Automated pipeline design algorithm with adaptive irrigation of agricultural facilities

Dmitry Polenov[*]

Moscow State University of Civil Engineering, 26, Yaroslavskoye Shosse, Moscow, Russia

Abstract. In this paper are addressed necessary steps to create a cost-effective pipeline system for plant irrigation. Particularly, focuses on properties of hydraulic dependencies, graph theory, plant productivity laws, which gives some information to design pipeline system. An algorithm for automated pipeline design. An important advantage of this algorithm is that possibility of changing the amount of irrigation due to the introduction of artificial intelligence in the water supply management system.

Providing irrigation of plant objects of the agricultural complex can be carried out manually, automatically or automatically. The last two are the most suitable ways to reduce a person's time, and there are many related irrigation management supplementary measures, including the use of plant productivity programming, the creation of adaptive water supply management systems, the introduction of artificial intelligence in the regulation of plant productivity factors [1], etc. As a rule, when implementing such irrigation methods, a pipeline is used to supply water to facilities. Pipeline design is a process inextricably linked to plant productivity. After all, their productivity depends on the quantity, type of irrigation of plants. When designing a pipeline therefore, it is of practical importance to know the:

- the size and features of the site, the division into zones of the agricultural complex;
- the crops that need to be grown, the amount of irrigation;
- the required productivity of the plants of the agricultural complex;
- analysis of existing, forecast values and known dependencies of factors affecting the productivity of plants of the agricultural complex;
- the cost of the elements of the pipeline, pump and other components of the irrigation system;
- hydraulic dependencies and much more.

Analyzing the above aspects, it is clear that the number of necessary actions in the design of the pipeline, their approximate order can be outlined by a specific set. There are a number of input data, when designing a pipeline. It is important to accept them, process and make a decision in accordance with the given subprogram and proceed to the next step. The result of the design will be a pipeline system ready for operation. All these features relate to the known characteristics of the algorithms [2]:

1. Discreteness - the algorithm is described by a sequence of actions.

---

[*] Corresponding author: PolenovDYu@mgsu.ru

2. The set of values of the source data.

3. Certainty - the activities of each step of the algorithm are strictly defined.

4. Finiteness - at the end of the implementation of the algorithm there should be a result.

In an automatic irrigation system for a plant growing objects after the completion of pipeline design it is difficult to change the amount of irrigation may become important for a plant productivity regulation. After all, it depends on the amount of irrigation. It is proposed to add such a function to the developed algorithm. After processing, analyzing productivity factors and obtaining its final physical value, it is possible to change the irrigation volume using various techniques. A useful and interesting case to consider is the use application of artificial intelligence (AI) [1]. The essence of the work of AI is to regulate the volume of irrigation of plants depending on the resulting productivity. The main AI element of such a system will be a mathematical neuron. It will contain the input, where the input signal x (the value of the obtained productivity) and the output y will be supplied - information about the decision to turn on and off the irrigation. At the same time, the signal x arriving at the neuron will be multiplied by some correcting weight coefficient b (1) are given in Eq.:

$$S = bx . \tag{1}$$

The output signal y of the neuron will take one of two values (2) and (3) - enable ($y = 1$) or turn off ($y = 0$) irrigation:

$$y = 1, \text{ if } S \geq \theta ; \tag{2}$$

$$y = 0 \text{ if } S < \theta , \tag{3}$$

where θ is the sensitivity threshold of a mathematical neuron.

The first algorithm step is to obtain and process the source data: it is necessary to obtain data on the size of the agricultural complex section, its features. These factors are:

1) the presence of objects that cannot be circumvented through the laying of the pipeline $\vec{O}$ (a well, a plant with a thick, deeply growing rhizome, various structures, etc.);

2) elevation $\vec{H}$ on the area;

3) geometric dimensions $\vec{S}$ of the area.

For next algorithm step a very important role are:

1) types of crop production $\vec{P}$ will grow on the area;

2) the need to create and the number of zones $\vec{P}$ of growth of various plant growing objects;

3) required plant productivity $\vec{E}$. This may include, for example, a satisfying customer weight of potatoes, carrots, beets, etc. The required yield of crops grown on the agricultural complex.
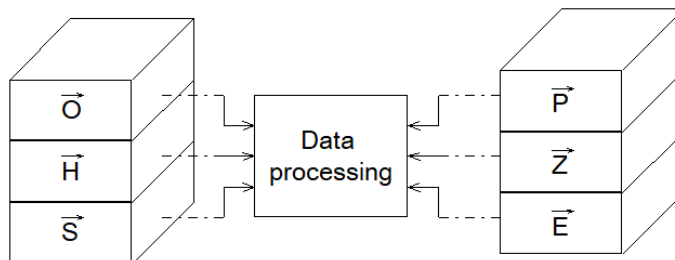

Fig. 1. The relationship between output and input external parameters.

