DEVELOPMENT OF A GRAPE HARVESTING MOBILE ROBOT

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ABSTRACT

With South Australia continually increasing its wine production, there is growing need for more efficient grape picking. This project aims to address this problem by investigating an alternative method of picking grapes. Adopting a similar approach to traditional hand picking, a robot will be used to manoeuvre itself around the vineyard, identify grapes and cut them as a bunch. By utilising a robot, harvesting could continue both day and night, enabling more grapes to be picked at their peak. The robot used for this task will essentially consist of two distinct parts, a device to identify and collect the grapes, and a base that will enable the complete robot to move around the vineyard. For this project, only the base will be manufactured, however, this will be designed to accommodate the entire robot.

KEYWORDS: MOBILE ROBOT, GRAPE HARVESTER, AUTOMATED FRUIT PICKER, VISION SENSING

1 INTRODUCTION

On completion of the entire mobile robot, it will be capable of navigating a vineyard, recognizing bunches of grapes, and obtaining them from the grapevine. It will then place these grapes in a container that follows the mobile robot. The robot will therefore have to deal with issues such as power for moving the payload (grapes), recognizing and then reacting to obstacles, and being able to navigate through the rows of the vineyard.

This project explores the fundamental concepts that will be used for the completed mobile robot. Issues such as robot navigation, and motion are investigated. Following the development of these investigations, a prototype robot has been constructed. The constructed robot base has been tested, to confirm that the adopted navigation method is suitable. A vision system has also been fitted for future development to enable recognition of the grapes. The vision system is comprised of a camera fitted to the robot, which transmits images to a computer for processing using a wireless link.

2 LITERATURE REVIEW

2.1 MOBILE ROBOTS

The aim of this literature review is to present an introduction to the field of mobile robotics. The first serious autonomous mobile robot was developed at Stanford Research Institute in 1970 and was called Shakey [1]. Since the 1970s, major developments in microelectronics and computer technology have led to significant advances in robotics [2]. In addition, developments in integrated circuits has allowed a trend towards miniaturization in computer technology that continually leads to robots that are much smaller and less expensive, yet are capable of much faster calculations. As a result, a wide range of application fields can now be considered for mobile robots, which includes manufacturing, space exploration, agriculture and human hostile environments.

The European Space Agency (ESA) determined the need to take scientific measurements of Mars from the immediate environment of static landing stations, to a radius of tens of metres. To achieve this, the ESA developed two mobile robots: the “Nanokhod” and the “SpaceCat”.

The Nanokhod design [3] is essentially a tracked rover concept. It consists of a central Payload Cab and two Locomotion Units that are connected by a mechanical bridge (Tether Unit). The two tether spools are used for wire-based power and telecommunication transmission between the rover and the landing station. The two tracked units provide locomotion. Each unit consists of a frame, a track chain with cleats and a powered drive wheel. The design for powering the Nanokhod was integrated into its communication with the landing station. This was achieved through the electrical tethers, which provide both power and communication. Control of the rover on the Mars surface consists of a path being plotted in waypoints by the human operator and then the robot is capable of autonomous piloting between waypoints.

The SpaceCat design [4] has a hybrid rolling stepping system, containing a stepping triple wheel design that allows both walking and rolling motion. The other significant structure on the SpaceCat is the scientific payload, which is used to collect samples from the Mars surface. The hybrid rolling stepping system of the SpaceCat is the most efficient design for planetary exploration. This is because although the rover moves mostly on flat surfaces where rolling motion is most effective, it still requires climbing ability. The rover control system is shared between the rover, the landing station and Earth. The vision system of the rover consists of a video camera mounted on the landing station to obtain a panoramic view of the site and observe the motion of the rover. Images obtained from the camera back on earth are viewed and used to send navigation commands to the rover.

