Computer Science and Information Systems 20(1):405–421 https://doi.org/10.2298/CSIS220227062I

Internet of Things and Agent-based System to Improve Water Use Efficiency in Collective Irrigation*

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Abstract. The efficient management of water resources is a major issue in the field of sustainable development. Several models of solving this problem can be found in the literature, especially in the agricultural sector which represents the main consumer through irrigation. Therefore, Irrigation management is an important and innovative field that has been the subject of several types of research and studies to deal with the different activities, behaviors, and conflicts between the different users. This article introduces an intelligent irrigation system based on smart sensors that can be used moderately and economically to monitor farms by integrating some connected electronic devices and other advantageous instruments widely used in the field of IoT, it determines the water requirement of each farm according to the water loss due to the process of evapotranspiration. The water requirement is calculated from data collected from a series of sensors installed in the plantation farm. This project focuses on smart irrigation based on IoT and agent technology, it can be used by farmer associations whose endowments and irrigation planning are defined according to the need and quantity of water available in the rural municipality. The system includes a microcontroller with the integration of sensors, actuators, and valve modules where each node serves as an IoT device. Environmental parameters are monitored directly through a multi-agent system that facilitates the control of each node and the configuration of irrigation parameters. The amount of water calculated for irrigation is based on the Penman model for calculating the daily evapotranspiration baseline. Compared to the conventional irrigation method, it is expected that the proposed irrigation model would contribute to saving water use and distributing it impartially without compromising its production.

Keywords: Agent technology, smart irrigation, sensors, internet of things, Evapotranspiration.

1. Introduction

In Morocco, irrigation systems are very diverse. The State is in the process of setting up a new strategy for water resources management. Also, different projects are being conducted to improve the collective management of irrigation. They are intended to be

* Extended version of a conference paper, MEDES '21, November 1–3, 2021, Tunisia.

participatory and aim to take charge of the management of irrigation networks according to the same model of association of agricultural water users.

Currently, we note that gravity-fed irrigation systems based on motorized wells have several limitations and cause a great loss of water. Good management of these irrigation systems is mainly characterized by better management and planning of water between the different actors and is therefore necessary. However, this management is subject to several constraints: the water allocation granted, the type of crop for each plot, the sowing date of each crop, climatic data, optimal irrigation planning, etc.

The most common irrigation technique used in Morocco is gravity-fed irrigation, which has several limitations since it does not take into account the type of crop and soil, the climatic conditions, and the actual water needs. Thus, for a better allocation of water resources in this type of irrigation system, it is necessary to involve all the actors concerned to establish negotiations between them on the planning of sowing, crop rotation, the water needs of the crop, and the water allocation.

The IoT (Internet of things) offers the possibility to optimize the irrigation of farms, the maintenance of agricultural machinery, the analysis and the remote control, and so on. The connected sensors placed in the field allow the optimization of irrigation by performing a complete analysis of the plant's elements.

To address this issue of water resource allocation in rural communities, we propose to model irrigation network management systems in an intelligent context based on a multi-agent approach coupled with IoT, which will form the basis for the development of a tool to assist in the negotiation of allocations and the planning of intelligent irrigation, which aims to improve profitability and better manage the distribution of water resources before the start of each agricultural season.

The system constructs a real-time irrigation decision based on the predicted soil moisture estimated at the moment of precipitation. The soil moisture prediction is performed depending on the analysis of the data sensed by the soil moisture sensor and the evaporation prediction. The evaporation is predicted using five factors (air temperature, wind speed and direction, and humidity). Furthermore, according to [1] an IoT-based Smart Greenhouse system is designed with a novel monitoring combination including warning, automation, disease forecast, and cloud repository; by employing a readily deployable complete package. It continually maintains dynamic conditions such as temperature, humidity, and soil moisture state to improve the crop yield and to guarantee an instantaneous reaction in the event of abnormal conditions.

The main reason why we opted for a smart solution is the complexity of managing in real time the water distribution operations that arrive asynchronously and dynamically and to be reactive and adaptive to the dynamic and unpredictable events that characterize the domain. In this work, we propose the design of a functional prototype based on the calculation of the water needs of different crops of farmers, a NodeMCU, a soil moisture sensor, a temperature sensor and humidity, a relay module, and a motor. The whole system is integrated into a multi-agent system in such a way that it monitors all the components of the system, allocates the endowments through negotiation with the farmers, monitors the irrigation plans and periods, and supports the endowments.

