Off Road Navigation of Autonomous Unmanned Ground Vehicle

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2023

Faculty of Engineering Sciences and Technology
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Under the supervision of
Engr. Musayyab Ali

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A project presented to the
Faculty of Engineering Sciences and Technology
In partial fulfillment of the
requirements for the degree of

Bachelors of Engineering
In
Electrical Engineering

Faculty of Engineering Sciences and Technology
Hamdard University, Islamabad Campus, Pakistan

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CERTIFICATE

This project **“Off Road Navigation of Autonomous Unmanned Ground Vehicle”** presented by **Arif Hussain, Hamza Mustafa, Junaid Asad, Mubariz-ul-Hassan** under the direction of their project supervisor and approved by the project examination committee, has been presented to and accepted by the Faculty of Engineering Science and Technology, in partial fulfillment of the requirements for Bachelor of Engineering (Electrical Engineering).

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ABSTRACT

Revolutionary developments had been brought about by automation technology considerable academic research expenditures as well as considerable business investment are made in autonomous driving. Due to improvements in manufacturing and automation, there is a greater need for unmanned ground vehicles in business, agriculture, and the military. The fundamental purpose of waypoint navigation is to follow user-defined pathways and locate goals. In this study, a user-specified set of waypoints was used to direct an Autonomous Unmanned Ground Vehicle (AUGV) along a course. The waypoints had been established using a mapping interface. The UGV uses magnetometer sensors, GPS receivers, and ultrasonic sensors combined with servomotors for autonomous navigation to avoid obstacles and follow a course indicated by GPS waypoints. To complete its goal and independently travel through its environment, it must be able to identify and avoid obstacles. This report consists of implementing a system that can detect any obstacles in its path. Autonomous UGV moves from source to destination point based on the input form the variety of sensors located at multiple parts of the AUGV. For most systems, one of the important tasks is to plan the vehicle's route. These areas had been covered in this thesis: Waypoint navigation, object identification, obstacle avoidance, and UGV path planning. The algorithm processes all these sensory inputs, determining the instructions to be sent for the AUGV’s actuation. All these technologies enable efficient autonomous navigation. The AUGV has tested several different environments which successfully have achieved accuracy and reliability.

FINAL YEAR DESIGN PROJECT AS A COMPLEX ENGINEERING PROBLEM

It is to certify here that the final year design project (FYDP) entitled,

"Off Road Navigation of Autonomous Unmanned Ground Vehicle"

is categorized as a Complex Engineering Problem (CEP) based on the preamble (in-depth engineering knowledge) and involvement of the following attributes.

1. Depth of knowledge required.
2. Range of Conflicting Requirements
3. Depth of analysis required.
4. Familiarity of issues
5. Interdependence

The above-listed attributes are thoroughly assessed after conducting meeting on 10th November 2022, with the following final year students, who proposed the idea of the titled FYDP.

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This project is going to be conducted in Fall semester 2022 and Spring semester 2023. Further, it is submitted that the proposed idea is worthy, and the required efforts are up to the level of a final year design project.

____

FYDP Supervisor

1.7 Complex Engineering Problem

This project satisfies the attributes of the complex engineering problem, in the given context, this section presents the justification that how the presented work addresses different attributes of the complex engineering problem. The details are presented in Table 1.

Table 11 CEP Attributes Mapping

Sr. No	**Attribute**	**Justification**
1	Depth of knowledge required	The project requires in depth knowledge of control system, image processing and algorithms.
2	Range of conflicting requirements	Efficient Path planning algorithm, Avoiding the obstacles and Trajectory following are the conflicting requirements.
3	Depth of analysis required	Analysis of different path planning techniques, to maintain the heading angle towards the destination and intelligent decision-making algorithms.
4	Consequences	Moving from source to destination avoiding all obstacles at an uneven terrain fulfills the delivery of required task.
5	Interdependence	Magnetometer, Controller interfacing, JATSON NANO are the independent components to get the desired results.

Sustainable Development Goals

This section presents a brief overview of all the SDGs and mainly justifies the contribution of the project to the sustainable development goals (SDGs). Detailed justification of the mentioned points is presented in Table 1.

Table 12 SGDS Table of the Project

Sr. No	**Title**	**Compliance (Y/N)**	**Remarks/Justification**
1	No poverty	No	Not applicable
2	Zero hunger	No	Not applicable
3	Good health/wellbeing	Yes	UGV can be used to timely deliver the first aid box / as a fire extinguisher in a high risk area.
4	Quality education	No	Not applicable
5	Gender equality	No	Not applicable
6	Clean water and sanitation	No	Not applicable
7	Affordable and clean energy	Yes	Not applicable
8	Decent work and economic Growth	yes	. Not applicable
9	Industry, innovation and Infrastructure	Yes	Project consists of implementing a system that can detect any obstacles in the way in real-time, along with path planning algorithms to plan the local and global path.
10	Reduced Inequalities	No	Not applicable
11	Sustainable Cities and	Yes	UGV will be useful for a variety

	Communities		of tasks that are too dangerous or inefficient for humans to carry out	
12	Responsible consumption and Production	No	Not applicable	
13	Climate action	No	Not applicable	
14	Life below water	No	Not applicable	
15	Life on land	No	Not applicable	
16	Peace, Justice and strong Institutions	No	Not applicable	
17	Partnerships for the goals	No	Not applicable	

ACKNOWLEDGEMENT

We must give credit to **Hamdard Institute of Engineering and Technology** for their assistance with this project, which was a major accomplishment for our undergraduate team.

We would like to thank the **Engr. Musayyab Ali** for being our supervisor. We would like to express our profound gratitude for their astute advice, generous assistance, and warm demeanor, which motivates us to succeed in the project and brings it to fruition.

We appreciate the assistance of our co-supervisor, **Engr. M. Najeeb**. We want to express our sincere appreciation for their astute advice and help in maintaining my progress on schedule.

Several people, particularly classmates and team members, provided insightful remarks and recommendations on this project, which inspired us to enhance the undertaking. We express our gratitude to everyone who contributed directly or indirectly to the project's completion.

TABLE OF CONTENTS

ABSTRACT 1

FINAL YEAR DESIGN PROJECT AS A COMPLEX ENGINEERING PROBLEM .. 2

1.7 Complex Engineering Problem 3

Sustainable Development Goals 4

ACKNOWLEDGEMENT 6

TABLE OF CONTENTS 7

LIST OF FIGURES 9

LIST OF TABLES 10

ABBREVIATIONS 11

CHAPTER 1 INTRODUCTION 12

1.1 Introduction 12

1.2 Motivation 13

1.3 Problem Statement 13

1.4 Proposed Solution 14

1.5 Utilization of the Proposed Outcome 14

1.5.1. Investigation and observation 14

1.5.2. Agriculture and Farming 14

1.5.3. Logistics and Warehousing 14

1.5.4. Mining and construction 15

1.5.5. Disaster Response and Relief 15

1.5.6. Automatic Transport 15

1.5.7. Defense and military 15

1.5.8. Personal Mobility and Assistive Devices 15

1.5.9. Environmental Monitoring and Conservation 15

1.5.10. Entertainment and Education 15
1.6 Aims and Objectives 16
1.7 Sustainable Development Goals 16
1.8 Complex Engineering Problem 17
1.9 Report Organization 18
CHAPTER 2 LITERATURE REVIEW 20
2.1 Background 20
CHAPTER 3 EXPERIMENTAL SETUP AND PROCEDURE 26
3.1 Important Characteristics of Autonomous UGVs 26
3.1.1 Sensory Perception 26
3.1.2 Navigation and Path Planning 26
3.1.3 Autonomous Decision-Making 26
3.1.7 Energy Efficiency 27
3.2 Phases of Project 27
CHAPTER 4 MATERIALS AND COMPONENTS 35
4.1 DC Motor 35
4.2 Motor Driver (BTS7960) 36
4.3 Arduino Mega2560 37
4.4 GPS Ublox Neo M8N 38
4.5 Magnetometer (QMC5883l) 39
4.6 Buck Converter (XL4015) 40
4.7 Batteries 41
4.8 Bluetooth Module (HC-06) 42
4.9 Ribbon Pins 43
4.10 Servo Motor 44
4.11 Ultrasonic Sensor 44

CHAPTER 5 METHODOLOGY AND BLOCK DIAGRAM 46
5.1 Methodology 46
5.2 Block Diagram 46
5.3 Flow Chart 48
CHAPTER 6 RESULTS AND DISCUSSION 50
6.1 Scenario 1 50
6.2 Scenario 2 55
6.3 Scenario 3 56
6.4 Performance Analysis 58
CHAPTER 7 CONCLUSION AND FUTURE RECOMMENDATIONS 59
7.1 Conclusion 59
7.2 Future Recommendations 60
REFERENCES 61
APPENDIX 63
SOURCE CODE 63
DATA SHEET OF H-BRIDGE DRIVE 7960 67
DATA SHEET OF BLUETOOTH MODULE (HC-06) 68
DATA SHEET OF MAGNETOMETER QMC (5883l) 69
DATA SHEET OF SERVO MOTOR 70
DATA SHEET OF ULTRASONIC SENSOR 71
DATA SHEET OF ARDUINO MEGA2560 72
DATA SHEET OF BUCK CONVERTER (XL4015) 73

LIST OF FIGURES

Figure 2.1: DARPA Robot [2] 21
Figure 2.2: CMU Rover [4] 21
Figure 2.3: DARPA AUGV [6] 22
Figure 2.4: Convolutional Neural Network [7] 23

Figure 2.5: SLAM Robots [9] ... 25
Figure 3.1: Metal Sheet ... 28
Figure 3.2: Vehicle chassis ... 28
Figure 3.3: Ground Clearance ... 29
Figure 3.4: Autonomous Unmanned Ground Vehicle ... 29
Figure 3.5: Flow Chart of YOLOv5 ... 30
Figure 3.6: Mobile application ... 32
Figure 4.1: DC Motor [10] ... 36
Figure 4.2: Motor driver H-Bridge BTS-7960 [11] ... 36
Figure 4.3: Arduino mega2560 [12] ... 37
Figure 4.4: Arduino Mega2560 Pin Layout [13] ... 38
Figure 4.5: GPS Ublox Neo M8N [14] ... 39
Figure 4.6 : Magnetometer (QMC5883l) [15] ... 40
Figure 4.7: Buck Converter (XL4015) [16] ... 41
Figure 4.8: Batteries ... 41
Figure 4.9: Bluetooth Module (HC-06) [17] ... 42
Figure 4.10: 40 Pin Connector [18] ... 43
Figure 4.11: Servo Motor [19] ... 44
Figure 4.12: Ultrasonic Sensor [20] ... 45
Figure 5.1: Block Diagram ... 47
Figure 5.2: Flow Chart ... 49
Figure 6.1: Source GPS info ... 50
Figure 6.2: Waypoint 1 Set ... 51
Figure 6.3: Source Point ... 51
Figure 6.4: Destination GPS info ... 52
Figure 6.5: Waypoint 2 Set ... 52
Figure 6.6: Waypoints Complete ... 53
Figure 6.7: Go To Waypoint ... 53
Figure 6.8: Destination Point ... 54
Figure 6.9: Final Waypoint Reached ... 54
Figure 6.10: Collision Avoidance ON ... 55
Figure 6.11: Object Detection ... 56
Figure 6.12: Off Road Source ... 57
Figure 6.13: Off Road Object Detection ... 57
Figure 6.14: Off Road Destination ... 58

LIST OF TABLES

Table 1.1: SDGS Table of the Project ... 16
Table 1.2: CEP Attributes Mapping ... 18
Table 3.1 Application Keys ... 32

No table of figures entries found.

ABBREVIATIONS

AUGVs	Autonomous unmanned ground vehicles
AUGV	Autonomous unmanned ground vehicle
UGV	Unmanned Ground Vehicle
I/O	Input/Output
UART	Universal Asynchronous Receiver and Transmitter
PWM	Pulse Width Modulation
ADC	Analog to Digital Converter
GND	Ground
RXD	Received Data
TXD	Transmitted Data
Vin	Input Voltage
YOLO	You Only Look Once
YOLOv5	You Only Look Once Version 5
COCO	Common Objects in Context
DARPA	Defense Advanced Research Projects Agency
CNN	Convolutional Neural Network
NMS	Non-Maximum Suppression
DC	Direct Current
RHT	Right
LFT	Left

CHAPTER 1
INTRODUCTION

1.1 Introduction

Recently, considerable advancements have been made in the discipline of robotics in the creation of Autonomous Unmanned Ground Vehicles (AUGVs). These vehicles have the potential to revolutionize several industries, including transportation, logistics, and military operations. Robotics has considerably aided humans in carrying out daily chores. Robots are made to operate in any setting and do tasks in place of people. They must be able to manage sensors and effectors with certain physical features since they function under real-world and real-time restrictions.

Significant study has been done in recent years on the creation of UGV systems. Important applications for these technologies have been discovered in both military and civilian settings. These robots are frequently operated manually as they move from one place to another. However, several research on autonomous robots have been conducted, leading to a wide range of prospective uses for these autonomous robots.

The autonomy of UGV systems ranges from a straightforward system that may be operated remotely by a person to a fully autonomous system that does not require human interaction. There are still many challenging issues to solve, nevertheless, to remove people from the loop. It may be preferable to use UGVs in place of human-operated vehicles when a work has the potential to be tedious or risky.

