Design of an Autonomous Vehicle for Precision Agriculture using Sensor Technology

T. SIREESHA[1], M.N.L. KALYANI[2], D.GOWTHAMI[3]
[1 2 3]Assistant Professors, Department of ECE,
Potti Sriramulu Chalavadi Mallikharjuna Rao College of Engineering and Technology,
Vijayawada, Krishna (Dt), Andhra Pradesh, INDIA
Email: sirishatammana@gmail.com[1], mlakshmikalyani@gmail.com[2], dukkagowthami@gmail.com[3]

Abstract: To avoid the various problems which affects the crop production, an autonomous vehicle is to be designed and used for crop transplanting and yielding, weed detection, crop protection, soil moisture properties, water status, temperature monitoring, fertilization and pesticides with their resource usage and also special focus on control and data monitoring with the embedded system. Some of the challenges and considerations on the use of these sensors and its technologies for crop production are also discussed in this paper. Fiber optic gyroscopes and multiple resolvers are employed to acquire the data for enhancing the accuracy of target positioning and in order to evaluate there is a method which describes the behavior of agricultural automation vehicle traveling along paths of any curvature.

Key-Words: Precision Agriculture, Autonomous vehicle, Fiber Optic Gyroscope, Sensors, Service Unit, SLAM Algorithm.

1 Introduction

Precision agriculture (PA) is an innovative; the fundamental requirement of the agricultural modernization is to improve the efficiency of agriculture production without affecting these various factors. In the agriculture automation technology is to correct identification and positioning for the agriculture objects with trajectory of tracking problems. The data which is monitored recorded automatically, accumulated easily and effectively is the basis to implement in precision agriculture. But the technology is playing an important and increasing role from past several years. Recently, the advent of different autonomous vehicles ranging from different fields of operations was developed in the industry, but all these products available are commercial and impressive having a substantial cost (depending upon their accuracy and functionality) to farmer.

The fully autonomous of all vehicle operations carried out by all control routines and this control relies on a central processing unit for coordination which was developed by many systems. But these systems have high unit cost due to high demands on the processing unit of this design place. A number of electronic components on agriculture equipment increases during the situations in the normal field and the spray rate controllers, variable rate planter controllers, and implement system controllers as well as controls are interact with a n ormal vehicle operation. This results a creation of standard communication link within all agricultural equipment. Therefore, a new methodology was needed in the agriculture autonomous vehicle which quantifies any auto-steering system level performance and different solutions are classified according to their accuracy and reliability [1,13].

2 Existing Methodology

In the existing methodology of an autonomous robot was developed by the API platform, which is able to survey an agricultural field autonomously and the robot is four-wheel drive and four-wheel steered as shown in Figure 1. The autonomous navigation of the vehicle is obtained by the crop and weed density measurements. For further processing of this information is done by combining the data into a digital map of the field.

The GPS, gyros, magnetometer and odometers was used in the equipment of the robot, in order to determine the exact location for image taking, as well as to estimate of the robot's position and orientation for a tracking algorithm was facilitated with providing these measurements [12]. Actuation is obtained only by drive on four wheel assemblies but not with steering. The platform is connected to a base station for enabling farmer supervision and on-line data transmission.

Fig 1: The API Platform

The API platform is equipped with a high resolution camera in order to map the growth and density of crops and weeds and also analyzing single plants at different growth stages implying that the position of the inspection camera must be accurate within few centimeters. This platform must move between the rows to avoid the damage on crops. So, the vehicle precision must be high, to operate in the field and its mapping can be done in a fixed spatial grid or by use of adaptive route planning. For further treatment, all pictures have to be transferred to the base station within a time. Some of the platform requirements based on these functionalities are considered in which robustness, reliability, safety and accuracy are major requirements in the field because this will not provide a satisfactory solution from the normal laboratory prototype equipment [2].

The Control, Reliability and Safety Issues are considered in an open environment; the platform has to move autonomous where unknown obstacles potentially can be in the vehicle moving direction, so there is necessity to require a high and reliable platform-self-control solution.

3 Proposed Methodology

In our proposed work, there is a need to add the additional hardware components and also consider some important aspects of software while designing an autonomous vehicle.

3.1 Software

In the system design, there are three kinds of operating models including regular collection model, threshold alarm and real time inquiry model [3].

