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A Virtual Reality System to Monitor and Control Diseases in Strawberry with Drones: A project

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Abstract: Strawberry (*Fragaria x ananassa Duchesne*) is an important fruit crop in Brazil. Strawberry cultivation interest occurs because of high profitability, consumer acceptance and crop production diversity. Notwithstanding, diseases caused by fungi are a major problem in strawberry fields. For this reason, growers adopt rigid phytosanitary management practices in order to prevent losses. In this context, growers rely on the use of pesticides for controlling diseases. However, pesticide usage increases the product costs, reduces fruit quality and increases rejection by consumers. This paper presents a Virtual Reality system project to assist integrated disease management in strawberry using image processing. High quality images captured in real time by drones will be analyzed and displayed in the system by an interactive 3D user interface. With this approach, we expect to warn growers about disease risk rationalizing chemicals use and increasing fruit quality and yield. In addition, this project aims to disseminate the use of these technologies, especially for small strawberry farms.

***Keywords**:* virtual reality; image processing; integrated disease management, warning system.

1 INTRODUCTION

Integrated pest management is a process that integrates practices for sustainable controlling of pests, minimizing contamination risks in humans and in the environment. Integrated pest management can use multiple strategies including early warning of outbreak risks. In general, these warning systems are based on empirical disease models that simulate a specific weather-related epidemiological process.

However, plant diseases warning systems have not yet met the expectations for appropriate disease management. Among the problems are the excessive complexity or simplicity of the models, the lack of portable solutions, implementation costs, weather stations maintenance and user risk aversion.

Ideally, a decision aid system for plant disease management should make projections considering the major stages of disease process, which most do not realize. Alternatively, a new and interesting facet is the real time scouting of fields by processing images captured by unmanned aerial vehicles (UAVs or drones). Besides disease scouting, crop phenology can be monitored as well. This is important because some diseases are associated to a particular crop development stage. For example, gray mold caused by the fungus *Botrytis cinerea* is one of the most important disease of strawberry worldwide. This disease causes severe preharvest losses primarily due to infections of fruit and flowers.

Traditionally, crop monitoring and spatial data acquisition are costly and laborious. By other hand, drones can be placed in the context of real time monitoring and disease control. Drones can quickly travel through strawberry fields, capturing and transmitting images. The technology already showed satisfactory results in other crops such as wheat, soybeans and corn (Zhang and Kovacs, 2012), increasing the value and the quality of products, decreasing costs, expanding the productivity and improving the proper use of agricultural supplies. In the case of strawberry, this scenario can be obtained through controlled, accurate and efficient application of pesticides using drones adapted to this task.

With this in mind, our paper presents a project that includes an innovative system to monitor and automatically detect diseases in strawberry using image processing and virtual reality. The real time captured images are analyzed and displayed in the system by an interactive 3D user interface. In a combination of susceptible crop stage and suitable environmental conditions growers can make a decision on precisely apply chemicals or biological control agents directly in the strawberry floral parts.

This article is organized as following: Section 2 extends our arguments about the context and related work. Section 3 includes material and methods for this project, whereas Section 4 describes the relevance and the potential for innovation. Finally, Section 5 concludes the paper highlighting the challenges of our approach.

2 BASIS AND VISION

Strawberry world production has been increasing in recent years, from 800 tons in 1970s to three million tons in 2011 (FAO, 2011). According to FAO (2011), in Brazil the area cultivated with strawberry is relative small (~370 ha), in comparison with other South America countries like Argentina (~950 ha) and Chile (~1546 ha).

Nevertheless, strawberry is an important fruit crop and a source of income, specially, to small growers in different regions of Brazil. High profitability, consumers' acceptance and crop diversity options have attracted the interest for new producers (Sanhueza *et al.*, 2005). Strawberry cultivation is labor intensive playing an important social role in family-based farms (Andrigueto and Kososki, 2004).