Programming is necessary for UGV deployment success and includes path planning and tracking algorithms. The controller should be able to handle the tasks of localization, GPS data analysis, sensor data analysis, and merging all the aforementioned while guiding the UGV. It is possible to direct the UGV's path-following control to waypoint guidance.

To travel to certain given points, waypoint guidance—the pursuit of several waypoints along an ill-defined trajectory—is crucial in UGV management. A waypoint is a landmark that may be used to locate specific locations. They have a particular value for latitude and longitude.

Planning a course for the vehicle to follow is one of these crucial issues for most systems. This study covers these topics: UGV path planning, object detection and obstacle avoidance and waypoint navigation. One potential setting for the deployment of a UGV is uneven terrain, which is the topic of the thesis on routes design.

A planning task would be interestingly challenged in such an environment because of the many obstacles and limitations on vehicle movement. The planning algorithms demonstrate how these methods apply to various locations while also being successful on uneven terrain. To get to its target as quickly as feasible, the UGV must be able to choose a course to take from source to destination waypoint.

1.2 Motivation

Autonomous Unmanned Ground Vehicles (AUGVs) have the potential to revolutionize a variety of industries, maybe even military operations, logistics, and transportation. The motivation is caused by several factors, including:

1. Technological advancements: UGVs are becoming more sophisticated because of advancements in artificial intelligence, machine learning, and sensor technologies. Investigating these advancements and how they impact autonomous navigation and decision-making may turn out to be highly intriguing.
2. Practical usages: UGVs may be utilized for a range of tasks that are practical, such as package delivery, agricultural labor, and search and rescue operations. Finding out how UGVs can effectively complete these tasks on their own might aid in providing workable solutions.
3. Security and effectiveness: Across a variety of applications, autonomous UGVs have the potential to enhance security and efficacy. Without the need for human operators, UGVs can work in hazardous conditions or perform repetitive tasks reliably and consistently.

These are the main reasons for motivation to lead this project.

1.3 Problem Statement

There are a variety of AUGVs in the market capable of moving from source point to destination point. Currently. AUGVs are not very accurate for object detection and avoidance, path planning and designed for all types of environments and unable to travel on uneven surfaces.

1.4 Proposed Solution

The proposed AUGVs can be able to travel in different conditions from source to destination point having the capability to detect obstacles efficiently and effectively in their path and avoid it. AUGV is operating in different environments including those that are hot, chilly, dusty, mountain, muddy, any terrain where ordinary AUGV are unable to operate in such environments.

1.5 Utilization of the Proposed Outcome

The creation of autonomous unmanned ground vehicles (UGVs) has enormous potential for use in many different sectors of the economy. These vehicles can operate without direct human direction, which has several benefits in terms of efficiency, safety, and economics. The following are some of the most important implications and possible uses of autonomous UGVs:

1.5.1. Investigation and observation

Autonomous UGVs can be used for exploration tasks including mapping and surveying undiscovered regions, monitoring the environment, and exploring dangerous or distant locations where human access is difficult or dangerous. They are useful for border patrol, monitoring important infrastructure, situational awareness, and surveillance and security applications.

1.5.2. Agriculture and Farming

In precision agriculture, unmanned ground vehicles (UGVs) outfitted with cutting-edge sensors and robotic arms may carry out operations like planting, weeding, fertilizing, and harvesting crops with more accuracy and efficacy. They can increase total agricultural yields, lower labor costs, and optimize resource use.

1.5.3. Logistics and Warehousing

By automating material handling operations, order picking, and inventory management, autonomous UGVs may completely transform the logistics and warehousing sector. They are capable of moving products in warehouses or distribution centers effectively while navigating through challenging situations and dodging hazards.

1.5.4. Mining and construction

Autonomous UGVs can be used for material transportation, shipping, and excavation on mining and construction sites. They may operate in dangerous environments, improving worker safety and lowering the possibility of mishaps.

1.5.5. Disaster Response and Relief

Autonomous UGVs might be extremely useful for search and rescue operations during emergencies or natural catastrophes. They can move through debris, evaluate damage, and identify survivors, facilitating effective and speedy disaster response.

1.5.6. Automatic Transport

The growth of autonomous transportation is greatly aided by the development of autonomous UGVs. They can be used for last-mile delivery, ride-sharing, and public transit in metropolitan areas, potentially lowering traffic, and pollution.

1.5.7. Defense and military

Autonomous UGVs can help in reconnaissance, surveillance, and intelligence collection in the military. Additionally, they can be used in battle zones for transportation, managing hazardous materials, and logistical assistance.

1.5.8. Personal Mobility and Assistive Devices

Autonomous UGVs may be created for personal mobility and assistive uses, assisting people with impairments or restricted movement. They can help with transit and increase accessibility in cities.

1.5.9. Environmental Monitoring and Conservation

Autonomous UGVs may be fitted with a variety of sensors to track and gather information on the state of the environment, the behavior of animals, and the preservation of habitat. They can support scientific investigation and conservation initiatives.

1.5.10. Entertainment and Education

Autonomous UGVs may be utilized as platforms for teaching robotics, programming, and artificial intelligence topics in schools as well as for entertainment reasons, such as autonomous robot races and tournaments.

1.6 Aims and Objectives

The objective of the project is to make a prototype of an autonomous unmanned ground vehicle capable of waypoint navigation, obstacle detection and path planning in all sorts of environments and uneven surfaces.

The aim of the project is AUGV can achieve a high level of autonomy wherein the AUGV itself is capable of navigating through GPS waypoints from a start point to a destination. The AUGV perception sensors must be able to perceive the environment and detect and avoid all kinds of obstacles in its path.

1.7 Sustainable Development Goals

This section presents a brief overview of all the SDGs and mainly justifies the contribution of the project to the sustainable development goals (SDGs). Detailed justification of the mentioned points is presented in table 1.1.

Table 1.1: SDGS Table of the Project

Sr. No	Title	Compliance (Y/N)	Remarks/Justification
1	No poverty	No	Not applicable
2	Zero hunger	No	Not applicable
3	Good health/wellbeing	Yes	UGV can be used to timely deliver the first aid box / as a fire extinguisher in a high-risk area.
4	Quality education	No	Not applicable
5	Gender equality	No	Not applicable
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7	Affordable and clean energy	Yes	Not applicable

8	Decent work and economic Growth	yes	. Not applicable
9	Industry, innovation and Infrastructure	Yes	Project consists of implementing a system that can detect any obstacles in the way in real-time, along with path planning algorithms to plan the local and global path.
10	Reduced Inequalities	No	Not applicable
11	Sustainable Cities and Communities	Yes	UGV will be useful for a variety of tasks that are too dangerous or inefficient for humans to carry out
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13	Climate action	No	Not applicable
14	Life below water	No	Not applicable
15	Life on land	No	Not applicable
16	Peace, Justice and strong Institutions	No	Not applicable
17	Partnerships for the goals	No	Not applicable

1.8 Complex Engineering Problem

This project satisfies the attributes of the complex engineering problem, in the given context, this section presents the justification that how the presented work addresses different attributes of the complex engineering problem. The details are presented in table

1.2.

Table 1.2: CEP Attributes Mapping

	Attribute	Justification
1	Depth of knowledge required	The project requires in-depth knowledge of control systems, image processing and algorithms.
2	Range of conflicting requirements	Efficient Path planning algorithm, Avoiding the obstacles and Trajectory following are the conflicting requirements.
3	Depth of analysis required	Analysis of different path planning techniques, to maintain the heading angle towards the destination and intelligent decision-making algorithms.
4	Consequences	Moving from source to destination avoiding all obstacles at an uneven terrain fulfills the delivery of required task.
5	Interdependence	Magnetometer, Controller interfacing, JATSON NANO are the independent components to get the desired results.

1.9 Report Organization

This report has a detailed explanation on AUGV.

Chapter 1: This chapter provides the basic introduction about the project to let the reader know about the overall of this proposed study.

Chapter 2: Explains the Literature review of autonomous unmanned ground vehicle and previous workings of other researchers followed by the latest research on which this prototype is based.

Chapter 3: Demonstrates the experimental setup and procedures. Here all the research and pre-design techniques have been applied and explained.

Chapter 4: This chapter contains all the materials and components used to make the prototype reach the final position, here all the components used in UGV are explained in detail.

Chapter 5: After chapter 3 and chapter 4, is where methodology of the system as well as the flow chart of the prototype is discussed, here the flow of control between different components are explained.

Chapter 6: Discussion of results and the testing phase is a part of chapter6, here all the results established by the system and the testing phase where this system has been moved from source point to destination point.

Chapter 7: Finally, future recommendations and conclusion of the system defining all the key features, flaws and what should be one in future to make the prototype more effective. A few paragraph details of the conclusion and brief details of future recommendation have been set forth.

CHAPTER 2
LITERATURE REVIEW

This chapter will give you a glimpse of the work that had been done on autonomous unmanned ground vehicles by engineers, researchers, and authors.

2.1 Background

Unmanned ground vehicles (UGV's) are specialized pieces of machinery that travel on the earth's surface while hauling and moving objects, but not people. Humans can effortlessly run or stroll on any surface. It is extremely difficult for machines to traverse the landscape like people. To create a machine that can be employed in locations where it is challenging for humans to walk through or get close to, several studies have been conducted. New discoveries and studies are still being made today to improve the capabilities of unmanned ground vehicles.

Shakey, created in the late 1960s at Stanford Research Institute (SRI) as a test platform for Defense Advanced Research Projects Agency (DARPA) funded AI research, was the first significant mobile robot development project [1]. Shakey robot was a wheeled platform equipped with steerable TV camera, an ultrasonic range finder, and touch sensors. It was connected to an SDS-940 mainframe computer, which handled exploration and navigational tasks, through an RF link. The Shakey robot could take directions in English from the terminal operator, instructing the robot to move big wooden blocks about in its lab environment "world" as befitted an AI test bed. Shakey was regarded as a failure in its day because it was never able to operate autonomously, but it did set functional and performance benchmarks for mobile robots, identify technical flaws, and help define the research agenda for artificial intelligence (AI) in fields like planning, vision, and natural language processing. Figure 2.1 shows Shakey robot moved at a speed of roughly 10 m/h, which is far too sluggish [2].

Figure 2.1: DARPA Robot [2]

Hans Moravec conducted research on navigation and obstacle avoidance using a powerful stereo vision system at the Stanford University AI Lab from 1973 to 1981 [3]. The photos were analyzed by the off-board KL-10 mainframe after the Cart's single TV camera was moved to each of nine distinct places atop its basic mobility base. An obstacle-free route to the target was planned to use a model of the 3-D environment that was recreated by feature extraction and picture correlation. Each one-meter movement took the system up to 15 minutes to complete. Moravec continued working on the smaller CMU rover indoor platform after relocating to Carnegie Mellon University (CMU) in 1981. During the 1980s, CMU emerged as a significant pioneer in the field of mobile robot research, concentrating much of its efforts on the Navlab vehicle [4]. CMU robot shows in Figure 2.2.

Figure 2.2: CMU Rover [4]

Path planning is the main component within autonomous vehicles whether they may be UAVs or UGVs and it's an established field. The pure pursuit algorithm is one of the most tried and tested ones, resulting in large accuracy and rare errors. The waypoints can be set up by selecting specific points. The vehicle kinematic model, on which the odometrical equations depend, will be set up; and hence the waypoint locations in relation to the vehicle position will be calculated.[5]

In the early 2000, a lot of work had been done on the UGV's but significant needs to be done on AUGV localization, navigation, object detection and obstacle avoidance. The Defense Advanced Research Projects Agency (DARPA) of the United States Department of Defense held the DARPA Grand Challenge to find autonomous ground vehicles that could successfully complete a difficult off-road desert course which is shown in figure 2.3. The Volkswagen Touareg R5 served as the foundation for the Stanley. It is specifically designed for high-speed desert driving. It has several sensors, including an inertial measuring unit (IMU) for detecting vehicle dynamics, GPS for location, and LIDAR (Light Detection and Ranging) for perception.

Figure 2.3: DARPA AUGV [6]

The control system for Stanley was made to work in real-time and carry out complicated actions including path planning and obstacle avoidance. Precision and stability of the control system decreases if there is time delay in steering angle control and signal processing. The relevance of ongoing research in the sector and the significance of autonomous vehicles in a variety of applications, such as transportation, military, and search and rescue. The difficulties encountered throughout the testing, such as the requirement for real-time processing, sensor noise, and the complexity of navigating an off-road environment [6].

Researchers had been working on technologies employing static sensors like Lidar or ultrasonic providing perception information about the objects. To enhance the perception of the AUGV real time object detection using computer vision was being introduced to provide comprehensive understanding of the environment. Finding occurrences of objects at the level of a particular scene category is the focus of object detection. The placement of the items in the image and their final classification into appropriate labels for them to be properly classified depend on object detection methodologies. By starting with simple Logistic Regression, were able to expand our research and simulations to more complex algorithms employing CNNs and YOLO techniques. Figure 2.4 shows the Convolutional Neural Network (CNN).

