REAL TIME IMAGE AND AUDIO TRANSMISSION USING A REMOTELY CONTROLLED MECHATRONIC AGENT

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DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FACULTY OF ENGINEERING

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A PROJECT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING, FACULTY OF EGINEERING, UNIVERSITY OF BENIN, BENIN CITY. IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELOR OF ENGINEERING (B. ENG) IN ELECTRICAL AND ELECTRONIC ENGINEERING

FEBRUARY, 2025.

CERTIFICATION

This is to certify that this project was carried out by **ERHUNMWUN OSAHENRUNMWEN SPECIAL (MISS)** with matriculation number **ENG1805061; ADOH OLISEH MICHAEL** with matriculation number **ENG1905527; UMOLE DANIEL OSHIOTSE** with matriculation number **ENG1905400; JOSEPH JEREMIAH EIBO** with matriculation number **ENG1805086; OBI CHEIJINE JOHN** with matriculation number **ENG1905351; ODEGE LAWRENCE OBAJE** with matriculation number **ENG1604171.**

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DEDICATION

We dedicate this work to our families, friends, and mentors, whose unwavering support, patience, and encourage have been instrumental in our journey.

We also extend our gratitude to our Supervisor, **Prof. (Mrs.) Patience E. Orukpe** and our Co-Supervisor, **Engr. Enosa N. Iyekekpolo** and all those who have inspired and guided us throughout this research. Their wisdom and dedication to knowledge have been a source of motivation.

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We extend our deepest gratitude to God Almighty for granting us the strength and perseverance to complete our journey at the University of Benin in pursuit of a Bachelor's degree in Electrical and Electronic Engineering. Through His grace, we successfully navigated this project despite the challenges posed by the condensed academic calendar and other obstacles.

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We would like to express special thanks to our parents and guardians for their constant encouragement and unwavering support throughout our academic journey. We are also immensely grateful to our friends who stood by us and provided assistance whenever we needed it—their kindness and support helped us overcome numerous challenges.

Lastly, a heartfelt appreciation goes to every member of the Electrical and Electronic Engineering graduating class of 2023/2024. The journey was far from easy, but together, we made it to the finish line.

Congratulations to us all!

ABSTRACT

There are several uses for real-time image and audio transmission through a remote-controlled agent in telepresence, remote monitoring, surveillance, search and rescue operation, healthcare and medical applications, industrial inspection and maintenance, and education alongside research. Hence, the aim of this work is to develop a real time image and audio transmission using a remotely controlled mechatronic agent.

This study describes a system that combines computer vision, audio processing, and wireless communication to provide real-time multimedia streaming via remotely operated agent. A mobile robotic platform with a camera embedded with a microphone feature that makes up the suggested system, which sends live audio and video data to a distant control center via a wireless network.
In order to maximize bandwidth utilization and guarantee low latency and high-quality transmission, sophisticated compression algorithms are used. To improve the clarity of the received data, the system also includes image stabilization and noise reduction. The effectiveness of several communication technologies, including Wi-Fi and 5G, in preserving a steady connection in changing settings is assessed. The recommended system consist of an ES-Custom RC transmitter and receiver for remote control, a lithium battery as the power source, a Standalone x360 mini camera with motion sensor and flash features for real-time streaming, a TP4056 charger module for battery management alongside a mobile platform being driven by two electric motors where one motor is controlling the front wheel responsible for the forward motion of the prototype and the other electric motor that is responsible for the rotational motion of the aforementioned system, and a servo motor that is responsible for the general motion (which can either be forward, backward, or rotational motion) of the camera system. The TP4056 charger module is connected

to an AC supply power source which has a BMS (Battery Management System) in place to prevent against overcharge of the system and also over-discharge of the system when it is in use. The power being supplied by the AC source is converted to a DC power source via the TP4056 charger module which charges the two Lithium battery and stores this energy within a voltage range of 3.7 – 4.2 volts, 1 Amp. The Step-up module helps to convert the voltage being provided by the two Lithium batteries to a steady 5 volts which is required by the camera for its utilization. The RV (Remote Vehicle) System contains several chips serving different functions – One of these chips manages the power that comes into the system (the single small black chip), there is a big black chip apart from the two black chips arranged side by side which manages the control and the other black chip is responsible for the light function. The video feedback from the Camera is displayed on an Android phone device via an app known as V380pro, and this app can be connected through a HotSpot and a Wi-Fi connection alongside with the barcode on the camera system being scanned.

The developed system when connected together performed satisfactorily. It will help to monitor an environment via mobile phone in which the system is placed.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

In recent years, the demand for intelligent surveillance systems has grown significantly due to the increasing need for security, safety, and real-time monitoring in both public and private domains (Zhang & Lee, 2021). Traditional surveillance systems, such as closed-circuit television (CCTV) cameras, have long been used to observe and record activities in various environments (Smith *et al*., 2020*)*. However, these systems often have limitations, including restricted field of view, lack of mobility, and delayed response times. To overcome these challenges, modern surveillance technologies have evolved to incorporate real-time image and audio transmission, remote control, and intelligent data analysis, making them more efficient and adaptable to dynamic security needs (Ibrahim, Advances in Remote Surveillance Technologies: A Review of Smart Security Systems, 2016). Recent studies highlight the importance of these advancements in enhancing surveillance capabilities (Smith *et al*., 2020*)*.

With the rapid advancement of Internet of Things (IoT) technologies, surveillance systems have become more interconnected and intelligent, enabling seamless communication between devices, real-time data processing, and automated decision-making. IoT-integrated surveillance solutions allow users to monitor environments remotely, detect anomalies, and respond promptly to security threats (Madsen & Sadowski, 2019). These systems are particularly useful in applications such as home security, industrial monitoring, traffic surveillance, and public safety, where real-time information is crucial for immediate action. The ability to transmit high-quality audio and video in real time enhances situational awareness and facilitates better decision-making for security personnel and emergency responders (Zhang & Lee, 2021). Nguyen et al (2022) further emphasize the role of IoT in revolutionizing real-time monitoring.

The development of remote-controlled surveillance agents has gained significant attention in recent years, particularly in the fields of electrical, electronics, mechatronics and robotics engineering. These agents, often designed as autonomous or semi-autonomous robotic platforms, are equipped with cameras, microphones, and various environmental sensors to capture and transmit real-time data from their surroundings. By leveraging wireless communication technologies, such as Wi-Fi, 5G, and radio frequency (RF) transmission, these agents can provide continuous live feeds to remote operators, making them highly effective for surveillance applications, especially in home security (Ibrahim, Advances in Remote Surveillance Technologies: A Review of Smart Security Systems, 2016).

One of the key advantages of remote-controlled surveillance agents is their mobility, which allows them to navigate complex environments and reach areas that static cameras cannot cover. This makes them particularly useful for high-risk areas, such as disaster zones, military operations, and hazardous industrial sites, where human presence may be unsafe (Gonzalez *et al*., 2020). Additionally, their ability to integrate with artificial intelligence (AI) and machine learning algorithms enables advanced functionalities such as object recognition, motion detection, and automated threat assessment (Madsen & Sadowski, 2019). Patel & Wang (2023) have demonstrated how AI integration significantly improves surveillance accuracy and efficiency.

Despite these advancements, several challenges remain in the development and implementation of real-time image and audio transmission systems. Factors such as latency, bandwidth limitations, data security, and power consumption must be carefully addressed to ensure the efficiency and reliability of these systems (Smith *et al.,* 2020). Moreover, designing cost-effective and scalable solutions is crucial for wider adoption across various industries (Zhang & Lee, 2021).

This study explores the design and implementation of a real-time image and audio transmission system using a remote-controlled agent, focusing on optimizing transmission quality, reducing latency, and ensuring secure data communication. By leveraging recent advancements in wireless networking, embedded systems, and AI-driven analytics, this research seeks to contribute to the ongoing development of intelligent surveillance technologies that enhance security, efficiency, and real-time decision-making (Nguyen *et al*., 2022). Patel & Wang (2023) suggest that integrating these technologies will set new standards for real-time surveillance capabilities.

1.2 Statement of Problem

Home surveillance has become a critical concern in modern society due to the increasing need for security and safety in residential areas. Traditional home surveillance systems, such as fixed CCTV cameras, are often limited in their ability to provide comprehensive coverage of a property. Being stationary, it makes it difficult to monitor large or dynamic areas effectively. Additionally, CCTV cameras rely heavily on visible light, which limits their effectiveness in low-light or nighttime conditions. As a result, homeowners often face challenges in ensuring continuous and reliable monitoring of their premises. Another significant challenge in home surveillance is the lack of real-time accessibility. Many existing systems require users to be physically present or rely on complex setups to access surveillance data remotely which can lead to delay in response in emergency situations, such as break-ins or accidents, where immediate action is crucial. This study therefore, offers a cost-effective, user-friendly, and versatile surveillance solution that can address the limitations of traditional home surveillance systems.

1.3 Aim and Objectives of the Study

The primary aim of this research is to design and implement a remote-controlled surveillance agent capable of real-time image and audio transmission for home surveillance applications. The study seeks to enhance security monitoring by integrating wireless communication, power efficiency, and remote control functionalities into a compact and mobile system.

The objectives of the study includes:

i. To design and construct a remote-controlled surveillance agent using a modified RC motor, equipped with a 360-degree rotating camera and audio capture capabilities to provide comprehensive environmental monitoring.

ii. To develop a reliable power management system

iii. To implement an intuitive remote control system that enables users to operate the agent movement.

iv. To establish a real-time image and audio transmission system by integrating a high quality video and audio streaming module/system. And to adjust the camera orientation via a user-friendly mobile application, ensuring seamless maneuverability and enhanced Surveillance coverage.

1.4 Methodology

The research methodology involves the following:

i. Design a modified RC motor chassis to be equipped with a front stepper motor for movement, rare wheels motor, a camera system for image and audio capture.

ii. Integrate a power management system, including a 3.7v lithium battery, 5v USB charging port, TP4056 DW01A Charger module, and voltage regulator module to ensure continuous operation.

iii. Enable remote operation of the agent movement through the use of ES-Custom RC receiver for rare and front wheel control through a ES-Custom RC transmitter.

iv. Control camera orientation via the V380 app, which enables users to view and hear what the camera is capturing in real-time.

1.4 Significance of the Study

This research contributes to the field of surveillance technology by providing a cost-effective and portable solution for real-time monitoring. The developed system can be used in various applications, including home security, elderly care, and environmental monitoring. By leveraging existing technologies such as RC vehicles, wireless communication, and mobile applications. This study demonstrates the potential for innovative and accessible surveillance solutions.

The mobility of the surveillance agent makes the system more versatile and reliable compared to traditional surveillance systems that are stationary and conformed to a particular location. Furthermore, the use of a user-friendly mobile application ensures that the system is accessible to a wide range of users, including those without technical expertise. The system's portability and ease of use also make it suitable for deployment in resource-constrained environments, where traditional surveillance systems may be impractical or too expensive.