The rest of the paper is organized as follows: The second section analyzes and discusses the related works about intelligent irrigation systems. The third section gives a global overview of the irrigation problem and the multi-agent system model. The fourth section details the proposed approach. The fifth provides the detailed results of the simulation and tests. Finally, we conclude in the Sixth section.

2. Related Works

Smart farming improves yields by using minimal resources such as water, fertilizers, and seeds. Farmers can easily deploy sensors to remotely monitor their crops, conserve resources, and reduce the impact of climate changes on crops [2]. Several values parameter detection technologies are used in this agriculture for providing data and helping farmers to monitor and optimize their crops [3], as well as to adapt to environmental change factors, including location, electrochemical, mechanical, airflow sensors, agricultural weather stations, humidity, and PH.

One of the main sensors in smart farming is that of soil moisture. It's used for measuring the present volumetric water content (humidity) in the soil. The threshold value is fixed, and the level of soil moisture value is measured and verified with the upper and lower thresholds at the necessary levels. Irrigation is the vital need of agricultural activities, there are three classic irrigation methods of which we can cite canal irrigation, sprinkler irrigation, and drip irrigation responding to the needs of plants, these three methods are used. Regarding the intelligent irrigation system, the researchers in [4] have shown that water consumption is minimized when an automated irrigation system relies on soil moisture as an implementation parameter. Among these irrigations, that of drip is the one where farmers can save the most water because it will provide water in the form of droplets directly on the plant root and the soil surface.

Intelligence farming had been implemented and many of them were incorporated with Artificial Intelligence and Internet of Things technologies to enhance agricultural production and optimize resource use. Some research reports using smartphones and sensors to remotely monitor the soil condition and enable smart irrigation [5]. A more complex system combines IoT and artificial intelligence techniques such as machine learning [6], Fuzzy logic [7], deep Q-learning [8], artificial neural network [9] and Multi-Agent systems [10] [11] , and to handle diverse aspects, e.g., irrigation, fertilization, or pesticide treatment and so on. In what follows we analyze and discuss succinctly several studies that use a multi-agent system and IoT to perform intelligent farming systems.

Since IoT deals with a large data set received from heterogeneous sensors and modeled in various formats, the necessity of a homogeneous data interpretation claims new and challenging methods for data treatment. To address such challenges, it is necessary to integer AI technologies (such as agent systems, MAS), allowing us to automate the uptake and analysis of the various sets of data that come from different sensors [12]. Many authors [13] use AI to develop data processing in agriculture by obtaining knowledge from the data collected through heterogeneous data sensors and acting continually and automatically and accordingly based on the collected data. In [14] propose an agent-based system is proposed to automate the data management process and provide an optimized irrigation system, the data collected from various sensors is through MAS to make a knowledge base used in the decision-process to develop an irrigation strategy that meets the environment needs and save the resource improving the agriculture production.

T. Wanyama and B. Far [15] combine Multi-Agent and Fuzzy Logic techniques to introduce a smart irrigation system, this study uses Fuzzy logic to deal with the uncertainty that characterizes the information that affects the irrigation schedule. Other research uses the MAS negotiation mechanism to improve the water allocation [16], agents represent different frames to calculate how much water is needed in the farm. The frame with excess water shares their water with those with other farmers needing water to ensure efficient water distribution.

The evapotranspiration (ET) estimation is at the queen's interest in the hydrologic cycle studies but still lay on the line to uncertainties. Hence, Estimates and predictions of the ET constitute an essential step of irrigation management over the world. In this context, a multitude of studies is made to improve ET Estimation. Especially, in [17] the study used Bowen ratio and eddy covariance methods for calibrating, extracting, and calculating relevant parameters necessary for guessing ET of tea canopy for the whole growing season, to provide further predictions about the adoption of this method for scheduling other crops irrigation as well. Also, another comparative study performed a comparison between three ET estimating methods, in particular the eddy covariance (EC) and Bowen ratio-energy balance (BREB), and the soil water balance (SWB) to measure their efficiency during the cropping season of corn in [18]. Moreover, the FAO Penman-Monteith (FAO PM) has been declared as the standard method to estimate ETo for over the last decades. This method takes into account many climatic variables linked to the evapotranspiration activity such as the net radiation (Rn), the air temperature (T), the vapor pressure deficit (Δe), and the wind speed (U); and its results are very satisfactory referring to [19].

