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## Wireless information system for frost detection in orchards

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**Abstract:** Electronic devices have been increasingly used in agriculture in the last years. Electronic sensor devices are particularly interesting since they enable measurement of parameters which have a major impact on agricultural production. The use of electronic devices additionally came to the fore with the development of wireless communication that allows gathering timely information about the status of important parameters for vegetables and fruit crops. Frost occurrence poses a high risk to orchards especially in the flowering stage since low temperature can destroy flowers and therefore the overall yield of fruit. This paper presents a system for frost detection in orchards and creation of a database with parameter values significant for system users. The system is based on wireless sensor devices which use the GPRS network to send collected data to a WEB server where they are stored for further analysis. Also, a WEB application was created to enable data distribution to users.

**Key words:** frost protection, orchard, intelligent sensors, wireless sensor network, WEB server.

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## Introduction

Under continental climatic conditions characteristic of Serbia, frost is a common occurrence likely to cause significant losses in fruit crops due to low temperature damage. This problem is faced by fruit growers after the planting stage.

From the beginning of vegetation to the stage of fruit set there is a risk of freeze injury to unopened flowers, opened flowers and newly set fruits. Unopened flowers are vulnerable to frost damage at a temperature of  $-5$  to  $-8^{\circ}\text{C}$ , opened flowers experience freeze injury at temperatures up to  $-2^{\circ}\text{C}$ , and fruit set is affected by frost at temperatures from  $-1$  to  $+2^{\circ}\text{C}$ . The last of the three phases shows the highest sensitivity to temperature since fruit set occurs at the time of the year when higher temperatures are reached. These suitable temperature conditions are essential for fruit set, but problems may arise due to frost occurrence during the late night hours when a drop in temperature may lead to flower damage. Protective measures must be taken to save the fruit under these circumstances, and some of them include smoke clouds, heating air, temperature inversion, protection by water sprinkle or irrigation, artificial fogs.

Dense smoke curtains can be used to prevent heat transfer from the ground and increase temperature in the orchard by  $0.5^{\circ}\text{C}$  to  $1.5^{\circ}\text{C}$ . However, this method does not offer reliable protection against strong frosts. Machines equipped with oil or other fuel fired heaters are used to warm and spread the air. Air cooling in the orchard can be prevented through continuous addition of warm air by moving the machine across the orchard. Temperature inversion can be established by a giant ventilator which can push warm air in the orchard area and increase temperature by 2 or  $3^{\circ}\text{C}$ , which is quite enough for protection. Orchard frost protection can be performed by irrigation involving spraying flowers or set fruit with a mist of fine water drops when the temperature decreases below  $0^{\circ}\text{C}$  and throughout the period of this critical temperature. The method is based on an exothermic process, where turning water into a solid physical state is accompanied by the release of heat. Due to the low temperature, the water on the sprayed fruit quickly freezes, forming a protective crust on the surface, while the inner tissue remains unaffected by cold due to the release of heat. Using higher amounts of water, within certain limits, frost protection can be accomplished at a lower temperature, which can be hardly feasible with other methods. Spraying with water must begin at the right time when temperature drops to  $0^{\circ}\text{C}$  and must continue throughout the period of low temperature without interruption. The interruption of water spray in the orchard is unacceptable if it lasts longer than 3 to 4 minutes (Perry 1998, Sugar *et al.* 2003, Zaštita voćaka od mraza).

Methods of frost protection are best applied if fruit growers have information when to intervene and prevent frost killing of flowers in the orchard. This information can be obtained by small wireless devices deployed in orchards.

Wireless devices are equipped with temperature and other sensors; they communicate with the main device and transmit gathered data to a remote station. A wireless sensor network (WSN) obtained in this way can monitor microclimatic conditions in orchards and send current data for an appropriate action to be conducted, such as notifying fruit growers about approaching low temperature in the field. An automated WSN frost protection system was presented in Alboon *et al.* 2012 where sensor data were collected and sent to the controller using a solid fuel burner to produce an artificial cloud of smoke to maintain temperature in the orchard.

The WSN technology is widely used in precision agriculture for frost protection of vegetable or fruit crops (Valente *et al.* 2011, Ghobakhlou *et al.* 2009, Panchard *et al.* 2008, Shanmuganathan *et al.* 2008). Apart from frost prediction and automated reaction or sending notifications to system users, a WSN system can be used in making decisions about a potential orchard site. The aim of this work was to present wireless sensor devices that send data by a gateway node to a remote server. This system is easily implemented, it gathers sensor data and sends them using GPRS services of mobile operators to servers. Then, the data are analyzed and notification is sent to users when conditions reach a critical value.

