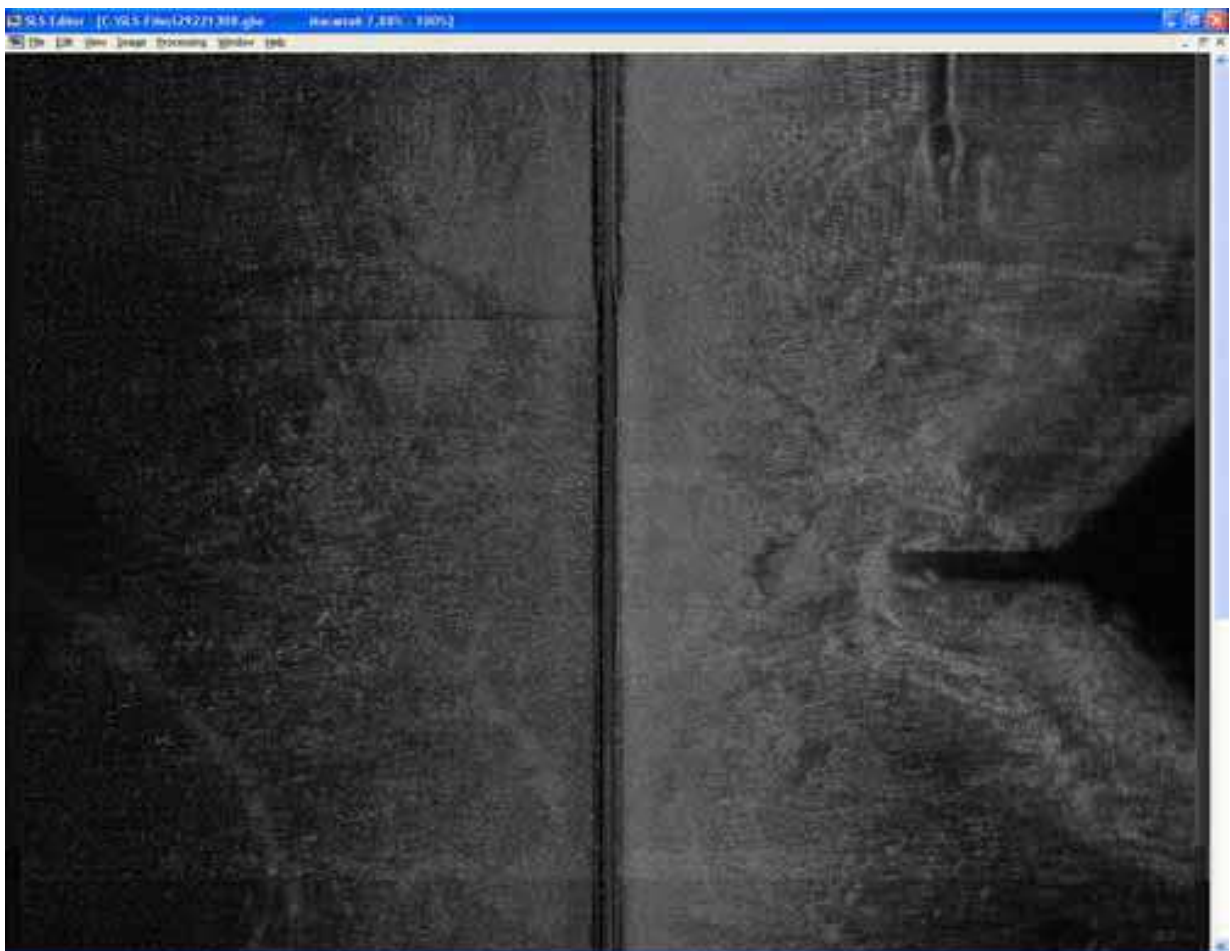

Fig. 7. The examples of the image before processing

The following advantages of developed TAGC program should be noted.

- Points of the diagram can be arbitrary moved in any direction. For this purpose it is enough to place the cursor in the chosen point and keeping the left key of the mouse operate the removing.
- For avoiding signal saturation in the program for every line (separately on each board) average value and an average deviation are calculated. If at tuning brightness, contrast and TAGC parameters the signal moves into saturation, the gain factor of amplification or brightness for each point of a line is automatically reduced.

Fig. 7 and Fig. 8 illustrates the examples of the sonar images before processing (Fig. 7) and after processing: filtrations of pulse noise ("New Filter") and TAGC adjustments (Fig. 8).

Fig. 8. The examples of the image after TAGC processing

Modes of the analysis and measurement of navigating parameters

The analysis of navigating parameters is made on the basis of additional *.idx file. The most important parameters are the periods of the beginning and the ending of a tack; latitude and longitudes of the beginning and the end of a tack; the probing period, etc. On their basis: average speed, tack length, traveling discreteness, discreteness (in meters) along a line and other parameters are calculated.

