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Smart Irrigation System for Wheat in Saudi Arabia Using Wireless Sensors Network Technology

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Abstract: Irrigated agriculture has been considered to be one of the most water consumers in the world. Shortage of water is more pronounced in semi arid and arid regions, where average rainfall is minimal and water limitation is the most affecting factor in crop production. Proper management of water irrigation is more needed than ever for sustainable productivity and improvement of water use efficiency of wheat crop. Irrigation timing and water dosage are the key aspects of watering scheduling. Available equipment specially soil moisture monitoring devices provide all the information required for irrigation management, but frequently lack in representativeness and reliability. Wireless sensor networks are a new technology that promises fine grain monitoring in time and space and at a lower cost, than is currently possible. In this paper we built a new sensors network for monitoring the soil moisture and, in a two way wireless communication, decision made for water irrigation will be transmitted to the nodes. The proposed system was proven to be cheap, reliable and simple to use. The effect of the built system on the plants growth and the soil were studied and the increase in the water used efficiency was monitored.

Key words: Smart sensors · Water use efficiency · Auto-irrigation · Wireless sensors networks

INTRODUCTION

More than 40% of wheat cultivation areas are under arid or semi-arid climatic conditions [1]. In the arid and semi-arid environments water is the most limiting factor in reducing agricultural production. Over the past thirty years many crop breeders and plant physiologists have made great efforts to improve the drought tolerance of a range of agricultural and horticultural crops. One of the main adopted approach to breeding for drought tolerance overcome the impacts of water shortage on agricultural production is to concentrate on increasing what has come to be known as "water productivity" or "water use efficiency of the crop [2].

Water Productivity / Water Use Efficiency: The water productivity concept emerged from different fields. In irrigation systems the term water use efficiency has been used to measure the effectiveness of delivered water to crops and the amount of wasted water through this delivery process. The term water use efficiency is based on the assumption that a plant with high water use efficiency should have a greater productivity under water-limited conditions than would a plant with low water use efficiency. Crop production may be expressed in terms of the total biomass or seeds weight or even in monetary units when production is transferred to monetary units [3]. The more common way of expressing water productivity is as the ratio of yield to water supply or total evapo-transpiration.

In Saudi Arabia agriculture is significantly affected by the rainfall water shortage due to its high water demands. It is important to adopt changes in agricultural practices and employ innovative ideas for the agricultural industry to improve its current rate of production. Sensor technology can be used to study soil dynamics based on information gathered at regular intervals and the data collected can be used as feedback to improve irrigation efficiency [4].

Wireless Sensor Networks (Wsn): A wireless sensornetwork is a wireless network consisting of spatially distributed devices integrated with sensors to cooperatively monitor physical or environmental

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conditions, such as temperature, pressure, humidity and soil moisture at different locations. Each wireless device, also called a node, behaves individually where it has one or more sensors integrated on it [5]. In addition to these sensors, a node is also equipped with a transmitter and a receiver that are used for wireless communications with other nodes or directly with the gateway. The gateway is responsible for transmitting sensor data from the sensor patch to the remote basestationthatprovides wirelessad-hocnetwork (WAN) connectivity and datab logging throughm a localtransit network. The other parts of a sensor node are the microcontroller and the battery as an energy source. When these small andlow power consumingdevicesdeployedinareasofinterest,eachindivi dualnodecollectsdataaboutits immediatesurroundings.

Why Wireless Sensors?
An obvious advantage of wireless transmission is a significant reduction and simplification in wiring and harness as well as saving the cost of the wires. Wireless sensors allow otherwise impossible sensor applications, such as monitoring dangerous, hazardous, unwired or remote areas and locations. This technology provides nearly unlimited installation flexibility for sensors and increased network robustness, [6]. Another advantage of wireless sensors is their mobility as they can be placed in transporting vehicles to monitor the "on-the-go" environment. Furthermore, wireless technology reduces maintenance complexity and costs. Most wireless sensors have signal conditioning and processing units installed at the location of the sensors and transmit signals in the digital form. As a result, noise pick-up becomes a less significant problem. Therefore, wireless sensors have been used in agriculture to assist in spatial data collection, precision irrigation and variable-rate technology.

Spatial Data Collection: A mobile field data acquisition system is developed to collect data for crop management and spatial-variability studies [7]. The system is able to conduct local field survey and to collect data of soil water availability.

