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Distributed Monitoring of Sensor Networks in Agriculture

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Abstract

Sensor networks provide a powerful combination of distributed sensing, computing and communication. The different traits of sensor networks have a direct impact on the hardware design of the sensor nodes at various levels: power source, processor, communication hardware, sensor nodes and actuation. Sensor networks are also widely applied in habitat monitoring and agriculture research. An integrated network of sensors combining on the ground sensors monitoring soil moisture levels, humidity, temperature, plant growth, ground water level, disease identification together with Global positioning system facilities and long term field monitoring to absorb the variations in the agricultural field will enable the determination of risk levels in targeted regions as well as valuable information on agricultural development. The overall goal of the research and development effort described in this work is to devise an integrated system in the form of plant growth monitoring and control system comprising a distributed network of sensors for sensing the plant growth activity, drip water irrigation, temperature sensing, ground water monitoring and environmental conditions to improve the productivity in agriculture.

Keywords: Wireless Sensor Networks, Global Positioning system, Communication Hardware, Agricultural productivity, Drip Irrigation.

1 Introduction

The continuous increasing demand of food requires the rapid improvement in food production technology. In a country like India, where the economy is mainly based on agriculture and the climatic conditions are isotropic, still we are not able to make full use of agricultural resources. The main reason is the lack of rains, scarcity of land reservoir water, plant diseases, lack of pesticide control and improper weather conditions. The continuous extraction of water from earth is reducing the water level due to which lot of land is coming slowly in the zones of un-irrigated land. Another very important reason of this is due to unplanned use of water due to which a significant amount of water goes to waste.

In modern drip irrigation systems, the most significant advantage is that water is supplied near the root zone of the plants drip by drip due to which a large quantity of water is saved.

At the present era, the farmers have been using irrigation techniques in India through manual control in which farmers irrigate the land at the regular intervals. This process sometimes consumes more water or sometimes the water reaches late due to which crops get dried. Water deficiency can be detrimental to plants before visible wilting occurs. Slowed growth rate, lighter weight fruit follows slight water deficiency. This problem can be perfectly rectified if we use automatic micro controller based drip irrigation system in which the irrigation will take place only when there will be acute requirement of water.

Irrigation system uses valves to turn irrigation ON and OFF. These valves may be easily automated by using sensors. Automating farm or nursery irrigation allows farmers to apply the right amount of water at the right time, regardless of the availability of labor to turn valves on and off. In addition, farmers using automation equipment are able to reduce runoff from over watering saturated soils, avoid irrigating at the wrong time of day, which will improve crop performance by ensuring adequate water and nutrients when needed. Automatic Drip Irrigation is a valuable tool for accurate soil moisture control in highly specialized greenhouse vegetable production and it is a simple, precise method for irrigation. It also helps in time saving, removal of human error in adjusting available soil moisture levels and to maximize their net profits

2 Sensors in Drip Irrigation

Drip irrigation saves water because only the plant's root zone receives moisture. Little water is lost to deep percolation if the proper amount is applied. Drip irrigation is popular because it can increase yields and decrease both water requirements and labor. Drip irrigation requires about half of the water needed by sprinkler or surface irrigation. Lower operating pressures and flow rates result in reduced

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energy costs. A higher degree of water control is attainable. Plants can be supplied with more precise amounts of water. Disease and insect damage is reduced because plant foliage stays dry.

Operating cost is usually reduced. Federations may continue during the irrigation process because rows between plants remain dry.

The automated control system consists of moisture sensors, analog to digital converter, microcontroller, Relay driver, solenoid control valves. The important parameters to be measured for automation of irrigation system are soil moisture.

The entire field is first divided into small sections such that each section should contain one moisture sensor.

These sensors are buried in the ground at required depth. Once the soil has reached desired moisture level the sensors send a signal to the micro controller to turn on the relays, which control the valves.

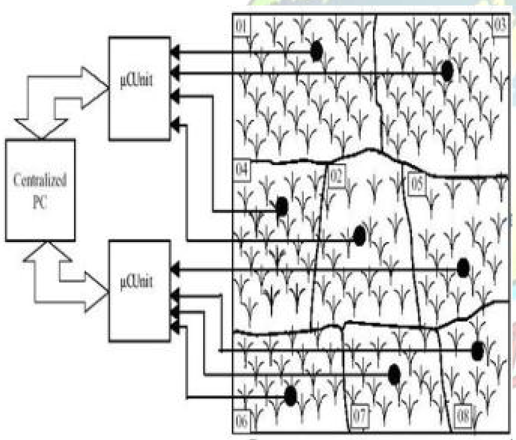

Fig: 1 Application of Smart Irrigation to Field

Soil moisture sensors are designed to estimate soil volumetric water content based on the dielectric constant (soil bulk permittivity) of the soil. The dielectric constant can be thought of as the soil's ability to transmit electricity. The dielectric constant of soil increases as the water content of the soil increases. This response is due to the fact that the dielectric constant of water is much larger than the other soil components, including air. Thus, measurement of the dielectric constant gives a predictable estimation of water content.