1.5 Scope of the Study

This study focuses on the design and implementation of a remote-controlled agent for real-time image and audio transmission. The system is designed for home surveillance applications. The study does not cover advanced features such as artificial intelligence-based object detection or long-range communication. However, the proposed system provides a foundation for future enhancements and integrations. The scope of this research is limited to the development and evaluation of a prototype system, with a focus on ensuring reliability, portability, and ease of use.

1.6 Justification of the Study

The need for effective and affordable surveillance systems has become increasingly important in today's world, where security threats are on the rise. Traditional surveillance systems are often expensive, require complex installations, and lack the flexibility needed for dynamic environments. This research addresses these limitations by developing a portable and cost-effective remote-controlled agent capable of real-time image and audio transmission.

The ability of the surveillance agent to move freely in a room makes the system more versatile and reliable compared to traditional surveillance systems that is stagnant and stationary. Additionally, the use of a user-friendly mobile application ensures that the system is accessible to a wide range of users, including those without technical expertise.

The findings of this research have the potential to contribute significantly to the field of surveillance technology by providing a foundation for future studies on advanced remote-controlled agents. The system's portability and ease of use also make it suitable for deployment in resource-constrained environments, where traditional surveillance systems may be impractical or too expensive.

CHAPTER TWO

LITERATURE REVIEW

RC surveillance agents, often embodied as robots or unmanned vehicles, represent a significant advancement in security and monitoring technologies. These agents offer a dynamic and adaptable approach to surveillance, providing real-time data collection, remote operation, and often, automated analysis capabilities. They are designed to extend human perception and presence into environments that may be difficult, dangerous, or simply too vast to monitor effectively with traditional methods. A key strength lies in their ability to be deployed rapidly and repositioned as needed, offering flexibility that fixed surveillance systems lack. This adaptability makes them valuable tools in diverse applications, from routine security patrols and industrial inspections to responding to emergencies and monitoring remote or hazardous locations. Furthermore, the integration of advanced sensor technologies, such as high-resolution cameras, thermal imaging, and environmental sensors, allows these agents to gather a rich array of data, providing a comprehensive understanding of the monitored environment. (Kaddouri, 2025)

The functionality of a RC surveillance agent hinges on a suite of interconnected systems. At its core is the mobile platform, the physical embodiment of the agent, which can take various forms, from wheeled robots and aerial drones to even underwater vehicles.

This platform is equipped with the necessary sensors to capture visual, auditory, and other relevant environmental data. The real-time transmission of this data to a remote control station is critical, enabling human operators to maintain situational awareness and make informed decisions. This transmission relies on robust communication links, often leveraging a combination of wireless technologies like Wi-Fi, cellular networks, or radio frequencies. The operator interface provides controls for navigating the agent, manipulating its sensors (e.g., adjusting camera angles), and often, receiving alerts triggered by specific events, such as motion detection or the detection of a specific object. In more sophisticated deployments, the agent may incorporate a degree of autonomy, allowing it to perform pre-programmed tasks or navigate using GPS and sensor data (Emil *et al*., 2004).

Beyond the basic functionalities of remote control and data transmission, modern RC surveillance agents increasingly incorporate sophisticated data processing and analysis capabilities. Onboard processing or transmission to a central server allows for real-time analysis of the collected data. This can include features like motion detection, object recognition, facial recognition (with careful attention to ethical considerations), and data logging for later review. These analytical tools significantly enhance the effectiveness of the surveillance agent, enabling it to automatically identify potential threats, anomalies, or areas of interest. This reduces the burden on human operators, allowing them to focus on critical events and make more informed decisions. Looking ahead, advancements in artificial intelligence and machine learning promise to further enhance the capabilities of RC surveillance agents, enabling them to operate more autonomously, adapt to changing environments, and provide even more insightful analysis of the data they collect. (What is on-board data processing?, 2025)

Figure 2. 1: RC SURVEILLANCE ROBOT *(Prebuilt PTW-42-L 4WD Inspection and Surveillance Robot with Scissor Lift and PTZ Camera, 2025)*

2.1 Core Functionality & Technology:

At the heart of surveillance robot lies its ability to capture and transmit high-quality image and audio data. This relies on several key technological components:

2.1.1 Image and Audio Capture Technologies.

The "eyes and ears" of the robot. Camera selection is crucial, encompassing factors like resolution (defining image clarity), frame rate (determining video smoothness), and low-light performance (essential for nighttime operation). Microphones must be sensitive enough to capture clear audio, often incorporating noise cancellation to filter out background interference. Efficient encoding/decoding algorithms are vital for compressing the captured data for transmission without excessive latency (VirtuGuard, 2025).

2.1.2 Real-Time Transmission Protocols and Networks.

Reliable, real-time data transmission is essential for effective surveillance robot operation. Protocols like TCP/IP, UDP, and WebRTC enable this communication. Bandwidth considerations are paramount, as they directly impact video resolution and frame rate. Optimization techniques and error correction mechanisms are vital for maintaining signal integrity, particularly in difficult environments. Support for mobile networks (3G/4G/5G) further enhances the robot's reach.

2.1.3 Remote Control Mechanisms.

The operator's interface with the robot. Control interfaces can range from simple web-based dashboards to sophisticated mobile applications. Low latency and responsive control signals are essential for precise maneuvering. Intuitive user experience and ease of control are crucial for effective operation.

2.1.4 Hardware and Software Architectures.

The foundation up on which the robot operates. Embedded systems offer dedicated processing power for specific tasks, while general-purpose computers provide more flexibility. The chosen software platforms and frameworks dictate the robot's capabilities and ease of development. Power management and battery life are critical, especially for autonomous or long-duration deployments.

2.2 Surveillance Specific Considerations:

Beyond the core functionality, surveillance robots require specialized features:

2.2.1 Video Analytics and Processing.

Transforming raw data into actionable intelligence. Object detection and tracking algorithms identify and follow specific targets. Motion detection triggers alerts when activity is detected.

Facial recognition, while powerful, raises significant ethical concerns and requires careful consideration. Efficient data storage and retrieval are essential for reviewing and analyzing recorded footage.

2.2.2 Security and Privacy.

Paramount concerns in any surveillance system. Data encryption and authentication protect data from unauthorized access. Access control and user management ensure only authorized personnel can control the robot and view the footage. Regular vulnerability analysis and penetration testing identify and address potential security weaknesses. The ethical implications of surveillance, particularly concerning privacy, must be carefully considered.

Figure 2. 2: A RC SURVEILLANCE ROBOT DOING SECURITY CHECK *(Unleashing Mobile Surveillance: The Power of Security Robots, 2024)*

2.2.3 Scalability and Deployment.

Managing a fleet of robots. Effective systems can handle multiple agents and video streams simultaneously. Centralized monitoring and control simplify management. Integration with existing surveillance systems enhances overall effectiveness.

2.2.4 Environmental Considerations.

Ensuring robust performance in diverse settings. Weatherproofing and ruggedization protect the robot from the elements. Power consumption and energy efficiency are crucial for extended deployments. The robot's design must be tailored to the specific environment it will operate in (indoor/outdoor, urban/rural).

2.3 Related Areas & Comparisons:

Understanding surveillance robots requires examining them within a broader context:

2.3.1 Comparison with other Surveillance Technologies.

Placing robots within the spectrum of available tools. CCTV systems offer static surveillance, while drone-based surveillance provides aerial perspectives. Cloud-based video surveillance offers remote access and storage. Understanding the strengths and weaknesses of each technology allows for informed selection.

2.3.2 Applications of Remote Controlled Surveillance Agents.

Exploring the diverse uses of these robots. Security and law enforcement are obvious applications, but environmental monitoring, industrial inspection, and even remote presence for specialized tasks are also potential uses.

2.4 Ethical and Legal Implications of Surveillance:

The use of surveillance robots raises several ethical and legal questions:

i. **Privacy concerns and data protection:** Balancing security needs with individual privacy rights. Robust data protection measures are essential to prevent misuse of collected information.
ii. **Transparency and accountability:** Ensuring that surveillance is conducted openly and responsibly. Clear guidelines and oversight mechanisms are necessary to prevent abuse.
iii. **Potential for misuse and abuse:** Recognizing the potential for surveillance technologies to be used for malicious purposes. Safeguards must be in place to prevent such misuse.

2.5 Human Factors and User Acceptance:

The human element plays a crucial role in the effectiveness of surveillance robots:

i. **Impact on perceived safety and security:** Understanding how the presence of surveillance robots affects public perception. Balancing the desire for security with potential concerns about privacy.

ii. **User training and acceptance of surveillance technologies:** Ensuring that operators are properly trained and that the public understands the purpose and limitations of surveillance robots.

In conclusion, surveillance robots offer a powerful tool for enhancing security and monitoring capabilities. However, their deployment must be carefully considered, taking into account not only the technical aspects but also the ethical, legal, and social implications. A balanced approach that prioritizes both security and individual rights is essential for the responsible implementation of this technology.

2.6 HARDWARE COMPONENT FOR RC SURVEILLANCE ROBOT

2.6.1 TP54056 BATTERY CHARGING MODULE

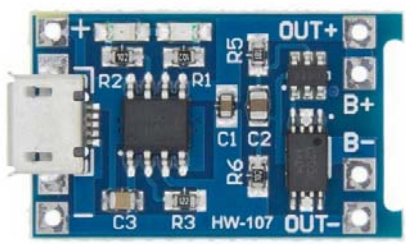

Figure 2. 3: TP54056 BATTERY CHARGING MODULE *(CONTROLLERSTECH, TP4056 Battery Charging Module – with Protection – For Li-ion Battery, 2025)*

This TP4056 Battery Charging Module (Micro USB/TYPE-C) is for Li-Ion Battery Charging. It supports USB Micro / TYPE-C with Current Protection, and is perfect for charging single cell 3.7V 1 Ah or higher lithium-ion (Li-Ion) cells such as 16550s that don't have their own protection circuit. It's based on the TP4056 charger IC and DW01 battery protection IC and provides 1A Charge Current.

When the battery voltage drops below 2.4V the TP4056 Battery Charging Module IC will switch the load off to protect the cell from running at too low of a voltage – and also protects against over-voltage and reverse polarity connection.

Furthermore, when the battery voltage drops below 2.4V the protection IC will switch the load off to protect the cell from running at too low of a voltage – and also protects against over-voltage and reverse polarity connection (it will usually destroy itself instead of the battery) however please check you have it connected correctly the first time.

The TP4056 is a complete constant-current/constant-voltage linear charger for single cell lithium-ion batteries. Its SOP package and low external component count make the TP4056 ideally suited for portable applications. It can work within USB and wall adapter.

No blocking diode is required due to the internal PMOSFET architecture and have prevent to negative Charge Current Circuit. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current can be programmed externally with a single resistor. The TP4056 automatically terminates the charging cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached.

