An Automatic Wireless-based Android Controlled Ground Robotic Spy Vehicle

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Certification

This is to certify that this study was conducted under my supervision by Nurudeen Babatunde YISAU with Matric No. LCU/PG/000382 for the award of Master of Science (M.Sc.) Degree in Computer Science in the Department of Computer Sciences, Faculty of Natural and Applied Sciences, Lead City University Ibadan, Oyo State, Nigeria under my supervision.

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Dedication

This thesis is dedicated to Almighty God, the enabler, source of strength and wisdom. The protector of mankind from whom all knowledge and understanding come.

Also dedicated to my late parent Mr. and Mrs. Yisau. May Allah comfort their soul. Amin

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Abstract

The pervasive fear among residents, loss of lives, both military and civilian, and the drain on government resources during occurrences and crises conflicts necessitate innovative solutions. This study explores the creation of an Unmanned Ground Vehicle (UGV) designed for remote-controlled surveillance to aid in addressing insurgency and terrorism issues that pose significant threats to national and international security. The aim of this research is to design and implement a wireless, android-based ground robotic system capable of performing sophisticated spying tasks thereby reducing risk in hostile environments. The methodology employed involves a modular design approach, integrating off-the-shelf components such as Arduino IDE, ESP32-camera, motor drivers, and various power sources. These components were selected for their reliability, availability, and alignment with the objectives of the system. The UGV prototype was developed to perform functions including patrolling and monitoring environments, potentially dangerous to human operators, such as military zones and conflict areas. Results from the implementation demonstrated the vehicle's ability to navigate and provide real-time feedback of live video streaming of what the robot "sees". This independence from network connectivity ensures reliability even in remote environments. The vehicle operates via commands transmitted from an android application, enabling it to move in pre-determined directions and relay visual data back to the base station through an ESP32-camera and a web-server that controls the robot which is being programmed with help of an Arduino IDE. This project successfully demonstrates a cost-effective and efficient approach to surveillance and reconnaissance in high-risk areas. The study recommends enhancing the UGV's capabilities, including extended battery life, improved sensor range, and autonomous navigation algorithms, to ensure a more reliable and performance-optimized vehicle suitable for various surveillance tasks while maintaining affordability.

Keywords: Android-based, ESP32-camera, Modular design, Remote-controlled, Surveillance, Unmanned ground vehicle.

Word Count: 279

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List of Acronym

Abbreviation	**Meaning**
ADC -	Analogy Digital Converter
AUV -	Autonomous Unmanned Vehicle
DARPA -	Defence Advance Research Project Agency
DC -	Direct Current
EOD-	Explosive Ordinance Disposal
IP -	Internet Protocol
ISR-	Intelligence Surveillance and Reconnaissance
RC-	Radio Controlled
ROV-	Remotely Operated Vehicle
UAV-	Unmanned Aerial System
UGV-	Unmanned Ground Vehicle
USV-	Unmanned Surveillance Vehicle

Chapter One

Introduction

1.1 Background of the Study

Everyday occurrences occur around the world that pose life-threatening effects of human intervention, and Nigeria has been classified as a country with high insecurity[1]. The value of remote patrol and surveillance in the face of terrorism and insurgency cannot be overstated due to its importance in lowering risk to human lives in situations where manual patrol is deemed hazardous. A ground spy vehicle serves this goal, in which a human operator operates a robot system to gather information about inaccessible environments[2]. Spy vehicles are now widely utilized in a variety of domains such as industries, academia, research and development, armies, and so on. Spy-vehicles are miniature vehicles used for spying, surveillance, and inspection. They can be tailored for specific purposes and have certain unique features. They are remotely controlled vehicles with cameras that relay video data to the intervention troop[3].

Investigating prospective crime scenes, such as bomb sites, and dealing with hostage situations, for example, can be dangerous for forces such as the police and army, as well as the hostages themselves. Terrorists will create havoc if they suspect that law enforcement is on their way to them. Something can go wrong that the authorities are unaware of, such as a bomb explosion or human casualties. The July 2016 Yobe attack at the Holy Artisan restaurant killed many innocent lives, including hostages and police officers, due to a lack of a proper strategic plan, as authorities were unaware of what was going on inside the restaurant [4]. This would not occur if enforcers conducted their operations without informing the terrorists.

The suggested Wireless Based Android Controlled Ground Robotic Spy Vehicle can handle these types of scenarios by carrying out stealth missions independently, such as locating vantage locations and threats and hostages, which require no human interaction other than remote control. An embedded system was used in the project's implementation. Embedded systems in electronics have given rise to a myriad of exciting applications that safeguard human comfort and safety. So, the system is based on the Arduino Uno, WIFI, web server, ESP32-camera, L2938 motor driver. In this project an IP surveillance camera will be built with the ESP32-CAM board. The ESP32 Camera module integrates the ESP32-S chip and a camera sensor, offering a compact solution for projects requiring wireless connectivity and image/video capturing capabilities. It is ideal for IoT (Internet of Things) applications, surveillance systems, and various smart devices where remote monitoring and image processing are essential. The ESP32 camera is going to host a video streaming web server that you can access with any device in your network.

It is also powered by a 5 Volt Lithium-Polymer rechargeable battery. To send an aerial image of the area, the Wireless Network Camera connects to a Wi-Fi network and is powered by a battery.

1.2 Statement of the Problem

The country's and international community's insurgency and terrorism problems are causing dread and concern among residents, as well as the deaths of ground military and civilians and the draining of government resources. To address this issue, a sophisticated ground spy vehicle with wireless camera surveillance and spying capabilities could be deployed as a first line of defense to assist soldiers and police in scanning an environment for terrorists and harmful devices from afar before approaching as an alternative line of defense. In light of the aforementioned issue, Kumar Bandani et al., 2023 developed a robot with "a wireless night vision camera and manual control via an Android Bluetooth application", capable of transmitting data to a remote IoT cloud database. The over reliance on manual control might restrict automated response capabilities, indicating a potential area for integrating more autonomous features. This study can be improved upon by building a robot vehicle device which can carry out a variety of activities like patrolling and monitoring, preserving human resources, and ensuring the security of diverse regions, including military installations. A security IP camera was used to build a ground vehicle prototype by providing a remote control as a stand-alone item. This project improves security and replaces the traditional way. In addition, the cost of spying with an affordable digital wireless camera was reduced by using software and a low-cost sensor and microprocessor module. And this technology will help all Nigerian security services tackle crime in the long run.

1.3 Aim and Objectives of the Study

The aim of this study is to design a wireless android-based ground robotic spying vehicle that does not require physical human labor using ESP32-camera. The specific objectives are to:

i. design a moveable robot spy vehicle using Esp32 camera, DC motors, Arduino Uno and motor driver L298N.

ii. enhance navigation and controlling of the precise movement of the robot vehicle using L298N motor driver that receives command from ESP32-camera.

iii. integrate sensors and camera communication between the robot vehicle and android controlled interface for livestreaming of videos and data.

1.4 Methodology

The implementation of this project appears straight forward at first consideration. Typically, it consists of three (3) major implementations as follows:

Web Server: the ESP32-CAM acts as a web server, which will allow the control of the robot through a web interface. The interface typically has buttons or sliders to send commands (e.g., move forward, turn left).

Motor Control: the L298N motor driver receives these commands from the ESP32-CAM and controls the motor accordingly by providing the necessary voltage and current on a 11.IV, 2200mAh LiPo battery or power bank to move the car.

Camera Streaming: The ESP32-CAM captures video and streams it over the network, allowing you to remotely see where the car is going in real-time.

The whole components are developed on Arduino IDE software. The result of the scan is the livestreaming of videos and data of any obstacle encountered over a distance (given in meters or centimeters) displayed on an android phone interface through a web user.

1.5 Significance of the Study

This study demonstrates the feasibility of developing a usable security device from existing components chosen based on the information provided by their various data sheets. This gadget is controlled wirelessly by transmitting navigation orders from web server through web-based interface with android phone as stand-alone remote control. Additionally, the gadget has esp32-camera sensor installed that give it strong and advanced radar capabilities. The Arduino board and the Processing software are used to construct the radar.

1.6 Scope of the Study

This study focuses on the range of sending information between wireless communication devices within a specific distance and transmitting an obstacle in the environment to the operator. It is an android-controlled ground vehicle, and perfect operation is purely dependent on the proximity of one communication device to the other. If an operator surpasses the maximum range of the transceiver modules (200 meters), communication between the operator and the spy vehicle will be lost.

1.7 Limitation of the Study

This Design as a prototype, demonstrates the possibility of coming up with a useful security device using existing components which were selected based on the information provided by their various data sheets. Due to the challenges in the designing of spy robot car, this research was based on the use of esp32 camera and motor drivers. Power bank was used to power the vehicle as battery 11.1V, 2200mAh LiPo can power up the system only for a limited duration after which the battery bank drains out, leaving the systems powerless because of the large power requirements of all components of this project combined. Arduino IDE software was used to implement the development of the robot there allowing the esp32 camera to communicate with the android phone for livestreaming of videos and data.

1.8 Organization of Research Report

This report would be divided into five (5) chapter parts, summarized as follows;

Chapter one, gives a background introduction of the study, statement of the problem, aim and objectives, methodology, significance, scope of study and limitation to the study.

Chapter two, delves into a literature review of published paper that are unmanned ground vehicle

Chapter three gives the method used in implementing the research study.

Chapter four would be presenting the results after the implementation.

Chapter five gives conclusion and recommendation.

1.9 Operational Definition of Terms

Analog: this is relating to or using signals or information represented by a continuously variable physical quantity such as spatial position, voltage.

Application: the action of putting something into operation.

Digital: refers to an electronic technology that generates, stores and processing data in terms of positive and non-positive states. It can also be (of signals or data) expressed as series of the digits 0 and 1, typically represented by values of a physical quantity such as voltage or magnetic polarization.

Effectors: is the part of the body which can respond to stimulus according to the instructions sent from the nervous system e.g. spinal cord and brain.

Esp 32-camera: The ESP32 camera is a device that is used to host a video streaming web server that you can use to access any device in your network.

Espionage: is practice of spying or using spies to obtain information about the plans and activities especially of a foreign government or a competing company.

Human Intervention: the action of becoming intentionally involved in a difficult situation, in order to improve it or prevent it from.

Insecurity: the state of being open to danger or threat; lack of protection

Inspection: careful examination or scrutiny.

Insurgency: an active revolt or uprising.

Network: a group or system of interconnected people or things.

Miniature: a thing that is much smaller than normal, especially a small replica or model

Module: contained unit or item, such as an assembly of electronic components and associated wiring or a segment of computer software, which itself performs a defined task and can be linked with other such units to form a larger system.

Patrol: is an expedition to keep watch over an area, especially by guards or police walking or driving around at regular intervals.

Prototype: is a rudimentary working model of a product or information system usually built for demonstration purposes as part of the development process.

Remote: is an act of conducting or working away from a usual workplace or location, making use of communications technology.

Robot: (especially in science fiction) is a machine resembling a human being and able to replicate certain human movements and functions automatically.

Sensor: a device which detects or measures a physical property and records, indicates, or otherwise responds to it.

Spy: discern or make out, especially by careful observation

Surveillance: Methods of surveillance are ways that investigators and agents actually conduct surveillance.

Teleoperated: *Teleoperation* (or remote operation) indicates operation of a system or machine at a distance. It is similar in meaning to the phrase "remote control".

Terrorism: the unlawful use of violence and intimidation, or method of coercion especially against civilians, in the pursuit of political aims.

Wireless: any system of sending electronic information, such as the internet, phone signals, etc. without using wires for the receiving equipment.

Endnote

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Chapter Two

Literature Review

2.1 Conceptual Review

2.1.1 Robotics and Robots

In recent time, robot has become an integral part of daily life and finds application in many fields of engineering and technology. Robots are electro-mechanical machines that can perform specific tasks on their own with some forms of artificial intelligence or with instructions from a human. [1]defined robots as a system that automates one or more tasks. Robot applications are of great importance in areas such as war zones, hazardous environments, natural living environments and remote, difficult-to-access environments like deep space[2]. Robots take the place of human in reforming repetitive and dangerous tasks which humans prefer not to do or unable to do or which take place in hazardous environments[3]. This chapter presents the concept of robots, the background and working principles of the device and the basic materials required to build the robot in this research work.

computers.

2.2. Theoretical Background

Robotics as the branch of technology that deals with the design, construction, operation, and application of robots as well as computer system for their control, sensory feedback and information processing[4]. Robots technology deals with automated machines that can take the place of human in dangerous environments and manufacturing processes. Robots may resemble human in appearance, actions and reasoning and the application in industries as increased over time, especially in car manufacturing; they are fund on assembly lines doing a variety of repetitive tasks. Only 50% of robots are in automobile plants, with the other spread out among hospitals, laboratories, warehouses, energy plants, factories, and many other industries[5]. Although robots have replaced humans in performing dangerous tasks, this however as raising serious concerns because of the rising rate of unemployment.

Many types of robots exists for as in many different environments but they all share some basic similarities when it comes to their construction. There are three (3) broad aspects of any robots:

i. The form: This is the mechanical construction or shape designed to achieve a particular task. The form of a robot is determined by the task assigned to it and the physical environment around it.

ii. The power source: Robots usually have electrical components which power and control their machinery. The power can originate from a battery. The electrical aspect of robots is used for movement and operation by supplying their motors and sensors electrical energy in order to activate and perform basic operations. Also, the electrical aspect of robots is used for sensing by using electrical signal to measure things like heat, sound and position.

iii. The program: Also known as the brain, the program is the core essence of a robot which serves as the robotic intelligence. The program contains some level of computer programming codes which helps the robot to make decisions on when and how to do something. There are three (3) different types of robots programs: Remote control (RC), artificial intelligence (AI) and hybrid. Remote controlled robots has a pre-existing set of commands that it will only perform if and when it receives a signal from a control source. Robot with artificial intelligence can interact with its environment on its own without a control source and can determine reactions to objects and problems it encounters using pre-existing programs. Hybrid, however, is a special form of programming that incorporates both artificial intelligence and remote control.

Robotic is a branch of technology that deals with designing, construction, operation, and application of robots. It also deals with the computer systems for their sensory, control, information processing and feedback. The focus of the technology is on the automated machines that can replace human in manufacturing processes in dangerous environments. Robots resembles humans in behavior, appearance, and/or cognition. Robots requires a working knowledge of mechanics, electronics, and software.[6] Robots are machines and are of a wide range. The common feature of robots is their capability to move and they perform physical tasks. Robots have many different forms which range from industrial robots, these appearance is dictated by the function they are to perform. Robots can also be humanoid robots, which mimic the human movement.

Robots can generally be grouped into three as follows:

1. Manipulator robots (for e.g. industrial robots)
2. Mobile robots (for e.g. autonomous vehicles),
3. Self-reconfigurable robots (i.e. robots that can conform themselves to the task at hand).

Robots may act according to their own decision-making ability based on artificial intelligence or may be controlled directly by a human such as remotely-controlled bomb disposal robots and robotic arms. However, the majority of robots fall in between these groups being controlled by pre-programmed

2.2.1 Robots Working Principles

Human beings, on a basic level, are made of five major components: (i) muscle system that can move the body structure, (ii) body structure itself, (iii) power source that can activate the muscles and sensors, (iv) sensory system which can receive information about the body and the surrounding environment, and (v) brain system which can process sensory information and tell the muscles what to do. Robots are made up of these same components. A typical autonomous robots has a sensor system, a movable physical structure, a power supply and a computer brain that control all of these elements. Basically, robots are man-made versions of the human beings. They are machines that can replicate human and animal behavior[7].

2.2.2 Military Robots as a Tactical and Operational Tool for Armed Forces

Today, the nature of warfare has changed drastically and technology plays a key role in shaping warfare tactics. The threats faced by militaries are uncertain with populated places often being the battlefields and the enemies are tactically innovative, highly networked and intelligent. This often overpowers the superiority an army may have in terms of conventional warfare capabilities. Technological advancements, however, have given robot in the Military in any countries the capability to map a potential large hostile area by accurately detecting a variety of threats from enemy and oppose the attack. They can be deployed in situations of areas which are dangerous and that can kill main troops. It can also provide a backup during heavy artillery fire and reduce the number of casualties[8]. Nowadays, robots in the military are an alternative to human soldiers. These robots are designed to handle a broader range of combat tasks including picking off snipers to carrying out target attack with greater efficiency as compared to human soldiers. They can be deployed in situations and areas which are dangerous. Army robots can provide a backup during heavy artillery fire and reduce the number of casualties. They can also map a potentially large hostile area by accurately detecting a variety of threats.

Military robots come in different shapes and sizes depending on the requirements and they may be remotely controlled or fully autonomous. Robots consist of different types of payloads depending on the application requirements, sensors, detectors, programmed software and other payloads can be equipped on robots used in the Military. Militaries are focusing increasingly on the development of various new robot technologies that can be helpful for armies in case of war. For example, the Defense Advanced Research Projects Agency (DARPA) is financing a robotic submarine system that could be used intelligently for several applications ranging from detecting underwater mines, engaging in anti-submarine operations, and protecting ships in harbors[9]. All these benefits are driving the Military and security agencies worldwide to employ robots for a new range of Military applications.

2.2.3. Types of Military Robots

There have been several major strides in the development of Military robotics due to the technological advancements in automation and sensors systems. Today, robots are equipped with advanced technologies of automated weapon systems having the capability to oppose any attack. Such military robots are assembled with several codes and algorithms. Companies are now configuring and testing advanced robots that can navigate vehicles around a series of pylons, traverse different terrains, climb ladders, remove debris, operate in a disaster situation, and close a series of valves.

Small robots are increasingly being used in military applications, from ISR (Intelligence, Surveillance and Reconnaissance) to underwater many clearance and inspection. Bluefin Robotics, a subsidiary of General Dynamics Corporation (in USA), has developed a miniature AUV (full meaning) named SandShark which has a diameter of 5 inches and length ranging from 23 inches to 60 inches depending on the payload. The company has delivered 10 SandSharks to Defense Advanced Research Projects Agency (DARPA) under the Adaptive Sensor System program. DARPA, along with some institutions, will use SandSharks for experimental purposes[10].

2.2.3.1 Intelligence, Surveillance and Reconnaissance (ISR) Robots

Intelligence, Surveillance and Reconnaissance (ISR) is one of the major applications where military satellites are used. UAVs, UGVs, SUVs, ROVs, AUVs, and others are extensively used in the ISR application. Small UAVs is used in the military sector mainly to provide battlefield intelligence. Currently, armed forces worldwide no longer rely on human scouts and instead use small robots, which can remain almost invisible to the enemy. These robots help monitor enemy forces or specific areas and send videos and images to the ground station with the assistance of GPS. UAVs are used for ISR operations to record potential target information that is difficult to detect[10]. For example, WASP, a lightweight, robust, low altitude remote-controlled Unmanned Aerial System (UAS), designed and manufactured jointly by Aero-vironment (US) and the Defence Advanced Research Projects Agency (DARPA), is used by the US for surveillance and reconnaissance[11].

i. Combat Support Robots

In the military, robots are used for combat support applications such as anti-submarine operations, landing parties, fire support, electronic warfare, battle damage management, intercept missions, aerial refueling, and so forth. They also play a vital part in crucial situations because of their enhanced powers and some level of autonomy. The advantages provided by robots include the capacity to attain information dominance, minimize collateral damage, and fight effectively in urban areas against widely distributed forces. Technological advancements in autonomous robots have resulted in arming them with weapons that provide them with lethal capabilities in combat operations and the capacity to make judgments without human intervention [12].

ii. Mine Clearance Robots

Another use for mine clearance is the use of armament robots for mine reconnaissance and aerial clearance operations to locate and remove landmines and marine mines. The likelihood of unexploded munitions and other hazardous materials is reduced with a robot. For mine clearance activities, land robots and remotely operated vehicles are utilized. For example, the Russian military used a high-tech "robot soldier" known as Uran-6 robots in 2016 to protect the ancient Palestine World Heritage site from Islamic State rule. Over 3,000 explosive devices, including mines, were deployed by Uran-6 robots [13].

iii. Explosive Ordnance Disposal (EOD) Robots

Robots known as Explosive Ordnance Disposal (EOD) devices are utilized to identify and neutralize traps, explosive devices, and other hazardous materials in enclosed spaces, buildings, and automobiles.

They are incorporated into bulk detection systems. The payloads they can carry vary based on the EOD mission. Robot 510 Pacakbo, Talon, Robot Andros, EODOR, and Dragon Runner are a few examples of EOD robots that have tremendous potential in the future [14].

iv. Fire-Fighting Robots

Firefighting robots are increasingly being used to respond to fire situations in order to prevent casualties. Initially deployed by the US Navy, these robots were known as Shipboard Autonomous Firefighting Robots (SAFFIR). Robots used in firefighting are capable of spotting fires, demonstrating a wide range of fire behavior, maintaining high temperatures for extended periods of time, and reacting to many types of movements. The robots are capable of detecting fire because they are outfitted with a variety of cameras, a gas detector, and a stereo infrared camera, all of which aid in guiding the robots through smoke and putting the fire under control [15].

v. Autonomous Robot

Robots with autonomy are not dependent on a controller and are capable of acting independently. The robot is programmed to respond to an external stimulus in a specific manner. The bump-and-go robot is a good illustration. This robot uses its bumper cameras to identify obstacles. The robot moves in a straight line when switched on, and its bumper opens when it encounters an obstacle. The robot provides a programming instruction that enables it to spin around, move forward, and back up. This allows the robot to change direction if it comes across an obstacle.

More sophisticated robots employ a more elaborate version of the same concept. Roboticists develop new vision systems and algorithms to make robots more intelligent and perceptive. These days, robots can move through a range of conditions with ease. Certain mobile robots also employ several types of ultrasonic sensors to detect obstructions or infrared light. These sensors function similarly to animal echolocation. The robot emits either a signal of sound or a beam of infrared light. Next, it identifies the reflection of the original. The robot determines the distance to the obstacles by measuring the time it takes for the insect to return to its original position.

A few very skilled robots also employ stereo vision. Robots with deep perception are provided by two cameras. The ability to recognize images then allows them to locate and classify a variety of objects. Robots also employ sound and touch sensors to learn about their surroundings. Robots with greater sophistication may analyze unfamiliar settings and adjust accordingly. They even work in regions that have hard terrain. This kind of robots can associate in particular terrain patterns with particular actions[16].

For instance, a rover robot constructs a map of the land using its visual indicators. When a rough terrain pattern is shown on the map, the robot chooses to travel in a different direction. These kinds of systems are very helpful for exploratory robots and can be used for operations on different planets. Figure 2.1 depicts the NASA-developed bot named Urbie. It is designed for multiple military applications and can navigate across obstacles and other similar paths. NASA created the Autonomous Urbie Robot, which is intended for use in a variety of urban applications, such as military search and rescue missions.

Figure 2.1: Autonomous Urbie Robot.

Source: The well-known QinetiQ North America's (ex-Foster-Miller) TALON. Initially deployed in 2000, the TALON family of robots has been widely used for various tasks, such as improvised explosive device (IED) and explosive ordnance disposal (EOD), reconnaissance, communications, CBRNE (Chemical, Biological, Radiological, Nuclear, Explosive) missions.

2.3 Actuators

An actuator is a device that uses a source of control to produce either rotary or linear motion from a power source. As devices, actuators influence motion in a robot; they are the "muscles" of a robot, the components that transform stored energy into motion. There are many different types of actuators that are used in industry. These include electric motors that rotate a wheel or gear, linear actuators that control industrial robots, hydraulic and pneumatic actuators, artificial muscles, and pneumatic actuators. The electronic microscopes were employed in this study. Electrical energy is converted into mechanical energy by an electronic motor. These are the most prevalent kinds of robot actors. Four (4) basic classifications exist: DC motors, synchronous motors, 3-phase induction motors, and single-phase electric motors. Direct current drives the DC motor. It's the most efficient type of electric motor, working on the force applied to a current-carrying wire in a magnetic field. Although, different types of DC motors exists but the permanent magnet DC motor and the Servo motor were used in this work [17].

Robots can be utilized to carry out tasks in dangerous areas and to achieve challenging degrees of unpredictability there. Robots are progressively becoming more and more essential for common subject applications like military and urban search and salvage. Nowadays, a wide range of small robotic applications are emerging, and robots are used to carry out a variety of tasks. Generally speaking, robots are used for tasks that are hazardous and harmful for humans, such as controller, spy, salvage, therapeutic, and other tasks. Though it has historically been the domain of science fiction, the use of robots in combat is currently being investigated as a potential strategy for waging war in the future. Autonomous or remotely controlled mobile robots with specialized functions for military use, such as attack, search and rescue, and transportation, are known as military robots.

2.3.1 Permanent Magnet DC Motors

Every time a current-carrying conductor is inserted into a magnetic field, a mechanical force is generated by that conductor. All types of DC motors operate based on this principle. An actuator rotates inside a magnetic field of a DC motor. Either a permanent magnet network or an electronic magnet network establishes the magnetic field. The permanent magnet DC motor is inexpensive and does not require field acceleration adjustment. It is highly efficient since it doesn't require an external power source for excitation because permanent magnet magnets generate the field. They also arrive in small sizes because field clearances are not necessary. The drawback of this particular motor is that, since the temperature cannot be regulated, the permanent magnet's magnetic field may weaken as a result of the demagnetizing effect of the temperature response. Furthermore, since the magnetic field intensity is set, this type of motor cannot be used in situations where speed control is required[18].