According to Pavan *et al.* (2011), yield and quality of strawberry fruits are influenced by biotic and abiotic factors, including the occurrence of plant diseases. Strawberry can be affected by several foliar and root diseases. To prevent losses, strawberry growers rely upon pesticide usage.

Strawberry integrated production advocates the correct diagnose in order to establish multidisciplinary measures leading to proper disease management. This may improve disease control, decrease costs, reduce environmental impact and prevent pesticide residues in fruits. Among the most important strawberry diseases in Brazil, are anthracnose and botrytis (Antunes *et al.*, 2007).

Spadotto and Gomes (2011) reported that the annual consumption of pesticides in Brazil has been more than 300, 000 tons in commercial products. This is of great concern since the indiscriminate use of chemicals has a significant impact on production costs, risk of environment contamination and human health risk. In the strawberry industry, excessive use of pesticides can increase production costs, reduce fruit quality and increase rejection by consumers.

It is worth noting that fruit appearance and uniformity are important traits in strawberry commercialization. By other hand, strawberry growers are willing to adopt new technologies that will increase yield and quality with lower environmental impact.

The use of computational resources in strawberry is recent. Most of them are based on climate related software to predict cultivation risks (Mackenzie and Peres, 2012a; Mackenzie and Peres, 2012b). The development and evaluation of strawberry-harvesting robots (Kondo *et al.*, 2001; Arima *et al.*, 2003; Hayashi *et al.*, 2005; Cui *et al.*, 2007; Hayashi *et al.*, 2010) have also being reported. These devices use computer vision techniques to analyze, select and harvest ripe fruits. They consist basically of a manipulator with three or more degrees of freedom (scissors or end-effectors), a fruit collector (with or without suction), a computer vision unit with two cameras to check the maturity and define the 3D positions for cutting, and a travelling system for harvest.

There is a demand to monitor and automatic detect objects of interest like diseases or strawberry plant parts. The use of drones in this context is innovative. Drones can be equipped to send high resolution images for a monitoring system (interactive 3D user interface) which, in turn, can navigate the device in flight. This system can also process images to detect morphological stages, used as a basis for disease management. Based on data received by the micro drone and climate sensors, this interface can also display virtual information using Augmented Reality techniques. This can be used to warn growers about an eminent risk of a pest.

In summary, the benefits of our project may be numerous. Besides the use of advanced technologies, we can highlight the proper disease management, reduction of chemicals in the environment, lower the risk on human health contamination, decrease of costs and improve yield and quality.

3 MATERIALS AND METHODS

Our project has a multidisciplinary feature bringing together experts from computer and agriculture science. Next topics introduce the steps to be applied to achieve specific aims of our approach. All project stages will be documented to facilitate knowledge dissemination and future improvement on components, systems and techniques. Figure 1 presents the architecture planned for the Virtual Reality system.

