Agris on-line Papers in Economics and Informatics

Volume IV Number 3, 2012

Precise Irrigation Process Support by Using a Computer Based Algorithm of Heuristics

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Abstract

Optimization of production processes are required to provide companies with a competitive advantage. In the production industry this optimization is already under control and optimization of complex end-optimal models has been proposed. Using these model processes in agricultural production is inappropriate because they calculate exactly a process without the influence of random variables and factors. At the present time is usual to develop specific processes operating under ideal conditions. Their disadvantage is that real data from them vary considerably. Therefore, there is a need to develop simple methods and tools which can optimize these processes.

Key words

Irrigation system, queuing theory, precise irrigation, heuristic algorithms.

Introduction

Every process manipulates with a specific object according to exact rules, methods and models. Objects enter to each operation are described by set of physical values, which reflect their current status and their links to other objects and to the environment. Change the input data to the required output data provides an action member. At this point it is important to decide how to achieve the required properties of the final output. Decision making is part of process management control and is determined by a sequence of steps leading from verification of the problem to choosing an optimal variant of the solution. Process optimization involves defining an algorithm for the calculation of ideal output values.

Material and methods

About 70% of global human water withdrawal from rivers, reservoirs, and aquifers is for irrigation of agricultural land, and about one third of global food production relies on irrigation water. Irrigation systems, however, are usually rather ineffective; much of the withdrawn water is lost before it reaches the plants that require the water for optimal growth. The efficiency of irrigation often is lower than half of the optimum (depending e.g. on climate and irrigation system) [1]. From this point of view, simulation models of optimal capacity of irrigation system may have strong effects on the irrigation efficiency. For the simulation modelling is necessary to save the huge amount of data in relational databases and the conventional concept of extraction is required. An analysis of this information is needed for effective decision making in process operation. The algorithm sequence is fixed and depends on a limited number of technological values. These methods are not effective for the precise irrigation process. The application of irrigation water by spraying, as the most widely used method of the artificial delivery of water to crops, requires the operator to have high professional standards. Unlike the commonly applied agro-technical methods, which are one-off, irrigation is split, so it must be repeated over time in the relatively long irrigation season.

The irrigation system remains the weakest part of soil management. Ignoring water regimes 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 [2].

Whereas the process of reproduction in agriculture is under the influence of many factors that are stochastic, building medium- and large-scale irrigation is not efficient and exactly possible using traditional methods, without using appropriate mathematical tools, simulation methods of solution and, of course, without the use of modern IC technologies. Simulating methods of operational analysis are effective tools suitable for the analysis and optimization of controlling complex processes and systems for irrigation systems.

The model of irrigation process using queuing theory

The process of irrigation management is relatively complex and has stimulated the development of major changes. A **simulation model** of the irrigation service is suitable for the operational management of irrigation management in terms of appropriate irrigation technology deployment and use in the irrigation process.

Since the model works with a large number of random variables, computer processing is necessary. Analytical solutions of the queuing theory models are from a mathematical point of view very difficult and it is necessary to make some simplifications. Therefore, with the current performance of computing systems the task is much easier solved using heuristic methods. For this purpose it is necessary to establish a simulation model of the system and ensure a sufficient number of times that we have achieved real results [3].

Queuing theory and its exploitation in the control of irrigation

Queuing theory (QT) deals with the study of systems where the process of handling between the „customers“ and „operator“ are created [6], [7], [8], [9], [10], [11]. These two concepts must be understood in the general scope. Resources requirements enter the system at a fixed time or at random times. In the present case, the requirements enter at random intervals. Upon entering the service system the requirement is immediately served if one channel is free. Otherwise, the requirement may be lost. The mechanism of operation is the way how units are selected from the waiting queue for a channel of service. We distinguish two types of service [4]:

a) a system without priority - processing according to specific criteria

b) a system with priority – system FIFO, requirements are processing in the order they enter in the system.

In the case of the 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 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 causing great economic damage.

Stochastic elements in the case of irrigation system are:

- the input stream of requirements,
- the time longitude of the requirements service.

