

Improved Control of Portal Washing Unit for Agricultural Machines Based on the Implementation of Neural Network Technologies

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Abstract— The problem of high-quality cleaning required for maintaining functional reliability of agricultural machines leads to the search for new ways and solutions, research, improvement and development of new methods and means of mechanization aimed at reducing material and labor costs, increasing productivity along with ensuring environmental safety of the process. The article provides rationale for the need to improve the management of portal washing unit which is automatic and requires new control algorithms for rational consumption of water, electricity, cleaning time. Neural network computing models are considered as a tool for washing unit control algorithm. They are modern computer technology tool that can be used in the agro-industrial complex; the architecture of neural network to perform the corresponding tasks was obtained. In recent years, neural network technologies and models based on them have been used in different sectors of national economy. This paper studies the possibility of using a neural network to recognize contamination level and the type of agricultural machinery in order to control the water supply in portal washing – all this should reduce water consumption and generally increase the energy efficiency of washing unit.

Keywords—*neural networks, computer vision, external cleaning of equipment.*

I. INTRODUCTION

The operation of agricultural machines takes place under severe conditions, so the outside surfaces are subject to intense contamination: dust, road dirt, plant residues, pesticides, corrosion products, residues of operating fluids, as well as products of chemical reactions. Removal of these contaminants is an important technological process that has a great influence on the safety of equipment, work productivity, the quality of repair and maintenance of machines, work culture, and human ill health. In recent years, neural network technologies and models based on them have been used in different sectors of national economy. Based on the analysis, the main technical and organizational measures were defined in this article which made it possible to pose the problem of improving the process control system of the portal washing for agricultural machines based on neural network technologies. As a mathematical model of water supply depending on the

shape, geometric dimensions and equipment contamination level, a neural network model was selected.

II. LITERATURE REVIEW

The following authors worked on increasing the efficiency of technological processes of agricultural production in Russia: A.V. Kirillin (Cleaning of agricultural machines before their preparing for storage, 2017), N.V. Byshov et al. (Improving the efficiency of cleaning and washing agricultural machines, 2016), A.V. Shemyakin (Contamination of agricultural machines and devices for their cleaning, 2016), M.B. Latyshyonok (Resource-saving technology for conservation of agricultural machines, 2016). During reading these papers, an analysis was made of existing models of washing units for external cleaning of agricultural machines which made it possible to compare their characteristics and to provide rationale for the use of AVIK Lafet automatic portal washing unit for cleaning agricultural machines. Among the authors involved in neural network modeling in the field of agriculture, the following works were studied: V.A. Golovko (Neural networks: training, organization and application, 2002), E.K. Zavadskas et al. (Fuzzy matrix games multi-criteria model for decision-making in engineering. Informatica, 2016), A.I. Galushkin (Neural networks: foundations of the theory, 2015), I.R. Kafiev et al. (On the issue of fuzzy control of electric drives of intelligent agricultural robots, 2017).

III. OBJECT AND SUBJECT OF THE STUDY

In recent years, neural network technologies and models based on them have been used in different sectors of national economy. This article describes main technical and organizational measures which made it possible to pose the problem of improving the process control system of the portal washing for agricultural machines based on neural network technologies. As a mathematical model of water supply depending on the shape, geometric dimensions and equipment contamination level, a neural network model was selected. Thus, the object of this study is the process of external cleaning of agricultural machines from functional and technological contamination. The subject of this study is a neural network algorithm that recognizes contamination

level and the type of agricultural machines for regulating the water supply in a portal washing unit.

IV. RESEARCH METHODOLOGY

It is known that the key issue in the implementation of the technology of preparing agricultural machines for storage is their cleaning [1].

Stationary high pressure washing systems have similar technical characteristics with mobile ones; they can be fixed on horizontal and vertical surfaces. All high-pressure units are partially or completely covered with protective covers preventing the surface of its constituent parts from water entry during cleaning [2]. Washing of agricultural machines has several peculiarities in comparison with the washing of commercial vehicles:

- large dimensions, with width up to 5 meters
- complex body profile.

During operation, different types of contamination accumulate on the surface of agricultural machines. All measures aimed at preventing contamination cannot completely exclude its formation. Almost all types of contamination can be found on the outside surfaces of agricultural machines due to their operational profile. Therefore, the use of effective methods and ways of cleaning agricultural machines is of critical importance. Contamination can be removed by one or more of the following methods [3]: 1) washing; 2) dissolution; 3) chemical reaction; 4) mechanical action. Comparative characteristics of methods that are or can be used for cleaning agricultural machines are shown in Tables 1 and 2.

