SMART IRRIGATION SYSTEM

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ABSTRACT

Decreasing the amount of water applied by residential irrigation systems without causing negative effects on turf grass quality is a challenge. A variety of technologies are available in the market that seeks to reduce irrigation water use .As water supplies become scarce and polluted, there is an urgent need to irrigate more efficiently in order to optimize water use. In this paper, we present a WSN based, smart home- irrigation system that consists of heterogeneous motes, special sensors and actuators. The treatments were: SMS an irrigation controller with a soil moisture sensor, (ET) an evapotranspiration based controller, (ED) a standard irrigation controller using seasonal runtimes based on historical climate data and Control) irrigation controller with no intervention. The system is fully adaptive not only to environmental conditions but also to the specific water needs that different plants may have. This way, it man- ages to perform efficient home irrigation, while it provides an IPv6-capable managing system.

***Keywords:* Evapotranspiration , Irrigation Controllers, Soil Moisture Sensor, Smart Watering, Wireless Sensor Network.**

I INTRODUCTON

Florida has sandy soils in many areas of the state resulting in poor water retention to meet plant water needs. During dry periods, there may not be enough rainfall to maintain acceptable landscape quality. Also, rainy periods have infrequent, high intensity rain events causing only a small portion of water to infiltrate and remain in the root zone while the rest is lost to deep percolation and runoff. Drought conditions can occur in as little as a few days without rain. Previous research has shown that homeowners using in-ground, automatic irrigation systems, typical in Florida, apply 47% more water for landscape irrigation than homeowners without automatic irrigation systems. This over-irrigation is largely due to a “set it and forget it” mentality despite seasonal fluctuations in plant water needs. Water agencies implementing water use efficiency programs have struggled to achieve quantifiable and reliable water savings. Historically, programs targeting landscape savings have focused on education pertaining to irrigation system maintenance, irrigation scheduling, and climate appropriate plantings. Although these efforts have garnered savings, much potential exists for further landscape irrigation efficiency improvements.

Irrigation scheduling can be done in a number of ways to allow proper irrigation of turf grass. Scheduling depends on the available water holding capacity of the soil, rooting depth effective rainfall and weather conditions including temperature, humidity, solar radiation and wind speed. Daily water replacement, fixed day irrigation, fixed amount irrigation, cycle start, percent-key change, soil water balance checkbook and historical ET override with rain sensor are some of the practical methods used for the purpose of scheduling irrigation . Smart irrigation technologies are regarded as a promising tool to achieve landscape water savings and reduce non-point source pollution. Application of smart irrigation controllers in an automated irrigation system has become a new trend in turf industry. There are numerous smart irrigation control manufacturers which already exist or are emerging in the marketplace. The Smart Water Application Technology (SWAT) committee of the Irrigation Association defines 'Smart controllers' as those technologies that

"*Estimate or measure depletion of available plant soil moisture in order to operate an irrigation system along with replenishment of water as needed while minimizing excess water use. A properly programmed smart controller requires initial site specific set-up and will make irrigation schedule adjustments, including run times and required cycles, throughout the irrigation season without human intervention*."

Basically smart irrigation controllers are irrigation clocks that adjust irrigation according to the changes in the environment. With the variation in environment there is a change in the plant water requirements which is updated by the smart irrigation controller. So for example a weather based smart controller will automatically reduce the watering times as the temperature gets cooler and increases watering time as the temperature increases. SMART Controllers can be divided into two categories- Soil Moisture Sensor (SMS) based controllers and Evapotranspiration (ET) Controllers. SMS controllers use information on the amount of water in the soil to regulate irrigation while ET controllers use weather data to estimate turf water use and replace water lost to evapotranspiration. The concept of using weather-based information to schedule irrigations of turf grass and other landscape plants is not new, but transferring this technology to the homeowner is new. In a residential irrigation based study in Florida, the soil moisture sensor treatment applied 7 mm of mean water depth per week while the control group without any sensor applied 15 mm of mean water depth per week.

