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Design, development & the Implementation of a explosive detector mobile robot that could be used for applications in defense activities using the concepts of AI-ML, Computer Vision & Pattern Recognition

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Abstract: In this article, we present the design, development & the Implementation of a explosive detector mobile robot that could be used for applications in defense.. The hardware has been designed and successfully implemented. This project focuses on the design, development, and implementation of an explosive detector mobile robot tailored for versatile applications in defense activities. The explosive detector robot is a technological solution aimed at enhancing security measures and minimizing risks for defense personnel. Equipped with advanced sensors and mobility features, the robot offers the capability to detect and identify explosive materials in diverse environments and situations. The project encompasses a comprehensive approach, integrating hardware and software components for efficient robot control, ensuring real-time monitoring and threat mitigation. The research and development process detailed in this project outlines the key steps, challenges, and innovations in creating a reliable and adaptable robotic solution for defense applications, ultimately contributing to improved safety and operational effectiveness in defense activities. The project presented here is the mini-project completed by second-semester students in the Electronics & Communication Engineering department at Dayananda Sagar College of Engineering in Bangalore..

Keywords: Bomb, Design, Implementation, Defense, PWM, Bluetooth, Arduino, and RF Transmitter.

1. Introduction

This introductory note provides a brief overview of the related work in this field. In the modern era, a substantial portion of the national budget is allocated to the military to implement high-security, low-tech measures and safeguard border security forces from potential intruders. Some defense groups have turned to robotics due to its superior effectiveness compared to human personnel in defense operations. Multifunctional robots play a critical role in minimizing human casualties and property damage in various scenarios, including disasters, armed conflicts, and mining. Consequently, their importance is expected to grow in the coming years.

These robots are equipped with vehicle-mounted cameras for image capture, and they utilize gesture recognition and body heat signatures to identify individuals. The collected images are then transmitted to the base operating station through the cloud. These robots have the capability to covertly access enemy territory, operate in deep underground mining environments, and enter disaster zones while continuously relaying data to the controller via their cameras.

The primary objective of this essay is to enhance defense capabilities by leveraging robots, which play a crucial role in saving lives during times of war and disasters. The system outlined in this paper incorporates an Arduino Raspberry Pi board along with various sensors, including metal detectors, gas sensors, IR avoidance sensors, PIR sensors, ultrasonic sensors, light detectors, and a GPS module. These components enable the robot to execute a wide range of rescue operations.

This mini project involves the design and operation of a bomb disposal model or a mobile robot tailored for bomb research and remote bomb disposal. A visual operator interface program has been developed using the Qt-Creator environment, ensuring compatibility with various operating systems. This program facilitates remote control and real-time tracking of the mobile robot. The robot demonstrates exceptional mobility, including the ability to pivot around its own axis. It features an Acorn RISC Machine (ARM)-based control board, a high-definition movable camera, and an articulated arm equipped with a Bomb Setup Disposal Weapon (AK-ER) for defusing bomb setups as needed.

The ARM-based control board is programmed through the transfer of C++-based control software via File Transfer Protocol after compilation. This model utilizes the User Datagram Protocol for communication between the mobile robot and the operator center, enabling various robot control functions. The entire operation of the robot can be executed wirelessly from a computer. The arm is actuated by a DC servo motor, with the servo's movements being controlled through a PWM signal generated by the microcontroller.

The robot's operations are wirelessly controlled, offering an extended range for effective functioning. It is designed as a fundamental bomb disposal robot capable of executing simple tasks like cutting wires, toggling switches, lifting lightweight objects, and assisting in the transportation of the bomb. The robot also provides real-time video feedback, enabling precise and safe robot handling. This setup incorporates a robotic arm with servo motors as actuators.

The robot's base can rotate 180 degrees, and its elbow, shoulder, and gripper can move in accordance with their designated directions, all under user control. The control input initially undergoes processing within the control application, after which it is transmitted serially via a Radio Link. Upon reception by the robot, the input is processed once more, and the resulting signal is routed to the relevant modules. These modules include the motor for the robot's base and the robotic arm.

