UDC 6-503.57:622.24

M. I. Horbiichuk, Dr. Sc. (Tech.), Prof.,
T. V. Humeniuk, Cand. Sc. (Tech.)

Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine, e-mail: ksm@nung.edu.ua

NEURAL NETWORK IDENTIFICATION TECHNOLOGY FOR MANUFACTURING OPERATIONS OF DRILLING RIG

М. І. Горбійчук, д-р техн. наук, проф.,
Т. В. Гуменюк, канд. техн. наук

Івано-Франківський національний технічний університет нафти і газу, м. Івано-Франківськ, Україна, e-mail: ksm@nung.edu.ua

НЕЙРОМЕРЕЖЕВА ТЕХНОЛОГІЯ ІДЕНТИФІКАЦІЇ ТЕХНОЛОГІЧНИХ ОПЕРАЦІЙ БУРОВОЇ УСТАНОВКИ

Purpose. The development of methods and algorithms of identifying rig manufacturing operations to ensure the optimal control algorithm of the process of deepening the well automatically.

Methodology. The problem of identifying the technical operations of a drilling rig is formulated as the problem of pattern recognition. The Hamming neural network method was used to solve this problem.

Findings. An analysis of the basic technological operations of a rig was conducted and the methods and algorithms for solving the problem of recognition rig manufacturing operations were developed. This will provide monitoring the sequence of technological operations of mechanical drilling, held by an operator, and automatic determining of the length of round-lifting operations for the current voyage, which in its turn will enable the implementation of the algorithm of the optimal control of the process of deepening the well automatically. A new approach for determining the start and duration of technological operations of the rig during the deepening hole was suggested on the basis of artificial neural networks. Analysis of artificial neural networks showed that for the problem of recognition of rig manufacturing operations the Hamming network should be used. The architecture and the algorithm of the performance of such artificial neural network were developed.

Originality. The method for recognition operations of rig using Hamming network has been suggested for the first time, allowing us to determine the duration of the round-lifting operations for the performance in real time automatically and to develop an efficient algorithm for optimal control of the process of deepening wells.

Practical value. Algorithms and software were developed to solve the problem of recognition of rig manufacturing operations, which provide the monitoring process of the sequence of manufacturing operations to deepen the well, which is held by an operator, and automatically determine the duration of launching gear operations for the current haul cycle in order to implement the algorithm of optimal control process of deepening the well automatically. Software, developed on the basis of the suggested method and algorithm, was integrated into complex SKUB-M2. This complex was a part of the rig during drilling of the well number 5 of Vasyshchivskyi gas condensate field, which made it possible to determine the efficiency and effectiveness of the developed methods and algorithms. The suggested method and algorithm of identification the process operation of the drilling rig can also be integrated into other control systems and automatic process control to deepen the well.

Keywords: *drilling rig, recognition of patterns, neural network*

Introduction. Mining holes are built for getting oil and gas. The basic processes of building mining holes are the drilling and fastening.

Building of mining holes includes a number of processes that are performed in a certain sequence [1] – it is construction of ground facilities; driving of barrel of mining hole; disconnection of layers; exploration of mining hole and handing it over in exploitation.

Hole-making is possible during realization of two parallel operations – deepening of coalface of mining-hole by means of rock cutting tools which carries out circulating motion, and cleaning of coalface from rocks.

Disconnection of layers is performed by successive implementation of two operations – fixing of walls of barrel of mining hole by casing pipes that form a casing column, and pressurizing of hole space.

A basic process when building a mining hole is the mechanical drilling, that is performed by implementation of such sequence of operations, despite the method of destruction of mountain breeds [1]:

- lowering of boring pipes with a rock cutting tools;
- destruction of rock at the coalface of a mining hole;
- lifting a column of boring pipes for replacement of threadbare chisel;
- fastening of mining hole by casing pipes and disperse grouting.

