Autonomic Model for Irrigation Control

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Summary
With the need of preserving water resources and the growing demand for food, new technologies and methods arise in trying to deal with these problems, and sustainable irrigation is one of these possibilities. Thus the Autonomic Computing can be used for automating irrigation processes, enabling the use of self-manageable systems where the behavior occurs in parallel with the environment, that is, their analysis and actions are adaptable and flexible according to the needs and characteristics of the environment. In this paper we propose a model for autonomic irrigation control that aims to provide a service to producers, seeking for a better performance in the food irrigation process. The proposed model uses the characteristics of autonomic computing, being able to identify and analyze the environmental parameters such as ambient temperature, humidity and soil moisture, determining the right time to irrigation and the volume of water that the plant and soil will need. This can allow a reduction in water consumption and a better utilization of the plant. A new parameter is expected to be reached through the water use system in agricultural production, minimizing any waste of water resources such as springs, rivers, lakes, reservoirs and dams; besides, providing the optimization for plant development and the maintenance of soil. The aim of the prototype is to provide a resource to the small, medium and large producers, given the specificities of each. It can be accessible and of easy installation field, as well as being autonomous, controlling all the steps necessary to irrigate the crop.
Key words:
Autonomic Computing, Irrigation, Sustainability.

1. Introduction

The irrigation process is used for thousands of years and it is improving over time. In its beginnings, the technique was only to use the available water in rivers to irrigate the plants [14]. Already today, we have many methods to do this work with such surface irrigation, sprinkler and sub irrigation, however many of them do not make sustainable use of water resources [13]. Cultivars require a specific amount of water to not produce a phenomenon called water stress, which is characterized by excess or shortage of water [11]. Furthermore, the soil requires a weighted amount of water to make its physical and chemical processes, independently of the use by the plant [12]. Thus, in this process of the Autonomic computing, the amount estimated to be provided according to demand of the soil and plant in this process the Autonomic computing is essential for being a technology based on the human body behavior, specifically the autonomic nervous system that is responsible for the control of vital functions such as breathing, adapting unconsciously the body to their needs and the needs generated by the environment without human intervention. In this process, the Autonomic computing [2] is essential for being a technology based on the human body behavior, specifically the autonomic nervous system that is responsible for the control of vital functions such as breathing, adapting unconsciously the body to their needs and the needs generated by the environment without human intervention.

Thus, the use of using the characteristics of Autonomic Computing system would enable a have the capability of self-management action, controlling all the processes in a flexible way according to the parameters issued by the environment without the need for end-user intervention in the execution of processes.

The Autonomic Computing provides the ability to create self-managed systems, where their analysis analyzes and actions are adaptable and flexible as environmental needs and characteristics, shown the viability of sustainable irrigation, because it will adapt the water supply plant and soil as the particularities of the same and environmental situations and may thereby have significant and exact parameters for the supply of water.

Therefore this work seeks to strengthen the development of sustainable agriculture, contributing to the reduction of water waste, where it represents seventy percent of the waste of water in the world [1].

2. Autonomic Computing

The autonomic computing (AC) is one of the newest novel concepts used in software development and management. Its appearance occurred during the manifesto on the main obstacles in the progress in the Information Technology (IT) industry, which was published by International Business Machines (IBM), which at the time, proposed a new challenge: to develop a new concept to solve the problem growing in software management complexity. Thus, we sought to study new possibilities for the industry. Autonomic computing is based on human behavior through the autonomic nervous system, responsible for the

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control of vital functions that adapt unconsciously the body to their needs and the needs generated by the environment in which takes care of bodily functions without the need for human attention and also i.e. takes care of actions without being noticed us noticing, as an example: cardiac control, temperature, digestive system, to the contraction or expansion of the pupil [2].

By linking human behavior with computational systems, notes a possible integration parameters is noticed, which is also noticeable the external and internal factor in human behavior the external and internal factor, and must be aligned to keep operating in the event of this imbalance is remarkable reactions and impulses to demonstrate such nuisance, and in this sense that the computer systems through autonomic computing can be agile, providing the necessary balance needed for the functioning of the implementation of goals. In this way it was tried to study this behavior and create mechanism to provide balance to the actions and goals of the business, being able to interfere in the functioning of essential factors for balance, determining the self-management capacity.

