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Development of an Automated Management System for the Traceability of Spraying in Fruit Orchads

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Abstract: A system for managing and monitoring agricultural labors at farm level was developed and tested in an agrochemical application. The system is constituted by an electronics box mounted on the tractor and software that acquire and analyze data from the application task. The electronics box consists of a microcontroller, a GPS, sensors, a keyboard, a SD memory reader and a LCD screen. This device is able to store in a SD's memory the data of the position and the instantaneous speed of the tractor, the applied dose, the speed and absolute wind direction, the temperature and relative humidity in-situ. In addition it can generate alert of unfavorable climatic conditions for the agro-chemical applications. The interface to the user is software that allows generating a job order identifying the operator name, the tractor, the spraying equipment, the pesticide, the dose and the sector of application. In addition it allows analyzing the output data in graphical form, generating maps of speed, applied volume and dose. The map of the route is also drawing up on Google-Earth for a better spatial visualization. All the tasks carried out are stored in a data base administered by this software. With this tool it is possible to verify if the norms that establish environmental conditions apt for the application of pesticide are fulfilled, besides checking the variability of the dose and jumps of rows, along with reports with indices of performance of the operator. The system has been tested in two important vineyards of Chile with promissory results.
Key words: Agricultural automation, precision farming, traceability, crop spraying, certification

INTRODUCTION

The fruit exports of Chile have increased in the last years due to the opening of new markets of destination, such as Europe and those that have been opened recently by treaties signed with countries of Asia, such as South Korea and China. This new scenario not only entails new exigencies in the scope of the quality, but also in the sense of a clean production, this means without damaging the environment nor the people, to be able to apply to a certification that allows us to compete with a comparative advantage at these markets. According to these previous considerations, the applications of agro-chemicals not only must be effective in the control of the pests, but in addition they must be executed according to the detailed environmental norms of the Green Code (Maff, 1998). This code specify that the application of pesticides must fulfill the objectives to protect the people who consume foods treated with these products, to protect the security of all the people related to the productive process, and to avoid the environmental pollution, protecting the wild life, the soil, the water and the air (FAO, 2002; SAG, 1996). The atmospheric conditions like rain, wind, temperature and relative humidity can very negatively affect the performance of an application, diminishing remarkably the effectiveness of the treatment and causing serious problems of environmental contamination by drift and dripping to the ground (Gil and Silfor, 2005; Gil et al., 2007; Reichenberger et al.,2007, Vischetti et al., 2008). Several authors (Magdalena et al., 1997; Wilkinson et. al., 1999; Matthews, 2000; Baldoin, 2001) have indicated that when certain environmental variables are exceeded such as precipitation (> 1-3 mm/d), wind speed (> 3-4 m/s), temperature (>28-30 ºC) and relative humidity (<30 % and >95%), the applications are ineffective and/or polluting by dilution, washing and dripping of the chemical agent, evaporation of the drops and derives towards places bordering to the orchard, with increase of the costs and probable occurrence of phytotoxicity, acid rain and potential damage to the health of the workers. It has been considered that the losses of phytosanitary product are between 25% and 50% of the total chemical applied, being able to reach up to 90% when the trees are without foliage (Riquelme, 1997).

On the other hand, a good application depends to a large extent on the speed of the tractor, which not always is constant, causing spatial dose variations. In addition it is necessary to verify if the task has been executed with complete foliage coverage, since often row jumps occur, which cause a plague focus that later expands to the all sector.

For these reasons the application of agro-chemicals is a questioned and complex but necessary practice, which has increased the interest to look for technological solutions that help to improve and to certify this type of application.

This work deals with the development and testing of an automated system called AgroTrack, for data acquisition and generation of reports of application of agro-chemicals. The system uses a combination of hardware and software.