## Results and Discussion

Wireless sensor devices were placed on two locations in the same orchard which had a large slope and, hence, a difference in altitude on the field. Another special circumstance occurring in the orchard was a small stream near the lower point. The use of the wireless devices and monitoring microclimatic conditions gave specific results showing a temperature difference between the two measuring points. Although there is no need for frost protection in the wide range, the small water stream is responsible for the lower temperature in its surrounding zone, and this part of the orchard requires some action from farmers in order to prevent total fruit loss.

The implementation of the wireless system in this case contributes to determining the zone with special microclimate conditions. This situation in the field leads to an additional requirement for fruit growers which was not taken into account. Experience in deploying wireless devices and gathering and processing data in this particular case can be mapped on a much larger area and used to assess a particular location for the most appropriate orchard site.

The frost detection system is composed of a number of mobile sensing stations capable of measuring temperature and relative air humidity (Figures 1 and 2). The stations are equipped with an SHT15 digital air temperature and relative air humidity sensor, which offers a small footprint and low power consumption for high precision and low sensor cost. Each sensor is individually

calibrated in a precision humidity chamber, which provides long term stability. Temperature is measured by a silicon bandgap sensor in the range from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  with an accuracy of  $\pm 0.3^{\circ}\text{C}$ . Relative air humidity is measured by a capacitive sensing sensor in the range from 0 to 100% with an accuracy of  $\pm 2\%$ . Sensors can be equipped with a protective membrane, which protects the sensor by preventing dirt and droplets from entering the sensor housing. Sensors are also equipped with a small heater which can be turned on in order to dry the sensor or test its functionality. Sensors are equipped with one time programmable memory which stores calibration data and with a digital I2C digital communication interface which reads air temperature and relative air humidity and issues commands by a microcontroller.

The digital microcontroller is the main component of the mobile sensing station responsible for overall control of mobile station functions. The microcontroller used in this station is based on a Telit GM862-GPS module, which controls the operation of the mobile sensing station using commands written in an Easy Python script. Apart from the microcontroller functions, it integrates a GSM/GPRS modem and a GPS receiver. The GSM/GPRS quad-band modem enables remote communication using the mobile network which is almost available worldwide. In addition to voice and SMS messages, the modem can communicate using Internet services through the GPRS service, such as HTTP, FTP and E-mail. This function enables simple interaction with users worldwide, using personal computers or smart telephones. The GPS receiver enables detection of a mobile station location, with a 2.5 m precision, using a 20-channel high sensitivity SiRFstarIII™ single-chip GPS receiver. Due to its low power consumption, the microcontroller is designed for battery powered operation with Lithium Ion or Lithium Polymer batteries, in the voltage range from 3.2 to 4.2V. In order to make mobile stations completely independent, they are equipped with photovoltaic solar cells which are used for recharging batteries. The use of solar energy power supply offers a cheap and reliable energy source, which requires no maintenance as does frequent battery replacement or any additional costs such as those associated with electricity used from a power distribution grid.

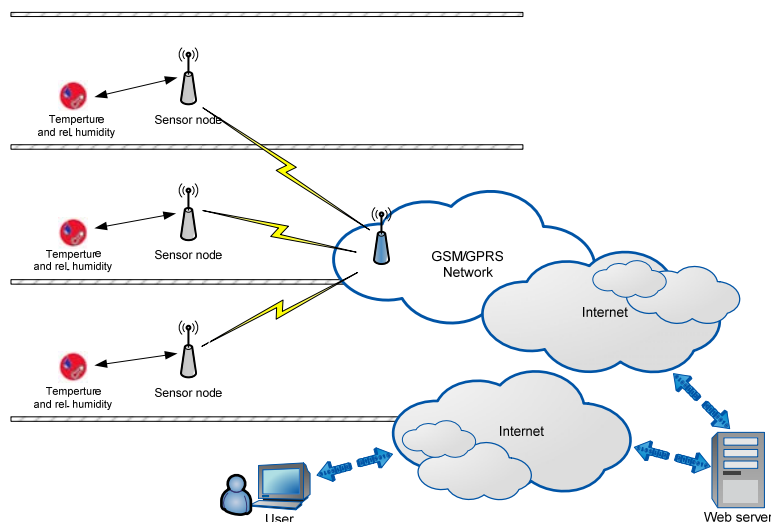


Figure 1. Wireless sensor stations placed in different zones

The mobile sensing station software, written in Python, first initializes the GPS service and tries to determine GPS coordinates of the mobile station. As a GPS fix is acquired, the station connects to the GPRS service, and registers at the web server reporting its identification number and the acquired GPS coordinates. After successful registration, the web server sends server time to the mobile station which presents its clock, in order to perform regular reports at certain instances in time (currently set to a 15 minute report interval). The microcontroller reads the measured air temperature and relative air humidity values from the SHT15 sensors and forms an HTTP GET request which is sent to the web server. Apart from these two values, the sensor reports a battery voltage level and the cycle ratio which is used for mobile station diagnostics. After successful transmission, the mobile station goes to the low power operating mode in order to preserve battery energy, and is woken up by the clock, at the start of another report interval.