3. Multi-agent Model for Irrigation Management

3.1. IoT and Multi-agent system

The Internet of Things is based mainly on sensors and connected objects placed in physical infrastructures. These sensors will transmit data that will be sent using a wireless network on IoT platforms. Thereafter, these data will be analyzed and enriched to get the most out of them. These data management and data visualization platforms are the new IoT solutions allowing territories, companies, or even users to analyze data and draw conclusions to be able to adopt practices and behaviors.

The proposed solution is based on microcontrollers and a multiagent platform. This choice is based on their computing power, their cost, and their scalability. With the use of various sensors, the variable parameters will be continuously monitored and the irrigation adapted to the type of crop.

This approach focuses on using multi-agent and IoT techniques to develop an efficient system for water management in a collective irrigation scheme. Farms are controlled by a MAS that can calculate the total water requirement of the farm based on the environment variable which are temperature, soil moisture, and rain, and control the water allocated to each farm. The multi-agent environment and the model of the multi-agent water management system are depicted in **Fig. 1** [20].

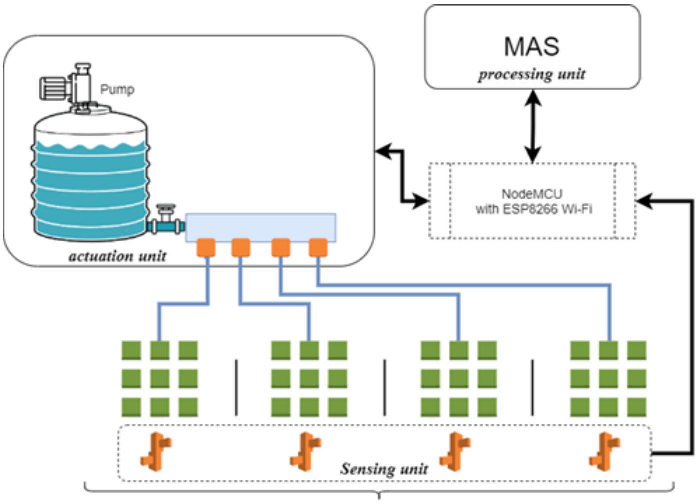


Fig. 1. Multi-agent irrigation management system

3.2. Materials And Methods

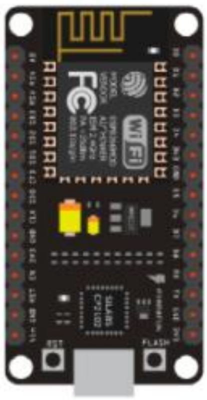
The system benefits from the communication rapidly growing in the Internet o things in recent years. This system consists of a wireless sensor network that collects different variables of the environment, the actuation unit that controls a mechanism of irrigation and water storage applying the strategy determined by the MAS, the NodeMCU smart gateway that connects the sensing unit and actuation unit with the agent-based management system.

The sensors placed in the farm field, measure continuously the soil humidity and temperature values, the measurement of rainfall, and the water tank level, then send these values through the network to MAS, that information is then sent to MAS that uses an intelligent algorithm to analyze the collected data and to extract insights that support decision-making.

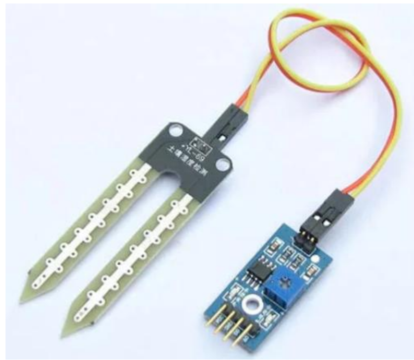
The model comprises the NodeMCU (Fig. 2 (a)) that operates synchronously with the sensor nodes that are physically installed in the farms. The sensors are deposited in the farm in the manner that they operate as the end devices of a point-to-point network. The end devices have the following features:

- be able to transfer data by connecting to a local area network
- allow the connection of any device.
- only send data and unable to edit this data.

