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Real time canopy density estimation using ultrasonic envelope signals in the orchard and vineyard

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ABSTRACT

This paper proposes a real-time method, based on an array of ultrasonic sensors, to estimate canopy density in apple orchards and vineyards. This estimation could be used as a reference to adjust the canopy spraying machine parameters with the aim of improving deposition and avoiding drift. Two sets of experiments were carried out, the first one using a single ultrasound sensor in a greenhouse to determine the signal behavior and adjust the algorithms. The second set of experiments were conducted in the orchard and vineyard, under real working conditions. Results show that the signal obtained is highly correlated with the growing season and it has similar values on both sides of the row, with an error of 14.1% in vineyards and 3.8% in apple trees and it is sensitive enough to detect hailstorm effects on the canopy.

1. Introduction

In the USA, as in many other countries, knowing how much water to apply to apple trees and grapevines has, for a long time, been based upon tree row volume in the case of orchards and good old-fashioned guess-work in the case of vineyards. Many pesticide sprays used in orchards have either the product rate per hectare or per 100 l of water on the label (Agnello, 2014). The actual amount of water to be used is based upon tree row volume (TRV), a simple formula developed in the 1960s (Morgan, 1964). Growers then use another formula to calculate the amount of spray to treat 1000 m^3 of tree. Often, in a desire to reduce water volumes and improve timeliness, a concentrate application is made. In the case of vineyards, product rate per hectare is the norm (Weigle and Muza, 2014). The amount of water to use with the product is determined by the individual grower, according to the characteristics of the product and the type of sprayer.

There are numerous row widths, varieties, spacing within the row and variations in canopy shape and style from spindle trellises to traditional large trees, from VSP canopies to GDC and Scott-Henry trellises. Even within the same orchard and vineyard, canopy characteristics (canopy height, width and density) change with the growing season. It is very important to apply the correct amount of spray as over-dosing at early growth stages and under-dosing at the later stages, can result in inadequate protection. Incorrect application may result in pest resistance and poor insect/disease control, increase costs for the grower, and the risks of chemical contamination in the environment. As many growers progress toward modern planting schemes, so the application rate/volume debate begins.

Tumbo et al. (2002) proposed the use of ultrasound sensors to estimate the volume of citrus trees using the principle of time of flight to determine the distance to the target. Adopting the same system, Zaman and Salyani (2004) had proved that the forward speed is not very important on the distance estimation, but the tree density plays an important role. Escolà et al. (2011) developed an ultrasound sensor in apple trees, establishing accuracy (±0.53 cm laboratory conditions) and reporting echo interference. This method assumes a constant distance from the sensor to the tree, and small variations on these distances results in a large error on the final volume estimation (Palleja et al., 2010).

Balsari et al. (2008) went one step forward analyzing the Crop Identification System (CIS), developed by the 3B6 company (C.O.B.O. Divisione 3B6, Sistemi Elettronici Industriali Company, Castelletto Ticino-NO, Italy) and concluded that there is a relationship between canopy density and its ultrasonic echo signal. The system was able to detect the major characteristics of the target canopy (i.e., thickness and density) in real time and the results had no significant differences according to the forward speed adopted. Also, Balsari et al. (2009) solved the target distance by

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using a GPS and reported better deposition by adjusting the sprayer parameters (air flow and nozzles) as a function of the CIS data.

A tour of orchards and vineyards shows large variations in application rate, even when climate, disease and insect pressures are similar. Adjusting forward speed, air and liquid flow to match the growing canopy as the season progresses is the key. In this work we developed an alternative system to determine canopy density and it was tested as the growing season progresses. Previous papers, Landers (2011) and Calveras et al. (2013) showed how electronics can be used to adjust both air and liquid volume in real-time using ultrasonic sensors to measure canopy volume (TRV). Using sensors to monitor variations in canopy density is the next challenge. This work proposes a low cost system based on 4 ultrasound sensors and a microcontroller board to estimate the canopy density based on a simplified CIS system.

An important goal for spraying systems would be real-time adjustment of the operating parameters (air flow, pressure, active nozzles, etc.) according to the target density, with the aim of keeping the droplets in the canopy, improving deposition and reducing drift (Landers, 2010). The objective of this work is to develop a method to estimate the canopy density in real time, based on the following hypothesis (Fig. 1): The ultrasound echoes and the canopy density are proportional. The greater the density the more echoes will be produced.

2. Materials and methods

This section describes the materials and methods used to carry out the experiments, which include a modified sprayer, ultrasound sensors, electronic devices and algorithms.

2.1. Modified sprayer

The spraying machine used in this work (Fig. 2) is a Berthoud S600EX axial fan sprayer (Berthoud, Cedex, France). It incorporates a GPS (Garmin 16x Series), a set of 4 ultrasound sensors and a louvre system (Landers, 2011), which allows air volume to be adjusted from 0% to 100%. Four ultrasound sensors were attached on the front of the sprayer, at 2.2 m from the nozzles and distributed at different height.

2.2. Ultrasound sensor

The ultrasound sensor (Fig. 3) used in this work was the XL-MaxSonar MB7092 (MaxBotix Inc., Brainerd, MN, USA). It is water resistant (IP67), generates 42 kHz ultrasound waves, has a resolution of 1 cm and a maximum range of 7.65 m. The power requirements are 3.0–5.5 V and 3.4 mA. This model has one pin (pin 2) to obtain the analog voltage envelope of the acoustic waveform and another one (pin 4) to switch it on/off. Using these pins,

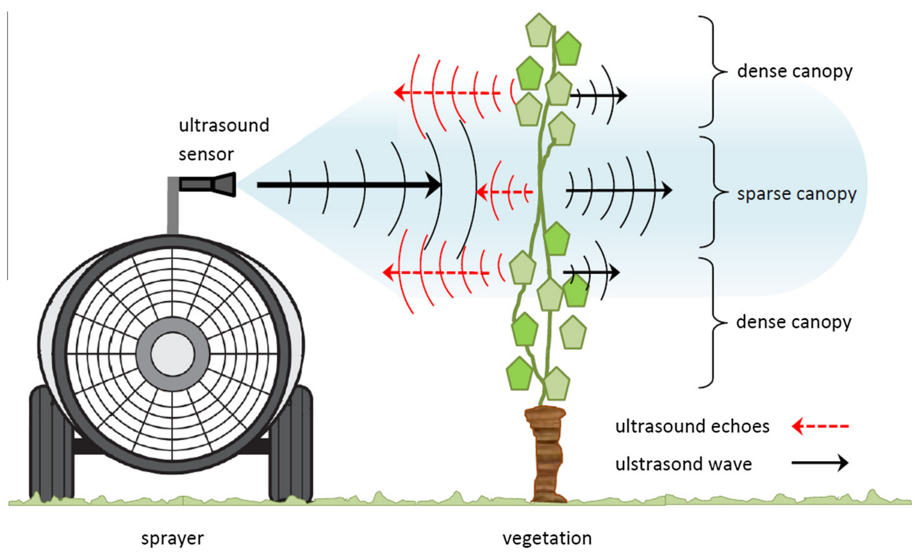

Fig. 1. Schematic hypothesis diagram.

Fig. 2. Modified sprayer and sensors distribution, right orchards and left vineyards. The ultrasound are highlighted by a white rectangle.