2.1 Autonomic Systems Features

In the development of autonomic systems various requirements that make their use must be met, understanding the autonomic operating parameters and essential properties in the development of autonomic processes. According to [2], [3], [4], as essential characteristics of autonomic computing we can cite:

- Self-awareness: The system knows himself: its components and interrelationships, their status and behavior;
- Context-aware: The system must be aware of the context of their execution environment and be able to react to changes in their environment;
- Self-configuring: The system should dynamically adjust its resources based on their status and implementation of environmental conditions;
- Self-optimizing: The system is able to detect performance degradations and perform functions for self-optimizing;
- Self-protecting: The system is able to detect and protect your assets from internal and external attackers, keeping their safety and overall health;
- Self-healing: The system must have the ability to identify potential problems and to reconfigure in order to continue operating normally;
- Open: The system must be portable to different hardware architectures and software and therefore must be built on open protocols and interfaces and standardized;
- Anticipatory: The system must be able to anticipate, to the extent possible, their needs and behaviors considering its context and to self-manage proactively;
- Reflexivity: An autonomous system must have detailed knowledge of its components, current status, capabilities, limitations, interdependencies with other systems, and available resources;
- Adaptation: It is the system's ability in decision making during the analysis of the parameters of autonomic elements to develop a mechanism to adapt to certain external and internal situations.

3. Related Work

3.1 Wireless Sensor Network for Collecting Data on Crops AgroMobile Architecture

In [5] is proposed the development of a wireless sensor network to collect crop data. The prototype was developed using the Arduino platform with integrated temperature sensor: Used to perform the moisture monitoring and soil temperature; GPS module: Used to transmit the geographical position of the sensor; Solar Power Card: Used to electrically supply autonomously (solar) sensor; Humidity Sensor OBSoil-01: Sensor used in reading the amount of moisture in the soil and around.

3.2 Sensor Network Application Wireless (WSN) in Agriculture

The work presented in [6] aims to compare through computer simulations the hierarchical protocols Leach and Leach-c, in order to prove its effectiveness in the management of a WSN in the case study proposing, i.e. applicability in agriculture, trying to verify the influence of configuration parameters, in order to obtain an increased life time of the network and optimize the amount of transmission carried out in an environment for the Precision Agriculture.

A total area was simulated 90 thousand square meters (300m x 300m), where the nodes were distributed evenly around the perimeter, with a total of 100 nodes, and one of these is the base station, changing the amount of clusters, comparing algorithms Leach and Leach-c, in order to analyze the situation in which the network would become more efficient. Other initial parameters were: (1) Transmission rate: 1 Mbps; (2) data block rate: 500 bytes; (3) simulation time: 3600 seconds; (4) Cluster change interval: 20 seconds; (5) Home Energy node: 15 Joules.

3.3 Micro controlled system for Soil Irrigation Automation

In [7] is shown an implementation of low cost automation for agricultural irrigation, seeking to reduce the waste of water and electricity, and maximize crop production. By seeking to establish puncture tensiometer piezo resistive pressure transducer and the need for irrigation, which provides tension and relates to the voltage threshold for plant cultivation.

3.4 Automatic Weather Station Network to Provide the Need for Irrigation of Crops

The work presented in [8] shows an innovative project in the field of automation in irrigation, which now has patent and provides services to many countries like Brazil, USA, Mexico and etc. Irriga® System has its own network of automatic weather stations, called Data Collection Platforms (PCDs), for the provision of meteorological data for each location monitoring. The system has more than 200 DCPs installed in the field with real-time data transmission to the central System.

4. Proposed Model

In this paper we propose a model for autonomic control of irrigation. This research is experimental and technological nature, proposes the development of a prototype based on the concepts of autonomic computing to the procedures of agricultural irrigation This model can be seen below in figure 1, aiming to display a physical infrastructure (network, irrigation), acquiring the environment specific parameters in the interpretation of the amount of water necessary for plant and soil, providing a model of rules to be interpreted by the system.