NodeMCU is an open-source IoT development platform that contains a firmware system development board operating on the ESP8266 Wi-Fi SoC. It is a small microcontroller with a Wi-Fi chip that allows to establish a communication between two ESP8266, when they are connected on the same network. The NodeMCU provides advanced hardware interfaces that take the complexity of hardware configuration and registry operations out of the hands of application developers.



(a) NodeMCU based on the ESP8266 development board. [1]



(b) The soil moisture sensor.[2]

(c) Temperature sensor.

(d) Water flow sensor (SeaYF-S201). [3]

Fig. 2. The infrastructure components.

The model also consists of sensor devices dedicated to detecting environmental parameters and sending the measured information to the NodeMCU. The proposed smart farm monitoring system consists of the following sensors resources:

[1] https://www.aranacorp.com/
[2] https://www.instructables.com/
[3] https://www.hobbytronics.co.uk/

The soil moisture sensor: illustrated in Fig. 2 (b) which has a working range of (0 to 1023 ADC value) and is used to measure the soil moisture content of the farm. It consists of two conductive probes that can perceive the soil moisture content in proportion to the change in resistance between the two conductive plates.

The temperature sensor (DS18B20): illustrated in Fig. 2 (c) which is a digital temperature sensor that has a working range from -55°C to +125°C with ±0.5°C Accuracy.

The Sea YF-S201 water flow sensor presented in Fig. 2 (d) is used to measure the rate of flow of water and calculate the amount of water followed through the pipe. It is characterized by a water pressure inferior to 1.95, Working Flow Rate from 1 to 30 L/min, and is connected to the pipe of the submersible water pump illustrated in figure 5.

4. Overview of the proposed approach

Multi-agent systems are today an emerging technology for the simulation, understanding, and resolution of complex problems through the design and implementation of open and distributed systems that can integrate human and/or artificial agents.

In this context, we are interested in the modeling of gravity irrigation systems, by applying agent technology. Nowadays, this technology has found its place in production systems (workshop scheduling, management of industrial processes, multi-sensor systems, etc.), control tasks (road traffic control, air traffic, distribution energy, ...)[21], telecommunications, transport systems [22], networks and many other applications. Furthermore, MAS integrates various intelligent techniques to optimize system performance[23].

As aforementioned, the objective of our work is the modeling of an intelligent irrigation management system by a multi-agent system that represents the different actors and defines the negotiation interactions between them and this before the start of each agricultural campaign for the resolution of the water allocation for irrigation problems. These negotiations are based on climatic constraints, agricultural constraints, and the various decisions and behaviors of the actors.

The application of this proposed approach will be carried out in four phases as shown in the Fig. 3:

- The first phase of collecting the data necessary for decision-making during the negotiation process.
- The second phase of analysis concerns the capture of needs and the functional specification.
- The third phase is Agent modeling : Based on the analysis the agent model identifies which agent class is tasked to play specific roles and how many instances of each class have to be instantiated.
- A fourth phase for the implementation and development of agents under the AnyLogic platform.

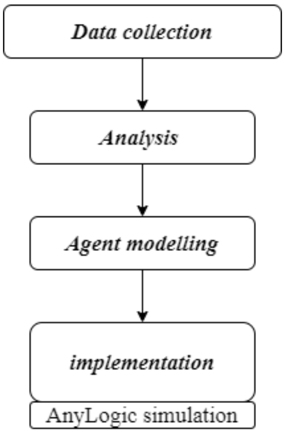


Fig. 3. The development process model

The irrigation system is functionally distributed. Commonly, agents are perceived as analyzing levels with abstraction upper than components and objects, which make MAS suitable with complex and distributed problems. In our proposed approach each farm is viewed as an isolated node monitored by a set of sensors. All nodes, as well as actuation units, are controlled by a community of autonomous, cooperative, and intelligent agents, this agent community is divided into subsystems tasked to achieve specific objectives.