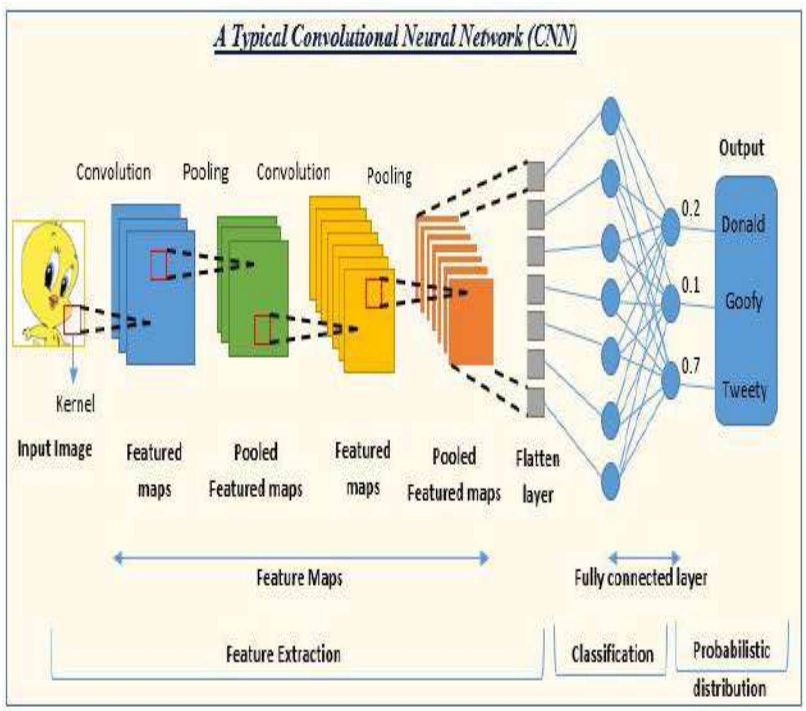

Figure 2.4: Convolutional Neural Network [7]

To get decent results in the setting, training is done utilizing proprietary datasets. An effective method for segmenting a variety of things in the environment is semantic segmentation. It is a highly supervised issue that calls for a big collection of 19 fully annotated datasets. By categorizing each pixel and determining its position and class, the challenge may be solved. Deep learning models are necessary to effectively handle this extremely difficult challenge. Fast SCNN algorithm which has a dual pipeline design to detect features on a course level and finer scale that are added to recognize the full picture, and labels the borders based on intra-class variations, is one effective method for semantic segmentation [7].

Work on autonomous navigation for indoors is also seriously under consideration as most of the work, especially in confined areas, requires UGV to complete a task satisfactorily. Bonatti, J., Melchior, P., & Guiochet, J. step towards indoor autonomous navigation for unmanned ground vehicles. The main goal of the research is to design and propose methods for autonomous navigation that is robust and dependable for UGVs operating in indoor environments, which frequently have complicated and dynamic situations. The unique difficulties UGVs confront when travelling inside, such as the existence of obstructions, irregular illumination, moving objects (like humans), and the requirement for exact localization. the significance of accurate localization and perception methods. For accurate mapping of the surroundings and exact positioning of the UGV, sensors like cameras and laser range finders are used. the use of mapping and SLAM methods to localize the UGV inside the interior environment while simultaneously building and updating a map of it. Algorithms for path planning enable the UGV to go from its present location to a target location while avoiding hazards and dynamically replanning in response to changing conditions. The necessity of reliable autonomous navigation in interior settings, where UGVs may be used for a variety of tasks, including logistics, surveillance, and search and rescue, is emphasized in the paper's conclusion. By addressing the difficulties of indoor navigation and providing methods for reliable sensing, localization, mapping, and path planning, the work contributes to the field of autonomous robotics [8].

Computer vision plays a very vital role in AUGV’s by providing essential capabilities that enable these vehicles to understand and interact with their environments.

Major contributions of computer vision in AUGV's are object detection and avoidance, line and road following, object detection and recognition, mapping and localization, semantic segmentation, visual odometry and a lot more. Hu, W., Tan, J., and Zheng, N., provides an extensive overview of Visual Simultaneous Localization and Mapping (Visual SLAM) algorithms. Visual SLAM is a crucial technology in the field of robotics and computer vision, allowing robots and autonomous systems to navigate and map their environments using visual sensor data.

The main goal of the research is to conduct a thorough survey of Visual SLAM algorithms, which are crucial for assisting robots and autonomous vehicles in understanding and navigating their environment by simultaneously estimating their own positions and mapping the surrounding area as shown in figure 2.5. In-depth examinations of feature extraction and matching, camera pose estimation, loop closure detection, map representation, and optimization techniques are provided in this thesis. The practical uses of Visual SLAM, highlighting its applicability in areas including robotics, autonomous navigation, augmented reality, and virtual reality. Scalability, resilience in dynamic situations, and real-time processing are some of the difficulties and outstanding research problems in the field of visual SLAM [9].

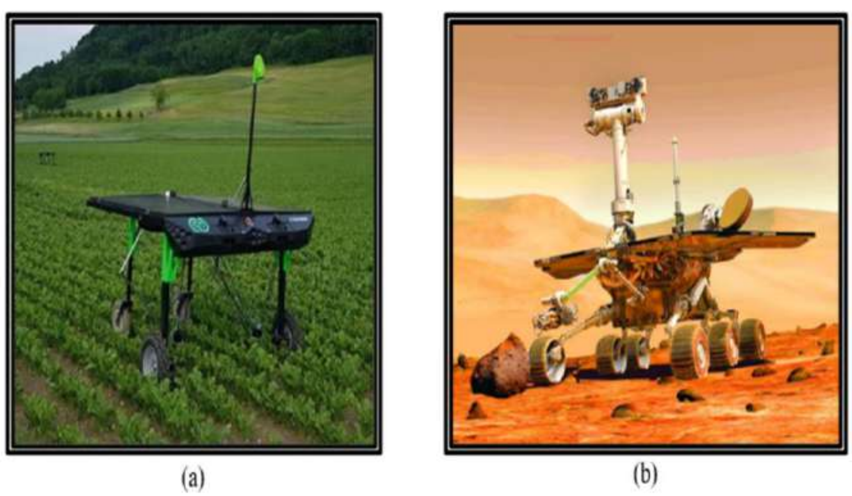

Figure 2.5: SLAM Robots [9]

CHAPTER 3
EXPERIMENTAL SETUP AND PROCEDURE

A cutting-edge technology called an autonomous Unmanned Ground Vehicle (UGV) has transformed many sectors by allowing vehicles to run autonomously. These automobiles, often known as "robots on wheels," are built to move around, interact with their surroundings, and carry out duties independently of human control. With uses in the military, agriculture, logistics, and transportation, the development of autonomous UGVs marks a significant achievement in robotics, artificial intelligence (AI), and mobility solutions.

3.1 Important Characteristics of Autonomous UGVs

Autonomous Unmanned Ground Vehicles (UGVs) possess a range of characteristics that are essential for their effective and safe operation. These characteristics enable them to navigate, interact with their environment, and fulfill their intended tasks without direct human control. Important characteristics of autonomous UGVs include:

3.1.1 Sensory Perception

Autonomous UGVs are fitted with a variety of sensors that offer real-time information about their environment, including lidar, cameras, radar, and GPS. These sensors enable the car to sense and comprehend its surroundings, including identifying barriers, other cars, and the state of the terrain.

3.1.2 Navigation and Path Planning

Autonomous UGVs use cutting-edge algorithms and AI to map out their routes, avoid hazards, and make snap judgments on the most effective and safest ways to get there. They can dynamically alter their courses and adapt to shifting circumstances.

3.1.3 Autonomous Decision-Making

These vehicles can make choices on their own, depending on information gathered from sensors and pre-programmed goals. They can respond to unforeseen circumstances and adjust to new information thanks to their independence.

3.1.4 Task Execution

Depending on their intended use, autonomous UGVs are built to carry out a variety of activities. They can be utilized for things like deliveries, agriculture, search and rescue missions, surveillance, and even reconnaissance.

3.1.5 Remote Control and Monitoring

While autonomous UGVs can operate without human supervision, they frequently feature the ability for remote control and monitoring. This enables human operators to step in, alter the goals, or give instructions as needed.

3.1.6 Safety and Reliability

Safety must always come first in the creation of autonomous UGVs. To reduce the risk of accidents and maintain their dependability under varied circumstances, these vehicles go through thorough testing.

3.1.7 Energy Efficiency

Using electric or hybrid power systems to increase their operational range and lessen their impact on the environment, many autonomous UGVs are built with energy efficiency in mind.

3.2 Phases of Project

This project is divided into two phases.

- Project hardware
- Project software

The project's initial phase involves creating the hardware framework. In this phase, a list of the hardware, tools, and materials required to complete the project is made. All the parts that will be employed in the project's hardware, such as the supplies, tools, machinery, and equipment, are referred to as project hardware.

An Unmanned Ground Vehicle (UGV)'s frame acts as the structure of the vehicle, offering structural support and a platform for mounting different parts. The material for the frame is iron as it is corrosion resistant and holds heavy impact. To form the frame first cut the iron sheet (2mm) of size 18 inches by 30 inches and make the base on frame shown in figure 3.1.

Figure 3.1: Metal Sheet

We first cut the iron sheet, then we measured where on the iron sheet to cut out four little pieces of the necessary shape to fit our vehicle's four wheels. Two adjustable plates that serve as a stand for motors are made separately and fastened to the base as shown in figure 3.2.

Figure 3.2: Vehicle chassis

We used four universal (adjustable) bearing brass cages and fixed with base through nut bolt and spacing pip to create clearance of vehicle from ground and four wheels of size six inches with shafts hold through universal bearing brass cages. In our vehicle we used universal bearing brass cage through which we can do alignment of wheel and adjust the clearance between ground and vehicle shown in figure 3.3.

Figure 3.3: Ground Clearance

Figure 3.4 shows a vehicle where we placed two high power dc gear motors in their adjustable stand and placed sprockets. We used a chain to connect two wheels with one motor. After placing the motors, we placed different components used in our project like batteries, H-bridge, GPS, magnetometer, ultrasonic sensor, servo motor, Arduino mega, connecting wires and Veroboard.

Figure 3.4: Autonomous Unmanned Ground Vehicle

Object detection is a phenomenon in computer vision that involves detection of various objects in digital images or videos. Some of the objects detected include people, a car, chair, etc. It defines the class of the object in an image or video. Object detection provides classification and localization of the object in an image.

The algorithm used for object detection is YOLO. It is abbreviated as You Look Only Once. This algorithm detects and recognizes various objects in the picture. The YOLO algorithm consists of various variants including tiny YOLO and YOLO V1, V2 and so on. It is popular because of its speed and accuracy. The version we are using is YOLO V5 for object detection.

A flowchart is a graphical representation of a process that shows the steps involved in performing a task. In the case of YOLOv5 (You Only Look Once version 5), it is a popular real-time object detection algorithm used in computer vision as shown in figure 3.5.

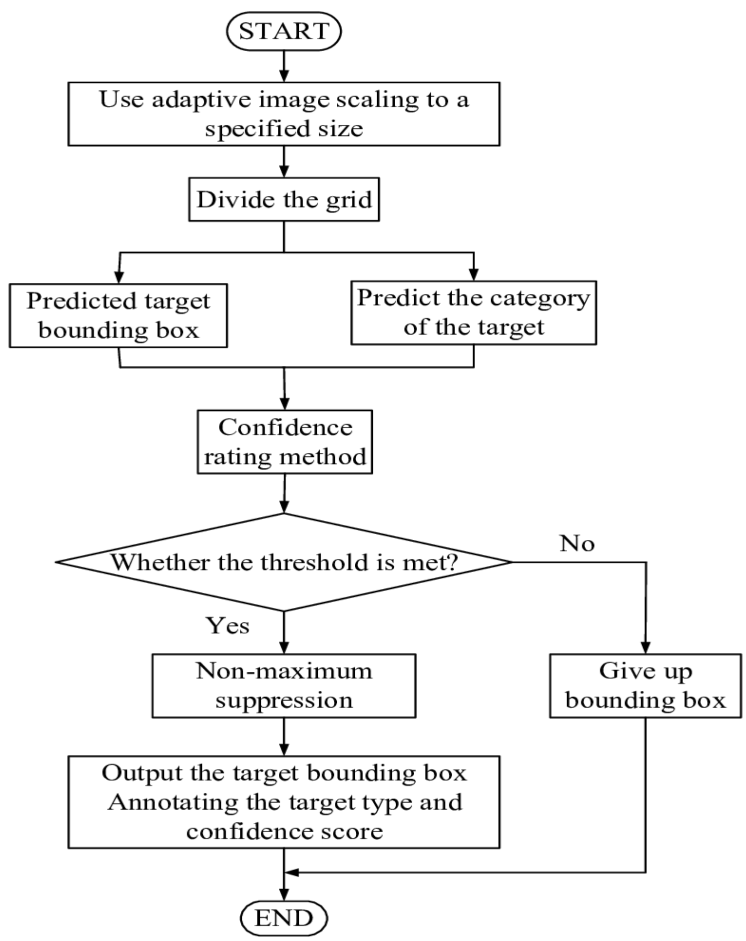

Figure 3.5: Flow Chart of YOLOv5

The process begins with the input of an image or a video frame that you want to perform object detection on. Before object detection can occur, the input image is preprocessed to prepare it for the neural network. This preprocessing may include resizing the image, normalizing pixel values, and handling data format conversions. YOLOv5 utilizes a convolutional neural network (CNN) as its backbone architecture. CNN extracts feature from preprocessed images. Common backbone architectures used in YOLOv5 include CSPDarknet53 and CSPDarknet53-PANet.YOLOv5's object detection head is responsible for generating bounding boxes, class predictions, and object confidence scores. It consists of multiple convolutional layers.

