Preliminary Study for the Development of an Electrical Autonomous Vehicle for Safe Agricultural Chemicals Distribution Inside Greenhouses

Balloni S.[1], Caruso L.[1], Conti A.[1], Schillaci G.[1], Longo D.[2] Muscato G.[2],

([1]) University of Catania – DIA, Mechanics Section, Via Santa Sofia 100 – 95123 Catania ITALY Tel. +39 095 7147512, Fax +39 095 7147600 giampaolo.schillaci@unict.it
([2]) University of Catania – DIEES, Viale A. Doria 6 – 95125 Catania ITALY, Tel. +39 095 7382321 Fax +39 095 330793 gmuscato@diees.unict.it

Abstract

The main target of this research activity is to develop an autonomous electrical vehicle able to spray agricultural chemicals inside greenhouses. This vehicle can increase operations safety level for operators and quality of the chemicals distribution, allowing lower environmental pollution and better greenhouse product quality.

As future development, also the vehicle's chemicals tank refuelling operations will be remotely operated, because this step is one with the highest risk for the operators due to possible contact of the operators with huge quantity of chemicals.

During a first step, the activity will be focused on the development of the electrical vehicle with remote control wireless capabilities. After the vehicle will be fully tested, a distribution and refuelling unit with sensors will be developed and optimised for the specific application.

Feasibility tests have been done using an outdoor remotely operated rover available at DIEES Robotic Laboratory; these tests have demonstrated the goodness of the idea. Moreover, due to constant reduction of electronic parts cost, like computer and power control system and to the presence on the market of new low cost devices for precision farming, the development of a dedicated autonomous vehicle is not as expensive as in the past.

Key words

Robot, tomatoes, safety, precision farming

State of the art

Leaving out direct costs, agricultural chemicals distribution has huge impact on social cost due to the high risk level for operators and to possible environmental pollutions.

To mitigate these problems, in recent past, some semi-automatic distribution methodologies, based on some fixed facilities build inside each greenhouse, have been developed. These can operate without human intervention inside the greenhouse and are composed by a number of sliding rods with nozzles. Due to their high cost and huge impact on the greenhouse, they are not so common.

Because of greenhouses are highly structured and regular environment with respect to the open field, they are well suited to be operated by some automatic machines. Moreover the high risk level for operators has driven different research group to find some solutions like autonomous or teleoperated robotics systems; hereafter a survey of past project in the field will follow.

The AURORA robot (Spain) is able to perform different tasks in an autonomous way with remote supervision [1].

Within the Italian project AGROBOT, a mobile rover bringing a 6 DOF manipulator with an end-effectors and a 'head' with 2 DOF, was developed. The system is dedicated to tomato cultivation inside greenhouse. The robot is able to inspect each plant and to plan individual treatment. Moreover it can distinguish the different maturity level of the fruits. In order to solve navigation problem, some visual feedback have been used [2]. Other manipulator was developed to pick citrus fruit [3].

At University of Genova a project named "Mobile robots in greenhouse cultivation: inspection and treatment of plants" [4] has been developed. The main target of the system was to monitor the health status of the plantation in order to plan dedicated treatment with precision farming methodology. Moreover the system can monitor the chemicals concentration inside the greenhouse to signal the possibility for human operator to enter or not.

A mobile platform for greenhouse chemicals spraying is being developed at University of Almerìa [5].

A commercial machine, named Fumimatic 400 [6], is available in Spain. It is not autonomous nor teleoperated but has is a complete spraying machine with a powerful Diesel engine and a 400 l tank for chemicals.

An experimental test has been done inside a greenhouse (fig. 1) using the outdoor rover Robovolc [6]. It has six fully actuated wheels and has several CCD cameras and a remote base station that allow the system to be remotely operated. It was developed at University of Catania in the framework of a European project for volcanoes environments inspection. In spite of its dimensions, it has demonstrated a high degree of manoeuvrability also in very narrow passage. In any case the entire system has to be optimised for agricultural applications.

