

DESIGN AND IMPLEMENTATION OF PRECISION AGRICULTURE (PA) FOR ANTIPESTICIDE SPRAYING AND INSECT REPELLENT MOBILE ROBOT

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering Degree in Electronics and
Communication Engineering

by

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this project Report is the bonafide work of **KURAKULA KHYATHI (37130215)** and **PANNEM SNEHA LATHA (37130299)** who carried out the project entitled “DESIGN AND IMPLEMENTATION OF PRECISION AGRICULTURAL (PA) FOR ANTIPESTICIDE SPRAYING AND INSECT REPELLENT MOBILE ROBOT” under our supervision from October 2020 to March 2021.

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DECLARATION

We, **KURAKULA KHYATHI (37130215)** and **PANNEM SNEHA LATHA (37130299)** hereby declare that the Project Report entitled “**DESIGN AND IMPLEMENTATION OF PRECISION AGRICULTURAL (PA) FOR ANTIPESTICIDE SPRAYING AND INSECT REPELLENT MOBILE ROBOT**” done by us under the guidance of **Mr.V.VEDANARAYANAN** submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

1)

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ABSTRACT

India is an agricultural based country. Spraying of pests is an important task for every Farmer. In ancient days Farmers have used hand operated or fuel operated spray pump for this task as a result carbon dioxide emitted as pollutant during the operation of such pumps has a unpleasant effect in the environment. Also there is a chance of directly getting in touch with of pesticides with human body which will be harmful. Hence, these conservative sprayers are not much appreciated. This project designed a pesticides spraying robot using Arduino. Fossil Fuels operated Sprayers are eliminated by DC pump which results in the reduction of vibrations and noise. This makes spraying system eco-friendly. To implement the idea a vehicle is made which is electronically operated by a remote. Sprayer is fitted the robot so that it can spray pesticides uniformly covering a large area in less time. The main advantage in this project is sprayer Height is Adjusted According to the Plant Height. Agricultural applications (farming) is one of the oldest profession for humankind. On the other hand, there are so many methods applied to keep plants health and condition in full life cycle to achieve sustainable without any chemical effects to human labor and to the environment as an output. This study represents design, build and testing of a low cost semi-autonomous robot called "X-Bot" to achieve agricultural tasks more efficient and precise by using current technological advancements. Main goal of this project is to design, fabricate, program a low-cost mobile robotic system to perform pesticide spraying and insect repelling tasks in the field efficiently without seeking any human interaction during operation.

Keywords – Agricultural robots; semi-autonomous robots; robotic spraying

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CHAPTER 1

INTRODUCTION

The application of precision farming will be more effective in a greenhouse because it is easier to engineer similar environmental conditions.

These devices are used because the price is low and easy to get on the market and can be designed so that technicians who have limited information technology knowledge can run it.

By using sensors, the hardware can detect what is happening in the greenhouse and make decisions based on the data acquired.

Some sensors that are often used in Precision Farming are temperature and humidity sensors, soil moisture sensors, and light sensors.

This system deals with the exposition of how robotics can be applied to various fields of agriculture. One of the most important professions in a developing country like India is agriculture. It is very important to improve the efficiency and productive capacity of agriculture by replacing laborers with intelligent solar-powered machines like robots using the latest technologies. The system proposes a new plan to put back humans in diverse agricultural operations like detection of the presence of pests, spraying of pesticides, spraying of fertilizers, etc. thereby providing safety to the farmers and accurate agriculture. The evolved system includes plotting a prototype that uses simple cost effective equipment like microprocessors, solar panels, wireless, different motors and terminal equipment which helps the farmers in different crop field activities. The main feature of this system is Electrostatic spraying. This application is adopted in crop protection to prevent pest infestation, to improve product quality and to maximize yield. It involves a superposition of charges to pesticide spray droplets to attract substrate ions at hidden surfaces. The droplets wraparound effect lowers off-target deposition, increases on-target spray and invariably improves spray efficiency. Electrostatic spraying system works productively at best suitable parameters in union with charging voltages, spraying

height arrangement, application pressures, flow rate, travel speed, electrode material, and nozzle orientation.

1.1 INTRODUCTION

Agriculture is one of the fundamental operation area in human life. Currently, this area heavily relies on man power to have sustainable farming. There is a direct relationship between number of labors and the yield of land. However, having high amount of labor brings an extra cost during production process. In addition to that having optimal product growth requires another important parameter that needs to be taken under consideration: keeping product (i.e. plant) healthy during farming until collecting them from soil. To achieve this, chemical pesticides is being used primarily to prevent plants from insects, diseases, harmful effects of climate change, etc. Current pesticides spraying techniques involve direct contact between plant and pesticide itself which causes significant harmful effects to both plant, environment and more importantly to the human labor. Another factor is human error causes unexpected issues while spraying. For instance, human labor may spray extra dosage to the plants that leads severe damage, or walk down to the field and damage them by stepping in. The usage of robotics related and automation technologies provides significant values to both farmers and agricultural field. These tools are used for common applications like seeding, spraying, fruit picking, plant classification, etc. Automated agricultural tasks bring many benefits to the field which avoids unexpected or dangerous effects of chemical exposure which also helps to improve overall efficiency and productivity. Automation enables many advantages to farmers or land owners which makes the task held more accurate, uniform and less costly [1]. Moreover, farmers have great benefits by having high technology automation which leads less work, requires less amount of labor that also eliminates both maintenance and labor costs while having high profit. Many studies related to mobile robots for agricultural applications can be found in recent literature. Singh et al demonstrated a robot system to establish spraying operations, which navigation is maintained by complex algorithms based on fuzzy logic. There also other studies investigated robot which can perform spraying, classifying, cleaning and harvesting tasks in the

greenhouse. This study proposes to automate entire process by using robot platform where it allows to avoid exposure of hazardous materials while improving the efficiency. To achieve this, a semi-autonomous mobile robot will be used to spray plants and repel insects from the field that enhances sustainable farming conditions by protecting health of the plants and soil. India is the farmland with a population of 3/4 in agriculture. In accordance with the climate and other resources accessible to them, farmers will grow multiple plants in their field. But some technological assistance are required to achieve high output and excellent quality. The increase in the demand of labour in the agriculture fields is increasing day by day as the people now a days are less interested in agriculture so all we need is a robot which can replace humans. Pesticide spraying plays a key role in protecting the field. Many people are not interested in spraying pesticides as they are getting harmful skin infections and breathing problems also carbon dioxide emitted as pollutant during the operation of such pumps has a harmful effect in the environment. Another important factor is human error which leads to unexpected issues while spraying. For instance, Due to lack of awareness human labor may spray extra dosage to the plants that leads severe damage to the field. We can find some of the robots available for pesticide spraying in the market but what makes robot presented in this project different from them are firstly we are designing a robot which is totally controlled by humans through mobile app using IOT, secondly live monitoring is the extra feature added to this project which gives more accuracy and uniformity in spraying this may increase the yield also. Agriculture in India constitutes more than 60% of the occupation. It serves to be the backbone of the Indian economy. It is very important to improve the efficiency and productive capacity of agriculture by simultaneously providing safe cultivation of the farmers. Operations like spraying of pesticides, sprinkling fertilizers are very tedious. Though spraying of pesticides has become mandatory it also proves to be a harmful procedure for the farmers. Farmers, especially when they spray pesticides, take too many precautions like wearing appropriate outfits, masks, gloves, etc so that, it does not cause any harmful effects on them. Avoiding pesticides is also not completely possible as the required outcome must be met. So, the use of robots in such cases gives the best of the outcomes for these problems, along with the required

production capacity and efficiency. Cost-effective technology using components such as ESP8266 / ESP32 Microcontroller for the control of agriculture robot, geared motors that facilitate the robot wheels to move and mobile application to guide the robotic movement are incorporated in this agriculture robotic vehicle to make all of the above feasible. The advancement in the field of robotics has widened and the fields of its application extend from home automation to the military. Application of Robotics in the field of machinery design and accomplishments of tasks using agricultural vehicles had resulted in increased investment and research. Continuous administration of the agricultural field is possible with the automatic performance of such agricultural fields is possible with the automatic performance of such agricultural vehicles. Abilities of the agricultural vehicles can be classified as guidance, detection, action, and mapping. The way of map-reading by the vehicle is termed as guidance, extraction of environmental features is termed as detection and execution of the assigned task is termed as action and plotting the field with its features is mapping. All four categories are independent. This system is based on developing a robotic vehicle used in agriculture for spraying harmful pesticides. This project involves the usage of PIC ESP8266 / ESP32 microcontroller to control the movement of the robot with the help of a mobile application. This cost-effective robotic vehicle can improve productive capacity, safety in agricultural applications and meet the demand for labour.

1.2 PRECISION AGRICULTURE

Agricultural irrigation always receives attention as an important application for the purpose of crop cultivation and production. A reliable and suitable irrigation water supply can significantly raise vast improvements in agricultural productivity and water savings. Clearly, traditional irrigation consumes not only bulk amounts of water, but electrical energy may also be required greatly, depending on the geographical location. The traditional irrigation practice involves applying water as uniformly as possible over every part of the field without taking the variability of soil and crop water needs into account. Consequently, some parts of the field are over-irrigated,

meanwhile, other parts of the field are under-irrigated [1]. In addition, variable rate irrigation (VRI) provides the flexibility to manage spatial and temporal variabilities within different zones of a production field. However, the adoption of VRI is very limited, and it does not always guarantee the best irrigation [2]. Presently, water demands are continuously increasing, whereas water resources are unfortunately limited. With water scarcity, precision irrigation (PI) systems have been focused and enabled by the advancement of sensor technologies and the internet of things (IoT). Currently, the new paradigm of massive measurements is represented in terms of wireless sensor networks (WSN). As the rapid growth of IoT, low-power and low-complexity communications are one of the greatest challenges faced by practitioners today. Back scatter communication was proposed based on a biostatic semi-passive scatter radio principle for a long-range WSN. However, the backscatter communication has several major limitations, such as short transmission range, low data rate, and unidirectional information transmission [4]. Hence, due to the development of network-based information technology, a WSN plays a significant role in the variety of agriculture applications. It becomes essential to integrate sensor technology and WSN to stimulate and perform precision irrigation. To date, along with those developments, the sensor-based automatic irrigation system has considerably been innovated and applied in widespread agriculture instead of the traditional irrigation, leading to smart and sustainable agriculture. In general, irrigation scheduling systems can be categorized into three approaches [5], i.e. (i) soil-based approach, (ii) weather-based approach, and (iii) plant-based approach. In the literature, automatic irrigation and monitoring systems are typically based on a soil approach. They can be achieved by using soil moisture content and climatic data. The soil moisture content is used to describe the water status in the uppermost part of a field soil [6]. The determination of soil moisture status has been considered regarding plant-water relations [7], while the climatic data are considered to perform a model-based real-time decision support system for irrigation systems together with the soil moisture status, such as air temperature, air humidity, solar radiation, and wind speed [8]. Furthermore, the smart watering system was developed for irrigation scheduling based on Block-chain and fuzzy logic approach by employing economical sensor

