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Intelligent Monitoring System To Combat Water Stress In Plant Crops

Laurentiu-Mihai Ionescu, Alin Mazare, Daniel Visan
Computers, Electronics and Electrical Engineering
University of Pitesti,Pitesti, Romania
laurentiu.ionescu@upit.ro

Belu Nadia,
Manufacturing and Industrial Management,
University of Pitesti
Adrian-Ioan Lita
Polytechnic of Bucharest
Bucharest, Romania

Abstract **– The solution proposed by us in this paper is an intelligent system for controlling an irrigation system, which considers the environmental parameters, the soil condition and the amount of electricity consumed by the irrigation system. Based on these data, the system finds the optimal irrigation sequence using a genetic algorithm. Unlike conventional irrigation solutions that involve the planning of irrigation sequences using timers or solutions that are proposed in research projects and work papers that monitor environmental parameters and soil parameters and decide, based on these parameters, the irrigation sequences, our solution brings an innovative element, namely the monitoring of energy consumption of the irrigation equipment .Thus, we obtain feedback not only from the target of the irrigation operation: plant crops but also from the irrigation installation itself. By taking over this additional parameter, an ecologically balanced farming scheme can be created where crop productivity and energy consumption (with environmental impact) are correlated to increase efficiency and protect the environment.**

Keywords: waterr stress, genetic algorithm, environment parameters monitoring, energy consumption monitoring, real time monitoring

I. INTRODUCTION

Our solution uses the latest research results in various fields.

First, our solution uses real-time multi-parameter monitoring of crops: monitoring of environmental parameters and soil parameters. Over time, several solutions have been used to plan plant irrigation as the resource used, water, was sometimes difficult to obtain. We have temporary irrigation systems for grain crops or fruit orchards or pulverized (drop) irrigation systems for legumes.

Recent studies have shown the effectiveness of monitoring environmental conditions or soil condition and introducing data obtained in response to the irrigation system. Thus, commands have been introduced to adjust the flow of water according to these parameters [1]. These control commands have become more and more complex in order to increase efficiency by exploring intelligent control algorithms [2]. By taking the feedback from the plant culture, the irrigation process can be optimized. This is because environmental conditions have changed today because of the global warming process and the nature's response to these conditions is often unexpected. There may be heavy rainfall over a short period of time in seasons where this would not have happened 20-30 years ago, for example. They can alternate with periods of drought in which the crop is subject to high water stress. Under these circumstances, it is difficult to create a fixed irrigation control scheme that only considers the time and season. That is why new schemes are being proposed and used which include culture monitoring.

Secondly, our system uses non-invasive monitoring techniques for power supply installations. Thus, we use solutions to determine the energy consumption by measuring the electric field around the isolated conductor, solutions of the type proposed in the paper, [3]. Instead of intervening on the conductor to place a series ammeter to determine the energy consumption, we will use clamps-type sensors that capture the electric field particles and determine the energy consumption. Such a solution would not be complete if it had no possibility of transmitting such data. In our case, there can only be wireless transmission - the presence of wires in the conditions where electricity can be supplied by a thermal engine generator on a field near an agricultural crop would be extremely difficult to implement. However, the acquisition of the electric field around the conductor and the wireless transmission of the data implies an electricity consumption. That's why we went to a self-harvesting supply solution. It uses the electric field around the cable to supply clamps sensors and local transceiver like the type proposed in the paper [4]. For low power, a low power wireless data transmission scheme (with efficient data packet allocation) of the type proposed in the paper [5] is used.

Thirdly, our system uses power management techniques and its on-demand supply to the customer. These modern techniques implement the flow of demand - producing electricity when the supplier can be configured to respond to customer requests [6]. So, instead of having a permanent production of electricity, with unnecessary fuel consumption, we will have a production according to the customer's needs. These needs can only be taken with a energyt consumption monitoring system of the type mentioned above.

Finally, we have multi-criteria optimization algorithms that work to determine the optimum having several different parameters. Such algorithms act to find solutions to problems where we have different input parameters that cannot be correlated. It's something like solving an equation with several unknowns. This must be solved here: finding the solution of an equation that gives the efficiency of our system in terms of productivity and consumption. Productivity is given by setting parameters such as humidity and soil temperature at the optimal level for plant cultivation. Consumption is given by the energy consumption of the water pumping installation. The optimal, impossible to determine by conventional solutions, is solved using specialized genetic algorithms in search of very large solution spaces [7].