The hardware consists of an electronic box installed in the tractor during the application task. This device is equipped with a microcontroller, a GPS, a graphical LCD screen, a SD ("Digital Secure") memory for data storage and the sensors. The GPS delivers data corresponding to the time, position and speed of the tractor. The sensors on board deliver the temperature, the relative humidity, the speed and wind direction and the applied volume of the sprayer. The microcontroller is in charge of acquiring all the data and to store them in the SD memory. In addition the microcontroller has environmental routines that allow generating application alerts. The communication with the operator is through a graphical LCD screen, on which appear the environmental details conditions of the application, the instantaneous dose and the eventual alert.

The software is in charge of reading the SD memory, updating the data base, reproducing the application and generating a final report. The general goal of this project is to develop a reliable automated system capable of generating reports of tasks in agro-chemical applications, specifying the average environmental conditions and maps of speed of application, applied volume and dose. In addition it must have the capacity to generate an environmental alert during the application, considering conditions of temperature relative humidity and wind speed.

In order to achieve the general objective it is required to develop a data acquisition hardware and software architecture. Hardware must be able to collect and to store the data originated by the sensors and GPS, besides generating environmental alert on the basis of these data. The software will be used to program a task, to read the data generated by the application from a SD memory, to unfold the maps of speed, volume and instantaneous dose and to generate a complete report of the application.

MATERIALS and METHOD

The project was divided in two main parts; the development of the electronics module called AgroTrack and development of the analysis software to generate reports called Software AgroTrack.

Electronics module

Figure 1 shows a schematic diagram with the components distribution of the developed electronics module, named AgroTrack.

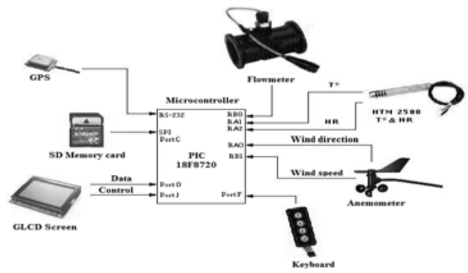

Figure 1. Outline of the system components

The module consists of a microcontroller model 18F8720 from Microchip, deployed in a development card of the same name.

The microcontroller runs at 24 MHz in HS-PLL mode, and includes a programming memory of 128 kB, 16 analog inputs of 10 bits each and a total of 68 digital inputs/outputs, and 5 timers. The development card has been implemented with a SPI port, two serial ports RS-232 and 7 I/O ports A, B, C, D, F, G, and J.

The SPI port, serves for direct contacting with the SD memories reader; one of the serial ports is used for the communication with the GPS and the other one for remote monitoring by using a RF modules (model XTend 900 manufactured by Digi).

The port A, configurable as analog port, is used to read the wind direction, the temperature (T) and the relative humidity (RH), through pins RA0, RA1 and RA2 respectively.

The port B can be implemented as counter and in this case pins RB0 and RB1 are used respectively to read the originating pulses of the flow-meter and the anemometer.

Ports D and J are used to handle a graphical screen or GLCD and port J is to send the signals of control and port D to transmit the data to unfold on screen. Finally port F is used to connect a membrane keyboard of four keys.

In order to acquire the temperature and RH, a dual sensor mark Humirel model HTM2500 was used with typical range of 0 to 100 % of RH and a ±2 % of accuracy at 55 % of RH when is fed with 5 V DC and a range of the temperature of -30ºC to 70ºC with a variation of ±3%.

The speed and wind direction were acquired using a commercial anemometer developed by Davis Instruments, number of part 6410. The wind direction was obtained directly from a potentiometer that varies of 0 V to 5 V in 360º.

The wind speed was obtained counting the pulses generated by a sensor of magnetic contact (Reed Switch), which generates a pulse by each turn.

The acquisition of the volume of the agrochemical was achieved with a flow-meter made by RAVEN model RFM15, with a range of 1 L min^{-1} to 56 L min^{-1}. This flow-meter gives a train of pulses proportional to the volume which goes from 44 to 47 pulses per liter.

The used GPS is a model ETEK 85-A, of 30 channels, with a frequency of 1 to 5 Hz and a precision CEP at 50 % of 3.3 m, depending on the environmental conditions and the number and space distribution of the satellites.