3.1.1 Structure of Software System

The μC/OS-II is a portable, scalable and preemptive operating system kernel that can be embedded into ROM and can carry out multi-tasks. It is widely used in microprocessors, microcontroller and digital signal processor. The structure of software system is shown as Figure 2.

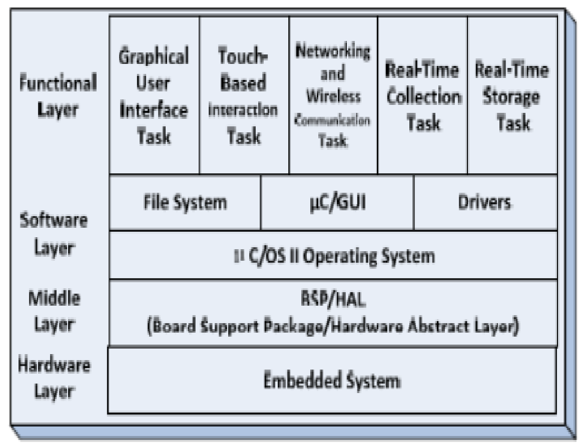

Fig 2: System Information.

3.1.2 Optimization of μC/OS-II

According to the application difference of system, the operating system needs to be clipped and optimized, and this optimized system can not only save expenditure of system resource but also create better overall performance. μC/OS-II is an embedded RTOS (real-time operating system) that can be clipped and configured depending on different needs of application, and the functions that are not used temporarily can be closed, thus not only saving memory space but also improving the overall efficiency of the system [3].

3.1.3 Flow Chart of Node Software

In this system there are two kinds of nodes. One is sensor node for collecting information of sensors; another is data central node for receiving data sent from sensor nodes and completing communication with computer.

3.1.3.1 Design of data central node software

If the system gets off the ground to initialize then hardware protocol begins to establish network after initialization. Firstly set up network in accordance with the sensor node list and modify lists through communication among sensor nodes. Then check whether there are new sensor nodes that are waiting for accession to network and complete the upgrade of network. Finally, operate the protocol tasks after successful accession to network, receive node data and sent them to PC. If the number of times it is a failure exceeds regulate done in the process of establishment, and the next one should continue. The flow chart is shown as in Figure 3.

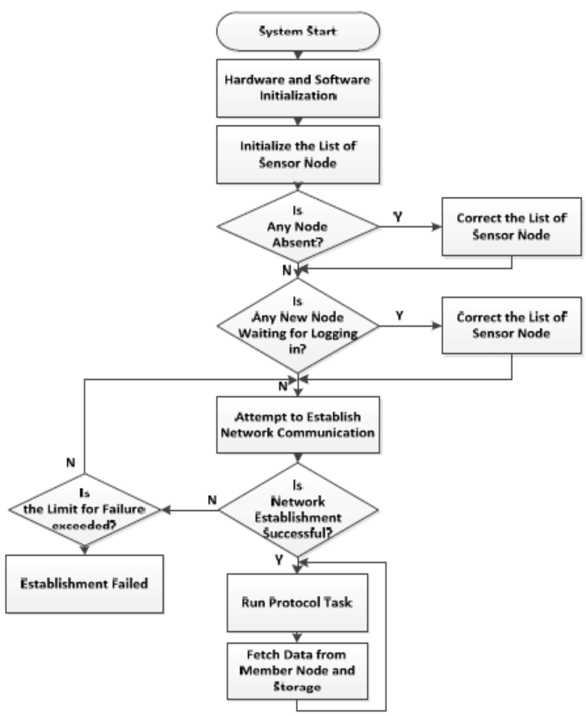

Fig 3: The flow chart of central node.

3.1.3.2 Design of sensor node software

Sensor nodes are mainly used for collecting sensors' data, receiving control data from data center and uploading collected data to data central node. If there is no transceiving of data, the nodes will enter into dormant state with the least power consumption.