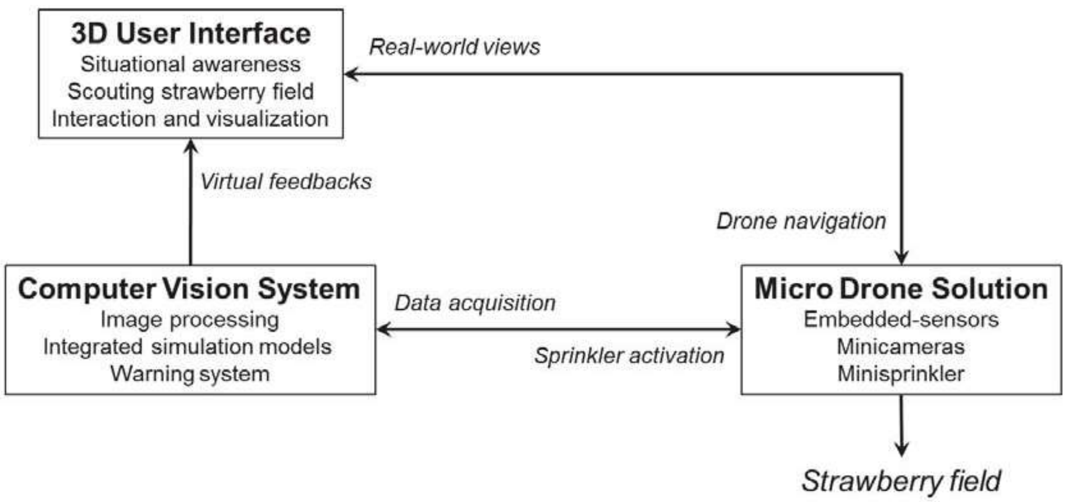

Figure 1. System architecture.

3.1 Design and assembly of drone

At this stage, part of the Computer Science team will work on the design and assembly of a micro drone (Figure 2). The drone will be equipped with two mini cameras and a mini sprinkler. In an effort to reduce costs, hardware and software open source solutions will be used the system development.

We intend to use an Arduino microcontroller board with five sensors (accelerometer, gyroscope, barometer, manometer and ultrasonic), brushless and coreless motors, electronic speed controllers, APC propellers, batteries, transmitter-receiver modules, a multispectral mini cameras and a GPS module.

3.2 Protocol to control remotely drones

In the second stage, Computer Science team will define a communication protocol for remote drone navigation using different interaction devices, such as radio control, joystick, haptic or motion sensors. The aim is to develop a methodology that enables safely and accurately spatial control during flight, take-off and landing.

We intend to use navigation input devices available in the research group (Figure 3). There will be a calibration and navigation time with agriculture experts for flight training and learn to use these devices.

Figure 2. Micro drone quadcopter.

Figure 3. Navigation devices: joystick, radio control, movement and haptic sensors.

3.3 Definition and implementation of autopilot system

Once the navigation control established, the team will work on an autopilot system based on geo-referenced information. Our idea is to enable autonomous drone flight avoiding collisions. Initially, we intend to use GPS coordinates of an experimental strawberry field as a way to consolidate the route mapping technique. We estimate an autonomy flight for this solution of approximately ~10 minutes.

Again, there will be a calibration and navigation time to test the autopilot system. An operator will monitor the process of taking navigation control in emergencies.

3.4 Interactive 3D user interface

The aim of this stage is to develop an interactive 3D user interface to remotely control the drones. This system should receive real time images sent by drone and display them in one of three viewing devices: desktop monitor, projection screen or head-mounted display (Figure 4). In this case, there is no image processing, but only the visual information over the field, allowing large field view for drone operator. Image projection should take place in reserved rooms installed near or far from the field.

Figure 4. Visualization devices: desktop monitor, portable projector and head-mounted display (Oculus Rift).

The idea is to increase user awareness for decision making and flight stability. In the case of the autopilot, users can focus on displayed images to view and analyze plant growing stages or important aspects for pest management.

3.5 Integration between 3D user interface control and navigation methods

In addition to previous stages, our idea is to perform the total integration of the 3D user interface, connecting visualization systems and input device controls.

This stage will define user movements to control the drone. These movements will also be previously mapped to a particular control action, which will be sending to the pilot system, to behave properly into the remote area. Drone sensors will also send information to the interface control in order to block or limit user interventions during flight, preventing collisions.

3.6 Epidemiological simulation models and strawberry phenology

The agriculture expert team will work on consolidation of epidemiological models to provide information that can be incorporated in the warning systems in the 3D user interface control. Our idea is to present virtual information during the interaction process, overlapping elements over the video feed on screen. This study will be executed in parallel with aforementioned stages.

Moreover, this stage also concentrates the study of recognizing important strawberry phenology events such as flowering. Subsequently, these features will be shared with the computer science team to determine the best image processing methods.