Precision Irrigation: Wireless sensors are used in the system to assist irrigation scheduling using combined on-site weather data, remotely sensed data and grower preferences [8, 9].

Variable-rate Technology: WSN are used for variable rate irrigation applications [10]. The system consists of real-time sensor data acquisition, a decision module for calculating the optimal quantity and spread pattern for a fertilizer and an output module to regulate the fertilizer application rate.

Commercially available wireless sensor network systems are still not cost effective, mainly for developing countries and have no appropriate features for the agricultural fields and practices. Therefore, we developed a proprietary wireless sensor network system adequate for remote monitoring and control in the arid area. In this paper we describe our design, development and deployment of a wireless sensor network to improve water use managements for crops production.

MATERIALS AND METHODOLOGY

Three sensor nodes were deployed at the College of Science, Taibah University. Each sensor node measures soil moisture and can also measure temperature and humidity o f the surrounding environments. The information was sent to the base station in the control unit. Preliminary r esults are now available. The data gathered was used to develop efficient data evaluation techniques so that irrigation regimes can be wirelessly fully automated. This will lead to precision agricultural techniques involving the close monitoring of the field state and the use of real time data to drive more efficient irrigation practices. The system was conceived to be low-cost, reliable and compatible with contemporary local wheat production practices agriculture.

Soil Sensor Nodes: A resistive soil moisture sensor was designed and built to fit of a wooden plate measuring 5cm wide and 10cm long. This piece was attached to the circuitry, sealed inside a plastic case with the antenna installed at its top. The antenna is a 6 dBi gain double dipole.

The sensor node circuit board consists of the sensor interface and signal conditioning circuits, as shown in Figure 1. The sensor is derived by a 200 KHz square wave. The frequency will be changed according to the moisture value. The output of the sensor will be low pass filtered and the DC output of the filter will indicate the level of the soil moisture. The moisture level will be between 2 and 3.5 V indicating 0-100% moisture. The output of the filter is fed to a comparator whose output will be active only

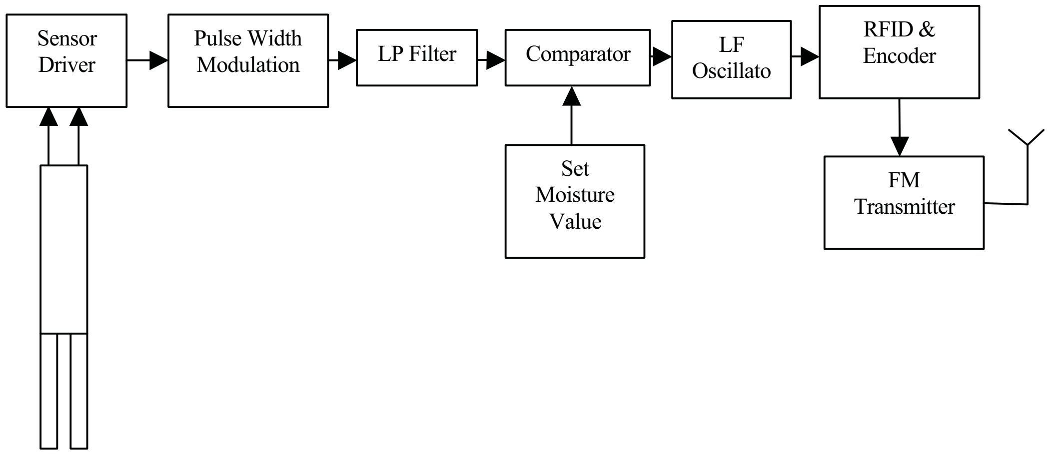

Fig. 1: Block diagram of the sensor node of the implemented system

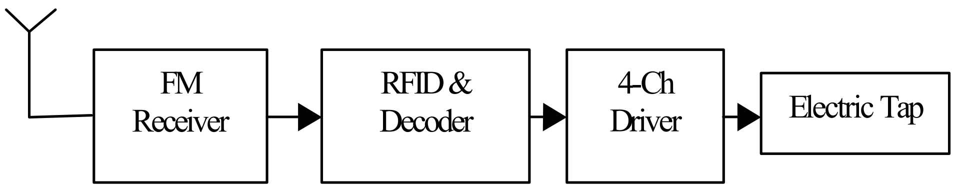

Fig. 2: Block diagram of the field station of the implemented system

when the measured moisture level is less that the preset value, which depends on the type of soil and the corps planted.The output of the comparator will activate a low frequency generator circuit that produces a square wave of 0.1 Hz. This will be fed to an encoder that carry a unique ID which in turn will fed its output to a wireless transmitter that will transmit the information that contains the ID of the transmitter and the data that indicate the need for water irrigation for that node. The soil sensor node is powered by a 5 V, 1000mAh NiCd battery. The nodes were programmed to remain most of the time in sleep mode and wake up only when the moisture level goes below the preset value and then communication with the field station occurs.

