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WAVELET DATA PROCESSING IN THE PROBLEMS OF ALLOCATION IN RECOVERY WELL LOGGING

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ABSTRACT

Methods of Geophysical Research (GRM) are widely used in order to construct valid models of oil and gas fields. The essence of these methods is the process of logging sounding, that means the following: in the oil well falls instrument for measuring various characteristic values, then these findings are processed. One of the commonly used methods are the method of high-frequency induction logging isoparametric sounding (HILIS) and the method of lateral logging sounding (LLS). General interpretation of the scheme used in these systems, as follows: in the first stage well logs analyzed, the data is processed and allocated beds - areas with homogeneous characteristics of the signal. Then, in the resulting layers are determined value of the electric resistance. These models are then visualized in the GUI.

To ensure proper construction of models and acceptable computing speed is a very important task of the initial treatment, as in the results of measurements is often present apparatus and geological noise, complicating analysis. This noise is a high frequency signal fluctuations, which often tend to smooth out the filtration transformation curve. In the same class of problems includes the correct alignment of the geological formations. Correctness is defined geo electric theory and empirical experiences geophysics specialists who often produce alignment layers boundaries manually, based on the image of the curves in the diagram.

The paper was presented to data processing algorithm based on the wavelet transform signal. Main research questions are define digital signal of well and processing methods for considered signals. This work is aimed at optimizing the transfer of digital signals in an oil well logging. Prior to that, the process was carried out by other methods, but the method presented me wavelet applied to this problem for the first time.The basic idea was to minimize the sent data - signals for subsequent processing. These results indicate that the proposed algorithm ensures real efficiency in processing signals for the primary task allocation layers [1].

Keywords: *Wavelet Processing, Well Logging, HILIS, GRM, Transformation, Horizontally-Layered Medium.*

1. INTRODUCTION

In general, the downhole geophysical surveys include measuring, transferring, recording and pre-processing of information. To implement them, are terrestrial laboratory, deep instrumentation and lowering - lifting equipment. Before the drilling is stopped and the GIS drilling tool recovered to the surface. Deep in this case the devices connected to the station special logging cable that serves for transporting them through the borehole, power supply and information transmission.

The downhole instrument (probe) placed primary sensors that convert the potential difference, tension, movement of particles in the medium, or the energy flux density of the radioactive particles, and so on. D. In the signal, which is a variable-largest electrical current or voltage. The probe also includes a device for the creation of appropriate artificial physical fields - electric, electromagnetic, neutron, and some specific elements: screens, filters, centralizers, collimators. In many cases, a deep device contains sensors and devices for the simultaneous research in different ways.

Typically, the output of the primary sensor is unsuitable for direct transmission through a long logging cable, therefore the signal is converted - is integrated, rectified, increase power encode. For this purpose, the device is placed in the downhole electronics devices, requiring special protection against high hydrostatic pressure. Therefore, the body of down hole tools are tight and pressure resistance.

Sensors located outside the protective housing (inside the body have only radioactive radiation sensors), combined with electronic transformers and wires Geophysical cables through special pressure resistance (in deep wells – heat pressure resistant) electrical drive. In addition, the housing units, electrical drive and rubber sealing device, as well as geophysical cable insulation must be resistant to chemically aggressive environment (solutions of salts, acids, alkalis, oil, gas).

The most widely used at present have a laboratory designed for simultaneous recording charts of different methods (eg, methods of COP, PS and with a current focus). Analog to digital laboratory designed for simultaneous recording charts in analog and digital form. Digital recording provides reliable, high quality materials and effective communication with the computer. It has now been developed and applied computerized laboratories. Automatic computerized laboratory is a system comprising on-board computer, which performs the following functions: manages the calibration of equipment; optimize the process of measurement, change the mode of deep and surface equipment, and lowering and lifting equipment; monitors the quality of the received information; provides operational interpretation of the material. The use of these labs significantly improves the efficiency of well logging [2,3].

2. SETTING OF THE PROBLEM

Consider the layered medium, which is characterized by resistance layers and coordinates of a plane-parallel boundaries. The geometry of such a model is described in a rectangular (x, y, z) coordinate system. The z axis is perpendicular to the boundaries and is directed downward. It is assumed that the clastic rocks that form the environment, non-magnetic (i.e., their magnetic permeability $\mu = 4*10^{-7}$ *Gh/m*). The model consists of two enclosing layers (lower and upper half-space) and one layer there between. In what follows we use the following symbols: z_1, z_2 - the depth of top and bottom layers; ρ_1, ρ_3– resistance overlying and underlying host rocks; ρ_2 – layer resistance;

$d=(z_2-z_1)$ – its power.

