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Non invasive moisture measurement in agricultural fields using a rolling spherical robot

Juan D. Hernández*, David Sanz, Jorge Barrientos, João Valente, Jaime Del Cerro, Antonio Barrientos.

Center for Automation and Robotics - CAR UPM-CSIC C/ Jose Gutirrez Abascal, 2 - 28006 Madrid, Spain ´(juandhv@etsii.upm.es)

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Abstract: Irrigation management in large crop fields is a very important practice. Since the farm management costs and the crop results are directly connected with the environmental moisture, water control optimization is a critical factor for agricultural practices, as well as for the planet sustainability. Usually, the crop humidity is measured through the water stress index (WSI), using imagery acquired from satellites or airplanes. Nevertheless, these tools have a significant cost, lack from availability, and dependability from the weather. Other alternative is to recover to ground tools, such as ground vehicles and even static base stations. However, they have an outstanding impact in the farming process, since they can damage the cultivation and require more human effort. As a possible solution to these issues, a rolling ground robot have been designed and developed, enabling non-invasive measurements within crop fields. This paper addresses the spherical robot system applied to intra-crop moisture measurements. Furthermore, some experiments were carried out in an early stage corn field in order to build a geo-referenced WSI map.

1. Introduction

Water is the most important resource in any agricultural scenario. It defines the cost of the production, the quality of the crop and the performance of the field. In this sense, the irrigation management is one of the main tasks/goals to be taken into account in the Precision Agriculture (PA) concept.

Many techniques have been used to make effective this control. Nevertheless, all of them are based in the moisture measurement. Without considering non-real time methods, the sensor types could be divided according with their nature: on the one hand, it could be classified between static and mobile sensors. Despite of being more accurate, static sensors (like WSN) requires lot of devices in large fields, being most of the times too expensive. On the other hand, the acquisition systems could be also split according to their range and precision. On the bases of range (not only sensor range, but also coverage) and accuracy have an inverse relation, a deal is required. In this sense, this paper presents the work done in this direction, by the usage of a rolling robot with a spherical shape, named "ROSPHERE" (RObotic SPHERE), as an alternative mobile platform to perform monitoring tasks in crops, particularly to measure moisture, but not limited to that function.

The main purpose of using this alternative vehicle is to minimize crops alterations, and at the same time, being able to have a direct measurement from plants surroundings. By doing so, an action needed over a crop can be done directly to the specific affected area, these actions may include water irrigation, application of pesticides or fertilizers, etc. This precise action results in economical and environmental costs minimization, while maximizing revenues.

Unmanned Aerial Vehicles (UAV) are also used for similar purposes. The UAV mission is to image survey the crop fields. The images acquired are used to build a high resolution map, which can then be employed in weeding tasks. An important research effort is dedicated to compute optimal trajectories for mini UAVs, such as quad-rotors (Valente, Barrientos, del Cerro, & Sanz, 2011a), (Valente et al., 2011b). The aim of the proposed system is not to replace what aerial systems do, but instead to complement it. While the UAV surveys the overall field and biophysical parameters can be obtained through image analysis. The ROSPHERE has the possibility to do *in situ* inspection and analysis. Thus, improving the reliability of the maps with further and more accurate data.

2. Problem statement and proposed solution

The main objective in PA is to minimize environmental impact while maximizing the usage of non-renewable resources (e.g. water). A local measurement of control variables such as temperature, pesticide concentration, luminosity, humidity, etc. might indicate a necessary and controlled action over the crop.

Accordingly, the main objective is to be able to evaluate the real status of the crop, not only from a global point of view but locally. The solution (system) must be able to assess the crop state without affecting the involved plants. This discards an important part of existent mechanisms, mostly because of their size and weight.

Taking into account the requirements mentioned before, a robotic sphere is proposed as an alternative solution. Robotic spheres are systems in which movements are induced by instability. Besides, considering its regular shape, the robot may recover easily from collisions, regardless the direction of the impact, the robot tends to fall into a recoverable configuration. Finally, in spite of its size, a robotic sphere is relatively lighter compare to analogous robot of the same size. Even though there are several alternatives to conceive this concept (Armour & Vincent, 2006), a fixed axis ballast system has been selected as the mechanical alternative (Michaud & Caron, 2002), (Kayacan, Bayraktaroglu, & Saeys, 2011).

3. System description

ROSPHERE is a spherical shape robot with the capacity to self-induce non-holonomic movements. To make that possible, the robot has an inner two-degree-of-freedom pendulum. The robot includes *a)* a spherical shaped body (30 cm of diameter), *b)* a fixed main axis, *c)* a central unit or ICU (Internal Control Unit) and *d)* the ballast or hanging mass. The first DOF rotates the ICU (consequently the hanging mass) about the fixed axis, while the second has a mechanically limited range of rotation, and rotates about a perpendicular axis. Current version of the robot (see Figure 1) was designed to get the Centre of Mass as far as possible to the geometrical center in order to induced movements easily.

a) b) c)

Figure 1: ROSPHERE v0.2. a) Concept. b) CAD design of inner mechanical system. c) Real prototype

3.1. Hardware architecture

ROSPHERE is equipped with all necessary resources in order to behave as an autonomous vehicle. Besides, the system includes an embedded computing system composed by a Robovero and a Overo Fire embedded computer. ROSPHERE has WiFi, Bluetooth and Xbee as communication alternatives, furthermore it also includes sensors to measure inertial quantities (IMU), location (GPS), temperature, humidity, and luminosity.

3.2. Software architecture

With respect to software, system architecture can be divided in two main parts. The first one corresponds to the high-level computation layer, which has to interpret primitive movement commands and generate the respective actuators commands, which could be provided by a human operator (in the teleoperation mode) or decided autonomously by the own navigation system (autonomous mode). On the other hand, there is a low-level computation layer that is in charge to collect (read) information from sensors and to control actuators.

4. Tests and results

ROSPHERE v0.2 was tested in two different crops, winter cereal and corn (See Figure 2), and it was provided with environmental sensors of temperature and humidity. For this test, the robot was teleoperated to move inside the crop in order to get information about mentioned variables. Temperature and humidity variations were registered and can be visualized in Figure 3.

Figure 2: ROSPHERE measuring enviromental variables. a) In winter cereals b) corn crops

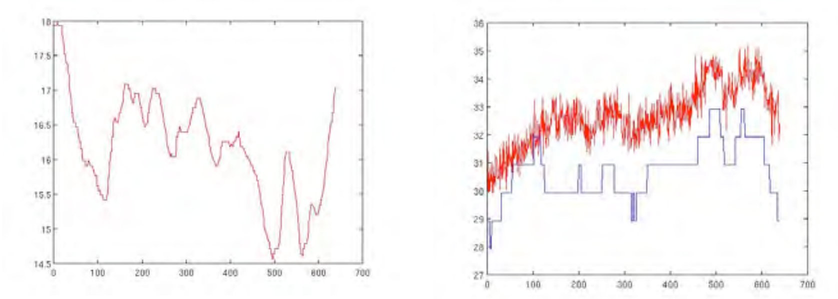

Figure 3: Temperature and humidity measurements

5. Conclusions

With these tests, it was validated ROSPHERE's capacity to move along the crop while taking environmental data. However, it was concluded that the robot should be used only in wide crop row spacing in order to guarantee the plant integrity. Furthermore, a possible enhancement is to locate the sensors outside of the sphere in each of the ends of the main axis. This will improve considerably data accuracy.

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