Figure 2.2: Permanent magnet DC motor

Source[17]

2.3.2 Motor Driver L298N

The L298N is a high-voltage, high-current motor driver IC (Integrated Circuit) designed to control DC motors. Here are some key features and specifications:

Features

1. High-voltage operation (up to 45V)

2. High-current output (up to 2A)

3. PWM (Pulse Width Modulation) control

4. Enable/Disable input

5. Overcurrent protection

6. Thermal shutdown protection

Some key specifications include:

1. Supply voltage: 5-46V

2. Output current: up to 2A channel

3. PWM frequency: up to 20 kHz

4. Enable/Disable input voltage: 0-5V

5. Operating temperature: -20°C to +150°C

Functions of Motor Driver L298N

The L298N is a dual H-bridge motor driver IC, meaning it can control two DC motors simultaneously. Its primary functions include:

1. Motor direction control: Controls the rotation direction of both motors.

2. Speed control: Regulates the speed of both motors using PWM (Pulse Width Modulation).

3. Current sensing: Monitors the current flowing through each motor.

4. Overcurrent protection: Automatically shuts down the motor in case of excessive current.

5. Thermal shutdown: Disables the motor driver if the IC overheats.

6. Enable/Disable input: Allows external control of the motor driver's state.

7. Voltage regulation: Can be used to regulate the motor voltage.

Important of Motor Driver L298N

The L298N motor driver is important for several reasons:

1. Flexibility: Controls two DC motors simultaneously, making it suitable for applications requiring multiple motor control.

2. High current handling: Can handle high currents (up to 2A per channel), making it suitable for applications requiring high torque.

3. PWM control: Allows for precise speed control using PWM, enabling smooth and efficient motor operation.

4. Protection features: Includes overcurrent protection, thermal shutdown, and undervoltage lockout, ensuring safe operation and preventing damage.

5. Wide operating voltage range: Can operate with supply voltages from 5-46V, making it suitable for various applications.

6. Compact design: Available in a compact IC package, saving space in design layouts.

7. Cost-effective: Provides a cost-effective solution for motor control applications.

8. Widespread adoption: Widely used in various applications, making it easy to find resources, documentation, and community support.

The L298N is a popular choice for:

1. Robotics

2. Automotive systems

3. Industrial automation

4. Medical devices

5. Power tools

6. Hobby projects (e.g., RC cars, drones)

Its versatility, reliability, and ease of use make it an essential component in many motor control applications[19].

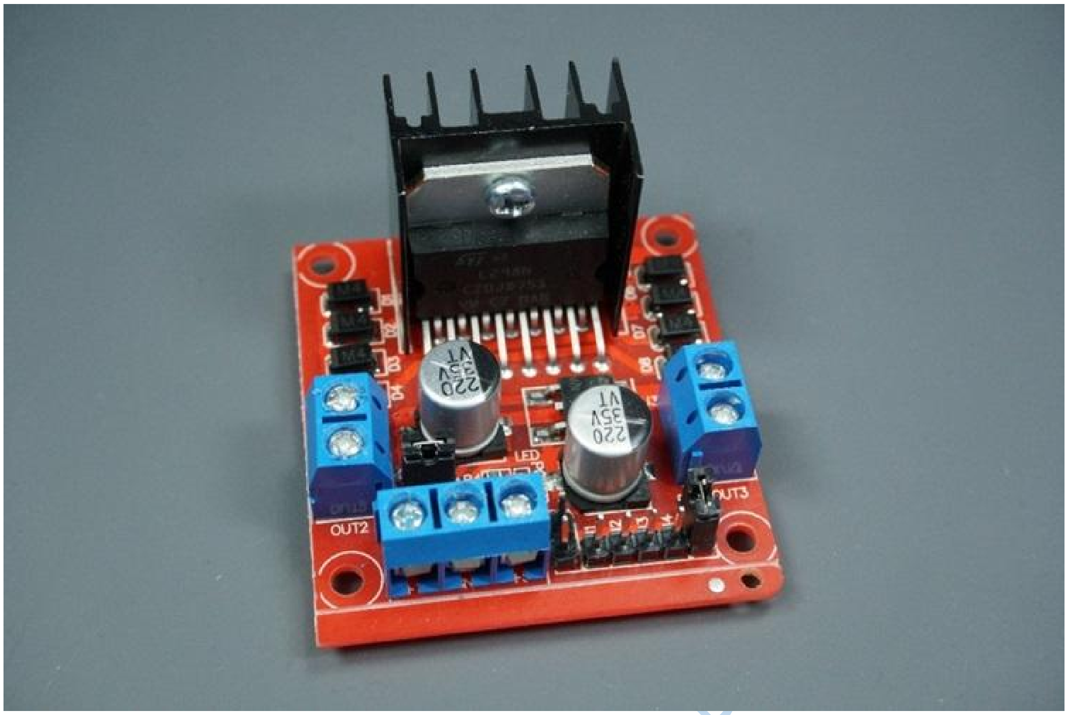

Figure 2.3: L298N Motor Driver

Source: Randomnerdtutorials.com/esp32-cam-car-robot-web-server

2.3.3 ESP 32-camera

The ESP32 Camera module integrates the ESP32-S chip and a camera sensor, offering a compact solution for projects requiring wireless connectivity and image/video capturing capabilities. It is ideal for IoT (Internet of Things) applications, surveillance systems, and various smart devices where remote monitoring and image processing are essential[19].

Key Features:

- ESP32-S chip with dual-core processor
- Integrated camera sensor (OV2640 or OV7670, depending on the module variant)
- Wi-Fi and Bluetooth connectivity (802.11 b/g/n, Bluetooth v4.2 BR/EDR and BLE)
- Support for microSD card for local storage

- GPIO pins for versatile connectivity and sensor integration
- USB interface for programming and power supply
- Low-power consumption for extended battery life
- Onboard antenna for wireless communication

Technical Specifications:

- Processor: ESP32 dual-core Tensilica LX6 microprocessor
- Camera Sensor: OV2640 (2MP) or OV7670 (VGA)
- Connectivity: Wi-Fi 802.11 b/g/n, Bluetooth v4.2 BR/EDR and BLE
- Memory: 520KB SRAM, 4MB flash memory
- Operating Voltage: 3.3V
- Interfaces: USB, SPI, I2C, UART, ADC, DAC
- Operating Temperature Range: -40°C to +125°C
- Dimensions: Compact module size for embedded applications

Applications:

- IoT devices with image capture and processing capabilities
- Surveillance cameras and security systems
- Remote monitoring and video streaming
- Smart home devices
- Industrial automation and monitoring

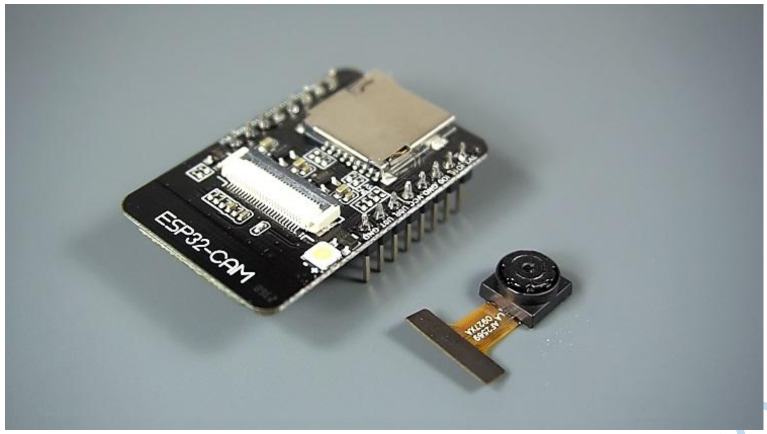

Figure 2.4: ESP32-camera
Source: randomnerdtutorials.com/esp32-cam-car-robot-web-server

2.3.4 Web Server

A web server with the ESP32 Camera will be built to control a DC motor remotely. The web server will serve a web page with buttons to make the motor spin forward, backward, and stop. To control the motors; we'll use the L298N motor driver and the ESP32 which will be programmed using Arduino IDE[20].

2.3.5 Wireless Technology

The WiFi coverage range of ESP32 mainly depends on product quality. There are many brands and types of ESP32 from different suppliers. According to the documents, it says in special protocol it can send data **over** 1 km in line of sight. 50m -200m depending on the antennas.[21].

2.3.6 Nrf24l01 Module

The NRF24L01 is a highly integrated, ultra-low power (ULP) 2Mbps RF transceiver IC for the 2.4GHz ISM (Industrial, Scientific, Medical) band, with peak RX/TX currents lower than 14mA, advanced power management and a 1.9V to 3.6V supply range. Due to the low cost, this technology is widely deployed in wireless control and monitoring applications. The ultra-low power usage allows longer lifetime when running on small batteries or coin cells. Also, the mesh networking provides high reliability and more extensive range. Typical application areas includes remote-controlled unmanned vehicles[22]. The NRF24L01 communicates with the microcontroller unit through SPI (Serial Peripheral Interface). This wireless module has eight (8) pins to interface with the microcontroller in which four (4) out of these eight (8) pins are SPI related and they are: MOSI, MISO, SCK and CSN. The others are VCC, GND, CE and IRQ. Although this transceiver module has an operating range of 1.9V to 3.6V for VCC pin, all other pins are 5V tolerant and can be connected to the microcontroller's input/output pins[22]. The NRF24L01 is shown in Figure 2.5.

Figure 2.5: NRF24L01 Transceiver Module.
Source[17]

The Atmega328 microcontroller SPI interface uses four (4) pins for data transmission and reception. These SPI pins correspond with those of the NRF module. CSN (Chip Select Not) pin is active-low and is normally kept high. When CSN goes low, the NRF24L01 begin to listen for data on its SPI port and processes the data accordingly. The MOSI (Master Output, Slave Input), MISO (Master Input, Slave Output) and SCK (Serial Clock) are tied to the microcontroller's SPI, the same pins as their name suggests. The CE (Clock Enable) pin is used to control data transmission and reception when in TX and RX modes respectively. IRQ, the interrupt pin is active-low. The NRF24L01 wireless transceiver module was chosen for this work because of the chip's low cost and ultra-low power solution. Also, SPI interface permits on to read/write registers in the chip, and transmit and receive data. It is a very simple way to communicate with any microcontroller [23].

2.3.7 DRF1605H Zigbee Module

Zigbee is a protocol stack suit for high level communication protocol using small, low power digital radios based on an IEEE 802 standard for personal area networks. The DRF1605H Zigbee module employed in this research works at 2.4GHz frequency[23]. This means smaller board size and small antenna size. The Zigbee module is capable of transmitting digital, PWM, analog or serial RS232 signals wirelessly. Communication between two (2) Zigbee modules is over UART or USART. Some basic features of Zigbee module are:

- Input Power: DC 3.3V.
- Interface: UART, 3.3V (TTL or 3.3V CMOS).
- UART baud rate: 9600bps, 19200bps, 38400bps (default), 115200bps.
- Wireless Protocol: ZigBee2007/PRO.
- Transfer Distance: 400 Meters.
- Max send current: 34mA.
- Max receive current: 25mA.
- Receiving sensitivity: -96dBm.

To interface the Zigbee module, only four basic signal pins are required which are RX (receiver), TX (transmitter), GND (common ground) and 3.3V supply. This module was chosen for the sensor unit of the automatic ground vehicle precisely because of the transfer rate and the simplicity of interface[24]. The DRF1605H Zigbee module is shown in figure 2.6.

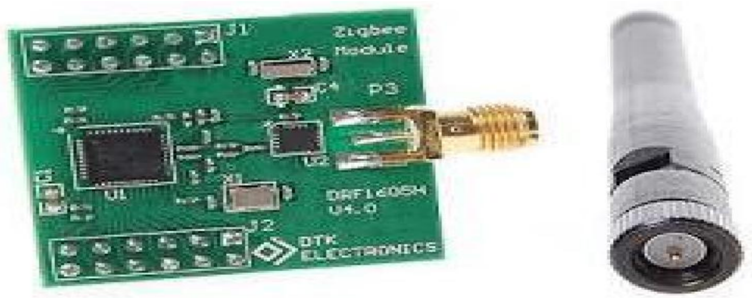

Figure 2.6: DRF 1605H ZIGBEE Module
Source[17]

2.3.8 ATMEGA328P Microcontroller

A microcontroller is a computer on a chip. These low cost, low power, small computers are built using Metal Oxide Semiconductor technology. A microcontroller contains the processor (the CPU), non-volatile memory for the program (ROM or flash), volatile memory for input and output (RAM), a clock and an I/O control unit on a single chip and they are available in different sizes and architectures. Ibrahim (2008), stated that a microcontroller is more economical than buying a large analogue component that could serve the same purpose[25]. These computers-on-chip find applications mostly in embedded systems such as automated controlled devices. The most common microcontroller families available are the 8051, AVR/AMTG and the PIC. The Atmega328P microcontroller is shown in Figure 2.7.

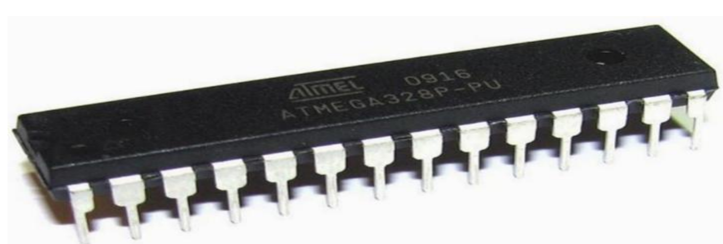

Figure 2.7: ATMEGA328P Microcontroller
Source[17]

The ATMEGA328P microcontroller was selected for this project because of some important hardware features listed as follows:

• High performance and low power consumption.

• Low operating voltage (1.8V -5.5V).

• 32 programmable input/output lines.

• Programmable Watchdog Timer with separate On-chip Oscillator.

• Programmable Serial USART

• Six (6) PWM channels k

• External and internal interrupt sources.

2.3.9 Arduino Uno Microcontroller;

Arduino UNO is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. The Uno is based on the Atmega328P microcontroller and can be programmed with the Arduino software IDE (Integrated Development Environment). The ATmega328 on the Uno comes pre-programmed with a boot-loader that allows new codes to be uploaded to it without the use of an external hardware programmer. It communicates using the original STK500 Protocol. The Arduino Uno board can be powered through a USB connection or with an external power supply. The Uno board can operate on an external supply from 6V – 20V. However, if supplied with less than 7V, the 5V Vcc pin may supply less than 5 volts and the board may become unstable. If more than 12V is supplied to the board, the voltage regulator may overheat and damage the board. The recommended range of operating voltage is 7V – 12V. The open-source Arduino environment makes it easy to write code and upload it to the input/output board. It runs on Windows, Mac OS X, and Linux operating systems. The environment is written in Java and based on processing, avr-gcc, and other open source software [26].

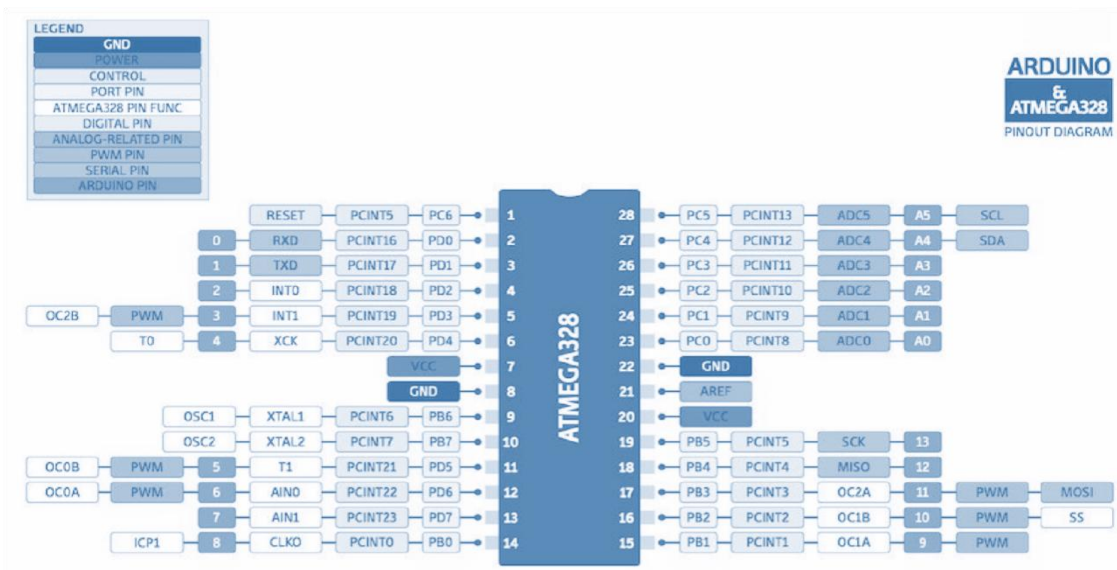

Figure 2.8: Arduino Uno Atmega328P Pin-out
Source[17]

2.3.9.1 Computer to Arduino Communication

In order to communicate with Arduino, we must first install its free firmware on the internet and install it. The software is really simple to use and install. It creates only one. There are one or more files on the microscope, and the user is becoming puzzled by these files due to the variety of different file formats. Once installed, Arduino is ready for use, even with dictionary searches. It's quite simple to use dictionaries on Arduino, and no configuration is needed for the software. These are the settings that the program itself makes in the background as it is programming. After connecting Arduino with a USB cable, the user can install codes on the device much more rapidly and easily than on a microcontroller.

2.4 Bluetooth Communication

Bluetooth is one of the popular devices to communicate in short range. It used computers, cell phones, head phones and many other devices. Bluetooth devices use 2.4 to 2.5 GHz frequency to communicate with each other. Bluetooth standardized is IEEE 802.15.1 and its range is 2400–2483.5 MHz approximately. Bluetooth devices generally use frequency-hopping spread spectrum communication technique to communicate each other. It can have approximately 40 channels and signals hops 1600 hop per second. Bluetooth devices firstly search each other, once one find other, it shows device to its user and if the user decides to communicate with device, he pairs those two devices to starts communication[27].

2.4.1. Benefits of Microcontroller, Chips and Modules for Robotic Automation

i. Microcontrollers Benefits

Certain tasks on the circuit are performed by microcontrollers, such as battery charging, printers, scanners, stereo systems, etc. For integrated systems, there are several general-purpose processors like Intel and AMD, microcontroller processors like PIC microchip and 8051, specialized processors like TMS320 series DSP, and finally, application-specific processors. Controller processors possess four main features. One of these involves switching from analog to digital converters, much like with televisions. Second, data memories and on-chip programs. The third option is direct programmer access to switches, and the fourth option is specific instructions for both manipulation and lower-level operations. Microcontroller applications are for reading sensor data, setting actuators, dealing with bits little amount of data. They can be using on the disk drive, digital camera, washing machine or etc and microprocessor works with using hex files [28].

ii. Computer Serial Data Transfer Benefit

Computers are used differently in today's engineering community to connect devices to computers and other similar computerized devices. Computers are equipped with a multitude of programs, which may be readily changed through the use of a keyboard and appropriate algorithms. A connected computer also gives the user easy control over their environment and makes it possible for them to frequently check that device. Using serial ports for data transfer from PCs to SD cards, flash drives, external memory, etc., is also important. People are also using this kind of communication to receive or send information to their phones, tablets, cameras, and other similar devices.

iii. Wireless Communication's Benefits

These days, wireless systems are quite significant because they eliminate cords from the environment and allow users to connect to the internet and wireless networks for a variety of purposes. With the rise of smart phones, wireless technology is constantly developing and is crucial to community activities. Government uses wireless networks in public spaces, such as the Istanbul metropolitan municipality, where wireless technology is used to locate the locations of its buildings and employ mobile applications to communicate information with the Istanbul citizens. These days, communication is crucial, and with advancements in wireless technology systems, communication is becoming much easier and more efficient. In this research work, two type of wireless devices used are Radio Frequency and Bluetooth[30].

iv. Benefits of Radio Frequency System

These days, radio frequency equipment is widely used and indispensable. Frequency modulation technology allows us to listen to music at a great distance from any radio station. It's also common for individuals to communicate with one another across great distances using this technique. Today, we utilize cell phones, and these phones employ radio frequencies with various modulation methods. Due to radio frequency, we were able to watch television with the help of a basic antenna, listen to music, and see pictures on the screen. Television stations also employ this frequency to convey messages and transmit their broadcast to the public. On the emergency situations, these Radio Frequencies are used to communicate with police, hospitals and similar companies [31].

v. Benefits of DC Motors;

People use DC motors in many ways every day and industrial applications, such as cars, elevators, and other things, to make their lives easier. However, without motors, people might perform many labor-intensive tasks with their bodies and strength, which are not as efficient in today's industry. DC motors are quite common, and managing them is crucial as engineers and scientists continue to strive for more efficient control over these machines. Industrial technology may be advanced considerably faster with efficient motor control, which has an impact on other areas of technology. There are many different types of motors in the industrial sector since their uses vary depending on the application.

v. Benefits of Bluetooth

Connecting devices is becoming; a very complex issue because there are too many cables and ports. With Bluetooth technology, this problem could be solved and people could connect their devices more easily. The main idea of this invention is cable-free computer connections, which means real freedom for working environment regardless of availability wired devices restriction. This bluetooth technology allows portable computers, notebooks, mobile phones, Personal Digital Assistant (PDA) and other helpful devices to use short range, low power Radio technology to easily connect to each other. Bluetooth is using 2.4 to 2.5 GHz frequency spectrum to communicate. During communication with other bluetooth device, it signals hops between channel and frequencies. It can communicate in the short range but its usage areas vary. Bluetooth can be used for data transmission between two devices like computer to computer, computer to cell phone, cell-phone to computer, cell phone to cell phone. Bluetooth can also use on head phones to connect musical devices, computers or cell phones wirelessly. Bluetooth can also easily choose device that it will send its data to. Firstly, bluetooth device searches device near it and second it asks user to allow it paired with this device to securely connect it and if user grants the permission, it starts to communicate [32].

2.5 Overview of Unmanned Ground Vehicle

An Unmanned Ground Vehicles (UGVs) is a vehicle that operates while in contact with the ground and without an onboard human presence. UGVs can be used for many applications where it may be inconvenient, dangerous, or impossible to have a human operator present. Generally, the vehicle will have a set of sensors to observe the environment, and will either autonomously make decisions about its behavior or pass the information to a human operator at a different location who will control the vehicle through tele-operation. The UGV is the land-based counterpart to unmanned aerial and unmanned underwater vehicles. Unmanned robotics are being actively developed for both civilian and military use to perform a variety of dull, dirty, and dangerous activities [33].

A working remote-controlled car was reported in the October 1921 issue of RCA's *World Wide Wireless* magazine. The car was unmanned and controlled wirelessly via radio; it was thought the technology could someday be adapted to tanks [5]. In the 1930s, the USSR developed Tele tanks, a machine-gun armed tank remotely controlled by radio from another tank. These were used in the Winter War (1939-1940) against Finland and at the start of the Eastern Front after Germany invaded the USSR in 1941. During World War II, the British developed a radio control version of their Matilda II infantry tank in 1941 then known as "Black Prince". It would have been used for drawing the fire of concealed anti-tank guns, or for demolition missions. Due to the costs of converting the transmission system of the tank to Wilson type gearboxes, an order for 60 tanks was cancelled.

The first major mobile robot development effort named Shakey was created during the 1960s as a research study for the Defense Advanced Research Projects Agency (DARPA). Shakey was a wheeled platform that had a TV camera, sensors, and a computer to help guide its navigational tasks of picking up wooden blocks and placing them in certain areas based on commands. DARPA subsequently developed a series of autonomous and semi-autonomous ground robots, often in conjunction with the U.S. army. As part of the strategic computing initiative, DARPA demonstrated the Autonomous Land Vehicle, the first UGV that could navigate complete autonomously on and off roads at useful speeds

The Objectives of Unmanned Ground Vehicle (UGV)

The Objectives of Unmanned Ground Vehicle (UGV) are;

i. The UGVs are built to undertake missions such as border patrol, reconnaissance and target acquisition.

ii. To assist in recovery and rescue operations.

iii. Surveillance in remote places.

iv. To collect and record environmental changes in inhabitable places.

v. To detect landmines.

Advantages of UGV

- Reduced manpower for surveillance purpose.
- Human intervention in hazardous conditions can be avoided.
- No need for humans to travel and record surrounding environment data.
- Reduce combat fatalities.
- Loss of lives caused by overstepping on land mines can be avoided.

Applications

- Assist soldiers in active combat.
- Helps in Surveillance, reconnaissance and target acquisition.
- Space applications.
- Agricultural applications.
- Supply chain management.
- Help provide supplies to soldiers.

Unmanned Ground Vehicle Categories

Depending on the degree of control (capability class), the categories of UGVs can be defined as follows:

1. **Teleoperated Ground Vehicle (TGV):** The control of the vehicle is entirely dependent on a human operator. Sensors and the communication system provide the operator with the image of the surrounding environment in order to transfer to the vehicle the appropriate commands. The proposed UGV, Kerveros I, belongs to this category.
2. **Semi-Autonomous Proceeder-Follower (SAP/FUGV):** These vehicles are designed to either follow or precede the combat units. Especially in the latter case, the vehicle must be equipped with an advanced guidance system to minimize the control requirements by the operator.
3. **Platform-centric Autonomous Ground Vehicle (PCAGV):** Fully autonomous vehicle entrusted with a mission, collecting information from other platforms and perhaps by the operator.

4. **Network-Centric Autonomous Ground Vehicle (NCAGV):** The level of autonomy of the vehicle allows operation in conjunction with other vehicles embedded in a Network Centric System.

Unmanned Ground Vehicles have drawn considerable attention during the last years. Several systems are being developed independently, in many countries, at various universities, private companies and military research institutes. UGVs started as simple remotely operated vehicles and are now moving gradually to the autonomous mobile robot domain. In any case, they can relieve humans from hard, difficult, dangerous, delicate or maybe boring tasks. Taking into account that research and development in the UGV area involves also (or mainly) military interest, it becomes evident that the progress made may have advanced much more than what it is publicly known [34].