The theory of the electromagnetic field based on a system of Maxwell's equations. In areas where the medium is homogeneous and isotropic, and in the absence of third-party sources of Maxwell's equations take the form:

$$\begin{cases} rot\vec{H}(t) = \vec{E}(t)/\rho + \varepsilon\ \partial\vec{E}(t)/\partial t \\ rot\vec{E}(t) = -\mu\ \partial\vec{H}(t)/\partial t \\ div\vec{H}(t) = 0 \\ div\vec{E}(t) = 0 \end{cases}$$

Where *E(t)* and *H(t)* - the electric and magnetic fields, ρ, ε and μ - properties of the medium (resistance, dielectric and magnetic permeability).

Nonmagnetic rocks are usually considered in the structural electrical exploration, for which μ equivalent to μ_0 - the magnetic permeability of vacuum.

In the quasi-stationary approximation bias currents (the second term on the right side of the first Maxwell's equations) are neglected with respect to the conduction currents (the first term). Then the first Maxwell equation is written as follows:

$$\text{rot}\ \bar{H}(t) = \bar{E}(t)/\rho$$

When considering harmonic fields in the electrical use symbolic method, which consists in the representation of vectors, describing the field as

$$\bar{A}(t) = Re\ (\bar{A}\ e^{-iwt}),$$

where $\bar{A}(t)$ - vector, $\bar{A}$ - its complex amplitude, ω

- angular frequency, t - the time. For the complex amplitudes of the electric $\bar{E}$ and magnetic $\bar{M}$ fields

Maxwell's equations take the form:

$$\begin{cases} rot\vec{H} = \vec{E}/\rho \\ rotE = i\omega\mu_0 H \\ div\vec{H} = 0 \\ div\vec{E} = 0 \end{cases}$$

Turning to the coordinates of the first record of Maxwell's equations, we get:

$$(\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z})\vec{1}_x + (\frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x})\vec{1}_y +$$
$$+(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y})\vec{1}_z = \sigma(E_x\vec{1}_x + E_y\vec{1}_y + E_z\vec{1}_z)$$

Since in our model field and not change incision horizontally all horizontal derivatives in this equation is zero, and it can be simplified:

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$$-\frac{\partial H_y}{\partial z}\vec{1}_x + \frac{\partial H_x}{\partial z}\vec{1}_y = \sigma E_x \vec{1}_x + \sigma E_y \vec{1}_y + \sigma E_z \vec{1}_z$$

The second Maxwell equation in the coordinate notation takes the form:

Now, one-dimensional Helmholtz equation take the form:

$$\frac{\partial E_x}{\partial z^2} - k^2 E_x = 0 \qquad \frac{\partial H_y}{\partial z^2} - k^2 H_y = 0$$

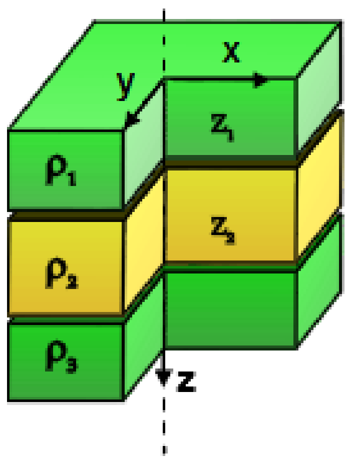

Figure 1. Horizontally-Layered Medium

The solution for the field component of an arbitrary magnetic dipole is represented as:

$$F(r,\varphi,z) = \frac{M}{4\pi}\int_0^\infty [f_1(t,z)G_1(r,\varphi) + f_2(t,z)G_2(r,\varphi)]\,d\tau$$

Consider the solution of this equation in the case of one or two boundaries. We use the following notation:

$$k_{12}^e = \frac{s_2p_1 - p_2}{s_2p_1 + p_2}, \quad k_{32}^e = \frac{s_2p_3 - s_3p_2}{s_2p_3 + s_3p_2},$$

$$k_{12}^h = \frac{s_2p_1 - p_2}{s_2p_1 + p_2}, \quad k_{32}^h = \frac{s_2p_3 - s_3p_2}{s_2p_3 + s_3p_2},$$

$$\Delta E = 1 - k_{12}^e k_{32}^e e^{2p_2 d},$$

$$\Delta H = 1 - k_{12}^h k_{32}^h e^{-2p_2 d}$$

$$p^2 = \tau^2 + k^2, \quad s_j = \frac{\rho_1}{\rho_j}$$

L= |z0 - z|, L – probe length.

