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ANALYTICAL MODEL OF THE OPTIMAL CAPACITY OF AN IRRIGATION SYSTEM

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Key words: irrigation system, queuing theory application, analytical model, process optimization.

Abstract

The size and stability of yield per hectare of agricultural crops are greatly affected by climatic conditions, temperature, solar radiation, but especially the quantity and quality of rainfall, which for most agricultural crops is insufficient. Building large-scale irrigation systems is difficult in terms of investment, as well as operating costs. Claimed agricultural yields often do not emanate from a set of certain claims for each of the crops, but are only an estimate based upon empirical experience. Precise determination of these data is very difficult and without the use of exact mathematical methods and information technology would be virtually impossible. Goal of this project is dedicated to enhance of an irrigation system analytical model usability, which would allow the determination of the optimal capacity of the irrigation system in response to microclimate and soil conditions with respect to the crops and irrigation facilities. Developing new methods of precise irrigation is the way of higher and ecological productivity in agricultural production subsystem.

ANALITYCZNY MODEL OPTYMALNEJ WYDAJNOŚCI SYSTEMU NAWADNIANIA

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Słowa kluczowe: system nawadniania, zastosowanie teorii kolejkowania, model analityczny, optymalizacja procesu.

Abstrakt

Wielkość oraz stabilność plonu z hektara uprawianego pola w dużej mierze zależy od warunków klimatycznych, temperatury, promieniowania słonecznego, ale w szczególny sposób od jakości oraz ilości opadów deszczowych. Opady te dla większości upraw rolniczych są niewystarczające. Oszacowanie wydajności systemu nawadniania nie wynika zatem jedynie z zapotrzebowania na wodę uprawianych roślin, lecz także zależy od czynników losowych – mikroklimatycznych. Aktualnie wydajność systemu nawadniania, wielkości jedynie przybliżonej, szacuje się często na podstawie doświadczeń empirycznych. Dokładne określenie wydajności systemu nawadniania jest bardzo trudne i praktycznie niemożliwe bez zastosowania dokładnych metod matematycznych oraz technologii informatycznych. Celem pracy było zwiększenie użyteczności matematycznego modelu systemu nawadniania, co powinno pozwolić na określenie optymalnej wydajności systemu nawadniania w zależności od mikroklimatu i warunków gruntowych, z uwzględnieniem upraw oraz urządzeń nawadniających.

Prepositions of project solution

Irrigation system remains the weakest part of soil management. Ignoring water regime of soil and various crops from the beginning to the end of vegetation is large obstacle to economic and ecological irrigation. Research in the irrigation sector has accumulated enough theoretical and practical knowledge and needs only to look for ways and methods as soon as possible to get it into irrigation practice (HENNYEYOVÁ, PALKOVÁ 2006).

Goal of process observation in the irrigation system is the monitoring and analysis of various factors affecting the growth of crops, depending on the optimum moisture requirements of individual crops, and achieve higher productivity per area unit.

Precise irrigation as an aspect of agriculture is just the start of the research and represents application of water to exact location and exact dose. Using precise agricultural irrigation management is still in a state development and needs a lot of research and experimental work to define its realization case study and applicability (SOURELL 2003).

We try to integrate the accumulated knowledge into complex unit and then pply existing models and simulations in the experimental conditions, where we compare the efficiency of various algorithms and models of irrigation. Analyzing model and its behaviors we expand existing models with new optimization features and compare their results with the original models.

Description of irrigation process method

Irrigation is part of wide structure of agricultural production processes. Contains very specific conditions like product resources in an open environment that fully interacts with surrounding. Irrigation system process, in our case, we consider as isolated part of the overall process. We monitor its impact on the overall output with markers like yield per hectare.