Analysis of the recent research. The existing technical equipment of control and management of the drilling process (SCUB-M1, SCUB-M2, "Geostat-5", "Leuza-1", "Leuza-2", "AutoTrack", and others) provides only control of basic technological parameters and indexes of a drilling process, but they do not solve the issue of processing technological information regarding corresponding algorithms [2, 3]. Partly this task was considered in works [2, 4]. Apart from realization of optimal algorithms of the drilling process, the major question of upgrading works in well-drilling is reduction of the number of complications and prevention of accidents by means of using modern control methods. Therefore, development of CAS of authentication of technological operations of wellsite is topical for today.

A number of scientists [1, 3, 4] offer formalized methods for recognition of technological operations of building a mining hole, prognostication of the crackpot modes and emergency situations. But in general the task of automatic authentication of operations of the boring setting and determination of the moment of their completion remains unsolved.

Presentation of the main research. Optimization of the process of deepening a mining hole is performed mostly according to minimum-cost criterion for meter of driving of a mining hole

$$q = \frac{c_d(t_d + t_{RLO}) + d}{h(t_d)}, \qquad (1)$$

where c_d is a cost of one hour of labour of the boring setting; t_d is duration of each drilling cycle; t_{RLO} is duration of round-lifting operations (RLO); d is a cost of rock cutting tools; $h(t_d)$ is headway per drill bit for a cycle.

Since a process of the drilling includes a certain number of operations that are realized in a certain sequence, an optimal management using a criterion (1) suggests that the task of determination of optimal actions of management must be started at a certain moment of time that corresponds to the beginning of the technological operation, – mechanical drilling. Duration of RLO in every cycle is determined by the expenditure of time on such technological operations as lowering and raising a column of boring pipes, increasing a column, replacing a chisel, circulation and washing of a mining hole [5, 6].

At the synthesis of an optimal control system for the process of deepening a mining hole it is necessary to provide an automatic mode of input of values t_{RLO} and start of a task of optimization at the moment that must be synchronized with the beginning of the mechanical drilling.

Interaction of algorithm of building a mining hole [2, 5, 6] with the algorithm of optimal process control of the mechanical drilling is shown in Fig. 1.

Technological parameters that are controlled in the process of implementation of basic technological operations of the boring setting in the process of deepening a mining hole are presented in Table 1.

To determine the duration of RLO we will take the moment of raising a chisel for its replacement as the initial account of time, and the moment of completion of RLO will coincide with the moment of completion of elaboration process of a chisel. We should add some time for increasing the length of a column of boring pipes to the value $t^{(1)}_{RLO}$ that we have just calculated. If the number of such increases is n, then

$$t_{RLO} = t^{(1)}_{RLO} + \sum_{i=1}^{n} t_{in,i} + t, \qquad (2)$$

where $t_{in,i}$ stands for time spent on the increase of column of boring pipes on every candle; t_c is time spent on circulation and washing of a mining hole.

Every state of the boring setting is characterized by a certain set of technological parameters. At the same

