International Scientific and Practical Conference "Digitization of Agriculture - Development Strategy" (ISPC 2019)

Intelligent process control system of water treatment for nutrient solutions of drip irrigation

Vladimir Kasatkin
Department of Technology and equipment of food and processing productions
Izhevsk state Agricultural Academy
Izhevsk, Russian
kasww@mail.ru

Nadezhda Kasatkina
Department of Technology and equipment of food and processing productions
Izhevsk state Agricultural Academy
Izhevsk, Russian
kasatnu@yandex.ru

Marianna Svalova
Department of water Supply and water treatment
Kalasnikov Izhevsk State University
Izhevsk, Russian
marianna.svalova@yandex.ru

***Abstract*—On the basis of theoretical and experimental studies on water treatment for nutrient solutions of drip irrigation technologies for growing cucumbers in protected soil, as well as experience in the development and technology of artificial intelligence (AI), the structure of an artificial neural network (ANN) for water treatment of joint stock company "Greenhouse complex "Zavyalovsky"was developed. Produced training the ANN based on experimental data and well-known algorithms, and provides aproximacion actual data and obtained by using the trained ANN of indicators proving viability and effectiveness of conducted research. The use of ANN in water treatment for drip irrigation allows you to save the components of the nutrient solution, which, as a result, can significantly increase the yield and quality of the grown fruits, without overdose of nitrates and other components from the nutrient medium.**

***Keywords—water treatment; nutrient solution; artificial neural network; technology*.**

I. INTRODUCTION

Today, against the background of increasing negative anthropogenic impact on the environment, the state of many water supply sources is deteriorating in a wide range of indicators. As a result, there is a problem of water for watering plants in greenhouses. The optimal solution is water treatment with the given parameters: the total concentration of soluble salts; the content of sodium, chlorine, boron and other elements absorbed by plants to a small extent and with the accumulation of acting toxic; the content of bicarbonate; the amount of calcium and magnesium.

For drip irrigation in greenhouses, it is better to use water with a salt content of up to 0.75 mS/cm. If it is necessary to work with water, the salt content of which is within 0.75-1.5 mS/cm, then it is very correct to approach the issue of choosing a substrate. The main requirement that must be taken into account – the possibility of washing in the case of accumulation of salts. In this case, it is better to give preference to inert substrates such as mineral wool, coconut, perlite. Water with a high and very high concentration of salts can not be used in greenhouses without pre-treatment of salts.

Carrying out experimental studies of water treatment directly in greenhouses is quite a costly process with the need to attract almost all the resources of the enterprise and the probability of water supply failure of the entire greenhouse complex, which is unacceptable. Therefore, promising in this area is to conduct research at the theoretical level, namely-the development of a mathematical model: it will save resources, to study the processes in time with the ability to predict them, as well as to identify common patterns. Of particular interest is the use of artificial intelligence (AI), in particular artificial neural network (ANN): in contrast to the linear methods of statistics, it allows you to create nonlinear relationships and thus more accurately describe the processes in question. In addition, the neural network is trained on the entire sample without fragmenting it, which increases the accuracy of the results.

II. LITERATURE REVIEW

A. Legislative framework

The Russian government adopted the "Federal scientific-technical program of development of agriculture for 2017 - 2025", developed with the food security Doctrine of the Russian Federation approved by the decree of the President of the Russian Federation of January 30, 2010 № 120 "On approval of food security Doctrine of the Russian Federation" and the Strategy of scientific and technological development of the Russian Federation approved by the decree of the President of the Russian Federation from December 1, 2016, № 642 "On the strategy of scientific and technological development of the Russian Federation" [1].