By introducing robotic assistance, the bomb disposal squad gains an additional layer of protection, allowing for the inspection and analysis of suspicious packages before approaching them for disposal. Mobile robots significantly reduce or eliminate the time bomb technicians spend in potentially life-threatening situations. These robots shift the focus from immediate danger to the technician's task in dealing with explosive devices. Even when a robot cannot physically reach an item for disruption, it can still relay valuable information to aid in the selection of tools and procedures. Moreover, events recorded by the robot's camera can serve as critical evidence for subsequent analysis..

2. Review of Literatures / Survey’s

In this section, we provide a concise overview of the literature that forms the foundation for numerous research endeavors. This mini project involves the development of a mobile robot designed for bomb investigation and the disposal of a bomb setup via remote control. To facilitate the remote operation and tracking of this mobile robot, a visual operator interface application has been meticulously crafted within the Qt-Creator environment, ensuring compatibility with a wide array of operating systems. This robot boasts exceptional mobility, with the ability to rotate around its own axis. Its core components include an Acorn RISC Machine (ARM) based control board, a high-definition moving camera, and a dynamic arm equipped with an AK-ER bomb setup disposal weapon..

Zhou Hongfu and colleagues [1] presented a research paper on the control system for DC servomotors in a bomb-disposal robot. Their system is grounded in PID control and PWM output to drive the DC motors. The study encompasses the design of a PID control system for 8 DC servomotors within the bomb-disposal robot, and the optimization of PID parameters is accomplished through experimentation. The control system for the DC servomotors is implemented as an embedded system, with encoder signals input and PWM output being processed by the PC 104 embedded system. The research involves simulation of the PID control model and PWM generator model using Matlab Simulink. For real-time control, xpc Target in Matlab is employed.

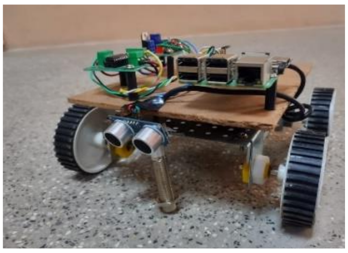


Fig 1: Typical ready made bomb disposal robo model 1 developed

Fig 2: Typical ready made bomb disposal robo model 2 developed

On the other hand, Akib Jayed Islam and colleagues [2] proposed a dual-arm bomb disposal robot designed to assist bomb disposal units. This robot features two segmented robotic arms (3 DOF and 3 DOF) mounted on a portable base, equipped with an IP camera for safe and efficient bomb disposal from a distance. The primary function of this model is wireless remote control to replace humans in bomb disposal operations. The study utilizes simulation-based direct kinematics to evaluate performance and includes mathematical modeling of the dual arms to create a mobile and secure bomb disposal robot.

Anjir Ahmed Chowdhury and colleagues [3] present a project that centers on the development of a remotely controlled bomb disposal robot, utilizing locally available hardware resources to reduce costs. The robot's body and arm are custom-designed and constructed using Aluminum alloy. It has been equipped with gas, fire, and obstacle detection sensors to enhance its capabilities. In its chassis, the robot can collect and transport dismantled bomb components weighing up to 10kg for evidential purposes. The mechanical design of the robot was validated using SolidWorks software. Proteus was employed for PCB and schematic design. The control system incorporates a Raspberry Pi as the processor, while sensing and communication are handled by an Arduino Mega. The robot can be controlled via the internet, facilitated by an additional Python script for web server-based control.

Rakshana Mohamed Ismail and colleagues [4] describe the design and construction of a semi-autonomous unmanned robotic system designed for a range of military and rescue operations. Utilizing live video feeds from wireless cameras and data analysis of the environmental composition using various sensors, this system aids soldiers in mission preparation. Arduino and Zigbee technologies are employed to accomplish these tasks. The diverse sensors and robotic arm are connected to the Arduino Mega, which, in turn, communicates through Zigbee.