The following section provides a description of our proposed system. An overview of how to install and experiment is presented in the experimental results section. The work ends with conclusions and future trends.

II. System presentation

The block diagram of Figure 1 shows the system proposed by us.

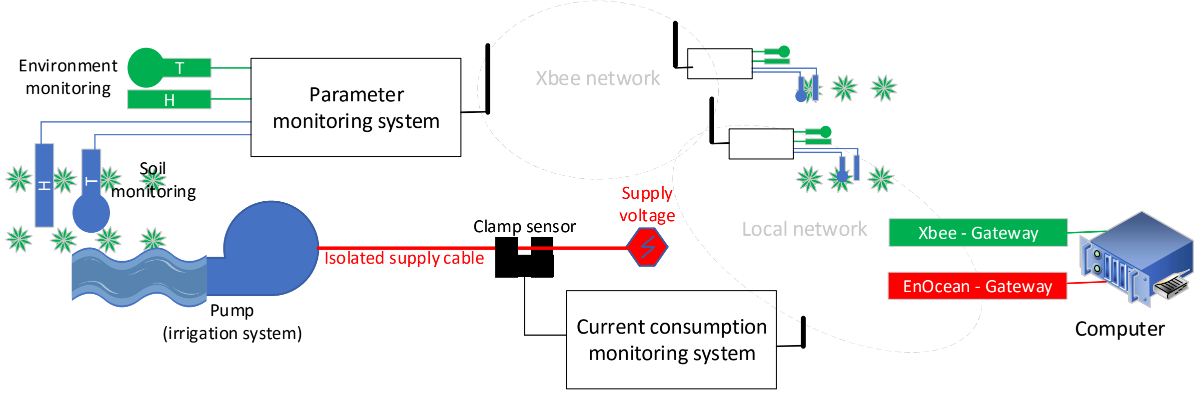

Figure 1. System block diagram

As can be seen, it consists of several components. On the one hand, we have the monitoring part of the environmental parameters: ambient temperature and humidity and the soil parameter monitoring part: soil moisture and temperature.

The parameter monitoring systems use a Waspmote microsystem from Libelium based on the ARM microcontroller ATMEGA369 (quite similar to Arduino) to which we have connected a shield manufactured by those from Libelium. To the shield we connect the four sensors: an air temperature sensor , an air humidity sensor, a probe type sensor that measures soil temperature and a soil humidity sensor. Shield ensures data acquisition from sensors and their conversion in digital format. Further, the micro-system takes digital data and assembles them into packages. Also on the micro-system we have a shield for transmitting wireless data - through the Xbee protocol. It allows wireless data transmission at 2.4GHz free (no cost). With the permitted emission power of maximum 10 dBm, we can cover an area of about 1.5 square kilometers. Emitted data arrives at a central server where they are retrieved through a complex process processing interface and then arrive at the intelligent search algorithm of the optimum. Supplying the monitoring system parameters is done by batteries that are charged to a small photo voltaic panel. It is sized so that it can provide the energy necessary for continuous system operation with a data acquisition rate and their transmission at 3 minutes.

On the other hand, we have the energy consumption monitoring system based on the clamps sensors and the EnOcean chipset. The sensors read energy consumption by simply connecting them to the isolated supply conductor and reading the electric field around the conductor. The monitoring system takes over the current and sends it to the central server via a radio transceiver. Transmission is through a low power protocol at 866 Mhz with a coverage area of about 20 meters. The data arrives at the central server where they are also retrieved and entered the smart optimal search engine. The monitoring system is powered by self-harvesting technology using the same electric field around the isolated conductor. This ensures continuous real-time monitoring, with the acquisition and transmission of energy consumption at 30 second.

The central system that takes the data from the monitoring and consumption monitoring system is a server that relies on a complex event processing engine and an optimal solution search engine using genetic algorithms.

A schema of the server is shown in Figure 2:

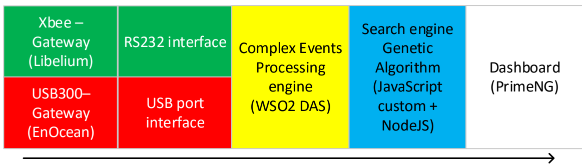

Figure 2. Server block diagram (layers)

A first problem is related to the reception of data through low power wireless protocols from the two monitoring systems. In this respect, a Xbee-USB Gateway from Libelium for data from the Xbee network and an EnOcean USB 300 gateway for data from the current monitoring system was used.

