Distributed Sensing System Model for Future Internet Agricultural Application

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1 RESEARCH PROBLEM

To assist the irrigation process is necessary to ensure the amount of water that we supply to the plants is on the correct amount. To achieve this we need to use reliable measuring systems for water amount but also the amount of chemical agents, like fertilizers, that contribute to the grow of the plants and also to the pollution of rivers and water supplies.

Distributed Sensing System Model allows continuous measurements over time and is based on unattended wireless sensors capable of measuring the parameters of interest, and all this information will then be sent to and stored at a central monitoring station.

Although there is a great number of sensors that measure with different techniques, the amount of water in the soils, the DSS System Model uses the Multi-functional Heat Pulse Probe (Valente, 2006) developed by António Valente in order to obtain not only the soil water content, but also, the electrical conductivity (EC - as a measure of total nutrients), soil thermal properties (temperature, thermal conductivity, heat capacity, and thermal diffusivity – as a measure of how energy is partitioned in the soil profile), water flux , and environmental temperature at the surface.

2 OUTLINE OF OBJECTIVES

The DSS System Model needs to be cost-effective, as less intrusive as possible and include a reliable data communications system that allows data collection from sensors monitoring the crops, land, and environment. Towards this goal, a non-intrusive approach is to use low-cost wireless sensors buried underground, which form a so-called Wireless Underground Sensor Network (WUSN), together with a Wireless Aboveground Sensor Network (WASN) capable of sensing and transporting data towards the central monitoring station.

The development of Wireless Sensor Technology (WST) applications in precision agriculture makes possible to increase efficiency, productivity and profitability while minimizing unintended impacts on wildlife and the environment, in many agricultural production systems.

Real time information from fields provides solid bases for farmers to adjust strategies and take decisions.

3 STATE OF THE ART

Agriculture is one of the most ancient activities of man and unless real and immediate solutions are found for specific problems or for improving production and quality is difficult to introduce innovation and technology. Nevertheless the use of information from the environment, especially when we speak about precision agriculture, where the development of wireless sensor networks and technology made possible some increases on productivity and profitability while minimizing unintended impacts on wildlife and the environment, in many agricultural production systems.

Therefore the implementation today, of a DDS system capable of monitoring a wide range of crops and lands and collecting information, such as soil water content, electrical conductivity (EC - as a measure of total nutrients), soil thermal properties (temperature, thermal conductivity, heat capacity, and thermal diffusivity – as a measure of how energy is partitioned in the soil profile), water flux, and environmental temperature at the surface, is accept by the framers because they understand the benefits of this systems based on the understanding of minimum cost versus increase of efficiency, productivity and profitability.

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In fact the first adopters, in 1994, found precision agriculture to be unprofitable. Moreover they found the instances of implementation of precision agriculture were few and far between. Further, the high initial investment in the form of electronic equipment for sensing and communication meant that only large farms could afford it. But over the last decade the advancement in sensing and communication technologies has significantly brought down the cost of deployment and running of a feasible precision agriculture framework. The development of new electronic low cost sensing probes (Valente,2006), and the emerging wireless technologies with low power needs and low data rate capabilities, which perfectly suites precision agriculture (Wang, 2006), completely transform this reality making today precision agriculture possible to any pocket.

Examples like Montepaldi vineyard where since 2005 a test pilot has been deployed and a commercial system "VineSense" developed by (Davide Di Palma, 2010), or the automated fertilizer applicator for tree crops developed by (Cugati et al., 2003) where an input module for GPS and 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. Data communications among the modules were established using a Bluetooth network.

USDA research group lead by Evans and Bergman (Evans, 2007) study a precision irrigation control of self-propelled, linear-move and center-pivot irrigation systems. Wireless sensors were used in the system to assist irrigation scheduling using combined on-site weather data, remotely sensed data and grower preferences.

A soil moisture sensor network for monitoring soil water content changes at high spatial and temporal scale has develop by the Institute Of Chemistry And Dynamics Of The Geosphere (ICDG, 2014).

A wireless infrared thermometer system for in-field data collection develop by Mahan and Wanjura (Mahan, 2004) with infrared sensors, programmable logic controllers and low power radio transceivers to collect data in the field and transmit it to a remote receiver outside the field.