Data transmission and reception occur via Zigbee technology. The C++-based control software, once compiled, is transferred to the ARM-based control board using File Transfer Protocol. The architecture employs the User Datagram Protocol for communication between mobile robots and operator centers, as well as for robot control operations. The robot's entire operation can be remotely managed from a computer. A DC servo motor serves as the actuator for the arm, with the servo being controlled through a PWM signal generated by the microcontroller.

3. Problem Statement

This research endeavor seeks to establish a straightforward, reliable, and resource-efficient method for identifying and neutralizing explosive devices. More precisely, the study endeavors to address the following key questions:

Fig 3: Problem Statement Block-Diagram

Our project has been conceived in light of the ongoing civil conflicts, military instabilities, and global terrorist threats. Almost daily, highly trained individuals find themselves either injured or losing their lives while dealing with or attempting to defuse explosive devices.

The primary objective of this robot is to safeguard bomb disposal teams from the imminent dangers they encounter in their daily operations. Equipped with a wireless camera for video feedback, it empowers the operator to work more efficiently. The robot's operations are remotely controlled through a wireless module, ensuring an extended operational range. It also includes a basic bomb disposal robot capable of performing tasks such as wire cutting, flipping switches, and lifting lightweight objects, thereby minimizing the risk to human bomb disposal personnel [3].

Robots venture into perilous environments that humans may fear to tread. Among their diverse applications, bomb disposal ranks among the most hazardous, where the threat of death looms with every move. For over four decades, bomb disposal robots have been deployed to safely neutralize explosive ordnance, with hundreds, if not thousands, of missions conducted [4].

Underground mining is fraught with numerous geological challenges, including roof and side collapses, flooding, air blasts, and more. Additionally, locating and rescuing individuals trapped in disaster zones during natural calamities like earthquakes, tsunamis, and floods presents a significant challenge for rescue teams [5].

4. Hardware & Software Used

Raspberry pie IDE
Python
Raspberry Pi Controller
LED Indicator
Gas Sensor
Motor Driver & wheel
Wi-fi modem
Power Supply
Battery level Indicator
PIR sensor
DC Motor
Light detector sensor
OLED display

Important Components

HC-SR04
Power Supply : DC 5V,
Working Current: 15mA,
Working Frequency: 40Hz,
Ranging Distance: 2cm – 400cm / 4m,
Resolution: 0.3 cm,
Measuring Angle: 15 degree,
Trigger Input Pulse width: 10uS,
Dimension: 45mm x 20mm x 15mm

Fig 4: HC-SR04 Sensor

Rasberry Pi B3

The Raspberry Pi 3 Model B+ offers notable performance enhancements compared to the Model B. These improvements encompass a swifter CPU clock speed (1.4 GHz as opposed to 1.2 GHz), elevated Ethernet throughput, and dual-band WiFi capabilities. Additionally, it extends support for Power over Ethernet through the use of a Power over Ethernet HAT [8].

Fig 5: Raspberry Pi Micro-Controller Board

PROXIMITY SENSOR

The Orange 8mm PNP Inductive Proximity Sensor RM18 DC6~36V is a novel inductive proximity sensor engineered to identify metal objects. These sensors can detect objects without physical contact, eliminating the risk of abrasion or damage to the object. In contrast to devices like limit switches that rely on physical contact for detection, Proximity Sensors can electrically discern the presence of an object without requiring any physical interaction [6].

Fig 6: Proximity Sensor

Mq2 Sensor

The MQ2 Gas Sensor Module is a durable gas sensor designed for the detection of LPG, Smoke, Alcohol, Propane, Hydrogen, Methane, and Carbon Monoxide concentrations in the surrounding air.

Fig 7: Sensor

Dc Motor

The DC motor operates at 30 RPM when supplied with 12V. It runs smoothly within a voltage range of 4V to 12V, providing a wide range of RPM and torque options. The motor shaft features a hole for improved coupling [7].

