System of microstations of data acquisition for wireless monitoring of the microclimate in crop areas

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Abstract. The weather is a key factor for outbreaks of plant diseases. Therefore, the monitoring of climate is essential to any intelligent system of cultivation. Usually, such monitoring is carried through agrometeorological stations that acquire data like temperature, humidity, wind speed and leaf wetness. Unfortunately, the high cost of stations limits the number of monitoring points within the same area. This forces the use of tools of mathematical interpolation. However, such procedure does not lead to good results in the estimation of precipitation and leaf wetness. In this work was developed a monitoring system, composed for a set of microstations of data acquisition. They presented low cost and highest autonomy. Therefore, they can be installed throughout the area of cultivation, collecting data like temperature and leaf wetness. The microstations communicate with each other through wireless communication. Thus, daily, the data collected are transferred to a central station, where become available for analysis. The system made it possible to monitor the entire area of cultivation, providing reliable data, which make it possible to characterize the microclimate. This makes it possible to, for example, the efficient use of pesticides, reducing production costs and generating healthy foods.

Keywords: ZigBee, meteorological stations, weather monitoring, precision farming.

Introduction

Tropical and subtropical plants are subject to diseases that are going to establish themselves depending on the environmental conditions. The meteorological variables that define the favorable terms to the diseases appearance are the temperature, the rain and the air humidity. The temperature works like a catalyst, defining the infection speed. Then, the rain and the air humidity supply water, indispensable element to the spore germination.

Almost all the processes involved in the disease cycle depend strongly of the temperature (Bonde et al., 2007; Vale et al., 1996). There are different types of temperature sensors, some of them are of very low cost and are used with success in the agriculture, there a long time ago. Moreover, in spite of depending strongly of the altitude, the temperature can be easily estimated and interpolated to distant geographical areas. On the other hand, leaf wetness, variable that defines the water quantity in the plant surface, it varies a lot in a same region and is hard to of being interpolated. Thus, wetness assessment in several points of a geographical region is indispensable to estimate the favorability to pathogens infection. Especially, such information can be used, for example, for a more intelligent use of pesticides, through a warning system of diseases, increasing farmer’s profits and the food quality (Magarey, 2001).

The most efficient form of measuring leaf wetness is through electronic sensors. A meteorological station, installed in the region that intent do be monitored, collect and store leaf wetness data in electronic form. However, such stations usually are very expensive. So, the leaf wetness monitoring usually occurs in just some few points of the cultivation region. Not monitored regions need to be estimated for the leaf wetness, what can results little precision, mostly when are not consider the differences among micro-climate (Koyama, 2009).

Motivated by the aforesaid, it presents a low cost acquisition system of meteorological data, friendly and with wireless transmission to facilitate the data acquisition. The system is composite of a group of reduced scale meteorological station fed by battery and that do continuous acquisition of the temperature and leaf wetness, greatnesses that own great variation inside the cultivation area. Such stations should not be used separately. A central station should also do data acquisition of other important greatnesses, but that present little space variation, as, for example, wind speed and direction, relative humidity of the air, rain, etc. As well, at the present paper, it was described a wetness sensor based on capacitance sensors, different of the resistance sensors used at the other papers. It will be demonstrated that capacitance sensors present sensibility and larger exactness, besides presenting a much more lineal characteristic.
Proposed System

The type comb electronic sensor is used to measure leaf wetness in most cases. It is composite for two conductive wires, in a comb form, separated by insulating material (air, ink latex, etc). The Figure 1 presents a typical sensor type comb. As the sensor surface becomes wet, they change the electric characteristics of the region among conductors A and B. So, it can be read the sensor surface area that is wet, supplying the leaf wetness estimative.

![Figure 1: The comb type electronic sensor presenting a board (Substrato), conductive ways (Condutor A and Condutor B) simulating a wetness area (Superficie molhada).](image)

The capacitance is an electric property of the type comb sensor that depends on its wet area. If the sensor surface is covered by insulating varnish, its resistance is made constant and can be considered infinite. This way, the capacitance effect of the type comb sensor is the dominant and can be used to estimate the sensor surface wet area.

The type comb sensor capacitance modeling is not so evident. Because of this, in this work, the capacitance was modeled using the application Maxwell 2D to electromagnetic modeling of the company Ansoft.

The Figure 2(a) presents the type comb sensor modeled in a situation in which it is partially covered by water. It is possible to see the surface in which the gold footpaths of the sensor are assembled. As well, just part of the sensor surface is covered by water, while the remaining is in touch with the air. The Figure 2(b) shows the results of simulation for sensor electromagnetic characteristics. It realizes the electric field armature passing of a conductor for another. That is a typical situation found in capacitance components.

![Figure 2: (a) Modeled of a type comb sensor partially covered by water (água) and (b) result of simulation demonstrating the capacitance characteristics (see the text above).](image)

In the sensor simulation were considered two situations. In the first one, a constant area of the sensor surface was cover by a water layer, varying the height (h) of the layer. For each value of h, the sensor capacitance was retained. In this situation the capacitance was higher when the h value increased (Figure 3a). However, the increment was non-linear. This was an undesirable behavior. However, it can be minimized if the sensor surface was covered by ink latex. Sentelhas et al. (2004) described that an ink latex layer on the sensor makes its behavior looks like a leaf. Moreover, the ink latex absorbs the water, avoiding formation of not-uniform drops with exaggerated height.
Figure 3: Capacitance variation for the wetness sensor when the height of the water layer was variable (a) and when the height of the water layer was constant (b).