TABLE I. COMPARISON OF WATER CONSUMPTION

Name	Water for washing one unit of agricultural machinery or truck	Description of cleaning method
GARO washing unit, model 1100	at the maximal working pressure 150 - 200 L	Waterblasting
Washing hose systems	360	Waterblasting
PMU-A/T-7 stationary washing unit	370 L	Rotating brushes with water supply
AVIK Lafet automatic portal washing system	350 L	Waterblasting based on water hammer force

TABLE II. COMPARISON OF WATER CONSUMPTION

Comparison of operating time of different units for trucks used in agriculture showed the following result (Table 3, Figure 17): Table 3 Comparison of operating time	Operating time for cleaning one truck, hours
GARO washing unit, model 1100	2.5
Washing hose systems	3.5
PMU-A/T-7 stationary washing unit	1
AVIK Lafet automatic portal washing system	0.8

Thus, according to the requirements for cleaning agricultural machines, AVIK Lafet automatic portal washing system is the most suitable. The technology used is waterblasting based on water hammer force which can be the basis for further improvement and application of an acoustic-cavitation device [2]. This washing system is automatic and has the following disadvantages due to its design, technical

characteristics and capabilities of used washing technologies: the quality of cleaning depends on the individual characteristics of the machine and on specific contamination parameters. In addition, programs for washing dirt of different contamination level using a different set of additional chemical products are designed to perform certain cycles with a strictly specified time, therefore, in order to improve the quality of washing you have to either repeat the washing cycle or choose a longer cycle. This is due to difficulties in the software implementation of all cases that arise during washing with the use of traditional mathematical models. Overcoming these difficulties is a relevant task. Programmed washing cycles do not regulate water supply depending on the design features of machine and contamination level. They simply repeat the entire washing cycle with repeated movement of the machine while the need for a second cycle is decided by operator. Thus, there is uncertainty that makes the use of accurate quantitative methods and approaches to control the washing process difficult or even impossible. This is due to the fact that they are mainly developed on the basis of traditional methods for making mathematical models. Approximately 350 liters of water are required per truck wash cycle, without regard to the design of machine and contamination level. The relevant task is to improve the washing control system through the application of an algorithm that will allow you to control water supply, power consumption and speed of equipment movement depending on the design and contamination level. In addition, the current state of computer technologies allows you to carry out this task without any operator who manually indicates the type of equipment and contamination level. Let us consider the parameters to be measured by a neural network in order to control washing unit; then let us create a training data set; test its ability to classify objects, and create a neural network training technology to control the washing of agricultural equipment [4, 5]. For programmed water supply control, we need the technical system to figure out the design of machine and contamination level of this machine – it will allow rational use of water and its feed rate, i.e. pressure. Traditional algorithms assume the presence of an operator that inputs certain parameters. Neural network that recognizes an image, namely, a photo of a machine that has come to washing unit, should independently define the design parameters of the machine (length, width, height and other design features) and contamination level and, in accordance with this, use a certain water volume and pressure for water supply. To test the ability of neural network to classify machines and control their washing, we specify parameters: “Water supply”, “Body shape”, “Machine size” and “Contamination level”. Input value of “Water supply” is defined by the design features of washing unit. Parameters for water consumption are “Body shape”, “Machine size” and “Contamination level” [4, 5]. The dimensions of the K-700 tractor are the following: length – 8,400 mm, width – 2,530 mm, height – 3,950 mm, body shape is coded as 1. KAMAZ 55102 dimensions are the following: length – 7,570 mm, width – 2,500 mm, height – 2,830 mm, body shape is coded as 2. Contamination level: low one is specified as 1-3, medium – as 4-6, high – as 7-9, and if it is 0, then the machine is clean.

Using Deductor application [6], let us check the ability of a neural network to classify objects (K-700 and Kamaz 55102) according to geometric parameters and shape and to contamination level. That is, neural network should figure out type of machine which is in washing unit and contamination

level – this will determine the required volume of water and pressure. At the output, it should give one of the following variants: we define K-700 with low contamination as Y11, K-700 with medium contamination as Y12, K-700 with high contamination as Y13, clean K-700 as Y10, Kamaz 55102 with low contamination as Y21, Kamaz 55102 with medium

contamination as Y22, Kamaz 55102 with high contamination as Y23, clean Kamaz 55102 as Y20. Length is coded as X1, width – as X2, height – as X3, shape – as X4, contamination level – as X5. Training sample is shown in Table 3.