The final appearance of the automated system is depicted in Figure 2.

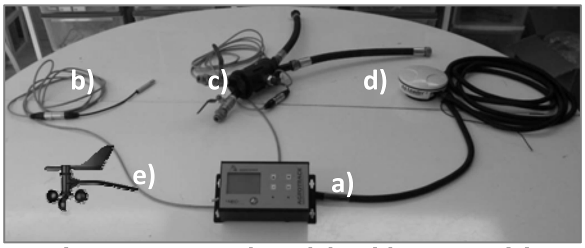

Figure 2. AgroTrack module with sensors. (a) Electronic box, (b) Tº & RH, (c) Flow meter, (d) GPS, (e) anemometer and wind vane

The different routines which were programmed under the platform MickroC and loaded into the microcontroller, permit executing the whole data acquisition process including the control of all the peripheral devices. The structure of the onboard program is detailed in Figure 3.

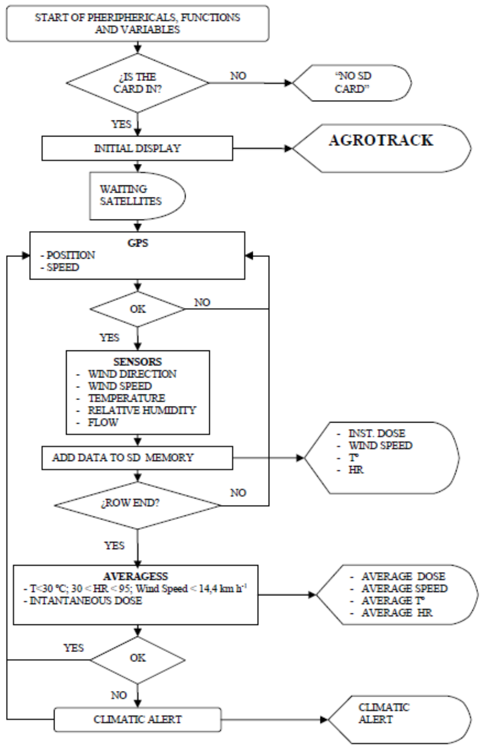

Figure 3. Flowchart of onboard data acquisition logic

At the time of plugging in the SD card in the electronic box, the basic information on the agricultural job order is shown on screen. After pressing an acceptance button the equipment begins to collect the data and adds it to the end of the file. Once the application starts, the value of the environmental conditions and the instantaneous dose unfold on screen in real time.

At the end of each row, a message of environmental alert unfolds if some of the established restrictions have been exceeded. The alert messages may or may not be considered by the operator. The environmental alert is based on the average value of one of the limiting variables throughout a row. The beginning and end of row are detected by the presence or not of volume in the flow meter.

Software Agrotrack

The software was developed in Microsoft Visual Basic 6.0 programming environment, with the objective to acquire and analyze the collected data of an application and generate a standard report of the process. For the basic handling and remotely query of the acquired information, a MySQL database was used. The function of the software is to generate a file with the basic information of the application, containing the following data: authentication code, date, estate, sector, quarter, operator, machinery, tractor, product and dose to apply. This file must be loaded in the SD memory before the application to be read later by the electronic box. During the application, the file is completed with data related to the target location of the tractor, speed of the tractor, temperature, relative humidity, wind speed, wind direction and volume of the agrochemical, acquired every three seconds. Once finalized the application, this file must be read by the visualization software and its information loaded to a data base. Using the data base, the software must be capable of generating reports of the job, including the average climatic conditions and geo referenced maps of the route of the tractor, speed of the tractor, applied volume and instantaneous dose.

Also, the software is capable to generate operating hours per Operator, Machine, Tractor, Quartel Management through Internet.

The human interface of the software has a main screen that is divided in two sectors as shown in Figure 4. To the right there is a graphical zone and to the left a zone to show data of interest following the option by selection on a sliding menu located in the upper area.

