Sensor and Vision based Autonomous AGRIBOT for Sowing Seeds

Palepu V. Santhi[1], Nellore Kapileswar[1], Vijay K. R. Chenchela[1], Venkata Siva Prasad. CH [2]

[1] Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa.
[2] Department of Electronics and Communication System, Dr.M.G.R Univesity, India
Email: u16275731@tuks.co.za1; u15342396@tuks.co.za1; u16326505@tuks.co.za1; siva6677@gmail.com

Abstract—**Autonomous agriculture robot is one of the promising solutions for precision agriculture. This paper presents the proposed sensor and vision based agricultural robot for sowing seeds. This prototype can navigate it on any agricultural land and perform seed sowing operation simultaneously. The on-board sensors along with vision system and vision based approaches achieves the navigation and localization tasks. Self-awareness of the robot's position is determined by the global and local maps generated from Global Positioning System (GPS) and on-board vision system paired with a personal computer. This paper also presents the proposed sensor based precision seed metering and sowing mechanism. The proposed robot is a micro planter whose primary task would be to sow seeds at prefixed seeding intervals in the field. The dimensions of the proposed robot are 26.5 x 18.5 x 19.65 mm as L x B x H respectively. A suspension system has been used to maintain the stability of the vehicle and prevent it from toppling in motion.**

Keywords— **Ultrasonic Sensor; IR sensor; Vision based navigation; GPS; Autonomous agricultural robot.**

I. Introduction

Robotics is a promising technology that contributes to almost every sector of the global economy, from medical to space study. Nevertheless, one sector that consistently lags behind is the agriculture. This is slightly mystifying because many farmers were used to the tools, heavy machinery and conventional agricultural techniques. The spread of robotics in agriculture in general is slow, but persistent. A significant research has taken place in the development of greenhouse grafting robots (in 1998), harvesting robots for strawberry and tomato (in 2008) and autonomous vehicles for orchards are in development. In past decades, many researchers have made significant research on agricultural weeding robot and vision based navigation of agricultural robots. The machine vision based approaches for navigation of agricultural robots allows the progress of future autonomous vehicles.

Navigation in an anonymous and amorphous outdoor location is a fundamental and challenging problem for autonomous mobile robots. The navigation task involves detecting safe, traversal paths that let the robot avoiding the obstacles to reach the goal. Standard approaches involve ranging sensors to complete the navigation task. The ranging sensors such as stereo vision gives short-range insight and obstacle detection in a range of 5m. Navigating exclusively on short-range perception can lead to inappropriate classification of safe and dangerous terrain in the far field and inefficient path following.
To reduce near sighted navigational errors, near-to-far learning-based, long-range perception methods are developed. The machine vision and GPS based autonomous navigation method is widely used in research work. The capability of self-localization is the significant requirement for a mobile robot. The Monte-Carlo-Localization (MCL) is a technique for estimating the location of the robot. Many sensors have been used for localization with MCL, including laser range sensors and vision sensors.

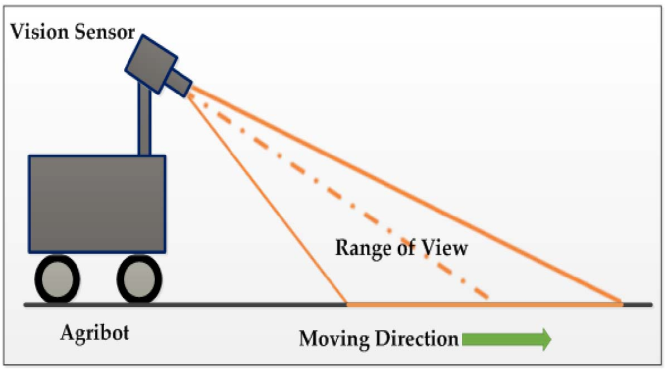

Figure 1.Arrangement of the vision sensor on the agriculture robot.

The rest of the paper is organized as follows: we review the related works in Section II. Section III presents the proposed methodology in detail. Section 4, presents the experimental results, and section V concludes the paper.

II. RELATED WORK

Agriculture has been playing a key role in the development of human life. Numerous technologies, including robotics, sensor and image processing have been investigated to be employed in agriculture. For the past decade, significant research has been done in robot based agriculture.