2.2 CURRENT GRAPE HARVESTING METHODS

Currently, grapes are picked from the grapevines either through manual labour or mechanical grape harvesters. Manual labour however is a time consuming process, as grapes need to be picked from the vines in a few weeks. This is because the grapes are at their optimal maturity for a short length of time. As a result, vineyards employ dozens of pickers over this period. This picking process involves using scissor-like cutters to cut the stem of each grape bunch. These bunches are placed in buckets or crates and collected by a tractor. This manual process is relatively expensive due to the cost of paying the pickers.

The other picking method is the mechanical harvester. Mechanical harvesters work by straddling the vine rows and shaking each vine so that individual grapes fall off into collection baskets, which are conveyed into a collection tank. This process has the advantage of being much faster than using human pickers. It uses minimal physical work, and only requires two operators. A disadvantage of this system is the possibility of damaging the vine branches due to excessive shaking, reducing crop productivity. It has been found that current mechanical harvesting methods do damage the vines for some grape varieties, to the extent that it affects the yield of the following season [5].

In addition, mechanical harvesters have a possibility of damaging the berries, by breaking the outer skin. This means that grape juice is lost and oxidation commences immediately, reducing the quality of the produce. Reports disagree about whether the quality of wine is affected by the harvesting technique. Generally, the softer skins of white grapes mean that mechanical harvesting can affect quality due to oxidation. Also, due to the additional leaves collected by mechanical harvesters, the colour of white wines become darker, which is undesirable. Economically, hand picking is marginally better than mechanical picking [5]. However, many factors can influence which method is more financially viable.

3 DESIGN REQUIREMENTS

- Design and build a prototype mobile robot
- The device should be able to maintain its position in the centre of each row of vines

- The robot must be able to sense the end of each row, and have a sufficient turning circle to turn around
- The robot must be capable of moving over uneven ground, and encounter obstacles such as leaves, small branches, rocks, grapes, long grass etc
- Capable of moving over wet terrain
- The robot must be equipped with a system capable of locating grapes
- The weight should be as low as possible
- The cost of the robot must be less than $250

4 DESIGN CONCEPT

In order for the mobile robot to pick grapes it must move between the grape vines, detect where the grapes are, remove them from the vine, and place them in a collection bin. To detect the grapes, the robot will contain cameras that will be focused on the vines to the side of the robot. This image will then be analysed by a computer to determine the location of any grapes.

For the full-scale grape picker, this vision system can be used to determine the distance between the robot and the vine. This means that the camera can be used to maintain the robot in a straight line. Furthermore, a computer located within the mobile robot will perform the processing of the image obtained from the camera.

Due to time constraints on this project, image processing has not been developed. As such, an alternative steering design is required. The steering solution for the prototype involves using two inductive sensors to detect the magnetic field produced by a current in a charged wire. When the robot veers off course, one sensor will be closer to the wire than the other sensor, thus detecting a larger magnetic field. Based on this, the control system drives each of the wheels at different speeds in such a way as to move the robot back to its desired course. For demonstration purposes, the prototype mobile robot contains a CCD camera to obtain an image as it moves. This image is sent to a computer at a fixed location through a wireless link and is displayed on the screen.

In developing a mobile base robot that will have the ability to pick grapes from the vine, the robot must have the ability to sense the grapes and be able to obtain them. As the mobile base traverses its current row, two cameras on each side are placed strategically on the base to capture images. These images are then sent to a computer via an RF transmitter/receiver and capture card system. The camera is connected to the transmitter, which sends the image as an RF signal that is collected by the receiver, which is tuned to the same frequency as the transmitter. Once the receiver has decoded the image from the signal it sends it to the computer to which it is wired. A capture card converts this data into computer format. As a result the computer can display the images being sent or can save the images to a file where they can be processed using an image detection library.

As the mobile base continues along its path and comes across a bunch of grapes, which are captured by the cameras, an image library enables the image to be processed. The library then uses pattern and colour recognition to identify the grapes. Once the grape bunch has been detected, the mobile robot base is signalled to stop. The two dimensional image is then analysed to determine the coordinates of the grape bunch in the viewing plane. As there are two cameras being used, the two images obtained of the scenery can be compared so that the grape bunch's position can be determined in three dimensions, provided that the grape bunch is not hidden behind leaves or other obstacles. Subsequently, the coordinates of the grape bunch are sent to the control system of a robot arm. The robot arm then moves its end effector to these coordinates and obtains the bunch of grapes, placing them in a bin that follows the main mobile base. On completion of this task the mobile base resumes its navigation through the vineyard.

