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Spatial Map Generation from Low Cost Ground Vehicle Mounted Monocular Camera

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Abstract: This paper presents a method for generating a spatial map of a particular plant or environmental property of a vineyard block based on low cost camera technology and existing vineyard vehicles. Such properties can range from leaf area, per vine bunch count or bare-wire detection. The paper provides a low cost ground vehicle based solution that does not rely on live GPS position recording. Rather, the relative estimated motion between video frames is used to localize each sensor reading within the bounds of each row. Row end locations are derived from post-processed GPS recorded locations of the perimeter of a block with an aerial photograph. This paper uses the proportion of leaf colored pixels in a video frame as a token example of measuring the relative growth of vines during the shoots stage.

Keywords: computer vision, viticulture, spatial mapping, proximal sensing

1. INTRODUCTION

The generation of spatial maps of certain plant properties within a vineyard is vital to management practices employed by vineyard managers. It is one of the key tools to assist in the practice of *precision viticulture* (Cook and Bramley (1998)). For example, a vine vigor map (Hall et al. (2001)) shows a vineyard manager the relative health of vines spatially. A vineyard manager may also want to know not only the percentage of the block that consists of bare wire, but also the approximate location of such non-productive regions. Yield prediction is also a vital practice that has recently become well adopted from the precision agriculture community. Jarrett et al. (2014) mention that a spatial measure of yield is vital to maintain a desired standard of fruit quality. Liu et al. (2015) also presented work that detected the proportion of shoots within a vineyard block to provide an early season yield forecast.

Many spatial data collection and mapping technologies exist, but the majority require an aerial vehicle or satellite imagery. Hall et al. (2003) produced a method of mapping pixel locations in aerial photography to individual vines within a given row. Johnson et al. (2003) and Johnson et al. (1996) presented a method to convert geo-referenced satellite images to a leaf area index to spatially map plant growth and specifically mention that manual ground based measurements are not suitable for vineyard managers with large scale sites. Johnson et al. (2003) make the assumption that manual measurements are performed destructively on foot, whereas the proposed method can capture chosen sensor data at 35 minutes per hectare on average.

A small amount of research is available on proximal ground based sensor systems. Rubio and Más (2013) presented a system for estimating vine vigor using an over the row IR sensor to detect the proportion of reflectance of leaves. This uses a similar technique of indirect vigor measurement as the Plant Cell Density (PCD) map. Their method used an on board GPS unit to approximate location, but could only generate a spatial map with $25m^2$ grid cell resolution. The method provided in this paper is capable of localization errors in the order of $2m$–$3m$ without no other sensor than a single camera.

The main objective of this research is to introduce a method for producing spatially self-consistent maps with low-cost hardware. Only a georeferenced block outline and single camera are required, as opposed to expensive and complicated positioning solutions such as GPS, IMUs, or wheel encoders. The example used in this paper is to detect and map the size of vine canopy throughout the block using a single low-cost camera, which relates indirectly to vine health and vine balance.

This paper begins by detailing the low cost method of localizing sensor measurements. Assumptions and limitations are discussed before results are presented using a proxy measurement for leaf area — the proportion of *leaf colored* or green pixels within video frames themselves.

2. METHOD

A spatial map is generated using a low cost portable video camera, an existing tractor or vehicle, and a pre-defined driving pattern. This technique can be used to generate spatial maps of any sensor reading, however for this paper, the amount of leaves in a video frame is estimated during the shoot stage of phonological growth using a basic measurement of the amount of *leaf colored* pixels in each

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Fig. 1. Mounting configuration of the GoPro camera.

frame. This section outlines the experimental equipment, collection process and processing required to turn video footage into a proper spatial map.

2.1 Video Recording Equipment and Procedure

A GoPro Hero 3+ camera was mounted on the side of a vehicle as shown in Figure 1. The camera was mounted horizontally facing the cordon with the aim to capture the majority of the immediate vine as centered in the camera's vertical field of view. Video was captured at 30 frames per second and the Medium (**M**) field of view option was selected, giving a horizontal and vertical angle of view of 94.4^o and 72.2^o, respectively (GoPro (accessed 2016)). The fish-eye distortion of captured frames was removed as the initial step of any video frame analysis.

Video recording was completed on a per row basis. For each row of the predetermined driving pattern, a vehicle was parked just before the beginning of a pair of rows. Video recording was started and confirmed to be running before the vehicle was driven the length of the row trying to maintain 10km/h. The vehicle was driven past the end of the last post before stopping. Video recording was then stopped while the vehicle was stationary before the vehicle was driven to just outside the next pair of rows in the driving pattern, and the process repeated.

2.2 Driving Patterns

Three different driving patterns were developed to assist in mapping a particular video file to the row, with the driving direction and side of vine being recorded. These are referred to as:

- single-pass
- double-pass single-sensor
- double-pass double-sensor

The *single-pass* driving pattern is used under conditions where a general spread of sensor readings were required across the block, but not every side of every vine required recording. In this driving pattern a vehicle starts at a predefined zero end, for example the Northern end of a block, and drives between rows 1 and 2. The vehicle then records between rows 3 and 4 driving in the opposite direction, and so on. Figure 2 demonstrates the row order and direction for the *single-pass* driving pattern.

Fig. 2. The *single-pass* driving pattern.

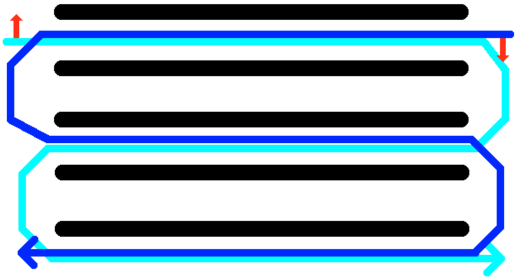

Fig. 3. The *double-pass single-sensor* driving pattern. The lighter path shows the first pass, while the darker path shows the second pass. Red arrows indicate the direction of the sensor for each pass if it were mounted on the left side of the vehicle.

The *double-pass single-sensor* driving pattern is used under conditions where only a single sensor is available on one side of the vehicle, with at least one side of every vine being required to be recorded. Here the *single-pass* driving pattern is used as a first pass of the block. Then a modified *single-pass* pattern is used for a second pass, where every pair of rows is recorded in the opposite direction to the initial pass. This pattern ensures that a sensor mounted on a particular side of the vehicle is able to sense at least one side of every vine. Figure 3 demonstrates the row order and direction for the *double-pass single-sensor* driving pattern.

The *double-pass double-sensor* driving pattern is used under conditions where two sensors are available, one on each side of the vehicle and both sides of every vine are required to be recorded. Here the *single-pass* driving pattern was again used for a first pass of the block. Then as a second pass, the *single-pass* driving pattern is used starting from the same predefined zero end of the block, but outside of row 1. That is, the first few pairs of rows recorded on the second pass are outside row 1, rows 2 and 3, then rows 4 and 5. With each driving pattern, if a single row remains unrecorded after all other pairs of rows have been recorded then the remaining row is recorded from the outside, so as to maintain the same progression of row numbers and directions for sensors on a particular side of the vehicle. Figure 4 demonstrates the row order