devices [9]. The decision-support system of this system mainly relied on five variables such as change rate of temperature, change rate of humidity, intensity of light, and change rate of moisture and type of plant. Similarly, the urban irrigation systems were introduced in [10] aiming at saving water and maintaining crop yields; nevertheless, the system was simply based on a soil moisture set-point to make a decision for irrigation. The web-based application was designed and implemented to manipulate details of crop data and field information using soil moisture sensors. Subsequently, the data were analyzed for the watering process and notifying to users via mobile application [11]. The smart irrigation system based on IoT was developed and implemented using a low-cost soil moisture sensor. The system was applied by the Neuron network for irrigation decisions, while the environment information can be monitored via the web-page [12]. Also, the IoT-based smart irrigation system was developed driven by a fuzzy logic system. The system could schedule irrigation employing soil moisture content, temperature, and humidity. This system could provide acknowledgment messages of the job's statuses via mobile phone [13]. Although numerous researches have presented the irrigation scheduling based on a soil-based approach, the irrigation scheduling using solely soil-based approach may fail to deliver enough amounts of water to plants as reported in [14], resulting in severe water stress of the plant.

Besides, the weather-based approach has been developed using environment variables and forecast methods. In [15], the environment parameters were monitored and controlled through WSN, including temperature sensor, humidity sensor, and illumination sensor, to provide optimal crop conditions. However, the above system only employed the pre-defined threshold value of those parameters to control irrigations. An automated greenhouse system was proposed using an affordable weather sensor network for cultivation in India [16]. Nevertheless, this automated greenhouse system only employed constant thresholds for environment variables to control the dynamic behavior of greenhouse micro-climate. In [17], an innovative irrigation scheduling was developed combining earth observation data, weather forecasts, and numerical simulations to plan more precisely water allocation in space

and time in the irrigated agriculture. The different types of weather forecasts were taken into account for irrigation scheduling [18]. Furthermore, a new methodology based on the use of weather forecast data was proposed to determine irrigation scheduling [19]. The results showed that there was only a minor difference between the proposed weather forecast and the measured weather data. It should be noted that there are two issues surrounding the use of available climate prediction and weather forecast for irrigation scheduling: forecast reliability and the dissemination of the forecast information to farmers. For the plant-based approach, crop water stress index (CWSI) is widely used as an estimator for quantifying plant water status (water deficit of crops) at any local point based on measurements of plant temperatures. Basically, temperature and temperature baselines are required to calculate an empirical CWSI. The temperature baselines can be obtained by artificial crop reference surfaces, while the canopy temperature can be measured directly by an infrared temperature sensor. To avoid the artificial crop reference surfaces, a temperature baseline prediction has been modeled and developed for the CWSI calculation. Based on the empirical method, the average CWSI was used for irrigation scheduling of bermudagrass in the Mediterranean region. CWSI in this technique was calculated based on the empirical method adapted for practical convenience and used to create the seasonal CWSI as a criterion for irrigation. In, the effect of water stress on crop yield was also evaluated. Furthermore, various physiological parameters were investigated including crop water stress index for drip and furrow irrigated processing for red pepper in Turkey. A threshold of CWSI was utilized by prior constant values with day-to-day changes for drip and furrow irrigation. In addition, a dynamic threshold of crop water stress index was employed to an automatic irrigation scheduling for apple trees. These thresholds were evaluated associated with stem water potential and canopy-air temperature difference during midday. In, seven irrigation scheduling algorithms were also evaluated and discussed for more accurate improvement of water use efficiency. The authors reported that the plant-based irrigation system was able to deliver enough irrigation water to the plant and avoid water stress. Moreover, CWSI could be used to measure crop water status and to improve irrigation scheduling for broccoli. The research indicated that the CWSI of about 0.51 before irrigation was able to produce

the maximum yield and water-saving irrigation. CWSI could reliably be used in irrigation scheduling for seed pumpkin plants. The lower limit baseline was determined by the data of 2015 and 2016. The aforementioned researches mainly relied on predefined CWSI thresholds to schedule irrigations; however, this could result in improper irrigations due to the lack of farmers' knowledge for the threshold setting. Recently, the sensitivity analysis was applied for CWSI to explore the most influential factors of ambient environment uncertainties to the output variance of the index. The research reported that CWSI was not recommended to use under shaded conditions. According to the review of the current literature, the authors have found the opportunities and challenges to bridge the gap of design and implementation of an intelligent irrigation scheduling system using a low-cost WSN. Particularly, most of the research has utilized merely soil water status or crop water variability for irrigation. Moreover, the limitations of soil moisture status or crop water stress have been addressed. Therefore, the proposed irrigation scheduling system simultaneously considers soil water variability obtained by soil moisture content and crop water variability obtained by CWSI. These two variabilities used by the proposed irrigation scheduling system, which give both soil and plant water status information, can improve the precision of irrigation. However, the implementation of precision irrigation systems, which may require a high financial investment, is very limited, especially farmers who have a tight budget. Thus, the development of a precision irrigation system using commercially inexpensive WSN is taken into account in this research. The proposed irrigation scheduling system is divided into 3 main parts, consisting of sensor aggregator, central controller unit, and irrigation unit. The sensor aggregator employs the availability of low-cost environment sensors, i.e. soil moisture content, canopy temperature, air temperature, humidity, and light. The soil moisture and climatic data are collected by the aggregator and transmitted to the central controller unit via a WSN. In the central controller unit, the solar irradiation is measured in addition to the measured data from the sensor aggregator. The received data are processed for noise elimination and data averaging. Afterward, the processed data are used to calculate the CWSI and soil moisture content. By taking the plant and soil variabilities into account, the fuzzy system receives the CWSI and soil moisture

content to make irrigation decisions and releases the control signal to the pump in the irrigation unit, according to the designed fuzzy system. In the experiment, the measurements are connected to measure water use and electrical energy consumed by the proposed system. The experimental results are evaluated to explore the effectiveness and efficiency of the proposed system compared with the existing systems. Furthermore, the cost analysis is performed to evaluate the cost-effectiveness of the proposed system.

Therefore, the main contributions of this paper, that reduce the knowledge gap between low-cost commercial available and system designs, are listed as follows.

- 1) A fuzzy-based intelligent irrigation scheduling system is designed and implemented using a low-cost WSN.
- 2) Crop water stress index (CWSI) and soil moisture content are simultaneously considered as variables for irrigation scheduling strategy.
- 3) The prototype of the proposed system is constructed and validated to gather data on the performance and functionality of the design.
- 4) The proposed irrigation scheduling system is experimentally tested to evaluate its effectiveness.
- 5) The comparative study is performed to explore the efficiencies of the proposed irrigation scheduling system in terms of water use and energy consumption.
- 6) The cost analysis is performed to assess the economic viability of an investment.

1.3 AUTONOMOUS CONTROL

Autonomously controlled drones are characterized by pre-programmed flight plans or more complex dynamic automation systems, where humans are not involved in the actual operation. These plans are developed in advance, but are individually realized afterwards [3]. The technology needs to be involved to improve agriculture. Smart, Connected Internet Applications Maximize Agricultural Business Performance by using Drones. In developing countries the agriculture business is driven by multiple intermediate hands that make the commodity to higher price and the farmer is getting lesser price for his work. Nowadays farming lands are sold as real estate plots because of no proper yields from farming / agriculture.

An unique opportunity is to create and deliver a transformational suite of Internet of Things-based agricultural management services. These services would be delivered as easy-to-use, smart, connected product applications that would provide customers with the ability to have a real-time big picture of the large and varying data points necessary for them to create optimal agricultural working and growing conditions [4]. To do so in agriculture requires optimizing three key variables: production yield, cost, and risk avoidance, and having a real-time and holistic big picture for optimizing each variable for maximum profitability.

1.4 Single person or shared remote-control

Drones can be remotely controlled either by one individual or by a group of people (shared control). In a shared control setup, when drones are controlled by so-called swarms, the UAV is based on a modified commercial flight platform that is controlled by a ground control station. The flight platform is a software that can be either selected or developed and can involve a range of sensors, an advanced control system and autonomous flight features. In Fig 3 shows (flying autonomously) the system has to be highly reliable and process sophisticated safety features in case of malfunction or unexpected events[5]. Using sensors, agriculture gains advantage of real-time traceability and diagnosis of crop, livestock and farm machine states. Genetic tailoring of food and producing meat directly in a lab.



Figure 1.1: Single or shared remote-control

Nightingale Intelligent Systems: is releasing a fully autonomous drone using an extensive background in robotics and flight navigation. The Nightingale BrdsEye Aerial Security System will help support your security operations by bridging the gap in the use of physical security assets and video surveillance technology by combining commercial drone technology and advanced robotics software. BrdsEye can be thought of as a mobile security camera, able to stream live video directly to mobile devices or a Security Operation Center (SOC) to help security teams quickly assess real threats from false. The Nightingale Flight Coordinator is designed to integrate with leading perimeter detection and video management systems. This will help security professionals design complete solutions aimed at addressing difficult to view areas. A BrdsEye autonomous drone can launch either automatically based on a perimeter alarm event, scheduled routine guard tours or manually by an operator to obtain video at a designated waypoint. Wirelessly transmitting a 1080p video feed back to security operators provides a level of response that will greatly improve perimeter protection and situational awareness. Nightingale BrdsEye will provide an effective surveillance system for remote sites (power substations, pumping stations, reservoirs, etc) The Nightingale solution truly brings a new paradigm in security technology to market and aims to help security professionals everywhere. Wave Representatives is the sole

North American manufacturer rep firm providing sales and marketing support. Using large-scale robotic and micro robots to check and maintain crops at the plant level will help to automate agriculture. Engineering involves technologies that extend the reach of agriculture to new places and new areas of the economy.

