IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 7.047 ⁜ Vol. 10, Issue 3, March 2022

DOI: 10.17148/IJIREEICE.2022.10309

Remote Monitoring of a bomb detection robot interfaced with IP camera for real time surveillance and detection of Improvised explosive Devices (IEDs) in an environment Using wireless sensor Networks (WSNs).

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Abstract: Insecurity have been a major challenge in our society due to the rising number of attacks by terrorist with the aid of improvised explosives devices (bomb) being their major arsenal, Many terrorist organizations always target public places like school, church, market and large gathering of many people. This paper is majorly concern with the designing and developing an intelligent system (bomb detection Robot) capable of sensing, monitoring, capturing real time event, and transmitting the data obtained from respective improvised explosive sensed wirelessly to a remote server for further analysis ,the work x-rays the design and implementation of bomb detection robot using wireless sensor network in the detection of explosive devices that will help improve our campus (Nnamdi Azikiwe University Awka and its environment) security system against terrorists, suicide bombers and other similar activities. This bomb detection robot incorporates multiple sensors such as gas and metal sensors which can detect gas concentration from 200 to 10000ppm and a distance of Seven to Eight millimeter from the target for metal detector. The wireless Bomb detection robot has a control graphical user interface, to control the robot remotely . The bomb technician controls the bomb using customized software at the control site or remote location. Input from the user is transmitted to the receiver, the functions is given to the appropriate modules in the robot to act according to system specifications. The Robot is made up of robot chassis, a wireless camera, an omni-directional antenna and other components on it. This robot can be deployed in schools, hospitals, churches, check-points and other public places without risking the life of a bomb expert personnel too. Hence introducing the safest way for detecting the explosives to save life of an environment with ease.

Keywords: Remote Monitoring , Bomb Detector, Metal detector , WiFi, IEDs , ESP32 cam, Ammonia gas, Nitrogen Gas, Wireless sensor network (WSN)

1.1 INTRODUCTION

There is lot of attention in the research area pertaining to detection of explosives in the wake of terror attacks across the globe. [1] The world has sufficient evidence of this violence and several thousands of people lost their lives and even more number of people injured. Government infrastructures and common people are targets to terrorists. Improvised Explosive Devices (IEDs) are used by anti-social elements for making terror attacks from a remote place using mobile phones and other devices. Therefore it is essential to have reliable detection systems to protect people and property from dangerous attacks. Conventional systems used to detect explosives are expensive and bulky in nature. Moreover they need manual attention besides being visible publicly which causes intruders to change their plans accordingly. [2] Building an automated detection network which can be deployed easily and the network is not physically visible is very important concern. In other words the network to detect explosives can be hidden from view of public so that it does its job automatically to detect explosives and intimate the people concerned. However, building such robust system is very challenging. Of late some attempts were found in the literature to safeguard interests of public and property by deploying

Impact Factor 7.047 ⚟ Vol. 10, Issue 3, March 2022

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sensors to form wireless sensor network which can detect IEDs and the chemicals used in the materials. [3] These research work is poised on developing an intelligent system that is capable of detecting some explosive material within the campus environment and transmitting the data via a wireless sensor network to the receiver where the data received is being processed and analyze. The proposed system consists of a processor, sensor and wireless transceiver equipment. The system will be able to collect sensor data and perform processing of data using the proposed methodology and notifies security officials about any suspicious material. [4]

2.1 LITERATURE REVIEW

A bomb is an explosive weapon that uses the exothermic reaction of an explosive material to provide an extremely sudden and violent release of energy. Detonations inflict damage principally through ground and atmosphere transmitted mechanical stress, the impact and penetration of pressure-driven projectiles, pressure damage, and explosion-generated effects. Bombs have been utilized since the 11th century starting in East Asia. [5]
The term bomb is not usually applied to explosive devices used for civilian purposes such as construction or mining, although the people using the devices may sometimes refer to them as a "bomb". The military use of the term "bomb", or more specifically aerial bomb action, typically refers to airdropped, unpowered explosive weapons most commonly used by air forces and naval aviation. Other military explosive weapons not classified as "bombs" include shells, depth charges (used in water), or land mines. In unconventional warfare, other names can refer to a range of offensive weaponry. For instance, in recent Middle Eastern conflicts, homemade bombs called "improvised explosive devices" (IEDs) have been employed by insurgent fighters to great effectiveness.

An improvised explosive device (IEDs) is a bomb constructed and deployed in ways other than in conventional military action. It may be constructed of conventional military explosives, such as an artillery shell, attached to a detonating mechanism. IEDs are commonly used as roadside bombs, or homemade bombs. [6]
An IED is a bomb fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic, or incendiary chemicals and designed to destroy or incapacitate personnel or vehicles. In some cases, IEDs are used to distract, disrupt, or delay an opposing force, facilitating another type of attack. IEDs may incorporate military or commercially sourced explosives, and often combine both types, or they may otherwise be made with homemade explosives (HME). An HME lab refers to a Homemade Explosive Lab, or the physical location where the devices are crafted.