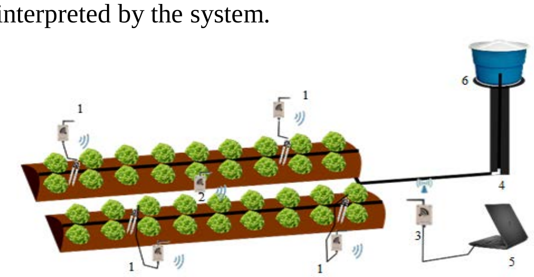

Fig. 1. Proposed Model

A. LEGEND	
1	Soil moisture sensor wireless 2.4GHz, Hermetic box with battery, sending every 30 minutes soil moisture;
2	Temperature / humidity sensor wireless 2.4GHz, Hermetic box, with battery;
3	Wireless Central 2.4GHz, Hermetic Box with USB connection and USB power;
4	Solenoid Valve;
5	Notebook;
6	Water Reservoir;

The network topology used in the application is star where all nodes must send data to the central processing unit, without communication between other nodes. The ZigBee [9] technology used is composed of three types of devices, known as coordinators, routers and sensor nodes. Coordinators are classified as FFD (Full Function Device), i.e., full function devices that can communicate with any device on the network and can act as coordinator, router or even sensor nodes. The RFD (Reduced Function Device) are reduced function devices, simpler, which act as end devices or sensor nodes. Routers are devices with RFD features, but provide information to other network devices, making the routing information.

Soil moisture sensor 2.4GHz wireless: has the function of sending voltage level parameter read by the analog and digital A/D converter from 0 to 1023, where 0 is dry soil parameter and 1023 extremely wet soil. In addition to sending battery level, signal quality and sensor address.

Example: ?04150000003,580410000001AM	
0415	value read from the analog digital converter 0 to 1023
000000	disregard, will always be sent 000000
3,58	Battery
041	quality of the signal 000 to 100%
0000001AM	sensor address

Temperature/humidity sensor wireless 2.4GHz: sending sensory data has temperature and humidity, battery level, signal quality and sensor address.

Example: +27,8161,603,6009100000018S	
+27,81	temperature
61,60	humidity
3,60	Battery
091	quality of the signal 000 to 100%
00000018S	sensor adress

Wireless Central 2.4GHz with USB and power via USB connection: is the access point to sensor network, send function and receive data over the network and make available the contents of the sensors in USB port. Solenoid valve input unit and output flux water, MAPE-K [10] proposed model becomes the executor of the shares determined by the system. Notebook equipment where the system is installed, you receive the central data communication by computer USB drive and send the system actions for the solenoid valve.

Water reservoir is the water source for system testing by providing the blade of water for irrigation of lettuce planting beds.

The model is aimed at proving the autonomic concept to drip irrigation process on lettuce, establishing climate indices and soil stress levels, generating rules for the proposed MAPE-K model, where sensors send to the central communication data collected in field, information analysis will be done by generating the base application of knowledge, planning of actions to be performed.
The element in question will be managed lettuce, which determines the maximum and minimum acceptable water tension in the soil to the plant, the system detects through rules if the measured level is within optimal parameters, establishing the following states: ideal, stable and critical.

5 . Implementation

The implementation phase and application development began with UML modeling of the proposed case study and MAPE-K model of autonomic rules.

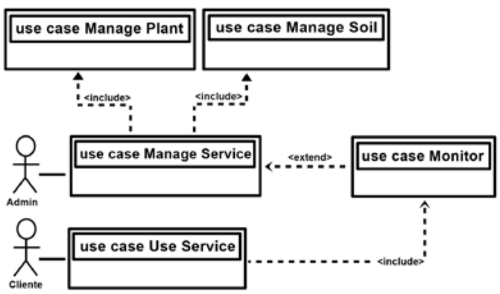

Fig. 2. Use Case Diagram.

In this use case we list the main steps that the user and the administrator should develop during the execution of the prototype. At first it is necessary for the administrator to manage the data of plant and soil in the database, thus providing parameters for application. So that the user can use the system must first set the service then monitor system steps, receiving notifications via text messages and audible alerts, and generate performance reports.
We can see with the application use case diagram the operation and the order of processes to be executed by the system.

Fig. 3. Working Process

This model sets out the steps and actions to be taken by the user during use, where the user makes its authentication in the system registers the ground where you will use the irrigation control system, choose the plant to be produced, defines the production cycle of plant and activates the service. After these procedures the humidity and temperature sensors are activated and begin to send information to the system that identifies addresses and use them as parameters for its operation, as the functions the system emits audible alert and text message warning the time of irrigation.