Description of the processes can be statistically manageable through mathematical models. Mathematical model is a simplified view of real objects by using mathematical description, usually in order to solve the problem. The problem can be solved if we have the appropriate methods. Methods and models of individual processes are classified as:

a) Deterministic models and methods, where values and relations between them are not random. These models are aplicated when examining the operations of production, distribution and production scheduling.

b) Stochastic models and methods, where values and relations between them have a probability character. These models are used in examining particular handling operations, supply and recovery. These includes models of processes in agriculture, in irrigation management too.

Individual factors and associated sub-processes entering the irrigation system are fully stochastic in nature. Solving problems in this area requires to use of methods of statistical analysis and mathematical probability. Application discipline for the monitoring and optimization of the irrigation system is the queuing theory(QT).

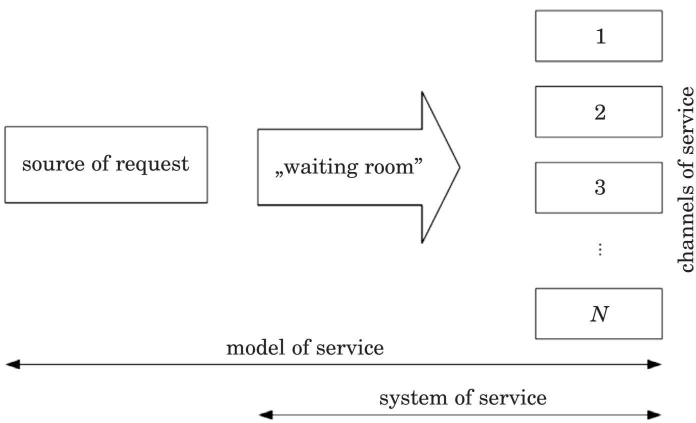

Fig. 1. The scheme of system of queuing theory

In our research based on existing mathematical models of irrigation systems are created on theoretical principles of queuing theory.

In agricultural practice are realised various combinations of systems based on queuing theory depending on the solution process. Standard QT process in irrigation system is defined as N-channel system, limited resource requirements, with a priority system in operation. Where the number of channels the system is defined as the available pool of technical device of irrigation, source of requirements as exact determined number of segment area units of agricultural crops, and priorities as currently requirements of individual segments on moisture in the soil.

In the case of irrigation system, the queuing system consists of service channels, which serve the requirements of current plants to supply additional irrigation. If the existing channels are not able to immediately serve the incoming requirements, they leave the system without serving, or are in the waiting queue, where they are for the release of a channel selected according to criteria given previously. This priority is necessary in the event that water demand is appearing for those crops which are economically important, or non-delivery of irrigation with them causing great economic damage.Stochastic elements in the case of irrigation system are:

– Input queue of requirements.
– Time longitude of requirements service.

Processing current mathematical QT is a complex process that requires the use of computing technology. Optimization can racionalize that process and achieve desired results in agricultural practice.

We define several possibilities of computing object simplification:

– Using only one channel of service – in this case we simplify handling process a we eliminate some algorithms from solution definition like channel of service choice.
– Rejection of priority – there is an elimination of algorithm for determining the order of the waiting room, where the solution is limited to servicing the requirements of a random stream of a final number of heterogeneous irrigation schemes.
– Discretization of requirements for heterogenous servicing channels – used to monitor and review the effectiveness of choosing the correct handling channel.

These simplifications creates separate groups of algorithms in the decision process:

– Algorithms for prioritizing requirements of different sectors of irrigation.
– Algorithms for efficient selection of technical equipment in the process of irrigation.
– Algorithms for modification of final order in the waiting room.

Described mechanisms determine individual factors of irrigation process. Each of element is based on unique inputs (database inputs). In fact, the algorithm outputs are counted in the overall impact on the effectiveness of decision-making. The overall process of irrigation using queuing theory is shown in the Figure 2.