The input stream of requirements

The input stream of requirements is a random process in continuous time, but with discontinuous requirements. The main majority of queuing models describe the input stream by a Poisson distribution. The probability that the providing system access k requirements for the time interval t is described by the Poisson distribution given by [5]:

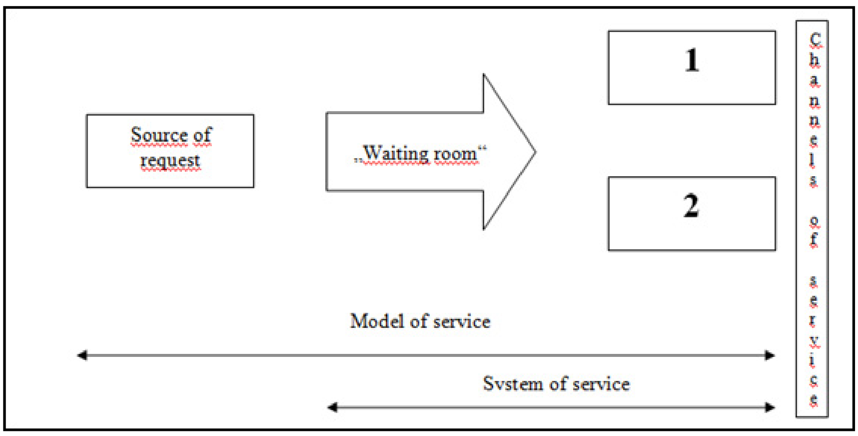

Fig. 1: The scheme of system of queuing theory

$$P_k(t) = \frac{(\lambda \cdot t)^k}{k!} \cdot e^{-\lambda \cdot t} \quad (1)$$

where λ represents the inputs, the number of inputs per unit of time.

In terms of applications in queuing theory, it is essential that the intervals between inputs are exponentially distributed. In terms of the model's practical application are important characteristics of independence, stationary and ordinary, which determine the conditions under which one is able to use the model with the Poisson distribution.

The time longitude of the requirements service

The time operator is the second important parameter in the queuing system, which determines their capacity. There are several factors influencing the service time and therefore it is needed to consider it as an exponentially divided variant with a distribution function [5]:

$$F(t) = 1 - e^{-\frac{t}{t_0}} \quad (2)$$

where t_0 is a mean time of service.

Exponential distribution of the time operator assumes that the majority of the operator is realized for a short time. The time longitude of the requirements service depends on several factors. Most interesting cases arise if the time of service depends on a long waiting queue.

The channels structure

This includes a number of channels and their mutual arrangement. In the base models is assumed parallel involvement of channels with one waiting queue. In the complex one is considered with the serial connection of channels, where each has its own waiting queue, or even with a multistage system of service and at each stage work several parallel channels.

Indicators of efficiency

There are relative or absolute values that characterize the degree to which the system performs the envisaged tasks. From the point of view of their content, they can be divided into parameters characterizing service quality and parameters characterizing the channel exploitation. Crucial elements of queuing appear:

- The input stream of requirements, its intensity, i.e. the average number of requests for service per unit time or the average length of the interval between two requirements.
- The channels of services, which carry out service features, their number and the average time needed for handling one request.
- Waiting queue and its restrictions.

The function of the queuing system is given by the mutual interaction of these three elements and can be expected from their parameters to be derivate global characteristics of the queuing system, called **indicators of efficiency** of queuing service. The choice of features first of all depends on the type of system and has to give a picture of the quality of service and the degree of utilization of queuing the system. This is a numeric type characteristic and the probability of mean values.

The number of channels of services $\boldsymbol{n}$, the density of the input stream of requirements λ, the mean service time for one requirement by one single channel $\boldsymbol{t}_{ob}$ and the mean waiting time for service $\boldsymbol{t}_{č}$, are the quantitative characteristics of the queuing process. If these values are known, it is possible to mathematically describe the process of queuing and thus predict the progress of this process in the future.

These procedures are used in modelling the irrigation system together with mathematical models of irrigation systems, where the queuing theory is using for developing of analytical solution of model of irrigation system. There are also designed algorithms of irrigation systems for each model.

Results and discussion

This paper deals with the possibility of creating functional methods of process control of artificial irrigation using modern computing technology. The proposed solution is based on current existing processes and models [5] and adds new knowledge. The aim is not to change or modify the currently used procedures and processes that have been verified by practice, but to help them optimize the new capabilities that enable these processes to optimize and increase the efficiencies of operations using modern information technologies. This area of investigation is complex, involving a large number of aggregated methods and procedures.

This work is specialized in creating optimized processing flow of input requirements with priority, where it focuses on the evaluation of priorities and the inclusion of requirements in the waiting queue. Whole process of statistical output are analysed and results are compared with other irrigation methods. All information and the history of operations are recorded and used for further processing. The aim is to continually refine and enhance the productivity of irrigation on the processed information from databases.

Modelling of processes in agricultural production requires the use of sophisticated tools. Processes and materials have highly stochastic and dynamic characters.

For the purposes of creating functional models of irrigation management it is necessary to record the status of soil and environment. States are divided into the following groups:

1. Parameters and variables bound to the current state of plants, respectively a set of plants of a particular sector.
2. Parameters and variables describing the environmental status of a particular sector.
3. Parameters and global variables.
4. Parameters and variables bound to the irrigation process.