During second situation, the height of water layer was kept constant, while it varied the length of the region among conductors A and B of the sensor. Again, the corresponding variation in to capacitance was retained. A sensibility of 913.12 pF/mm and a linearity of 0.1 % was observed (Figure 3b), in other words, once the height of water layer can be considered constant, the sensor capacitance grows with the sensor area that is cover by water. Thus, it can express the leaf wetness, \( m \), in capacitance function, \( C_s \), as being

\[
m = k_1 C_s + k_2, \tag{1}
\]

where \( k_1 \) and \( k_2 \) are constant that should be determined via calibration.

Of (1), if it was assessed the capacitance in a comb type sensor, it will measure the leaf wetness. In this work, the capacitance was measure indirectly, through an implemented oscillator with the integrated circuit LM555, where the oscillation period was proportional to \( C_s \).

In this work, the sensor used in the temperature mensuration was LM92 from National Instruments, who owns a precision of ±0.33 oC and 12 resolution bits. Its interface is digital (protocol I2C), what allowed easy assessment without the influence of external bias to the system.

The blocks diagram of the developed system of data acquisition is presented in the Figure 4. It was used a microcontroller for data acquisition of temperature and for the wetness sensor. Low cost microcontrollers concentrate in an only integrated circuit most of the peripherics (timers, converters A/D, memory, I/O doors and communication) necessaries for data acquisition. In this work the microcontroller used was the MSP430F2013 of the Texas Instruments. Such microcontroller was chosen mostly by the low consumption (maximum of 220 uA to 1 MHz and 2.2 V), that enables larger autonomy to the system. As well, MSP430F2013 has a timer of 16 bits, allowing do acquisition of period oscillator of wetness sensor.

![Block diagram for the developed system](image-url)
The data were stored in a flash memory of 1 kbyte, external to microcontroller (chip 24AA08 of Microchip who also owns interface I2C). The data was saved every hour and corresponded of average values of sampling period. For each sensor were necessary 2 bytes for storage. The memory of 1 kbyte supplied autonomy for 10 days. The autonomy can be extended increasing the capacity of the external memory. For that, the changes in the system would be minimum.

When the system memory was full, the data were transmitted for a computer, for definitive storage. Because of this, the micro-stations system depends on an efficient data transmission method. The data of all micro-stations are centralized in an only location and are quickly available for analysis.

In this work, the wireless data transmission was made through a module XBee-PRO® from Digi International. This module allows send data using ZigBee protocol (Eady, 2007). It operates with low electric demand (transmission with 709,5 mW; reception with 181,5 mW and 33 uW in stand by) and work with cryptography of 128 bits to guarantee the data integrity (IEEE, 2003). The data reception was made using the board CON-USBBEE from Rogercom Company, compatible with the XBeepRO module. The CON-USBBEE was connected through the USB connector of the computer. In the computer, the data were received by a very simple program that stores the temperature and leaf wetness data in a text file, where these are available for analysis. As well, aiming to amplify the reach of data transmission, every micro-station works with a router, in other words, the signal transmitted by a micro-station is retransmitted by neighboring stations, so that it can reach a larger distance.

Experimental Results

The Figure 5 presents the wetness sensor. It was implemented as a board of printed circuit, where was used a varnish to eliminate the wetness influence in its electric resistance. Moreover, as described in the previous section, a latex layer on the sensor made the water spreads uniformly. In the accomplished tests, the oscillation frequency varied when the sensor is completely wet and completely dry.

The Figure 6 presents the agro-meteorological station developed yet without a water proof box. This way, few tests in field were done. The only tests in field conditions were made testing the wireless data transmission. The goal was to evaluate the maximum distance of data transmission. According to manufacturer's specifications, the module Xbee-PRO® can transmit data until a distance of 1.5 Km. However, in the tests, this distance was obtained only in a flat area, when there were not obstacles or water sources (rivers, lakes, etc). A typical cultivation region presents a great density of leaves among data transmission points and the distance transmission was limited to the order of 100 meters. That does not make unfeasible the system, just suggests that the antenna from data module transmission/reception should stay above of the foliages, in a height place, so the signal can propagate freely, without being obstructed by the vegetation.

Conclusions

The environmental variables are important factors for the agriculture. They could affect since the germination until the plantation harvest. For example, the temperature changes metabolism of beings' alive, while the leaf wetness can contribute for the plants infection, mostly for fungi. Using agro-meteorological stations the measurement of variables are desirable and important. Such stations contribute for the rational utilization of agricultural defensive, collaborating for the cultivation of more healthy food and the profits increase.

Figure 5: Wetness sensor comb type used for the tests.
Monitoring a great area needs a great number of agro-meteorological stations. The high cost of such stations does not allow monitoring in many points of the cultivation region. So, the data of the not monitored areas are estimate by mathematical interpolation, reducing the precision.

In this work, it was presented an acquisition system for the more influential variables in the plant diseases development: temperature and leaf wetness. The system is low cost and easy handling, making possible to increase the rationality in plant diseases control as, for example, the Asian soybean rust. The agro-meteorological data can be collected with higher precision because the stations can be installed in a larger number.

In the leaf wetness estimation, besides the higher use of resistance sensor of comb type, was verified that the capacitance sensor has larger sensibility, presenting linear answer. In this work, to accomplish the instrumentation of the capacitance sensor, it was used a circuit oscillator, in which the oscillation period was proportional to the capacitance.

The data acquisition from micro-stations through wire transmission lines was unfavorable for the project. They needed to have big length, complicating the cultivation. So, it was used wireless communication. It facilitates the installation of new stations and present low-cost (due to the transmission long wire lines absence).

The system development has, as main benefits, the low-cost, that enables its acquisition for little properties, allow to decrease the economic impacts caused by diseases in the cultivation, allow reduction in the costs of agricultural production (due to the rational use of pesticides) and allow production of more healthy food and decrease of the contamination of the natural resources.

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References