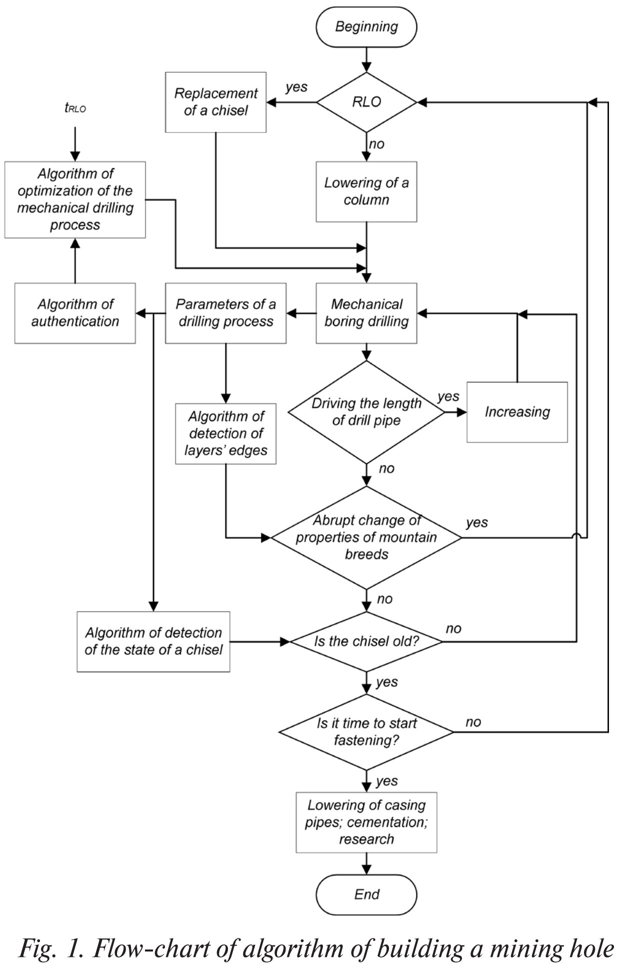

Fig. 1. Flow-chart of algorithm of building a mining hole and its interaction with the algorithm of optimal technological process control of the drilling

Table 1

Major technological operations of boring setting and controlled settings

Technological operation	The controlled technological parameters
Deepening of wells	axial load on a chisel
	frequency of rotation of a rotor
	a circulating moment on a rotor
	consumption of drilling solution
	load on the hook
	the position of a hoist block
	pressure in the line of pumping drilling solution
Elaboration of a chisel	axial load on a chisel
	frequency of rotation of a rotor
	a circulating moment on a rotor
	load on the hook
	pressure in the line of pumping drilling solution
	the position of a hoist block
Circulation and washing of a mining hole	load on the hook
	consumption of drilling solution
	pressure in the line of pumping drilling solution
	the position of a hoist block
Increase	load on the hook
	a circulating moment on a rotor
	the position of a hoist block
	frequency of rotation of a rotor
Lifting a column	load on the hook
	a circulating moment on a rotor
	the position of a hoist block

time there is no necessity to know their absolute values in physical units, it is enough to establish the fact of their presence, in other words the controlled parameters must be within certain limits that are predefined by technological regulation.

The process of forming of signals, that will be features in the task of recognition of operations of the boring setting, is shown in Fig. 2. In the case when a technological parameter that characterizes a corresponding technological operation is in the set norm, then it is assigned a value "unit", otherwise – "zero".

The task of authentication of operations of the boring setting will be set forth as a task of recognition of images.

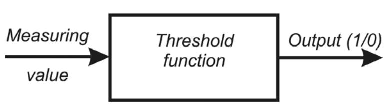

Fig. 2. The formation features

Every technological operation of the boring setting (Table 2) will be an image. A set of technological operations of the boring setting forms space of images. If ω is a particular image, then $\omega \in \Omega$. An appropriate ordinal number 1, 2, ..., m, will be assigned to every image (the technological operation), so that $M = \{1, 2, ..., P\}$ is a set of numbers of classes Ω_1, Ω_2, ..., Ω_P. Every image is characterized by the set of features that form the vector $\bar{x} = \left(x_1, x_2, \ldots, x_n\right)^T$ in space of features; components of that vector are sequences of zeros and units [7, 8].

As physical parameters that characterize some state of the boring setting are positive sizes, then forming of features occurred in the following way

$$x_i = sign(p_i(t)); \quad i = \overline{1,n},$$

where $p_i(t) = P_i(t) - P_{\max,i}$; $P_i(t)$, $P_{\max,i}$ are current and minimum values of the technological parameter;

$$\mathrm{sign}\,(p_i(t)) = \begin{cases} 1 & \text{when} \quad p_i(t) > 0 \\ 0 & \text{when} \quad p_i(t) = 0 \end{cases}.$$

If value $p_i(t)$is taken into account, then

$$\mathrm{sign}\,(p_i(t)) = \begin{cases} 1 & \text{when} \quad P_i(t) > P_{\min,i} \\ 0 & \text{when} \quad P_i(t) = P_{\min,i} \end{cases}. \qquad (3)$$

It is now possible to form the task of recognition of images in relation to authentication of technological operations of the boring setting.

We will form space of images Ω from classes Ω_1 (deepening of a mining hole), Ω_2 (elaboration of a chisel), Ω_3 (increase), Ω_4 (circulation and washing of mining hole) and Ω_5 (lifting a column).

