A Multifunctional Tracked Vehicle Able to Operate in Vineyards Using GPS and Laser Range-finder Technology

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Abstract
Work in agriculture and in particular in some local sloping vineyards require a great deal of resources and effort. But regular geometry of most vineyards rows can help the automation of some cultivation processes. With the aim to facilitate workers during harvesting, pruning and to carry bins full of bunches of grapes up to the end of the rows, a versatile multifunction electrical vehicle is under development.
The vehicle, named U-Go, has been built in order to be used as a multipurpose outdoor vehicle in different applications, so the control electronics have been designed to provide different choices for control modalities. The simplest one is the teleoperated modality. In this situation a remote user, using a joystick, can send direct commands to the robot in order to move forward, backward or turn left or right at different speeds. In order to allow the totally autonomous operations in the vineyards, different sensors were tested. In this work, system test using a Laser Range Finder and a DGPS have been performed using an obstacle avoidance methodology named Potential Field Method (PFM). This algorithm allows the robot to follow a specified trajectory, defined by means of some GPS waypoints, while avoiding unexpected obstacles. This control algorithm has been developed using the Microsoft Development Robotic Studio that allows for code development and simulation for robotics application.
Different tests on the U-Go Robot have been performed in order to demonstrate its capabilities on the two different modalities with promising results.

Introduction

In viticulture the development of autonomous systems able to remove or facilitate the operators in the workplace comes from the sensitivity to the issues of health and safety. In the vineyards with a close layout and in steep slope, the distribution of agrochemicals, the handling of the bins with the grape, during the harvest, from the spin to the trailer, is performed mostly by hand and place the operator at risk to his health (chemical risk, effort the back and upper limbs). In the low strain vineyards (goblet, spurred cordon and Guyot), typical Mediterranean viticulture, some cultivation operations (green pruning, sucker removal, vine tying) lead the operator to work bent toward the ground, in difficult and incorrect positions. There are commercially available electric trucks (Damascus, VITIJAMBEUR) fitted with seats built with the aim to reduce operator fatigue and increase productivity, but the seat position is often not adapted to the habits of the worker who, while working sitting, continues to maintain an incorrect posture of the back.
There aren't in literature, till this moment, existing systems, reliable and robust, suitable to be used in vineyard. In general, the potential of robotics has not been fully exploited in the field

mentioned above and there aren't robots, to be created and commercialized, as dexterous and skilful as trained workers. From the robotics viewpoint, there are some advantages to use a typical structured vineyard environment such as: controllable and/or partially known position of the plants, controllable shape of the plants (e.g. the growing direction and the height), ground floor (at least in the drivable surface) more regular than in the open field etc. (Will J. D. et al, 1998).

In literature, different automatic guidance systems that allows to reduce driver stress and a more relaxed working and an efficient use of machines and resources, were presented. Auto-guidance, also called auto-steer, of tractors and self-propelled agricultural machines that is based on a global navigation satellite system (GNSS) represents one currently available technology that can provide significant benefits for crop production in different growing environments. Today, numerous farmers have suspended the use of conventional markers from their operations and rely on cost-effective alternative methods to steer their farm equipment based on continuously measured geographic coordinates. There are several companies that sell such GPS systems for tractors or machines and other automated solutions (e.g. sprayers) (Deere, Trimble, Arvatec). Some papers highlight different approaches for guiding a vehicle using a Differential Global Positioning System (DGPS) based position sensor as the only external posture sensor. (Builk R. 2006; Heraud J. A. and Lange A. F., 2009). Some machine adopts multiple guidance sensors (Holpp et al, 2006; Ming et al, 2009; Wan et al, 2008; Murakami et al, 2008; Toru et al, 2000).

The objective of this research is to develop a versatile multifunction electrical vehicle able to operate in high density planting vineyard to facilitate the workers during harvesting and cultivating.