Specifications:

Operating Voltage: 12V

Rated Torque: 4.2 kg-cm

Stall Torque: 16 kg-cm

Fig 8: DC Motor

5. Robotic Operations

The robotic operation is remotely controlled via a wireless module, allowing for an extended operational range. Additionally, we've developed a basic autonomous robot to aid in bomb transportation and a straightforward bomb disposal robot capable of tasks such as wire cutting, switch activation, and light object lifting. It provides us with video feedback, enhancing our ability to efficiently control the robot. The robot features a robotic arm, and we utilize a servo motor as the actuator.

This setup enables the robot base to rotate 180 degrees, while the elbow, shoulder, and gripper respond to user input. The control application processes this input initially, transmitting it serially via a radio link. The robot then receives and further processes the information, and the resulting signal is sent to the appropriate module. The robotic armor robot enhances bomb disposal operations by allowing a thorough inspection of suspicious packages before approaching them for disposal. The module could control the robot's motor or base, adding an extra layer of security [9].

The use of mobile robots reduces or entirely eliminates the time that a bomb technician must spend in a hazardous location. Robots remove the risk from potentially life-threatening scenarios, enabling bomb technicians to focus on dealing with explosive devices rather than the immediate dangers to their own lives. Even when a robot cannot directly intervene, it serves as a means of conveying critical information to assist in selecting the appropriate tools and facilitating the advancement of the operation downrange. Furthermore, events documented by the robot's camera can serve as valuable evidence for further investigation [10]..

6. Proposed Research Methodologies In Implementation Of The Mini-Project

Acquiring a foundational understanding of the system is crucial for recognizing the factors influencing human-robot interactions and for devising strategies to enhance robot design, optimize human-robot training, and enable efficient mission collaborations between humans and robots. In this context, our study delves into the human user experience of Explosive Ordnance Disposal (EOD) human-robot interactions, aiming to establish a fundamental understanding upon which informed discussions of robot design and integration within close-knit teams, such as EOD units, can be based. This study employs qualitative research methodologies to explore the environment, expectations, attitudes, and emotions that shape the human-robot relationship.

We propose a method that utilizes an Android device's Wi-Fi capabilities for robot control. An Android application has been developed with dedicated controllers for managing the robot's movements. The functioning of these controllers is defined by embedded C and Python programs that are loaded onto the Raspberry Pi and displayed on a monitor connected to the Raspberry Pi. Motor control involves turning DC motors on or off using switches, relays, transistors, or MOSFET circuits, with multi-directional control being the fundamental motor control mode.

The robot's location is determined using GPS, which also provides coordinates for identifying metal objects, barriers, and gas emissions. To facilitate the robot's movement, DC motors and sensors are incorporated as additional hardware components. Gas sensors are employed for toxic gas detection, while metal detectors are used for bomb detection. An ultrasonic sensor gauges proximity to objects or individuals. Control over the robot's movement can be exercised through a monitor or a mobile phone, allowing it to navigate in various directions depending on the situation, with the goal of detecting any explosive devices or hazardous materials in its vicinity [11]..

7. Proposed Methodology

In this section, we introduce the proposed methodology employed in the mini-project work, encompassing both hardware and software components. The mini-project leverages various tools and technologies, including Arduino Uno boards, relays, DC motors, LCD displays, wires, wheels, and sensors. These elements collectively form the foundation of our project [11].

7.1 Analysis

The paper reports the findings of Zhou Hongfu et al.'s research on a DC servomotor control system for bomb-disposal robots. This study employs PID control and PWM output for driving the DC motors. Specifically, the research involved the design of eight DC servomotors in the bomb-disposal robot with PID control, and optimal PID parameters were determined through experimentation. The embedded PC104 system processes input encoder signals and PWM output for controlling the DC servomotors.

Furthermore, Matlab Simulink was used to simulate both the PID control model and the PWM generator model in this research. To achieve real-time control, the study utilized Matlab's xpcTarget [1]. On the other hand, Akib Jayed Islam et al. [2] introduced a dual-arm bomb disposal robot designed to assist bomb disposal units. This robot features two segmented robotic arms (3 DOF and 3 DOF) mounted on a mobile base, along with an IP camera, enabling safe and remote bomb disposal. The primary function of this model is wireless remote control, aiming to replace human intervention in bomb disposal operations. The research successfully created an efficient, mobile, and secure bomb disposal robot by employing mathematical modeling of the dual arm and simulation-based direct kinematics to assess its performance [2].