We get a functional relationship between the weekend $\vec{Y}$ and input external parameters are given in Eq. (4) and shown on Fig. 1:

$$\vec{Y} = \vec{F}(\vec{O}, \vec{H}, \vec{S}, \vec{P}, \vec{Z}, \vec{E}),\qquad(4)$$

where $\vec{F}$ is vector-function.

There is the possibility of predicting the productivity of crop production. It takes some confederation [1] some:

1) the amount and volume of precipitation;
2) soil parameters;
3) ambient temperature;
4) the level and duration of illumination, etc.

A striking increase in plant productivity is achieved by application of regulatory laws. The laws of regulating plant productivity are known, among which the «Law of Plant Efficiency» [3] stands out, which states: the value of plant productivity depends on the whole series of factors x_n acting on productivity simultaneously are given in Eq. (5):

$$\varphi = \varphi(x_1, x_2, ..., x_n).\qquad(5)$$

After all, knowing the average annual precipitation, the ambient temperature and its forecast, the average soil parameters, the dependence of plant productivity on these factors, etc., one can also predict the resulting productivity. All this applies to districts, regions and other territorial units of countries where the agricultural complex is located.

After analyzing the factors affecting the productivity of plants, its forecasting, a plot and growing areas of a particular crop are built. Once this is done, the pipeline topology design phase begins. Hence, there is a need for:

1) choose an underground or elevated installation of the pipeline;
2) select an irrigation nozzle;
3) select the location of the nozzles;
4) pick up the pump.

It is important to make the pipeline topology effective (so that the plants are irrigated in accordance with the necessary requirements) and cost-effective (with the lowest price).There are several important pipe prices parameters that immediately come to mind:

• material, length, diameter of pipes;
• characteristics of nozzles, their quantity.

As matter of record Fig. 2 shows that the dependence of the price of the pipe on its internal volume, and therefore the volume of fluid passing through it.
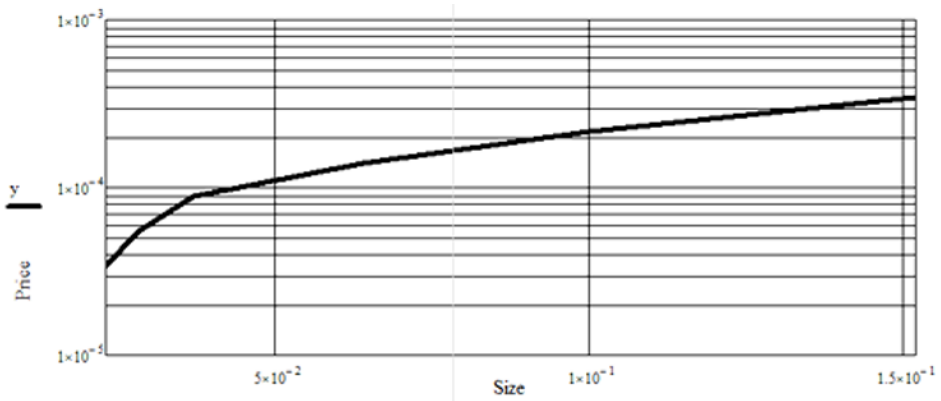

Fig. 2. The dependence of the price of the pipe on its internal volume.

Obviously, the calculation of the price of the pipeline can be carried out only after building the topology. It is therefore necessary to consider:

- the efficiency of irrigation of agricultural facilities;
- dependence of the volume of fluid passed on the diameter of the pipe;
- loss in pump head, depending on the characteristics of the pipeline;
- the presence of irrigation zones;
- dependence of the price of pipes and auxiliary parts on the characteristics - material, diameter, length, etc.

It is known that, depending on the resulting pipeline topology, the technical characteristics of the pump depend are given in Eq. (6):

$$H_{\max} = A - NPSH - H_{fric} - H_{vap} - H_{res} , \qquad (6)$$

where $H_{\max}$ is a pump suction height, A is a atmosphere pressure, $NPSH$ is a minimum suction pressure, H_{fric} is a friction losses in the suction pipe and valve, H_{vap} is a saturated vapor pressure, H_{res} is a factor of safety.

It is necessary to strive for the lowest possible price of the pipeline. It is given in Eq. (7):

$$L(Z) = z_i \rightarrow \min , \qquad (7)$$

where $i = \overline{1, n}$.

To determine the price of the pipeline, a table is compiled with all possible components e_i of the pipeline and their prices c_i . It presented in Table 1.