Field Station: The field station is the data sink of this wireless sensor network. Its primary function is to receive, process and temporarily store data in the field. It also performs the valve actuation. Another important function executed by the field stations is the sensor network routing. The field station consists of FM receiver that receives the digital data sent by different transmitter, identify the node then decode the transmitted information. The water irrigation request sent by different nodes is used to drive up to 4 different water valves. The receiver can identify up to 48 different nodes. The field station block diagram is shown in Figure 2. The RF module is the only commercial part used in the system.

RESULTS AND DISCUSSIONS

Plant Growth: This study was conducted on seeds of the local Saudi wheat cultivar (Triticum durum), Sindi 2. Seeds were sown in 12 cm plastic pots containing soil-compost (1:3 v:v). Figure 3 shows the set up of the experiments. Soil mixtures were set at 80% field capacity and the set point of the moisture level was set to the same field capacity. Sensors were placed inside the pots to measure the amount of water to be delivered to the plants while the node circuit was placed next to the pot. Data communication between the three nodes and the field station were recorded using RS232 serial communication port in order to show the ID of the nodes and the time of irrigation and volume of water used. Figure 4 shows the sensor output DC voltage level over a period of two weeks. The readings were captured daily at the same time. Figure 5 shows the percentage of the soil moisture over the same period due to the auto-irrigation system. The percentage of the soil moisture varied between 66 and 76 percent, having a hysteresis of about 10 per cent.

Fig. 3: The set up of the experiment

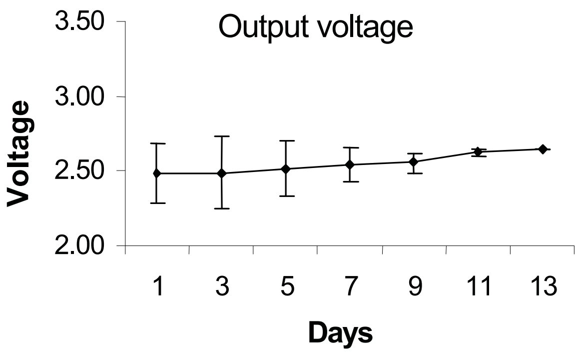

Fig. 4: The sensor output voltage over the experiment period

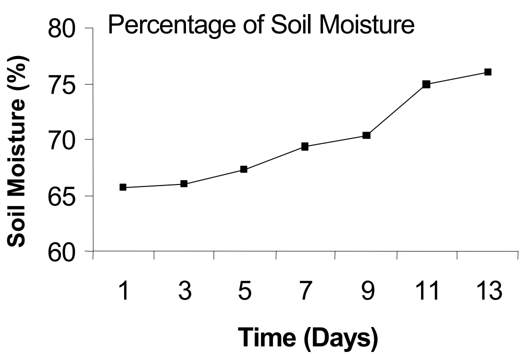

Fig. 5: The sensor output voltage over the period of the experiment

After two weeks, the plants were harvested to estimate growth by measuring the fresh and dry weight of both shoot and root and the amount of water used by the plants. A photograph of the harvested plant is shown in Figure 6. The average shoot fresh weight was 1.05g and the average root weight was 0.4g. The shoot dry weight was 0.115g and the root dry weight was 0.034 g. These figures showed that plant growth was normal and that the root to shoot ratio was also normal compared to the harvest under different irrigation methods.

Fig. 6: A photograph of the harvested plant.

The average amount of water used by manually irrigated plant system was 2 liters, while the average amount used by plant irrigated by the suggested systems was 1.5 liters. This indicated that the average saving of water was 0.5 ml by 14-day-old plants, i.e. a 25% water savings.

CONCLUSIONS

In the present study, a more advanced technology has been used to prove the possibility of using a wireless automated system and that it is a better water management system that leads to water savings when irrigating plants. The suggested wireless automated irrigation system appears to perform well in maintaining the normal growth of plants while saving in the amount of water used by around 25%. This is very valuable in semi-arid and arid regions such as Saudi Arabia where water is very limited.

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