This project's planned work by Anjir Ahmed Chowdhury, et.al. [3] focuses on the design and deployment of a remotely controlled bomb disposal robot utilising locally accessible hardware resources to reduce cost. The robot's body and arm were specially created and constructed out of aluminium alloy. The robot was outfitted with gas, fire, and obstacle detection sensors to make the most of its capabilities. It can gather and transport disassembled bomb components (up to 10 kg) in the chassis as proof. With the help of the solid works programme, the robot's mechanical design was verified. For PCB and schematic design, Proteus was utilised. Raspberry Pi served as the system's processor, and Arduino Mega was used for sensing and communication. Through the internet, the robot can be managed. In order to operate the robot via a web server, an additional Python script has been used.

7.2 Objectives of the Project Work

It was a good idea to work on this project because it has a great scope in future. It can be used by military for spying the enemy and also at the border to guard the line of control. This also help in the protecting our soldiers from injury caused due to unwanted fire seizure from neighbouring countries. It is mainly prepared to detect and dispose the bomb to safe place and safe distance so that no human is affected in case of sudden explosion of bomb. Basically, bomb disposal robot will help in protecting people from any damage due to bomb. It has grippers on it which help in grabbing the objects, so the suspected unknown object can be picked up with the help of this robotic arm.

- Construct a wireless robot integrated with diverse gas sensors and cameras to enhance visibility in challenging environments characterized by extremely low light and harsh conditions.
- In future we can make a lot like this and instead of soldier we can use them this will save more and soldiers.
- From the starting of the project we had the objectives as follows:
- To enhance the safety of the bomb disposal squad by offering an additional layer of protection..
- To build a robot with the capability to perform missions remotely in the field without endangering human lives and to help majorly in a rescue operation
- To control the robot wirelessly (Bluetooth) and find undiscovered places in mines where people cannot venture and gather information about those places.
- To design a model that intimates the soldiers about the obstacle, traps, and the distance from the location of the target, using a camera.
- Use of gas sensors which can detect the gases present in bomb.

The study conducted by Rakshana Mohamed Ismail and others [4] focuses on designing and building a semi-autonomous unmanned robotic system for diverse military and rescue operations. The soldiers can enhance their operational preparedness through live video feeds and environmental data analysis provided by various sensors in the monitored area. This is accomplished by leveraging Arduino and Zigbee technology. The Arduino Mega is connected to Zigbee, which, in turn, is linked to different sensors and the robotic arm, facilitating data transmission and reception via Zigbee technology.

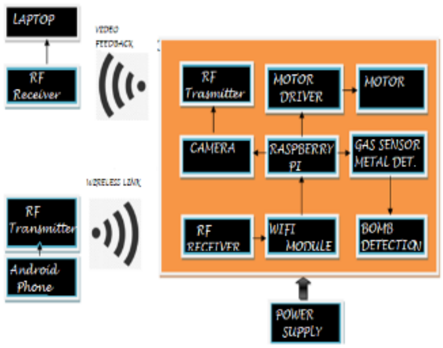


Fig 9: Proposed block diagram of the bomb detection robot system

7.3 Proposed Methodology

We propose a system for controlling the robot using Wi-Fi from an Android device. The Android application provides controllers for managing the robot's movements. These controllers define the robot's operation and are implemented using embedded C and Python programs loaded onto the Raspberry Pi. The robot's movements are displayed on a monitor connected to the Raspberry Pi. Motor control is achieved by turning DC motors "On" or "Off" through the use of switches, relays, transistors, or MOSFET circuits, with the basic motor control mode being "Multi-directional." The robot's location is determined using GPS, which transmits coordinates indicating the presence of metal, obstacles, and gases. Additionally, the robot is equipped with DC motors to facilitate its movement, and various sensors are employed for specific functions. Gas sensors detect toxic gases, a metal detector identifies bombs, and an ultrasonic sensor measures the distance to nearby objects or individuals. The robot's movements can be controlled via a monitor or a mobile phone, enabling it to navigate in various directions, such as forward, backward, left, and right, to detect hazardous materials and bombs in its vicinity..