Fig. 4. Prototype Structure

To the prototype functioning the integration of three segments is necessary:

- The Sensor Wireless Network, responsible for providing parameters and act as actuator in the execution module.
- The irrigation module, procedure adopted to drive the water environment for lettuce crop.
- Model MAPE-K rules, the main function of the system, accounting for monitor, analyze, plan, implement and learn. It determines the action during program is running.

5.1 Network Structure

The network topology used for the application is the star, with central module information and three water tension level sensors on the ground and a temperature sensor and humidity.

Fig. 5. Wireless Network Sensor - WSN

1. The sensors send the information to the monitoring station that has USB port, which allows interaction with computer, putty application for capturing frames is used, and generate a .txt file so that the user can see the information as needed.

5.2 MAPE-K Module Developed

MAPE-K model proposed for the present work aims to use parameters acquired by sensors in the field, which is determined as part managed the land site with lettuce planting. After this information capture data is directed to a new cycle, where information is monitored, setting the signal level and message quality, then are analyzed parameters, time where the system interprets the information and decides whether the information is useful or not for the application.
In the planning phase, is determined the moment of decision-making, being sent to the executing module the system actions, in the case: ideal level of irrigation, stable and critical level. The executing module activates actuators which has the function of acting in the irrigation process in this case could be a solenoid valve coupled to the relay to open the arterial runoff water required to irrigate the crop until the level stabilizes.

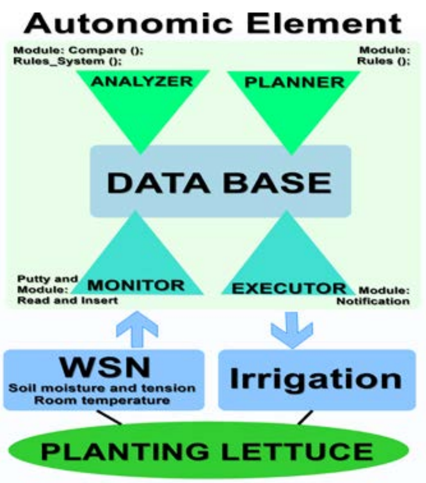

Fig. 6. Autonomic Model

The figure above shows the MAPE-K model and exemplifies the procedures used in the application. When starting the application the system trigger the wireless sensor network via the USB port, start putty program, which captures network information packages and saved in .txt file. The duration of the delivery cycle is about three minutes.
This initial procedure is the sensing phase of mape-k element proposed, in order to provide the system with the information acquired on the managed element, in this case the lettuce planting.

Fig. 7. Index and Selection Plant

5.3 Notification Module

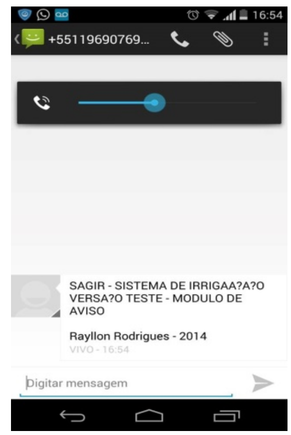

Fig. 8. Notification via SMS

A This step aimed to meet the need to inform the User about the procedures that occurs when the system is running, without human interference appeared. Thus the system notifies users via the communication module, which performs the actions of audio and instant messaging by cell phone, using a package of messages and internet, this occurs when the system developed a need to irrigate according to the parameters defined in sets rules and if it determines that it is necessary to irrigate fires an audio to warn people near the study site and sending messages to project members, so that they can perform manually irrigation.

6 Results And Discussions

During system implementation phase it was noticeable that it responds as Mape-k model developed, which captures the information from the sensors via WSN using the putty application to capture data, this information feeds a .txt file where in a period about three minutes is consulted and the information stored in the application database, and is reset after consultation, getting ready to receive new data.

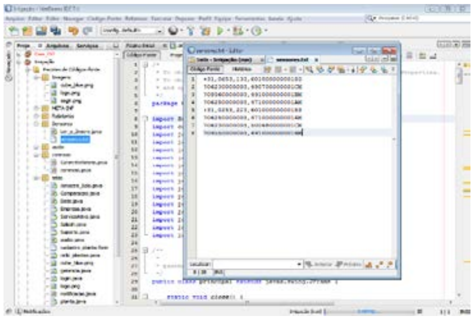

Fig. 9. Txt File – Information Storage of Sensor Network

The first tests were made in the use of sensors in vessels of glasses with different soils: wet, dry and extremely wet. The objective was to identify whether the sensors under conditions similar measure equally, thus applying quality of context (QoC) principle [15], where information must be trusted for a good application performance. After the tests were performed with sensors in the greenhouse with lettuce, which was up about two days measuring the information and the system notifies the time to irrigation via text message and audible alert, so he could irrigate the site at the time suitable and ideal water level.