4.1. Data Collection

The first step for the implementation of an intelligent irrigation system for agricultural automation is to place the wireless sensor network, each node is interconnected by a Wi-Fi module and deposits data on a common server, this server can continue to query the data and then send a commands signal for the required operation. Figure. 1. represents an overview topology of various sensor nodes, however, the actual network topology depends on the demographics of the region. The first step is to collect data via various sensors connected to the farms. The MAS will act as the gateway node responsible for communicating with all other sensor nodes. Each farm node consists of an advanced soil moisture sensor, Wi-Fi module, temperature and humidity, temperature sensor, water level indicators, alarm, clock module, battery, relay module. Ultrasonic sensor for the detection of intruders. Each of the nodes will relay the information to the Gateway which is the MAS which will be responsible for storing the data, analyzing it, and presenting it to the end-user through an application layer. The connection of various sensors to the microcontroller is based on the fundamental concept of receiver, transmitter. The first phase of the suggested system is complete after establishing the network topology and collecting data. Collecting data through various sensors is the prerequisite and the first step in data processing.

4.2. Analysis

All the data that has been collected by the sensors must be analyzed and processed so that the subsequent signal can be sent to the actuators as well as alerts can be sent to the end-user in case of manual interaction is required. The MAS will check various conditions from the data received from the nodes as well as from the web. Irrigation would be based on soil type and specific crop to automate the systems. Thus, after processing all the parameters, a control signal from the gateway node to the actuators will start the water pump. A continuous and recursive survey of soil moisture will be done at a fixed time interval and after a certain humidity level, irrigation will be stopped.

4.3. Agent Modeling

In this stage, we will establish the MAS infrastructure capturing the distributed aspect of the system, the interactions, and relationships that can take place between the different constituents of the system. For this, we based on the classification of the intelligent irrigation system on different tasks. This classification would make it possible to group all the tasks that are strongly linked in a subsystem and those that have little or no relationship to each other in different subsystems [22]. Thus, all the tasks relating to the preparation of the agricultural campaign, the negotiation of the annual water allocation in a first sub-system, the tasks relating to the execution of irrigation, and the allocation of water resources are negotiated in the second sub-system. A third subsystem is tasked to monitor the good progress of the agricultural campaign. Therefore, the intelligent irrigation system will be composed of the following three subsystems (see Fig. 4):

- Supervision and planning subsystem: responsible for the supervision of the whole system, the management of negotiations, the management of irrigation, the programming of the water tower, and the planning of the opening and closing operations of the irrigation valves. This subsystem serves a set of farmers, it must optimize the irrigation process (by deploying certain heuristics) to minimize the duration of the tour. Water and flow variations at the secondary canals. This subsystem will be modeled by two agents: Supervisor Agent, Scheduling Agent, and Water need Agent.
- Execution sub-system: responsible for monitoring the smooth running of the agricultural campaign through the execution of the water tower program established by the scheduling agent. This subsystem will be modeled by two agents: Agents Farm, Agent Source, Tank Agent, Pump Agent.
- Users' subsystem: made up of all the farmers who form the Water User Association (WUA), responsible for monitoring the progress of the irrigations and the negotiation of the water supply. This subsystem will be modeled by a WUA Agent.

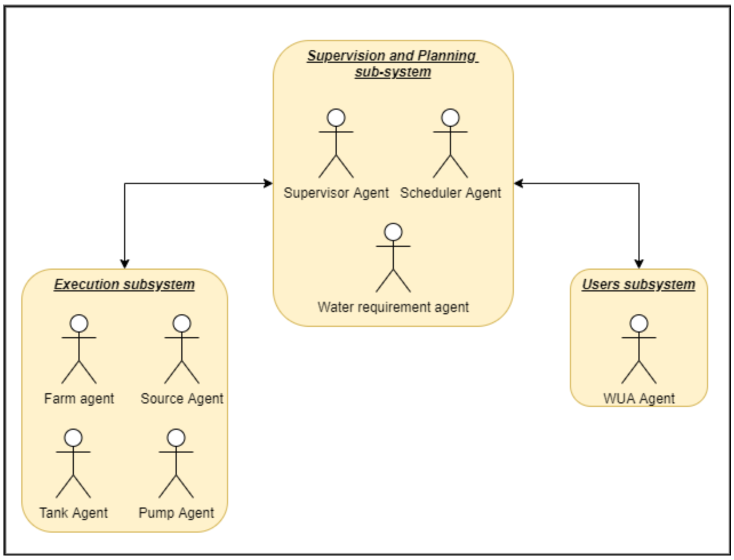


Fig. 4. The organization of the multi-agent system

Supervision and planning sub-system

The prescribed agent-based model defines specific agents in correspondence with the types of tasks in the precision subsystem. Each agent achieves a specific role, through cooperation and interaction with other agents in the same subsystem and the other subsystems. Various types of agents are conceived in the structuring process, dedicated to achieving different roles:

Supervisor Agent: The Irrigation Supervisor will operate and perform the supervision of all the irrigation processes and will assist the scheduler agent in the scheduling process. The Supervisor Agent represents a Development Center for the irrigation of the plots, it receives the needs of each crop and defines the allocations according to the availability of an annual water allocation from the Hydraulic Basin Agency (HBA), the annual water allocation will be subject to negotiation with the WUA agents in order to reach a compromise for its allocation. The Supervisor Agent will therefore be responsible for the following tasks:

- Inform the Scheduling Agent of the water allocation granted and of the list of farmers entitled to irrigate their plots.
- Negotiate the water supply with the farm agents.
- Send the final water allocation to the Scheduling Agent.
- Transmit the program of the water tower received by the Scheduling Agent to each farm Agent.
- Receive the authorization to start irrigation from the Source Agent and inform the Farm Agent.

- Manage the no satisfaction received from the farm Agent and manage the incidents during the irrigation planning.
- Establish reports on each farm.

Scheduling Agent: The Scheduling Agent is responsible for scheduling the tour by providing an optimal timing diagram for the filling of the channels of the network which will be sent to the Supervisor Agent.

Water requirement agent: calculate water requirements for each farm based on environment variables and water demand prediction process.

To ensure potential crop yields, the water requirements of the zone of a crop must be met. These needs are generally defined by the evapotranspiration of crops and represented by ETc. Evapotranspiration combines evaporation from the soil surface or wet surfaces of plants, and transpiration from leaves. Water needs could be met through precipitation, groundwater, or irrigation. Irrigation is therefore necessary when the crop water requirement (ETc) exceeds both stored water and rainfall. Since ETc is dependent on crop stage and weather changes, the amount and timing of irrigation are critical. The water balance approach allows easy estimation of water requirements for irrigation planning. This method is based on several factors, in particular, the initial soil water content in the root zone, ETc, rainfall, and soil capacity. The Daily crop evapotranspiration (ETc) can be accessed as follows:

$$\mathrm{ETc} = \mathrm{ETr} \times \mathrm{Kc} \times \mathrm{Ks}. \quad (1)$$

Where *ETr* is the evapotranspiration rate of the reference crop, *Kc* is the crop coefficient which depends on the stage of development (0 to 1) and *Ks* is the water stress coefficient (0 to 1). At each stage of the growing season, the Kc of each crop is essentially estimated as the ratio of its *ETc* to the *ETr* of the reference crop [24].

ETr (reference evapotranspiration) is estimated from climatological variables and expresses the effect of meteorological conditions on the net water requirements of crops, while *Kc* marks the characteristics of the crop and its effect on the requirements of plants. Water (type of crop, development, phonological stage, etc.). Third, the quality of the irrigation water, the uniformity coefficient of the irrigation system, the size of the field, etc., determine the actual amount of irrigation. This value gives a rough idea of the volume of water needed to meet the crop's water needs. This value is balanced with the water state of the soil to obtain the irrigation volume for the contribution to the harvest stage.

Execution sub-system

Farm Agent: each farm is assigned to an agent farm; its main task is to monitor the execution of the irrigation schedule transmitted by the Supervisor Agent. It is responsible for the irrigation of crops belonging to the zone for which he is responsible, in the form: "*distribute the quantities* Q_1, Q_2 ..., Q_n *respectively on the crops* C_1, C_2, ..., C_n".

Agent Source: The Source Agent represents the rural commune; its role is to allocate the flow requested by the fam agent by opening the flow control valves which are installed at the level of the tank and which are under his responsibility. This agent also reads the tank level information from the sensors and makes sure this level is in the convenient degree.