Field Preparation: The ground control station is a system for managing sensor data acquisition with stationary sensors, mobile ad hoc networks and mobile sensor platforms. Ground control stations function as ergonomic user interfaces and data integration hubs between multiple sensors and a super-ordinated control center, representing are the core purposes of it. Functions range amongst task management, mission planning, control of mobile platform, sensor control, dynamic situation display/awareness, fusion of sensor data, sensor data exploitation, reporting, generation or alarms and archiving. The ground control station can be realized in a modular framework that enables the adaption of the system to different operational needs and can result in a variety of setups. Figure 1 illustrates one type of setup. Crops can be monitored, measured and responded back using Precision Agriculture (PA) or satellite farming which is a farming management concept [8]. GPS is a space-based global navigation satellite system that provides location and time information in all weather and at all times and anywhere in the earth.

Mobile control (lateral)

Possible for both types of control (autonomous and shared), drones can be controlled via mobile devices. Due to the widespread adoption of smart mobile devices, such as smart phones and tablets, mobile controlling of UAVs can evolve to a widely accepted way of steering drones. Mobile devices already contain native sensing, communication, computation, storage and actuation capabilities, providing the basis of mobile control. However, drawbacks result from strongly coupling with mobile Operating Systems (OS). WebGIS is a very important milestone of GIS that marks the GIS to shown in the web and which is used to store, process, analyze, display and apply spatial data[9]. This will be done using GPS and Machineries like drone or

movable vehicles along with the sensors and central server and databases. The concept of Precision Agriculture has been designed and the system model has been tested

Soil Testing

Environmental monitoring is a significant driver for wireless sensor network research, promising dynamic, real time data about monitored variables of a landscape and so enabling scientists to measure properties that have not previously been observable. Soils are composed mix of solids, liquids and gases variable proportions. For larger area of soil testing we can use radiometers and microcomputer system for data preprocessing and recording on board an aircraft. There are software available for estimating and mapping the water content in the top one meter layer using both radiometer data and a priori information on hydro physical properties of soils. Reasons for this high application rate are first of all the need for close monitoring of crops to improve management and yields on a regular basis and with cheap measures. Furthermore, the environment of private land is geographically limited and hence, restricts drones being a threat to others. One example of sensors in use is near-infrared sensors that can be tuned to detect crop health, providing farmers with the ability to react and improve conditions locally with inputs of fertilizer or insecticides quickly.

Storage Built for the Challenge

With Quantum, you no longer have to choose between performance, reliability and cost effective storage - you get it all. We help you design and implement a storage solution that puts your data in the right place at the right time. The crops growth and product quality in greenhouse are dependents on temperature and humidity. The greenhouse humiture monitoring system based on ZigBee wireless sensor networks (ZWSN) is the best solution. Adopting the technology of wireless sensor network based on Zigbee, GPRS and Web Services technology, we can get a set of low cost, low power consumption, flexible automatic networking temperature humidity monitoring system of soil.

Water flow

An optimized irrigation system has become a necessity due to the lack of the exhausting resources like water, oil etc. Automatic irrigation of wireless sensor network and Internet technology can be used to improve irrigation water and to reduce cost of irrigation water. Use of Smart phones or wireless PDA can easily monitor the soil moisture content and control the irrigation. Irrigation using sprinklers is widely adopted in agriculture. When a rotating sprinkler malfunctions due to jamming, clogging or being worn out, may cause over watering in some small areas. To overcome the issue the camera based irrigation control system can monitor the sprinklers using standard security cameras and control the sprinklers. The drip irrigation schedule system can saves the cost of water, price of yield, uniformity of the drip irrigation system, crop response to water.

Pesticide

Identification and monitoring of plant diseases, nutrient deficiency, controlled irrigation and controlled use of fertilizers and pesticides needs to be managed for crops from early stage to mature harvest stage. eAGROBOT (a prototype) is a ground based agricultural robot that overcomes the challenges existing in large and complex satellite based solutions and helpdesk form of solutions available as m-Services. Variable rate spraying control system can automatically change with the variation of duty factor at the fix frequency[10,11]. The characteristics of the flow control system provides development platform, fuzzy control, PID algorithm, PWM, temperature property, response speed for spraying. An optimal pest management strategy of the chemical control needs to be maintained the level below the economic threshold, which makes pesticide residuals and the total dose of the spraying pesticides least, and reduced pest populations. There are several ways for spraying pesticide together with their possible disadvantages such as crops may be crushed when using tractor, pesticide droplets may be perfused unevenly when it is applied by a person, or using aircrafts such as helicopter or plane for spraying may contaminate regions surrounding

the target area. We can use Unmanned Aerial Vehicle (UAV) that is able to fly on and spray farmland autonomously.

Harvesting

At the harvest season, crops are harvested using various methods at different times. Mapping and monitoring of the patterns of croplands during the harvest provides information for farmers to help guide the harvest practices that are time critical and to support early warning of threats to food security. Harvesting labor is a major cost factor in the production of specialty crops. Today accruing harvest labors is still done by hands, which is error-prone and costly. By integrating cloud-based web application with purposely designed Labor Monitoring Devices (LMDs), we can attain the monitoring and accruing harvest labors. Automatic detection of harvesting using multi-source information fuzzy inference with the overall accuracy of 93% will lead to effect decides the harvesting time.

Drying, Monitoring and control

The grain moisture sensors are already in yield monitoring processes on harvesters employing precision farming. High-quality products can be yield with better grain handling and storage operation management. This can be achieved through the ability to more closely monitor the grain moisture content, which will provide important information of grain status on time. The trend is towards simplified methods of drying in which the advantage is of the drying properties of unheated air and towards techniques which gives to a favorable and economic use of electric heating of the air. An intelligent control method for the cold-storage of fruits and vegetables, humidity will make a direct impact on the quality of the food storage of high-precision monitoring environmental parameters which can effectively improve the quality of food storage, energy conservation significantly, the cost.

Similar to emergency response applications, drones can reduce risks of human health in the field of environmental monitoring, because they fill the gap between manned aerial inspections and traditional fieldwork. This way, areas that are difficult to reach,

such as contaminated places can be monitored by UAVs, not people in person. Habitat restoration, environmental assessments, monitoring and remediation can be improved by e.g. near-infrared sensors that give insights into details.

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE REVIEW

Recent advances in wireless communication and micro-electro-mechanical systems (MEMS) have led to the development of implementation of low-cost, low power, multifunctional sensor nodes. These sensor nodes are small in size and communicate themselves to transfer the data. The nodes in sensor networks have limited battery power (<0.5 Ah, 1.2 V) and it is not feasible or possible to recharge or replace the batteries, therefore power consumption should be minimized so that overall network lifetime will be increased. Mainly power dissipated during data processing, data transmission, data reception and idle listening. The power consumed during transmission is the greatest portion of energy consumption of any node. In this survey we studied various techniques and algorithms to increase the network lifetime.

With the recent advances in Micro Electro-Mechanical Systems (MEMS) technology, low power digital circuitry and RF designs, WSNs are considered to be one of the potential emerging computing technologies. Several useful and varied applications of WSNs include applications requiring information gathering in harsh, inhospitable environments, weather and climate monitoring, detection of chemical or biological agent threats, and healthcare monitoring. These applications demand the usage of various equipment including cameras, acoustic tools and sensors for measuring different physical parameters.

Wireless Sensor Networks (WSNs) are consists of number of typically tiny sensors called as sensor node and each sensor node consist of four parts: sensor, processor, transceiver, and battery (as energy source). The sensor node is a low-cost, low-power, and multifunctional tiny embedded system. The main aim in Wireless Sensor Networks is how to handle with their limited energy resources. The performance of Wireless Sensor Networks strongly depends on their lifetime. As a result, Dynamic

Power Management approaches with the purpose of reduction of energy consumption in sensor nodes.

The sensor nodes have a limited battery power and batteries of node are difficult to replace or recharge. Once the nodes are deployed, node sends the sensed data while the battery power is sufficient. Since the batteries of sensor nodes are small with limited power capacity, minimizing the energy consumption for maximizing the life time becomes a key challenge of the design of the WSNs. Therefore, energy conservation is a serious and critical issue in designing of WSNs with longevity. More Energy is consumed in communication than that of processing, that is consumed energy in radio modes like reception, transmit and idle or listening mode, it can be reduced at least an order of magnitude in sleep mode [2, 10, 37]. Thus it is very important to turn off the radio as early as possible and it depends on the specific application. Many research studies around the world have been done to reduce the energy consumption in radio communications. Several energy conservation schemes have been proposed in the literature and comprehensive survey studies on them as perfect taxonomy which divides all energy efficient approaches into three main groups: duty-cycling, data reduction, and mobility based approaches [11]. Duty cycle control divided into two types one topology control, in this various topology algorithm are developed such as Low Energy Adaptive Clustering Hierarchy (LEACH), Directed Diffusion [10], Energy Efficient Sensor Routing (EESR), Adaptive Self-Configuring Sensor Network Topologies (ASCENT) [17] etc, each having advantages and disadvantages, Second type is power management which categorized into three types on-demand wakeup, scheduled wakeup, and asynchronous wakeup [18].

The hybrid approach is topology control technique that uses some form of clustering and other approach like power adjustment or power mode to increase the network lifetime [17]. There are several factors which determine the energy efficiency of a sensor network such as network architecture, the data aggregation mechanism and the underlying routing protocol [1]. Till now several techniques have been proposed and implemented for energy efficient WSNs. Our goal is to design and develop a new algorithm to increase the lifetime of Wireless Sensor Networks.

Wireless Sensor Networks (WSNs), are set of many sensor nodes that have some limitations of energy and dimension. Because of the energy limitation for these nodes, we must use their energy very usefully such that the network lifetime increases. Hundreds to thousands of micro nodes can be deployed in many domains including health, environment and battlefield monitoring in order to resolve specific problems that cannot be addressed by using human being, so WSN is the good solution for such situation. Some interventions can damage the WSN monitored area and thus disturb the accuracy of the observations. Once a wireless sensor network is in place, its lifetime should as long as possible based on the initially provided energy in the form of battery. Reducing the energy consumption is only the option to increase the lifetime of wireless sensor networks. There are some method such as data aggregation, routing protocol and network topology which are used to increase the lifetime of WSN.