Every class is characterized by the vector $\bar{x}$, whose components take on binary values of "0" or "1".

It is obvious that every class contains one image that is determined by a concrete technological operation that is shown in Table 2.

A task lies in attributing an object to one of five classes after producing the vector $\bar{x}$. To solve this task, it is expedient to take advantage of the neural network technology.

As components of the vector $\bar{x}$ take on only discrete values 0 (–1) or 1, then in such cases the effective decision of task of authentication of technological operations of the boring setting is reached using artificial neural networks (ANN) of Hopfield or Hamming [8].

Architecture of the network of Hopfield [9] is shown in Fig. 3.

P is a number of images that acts at the network input, each of that is presented by vectors $\bar{x} = \left(x_1, x_2, \ldots, x_n\right)^T$ with components that have binary values "–1" or "1".

In the case when the components of a vector take on a value of "0" or "1" they are enumerated so that the value "0" transforms in "–1". Such recalculation is performed according to the following formula

$$\hat{x}_i = 2x_i - 1. \qquad (4)$$

The particular image Ω_i, $i = \overline{1,P}$ is characterized by the vector of input signals $\bar{x}^{(p)}$. When at the network

Table 2

Major technological operations of the boring setting

Technological operation of the boring setting	Technological parameters							
	Load on the hook	Axial load on the drilling tool	A circulating moment on a rotor	A circulating moment on a machine key	Pressure in the line of pumping drilling solution	The position of a hoist block	Consumption of drilling solution at the inlet and outlet of a mining hole	Frequency of rotation of a rotor
Deepening of wells	1	1	1	0	1	1	1	1
Elaboration of a chisel	1	1	1	0	1	1	0	1
Increase	1	0	0	1	0	1	0	1
Circulation and washing of a mining hole	1	0	0	0	1	1	1	0
Lifting a column	1	0	0	1	0	1	0	0

input of Hopfield vector value $\overline{x}^{(p)}$ is given, then at its exit the vector of output signals will be formed, that will coincide with $\overline{x}^{(p)}$, in other words $\overline{y}=\overline{x}^{(p)}$, where $\overline{y}=\left(y_1,y_2,\ldots,y_n\right)^T$.

There are three stages [8, 9] of functioning of network – initialising, representation of the image at the network input and calculation of operations of neurons.

The weigh coefficients of W matrix (Fig. 3) are calculated at the stage of initialising using such formulas

$$w_{ij}=\begin{cases}\overline{x}_i^T\overline{x}_j, & i\neq j\\ 0, & i=j\end{cases}, \qquad (5)$$

where $\overline{x}_i=\left(x_i^{(1)},x_i^{(2)},\ldots,x_i^{(p)},\ldots,x_i^{(P)}\right)^T$; $\overline{x}_j=\left(x_j^{(1)},x_j^{(2)},\ldots,x_j^{(p)},\ldots,x_j^{(P)}\right)^T$; $x_i^{(p)}$, $x_j^{(p)}$ are corresponding components of the vector $\overline{x}^{(p)}$.

This stage is supposed to be examined as training of a network after which it is able to distinguish images correctly.

The preset of components of output signals comes true at the second stage by representation of incoming image

$$\overline{y}(0)=\overline{x}.$$

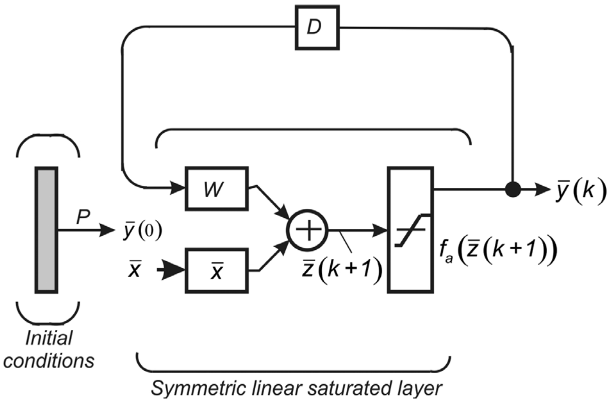

Fig. 3. Architecture of the network of Hopfield

At the third stage the consecutive states of neurons are determined

$$\overline{z}(k)=W\,\overline{y}(k-1)+\overline{x},$$

which allows calculating the value of the output signals

$$y_i(k)=f_a(z_i(k)),\quad i=\overline{1,n}, \qquad (6)$$

where $f_a(z_i(k+1))$ is neuron activation function (Fig. 4);