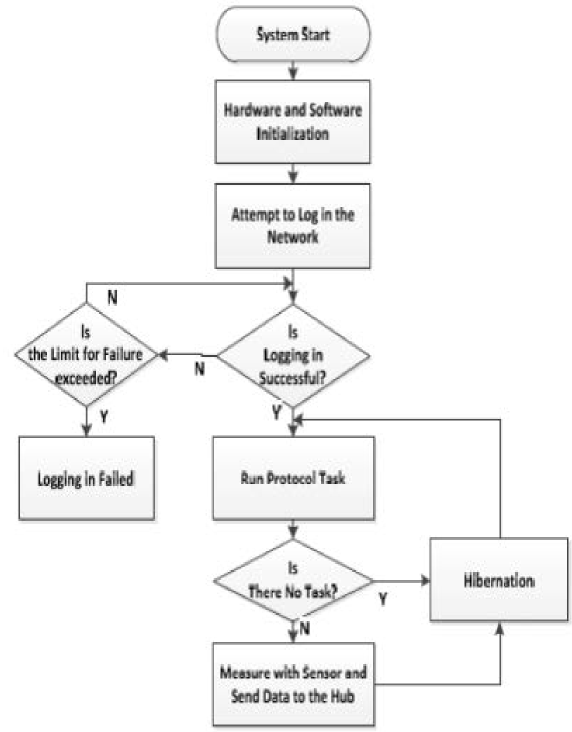

Fig 4: The flow chart of sensor nodes.

The hardware and protocol initialization is to be done after the system initialization. Protocol tasks are carried out after successful loading. After judgment of tasks, the sensor's data is to be measured and are sent to data center node. Then the next task is undertaken after the node enters into dormant state [3]. The establishment of network fails if the number of times exceeds the regulated one. The flow chart is shown as Figure 4.

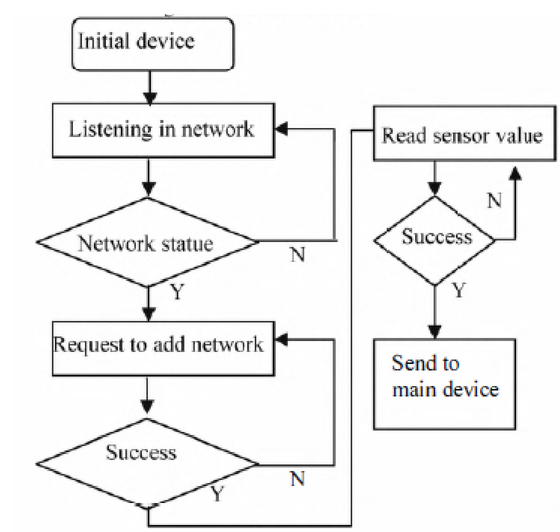

Fig 5: Host Device Control Flowchart Diagram

After completion of connection to the network, the data from each node is received and this data is sent to the embedded module via serial port [4]. And then sends processed data to a remote control center through a network in Figure 5.

3.2 Hardware

An additional hardware components required in autonomous vehicle is discussed below:

3.2.1 Multimodal Sensor

In precision agriculture, soil characteristics plays an important role for absorption and desorption of water and nutrient ions, nutrient solution changes in surface soil area, deep soil area, and near roots area have different behavior and time delay by the hour or day [5]. Therefore, a pinpoint measurement is required in precision agriculture. So, in our proposed work rather than using a normal temperature sensor in precision agriculture, we have to replace with a miniaturized and insertion type multimodal sensor used for precise control of the plants growth conditions in medium culture measures directly.

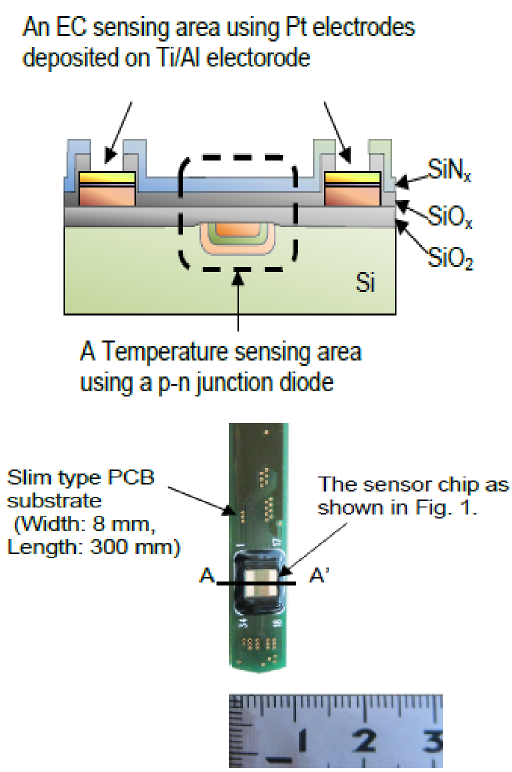

Fig 6: A cross-section structure image of a sensor chip and bounded on PCB substrate

The diffused solution in soil and the time lag between supplying solution and soil condition change were visualized by using the multimodal sensor in actual cultivation environment, for the first time [5].