II EVAPOTRANSPIRATION

The water requirement of plants can be determined from a balance of water inputs and outputs to the root zone and is called a soil water balance (Figure 1). Rainfall and irrigation enter the root zone as inputs. A shallow water table could also provide water for plant needs through capillary action. Water exits the soil and plant system from runoff, deep percolation, evaporation, and transpiration; these are considered outputs from the soil water balance. Evaporation is the loss of water to the atmosphere from the soil surface and transpiration is the loss of water from respiration of the plants. When calculating the soil water balance, evaporation and transpiration are combined into one term called evapotranspiration (ET).

The first consideration when selecting an ET-based irrigation controller is the financial capital costs of some of the systems. Do-it-yourself ET irrigation systems require no additional up-front costs, but may require more capital with time, as effort must be given to obtaining ET data and updating the irrigation timer. Smart ET controllers, which use automated features for modifying ET, cost about $500 to install but require less effort over time because they automatically update their irrigation schedule.

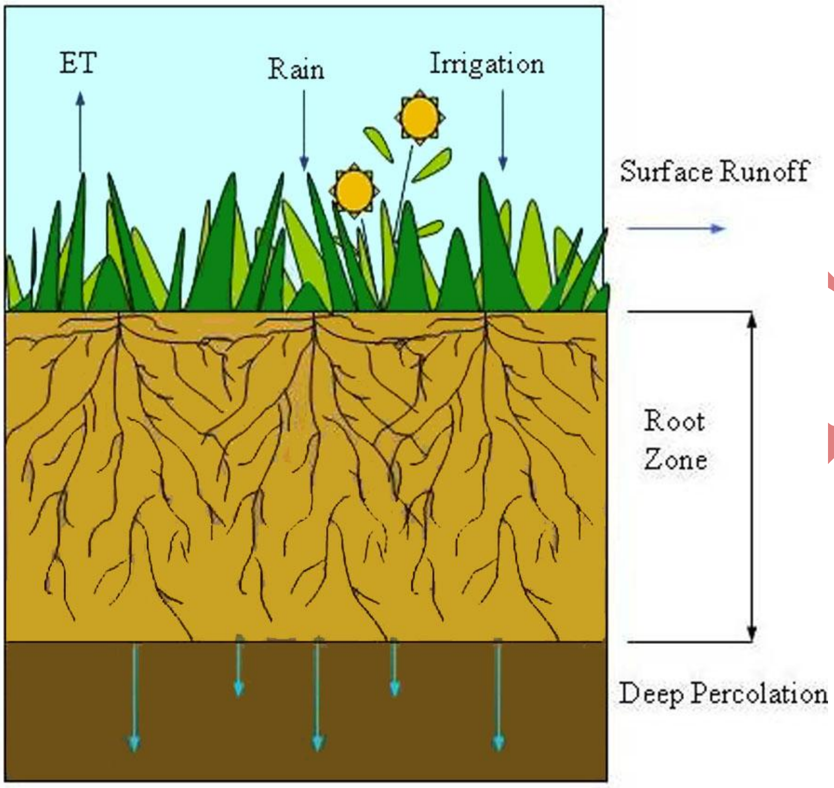

Fig1. Water-based inputs and outputs occur in the root zone of a plant assuming well drained conditions without a shallow water table.

If a smart ET controller is selected as the ideal choice, another decision must be made: smart ET controllers may be fully automated such that real-time updates are received through an annual subscription service (signal based technology) ($50/year) or may be connected to onsite weather sensors.