YOLOv5 employs anchor box clustering to define different anchor box sizes and aspect ratios. These anchor boxes are used to predict object locations and dimensions in the image. The neural network makes predictions for object locations, dimensions, objectness scores, and class probabilities for each anchor box. These predictions are usually represented in a grid-like format. To filter out redundant bounding box predictions, a non-maximum suppression algorithm is applied. Non-Maximum Suppression (NMS) removes duplicate or highly overlapping bounding boxes, leaving only the most confident detection. The output of the YOLOv5 object detection process is typically a visual representation of the input image with bounding boxes drawn around detected objects and their associated class labels.

Object detection is performed on Google Colab by using YOLOv5. Google Colab, sometimes known as Colaboratory, is a free cloud-based tool made available by Google that enables group Python code writing and execution. It is extensively utilized in the disciplines of education, data analysis, and machine learning.

To able AUGV to move autonomously, it requires to give waypoints of the path to AUGV wirelessly to Arduino mega via mobile. For this purpose, develop a mobile application whose name is ‘Bluetooth robot’. Using this application, we can move AUGV from source to destination as shown in figure 3.6.

Figure 3.6: Mobile application

The function of keys display of the mobile application is shown in table 3.1.

Table 3.1 Application Keys

KEYS	FUNCTIONS
Connect BT key	This key is used for the connectivity of AUGV with mobile application whenever we want to use it.
Disconnect BT key	This key is used to disconnect the AUGV from mobile application when we don’t need to use it.
GPS Info key	This is used to check the GPS information which provides current location of the AUGV, and display numbers of satellites relate to the GPS module and show the latitude and longitude of the AUGV on the application.

Set Way key	This key is used for autonomously moving our AUGV with human interaction we save the different way points along the path of AUGV from source to destination.
Done key	This key is used for saving all the given waypoints of latitude and longitude in the Arduino mega.
Go To Waypoint key	This key is the last command given to AUGV which makes sure that our vehicle moves from source to destination and vice versa.
Clear all key	This key is used to clear all the saved waypoints in the Arduino mega when we need to move our vehicle in a new path.
Forward key	This key is used to move the vehicle in forward direction.
Reverse key	This key is used to move the vehicle in reverse direction.
Left key	This key is used to moves our AUGV in left direction.
Right key	This key is used to moves the vehicle in right direction.
Stop key	This key is used to stop the vehicle.
Turn Around key	This key is used whenever we need to rotate the vehicle 180 degrees.
Left 90 key	This key is used to rotate the vehicle 90 degrees to left.
Right 90 key	This key is used to rotate the vehicle 90 degrees to right.
Calibrate key	This key is used for calibration of the compass of the

	vehicle.
Set Heading key	This key is used to set the current heading angle of the vehicle.
Compass Drive	This key is used to move a vehicle in the direction of set heading direction.
Ping on/off key	This key is used to collision avoidance ON/OFF in the path.

CHAPTER 4
MATERIALS AND COMPONENTS

The UGV has the ideal sensors throughout since it was built to move across difficult terrain and overcome tracking issues on unknown pathways. The appropriate array of sensors, physical, electrical, and mechanical components must be installed on the UGV to assist it accomplish a smooth course over various topologies and terrain characteristics.

4.1 DC Motor

A DC (Direct Current) motor is a type of electric motor that converts electrical energy into mechanical motion. It's one of the most common types of motors and is used in a wide range of applications due to its simplicity, controllability, and reliability. DC motors operate on the principle of electromagnetism, specifically the Lorentz force law. When a current-carrying conductor (a wire) is placed in a magnetic field, it experiences a force perpendicular to both the direction of the current and the magnetic field lines. In a DC motor, this force causes the rotor (the rotating part) to turn, creating mechanical motion.

Due to its adaptability and controllability, DC motors are used in a variety of products and sectors. In the Automotive sector DC motors are used to power a variety of car parts, such as the fans, power windows and windscreen wipers. Conveyor belts, robotic arms, and production tools all employ industrial automation. In consumer electronics devices like hairdryers, electric razors, and DVD players all use DC motors. In the aerospace industry, they are employed in aircraft systems like the flap and landing gear actuation. DC motors are used in surgical instruments, imaging equipment, and medical pumps.

The advantages of DC motor are its precision speed control, reversibility, high torque at low speed, simple control, and reliability. DC motors come in a variety of forms, such as brushed DC motors, brushless DC motors (BLDC), stepper motors, etc. The oldest and most popular kind of DC motors are brushed motors. Figure 4.1 shows the DC motor as below.

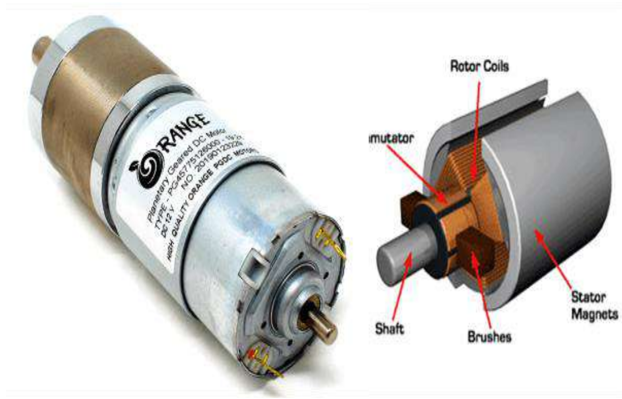

Figure 4.1: DC Motor [10]

4.2 Motor Driver (BTS7960)

In situations where bidirectional control is necessary, an H-bridge motor drive is a type of electrical circuit used to regulate the direction and speed of a motor with Pulse Width Modulation (PWM) input. Electric cars, robots, and other industrial systems that require precise motor control frequently employ it. By switching the direction of the current flow via the motor's coils, the H-bridge design enables the motor to rotate forward or backward.

It is a dual full bridge driver IC, which can deliver up to 43A of continuous current. The main feature of this component can operate at high frequency. IC has logic level inputs, current sensing diagnostics, dead time creation, and protection against high temperatures, excessive voltage, excessive current, and short circuits.

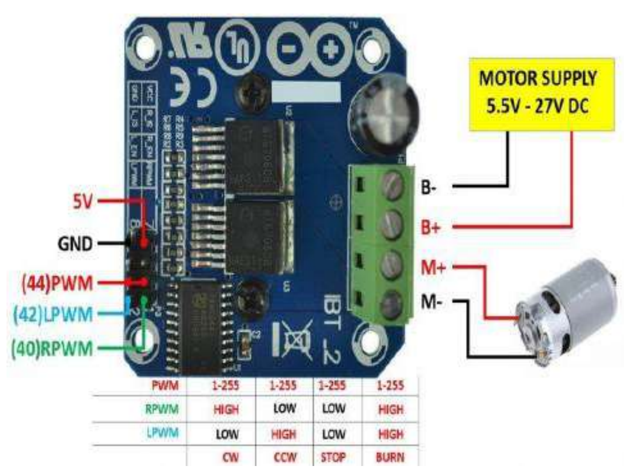

Figure 4.2: Motor driver H-Bridge BTS-7960 [11]

It also has a wide range of supply voltage from 7V to 45V. The BTS7960 offers a very space-efficient, cost-optimized solution for protected, high-current PWM motor drives. It is available in a DIP-16 package and is ideal for motor control applications. Figure 4.2 shows H bridge motor driver.

4.3 Arduino Mega2560

The Arduino mega 2560 is the microcontroller which is the main controller of the UGV. All the components are connected to it. Input data from different sensors are being processed and execution commands are generated to the respective components. More components are connected and processed as compared to Arduino uno. Detail description and specifications about the Arduino mega2560 will be defined in the following paragraphs. A crucial part of boards for microcontrollers like the "Arduino Mega" is the ATmega2560 microcontroller. A USB cable may be used to connect this board to a PC, a battery, or an AC-DC converter to provide power.

There are 16 analogue input pins, and the DC current utilized for the 3.3 V pin is 50 mA. An ICSP header, a power connection, a USB port, four hardware serial ports (UARTs), and RST button are also included. Arduino boards are reset using the RESET pin. The input/output reference is represented by the pin I/O Reference Voltage (IOREF). The voltage reference at which the microcontroller is now functioning is provided. Nothing happens if a signal is sent to this pin. AREF stands for Analogue Reference. It serves as the standard reference voltage for measuring all other analogue voltages (analogue inputs). The external components attached to the board get regulated 5V and 3.3V from the 3.3V and 5V pins, respectively. Figure 4.3 shows the Arduino mega2560 as below.

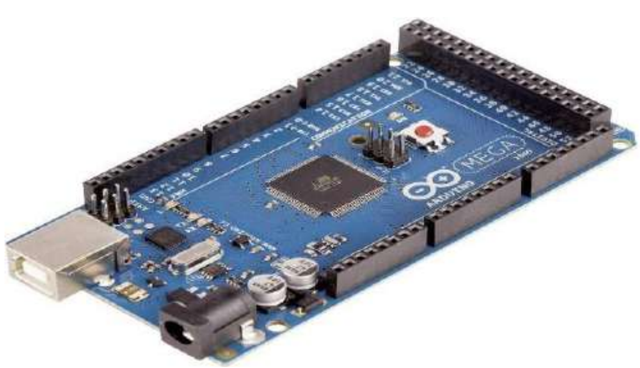

Figure 4.3: Arduino mega2560 [12]

Figure 4.4 shows the Arduino mega2560's pins, which are categorized into several groups, including power, reset, analogue pins, I/O pins, serial pins, external interrupt pins, PWM pins, SPI, I2C, AREF, and UART. PWM (Pulse Width Modulation) pins make up 15 of the total number of digital pins. PWM pins are located on digital pins 2 through 13, as well as pins 44, 45, and 46. On the PCB, there are 7 ground pins accessible. ADC (Analogue to Digital converter) is used on the 16 analogue pins that make up the Arduino Mega. These pins can be used as digital inputs or digital outputs in addition to being analogue inputs.

Universal Asynchronous Receiver and Transmitter is referred to as UART and makes it possible for the Arduino to talk to serial devices. The Arduino Mega has 4 UARTs. These pins are utilized for data exchange and logging via serial UART connection with a computer or other serial devices. It's applied in series.

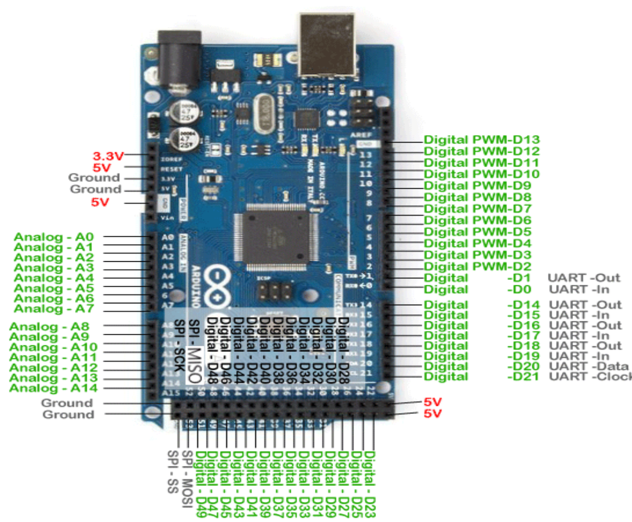

Figure 4.4: Arduino Mega2560 Pin Layout [13]

4.4 GPS Ublox Neo M8N

Navigation of the system is a vital part of today's world. For autonomous system navigation can be achieved via GPS modules. GPS modules are used for transportation, emergency and distress situations, agriculture, entertainment, and a lot of fields. The navigation module for this AUGV is GPS Ublox Neo M8N.

The M8N GPS module is a multifunctional, high-performance GNSS receiver that provides precise location and a variety of capabilities to meet a variety of application needs. It is a popular choice due to its multi-constellation compatibility, high accuracy, and variety of interfaces. The M8N is a GPS module from u-blox's M8 series that is used in several applications, such as navigation systems, drones, robots, and other gadgets that need precise location data. Figure 4.5 shows GPS Ublox Neo M8N.

In addition to GPS (USA), GLONASS (Russia), Galileo (Europe), and BeiDou (China), it supports several satellite constellations. The module may be used with a variety of electronic systems since it runs on a common 3.3V or 5V supply voltage. Because of its low power consumption, it is appropriate for battery-powered gadgets.

Figure 4.5: GPS Ublox Neo M8N [14]

4.5 Magnetometer (QMC5883l)

A sensor or device called a magnetometer is used to determine the direction and strength of a magnetic field. It is an essential instrument in many fields, including consumer electronics, geophysics, and navigation. Magnetometers use a variety of physical principles to function, although the Hall effect, fluxgate, and magneto resistive kinds are the most often used. These sensors track changes in the strength or direction of the magnetic field.

As a 3-axis magnetometer sensor, the QMC5883L can detect magnetic fields in the X, Y, and Z dimensions. It uses the I2C (Inter-Integrated Circuit) communication standard to connect to microcontrollers or other digital devices, making it very simple to interface with microcontrollers like Arduino and Raspberry Pi. The QMC5883L measures changes in magnetic fields by using the Hall effect, more particularly the Anisotropic Magneto-Resistive (AMR) technology. It can identify the Earth's magnetic field and any surrounding magnetic disturbances thanks to its technology.