Bypass type soil moisture irrigation controllers use water content information from the sensor to either allow or bypass scheduled irrigation cycles on the irrigation timer. The microcontroller has an adjustable threshold setting and, if the soil water content exceeds that setting, the event is bypassed. The soil water content threshold is set by the user.

The required readings can be transferred to the Remote Computer via ZigBee for further analytical studies, through the serial port present on microcontroller unit. While applying the automation on large fields more than one such microcontroller units can be interfaced to the Centralized Computer the microcontroller unit has in-built timer in it, which operates parallel to sensor system. In case of sensor failure the timer turns off the valves after a threshold level of time, which may prevent the further disaster. The microcontroller unit may warn the pump failure or insufficient amount of water input with the help of flow meter.

The Microcontroller based irrigation system proves to be a real time feedback control system which monitors and controls all the activities of drip irrigation system efficiently.

The present proposal is a model to modernize the agriculture industries on a small scale with optimum expenditure. Using this system, one can save manpower, water to improve production and ultimately profit

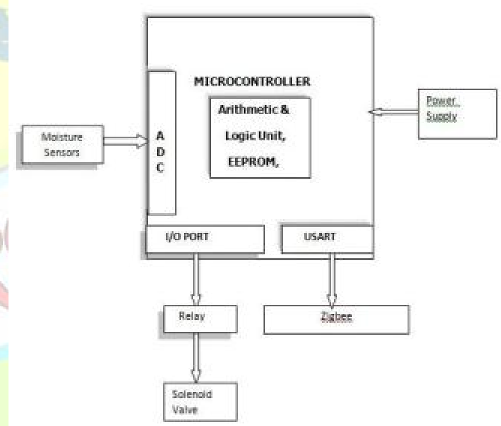

Fig: 2 Real Time Automated Irrigation System

3 Soil Moisture

Soil moisture is an important component in the atmospheric water cycle, both on a small agricultural scale and in large-scale modeling of land/atmosphere interaction. Vegetation and crops always depend more on the moisture available at root level than on precipitation occurrence. Water budgeting for irrigation planning, as well as the actual scheduling of irrigation action, requires local soil moisture information. Knowledge of the degree of soil wetness helps to forecast the risk of flash floods, or the occurrence of fog.

3.1 Soil Water content

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Soil water content is an expression of the mass or volume of water in the soil, while the soil water potential is an expression of the soil water energy status. The relation between content and potential is not universal and depends on the characteristics of the local soil, such as soil density and soil texture.The basic technique for measuring soil water content is the gravimetric method. Because this method is based on direct measurements, it is the standard with which all other methods are compared.Unfortunately; gravimetric sampling is destructive, rendering repeat measurements on the same soil sample impossible. Because of the difficulties of accurately measuring dry soil and water volumes, volumetric water contents are not usually determined directly.

3.2 Radiological Methods

Two different radiological methods are available for measuring soil water content. One is the widely used neutron scatter method, which is based on the interaction of high-energy (fast) neutrons and the nuclei of hydrogen atoms in the soil. The other method measures the attenuation of gamma rays as they pass through soil.Both methods use portable equipment for multiple measurements at permanent observation sites and require careful calibration, preferably with the soil in which the equipment is to be used.

Soil water dielectrics When a medium is placed in the electric field of a capacitor or waveguide, its influence on the electric forces in that field is expressed as the ratio between the forces in the medium and the forces which would exist in vacuum. This ratio, called permittivity or “dielectric constant”, is for liquid water about 20 times larger than that of average dry soil, because water molecules are permanent dipoles. The dielectric properties of ice, and of water bound to the soil matrix, are comparable to those of dry soil. Therefore, the volumetric content of free soil water can be determined from the dielectric characteristics of wet soil by reliable, fast, non- destructive measurement methods, without the potential hazards associated with radioactive devices. Moreover, such dielectric methods can be fully automated for data acquisition. At present, two methods which evaluate soil water dielectrics are commercially available and used extensively, namely time-domain reflectometry and frequency domain measurement.

3.3 Time-domain reflectometry

Time-domain reflectometry is a method which determines the dielectric constant of the soil by monitoring the travel of an electromagnetic pulse, which is launched along a waveguide formed by a pair of parallel rods embedded in the soil. The pulse is reflected at the end of the waveguide and its propagation velocity, which is inversely proportional to the square root of the dielectric constant, can be measured well by actual electronics.

