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A Review on Automated Irrigation System using Wireless Sensor Network

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Abstract*— Automated irrigation system consists of a feedback control system that employs monitoring of environmental parameters and controlling irrigation. Environmental parameters such soil moisture, temperature and humidity plays an important role in overall development of the crop and good yield. Conservation of water and other resource can be achieved by optimizing these parameters. The advancements in science and technology have enabled the use of modern technology, like Wireless Sensor Network (WSN), in such system at very low cost. WSN can be incorporated to distribute the monitoring over entire crop field. This paper reviews for various sensors available to monitor above environmental parameters and focuses on wireless technologies to suite such types of end application.

Index Terms— **Moisture, Humidity, WSN, Bluetooth, ZigBee, ARM7, Infrared (IR) image, Plant Canopy** ***etc.***

I. Introduction

Agriculture has been the most important practice from very beginning of the human civilization. It has seen many iterations of development in technology with time. A good agricultural practice is still an art. Environmental parameters such as soil moisture, temperature, humidity, pH, solar radiation *etc*. plays very important role in overall development of the plant. Temperature affects many of plant activities such as pollination, germination *etc*. It is observed that, at higher temperature, respiration rate increases that result in reduction of sugar contents of fruits and vegetables. At lower temperatures photosynthesis activity is slowed down [1]. *Humidity* is responsible for moisture loss and temperature management of the plant. For high humid environment, evapotransmission will be less and more water will saturated in the leaf area. This results in enlargement and formation of fungus in the porous area of the leaf. *Moisture* is critical for seed germination and uptake of nutrients by the plant. Excess water may stop gaseous exchange between soil and the atmosphere which reduces root respiration and root growth. Optimum level of moisture ensures healthy growth of the root and overall development of the plant [2]. A sustainable approach is required to maintain balance between these parameters and environment. Hence there is a need of efficient monitoring and control system. In today's era, the traditional methods that are used for irrigation, such as overhead sprinkler and flood type, is not that much efficient. They results in a lot of wastage of water and can also promote disease such as fungus formation due to over moisture in the soil. Automated irrigation system is essential for conservation of the water and indirectly viability of the farm since it is an important commodity. About 85% of total available water resources across the world are solely used for the irrigation purpose [3]. In upcoming years this demand is likely to increase because of increasing population. To meet this demand we must adopt new techniques which will conserve need of water for irrigation process. In automation system water availability to crop is monitored through sensors and as per need watering is done through the controlled irrigation.

The advancement in the technologies has enabled the use of state-of-art technology at a reasonably low cost. Wireless sensor network (WSN) can be used in such system to enhance its monitoring capability by distributing sensors all over the field and monitoring environmental parameters remotely. WSN consist of small nodes which work on its own and has a sensors embedded. They collect the data and transmit it over wireless medium to a central system where data from all the nodes is collected and processed. In this paper technological review is undertaken for various sensors which are used for measurement of environmental parameters. And also various type of wireless protocols which are used to form a network of wireless sensors. This paper is organized into 4 sections. An introduction in first section is followed by background of the topic. Third section describes the implementations done in given area. Fourth section briefly describes outline of the proposed system. Conclusion and future work is stated in the fifth and sixth.

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I. Background

A. Moisture Measurement

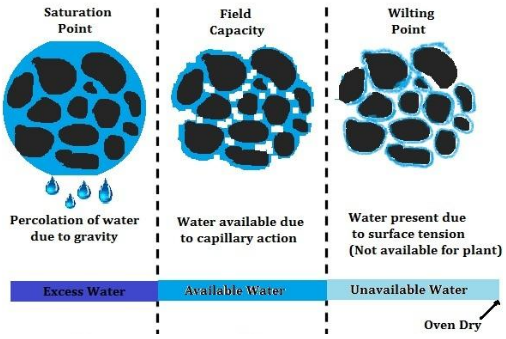
Soil is made up of mixture of components including mineral and organic particles, with water and air making up the spaces in between. Soil can be mainly classified into following 4 categories:

Clay	Silt	Sand	Gravel
0-0.002 mm	0.002-0.075mm	0.075-4.75mm	4.75-80mm

It is advised to analyze soil to deduce its category. Each category has different properties hence their water holding capacity changes from one type to the other.

