Artificial Intelligence of the Water Supply System of Plant Growing Objects

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Abstract. The article proposes a solution to the problem of achieving the maximum value of productivity of plant growing objects based on the introduction of artificial intelligence on the basis of neural networks in the water supply system of plants. Various factors affecting crop yields and plant growth are presented. Factors are considered as incoming signals for mathematical neurons of artificial intelligence. A diagram of the artificial intelligence neural network of the plant water supply system, its topology, and the corresponding mathematical model are constructed.

1. Introduction

AI is used in medicine, forensics, diagnostics of malfunctions of technical objects, etc. [1, 2, 3]. As for plant growing objects in terms of their water supply, it is necessary to make decisions of the following nature: turn on/turn off the water supply, reduce / increase the volume of its supply, etc. If such decisions are timely (based on the readings of soil moisture sensors, temperature and other properties of the water used, its consumption for each crop, etc.), the growth and productivity of plants will increase, which means their productivity.

Plant productivity is influenced by a large number of factors. At the same time, one set of factors can be easily regulated (water supply, aeration and soil moisture), another complex can be regulated with difficulty using high energy consumption (humidity, soil acidity, ambient temperature, light exposure), and the third is the presence and volume of snow cover, the duration of the frost-free period, the amount of precipitation, their distribution by months - to compensate as much as possible by regulating the first and second parts of the factors. It is known, for example, that productivity will not be affected if watering volume is reduced while the ambient temperature is lowered, etc. The aforesaid allows us to conclude that achieving the maximum value of the productivity of plant production objects, taking into account the influencing factors, is a rather difficult task.

It can be solved by introducing AI into the water supply system of plant growing objects (hereinafter - the system). In other words, it is recommended to make the so-called “smart” irrigation system. Due to the presence of AI, the system will be adapted to the characteristics of the environment (region, country) of the plants, it will follow year-round weather conditions, receive and process weather forecast information from a hydro meteorological center, etc. - the system will be based on the principle of watering plants with such a volume of water that they need. This can be done by:

1) the information stored in the memory when the system was put into operation and the system received experimental information over time (including from the sensors) regarding the required volume of water supply for each plant;

2) obtaining weather forecast information on the amount of precipitation in the form of rain, both in real time and in total for months, seasons, etc.;
3) dividing the site of the location of objects containing various crops in water supply zones;
4) processing the above data;
5) making decisions on the water supply of a separate plant area of the facility.

Table 1 provides indicative data for the analysis of AI, on the basis of which a decision will be made on the water supply of plant growing objects.

Table 1. The accumulated knowledge for the analysis of AI.

Information from sensors	Persistent memory	Information from a hydro meteorological center
1. The pressure	1. Dependences of soil acidity, ambient temperature, soil moisture, pressure, illumination	1. Weather forecast
2. Illumination		2. The direction and speed of the wind
3. Humidity		3. The distribution of precipitation by month
4. The presence of precipitation		
5. The temperature of the environment		
6. The acidity of the soil		
7. Soil moisture		
8. Water hardness		

Having explained the essence and need for the development and implementation of AI in the water supply system of plant growing objects, we proceed directly to the description of the principles of its organization. As you know, there are two main approaches used in creating systems containing AI: the creation of expert systems and the use of neural network technologies [4]. As a rule, a person directly deals with the water supply to plant growing objects - he either manually irrigates his plot or includes the available irrigation system. In this regard, the water supply system will consider the features of the use of AI based on neural network technologies - a system with AI in the image and likeness of the human brain.

The core of the AI of such a system will be considered a mathematical neuron - an object that is a mathematical model of the neuron of the human brain. It will have similar properties: contain inputs *i*, where will the input signals x_{ij} and one way out y_i.

Moreover, each signal arriving at the *j*-neuron signal x_{ij} will be multiplied by some corrective weighting coefficient b_{ij} (1):

$$S_j = \sum_{i=1}^{i} b_{ij} x_{ij} \tag{1}$$

The output signal y_i of a *j*-th mathematical neuron will take one of two values (2), (3):

$$y_i = 1 \text{, if } S_j \geq \theta_j \tag{2}$$

$$y_i = 0 \text{, if} S_j < \theta_j \tag{3}$$

where θ_j – sensitivity threshold of the *j*-th mathematical neuron.

If the resulting total value S_j *j*-th mathematical neuron of the water supply system does not reach a certain value of the sensitivity threshold θ, then the mathematical neuron will not be excited - its output will be zero, and vice versa [5, 6].