Each of these groups determines the set of physical parameters describing the current status. The process of precise irrigation requires the efficient management of irrigation, and the following parameters to be measured:

- the current temperature in the sector,
- the current soil moisture in the measured area.

Based on this information the priority requirements may be assessed and thereby added to the waiting room to be served by the channel of service.

The result of the algorithm determines the effective value priorities and requirements of its proper order in the waiting order.

Ways of defined problem solution

The essence of the solution is an effective repository of collected data, which provides the necessary information relevant to the evaluation of the algorithm. The second part is the actual algorithm based on an heuristic analysis of available data indicating the value of priority requirements. There are several groups of algorithms corresponding to the fundamental questions of queuing theory:

- algorithm for determining priorities and front enlistment,
- algorithm for front update depending on the application data,
- algorithm for specification of channel of service,
- algorithm for filtering input data.

In this project, the algorithm of requirements priority determination is optimised. Similar procedures can be applied to other parts of the decision making process in determining the dose of moisture for plants.

The solution is to provide relevant information to determine the optimal operating sequence of the operations performed. The effectiveness of the proposed solutions will be judged on the basis of comparisons carried out experimentally and by comparing the measurements of values in real terms.

Database storage of analyzed Data

The standardized storage of the obtained data is a relational database. Because describing reality in complex simulation models based on relational databases is difficult and not effective, a technology of hybrid object-relational database system is used. The main advantage is the arrangement of data structure, precise modelling of processes of irrigation and quick access to hierarchical data. We are implementing Object properties such as object inheritance, time links and object links between objects are implemented. These properties give more possibilities of quick access to relevant data the possibility to lookup data from different angles of view. Another site is using Data Sets, which are represented as effective segments of the entire data model. This allows the evaluation of data in the logic of a database engine; it suppresses need of evaluation on side of application logic.

The determination of priorities of requests in QT requires the following data structures:

- Classification and definition of cultural crops
  - Basic properties
  - Moisture and temperature requests during vegetation
  - Economic importance of crops (like coefficient of economic rentability)
  - Moisture resistance
- Definition of measured sectors
  - Basic information
  - Position and allocation of seed plan
  - Yield history and irrigation history
- Input application data
  - Measured data form sectors

- Global parameters and conditions
- Time stamps (last irrigation time stamp etc.)

Procedure of data analysis

Each described structure is part of algorithm evaluation. Application data from measured sectors are then are posted to the database with a time link. Information is imported to the system by a TXT type file, which is generated by physical sensors. The procedure of analysis is as follows:

1. Identification of file change LOG – by date and time of last edit
2. Verification of import file – check the correct file structure. If indicated error, file is deleted.
3. Import filter – checks values in range of minimal and maximal values
4. Request generation and values posting to database application logic
5. Run of evaluation algorithm
6. Posting of result value to the „waiting room“ front
7. Export to external format

Algorithm of evaluation

Evaluation of the created request in the system passes several steps. First is defined an instance of request with appropriate properties. Then is request running test procedures, which results are stored in instance of request. Values were determined in an interval from 1 to 100. After finishing all tests is the whole request verified and finally is called the evaluation method, which summarizes all results and returns values of priority. Priority is in interval 1 to 100 too (100 id highest priority). After that, request object is sent do the front enlistment, where on base of priority value is object written to the front and calls method of export file update.

For an example of a test, is the irrigation urgency determination test of dedicated sector. We are testing date and time of request generation against date and time of last executed request in the dedicated sector. The value of result is calculated according to result table.

$$H_{12} = \frac{\Delta T_Q}{T_D} * R \qquad (3)$$

where H_{12} is coefficient of time,

ΔT_Q is DateDiff between current and last irrigation request,

T_D is optimal irrigation interval determined by average of last 24 DateDiff`s.

R is a coefficient of moisture resistance

Export format is a XML file containing actual front of requests in system. XML file is updated immediately after order change (open by XML parser, update, save). This XML type file can be starting point for next analysis, or can be distributed and printed as final result in HTML code web page. That provides needed information about status and priority of irrigation in terrain.

Conclusion

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

***H* value**	**Output Result of Test**
< 0,7	0
0,7 – 0,9	Cumulative 1-20 step by 0,01
0,9 - 1	Cumulative 20-40 step by 0,005
1-1,1	Cumulative 40-60 step by 0,005
1,1 – 1,2	Cumulative 60-70 step by 0,01
1,2 – 1,3	Cumulative 70-80 step by 0,01
1,3 – 1,5	Cumulative 80-99 step by 0,01
> 1,5	100

Table 1 Result table of H12 coefficient.

The wide cause of this state is extreme environment behaviour, which cannot guarantee an adequate supply of moisture during the vegetation period. Finally, it calls for socio-political pressure to support the idea of organic Agriculture, to which irrigation also belongs.

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