As water infiltrates soil, it starts to fill the gap between the void spaces in between soil particles (Fig. 2.1a), when all the spaces are completely saturated with the water, the state is known as *saturation point*. This state lasts for very short time. With time excess water percolates downward through water profile due to gravitational force. At same time capillary action provide opposite force to gravity and provide balanced condition so downward movement of water is hindered. This stage is called as the *field capacity*. Void spaces are now filled with water and air packets (Fig. 2.1(b)). Every crop has a Critical Soil Moisture Deficit level, allowing soil to dry out beyond this level, water pulling from crop can't happen, decreasing the yield. Further more water removal from soil lead small holding of water by soil particles much tightly because of surface tension effect for the crop to extract This is said to be as *wilting point* as shown in figure 2.1(c).

The available water capacity is the amount of water a soil can make available to plants, generally defined as the difference between amount of water stored in a soil at field capacity and the amount of water stored in the soil at the permanent wilting point. Plants get most of water from the upper portion of the root zone.



(a) (b) (c)

Fig. 2.1 water holding property of soil

The term effective root zone refers to about the upper half of the root zone depth, where roughly 70% of crops water is taken up.

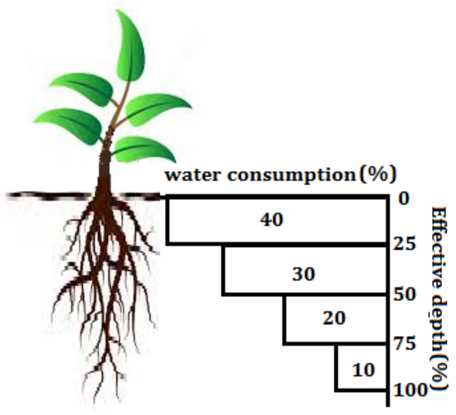


Fig 2.2 Effective root zone

Numbers of methods are developed for soil moisture measurement from simple feel method to most advance electronic ones. Some of the techniques are discussed below:

2.1.1 *Gravimetric method*

Gravimetric being simplest and oldest approach to measure soil moisture was first introduced in year 1894 [4]. In this method a soil sample is considered, weighted and then dried in oven for about 24 hours and weighted again. The ratio of two weights gives the %moisture contents of the soil. In spite of its simplicity it is not widely used because of large time required and labor cost involved for collecting sample and measurement. This is suitable for single time measurement applications.

2.1.2 *Electrical conductivity measurement*

This method was first reported in 1897 but its first successful demonstration was given only after development of electrical unit in 1940s [4]. It is based on principle of electrical conductivity. A Soil having more moisture content offer less resistance in comparison with the dry soil. The change in resistance is directly proportional to the moisture content. It is very simple and inexpensive method.

2.1.3 *Tensiometer*

Tensiometer method based on measurement of the soil moisture tension was first used in 1936. In this method a hollow tube is filled with water. The tube is porous at bottom end through which water can flow in both the directions. Its other end is connected to the pressure meter. When moisture is low, water flows from the tube to soil thereby creating vacuum which increases pressure in the tube. When moisture is excess, water flows from soil into the tube decreasing the tension. This tension change is measured by tension meter and further it can be connected to electrical transducer for data logging purpose [5].

2.1.4 *Radioactivity*

Radioactive method using neutron probe was first introduced in 1950 [5]. It involves emission of neutrons into the soil. These neutrons are slowed down by lightweight atom. The soil with greater moisture has large number of hydrogen atoms, which have love atomic weight, slows down neutrons. At other end number of slowed neutrons are calculated and converted into electrical quantity. Its radioactive nature requires skilled personnel to handle the process. This method is slow and costly. All above reasons makes it unsuitable to be used in real time environment.