The amplitude of the current in the source varies according to the law e^{-iwt}, w– frequency. Here: $k^2 = -iwp/\rho$, τ – spatial frequency, k^2 – the square of the wave number. Hereinafter, it is assumed that the source is located at point (0, 0, z0) [2-4].

Now comes the process of signal processing received from the well. Let real continuous function f (z) represents the value of the signal from the depths.

In the areas of formation, where there is a constant signal, we assume for a homogeneous medium.

The emergence of rapid change signals will take for the transition from one medium to another. Perhaps occurs transition from clay to sandy environment.

Since the layers do not occur in an ideal homogeneous uniformity is received with a certain degree of accuracy δ. In this case it is advisable to introduce a variable for this purpose δ,

$$\forall z \in (a,b)\ |\, f(z) - c\,| \le \delta$$

f (z) — the reporting signal,

$$c = \frac{1}{b-a}\int_a^b f(z)dz, \quad a < b,$$

then f (z) relies relatively constant in the interval (a, b).

Additional criteria averaging depth, when the high frequency details (noise) are ignored, and only the highlighted key features of the signal.

We describe the mathematical formulation of the problem of arrangement of layers boundaries. Let f: [a, b] → R , where 0 < a < b — continuous signal function and c: [0...N] ⊂ N → R — its discrete version, which is defined as:

$$c(0) = a, \ c(i) = f(a + ih),$$

where h∈(0,∞) — the sampling step,

$$a + Nh < b, \ a + (N+1)h \ge b.$$

Let $x_i = c(i)$ A partition depth interval will be called the set of points $a = r_0 < r_1 < \ldots < r_k = b$, which satisfies some of the above criteria. Existing algorithms for alignment boundaries in IFS HILIS described in [3], working with the function of vertical resolution, which is a derivative values the probes pretreated taking into account the specifics of the geophysical instrument. Borders ri meet local maxima of this function. In the practical implementation of the algorithm works with discrete signal values; calculated difference derivatives. Using this approach is difficult and limited, the main of which is the large noisiness of data, characterized by high-frequency oscillations of the signal. Also not counted criteria 3) and 4), when the algorithm cannot distinguish between low-amplitude vibrations from the large jumps and fine frequency sift [5].

As a result of the algorithm on noisy data sampling reservoir capacity is close to the curve step, the reservoir contains about 1-2 points, which is unacceptable from the point of view of interpretation algorithms and does not reflect the properties of the geological section.

Currently used to filter the data, which is before the application of the algorithm allows to smooth the values and get rid of the small unimportant details.

Filtering is a function f: $[x_1 \ldots x_n] \rightarrow [y_1 \ldots y_n]$, which is defined as:

$$y_i = f(x_i) = \sum_{j=-k}^{k} a_j\, x_{i+j},$$

where $a_j \in R$, $[x_1 \ldots x_n]$ — vector of values of the log curve. Typically, the coefficient vector $[a_{-k} \ldots a_k]$ symmetric with respect to a_0, and a_0 more by module remaining value, $a_i > 0$,

$$\sum_{i=-k}^{k} a_i = 1.$$

The transformation is averaged with the weighting factors and to some extent solves the problem of filtering depth and using four criteria) as smooths the signal parts with characteristic dimensions in the depth less than 2k. However, a comparison of the work placement algorithms boundaries experts-geophysicists using filtering and without it indicates that a significant improvement in the quality of the geological section of the partition does not occur.

The formulation of the problem of the partition of the section on layers based on the criteria of 1) and 3) for any interval (ri, ri + 1) splitting the conditions of relative constancy of *f* with error ε. In order to develop an algorithm that best takes into account all the criteria, it was decided to investigate the signals using wavelet transforms, which can provide information on both the amplitude and the frequency component of the geophysical signal, and also allow flexibility to solve problems of data averaging [6].