Fig. 10. Application of WSN in Greenhouse.

After the prototype implementation phase it was possible to generate information about the period of time that the plant suffers more water stress, verify the system efficiency in processing information and certifies the communication module, which informs the user the ideal time to irrigate the crop.

The production cycle takes into consideration the time required to pass through the plant growth stages from germination until the harvest time. The following figure shows through the application putty receiving data packets, which are used as parameters for the application.

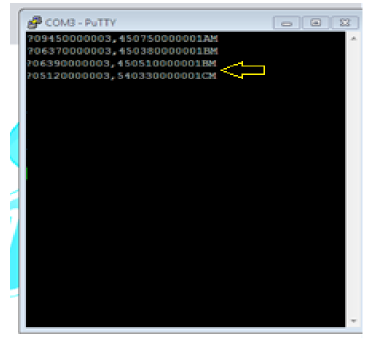

Fig.11. Sensor Information.

The system displays data from sensors AM, BM and CM where it is clear a change between the sensors, showing the importance of identifying where you need to irrigate, however as the goal of this study is to show that it is possible to create a prototype able to manage the procedures irrigation as a result of the principles of autonomic computing has established a set of rules in which receive data, break down and store information in the database through some SQL statements, then consult the latest data from the database, calculates the average of the information and compared with the standard data to the production cycle in which the plant is located.

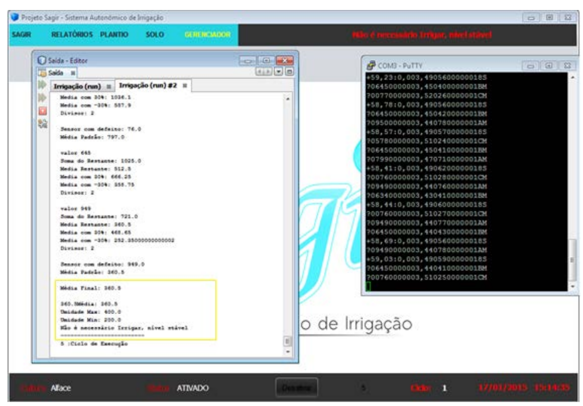

Fig. 12. Running Application.

The figure above depicts the execution of the application, which is highlighted the final average of the information and the ideal humidity levels, and notifies whether to irrigate or not planting.

Thus is portrayed the possibility of using autonomic concepts in irrigation procedures, but it is clear to demonstrate that application to become efficient and autonomic it is necessary to reach all levels of maturity, and is application focuses on the presentation autonomic computing and its application in irrigation reaching two maturity levels: Basic Skills and Managed Level.

Tests were conducted aimed at the simulation of the operation of the prototype into a complete production cycle of the lettuce crop, passing through all the steps and parameters required for plant development. Approximately, 400 read cycles with three minutes each, through various production cycles of the plant, aiming at studying the application response to the change in behavior of the information. Data for this execution information is available in the appendices of this work.