Xue et al. developed the variable field of view (FOV) machine vision based guidance system [1], which allows the robot to navigate between the rows. The proposed machine vision hardware involves a camera with pitch and yaw motion control. Image processing algorithm and morphological features were used to detect the guidelines and fuzzy logic control technique was employed to guide the robot along the lines. The developed system was tested with the three FOV arrangements: (1) near FOV, (2) far FOV and (3) lateral FOV and all the three methods had acceptable accuracy. The results have shown that the far FOV outperforms the other two.

Wang et al. [2] proposed a statistical prediction framework to enhance long-range terrain perception for autonomous mobile robots. Their framework includes appearance features and spatial relations between terrain regions for prediction.

Hague et al. [3] examined ground based sensing approach for vehicle position fixing. They considered the sensors in several categories: odometer, inertial sensor (for motion

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measurement), laser positioning, millimeter wave radar (for artificial landmarks), and sonar, machine vision (for local feature detection). Vehicle scheduling approach using visual sensing methods [4]. They have also presented the protocol to achieve low transmission delay [5].

Qin et al. [6] proposed a visual navigation based weeding robot. They designed a compact robot with special structure and implemented the navigation algorithm in TISOC DM6446. The weeding robot walks along the line and cut off the weeds and adjusts its supporting devices to change lines automatically. The seedlings centerline detection and nonlinear motion control strategy are combined to allow the weeding robot to realize the weeding function of the inter-row weeding in the paddy fields. The success of the proposed system was validated by paddy field tests and the results have shown that the weeding robot can properly realize line-changed action and meets accurate and fast weeding job desires. An improvement in the WSN lifespan using the CSMA/SDF scheme is given in [7].

Even though the research advances are ample, still few shortcomings are suspending the enhancements essential for the commercialization of the guidance systems. Better results are observed by combining both GPS and machine vision technologies together or one of them with laser or radar technology. The vision based systems have become the promising alternatives, mainly considering the present availability of low cost image sensors and high performance processors and the machine and software worked very well with corn seeds [8].

Dworak et al. [9] proposed a plant camera and cross-correlation algorithm based solution for robots functioning with sensitive plants and proved that their proposed approach overcomes the problem of jumps that hinder GPS-driven solutions. They described plant based navigation by combining the image of a known scene with a known plant camera system. A typical arrangement of the vision sensor on the agriculture robot is shown in Figure 1. The mounting angle and viewing angle has to be chosen properly. Most of the schemes are associated with designing an intelligent control system [10] and vision bases approaches to clear view lane center edges [11].

For accurate navigation control, the best practice is to use an actual view of the plant lines to determine the exact direction to navigate [12, 13, 14]. For an agricultural vehicle, navigational laser scanners and vision sensor (camera) systems are common [15]. The laser scanners are very expensive but, they are best for agriculture vehicle applications as they have huge and overlapping spots to guarantee the safe detection of obstacles [16, 17]. The performance of the robot on uneven terrain is strongly connected with the minimization of wheel skidding and slipping. The way to minimize the occurrence of wheel skidding and slippage is the use of a Cross-Coupled Control (CCC) strategy. This methodology was developed by Borenstein and Koren for a two-wheel differential drive vehicle. Later, it was refined and applied to a four-wheel drive skid-steer robot to improve odometer accuracy [18]. Low computational complexity, better QOS, increased throughput and reduced delay [19, 20]. Giulio Reina proposed a cross-coupled controller for a 4-wheel-drive/4-wheel-steer robot [21] to improve the wheel motor control algorithm to minimize the synchronization errors that results in wheel slip.

III. PROPOSED METHODOLOGY

In precision agriculture, the optimum utilization of resources like land and seed is a challenging task. There is a need for a robotic solution for sowing the seed at optimal depths and to ensure that only one seed at one place. Designing a seed sowing agribot to perform precision agriculture is our intention. Sensors, GPS and machine vision technologies are collectively used in our research to attain optimal results.