Other features of the TP4056 charger module include current monitor, under voltage lockout, automatic recharge and two status pin to indicate charge termination and the presence of an input voltage (CONTROLLERSTECH, TP4056 Battery Charging Module – with Protection – For Li-ion Battery, 2025)

SPECIFICATION

i. Charging IC: TP4056
ii. Input voltage: 4V~8V
iii. Current protection: YES
iv. Input interface micro: USB/TYPE C
v. LED indicator: RED (CHARGING), GREEN CHARGING
vi. Product dimension: 28×17.3mm
vii. Product weight: 5 GRAMS

2.6.2 RC Surveillance Agent

The RC Surveillance Agent is the tangible, mobile component of the surveillance system. It's a carefully engineered platform, combining mechanical design, electronic systems, and software intelligence to effectively carry the essential equipment and achieve its surveillance goals. The RC (Remote-Controlled) Surveillance Agent serves as the mobile platform that carries the camera and other electronics. It consists of a chassis, wheels, motors, and a control system to navigate and transmit data remotely.

Figure 2. 4: RC SURVEILLANCE ROBOT

2.6.3 360-Degree Rotating Camera with Audio Capturing Abilities

Key Features:

i. High-resolution video (e.g., 1080p or 4K) for clear image transmission.
ii. Pan-tilt-zoom (PTZ) functionality for flexible viewing angles.
iii. Noise-canceling microphone for clear audio capture

This camera provides a full panoramic view and includes a microphone for real-time audio transmission. It is mounted on a rotating mechanism to cover all angles and can be controlled remotely.

Figure 2. 5: Camera

2.6.4 3.7V Lithium Batteries

These rechargeable batteries provide the necessary power for the system. They are lightweight and have a high energy density, making them ideal for prolonged operations.

Figure 2. 6: LITHIUM BATTERIES

2.6.5 Remote Control

A remote control is used for both the motion and direction of the remote-controlled surveillance agent.

Function and Features:

i. Dual Joysticks: This is the most prominent feature. These likely provide direct control over the robot's movement.

ii. Left Joystick: Potentially for steering or turning (tank-like steering where each joystick controls one side of the robot).

iii. Right Joystick: It is for forward/backward movement or controlling another degree of freedom.

iv. Auto control bottom: it has an auto-drive button

v. Power Button: It is used to turn the remote on and off.

Figure 2. 7: REMOTE CONTROL

2.6.6 Motors

A motor is an electromechanical device that converts electrical energy into mechanical motion. Motors are widely used in robotics, automation, and Internet of Things, IoT-based systems for movement and actuation.

Types of Motors used:

SERVO MOTOR

Servo Motors - Provide high precision and controlled motion, often used in robotic arms and camera positioning. It was used in the motion of the camera and front.

Figure 2. 8: SERVO MOTOR *(Roy Kok, Thomas J. Burke, 2023)*

Figure 2. 9: DC MOTOR

2.6.7 Wheels

Figure 2. 10: WHEEL

The agent is equipped with DC motors and wheels (or tracks) for movement. The motors are controlled via an H-bridge motor driver to allow speed and direction control.

Wheel Features:

i. Knobby Tread Pattern: The tire exhibits a knobby, off-road tread pattern with large, irregularly spaced blocks. This indicates a design geared towards high traction on uneven or loose surfaces like dirt, gravel, grass, or even potentially rocky terrain.

ii. Large Diameter: The wheel appears to be of a relatively large diameter compared to its width. This suggests an ability to traverse obstacles more easily and provide a smoother ride over rough terrain.

iii. Red Hub/Rim: The distinct red hub or rim is likely a design choice for aesthetics or visual identification. It doesn't directly impact performance but could be a feature for differentiating between different robots or teams.

iv. Pneumatic Tire: The tire have some give and flexibility, suggesting it's likely a pneumatic (air-filled) tire or a solid rubber tire with some flex. Pneumatic tires offer better shock absorption and adaptability to uneven surfaces compared to solid tires.

v. Text on Sidewall: "DRIFT VEHICLE" & "DRIFT VEHICLE": This is the most crucial clue. It clearly indicates this wheel is designed for "drifting." In the context of RC vehicles, this implies a tire that allows for controlled slides and loss of traction. This is achieved through a specific tread compound and sidewall construction that balances grip and slip.

Relevance to a Remote Control Surveillance Robot:

i. Mobility in Varied Terrain: The knobby tread pattern and large diameter make this wheel suitable for a surveillance robot expected to operate in diverse environments. It could navigate off-road areas, parks, or even potentially challenging indoor spaces with obstacles.

ii. Maneuverability: The "drift" characteristic, while primarily for specialized RC vehicles, could be beneficial in a surveillance robot. It suggests a tire that allows for quick changes in direction and pivoting, useful for navigating tight spaces or keeping a target in view.

Potential Drawbacks:

i. Noise: Knobby tires generally produce more noise on hard surfaces compared to smoother tread patterns. This could be a concern for covert surveillance, though not necessarily a major one.

ii. Wear: Aggressive tread patterns can wear faster, especially with frequent drifting or use on abrasive surfaces.

iii. Control Complexity: The "drift" characteristic might make precise control more challenging for certain applications. A surveillance robot might require sophisticated control algorithms to manage the tire's slip properties for smooth and predictable movement.

2.6.8 Custom RC Transmitter and Receiver Module:

This custom-built RC transmitter and receiver module offers a robust and reliable solution for wirelessly controlling DC and stepper motors. Featuring an L298N motor driver IC, it provides precise direction and speed regulation for two DC motors. The integrated 78M05 voltage regulator ensures stable 5V power for the module's circuitry. This high-power module is well-suited for applications like robotics, drones, and remote-controlled vehicles

2.7 Summary of Findings on Current Uses and Outcomes

2.7.1 Current Uses:

i. Security and Law Enforcement: RC surveillance robots are deployed for patrolling sensitive areas, responding to alarms, monitoring borders, and assisting with crowd control.

ii. Industrial Inspection: Robots inspect pipelines, power lines, and other infrastructure in hazardous or difficult-to-access environments, improving safety and efficiency.

iii. Environmental Monitoring: They are used for wildlife monitoring, pollution detection, and assessing disaster damage, providing valuable data for conservation and response efforts.

iv. Search and Rescue: RC robots assist in locating missing persons in challenging terrains, increasing the chances of successful rescues.

v. Military and Defense: They perform reconnaissance, border patrol, and target identification, enhancing situational awareness and reducing risks to human personnel.

2.7.2 Outcomes:

i. Enhanced Security: Robots can deter crime, provide real-time situational awareness, and improve response times to security incidents.

ii. Increased Efficiency: They automate tasks, reduce the need for human presence in hazardous environments, and improve the speed of inspections and monitoring.

iii. Improved Safety: Robots can reduce risks to human personnel in dangerous situations, such as industrial accidents or search and rescue operations.

iv. Data-Driven Insights: They collect valuable data that can be used to improve decision-making and optimize operations.

2.8 Barriers to Wider Adoption

2.8.1 Technical Barriers:

i. Communication Reliability: Maintaining a stable, high-bandwidth connection, especially in cluttered environments or over long distances, can be challenging. Signal loss or interference can disrupt control and data transmission.

ii. Power Limitations: Battery life remains a constraint for mobile robots. Extended deployments require efficient power management or frequent recharging, which can be logistically difficult.

iii. Sensor Limitations: Current sensor technology may not provide the desired level of detail or accuracy in all situations. For example, low-light performance or adverse weather conditions can limit camera effectiveness.

iv. Autonomous Navigation: While some robots have limited autonomy, truly robust and reliable autonomous navigation in complex and dynamic environments is still a challenge. This limits the robot's ability to operate independently and requires constant human oversight.

v. Integration Complexity: Integrating the robot with existing security systems or other technologies can be complex and expensive.

2.8.2 Economic Barriers:

i. High Initial Cost: Developing and deploying sophisticated RC surveillance robots can be expensive, including the cost of the robot itself, sensors, communication equipment, and control infrastructure.

ii. Maintenance Costs: Regular maintenance, repairs, and software updates can add to the overall cost of ownership.

2.8.3 Legal and Ethical Barriers

i. Privacy Concerns: The use of surveillance robots raises significant privacy concerns, particularly regarding the collection and storage of personal data. Clear regulations and guidelines are needed to address these concerns.

ii. Data Security: Protecting the data collected by surveillance robots from unauthorized access or misuse is crucial. Robust security measures are necessary to prevent data breaches.

iii. Accountability and Transparency: It's important to establish clear lines of accountability for the use of surveillance robots and to ensure transparency in their operation. The public should be informed about how these robots are being used and what data they are collecting.

iv. Potential for Misuse: There is a risk that surveillance robots could be misused for purposes other than those intended, such as spying on individuals or suppressing dissent. Safeguards are needed to prevent such misuse.

2.8.4 Social Barriers:

i. Public Perception: Public perception of surveillance robots can be negative, particularly if they are seen as an intrusion on privacy. Building public trust in the use of these technologies is essential.

ii. Lack of Awareness: Many people are not aware of the capabilities and limitations of surveillance robots. Education and outreach are needed to improve public understanding.

2.8.5 Operational Barriers:

i. Skilled Personnel: Operating and maintaining sophisticated surveillance robots requires skilled personnel. Training programs are needed to develop the necessary expertise.

ii. Deployment Challenges: Deploying surveillance robots in certain environments can be logistically challenging, particularly in remote or hazardous areas.