Vehicle Description

The robot structure

The mechanical structure has been designed in order to be compliant to different requirements. First of all, the robot must be able to move inside vineyard corridors; moreover it must be able to move on different uneven terrains and must not generate too high pressure on the terrain (in order to meet agricultural requirements). The robot must be able to carry at least 200 kg payload over a flat road (in order to be able to transport boxes full of bunches of grapes, an agricultural spraying machine or other tools) and climb on sloping roads with a suitable payload.

According to these specifications, the robot two main dimensions are 0.6 m wide and 1.2 m in lenght. Moreover it uses rubber tracks instead of wheels for locomotion and its weight is about 250 kg. Figure 1 shows the U-Go Robot.

Four sealed lead-acid batteries are mounted on the mechanical structure on the rear side of the robot. Each rubber track is actuated by means of brushed DC motor and suitable gearboxes. Finally, on the top of the robot there is another box that contains a computer, all the necessary electronic circuits needed for autonomous navigation, the emergency stop button and the safety flashing light.

Figure 1. The tracked U-Go Robot during a teleoperated outdoor test.

Robot moving modalities

The control electronics have been designed to provide different choices for the control modalities. The whole control architecture is managed with a joystick which allows to select the Navigation Modality and to manage the motor drivers (i.e., reverse, gears and emergency stop). The simplest one is the *teleoperated modality* (Livatino S. et al,2008, 2009). In this situation a remote user, using a joystick or simply a computer keyboard, can send direct commands to the robot in order to move forward, backward or turn left or right at different speeds.
The other two possible modalities for controlling the robot are *semi-autonomous mode* and *autonomous mode*. All the implementations of these modalities relay on an onboard computer, on several sensors mounted on the robot and on a remote base station. Next chapters will briefly describe the different sensors and algorithms used.

Semi and totally Autonomous Operations

The system control architecture is shown in Figure 3. It mainly consists of one computer, in which reside software modules used to receive information from the various sensors
One of the possible applications of this electrical tracked robot is as a semi-automatic barrow to carry bins with grapes out of the rows. To perform these tasks, the operator can just drive the robot between two different rows, while the robot can autonomously move along the row using GPS and Laser range finder. In this way the operators can concentrate in the harvesting task, while the robot performs the transport task; it also has special safety algorithms in order to not be dangerous for operators and vineyards. Moreover, because the robot is electrically powered, there is no danger for operators of toxic exhausts. When the robot uses a D-GPS, it can be fully autonomous. The on-board sensors suite is composed by a Laser range finder (LRF, SICK LMS200) and a Global Navigation Satellite System (GNSS) receiver (Ashtech Z-Extreme).
Navigations algorithms have been developed using the Microsoft Robotics Developer Studio (MRDS) tool (Microsoft). This programming platform is developed by Microsoft just to interact with different and customizable robotic devices and integrate also a Visual Simulation Environment (VSE). This permits easily to simulate control algorithms and architectures before real robot testing. MRDS is particularly useful for moving easily a project from simulation toward the real robot implementation. It is in fact possible to replace each simulation entity with a corresponding tool of the real world. The control module, therefore,

resides in a PC that receives and processes sensors information provided by the GPS device and the laser scanner.

The navigation algorithm, running on the MRDS platform, takes care of generating the control reference for the used robot; in our case the code has been customized for the U-Go Robot. First of all, different algorithms were tested using data coming from the laser scanner and the DGPS. Relying on these data an Obstacle Avoidance (OA) algorithm was developed. One of the techniques used for OA was the Potential Field Method (PFM) which allows the motion control to avoid collisions with the obstacles detected by sensors during the motion itself, without losing the main task. For example to achieve a target configuration identified by a GPS waypoint. The result of this technique is a sequence of movements that allows to safely drive the vehicle towards the target without collisions.