The multimodal sensor chip integrated with an electrical conductivity (EC) sensor and temperature sensor for pinpoint measurement using Si large-scale integration (LSI) processes [15], and also the chip was bonded on the PCB package with the size of 8 mm and the length of 300 mm was designed to be capable of insertion, as shown in Figure 6.

3.2.2 Soil Moisture Sensor

Focusing on soil moisture monitoring, it has been shown that the mobile agents, performing data acquisition, data analysis, data aggregation and decision making directly on the nodes, are able to respond in a timely manner to changes in the soil and to precisely schedule irrigation events that results in a reduction of freshwater consumption and lowered irrigation costs [6]. The structure of agriculture soil under irrigation is as shown in Figure 7 [7].

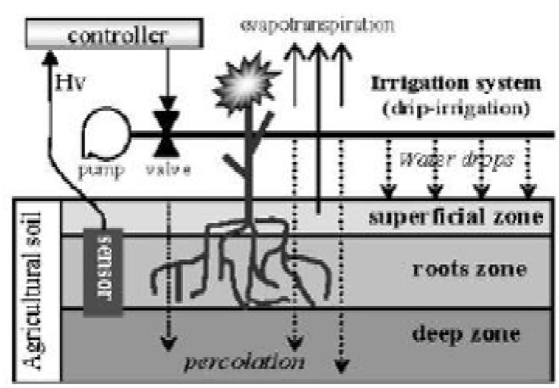

Fig 7: Structure of agriculture soil under irrigation

The VG400 is a low-power and robust soil moisture sensor, it senses volumetric water content based on measurements of the dielectric constant of the soil, a technique known to provide highly accurate results. The sensor is insensitive to water salinity and cannot corrode over time as, for example, traditional conductivity based sensors. And also by monitoring, crop and climate in a field and providing the useful information which can be used in making efficient use of water resources and also achieving in high yield. If an additional sensors, such as rain sensors may be integrated into the monitoring system to further reduce the freshwater consumption and the irrigation costs [6].

3.2.3 Rainfall Sensor

The rain sensor or rain switch is a switching device, which is activated by rainfall and having two main applications in rain sensors. Initially for an automatic irrigation system, a water conservation device is to be connected then causes the system to shut down in the event of rainfall and in the next section, by using a device protection of automobile interior parts from rain was done, which supports the automatic mode of windscreen wipers [8].

3.2.4 Humidity Sensor

SHT11, a digital temperature and humidity sensor chip is widely used in fields like heating and ventilation, air conditioning, automobile, consumer electronics and automatic control [3].

The chip integrates with a unique capacitive sensor element for measuring relative humidity and a band-gap sensor for temperature, additionally the signal processing on a tiny foot print provides a fully calibrated digital output, featuring in excellent reliability and long term stability [16]. The design of sensor module SHT11 is as shown in Figure 8. The ultimate choice for this design of SHT11 is tiny size and low power consumption [3,14].

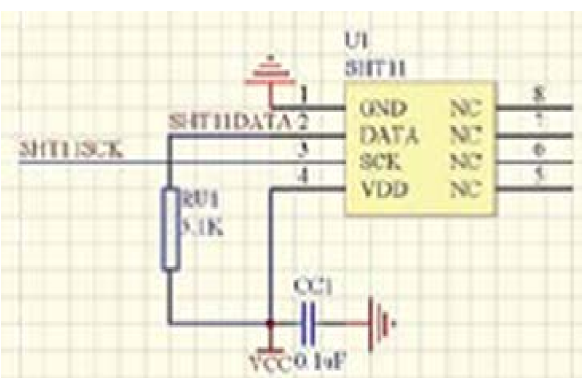

Fig 8: SHT11 Sensor

3.2.5 Spraying Operation

In agricultural areas, the application of pesticides and fertilizers is having a c rucial importance for crop yields to carry out this task mainly by using this aircrafts because of their speed and effectiveness in the spraying operation but some of the factors causes to reduce the crop yield, or damage. Weather conditions, such as the direction of the wind and its intensity during the spraying process will add further complexity to the problem of maintaining control. To avoid this problem consider the architecture, which is to address the problem of self-adjustment of the UAV routes when spraying chemicals in a crop field.