2.8.6 Block Diagram:

A simple block diagram showing the basic components of the RC surveillance robot and how they interact

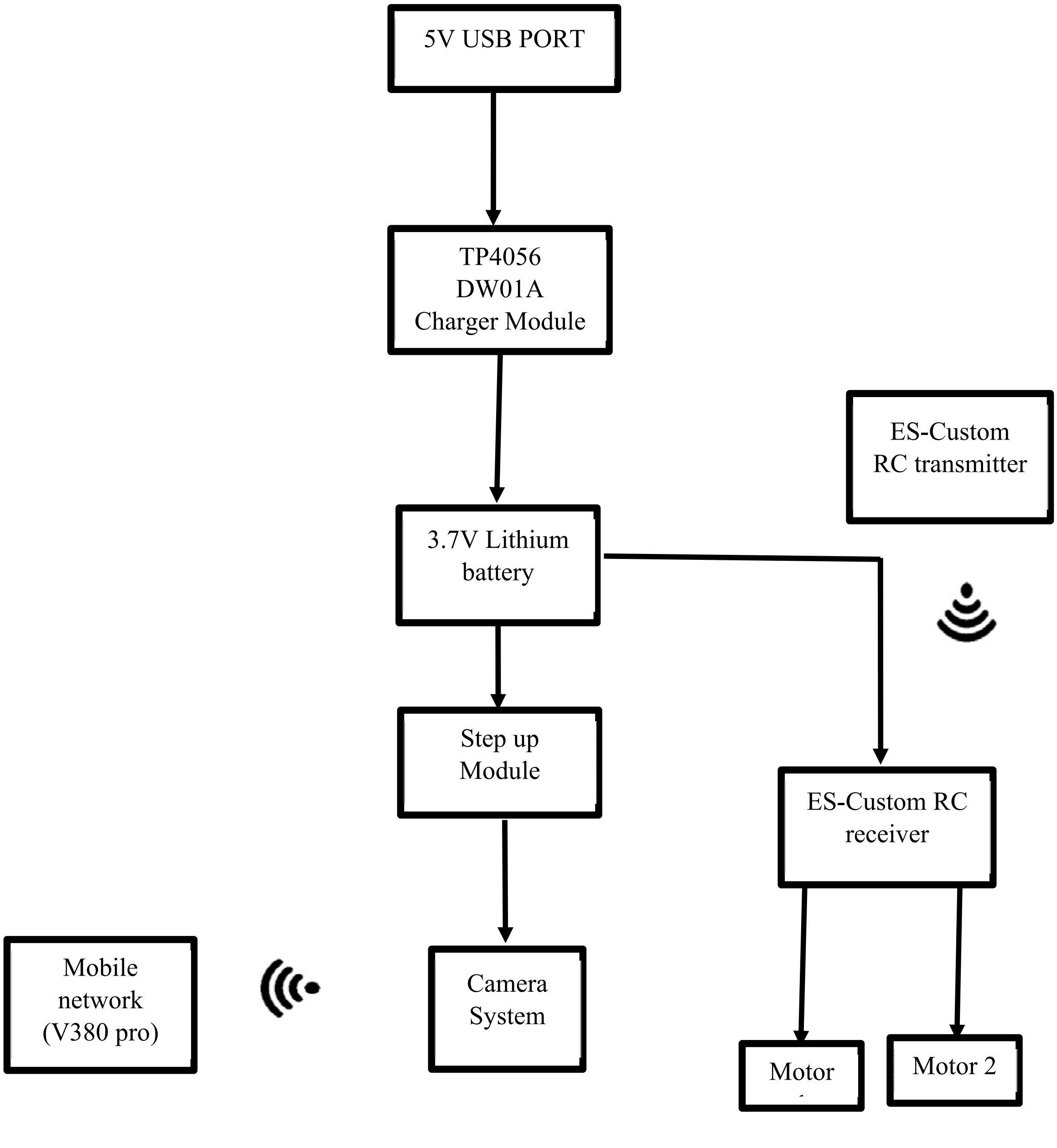

Figure 2. 11: Simple block diagram of a RC surveillance robot

CHAPTER THREE

METHODOLOGY

3.1 Design Framework

Our project's design framework is built on a comprehensive approach that seamlessly integrates both hardware and software components to achieve real-time image and audio transmission. Central to this framework is the Remote Controlled Agent (RCA) robot, which serves as the primary medium for navigation, surveillance, and data acquisition. The design focuses on enhancing the RCA's ability to capture, process, and transmit multimedia data efficiently while maintaining stable remote operation. This section outlines the fundamental principles that guide our design decisions, emphasizing the RCA's role in enabling seamless real-time communication and monitoring (Razavi, 2018).

3.2 Hardware Design

The hardware design for the Real-Time Image and Audio Transmission Using a Remote-Controlled Agent project is centered on creating a reliable, mobile, and efficient system capable of capturing, processing, and transmitting real-time data. The design integrates a combination of mechanical, electrical, and communication components to ensure seamless operation. Key elements include the Remote Electronic Agent (REA) chassis, a 360-degree rotating camera with audio capture, power management modules, and a user-friendly remote control (Boltan, 2021). Additional components such as wheels, motors, and sensors enhance mobility and functionality. The hardware is designed to be lightweight, durable, and energy-efficient, ensuring reliable performance in real-world applications (Kurniawan, 2018).

3.2.1 Features of Hardware components

i. Hardware Design Overview

The hardware design of the real-time image and audio transmission system using a remote-controlled agent consists of several key components. Each component plays a crucial role in ensuring the functionality, mobility, power management, and communication capabilities of the system. Below is a detailed explanation of each component:

a. RC Surveillance Agent

The RC (Remote-Controlled) Surveillance Agent serves as the mobile platform that carries the camera and other electronics. It consists of a chassis, wheels, motors, and a control system to navigate and transmit data remotely (Texas Instruments, 2017).

b. 360-Degree Rotating Camera with Audio Capturing Abilities

Key Features:

i. Pan-tilt-zoom (PTZ) functionality for flexible viewing angles.

ii. High-resolution video (e.g., 1080p or 4K) for clear image transmission.

iii. Noise-cancelling microphone for clear audio capture

This camera provides a full panoramic view and includes a microphone for real-time audio transmission. It is mounted on a rotating mechanism to cover all angles and can be controlled remotely. The camera features pan-tilt-zoom (PTZ) functionality for flexible viewing angles, high-resolution video (e.g., 1080p or 4K), and a noise-cancelling microphone for clear audio capture (Espressif Systems, 2022).

c. Two 3.7V Lithium Batteries

These rechargeable batteries provide the necessary power for the system. They are lightweight and have a high energy density, making them ideal for prolonged operations (Yang *et al*., 2020).

d. 5V USB Charging Port

This port allows convenient recharging of the lithium batteries using a standard USB power source, ensuring ease of use and accessibility.

e. Voltage Regulator Module

This module stabilizes the voltage output to ensure that all electronic components receive the appropriate power levels, preventing damage due to fluctuations. (Srbinovska *et al*., 2015).

f. Micro USB with Protection Circuit

This component ensures safe charging and protects the circuit from overvoltage, overcurrent, and short circuits, thereby increasing system longevity. (Arduino.cc, 2023).

g. TP4056 DW01A Charger Module

A dedicated lithium battery charging module that manages battery charging and protection, ensuring safe and efficient recharging.

h. Remote Control

This handheld controller sends wireless commands to the surveillance agent, allowing remote navigation and camera control. It typically operates on infra-red (IF) communication.

i. Motors and Wheels

The agent is equipped with DC motors and wheels (or tracks) for movement. The motors are controlled via an H-bridge motor driver to allow speed and direction control.

j. Microcontroller Unit (MCU)

A microcontroller (such as an Arduino, ESP32, or Raspberry Pi) serves as the brain of the system, handling signal processing, camera control, motor movement, and wireless communication.

k. Antenna and Wireless Module

A wireless module (such as NRF24L01 or Wi-Fi/Bluetooth module) is used for communication between the RC agent and the remote control, enabling real-time data transmission. (Raspberry Pi Foundation, 2023).

This hardware setup ensures efficient real-time image and audio transmission with remote-controlled mobility, making it suitable for surveillance and monitoring applications.

3.2.2 Selection Criteria

The selection criteria are:

i. Processing Power

The microcontroller or processor must be capable of handling real-time image and audio processing, compression, and transmission. Since the project involves live data streaming, a high-performance processor with a fast clock speed and parallel processing capabilities is essential. Additionally, the processor should efficiently handle communication protocols such as **Wi-Fi, Bluetooth, or RF transmission** to ensure low-latency data transfer (Smith, 2008).

ii. Memory

Sufficient **RAM** is required to store image frames, audio buffers, and temporary data during real-time processing. Adequate **ROM/Flash memory** is necessary to accommodate the firmware, control algorithms, and communication protocols. Since real-time transmission demands quick access to data, a processor with high-speed memory architecture is preferred to avoid bottlenecks (Beckmann & Fung, 2010).

iii. **I/O Ports & Connectivity**

The selected microcontroller must support multiple **I/O ports** for interfacing with:

i. **Camera modules** (e.g., CSI, USB, or SPI for image capture)
ii. **Microphone/sound sensors** (e.g., I2S, ADC for audio input)
iii. **Wireless communication modules** (e.g., Wi-Fi, Bluetooth, RF transceivers)
iv. **Motor drivers & actuators** (for controlling movement if applicable)
v. **External storage devices** (SD card or flash memory for temporary data buffering).
vi. A processor with **multiple GPIOs, UART, I2C, SPI, and USB support** will be preferred to ensure seamless integration of all components (I/O Ports, 2015).

iv. **Power Efficiency**

Since the remote-controlled agent is likely to be battery-powered, energy consumption is a crucial factor. The microcontroller must offer **low-power modes** and efficient power management to maximize battery life while maintaining real-time performance. A balance between processing power and energy efficiency is essential to prevent excessive power drain during operation (Chevallier, 2024).

v. Availability and Cost

The microcontroller should be:

a. Easily available in the market to ensure maintainability and scalability.
b. Affordable without compromising the necessary performance required for real-time transmission.

c. Well-supported with an active community, extensive documentation, and compatibility with development tools to simplify implementation. These criteria ensure that the selected microcontroller or processor meets the demands of real-time image and audio transmission while maintaining efficiency, cost-effectiveness, and reliability (Design, 2023).

3.2.3 IoT Components in Real-Time Image and Audio Transmission using A Remote-Controlled Surveillance Agent

In this project, IoT plays a crucial role in enabling seamless real-time image and audio transmission. The remote-controlled agent, equipped with a camera and microphone, captures live data and transmits it wirelessly. A **microcontroller or microprocessor**, such as the **NodeMCU ESP8266**, processes the data and facilitates communication with external systems (R.Santos, 2015). Wireless transmission is achieved through Wi-Fi, Bluetooth, or RF modules, ensuring that image and audio data reach the remote operator with minimal delay. IoT communication protocols, such as **MQTT, HTTP, or WebRTC**, enable efficient data exchange while maintaining low latency (MQTT vs HTTP for IoT: Detailed Protocol Comparison, 2023). Additionally, a smartphone app, web interface, or dedicated control panel allows users to monitor and control the agent remotely, providing a responsive and interactive experience. This integration of IoT ensures real-time data streaming, effective communication, and remote accessibility, making the system more efficient and scalable.

3.2.4 Custom RC Transmitter and Receiver Module: Wireless High-Power Control for DC and Stepper Motors

The Custom RC Transmitter and Receiver Module is designed for wireless motor control, enabling seamless communication between a remote controller and a motorized system. It integrates with motor drivers like the **L298N**, which is a high-power module specifically built for controlling DC and stepper motors (L298N Motor Driver Module Pinout, Datasheet, Features & Specs, 2025).

At its core, the L298 motor driver IC facilitates precise direction and speed regulation, ensuring smooth operation. Additionally, the built-in **78M05 voltage regulator** provides a stable **5V output**, supporting the module's logic circuitry. The **L298N module** can independently drive two DC motors, making it suitable for robotics, automation, and remote-controlled vehicles (Balboni *et al*., 2022)

When paired with a **custom RC transmitter and receiver**, the system enables real-time wireless control, allowing users to regulate motor movement remotely. The module's capability to handle high currents and voltages ensures efficient and reliable performance, making it ideal for applications requiring precision, power, and stability in wireless motorized control.