$$y_i(\mathrm{k})=f_a(z_i(\mathrm{k}))=\begin{cases}1, & \text{if } z_i(k)>1\\ 0, & \text{if } z_i(k)<-1.\\ y_i(\mathrm{k}) & \text{in other cases}\end{cases} \qquad (7)$$

The network of Hopfield does not use training with a teacher or training without a teacher [8, 9]. The calculation of weight coefficients using a formula (5) is performed only before the beginning of functioning of network on the basis of a priori information, which is possible to consider as help to the teacher. On the other hand, a network simply memorizes images and it cannot change the behavior after the real data act at its entrance. Therefore it is impossible to state that there is a feedback with a teacher.

Thus, if incoming values change, the output signals of the network are calculated according to formulas (6) and (7), after which the state of object is determined; if the values do not change – the work of the network is completed and the network is in a steady state.

There are cases, when the network of Hopfield is not able to carry out recognition and non-existent image

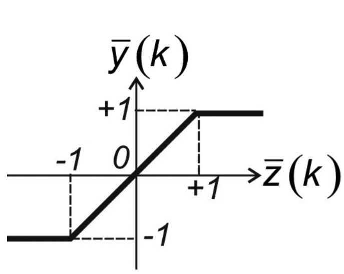

Fig. 4. Neuron activation function

can appear on an exit. The number of images that the network of Hopfield is capable of memorizing must not exceed $1.5n$ [9]. If some images A and B hardly differ from each other, the representation of the image A may result in the output image B and vice versa.

When there is no need for a network to give out an image in an obvious way, then it is possible to apply the network of Hamming [9], which is characterized by fewer expenses on memory and a smaller volume of calculations comparing to the network of Hopfield.

Hamming network consists of two layers (Fig. 5).

The first layer is a network of direct distribution, at the output of which such signal is formed

$$\overline{s} = W\overline{x} + \overline{b}, \qquad (8)$$

where W is matrix of elements

$$w_{ij} = \frac{x_j^i}{2}, \qquad (9)$$

where x_j^i is an element of a corresponding image j, $i = \overline{1,n}$; $j = \overline{1,M}$; n is dimension of the vector x; M is a number of the stored images in the memory of the network; $\overline{b}$ is a vector that has identical components, the number of which is n

$$b_1 = b_2 = \cdots = b_M = \frac{n}{2}. \qquad (10)$$

Thus, every component of vector $\overline{s}$ is calculated according to

$$s_i = \frac{1}{2}\left(\sum_{j=1}^{M}\left(x_j^i x_j + n\right)\right).$$

As well as in the network of Hopfield, in the network of Hamming vectors $\overline{x}^j$ and $\overline{x}$ take on a value of "–1" or "+1".

In case when the components of vector coincide

$$s_i = n.$$

In case of difference between the components of vectors $\overline{x}^j$ and $\overline{x}$ the number of their non-coincidences equals h, that is Hamming distance between vectors $\overline{x}^j$ and $\overline{x}$. In this case

$$s_i = n - h\, s_i = n - h.$$

If $h = 0$, then vectors $\overline{x}^j$ and $\overline{x}$ completely coincide.