Figure 4.6 displays a QMC5883L multi-chip. It offers the benefits of low noise, high precision, low power consumption, offset cancellation, and temperature management in addition to a specially developed 16-bit ADC ASIC. Compass heading precision of 1° to 2° is possible with the QMC5883L.

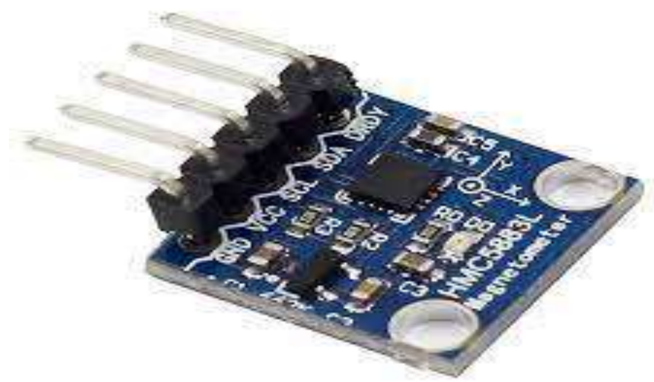

Figure 4.6 : Magnetometer (QMC5883l) [15]

4.6 Buck Converter (XL4015)

The DC-to-DC converter is converted by a buck converter, sometimes referred to as a chopper. It functions as a transformer step-down. To run the Arduino mega2560, a buck converter in this project converts 12 V from a battery to 5.3 V. It's made to effectively drop a greater input voltage to a lower output voltage while keeping the output constant. It can drive a 5A load. The regulator contains a fixed-frequency oscillator as well as an internal frequency correction, is simple to use, and only needs a small number of external components.

Figure 4.7 shows buck converter which has features and specifications. The XL4015 typically supports input voltages ranging from 4V to 38V, although specific module versions may vary. This wide input voltage range makes it versatile for various applications. The module allows you to adjust the output voltage within a specified range, often around 1.25V to 36V, using a potentiometer or trimmer resistor. This flexibility is useful for adapting the module to different power requirements. The XL4015 can handle a maximum output current, which can vary between different module versions.

Figure 4.7: Buck Converter (XL4015) [16]

4.7 Batteries

Batteries are used to provide power to components in the AUGV. Batteries are electrochemical devices that use reversible chemical processes to store and release electrical energy. They are an essential part of modern technology, powering a wide range of mobile electronics, automobiles, and renewable energy systems. Batteries are available in a variety of shapes, sizes, and chemistries, each designed for a particular use.

Figure 4.8: Batteries

Figure 4.8 shows a battery. The batteries are connected in parallel which makes it provide more current to DC Motors which makes them move smoothly and for long run as well. If not handled properly, batteries may be dangerous. Short circuits, overheating, and overcharging can cause leaks, fires, and explosions, among other safety-related problems. Many modern electronics and automobiles have safety features like battery management systems (BMS) built in to reduce these dangers.

4.8 Bluetooth Module (HC-06)

Bluetooth modules are electronic components that enable wireless communication between devices using Bluetooth technology. These modules are widely used for various applications, including wireless data transfer, remote control, and connectivity between devices. In the AUGV it is used to receive the waypoints coordinates from mobile. Its integrity is very crucial during the operation of AUGV.

Figure 4.9 shows the Bluetooth module. The module typically has a communication range of approximately 10 meters (or 33 feet), but this range can vary depending on factors like the power supply voltage and external interference. The HC-06 module operates as a transparent serial bridge, allowing you to send and receive data between devices over a UART (Universal Asynchronous Receiver-Transmitter) serial interface. This makes it easy to use with microcontrollers like Arduino and Raspberry Pi.

Figure 4.9: Bluetooth Module (HC-06) [17]

The HC-06 module typically operates in slave mode, which means it can be paired with a master device (e.g., a smartphone or computer). Once paired, it establishes a serial connection for data exchange. In comparison to other techniques, this one is more versatile and less expensive, and it can even send files at a pace of up to 2.1Mb/s. Authentication and encryption are security features, -20°C to +55°C is the operating temperature range, 40 mA operating current.

4.9 Ribbon Pins

Figure 4.10 displays a 2.54mm Pitch 40 Pin 40 Way F/F Stecker IDC Flat Ribbon Cable 1.6ft is an ideal solution for applications requiring a reliable and efficient data connection. It features 40 IDC connectors on both ends and is designed to provide a secure and reliable connection between two devices. The cable is 1.6 feet in length and has a flat ribbon design that helps to reduce interference and crosstalk. The connectors are gold plated for added durability and corrosion resistance. The cable is also designed to meet UL and CSA requirements.

Figure 4.10: 40 Pin Connector [18]

The IDC flat ribbon cable is designed to be both flexible and durable. It features a flat ribbon cable design that provides increased data transmission speeds and flexibility. The cable also has a 2.54mm pitch which provides an improved contact area and better electrical performance. The cable is constructed from high quality materials and is rated for temperatures up to 80°C. The cable is also RoHS compliant and is an ideal solution for a wide range of applications.

4.10 Servo Motor

A popular electric motor used in control systems is the servo motor. It is a kind of electric motor that has a fixed rotational direction and holds that position, unlike a regular DC motor which rotates continuously. Servo motors are equipped with a control circuit that allows them to receive commands from a control system and rotate to the specified position with high accuracy and precision. Figure 4.11 displays servo motor is a highly versatile and can be used in a range of different types of applications from simple projects to complex industrial applications and systems. Servo motors are a cost-effective option for many applications due to their versatility, accuracy, and great efficiency. They also use less power than other types of motors.

Figure 4.11: Servo Motor [19]

4.11 Ultrasonic Sensor

An ultrasonic sensor is a type of sensor that uses sound waves of high frequency (ultrasonic waves) to measure distances, detect objects, or provide proximity information. The principle of ultrasonic sensor operation is that ultrasonic sensors produce high-frequency sound waves that are inaudible to human ears, often in the ultrasonic range (above 20 kHz). These sound waves propagate through the air until they encounter an object in their path. Upon hitting the object's surface, the sound waves are reflected back toward the sensor. The sensor measures the time it takes for the emitted sound waves to bounce off the object and return to the sensor. The sensor determines the object's distance based on the time delay and the speed of sound in the medium, typically air.

The key features of ultrasonic sensors are they are useful in applications where physical touch is impractical or undesirable because they offer non-contact distance measuring. Depending on the design and parameters of the sensor, they provide reasonably high measurement accuracy, frequently with millimeter-level precision. Depending on the kind and strength of the sensor, ultrasonic sensors are capable of detecting things at both close and far distances. A few centimeters to several meters can be measured by some sensors. Most ultrasonic sensors produce sound waves in a pattern resembling a cone, enabling them to cover a large field of vision.

Figure 4.12: Ultrasonic Sensor [20]

A distance measurement device with an ultrasonic range of 1 to 13 inches is shown in Figure 4.12. The sensor has two ultrasonic transducers. One serves as a transmitter for ultrasonic sound pulses, and the other takes on the role of a receiver to catch reflected waves. It uses a 5V operating voltage and a 15mA operational current. 40KHz is the operational frequency.

CHAPTER 5
METHODOLOGY AND BLOCK DIAGRAM

The principle of this chapter is to define and explain systems block diagram which tells about the interconnection of the components mounted on the Autonomous Unmanned Ground Vehicle (AUGV). In this chapter also defined the flowchart which explains how the instructions are being followed, interpreted, and executed by the algorithm.

5.1 Methodology

The methodology for creating off road navigation of autonomous unmanned ground vehicle (AUGV) involves several key steps. First, the project's objectives are defined, aiming to make autonomous vehicles for any surface. A review of existing literature informs the design by examining hardware mechanisms, navigation, and obstacle avoidance techniques. Sensors are carefully chosen and integrated into the car's structure to meet all our requirements. Algorithms for path planning and obstacle detection and avoidance are developed, followed by rigorous testing to ensure accuracy and effectiveness. A friendly interface is designed, considering ethical and safety concerns. After deployment, continuous refinement is pursued based on feedback, ensuring a comprehensive capability.

5.2 Block Diagram

Figure 5.1 shows the block diagram of AUGV which shows the connection of components to each other. The Arduino Mega is the main controller of the AUGV as it gets all the input data from the sensors collect process and control signal is generated to actuate the AUGV. Battery gives power to all the sensors and controllers to calculate and perform functions as they were intended for in the AUGV system. The vehicle moves from source to destination via motors which relate to H-bridge drivers powered from batteries. H-bridge driver is a bidirectional controller type of electrical circuit used to regulate the direction and speed of a motor with Pulse Width Modulation (PWM) input. The PWM input to H-bridge drive is from Arduino Mega according to the inputs from other sensors. Ultrasonic sensor measure the distance of the object by transmitting and receiving sound waves reflected from the obstacle. It is mounted on the servo motor which is powered from the buck converter. As ultrasonic sensor gives the data of any obstacle to Arduino Mega, it gives command to the dc motors via H bridge drive and servo motor will sweep the ultrasonic sensor to give the obstacle data of the surrounding to Arduino mega and accordingly vehicle proceed to its destination by avoiding hurdles.

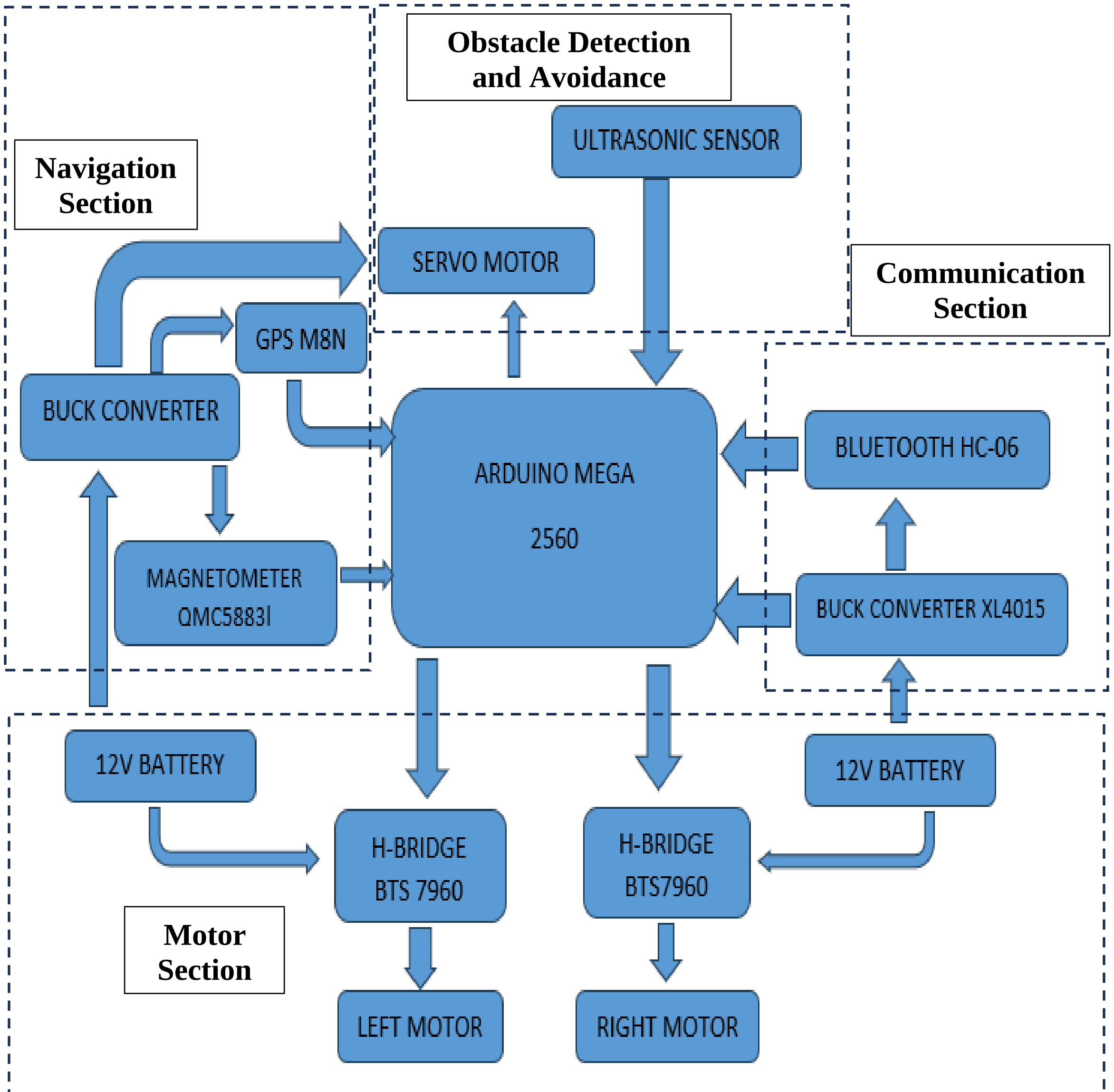

Figure 5.1: Block Diagram

The buck converter is used to provide 5V power to GPS and servomotor and 5V to Arduino Mega from 12V battery. For navigation GPS receiver is used to provide current location to vehicle and helps in approaching to waypoints along the path from source to destination. The vehicle current location from GPS will be seen on the application of

AUGV. The magnetometer is used as compass to provide heading of the vehicle by measuring the earth's magnetic field. It is also used to measure the heading angle and used to correct the offset value between the vehicle and the approaching waypoint. To sense and avoid the obstacle ultrasonic sensor is being deployed on the front of the AUGV chassis. Bluetooth HC-O6 is used for communication between AUGV and mobile application to send designated waypoints of the path it followed. Bluetooth module not only used for sending the waypoints, but it also shows the status like GPS coordinates, source, or destination points of AUGV.