2.6 Review of Related Works

This section gives an overview of the related researches that have been done regarding different techniques for unmanned ground vehicles. Some of these related researches are as following.

Security applications such as superintendence, road safety, unmanned ground or aerial vehicles, and human-computer interactions require human tracking and detecting. An increase in robots and communication technology has led researchers to study on these systems. The objective of this design addresses the implementation of a low cost, user friendly and real time autonomous human tracking system for unmanned ground vehicle. Design and properties of an Android-based autonomous human tracking vehicle have been presented in this work in which the vehicle was developed by using 3G technology with smartphone. There have been some studies on autonomous human tracking functions purposely to increase speed and reduce errors by using different communication technologies, advanced algorithms and communication tools such as GSM, Wi-Fi, Bluetooth, radio control, GPRS, 3G, satellite and similar technology[35]. This study was realized with minimum hardware materials and minimum cost. The system was tested on some images and data transfer during experiments. The vehicle is stopped reactively after a crash. In this study, the remote control of vehicle, image transfer, objects tracking, and above all, human tracking were realized.

Currently, android phones (or smart phones) are becoming stronger with the addition of an enhanced processor, both in terms of greater storage capacity, richer entertainment functions and more communication methods and others facilities especially Bluetooth which is often used for data exchange; add new features to smart phones[36]. A smart phone is a mobile built on a cellular computing platform, with computational capabilities and connectivity more advanced than feature phones. Smartphones are more affordable and efficient handheld devices that can be used to support collaborative activities in a community. This system aims to achieve targets in designing systems that can provide the following functionality:

- Development of robots that will assist applications in spying.
- Develop robots that are easily developed with minimum cost and complexity.

Here, the focus is on the latest android technology and robots are also referred to as robot. The mobile application used here is a spy robot that is controlled by an android (mobile) Bluetooth. Wireless control is one of the most important basic needs for everyone throughout the world. Unfortunately, this technology is not fully used because of the large amount of data and communication costs. Generally, many robots are controlled wirelessly using RF modules. However, this research attempts to control robots using Android phone which is very cheap and easy to obtain. For this purpose, the android mobile user must install the application designed on his cellphone. Users can use several commands such as moving backward or forward, left or right using these commands given from an Android phone. The proposed system also shows that robots can be used for the purpose of spying. For this purpose, a wireless camera has been used which we can see, click photos and record videos on laptops. This has been proven to enable meaningful two-way communication between Android phones and robots that will allow unskilled people to interact with and adjust the functionality of systems that use Arduino Uno. The use of sensors also helps the robot to act without commands being received. After the obstacle is felt, it will automatically move in the opposite direction.

In a study where the surveillance operation is required in war fields with an unknown territory and under emergency situations that cannot be reached by soldiers, the soldiers are to be replaced with robots which operates remotely [34]. These spy robots are also required for security enforcement in public service buildings and during terrorists' attacks. The choice of this research work is to replace human operation and control of attacks automatically by a spy robot. The critical issues faced by the human operators are bomb detection, spying an unusual activity, surveillance on border areas, patient monitoring in hospitals and industries, search and rescue operation during nature disastrous. There is necessity to identify the objects located in unknown territory, video streaming of live activities and move in any terrain without hassle. The spy robot under development is unlike many other traditional mobile robots such as legged or wheeled robots. They have shortcomings in speed, travelling on any terrain and visibility of the robot. The spherical shape is ideal for inspection in environment where humans cannot possibly reach. This is achieved by placing car model inside the spherical ball. Research on different mechanisms for spy robot has been derived using car-based models, two independent hemispheres, relocation of center of gravity. The first spherical mobile robot developed uses wheel contact with the bottom of the sphere and drive unit with power and communications on the opposite end of the powered wheel. The design addresses the problem of pick and place, object detection, surveillance operation, search and rescue operations[37].

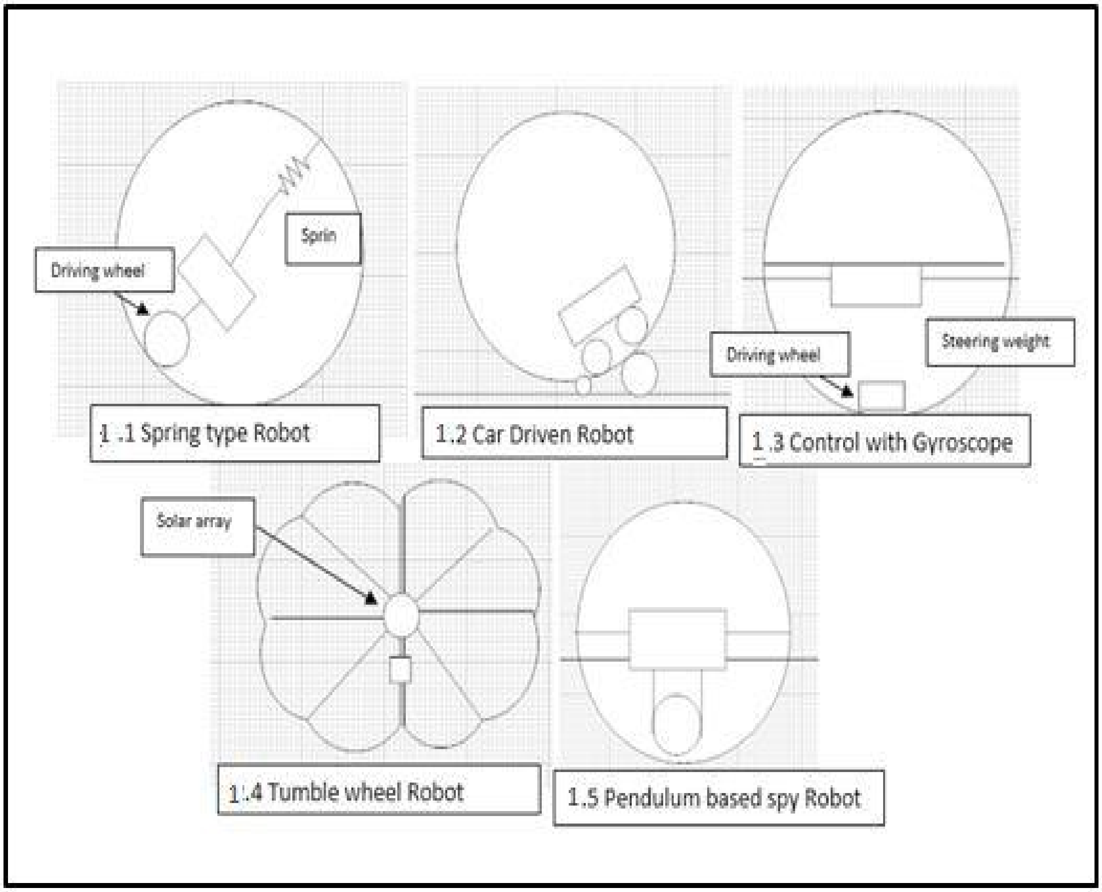

Figure 2.9: Concepts of Spherical Robot.
Source[34]

It can be opined that the spherical robot has been designed and assembled with electronics, motors, camera and Bluetooth. The spherical robot moved on the ground by transmitting the video and audio according to the control commands from the controller up to 150ft. This spherical robot system can be used in the attack and rescue operation to get the information from the human unreachable areas while carrying out military operations. The study focuses mainly on supporting manual control methods. The

CAD model developed shows maximum stress of 273mps and is observed in the mass of the pendulum. This signifies that the appropriate control of right position of pendulum will balance the spherical spy robot movement. Pure automated control without any manual operation, localization and navigation method of the robot can be implemented as a future study.

In a related study that used a Bluetooth-controlled spy robot is an Arduino Uno-based robot that can be monitored and controlled by an Android device using an Android application. The wireless network camera mounted on the robot can also be displayed on any other Android/iOS device for monitoring. In this work, simple materials are used like plastic wood for the chassis, cycle spokes for the wheel axle, L293D motor driver and two 600 rpm DC motors for propulsion in four directions, namely: front, reverse, left and right. Bluetooth module HC-05 is used to receive commands in the form of strings from the Android application. The robot is covered with camouflage texture so that it does not alert surroundings. It is made up of simple materials rather than pre-assembled kits because the materials are readily and cheaply available. The robot becomes very lightweight and it can be formed into any desired size. The design, functions and capabilities of the robot is inspired from this work[38].

Commercial spy robots do exist that are used extensively in military operations but are very expensive. Unlike most related systems which use remote controllers that communicate with robot through Radio Frequency (RF) signals, the proposed system uses an Android device that communicates with robot through Bluetooth signal. The proposed work makes it easier for people, especially the security agencies, to monitor persons and places. Secret Bot is created very simple and ease mass production of this robot takes very little time. Therefore, if one Bot is attacked, then another one can be deployed when needed. This way, human lives can be saved in critical situations. As smart mobile devices are readily available to almost everyone, and the Botis can be made smaller, the audio transmission between the Botis and mobile device is possible. The Botis is useful also in many other applications like home surveillance, getting news information about trapped humans under rubble and in similar conditions[39].

Another study used recent technological advances have made possible the development of Unmanned Ground Vehicles (UGV), which are able to perform various tasks efficiently, such as patrolling and surveillance, sparing human resources. In fact, a UGV is a perfect candidate for patrolling missions since it can provide enhanced mobility, endurance and surveillance capabilities, day and night and in adverse weather conditions. In this way, it can be used to ensure the security of various areas such as military facilities. Following these principles, a UGV prototype has been constructed, operating on electrical power and receiving commands via remote control software from a computer, featuring a surveillance IP camera. It is based on a simple tricycle chassis and it is powered by a high-capacity automotive battery, which provides adequate power for several hours of use. An electric motor moves the vehicle quietly and efficiently, while the vehicle motion controller is connected to a small on-board laptop, receiving commands via Wi-Fi. The combination of a common 12-volt battery and the electric motor provides a reliable and relatively low-cost solution to the UGV mobility issue, thereby minimizing maintenance requirements. The vehicle is equipped with an IP camera, which transmits real time image and sound via Wi-Fi. Using some IR LEDs, it can also see at night up to a certain distance. Both the UGV and the camera can be remote-controlled using a web-based interface. This prototype is proposed as a basis for further development. The construction was deliberately kept as simple as possible, allowing for future upgrades and keeping the development cost low. As good as those design is, the device is tele-operated but it is solely dependent on the availability of network[40].

In a work that stated that in the present-day world, a lot of research has been going on in the field of unmanned vehicles, which includes Unmanned Ground Vehicles (UGVs), Unmanned Aerial Vehicles (UAVs) and Unmanned Water Vehicles (UWVs). UGV technology is for commercial use such as transportation service. The UGV system generally consists of four parts such as vehicle control system, navigation system, obstacle detecting system and traffic signal monitoring and detection system. In this research work, the researcher designed and implemented a prototype of UGV using PIC 16F microcontroller. This UGV prototype was used to simulate acts performed by a real car on urban environment which include navigation, obstacle avoidance, collision avoidance at intersection of two roads, traffic signal detection and feed backing the current co-ordinates of the vehicle to the control room for tracking of the vehicle. The UGV was successful in detecting the obstacles placed both at the linear as well as the corner of the path. The Boe-bot detects the obstacles from a distance of 5cm. The design is limited to device signals was easily jam by enemy to prevent transmission of its location to an operator in a control room. Due to the mobility constrains of the Boe-bot on rough terrain or on real roads, the entire experiment was carried out indoor only[41].

In the recent past, wireless controlled vehicles had been extensively used in a lot of areas like unmanned rescue missions, military usage for unmanned combat and many others. But the major disadvantage of these wireless unmanned robots is that they typically make use of RF circuits to maneuver and control. Essentially, RF circuits suffer from a lot of drawbacks such as limited frequency range (i.e. working range) and limited control. To overcome such problems associated with RF control, some papers have been written, describing methods which make use of the GSM network and the DTMF function of a cell phone to control the robotic vehicle. Although, the research uses the same principled technology of the GSM network and the DTMF based mobile phone but it essentially shows the construction of a circuit using only 4 bits of wireless data communication to control the motion of the vehicle without the use of any microcontroller. This improvement results in considerable reduction of circuit complexity and of manpower for software development as the circuit built using this system does not require any form of programming. Moreover, practical results obtained showed an appreciable degree of accuracy of the system and friendliness without the use of any microcontroller[42].

Another related study designed and developed an android-based app with user interface to control a robotic vehicle using wireless Bluetooth technology. The entire system consists of carefully selected replaceable low-cost components to meet the rugged industrial environment. Recent advancement in semiconductor material results in smart devices such as smart phones and they become a basic need in day-to-day life with massive storage capacities, powerful with reinforced processors, richer entertainment function and vast communicating methodologies. Bluetooth technology, created by telecom vendor Ericsson in 1994, shows its advantage by integrating with smart phones. Bluetooth raised as one of the popular communications in which the user can transfer files, documents etc. Utilizing its flexibility in communication, Bluetooth controlled devices are occupying rightful place in the market especially in controlling the robotic vehicle. Robots are electromechanical machine which can be controlled by artificial programming using high speed microcontroller. They are found in wide area of applications such as industry, manufacturing, production lines, health, etc. The robots work in rough industrial environment and designed to reduce human effort, to improve productivity and to reduce overall manufacturing cost. Bluetooth-controlled robotic vehicle is one solution to design and develop the cheap and rugged robots to perform any task with safe distance operation. Bluetooth communication will enable us to control the robot up to 100 meters without the need for direct sight which means that the robot could be located behind a wall or some other object and the communication would not be lost[43].

In recent years, an open-source platform called "Android" has been widely used in smart phones in which the smart phones have gradually turned into an all-purpose portable device. Android has complete software package consisting of an operating system, middleware layer and core applications.

Using a smartphone as the “brain” of a robot is already an active research field with several open opportunities and promising possibilities. The in-vehicle electronics hardware is developed around the ATmega328P microcontroller and Bluetooth module is interfaced with microcontroller through the UART protocol to exchange the data with android app. By pressing remote button developed in the android app, the direction of the robotic vehicle can be decided. The major advantage of the design is that minimum version of in-built Bluetooth smartphone is used to install the developed app and wireless Bluetooth technology offers zero communication cost. Moreover, this robotic vehicle can also be utilized other application such as exploring the toxic area, detection of explosive landmines, multipurpose surveillance vehicle. The proposed system shows how the android smartphone can be used as remote controller for robot and various embedded technologies with the help of the Bluetooth technology. The proposed system also shows that how a robot can be used for travelling purpose. The operating system of smartphone is Android, and it can develop effective remote-control program and by using Wi-Fi wireless network, the communication between smartphone and robot can be realized, which makes it simple and convenient to control robot[44].

A work developed the android smart phone to control the unmanned ground vehicle. The unmanned ground vehicle is mainly used in secured places. The controller can run the software and touch the screen on the smart phone to drive the vehicle. The vehicle is connected via Bluetooth with help of smart phone application software. When a person or motor enters a monitored area, camera capture the image which is continuously sent to the control room. Camera connected to microcontroller keeps on capturing the secured places and view all information of the secured section images by PC or TV. Voice communication is also enabled by using microphone. The communication between device and vehicle is established by ZIGBEE technology and the robot is controlled by the computer which can be used in any of the terrain. In the work, the researcher achieved control both wireless communication between the mobile Robot Android GUI applications. The main task of the research is to make a security robot which can be controlled by emerging android technology. It gives versatile operation of robot controller which need not modify the hardware. Further development of the system depends on the application used. The system added features like gas sensor, thermal image sensing, connecting robotic arms and can be used in pick and place purposes. The development of the system has wide area of applications such as in law enforcement, industrial and disaster management and so on[45].

According to research, the growing trend of mobile and pervasive computing towards the development of several embedded system has brought about an evolutionary, dramatic, spectacular and unprecedented change in the field of technology specially in the mobile and robotics field which has provided the opportunity to lead improved life for the people as well as beneficial to researchers in endless research arenas. Several computing platforms have been evolved so far, several versatile devices are now at the shore, several research fields have been opened but there is still lack of ample research minds in some specific areas. Meanwhile, applying well-designed projects in the new emerging areas in mobile computing to the software engineering and object-oriented programming and design classroom can dramatically motivate students and improve learning outcomes toward the conceptual learning and context understanding. The research work aims at designing and developing robust, reliable, and correct software intensive system for pursuing top level, incomparable and preeminent research objectives by consolidating several techniques and methodologies to make the proposed system more responsive, user friendly and more communicative with the robot. To fulfill the system requirements and reach research objectives, the UML diagrams are simply adopted for the structural and behavioral modeling. As a de facto standard, visual representation of object-oriented software system, UML provides a seamless connection between the system implementation and design model in both robotics and android platform. Therefore, it is straightforward to show the implementation has a consistent relation to the design model. Other than this, the researcher set out to achieve the high degree of portability by using the mobile platform which can be carried out in any Android supported device.

Moreover, tracking the robot is a big issue as well as a challenge for the system because of its varying accuracy and robot's frequent movement on the ground and Android is highly capable of detecting and then pin-point location by finding the absolute position of objects as it supports very strong GPS positioning API. To ensure the proposed system achieve desired properties in terms of robustness and reliability, a systematic specification-based unit testing methodology was adopted and implemented on the Android controlled robotics system. The assertions are defined on the structural and behavioral model of UML diagram for the purpose of validating the prospective system. Fundamentally, finding out the possible crash points, potential execution fault, conventional mistakes in robotic software development and efficacious solutions to those problems are the broader research objectives of the system[46].

Another study opined that Wireless Sensor Network (WSN) can be defined as a group of sensors for monitoring and recording system conditions, which are wirelessly transferred to a central location. In recent years, the development of smart sensors has led WSNs to gain worldwide attention. Some trending applications on WSNs are target tracking, health monitoring, and environment exploration. Smart sensor nodes are low-power devices equipped with one or more sensors, a digital processor, memory, a power module, a wireless communication module, and an actuator. Sensors of different nature (mechanical, optical, magnetic, etc.) may be attached to the sensor node to measure system variables. Since memory of the sensor nodes is limited, the wireless communication enables transferring of the measured data to a base station (e.g. a laptop), which is usually provided with powerful processing and storage capabilities. In this way, the base station may be able to compute complex control algorithms. The proposed energy-efficient control solution for a UGV in a WSN enables lowering the number of transmissions through the network, which results in bandwidth and battery saving, despite keeping a satisfactory system performance. The solution integrates dual-rate control, periodic event-triggered control, packet-based control, and time-varying dual-rate Kalman filter-based prediction techniques. Additionally, the approach deals with wireless communication problems (such as time-varying delays, packet dropouts, and packet disorder) and copes with a realistic scenario where measurement of noise and external disturbance can occur[47].

According to a study, science has brought out wondering technologies to ease human life. Robotics is one of the branches of science which has made human life easier and lessened the workload. It has also enabled us to reduce the participation of human in risky works. Nowadays, robots are being used for various purposes in industries, laboratories, space and also in battlefield. People are sending robots to places where man can hardly go like in space, underwater, bomb surrounded areas. Wireless communication system has become one of the essential features for commercial products and a popular research topic within the last ten years. There are now more mobile phone subscriptions than wired-line subscriptions. Lately, one area of commercial interest has been low-cost, low power and short distance wireless communication used for personal wireless networks. Technology advancements are providing smaller and more cost-effective devices for integrating computational processing, wireless communication and a host of other functionalities. Sophisticated technology advancing day-by-day and robotics has become a promising field for research in this race. Military personnel now use robots for reducing causalities and to defeat their enemies. The major focus of the research is on the use of robot in war, peace and as well as their impact on society. Here, Radio Frequency (RF) module signals are used in wireless remote-control system for transmitting and receiving wireless signals to control the motors and actuators of robot control system. Night vision monitoring system has been added which will capture and transmit the information surrounding the robot to the operator. With this feature, the robot can not only transmit real time videos with night vision capabilities but cannot be identified by the enemies in war zone. A metal detector and GSM module have also been added which will inform the user about any bomb underneath the robot vehicle. Another assistive feature here added is a robotic arm that has been installed to pick or drop some object if needed[48].

For the past decade, robotic systems have been successfully used to perform specific tasks with various degree of intelligence. Now-a-days, commercial robotic solutions are focusing more on personal services. Personal services robots are designed with necessary mobility and functional capabilities so that they can operate in a wide range of environment and can provide variety of services including health care, educational, domestic chore, entertainment, and rehabilitation. These personal robots perform various tasks that are often unpredictable in nature. But there are some technological challenges that need yet to be resolved. Integrating a robotic system with its components is usually a very complex task. Developing a modular robotic system that can perform well in various environments is also challenging. In addition, robots should be provided with necessary skills so that they can perform various tasks. Keeping all these challenges in mind, a networked robotic system was presented in the work. The system is controlled by a smart phone. The path followed by the robot can be monitored via a LED panel. In order to control the operation, an Android OS mobile application was developed. Through this application, a user can set a path for the robot to follow or can choose a path from a set of already defined paths. We tested our system in a controlled environment and the test results show that the robot can follow a path (either user defined or chosen) with a high accuracy[49].

Design, construct and fabricate a multi-purpose field surveillance robot that can be used for land mine detection, toxic gas sensing temperature and humidity sensor monitoring in war fields without putting serious manual risks. The land mine detector can detect covered metals, gas sensor can detect toxic gas attacks and the robot can be controlled wirelessly by Android phone. The robot uses Arduino Uno microcontroller to gather sensor information and Node MCU Wi-Fi to interface the controller and the robot. Based on the input information from Android application, the robot can move and climb on any terrains. The distinguishing feature of the system from traditional one is that the integrated design of Android phone operation and multiple IoT cloud servers. All robotic sensor information is delivered to the cloud servers and viewed through webpage. This way, the robot can be used both at military war fields and monitored at military headquarters simultaneously. This is a novel attempt to integrate field robots and IoT technologies at an expandable mode of design. Additional enhancement of the design made it an outstanding choice for deployment and use in dangerous zones infested with land mines and other hazardous metallic items. Integration of modern IoT technology has profoundly supplied bounteous information of the field area at anytime and anywhere in the world. Use of cloud technology makes the robot a market demand product and a must for military operations[50].

The motion control of unmanned ground vehicles is a challenge in the industry of automation. In the system, a fuzzy inference system based on sensory information is proposed for the purpose of solving the navigation challenge of unmanned ground vehicles in clustered and dynamic environments. The representation of the dynamic environment is a key element for the operational field and for the testing of the robotic navigation system. If dynamic obstacles move randomly in the operation field, the navigation problem becomes more complicated due to the coordination of the elements for accurate navigation and collision-free path within the environmental representations. The research considered the construction of the fuzzy inference system which consists of two controllers. The first controller uses three sensors based on the obstacle's distances from the front, right and left. The second controller employs the angle difference between the heading of the vehicle and the targeted angle to obtain the optimal route based on the environment and reach the desired destination with minimal running power and delay. The design shows an efficient navigation strategy that overcomes the current navigation challenges in dynamic environments. Experimental analyses were conducted for three different scenarios to investigate the validation and effectiveness of the introduced controllers based on the fuzzy inference system. The reported simulation results were obtained using MATLAB software package. The results show that the controllers of the fuzzy inference system consistently perform the maneuvering task and manage the route plan efficiently, even in a complex environment that populated with dynamic obstacles. The design demonstrates that the destination was reached optimally using the shortest-free route. **T**he work represents efforts toward building a dynamic environment filled with dynamic obstacles that move to at various speeds and directions. The methodology of designing the fuzzy inference system is accomplished to guide the unmanned ground vehicle to the desired destination while avoiding collisions with obstacles. However, our methodology is approached using two-dimensional analyses. Hence, the work suggests several extensions and variations to develop a three-dimensional strategy for further improvement. This research presents the design of a fuzzy inference system and its characterizations in dynamic environments, specifically for obstacles that move at different velocities. That facilitates an improved functionality of the operation of unmanned ground vehicles[51].

The intention of the high-level technology is that it serves with high speed to command the robots. To realize the above standards, some technical improvements along with the need of high-performance robot is for a faster, reliable, accurate and intelligent robot which is devised by advanced control algorithm, devices and new drivers. In the olden days, robots were working based on the wired networks but now-a-days, they are made to follow the user commands. So, robots are very user friendly. Technologies have developed far aside in the defense field. To make more efficient, we have designed a new modern efficient SPY BOT which plays a major role in spying as a support. This robot is small and easy to transport. The intervention troop uses a camera to capture the data such as images and videos. The intention is to reduce human victims in terrorist attacks. Thus, by designing a RF-based spy robot which has a wireless camera and nano-quad which can spy enemies secretly and also enter in restricted areas[52].

Robots remain the focus of researchers and developers, and now they are moving towards IoT based devices and mobile robots to take advantage of the different sensor-enabled facilities. A robot is a machine capable of carrying out a series of complex actions automatically, especially one programmable by a computer. A robot can be controlled by a human and modified by its functionality at runtime by the operator. From past few decades, researchers are contributing towards robotics. There is no end of technology, creativity and innovation. The system was designed to develop a robot using android application for remote operation attached to the wireless camera for monitoring purpose. Surveillance using the camera can help the soldier team to make strategies at run-time. This kind of robot can be helpful for spying purpose in war fields. The android application loaded on mobile devices can connect to the security system and easy to use GUI and visualization of the Warfield. The security system then acts on these commands and responds to the user. The camera and the motion detector are attached to the system for remote surveillance using wireless protocol 802.11, ZigBee and Bluetooth protocols. This robot is having the functionality of mines detection, object detection, GPS used for location and navigation, and a gun to fire the enemy at the runtime. Army is doing researches on this type of ideas and doing their laboratory works to build a capable working robot. It will replace the humans and will save many lives in critical situations. It is believed and hopeful that the idea will bring a significant change in our technical field and our minds[53].