3.4 Frequency Domain Measure

While time-domain reflectometry uses microwave frequencies in the gigahertz range, frequency domain sensors measure the dielectric constant at a single microwave megahertz frequency.

The microwave dielectric probe utilizes and open-ended coaxial cable and a single reflectometer at the probe tip to measure amplitude and phase at a particular frequency. Soil measurements are referenced to air, and are typically calibrated with dielectric blocks and/or liquids of known dielectric properties. One advantage of using liquids for calibration is that a perfect electrical contact between the probe tip and the material can be maintained (Jackson, 1990).

As a single, small probe tip is used, only a small volume of soil is ever evaluated, and soil contact is therefore critical.

3.4 Resistance block

Electrical resistance blocks, although insensitive to water potentials in the wet range, are excellent companions to the tensiometer. They consist of electrodes encased in some type of porous material that within about two days will reach a quasi-equilibrium state with the soil. The most common block materials are nylon fabric, fiber glass and gypsum, with a working range of about –50 kPa (for nylon) or 100 kPa (for gypsum) up to –1 500 kPa. Typical block sizes are 4 cm × 4 cm × 1 cm. Gypsum blocks last a few years, but less in very wet or saline soil (Perrier and Marsh, 1958). This method determines water potential as a function of electrical resistance, measured with an alternating current bridge (usually 1000 Hz) because direct current gives polarization effects. However, resistance decreases if soil is saline, falsely indicating a wetter soil. Gypsum blocks are less sensitive to soil saltiness effects because the electrodes are consistently exposed to a saturated solution of calcium sulphate. The output of gypsum blocks must be corrected for temperature (Aggelides and Londra, 1998).

Because resistance blocks do not protrude above the ground, they are excellent for semi- permanent agricultural networks of water potential profiles, if installation is careful and systematic (WMO, 2001). When installing the resistance blocks it is best to dig a small trench for the lead wires before preparing the hole for the blocks, in order to minimize water movement along the wires to the blocks. A possible field problem is that shrinking and swelling soil may break contact with the blocks. On the other hand, resistance blocks do not affect the distribution of plant roots. Resistance blocks are relatively inexpensive. However, they need to be calibrated individually.

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This is generally accomplished by calibrating the sensors for maximum point and minimum points of the range. Unfortunately, the resistance is less on a drying curve than on a wetting curve, thus generating hysteresis errors in the field because resistance blocks are slow to equilibrate with varying soil wetness (Tanner and Hanks, 1952). As resistance- block calibration curves change with time, they need to be calibrated before installation and to be checked regularly afterwards, either in the laboratory or in the field. This last method mentioned was the one we have used in this project. We picked it for feasibility and fairly accurate readings that the sensors provided. Let us look at the construction of the sensor.

Technically a resistance blocks measures soil water tension. When the soil is dry it is not possible for electricity to pass between the probes, essentially making the probe an insulator with infinite resistance.

As water is added to the soil more electrons can pass between the probes effectively reducing the amount of resistance between the problems to the point when it is fully saturated where the probe has virtually zero resistance.By using this range of values you can determine the amount of water than exists in your soil.

3.5 Making of the Soil Moisture Sensor

Parts:
1. A pair of 5 inch nails.
2. A block of wood (2 inch by 2 inch by 1 inch in length width and height)
3. Insulation Tape
4. Soldering Iron
5. Signal processing board.
6. Connecting Wires

The steps involved in the construction are as follows:
Prepare 4 blocks (for 4 sensors) of wood.
1. Drill two holes through each block of wood, for the nails to go through. These holes must be at a constant distance from one another for all blocks. (The distance used was 1 inch)

2. Insert the nails through the holes.

3. Insulate the exposed part of the nails from top to bottom leaving a certain length of nail exposed at the bottom. This length that is left insulated will act as the probes. This length must be common to all nails. The length also determines the depth of soil which is tested for soil moisture.

4. Solder connecting wires onto the top of the nails.

5. Take leads from the signal processing board and connect it to the sensor via these connecting wires.

6. (Optional) to make the wood water resistant, oil paint the blocks of wood.

The working of the sensor is simple and straightforward. The probes (the 5 inch nails) will be connected to the signal processing board via the soldering at the top of the nails as shown in the figure. The resistance of the soil between the probes changes with changes in soil moisture content. The signal processing board basically consists of a voltage divider circuit as shown below.

With increasing levels of soil moisture, the voltage output between the probes will decrease. By tabulating the output voltage values for different levels of soil moisture, we can calibrate the sensors. The table below shows the tabulated values for the following values of resistance and capacitance in the signal processing board.

The calibration of all sensors was done at room temperature (28 degrees Celsius). The power supply to the sensors was 5.07 volts.