As signals entering the inputs x_{ij} *j*-th mathematical neuron of the water supply system, the output values of the sensors included in its composition will be used. Such sensors include: humidity, temperature, pressure sensors, etc. In addition to sensors, information from the Hydro Meteorological Center containing data on upcoming precipitation will be sent to the inputs of mathematical neurons: estimated time of precipitation, duration of exposure.

We list the main types of sensors, the output signals of which will arrive at the inputs of the mathematical neurons of the AI System, and briefly describe their purpose:

- pressure and temperature sensors monitor the current values of atmospheric pressure and ambient temperature (*T1*);
- the illuminance sensor of the plot shows the level of illumination of plants (*L1*);
- rainfall sensor detects rainfall / snowfall (*S1*);
- moisture sensors monitor current moisture values in the plant rhizome area (*W1*).

Let us present in figure 1 an image of the topology of the water supply system of plant growing objects, where *BUP* is the irrigation control unit, *G1* is the GSM-module for connecting the system to the Hydro meteorological Center website and receiving a weather forecast from there, *L1* is the light sensor, *S1* is the precipitation sensor, *T1*is the ambient temperature sensor, *W1 - W5*are the soil moisture sensors, *K1 - K5*are the valves for turning on / off the water supply to sections *Z1 - Z5* of planted plants.

The AI of the System is located in the *BUP* unit, to which all “sensory organs” are connected (sensors *L1, S1, T1, W1 - W5*) and output commands are generated for the electromagnetic valves (*K1 - K5*) for switching on / off the water supply of the sections (*Z1 - Z5*), where the plants are planted. Proceeding from this, the neural network of the AI System shown in figure 1 can be represented in accordance with figure 2.

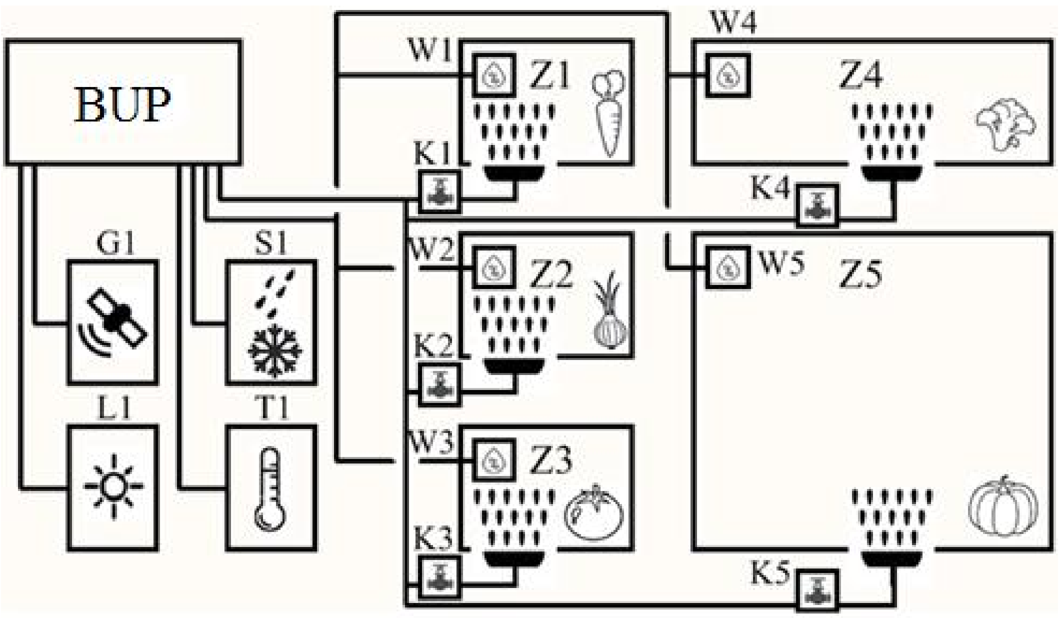

Figure 1. Schematic representation of a water supply system.