Tank Agent: This agent charges to control the tank**.**

Pump Agent: this agent monitors the initial condition requiring the tank to be full before water circulation is started.

Users' subsystem

WUA Agent: The WUA Agent represents a Water User Association which is made up of a representative and the farmers belonging to it, its role is to negotiate the annual water allocation with the Supervisory Agent before the agricultural campaign. This agent also has the role of monitoring the progress of irrigations and informing the agent farm or the supervisor Agent of incidents in the irrigation canals. This agent plays the role of the user interface. It represents the human-machine interface and focuses on displaying the irrigation state to the final users.

Each agent acts according to a set of rules, whose format depends on its variables.

Fig 5 represents the architecture of the intelligent irrigation system and interactions between agents.

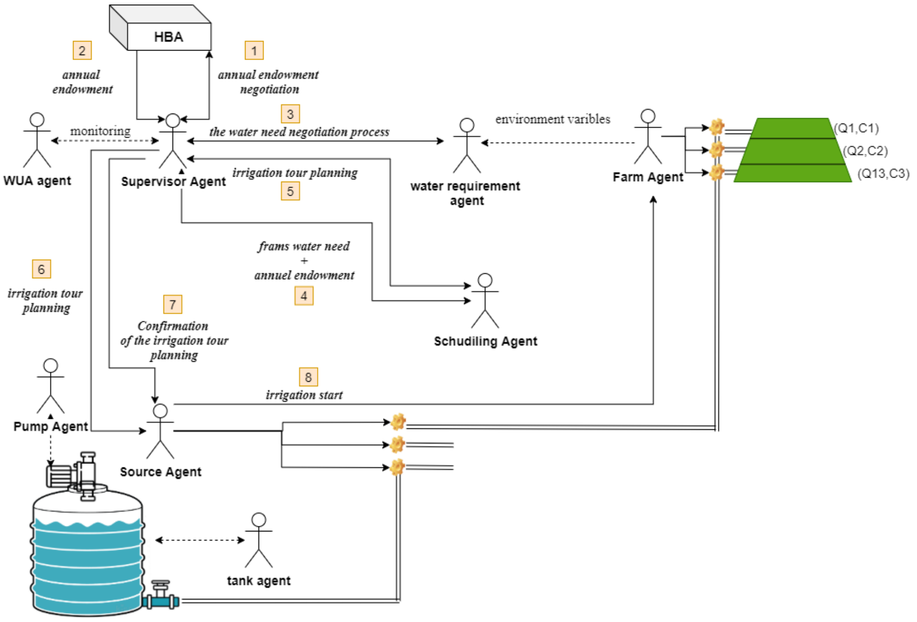


Fig. 5. The architecture of the MAS smart irrigation system

5. Experimental Results and Performance Analysis

5.1. Case Study

Our study area is jointly managed by three farmers' associations and the local center of the Haouz Regional Agricultural Development Office, especially in terms of irrigation. At the start of the season, they decide on the number of water towers and the quantities allocated for irrigating cereal crops. This quantity depends on the annual allocation granted and negotiated with the Hydraulic Basin Agency, which is the main supplier of irrigation water. At each turn, farmers receive a volume of water according to the size of the farms, regardless of the type of crop and its water needs, even if some areas are unexploited or in biological comfort time.

5.2. Workflow of The System

At the start, the water pump is disabled, then if the sensed values go beyond the threshold values set in the program (soil moisture< soil saturation = 360 = 64.80% or temperature > 30°C), it turns ON and irrigates the soil of the farm. Whenever the pump is turned ON, the flow sensor restarts measuring the irrigation flow, the horologe sleeps for a predetermined time, then the measures are recorded again until the soil moisture outperforms the soil saturation. This time control allows an optimized irrigation time which optimizes the amount of water flowing to the farm by minimizing the water loss that may be related to a long period of irrigation time before restarting the sensing and the threshold verification. In the case where the soil moisture exceeds the configured soil saturation level, the pump turns off, and the horologe sleeps for a second predetermined time before repeating the iteration. This process can be summarized as follows:

Step 1. Start.

Step 2. The system’s parameters can be initialized.

Step 3. The clock date is initialized on the Arduino UNO board, and the water pump is set to OFF.

Step 4. The farm agent checks the soil parameters level constantly.