B. Analysis of experimental and theoretical works on water treatment and application of intelligent systems

V. Alekseev made a great contribution to the theory and practice of water treatment and rational use of water resources., I. Weisman., V. Isakov. V. Karpov etc. the Application of intelligent and information systems were considered in A. Beltyukova , T. Gabrichidze, M. Gorokhov, V. Zaitseva, O. Malinoy, A. Niluka, S. Popova , V. Trusov, A. Trusov et al. Based on research over the past decade in the field of system analysis, automation, control and information processing, mathematical modeling [4, 5, 9, 12...15] of particular interest is the application of a new applied field of data science that specializes in intelligent support and artificial

neural networks. The relevance of the application of methods based on artificial neural networks is proved by numerous examples: pattern recognition, intellectualization of technological processes, management with subsequent adaptation, forecasting using training, memory organization and much more. The possibility of using ANN in various fields in industries (for example, such as the technological process of water treatment) is of great interest to science. By means of methods based on ANN it is possible to make recognition of objects of environment at the program level, to visualize optical signals, to develop self-learning systems and to solve other problems [2, 7, 8, 10, 11].

The range of tasks for which neural networks are used largely coincides with the tasks solved by traditional statistical methods [3, 6]. A neural network is created by specifying the type of structure, the number of layers, and the number of neurons in each layer.

III. RESEARCH METHODOLOGY

From the analysis of experimental and theoretical works on water treatment and the use of intelligent systems the most suitable solution to the problem of water treatment for drip irrigation will be used in the development of artificial neural network for the enterprise sigmoidal or so-called logistics function (s-shaped function) activation

$f(s) = 1/(1+e^{-x})$ [6].

The rationale for this choice is primarily the fact that the function is differentiable. This property is very convenient to use when training a neural network. Secondly, it has the ability to amplify weak signals, the ability to prevent "overtraining" from large values of signals, as they correspond to areas where the sigmoid function has a fairly gentle slope. The range of values from 0 to 1 is also a big advantage. Figure 1 shows an example of a neural network with a sigmoidal activation function *f(s)* with the values of the source water parameters as an input signal (I_n) and the values of the sorbent parameters as an output signal (O_n).

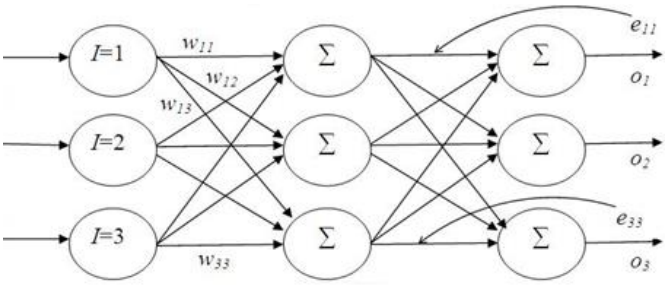

Fig. 1. Neural network with sigmoidal activation function f(s) with values of source water parameters as input signal (In) and values of parameters as output signal (On)

A. *Development of a model of ANN for fixed values of the parameters of the nutrient solution*

As input signals, the parameters of the incoming water X (X_1 -organoleptic water index, points; X_2 - temperature of the incoming water, C°; X_3-ambient temperature, C°; X_4-phenolic index; X_5-chloride concentration, mg / l; X_6-biological oxygen consumption, mg/l; X_7-concentration of blue-green algae, thousand cells/ml; X_8 - turbidity of the source water, mg/l; X_9-chromaticity of the source water, degrees) from the correlation analysis of the data, formed on the basis of MUE "Izhvodokanal". Water treatment parameters (*Yn*) were selected as outgoing signals: Y_1 – Filtration activity of the substrate, mg/g; Y_2 – contact time of the substrate with filtered water, minutes; Y_3 –Dosing of the nutrient medium or corrective additives, mg/dm^3. The parameters of the nutrient solution (*Zn*) were adopted as a prerequisite, which is based on agronomic requirements for drip irrigation of cucumbers. The data were translated into a dimensionless form by subtracting the mean and normalizing the variance. To assess the significance, the Boxcounting algorithm was used. The results of determining the incoming signals relative to the outgoing ones are shown in figure 2.