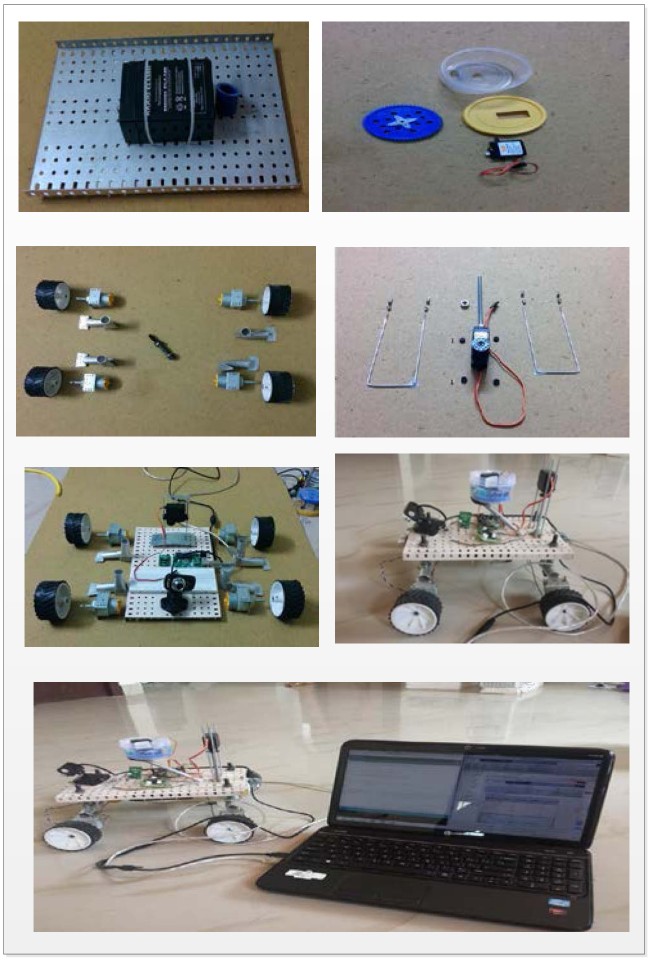

Figure 2.The selected components and their arrangement to form a seed sowing robot.

A. Fabrication of seed sowing robot.

The conceptual idea is framed into a three dimensional model using solid works software. Various calculations are performed, including load calculations, and torque required. Fabrication of the robot is done by selecting appropriate materials and methods. Frame has been designed in solid works for carrying a payload of 2kg and has provisions for mounting the sensors. This is the time to concentrate on stability and minimization of wheel skidding. The suspension system can help to maintain the stability of the robot. The suspension system here proposed is a swing axle strut tyre and is designed for a maximum camber angle of 10°. Wheel selection is done based on parameters and properties of soil, including plasticity index, bearing capacity, foot print area and soil tyre contact pressure. The typical accelerometer employed in this research work is a 3-axis sensor. The selected components and their arrangement to form a seed sowing robot is shown in Figure 2.

B. Controller and Sensors.

The key hardware components of the robot are controller (Arduino) and sensors. Ultrasonic sensors and IR sensors are employed in this seed sowing robot. Ultrasonic sensors are used to detect the obstacles and to measure the soil level while performing the seed sowing mechanism. IR sensors are used to meter the seeds.

C. Vision based row guidance system.

The vision based systems have become the promising alternatives, mainly considering the present availability of low cost image sensors and high performance processors. The machine vision based guidance system allows the robot to navigate between the rows. The proposed hardware involves a camera with pitch and yaw motion control. Image processing algorithm and morphological features were used to detect the edges and Cartesian coordinates. These coordinates are given to the controller. The vision based system also guides the robot while steering at the corners. The steps involved in image processing algorithm to extract edges are given below:

Step1: Image acquisition
Step 2: Noise elimination
Step 3: Sobel operation
Step 4: RGB to BW conversion
Step 5: Extract the edges
Step 6: Calculate the centroid
Step 7: Convert the centroid point to Cartesian coordinates.

D. Seed sowing and seed metering mechanism.

For proper germination of the plant, seed has to be sown at optimal depth. A lead screw mechanism with closed loop control system is employed to sow the seed at an optimal depth of 2.5cm from the surface. A combination of external force feed and vacuum metering has been employed to attain a controlled quantity of seed sowing. This setup consists of the lead screw and rotating disc perforated at an interval of 60°. The robot measures the soil level using an ultrasonic sensor and determines the sowing depth. The lead screw is moved using a servo motor in a clockwise direction to make a provision for seed sowing. The seed is dropped and is observed by the IR sensor. The lead screw is moved in a counter clockwise direction to come back to initial position. This is how the robot sows a seed at an optimal depth.