An IED has five components: a switch (activator), an initiator (fuse), container (body), charge (explosive), and a power source (battery). An IED designed for use against armored targets such as personnel carriers or tanks will be designed for armor penetration, by using a shaped charge that creates an explosively formed penetrator. IEDs are extremely diverse in design and may contain many types of initiators, detonators, penetrators, and explosive loads. [7]
Antipersonnel IEDs typically also contain fragmentation-generating objects such as nails, ball bearings or even small rocks to cause wounds at greater distances than blast pressure alone could. In the conflicts of the 21st century, anti-personnel improvised explosive devices (IED) have partially replaced conventional or military landmines as the source of injury to dismounted (pedestrian) soldiers and civilians. These injuries were reported in BMJ Open to be far worse with IEDs than with landmines resulting in multiple limb amputations and lower body mutilation. This combination of injuries has been given the name "Dismounted Complex Blast Injury" and is thought to be the worst survivable injury ever seen in war.

IEDs are triggered by various methods, including remote control, infrared or magnetic triggers, pressure-sensitive bars or trip wires (victim-operated). In some cases, multiple IEDs are wired together in a daisy chain to attack a convoy of vehicles spread out along a roadway.

IEDs made by inexperienced designers or with substandard materials may fail to detonate, and in some cases, they detonate on either the maker or the placer of the device. Some groups, however, have been known to produce sophisticated devices constructed with components scavenged from conventional munitions and standard consumer electronics components, such as mobile phones, consumer-grade two-way radios, washing machine timers, pagers, or garage door openers. The sophistication of an IED depends on the training of the designer and the tools and materials available.

IEDs may use artillery shells or conventional high-explosive charges as their explosive load as well as homemade explosives. However, the threat exists that toxic chemical, biological, or radioactive (dirty bomb) material may be added

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to a device, thereby creating other life-threatening effects beyond the shrapnel, concussive blasts and fire normally associated with bombs. [8]

2.2 Types of Improvised Explosive Devices (IEDs)
Experts commonly distinguish between civilian and military bombs. The latter are almost always mass-produced weapons, developed and constructed to a standard design out of standard components and intended to be deployed in a standard explosive device. [9]
Improvised explosive materials are typically unstable and subject to spontaneous, unintentional detonation triggered by a wide range of environmental effects, ranging from impact and friction to electrostatic shock. Even subtle motion, change in temperature, or the nearby use of cellphones or radios can trigger an unstable or remote-controlled device. Any interaction with explosive materials or devices by unqualified personnel should be considered a grave and immediate risk of death or dire injury. The safest response to finding an object believed to be an explosive device is to get as far away from it as possible (this is why a system of detection is introduced). There are three types of an improvised explosive devices:

- Packaged IEDs
- Vehicular-borne IEDs (VBIEDs)
- Personal-borne IEDs

2.2.1 Packaged IEDs
Packaged IEDs are the standard homemade bomb used by insurgents. Although variable in size, they are generally small enough to be carried by one person. These types of IEDs can be buried underground, placed in trashcans, or even thrown at their intended target. Packaged IEDs usually contain military munitions as its explosive component.

2.2.2 Vehicular-Borne IEDs (VBIEDs)
Vehicular-borne IEDS (VBIEDs) are bombs constructed with a vehicle as the delivery device. Much larger than the packaged IEDs, VBIEDS contain more explosive material and are more lethal than typical IEDs. [10]

2.2.3 Personal-Borne Improvised Explosive Devices (PBIEDs)
The Personal-borne IEDs (PBIEDs) is a suicide bomber using explosives tied to the body. The Personal-borne improvised explosive device is often well hidden on the body and difficult to see without personal inspection. Suicide bombers are very mobile and cause maximum damage in crowded urban areas. The suicide bomber dies after Personal-borne IEDs detonates, this type of enemy is extremely difficult to fight. [11]

2.3 Techniques Used In Bomb Detection
Over the years a lot of techniques has been implemented by various security agencies to carry out proper surveillance and detection of these bombs or IEDs [12,13,14, 15, 16] . Some of these techniques are:

1. Colorimetric and automated Colorimetric
2. Dogs
3. Mechanical scent detection
4. X-ray machines
5. Neutron activation

3.1 MATERIALS AND METHOD

To achieve the aim of this work. The different subsystems when implemented will make up for the whole system which is the remote monitoring of bomb detector. These requirements are listed ;

1. A battery. 2. A Metal detector unit. 3. A Gas detection unit. 4. A microcontroller unit.
5. A motor driver unit. 6. A video surveillance unit.
7. DC TO DC buck converter 8. DC motors for navigation.
9. Servos for pan and tilt motion