Figure. 1 – The Robovolc rover during tests inside a greenhouse

System specification

From analysing a typical spraying application inside greenhouses, a set of system specifications have been found.

The maximum width should be 0.8 m with typical greenhouse configuration. The minimum speed should be about 1.5 m/s while the maximum speed should be high enough to make fast chemical refuelling and system transfer on road. Because of short rows in the greenhouse, the robot must reach its target travel speed as soon as possible in order to guarantee uniform spraying as soon as possible in the row, so it should have a suitable acceleration.

At the end of each row, the robot must turn in order to re-enter next row. In order to turn using as less space as possible, the robot will use special kinematics manoeuvring, like skid steering. Moreover it will have not to damage the terrain or the plastic mulch. To not compress the terrain, the robot must use chain-like wheels; with this solution the pressure on the terrain could be less than 60 kPa considering the mass of the robot and the chemicals full tank weight. During system manoeuvring, spraying unit must be turned off. This should happen also in case of reverse motion or stop. An acoustic signal and security supervision module will be also available in order to allow the system to operate autonomously. A suitable high efficiency engine with very low pollution will be mounted on-board to provide electrical traction power and suitable spraying pressure.

The main structure of the system is represented by an electrical machine widely used in the south-east coast of Sicily [7]. This machine, named "Vanco", is derived from some small manual trucks used in the past. It is actually used in helping human operation in outdoor operations as harvesting and to arrange cultivations (fig. 2).

Figure 2 – The "Vanco" system

The manufacturer, in collaboration with farmers, has so developed the electrical version of the trucks.

In the current implementation, it use two robust rubber chains with gearboxes instead of wheels, actuated by one brushed DC motor of about 630 W with 3000 RPM at no load conditions. The system has moreover a hydrostatic mechanical power distribution with two speed and reverse motion. The power supply is obtained from two series connected lead-acid 12 V, 180 Ah batteries. The weight of the metallic structure is about 100 kg while the total mass, including motor, gearboxes, the two batteries and so on, is about 300 kg. Because the two batteries, DC motor and gearboxes are mounted on the lower part, the whole system can guarantee very high stability.

Thanks to the special shape of the two rubber chains, the system is able to overcome obstacles and to move over concrete tracks as well as over rough terrain.

Project steps

The design of the system will be performed in different steps. Mainly, first the mobile rover will be realised; after that the navigation and the spraying systems will be developed.

The rover will accomplish the specification described before and its functionality could be synthesised as:

- Should be able to deftly move inside the greenhouse;
- Should be able to carry the spraying unit and all the necessary devices and their weight;
- Should not damage greenhouse and related facilities;
- Should be at least teleoperated or autonomous.

After the rover has been tested, all the device related to remote operation and to autonomous navigation will be developed.

The navigation subsystem will comprise two different modes:

- Remote control, in which the user will send command to the rover from a safe place outside the greenhouse;
- Autonomous navigation, in which the user will program some tasks for the robot and then these tasks will be autonomously performed by the robot.

The system will be able to store at predefined time step its position and the related spraying flow in order to allow treatment traceability.

In Fig. 3 it is shown a block diagram of the system. Among the most important blocks there are the "*User Interface*" that allow the operator to plan the mission in autonomous mode or to send direct command to the whole system (rover and spraying unit) in teleoperated mode and in any case to receive system status. It is wireless connected to the robot and can receive video information taken from the on-board cameras.

The block named "*Task Generator*" translate user command (sent in an high level language) into low level command sequence for the system. The block named "*Trajectory Generator*" calculate the system trajectory in autonomous mode, on the base of the assigned task and on the greenhouse map. The block named "*Map Database*", holds all the map of the greenhouses where the system will be used inside. The block named "*Obstacle Avoidance*" is responsible to detect and to warn about unexpected obstacles. The block named "*Localization*" will allow system localization inside the greenhouse using triangulation methodology. The block named "*Traceability Database*" will store position of the robot and related sprayed flow for post-processing purpose.