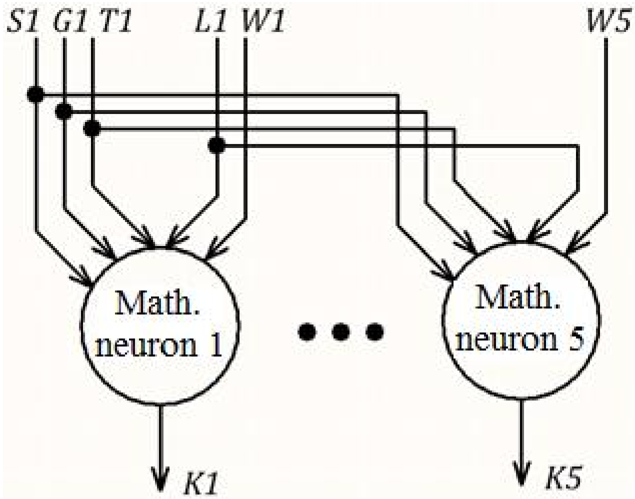

Figure 2. System Neural Network.

Marking $\overrightarrow{X_j}$, as a vector of input signals, and $\overrightarrow{Y_j}$, as a vector of output signals, based on figure 2 we get (4) and (5):

$$\overrightarrow{X_j} = \begin{pmatrix} S_1 \\ G_1 \\ T_1 \\ L_1 \\ Wj \end{pmatrix} \tag{4}$$

$$\overrightarrow{Y_j} = (K_j) \tag{5}$$

Moreover, the training vector $\overrightarrow{B_j}$ with correction factors $b_{ij} = \overline{0,1}$ is equal to (6):

$$\overrightarrow{B_j} = \begin{pmatrix} b_{11} \\ \ldots \\ b_{ij} \end{pmatrix} \tag{6}$$

For the case shown in figure 2, according to expressions (1), (4) and (6) we have:

$$S_1 = b_{11}x_{11} + \ldots + b_{51}x_{51} = b_{11}s_1 + b_{21}g_1 + b_{31}t_1 + b_{41}l_1 + b_{51}w_1 \tag{7}$$

$$\ldots$$

$$S_5 = b_{15}x_{15} + \ldots + b_{55}x_{55} = b_{15}s_1 + b_{25}g_1 + b_{35}t_1 + b_{45}l_1 + b_{55}w_5 \tag{8}$$

Based on (1) - (3), we can construct the threshold activation function [2] of the *j*-mathematical neuron for it output signal y_i (figure 3). The figure shows that after accepting the input signals x_{ij}, multiplied by correction factors b_{ij}, calculated weighted sum of input signals S_j, and based on its value, a decision is made on the output value y_i *j*-mathematical neuron. It is worth noting that the values of the correction factors will change over time (9):

$$b_{ij}(t+1) = b_{ij}(t) + \Delta b_{ij} \tag{9}$$

where $b_{ij}(t+1)$ – the new value of the correction factor, $b_{ij}(t)$ – the old value of the correction factor. Reason for changing odds Δb_{ij} will depend on the volume and quality of plant productivity obtained at the end of the reporting period.

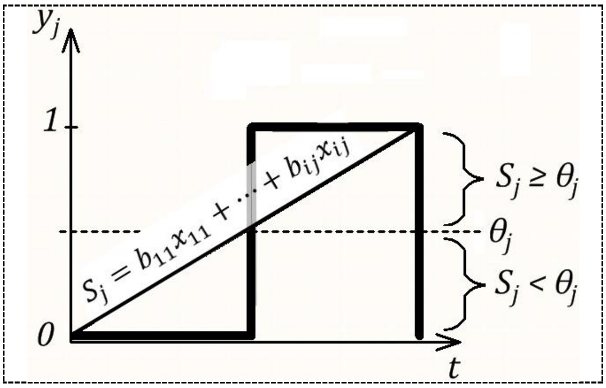

Figure 3. Threshold activation function.

As further research prospects, it is proposed to carry out work in the following areas:

- research and identification of additional input parameters of a mathematical neuron, identification of significant and insignificant parameters, exclusion (minimization) of insignificant ones. This should improve the quality of the neural network. However, it must be taken into account that too few input parameters may not be enough for the neural network to correctly determine the result y_i;
- the complexity of the algorithm for adjusting the weight coefficients b_{ij}.

As a result of the research, the following results were obtained:

1) a solution has been developed to achieve the maximum value of productivity of plant growing objects, taking into account various factors affecting the growth and productivity of plants. Its solution is proposed by introducing artificial intelligence into the water supply system of plant growing objects;

2) the organization of artificial intelligence has been developed for the water supply system of plant growing objects based on neural network technologies;

3) the organization of a water supply management system based on artificial intelligence has been developed; the topology of water supply for crop production facilities has been developed with the division of the entire irrigation area into zones;

4) a mathematical model of a water supply system with control based on artificial intelligence was developed.

References

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