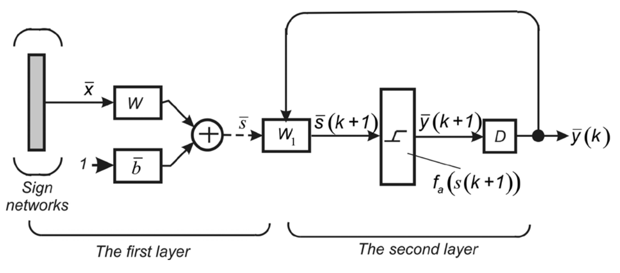

Fig. 5. Architecture of Hamming network

The output signal of the first layer acts at the entrance of the second layer, that consists of a block of calculation of the vector $\overline{s}(k+1)$, of function of activating (Fig. 6) and an element of delay D (Fig. 5). The value of threshold F (Fig. 6) must be large enough [9] in order to avoid a satiation. Such a signal acts at the entrance of element of activating

$$\overline{s}\left(k+1\right) = W_1\overline{y}\left(k\right), \qquad (11)$$

where $W_1 = \begin{bmatrix} 1 & -\varepsilon & -\varepsilon & \cdots & -\varepsilon \\ -\varepsilon & 1 & -\varepsilon & \cdots & -\varepsilon \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ -\varepsilon & -\varepsilon & -\varepsilon & \cdots & 1 \end{bmatrix}$; $\varepsilon < \frac{1}{n}$, and such a signal is formed at its output [9]

$$y_i(k+1) = f_a(s_i(k+1)),$$

where

$$f_a(s_i(k+1)) = \begin{cases} y_i(k+1) = F, & \text{if } s_i(k+1) > F \\ y_i(k+1), & \text{if } 0 < s_i(k+1) < F. \\ 0, & \text{if } s_i(k+1) < 0 \end{cases} \qquad (12)$$

The fact that the value $\overline{s}$ does not take part in further recurrent procedure of calculation of $\overline{y}(k)$ is represented by the dotted arrow in the Fig. 5. The value $\overline{s}$ serves as an initial condition in recurrent procedure of calculation of $\overline{y}(k)$.

After signal $\overline{y}(k+1)$ passes a delay line D at the output of the network we obtain $\overline{y}\left(k\right)$.

Thus, a signal that appeared at the output of a network after a certain number of iterations determines the number of the stored image.

The program that realizes the network of Hamming is written using the algorithmic language of MatLab. The main program feature is that a value "1" appears at one of the outputs of neuron, which determines the number of the stored image, while – "0" appears at others. For that a threshold function is used with a "sign" type

$$Y_i = \begin{cases} 1 & \text{when } y_i > 0 \\ 0 & \text{when } y_i \le 0 \end{cases}, \qquad (13)$$

where Y_i, $i = \overline{1,m}$.

A capacity and efficiency of the worked out algorithm was checked up by the imitation of operations of the boring setting. According to Table 2 such matrix was formed:

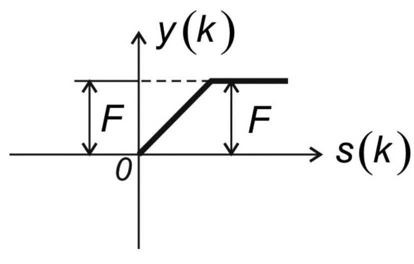

Fig. 6. Function of activating of a neuron of Hamming network

% Technical operations of the boring setting

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X = [1 1 1 0 1 1 1 1;...   % Deepening mining holes
     1 1 1 0 1 1 0 1;...   % Elaboration of chisels
     1 0 0 1 0 1 0 1;...   % Increase
     1 0 0 0 1 1 1 0;...   % Circulation and washing
     1 0 0 1 0 1 0 0];     % Lifting the columns.
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We got another matrix after the recalculation of elements of the matrix X using a formula (4)

$$\hat{X}=\begin{bmatrix}1 & 1 & 1 & -1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & -1 & 1 & 1 & -1 & 1\\ 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1\\ 1 & -1 & -1 & -1 & 1 & 1 & 1 & -1\\ 1 & -1 & -1 & 1 & -1 & 1 & -1 & -1\end{bmatrix},$$

whose lines are images-standards. Weight coefficients ε are chosen as follows: $\varepsilon=\frac{0.5}{n}$, where n is dimension of vectors of standards $\bar{x}_i^*=x_{i\bullet}^T,\quad i=\overline{1,m}\,(m=4),$ where $x_{i\bullet}^T$ is a corresponding line of the matrix $\hat{X}$.