The table of parameters with the received information on a tack can be looked using the tools panel: "Processing" - "Tack". The user can find more detailed navigating information

on a tack heading ("Processing" - "IDX-file" - "Header") and on each line ("Processing" - "IDX-file" - "Data"). Observing the data on each line the user has the opportunity to choose the lines with the help of buttons " Step " and « Next line number ».

For calculation of navigating parameters in the fixed points of the sonar images the following ratio is used.

Angular coordinates of the sonar targets ($\varphi_{T,i}$, $\lambda_{T,i}$), fixed on SLS echograms are determined on the basis of formulas (Zolotarev & Kosarev, 2007):

$$\varphi_{T,i} = \varphi_{A,i} + sin(-\kappa) \cdot \left(\frac{D}{R} \right),$$ (9)

$$\lambda_{T,i} = \lambda_{A,i} + cos(\kappa) \cdot \left(\frac{D}{R \cdot cos\,\varphi} \right),$$ (10)

where $\varphi_{A,i}$, $\lambda_{A,i}$ is the coordinates of SSS antenna in *i-th* time moment received from a IDX-file; κ — the current course values for *i-th* lines; R is the value of Earth radius of the at average latitude φ; D is the distance up to the target.

In case of the towed device the correction between coordinates of SSS and GPS antenna's is entered.

As the current course values (κ) at shooting from AUV board are not always contained in data of a IDX-file, in this case the program uses the approximate calculations, where instead of course value in expressions (9) - (10) quantity ($k = \eta_T + \delta_K$) is substituted, where η_T is the current value of a traveling angle average on some interval, and quantity δ_K is the angular additive to the current traveling angle, describing lateral AUV drift way. The quantity (δ_K) is entered manually.

The current value of a traveling angle in *i-th* point is estimated under the approximate formula:

$$\eta_{Ti} = a\,tan\,2\big((\lambda_i - \lambda_{i-m}) \cdot cos\,\varphi, (\varphi_i - \varphi_{i-m})\big),$$ (11)

where φ_i and λ_i is the latitude and longitudes of SLS antenna in *i-th* moment of time, φ_{i-m} and λ_{i-m} is the latitude and longitudes of SSS antenna in *i-m -th* moment of time.

Value *m* for the towed device is calculated on the basis of a preset value δL of horizontal position of a cable (i.e. on the basis of the set distance between SSS and GPS antenna), and for AUV (in case of absence of course values *k* in each scan-line, it is set manually).

Calculation *m* on the basis of a preset value of cable horizontal position is made as follows. Under the formula

$$\delta L = R \cdot \sqrt{(\varphi_i - \varphi_{i-m})^2 + (\lambda_i - \lambda_{i-m})^2 \cdot cos^2(\varphi)}$$ (12)

in a cycle with increasing *m* the length of a segment δL between points with coordinates (φ_i, λ_i) and (φ_{i-m}, λ_{i-m}) is calculated. The length of this segment is being constantly compared with the entered value of horizontal position. As soon as δL exceeds the parameter of horizontal position, a cycle on *m* is stopped and under the formula (11) the value η_{Ti} for received *m* is calculated.

Further, substituting ($k = \eta_T + \delta_K$) in formulas (9) - (10), the corrected coordinates of SLS targets having taken into account the horizontal position of a cable will be received:

$$\varphi_{T,i} = \varphi_{A,i-m} + sin(-(\eta_{Ti} + \kappa)) \cdot \left(\frac{D}{R}\right),$$ (13)

$$\lambda_{T,i} = \lambda_{A,i-m} + cos(\eta_{Ti} + \kappa) \cdot \left(\frac{D}{R \cdot cos \varphi}\right).$$ (14)

Before the beginning of measurements the user establishes the initial parameters in a window of adjustment ("Processing" - "Option"). Further parameters of initial installation are used at calculation of target coordinates.

During measurements ("Processing" - "Measurement") the index point is fixed with the help of the mouse and further after removing to the following point. In the table navigating parameters are displayed. The program allows allocating any area and, thus, its navigating parameters are fixed in the table. It should be noted, that at drawing a contour, last point connects to the first point with the help of pressing of the right key of the mouse.

As a whole, the developed program is effective for the analysis and processing of sonar images of a sea-bottom, includes original decisions and represents the competitive product in a comparison with analogues.

5. Conclusion

In the present work the brief description of the following basic algorithms of computer processing and the analysis of underwater sonar images is submitted: *Filtration, Compression, Time automatic gain control, Editing, Measurement of navigating parameters*. The given algorithms are realized as the computer program - editor of sonar images. The developed program has passed successful tests on research expeditions on studying World Ocean which were carried out by the Institute of Marine Technology Problems FEB RAS.

The basic results of scientific researches include the following.

1. The alternative criteria of the analysis of noisy sonar images is developed taking into account the properties of visual perception of fine details contrast.
2. The new filtration algorithm allowing to filter a pulse noise effectively and to keep the image sharpness is developed.
3. Results of the comparative analysis of compression efficiency of sonar images in real time on a basis of discrete cosine transformations, Haar transformations and wavelet transformations are received.
4. The original algorithm of time automatic gain control (TAGC) of sonar images signals is developed.
5. The original program - editor, allowing to increase the efficiency of processing and analyzing of underwater images is developed.