E. Workflow of proposed sensor and vision based Autonomous agribot for sowing seeds.

Designing a seed sowing agribot to perform precision agriculture is our intention. Sensors, GPS and machine vision technologies are collectively used in our research to attain optimal results. The workflow of the proposed autonomous robot for sowing seeds involves the following steps:

Step 1: Get map from vision based row guidance system.
Step 2: Check for obstacles using ultrasonic sensor.
Step 3: If no obstacles, robot start to move on the map.
Step 4: The controller cross correlates the map and GPS coordinates to localize the robot. The controller continuously evaluates the current position of the robot.
Step 5: The robot starts the seed sowing operation by following the seed sowing and metering mechanism.
Step 6: The robot stops the work if all the defined rows are completed.

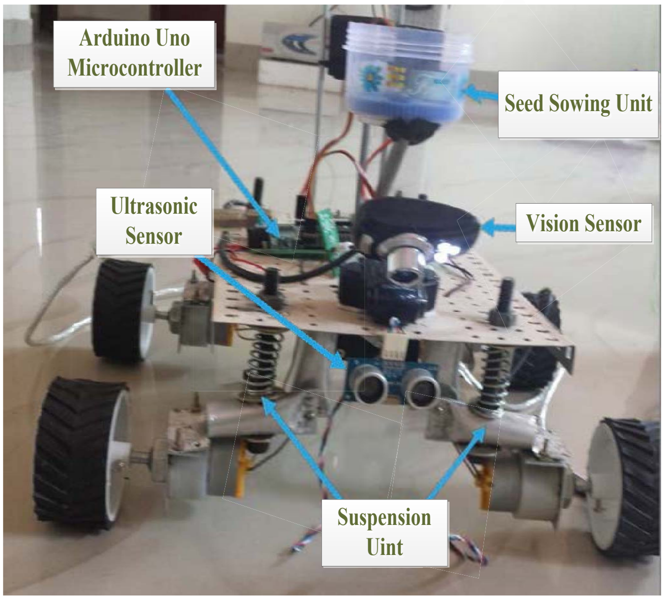

Figure 3. Vision and sensor based autonomous seed sowing robot.

IV. RESULTS AND DISCUSSION

The theoretical idea of the research work is transformed into a three dimensional model using solid works software. Fabrication of the robot is completed by choosing suitable materials and devices. The suspension system used here is a swing axle strut tyre and is designed for a maximum camber angle of 10°. Selection of wheels is based on the parameters and properties of soil. The accelerometer employed in this work is a 3-axis sensor. The vision and sensor based autonomous seed sowing robot is successfully fabricated and is shown in Figure 3.

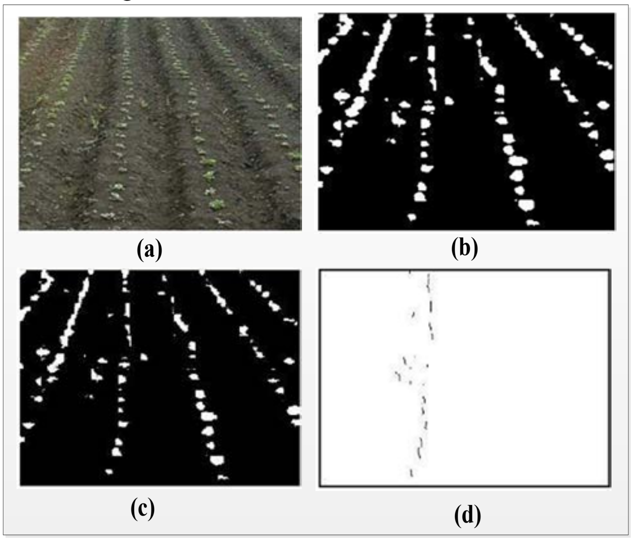

Figure 4. Edge detection process: a) original image, b) Binary image, c) Dilated image and d) Edge detected image.

The images of the land scene are acquired from the on board vision system. The image processing steps and morphological operations are performed on the acquired image in Mat lab software and the edges are extracted as shown in Figure 4.

V. CONCLUTION AND FUTURE WORK

In this paper, we have proposed a sensor and vision based autonomous agribot for sowing seeds. The proposed robot was successfully designed and fabricated. The errors and inaccuracies have been eliminated and calibration is done. The suspension system is tested and found that it is able to handle bumps up to 3cm. We have extracted the edges from the acquired image. A lead screw mechanism along with ultrasonic sensor and IR sensor were used to sow the seed at an optimal depth for proper germination of the plant. Further, the swarming technology can be incorporated to use multiple robots to reduce sowing time.

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