3.7 Development of a computer vision system

Part of the computer science team will implement the computer vision system. This activity will be executed in parallel with design and drone assemblage.

Firstly, our aim is to study and define the image processing libraries that can be added into the project, considering previous studies about strawberry phenology. Our intention is to use open source solutions, like IM toolkit (http://www.tecgraf.puc.rio.br/im), VTK toolkit (http://www.vtk.org) and OpenCV library (http://sourceforge.net/projects/opencvlibrary).

We intend to validate this system using static and dynamic images, captured in strawberry experimental fields using low resolution cameras and mini multispectral cameras mounted in the drones. Our expectation is to select and training algorithms for image acquisition, pre-processing, segmentation, feature extraction, recognition and interpretation of results.

3.8 Integration between user interface control and computer vision system

This stage only aims sharing images for on flight drone control and to detect patterns of strawberry phenology based on image processing. Visual and aural feedbacks presented in the virtual and augmented reality environments depend on this integration.

3.9 Augmented and virtual reality in 3D user interface control

This stage includes the exhibition of virtual information on real-world views during projection. Our aim is to present to the operator useful data related to the strawberry field, during the scouting in 3D user interface. Augmented Reality techniques will be used in an effort to combine virtual elements to the real environment, presenting an interactive and digital data manipulation.

Inside this context, we intend to add information and warnings about the strawberry field being scouted by the drone. As an example, we could use data from: simulation models, weather sensors (temperature, humidity, etc.), GPS, computer vision system (highlighting objects of interest like flowering in plants).

Another aim is to develop a virtual environment for flight training, using this information to familiarize the operators with the real scenario, improving their situational awareness.

3.10 Mini sprinkler procedures

This stage will define how to attach a mini sprinkler and how to trigger it from the drone. Our idea is to automate the spraying of a biological product, applying an aqueous solution directly in the plant parts of interest. The aim is to present an innovative disease management for controlling anthracnose and botrytis in strawberry fields.

For this procedure, the computer vision system will signal the drone to trigger the mini sprinkler. So, our approach will need to perform tests for fine-tuning the spraying method.

4 INNOVATION POTENTIAL

Our project presents challenges and a transformative impact on the study of new technologies to control floral diseases of strawberry.

We aim to develop innovative and integrated solutions to carry out tasks like plant management and traceability. An image processing system using computer vision techniques would provide an important tool to assist researchers and growers in the understanding of strawberry phenology stages.

An augmented reality environment using real-time images, simulation models and weather data, would offer new warning formats to assist researches and producers in decision-making. Agriculture professionals could be trained for the use of technologies through a virtual reality environment that simulates all these scenarios using real data.

This work also encourages collaboration between agriculture and computer science experts. The collaborative work of a multidisciplinary team may produce high tech solutions opening new thematic areas.

Considering new products and processes related, it can be highlighted:

- Design and assembly of a micro drone using open source solutions, embedded-sensors, mini cameras and mini sprinkler;
- Design and development of an interactive 3D user interface control, using Virtual and Augmented Reality solutions for scouting strawberry fields and drone navigation;
- Development of a computer vision system for image analysis and processing;
- Integrating simulation models and warning system for strawberry disease management.

5 FINAL REMARKS

This work presents a 3D user interface project using Augmented and Virtual Reality to develop an integrated system capable of recognizing crop phenology stages and dispatch disease control measures based on image processing.

Various benefits of this integration can be highlighted. By combining the susceptible crop phenology stage and weather factors associated to disease development the system can produce warnings of pest outbreaks. If successfully and adopted the system has potential to improve disease management, minimize the use of chemicals, reduce indirect contamination and costs, increase yield and offer high quality products for final consumer. Our proposal aims to use applied computing, allied to scientific advances, to solve real problems.

In conclusion, knowledge acquisition on epidemiology, plant physiology, robotics, computer vision, virtual reality and augmented reality will be essential to overcome challenges in this project.

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