4 METHODOLOGY

This PhD work will consider the design and implementation of a Distributed Sensing System (DSS) capable of monitoring a wide range of crops and lands and collecting information such as soil water content, electrical conductivity (EC - as a measure of total nutrients), soil thermal properties (temperature, thermal conductivity, heat capacity, and thermal diffusivity – as a measure of how energy is partitioned in the soil profile), water flux, and environmental temperature at the surface. The DSS system will use the Multi-functional Heat Pulse Probe (Valente, 2006), developed by António Valente. This information will then be sent to and stored at a central monitoring station. The DSS will be based on unattended wireless sensors capable of measuring the parameters of interest, including aboveground and underground. The DSS needs to be cost-effective, as less intrusive as possible, and include a reliable data communications system that allows data collection from sensors monitoring the crops, land, and environment. Towards this goal, a non-intrusive approach is to use low-cost wireless sensors buried underground, which form a so-called Wireless Underground Sensor Network (WUSN), together with a Wireless Aboveground Sensor Network (WASN) capable of sensing and transporting data towards the central monitoring station. In order to fulfill these requirements three major design options will be considered:

1) the use of commercial off-the-shelf and low-cost devices;
2) the use of open communications technologies supporting adaptive modulation-coding techniques and energy-efficiency mechanisms and multi-hop routing;
3) a three-tier integrated and open IP-based communications architecture.

The first-tier will be defined by the Wireless Underground Sensor Network (WUSN) formed by a set of nodes (sensor nodes with Multi-Functional Heat Pulse Sensors), buried underground, which are connected to one or more aboveground nodes. Underground sensors may communicate using technologies such as IEEE 802.11g/n/ah and IEEE 802.15.4/g/m. The use of the 433 MHz and 868 MHz bands will be considered to provide underground-to-aboveground long range communications. The underground sensors will send data to the central monitoring station through the second-tier.

The second-tier will be defined by the Wireless Aboveground Sensor Network (WASN) supported by standard wireless technologies, e.g., IEEE 802.11n/ac/af, together with existing mesh routing protocols. Each WASN node will be in charge of relaying the data generated by the WUSN nodes connected to it, as well as the data generated by the local sensors, towards the ground central station. The use of the 433 MHz and 868 MHz bands will also be considered, which together with wireless multi-hop communications, will enable long range communications and ensure the coverage of wide distances. The third-tier will be defined by a reliable sensing infrastructure deployed on top of the less reliable node to node communication layers defined by the first and second tiers, by taking advantage of in-network distributed aggregation protocols. This approach will allow operating over the less reliable WUSN and WASN with a reduction on the amount of data transmitted via information aggregation, processing, and compression in each intermediate node. Several of these protocols can also deliver reliable communication and continuous monitoring, by building a reliable layer and transforming the data to make it resilient to retransmission, data loss, and data duplication.

5 CHALENGES OF THE IMPLEMENTATION SITE

The layout of hillside vineyards in the Douro Region is strongly conditioned by the original slope and relief of the parcels of vines. Also, the soil is mainly based on complex schist which imposes some constrains in the assessment of its hydrological aspects. The unique characteristics of these vineyards, as well as the topographic aspects, erosion control, vertical planting, the intrinsic limited water availability, and wide temperature span across all day and year. Distributed Sensor System monitoring and information processing can help in understanding vineyard variability and therefore how it might be managed, thus improving the quantity and quality of the wines.

A feasibly ZigBee based remote sensing network, intended for precision viticulture has shown by Morais et al. The network nodes were powered by batteries that are recharged with energy harvested from the environment (Morais, 2010).

Figure 1 shows the implementation of an in-field data acquisition network.

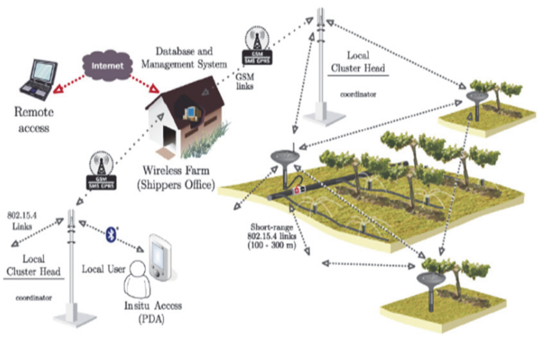

Figure 1: Implementation of an in-field data acquisition network.

The implementation site is a precision viticulture environment of “Quinta do Castro”.

To achieve maximum flexibility, the system should recharge its batteries using energy harvested from the surrounding environment, from up to three sources (photonic energy, kinetic energy from moving water in irrigation pipes and from wind), avoiding maintenance and human interference.

The DSS platform incorporates information from remote sensing, from in situ weather conditions, from water source levels, from soil history, and from farmer knowledge about the relative productivity of selected “Management Zones” of the vineyard, can be applied, for instance, to predict yield and diseases, and to disseminate advice throughout the growing season about the optimum usage of water and the chemical treatments needed.

6 SENSORS HARDWARE

The sensor nodes hardware is based on the multi-functional probe (MFP) schematically represented in Figure 2.