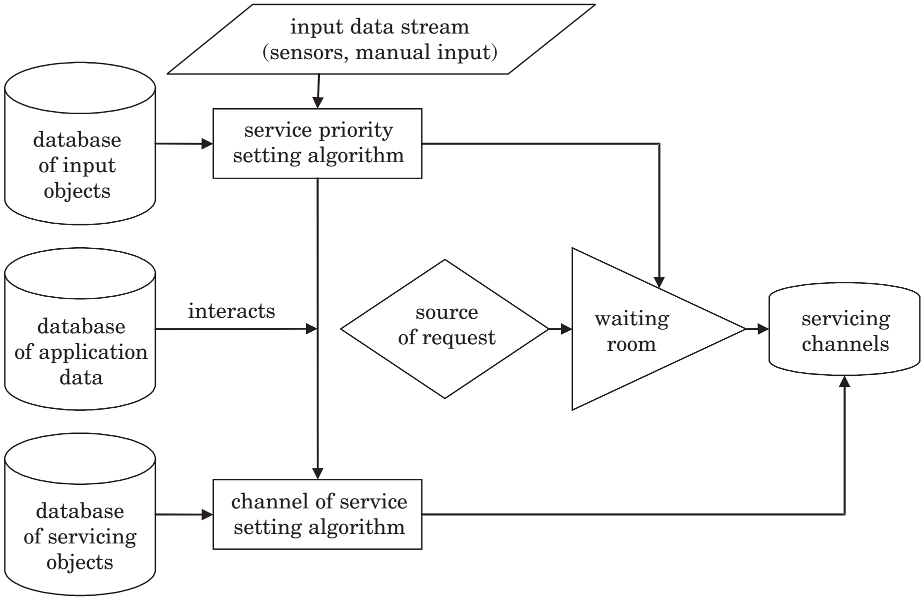

Fig. 2. The scheme of proccess of analytical model

Analytical model description

The basic idea of modeling real process, which include irrigation is possible in the simulation of real processes. Using modern CASE tools we can design a database model that corresponds to each element of the process operations of irrigation. The elements of the model between create relational links according to the reporting process steps. Particularity of this model is the use of hierarchical links between records, and implementing the potential of object databases. Then we can effectively manage data realtime, we can react quickly and data would be efficiently processed.

Input data stream represents data entering into the system from outside. That are inputs from measurements of soil moisture, temperature, plant life cycle, period and manual input about service device operators and others factors. The database of input objects, which consists of object-hierarchical database of product plants, database moisture requirements of plants and priorities of the rules table, creating input to decision-making algorithm for assigning priorities of requests and its enlistment in the waiting room. Database of servicing objects includes object-hierarchical database ofservice channels, their properties and methods from which we can determine the deployment of various devices to specific requirements.

The next section will present an algorithm based on a sample of database entry objects.

Alorithms determining priority of requests entering "waiting room"

We choose the model with one channel of service with priority of requirements, where the requirements do not leave the waiting room in the time interval. This process model considers an isolated instance, the weight of decision-making is based on a single algorithm that determines the priority of requests entering the system. By isolation of algorithms in the right combinations can objectively evaluate the effectiveness of algorithms. Evaluation of the results in this case is judged on the basis of the total time needed for the quantity served exactly the requirements of channel operation (in this case, the technical equipment of mobile irrigation system). Requirements entering the system are Poisson stream.

The probability of k number of requirements to time interval t is then determined by:

$$P_k(t) = \frac{(\lambda \cdot t)^k}{k!} \cdot e^{-\lambda \cdot t},$$

where λ is the parameter of arrival of requirements.

Requirements are random generated for the simulation. Real requirements entering the system on condition of achievement of critical levels of soil moisture measured by soil sensors. Any requirement in the stream carries the basic information that is stored (Input data stream buffer):
- Location of measured sector requirement by the sector ID,
- Requirement time of creation,
- Unique identification of plants according to the code of plant input DB,
- Current value of sensor measurement: current humidity, current temperature.