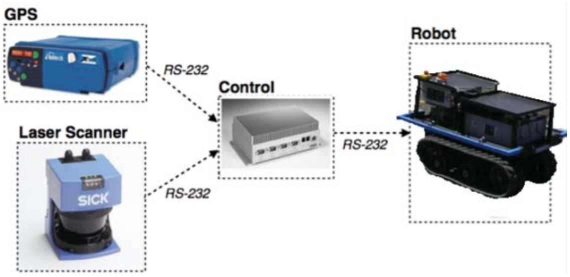

Figure 2. First autonomous navigation tests: robot configuration

Results

Different test have been performed using the U-Go Robot. During the first trials, teleoperated mode has been used on a volcanic environment in order to test the system reliability and payload capabilities. About 180kg of materials and instrumentation were carried on the top of the Mt. Etna volcano (about 3300 m asl) on behalf of INGV (Istituto Nazionale di Geofisica e Vulcanologia) in order to allow their technicians to build some gases monitoring stations. In Figure 4a the U-Go Robot during this test is shown. Other teleoperated tests were done in greenhouses (Figure 4b).

Figure 3. Teleoperated robot test on the Etna volcano(a) and inside a greenhouse (b)

Other tests were regarding autonomous navigation capabilities. During these tests, the robot, with the configuration shown in Figure 2 and the navigation algorithms described before, had to travel along a pre-defined path.

The Figure 4a shows a predefined winding path performed by the robot. The red circles show the GPS waypoints assigned by the user; the small blue circles represent the real path of the robot during the trial while the solid line represents the ideal trajectory.

The Figure 4b shows as the robot was able to reach different targets (waypoints) avoiding some boxes positioned (black square) along a rectangular path in an outdoor area situated near our laboratory. The results of these tests were satisfactory.

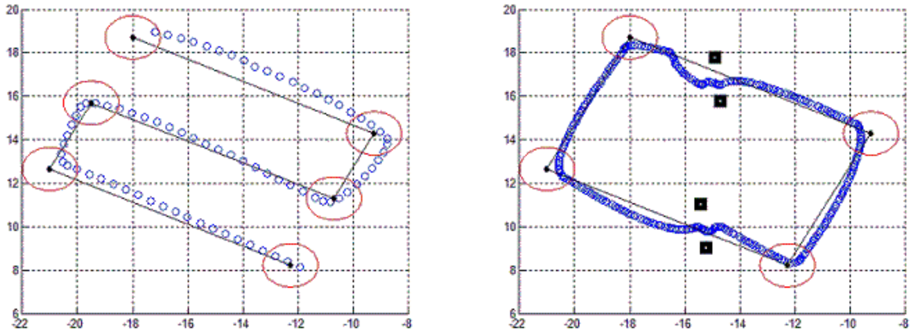

Figure 4. U-Go robot while travelling along a predefined winding path (a) or while moving along a rectangular path avoiding obstacles (b)

In order to test both teleoperated and autonomous modalities and related performance, other trials were carried out in some vineyards of Monte Serra - Viagrande (Catania), showing the accuracy and the reliability of the system as well as the benefits that could derive from his use.

Figure 5. U-Go Robot test on the vineyard of Monte Serra - Viagrande (Catania)

Conclusions

The U-Go Robot has been built in order to be used as a multipurpose outdoor vehicle in different application. Its technical specification meets requirements both for teleoperated as for autonomous motion. Different sensors were tested to allow for autonomous operations in wineyards or greenhouses. In this work, system test using a Laser Range Finder and a DGPS have been performed using an obstacle avoidance methodology named Potential Field Method (PFM). This algorithm allows the robot to follow a specified trajectory, defined by means of several GPS waypoints, while avoiding unexpected obstacles. This control algorithm has been implemented by using the Microsoft Development Robotic Studio that allows fast code development and simulation for robotic applications. Different tests on the U-Go Robot have been performed in order to demonstrate its capabilities on the two different modalities with promising results. The mechanical structure of the robot described in this study, will be adopted to transform a small self-propelled sprayer, already under development for the vineyards and the confined environment of the greenhouses, which can operate by remote control. The sprayer will be equipped with a suitable donor of pesticides and with monitoring devices (remote controller) with on board sensors.

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