Through these readings were evident some critical points, where need better adaptations as the ultimate goal of application, such as critical point can cite the lack of precision in the time that the WSN delay to provide the information to the monitoring station in precision tests before and mentioned above in this work, a time to the cycles of consultations with the information in the database three minutes was set, but when we observe the data collected noticed that at times the sensor network not can make available all information and this can result in failures in the application.

```
Var
        data_teste,max_umidity, min_umidity : double;//variable declaration type double
        cycle, N, v[n]: int;//integer variable declaration
        Result: char;variable declaration of type text
Begin
        Write( " Enter the amount of productive cycles")//inform the amounts of production cycle is required
        Read (temp, soil_umidity, air_umidity,cycle)
        T<-temp
        Su<-soil_umidity
        Au<-air_umidity
Set (TypePlan)
        cycle<-true
        While (cycle) {
        Write ( " Enter the specific values for the cycle of Plant")
        //User must choose the plant be managed
      While (time_cycle>0){
        Write ("Starting Cycle 1")//Starting the first agricultural year
        If ((average(soil_umidity) > min_umidity) and (average(air_umidity)> min_umidity) and (average(temp)< max_temp) {
// Compares the mean of current soil moisture with the need for plant
        Result "Stable Level"//user warning
Do not irrigating the crop
                }
        If ((average(soil_umidity) > min_umidity) or (average(air_umidity)> min_umidity) or (average(temp)< max_temp) {
        //Compares the average of current soil moisture with the need for plant
        Result "Ideal Level"//user warning
Do not irrigating the crop                }
        If ((average(soil_umidity) < min_umidity) or (average(air_umidity)< min_umidity) or (average(temp)> max_temp) {
        //Compares the average of current soil moisture with the need for plant
        Result "Alert Level"//user warning
irrigating the crop                }
        If ((average(soil_umidity) < min_umidity) and (average(air_umidity)< min_umidity) and (average(temp)> max_temp)
{//Compares the average of current soil moisture with the need for plant
        Result "Critical Level"//user warning
irrigating the crop                }
Decrement (time_cycle)
    }
Set(TypePlant2)
        If TypePlant2<>TypePlant{
Cycle false  }
end algorithm // ending the algorithm
```

This algorithm has the functionality of the autonomic system proposed for the management of Agricultural irrigation. It is possible to view the structural process of organizing variables, definition of culture, in the case of this study, lettuce crop, the activation of the production cycle, analysis of water content and finally, the required notifications.

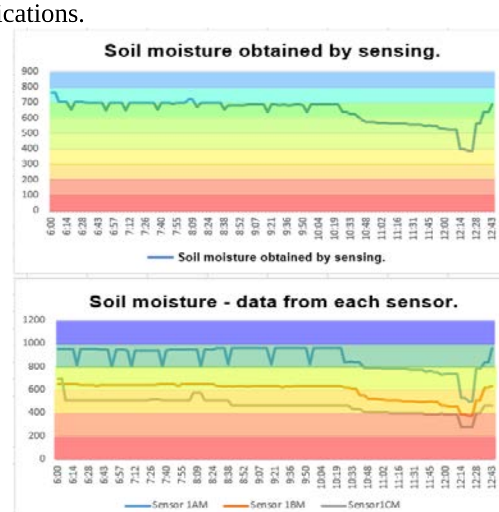

Fig. 11. Sensing Function Test.

The graphs shown in figure 11 expose a sensing report conducted for a period of about 6 hours, which obtained the amount of 113 readings related to soil moisture, three sensors arranged in the test greenhouse.

The sensing was held in lettuce cultivation, and along one morning, where you can see that even the sensors presenting individual divergences as reading, the pattern of soil moisture oscillation accompanied the real hydro situation in the analyzed soil.

As time went on, approaching noon, soil moisture obtained a gradual decrease in the long period, and sharp at any given moment. Thus, proved efficient, determining the exact time of irrigation to autonomic system, with the parameters levels 0-200 to dry, 201- 400 for ideal level, 401-800 for damp level and 801-1023 for extremely wet.

7 CONCLUSION

This article, the result of encouraging on the development of scientific research that provides in some way, the improvement of life quality, especially in the sectors of production, proposed the implementation of a prototype with autonomic concepts to the agricultural irrigation control.

The developed MAPE-K model provided the ability to modify the data as the production cycle of the plant and the power of response in identifying defective sensors.

The first two levels comprises an autonomic system, i.e. Basic and managed, have been achieved because the presented application is capable of capturing the environment information and managing them, identifying when the plant and soil need irrigation. However it is still necessary to achieve the following maturity levels: prediction, adaptation and automation.

For all observed aspects and the development of the prototype, we can say that the autonomic computing is applicable as a means of managing the irrigation processes for efficiency and optimization of resources through more sustainable production technique.

FUTURE WORK

As future work we propose:

- Achieve levels of Autonomic Computing Forecast, Adaptation and Self-Government in relation to the maturity levels;
- Implement automatic drive module wireless irrigation;
- Collect and use more parameters of the plant, soil and the environment;
- Estimate water depth in the exact amount;
- Provide an affordable product financially to producers;
- Develop a MAPE-K model for diverse cultures and soils;
- Analyze the operation in full production cycles, cultures watermelon and lettuce.

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