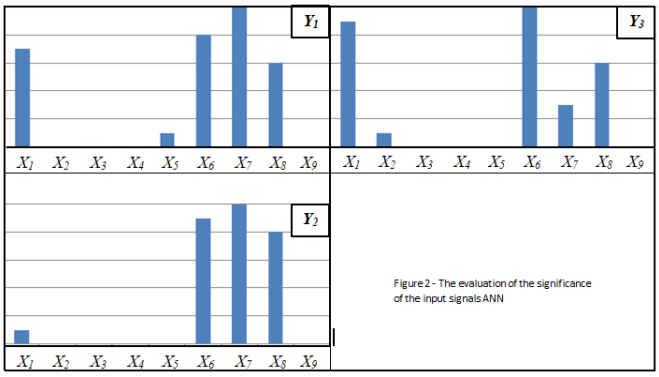

Fig. 2. The evaluation of the significance of the input signals ANN

To improve the predictive power of ANN, the least significant incoming signals were discarded. Thus, for the parameter filtration activity of the substrate (Y_1) for the ratio of the mean value of the normalization and dispersion parameter changed from 2.55 to 2.84; for the contact time of the substrate with filtered water (Y_2) from 3.55 to 4.86; for the dosing of the nutrient medium or corrective additives (Y_3) from 3.36 to 7.39.

B. *Designing the structure of ANN and training*

On the basis of determining the significance of the parameters of incoming water for each of the main parameters of the technological process of water treatment, the structure of ANN was developed, which was further trained (figures 3, 4). When developing the structure of the ANN, it was taken into account that the total number of network links (weights) should be several times less than the volume of the training sample.

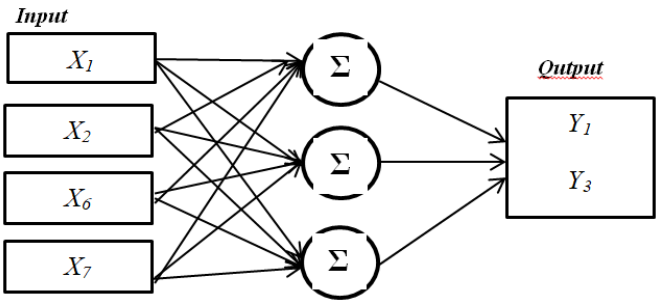

Fig. 3. The structure of the ANN for the filtration activity of the substrate and the dispensing of the power environment

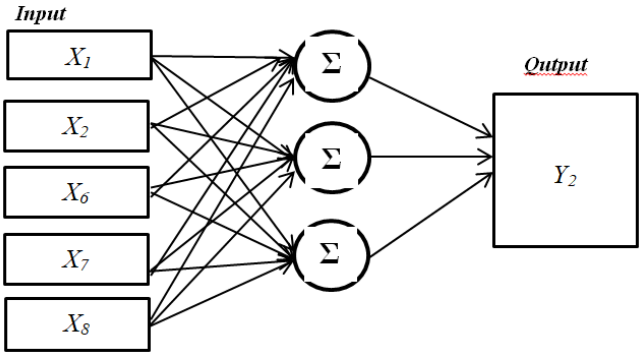

Fig. 4. The structure of the ANN for the contact time

Further training of ANN was carried out. Excel Neural Package was used to implement the learning process of ANN. Initially, the error of ANN for the filtration activity of the substrate was 0.91. After 7273 epochs of training, the error of ANN was reduced to 0.46. For the contact time of the substrate with the filtered water, the initial error was 1.47. After training through 6134 epochs the error of the ANN made up of 0.50. For the dosing of the nutrient medium or corrective additives, the initial error was 1.09. After training in 6152 eras, the error of ANN was 0.19.

Using the Fisher criterion, it was proved that the developed ANN for the deodorization process adequately calculates the values of indicators (for the filtration activity of the substrate-23,23, the contact time of the substrate with filtered water-81,14, dosing of the nutrient medium or corrective additives-43,16).

IV. VERIFICATION OF THE RESULTS

The adequacy and applicability of the developed model as an intelligent decision support system and adjusting the values of the main parameters of water treatment to the actual data in for 2018 for each month.