2.2 DATA AGGREGATION

Data Aggregation is defined as process of gathering of data from multiple sensors to eliminate redundant transmission and provide fused information to based station. The main goal of data aggregation algorithms is to gather and aggregate data in an energy efficient manner so that network lifetime is enhanced. Architecture of sensor network plays important role in Data aggregation protocol [1, 13]. There are two main types of data aggregation, Structure and Structure free data aggregation, each having merits and limitation. Again structure networks categorized into two types Hierarchical networks and Flat networks. The comparison between two is given in Table 1.

Hierarchical networks	Flat networks
Data aggregation performed by cluster heads or a leader node.	Data aggregation is performed by different nodes along the multi-hop path.
Overhead involved in cluster or chain formation throughout the network.	Data aggregation routes are formed only in regions that have data for transmission.
Even if one cluster head fails, the network may still be operational.	The failure of sink node may result in the breakdown of entire network.
Lower latency is involved since sensor nodes perform short range transmissions to the	Higher latency is involved in data transmission to the sink via a multi-hop path.
Routing structure is simple but not necessarily optimal.	Optimal routing can be guaranteed with additional
Node heterogeneity can be exploited by assigning high energy nodes as cluster heads.	Does not utilize node heterogeneity for improving energy efficiency.

Table 2.1 Data Aggregation in hierarchical network versus flat networks

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is the protocol in which only one node is chosen as a head node that sends the fused data to the Base Station per round. PEGASIS protocol requires the formation of a chain, which is achieved in two steps. During the chain construction phase, the extreme node from the Base Station is considered first. During the data gathering phase, a leader of each round is selected randomly. Randomly selecting the head node also provides a benefit as it is more likely for nodes to die at random locations, thus providing a robust network. When a node dies, the chain is reconstructed to bypass the dead node. After the leader is selected, it passes the token to initiate the data gathering process.

Passing the token also requires energy consumption but the cost of passing the token is very small because the token size is very small. In PEGASIS, the transmitting distance is reduced for the sensor nodes. Since each node gets selected once, energy dissipation is also less.

A question in WSNs is to schedule nodes' activities to reduce energy consumption. Focus on designing energy-efficient protocol for low-data-rate WSNs, where sensors consume different energy in different radio states (transmitting, receiving, listening, sleeping, and being idle) and also consume energy for state transition. To use TDMA as the MAC layer protocol and schedule the sensor nodes with consecutive time slots at different radio states while reducing the number of state transitions.

Symbol	Meaning	Typical Value
P _{tx}	Energy consumption in transmitting	60 mW
P _{rv}	Energy consumption in receiving	40 mW
P _{lst}	Energy consumption in listening	45 mW
P _{slp}	Energy consumption in sleeping	90 μ mW
T _p	Time needed to poll channel once	3 ms
R _{vi}	Data packet per period by v _i	Varying
L _{data}	Data packet length	36 Bytes
t _B	Time to transmit or receive a byte	416E-6s

T	A scheduling period (# of time- slots)	1s to 60s
T _s	Slot size	30ms
P _s	# of packets transmitted in a lot	~10

Table 2.2 typical values of the energy cost for different operations

In scheduling period, any sensor node needs only to wake up at most twice : one for continuously receiving all packets from its children nodes and ones for sending its own data to its parent node, proposed in by Y. Wu. Table 2.2 summarizes some typical values of the energy cost for different operations.

Two challenges in Structure free data aggregation is defined with their solution by Kai-Wai Fan in is i) no pre-defined structure and routing decision. ii) Node does not know their upstream node and they cannot wait on data from any particular node before forwarding their own data. The solution is Data Aware Any cast (DAA) and Randomized Waiting (RW) respectively to improve data aggregation.

In order to support data aggregation through efficient network organization, nodes can be partitioned into a number of small groups called clusters. Each cluster has a coordinator, called as a cluster head (CH). The member nodes report their data to the respective CHs. The CHs aggregate the data and send them to the central base through other CHs. Ossama younis in proposed, classification of clustering technique based on two criteria: the parameter used for electing CHs and the execution nature of a clustering algorithm. Hongbo Jiang proposed energy efficient data collection which is clustering and prediction based, that is author use past input values from the sensor to perform prediction operation. It implies that the sensor does not need to transmit the data values if they differ from predicted values by less than certain specified threshold or error values.

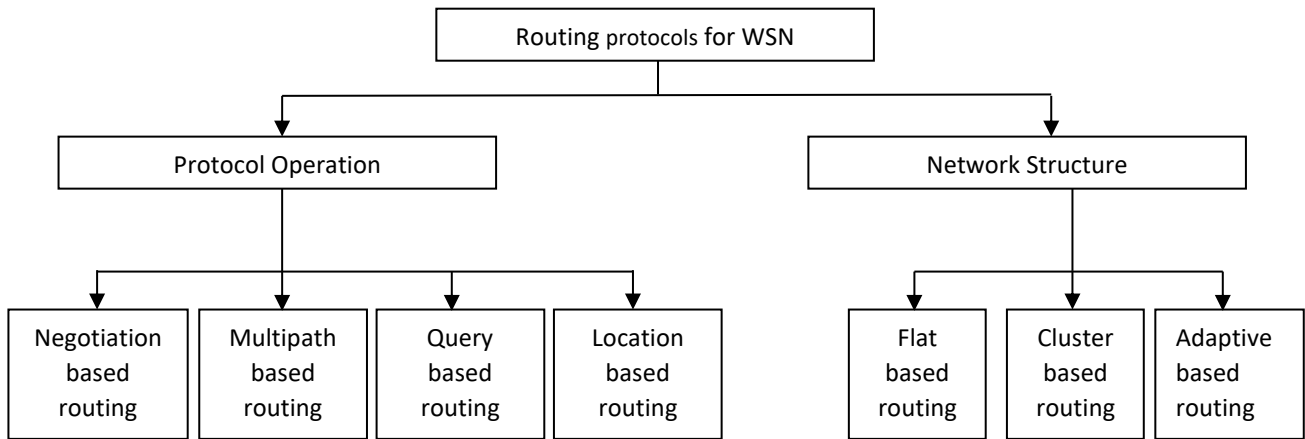


Figure 2.1 protocol for WSN

By combining cooperative Multiple Input Multiple Output (MIMO) with data aggregation to reduce the power consumption, But for this cluster size cannot be very big and sensor node should be proper clustered [4].

Flexible-Schedule-Based TDMA Protocol (FlexiTP) have been developed by Winnie Loius [7], it provides end-to-end guarantees on data delivery such as predictable throughput for gathered data, fair access to the network for all sensor nodes. FlexiTP is the first integrated protocol for sensor networks that proposes a scheduling scheme that provides a balance among end-to-end guarantees on data delivery, energy efficiency, and memory efficiency. This protocol is self healing designed for periodic data gathering application, nodes only transmit and receive packets at their own time slot(s) and sleep until their slots turns up again.

In Duty cycle control, sensor nodes dynamically create on- off schedules such that the node will be awake only when they are needed. Christophe J. [8] proposed two new approaches to control duty cycle for target rate of transmitted packets by Asymmetric Additive Duty Cycle Control (AADCC) and Dynamic Duty Cycle Control (DDCC).

2.3 ROUTING PROTOCOL

One of the most important causes for energy consumption in WSN is routing protocol and it classify into two parameters. First classification is based on the protocol operation that classifies all routing algorithms to negotiation-based routing, multi-path based routing, query-based routing and Location-based routing algorithms. Second classification is based on the network structure that classifies all routing algorithms to flat, Cluster based routing and Adaptive based routing algorithms.

In flat networks, each node plays the same role and all sensor nodes collaborate together to perform the sensing task and to transmit the data packets to the base station.

Cluster based algorithms, classify all nodes to some clusters and specific number of nodes are responsible for data transmission to base station. In Cluster based routing algorithms, the role of the nodes is different from each other. In terms of network lifetime and the energy consumption over these networks show that cluster-based algorithms or hierarchical routing algorithms have the best work in contrast to other algorithms [9, 15].

Hana Khamfroush in [9] Proposed algorithm works on the nodes clustering. And it did by considering the residual energy of nodes and the distances between those nodes to Base Station. Load sharing routing algorithm is proposed in [10] by Asjd Amin which save the energy of node by changing route of data transmission with respect to power resource of each node but it increase the transmission time.

Lucia LoBello [16] introduces a novel energy balancing feature that is able to significantly increase the overall network lifetime, first provides support for both periodic and non periodic transmissions. Second, it allows for dynamic clustering set up of aggregated units, when the density of nodes is non uniform. Finally, it introduces a novel energy balancing feature that is able to significantly increase the overall network lifetime through a node exchange policy.

2.4 TOPOLOGY CONTROL

In WSN, Topology provides information about set of node and connectivity link between pair of nodes. To construct the network topology each sensor node discovers its neighbors and relative link using its maximum power and transmission power, based on this gathered information the node can make decisions to build a network. Application of topology control methods will have an impact on energy efficiency and hence battery lifetime. WSNs are also different from other networks in the following aspects: they are densely deployed, nodes are susceptible to failure, and heavily rely on broadcast communications. So they have to be properly deployed to avoid the neighboring interference.

Topology is dynamic, in which node-to-node links are established and broken quite often due to various reasons including deliberate changes to the transmission power of the nodes, node failure or mobility. Maintaining a fully connected topology for such networks is a challenge and requires careful application of topology control. Distributed topology control algorithms according to their energy conservation technique are categories into four groups: power adjustment, power mode, clustering and hybrid. Power adjustment deals with a technique that reduces energy consumption by varying the transmission power of nodes. Power mode deals with switching of radio in sleep, weak up and transmission mode. Clustering approaches conserve energy by critically selecting a set of neighbor nodes to construct an energy efficient backbone in the network and challenging hybrid approaches further improve the energy saving by integrating the clustering approach with either power mode or power adjustment approaches.

Experimental studies show that 95% of total energy is consumed by idle listening mode searching for neighbors, the new sleep scheduling protocol, based on hierarchical arrangements proposed by Bong Jun Choi. Various energy efficient approaches in WSN are proposed by Neha Enami, like duty cycle, mobility based, topology control, power management etc. comparison of various existing algorithm with their advantages and disadvantages is given by Alauldin Ibrahim, Azrina Abd Aziz and Cosmin Cirstea.