3. MAIN METHOD OF SOLVING AND ITS APPLICATION

Wavelet signal transformation, the theory which is founded in the early 90s, is no less common on areas of their applications than the classical Fourier transform. Wavelets are a special function in the form of short waves (wavelets) with zero integral value and the localization of the independent variable axis (t or x), able to shift along this axis and scaling (expansion/compression).

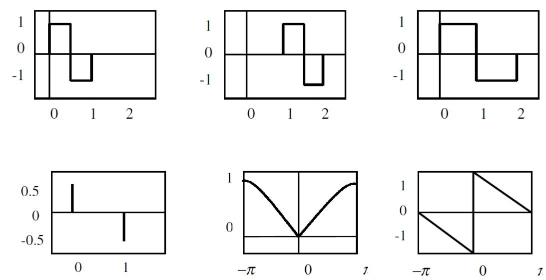

Figure 2. Example of wavelet function: (a) $\varphi(x)$; (b) $\varphi_{0,1}(x)$; (c) $\varphi_{1,0}(x)$; (d) arrange of h_n; (e) $|H(w)|$; (f) $\arg(H(w))$[7]

We presents the implementation of wavelet transform in Matlab environment using the matrix method to function. Application of wavelet analysis of the most suitable for the study of local signals change (identifying the fine structure of signals containing jumps, sharp transitions through zero of derivatives, etc.).

The first WT was used by the Hungarian mathematician Alfréd Haar. For an input represented by a list of 2 numbers, the Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to provide the next scale: finally resulting in 2n-1 differences and one final sum [6, 8].

Let these functions is for the sake of simplicity are integral, i.e. type

$$\phi(t) \rightarrow \phi(2^j t + k) \qquad (1)$$

Thus, we can cover the entire real axis defined system functions. If the basis function

$$\phi(t) \in L_2(R) \qquad (2)$$

it has unit norm, then all functions

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$$\phi^{jk}(t) = 2^{j/2}\phi(2^j t + k) \tag{3}$$

are normalized to unity, ie,

$$\left\|\phi^{jk}\right\| = \sqrt{\int_{-\infty}^{+\infty} \phi^{jk}\phi^{jk}\,dt} = 1 \tag{4}$$

If a family of functions $\phi^{jk}(t)$ is an orthonormal basis of $L_2(R)$, space, i.e.,

$$\left(\phi^{jk}(t)\phi^{lm}(t)\right) = \int_{-\infty}^{+\infty} \phi^{jk}(t)\phi^{*lm}(t)dt = \delta_{jl}\delta_{km} \tag{5}$$

and each function can be represented as a series (in a basis decomposition)

$$f(t) = \sum_{j.k=-\infty}^{\infty} c_{jk}\phi^{jk}(t) \tag{6}$$

which is uniformly convergent in $L_2(R)$, that is,

$$\lim\left\| f - \sum_{-M}^{M}\sum_{-N}^{N} c_{jk}\phi^{jk} \right\| = 0 \text{ при } M,N \to \infty, \tag{7}$$

then the basic conversion function $\phi(t)$ is called orthogonal wavelet.

Orthogonal systems of functions $\phi^{jk}(t)$ can be tested directly. Proof of completeness and closure of the base for each specific system should be carried out separately. As a rule, they are very complex and cumbersome. Links to these can be found in reviews [9-12].

Based on this algorithm, experiments were performed with different parameters and levels of l, we implemented using MatLab package. In the figure below, the results of the algorithm are shown. Analysis of the graphs shows that at lower values of coefficient c layers are broken more finely, but bring a good accuracy, while for large values of the coefficient c stand out more and more large reservoirs, but lost the small signal characteristics [13-15]. To verify the results obtained will be sufficient to carry out the inverse wavelet transform, which will provide an initial signal to the original view of the possible small losses.