Table 1. Pipeline components and it prices

Pipeline element	Number of pipeline elements				One element price
e_1	a_{11}	a_{12}	…	a_{1n}	c_1
e_2	a_{21}	a_{11}	…	a_{2n}	c_2
…	…	…	…	…	…
e_n	a_{m1}	a_{11}	…	a_{mn}	c_n
Pipeline price	z_1	z_2	…	z_n	–

The price of the pipeline option are given in Eq. (8):

$$z_n = \sum a_{mn} c_m , \qquad (8)$$

where $m = \overline{1, \infty}$ and $n = \overline{1, \infty}$.

Investigation of the pipeline topology, that depends on the above dependencies, is the problem of from both theoretical and experiential viewpoints, especially for graph theory. The vertices of the graph can be both nozzles and dividing tees and crosses, and the arcs of the graph can be pipes. In this case, the pipe length will be the weight of the corresponding arc. To perform the task of finding the lowest possible price for the pipeline, you can build a directed graph. The Max-Flow Min-Cut Theorem, Making a Road System One-Way and etc. methods are capable of fulfilling these requirements [4]. The choice of appropriate

method depends on the application under consideration as each method presents specific advantages and disadvantages.

The algorithms block diagram illustrated in Fig. 3.

At the beginning of the automated design of the pipeline, initial data are collected and analyzed, which include the characteristics of the area, the types of plants that I will grow, their required productivity, as well as an analysis of existing and forecast factors, governing the plant productivity. After that, the control system of the constructed automated irrigation complex has information on turning on/off the irrigation of plants. At the same time, it is possible to adjust this parameter after obtaining productivity values, which makes the system adaptive.

This paper presents the recent development of a new design pipeline for irrigation area of agricultural facilities. It has demonstrated the validity to use the irrigation process hydraulic dependencies, graph theory, plant productivity laws, which gives some information to design pipeline system. It has considered the properties of:

1) the various aspects affecting the design of the pipeline are investigated. Among them are noted: the features of the site, the types of plants that I will grow, their required productivity, as well as an analysis of existing and forecast values of factors, governing the plant productivity. The functional dependence of the output and input parameters of the pipeline design is built;

2) the factors affecting the price of the pipeline while maintaining the efficiency of irrigation of plants are investigated. Among them are highlighted: the dependence of the volume of fluid passed on the diameter of the pipe, the loss in pressure of the pump, the presence of irrigation zones, etc.;

3) to construct the pipeline topology, it is proposed to use the theory of graphs, where the vertices of the graph can be both nozzles and dividing tees and crosses, and the arcs of the graph can be pipes;

4) the problem of regulating the volume of irrigation of plants in an automatic water supply system has been solved. It is solved by introducing into the algorithm a routine for processing the values of the obtained plant productivity and the known dependences of plant productivity on the volume of their irrigation. In this case, the work of the subprogram will be based on the use of artificial intelligence.
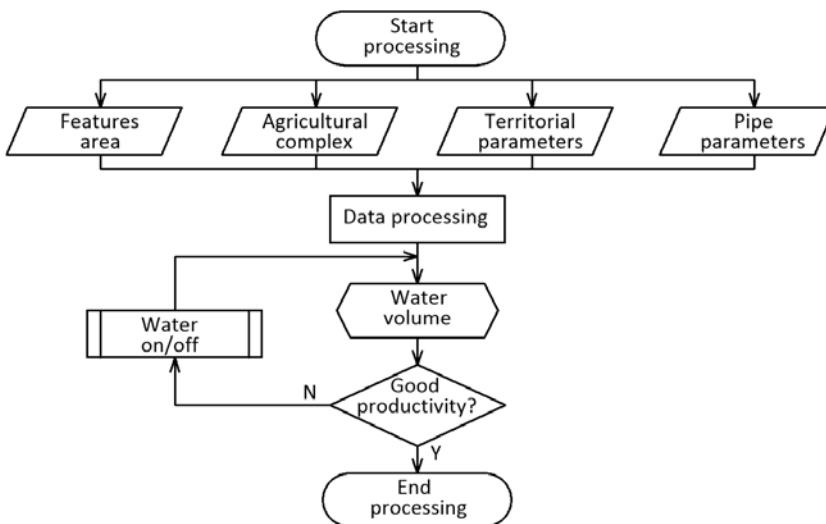

Fig. 3. The block diagram of the algorithm for the automated design of the adaptive irrigation pipeline for agricultural facilities

References

1. D. Polenov, Informatsionno-tekhnologicheskiy vestnik *The system of intelligent managment of water supply of plant growing objects.* – V. **4** (22). p. 91-97 (2019).
2. V. Zavyalov, V.Velichkin, A. Tikhonov *Razrabotka algoritmov upravleniya tekhnologicheskimi protsessami*. M.: MGSU. p. 4 (2009).
3. G. Bazdyrev, V. Loshakov, A. Puponin *Zemledelie*. M.:Izdatelstvo: Kolos, p. 24 (2000).
4. J. Bondy, U. Murty *Graph Theory. Springer*, p. 182 – 200 (2008).