5.3 Flow Chart

A flowchart is a graphical representation of a process that shows the steps involved in performing a task. The flowchart of off-road navigation of autonomous unmanned ground vehicle is shown in figure 5.2 shows the flow chart which indicates flow of instruction to move the AUGV from waypoint A which is source point to waypoint B which is destination point also called waypoint navigation. At first battery gives the power to AUGV sensors which initialize Bluetooth module to make a connection with application on mobile. Then do a compass initialization which lasted for 20 seconds. After initialization compass will calibrate itself to give accurate heading data to Arduino mega. Then GPS will be active after receiving a minimum of 4 satellite signals. Bluetooth and GPS setup, waypoints are set on the application and send those waypoints to Arduino Mega. If two or more waypoints are set, then GPS coordinates are checked if there is difference between compass angle and GPS angle then it approaches to waypoint along moving to left or right sides according to the angle. If there is no angle difference the AUGV approaches the waypoint without any turn. As AUGV approaches the waypoint and any obstacle comes in its path, it gets the sense of obstacle from ultrasonic sensor. The ultrasonic sensor has provided a coverage of 180 degrees via servomotor. If multiple obstacles come in the path towards reaching waypoint the AUGV makes a turn either left or right where the distance between obstacle is greater from AUGV. Once all the obstacles are avoided and AUGV approaches its final waypoint the message vehicle has arrived will be displayed on the robot application. If there is another waypoint available to reach after arrived final waypoint the AUGV checked the GPS coordinates and ran the loop onwards till the last waypoint.

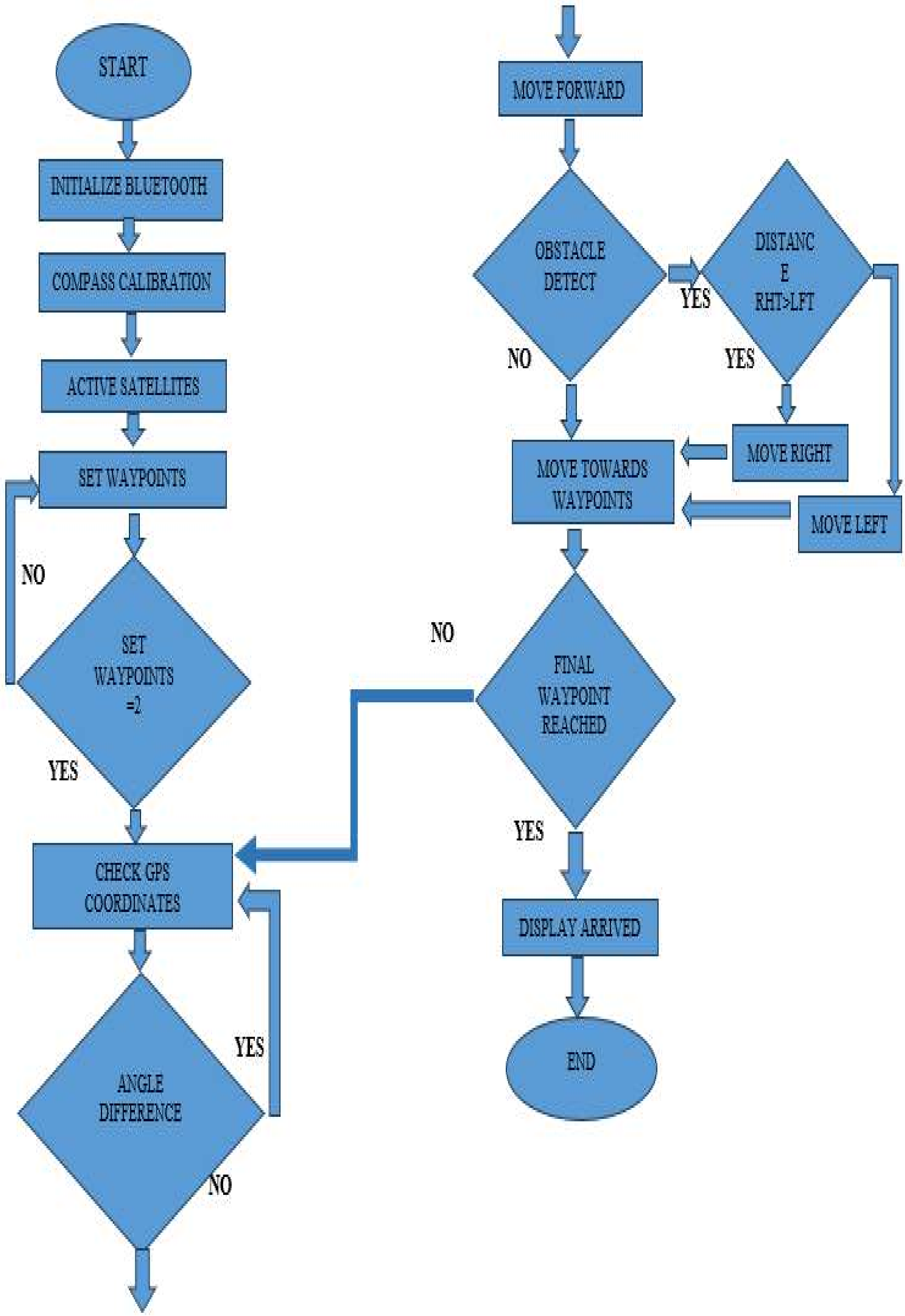

Figure 5.2: Flow Chart

CHAPTER 6
RESULTS AND DISCUSSION

The main goal of this project is to make an autonomous vehicle having features to navigate on off-road surface. Vehicle have the capability to make their way from source to destination without human interference. The AUGV is tested in different environments and conditions to make sure that it moves in an off-road terrain by avoiding obstacles which come in its path while approaching waypoints. In the following section discussing about the results of AUGV take on different environments and scenarios.

6.1 Scenario 1

In this scenario, first we enter the waypoints and store them in the controller of the AUGV using robot application in our mobile. The waypoints we assign are the fest department as a source point which is waypoint 1 and define four more points before the destination waypoint 2 which is pharmacy department. Once all the waypoints define AUGV, it successfully follows its path with accuracy and reaches its destination. Now we need our AUGV to come back to source point we only click go to waypoint button on the application and AUGV successfully reaches to fest department.

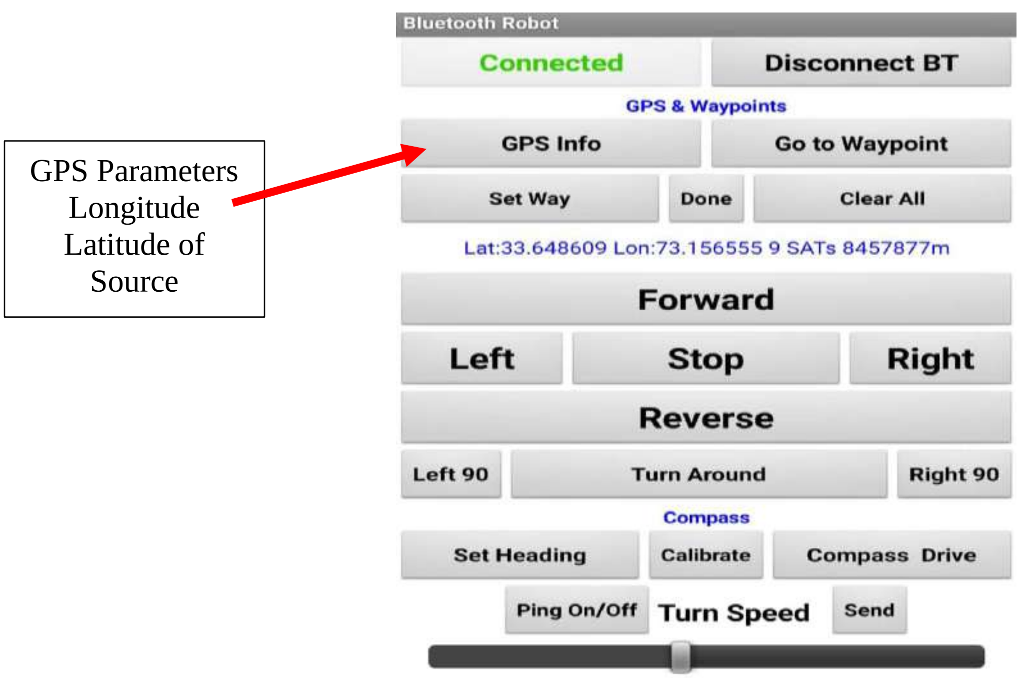

Figure 6.1: Source GPS info

Figure 6.1 shows the AUGV application, here we get the source point latitude and longitude values from the GPS to use as a reference by our vehicle as it approaches its destination. Figure 6.2 shows the waypoint values get from the GPS are stored in the Arduino mega by pressing the button set way and GPS waypoint 1 set will be display on the application.

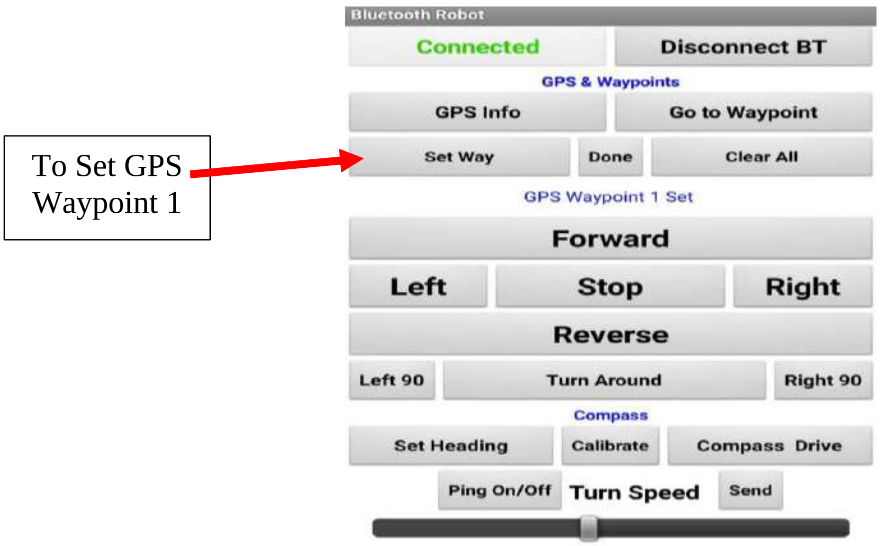

Figure 6.2: Waypoint 1 Set

Figure 6.3: Source Point

Figure 6.3 shows the actual position of vehicle in the real environment which is the source point. Figure 6.4 shows the destination point latitude and longitude values from the GPS to use as a reference by our vehicle as it reaches from the source point.

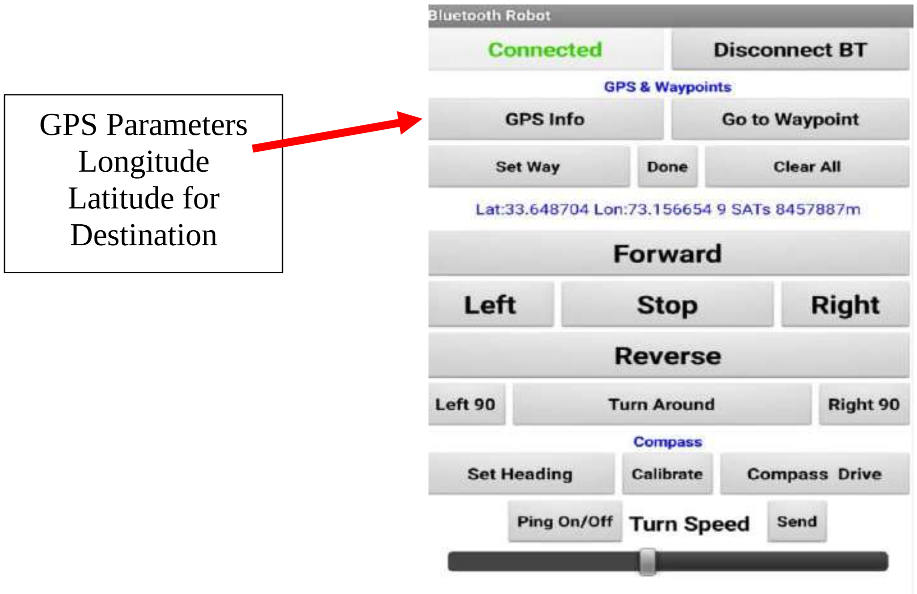

Figure 6.4: Destination GPS info

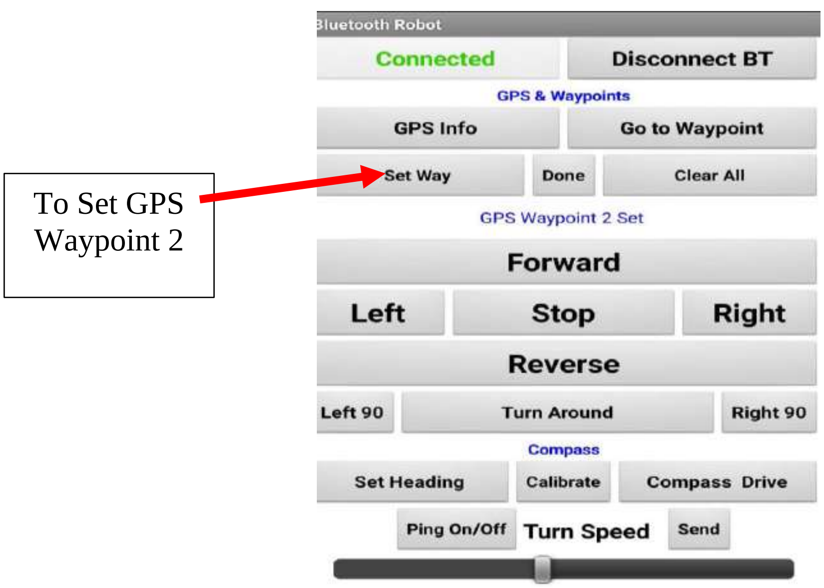

Figure 6.5: Waypoint 2 Set

Figure 6.5 shows the waypoint values get from the GPS are stored in the Arduino mega by pressing the button set way and GPS waypoint 2 set will be display on the application. Figure 6.6 shows that when all the waypoint of the designated path are stored in the AUGV and Done key pressed, now all stored waypoints' values arranged in ascending order of set waypoints and 'waypoints complete' will be displayed on the application.