TABLE III. TRAINING SAMPLE

X1, mm	X2, mm	X3, mm	X4	X5	Y11	Y12	Y13	Y10	Y21	Y22	Y23	Y20
8,400	2,530	3,950	1	1	1	0	0	0	0	0	0	0
8,400	2,530	3,950	1	2	1	0	0	0	0	0	0	0
8,400	2,530	3,950	1	3	1	0	0	0	0	0	0	0
8,400	2,530	3,950	1	4	0	1	0	0	0	0	0	0
8,400	2,530	3,950	1	5	0	1	0	0	0	0	0	0
8,400	2,530	3,950	1	6	0	1	0	0	0	0	0	0
8,400	2,530	3,950	1	7	0	0	1	0	0	0	0	0
8,400	2,530	3,950	1	8	0	0	1	0	0	0	0	0
8,400	2,530	3,950	1	9	0	0	1	0	0	0	0	0
8,400	2,530	3,950	1	0	0	0	0	1	0	0	0	0
7,570	2,500	2,830	2	1	0	0	0	0	1	0	0	0

During the program running, we indicate that X1-X8 are input parameters, and Y10-Y13 and Y20-Y23 are output ones. First of all, for recognizing images by a neural network, you should decide how to enter input data. A common solution is to express a two-dimensional image matrix as a one-dimensional vector. Next, the question arises related to the choice of architecture. In general, there are still no methods to definitely determine the structure and composition of neural network based on task description [7–9]. Modeling the

operation of neural network to accomplish the task – control of portal washing unit –made it possible to determine required architecture and activation functions.

V. RESULTS

Data entry into Deductor program [6] is shown in Figure 1.

X1, mm	X2, mm	X3, mm	X4	X5	Y11	Y12	Y13	Y10	Y21	Y22	Y23	Y20
8400	2530	3950	1	1	1	0	0	0	0	0	0	0
8400	2530	3950	1	2	1	0	0	0	0	0	0	0
8400	2530	3950	1	3	1	0	0	0	0	0	0	0
8400	2530	3950	1	4	0	1	0	0	0	0	0	0
8400	2530	3950	1	5	0	1	0	0	0	0	0	0
8400	2530	3950	1	6	0	1	0	0	0	0	0	0
8400	2530	3950	1	7	0	0	1	0	0	0	0	0
8400	2530	3950	1	8	0	0	1	0	0	0	0	0
8400	2530	3950	1	9	0	0	1	0	0	0	0	0
8400	2530	3950	1	0	0	0	0	1	0	0	0	0
7570	2500	2830	2	1	0	0	0	0	1	0	0	0
7570	2500	2830	2	2	0	0	0	0	1	0	0	0
7570	2500	2830	2	3	0	0	0	0	1	0	0	0
7570	2500	2830	2	4	0	0	0	0	0	1	0	0
7570	2500	2830	2	5	0	0	0	0	0	1	0	0
7570	2500	2830	2	6	0	0	0	0	0	1	0	0
7570	2500	2830	2	7	0	0	0	0	0	0	1	0
7570	2500	2830	2	8	0	0	0	0	0	0	1	0
7570	2500	2830	2	9	0	0	0	0	0	0	1	0
7570	2500	2830	2	0	0	0	0	0	0	0	0	1

Fig. 1. Entering data into Deductor program

As a result of simulation, the working network architecture was obtained in Deductor application [6]: 5x8x8x8, that is, in the first layer there are 5 neurons by the number of parameters, in the second and third (hidden) layers by 8 neurons, and at

the output – 8 neurons according to studied classification. The structure of the neural network in the form of a graph obtained via the application is shown in Figure 2.