Recently WSN is used in various filed for continuous monitoring like industrial monitoring real time application like smart grid monitoring, land slide detection, water quality monitoring warehouse, wind mill, medical and in agriculture monitoring. In the real time application there is various ways to increase the life time of sensor node by using the different transmitting method like Wi-Fi, Zigbee, UWB or Bluetooth depends on requirement of application. In some of the application sensor node consists of ARM based 32 bit microcontroller that consume less power to increase the node lifetime.

2.5 PROBLEM DEFINATION

By analyzing literature, it has been found that the energy efficiency issue and a comprehensive study of data aggregation, routing control and topology control techniques for extending the lifetime of battery powered WSNs.

In data aggregation technique different alorisms are used depend on the network structure like hierarchical network or flat network. We compare and contrast different algorithms on the basis of performance measures such as lifetime, latency and data accuracy. Although, many of the data aggregation techniques presented look promising, there is significant scope for future research. Combining aspects such as security, data latency and system lifetime in the context of data aggregation is worth exploring. A systematic study of the relation between energy efficiency and system lifetime is an area of future research. In future several challenges are worth exploring in the Data aggregation.

Routing is the most important cause for energy consumption in WSN. In Cluster based routing algorithms, the role of the nodes is different from each other. In terms of network lifetime and the energy consumption over these networks show that cluster-based algorithms or hierarchical routing algorithms have the best work in contrast to other algorithms.

Topology is dynamic, in which node-to-node links are established and broken quite often due to various reasons including deliberate changes to the transmission power of the

nodes, node failure or mobility. Maintaining a fully connected topology for such networks is a challenge and requires careful application of topology control. Further, these algorithms are classified according into four groups: power adjustment, power mode, clustering and hybrid. Challenging hybrid approaches further improve the energy saving by integrating the clustering approach with either power mode or power adjustment approaches.

Due to the cost, time and expertise required to deploy a Wireless Sensor Networks (WSN), simulation is currently the most widely adopted evaluation method. Network simulation is well established for mobile ad hoc networks. Various simulator is used for WSN like OMNET++, OPNET, WSNsim, ns2 etc. By comparing, Network simulator 2 (NS2) is most widely used open source simulator for developing energy efficient algorithms in WSN. As a result, simulation is currently the most widely adopted method of analyzing WSNs, allowing the rapid development, evaluation and optimization to propose algorithms and protocols. In view of the above related literature review is aiming to concentrate on research activity to investigate the design and simulate new algorithms to increase the lifetime of Wireless Sensor Networks by using existing algorithms in data aggregation, topology control or hybrid approach.

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 SYSTEM MODEL

Feeding the growing global population requires an annual increase in food production. This requirement suggests an increase in the use of pesticides, which represents an unsustainable chemical load for the environment. To reduce pesticide input and preserve the environment while maintaining the necessary level of food production, the efficiency of relevant processes must be drastically improved. Within this context, this research strived to design, develop, test and assess a new generation of automatic and robotic systems for effective weed and pest control aimed at diminishing the use of agricultural chemical inputs, increasing crop quality and improving the health and safety of production operators. To achieve this overall objective, a fleet of heterogeneous ground and aerial robots was developed and equipped with innovative sensors, enhanced end effectors and improved decision control algorithms to cover a large variety of agricultural situations. This article describes the scientific and technical objectives, challenges and outcomes achieved in three common crops.

3.2 SYSTEM DESCRIPTION

The growing global demand for food will be a major challenge for agriculture, together with the necessity to support the emergence of technologies able to meet environmental and ethical standards, promoting also efficiency and healthy work environments [1]. The UN Food and Agriculture Organization (FAO) and other research studies estimate that 20–40% of global crops are lost due to plant pests and diseases [2]. Farmers use chemicals to mitigate damages caused by pests, which interferes with the production of crops, affecting quality. Pesticide residues resulting from the use of plant protection products on food or feed crops may be a risk to public health. Precision spraying in

agriculture represents an innovative methodology that can help farmers to spray only where needed, using the right amount of chemicals [3]. This can improve the efficiency of treatments, reducing costs and chemical waste. Moreover, precision spraying can help to fulfil legal requirements, in terms of worker health [4], environmental sustainability, and food safety and quality. However, most suppliers do not offer robots and integrated systems that are able to operate in narrow and steep spaces or in the presence of obstacles, as in the case of greenhouses or terraced cultivations. The subject of this work is a system capable of distributing inputs (e.g., crop/plant protection products, bio-agro drugs, pesticides, powders) in an efficient, sustainable, and safe way, in environments where standard agricultural machineries (automated or autonomous) cannot operate: greenhouses, mountainous areas, and heroic cultivations. The adoption of autonomous robots can help in optimizing the agricultural operations, increasing productivity and safety. Moreover, the costs of technological devices (e.g., electrical motors, batteries, computers, sensors) is reduced from year to year, allowing these robotic systems to become easily wide-spread of among farmers. A quite complete review of the basic concepts of agricultural robotics is reported in [5,6]. Here common robotic architectures, components, and applications are discussed in depth. Many research activities deal with the adoption of robotics in agriculture [7]. For example, a robot for crop and plant management is presented in [8], while Vasconez et al. [9] provide a general description of the potentiality of human–robot interaction (HRI) in many agriculture activities, such as harvesting, handling, and transporting. Agricultural robots are typically autonomous or semi-autonomous systems that can be operated in several stages of the process. In particular, robots that must operate inside greenhouses and vineyards have to deal with very tight passages while avoiding damages to the plants. Moreover, they should have very good performance regarding path following, during turn maneuvers at headlands. Several localization and navigation solutions have been implemented. A laser-guided path follower technique was tested in [10]. The system is stated to be very reliable, but requires several lasers to be mounted in the proximity of corridors. In [11], different

approaches were used regarding sensors and algorithms. Some trials were performed using map-based techniques and using motor encoders for localization. A combination of the Hector Simultaneous Localization and Mapping (SLAM) and an artificial potential field (APF) controller is used in [12] to estimate the robot's position and to perform autonomous navigation inside the greenhouse. In Reis et al. [13], a multi-antenna receiver Bluetooth system and the obtained transfer functions (from received signal strength indication (RSSI) to distance estimation) are used as redundant artificial landmarks for localization purposes.

In Tourrette et al. [14], a solution based on the cooperation of at least two mobile robots—a leader and a follower, moving from either side of a vine row—is investigated thanks to ultra-wideband (UWB) technology. In particular, the formation control of the follower with respect to a leader is proposed, allowing relative localization without visual contact and avoiding the limitations of GPS when moving near to high vegetation.

Many EU-funded projects concerning vineyards have recently concluded. One of these is Vinerobot [15], whose aim was the development of a system able to monitor vineyard physiological parameters and grape composition. Another European project is VinBot [16]. VinBot is an all-terrain autonomous mobile robot with a set of sensors capable of capturing and analyzing vineyard images and 3D data by means of cloud computing applications, in order to determine the yield of vineyards and to share this information with the winegrowers. The robot will help winegrowers in defoliation, fruit removal, and sequential harvesting by grapes' ripeness.

As regards spraying robots, image processing algorithms for the detection and localization of the grape cluster and of the foliage for selective spraying are presented in Berenstein et al. [17]. In this case, the system was tested on a manually driven cart. A specially designed algorithm to measure complex-shaped targets using a 270° radial laser scanning sensor is presented in Yan et al. [18] for the future development of automatic spray systems in greenhouse applications. Adamides et al. [19] compare different user interfaces (i.e., human-machine interface, HMI) for a teleoperated robot for targeted

spraying in vineyards. It compares different approaches with dedicated input devices such as a joystick or a standard keyboard, different output devices such as a monitor or a head-mounted display, and different vision mechanisms. Within the project CROPS [20], a robotic system with a six degrees of freedom manipulator, an optical sensor system, and a precision spraying actuator was developed. The precision spraying end-effector is positioned by the robotic manipulator to selectively and accurately apply pesticides. The project Flourish [21] is also concerned with autonomous selective spraying operations in open fields using a cooperative unmanned aerial and ground vehicles approach. However, in most cases, the developed prototypes presented above are just proof-of-concept, and are not sufficiently robust for the real agricultural environment. Our system attempts to bridge the gap between all the prototype solutions described above and those big machines that already work in large crops and farms (i.e., John Deere, New Holland, etc.), which cannot be considered as solutions applicable in greenhouses or heroic cultivations and vineyards. Moreover, in terms of versatility, compared to some of the previous solutions, our system does not require the installation of rails between the rows and can be used in different kinds of crops and terrains. The heart of the system we developed is represented by an agile autonomous robotic vehicle able to move in environments where standard agricultural machineries (automated or autonomous) cannot operate: greenhouses, mountainous areas, and heroic cultivations. The vehicle, shown in Figure 1, is equipped with a “smart spraying system” capable of optimizing the spraying operations. Furthermore, the developed human-machine interface also allows unskilled operators to plan spraying treatments, to monitor the mission from a safe distance, and to generate a report of the treatments at the end of the operations.

The robot is based on the “U-Go” robot—one of the multifunctional vehicles developed in our DIEEI Robotic Laboratories at University of Catania, mainly to solve problems like transportation, navigation, and inspection in very harsh outdoor environments. It is a rubber-tracked vehicle equipped with electric traction: two motor drivers, connected to

two 1 kW 24 V DC brushed motors, acting on the tracks, can be commanded via CAN bus. The compact external dimensions.