A. Comparison between actual and obtained by the trained ANN data

The results of comparison of actual and model-derived values for water treatment parameters the year 2018 is given in table 1.

TABLE I. COMPARISON BETWEEN ACTUAL AND OBTAINED BY THE TRAINED ANN DATA

N	Actual value			Model values ANN		
	Filtration activity of substrate	Contact time	Dosing of the supply medium	Filtration activity of substrate	Contact time	Dosing of the supply medium
1	0,80	180,00	2,00	0,85	180,93	2,00
2	5,50	180,00	2,00	5,30	180,93	1,99
3	9,90	212,71	3,95	9,90	202,88	3,95
4	11,00	225,00	5,25	14,58	225,00	5,25
5	16,00	225,00	6,00	14,58	225,00	6,00
6	16,00	225,00	5,65	14,58	225,00	5,65
7	16,70	212,71	4,65	14,58	212,71	4,64
8	6,00	180,00	3,65	6,00	202,88	3,65
9	0,90	182,80	2,00	0,85	180,93	2,00
10	5,60	215,93	2,90	5,30	202,88	2,89
11	3,93	225,00	3,50	5,30	225,00	3,50
12	8,28	225,00	3,50	8,28	225,00	3,50

B. Graphical representation of data

On the basis of the developed tables, graphs comparing the actual and model-derived values for the parameters of the filtration activity of the substrate, the contact time of the substrate with water and the dosing of the nutrient medium were compiled (figures 5…7).

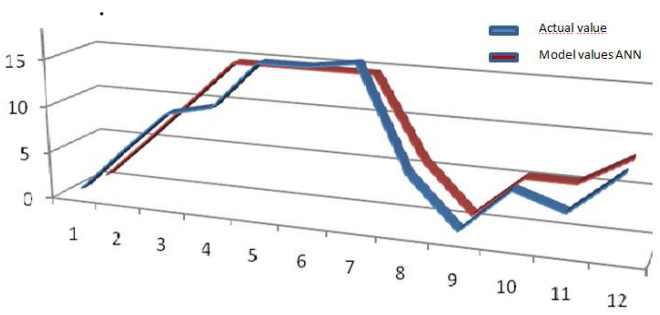

Fig. 5. Filtration activity of substrate

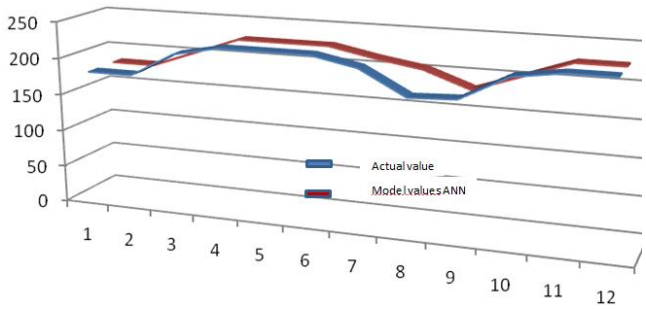

Fig. 6. Contact time

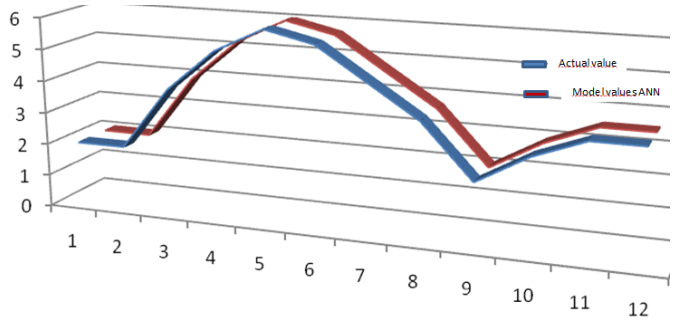

Fig. 7. Dosing of the supply medium

CONCLUSION

Derived from the trained ANN results are in good approximiert the actual data. The average approximation error for the filtration activity of the substrate is 9.5%, for the contact time of the substrate with the filtered water - 1.7%, for the dosing of the nutrient medium or corrective additives - within 1%. The results based on the equations of neurologische give a greater error, indicating that the advantage of applying the trained ANN on the equations of neuroreplete for technological process of water treatment at drip irrigation of cucumbers.