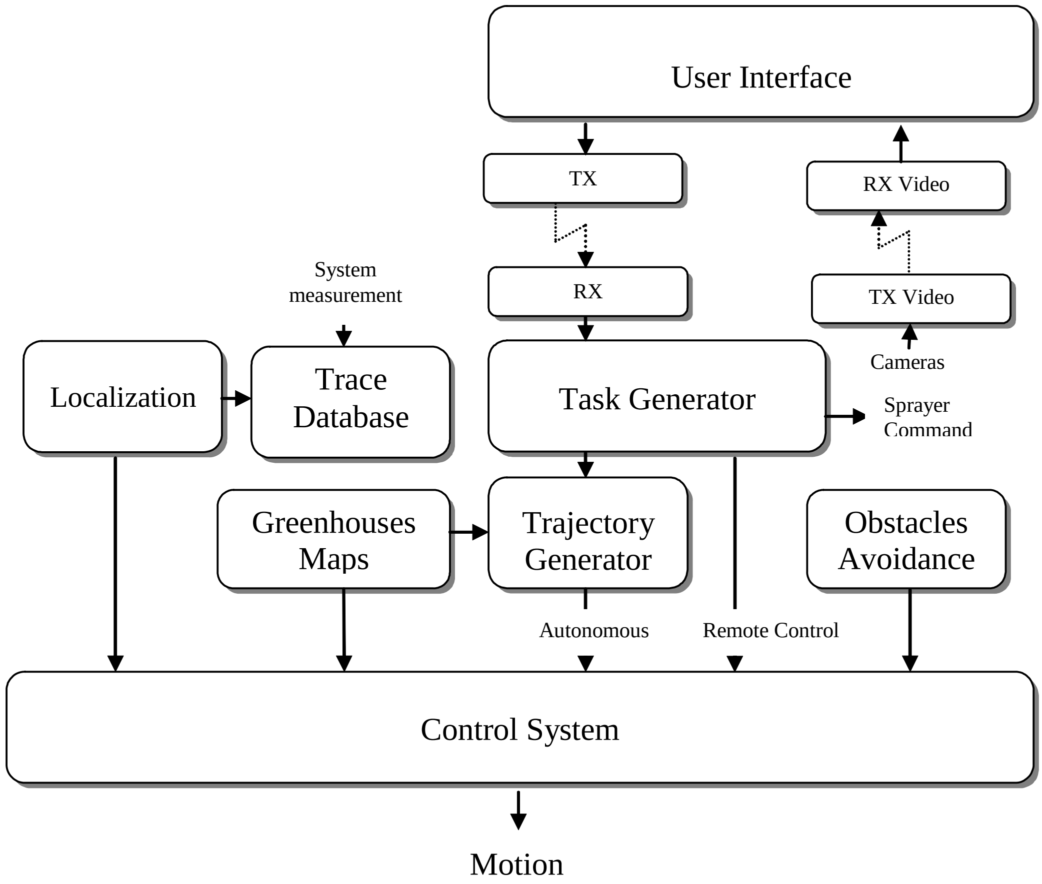

Figure 3. Block diagram for the main functionality of the system

Results

Expected results from this activity are a rover able to move inside different kind of greenhouses with actuators and a control system for remote/autonomous operations. Moreover a navigation/localization system will be implemented on-board; this capability will allow traceability of treatment as required by the precision farming methodology and will guarantee safe system operation inside the greenhouse also in case of unexpected situations. The system will be completed with a spraying unit, a tank for chemicals, control system for the hydraulic components, filters and so on.

Using this kind of robot, one could expect to increment the efficiency of each operation of about four times when the system in autonomous mode with respect to a team of 6-7 worker. In standard conditions this team can spray about 1.8 ha in about three hours. This machine could operate also during night time in autonomous mode.

On the other side, using an autonomous machine for greenhouse spraying operation, it is avoided the exposition of worker to chemicals, also during refuelling operation that will be autonomous also, increasing the operators safety.

It can also be used by the farmer for other tasks than spraying by removing the tank and the spraying unit, so the cost of the whole system can be distributed along different areas of applications, attracting farmer towards this product.

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