The server side web application was developed using Java technology. The software application has three main parts: HTTP GET request parsing, application logic and presentation data. The role of the first segment of the software solution is to parse and accept data sent from mobile stations. It was realized with a servlet which has the ability to communicate by the HTTP protocol. The accepted data are stored to a database and used for further analysis. The application logic is used for data calculation and creating an array of data for web presentation to users. For decision making purposes, system users require some calculated values such as average or minimal and maximal values for a defined time period. The user can interact with Web applications through an appropriate user interface and set tasks to

the system according to their needs. Results of users requests are presented on the web page while stored data are processed in the background.

In addition to searching and analyzing data stored in the past, the web application has the ability to present current data in real time. The data last arriving from the field station are shown on the main page of the web application. Therefore, the user can monitor field conditions from any computer which has Internet access. The server side system can be upgraded with a web application customized for smart phones or with a module for sending SMS to users based on the set tasks.



Figure 2. Wireless sensor station in the orchard

### **Conclusion**

The development of new electronic devices, such as smart sensors, ensures the expansion of their use. One of the new fields of application of smart sensors is agriculture. This paper gives an example of using smart sensors and their networks to detect frost occurrence in orchards. Both the developed system and the conducted measurements show that frost occurrence can be detected successfully. The system enables detection of frost occurrence in orchards and memorizing the received data on the web server. Plans for further research include the implementation of a system for informing users about the occurrence of frost events and activation of adequate protection in the case of frost occurrence.

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### References

- Alboon A. S., Alqudah T. A., Al-Zoubi R. H., Athamneh A. A. 2012. Fully automated smart wireless frost prediction and protection system using a fuzzy logic controller. *Int. J. of Artificial Intelligence and Soft Computing*, **3**: 165 - 184.
- Časopis Voćarski Glasnik 2008, "Zaštita voćaka od mraza", *Časopis za savremeno voćarstvo*, Voćarski Glasnik br. 1.
- Ghobakhlou A., Shanmuganthan S., Sallis P. 2009. Wireless Sensor Networks for Climate Data Management Systems. *18<sup>th</sup> World IMACS / MODSIM Congress, Cairns, Australia*, 959-965.
- Panchard J., Rao S., Sheshshayee S. M., Papadimitratos P., Kumar S., Hubaux J-P. 2008. Wireless Sensor Networking For Rain-fed Farming Decision Support, *Proceedings of the second ACM SIGCOMM workshop on Networked systems for developing regions*, Seattle, WA, USA.
- Perry B. K. 1998. Basics of Frost and Freeze Protection for Horticultural Crops. *Hort Technology*, January-March 1998 8(1).
- Shanmuganathan S., Ghobakhlou A., Sallis P. 2008. Sensors for modeling the effects of climate change on grapevine growth and wine quality. *Proceeding of the 12th WSEAS International Conference on CIRCUITS Heraklion, Crete Island, Greece*, 315-321.
- Sugar D., Gold R., Lombard P. and Gardea A. 2003. In: *Oregon Viticulture, Strategies for frost protection*, Editor, E.W. Hellman, Oregon State University, pages 213-217.
- Valente J., Sanz D., Barrientos A., del Cerro J., Ribeiro A., Rossi C. 2011. An Air-Ground Wireless Sensor Network for Crop Monitoring. *Sensors*, **11**: 6088-6108.

## **BEŽIČNI INFORMACIONI SISTEM DETEKCIJE MRAZEVA U VOĆNJACIMA**

- originalni naučni rad -

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### **Rezime**

Poljoprivreda je postala jedna od oblasti u kojoj primena elektronskih uređaja dobija na intenzitetu. Posebno značajan aspekt primene obuhvata oblast merenja različitih parametara koji utiču na poljoprivrednu proizvodnju. Primena elektronskih uređaja u poljoprivredi dodatno je došla do izražaja sa razvojem bežičnih komunikacija, jer se na taj način omogućava pravovremena informacija o stanju parametara važnih, npr. za voćnjake, povrtnjake i dr. Pojava mraza predstavlja veliku opasnost za voćnjake posebno u fazi cvetanja, jer može doći do uništenja celokupnog roda. U ovom radu je prikazan sistem za detektovanje mraza u voćnjacima i formiranje baze podataka o intenzitetu mraza i vremenu kada je do njega došlo. Sistem je realizovan na bazi bežičnih senzora, koji prikupljene podatke putem GPRS mreže prosleđuju WEB serveru na kome se podaci upisuju u odgovarajuću bazu podataka. Realizovana je i odgovarajuća WEB aplikacija koja omogućava distribuciju zapamćenih podataka do krajnjeg korisnika.

**Ključne reči:** Mraz, voćnjak, inteligentni senzori, bežične senzorske mreže, WEB server