Step 5. The microcontroller updates the current date and checks for the threshold condition. If the water content level is inferior to the soil saturation level (360) of the farm, which means that the soil becomes dry or the temperature surpasses (30°C), then the relay that is connected to the Arduino UNO will turn ON the motor to irrigate the field. The delay is set to (5 seconds) to repeat step 3. Otherwise, if the threshold condition isn't satisfied, the motor will be turned OFF, and the delay will be set to (1 hour) before repeating step 4.

The performance of the proposed system is validated and designed in the ANYLOGIC simulator, which is used to handle the MAS. Based on the JAVA language, AnyLogic is a programing and simulation platform used to model hybrid systems, it allows to handle agent modeling, graphical model editor and code generator.

5.3. Results and Analysis

Environment parameters are generated and adjusted to simulate different scenarios. The measures are recorded after a sleep time equal to (1 hour). (Fig. 6 and 7) show the temperature fluctuations and experimental results.

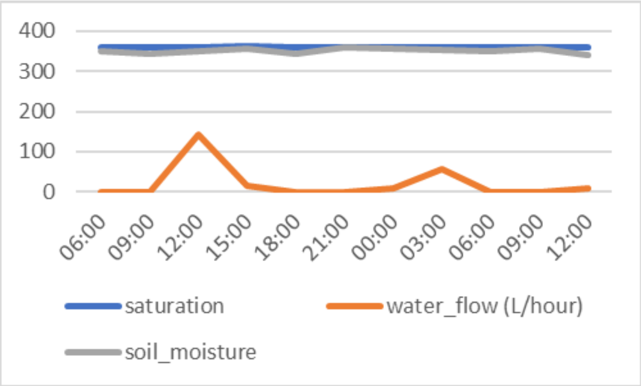


Fig. 6. Soil moisture changes and water flow fluctuations over time

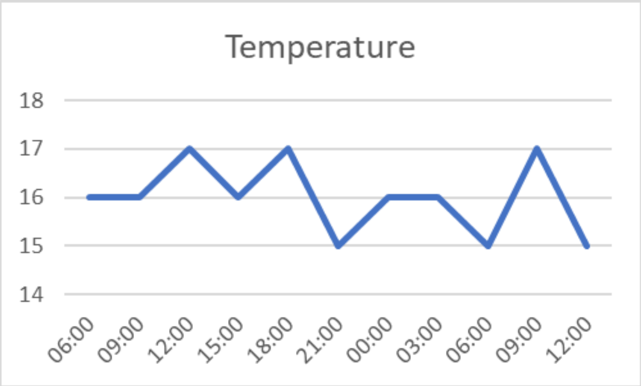


Fig. 7. Temperature fluctuations over time

6. Conclusion

In this paper, we propose a smart collective irrigation system using an agent and the internet of things technologies. The development of the proposed system is based on a specific methodology to design an intelligent irrigation system that determines the water requirement of each farm according to the water loss due to the process of evapotranspiration. The water requirement is calculated from data collected from a series of sensors installed in the plantation farm. This project focuses on smart irrigation based on IoT that is effective and can be used by farmer associations whose endowments and irrigation planning are defined according to the need and quantity of water available in the rural municipality.

The designed system can operate successfully for irrigation purposes with equity in calculating needs and allocating endowments in proportion to those needs. It frees farmers from the tedious task of irrigation while optimizing considerable quantities of water as well as preventing rural communities from managing water allocation and distribution. The system provides a suitable working device and allows the farmer to monitor his fields from a distance. Excessive irrigation can be avoided with this system, which can damage crops. The system can reduce the problems encountered in traditional agriculture and collective irrigation.

Our solution is very generic and adaptable to different contexts and collective irrigation issues. However, applying the solution in certain situations requires more functional and technical specifications. Specific modules that can be integrated into the management systems will have to be developed separately. In addition, we have implemented prototype applications, the implementation of such systems in practice requires the contribution of several contributors and experts in the field, as well as the implementation of various equipment and important material resources.

In the future, the proposed system will be tested and instantiated in an adequate simulation platform. The experimental result and performance analysis can provide information about the proposed system's effectiveness and performance.

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Received: February 27, 2022; Accepted: August 22, 2022.