2.1.5 *Time domain reflectometry*

Time domain rate method is based on the transmission of electromagnetic (EM) waves. Propagation of EM wave in soil depends on soil properties especially water content and electrical conductivity. An EM wave is passed through rod or transmission lines and reflected wave is collected. The change in propagation constant (*i.e.*, velocity and attenuation) is the measure of soil moisture content. This technique is very costly but it is accurate and measurement is independent of soil texture, temperature and salt contents [5].

2.1.6 *Plant canopy temperature measurement*

It is based on the thermal imaging of the plant canopy. Initially a digital image of the crop is captured and then from same position thermal image is obtained via IR imaging. These two images are then superimposed which can identify water deficit area of the canopy. From this information Crop

Water Stress Index is calculated and irrigation is carried as per need. This is most advance and effective method for moisture monitoring. Additionally it is totally non-invasive requiring no distributed sensors across the field and no contact based measurement. On the other hand high end equipment increases its overall cost and skilled professional required. For measurement of moisture across total field, imaging is to be done well above from the ground for which helicopters or Unmanned Ariel Vehicles are generally used.

B. Temperature measurement

Temperature monitoring is vital in many industrial scenarios. It also plays very important role in plant growth hence monitoring temperature is essential for good agricultural practice. Many standard techniques exist which depends upon measurement of physical properties of the working material that varies with temperature. Thermocouple, thermistor, RTD, pyrometer, Langmuir probes, infrared, *etc.* are some of the examples.

C. Humidity measurement

There are three ways to represent Humidity. It is the amount of water vapor (water that has turned from a liquid to an invisible gas) in the air. *Absolute humidity* is the actual amount of water vapor in a specified volume of air. *Relative humidity* is the ratio of moisture in the air as compared to the maximum amount of moisture the air can hold, which varies depending on the air temperature. Hotter air, for example, can hold more moisture.

D. Wireless Sensor Network

Recent advancement in science and technology has diverted a broad attention towards WSN because of its increasing popularity in the field of distributed monitoring. These are very tiny, low cost, power, self-sustained systems distributed across entire monitoring field and collect data in real time. A WSN node is made up of one or more sensors, processing unit and wireless transceiver. The processing infrastructure is minimal, battery operated and rely on secondary sources such solar, vibration, fuel cells, acoustic noise and mobile supplier for replenishment. Out of these sources solar energy is widely used because of its convenience and easy availability [6].

There are two types of sensor nodes. First one is generic node, embeds multiple sensors and second is gateway node, collects data from generic nodes and relay them to main unit. WSN depending upon its deployment can be categorized in five categories, namely terrestrial, under-ground, underwater, Multimedia and Mobile WSN. In different environment WSN faces different challenges and constraints [7].

WSN can have broad application areas such as military tracking and surveillance, biomedical health monitoring, in industrial automation and inventory tracking, hazardous environment exploration and seismic sensing and environmental parameter monitoring in agricultural sector [7].

There are some key issues while designing WSN. First issue is regarding its infrastructure as it is very tightly constrained. A new platform, operating system and storage schemes are required to facilitate the use of different types of user application to run on node. Second is communication protocol which is used for wireless communication. Conventional protocols are not suitable for wireless node as it requires more resources and power. New protocols which have small range, low cost, low resource and low power requirement are need to be developed. Some of the examples are Bluetooth, ZigBee [IEEE 802.15.4], WirelessHART, *etc.* [8].

II. Literature Review

For development of automated irrigation system, soil moisture content is more important parameter as compared to others as it has crucial role in plant growth mechanism and availability of water for irrigation is major concern for the farmers specially the ones who are dependent on rain. Hence water management has high priority while designing automated irrigation system as seen in most of the literature. The researchers have used various techniques [21]-[26] to measure moisture contents precisely. The electrical conductivity measurement is the most simple, cost effective and power efficient method of all. But it is not precise and its results vary over time. In spite of its disadvantages it is widely preferred by many researchers. [9] Have used this method to implement automated irrigation control system using drip irrigation methodology. The data was collected and processed by ARM7 board. To provide user interface GSM technique was employed and at the user end android based application was developed to display data and with that information user can decide what action to take. According to the command given by user, solenoid valve were operated to control the irrigation. A high degree of flexibility was obtained with this implementation. Workload for the farmer was reduced and also increase in the productivity of the farm was observed.