Vectors $\bar{x}_i^*=x_{i\bullet}^T,\ i=\overline{1,m}$ were represented at the input of the network alternately. The result of the network Hamming was

$$\bar{y}_1=\begin{pmatrix}3.26 & 0 & 0 & 0 & 0\end{pmatrix}^T;\ \bar{y}_2=\begin{pmatrix}0 & 3.30 & 0 & 0 & 0\end{pmatrix}^T;$$
$$\bar{y}_3=\begin{pmatrix}0 & 0 & 3.29 & 0 & 0\end{pmatrix}^T;\ \bar{y}_4=\begin{pmatrix}0 & 0 & 0 & 4.80 & 0\end{pmatrix}^T;$$
$$\bar{y}_5=\begin{pmatrix}0 & 0 & 0 & 0 & 3.26\end{pmatrix}^T.$$

We received such vectors after applying the threshold function (13)

$$\bar{Y}_1=\begin{pmatrix}1 & 0 & 0 & 0 & 0\end{pmatrix}^T;\ \bar{Y}_2=\begin{pmatrix}0 & 1 & 0 & 0 & 0\end{pmatrix}^T;$$
$$\bar{Y}_3=\begin{pmatrix}0 & 0 & 1 & 0 & 0\end{pmatrix}^T;\ \bar{Y}_4=\begin{pmatrix}0 & 0 & 0 & 1 & 0\end{pmatrix}^T;$$
$$\bar{Y}_5=\begin{pmatrix}0 & 0 & 0 & 0 & 1\end{pmatrix}^T.$$

The network of Hamming puts a particular technological operation that is presented on the screen of an operator in accordance to every vector.

If, for example, we give a vector $\bar{x}_1^*=\begin{bmatrix}1 & 1 & 1 & 0 & 1 & 1 & 1 & 1\end{bmatrix}$, that answers to the technological operation of the drilling at the input of Hamming network, then the following information will appear on monitoring of an operator:

CURRENT TECHNOLOGIC OPERATION

Deepening of mining hole.

Thus, the Hamming network faultlessly recognized unknown images according to images-standards.

It should be noted that provided the same capacity the Hamming network contains fewer connections between neurons than the network of Hopfield. In the network of Hopfield dependence between the number of neurons and number of connections is quadratic, and in the network of Hamming it is linear [8, 9].

Conclusions.

1. Major states of the boring setting were worked out on the basis of the analysis of the process of construction of deep wells for oil and gas as well as the algorithm of technological processes of the drilling with the algorithm of optimal process control of mining hole deepening.

2. The method of authentication of operations of the boring setting was worked out. It is based on information about the technological parameters of a process of building of mining hole. An image of a corresponding process of the drilling is formed by means of threshold function as a binary signal that characterizes the certain state of the boring setting.

3. It is suggested to use artificial neural networks for authentication of operations of the boring setting. It is shown that the usage of the artificial neural networks of Hopfield or Hamming is extremely expedient for the task of recognition of operations of the boring setting.

4. Analyses of Hopfield or Hamming networks show that it is expedient to use the network of Hamming for the task of recognition of operations of the boring setting provided there is no need to get an image in an obvious way. The architecture of this network has been developed, and is given in the terms of matrix-vector sizes, and the algorithm of functioning of the network has been developed as well.

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Мета. Розробка методу й алгоритму ідентифікації технологічних операцій бурової установки з метою забезпечення роботи алгоритму оптимального керування процесом поглиблення свердловини в автоматичному режимі.

Методика. Задачу ідентифікації технологічних операцій бурової установки сформулюємо як задачу розпізнавання образів. Для розв'язання даної задачі використано метод штучної нейронної мережі Хеммінга.

Результати. Проведено аналіз основних технологічних операції бурової установки й розроблені метод та алгоритм розв'язання задачі розпізнавання технологічних операцій бурової установки, що дадуть можливість забезпечити моніторинг оператором послідовності технологічних операцій механічного буріння, а також автоматичне визначення тривалості спуско-підіймальних операцій для поточного рейсу. Це дасть можливість реалізувати роботу алгоритм оптимального керування процесом поглиблення свердловини в автоматичному режимі. Запропоновано новий підхід для визначення початку й тривалості технологічних операцій бурової установки у процесі поглиблення свердловини. Аналіз штучних нейронах мереж показав, що для задачі розпізнавання технологічних операцій бурової установки доцільно використовувати мережу Хеммінга. Розроблена її архітектура та алгоритм функціонування даної мережі.