DISCUSSION OF RESULTS

- The possibility of using an artificial neural network for modeling the main parameters of the process of drinking water deodorization is proved.
- Based on the neural network and regression analysis of the data, a model was developed for such parameters as the filtration activity of the substrate, the contact time of the substrate with the filtered water, the dosing of the nutrient medium or corrective additives, depending on the parameters of the source water. The use of ANN in water treatment for drip irrigation allows you to save the components of the nutrient solution, which, as a result, can significantly increase the yield and quality of the grown fruits, without overdose of nitrates and other components from the nutrient medium.
- Using the Fisher coefficient, it was proved that the obtained model of water treatment adequately calculates these indicators (for the filtration activity of the substrate – 23,23 , the contact time of the substrate with filtered water – 81,14, dosing of the nutrient medium or corrective additives – 43,16). The results of neural network modeling well approximiert actual data.
- The technique allowing to adapt the system of water treatment to the changing parameters of water supply sources, based on neuroregressive modeling, which will allow real-time control of the technological process of water treatment, obtaining a nutrient solution of the required quality, with the lowest possible consumption of materials and energy.

REFERENCES

[1] Decree of the government of the Russian Federation No. 996 of August 25, 2017 on approval of the Federal scientific and technical programs for the development of agriculture.

[2] F. Bloom, A. Lazerson, L. Hofstadter, “Brain, mind and behavior,” M.: World, p. 219, 2001.

[3] Yu. Borisov, V. Kashkarov, S. Sorokin, “Neural network methods of information processing and means of their hardware and software support,” Open systems, № 4, p. 215., 2001.

[4] T. Gabrichidze, “Complex multistage security system of critical, potentially dangerous objects: dissertation of doctor of technical Science,” Izhevsk, p 406, 2008.

[5] V.A. Zaitsev, “To the theory of stabilization of controlled systems: dissertation of doctor of physical and mathematical Sciences,” Izhevsk, p. 293, 2015.

[6] V. Kruglov, V. Borisov, “Artificial neural network. Theory and practice - 2nd publishing house, stereotype,” - M.: Hot line-Telecom, p. 382, 2002.

[7] A. Makarenko, “Algorithms and software system of classification of halftone images based on neural networks,” PhD thesis, Tomsk, p. 117, 2007.

[8] D. Pospelova, “Fuzzy sets in control models and artificial intelligence,” M.: Nauka, p. 312. 1986.

[9] L. Rodina, “Invariant and statistically weakly invariant sets of controlled systems: thesis of doctor of physical and mathematical Sciences,” Vladimir, p. 246, 2012.

[10] B. Silov, “Strategic decision Making in fuzzy environment,” M: INPROGRESS, p 228, 1995.

[11] V. Tenenev, B. Yakimovich, M. Senilov, N. Paklin, “Intelligent systems of interpretation of well logging data,” Artificial intelligence: Donetsk, Science I Osvita, № 3, pp. 439-447, 2002.

[12] A. Trusov, V. Trusov, “System of information and analytical support of scientific and technological development of branches of fuel and energy complex,” Information resources of Russia, No. 3, pp. 2-5, 2017.

[13] S. Yuran, “Methods and means of automated control of optical density of biological tissues when changing their blood filling under the conditions of artifacts: thesis of doctor of technical Sciences,” Izhevsk, p. 439, 2008.

[14] V. Kasatkin, “Scientific substantiation of energy-saving technology and equipment for freeze-drying liquid thermolabile products and purpose: the thesis. doctor of engineering,” Izhevsk, p. 271, 2004.

[15] A. Shevtsov, L. Lytkina, S. Antipov, “Mathematical modelling of light dependent microorganisms cultivation in countercurrent film reactor,” Theoretical foundations of chemical engineering, vol. 50, number 3, pp. 335-342, 2016.