In [10] acoustic method has been used to measure water content of the soil on the fact that travel time of sound wave is different in dry and wet soil. Based on the observation chart was prepared for travel time versus moisture content from which moisture can be deduced. Another approach for moisture measurement is measuring variation in dielectric constant [11]. Dielectric constant of water is (~80) very high as compared to dry soil (2-3). In [12] variation of dielectric was measured as a variation in capacitor using capacitor and resistor bridge. The response is almost linear which is required in case of precision agriculture. S. S. Mathurkar and D. S. Chaudhari [13] presented a prototype model based on moisture, temperature and humidity sensor. All the sensors were calibrated for linear response. The main aim of system is to develop an accurate system which can be utilized in actual farm and provide benefits to the farmer.

A novel approach to design automated irrigation system is the use of Plant water stress analysis. It is obtained through registration of optical and IR images of plant canopy. This particular registration poses several challenges as no consistent common feature or exact matching can be found from the input images. X. Wang *et al* [14] developed an Automatic Cross-Correlation alignment algorithm which uses the information of coherent image structure but eliminates the influence of image color and intensity in the correlation process and therefore achieves a satisfactory registration result. They also implemented efficient computation approach which can substantially reduce the computation complexity of the ACC algorithm while maintaining desired accuracy. Alignment robustness was also improved by adopting N-maxima method in the control point computation. Experimental results indicated that proposed system outperformed all other techniques for area based methods.

J. Gutierrez *et al* [15] implemented very efficient automated system with wireless sensor network. Remote interface was provided through GPRS module (MTSMC-G2-SP). The system has two input parameters first is moisture sensor (VH400) based on electromagnetic measurement and second is soil temperature sensor (DS1822). The recorded data was stored locally in memory chip and was also transmitted to the web. The system is power efficient and completely works on solar energy. The promising result of around 90% water saving was observed.

P. Bhosale and V. Dixit developed weather monitoring system. They used wide range of sensors for monitoring namely atmospheric temperature and humidity (SHT1x), Soil temperature (LM35), Radiation and sunshine, soil moisture (gypsum block based on resistive technique), wind speed and direction (anemometer) and rain fall. In control board PIC microcontroller was used. The collective data was stored in memory card storage and was also sent to remote user via GSM module. Efficient use of water was achieved through this system [16].

An efficient automation system is vital for greenhouse management [17]. It was designed to monitor soil moisture, temperature and humidity. Sensors were distributed using wireless technology with the help of ZigBee protocol. Soil moisture was controlled with irrigation, temperature was controlled by fan and humidity was controlled by light. Individual threshold for all these parameters were already set at the time of programming. Conservation in resources was obtained through this implementation. In another case Orazio Mirabella and Michele Brischetto implemented hybrid model for automation of greenhouse [18]. In this case monitoring and controlling was done over multiple greenhouses. Small wireless sensor network was established in each green house and all green houses were connected using wired media with Controller Area Network (CAN) protocol. Wireless network in the greenhouse was used to facilitate the movement of sensor node freely. The central controlling was done by SCADA system.

Monitoring system is deployed over very large area to collect huge amount of data. It becomes very difficult to analyze this data and deciding control action especially in the case where limited number of resources is available. Different data aggregation techniques can be used to determine controlling action [19]. In [20] linear programming algorithm is designed for the implementation of intelligent drip irrigation system. The main aim of the linear programing is to optimize resources and provide automatic decision support. Separate Graphical User Interface was designed in the regional language for interaction with the farmer. The system is comprised of ATmega32 based board and the input parameters are soil temperature, for which they used LM35 temperature and tensiometer for moisture measurement. WSN was used to distribute sensors all over the field using ZigBee protocol. Data collected through all nodes was fed to the PC here decision was made through the linear programming. The ON and OFF timing of motor was the main parameter into consideration. Optimization for manpower, resources and water was achieved by use of this system.