Robotics have helped humans greatly in achieving everyday tasks. Robots are designed to work in any environment and perform task on behalf of humans. They operate under real-world and real-time constraints where sensors and effectors with specific physical characteristics have to be controlled. In many cases, those robots are controlled manually to move from one destination to another. However, a number of studies have been carried out on autonomous robots leading to a whole panoply of potential applications of these autonomous robots. An Unmanned Ground Vehicle (UGV) is a vehicle that operates while in contact with the ground and without an onboard human presence. An in-depth literature review was carried out in this research so as to explain the techniques and algorithms used in the design of autonomous vehicles. The different techniques for object detection and avoidance have been critically analyzed. After having done a thorough study and analysis of related approaches, the low-cost Autonomous Unmanned Ground Vehicle (AUGV) was designed. A prototype has been developed and was tested based on a number of scenarios. A list of lessons learnt in the implementation of the low cost AUGV has been identified. In this design, a low cost has been implemented using a Raspberry Pi, DC motors, a webcam, infrared, servo and ultrasonic sensors. The AUGV operates in two modes: the remote-controlled mode, and the autonomous mode. In the remote-controlled mode, the user has complete control over the vehicle and move the vehicle similar to a remote-controlled car with live video streaming on a mobile application. In the autonomous mode, the mobile application is used to select the source and destination of the Autonomous Unmanned Ground[54].

In this; research, a strategy based on model predictive control consisting of path planning and path tracking is designed for obstacle avoidance steering control problem of the unmanned ground vehicle. The path planning controller can reconfigure a new obstacle avoidance reference path where the constraint of the front-wheel-steering angle is transformed to formulate lateral acceleration constraint. The path tracking controller is designed to realize the accurate and fast following of the reconfigured path, and the control variable of tracking controller is steering angle. In this work, obstacles are divided into two categories: static and dynamic. When the decision-making system of the UGV determines the existence of static obstacles, the obstacle avoidance path will be generated online by an optimal path reconfiguration based on direct collocation method. In the case of dynamic obstacles, receding horizon control is used for real-time path optimization. To decrease online computation burden and realize fast path tracking, the tracking controller is developed using the continuous-time model predictive control algorithm, where the extended state observer is combined to estimate the lumped disturbances for strengthening the robustness of the controller. Finally, simulations show the effectiveness of the proposed approach in comparison with nonlinear model predictive control, and the Car Sim simulation is presented to further prove the feasibility of the proposed method[55].

An alarming increase in risks has recently been observed, coming from both natural and artificial sources. Among the risks caused by technological hazards, the most frequent and significant risks are estimated for fires and radiation, depending on their frequency, complexity, and consequences. The risks by natural causes which contribute to the worsening of emergencies, include climate change as in the "Hyogo Framework for Action". Response personnel in reported cases are permanently at risk, which could even include death, regardless of the equipment and substances used to protect them from the effects of radiation and fire. The multiple causes of death of firefighters during missions include smoke inhalation, burns, crush injuries, and trauma. The design errors of the intervention robots are mainly due to the lack of standards for their geometric aspects. The size of an intervention robot must take into account certain factors determined by the characteristics of the missions it must perform. As no standardization is available to facilitate the preparation of specifications, we focused our research on proposing an intervention robot system. The proposed system is an integrated model, with a propulsion/transport platform and an operational platform, which allows the simultaneous acquisition of data and their transmission to a ground control station (GCS) with movement in the area of action, which allows data analysis, decision making, and autonomous intervention. The solution implemented with inertial sensors proves its effectiveness, especially when the robot is moving on rough terrain (specific to an unstructured environment). These results also reaffirm the idea that if the missions could be conducted in screen). These results also reaffirm the idea that if the missions could be conducted in screened areas where satellite systems have no signal (caves, salt mines, subway, etc.), the inertial sensory system would allow the identification of specific parameters[56].

Quadruped robots have increasingly been used in complex terrains where barriers and gaps exist. In this paper, a four-legged robot with intelligent controllers is designed and simulated. The designed architecture comprises 12 servo motors, three per leg, to provide considerable flexibility in movement and turning. Proportional Integral Derivative (PID) controllers and fuzzy controllers are proposed to control and stabilize the motion of the quadruped robot. An ant colony optimization algorithm has been utilized to tune the parameters of the PID controller and the fuzzy controller. After obtaining the optimal values of both controllers, the entire architecture is implemented using the Multibody Simscape package in MATLAB which models multidomain physical systems. The simulation results are conducted in a 3-dimensional environment and they are demonstrated in three case studies; firstly, when the system is simulated without using a controller which leads to a collapse of the quadruped robot. Secondly, when the PID controller is combined with the system, better movement is obtained. However, the quadruped is unable to complete its path and collapses after a few meters. Thirdly, when the fuzzy controller is integrated into the designed architecture, a significant improvement is observed in terms of minimizing elapsed time and improving the overall performance of the motion. The stability of the fuzzy controller has been examined using Lyapunov criteria to; validate its overall performance. Comparisons are conducted based on control efforts and travelled distances to demonstrate the suitability and effectiveness of Fuzzy controllers over PID controllers[57].

Unmanned Ground Vehicles (UGV) modeling with traditional force analysis may cause mismatching between the established model and actual system due to parameter uncertainty and inconsistency. So, the simulation of traditional model makes no sense while applied to actual use. In this paper, an attempt is made to establish a function relationship among variables based on force analysis, then consider the inherent delay characteristics of the UGV and add the road slope as disturbance. Thus, by means of learning algorithm to fit parameters, the optimized model in complex environment is built. The fitted parameters and simulation results show that the established optimization model is consistent with actual system. A split-phase controller is designed for vehicle longitudinal speed control and a selection strategy of throttle threshold and brake threshold in phase controller is proposed. Simulation results in MATLAB/Simulink shows that the proposed threshold selection strategy can make the system response fast and stable without frequently switching the controller[58].

In a work to illustrate the benefits of an autonomous fire-fighting robot design as an effective tool for undergraduate education. The primary goal of the design work is to create an autonomous mobile robot that navigates through a maze searching for a fire (simulated by a burning candle), detects the candle's flame, extinguishes the flame and returns to a designated starting location in the maze. The fire-fighting design contest promotes interdisciplinary design and teamwork. Three themes appear throughout the research: the fire-fighting robot project promotes interdisciplinary team-based education; students benefit from contest participation, and fire-fighting robot design promotes realization of the ABET educational outcomes.

Creating a fire-fighting robot provided a valuable experience to students from the three institutions. First, the work encourages students to incorporate their skills and knowledge, applying them to a real-world problem which is one of the desired characteristics for engineers. Second, the project gave ample opportunities for students to practice technical skills learned in their engineering courses, benefiting the students with practical applications of the skills they learned. Third, the work was a motivational tool for students to learn new concepts on their own. In summary, the study showed that the fire-fighting robot system is an effective educational tool to encourage and motivate engineering students to be innovative in combining knowledge and concepts learned into a real-life system[59].

Security robot has become one of the most important research topics over the past decades. A number of robots have been designed to safeguard human life and wealth. The paper focuses on design and implementation of mobile robot with three subsystems: The obstacle avoidance, face recognition and detection leakage of combustible gases. In the first subsystem, an implementation of artificial neural network on field programmable analog array has been used to control the motion of the robot. A combination of principle component analysis and linear discriminate analysis feature extraction algorithms with support vector machine classifier is used in the second schema. The third subsystem uses MQ4 sensor with addition circuit to detect the leakage of combustible gases. Finally, the MATLAB environment is used to implement the proposed subsystems and the experimental results demonstrate the efficiency and robustness of these subsystems[60]..

Current practice for the detection of Chemical Biological and explosive (CBE) agent contamination on environmental surfaces requires a human to do protective gear, manually take a sample and then package it for subsequent laboratory analysis. The design describes the feasibility demonstration of a CBE detection system based on Raman spectroscopic measurements integrated to a commercially available UGV platform. Raman detection offers potential advantages over immunoassay and DNA–

based biological detection strategies using reagents, especially when configured for use on an unmanned vehicle. Raman measurements are reagent less, greatly simplifying the logistics of deployment. In addition, Raman measurements can be used to detect a broad range of CBE threats in a single measurement cycle. No assumption of the possible threat is required as in the case of reagent-based detection schemes[61].

The Raman detector built in this study consists of a detector head mounted in the gripper of a UGV manipulator arm and an instrument package mounted on the UGV chassis. The UGV chosen for the integration testing was the ARES (Applied Perception). This UGV is built on the RMP 400 mobility platform (Segway) and provides a JAUS compliant environment for up to two payload modules. The feasibility of a Raman detector integrated in a JAUS-compliant UGV for use in the remote detection and identification of CBE agents in military and homeland security situations was demonstrated. This study showed that a Raman sensor designed for the detection of biothreat agents could also be extended to the detection of RDX explosive on surfaces[62].

Robots are smart machines that can be programmed and used in many areas such as industry, manufacturing, production lines, or health, etc. Today, human-machine interaction is moving away from mouse and pen and is becoming pervasive and much more compatible with the physical world. With each new day, the gap between machines and humans is being bridged with the introduction of new technologies to ease the standard of living. As the smartphone era has evolved with innovative android-based applications, engineers are improvising them to improve robotic vehicles which diminish the aforesaid abyss. In the paper, the researcher developed a three-way control for the robotic vehicle in which we have used Bluetooth communication to interface the microcontroller and the inbuilt sensors in the android smartphone. According to commands received from android phone, the kinematics of the robot is controlled. The developed robotic vehicle can be used for numerous applications in the future especially in the field of surveillance and security. Smartphone, a compact rather powerful device is rapidly breaking the traditional barriers that come in the way of human-machine interaction. Smartphone in the recent times have become more affordable and efficient devices which can be used to support collaborative activities in a community. It is a result of a huge advancement in mobile phones technology. Humans are anxiously working on finding new ways of interacting with machines. Modern smartphone comes equipped with different sensors such as proximity sensor, accelerometer sensor, ambient light sensor and many more. They also have features like Bluetooth and extremely powerful operating systems such as Symbian, Bada, and Android OS and so on. This design presents three approaches of controlling a robotic vehicle using an android smartphone. Android smartphones are available at reasonable price in the market. As there is a huge increment in the number of people using android smartphone, the possibility of exploiting various applications using the smartphone also increases. Every android smart phone has a Bluetooth which provides the ability to connect to other Bluetooth devices wirelessly without an internet connection. The robotic vehicle can be easily controlled by installing the Android Application Package (APK) files of the three applications on the android smartphone. Then, a connection is established between the application and the Arduino via the Bluetooth module. The instructions are passed from the smartphone to the microcontroller. Based on the instructions, different signals are sent out to the motor driver, which ultimately drives the motors attached to the wheel. This technique could be easily used in other applications. Instead of just one, multiple motor drivers can be used. These motor drivers can be used to control any kind of motor[63].

Robot is a reprogrammable, multifunctional device which is primarily designed to do work like human such as pick and place, loading and unloading, surveillance, health care, industrial, aerospace application. This is also an electromechanical machine that is controlled by computer programs to perform various operations. Robots can perform dangerous and accurate work to increase the productivity as they can work 24 hours without rest. This work deals with the design and control of automated vehicle type robot which can move in desired direction and captures pictures and videos of required location. An android application was developed using MIT App inventor and a Bluetooth communication is made with robot which interfaces with microcontroller to control its speed and direction. The work aims to design and control the motion of robot using Bluetooth device of an Android phone[64].

Nowadays, android smartphones are the most popular gadgets. There are multiple applications on the internet that exploit in-built hardware in these mobile phones, such as Bluetooth, Wi-Fi and ZigBee technology to control other devices. With the development of modern technology and Android smartphone, Bluetooth technology aims to exchange data wirelessly at a short distance using radio wave transmission comprising features to create ease perception and controllability. In the paper, a robot was designed that can be controlled using an application running on an android phone. It sends control command via Bluetooth which has certain features like controlling the speed of the motor, sensing and sharing the information with phone about the direction and distance of the robot from the nearest obstacle. The design was developed using other equipment like ultrasonic transceiver module, ATmega328 controller and L293D. Although, the research is still open for further development, it has proven to allow for meaningful two-way communication between the Android phone and the robot which would makes a non-expert to interact with and adjust the functionality of a system which uses ATmega328 controller. A single board micro-controller made the application of interactive objects or environments more accessible[65].

According to the paper, it is concentrated on the terrorists and their bomb attacks. Even though a bomb is found, it is much more complicated to remove the bomb safely. Many lives are depending on the bomb diffusion. The research work helps in diffusion of bombs with safe distance from the bomb. The bomb diffusion was control using wireless communication via android phones. Based on the work, bomb can be diffused from safe distance and it can save more lives. Bomb can also be sent by issuing few commands to the robot situated at a particular location and controlled by two motors situated at the wheels for direction control and other two motors at robot hand. With these four motors, the bomb can be used to control all the directions of the robot and at the same time and can pick any object at any direction. The design was developed using the Bluetooth module, motor driver (L293D), gear motors, wireless camera and LPC2148 micro controller. As the successful connection is established by switching on the robot, Bluetooth and the wireless camera video, the output is displayed on the monitor of the PC. Robot is moved as per the commands sent by the android phone and picked the object and placed at the safe place where they are needed to be placed. The work is very useful in industrial applications like assembling the parts and also mostly useful for defense operations like bomb diffusion. Even though bomb is detected, it is not easy to defuse by staying nearby. The work is as well useful in such that it can defuse the bomb by staying at safe distance[66].

The robotics and automation industry has ruled the sectors from manufacturing to household entertainments. It is widely used because of its simplicity and ability to meet changes needed. The research work is designed to develop a robotic vehicle using android application for remote operation attached with wireless camera for monitoring purpose. The robot along with camera can wirelessly transmit real-time video with night vision capabilities. This is kind of robot can be helpful for spying purpose in war fields. The work is designed to control a robotic vehicle using an android application. Bluetooth device is interfaced to the control unit on the robot for sensing the signals transmitted by the android application. The design used Atmel 89C51 microcontroller as control device. Remote operation is achieved by any smartphone, tablet etc. This work was able to achieve the control both wireless communication between the mobile robot android GUI Application. The work makes a surveillance robot which can be controlled by emerging android technology. It also gives versatile operation of robot controller which needs not modify the hardware. This system can further be developed by enhancing the performance and adding more features. The further development of the system depends on the application used. The system can add features like gas sensor, thermal image sensing, connecting robotic arms and can be used in pick and place purposes etc. The development of this system has wide area of applications such as in military and law enforcement agencies, industrial, disaster management and so on[67].

The objective of the research work is geared towards the development of a program or an Android app to control a robot powered by Arduino uno to using a motor driver shield, Bluetooth, modem and circuit design. The process involved building the robot which includes the assembling of a chassis used for the robot and programing the Arduino as well as the interface for the android device. This work documents the design process for the robot and programming for the android interface. The details of the project give the information about the different aspects of computing involved in whole project. The outcome of the work is a combination of embedded computing and; programming and the outcome is a simple robot which is controlled by a smartphone and also receives the voice commands. This work aims to provide simple guidelines for people interested in building robots. As mentioned earlier, the work has been carried out several times and the aim is to familiarize the students with fundamentals of Arduino and android to build useful system. Although the work focuses a very little about the use of robot in real world but with the help of guidelines and the abundance of resources, the outcome could be very beneficial for many people in the world. People with physical limitations such as handicapped people could use the feature from this system to compensate their abilities. The system gives detailed information about Arduino and the use of App Inventor for android application design.

The guidelines provided are very simple to use and understand and thus, making it very easy for the new students to build a foundation in their robotics learning as well as app design[68].

This research work is based upon electronic automation and smart control techniques, which constitute the basis of Control Area Network (CAN) and Personal Area Network (PAN). Bluetooth technology has been interfaced with a programmable controller to provide multi-dimensional vehicle control. A network is proposed which contains a remote, mobile host controller and an android-based operating system mobile set as client. The client communicates with host controller through Bluetooth device. The system incorporates duplex communication after successful confirmation between the host and the client. The android based mobile unit controls the vehicle through the Bluetooth module. A simple, low cost, user friendly and effective control system for MSV has been implemented using the android based SMART phone and the Bluetooth technology that is ideal for tactical remote surveillance and monitoring. The connected GUI is synchronized with the control board to indicate the real-time control action implementation feedback. For future development, the android GUI could be implemented with voice control. The android based GUI could also be replaced with windows-based GUI for making the system compatible with non-android based applications. The system can also be equipped with a wireless camera that transmits the real time images. The vehicle can also be replaced by an intelligent remote sensing robot with decision making capabilities[69].

New technology may be able to help answer the yearning to reduce casualties resulting from unfriendly fire and collateral damage, as well as assist the military in performing urban operations. Unmanned vehicles in the air, land or sea, are one means to get our airmen, soldiers, marines and sailors out of danger are most likely a key driver to an upcoming revolution in military affairs. The major objective of the paper is to bring attention to of Tactical Mobile Robots (TMR) and hopefully encourage follow up studies and to cultivate an enthusiasm to employ them correctly to help get our troops out of harms and win battles. The study also focuses primarily on the use of TMRs in the special operations environment. The work further discusses the current and immediate TMR capabilities; key logistics concerns regarding maintenance, supply, and transportation; and two possible scenarios, one in an unconstrained battlefield and t;he other in an urban environment. The methodology used was primarily via conducting interviews and witnessing experiments and they highlight a few barriers, which must be addressed if unmanned platforms are to keep pace with congressional orders[70].

The Android Mobile Phone Platform by Google becomes more and more popular among software developers because of its powerful capabilities and open architecture. It is based on the Java programming language. The researcher thinks it is a great platform for a robotic system control, as it provides plenty of resources and integrates a lot of sensors. The Java language makes the system very attractive to apply state-of-the-art software engineering techniques which is the main aim of research work. The unsolved issue makes the android device interoperate with the remaining parts of the robot components: actuators, specialized sensors and maybe coprocessors. In this work, the researcher discussed various connection methods and presents a first approach to connect android with the LEGO Mindstorms NXT robotic system which he successfully used in the robotic/software engineering courses[71].

The project aims at designing a robot that can be operated using android mobile phone. Operating the Robot wirelessly through mobile phone, usage of android touchscreen smartphone in performing the task with Bluetooth wireless transmission and indicating robot directions using LED indicators. The controlling device of the whole system is a microcontroller. Bluetooth module, DC motors are interfaced to the microcontroller. The data received by the Bluetooth module from android smartphone is fed as input to the controller. The controller acts accordingly on the DC motors of the robot. The robot in the system can be made to move in all the four directions using the android phone. The direction of the robot is specified using LED indicators of the robot system. In achieving the task, the controller is loaded with a program written using embedded C language. Bluetooth is an open standard specification for a Radio Frequency (RF)-based, short-range connectivity technology that promises to change the face of computing and wireless communication. It is designed to be an inexpensive, wireless networking system for all classes of portable devices, such as laptops, PDAs and mobile phones. It will also enable wireless connections for desktop computers, making connections between monitors, printers, keyboards and the CPU cable-free[72].

In industrial robotic environments, there are many different robots performing a variety of tasks. Each robot is controlled by its own teach pendant or via a networked socket application. However, to monitor the status or make minor changes to the programming of the robot, the user must obtain access to the teach pendant or terminal. In an effort to eliminate this need, this researcher introduces an android platform that communicates with robots over a Bluetooth connection[73].

In a study that proposed an autonomous robot system which can sense the environment temperature and transfer the value to a PHP server via Bluetooth android application. Temperature is a common variable in many systems and processes. In most industries, there are several equipment to sense the temperature, but it is preferable to automate the measurement process. Thus, robot can be used as an early detector of fire in forest and also as a sensor kit in warehouses, hospitals, etc. In the work, the researchers explore a mobile robot which is used for autonomous temperature measurement. It is controlled by the instruction of the user from mobile phone. The sensed temperature data are sent to a web server via Bluetooth. It is also possible to view the temperature details in a mobile phone with the use of a simple android application. The idea of implementing Bluetooth technology is for safety purpose and is very useful especially in application where risk is a concern[74].

In this work, an algorithm is used for path planning in a fixed range-only beacon field. In this design, entropy is calculated for values for regions of interest and provides a method for finding safe, low-entropy paths between regions. The researcher went on to describe a robotic system for performing range-based localization experiments, developed using inexpensive off-the-shelf components. This system uses a commercial robot as a mobile platform and custom acoustic beacons for ranging[75].

Considering the aforementioned literature, this project is an improvement on the conventional method through the provision of android phone as control remote using WIFI. This control remote is created via WIFI using ESP32 camera that can be assessed in any device inside any local network area. The independence from network connectivity and sophistication of ESP32 camera ensures reliability even in remote environments which improve the automated response capabilities, indicating a potential area for integrating more autonomous features.

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Chapter Three
Methodology

3.1 Introduction

The research design, implementation, testing and troubleshooting are all covered in this chapter. This research is a prototype that shows how available components may be combined to create a functional security device. The components were chosen based on the information supplied by the different data sheets. In a big system, all of the units that make up this type of research work will require accurate and detailed designs. Individual elements were designed individually and then merged to build up the proposed system using a modular design methodology.

3.1.1 Components of the Robot

a. L298N Motor Driver Module
b. Power supply (Battery pack, e.g., 18650 batteries or Power Bank)
c. 1K and 2K Resistors
d. Esp32-camera module
e. Mini Breadboard ES
f. Screws and Nuts
g. Gum and Seal Tape
h. Smart Robot Chassis Kit (with motors and wheels)
i. Breadboard (optional, for easier connections)
j. USB to Serial Adapter (for programming the ESP32-CAM)
k. Capacitors and Resistors (as needed for stabilizing power)

3.2 Component Diagrams

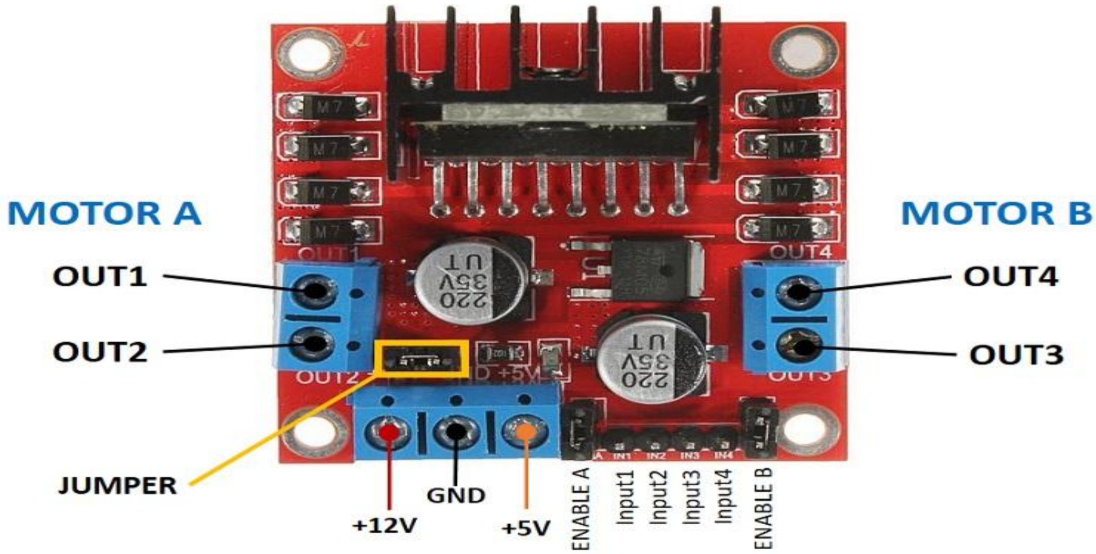


Figure 3.1: L298N Motor Driver Pin Point
Source[4]

Figure 3.2: The Spy Vehicle Chassis with Wheels mounted
Source[4]

Figure 3.3: Arduino UNO Board smd
Source[4]

3.3 System Design

The design methodology employed in this project involves a modular design approach, integrating off-the-shelf components such as Arduino IDE, ESP32-camera, motor drivers, and various power sources. The robotic vehicle operates via commands transmitted from an android application, enabling it to move in pre-determined directions and relay visual data back to the base station through an ESP32-camera that controls the robot using a web server programmed with the help of an Arduino IDE. This independence from network connectivity ensures reliability even in remote environments. These processes were well explained thus below.

3.4 The Ground Vehicle (Robot)

The spy vehicle consists of units as follows:

- The chassis
- The power supply unit
- Control Unit (wi-fi)
- ESP 32 CAMERA
- Motor Driver L298N

A. The Chassis

As a result of the fact that the ground vehicle has four (4) wheels, the chassis is designed to resemble a car. The chassis was made by cutting a flat piece of polyvinyl chloride (PVC) into a suitable frame for mounting four brushed DC motors. The DC motor connections were wired and dragged to the backside of the chassis where they would be connected to the control unit. With the motors held in; place on the chassis, the wheels were then attached to each motor at the edge of the chassis to allow easy movements of the vehicle.

Figure 3.4 Robot Car Chassis Kit
Source[4]

B. Power Supply Unit

We suggest soldering a 0.1 uF ceramic capacitor to the positive and negative terminals of each motor to help smooth out any voltage spikes. Additionally, you can solder a slider switch to the red wire that comes from the power bank. This way, you can turn the power on and off. each motor to its terminal block.

Finally, apply power with a power bank. You need to strip a USB cable. In this example, the ESP32-CAM and the motors are being powered using the same power source and it works well.

C. The Control Unit (Wi-Fi)

The robot will be controlled via Wi-Fi embedded in ESP32-CAM. A web-based interface is created to control the robot, that can be accessed in any device inside any local network area.

Figure 3.5: Control Unit wi-fi
Source[4]

Important to note: without an external antenna the video stream lags and the web server is extremely slow to control the robot.