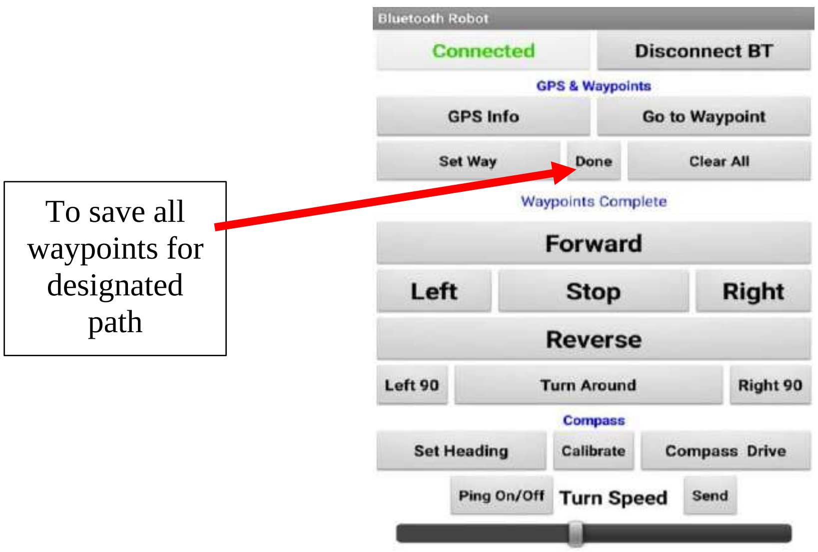

Figure 6.6: Waypoints Complete

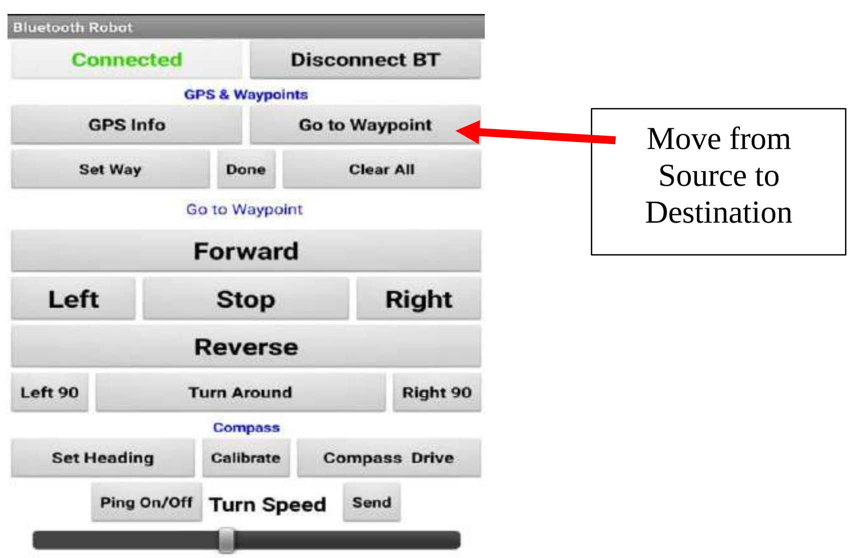

Figure 6.7: Go To Waypoint

Figure 6.7 shows the vehicle moves autonomously from source to destination by pressing only Go To waypoint key and vehicle travel to destination. Figure 6.8 shows the actual position of vehicle in the real environment which is the destination point.

Figure 6.8: Destination Point

Figure 6.9 shows as the vehicle reached its destination point, Final Waypoint reached will be displayed on the application.

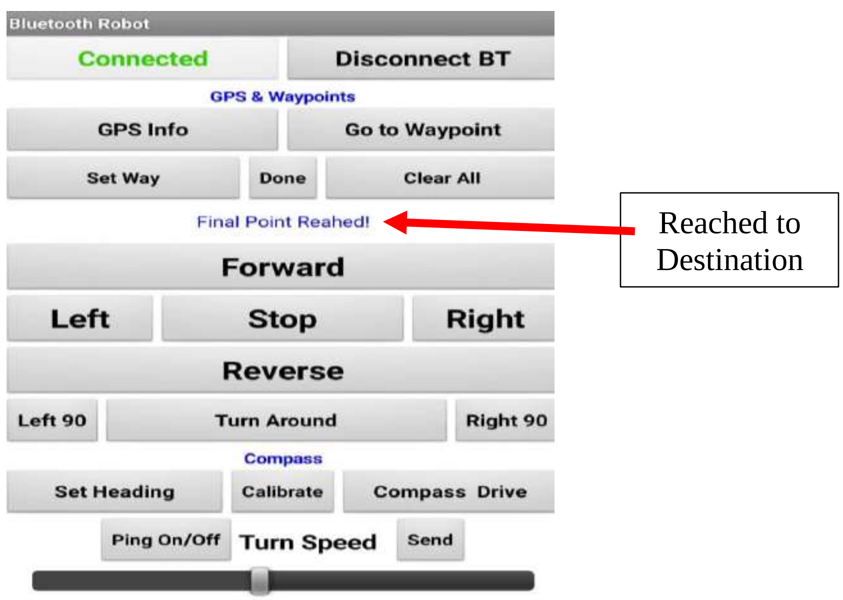

Figure 6.9: Final Waypoint Reached

6.2 Scenario 2

In this scenario, as we did in the first scenario, we enter the waypoints and store them in the controller of the AUGV using robot application in our mobile, but difference is AUGV not only moves from source point to destination point also avoids any kind of obstacle in the path. The waypoints we assign are the football ground as a source point and define three more points before the destination waypoint which is university cafeteria. Once all the waypoints define AUGV, it successfully follows its path while avoiding obstacles like people, benches and reaching its destination. Now we need our AUGV to come back to source point we only click go to waypoint button on the application and AUGV successfully reaches to football ground with avoiding all the hurdles.

Figure 6.10 shows the amazing feature of our AUGV is to detect any obstacle and avoid it. For that use ping ON/OFF key, by pressing it collision avoidance will be displayed on the application. Figure 6.11 shows a vehicle detecting and avoiding the obstacle in real time environment and after avoiding follows its defined path.

Figure 6.10: Collision Avoidance ON

Figure 6.11: Object Detection

6.3 Scenario 3

In this scenario, the surface on which the vehicle is moving is muddy having bumps on the surface. This feature makes our AUGV widespread to use in all conditions. As always, first we enter the waypoints and store them in the controller of the AUGV using our robot application in mobile. The waypoints we assign are the corner point of university ground as a source point and define two more points before the destination waypoint which is other corner of ground. Once all the waypoints define AUGV, it successfully follows its path with accuracy and stability along avoiding hurdles to reach its destination point. Now again we need our AUGV to come back to source point we only click go to waypoint button on the application and AUGV successfully reaches to ground source point with avoiding all the hurdles.

Figure 6.12 shows the actual position of vehicle in the off-road environment which is the source point. Figure 6.13 shows a vehicle detecting and avoiding the obstacle in off road surface environment and after avoiding follows its defined path.

Figure 6.12: Off Road Source

Figure 6.13: Off Road Object Detection

Figure 6.14 shows the actual position of vehicle in the off-road environment which is the destination point.

Figure 6.14: Off Road Destination

6.4 Performance Analysis

In the above scenarios we tested AUGV on different environments and observed the result of its performance. In scenario 1 moves AUGV from source to destination point on plain path. Here the Waypoint precision is good. The heading data is excellent. Tire grip with the surface is average. The performance of AUGV in this scenario is good. In scenario 2 moves AUGV from source to destination point with avoiding obstacles on plain path. Here the Waypoint precision is good. The obstacles are detected by 12 inches distance. Tire grip with the surface is average. The performance of AUGV in this scenario is good. In scenario 3 moves AUGV from source to destination point with avoiding obstacles on off road. Here the Waypoint precision is good. The obstacles are also detected by 12inches distance. Tire grip with the surface is excellent. The performance of AUGV in this scenario is also average. The overall performance of AUGV is average.

CHAPTER 7
CONCLUSION AND FUTURE RECOMMENDATIONS

7.1 Conclusion

Unmanned ground vehicles make a significant advancement in the field of robotics during the current period of innovation and progress towards autonomous systems. These AUGVs have the capacity to benefit humanity. These vehicles bring about a significant shift in the areas of logistics, transportation, and military operations. To go from the current source to the destination waypoint while avoiding obstacles, the AUGV contains several interconnected components.

A battery, two motor controllers, two motors, and a wheel make up the UGV powertrain. The two motors convey their power to the front and back tires, which are powered by batteries. Due to the differential drive of the UGV, changing the motor's speed essentially changes the direction of travel. The motors of AUGV are controlled by the H bridge motor drivers via Arduino mega. Motors RPM are 112 r/min.

The vehicle will be powered by rechargeable batteries. Due to its higher performance, higher energy efficiency, and higher power density, lithium-ion batteries will be employed. The battery must provide 12V and 7.5Ah, which will be accomplished by using a 9-cell arrangement given that each cell has a capacity of 2.8Ah. The batteries are connected parallel to increase the amp-hour capacity.

Bluetooth is used for communication, allowing the Arduino Mega to transmit and receive data wirelessly. Bluetooth is used to transfer the waypoint data from the mobile device to the Arduino. GPS and Magnetometer are integrated into localization and navigation systems to provide information about the vehicle's current position and heading as it gets closer to its destination.

The vehicle has been tested in different environments in scenarios in which observed the performance of the vehicle. The vehicle successfully moves from source to destination points given by GPS module and avoids the hurdles in its path. The AUGV has traveled successfully on off road surfaces. The overall performance of the AUGV is average.

7.2 Future Recommendations

Future advancements are always possible with the development of technology, particularly around autonomous navigation. There were various potential causes of inaccuracy. Thorough testing led to the discovery of these mistakes. Therefore, enhancing/removing the faults will significantly increase the UGV's efficiency and capacity for autonomous mission execution.

The accuracy of the algorithm would be significantly improved using a better GPS sensor. We will recommend RTK GPS you can use your AUGV indoor as well. As the code uses the GPS provided AUGV position to determine what to do next. Therefore, obtaining an accurate position with the least amount of delay would improve performance.

The controller occasionally disconnected itself from the network during testing. A better router or Bluetooth module would thereby increase network connection. In a similar manner, fail-safe can be included to switch off the motors if the network disconnects or the UGV is outside of its range. A better connection would also lessen the delay between sending and receiving orders.

The batteries are connected in parallel to deliver current for extended period of duration. The UGV would be deployed in large environments, therefore, improved battery life would increase the working hours of the UGV. This can be achieved by using a battery with a greater mAH rating.

Object detection requires high computational power for processing the image. Instead of using the Raspberry pi 4 for object detection for real time detection it is recommended to do object detection in Graphics Processing Unit (GPU) which has high computational power also used in developing autonomous UGV.