The data reaches the server level and is retrieved by a complex event processing engine specializing in retrieving multi-source and real-time data packets and batch analysis.

From the complex processing engine, the data reaches the search engine for the optimal solution based on genetic algorithm.

The coding scheme is shown in Figure 3. Basically, the chromosome (potential solution) is given by the association of environmental parameters, soil parameters and the power consumption profile.

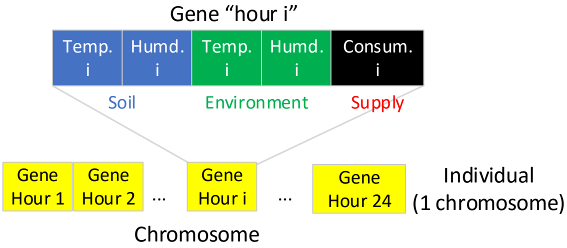

Figure 3. Coding schema (chromozome structure)

The objective function is given by the relationship below which introduced a relation between the water stress due to the evolution of the environmental parameters and the soil condition with impact on the productivity and evolution of the energy consumption.

$$Objective = \frac{1}{N} \times \sum_{i=1}^{N} P[\Delta_i] - C_i \qquad (1)$$

Where:

$\Delta_i = (0.7 \times H_i^s + 0.3 \times H_i^e) - (0.6 \times T_i^s + 0.4 \times T_i^e)$

H_i^s: *soil humidity*

H_i^e: *environment (air) humidity*

T_i^s: *soil temperature*

T_i^e: *environment (air) temperature*

P: *productivity − empirical relation of delta*

C_i: *current consumption depends of* H_i^s

A presentation of the genetic algorithm is in the figure below. You can see the steps in the algorithm. First, we have the generation 0 where a population (a set of potential solutions) is generated randomly. Then there is the evaluation (assessment) where each individual (chromosome) is taken from the population and tested. The lower the objective function in the mode, the better the result provided by the solution. Following the assessment for each individual, a score (fitness) is given that shows how efficient is the system with the proposed irrigation control scheme.

Next, individuals are selected to be modified by a pseudo-heuristic selection method called roulette rule. It uses a random selection but favors the best individuals. Further, the new individuals (offspring) are generated by crossing and mutation. The loop is repeated until the solution has been found with a degree of accomplishment of the objective function (in us it means a absolute value less than 1) or when the number of generations has been reached.

III. Experimental Results

Using the components described in the previous section, we did the following.

A. *Simulation of the system*

We have developed a simulator in which we modeled the behavior of a culture that, depending on the evolution of the environmental parameters combined with the soil, shows the occurrence of water stress or not at the level of culture.

Also, with activation commands to the irrigation system (identified by energy consumption) there is a change in soil parameters - to reduce the water stress (so simulate the impact of the irrigation process on the crop).

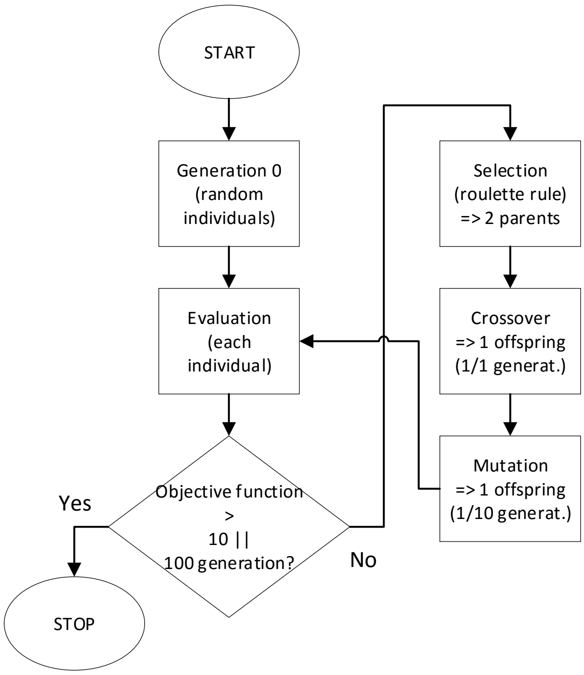

Figure 4. Genetic algorithm used in our solution

Under these circumstances, we run a genetic algorithm composed of 10 individuals / generation (the coding scheme presented in the previous section), having the objective function that we also presented in the previous section, to find an optimal solution where the objective function has a maximum value.

