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Development of a prototype of telemetry system for monitoring the spraying operation in vineyards

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ABSTRACT

Modern technology and telecommunication systems enable precision field data to be acquired which improves agricultural operations management. The aim of this work was to develop and operate a prototype telemetry system suitable for winemakers to monitor the performance of their spraying operations in real-time, and to acquire useful data. The prototype telemetry system was composed of a tracking module for data acquisition, a server for remote monitoring and data storing, a GSM/GPRS/GPS module for data transmission and a GNSS for sprayer localization. Data that could be acquired were the latitude, the longitude, the speed of the sprayer, the status of the lift, the PTO, the functioning side of the sprayhead (left and right), the presence of the operator, the values of pressure at the centrifugal pump and in the sprayhead, and the flow rate. This telemetry system was tested in different vineyards to evaluate the proper functioning of all the components. Results showed that the spray pressure and the flow rate measured by the sensors of the telemetry system were similar to the theoretical values defined for the regulation of the sprayer. The estimated value of application rate, which was a number derived from the provided forward speed, was also similar to the theoretical value, indicating that the forward speed recorded by the telemetry system was accurate. The telemetry system was also useful to detect a weak point in the spraying operation management, consisting of a different application rate when the forward direction of the tractor was uphill compared with downhill.

1. Introduction

The promotion of policies aimed at environmental sustainability achieved by optimizing the use of plant protection products is one of the strategic actions in the European Community framework directive 2009/128/EC (OJ, 2009). The EC guidelines are directed towards the promotion of sustainable use of pesticides by actively involving all the stakeholders, i.e., the air blast sprayer manufacturers, users and consumers. At the same time, the European Community is promoting scientific research on precision agriculture (EPRS, 2016). There are many recent research projects that include developing advanced robotic technological solutions for precision spraying, such as those identified in the ISAFRUIT (Wenneker et al., 2009), in the RHEA (Vieri et al., 2013; Gonzalez-de-Santos et al., 2016) and in the CROPS (Oberti et al., 2016) projects.

Previously, data collection and management were highly time-consuming and labour-intensive tasks, but modern technologies and telecommunication systems enable more and precision field data to be acquired (Tseng et al., 2006). Sensors, Global Navigation Satellite Systems (GNSS), Global System for Mobile communication (GSM) and Short Message Services (SMS) have all been successfully used to monitor the agricultural operations and to acquire field data (Castillo-Ruiz et al., 2015; Hejazian et al., 2013; Pierce and Elliott, 2008; Tseng et al., 2006; Vellidis et al., 2008). Furthermore, the availability of client web servers for data storage allows for the immediate accessibility of machinery information (Castillo-Ruiz et al., 2015). In addition to acquiring data, it must also be stored, processed, analysed and interpreted. The server is where all actual processing takes place. The software and telemetry devices work together to form the telemetry system, i.e. a system that allows the user to measure certain parameters over a predefined area, send those parameters to a central point, and process them as needed for agriculture analysis (Suciu et al., 2015).

GSM is the widest deployed digital mobile communication system worldwide. GSM utilizes 900 and 1800 MHz frequencies and time division multiple access (TDMA) technology to send and receive mobile data. In addition, with the introduction of general packet radio service (GPRS) the transmission speed is increased. GSM also converts analog communication data into digital (Tseng et al., 2006). SMS is an improved paging service using the GSM

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capability to send alphabetic/numeric data by using a low power transmission channel (Tseng et al., 2006).

Georeferencing is the process of establishing the relationship between spatial information and its geographical position. This makes a comparison possible among the spatial data detected in the field. GNSS are of primary importance for geographical position data acquisition and the real-time tracking of operative machines. The machine coordinates data recorded can be transmitted by a GSM/GPRS modem through the mobile network and stored in information technology (IT) systems located in the Internet. The remote monitoring of the machine displacements is therefore possible with a computer (Oksanen et al., 2016; Pham et al., 2013).

Sensors can monitor field operations, take repeated measurements and transmit data over GSM/GPRS services (Suciu et al., 2015). Many sensors are available for continuous measurements of field operations, which can be mounted on tractors or operative machines for supplying information at relatively low cost (Arnó et al., 2009).

All these technologies will improve agricultural production, optimise returns, minimise risks for crops, and reduce the environmental impact (Tseng et al., 2006). Data obtained can be used by producers and entrepreneurs to facilitate theirs decision-making, reduce costs and improve the quality of the product (Abeledo et al., 2016).