This custom solution is perfect for applications requiring robust, wireless control of motorized systems, such as robotics, drones, and remote-controlled vehicles. Its ability to deliver high-power performance while maintaining stability and efficiency makes it a reliable choice for advanced motor control projects (XRC PRO: Open-Source RC Transmitter and Receiver System with STM32 & NRF24L01, 2022).

Table 3. 1: For ES - Custom RC Transmitter and Receiver Pin out Module Table

PIN NAME	DESCRIPTION
VCC	Powers the transmitter module.
GND	Common ground connection.
ENA	Enables PWM signal for Motor A
ENB	Enables PWM signal for Motor B
ANT	External antenna connection for extended range.
SDA/SC	For advanced configurations or communication with microcontrollers
LED	Indicates power and signal reception status.
5V Out	Provides 5V for powering low-voltage components
M1A/M1B	Output pins for controlling Motor 1 (direction and speed).
M2A/M2B	Output pins for controlling Motor 2 (direction and speed).
GND	Ground pin's switching logic circuitry.

3.2.5 Overview of Custom RC Transmitter and Receiver Module: Wireless High-Power Control for DC and Stepper Motors (Module Pins)

The Custom RC Transmitter and Receiver Module is a wireless motor control system that enables real-time remote operation of DC and stepper motors. It consists of a transmitter unit (remote control) and a receiver unit (motor driver integration). The receiver module connects to a motor driver (e.g., L298N, TB6612FNG) to process the transmitted commands and control motor speed and direction. This custom solution is perfect for applications requiring robust, wireless control of motorized systems, such as robotics, drones, and remote-controlled vehicles (Balboni *et al.,* 2022). Its ability to deliver high-power performance while maintaining stability and efficiency makes it a reliable choice for advanced motor control projects. In terms of module pins, typical connections include VCC/GND power supply pins; TX/RX data transmission/reception pins; CE/CSN chip enable/select pins specifically used with wireless modules like NRF24L01; SCK/MOSI/MISO SPI communication pins between microcontrollers and wireless modules. These components work together seamlessly when properly configured with appropriate code uploaded onto the microcontrollers at both ends of the system. For example, using NRF24L01 with Arduino involves defining radio objects based on CE & CSN pin connections in our setup function before setting channels or power levels. (nRF24L01 – How It Works, Arduino Interface, Circuits, Codes, 2023).

3.3 Module Pin Configuration

3.3.1 Transmitter Module Pins (e.g., NRF24L01, Bluetooth, or Wi-Fi module)

i. **VCC** – Power supply (typically **3.3V or 5V**).

ii. **GND** – Ground connection.

iii. **CE (Chip Enable)** – Activates the module for data transmission.

iv. **CSN (Chip Select Not)** – Enables SPI communication with the Es-custom RC Transmitter and Receiver.

v. **MISO (Master In Slave Out)** – Data received from the receiver module.

vi. **MOSI (Master Out Slave In)** – Data sent from the transmitter to the receiver.

3.3.2 How the Pins Work Together

The Custom RC Transmitter and Receiver Module operates through a coordinated interaction between the transmitter, receiver, and motor driver module. The **transmitter module** reads user inputs from joysticks, buttons, or sensors and sends the corresponding control signals wirelessly via an RF module such as **NRF24L01, Bluetooth, or Wi-Fi**. These signals are received by the receiver module, which processes the data and transmits it to a microcontroller **(Arduino, ESP32, or STM32)** for interpretation (Ali, Rehman, & Khan, 2014).

The transmitter then generates the necessary control signals for the **receiver** (Es-custom RC Receiver), which regulates the movement of the **DC or stepper motors**. The **IN1 and IN2 pins** determine the **direction** of **Motor A**, while **IN3 and IN4** do the same for **Motor B**. The **ENA and ENB pins** enable motor operation and allow for **Pulse Width Modulation (PWM) speed control**, which adjusts the motor speed by varying the duty cycle of the signal. The **OUT1 and OUT2 pins** provide power output to **Motor A**, and **OUT3 and OUT4** do the same for **Motor B**, ensuring the motors receive the appropriate voltage and current for movement (Joshi, 2013).

This entire system enables **real-time wireless motor control**, allowing users to adjust motor speed and direction remotely with precision and efficiency. The integration of wireless communication, microcontroller processing, and agent operation ensures smooth and reliable performance in applications such as remote-controlled robots, RC vehicles, and industrial automation systems (Balboni, Bianco, & Mongelli, 2022.).

i. **IN1 & IN2 (Motor A Direction Control)**
   - **a.** These pins determine the spinning direction of **Motor A.**
   - **b.** By setting these pins to **HIGH (1) or LOW (0)** in different combinations, you can control whether the motor moves forward, backward, or stops.

ii. **IN3 & IN4 (Motor B Direction Control)**
   - **a.** Similar to **IN1 & IN2,** these pins are used to regulate the spinning direction of **Motor B.**
   - **b.** Changing the **HIGH** and **LOW** states of these pins controls **Motor B's** motion.

iii. **ENA (Enable for Motor A)**
   - **a.** This pin enables **Pulse Width Modulation (PWM)** control for **Motor A.**
   - **b.** By adjusting the **PWM signal,** you can control the speed of **Motor A.**
   - c. If **ENA** is **HIGH, Motor A** is enabled and can spin**;** if **LOW,** it is disabled.

iv. **ENB (Enable for Motor B)**
   - **a.** This pin functions the same as **ENA,** but it controls **Motor B** instead.
   - **b.** A **PWM** signal sent to **ENB** will regulate **Motor B's** speed.

v. **OUT1 & OUT2 (Motor A Outputs)**
   - **a.** These are the output terminals where the two wires of **Motor A** are connected.

b. The voltage applied to these pins, based on **IN1 and IN2,** determines the motor's movement.

vi. **OUT3 & OUT4 (Motor B Outputs)**

a. These work the same way as **OUT1 & OUT2,** but for **Motor B.**

b. The applied voltage from **IN3 and IN4** determines the spinning direction.

3.3.3 Features and Specifications of the ES-Custom RC Transmitter and Receiver

i. **Features of ES-Custom RC Transmitter and Receiver Module**

a. **Wireless Communication:** Utilizes NRF24L01, LoRa, Bluetooth, or Wi-Fi for long-range, low-latency control**.**

b. **Bidirectional Motor Control:** Supports forward and reverse motion for DC and stepper motors.

c. **High Power Handling:** Capable of driving high-current motors with the help of motor drivers like L298N or TB6612FNG.

d. **PWM Speed Control:** Supports Pulse Width Modulation (PWM) to enable smooth speed variation.

e. **Multiple Control Channels:** Can handle multiple motors or actuators for complex movement.

f. **Stable Signal Transmission:** Advanced error correction ensures reliable data transfer.

g. **Low Power Consumption:** Optimized for battery-powered systems in portable applications.

h. **Customizable Frequency and Range:** Can be tuned for short-range or long-range control using RF settings.

i. **Microcontroller Compatibility:** Works with Arduino, ESP32, STM32, Raspberry Pi, and other embedded systems**.**

j. **Compact and Lightweight Design:** Easy to integrate into robotic and automotive applications.

Table 3. 2*:* Specifications

FEATURE	**SPECIFICATIONS**
Motor Compatibility	L298N,TB6612FNG,DRV8825 (Stepper), BTS7960 (High Power)
Operating Voltage	3.3V – 5V (logic), 6V – 35V (motor power)
Frequency Band	2.4GHz-(NRF24L01,Wi-Fi, Bluetooth), Sub-GHz (LoRa,HC-12)
Current per Channel	Up to 4A per motor
Control Channels	Supports multiple motors (up to 4 DC motors or 2 stepper motors)
Total Power Dissipation	25W (max)
PWM Control	Yes (via ENA & ENB pins)
Number of Motors Supported	2 DC motors or 1 stepper motor

Communication Interfaces	IN1, IN2, IN3, IN4 (direction control), ENA, ENB (speed control)
Weight	460g

3.3.4 Applications of ES - Custom RC Transmitter and Receiver Module

i. **Robotics –** Used in mobile robots, robotic arms, and automated systems.

ii. **IoT Projects –** Remote-controlled vehicles and smart automation systems.

iii. **Industrial Automation –** Conveyor belts, robotic grippers, and machinery**.**

iv. **Smart Home Automation –** Automated doors, fans, and motorized curtains**.**

v. **Remote-Controlled Robotics-** Used in autonomous and manually controlled robots for industrial, educational, and military applications**.**

The **ES - Custom RC Transmitter and Receiver** is a reliable choice for motorized systems due to its high power capacity, efficiency, and ease of integration with microcontrollers. (Texas Instruments, 2017).

(Raj, 2023)

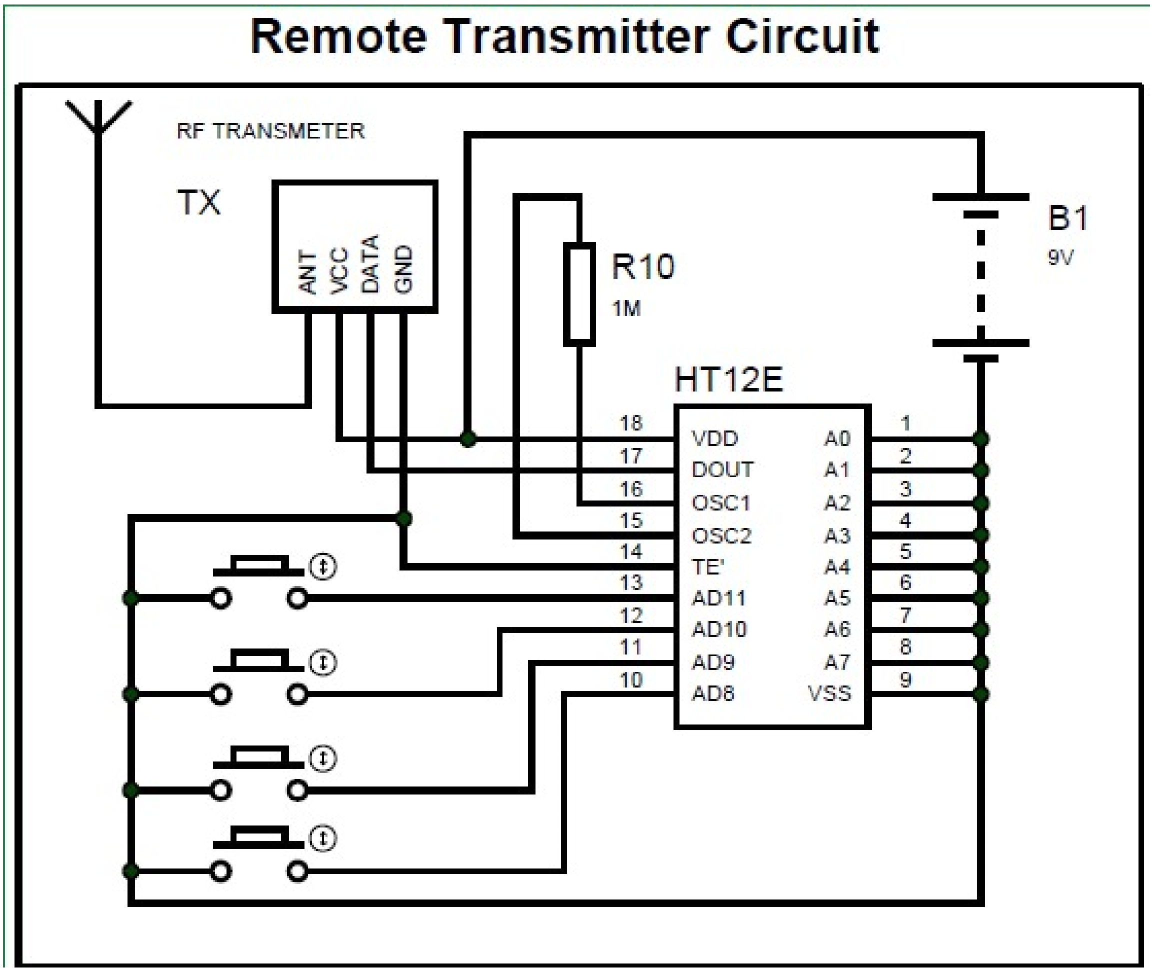

Figure 3. 1: Internal circuit diagram of ES - Custom RC Transmitter and Receiver module{circuitdigest.com}.