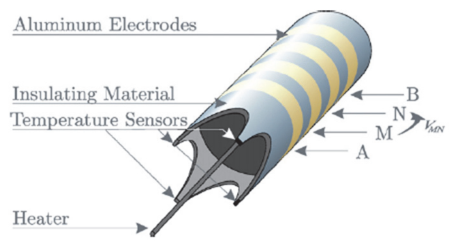

Figure 2: Multi-functional probe (Valente, 2006).

The MFP consists of one central heater needle and four surrounding thermistors, as reported by Mori et al., (2003). The needles are made from stainless steel tubing, 0.912m min diameter, protruding 40mm beyond the edge of the PVC mounting. Spacing between the heater and temperature sensors is about 8.5 mm. The heater was made from enameled Stablohm 800A wire (0.062mm in diameter and 440.8 Ω m−1 of resistivity), which was inserted in the heater needle. The heater resistance was 100 (heater resistivity of 2010 Ω m−1). The needle is then filled with high thermal-conductivity epoxy glue to obtain water resistant and electrically insulated heater.

The Wenner array is formed by four aluminium ring electrodes equally spaced with 3mm separation. The outer electrodes (denoted as A and B in Figure 2) provide for an alternated current source (1mA peak-to-peak and 100 Hz frequency), whereas the potential difference is measured across the two inner electrodes (M and N).

The overall system, including battery, fits in a cylinder with 21.4mm in diameter and approximately 50mm long.

Figure 3 shows the MFP probe before installation.

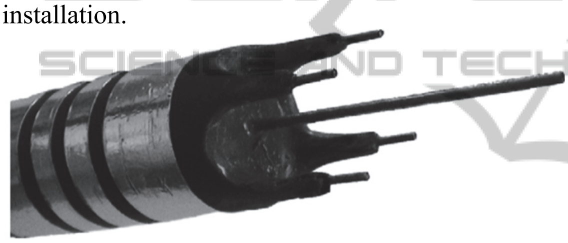

Figure 3: Multi-functional probe (Valente, 2006).

For temperature measurements, four thermistors are used where an excitation current of 200 µA is used. This excitation current flows directly through the thermistor generating a voltage across the thermistor proportional to its resistance.

For the heat pulse, a voltage (VHP = 24 V) is applied to the heater (RHEATER = 100Ω) 3. The control is made by turning on the transistor Q1 switch for 8 s and then off for 900 s. The accuracy of q’ in Eq. (1) is very important for the ΔT determination. The power dissipated per unit length of heater needle, q’ is then calculated as,

$$q' = I_h^2 \mathrm{R_m} \tag{1}$$

where Ih (A) is the current through the heater and Rm (Ωm−1) is the resistance per unit length of the heater wire. If the values of Ih and Rm are accurate, this calculation gives an accurate value for q’. This requires a voltage measurement of the voltage drop across a current-sensing resistor, VRSENS.

Electrical conductivity measurements are performed using a Wenner array where a alternated current (1mA peak-to-peak and 100 Hz frequency) is applied to the outer electrodes, whereas the voltage across the inner electrodes is measured. To efficiently measure the electrical conductivity, an integrated sinusoidal current source is needed due to interactions between the capacitive (dielectric) and conductive behaviors of soils (Zhang, 2004). Most sine current generators are based on a direct digital synthesizer (DDS), which requires a read-only memory (ROM) sine look-up table and a current mode digital-to-analog converter (DAC). This solution requires a large integration area since waveform generation is closely related to the ROM size and the DAC resolution. Instead of using such approach, a set of precisely scaled current mirrors can be used to produce sine steps (Donfack, 2000). Sizes of individual current mirror transistors have been calculated according to sine wave values. The current increments, Δ sin(αi), after sin(αi−1) are given by:

$$\begin{cases} \Delta \sin(\alpha_i) = \sin(\alpha_i) - \sin(\alpha_{i-1}) & \text{for } i \in \{1, 2, 3, 4, 5, 6\}; \\ \Delta \sin(\alpha_0) = \sin(\alpha_0) \end{cases} \tag{2}$$

The voltage drop at the inner electrodes of the Wenner array is measured using two peak detectors for amplitude measurement. These are used to detect and hold the minimum and the maximum values of the signal. Due to the switching action of the excitation circuit, a first-order gm-C filter is used before the peak detectors.

7 EXPECTED OUTCOME

The use of the proposed DDS System Model is expected to improve productivity and profitability of precision agriculture; with the present work we expect in the near future show that this model can provide the technology means to farms in order to achieve the minimum costs versus increases in efficiency.

The system must provide, with minimum intrusion and assistance, reliable communications and data collection from sensors monitoring the crops, land, and environment.

Provide real time information, from fields, for farmers to adjust strategies and take decisions.

8 STAGE OF THE RESEARCH

The research is on the initial stage with the implementation of the wireless sensors and testing of the communications.

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