D. ESP32-Cam Video Streaming Web Server (works with Home Assistant)

In this project an IP surveillance camera with the ESP32-CAM board will be used. The ESP32 camera is going to host a video streaming web server that you can access with any device in your network.

Figure 3.6: ESP2-CAM Surveillance Camera
Source[4]

Video Streaming Server

Installing the ESP32 add-on

An Arduino IDE is used to program the ESP32-CAM board and so an Arduino IDE will be installed as well as the ESP32 add-on.

Then, we have to make sure we select the right camera module. In this case, we're using the AI-THINKER Model.

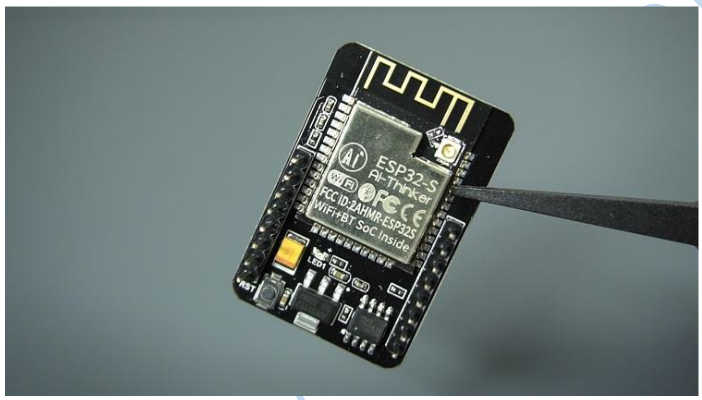


Figure 3.7: ESP32-AI Thinker Camera Model
Source[4]

Uploading the Code

Connect the ESP32-CAM board to your computer using an FTDI programmer. Follow the next schematic diagram:

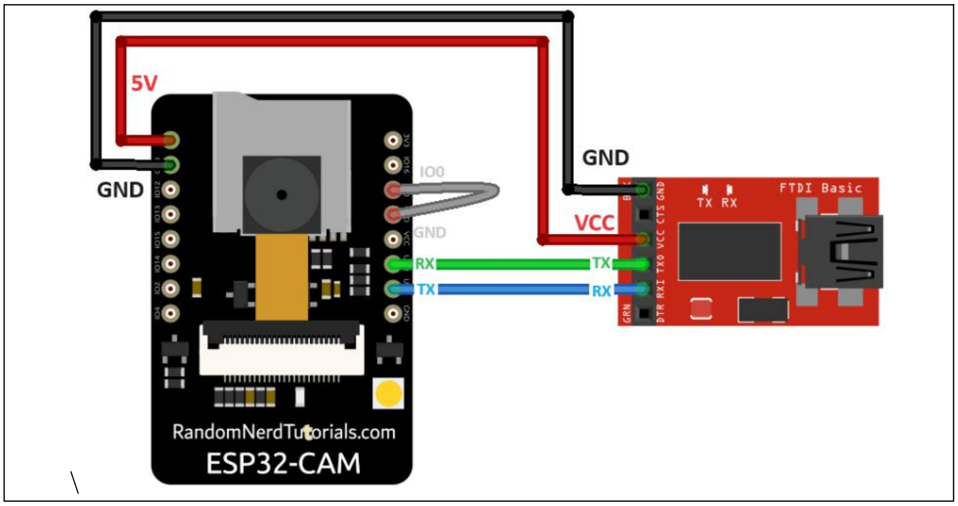


Figure 3.8: System Diagram of uploading the ESP32-camera
Source[4]

Many FTDI programmers have a jumper that allows you to select 3.3V or 5V. Make sure the jumper is in the right place to select 5V.

Important: GPIO 0 needs to be connected to GND so that you're able to upload code.

ESP32-CAMERA	**FTDI PROGRAMMER**
GND	GND
(5V)	VCC (5V)
U0R	TX
U0T	RX
GPIO 0	GND

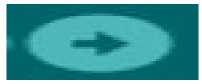
Table 3.1: GPIO connection to GND
Source[4]

To upload the code, follow the next steps:

1) Go to Tools > Board and select AI-Thinker ESP32-CAM.

2) Go to Tools > Port and select the COM port the ESP32 is connected to.

3) Then, click the upload button to upload the code.



4) When you start to see these dots on the debugging window as shown below, press the ESP32-CAM on-board RST button.

After a few seconds, the code should be successfully uploaded to your board.

Getting the IP address

After uploading the code, disconnect GPIO 0 from GND. Open the Serial Monitor at a band rate of 115200. Press the ESP32-CAM on-board Reset button.

The ESP32 IP address should be printed in the Serial Monitor.

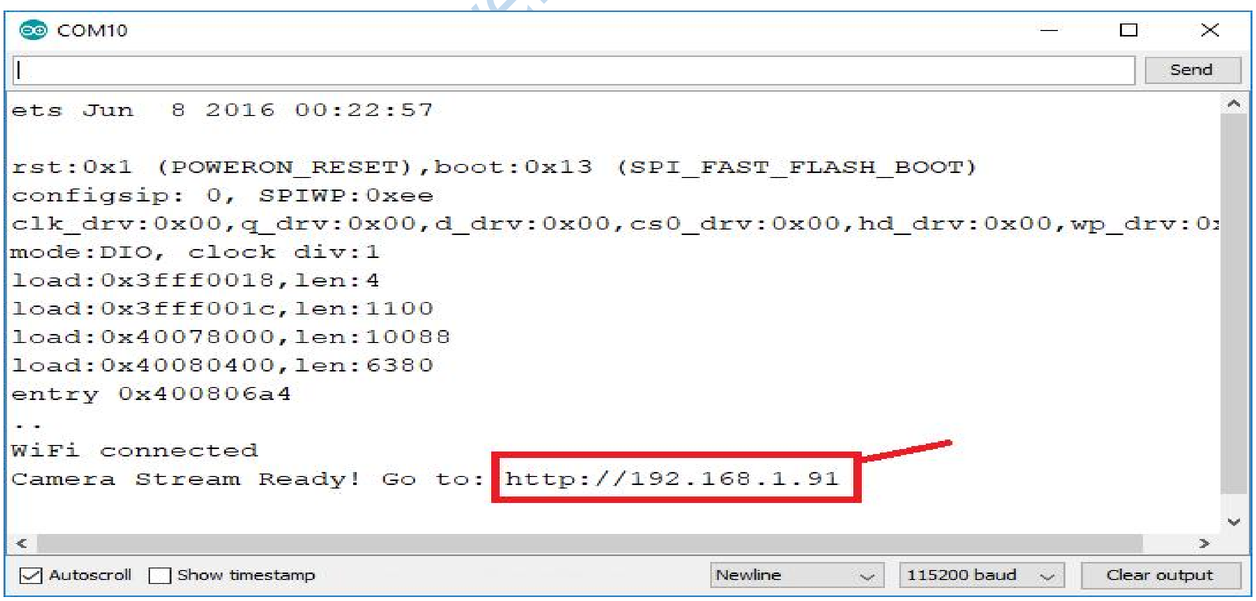


Figure 3.9: ESP32 IP address generation
Source[4]

Accessing the Video Streaming Server

By accessing the access, the camera streaming server on the local network. We need to open a browser and type the ESP32-CAM IP address. A page with the current video streaming should load thus below:

Source[4]

Home Assistant Integration

Having just the ESP32-CAM working via IP might be useful for most people, but you can integrate this project with Home Assistant (or with other home automation platforms).

Troubleshooting

- Failed to connect to ESP32: Timed out waiting for packet header
- Camera in it failed with error 0x20001 or similar
- Brown out detector or Guru meditation error
- Sketch too big error – Wrong partition scheme selected
- Board at COMX is not available – COM Port Not Selected

- Program error: GPIO service is not installed
- Weak Wi-Fi Signal
- No IP Address in Arduino IDE Serial Monitor
- Can't open web server
- The image lags/shows lots of latency

E. L298N Motor Driver

There are many ways to control DC motors. The use of L298N motor driver that provides an easy way to control the speed and direction of 2 DC motors was used as part of the robot components.

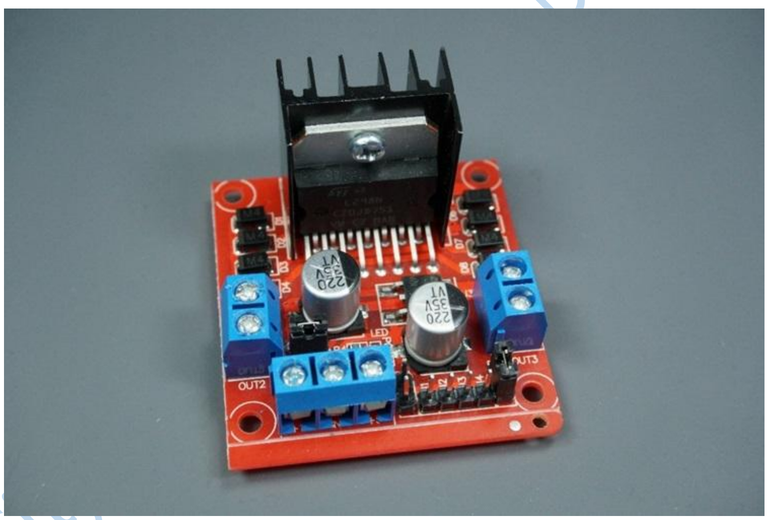


Figure3.10: L298N Motor Driver
Source[4]

3.5. Robot Controls

The web server has 5 controls: **Forward**, **Backward**, **Left**, **Right**, and **Stop**.

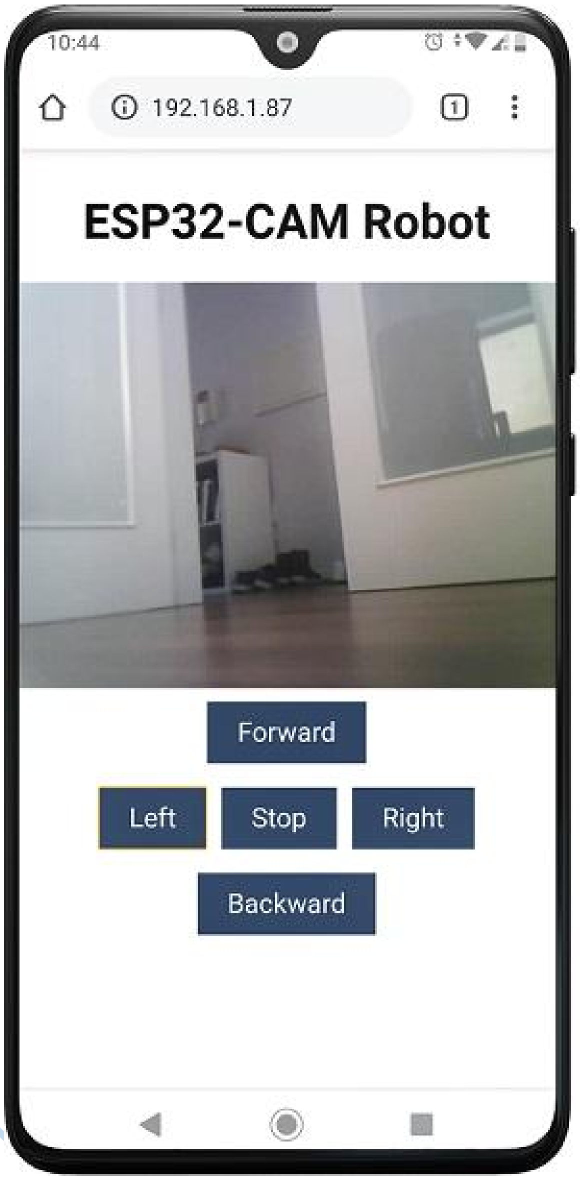


Figure 3.11: Robot Controls image

Source[4]

The robot moves as long as you're pressing the buttons. When you release any button, the robot stops. However, we've included the **Stop** button that can be useful in case the ESP32 doesn't receive the stop command when you release a button.

3.6 How the Code works with the relevant parts to control the robot

Let's take a look at the relevant parts to control the robot. Define the GPIOs that will control the motors. Each motor is controlled by two pins.

3.6.1 The requests made depending on the button that is being pressed:

Forward:

<ESP_IP_ADDRESS>/action?go=forward

Backward:

/action?go=backward

Left:

/action?go=left

Right:

/action?go=right

Stop:

/action?go=stop

When you release the button, a request is made on the /action?go=stop URL. The robot only moves as long as you're pressing the buttons.

3.6.2 Handle Requests

To handle what happens when we get requests on those URLs, we use these if… else statements

3.7 Testing the Code

After uploading, open the Serial Monitor to get its IP address.

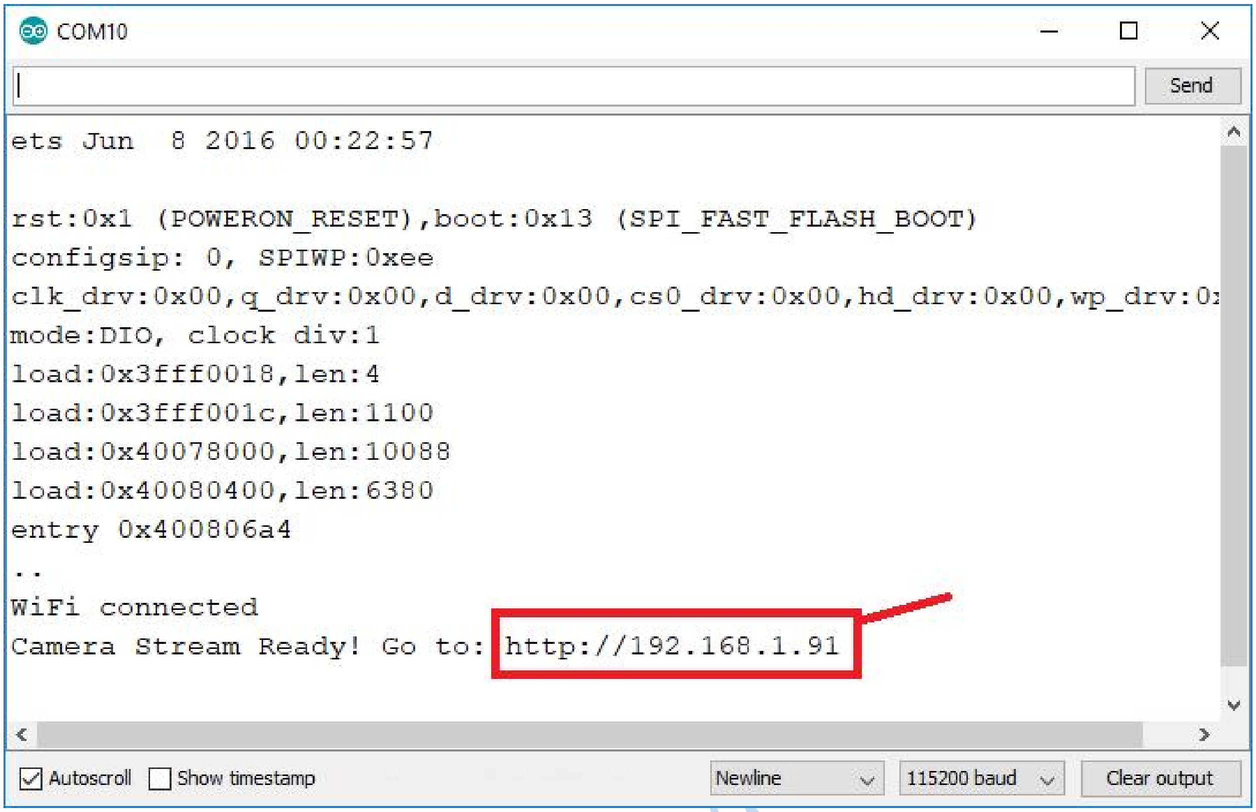


Figure 3.12: Test code display page

Source[4]

Open a browser and type the ESP IP address. A similar web page should load:

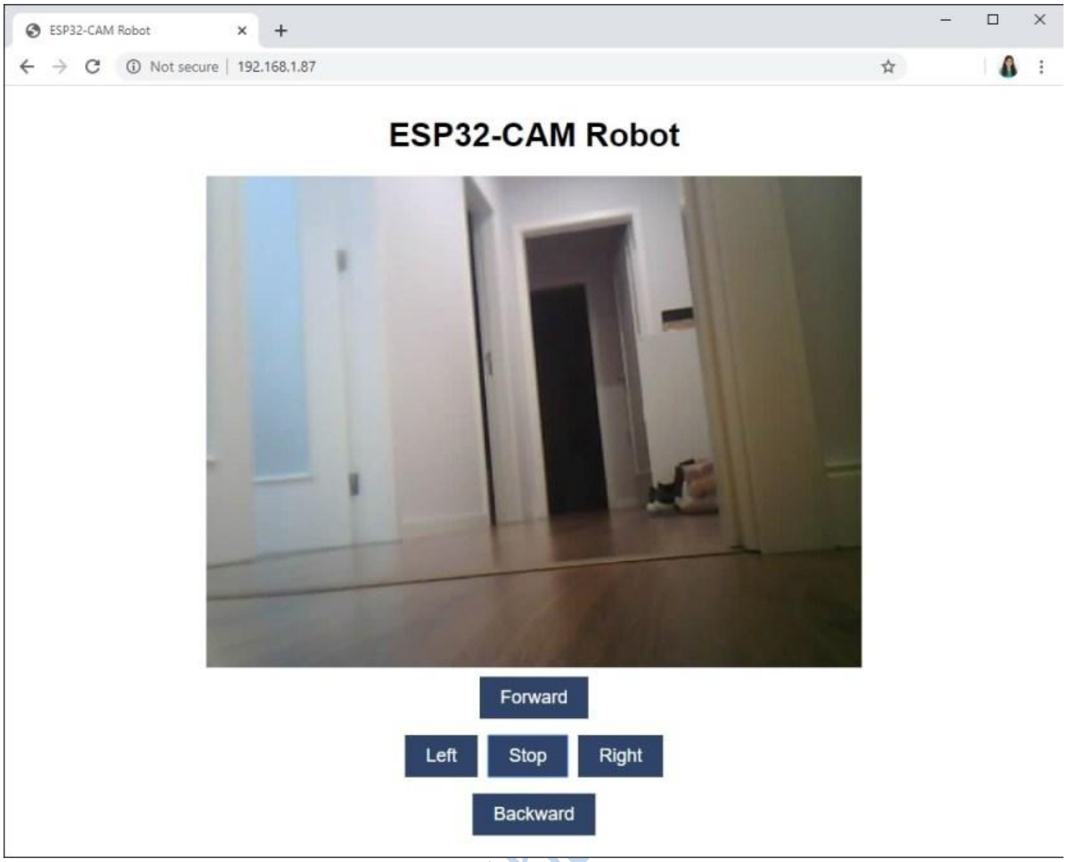


Figure 3.13: ESP32-cam web screen display page

Source[4]

Press the buttons and take a look at the Serial Monitor to see if it is streaming without lag and if it is receiving the commands without crashing.

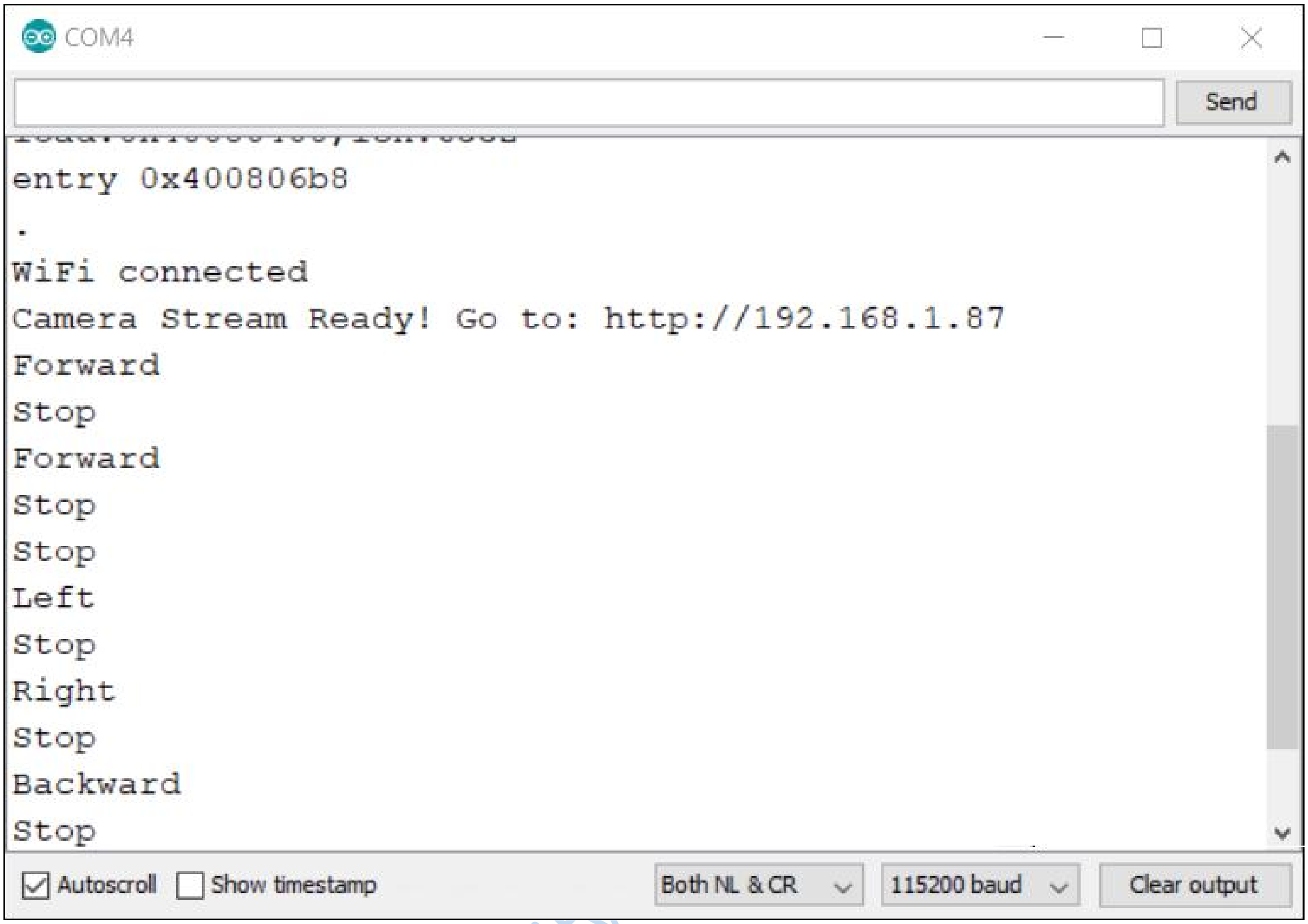


Figure 3.14: WI-FI connection display page

Source[4]

If everything works properly, then we assemble the circuit.

3.8 Circuit

After assembling the robot chassis, you can wire the circuit by following the next schematic diagram below:

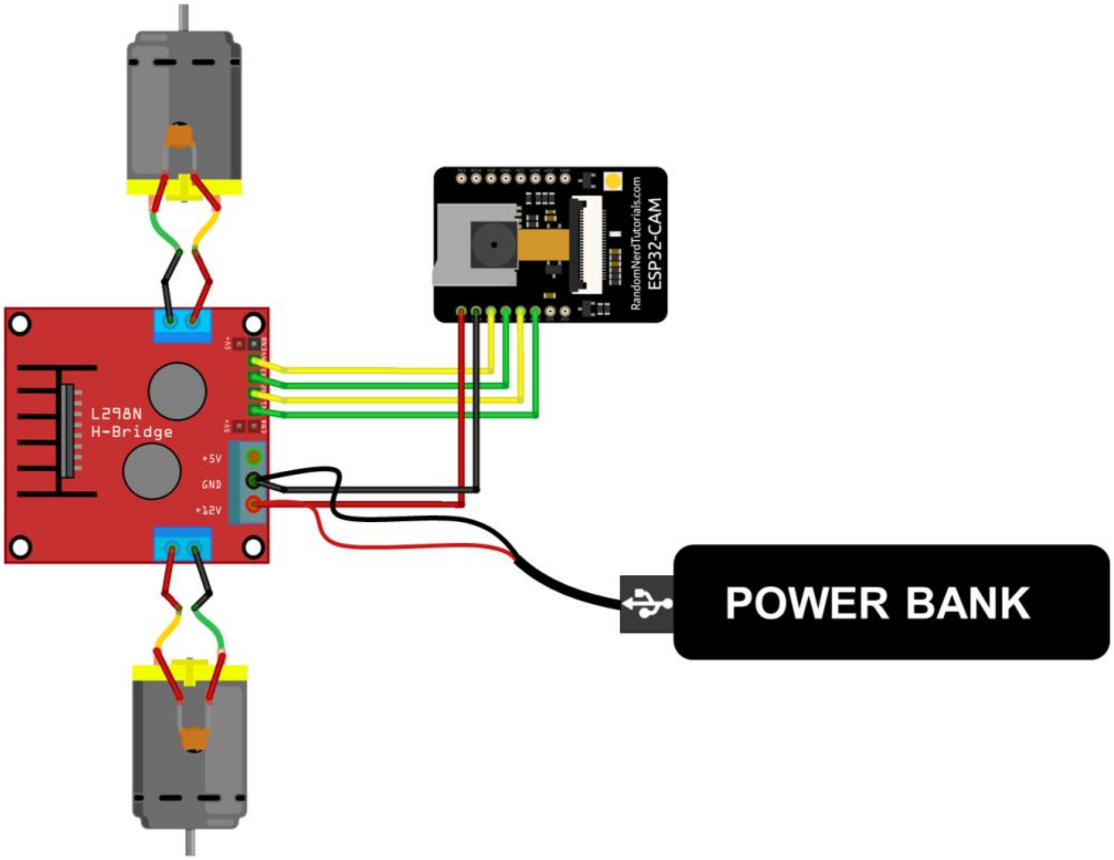


Figure 3.15: Circuit connection image
Source[4]

Start by connecting the ESP32-CAM to the motor driver as shown in the schematic diagram. You can either use a mini breadboard or a stripboard to place your ESP32-CAM and build the circuit.