3.3.5 Pins for Speed Control (ENABLE) – ES Custom RC Transmitter and Receiver Module

The speed and ON/OFF states of the DC motors connected to the ES Custom RC Transmitter and Receiver Module are managed by the speed control pins labeled ENA (for Motor A) and ENB (for Motor B).

i. Motor A's speed is controlled by ENA, while Motor B's speed is managed by ENB.

ii. When both ENA and ENB are set to HIGH (5V), both motors run at full speed.

iii. When both pins are LOW (0V, Ground), both motors are turned off.

iv. The Pulse Width Modulation (PWM) feature allows for precise speed control by varying the duty cycle of the signal.

By default, these enable pins have a jumper connection that keeps them HIGH, meaning the motors operate at full speed. However, to enable variable speed control, the jumpers must be removed, and the ENA and ENB pins must be connected to PWM-capable pins on the ESP8266 (or any compatible microcontroller).

i. **LOW Signal (0V):** Turns off the motor.

ii. **HIGH Signal (5V):** Enables full-speed operation.

iii. **PWM Signal:** Adjusts motor speed proportionally to the **duty cycle** (higher duty cycle = higher speed).

Note: At low PWM duty cycles, the motors may not spin smoothly and could produce a continuous buzzing sound due to insufficient torque.

Table 3. 3*:* Speed control for motor A

ENA (Enable Pin for Motor A)	Motor A State	Speed Control (PWM Duty Cycle)
LOW (0V)	Motor OFF	No movement
HIGH (5V)	Motor ON (Full Speed)	100% Duty Cycle (Max Speed)
PWM Signal (0–5V variable)	Motor ON (Variable Speed)	Speed is proportional to duty cycle (e.g., 50% duty cycle = 50% speed)

Motor A's **spinning direction** is controlled by the input pins **IN1** and **IN2**, which determine the **rotation direction** based on the logic levels applied.

Table 3. 4*:* Spinning Direction of Motor A

IN1 (Motor A Input 1)	**IN2 (Motor A Input 2)**	**Motor A Direction**
LOW (0V)	LOW (0V)	Motor OFF (No Rotation)
HIGH (5V)	LOW (0V)	Motor Rotates Forward
LOW (0V)	HIGH (5V)	Motor Rotates Backward

ANALYSIS

- **i.** Forward Rotation → Set **IN1 = HIGH** and **IN2 = LOW**.
- **ii.** Backward Rotation → Set **IN1 = LOW** and **IN2 = HIGH**.
- **iii.** Stop Motor (Coasting) → Set **IN1 = LOW** and **IN2 = LOW**.

3.3.6 Connecting a DC Motor to the ES Custom RC Transmitter and Receiver Module and Microcontroller (ESP8266)

For wireless high-power control of a DC motor, the ES Custom RC Transmitter and Receiver Module was interfaced with the **ESP8266 microcontroller**. The module facilitated real-time remote control of motor speed and direction.

A reference schematic was used to establish proper connection**s** between the DC motor, ES Custom RC Receiver Module, and ESP8266 NodeMCU. The custom receiver module received signals from the wireless transmitter, allowing seamless motor operation.

The ESP8266 microcontroller was chosen based on project requirements, particularly for its Wi-Fi connectivity, which allowed integration with a smartphone-based remote control system

(Razavi, 2018). Custom firmware was developed and uploaded to the ESP8266 to handle motor control commands received from the ES Custom Receiver Module.

A systematic wiring approach ensured proper signal transmission and power distribution (Razavi, 2013). The DC motor, responsible for driving a tyre mounted on a chassis, was powered by 3.7V Li-ion batteries connected in series to ensure adequate power for both the motor and ESP8266 (Association, 2011). A charging circuit was included to allow convenient recharging of the batteries.

The DC motor was securely attached to the chassis, with the tyre directly connected to its shaft for effective movement and maneuverability (Scoggin, 1974). The ES Custom RC Transmitter and Receiver Module provided real-time wireless control, enabling precise adjustments to the motor's speed and direction.

A stable 5V power supply was provided to the ESP8266 and other components using a voltage regulator (such as an AMS1117-5.0V) to step down the volts from the Li-ion batteries, ensuring consistent operation without voltage fluctuations (J. G. Kassakian, 1991).

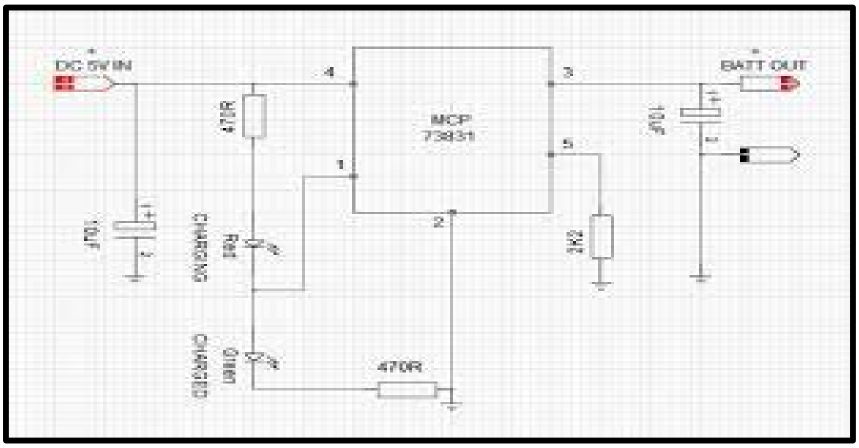

Figure 3. 2: Circuit Schematics of AC-DC- Adaptor for 3.7V DC Battery *(HAREENDRAN, 2011)*

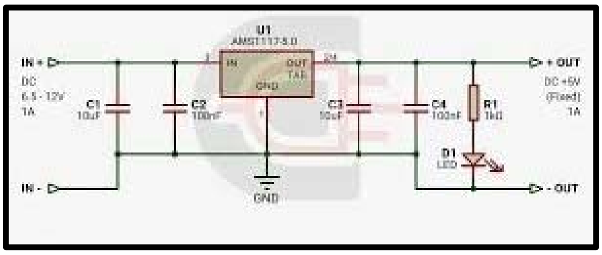

Figure 3. 3: Voltage Regulator (such as an AMS1117-5.0V) circuit *(Barman, 2013)*

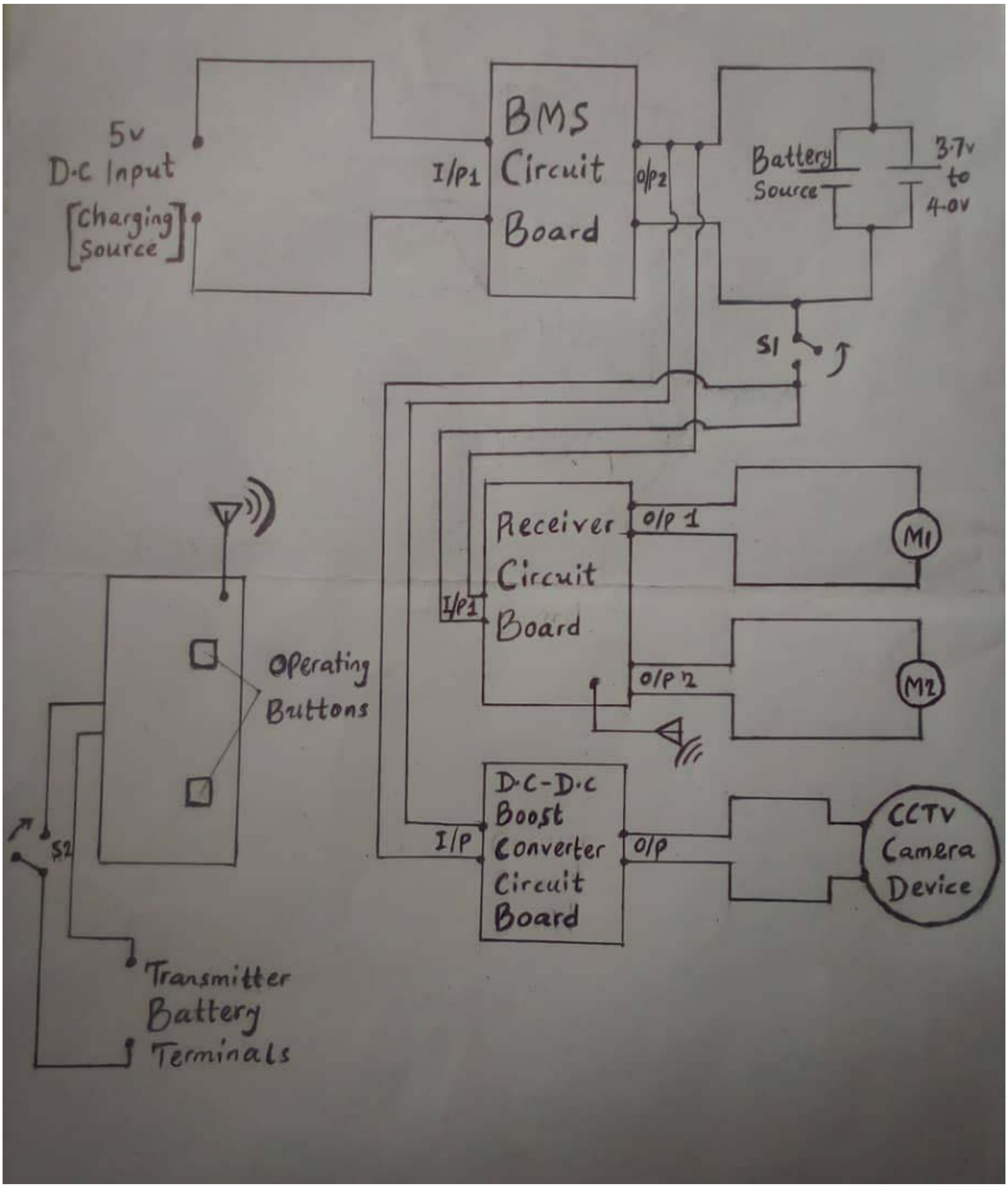

Figure 3. 4: A circuit schematic for a remote-controlled system

3.4 Main Components & Their Functions:

i. **BMS (Battery Management System) Circuit Board**

a. Manages charging and protection of the 3.7V to 4.0V battery source.