It should be noted, that the results of the quality analysis of underwater sonar images are received on the basis of the developed algorithms and criteria of the analysis of fine details quality of a photo and video images the description of which was submitted in the previous author article (Sai, 2007).

The received results do not limit the development of vision systems of the autonomous unmanned underwater devices. At the present time in joint research laboratory of the

Institute of Marine Technology Problems FEB RAS and the Pacific National University perspective researches are carried out in areas: transmission of underwater images signals on a hydro acoustic communication channel; noise proof coding; 3-D processing of images; recognition of underwater objects, etc.

6. References

Ageev, M.D., Kiselev L.V., & Matvienko Yu.V. (2005). *Autonomous underwater robots : systems and technology,* Nauka, ISBN 5-02-033526-6, Moscow, Russia.

Gonzalez, R.S., Woods, R.E. (2002). *Digital Image Processing*. Prentice Hall. New Jersey, ISBN 0-201-18075-8

Krivosheev, M.I. & Kustarev, A.K. (1990). *Color Measurements*. Energoatom, Moscow, ISBN 5-283-00545-3.

Kravhenko, A.P. (2007). Sonar System of Time Automatic Gain Control, *Proceedings of the Scientific and Technical Conference on Technical Problems of Development of the World Ocean*, pp. 348-352, ISBN 978-5-8044-0794-1, Vladivostok, October 2007, Dalnauka, Russia.

Mallat, S. (1999). *A Wavelet Tour of Signal Processing*. 2nd Edition. ISBN 0-12-466606-X, Academic Press, London, UK.

Mastin, G.A. (1985). Adaptive filters for digital image noise smoothing: an evaluation, *Computer Vision, Graphics and Image Processing*, No. 31, 103-121.

Mertins A. (1999). *Signal Analysis: Wavelets, Filter Banks, Time-Frequency Transforms and Applications*, John Wiley & Sons Ltd., ISBN 0-471-98627-7, Baffins Lane, Chichester, West Sussex, England.

Olyshevsky, V.V. (1983) *Statistical methods in a hydrolocation*. Shipbuilding, Leningrad, Russia.

Pratt, W.K. (2001) *Digital Image Processing*. Wiley, ISBN 0471374075.

Sai, S.V., (2007). *Methods of the Definition Analysis of Fine Details of Images*. Chapter in the book: Vision Systems: Applications, G. Obinata and A. Dutta (eds.), pp. 279-296, Advanced Robotic Systems, ISBN 978-3-902613-01-1, Vienna, Austria.

Sai, S.V. & Gerasimenko K.A. (2007). Efficiency Analysis of Compression Algorithms of Underwater Sonar Images, *Proceedings of the Scientific and Technical Conference on Technical Problems of Development of the World Ocean*, pp. 287-290, ISBN 978-5-8044-0794-1, Vladivostok, October 2007, Dalnauka, Russia.

Sai, S.V. & Sorokin, N.Yu. (2008). Search Algorithm and the Distortion analysis of Fine Details of Real Images, *Proceedings of the 1st International Workshop on Image Mining Theory and Applications IMTA 2008*, pp. 58-64, ISBN 978-989-8111-25-8, Madeira, Portugal, January 2008, INTTICC, Funchal, Portugal.

Shoberg, A.G. (2007). Use of Algorithms of Images Processing in Work with SSS Files, *Proceedings of the Scientific and Technical Conference on Technical Problems of Development of the World Ocean*, pp. 291-295, ISBN 978-5-8044-0794-1, Vladivostok, Octorber 2007, Dalnauka, Russia.

Wyszecki, G. (1975). Uniform Color Scales: CIE 1964 U*V*W* Conversion of OSA Committee Selection. *JOSA*, Vol. 65, pp. 456-460.

Zolotarev, V.V. & Kosarev, G.V. (2007). Dialogue Program Complex for a Coordinate Fixation of the Sonar Targets, *Proceedings of the Scientific and Technical Conference on Technical Problems of Development of the World Ocean*, pp. 354-359, ISBN 978-5-8044-0794-1, Vladivostok, October 2007, Dalnauka, Russia.

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This book presents research trends on computer vision, especially on application of robotics, and on advanced approachs for computer vision (such as omnidirectional vision). Among them, research on RFID technology integrating stereo vision to localize an indoor mobile robot is included in this book. Besides, this book includes many research on omnidirectional vision, and the combination of omnidirectional vision with robotics. This book features representative work on the computer vision, and it puts more focus on robotics vision and omnidirectioal vision. The intended audience is anyone who wishes to become familiar with the latest research work on computer vision, especially its applications on robots. The contents of this book allow the reader to know more technical aspects and applications of computer vision. Researchers and instructors will benefit from this book.

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