The options that the sliding menu can display are: Informes (Reports), Operación Diaria (Dairy Operation), Lecturas (Readings), Operarios (Operators), Cultivos (Crops), Labores (labors), Productos (products), Unidades (Units), Manejo Cuartel (Quartel Management), Tractores and Maquinarias (Tractors and Machinery).

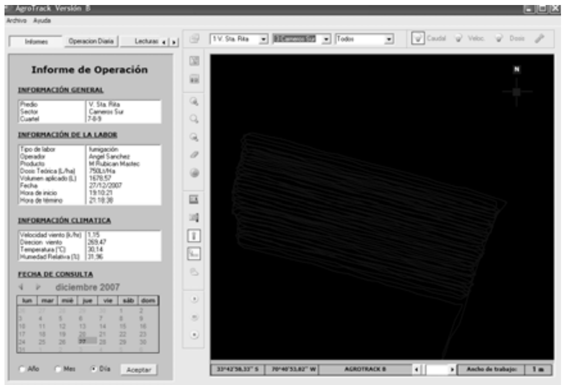

Figure 4. Main screen of the Software Agrotrack

The options Operators, Crops, operations or tasks, Products, Tractors and Machineries allow to add, to eliminate and to edit data from the farm data base, the option Reports generates a report of the operation previously selected. To facilitate the search of an operation there is a small movable calendar and the alternative to limit the search per day, month and year. The option Dairy Operation is used to issue a job order which in turn generates a file that will be read by the electronic module Agrotrack. The option Readings serves to read, store in the data base and erase the file of the SD memory. The option Units is used to add and to eliminate estates, sectors and quarters. The option Quartel Management is thought to assign to name to a culture and variety of a quarter.

On the other hand the software offer visualization tools, which are deployed on a vertical bar in the center of the screen, which are: zoom lens, link with Google Earth, dimensioning ruler and bar of ranks. In addition the software includes the functions play, stop and pause for the reproduction of the trajectory followed by the tractor.

In the lower right corner a bar has been implemented that allows varying the width of the application so that the line representing the path of the tractor is displayed on the screen with a width proportional to the selected working width. Finally on the superior right corner of the screen there is an option to interchange between the instantaneous data related to operation speed, applied volume and agrochemical dose.

RESULTS and DISCUSSION

The developed system has been tested in two different vineyards in Chile, Santa Rita Vineyard, located near the town of Buin in the Metropolitan region and Concha y Toro Vineyard, located near the town of Peumo in the VI region, with similar results. The field data reported in this article corresponds to the testing carried out in Santa Rita vineyard on December 27th of 2007.

The Figure 5 depicts the path of the tractor with the spraying equipment on Google Earth. In order to build this graphical representation, the visualization software generates a KML file, which is called with the link to Google Earth to match both data bases. It is possible to see that the route starts off from the farm workshop through a farm interior street and ends at the former starting point. The image shows the coincidence between the data provided every three seconds by the GPS of the Agrotrack module and the data base of Google Earth. This resolution level allows detecting row jumps which may constitute infections centers for possible new sprouting of the disease.

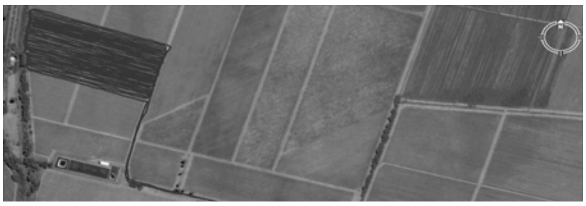

Figure 5. General path of the application in Santa Rita Vineyard

In Figures 6 the most important data of the tested operation is presented by means of the visualization Software Agrotrack. The analyzed and displayed data of Figure 6 corresponds to the dose applied along the path followed by the tractor and sprayer that was acquired with the Agrotrack module.