b. Takes 5V DC input as a charging source.

c. Protects against overcharge, over-discharge, and short circuits.

ii. **Receiver Circuit Board**

a. Receives signals from the transmitter (remote control).

b. Outputs control signals (OP1 & OP2) to drive two motors (M1 & M2).

iii. **DC-DC Boost Converter Circuit Board**

a. Converts low 3.7V – 4V battery voltage to a higher voltage 5V for the CCTV Camera Device.

b. Ensures stable power supply to the camera.

iv. **Transmitter Section**

a. Consists of operating buttons to send control signals wirelessly.

b. Connected to a transmitter battery terminal (powered by a separate battery).

c. Uses a switch (**S2**) to turn the transmitter ON/OFF.

v. **Motors (M1 & M2)**

a. Likely used for movement control of a remote-controlled vehicle.

b. Controlled by the Receiver Circuit Board.

vi. **CCTV Camera Device**

a. Powered by the DC-DC Boost Converter.

b. Likely used for real-time **video streaming**.

3.4.1 Functionality Overview:

i. The **BMS circuit charges the battery** when a **5V DC source** is connected.

ii. The **receiver circuit** processes signals from the remote control to operate **motors M1 and M2**.

iii. The **DC-DC boost converter** ensures that the CCTV camera gets adequate power.

iv. The **transmitter section** sends commands wirelessly to control the system.

3.5 SOFTWARE DESIGN

3.5.1 Software and Communication System Design

i. Software Design **– V380 Pro User Interface & Usability**

The **V380 Pro** software is designed to provide a seamless and user-friendly experience for managing security cameras and monitoring live feeds. It features an intuitive graphical user interface (GUI) that allows users to navigate easily and access core functionalities. The software is structured to provide quick access to essential operations, such as:

a. Live video streaming from connected cameras**.**

b. Playback of recorded footage for review.

c. Two-way audio communication with supported devices.

d. Remote camera control with pan, tilt, and zoom (PTZ) functions.

e. Motion detection and instant alerts.

f. Multiple camera management with multi-device support.

The software interface is built with a modern layout, ensuring responsive control across multiple platforms, including smartphones, tablets, and PCs. Users can manage cameras efficiently using WiFi connectivity, making it a versatile and portable surveillance solution.

ii. Core Features

a. Live Video Streaming – Offers real-time video monitoring with minimal latency.

b. Two-Way Audio – Built-in microphone and speaker functionality allow remote communication.

c. Motion Detection & Alerts – Intelligent motion detection sends instant push notifications.

d. Cloud Storage & Local Recording – Supports recording to SD cards and cloud storage for flexible data management.

e. Playback & Video Management – Users can rewind, fast-forward, and review past footage within the app.

f. Remote Camera Control – Users can pan, tilt, and zoom (PTZ) cameras remotely to adjust viewing angles.

g. Night Vision Support – Enhances visibility in low-light or nighttime conditions.

h. Multi-Device Connectivity – Allows simultaneous access to multiple cameras across different locations.

i. Encryption & Security – Implements AES encryption to protect video feeds from unauthorized access.

iii. **Connection and Setup Process**

a. Download & Install the App

b. Available on Google Play Store, Apple App Store, and official V380 Pro websites.

c. Install the app and launch it on your device**.**

d. Create an Account

e. Register using either an email or phone number.

f. Log in to access the device management interface.

g. Add a Camera/device to V380 Pro

h. Power On the Camera – Ensure the camera is properly powered and functional.

i. Connect to Wi-Fi – The camera must be connected to a 2.4GHz WiFi network (5GHz is not supported).

j. Pairing Process - Open the app and tap on the plus sign, "+" (Add Device).

Select "Wi-Fi Smart Camera" or the relevant device type.

Scan the QR code on the camera or enter the device ID manually.

Enter Wi-Fi credentials to pair the camera with the app.

Wait for confirmation and set a secure password for the camera**.**

k. **Remote Access & Control:** Once paired, the camera can be accessed remotely from anywhere with an active internet connection. Users can enable motion alerts, adjust recording preferences, and control PTZ functions from within the app.

3.5.2 Transmitter - Receiver Interface

i. Overview of Wireless Communication

The ES Custom RC Transmitter and Receiver Module is designed for high-power wireless control of DC and stepper motors. It operates using radio frequency (RF) communication at 2.4GHz, ensuring stable and interference-free signal transmission. The transmitter sends control signals wirelessly, which are received and decoded by the receiver. These signals are then processed to control the speed, direction, and functionality of motors or other connected actuators.

3.5.3 Key Design Components

i. RF Transmission & Reception

a. The transmitter unit generates a 2.4GHz RF signal modulated with control data.

b. The receiver unit houses an RF module (such as NRF24L01, CC2500, or a custom transceiver) that demodulates and processes the signal.

c. The transmitted signals follow a secure pairing mechanism, preventing interference from external transmitters.

3.5.4 Signal Modulation and Demodulation

i. Modulation in the Transmitter

a. The transmitter encodes user input (e.g., joystick movements or button presses) into a Pulse Position Modulation (PPM) or Pulse Width Modulation (PWM) signal.

b. This modulated signal is then sent wirelessly to the receiver.

ii. Demodulation in the Receiver

a. The receiver captures the transmitted RF signal and demodulates it into control data.

b. These signals are converted into PWM signals, which are used to drive motors or actuators.

3.5.5 Signal Processing & Output to Motors

i. Microcontroller Processing (MCU or RF Decoder)

a. The receiver module consists of a microcontroller (MCU) or dedicated RF signal decoder.

b. It reads and interprets incoming RF signals, then generates control signals for the connected motors.

ii. Output to ESC or Motors

a. If controlling brushed DC motors, the receiver may feature an integrated motor driver for direct motor control.

b. If controlling brushless motors, the receiver sends signals to an Electronic Speed Controller (ESC), which regulates motor speed and direction.

3.5.6 Working Principle of Wireless Motor Control

i. User input (joystick movement, button press) is converted into an RF signal in the transmitter.

ii. The transmitter sends this signal wirelessly over 2.4GHz frequency.

iii. The receiver module captures & demodulates the RF signals.

iv. The microcontroller or RF decoder processes the signals and generates appropriate PWM outputs.

v. The PWM outputs are sent to an ESC or motor driver, which controls the motor's speed and direction.

3.5.7 Enhancements & Integration with ES - Custom RC System

i. **Extended Control Range:** The system ensures long-range communication with minimal latency, making it ideal for real-time remote control applications**.**

ii. **Improved Signal Stability:** Using adaptive frequency hopping and error correction, the ES Custom RC Transmitter minimizes signal interference.

iii. **Multi-Channel Support:** Allows multiple devices to operate independently without interference.

iv. **Low Power Consumption:** Designed for efficient battery usage, ensuring longer operation time.

CHAPTER 4

CONSTRUCTION, TESTING, AND RESULTS

4.1 Introduction

This chapter provides a detailed explanation of the construction, testing, and performance analysis of the real-time image and audio transmission system using a remote-controlled agent. The construction phase covers the integration of components, circuit connections, and assembly of the system. The testing phase evaluates the system's functionality and efficiency under different conditions. Finally, the results obtained are analyzed and discussed in detail.

4.2 Construction of the System

4.2.1 System Overview

The project involves designing and implementing a remote-controlled agent capable of transmitting real-time images and audio. The system consists of an ES-Custom RC transmitter and receiver for remote control, a lithium battery as the power source, a Standalone x360 mini camera with motion sensor and flash features for real-time streaming, and a TP4056 charger module for battery management.

4.2.2 Components and Their Integration

i. ES - Custom RC Transmitter and Receiver

The ES - Custom RC transmitter sends control signals wirelessly to the receiver, which operates the agent. The receiver being an ESC (Electronic speed controller) has the motor driver that control the movement of the agent integrated into it. The communication operates within a specific frequency range, ensuring reliable data transmission.

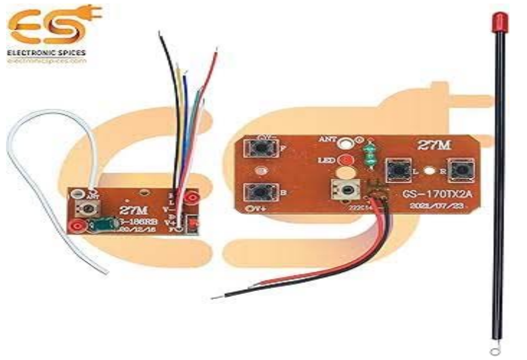

Figure 4. 1: An image of the ES - Custom RC Transmitter and Receiver

ii. **Lithium Battery and TP4056 Charger Module**

The Lithium battery provides the required power to all components, ensuring efficient operation. The TP4056 charger module is integrated for safe charging and overcharge protection. A voltage regulator is used to maintain a stable power supply to the components.

Figure 4. 2: An image of the TP4056 Charger Module and the Lithium Battery

iii. The Camera

The camera is mounted on the agent and connected to the power source for continuous operation. The selected camera has the ability to perform a 360 motion, and it comes alongside with a lighting features that can both be operated remotely and automatically. The V380 mobile application is used to access real-time footage remotely. The V380 app is selected due to its high-resolution image transmission capability and Wi-Fi connectivity.

Figure 4. 3: An image of the 360 Camera system

4.2.3 Circuit Diagram and Wiring

A circuit diagram was designed to interconnect all components properly. The major connections include:

a. The lithium battery connected to the TP4056 charger module for controlled charging.
b. The output of the Lithium battery providing power to the RC receiver, camera, and motor driver.
c. The RC receiver interfaced with the motor driver to control the movement of the agent
d. The camera connected to the battery via the step up module and transmitting real-time data over Wi-Fi connectivity.