The following table shows the connections between the ESP32-CAM and the L298N Motor Driver.

L298N Motor Driver	ESP32-cam
IN1	GPIO 14
IN2	GPIO 15
IN3	GPIO 13
IN4	GPIO 12
GPIO 0	GND

Table 3.2: ESP32-CAM and the L298N Motor Driver connection

Source[4]

Note: the motors draw a lot of current, so if the robot is not moving fast enough, we may need to use an external power supply for the motors. This means we need two different power sources. One to power the DC motors, and the other to power the ESP32. We can use additional 4 AA battery pack to power the motors. When we get the robot chassis kit, a battery holder is usually getting for 4 AA batteries.

We should not forget that we should use an external antenna with the ESP32-CAM, otherwise the web server might be extremely slow.

3.9 Algorithm

Step 1: Assemble the Smart Robot Chassis Kit

i. **Mount the Motors:** Attach the DC motors to the chassis according to the kit instructions.

ii. **Attach the Wheels:** Fix the wheels onto the motor shafts.

iii. **Fix the Caster Wheel:** Attach the caster wheel to the chassis.

iv. **Mount the Battery Holder:** Secure the battery holder onto the chassis.

Step 2: Wiring the L298N Motor Driver

i. Connect Motors to L298N: Connect the two motors to the L298N motor driver outputs (OUT1/OUT2 for one motor and OUT3/OUT4 for the other motor).

ii. Connect ESP32-CAM to L298N: Connect the IN1, IN2, IN3, and IN4 inputs of the L298N to GPIO pins of the ESP32-CAM (e.g., GPIO12, GPIO13, GPIO14, GPIO15).

iii. Power the L298N:

- Connect the VCC of the L298N to the battery's positive terminal.
- Connect the GND to the battery's ground terminal and the GND of the ESP32-CAM.

Step 3: Power Supply

i. Power the ESP32-CAM:

- The ESP32-CAM can be powered via the 5V pin (connect to the battery's positive terminal) and GND (connect to the battery's ground terminal).

ii. Stabilize Power:

- Use capacitors (e.g., 100µF) across the power lines to reduce noise.
- Use resistors for proper voltage division if needed.

Step 4: Program the ESP32-CAM

i. Prepare the IDE:

- Install the Arduino IDE and add the ESP32 board package via the Boards Manager.
- Install necessary libraries, such as WIFI. h and ESP32WebServer.h.

ii. Connect the ESP32-CAM to the Computer:

- Use a USB-to-Serial adapter to connect the ESP32-CAM for programming.

iii. Upload Code:

- Write or use a pre-existing code to create a web server on the ESP32-CAM.
- The web server should allow you to control the motor driver via a web interface.
- The code should also include the camera streaming functionality.

Step 5: Testing and Troubleshooting

i. Power On: Insert the batteries and power on the setup.

ii. Connect to the Web Server:

- Use your smartphone or computer to connect to the ESP32-CAM's web server by entering its IP address in a browser.

iii. Control the Car:

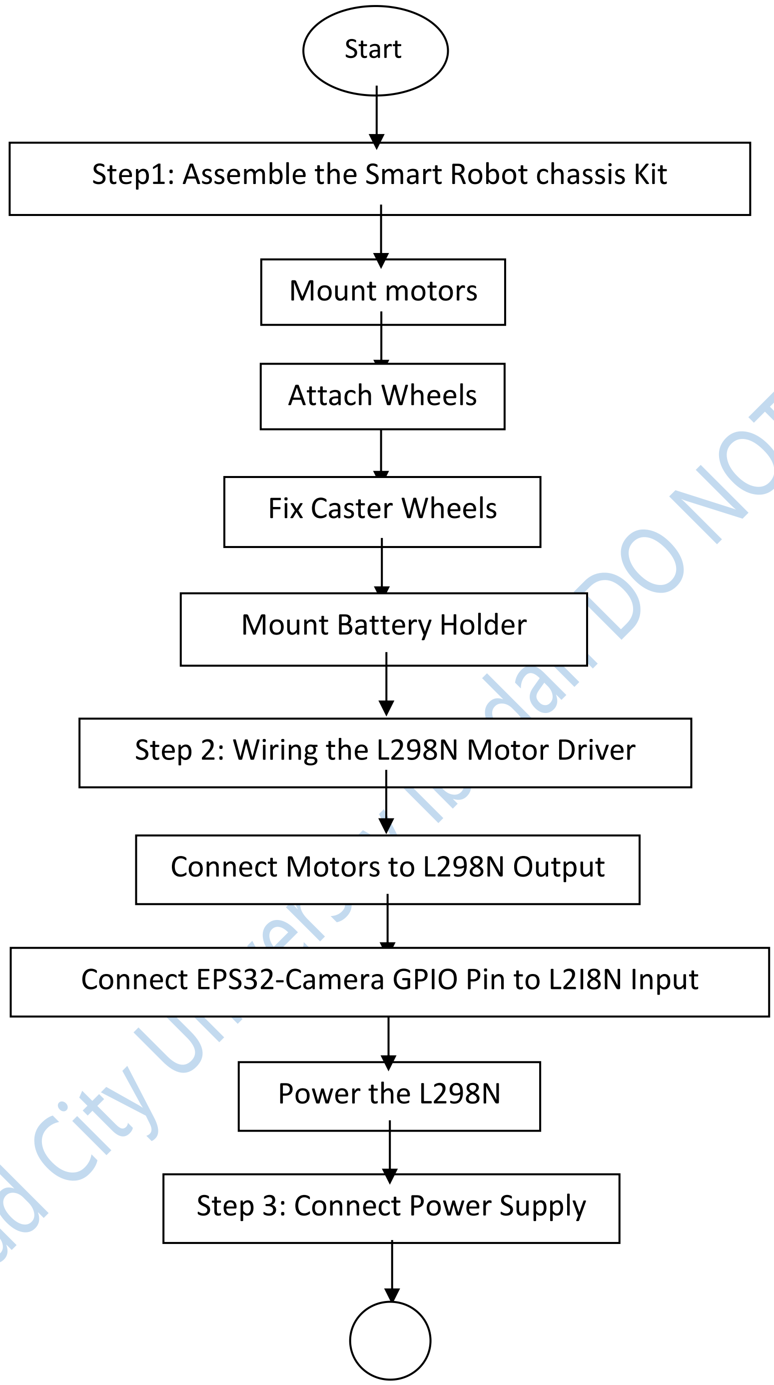
- Use the web interface to control the direction of the motors.
- The camera feed should stream in real-time.

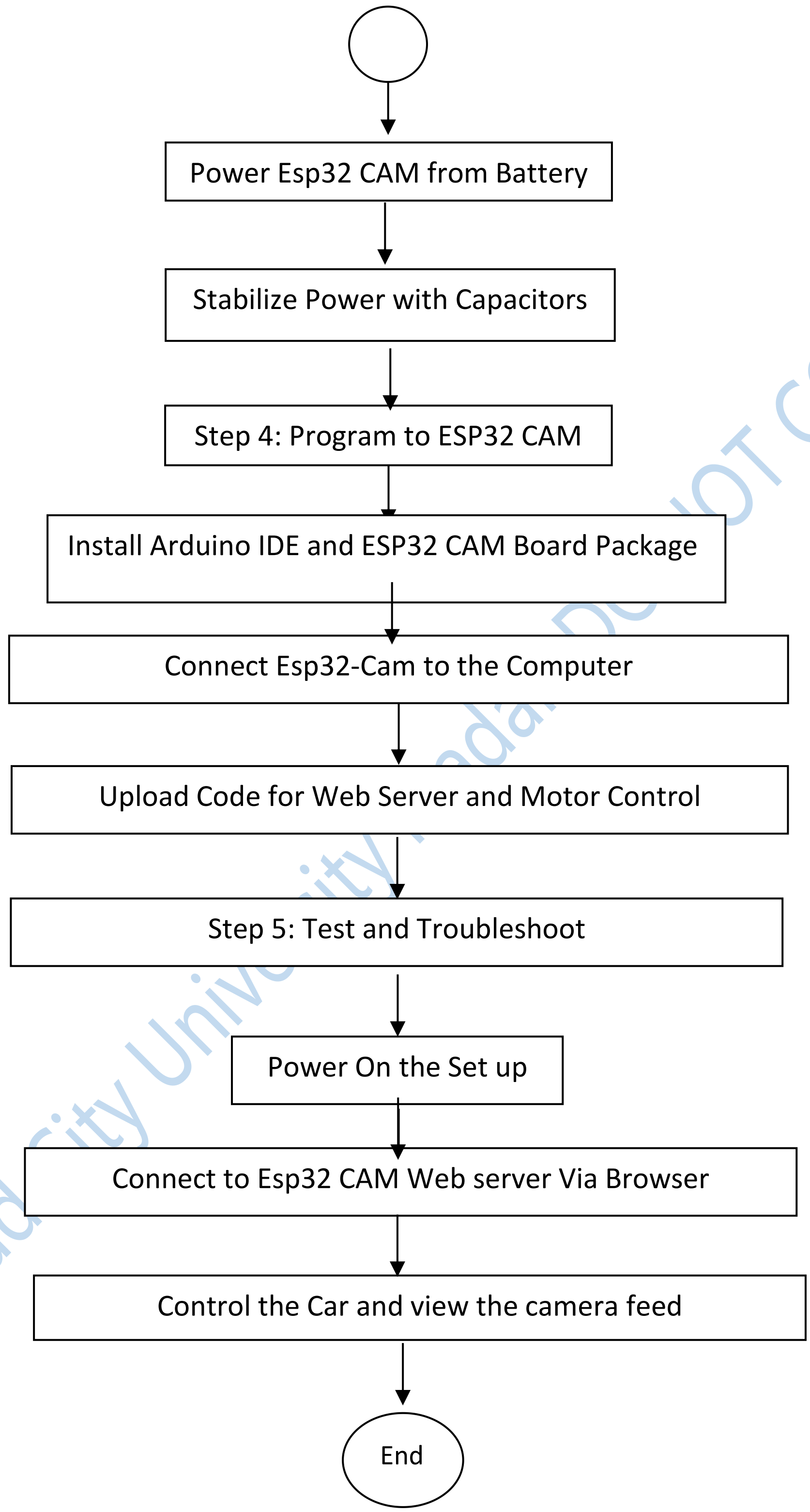
Note

How It Works:

- **Web Server**: The ESP32-CAM acts as a web server, allowing you to control the robot through a web interface. The interface typically has buttons or sliders to send commands (e.g., move forward, turn left).
- **Motor Control**: The L298N motor driver receives these commands from the ESP32-CAM and controls the motors accordingly by providing the necessary voltage and current to move the car.
- **Camera Streaming**: The ESP32-CAM captures video and streams it over the network, allowing you to remotely see where the car is going in real-time.

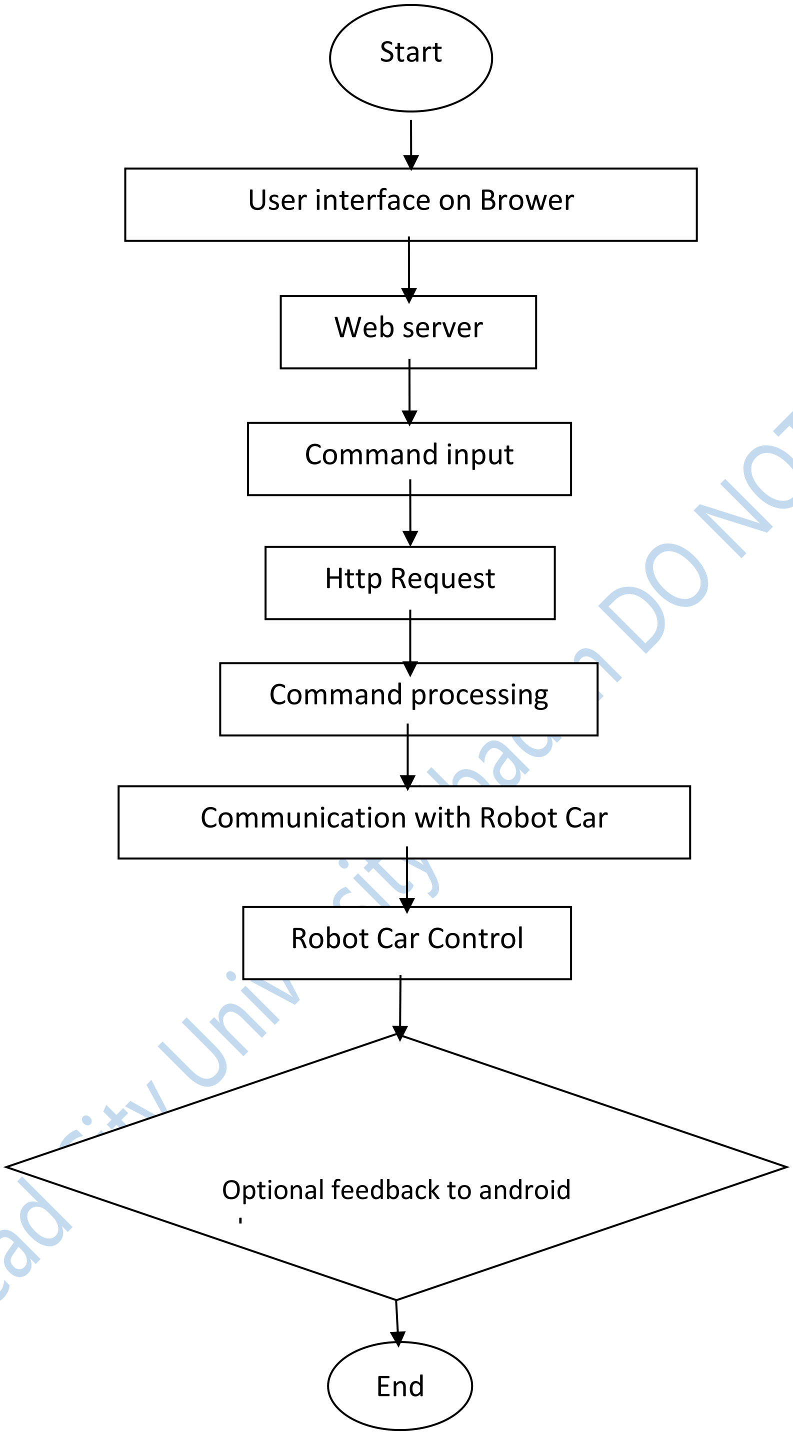
3.10 Flow Chart of the Robot Vehicle





Source: Author's flowchart of the Robot Vehicle

3.11. Flowchart of the link between the Phone and the Robot



Source: Author's flowchart of the link between the Phone and the Robot

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Chapter Four

Results And Discussions

4.1 Results

The results obtained for tests carried out on power supply unit are presented in Table 4.1.

Table 4.1: Test on power supply unit

Battery Bank	Voltage Output (V)
Remote control unit	5.09
Spy communication unit	=5.12
Spy control unit	5.12
Camera sensor unit	=5.03

Source: Author's readings (2024)

The results obtained for test performed on the control unit are shown in Table 4.2.

Table 4.2: web server android control readings

Direction	X-Axis	Y-Axis
Forward	499, 500	1021, 1022, 1023
Backward	499, 500	0, 1
Left	0, 1	531, 532, 533
Right	1022, 1023	521, 532
Right	1022, 1023	521, 532

Source: Author's readings (2024)

For test performed on the unmanned ground vehicle camera unit, the values received by an operator in a remote location is shown in the screenshot of Figure 4.1.

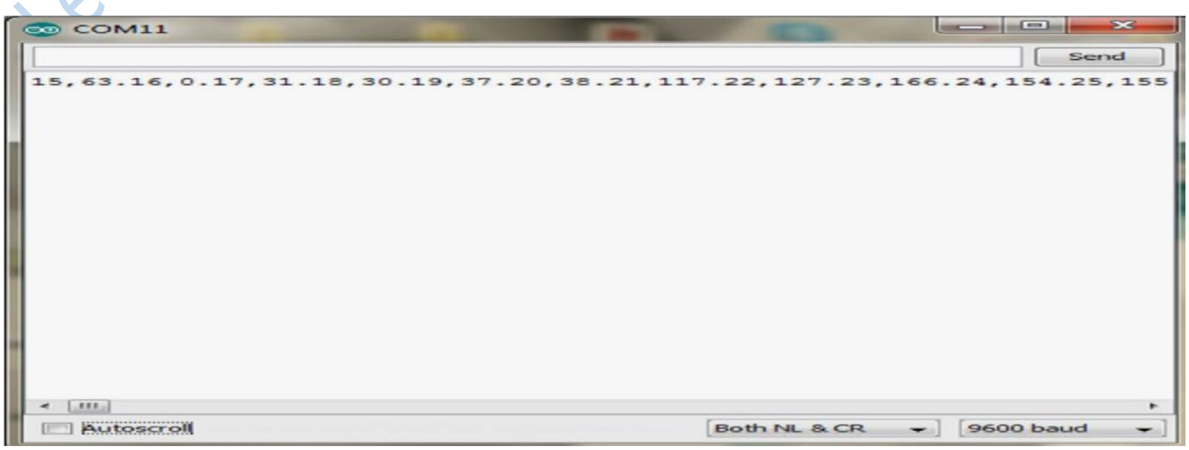

Figure 4.1: Screenshot of Sensor Unit Readings
Source: Author's readings (2024)

The results of testing the power supply unit of each system module are presented in Table 4.1. The purpose of these tests was to confirm that the battery banks of each module provided the rated voltages required by their related circuitry, as indicated on the data sheets of the different components. The digital equivalents of analog voltages read from the control module potentiometers are shown in Table 4.2.

4.2 Output of the design of the robot car

The results obtained for designing, tests and output of the vehicle were presented in the figure 4.1 to figure 4.4 as follows:

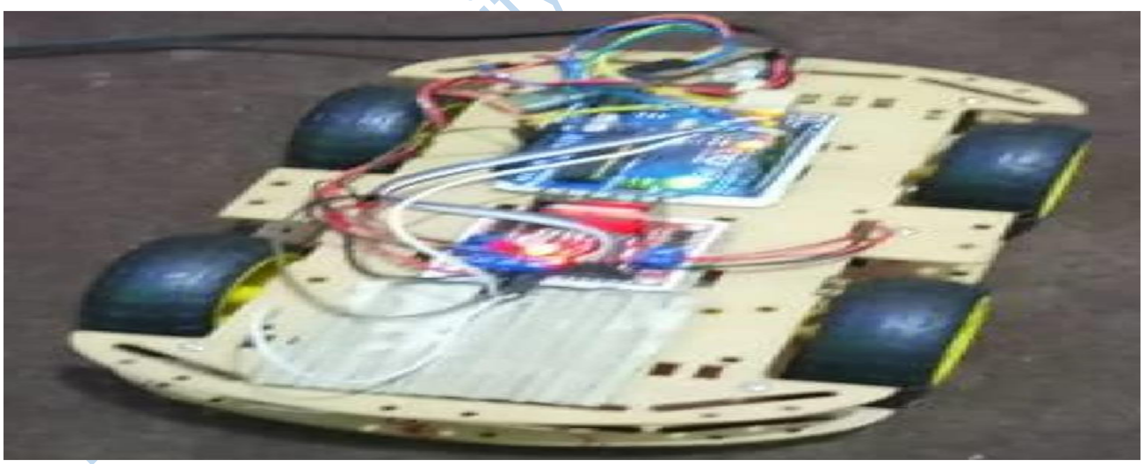

Figure 4.1: Vehicle Ground Chassis
Source: Author's Vehicle Chassis (2021)

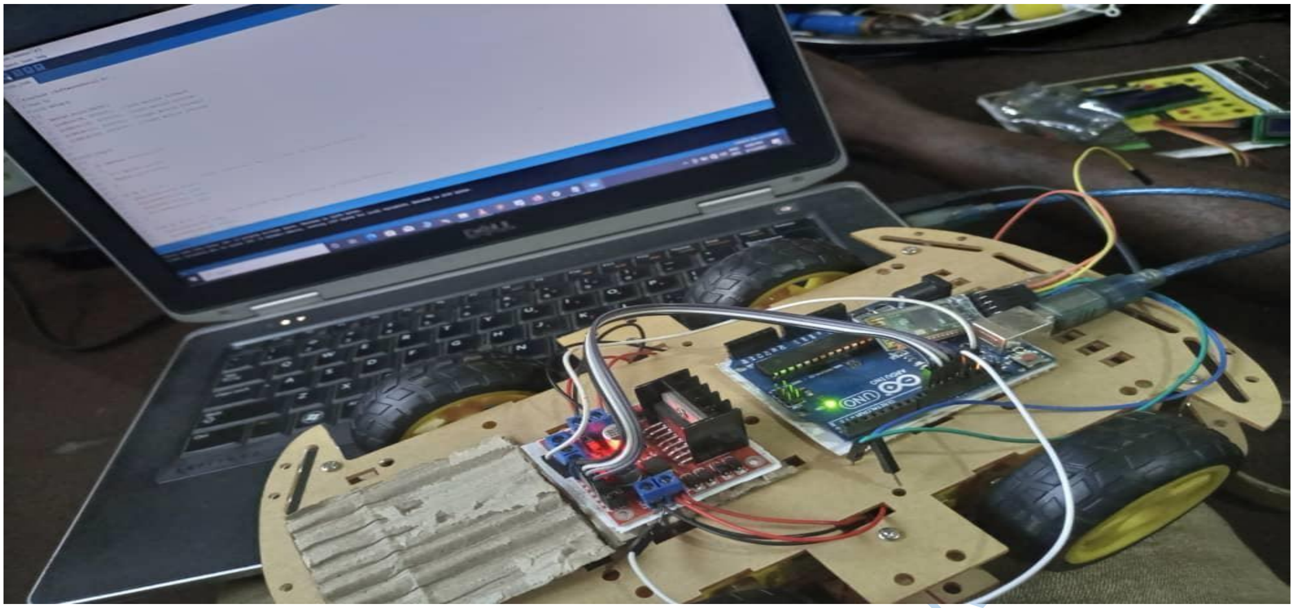

Figure 4.2: Decoding and coding the Spy Robot Car
Source: Author's coding of the Vehicle Chassis (2021)

Figure 4.3: The Remote-Controlled Spy Vehicle Test 1
Source: Author's remote controlled Spy Vehicle test (2024)

Figure 4.4: Ground Vehicle Test 2
Source: Author's Ground Vehicle Test (2024)

4.3 Output of the livestreaming videos and images

Having deployed the necessary coding and software connection between the esp32 camera module and the android phone, the livestreaming videos and images through the functional web-based interface were Having deployed the necessary coding and software connection between the esp32 camera module and the android phone, the livestreaming videos and images through the functional web-based interface were presented in the figure 4.5 and figure 4.6.