In precision viticulture telemetry systems are used to statically monitor the temperature, the precipitation, wind speed, and leaf wetness to forecast disease and treatment recommendations (Suciu et al., 2015). Other researchers have focused on the recording of various vineyard status data such as pruning, phenology, count of grape clusters, growth values, ripening and harvest by using wireless technology (Abeledo et al., 2016). Gil et al. (2014) used sensors to retrieve data from vineyard canopies and to monitor the drift produced during the spraying operation. Reyes et al. (2012) developed and tested an automated system called Agrotrack in vineyards for data acquisition and generation of reports in the application of pesticides. This system provided data of average weather conditions and alerts, maps of speed of application, applied volume and applied rate through a combination of software and hardware. Data were then stored in an SD memory, without the transmission to a web server (Reyes et al., 2012).

To the best of our knowledge there have been no previous studies reporting the application of telemetry systems in vineyards for the monitoring and the real-time data acquisition of agricultural operations (e.g., the spraying operative parameters). The aim of this work was to develop and operate a prototype telemetry system suitable for winemakers to monitor the performance of the spraying operation in real-time and to acquire useful data. The telemetry system was tested in different vineyards to evaluate the proper functioning of the instruments.

2. Material and methods

2.1. Prototype telemetry system architecture

The telemetry system was developed and operated to acquire and manage data of the spraying operation in vineyard. Data that could be acquired were the latitude, the longitude and the speed of the sprayer; the status of the lift, the PTO, and the functioning side of the sprayhead (left and right); the presence of the operator; the values of pressure at the centrifugal pump and in the sprayhead; and the flow rate. The main components of the system were a sprayer tracking module (TM) and a monitoring system consisting of a host control server platform (HCSP). The TM consisted of a GNSS receiver, a GSM/GPRS/GPS modem, a liquid flowmeter, a pressure sensor and a microcontroller unit. The pressure sensor and the flowmeter were mounted on a pneumatic sprayer (Blitz55T, TC/TCS.4M2C.55P.12, Cima®) (Cima, 2017). The HCSP provided an accessible interface for the end user to acquire real-time information about the spraying operation via the Internet, verify the progress and the proper execution of the work, and search for any problems that may occur. A GSM/GPRS/GPS module ensured communication between the sprayer and the HCSP. Fig. 1 shown the main components of the prototype telemetry system.

2.2. Hardware design: the tracking module (TM)

The main criteria for the design of the system were the versatility of sensors signal acquisition, the system storage capacity, the operation speed, the communication protocol and the physical robustness. The physical size and the power supply were not assessed as critical constraints. The components of the TM are illustrated in Fig. 2.

The tracking prototype module utilized as its main element an 8-Bit microcontroller (Table 1) with USB and extra low-power sleep technology (XLP). This microcontroller had an operating frequency of 64 MHz, 9 I/O port and a 12-bit analog-to-digital module to manage up to 24 input channels. The chip has 128 kbytes of program memory, which allows the storage of up to 65,536 single-word instructions and 4,000 bytes of static random access memory (SRAM). A universal asynchronous receiver/transmitter communications interface (USART) was also provided, giving full duplex communication between connected devices and performed data assembling, processing and sequencing. The USART was adopted to use an asynchronous communication interface instead of data clocking. The TM design was aimed at monitoring the spraying operation. Relevant data was considered to be the pressure at the centrifugal pump and in the sprayhead in both left and right sides, the liquid flow rate, the PTO status, the lift status and the presence of the operator on the tractor. The GNSS (Table 1) provided the sprayer geographical location data, the working time, and the forward speed as digital input (DIN8) (Table 2). An external 16 Mbit serial flash memory A25L016 (AMIC Technology Corp, Hsin-Chu City, Taiwan) was used to store the sequence of instruction that the TM had to follow. This flash memory supported a serial peripheral interface (SPI) and had high writing speed of 100 MHz Clock Rate. It was managed by the SPI direct memory access (DMA) channel of the microcontroller, which performed the local storage. This was accomplished with a micro SD/MMC card interfaced with SD-CS, SD-D I/O, SDCLK and SDCS pins to general purpose I/O pins.

A multichannel RS-232 driver/receiver (Maxim Integrated™, San Jose, CA, USA) was used for the communication between the microcontroller and the GSM/GPRS/GPS module. To supply the TM elements (i.e., microcontroller, analog inputs, GSM/GPRS/GPS module) a regulator circuit was designed. A DC/DC circuit was implemented to reduce and stabilize the +13.8 V tractor electrical supply voltage to the +12 V outputs, and the range of +3.2 to 4.8 V to supply the GPRS module. These voltages were achieved by a LM2596 chip (Texas Instruments, Texas, USA) that operated at a switching frequency of 150 kHz, which used smaller sized filter components and allowed for a high accuracy and stability of DC output voltages. Three LEDs indicated the status of the TM. When the system was properly powered the LEDs were switched on and if malfunctioning occurred (e.g., the power supply lower than the minimum sill) they switched off.

2.2.1. Sensors

To acquire the sprayer status a set of three piezoresistive pressure transmitters were used (Table 2). The first pressure sensor was placed on the centrifugal pump to check the working pressure of the sprayer. The other two were mounted on each part of the