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APPENDIX

SOURCE CODE

```
//#include <Wire.h>                                  // Used by I2C and HMC5883L
compass
//#include "I2Cdev.h"                                // I2C Communications Library (used
for compass)
#include <MPU9250_asukiaaa.h>
#include <Servo.h>                                   // Servo library to control Servo arm for
metal detector
#include <SoftwareSerial.h>                          // Software Serial for Serial
Communications - not used
#include <TinyGPS++.h>                                                   // 9600-baud serial
GPS device hooked up on pins 16(tx) and 17(rx).
//*********************************************************************
******
// GPS Variables & Setup
int GPS_Course;                                      // variable to hold the gps's determined
course to destination
int Number_of_SATS;                                  // variable to hold the number of
satellites acquired
TinyGPSPlus gps;                                     // gps = instance of TinyGPS
//*********************************************************************
******
// Setup Drive Motors using the Adafruit Motor Controller version 1.0 Library
#define M1A 7
#define M1B 6
#define En1 8
#define M2A 3
#define M2B 4
#define En2 5
int turn_Spd = 130;                                  // motor speed when using the compass
to turn left and right
int mtr_Spd = 150;                                   // motor speed when moving forward
and reverse
//*********************************************************************
******
// Compass Variables & Setup
#define CALIB_SEC 20
MPU9250_asukiaaa mySensor;
```

```
uint8_t sensorId;
float mDirection, mX, mY, mZ;
int calibrationData[3][2];
bool changed = false;
bool done = false;
int t = 0;
int c = 0;
int16_t mx, my, mz;                                   // variables to store x,y,z axis from
compass (HMC5883L)
int desired_heading;                                  // initialize variable - stores value for
the new desired heading
int compass_heading;                                  // initialize variable - stores value
calculated from compass readings
int compass_dev = 5;                                  // the amount of deviation that is
allowed in the compass heading - Adjust as Needed
int Heading_A;                                        // variable to store compass heading
int Heading_B;                                        // variable to store compass heading in
Opposite direction
int pass = 0;                                         // variable to store which pass the robot is
on
//*********************************************************************
******// Servo Control
Servo myservo;                                        // create servo object to control a servo
int pos = 0;                                          // variable to store the servo position
#define ServoPin 2
//*********************************************************************
******// Ping Sensor for Collision Avoidance
boolean pingOn = false;                               // Turn Collision detection On or Off
#define trigPin 10                                    // Trig - Orange
#define echoPin 9                                     // Echo - Yellow
long duration,Ping_distance;
int DistCheckL;
int DistCheckR;
unsigned long currentMillis = 0;
unsigned long previousMillis = 0;                     // Store last time Ping was updated
const long interval = 200;                            // Ping the Distance every X
miliseconds
//*********************************************************************
******// Bluetooth Variables & Setup
String str;                                           // raw string received from android to
```

```
arduino
int blueToothVal;                                  // stores the last value sent over via
bluetooth
//*********************************************************************
**
// GPS Locations
unsigned long Distance_To_Home;                                  // variable for storing the
distance to destination
int ac = 0;                                  // GPS array counter
int wpCount = 0;                                  // GPS waypoint counter
double Home_LATarray[50];                                  // variable for storing the
destination Latitude - Only Programmed for 5 waypoint
double Home_LONarray[50];                                  // variable for storing the
destination Longitude - up to 50 waypoints
int increment = 0;
bool Decrement = false;
#define GpsModule Serial3
#define Hc05 Serial2                                  // pin 17 (blue)   is connected to the
TX on the GPS
// pin 16 (yellow) is connected to the RX on the GPS
//*********************************************************************
****
bool GoForward = false;
void setup()
{
 Serial.begin(115200);                                  // Serial 0 is for communication with
the computer
  Hc05.begin(9600);                                  // Serial 1 is for Bluetooth
communication - DO NOT MODIFY - JY-MCU HC-06 v1.40
  GpsModule.begin(9600);                                  // Serial 2 is for GPS
communication at 9600 baud - DO NOT MODIFY - Ublox Neo 6m
  myservo.attach(ServoPin);                                  // attaches the servo to pin 9
(Servo 0 on the Adafruit Motor Control Board)
 // Ping Sensor
  pinMode(trigPin, OUTPUT);                                  // Ping Sensor
  pinMode(echoPin, INPUT);                                  // Ping Sensor
 // Motors Pins
  pinMode(M1A, OUTPUT);
  pinMode(M1B, OUTPUT);
  pinMode(En1, OUTPUT);
```

```
  pinMode(M2A, OUTPUT);
  pinMode(M2B, OUTPUT);
  pinMode(En2, OUTPUT);
  digitalWrite(M1A, LOW);
  digitalWrite(M1B, LOW);
  analogWrite(En1, 0);
  digitalWrite(M2A, LOW);
  digitalWrite(M2B, LOW);
  analogWrite(En2, 0);
  //  Compass
  Wire.begin();
  mySensor.setWire(&Wire);
  while (mySensor.readId(&sensorId) != 0) {
    Serial.println("Cannot find device to read sensorId");
    delay(2000);
  }
  mySensor.beginAccel();
  mySensor.beginGyro();
  mySensor.beginMag();
  Hc05.println("Welcome ");
  Serial.println("Welcome ");
  //  Startup();                                    // Run the Startup procedure on power-up
one time
}
//***********************************************************************
*****
// Main Loop
void loop()
{
bluetooth();                                      // Run the Bluetooth procedure to see if
there is any data being sent via BT
  getGPS();                                       // Update the GPS location
  getCompass();                                   // Update the Compass Heading
  Ping();                                         // Use at your own discretion, this is not fully
tested
}
```

DATA SHEET OF H-BRIDGE DRIVE 7960

HT Handson Technology

User Guide

BTS7960 High Current 43A H-Bridge Motor Driver

The BTS7960 is a fully integrated high current H bridge module for motor drive applications. Interfacing to a microcontroller is made easy by the integrated driver IC which features logic level inputs, diagnosis with current sense, slew rate adjustment, dead time generation and protection against overtemperature, overvoltage, undervoltage, overcurrent and short circuit. The BTS7960 provides a cost optimized solution for protected high current PWM motor drives with very low board space consumption.

SKU: DRV-1012

Brief Data:

- Input Voltage: 6 ~ 27Vdc.
- Driver: Dual BTS7960 H Bridge Configuration.
- Peak current: 43-Amp.
- PWM capability of up to 25 kHz.
- Control Input Level: 3.3~5V.
- Control Mode: PWM or level
- Working Duty Cycle: 0 ~100%.
- Over-voltage Lock Out.
- Under-voltage Shut Down.
- Board Size (LxWxH): 50mm x 50mm x 43mm.
- Weight: ~66g.

DATA SHEET OF BLUETOOTH MODULE (HC-06)

HC 06 Core Bluetooth Module

HM-06 is a Bluetooth module designed for establishing short range wireless data communication between two microcontrollers or systems. The module works on Bluetooth 2.0 communication protocol and it can only act as a slave device. This is cheapest method for wireless data transmission and more flexible compared to other methods and it even can transmit files at speed up to 2.1Mb/s.

HC-06 uses frequency hopping spread spectrum technique (FHSS) to avoid interference with other devices and to have full duplex transmission. The device works on the frequency range from 2.402 GHz to 2.480GHz.

FEATURES:

- HC-06 is best option when short distance wireless communication is needed. The module is used for wireless communications of less than 100 meters.
- The module is very easy to interface and to communicate.
- The module is one of the cheapest solutions for wireless communication of all types present in the market.
- The module consumes very less power to function and can be used on battery operated mobile systems.
- The module can be interfaced with almost all controllers or processors as it uses UART interface.

DATA SHEET OF MAGNETOMETER QMC (5883l)

3-Axis Magnetic Sensor QMC5883L

The QMC5883L is a multi-chip three-axis magnetic sensor. This surface -mount, small sized chip has integrated magnetic sensors with signal condition ASIC, targeted for high precision applications such as compassing, navigation and gaming in drone, robot, mobile and personal hand-held devices.

The QMC5883L is based on our state-of-the-art, high resolution, magneto-resistive technology licensed from Honeywell AMR technology. Along with custom-designed 16-bit ADC ASIC, it offers the advantages of low noise, high accuracy, low power consumption, offset cancellation and temperature compensation. QMC5883L enables 1° to 2° compass heading accuracy. The I²C serial bus allows for easy interface.

The QMC5883L is in a 3x3x0.9mm³ surface mount 16-pin land grid array (LGA) package.

FEATURES	BENEFIT
3-Axis Magneto-Resistive Sensors in a 3x3x0.9 mm³ Land Grid Array Package (LGA), guaranteed to operate over an extended temperature range of -40 °C to +85 °C.	Small Size for Highly Integrated Products. Signals Have Been Digitized And Calibrated.
16 Bit ADC With Low Noise AMR Sensors Achieves 5 Milli-Gauss Field Resolution	Enables 1° To 2° Degree Compass Heading Accuracy , Allows for Navigation and LBS Applications
Wide Magnetic Field Range (±8 Gauss)	Maximizes Sensor's Full Dynamic Range and Resolution
Temperature Compensated Data Output and Temperature Output	Automatically Maintains Sensor's Sensitivity Under Wide Operating Temperature Range
I²C Interface with Standard and Fast Modes.	High-Speed Interfaces for Fast Data Communications. Maximum 200Hz Data Output Rate
Wide Range Operation Voltage (2.16V To 3.6V) and Low Power Consumption (75μA)	Compatible with Battery Powered Applications
Lead Free Package Construction	RoHS Compliance
Software And Algorithm Support Available	Compassing Heading, Hard Iron, Soft Iron, and Auto Calibration Libraries Available

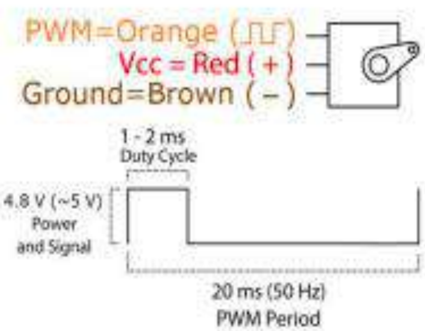
DATA SHEET OF SERVO MOTOR

31002-MD

SG90 MINI SERVO MOTOR

Mini servo for robotics & modeling. Nylon gears for smoot quite operation. Rated: Op. Voltage 3.5-6VDC,
Stall Torque: 1.2kg/cm @ 4.8V, 1.6kg/cm @ 6V, Speed: 300Deg./Sec (60/.12sec.),
Dead Bandwidth: 5us.
Pulse Cycle: 20mS
-90deg (Max "Left") ~1mS
0deg (Center) ~1.5mS
+90deg (Max "Right") ~2mS
Futaba/JR 0.1 pitch connector on 9in. cable.
Includes 3 control Arms and screws

L: 23mm **W:** 12mm O/A **T:** 29mm **WT:** .02



DATA SHEET OF ULTRASONIC SENSOR

Ultrasonic Ranging Module HC - SR04

Product features:

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle of work:

(1) Using IO trigger for at least 10us high level signal,

(2) The Module automatically sends eight 40 kHz and detect whether there is a pulse signal back.

(3) IF the signal back, through high level , time of high output IO duration is the time from sending ultrasonic to returning.

Test distance = (high level time×velocity of sound (340M/S) / 2,

Wire connecting direct as following:

- 5V Supply
- Trigger Pulse Input
- Echo Pulse Output
- 0V Ground

Electric Parameter

Working Voltage	**DC 5 V**
Working Current	**15mA**
Working Frequency	**40Hz**
Max Range	**4m**
Min Range	**2cm**
MeasuringAngle	**15 degree**
Trigger Input Signal	**10uS TTL pulse**
Echo Output Signal	**Input TTL lever signal and the range in proportion**
Dimension	**45*20*15mm**

DATA SHEET OF ARDUINO MEGA2560

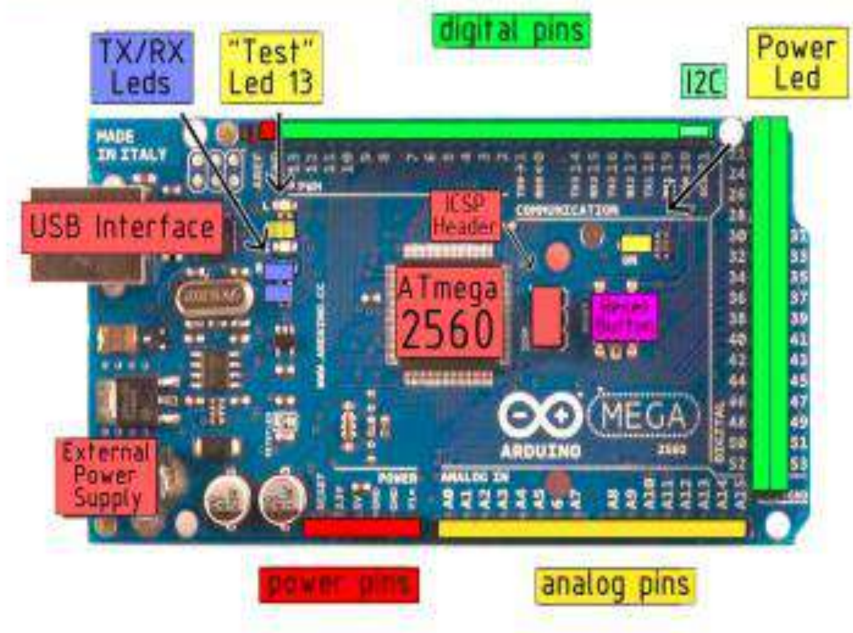
Technical Specification

EAGLE files: arduino-mega2560-reference-design.zip Schematic: arduino-mega2560-schematic.pdf

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

the board



DATA SHEET OF BUCK CONVERTER (XL4015)

HT Handson Technology

Data Specs

XL4015 Step-Down DC Module with CV/CV Control

XL4015 is a 180KHz fixed frequency PWM buck (step-down) DC/DC converter module, capable of driving a 5A load with high efficiency, low ripple and excellent line and load regulation. This module is with constant Voltage (CV) and constant current (CA) adjustment control. Suitable for general purpose DC regulator and battery charger application.

SKU: PSU1031

Brief Data:

- Input Voltage: 8Vdc~36Vdc.
- Output voltage: 1.25Vdc~32Vdc.
- Output current: Adjustable maximum 5A.
- Voltage Regulation: ± 2.5%
- Load Regulation: ± 0.5%
- Output ripple: 50mV (max) 20M bandwidth
- Switching frequency: 300KHz
- Conversion efficiency: 95% (the highest)
- Rectification: non-synchronous rectification
- Module Properties: non-isolated constant current and voltage module.
- Size: 51x26.3x14 (LxWxH) (mm).
- Operating Temperature: -40 ° to +85 °