3.3 PROPOSED MODEL

PROPOSED BLOCK DIAGRAM

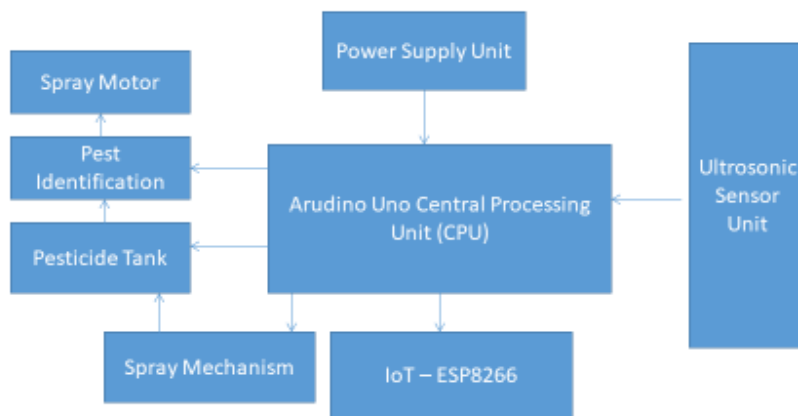


FIGURE 3.1 PROPOSED BLOCK DIAGRAM

3.4 SMART SPRAYING SYSTEM

The smart spraying system is based on a standard spraying machine made “smart” by add-on technologies enabling the automatic control of the system. The sprayer unit is composed of a hydraulic subsystem and an electronic control unit. The hydraulic part of the sprayer is composed of a 130 L tank with a 5 L hand-wash separated reservoir, an electrical (for safe operations inside greenhouses) actuated pump with a 1 kW DC motor with a gearbox, a manual pressure regulator with pressure indicator, an electric flux regulator valve, a pressure sensor, a flow rate meter, and two electric on/o_ valves. These two valves can supply, with the chemical fluid, two vertical stainless-steel bars equipped with anti-drop high-pressure nozzles for spraying operations inside a standard tomato

greenhouse. The two bars are respectively placed on the left and right sides of the sprayer, and can be operated separately. The pump has a nominal maximum pressure of 25 bar and a maximum flow rate of 20 L/min. Furthermore, the system is equipped with wind speed and temperature/humidity sensors to alert if weather conditions are inadequate for the treatment.

The electronic control unit is composed of one digital I/O module and one analog I/O module with Ethernet interface. A TCP-based protocol allows for interactions with the modules from the on-board computer as well as from any other remote station with a wireless connection: by using a suitable commands set, it is possible to operate the hydraulic components (i.e., valves, flow regulator, pump) and to read information from the pressure sensor and the flow rate sensor, as well as other control unit parameters (e.g., main breaker status, pump current, flux regulator valve status). A dedicated ROS node, running on the Arudino, is devoted to the management of the smart sprayer (“Sprayer Node” in Figure). This node interacts with the modules of the sprayer control unit via the ROS2IP node, which translates TCP messages to ROS messages and vice versa. While communicating with the Navigation node and Localization node, the Sprayer Node controls the sprayer, relying on the spraying treatments previously planned by the user (as described in the next subsection) or scheduled from a spraying map. While moving, the robot automatically activates the requested valves at the correct waypoint. This aim of this work was not to determine how to obtain the spraying map; nevertheless, when the spraying map is available, the system can use it and locally sprays the required quantity.

3.5 HUMAN–MACHINE INTERFACE (HMI)

The HMI, running on a tablet PC, allows operators with no engineering knowledge to manage the system. The interface communicates with both the sbRIO and the Arudino sing aWiFi connection. The HMI can be used for four main operations:

To visualize the position of the vehicle on a map and to monitor the status of the system (battery level, liquid level in the tank, state of the valves).

To plan the mission. This operation can be scheduled on the basis of a spraying map from which WP and required chemical dose can be processed. It is also possible to select the WPs by clicking on a georeferenced map, if available. The trajectories can also be assigned by using a teach-and-repeat strategy, driving the robot through the corridors along the desired trajectory: the WPs are automatically stored in the tablet PC. In this case, a joystick connected to the tablet PC allows the operator to manually guide the robot. At the end of the procedure, WPs are uploaded to the Navigation node and stored on-board the Arduino.

To plan the spraying treatments. For each waypoint, the operator can define whether to activate the right or left sprayers and the quantity of sprayed product. This info is sent to the Sprayer Node of the Arduino and stored on-board the Arduino.

To generate a report. At the end of the spraying mission, a logbook is automatically generated on-board the Arduino, according to the national legislation implementing the European directives. The log contains personal data concerning the company, the name of the treated crop and its related extension, date of the treatment, and the type and quantity of chemical products. It is possible to retrieve this data from the HMI to generate a report.

CHAPTER 4

MATERIALS AND METHODS USED

4.1 COMPONENTS

In this project, Arduino Uno is used as a central processing unit for controlling anti-pesticide spraying and insect repellent mobile robot.

4.1.1 ARDUINO UNO Rev3

Arduino Uno Rev3 is a microcontroller board based on the ATmega328P, an 8-bit microcontroller with 32KB of Flash memory and 2KB of RAM. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, and a reset button.

The user is required to switch on the robot from his mobile phone which is paired via Bluetooth to the Bluetooth module fixed on the robot. The Arduino processes the distance measurements from the ultrasonic sensor and decides to move forward or take a slight turn due to an object in near vicinity.

Simultaneously, the pump is turned on which pumps the pesticide or any nutrient medium, the direction of the nozzle is swayed in a periodic motion by a servo motor.

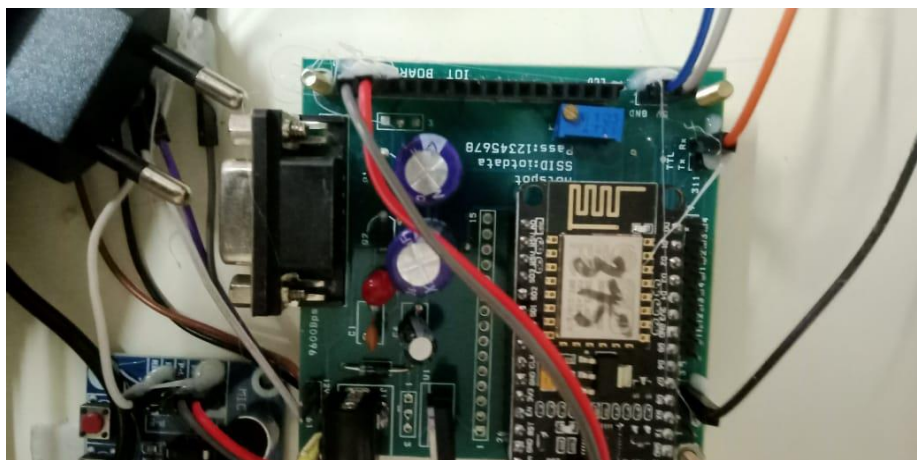


Figure 4.1.1 ARDUINO UNO

4.1.2 POWER SUPPLY UNIT

When developing projects, the power supply is one of the most important part of whole project and there is always need of multiple output voltage power supply. This is because different sensors need different input voltage and current to run efficiently. In this scenario, a power supply which can output multiple voltages becomes very important. There are options that an engineer can use for external power supply like RPS (regulated power supply) or AC adaptors but then multiple power supplies will be needed and the whole system will become bulky.

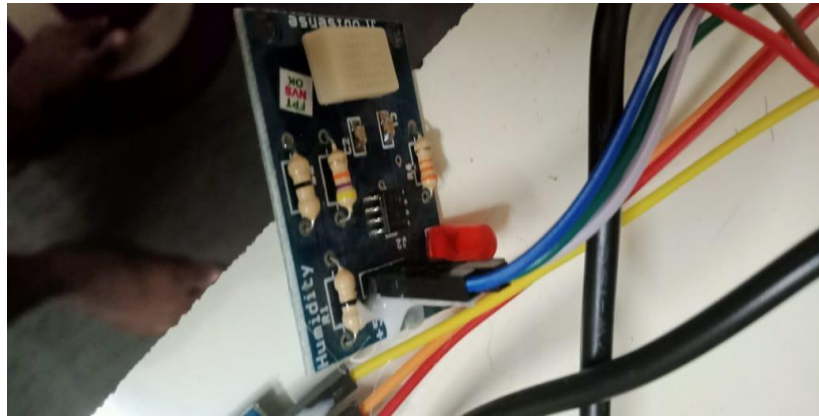


Figure 4.1.2 POWER SUPPLY UNIT

4.1.3 SPRAY MOTOR

The spray motor is used to spray pesticide to control insect based on the Arduino unit instruction. Spray Pump DC 4v-9V Spray motor for Arduino based Robotics.



Figure 4.1.3 DC MOTOR

4.1.4 IoT – ESP8266

This is a IoT module, it used to store all data in the cloud. The sensor information, arduino controlling information, water tank information are stored in the cloud using IoT.



Figure 4.1.4 IOT MODULE

4.1.5 ULTRASONIC SENSOR UNIT

Precision Agriculture (PA) systems regulate insect repellent application, monitor irrigation based on ultrasonic sensor. These systems basically enhance farming efficiencies to enable obtaining higher outputs and crop yield in order to feed an ever-growing world population.

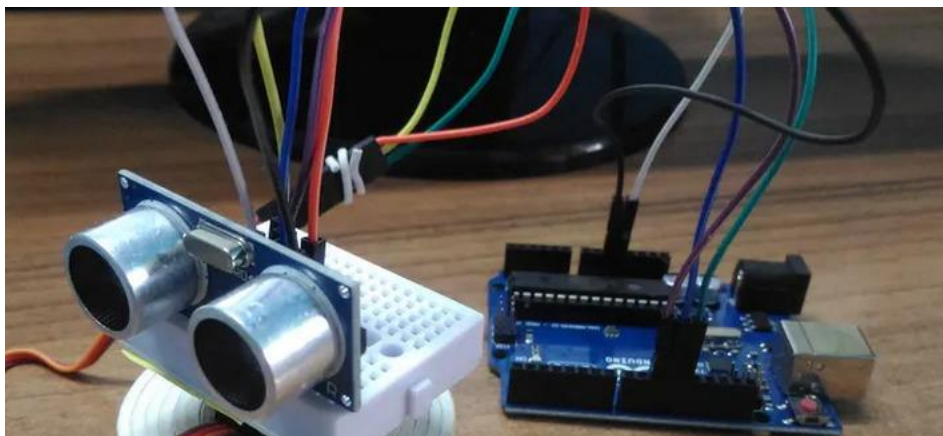


Figure 4.1.5 ULTRASONIC SENSOR

4.1.6 SERVO MOTOR

A **servo motor** is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit that provides feedback on the current position of the motor shaft, this feedback allows the servo motors to rotate with great precision. If you want to rotate an object at some specific angles or distance, then you use a servo motor. It is just made up of a simple motor which runs through a **servo mechanism**. If motor is powered by a DC power supply then it is called DC servo motor, and if it is AC-powered motor then it is called AC servo motor. For this tutorial, we will be discussing only about the **DC servo motor working**. Apart from these major classifications, there are many other types of servo motors based on the type of gear arrangement and operating characteristics. A servo motor usually comes with a gear arrangement that allows us to get a very high torque servo motor in small and lightweight packages. Due to these features, they are being used in many applications like toy car, RC helicopters and planes, Robotics, etc.

Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm tells you how much weight your servo motor can lift at a particular distance. For example: A 6kg/cm Servo motor should be able to lift 6kg if the load is suspended 1cm away from the motors shaft, the greater the distance the lesser the weight carrying capacity. The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor.

Servo Motor Working Mechanism

It consists of three parts:

1. Controlled device
2. Output sensor
3. Feedback system

It is a closed-loop system where it uses a positive feedback system to control motion and the final position of the shaft. Here the device is controlled by a feedback signal generated by comparing output signal and reference input signal.

Here reference input signal is compared to the reference output signal and the third signal is produced by the feedback system. And this third signal acts as an input signal to the control the device. This signal is present as long as the feedback signal is generated or there is a difference between the reference input signal and reference output signal. So the main task of servomechanism is to maintain the output of a system at the desired value at presence of noises.

Servo Motor Working Principle

A servo consists of a Motor (DC or AC), a potentiometer, gear assembly, and a controlling circuit. First of all, we use gear assembly to reduce RPM and to increase

torque of the motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now the difference between these two signals, one comes from the potentiometer and another comes from other sources, will be processed in a feedback mechanism and output will be provided in terms of error signal. This error signal acts as the input for motor and motor starts rotating. Now motor shaft is connected with the potentiometer and as the motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stops rotating.

Interfacing Servo Motors with Microcontrollers:

Interfacing hobby Servo motors like s90 servo motor with MCU is very easy. **Servos have three wires coming out of them.** Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU. An **MG995 Metal Gear Servo Motor** which is most commonly used for RC cars humanoid bots etc. The picture of MG995 is shown below:

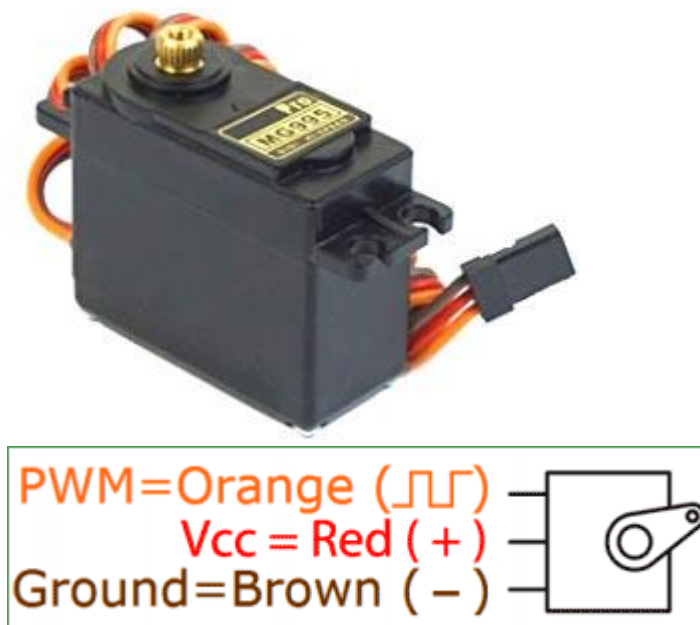


Figure 4.1.6

The color coding of your servo motor might differ hence check for your respective datasheet.

All servo motors work directly with your +5V supply rails but we have to be careful on the amount of current the motor would consume if you are planning to use more than two servo motors a proper servo shield should be designed.

4.2 SOFTWARE MODULE DESCRIPTION

4.2.1 Arduino Installation

After learning about the main parts of the Arduino UNO board, we are ready to learn how to set up the Arduino IDE. Once we learn this, we will be ready to upload our program on the Arduino board.

In this section, we will learn in easy steps, how to set up the Arduino IDE on our computer and prepare the board to receive the program via USB cable.

- First you must have your Arduino board (you can choose your favourite board) and a USB cable. In case you use Arduino UNO, Arduino Duemilanove, Nano, Arduino Mega 2560, or Diecimila, you will need a standard USB cable (A plug to B plug), the kind you would connect to a USB printer as shown in the following image.
- Download Arduino IDE Software. You can get different versions of Arduino IDE from the Download page on the Arduino Official website. You must select your software, which is compatible with your operating system (Windows, IOS, or Linux). After your file download is complete, unzip the file

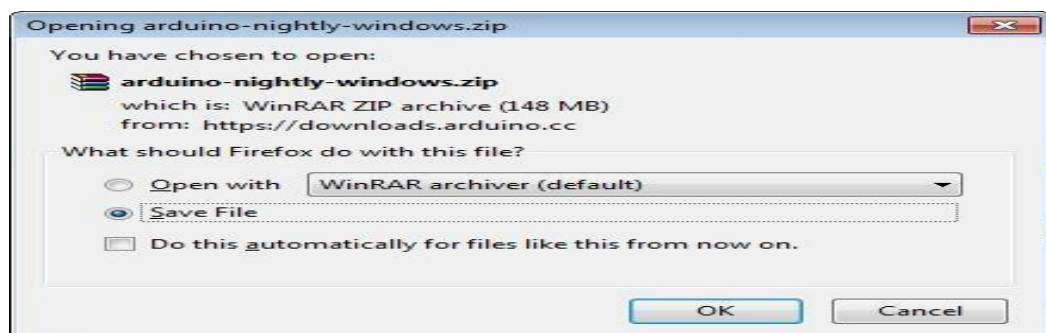


Figure 4.2a Installation

Power up your board. The Arduino Uno, Mega, Duemilanove and ArduinoNano automatically draw power from either, the USB connection to the computer or an external power supply. If you are using an Arduino Diecimila, you have to make sure that the board configured to draw power from the USB connection. The power source selected with a jumper, a small piece of plastic that fits onto two of the three pins between the USB and power jacks.

Check that it is on the two pins closest to the USB port. Connect the Arduino board to your computer using the USB cable. The green power LED (PWR) should glow.

Launch Arduino IDE. After your Arduino IDE software downloaded, you need to unzip the folder. Inside the folder, you can find the application icon with an infinity label (application.exe). Double-click the icon to start the IDE.

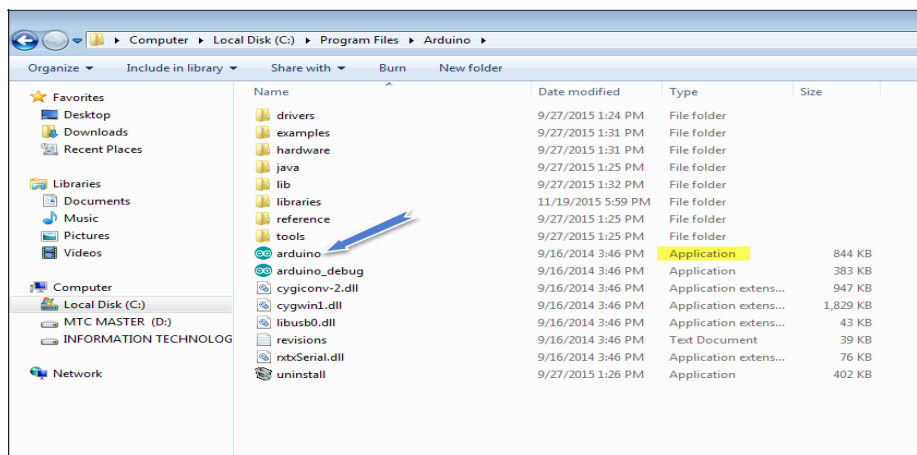


Figure 4.2b Application

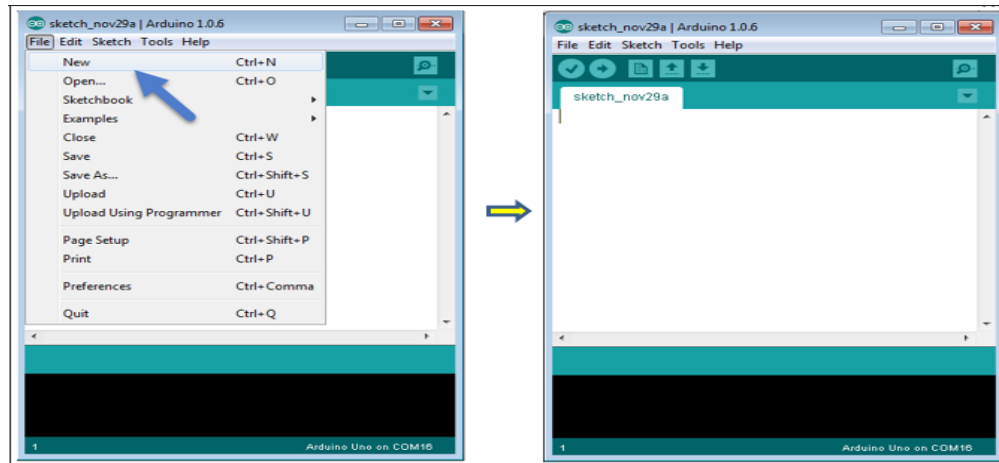


Figure 4.2c Creating a File

- Open your first project. Once the software starts, you have two options:
 - Create a new project.
 - Open an existing project example.
 - To create a new project, select File --> New
 - To open an existing project example, select File -> Example -> Basics -> Blink
- Here, we are selecting just one of the examples with the name Blink. It turns the LED on and off with some time delay. You can select any other example from the list.