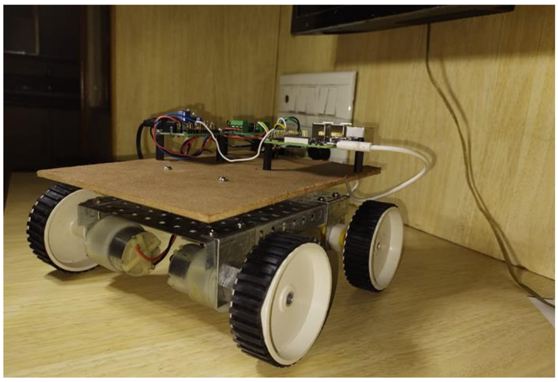
7.4 Possible Outcomes Of Our Project

The result of our first year is to build a multi-functional robot that not only is used in military applications, but also in mining applications, disaster rescue applications, and exploration of the undiscovered region. We are concluding our first year project, that BOMB DETECTION ROBOT can be used in Defence, Post Disaster Recovery, Hazardous environment, it also detects the gases that are present in the surroundings, by the use of cloud we can give the commands and send the information to the nearest camp bases that recognized. It can provide emergency treatment to soldiers during war times. It can help to pass the information on the battlefield & other terrains. This Bot can also provide a major contribution to the mining sectors and disaster rescue.

Advantages of the Mini-Project

- Wireless remote control
- Surveillance system
- Vehicle navigation using 4G technology
- Utilizes ubiquitous mobile technology
- Operates within the range of a cellular network
- Safety and life-saving.
- Makes an activity safer and easier.