In our proposed methodology, an algorithm was evaluated to adjust the UAV route in order to change the direction and wind intensity. To adapt the path runs in the UAV, the wireless sensor network (WSN) deployed in the crop field which was obtained by input feedback. This shows the sensors can use the feedback information in order to make adjustments to the routes could significantly reduce the waste of pesticides and fertilizers. Evaluation can be done in this algorithm, because there is an impact with the number of communication messages between the UAV and the WSN [9].

3.2.6 Attitude Sensor

Due to random generating and the attitude of the vehicle rapid changes, most of the agricultural fields are uneven, so that quick response is required for the measurement of the attitude of an off-road vehicle. A low-cost electrolytic fluid inclinometer method is used to sense tilt angles (roll and pitch), this is to be resolved with several issues such as poor accuracy and sensor noisy response due to lateral acceleration of the vehicle. But in real time, there is a necessity of noise correction in the sensor was required for operation [10].

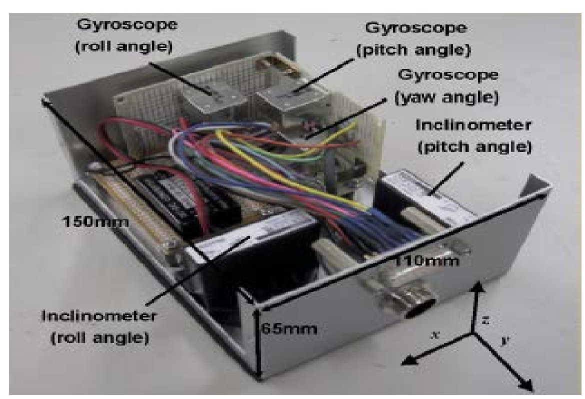

Fig 9: An overview of an attitude sensor prototype

Two inclinometers and three vibratory gyroscopes are used in low-cost attitude sensor with a quicker responses and higher signal to noise ratios in their development while compare with the other inclinometers which was used alone as shown in Figure 9. These developed attitude sensor evaluates an accurate results on field tests on a flat field, a sloping ground and a bumpy road. So this low-cost attitude sensor is preferable and to replace fiber optic gyroscope which is cost effective in agriculture [10].

3.2.7 Service Unit

To improve the productivity and efficiency in precision agriculture by doing these processes such as seeding, harvesting, weed control, grove supervision, chemical applications, etc. In an autonomous vehicle require a (unmanned) service unit which is to perform the primary or secondary tasks in the agricultural environment.

The most important current abilities in the autonomous vehicles are performed by the agricultural tasks, which can be grouped into four categories: guidance, detection, action, and mapping, and the relation between its four abilities are as shown in Figure 10 [11].

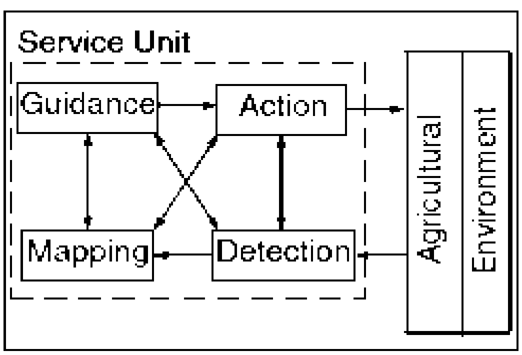

Fig10: Relation between the four most important implementations of a service unit

But there exists a localization problem (i.e., not able to perform the action associated with the agricultural task such as path-following, path-tracking, or trajectory-tracking activities), even though these stages are intrinsically related. If the localization system fails or is inaccurate, then this inaccuracy is propagated to the four abilities of the service unit. The SLAM algorithm was considered as an inexpensive solution for the localization problem.

The simultaneous localization and mapping SLAM algorithm minimizes the estimation and positioning errors in both the localization and the mapping processes and this algorithm concurrently estimates both the pose (position and orientation) of a vehicle and the map of the environment in which the vehicle is located. The sensors mounted on the vehicle have an extract features from the surrounding environment and these are located within a map, which is maintained and updated by the SLAM algorithm.