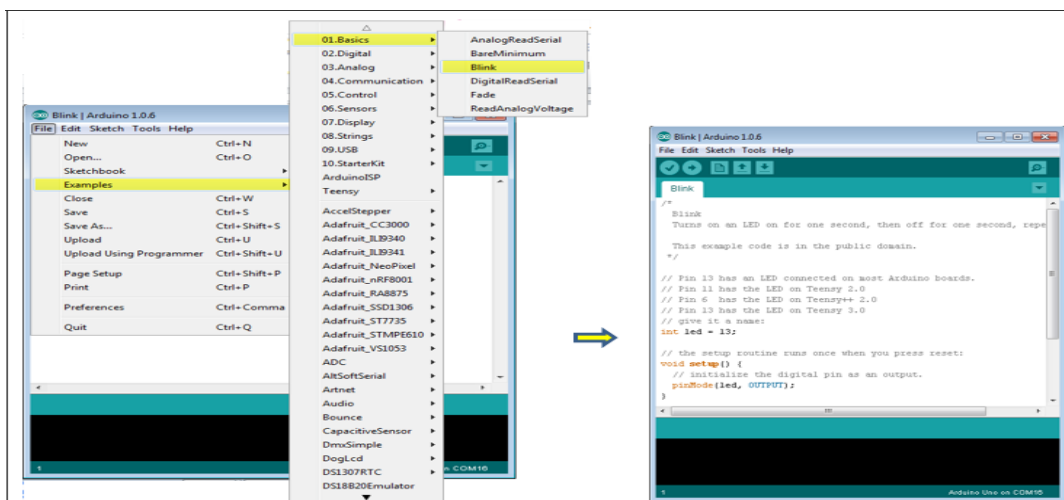


Figure 4.2d Code status by compiling

- Select your Arduino board. To avoid any error while uploading your program to the board, you must select the correct Arduino board name, which matches with the board connected to your computer. Go to Tools -> Board and select your board.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 RESULTS

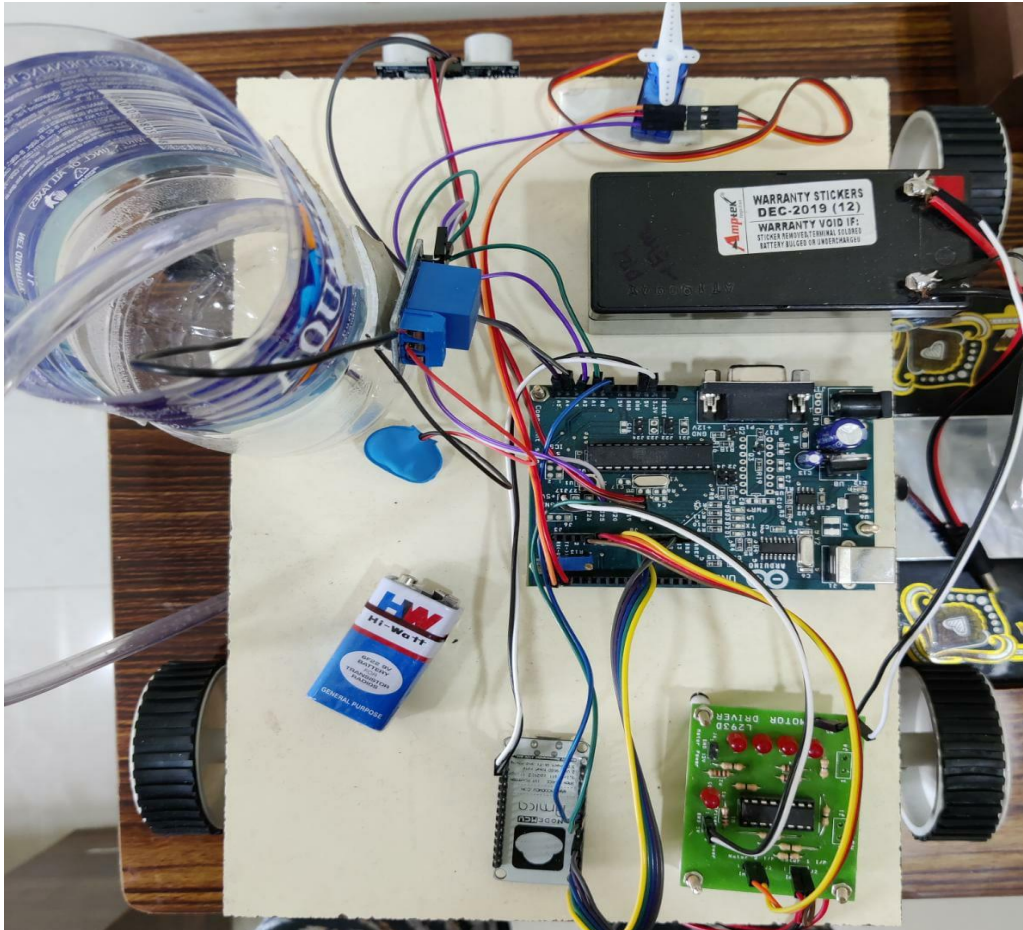


Figure 5.1 DEMONSTRATION

The user is required to switch on the robot from his mobile phone which is paired via Bluetooth to the Bluetooth module fixed on the robot. The Arduino processes the distance measurements from the ultrasonic sensor and decides to move forward or take a slight turn due to an object in near vicinity.

Simultaneously, the pump is turned on which pumps the pesticide or any nutrient medium, the direction of the nozzle is swayed in a periodic motion by a servo motor.

5.2 IDEAL VIEW OUTPUT

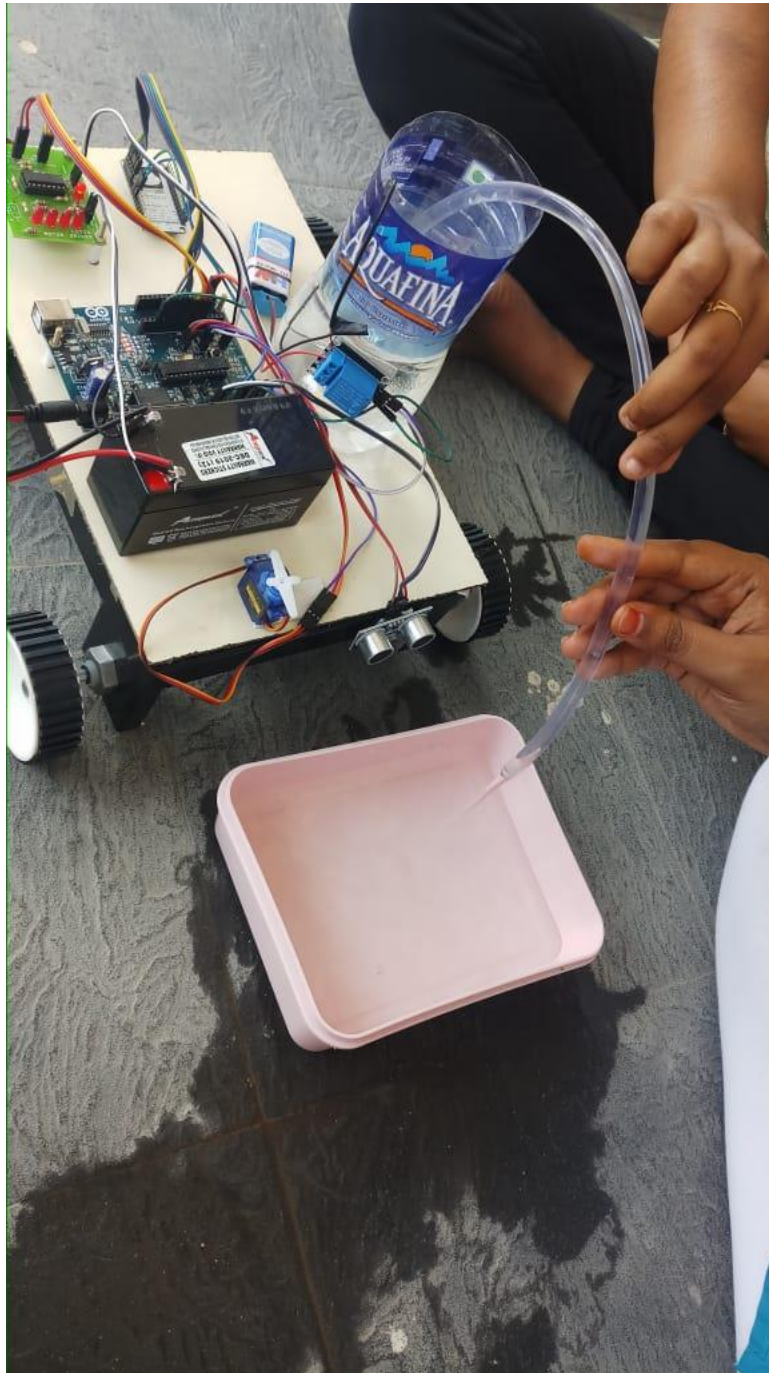


Figure 5.2.1 WITHOUT SPRAY MOTOR



Figure 5.2.2 WITH SPRAY MOTOR

CHAPTER 6

CONCLUSION AND FUTURE WORK

The interaction between the autonomous vehicle and the spraying management system is a solution with high technological content that allows safe and accurate autonomous spraying operations. As demonstrated by the experimental results, the proposed architecture showed good performance, even in a scenario such as a greenhouse that could introduce GNSS signal attenuations and create multipath reflections. All the trials were performed without any significant degradation. The robot autonomously carried out the assigned path between the rows for about 8 h, maintaining a sufficient safe distance from the plants. The smart spraying system regulated the amount of sprayed products in terms of quantity and selective activation of the nozzles based on the planned spraying treatments. The compactness and robustness of the system paves the way for its adoption in environments where other normal agricultural machinery cannot operate, such as greenhouses, mountains, terraced and heroic cultivations. Further development and trials are needed to confirm the robustness of the system in more challenging environments than those presented here. However, from our preliminary tests, the platform shows good potential to be able to carry out the work also in harder conditions. Further tests in this direction will be done in the near future. Moreover, it must be noted that even though the proposed solution comprises a robotic approach to perform a specific agricultural task (spraying activities in this case), thanks to its modularity, other applications could be investigated in the future (e.g., harvesting, pruning, powder distribution, weed removal, soft tilling). Therefore, the potential applications could be expanded by the high flexibility of the proposed platform in relation to the various possible configurations. Indeed, a future system could be customizable through the use of specific tools that allow different types of tasks to be performed.

Although the basic architecture will remain unaltered (i.e., a robotic platform equipped with an independent navigation system), any particular application could be developed through the addition of further equipment and tools. At the moment, we are working on a software tool for the automatic planning of the whole mission: a georeferenced map of the plantation will be used to automatically generate the trajectory, with the aim of efficiently covering the area of interest. Moreover, the tool will plan the amount of product to spray, in terms of quantity and selective activation of the nozzles on the basis of presence of the plant, foliage density, type of crop, and forward speed of the machine.

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