III. Proposed System

In the proposed design Micro Drip Irrigation System for citrus (orange) plant is implemented. The field is distributed over 18 x 66 sq m. It contains 44 plants in (11 x 4). The graphical view is as shown in fig. 4. Monitoring is done using sensor node which will measure environmental parameters in real time.

System input parameters are soil moisture, temperature and humidity. Data are collected at center node and used for deciding control action based on settings feed earlier. The settings can be altered anytime later. Collected data is stored in memory card with time label for data logging and for scheduled timing current state of the farm will be notified to the user via GSM service. At user end android application is to be developed which will provide interface between the system and the user for further information and processing.

A. Center Node

- Arduino Mega launchpad (ATMega2560 core)
- GSM Module (GSM 300)
- Bluetooth module (HC-05)
- Card reader/writer
- RTC (DS1307)
- Water flow meter
- Solenoid valve and drive

B. Sensor Node

- MSP430G2 Launchpad (MSP430G2553 core)
- Integrated humidity and temperature sensor (DHT11)
- Bluetooth module (HC-05)

IV. Conclusion

In light of all above discussion it can be conclude that automatic irrigation system using wireless technology can provide efficient system capable of conserving resources and human effort. The system also facilitates real-time remote monitoring of the current environmental condition of field.

Modern technology can be incorporated to lower down the cost. These electronic systems are power efficient hence consumes very less power and rely on secondary sources such solar energy for complete autonomy.

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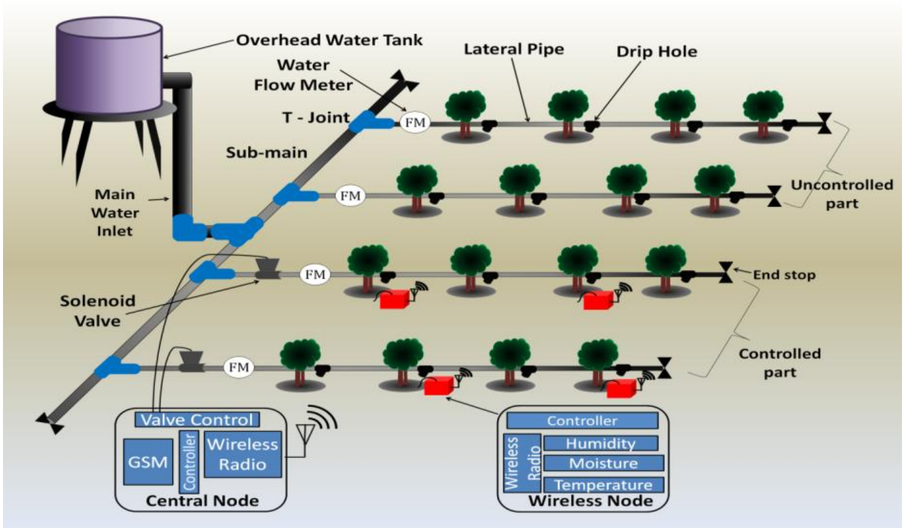

Fig. 5 Overview of Proposed System

REFERENCES

[1] Plant Growth Factors: Temperature, Colorado State University, Available (as on 14-09-2015) at: http://www.ext.colostate.edu/mg/Gardenno-tes/143.html#heat.

[2] Plant Growth Factors: Water, Colorado State University, Available (as on 14-09-2015) at: http://www.ext.colostate.edu/-mg/Gardennotes/144.html.

[3] Harriot Bigas (Ed.), "The Global Water Crisis: addressing an urgent security issue", Paper for InterAction Council, Hamilton, Canada: UNO-INWEH, 2011-12.

[4] A. I. Johnson, "Methods of measuring soil moisture in the field", U. S. Geological Survey, 1992 (Third Reprint).

[5] Mike Morris, NCAT Energy Specialist, "Soil moisture monitoring: low-cost tools and methods", *ATTRA*, 2006.

[6] W. K. G. Seah, Z. A. Eu, and H. P. Tan, "Wireless sensor networks powered by ambient energy harvesting (wsn-heap)—survey and challenges," in Proc. 1st International Conference on Wireless VITAE, pp. 1–5, May 2009.