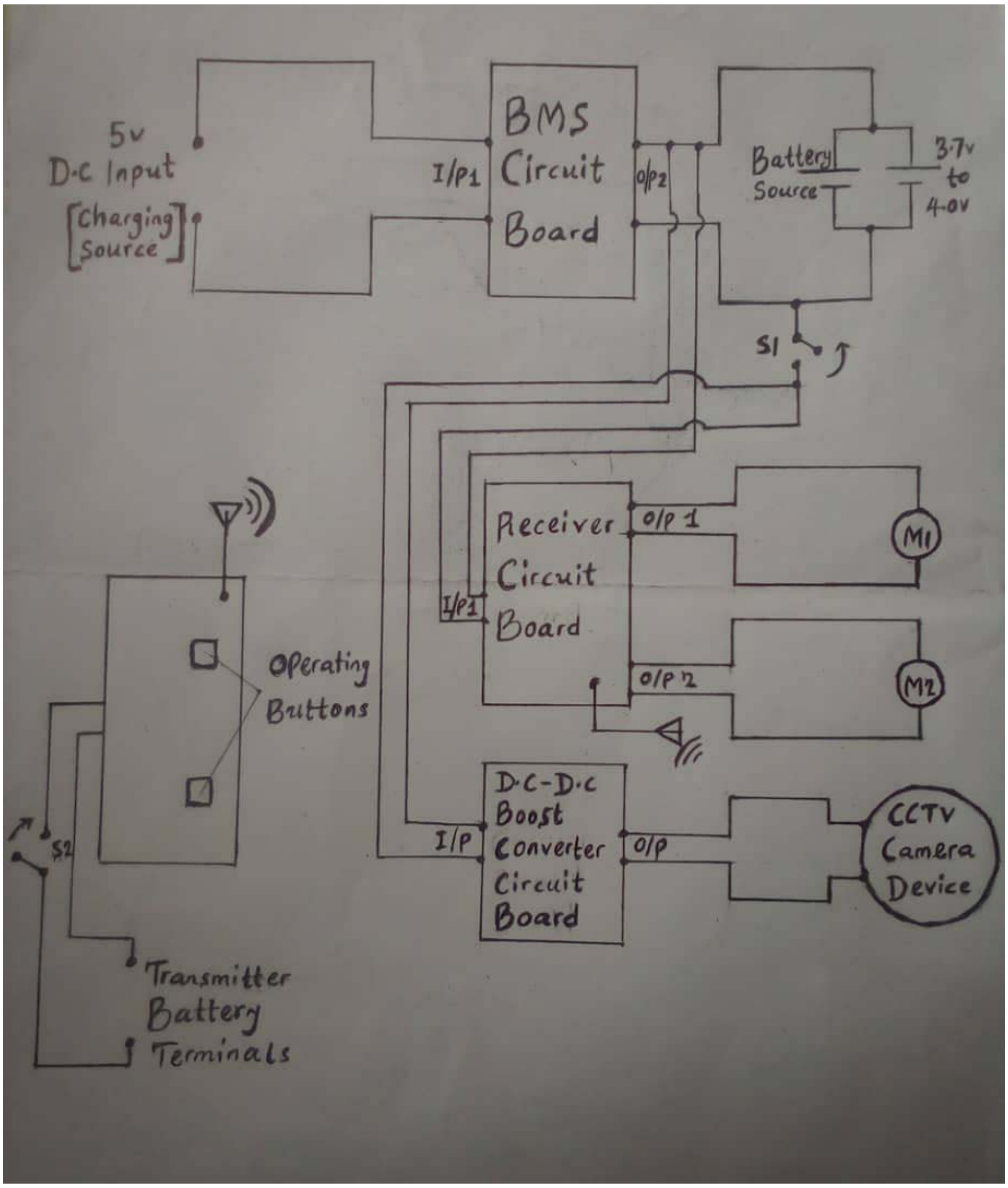

Figure 4. 4: A block diagram showing how the components are interconnected.

4.3 Testing Procedures

4.3.1 Power Supply Testing

i. The voltage output from the Lithium battery was measured using a multimeter to ensure it meets the required operating range.

ii. The TP4056 charger module was tested to verify proper charging and overcharge protection.

4.3.2 RC Communication Testing

The ES-Custom RC transmitter was paired with the receiver. Various control commands were tested to check the response time and range of the wireless communication.

4.3.3 Camera and Audio Transmission Testing

The 360 CCTV camera was configured and connected to a mobile device via the V380 app. Live video and audio transmission were tested in different environmental conditions, including indoor and outdoor scenarios. The latency of the video stream was measured to ensure real-time functionality.

4.3.4 Mobility and Navigation Testing

The remote-controlled surveillance agent was placed on different surfaces to evaluate its mobility, and ability to climb over obstacles. Speed, turning ability, and response time to control signals were also analyzed.

4.4 Results and Observations

4.4.1 Power Supply Performance

i. The Lithium battery provided a stable output voltage, ensuring uninterrupted operation.

ii. The TP4056 charger module effectively prevents overcharging and extended battery life.

4.4.2 RC Communication Performance

The ES - Custom RC system exhibited a strong and stable connection within a certain range (based on the test results). The control response was almost instantaneous, ensuring precise maneuvering of the agent.

4.4.3 Image and Audio Transmission Performance

The V380pro application successfully transmitted real-time video and audio with minimal latency. The video quality was clear, with a high resolution of pixels (based on test results). The transmission range of the camera depended on the Wi-Fi signal strength.

4.4.4 Mobility and Navigation Performance

i. The agent moved smoothly on flat, rough, and inclined surfaces, demonstrating its adaptability.
ii. It effectively responded to remote commands, making navigation easy.
iii. The system's performance slightly decreased in areas with strong wireless interference.

4.5 Challenges Encountered and Solutions

4.5.1 Power Consumption Issues

Challenge: The camera and motor system consumed significant power, reducing battery life.

Solution: A higher-capacity lithium battery was used and, power-saving settings were enabled for the camera.

4.5.2 Wireless Interference

Challenge: In areas with multiple Wi-Fi networks, the V380pro application occasionally lost connection.

Solution: Switching to a dedicated Wi-Fi channel and improving antenna placement helped stabilize the connection.

4.5.3 Latency in Video Transmission

Challenge: A slight delay was observed in real-time video streaming.

Solution: Optimizing network bandwidth and reducing the camera resolution slightly improved the transmission speed.

Table 4. 1**: BILL OF ENGINEERING MEASUREMENT AND EVALUATION (BEME)**

S/N	MATERIAL	QUANTITY	UNIT PRICE	AMOUNT
1.	ES – Custom RC Transmission & Receiver Module	**1**	**5,000**	**5,000**
2.	360 – degree Rotating Camera	**1**	**10, 000**	**10, 000**
3.	TP4056 Battery Charger Module	**1**	**600**	**600**
4.	Lithium Battery (3.7v)	**2**	**1, 500**	**3, 000**
5.	DC Motor for Front-wheel Motion	**1**	**2, 000**	**2, 000**
6.	DC Motor for Rotational Motion	**1**	**2, 000**	**2, 000**
7.	Servo Motor for Camera Motion	**1**	**2, 500**	**2, 500**
8.	Remotely Controlled Chassis	**1**	**8, 000**	**8, 000**
9.	Custom RC Transmitter	**1**	**58, 000**	**58, 000**
10.	Voltage Step-up Module (3.7v to 5v)	**1**	**800**	**800**
11.	Power Management System (BMS)	**1**	**1, 500**	**1, 500**
12.	V380 Pro App (Android/ ioS)	**1**	**Free**	**Free**
13.	Screws, Fasteners & Connectors	**Multiple**	**500**	**500**
14.	PCB Board for Circuit Integration	**1**	**1, 000**	**1, 000**
15.	Chassis Mounting Components	**Multiple**	**1, 000**	**1, 000**
16.	Mobile Device (Android)	**1**		**150, 000**
17.	Miscellaneous			**11, 000**
	TOTAL			**256, 900**

4.6 Conclusion

The construction and testing of the real-time image and audio transmission system using a remote-controlled surveillance agent were successfully completed. The system demonstrated stable operation, efficient control, and real-time transmission of video and audio. Despite minor challenges, appropriate solutions were implemented to enhance performance. The results confirm that the project is effective for applications requiring remote monitoring and surveillance.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In conclusion, this report has presented a versatile surveillance remote agent with applications that span across multiple industries, including healthcare, agriculture, and more. This project has also led to the advancements in our interactions with essential personnel across diverse professional fields, making significant strides in the integration of robotics and remote operations. However, while the achievements are notable, the project also faces several limitations, which are detailed below:

i. **Obstacles and Navigation Challenges:** Difficulty is being experienced in navigating the surveillance agent in places where space is constricted (tight) or cluttered and these may cause reduction in coverage in critical areas hence creating blind spots.

ii. **Detectability:** Being that the agent is being used for the purpose of surveillance there's a need for the agent to not be easily detectable as this can easily alert targets giving them the ample opportunity the evade surveillance or disable the system. Thereby, making it ineffective for covert operation.

iii. **Lagging in Video feedback:** One of the challenge of the agent is the fact that the video feedback being produced is not in synchronization with the time the particular action is being carried out. Hence, leading to a delay between the real time an action is performed and when the agent produces the feed of that particular action.

iv. **Human intervention:** Since the agent is being used for the purpose of surveillance then it should require little or no human effort. As reliance on human interactions will tend to reduce the effective performance of surveillance being carried out by the agent.

v. **Ergonomic and User Interface Challenges:** A significant drawback of the remote surveillance agent is the complexity of its user interface (UI) and control system, which can hinder operational efficiency. If the interface is not ergonomically designed and intuitive, users may find it difficult to navigate controls, analyze surveillance data, or respond promptly to security threats. A poorly designed UI can result in delayed decision-making, increased human errors, and reduced system effectiveness. To mitigate this, the system should feature a user-friendly dashboard, simplified controls, and real-time feedback mechanisms to enhance usability and improve operator experience.

5.2 FUTURE RECOMMENDATION

To overcome these challenges and foster further advancements in the field, the following comprehensive recommendations are suggested for future development and research.

i. **Advanced Navigation Capabilities:** Incorporating intelligent obstacle detection and avoidance systems, such as LiDAR technology and AI-powered path optimization, can enhance the agent's ability to move efficiently in tight or cluttered environments. This will help eliminate blind spots and ensure comprehensive area coverage.

ii. **Improved Concealment and Noise Reduction:** To enhance its stealth capabilities for covert surveillance, the agent should be designed with low-noise components, non-reflective surfaces, and AI-driven movement control. These modifications will reduce the chances of detection and improve operational efficiency.

iii. **Enhanced Real-Time Video Transmission:** To address delays in video feedback, high-performance processors, advanced data transmission technologies, and edge computing should be integrated. These improvements will help synchronize the visual feed with real-time events, ensuring accurate and timely surveillance.

iv. **Greater Autonomy through AI Integration:** Minimizing human intervention by equipping the agent with AI-driven automation will allow it to conduct surveillance independently. By utilizing machine learning techniques, the agent can recognize, track, and analyze targets more effectively, leading to enhanced overall performance.

By implementing these enhancements, the virtual remote agent can operate with greater precision, efficiency, and autonomy, improving its effectiveness in various applications.

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