In the Figure 6, five colors corresponding to different dose ranges are shown, these ranges are mobiles. The Figure 6 allows observing that the instantaneous dose generally stayed at a level below 720 L ha^{-1}, even though the theoretical dose for this application was set at of 750 L ha^{-1}. The low dose in this case is explained by a previous error of calibration of the spraying equipment which was enhanced by the high speed of the tractor during the application.

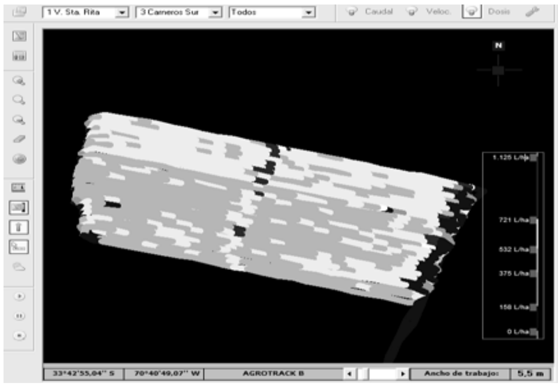

Figure 6. Display of the dose of the application in Santa Rita Vineyard

Figure 7 shows plotting of the source data of dose and speed acquired by the hardware that confirm the information unfolded in Figures 6.

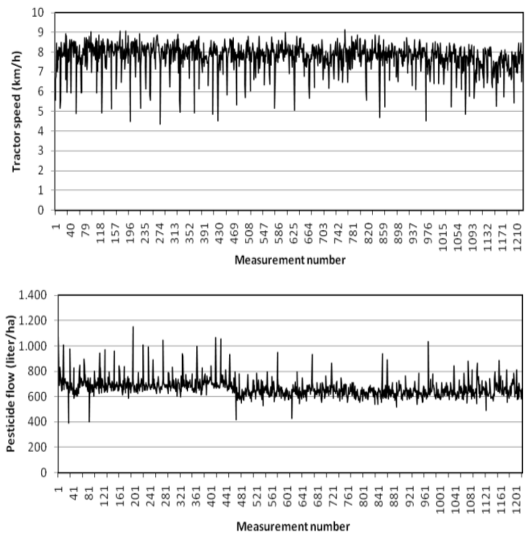

Figure 7. Plots of pesticide flow and tractors speed

Finally in Figure 8 there is a sample of the general operation report generated for this application. Three blocks of information can be distinguished. In the first block it appears the information that allows identifying the application place: Farm, Sector, Quartel.

The second block corresponds to direct labor information: Tipo de labor (Type of labor), Operador (Operator's name), Producto (Agrochemical product), Dosis teórica (Theoretical dose), Volumen (Volume applied), Fecha (Date), Hora de Inicio (Starting time) and Hora de Término (Ending time).

The third block display the average climatic conditions of the spraying labor: Velocidad del viento (Wind speed), Dirección del viento (Wind direction), Temperatura (Temperature) and Humedad Relativa (Relative Humidity). The last block is a calendar to indicate: Año (Year), Mes (Month) and Día (Day) of the retrieved information from the data base managed by the Software Agrotrack.

Figure 8. General report of the application in Santa Rita Vineyard

CONCLUSIONS

A system for managing and control of pesticide application was developed, which has been successfully tested in an important vineyard of Chile. This automated data acquisition system has demonstrated to be an important tool of analysis and management for the application of agro-chemicals particularly in the following aspects: (a) capacity to reproduce the trajectory followed by the tractor and spraying equipment and consequently to verify if the pre-established tractor speed is fulfilled, (b) generation of dose maps to be able to decide when and how much pesticide has to be to eventually applied again, (c) detection of row jumps or rows without pesticide application that allows to correct the errors by eliminating the possible new sprouts of the disease, (d) generation of yield indices of each operator to be able to rank them and to take action to improve the training of field workers and operators, (e) availability of an open modular software that permits the addition of any agricultural labor as a new module to be monitored with this technology, (f) the generated report since incorporate the climatic variables serves to certify a good practice of any agrochemical application.

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