Fig 10. Overall block-diagarm of the project work undertaken



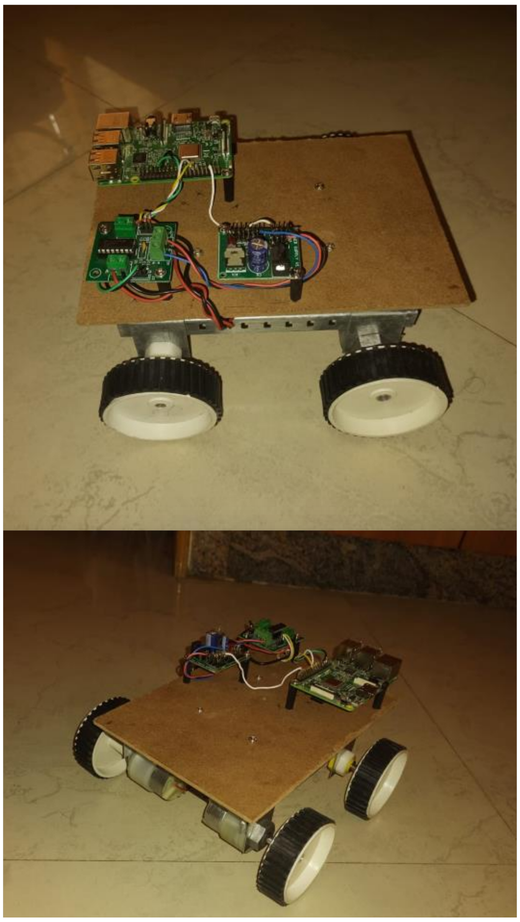


Fig 11: Prototype of the bomb-disposal robot model - 1

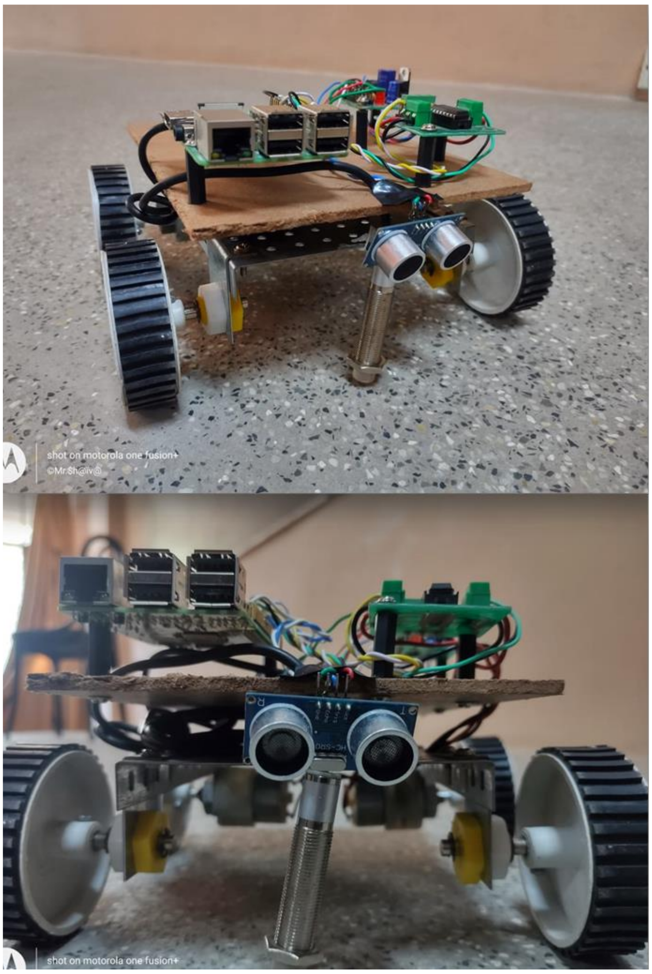


Fig 12: Prototype of the bomb-disposal robot model – 2

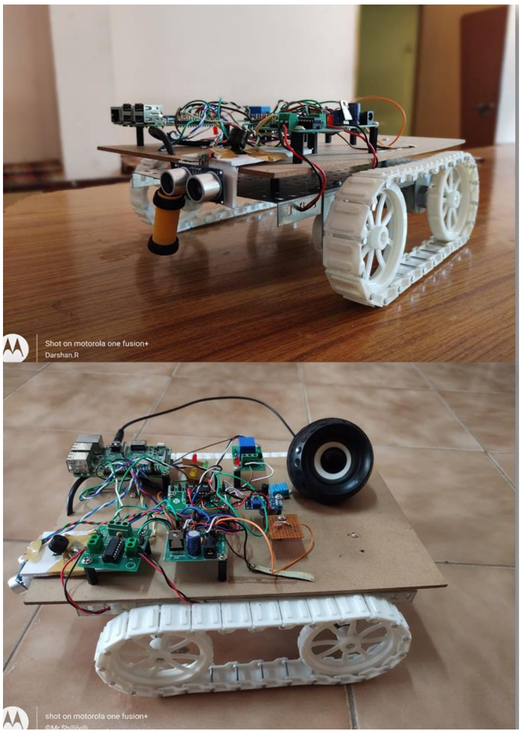


Fig 13: Prototype of the bomb-disposal robot model - 3

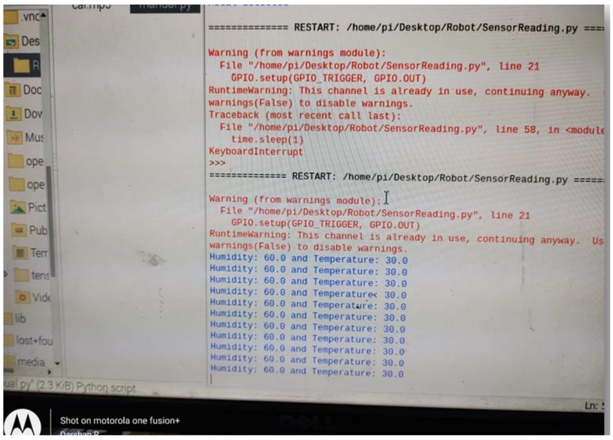


Fig 14: Programming the mobile bomb disposal robot

Fig 15: Prototype of the bomb-disposal robot model – 4

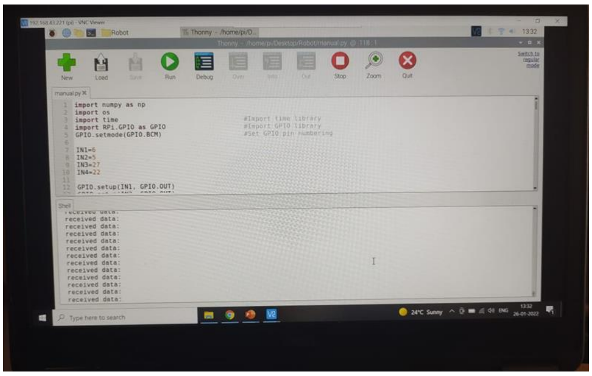


Fig 16: Programming the mobile bomb disposal robot

7.5 Implementation Procedures Carried

Establishing a fundamental understanding of the system lays the groundwork for better recognizing the factors that influence human-robot interactions. It also aids in enhancing human-robot training, refining robot design, and supporting efficient mission collaboration between humans and robots. As a result, this study delves into the human user experience of interactions between humans and robots in the context of Explosive Ordnance Disposal (EOD) to establish a foundational understanding for informed discussions regarding robot design and integration within close-knit teams like EOD. To accomplish this objective, the study employs qualitative methodologies to investigate the context, expectations, attitudes, and emotions that encompass these human-robot relationships..

7.6 Conclusive Remarks

Hence, the proposed approach provides insights into the development of uncomplicated robots designed to serve military purposes. The robot is operated remotely from a control room under manual control. Following simulation tests to confirm the DC motors' functionality, the robot's hardware is assembled. It incorporates a wireless camera to assess objects whenever the metal detector alarm is triggered, determining the potential danger. In the event of a threat, the robotic arm is manually controlled to safely neutralize or eliminate the explosive. Robots designed using this method could effectively assume the responsibilities of bomb disposal teams within military and law enforcement agencies..

Fig 17: App based control

8. Results And Discussion

- The objective of the project are completely fulfilled and the model is working perfectly without any problem.
- With the help of the android or and laptop with authenticate IP, we can operate the robot.