Наукова новизна. Уперше запропоновано метод розпізнавання технологічних операцій бурової установки із застосуванням мережі Хеммінга, що дало змогу в автоматичному режимі визначати тривалість спуско-піднімальних операцій для забезпечення роботи в реальному режимі часу й розробити ефективний алгоритм оптимального керування процесом поглиблення свердловини.

Практична значимість. Розроблені алгоритм і програмне забезпечення для розв'язання задачі розпізнавання технологічних операцій бурової установки, що забезпечують моніторинг оператором послідовності технологічних операцій поглиблення свердловини, а також автоматичне визначення тривалості спуско-піднімальних операцій для поточного рейсу, з метою реалізації роботи в автоматичному режимі алгоритму оптимального керування процесом поглиблення свердловини. Програмне забезпечення, розроблене на основі запропонованого методу та алгоритму, інтегровано в комплекс СКУБ-М2. Даний комплекс був складовою частиною бурової установки при бурінні свердловини № 5 Васищівського газоконденсатного родовища, що дало змогу визначити працездатність і ефективність розроблених методу та алгоритму. Запропонований метод і алгоритм розпізнавання технологічних операції бурової установки може бути інтегрований також і в інші системи контролю та автоматичного управління процесом поглиблення свердловини.

Ключові слова: *бурова установка, розпізнавання образів, нейронна мережа*

Цель. Разработка метода и алгоритма идентификации технологических операций буровой установки с целью обеспечения работы алгоритма оптимального управления процессом углубления скважины в автоматическом режиме.

Методика. Задачу идентификации технологических операций буровой установки сформулируем как задачу распознавания образов. Для решения данной задачи использован метод искусственной нейронной сети Хемминга.

Результаты. Проведен анализ основных технологических операции буровой установки и разработаны метод и алгоритм решения задачи распознавания технологических операций буровой установки, что позволит обеспечить мониторинг оператором последовательности технологических операций механического бурения, а также автоматическое определение продолжительности спуско-подъемных операций для текущего рейса. Это даст возможность реализовать работу алгоритм оптимального управления процессом углубления скважины в автоматическом режиме. Предложен новый подход для определения начала и продолжительности технологических операций буровой установки в процессе углубления скважины. Анализ искусственных нейронных сетей показал, что для задачи распознавания технологических операций буровой установки целесообразно использовать сеть Хемминга. Разработана ее архитектура и алгоритм функционирования данной сети.

Научная новизна. Впервые предложен метод распознавания технологических операций буровой установки с применением сети Хемминга, что позволило в автоматическом режиме определять продолжительность спуско-подъемных операций для обеспечения работы в реальном режиме времени и разработать эффективный алгоритм оптимального управления процессом углубления скважины.

Практическая значимость. Разработаны алгоритм и программное обеспечение для решения задачи распознавания технологических операций буровой установки, обеспечивающих мониторинг оператором последовательности технологических операций углубления скважины, а также автоматическое определение продолжительности спуско-подъемных операций для текущего рейса, с целью реализации работы в автоматическом режиме алгоритма оптимального управления процессом углубление скважины. Программное обеспечение, разработанное на основе предложенного метода и алгоритма, интегрировано в комплекс СКУБ-М2. Данный комплекс был частью буровой установки при бурении скважины № 5 Васищевского газоконденсатного месторождения, что позволило определить работоспособность и эффективность разработанного метода и алгоритма. Предложенные метод и алгоритм распознавания технологических операции буровой установки могут быть интегрированы также и в другие системы контроля и автоматического управления процессом углубления скважины.

Ключевые слова: *буровая установка, распознавания образов, нейронная сеть*

Рекомендовано до публікації докт. техн. наук Г. Н. Семенцовим. Дата надходження рукопису 20.04.16.