[7] J. Yick, B. Mukherjee, and D. Ghosal, "Wireless sensor network survey," Comput. Netw., vol. 52, no. 12, pp. 2292–2330, Aug. 2008.

[8] J. S. Lee, Y. W. Su, and C. C. Shen, "A compara-tive study of wireless protocols: Bluetooth, UWB, ZigBee, and Wi-Fi," in Proc. IEEE 33rd Annu. Conf. IECON, pp. 46–51, Nov. 2007.

[9] V. Divya, A. Akhouri, C. Kumar, R. Rishabh, R. Bagla, "A Real time implementation of a GSM based automated irrigation control system using drip irrigation methodology", International Journal of Scientific and Engineering Research, Vol. 4, Issue 5, pp. 146-151, May 2013.

[10] F. Adamo, "An acoustic method for soil moisture measurement", IEEE transactions on Instrumentation and Measurement, Vol. 53, No. 4, pp. 891-898, May 2004.

[11] Darold Wobschall, "A frequency shift dielectric soil moisture sensor", IEEE Transactions on Geoscience Electronics, Vol. 16, No. 2, pp. 112-118, Apr. 1978.

[12] S. Saxena and G. M. Tayal, "Capacitive moisture meter", IEEE Transaction on Industrial Electronics and Control Instrumentation, Vol. 28, No. 1, pp. 37-39, Feb. 1981.

[13] S. Mathurkar and D. Chaudhari, "Smart Sensors Based Monitoring System for Agriculture using Field Programmable Gate Array", International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol. 3, Issue 4, May 2013.

[14] X. Wang, W. Yang, A. Wheaton, N. Cooley, and B. Moran, "Efficient registration of optical and IR images for automatic plant water stress assessment," Comput. Electron. Agricult., vol. 74, no. 2, pp. 230–237, Nov. 2010.

[15] J. Gutiérrez, J. F. Villa-Medina, A. Nieto-Garibay, and M. Á. Porta-Gándara, "Automated irrigation system using a wireless sensor network and GPRS module", IEEE transactions on instrumentation and measurement, Vol. 16, Issue 1, pp. 166-176, 2013.

[16] P. Bhosale and V. Dixit, "Water saving-irrigation automatic agricultural controller", International Journal of Scientific and Technology Research, Vol. 1, Issue 11, Dec. 2012.

[17] V. S. Jahnavi and S. F. Ahmed, "Smart wireless sensor network for automated greenhouse", IETE Journal of Research, Volume 61, Issue 2, pp. 180 – 185, 2015.

[18] O. Mirabella and M. Brischetto, "A hybrid wired/wireless networking infrastructure for greenhouse management," IEEE Tranactions on Instrumentation Measurement, vol. 60, no. 2, pp. 398–407, Feb. 2011.

[19] C. Lozoya, G. Mendoza, C. Mendoza, V. Torres and M. Grado, "Experimental evaluation of data aggregation methods applied to soil moisture measurement", IEEE, pp. 134-137, 2014.

[20] D. Wavhal and M. Giri, "Intelligent Drip Irrigation System", International Journal of Engineering Sciences and Research Technology, May 2014.

[21] D. Wobschall, "A Frequency Shift Dielectric Soil Moisture Sensor", IEEE Transactions on Geoscience Electronics, Vol. 16, No. 2, pp. 112-118, Apr. 1978.

[22] R. Dean, "A Capacitive Fringing Field Sensor Design for Moisture Measurement Based on Printed Circuit Board Technology", IEEE Transactions on Instrumentation and Measurement, Vol. 61, No. 4, pp. 1105-1112, Apr. 2012.

[23] J. Mizuguchi, J. Chico Piai, José Al-exandre de França, Maria Bernadete de Morais França, Karina Yamashita, and Luis Carlos Mathias, "Fringing field capacitive sensor for measuring soil water contents: design, manufacture and testing", IEEE Transactions on Instrumentation and Measurement, Vol. 64, No. 1, pp. 212-220, Jan. 2015.

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