5 THEORETICAL WORK

The design of our mobile robot is summarised below:

- Three wheel design with front two wheels driven differentially for steering. The rear wheel is a freely rotating castor wheel
- The wheels chosen are sufficient to facilitate motion over small obstacles and wet terrain
- DC motors to provide sufficient torque at low motor speed to enable the robot to traverse rough terrain
- Reduction unit (pulley) from motor to wheel for improved torque at low motor speed
- 12 V battery power supply
- Aluminium chassis and covers, for weather resistant design and good strength to weight ratio

A CAD drawing of the mobile robot (without covers or ancillaries) is shown below in Figure 1.

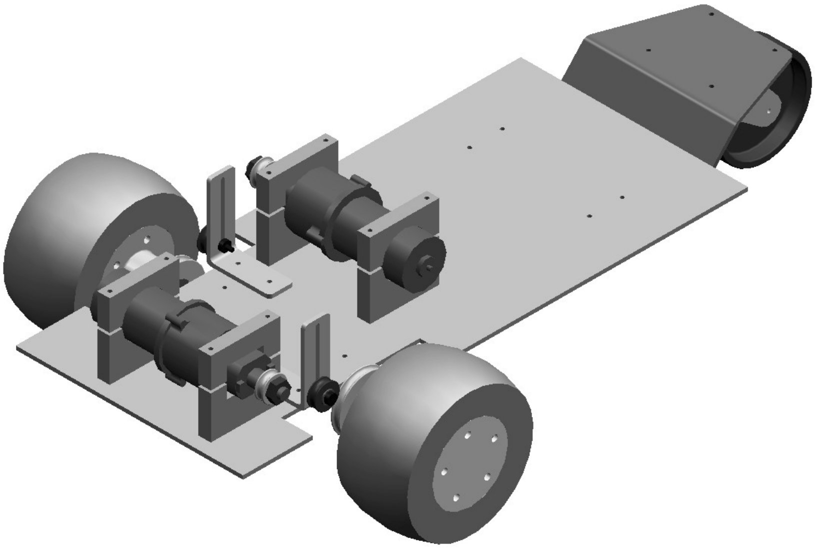

Figure 1

6 RESULTS

After the mobile robot was assembled, measurements were taken to investigate the response of the motors to some varying conditions. The wheel speed was measured upon varying the following parameters; wire position relative to the centreline of the robot, wire frequency, and wire current.

Two of the graphs produced as a result of testing are shown in Figures 2 and 3. Figure 2 shows how the speed of each wheel is affected due to the position of the wire relative to each sensor. When the wire is located directly beneath the left sensor, the right wheel rotates at its maximum speed, and the left wheel is stationary. As the wire moves closer to the right sensor, the speed of the right wheel decreases, while the speed of the left wheel increases. These results were taken with no load applied to the vehicle. A constant 12 V input was supplied to the motors, and the frequency of the wire was fixed at 0·93 kHz, with a current of 0·9A.

Figure 3 shows the relationship between the current frequency in the guidance wire and the average wheel speed. For this test, a constant 12 V input was supplied to the motors, and the guidance wire was held in a fixed location relative to the sensors. As Figure 3 shows, the average wheel speed decreases when compared to the current frequency. This is due to high frequency rolloff of the system. Based on this data, the maximal wheel speed is obtained between about 20 Hz and 500 Hz. However, as we require a lower wheel speed, we will use about 1 kHz.