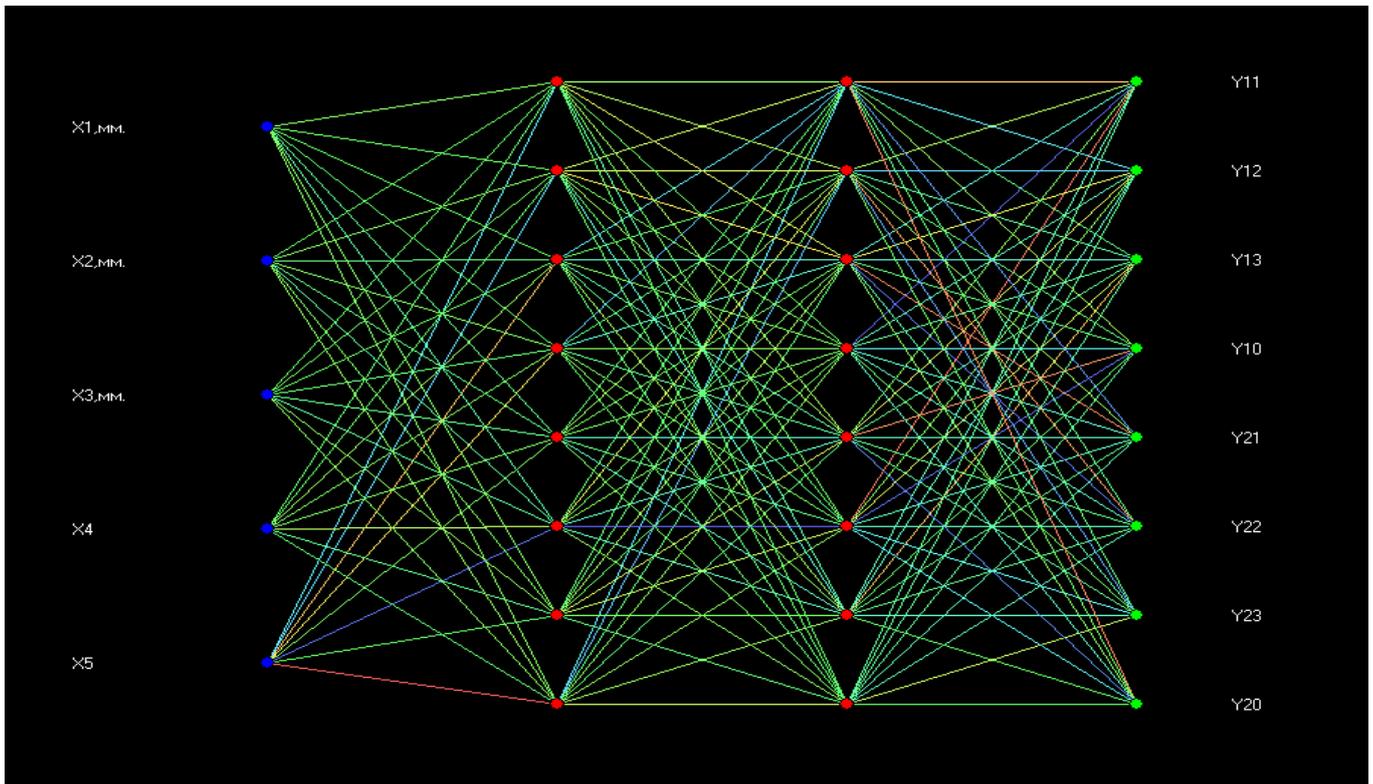


Fig. 2. Neural network 5x8x8x5

Deductor application checked the operation of neural network for the sample, as a result the neural network correctly selected all weights, since with the input parameters from the training sample, it produced the same output parameters, i.e. the neural network was trained and according to the input parameters from the sample from Table 2, its results coincided with the results in this sample.

Next, the operation of neural network was checked. For this, data was entered from 1st sample variant (Table 2).

As a result, the neural network correctly selected all the weights, that is, when simulating in Deductor program [6]

with the input parameters from the training sample, the output parameters had the corresponding values of this sample what shows that the neural network was trained and according to the input parameters from the sample in Table 3 her results coincided with the results in this sample.

So with the input values X1 = 8,400 mm, X2 = 2,530 mm, X3 = 3,950 mm, X4 = 1, X5 = 1, neural network gave the correct answer Y11 that is “K-700 with low contamination” (Figure 3).

Field	Value
Input	
9.0 X1,MM.	8400
9.0 X2,MM.	2530
9.0 X3,MM.	3950
9.0 X4	1
9.0 X5	1
Output	
9.0 Y11	1
9.0 Y12	0
9.0 Y13	0
9.0 Y10	0
9.0 Y21	0
9.0 Y22	0
9.0 Y23	0
9.0 Y20	0

Fig. 3. Operational result on variant 1

The article provides rationale for the need to improve the management of portal washing unit which is automatic and requires new control algorithms for rational consumption of water, electricity, cleaning time. Neural network computing models are considered as a tool for washing unit control algorithm. They are modern computer technology tool that can be used in the agro-industrial complex. The ability of neural network to perform classification based on the parameters of machine which was displayed in the photos was tested. 5x8x8x8 architecture was obtained, with sigmoid activation function. Further research on this issue may consider this result, since the question of which architecture and activation function should be selected is the first one for the development of neural networks.

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