2.1. Calculation of Evapotranspiration

Reference evapotranspiration (ETO) is defined as ET from a reference surface using grass at a 0.12 m height that is adequately-watered, actively growing, completely covering the soil, and with a fixed surface resistance. The ASCE standardized reference evapotranspiration equation is considered the standard for ET calculations and is commonly used to calculate ETO as seen in Equation 1. This equation is used for daily ETO calculations and is based on wind speed, temperature, relative humidity, and solar radiation. (Figure 3). Plant ET (ETC) is defined as ET applicable to a specific plant other than the reference crop. ETC can be calculated for a specific plant material by applying a crop coefficient (KC), using the following equation. Crop coefficients can be found in a number of references depending on the specific crop, horticultural practices, and geographical location.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{C_n}{T + 273}(e_s - e_a)u_2}{\Delta + \gamma(1 + C_d u_2)}$$

Equation 1. ASCE standardized reference evapotranspiration equation.

The variables used in the ASCE standardized reference evapotranspiration equation are:

ET_0= Reference ET (mm/day)

R_n=Net radiation (MJ/m^2/day)

G=Heat flux (MJ/m^2/day)

U_2=Wind speed (m/s)

T= Temperature(^oC)

Δ= Vap or pressure (kPa/^0C)

e_s= saturation vap or pressure (kPa)

e_a= actual vap or pressure (kpa)

C_n= Constant(900)

C_d= Constant(0.34)

This equation is used to calculate ET loss for a specific crop or plant from reference ET using a crop Coefficient.

$ET_C = K_C \times ET_0$

Where, ET_C = Crop evapotranspiration (in/day)

K_C = Crop coefficient

III IRRIGATION CONTROLLER

A large part of our household water use goes to watering our landscape and many households rely on automatic in-ground irrigation systems to accomplish this. One of the most important components of an automatic in-ground irrigation system is the irrigation controller (also called a timer or clock). The controller turns the automated irrigation system on and off at the times you select. In other words, the controller controls the irrigation system and you control the controller. Having a controller with certain minimum performance capabilities is vital to efficient watering. The right controller, properly scheduled, can result in significant water savings and lower water bills. While controllers come in all types of shapes and sizes, the most important features are how well they can be programmed to handle diverse landscape and weather conditions.

An automatic in-ground irrigation system is a collection of pipes, tubing, valves, sprinkler heads, and circuitry used to irrigate a landscape. Automatic valves (also called stations or zones), which control the flow of water to different parts of the landscape, open and shut upon a signal from the controller. For example, there may be one valve that controls the water flow to some groundcover, another valve for some shrubs and another valve for the lawn. Once programmed, the controller determines when, how often, and how long each valve is open. It controls how much water goes where and when in your landscape based upon your instructions. The more programming flexibility the controller has, the more efficiently water can be applied to the landscape.

Besides obtaining an irrigation controller with the recommended features, there are other irrigation components that should be used with irrigation systems to save additional water. Control valves control the flow of water to different parts of the landscape and are used for the separate watering of plants with different watering needs. Check valves can be installed in sprinkler heads to prevent water from draining out of the irrigation line when the water is turned off and are most useful on sloped landscapes. Rain shutoff devices can be wired to a controller to shut off the system when it is raining. Moisture sensors can be wired to control valves to override the call for water if they "sense" that enough moisture is already present in the soil. Moisture sensors, therefore, "monitor" the irrigation schedule for over watering. Drip or bubbler irrigation can be used to irrigate slowly and minimize or eliminate evaporation, runoff and overspray. Finally, low precipitation spray, stream, and sprinkler heads with matching precipitation rates can dramatically improve efficiency that automatic irrigation systems, if not properly managed, can waste a lot of water."

IV SOIL MOISTURE SENSOR

Most 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. For more information on soil moisture sensors. 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 (Figures 1).The SMS controller 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. Another type of control technique with SMS devices is "on-demand" where the controller initiates irrigation at a low threshold. Simplified diagram showing how a soil moisture sensor (SMS) is typically connected to an automated irrigation system. The irrigation timer is connected to a solenoid valve through a hot and a common wire. The common wire is spliced with the SMS system (a controller that acts as a switch, and a sensor buried in the root zone that estimates the soil water content). As shown in fig 2.