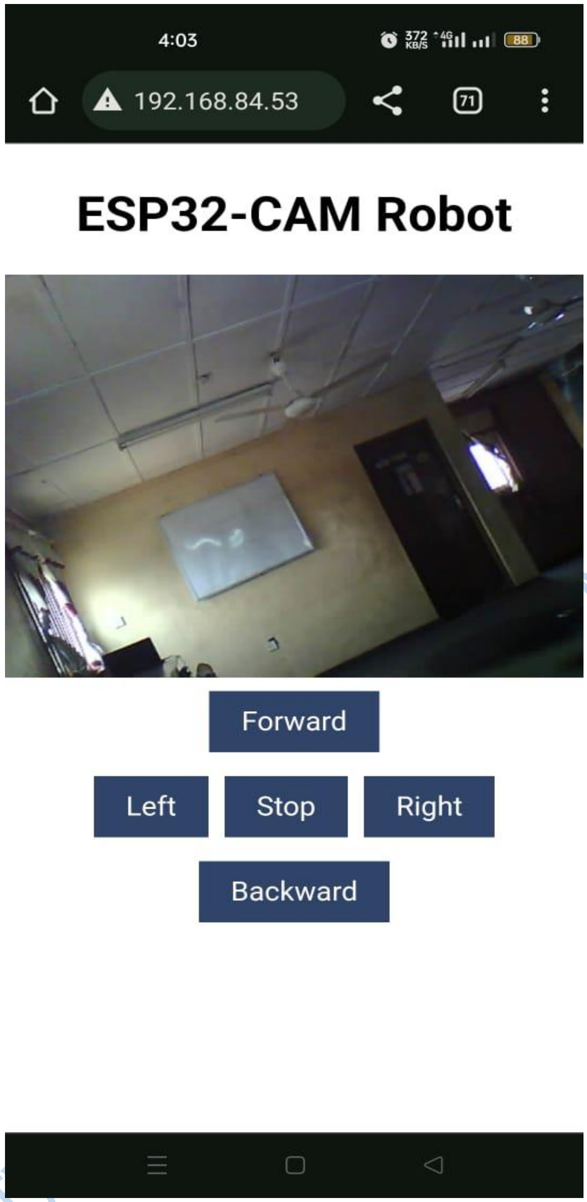

Figure 4.5: ESP32-Camera streaming image 1
Source: Author's Camera livestreaming image (2024)

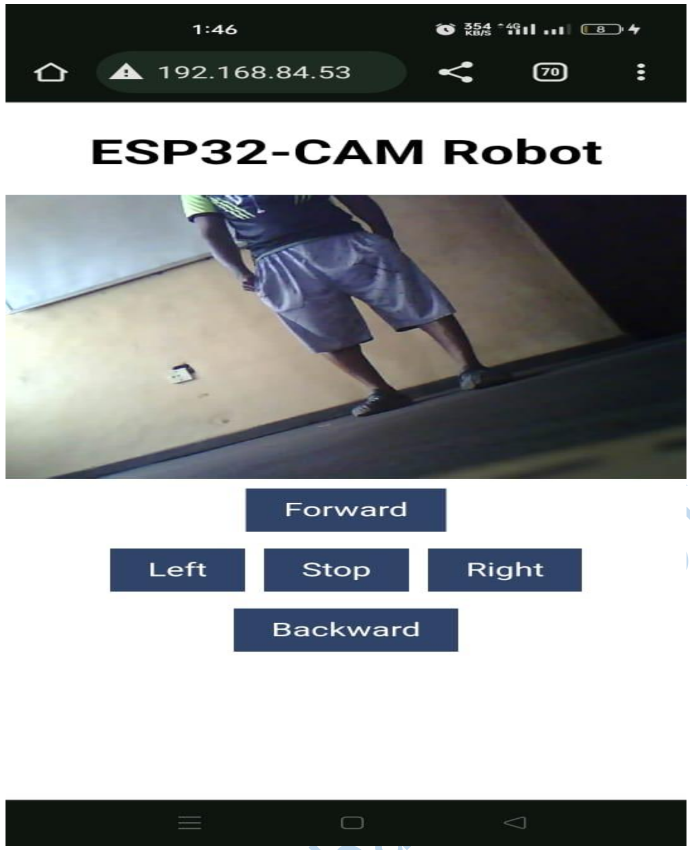

Figure 4.6: ESP32-Camera streaming image 2
Source: Author's Camera livestreaming image (2024)

4.4 Evaluation

The design of the robot car project, which integrates an ESP32-CAM module for video streaming, an L298N motor driver for motor control, and wireless remote control via a web interface, reveals both successes and areas for improvement. This project aims to provide a functional autonomous ground vehicle capable of live video streaming and real-time control, achieved through a series of hardware and software configurations. In this evaluation, we look at the effectiveness of these components, the challenges encountered, and the overall functionality of the robot car. The ESP32-CAM module played a crucial role in the project by providing real-time video streaming via a web server that can be accessed on any device within the same network. The camera's ability to stream live video is essential for remote monitoring and navigation of the vehicle. Initial tests showed that the module was able to stream videos successfully, allowing the user to see the vehicle's surroundings in real-time. However, significant latency issues were observed when the ESP32-CAM was operated without an external antenna. The video stream lagged, and the web server's responsiveness was considerably slow. This issue was attributed to the weak Wi-Fi signal strength, especially when the robot was operated at a distance from the router or in areas with obstructions. To overcome this, an external antenna was added, which significantly improved the Wi-Fi signal and reduced lag, enhancing the user experience during remote control operations.

The L298N motor driver was used to control the movement of the robot's two DC motors. The motor driver proved to be effective in controlling the speed and direction of the robot. Commands such as forward, backward, left, right, and stop were successfully executed through the web-based control interface. The vehicle's movement was smooth, and the motor driver provided the necessary current and voltage for the motors to perform as expected. However, the motors drew a considerable amount of current, and the robot's speed was slower than expected when powered solely by the same battery as the ESP32-CAM. This challenge was addressed by using a separate power supply for the motors. A 4-AA battery pack was used to power the motors independently, ensuring sufficient current supply and improving the vehicle's performance. Testing the code revealed some common issues, including difficulty in connecting the ESP32-CAM to the network and errors during the uploading of the code. Errors such as "Timed out waiting for packet header" and "Camera in it failed" were encountered. These issues were resolved by ensuring proper connections and selecting the correct partition scheme in the Arduino IDE. In addition, troubleshooting steps such as verifying COM ports, resetting the ESP32-CAM, and ensuring a stable power supply helped resolve most of the common issues encountered during the coding and testing phase.

The integration of the web server allowed seamless control of the vehicle through any device connected to the same network. By entering the IP address of the ESP32-CAM, users could access the control interface and stream the live video feed. The camera feed was generally smooth with the external antenna, and the commands to control the motors were received promptly, with no noticeable delay. This provided an intuitive and user-friendly way to control the robot remotely. In terms of functionality, the project met most of its intended goals. The autonomous vehicle was able to stream real-time video and respond to user commands via a web interface. The inclusion of the external antenna and the separate power supply for the motors were crucial adjustments that improved the overall performance of the robot. However, some areas still need refinement, such as ensuring consistent and reliable Wi-Fi connectivity in different environments and optimizing the code to reduce latency further. Additionally, incorporating error handling mechanisms and optimizing power management could further enhance the robot's reliability. In conclusion, the robot car project demonstrates the successful integration of hardware and software components to achieve a functioning autonomous vehicle. Despite some challenges with Wi-Fi signal strength and motor power supply, the project was able to deliver real-time video streaming and motor control, fulfilling the primary objectives. Future improvements could focus on enhancing connectivity and power management to further refine the performance of the robot.

4.5 Discussion of Results

This section presents all the results of the testing that has taken place. After it is put to test, it is checked whether the functional output requirements of the application were successfully fulfilled. The motors' motions were assigned the functions FORWARD, BACKWARD, LEFT TURN, RIGHT TURN, and RELEASE in the autonomous ground vehicles through web server. The remote control sends orders to these functions, which are then carried out. The camera sensor unit's purpose is to give the autonomous ground vehicle with environmental sensing and tracking capabilities.

Chapter Five

Conclusion

5.1 Summary

This study explores the creation of an unmanned ground vehicle (UGV) designed for remote-controlled surveillance to aid in addressing insurgency and terrorism issues that pose significant threats to national and international security. The aim of this research is to design and implement a wireless, android-based ground robotic system capable of performing sophisticated spying tasks thereby reducing risk in hostile environments. The methodology employed involves a modular design approach, integrating off-the-shelf components such as Arduino IDE, ESP32-camera, motor drivers, and various power sources. These components were selected for their reliability, availability, and alignment with the objectives of the system. The UGV prototype was developed to perform functions including patrolling and monitoring environments, potentially dangerous to human operators, such as military zones and conflict areas. Results from the implementation demonstrated the vehicle's ability to navigate and provide real-time feedback of live video streaming of what the robot "sees". This independence from network connectivity ensures reliability even in remote environments. The vehicle operates via commands transmitted from an android application, enabling it to move in pre-determined directions and relay visual data back to the base station through an ESP32-camera and a web-server that controls the robot which is being programmed with help of an Arduino IDE. This project successfully demonstrates a cost-effective and efficient approach to surveillance and reconnaissance in high-risk areas. The study recommends enhancing the UGV's capabilities, including extended battery life, improved sensor range, and autonomous navigation algorithms, to ensure a more reliable and performance-optimized vehicle suitable for various surveillance tasks while maintaining affordability.

There exist several potential practical applications of the unmanned ground robotic. The idea can be extended to fit into the untapped indoor commercial environments such as malls, hotels, banks, nursing homes, hospitals, offices, stores, schools, museums and many more. They can be customized for specific applications and are made with some special features which can be widely used in various kinds of works of life like industries, academic, research and development

5.2 Conclusion

The major goal of this research design was to develop and build a wirelessly controlled unmanned ground robotic spy vehicle using esp32-camera. The use of numerous technologies in this project work assisted in the achievement of this goal. This sophisticated equipment has a wide range of applications, from border patrol surveillance to reconnaissance. This gadget is controlled wirelessly by a standalone remote control composed of an esp32 camera the rough web-server that sends operations navigation commands. The gadget may go from point A to point B using navigation commands, thanks to the remote control. The gadget also has camera sensors, allowing it to perform complex and sophisticated radar. The radar is designed using the Arduino, esp32-camera and processing software.

5.3 Recommendations

The following recommendations are proposed:

1. In order to guarantee that a more dependable robot in terms of power and performance is created for these specific duties while also keeping costs low, detailed designs of all the units that make up the remote-controlled radar unmanned ground vehicle are required.

2. To improve the robot's senses, more sensors such as gas sensors, sound detection sensors, cameras, and so on should be added to the unmanned ground vehicle.

3. The physical structure should be as straightforward as possible to allow for future improvements.

5.4 Contributions of the Research

This research set out to contribute to the existing body of knowledge through a more extensive understanding of emerging technologies in three major ways namely below:

Security: the Wireless Based Android Controlled Ground Robotic Spy Vehicle is a stepping stone to Nigeria security defence system using robot to combat crime. Spy vehicles have been widely used in various kind of fields and if some features are added onto the existing design; they can be good in various kinds of field like industries, research and development, militaries etc. they are good for spying, surveillance and inspection.

Economy: Demonstrates cost-effective security solutions through innovative component integration and it leads to reduction in destroying of government properties.

Academics: Provides insights into design, implementation, and testing of prototype security device and serve as a foundation for further research and advancements for students.

5.5 Limitations

The shortcomings encountered in the implementation of this research work are enumerated as follows:

1. As a prototype, this research shows how to make a suitable security device using of existing components that were chosen based on the information supplied by their different data sheets. Current capacities of battery banks used can power up the system only for a limited duration after which the battery bank drains out, leaving the systems powerless.

2. The motors draw a lot of current, so if you feel your robot is not moving fast enough, you may need to use an external power supply for the motors. This means you need two different power sources. One to power the DC motors, and the other to power the ESP32. You can use a 4 AA battery pack to power the motors. When you get your robot chassis kit, you usually get a battery holder for 4 AA batteries.

3. Network delay: The system's response to orders received from the remote control must be as quick as feasible. The unmanned ground vehicle, on the other hand, takes longer to respond to navigation directions. At this time, the specific source of the problem is unknown, although it might be a flaw in the microcontroller software.

4. Wireless Transceiver Communication: Before the wireless communication modules' transmitters, the receivers must be turned on. Failure to do so would result in misunderstanding amongst all of the project's parts. At this time, the source of the problem is likewise unknown.

5. External Device Assistant Integration: Having just the ESP32-CAM working via IP might be useful for only one device because the project can only have the web server open in one device/tab at a time. We can integrate the project with another additional device with an external antenna.

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Appendix

Video Streaming Web Server Code

HTML

```
*********/
#include "esp_camera.h"
#include <WiFi.h>
#include "esp_timer.h"
#include "img_converters.h"
#include "Arduino.h"
#include "fb_gfx.h"
#include "soc/soc.h" //disable brownout problems
#include "soc/rtc_cntl_reg.h"  //disable brownout problems
#include "esp_http_server.h"

//Replace with your network credentials
const char* ssid = "REPLACE_WITH_YOUR_SSID";
const char* password = "REPLACE_WITH_YOUR_PASSWORD";

#define PART_BOUNDARY "123456789000000000000987654321"

// This project was tested with the AI Thinker Model, M5STACK PSRAM Model and
M5STACK WITHOUT PSRAM
#define CAMERA_MODEL_AI_THINKER
//#define CAMERA_MODEL_M5STACK_PSRAM
//#define CAMERA_MODEL_M5STACK_WITHOUT_PSRAM

// Not tested with this model
//#define CAMERA_MODEL_WROVER_KIT
```

```
#if defined(CAMERA_MODEL_WROVER_KIT)
  #define PWDN_GPIO_NUM    -1
  #define RESET_GPIO_NUM   -1
  #define XCLK_GPIO_NUM    21
  #define SIOD_GPIO_NUM    26
  #define SIOC_GPIO_NUM    27

  #define Y9_GPIO_NUM      35
  #define Y8_GPIO_NUM      34
  #define Y7_GPIO_NUM      39
  #define Y6_GPIO_NUM      36
  #define Y5_GPIO_NUM      19
  #define Y4_GPIO_NUM      18
  #define Y3_GPIO_NUM       5
  #define Y2_GPIO_NUM       4
  #define VSYNC_GPIO_NUM   25
  #define HREF_GPIO_NUM    23
  #define PCLK_GPIO_NUM    22

#elif defined(CAMERA_MODEL_M5STACK_PSRAM)
  #define PWDN_GPIO_NUM     -1
  #define RESET_GPIO_NUM    15
  #define XCLK_GPIO_NUM     27
  #define SIOD_GPIO_NUM     25
  #define SIOC_GPIO_NUM     23

  #define Y9_GPIO_NUM       19
  #define Y8_GPIO_NUM       36
```

```
  #define Y7_GPIO_NUM       18
  #define Y6_GPIO_NUM       39
  #define Y5_GPIO_NUM        5
  #define Y4_GPIO_NUM       34
  #define Y3_GPIO_NUM       35
  #define Y2_GPIO_NUM       32
  #define VSYNC_GPIO_NUM    22
  #define HREF_GPIO_NUM     26
  #define PCLK_GPIO_NUM     21

#elif defined(CAMERA_MODEL_M5STACK_WITHOUT_PSRAM)
  #define PWDN_GPIO_NUM     -1
  #define RESET_GPIO_NUM    15
  #define XCLK_GPIO_NUM     27
  #define SIOD_GPIO_NUM     25
  #define SIOC_GPIO_NUM     23

  #define Y9_GPIO_NUM       19
  #define Y8_GPIO_NUM       36
  #define Y7_GPIO_NUM       18
  #define Y6_GPIO_NUM       39
  #define Y5_GPIO_NUM        5
  #define Y4_GPIO_NUM       34
  #define Y3_GPIO_NUM       35
  #define Y2_GPIO_NUM       17
  #define VSYNC_GPIO_NUM    22
  #define HREF_GPIO_NUM     26
  #define PCLK_GPIO_NUM     21
```

```
#elif defined(CAMERA_MODEL_AI_THINKER)
  #define PWDN_GPIO_NUM     32
  #define RESET_GPIO_NUM    -1
  #define XCLK_GPIO_NUM      0
  #define SIOD_GPIO_NUM     26
  #define SIOC_GPIO_NUM     27

  #define Y9_GPIO_NUM       35
  #define Y8_GPIO_NUM       34
  #define Y7_GPIO_NUM       39
  #define Y6_GPIO_NUM       36
  #define Y5_GPIO_NUM       21
  #define Y4_GPIO_NUM       19
  #define Y3_GPIO_NUM       18
  #define Y2_GPIO_NUM        5
  #define VSYNC_GPIO_NUM    25
  #define HREF_GPIO_NUM     23
  #define PCLK_GPIO_NUM     22
#else
  #error "Camera model not selected"
#endif

static const char* _STREAM_CONTENT_TYPE = "multipart/x-mixed-replace;boundary=" PART_BOUNDARY;
static const char* _STREAM_BOUNDARY = "\r\n--" PART_BOUNDARY "\r\n";
static const char* _STREAM_PART = "Content-Type: image/jpeg\r\nContent-Length: %u\r\n\r\n";

httpd_handle_t stream_httpd = NULL;
```

```
static esp_err_t stream_handler(httpd_req_t *req){
 camera_fb_t * fb = NULL;
 esp_err_t res = ESP_OK;
 size_t _jpg_buf_len = 0;
 uint8_t * _jpg_buf = NULL;
 char * part_buf[64];

 res = httpd_resp_set_type(req, _STREAM_CONTENT_TYPE);
 if(res != ESP_OK){
  return res;
 }

 while(true){
  fb = esp_camera_fb_get();
  if (!fb) {
   Serial.println("Camera capture failed");
   res = ESP_FAIL;
  } else {
   if(fb->width > 400){
    if(fb->format != PIXFORMAT_JPEG){
     bool jpeg_converted = frame2jpg(fb, 80, &_jpg_buf, &_jpg_buf_len);
     esp_camera_fb_return(fb);
     fb = NULL;k
     if(!jpeg_converted){
      Serial.println("JPEG compression failed");
      res = ESP_FAIL;
     }
```

```
        } else {
          _jpg_buf_len = fb->len;
          _jpg_buf = fb->buf;
        }
      }
    }
    if(res == ESP_OK){
      size_t hlen = snprintf((char *)part_buf, 64, _STREAM_PART, _jpg_buf_len);
      res = httpd_resp_send_chunk(req, (const char *)part_buf, hlen);
    }
    if(res == ESP_OK){
      res = httpd_resp_send_chunk(req, (const char *)_jpg_buf, _jpg_buf_len);
    }
    if(res == ESP_OK){
      res = httpd_resp_send_chunk(req, _STREAM_BOUNDARY,
strlen(_STREAM_BOUNDARY));
    }
    if(fb){
      esp_camera_fb_return(fb);
      fb = NULL;
      _jpg_buf = NULL;
    } else if(_jpg_buf){
      free(_jpg_buf);
      _jpg_buf = NULL;
    }
    if(res != ESP_OK){
      break;
    }
    //Serial.printf("MJPG: %uB\n",(uint32_t)(_jpg_buf_len));
```

```
  }
  return res;
}

void startCameraServer(){
  httpd_config_t config = HTTPD_DEFAULT_CONFIG();
  config.server_port = 80;

  httpd_uri_t index_uri = {
    .uri       = "/",
    .method    = HTTP_GET,
    .handler   = stream_handler,
    .user_ctx  = NULL
  };

  //Serial.printf("Starting web server on port: '%d'\n", config.server_port);
  if (httpd_start(&stream_httpd, &config) == ESP_OK) {
    httpd_register_uri_handler(stream_httpd, &index_uri);
  }
}

void setup() {
  WRITE_PERI_REG(RTC_CNTL_BROWN_OUT_REG, 0); //disable brownout detector

  Serial.begin(115200);
  Serial.setDebugOutput(false);

  camera_config_t config;
```

```
config.ledc_channel = LEDC_CHANNEL_0;
config.ledc_timer = LEDC_TIMER_0;
config.pin_d0 = Y2_GPIO_NUM;
config.pin_d1 = Y3_GPIO_NUM;
config.pin_d2 = Y4_GPIO_NUM;
config.pin_d3 = Y5_GPIO_NUM;
config.pin_d4 = Y6_GPIO_NUM;
config.pin_d5 = Y7_GPIO_NUM;
config.pin_d6 = Y8_GPIO_NUM;
config.pin_d7 = Y9_GPIO_NUM;
config.pin_xclk = XCLK_GPIO_NUM;
config.pin_pclk = PCLK_GPIO_NUM;
config.pin_vsync = VSYNC_GPIO_NUM;
config.pin_href = HREF_GPIO_NUM;
config.pin_sscb_sda = SIOD_GPIO_NUM;
config.pin_sscb_scl = SIOC_GPIO_NUM;
config.pin_pwdn = PWDN_GPIO_NUM;
config.pin_reset = RESET_GPIO_NUM;
config.xclk_freq_hz = 20000000;
config.pixel_format = PIXFORMAT_JPEG;

if(psramFound()){
  config.frame_size = FRAMESIZE_UXGA;
  config.jpeg_quality = 10;
  config.fb_count = 2;
} else {
  config.frame_size = FRAMESIZE_SVGA;
  config.jpeg_quality = 12;
```

```
    config.fb_count = 1;
  }

  // Camera init
  esp_err_t err = esp_camera_init(&config);
  if (err != ESP_OK) {
    Serial.printf("Camera init failed with error 0x%x", err);
    return;
  }
  // Wi-Fi connection
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");

  Serial.print("Camera Stream Ready! Go to: http://");
  Serial.print(WiFi.localIP());

  // Start streaming web server
  startCameraServer();
}

void lkoop() {
  delay(1);
}
```

Before uploading the code, you need to insert your network credentials in the following variables:

```
const char* ssid = "REPLACE_WITH_YOUR_SSID";
const char* password = "REPLACE_WITH_YOUR_PASSWORD"
```