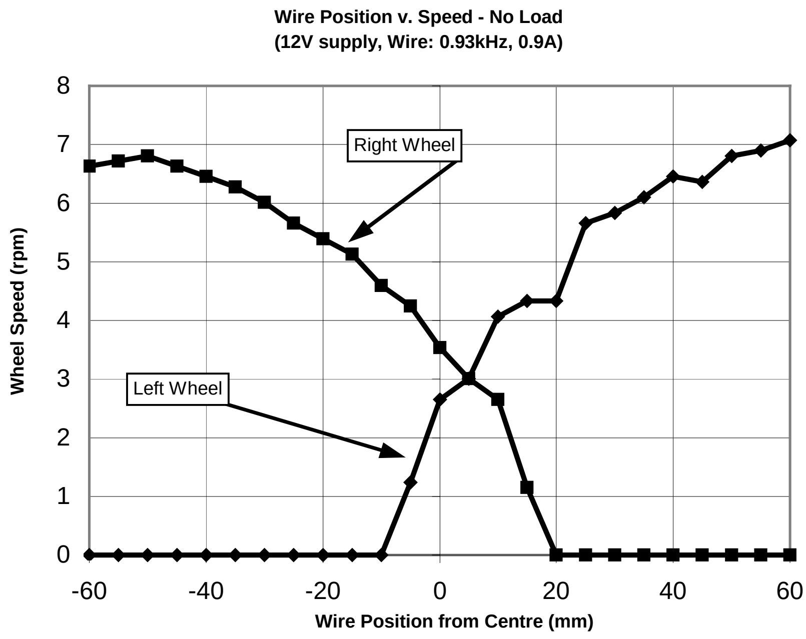

Figure 2

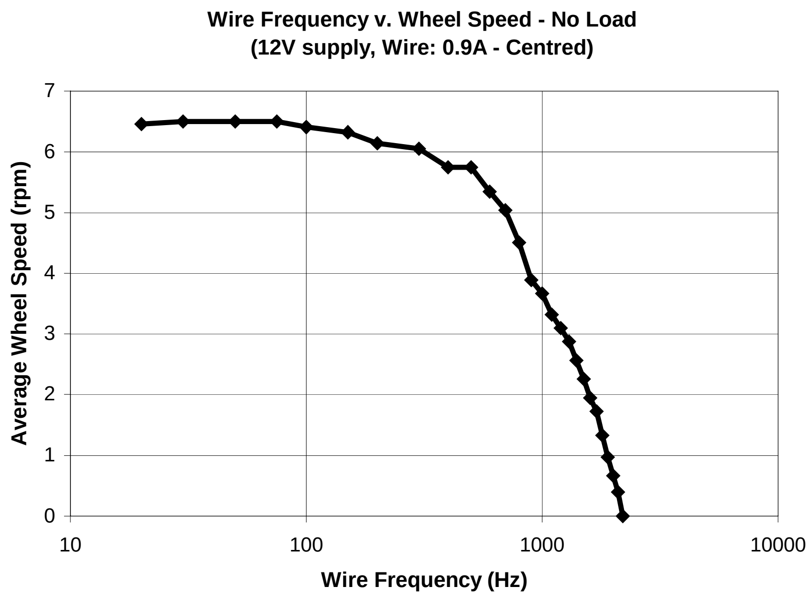

Figure 3

7 FUTURE WORK

Before the commissioning of the robot, substantial work must be done. Research needs to be done in the field of pattern and colour recognition in order to develop a successful vision imaging system. To pick the grapes, a robotic arm needs to be developed, along with communication between the computer and arm. This is required so that once the three dimensional position of the grapes is determined, the information can be sent to the robotic arm to act on. Development of a second vehicle in which the picked grapes can be couriered is also required.

8 CONCLUSION

The work that we have done so far is a platform for future work on both mobile robots and mechanical fruit harvesters. Although we have made good progress on this project, additional work is required to develop effective pattern and colour detection software. This perhaps poses the greatest obstacle in the final development of the project. However, with establishment of the vision system and on completion of the unfinished sections, the project shows great promise of being successful both on an operational and commercial level. Whether our design will decrease the cost of picking grapes is not yet known. If our mobile robot can be financially beneficial, we believe it could become a better grape picking method than hand or mechanical picking.

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