The evolution of the algorithm over time (fitness on the best individual) can be seen in the figure below.

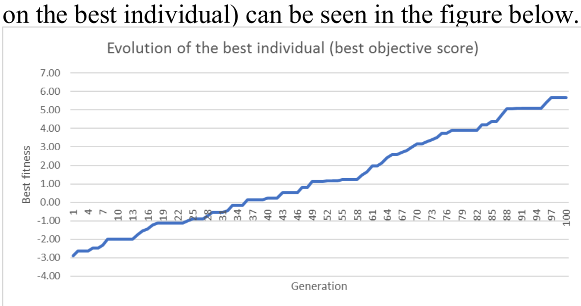

Figure 5. Evolution of the objective function (fitness) for the best individuals / generation

In a small number of generations, the algorithm has found the optimal solution. The optimal solution is presented in the table below.

The parameters of the genetic algorithm deduced in the simulation phase (which found the optimum most quickly) are the following:

TABLE I. Genetic Algorithm Parameters

Population size (individuals / generation)	Constant, 20 individuals
Maximum number of generations	1000
Objective value when the solution is found	< 0.1
Selection	Roulette rule: 2 parents selected
Crossover rate	1 / generation : 1 offspring resulting
Crossover points	1 point

Mutation rate	0.1 / generation
Mutation selection	1 individual : 1 offspring resulting
Mutation points	1 point
Elimination rule	Offspring from crossover replace worst individual

B. Deployment and setup for an experimental model

The installation of an experimental model was carried out: a field monitoring system for strawberry crops, a energy consumption monitoring system from a hydro-phore pump and a computer with the two gateways that acquire the data from the two systems monitoring as shown in Figure 1.

The system is in data acquisition mode - data on how the pump commands interact on soil parameters for one day for different pump operating times (the amount of water adjustable) is collected in the server.

With these data (ground and air parameters, energy consumption) we run a genetic algorithm with the parameters mentioned above (in the simulation phase).

TABLE II. RESULTS AFTER MORE EXPERIMENTAL TESTS

Environment conditions:	**Results without any feedback (constant irrigation schema)**	**Results with feedback & intelligent irrigation schema**
Environment temperature=35 C Environment humidity = 45% Soil temperature=45 C	Economical irrigation schema: Soil humidity=20% Productivity= 1 Objective = -1.6	Solution: Soil humidity=68% => Productivity = 15 Objective = 8.84
	Rich irrigation schema: Soil humidity=70% Productivity= 15 Objective = 5.9	
Environment temperature=35 C Environment humidity = 55% Soil temperature=55 C	Economical irrigation schema: Soil humidity=50% Productivity= 2 Objective = -4.5	Solution: Soil humidity=73% => Productivity = 15 Objective = 5.51
	Rich irrigation schema: Soil humidity=80% Productivity= 15 Objective = 4.6	
Environment temperature=30 C Environment humidity = 20% Soil temperature=45 C	Economical irrigation schema: Soil humidity=60% Productivity= 2 Objective = -5.8	Solution: Soil humidity=73% => Productivity = 15 Objective = 5.12
	Rich irrigation schema: Soil humidity=80% Productivity= 15 Objective = 4.6	

C. Testing the experimental model

After the setup phase, the system was tested using the data acquired during the setup phase. The system was tested considering the soil parameter evolution for one day, over a weekly interval (to be able to test more "sets of environmental parameters"). The system was able to find the optimal configuration following a development of the genetic algorithm on several generations ranging from 10 to approx. 50.

IV. CONCLUSIONS

The paper presents a complete monitoring solution for an irrigation system, which considers both the environmental parameters, the soil parameters and the consumption that the irrigation system does. Using an intelligent algorithm (genetic algorithm), an optimal production / consumption ratio is determined. Thus, on the one hand, productivity increases by crop irrigation on time, on the other hand consumption is reduced by monitoring and implementing a consumption scheme on demand. As we have said, we have developed a complete solution: it consists of monitoring platforms with sensors for environmental parameters, soil parameters and energy consumption, data communication solution and centralized data acquisition and intelligent analysis solution.

The solution proposed and experienced by us follows only the irrigation process for crops. Future research will continue with monitoring and other parameters along with crop irrigation (e.g. monitoring the occurrence and evolution of pests).

ACKNOWLEDGMENT (HEADING 5)

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