The SLAM algorithm have an advantage is that they can optimally perform in places where other positioning systems fail and can be used to further improve GPS-based localization systems. In addition to this, a ground station allows the tele-operation of the vehicle. Thus, there are some specific strategies that are directly related to the environment disposition and the vehicle's capabilities during navigation, positioning, orientation, and turning maneuvers. The functional structure of the autonomous vehicle is as shown in Figure 11.

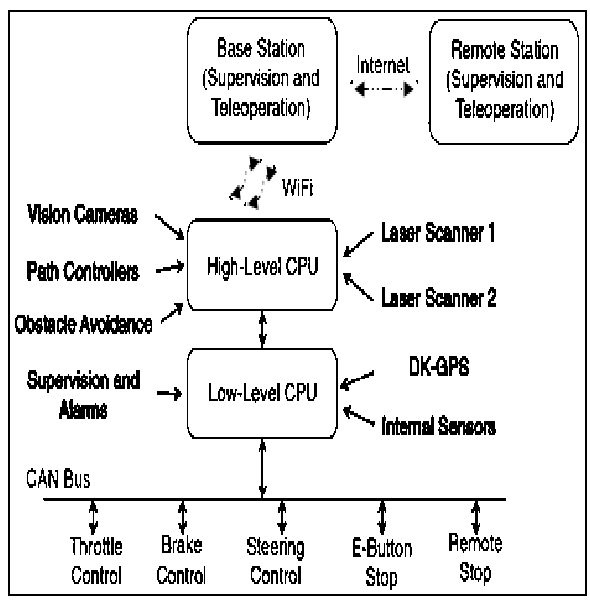

Fig 11: Functional structure of an autonomous vehicle

3.2.7.1 Guidance:

The guidance requires information regarding the surrounding environment (mapping) and the features are currently detected (detection). In the service units, the control and motion-planning strategies are applied to drive the vehicle within the agricultural field for specific purposes which are closely related to the action stage. Thus, the way the vehicle navigates within the agricultural environment needs information regarding its location in the field (localization system) and this system uses the sensors for a co rrect localization of the extracted features within the map.

3.2.7.2 Mapping:

The most important stage is to plan feasible and safe paths or trajectories for the navigation process by using the mapping and the construction of a map in agricultural field will provide most relevant features. Thus in a service unit, the map of the environment is to navigate safely, and the detected features will allow appropriate planning for performing actions (e.g., terrain leveling, chemical spreading, etc.).

During mapping, a map of the surrounding environment is built and to maintain with the aid of navigation (guidance) process. The measurements acquired from the environment (detection) and the information regarding the location of the service unit within such a map (for guidance and action). The ability of detection is done by this stage and the localization system (the DK-GPS, the internal sensors, and the low-level CPU).The high-level CPU generates a map of the environment based on the exteroceptive sensors whereas the low-level CPU provides the localization information.

3.2.7.3 Detection:

In the agricultural environment, the information is directly acquisited by using the detection (i.e., the extraction of biological features from the environment). At the mapping stage only, this information is to build and maintain an updated map of the surrounding environment to guide the navigation process (guidance) or to perform a given action (e.g., weed detection, grove maturity inspection, or agrochemical disposal). In this stage, it consists of two range laser sensors, the stereo vision system and the high-level CPU processes the sensors information.

3.2.7.4 Action:

The action means interaction of the service unit with the agricultural field (e.g., radicchio harvesting in which the vehicle was designed for the execution of the task), but it can be performed on the basis of a guidance process (e.g., harvesting or seeding), detection (e.g., weed removal), or mapping (e.g., agrochemical disposal based on previously acquired tree top information).This stage was designed to monitor and supervise a grove. Therefore, a robotic arm, controlled by a high-level CPU, can be mounted on t he vehicle for manipulation purposes [11].

4 Conclusion

In precision agriculture the autonomous vehicle plays a most important role, to improve the efficiency of crop production without affecting the various factors in agriculture and also reducing the cost of production. In this paper, to develop the design of an autonomous vehicle by considering the current developments and future perspectives of the Precision Agriculture (PA) for crop production. It provides a b etter solution that optimizes product quality and quantity of crop production by the cost minimization, human intervention and the variation caused by environment due to unpredictable nature.