Appendix B1

Code for the car Robot control

```
/*********
#include "esp_camera.h"
#include <WiFi.h>
#include "esp_timer.h"
#include "img_converters.h"
#include "Arduino.h"
#include "fb_gfx.h"
#include "soc/soc.h"             // disable brownout problems
#include "soc/rtc_cntl_reg.h"    // disable brownout problems
#include "esp_http_server.h"

// Replace with your network credentials
const char* ssid = "REPLACE_WITH_YOUR_SSID";
const char* password = "REPLACE_WITH_YOUR_PASSWORD";

#define PART_BOUNDARY "123456789000000000000987654321"

#define CAMERA_MODEL_AI_THINKER
//#define CAMERA_MODEL_M5STACK_PSRAM
//#define CAMERA_MODEL_M5STACK_WITHOUT_PSRAM
//#define CAMERA_MODEL_M5STACK_PSRAM_B
//#define CAMERA_MODEL_WROVER_KIT
```

```
#if defined(CAMERA_MODEL_WROVER_KIT)
  #define PWDN_GPIO_NUM    -1
  #define RESET_GPIO_NUM   -1
  #define XCLK_GPIO_NUM    21
  #define SIOD_GPIO_NUM    26
  #define SIOC_GPIO_NUM    27

  #define Y9_GPIO_NUM      35
  #define Y8_GPIO_NUM      34
  #define Y7_GPIO_NUM      39
  #define Y6_GPIO_NUM      36
  #define Y5_GPIO_NUM      19
  #define Y4_GPIO_NUM      18
  #define Y3_GPIO_NUM       5
  #define Y2_GPIO_NUM       4
  #define VSYNC_GPIO_NUM   25
  #define HREF_GPIO_NUM    23
  #define PCLK_GPIO_NUM    22

#elif defined(CAMERA_MODEL_M5STACK_PSRAM)
  #define PWDN_GPIO_NUM     -1
  #define RESET_GPIO_NUM    15
  #define XCLK_GPIO_NUM     27
  #define SIOD_GPIO_NUM     25
  #define SIOC_GPIO_NUM     23

  #define Y9_GPIO_NUM       19
```

```
  #define Y8_GPIO_NUM       36
  #define Y7_GPIO_NUM       18
  #define Y6_GPIO_NUM       39
  #define Y5_GPIO_NUM        5
  #define Y4_GPIO_NUM       34
  #define Y3_GPIO_NUM       35
  #define Y2_GPIO_NUM       32
  #define VSYNC_GPIO_NUM    22
  #define HREF_GPIO_NUM     26
  #define PCLK_GPIO_NUM     21

#elif defined(CAMERA_MODEL_M5STACK_WITHOUT_PSRAM)
  #define PWDN_GPIO_NUM     -1
  #define RESET_GPIO_NUM    15
  #define XCLK_GPIO_NUM     27
  #define SIOD_GPIO_NUM     25
  #define SIOC_GPIO_NUM     23

  #define Y9_GPIO_NUM       19
  #define Y8_GPIO_NUM       36
  #define Y7_GPIO_NUM       18
  #define Y6_GPIO_NUM       39
  #define Y5_GPIO_NUM        5
  #define Y4_GPIO_NUM       34
  #define Y3_GPIO_NUM       35
  #define Y2_GPIO_NUM       17
  #define VSYNC_GPIO_NUM    22
  #define HREF_GPIO_NUM     26
```

```
  #define PCLK_GPIO_NUM     21

#elif defined(CAMERA_MODEL_AI_THINKER)
  #define PWDN_GPIO_NUM     32
  #define RESET_GPIO_NUM    -1
  #define XCLK_GPIO_NUM      0
  #define SIOD_GPIO_NUM     26
  #define SIOC_GPIO_NUM     27

  #define Y9_GPIO_NUM       35
  #define Y8_GPIO_NUM       34
  #define Y7_GPIO_NUM       39
  #define Y6_GPIO_NUM       36
  #define Y5_GPIO_NUM       21
  #define Y4_GPIO_NUM       19
  #define Y3_GPIO_NUM       18
  #define Y2_GPIO_NUM        5
  #define VSYNC_GPIO_NUM    25
  #define HREF_GPIO_NUM     23
  #define PCLK_GPIO_NUM     22

#elif defined(CAMERA_MODEL_M5STACK_PSRAM_B)
  #define PWDN_GPIO_NUM     -1
  #define RESET_GPIO_NUM    15
  #define XCLK_GPIO_NUM     27
  #define SIOD_GPIO_NUM     22
  #define SIOC_GPIO_NUM     23
```

```
  #define Y9_GPIO_NUM      19
  #define Y8_GPIO_NUM      36
  #define Y7_GPIO_NUM      18
  #define Y6_GPIO_NUM      39
  #define Y5_GPIO_NUM       5
  #define Y4_GPIO_NUM      34
  #define Y3_GPIO_NUM      35
  #define Y2_GPIO_NUM      32
  #define VSYNC_GPIO_NUM   25
  #define HREF_GPIO_NUM    26
  #define PCLK_GPIO_NUM    21

#else
  #error "Camera model not selected"
#endif

#define MOTOR_1_PIN_1    14
#define MOTOR_1_PIN_2    15
#define MOTOR_2_PIN_1    13
#define MOTOR_2_PIN_2    12

static const char* _STREAM_CONTENT_TYPE = "multipart/x-mixed-replace;boundary=" PART_BOUNDARY;
static const char* _STREAM_BOUNDARY = "\r\n--" PART_BOUNDARY "\r\n";
static const char* _STREAM_PART = "Content-Type: image/jpeg\r\nContent-Length: %u\r\n\r\n";

httpd_handle_t camera_httpd = NULL;
httpd_handle_t stream_httpd = NULL;
```

```
static const char PROGMEM INDEX_HTML[] = R"rawliteral(
<html>
 <head>
  <title>ESP32-CAM Robot</title>
  <meta name="viewport" content="width=device-width, initial-scale=1">
  <style>
   body { font-family: Arial; text-align: center; margin:0px auto; padding-top: 30px;}
   table { margin-left: auto; margin-right: auto; }
   td { padding: 8 px; }
   .button {
    background-color: #2f4468;
    border: none;
    color: white;
    padding: 10px 20px;
    text-align: center;
    text-decoration: none;
    display: inline-block;
    font-size: 18px;
    margin: 6px 3px;
    cursor: pointer;
    -webkit-touch-callout: none;
    -webkit-user-select: none;
    -khtml-user-select: none;
    -moz-user-select: none;
    -ms-user-select: none;
    user-select: none;
    -webkit-tap-highlight-color: rgba(0,0,0,0);
   }
```

```
    img {  width: auto ;
      max-width: 100% ;
      height: auto ;
    }
  </style>
</head>
<body>
  <h1>ESP32-CAM Robot</h1>
  <img src="" id="photo" >
  <table>
    <tr><td colspan="3" align="center"><button class="button" onmousedown="toggleCheckbox('forward');" ontouchstart="toggleCheckbox('forward');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Forward</button></td></tr>
    <tr><td align="center"><button class="button" onmousedown="toggleCheckbox('left');" ontouchstart="toggleCheckbox('left');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Left</button></td><td align="center"><button class="button" onmousedown="toggleCheckbox('stop');" ontouchstart="toggleCheckbox('stop');">Stop</button></td><td align="center"><button class="button" onmousedown="toggleCheckbox('right');" ontouchstart="toggleCheckbox('right');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Right</button></td></tr>
    <tr><td colspan="3" align="center"><button class="button" onmousedown="toggleCheckbox('backward');" ontouchstart="toggleCheckbox('backward');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Backward</button></td></tr>
  </table>
 <script>
 function toggleCheckbox(x) {
   var xhr = new XMLHttpRequest();
   xhr.open("GET", "/action?go=" + x, true);
   xhr.send();
 }
```

```
  window.onload = document.getElementById("photo").src = window.location.href.slice(0, -1) +
":81/stream";
  </script>
  </body>
</html>
)rawliteral";

static esp_err_t index_handler(httpd_req_t *req){
  httpd_resp_set_type(req, "text/html");
  return httpd_resp_send(req, (const char *)INDEX_HTML, strlen(INDEX_HTML));
}

static esp_err_t stream_handler(httpd_req_t *req){
  camera_fb_t * fb = NULL;
  esp_err_t res = ESP_OK;
  size_t _jpg_buf_len = 0;
  uint8_t * _jpg_buf = NULL;
  char * part_buf[64];
k
  res = httpd_resp_set_type(req, _STREAM_CONTENT_TYPE);
  if(res != ESP_OK){
    return res;
  }

  while(true){
    fb = esp_camera_fb_get();
    if (!fb) {
      Serial.println("Camera capture failed");
      res = ESP_FAIL;
```

```
} else {
  if(fb->width > 400){
    if(fb->format != PIXFORMAT_JPEG){
      bool jpeg_converted = frame2jpg(fb, 80, &_jpg_buf, &_jpg_buf_len);
      esp_camera_fb_return(fb);
      fb = NULL;
      if(!jpeg_converted){
        Serial.println("JPEG compression failed");
        res = ESP_FAIL;
      }
    } else {
      _jpg_buf_len = fb->len;
      _jpg_buf = fb->buf;
    }
  }
}
if(res == ESP_OK){
  size_t hlen = snprintf((char *)part_buf, 64, _STREAM_PART, _jpg_buf_len);
  res = httpd_resp_send_chunk(req, (const char *)part_buf, hlen);
}
if(res == ESP_OK){
  res = httpd_resp_send_chunk(req, (const char *)_jpg_buf, _jpg_buf_len);
}
if(res == ESP_OK){
  res = httpd_resp_send_chunk(req, _STREAM_BOUNDARY,
strlen(_STREAM_BOUNDARY));
}
if(fb){
  esp_camera_fb_return(fb);
```

```
      fb = NULL;
      _jpg_buf = NULL;
    } else if(_jpg_buf){
      free(_jpg_buf);
      _jpg_buf = NULL;
    }
    if(res != ESP_OK){
      break;
    }
    //Serial.printf("MJPG: %uB\n",(uint32_t)(_jpg_buf_len));
  }
  return res;
}

static esp_err_t cmd_handler(httpd_req_t *req){
  char*  buf;
  size_t buf_len;
  char variable[32] = {0,};

  buf_len = httpd_req_get_url_query_len(req) + 1;
  if (buf_len > 1) {
    buf = (char*)malloc(buf_len);
    if(!buf){
      httpd_resp_send_500(req);
      return ESP_FAIL;
    }
    if (httpd_req_get_url_query_str(req, buf, buf_len) == ESP_OK) {
      if (httpd_query_key_value(buf, "go", variable, sizeof(variable)) == ESP_OK) {
```

```
    } else {
      free(buf);
      httpd_resp_send_404(req);
      return ESP_FAIL;
    }
  } else {
    free(buf);
    httpd_resp_send_404(req);
    return ESP_FAIL;
  }
  free(buf);
} else {
  httpd_resp_send_404(req);
  return ESP_FAIL;
}

sensor_t * s = esp_camera_sensor_get();
int res = 0;

if(!strcmp(variable, "forward")) {
  Serial.println("Forward");
  digitalWrite(MOTOR_1_PIN_1, 1);
  digitalWrite(MOTOR_1_PIN_2, 0);
  digitalWrite(MOTOR_2_PIN_1, 1);
  digitalWrite(MOTOR_2_PIN_2, 0);
}
else if(!strcmp(variable, "left")) {
  Serial.println("Left");
```

```
  digitalWrite(MOTOR_1_PIN_1, 0);
  digitalWrite(MOTOR_1_PIN_2, 1);
  digitalWrite(MOTOR_2_PIN_1, 1);
  digitalWrite(MOTOR_2_PIN_2, 0);
}
else if(!strcmp(variable, "right")) {
  Serial.println("Right");
  digitalWrite(MOTOR_1_PIN_1, 1);
  digitalWrite(MOTOR_1_PIN_2, 0);
  digitalWrite(MOTOR_2_PIN_1, 0);
  digitalWrite(MOTOR_2_PIN_2, 1);
}
else if(!strcmp(variable, "backward")) {
  Serial.println("Backward");
  digitalWrite(MOTOR_1_PIN_1, 0);
  digitalWrite(MOTOR_1_PIN_2, 1);
  digitalWrite(MOTOR_2_PIN_1, 0);
  digitalWrite(MOTOR_2_PIN_2, 1);
}
else if(!strcmp(variable, "stop")) {
  Serial.println("Stop");
  digitalWrite(MOTOR_1_PIN_1, 0);
  digitalWrite(MOTOR_1_PIN_2, 0);
  digitalWrite(MOTOR_2_PIN_1, 0);
  digitalWrite(MOTOR_2_PIN_2, 0);
}
else {
  res = -1;
```

```
  }

  if(res){
    return httpd_resp_send_500(req);
  }

  httpd_resp_set_hdr(req, "Access-Control-Allow-Origin", "*");
  return httpd_resp_send(req, NULL, 0);
}

void startCameraServer(){
  httpd_config_t config = HTTPD_DEFAULT_CONFIG();
  config.server_port = 80;
  httpd_uri_t index_uri = {
    .uri       = "/",
    .method    = HTTP_GET,
    .handler   = index_handler,
    .user_ctx  = NULL
  };

  httpd_uri_t cmd_uri = {
    .uri       = "/action",
    .method    = HTTP_GET,
    .handler   = cmd_handler,
    .user_ctx  = NULL
  };
  httpd_uri_t stream_uri = {
    .uri       = "/stream",
```

```
    .method    = HTTP_GET,
    .handler   = stream_handler,
    .user_ctx  = NULL
  };
  if (httpd_start(&camera_httpd, &config) == ESP_OK) {
    httpd_register_uri_handler(camera_httpd, &index_uri);
    httpd_register_uri_handler(camera_httpd, &cmd_uri);
  }
  config.server_port += 1;
  config.ctrl_port += 1;
  if (httpd_start(&stream_httpd, &config) == ESP_OK) {
    httpd_register_uri_handler(stream_httpd, &stream_uri);
  }
}

void setup() {
  WRITE_PERI_REG(RTC_CNTL_BROWN_OUT_REG, 0); //disable brownout detector

  pinMode(MOTOR_1_PIN_1, OUTPUT);
  pinMode(MOTOR_1_PIN_2, OUTPUT);
  pinMode(MOTOR_2_PIN_1, OUTPUT);
  pinMode(MOTOR_2_PIN_2, OUTPUT);

  Serial.begin(115200);
  Serial.setDebugOutput(false);

  camera_config_t config;
  config.ledc_channel = LEDC_CHANNEL_0;
```

```
config.ledc_timer = LEDC_TIMER_0;
config.pin_d0 = Y2_GPIO_NUM;
config.pin_d1 = Y3_GPIO_NUM;
config.pin_d2 = Y4_GPIO_NUM;
config.pin_d3 = Y5_GPIO_NUM;
config.pin_d4 = Y6_GPIO_NUM;
config.pin_d5 = Y7_GPIO_NUM;
config.pin_d6 = Y8_GPIO_NUM;
config.pin_d7 = Y9_GPIO_NUM;
config.pin_xclk = XCLK_GPIO_NUM;
config.pin_pclk = PCLK_GPIO_NUM;
config.pin_vsync = VSYNC_GPIO_NUM;
config.pin_href = HREF_GPIO_NUM;
config.pin_sscb_sda = SIOD_GPIO_NUM;
config.pin_sscb_scl = SIOC_GPIO_NUM;
config.pin_pwdn = PWDN_GPIO_NUM;
config.pin_reset = RESET_GPIO_NUM;
config.xclk_freq_hz = 20000000;
config.pixel_format = PIXFORMAT_JPEG;

if(psramFound()){
  config.frame_size = FRAMESIZE_VGA;
  config.jpeg_quality = 10;
  config.fb_count = 2;
} else {
  config.frame_size = FRAMESIZE_SVGA;
  config.jpeg_quality = 12;
  config.fb_count = 1;
```

```
  }

  // Camera init
  esp_err_t err = esp_camera_init(&config);
  if (err != ESP_OK) {
    Serial.printf("Camera init failed with error 0x%x", err);
    return;
  }
  // Wi-Fi connection
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");

  Serial.print("Camera Stream Ready! Go to: http://");
  Serial.println(WiFi.localIP());

  // Start streaming web server
  startCameraServer();
}

void loop() {
}
```

How the Code works with the relevant parts to control the robot

Let's take a look at the relevant parts to control the robot. Define the GPIOs that will control the motors. Each motor is controlled by two pins.

```
#define MOTOR_1_PIN_1 14

#define MOTOR_1_PIN_2 15

#define MOTOR_2_PIN_1 13

#define MOTOR_2_PIN_2 12
```

When you click the buttons, you make a request on a different URL.

```
<table>

  <tr><td colspan="3" align="center"><button class="button" onmousedown="toggleCheckbox('forward');" ontouchstart="toggleCheckbox('forward');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Forward</button></td></tr>

  <tr><td align="center"><button class="button" onmousedown="toggleCheckbox('left');" ontouchstart="toggleCheckbox('left');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Left</button></td><td align="center"><button class="button" onmousedown="toggleCheckbox('stop');" ontouchstart="toggleCheckbox('stop');">Stop</button></td><td align="center"><button class="button" onmousedown="toggleCheckbox('right');" ontouchstart="toggleCheckbox('right');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Right</button></td></tr>

  <tr><td colspan="3" align="center"><button class="button" onmousedown="toggleCheckbox('backward');" ontouchstart="toggleCheckbox('backward');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Backward</button></td></tr>

</table>

<script>

  function toggleCheckbox(x) {

    var xhr = new XMLHttpRequest();

    xhr.open("GET", "/action?go=" + x, true);

    xhr.send();

  }
```

```
  window.onload = document.getElementById("photo").src =     window.location.href.slice(0, -1) + ":81/stream";
</script>
```

Here's the requests made depending on the button that is being pressed:

Forward:

<ESP_IP_ADDRESS>/action?go=forward

Backward:

/action?go=backward

Left:

/action?go=left

Right:

/action?go=right

Stop:

/action?go=stop

When you release the button, a request is made on the /action?go=stop URL. The robot only moves as long as you're pressing the buttons.

Handle Requests

To handle what happens when we get requests on those URLs, we use these if… else statements:

```
if(!strcmp(variable, "forward")) {
    Serial.println("Forward");
    digitalWrite(MOTOR_1_PIN_1, 1);
    digitalWrite(MOTOR_1_PIN_2, 0);
  k digitalWrite(MOTOR_2_PIN_1, 1);
    digitalWrite(MOTOR_2_PIN_2, 0);
 }
 else if(!strcmp(variable, "left")) {
   Serial.println("Left");
   digitalWrite(MOTOR_1_PIN_1, 0);
   digitalWrite(MOTOR_1_PIN_2, 1);
```

```
    digitalWrite(MOTOR_2_PIN_1, 1);
    digitalWrite(MOTOR_2_PIN_2, 0);
  }
  else if(!strcmp(variable, "right")) {
    Serial.println("Right");
    digitalWrite(MOTOR_1_PIN_1, 1);
    digitalWrite(MOTOR_1_PIN_2, 0);
    digitalWrite(MOTOR_2_PIN_1, 0);
    digitalWrite(MOTOR_2_PIN_2, 1);
  }
  else if(!strcmp(variable, "backward")) {
    Serial.println("Backward");
    digitalWrite(MOTOR_1_PIN_1, 0);
    digitalWrite(MOTOR_1_PIN_2, 1);
    digitalWrite(MOTOR_2_PIN_1, 0);
    digitalWrite(MOTOR_2_PIN_2, 1);
  }
  else if(!strcmp(variable, "stop")) {
    Serial.println("Stop");
    digitalWrite(MOTOR_1_PIN_1, 0);
    digitalWrite(MOTOR_1_PIN_2, 0);
    digitalWrite(MOTOR_2_PIN_1, 0);
    digitalWrite(MOTOR_2_PIN_2, 0);
  }
```


How the Code works with the relevant parts to control the robot

Let's take a look at the relevant parts to control the robot. Define the GPIOs that will control the motors. Each motor is controlled by two pins.

```
#define MOTOR_1_PIN_1 14

#define MOTOR_1_PIN_2 15

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#define MOTOR_2_PIN_2 12
```

When you click the buttons, you make a request on a different URL.

```
<table>

  <tr><td colspan="3" align="center"><button class="button" onmousedown="toggleCheckbox('forward');" ontouchstart="toggleCheckbox('forward');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Forward</button></td></tr>

  <tr><td align="center"><button class="button" onmousedown="toggleCheckbox('left');" ontouchstart="toggleCheckbox('left');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Left</button></td><td align="center"><button class="button" onmousedown="toggleCheckbox('stop');" ontouchstart="toggleCheckbox('stop');">Stop</button></td><td align="center"><button class="button" onmousedown="toggleCheckbox('right');" ontouchstart="toggleCheckbox('right');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Right</button></td></tr>

  <tr><td colspan="3" align="center"><button class="button" onmousedown="toggleCheckbox('backward');" ontouchstart="toggleCheckbox('backward');" onmouseup="toggleCheckbox('stop');" ontouchend="toggleCheckbox('stop');">Backward</button></td></tr>

</table>

<script>

  function toggleCheckbox(x) {

    var xhr = new XMLHttpRequest();

    xhr.open("GET", "/action?go=" + x, true);

    xhr.send();

  }

  window.onload = document.getElementById("photo").src =     window.location.href.slice(0, -1) + ":81/stream";

</script>
```

Here's the requests made depending on the button that is being pressed:

Forward:

<ESP_IP_ADDRESS>/action?go=forward

Backward:

/action?go=backward

Left:

/action?go=left

Right:

/action?go=right

Stop:

/action?go=stop

When you release the button, a request is made on the /action?go=stop URL. The robot only moves as long as you're pressing the buttons.

Handle Requests

To handle what happens when we get requests on those URLs, we use these if… else statements:

```
if(!strcmp(variable, "forward")) {
    Serial.println("Forward");
    digitalWrite(MOTOR_1_PIN_1, 1);
    digitalWrite(MOTOR_1_PIN_2, 0);
   k digitalWrite(MOTOR_2_PIN_1, 1);
    digitalWrite(MOTOR_2_PIN_2, 0);
 }
 else if(!strcmp(variable, "left")) {
   Serial.println("Left");
   digitalWrite(MOTOR_1_PIN_1, 0);
   digitalWrite(MOTOR_1_PIN_2, 1);
   digitalWrite(MOTOR_2_PIN_1, 1);
   digitalWrite(MOTOR_2_PIN_2, 0);
}
```

```
else if(!strcmp(variable, "right")) {
  Serial.println("Right");
  digitalWrite(MOTOR_1_PIN_1, 1);
  digitalWrite(MOTOR_1_PIN_2, 0);
  digitalWrite(MOTOR_2_PIN_1, 0);
  digitalWrite(MOTOR_2_PIN_2, 1);
}
else if(!strcmp(variable, "backward")) {
  Serial.println("Backward");
  digitalWrite(MOTOR_1_PIN_1, 0);
  digitalWrite(MOTOR_1_PIN_2, 1);
  digitalWrite(MOTOR_2_PIN_1, 0);
  digitalWrite(MOTOR_2_PIN_2, 1);
}
else if(!strcmp(variable, "stop")) {
  Serial.println("Stop");
  digitalWrite(MOTOR_1_PIN_1, 0);
  digitalWrite(MOTOR_1_PIN_2, 0);
  digitalWrite(MOTOR_2_PIN_1, 0);
  digitalWrite(MOTOR_2_PIN_2, 0);
}
```

Bio-data

i. Full Name:	**YISAU**, NURUDEEN BABATUNDE
ii. Date of Birth & Place of Birth:	26th April, 1979 & Ijebu-Igbo
iii. Nationality:	Nigerian
iv. State of Origin:	Ogun State
v. Local Govt Area:	Ijebu North
vi Home Address:	8, Alfred Aken Street, Olowora, Lagos
vii. Postal Address:	Sikiru Adetona, College of Education, Science and Technology, In Affiliation with Olabisi Onabanjo University, P.M.B 2128, Omu-Ajose, Ogun State
viii. Office Address:	Sikiru Adetona, College of Education, Science and Technology, Omu-Ajose, Ogun State
ix. Permanent Home Address:	4, Oridan, street, Okemoje, Ijebu Igbo.
x. e-mail Address:	yisautunde@gmail.com
xi. Mobile No:	08056178984 / 08034084316
xii. Marital Status:	Married
xiii. Next of Kin:	Mrs. Yisau Aminat Bukola. Trust Arthur Limited 11, Oko-Owo, Victoria Island, Lagos. Tel: 08180287046 / 07034733334
xv. Relationship of Next of Kin:	Wife

B. EDUCATIONAL BACKGROUND:

i. Institutions Attended with dates:

a. Primary School:

- St James' Anglican Primary School, Atikori, Ijebu Igbo — 1988

b. Secondary School:

- Molusi College, Ijebu Igbo — 1994

- Seico International Educational Institutions 2000
- Centre for Preliminary Studies, Michael Otedola
- College of Primary Education, Noforija, Epe, Lagos 2021

c. Post-Secondary School:

- Ogun State University, Ago-Iwoye 1999
- Olabisi Onabanjo University, Ago-Iwoye 2009
- Lead City University, Ibadan 2018

ii. Academic Qualifications with dates:

a.	Primary School Leaving Certificate	1988
b.	Secondary School Leaving Certificate	1994
c.	National Examination Council	2000
d.	Diploma in Data Processing	1999
e.	B.Sc. (Hons) Computer Science	2009
f.	National Examination Council	2021
g.	M.Sc. Computer Science	in view
h.	Professional Diploma in Education (PDE)	in view

iii. Professional Qualifications with dates:

Science Association of Nigeria (SAN)

iv. Discipline: Computer Science

v. Area of specialization: Information Security

vi. Other areas of Interest: Networking/Web Design

C. RESEARCH AND PUBLICATIONS

a. Journal Publications:

International

1. **Kaka, O. A,** Ayeni, A.G & Yisau N.B (2019): Infusion and Diffusion of Social Media usage in University Administration during COVID-19 Pandemic. *Social Informatics, Business, politics, Law and Technology Journal, Vol. 5, No3,*

September, 2019 Available online at https://www.isteams.net/socialinformaticsjournal

National

2. Akinmeji, O. O, Dairo, A. J & **Yisau, N. B** (2017) Re-Positioning Science and Mathematics Instructional Strategy Through Electronic Learning (e-learning) National Journal of Sciences and Education Studies (NJSES) Mihael Otedola College of Primary Education, Noforija- Epe Vol. * N0. 7 November 2017 pp. 321-330

3. **Abass, O. A,** Folorunso, O and Yisau, N. B. (2018): Web Page Ranking Algorithms For Text-Based Information Retrieval. Abubakar Tafawa Balewa University, Journal of Science, Technology & Education (JOSTE); Vol. 4 (4), December, 2016 ISSN: 2277-0011. Available at **www.atbuftejoste.com.**

5. Ayeni, A. G., **Kaka, O. A** & Yisau, N. B (2019): Virtual Reality Based Model For Augmented Response to Disaster in Academic Community; National Journal of Sciences and Education Studies (NJSES) Michael Otedola College of Education, Noforija-Epe, April, 2019 Vol. 8 No. 9 Pg. 287-293

6. **Kaka, O, A**, Yisau N. B. & Akinyosade, E O (2020); Use of Online Social Networks And Academic Performance at Tai Solarin College of Education, Omu -Ijebu Nigeria; National Journal of Sciences and Education Studies (NJSES) Michael Otedola College of Education, Noforija-Epe, February 2020 Vol. 9 No.10 Pg. 14 – 33

7. **Abass, O.A,** Dawodu, Adekunle A. and Yisau, Nurudeen B. (2021): Towards SDG-9: An IoT Architecture for Converging OT-IT in Industry 4.0 and Digital Economy Era. University of Ibadan Journal of Science and Logics in ICT Research (UIJSLICTR), Vol. 6 No. 2, pp. 57-67 ©U IJSLICTR Vol. 6, No. 2, June 202

b. Publications in Edited and Published Conference Proceedings:

International

1. International Science, Technology, Education, Arts, Management and Social Sciences (SMART-iSTEAMS), Scaling Multi-Thong Allied Research Using Advance Research Techniques (SMART-2018) Conference, Delta State Polytechnic, Ogwuashi-Uku, Delta State, Nigeria – Feb.27 – 1 March, 2018

Paper Presented

Kaka, O.A, Arowolo, O. A, **Yisau, N. B**, & Longe, O. B (2018) "Filtering Offensive Language in Online Social Networks Using Natural Language Processing".. Pages 441 – 452

National

2. Basic Science Education and Entrepreneurship for Sustainable Development. National Conference of Sciences held at Michael Otedola College of Primary Education (MOCPED), Lecture Theater II, Noforija, Epe, Lagos State from 8th-11th November, 2016

Paper Presented

Olusanya A.O, Dairo A.J & **Yisau N.B** (2016): Prospects of Electronic Library As A Resource for Effective Teaching and Learning in Nigerian Educational System

c. Unpublished theses:

Diploma Theses: Computerized Examination Compilation and Grading System (A case study of Diploma in Data Processing Programme in OSU), 1999

B.Sc. Degree Theses: On-Line Job Placement and Recruitment System 2009

D. Mimeograph

- Operating System
- Introduction to Database Management System
- Computer Graphics and Desktop Publishing
- Electronic Data Processing
- Computer Operation and Applications
- Operation Research

E. WORKSHOP/SEMINAR ATTENDED

Workshop on Advanced Digital Appreciation Programme for Tertiary Institutions, Organized by Digital Bridge Institute, International Centre for Information and Communications Technology Studies, held at Tai Solarin College of Education, Omu- Ijebu, Ogun State from 14th – 18th, 2018.

A 2-day Capacity Building Workshop on Innovative Pedagogy & Grant-winning Research Proposal Writing jointly organized by Tai College of Education, Omu-Ijebu, Nigeria and University of Education, Winneba, Ghana, from 30th October, 2018.

Workshop on Advanced Digital Appreciation Programme for Tertiary Institutions on Statistical Package for Social sciences, organized by Digital Bridge Institute, International Centre for Information and Communications Technology Studies, held at Tai Solarin, College of Education, Omu-Ijebu, Ogun State from November, 2018

F. CURRICULAR ACTIVITIES

- Computation officer for 300 level students 2019/2020 graduating year set.
- Level Adviser officer, 200 Level students 2016/2017 admission year set.
- Present 100 level 2019/2020 admission year set computation officer.

G. CONTRIBUTION TO THE COLLEGE:

- Member, COAESU TASCE, Omu-Ijebu
- Member, College Accreditation Committee, 2016
- Member, Muslim Community TASCE chapter, Omu-Ijebu
- Computer Science Departmental Secretary
- CEVOVED Computer Departmental Coordinator
- Member, TASCE Retirement Benefits Scheme (RBS)

H. CONTRIBUTION TO THE COMMUNITY LIFE:

- Member, OOU Old Student Association Ijebu Ode chapter
- Member, Alfred Aken, Olowora Community Development Association

- Member, Alfred Aken, Olowora Community Vigilante Group
- Member, Alfred Aken, Olowora Muslim Community
- Member, Molusi College, Ijebu Igbo Secondary School Old Student Association
- Member, Molusi College Old Student Association, Lagos Branch
- Member, Alfred Aken, Olowora, Lagos youth wing
- Member, Alfred Aken Tenants Group Association
- Member, Alfred Aken Muslim Community Group

I. HOBBIES:

Playing Football, Reading, Discovery on Science and Watching documentaries

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Yisau, Nurudeen Babatunde **Date**

University Compliance Certification

This is to certify that this thesis by Yisau, Nurudeen Babatunde with Matriculation Number LCU/PG/000382 in the department of Computer Science, Faculty of Natural and Applied Sciences, Lead City University Ibadan, Oyo State, Ibadan is in full compliance with the approved University's Format and Style.

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Name Date