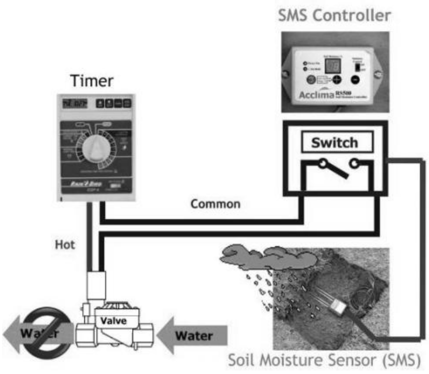

Fig 2:. Soil moisture sensor

The SMS takes a reading of the amount of water in the soil and the SMS controller uses that information to open or close the switch. If the soil water content is below the threshold established by the user, the controller will close the switch, allowing power from the timer to reach the irrigation valve and trigger irrigation. In this example the controller opens the switch, bypassing irrigation, because of rainfall wetting the soil around the soil moisture sensor.

V SMART WATERING

In an effort to set an industry conservation standard, the Irrigation Association (IA) has organized the Smart Water Application Technologies (SWAT) initiative. This initiative functions as a partnership among water providers, the irrigation industry, and other related organizations with constituents from public entities and private companies. The first products for which testing protocols have been developed are for climatologically based irrigation control products. The current climatologically based testing protocol was approved in September 2008 and has been implemented for testing. The current draft soil moisture sensor calibration protocol was released for public review in August 2011. This testing protocol combines Phase 1 and Phase 2 testing protocols into one testing protocol. Appropriate comments from the 30-day public comment period for have been incorporated into, which will now be the testing protocol for soil moisture sensors and soil moisture-based controllers.

The purpose of the testing is to evaluate the ability of a device to adequately and efficiently irrigate the virtual landscape without over watering. Although actual irrigation does not occur, the test measures the irrigation quantities prescribed by the device for six different zones with varying site conditions (soil and plant types, ground slope, sun/shade, irrigation system, etc.) The test duration is for 30 consecutive days with total minimum rainfall and evapotranspiration (ET) of 0.4 and 2.5 inches, respectively.

VI WIRELESS SENSOR NETWORKS

Wireless Sensor Networks consist a crucial part of the Future Internet. Thus, they will play an important role in our everyday life in years to come. The applications of WSNs range from distributed monitoring systems to smart embedded managing systems. As water supplies become scarce and polluted, there is a dire need to irrigate more efficiently in order to optimize water use. Recent advances in soil water monitoring combined with the growing popularity of Wire- less Sensor Networks make the commercial use of such systems applicable not only to agriculture and industry but to homes as well.

To date, typical irrigation automations include electromechanical programmers that can control the watering procedure. These systems are programmed to irrigate at regular time intervals for reddened periods of time; e.g. once a day for half an hour. The programming of these automated systems is heuristically based on experience and is poorly adaptable to changes in weather conditions, as well as the existence of different water needs by di_erent kind of plants. As a result, water resources are poorly used, plantation is over- or under-irrigated and increased costs of garden maintenance are introduced. Furthermore, the use of Wireless Sensor Networks gives watering systems monitoring as well as remote management capabilities. With sensor motes being IPv6 capable, they can be represented as resources in a Restful architecture, thus allowing remote access and control to the system (e.g. via Android devices).

VII CONCLUSION AND FUTURE WORK

In this paper we presented the architecture and the implementation of a smart home irrigation system. The system consists of two types of sensors motes (TelosB and IRIS), special soil humidity sensors, that are mote-driven with the use of relays and a Java application that is used for data collection. Performance evaluation showed that our system manages to maintain soil humidity levels regardless of external factors (i.e. variations at temperature and sunlight). It also proved that the system is aware of the different watering needs each.

In future work, we plan to use solar panels along with rechargeable batteries in order to make our system self sustainable in terms of energy consumption. We also plan to in- corporate to our system the ability to be managed remotely. This will be done by representing sensor motes as resources in a Restful architecture, thus allowing to access and control the system with the use of web-services (e.g. via An- droid smart-phones).

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