References:

[1] Darr Matthew John, “Development and Evaluation of a Controller Area Network based Autonomous Vehicle”, *University of Kentucky,* (2004), Paper 192.

[2] Jens Dalsgaard Nielsen, Kirsten Mølgaard Nielsen, Jan D. Bendtzen, “Design of Embedded System and Data Communication for an Agricultural Autonomous Vehicle”, *Aalborg University, Denmark,* CATA-2005, pp.494-499.

[3] Zheng Ma and Xing Pan, “Agricultural Environment Information Collection System based on Wireless Sensor Network”, *Nankai University, China, IEEE Global High Tech Congress on Electronics,* 2012,978-1-4673-5085-3/12,pp:24-28.

[4] Lei Xiao, Lejiang Guo, “The Realization of Precision Agriculture Monitoring System Based on Wireless Sensor Network”, *International Conference on Computer and Communication Technologies in Agriculture Engineering,* CCTAE2010, pp: 89-92.

[5] M. Futagawa, Y. Ban, K. Kawashima, and K. Sawada Toyohashi, “On-Site Monitoring of Soil Condition for Precision Agriculture by

using Multimodal Micro-Chip Integrated With EC and Temperature Sensors", *JST, JAPAN, M3P.025, Transducers 2013, Barcelona, SPAIN, IEEE,* 16-20 June 2013, pp:112-115.

[6] Kay Smarsly, Berlin Institute Of Technology, Berlin, Germany, "Agricultural Ecosystem Monitoring based on Autonomous Sensor Systems", *Agro-Geoinformatics, 2nd International Conference on IEEE,* 2013.

[7] Prakashgoud Patil, Vidya H, Shreedevi Patil, "Wireless Sensor Network for Precision Agriculture", *B.V.B College of Engg. & Tech, Hubli, Karnataka, India, International Conference on Computational Intelligence and Communication Systems, IEEE Computer Society,* 2011, Pp:763-766.

[8] P.Satyanarayana, A.Gopala Krishna, J.Archana, "Intelligent Low Cost Mobile Phone based Irrigation System using Arm", *International Journal of Scientific & Engineering Research, IJSER,* July-2013,Vol 4, Issue 7,1699 ISSN 2229-5518, pp:1699-1704.

[9] Fausto Costa, Jo Ueyama, Torsten Braun, Gustavo Pessin, Fernando Osorio, Patricia Vargas, "The Use of Unmanned Aerial Vehicles and Wireless Sensor Networks in Agricultural Applications", *IEEE International and Remote Sensing Symposium,* Munich, Germany; 01/2012.

[10] Akira Mizushimaa, Kazunobu Ishii, Noboru Noguchib, Yousuke Matsuoc, Renfu Lua, Japan, A. Mizushima et al. "Development of a Low-Cost Attitude Sensor for Agricultural Vehicles", *Computers and Electronics in Agriculture,* 76 (2011), pp: 198-204.

[11] "Agriculture Robotics Unmanned Robotic Service Units in Agriculture Tasks", *IEEE Industrial Electronics Magazine,* 1932-4529/13, 2013 IEEE, 19 September 2013, pp: 48-58.

[12] Thomas Bak, "Hybrid Control Design for a Wheeled Mobile Robot", *Lecture Notes in Computer Science,* 2003.

[13] Rovira-Mas, Francisco, Shufeng Han, and John F. Reid, "Evaluation of Automatically Steered Agricultural Vehicles", *2008 IEEE/ION Position Location and Navigation Symposium,* 2008.

[14] Murad, Mohsin, Khawaja Mohammad Yahya, and Ghulam Mubashar Hassan, "Web Based Poultry Farm Monitoring System using Wireless Sensor Network", *Proceedings of the 6th International Conference on Frontiers of Information Technology - FIT 09,* FIT 09, 2009.

[15] Futagawa, Masato, Taichi Iwasaki, Hiroaki Murata, Makoto Ishida, and Kazuaki Sawada, "A Miniature Integrated Multimodal Sensor for Measuring PH, EC and Temperature for Precision Agriculture", *Sensors,* 2012.

[16] Xu. Bo. Yong Jun Zheng, Yan Xin Yin, and Yu Tan, "Temperature and Humidity Monitoring System based on CC2530", *Applied Mechanics and Materials,* 2013.