R=50 KΩ VARIABLE (POTENTIOMETER)

C=220μF

Soil Moisture Level in ml	Sensor 1 Output (V)	Sensor 2 Output (V)	Sensor 3 Output (V)	Sensor 4 Output (V)
0	4.6	4.59	4.6	4.62
50	4.6	4.55	4.58	4.62
100	4.35	4.44	4.35	4.5
150	4.2	4.25	4.27	4.3
200	3.8	3.75	3.8	3.9
300	2.9	2.83	2.82	2.9
400	2.56	2.63	2.45	2.60
500	2.18	2.13	2.35	2.15
800	1.7	1.7	1.7	1.7

Table: 1 Calibration of the Sensors

The key elements that can be considered while designing an advanced mechanical model are:
i) Flow: -You can measure the output of your water supply with a one or five gallon bucket and a stopwatch. Time how long it takes to fill the bucket and use that number to calculate how much water is available per hour. Gallons per minute x, 60=number of gallons per hour.
ii) Pressure (The force pushing the flow): -Most products operate best between 20 and 40 pounds of pressure. Normal household pressure is 40-50 pounds.
iii) Water Supply & Quality: - City and well water are easy to filter for drip irrigation systems. Pond, ditch and some

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well water have special filtering needs. The quality and source of water will dictate the type of filter necessary for your system. .

iv) Soil Type and Root Structure: – The soil type will dictate how a regular drip of water on one spot will spread. Sandy soil requires closer emitter spacing as water percolates vertically at a fast rate and slower horizontally. With a clay soil water tends to spread horizontally, giving a wide distribution pattern. Emitters can be spaced further apart with clay type soil. A loamy type soil will produce a more even percolation dispersion of water. Deep-rooted plants can handle a wider spacing of emitters, while shallow rooted plants are most efficiently watered slowly (low gap emitters) with emitters spaced close together. On clay soil or on a hillside, short cycles repeated frequently work best. On sandy soil, applying water with higher gap emitters lets the water spread out horizontally better than a low gap emitter.

v) Elevation: - Variations in elevation can cause a change in water pressure within the system. Pressure changes by one pound for every 2.3 foot change in elevation.Pressure-compensating emitters are designed to work in areas with large changes in elevation.

vi) Timing: - Watering in a regular scheduled cycle is essential. On clay soil or hillsides, short cycles repeated frequently work best to prevent runoff, erosion and wasted water. In sandy soils, slow watering using low output emitters is recommended. Timers help prevent the too-dry/too- wet cycles that stress plants and retard their growth. They also allow for watering at optimum times such as early morning or late evening.

vii) Watering Needs: - Plants with different water needs may require their own watering circuits. For example, orchards that get watered weekly need a different circuit than a garden that gets watered daily. Plants that are drought tolerant will need to be watered differently than plants requiring a lot of water.

Having taken all these additional variables into account, we can design and implement a Smart Irrigation System for the growing needs of farmers in the future.

4 Conclusion

Usage of drip irrigation system is also a huge boost for later enhancements since it is the most sought after, when it comes to irrigation. Fertilizers can be applied through this type of system. This can result in a reduction of fertilizer and fertilizer costs. When compared with overhead sprinkler systems, drip irrigation leads to less soil and wind erosion. Drip irrigation can be applied under a wide range of field conditions.

As for the sensors, soil measurement techniques other than resistance blocks that are mentioned in this report can help improve the efficiency of the sensors. For e.g. if feasible, the neutron scattering method provides excellent readings. But it needs to be calibrated carefully with different frequencies. From a practical standpoint, an upgrade of sensor technique from resistance to dielectric is definitely feasible. The dielectric sensors provide a better range and more accurate values. Resistance blocks based sensors that have been used for this project are fairly accurate. Their major drawbacks are

1. Low resolution and hence limited use in research
2. Slow reaction time, i.e. when water is added, the sensor will take a while to arrive at the actual reading since it takes time for the water to seep through the soil.
3. Temperature dependant. With changes in temperature there must be a compensation provided via the variable resistance in the signal conditioning board.
4. The technique cannot be used to measure soil moisture around the saturation limits of the soil sample

With the use of dielectric technique based sensors, all these drawbacks can be overcome.

Using all the above mentioned changes, and any more that are realized with the help of ever growing technology, we can expect to have a smart irrigation system which simply needs a power up module via a remote PC with the following features:

1. Optimum soil moisture level sensor
2. Temperature, humidity and pressure compensations
3. Different water requirements for different types of soil
4. Different water requirements for different crops and seasons
5. Facility to add minerals and fertilizers to the soil as required

From the points mentioned above it is clear that a complete module of an upgraded smart irrigation system is a plausible and feasible enhancement option.

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