- The wheel are moving forward backward and controlling the moment of the robotic chassis.
- The information is transferred from raspberry pi and from there it is transferred to laptop / android phone where the some of the information obtained from PIR sensor are taken and are processed
- The sensory unit is able to detect the approaching traps, obstacles, or hostile targets. The controller obtains the data and processes required operation from the instructions of the human controller.
- The gas sensor ae working properly and are sensing gases like methane which is major content of explosion. Not only explosion it also helps in some of non-hostile conditions like recent warzone and etc. The metal sensors detect any kind of metal which helps easy detection of bombs.

9. Conclusions

Thus, the proposed system provides an opportunity to design uncomplicated robots that serve military purposes. Remote control from a control room allows manual operation of the robot. The functionality of DC motors is initially assessed through simulations before the physical robot assembly is completed. A wireless camera integrated into the robot becomes active when a metal detector triggers an alarm, enabling the verification of potentially hazardous objects. In such cases, the robot's robotic arm can be manually maneuvered to safely disarm or dispose of the explosive. As a result, this designed robot has the potential to replace bomb disposal teams in both military and police operations. The wireless Bomb Disposal Robot has been developed to meet the requirements of bomb disposal squads, military personnel, police units, and individuals working with radioactive materials. It boasts versatile applications suitable for various environments and scenarios. For example, it can be deployed by bomb disposal squads in one instance and utilized for mine handling in another. In a hostage situation, it can provide real-time information, among other potential applications..

10. Final Remark

The wireless Bomb Disposal Robot has been designed to fulfill the requirements of bomb squads, the military, police forces, and individuals dealing with hazardous materials. It possesses diverse applications suitable for various contexts and scenarios. For example, it can be employed in mine management in one situation and by bomb disposal teams in another. In different circumstances, it can provide up-to-date information during a hostage situation..

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