4. MAIN RESULTS

The program has been implemented in a software environment Matlab R2010a. Digital signals obtained by well logging treated proposed algorithm. As a result, solutions 1D problem for 27 layers following results were obtained:

SqrtT	RoT	PhT
0.10	993.01	-45.00
0.14	1011.83	-43.78
0.20	1176.27	-45.00
0.28	1278.06	-54.30
0.40	1000.00	-67.08
0.57	599.27	-76.49
0.80	323.14	-81.54
1.13	169.90	-83.67
1.60	89.61	-84.04
2.26	48.01	-83.26
3.20	26.36	-81.62
4.53	14.98	-79.22
6.40	8.90	-76.15
9.05	5.59	-72.53
12.80	3.75	-68.55
18.10	2.70	-64.48
25.60	2.08	-60.60
36.20	1.70	-57.14
51.20	1.46	-54.22
72.41	1.31	-51.87
102.40	1.21	-50.05
144.82	1.15	-48.67
204.80	1.10	-47.65
289.63	1.07	-46.90
409.60	1.05	-46.36
579.26	1.03	-45.97
819.20	1.02	-45.69

Figure 3. Results of calculations

For the experiment, we looked at a grid of 512x512 nodes. At each iteration of the algorithm implementing the number of nodes decreased 2-fold.

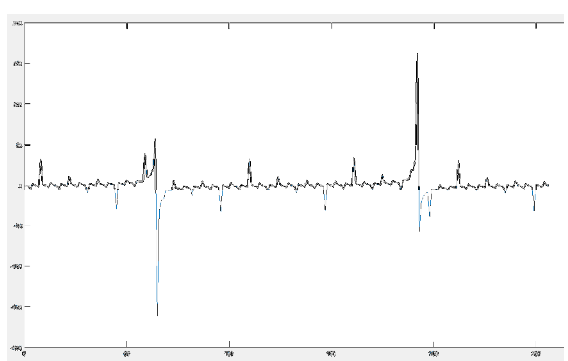

Figure 4. The initial signal from the considered well

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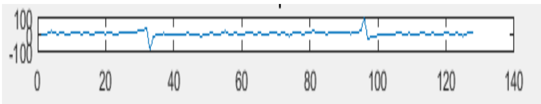

Figure 5. The processed signal, level 1

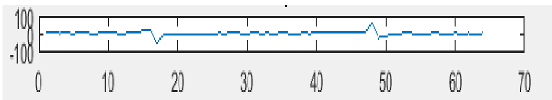

Figure 6. The processed signal, level 2

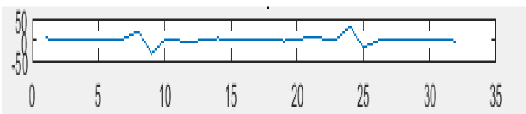

Figure 7. The processed signal, level 3

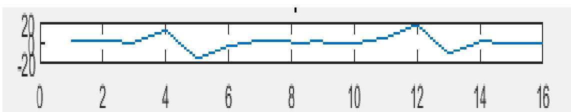

Figure 8. The processed signal, level 4

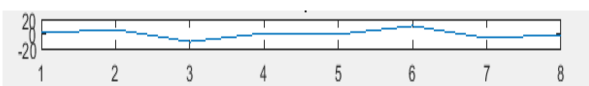

Figure 9. The processed signal, level 5

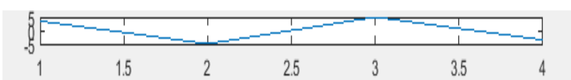

Figure 10. The processed signal, level 6

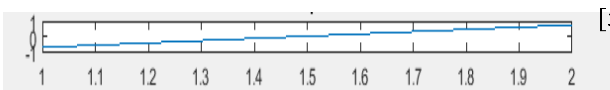

Figure 11. The processed signal, level 7

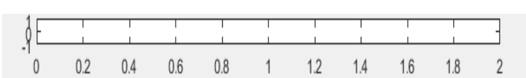

Figure12. The processed signal, level 8

5. CONCLUSION

The paper was presented to data processing algorithm based on the wavelet transform signal. The basic idea was to minimize the sent data - signals for subsequent processing. These results indicate that the proposed algorithm ensures real efficiency in processing signals for the primary task allocation layers. In the future it is planned to develop a 3D implementation tasks for logging wells. In light of the findings, there are plans for the future - to design and develop the program for processing the signals from several wells.

The goal was to - digital signals are processed in the oil well logging by wavelet transform. The goal has been achieved and the results testify to their authenticity.

Prospects for the development of this approach is the development of software modules that allows you to configure changes in the user interface, as well as the improvement of the algorithm. It is also important to determine how it will emerge from a reading of the function of various probes HILIS device and a more detailed evaluation of the effectiveness [16, 17].

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