In this case, data from the sensor data stream pass throught filter, which decides whether it is a legitimate request. The filter has several factors:
- Current soil moisture,
- The time interval from the last irrigation time,
- Coefficient of decline of soil moisture.

Coefficient of moisture loss in the soil determines the relative value of measurement for adding to list of requirements:

$$R_{koef} = \frac{\Delta t_{\text{int}}}{L},$$

where Δt_{int} is the time interval since the last irrigation in hours, L is the ratio of intensity of crop moisture.

Each sensor records are stored in a database for need of algorithm analysis, especially for comparing current values with historical measurements.

Optimization algorithm for priority requirements determination compares the current entry requirements and information. Then the algorithm enters into a database application data, where information on measurements taken from sector and there are the values of other environmental variables.

Each incoming request gets to witing room as the output value of the priority algorithm in the range of 1–100 points, which is the sum of the individual factors assessed. The value of 100 means the highest priority. The request in waiting room is placed in order according to its priority. In the waiting room is scheduled control mechanism that controls the duration requirement in a waiting room and this time changing the current priority of requirements depending on the complexity, the importance of technical crops, etc.

Analysis of the priority of each requirement monitors and compares the following parameters:

- The time interval from the last irrigation,
- The ratio of crop water demand balance in sector and current moisture,
- Compare the current value of moisture to the process of water balance during the crop vegetative life,
- The economic importance of crop,
- Progress of current environmental temperature vs. history with regard to the temperature requirements of plants,
- Inclusion of global climate variables: the probability of precipitation in the hours, service coefficient (you can manually adjust the priority according to the contingencies) and others.

Input data stream database record example:

ID_Request	ID_Sector	ID_Plant	Time [dd.MM.yyyy]	Moisture [%]	Temp. [°C]
103243200	2010-R-0013	808-003	12.06.2010 14:33	15	18
103245601	2010-R-0126	808-002	13.06.2010 10:28	30	22

Algorithm procedure fragment for time interval between different irrigation priority processing:

```
function SetTimeIntervalPriority(parID_Request,parInputValues:TstringList); // procedure input
  var // variables definition                                   // parID-Reguest – ID of request
    DS: TappDataSet // Data stream data set                     // parInputValues – set of global
    Filter: string;                                             //        variables selected from
Priority,Interval:Integer;                                      // application database by SQL query
begin // core
```

```
  try
  DS := TappDataSet.Create; // instance constructor
  Filter := 'DS.Value(''ID_Request'') = parID-Request';
  DS.SetDSParams("10020,10203",filter); // opens data set of concrete data stream
  DS.Open; DS.First;
  If DS.RecordCount = 1 then // if record found
    Interval := DateDiff(day,DS.Value(Time), ParInputValues.strings[TimeLast]); // interval of last irrigation
    CASE // condition of priority
    ((Interval – ParInputValues.strings[water_need]) <= 0) : Priority := 10;
    ((Interval – ParInputValues.strings[water_need]) > 0) : Priority := 10 – ParInputValues.strings
    Else Priority:= 1;                                                                    [water_need]);
    END
finally
  Result := Priority;
  DS.Free;
  end;
  end;
```

Conclusion

The project currently in phase of additional algorithm tuning on virtual data, where we try to adjust the decision process and designed model aproximately to real conditions. The main difficulty in our testing of solution is availability of databases with real input data, so we use data obtained primarily by internal measurements of our institution experiments.

The definitive effect of process optimization is getting in importance, depending on the size of irrigated area in the number of sectors and the number of technical resources. In small agricultural units we do not expect a visible effect of applying this method of process optimization.

The expected trend in near future is a significant turnover in irrigation look, as possibility how to solve the current problems. Some intensification tools have achieved an roof effect and therefore producers are looking for sub-options.

Wide cause of this state is extreme environment behavior, which can not guarantee an adequate supply of moisture during the vegetation period.Finally, it begins socio-political pressure to support the idea of organic agriculture, to which irrigation belongs too.

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