3.2 System Design
This phase shows how the requirements integrate together to form the entire system. This phase further explains how the subsystems will be implemented.
A number of tests were done to check the operations of the system. During our final result analysis of the project, the following parameters necessary for the proper functioning of bomb detection were recorded in order ascertain the necessary conditions needed for the optimum performance of the system. The recorded parameters are as follows:

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1. The sensitivity of the metal detector using the buzzer sound intensity and the distance of the metal from the surface of the detector.
2. The image quality of the video feedback from the live-cam against the distance of the robot from the remote operator.
3. The battery voltage against the sensitivity of the metal detector.
4. The various gases that can be detected by our system

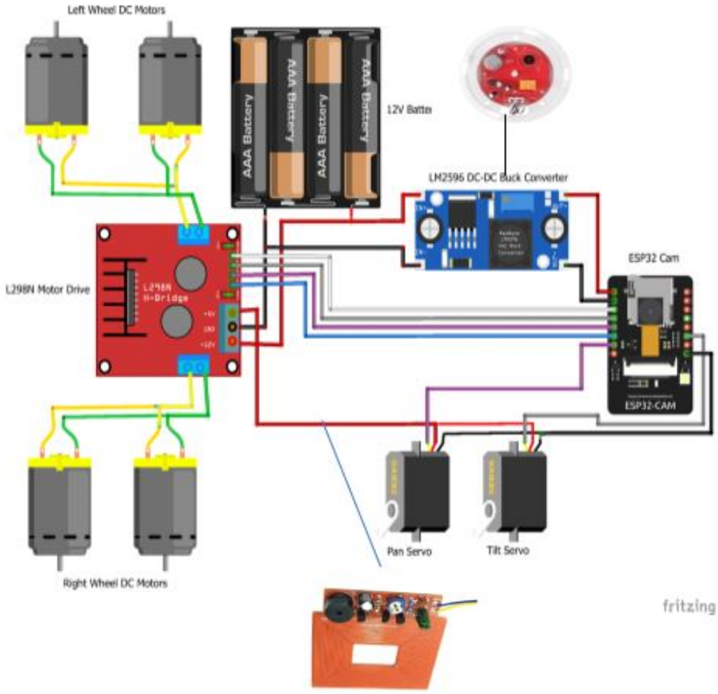

Fig 3.1 schematic diagram of the system

3.3 Dc to Dc Converter Subsystem

Operating Principle

DC-DC Buck Converter Step down Module LM2596 Power Supply is a step-down (buck) switching regulator, capable of driving a 3A load with excellent line and load regulation. This module has an adjustable output. The LM2596 series operates at a switching frequency of 150 kHz, thus allowing smaller sized filter components than what would be required with lower frequency switching regulators. It has an Input voltage of 4.75-35V, output voltage: 1.25-26V (Adjustable) and an output current of 2A. In this work, we used the buck converter to step down DC voltage from the battery to get a regulated 5V, 2A DC output. This output voltage is used to power the micro controller subsystem (ESP32 CAM Module), servos and the sensors.

3.4 Motor Driver Subsystem

The major function of the motor driver subsystem is to control the DC motor attached to the system according to the PWM signal from the control subsystem. The motor driver subsystem acts as a bridge between the controller and the DC motor in the system. To control the speed of each motor pulse width modulation is used The major components for the motor driver subsystem are: a controller, a motor driver IC or a motor driver module, DC motor, power supply unit and the necessary pin out to the motor.

1. Controller: The controller can be a microprocessor or a microcontroller.
2. Motor Driver IC or Motor Driver Circuits: They are basically current amplifiers which accept the low current signal from the controller and convert it into a high current signal which helps to drive the motor.
3. Motor: Motor is defined as an electric or mechanic device that can create a motion.
4. Power Supply Unit: Provides the required power to the motor drive.

For this work we used the L298N motor driver module due to its high output current and big heat sink to cool the driver IC for better performance. The Motor Driver module consists of an L298 Motor Driver IC, 7805 Voltage Regulator, resistors, capacitor, Power LED, 5V jumper in an integrated circuit. 7805 Voltage regulator will be enabled only when the jumper is placed. When the power supply is less than or equal to 12V, then the internal circuitry will be powered by

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the voltage regulator and the 5V pin can be used as an output pin to power the microcontroller. The jumper should not be placed when the power supply is greater than 12V and separate 5V should be given through 5V terminal to power the internal circuitry. ENA& ENB pins are speed control pins for Motor A and Motor B while IN1& IN2 and IN3 & IN4 are direction control pins for Motor A and Motor B.

3.5 Metal Detection Subsystem

This subsystem works on the principles of electromagnetic induction. Metal detectors contain one or more inductor coils that are used to interact with metallic elements. When the detector moves near a metallic object an electrical current is induced in the metallic object. This minute induced current in the metallic object produces another magnetic field resulting from the variable induced current which is detected by the detector unit. Metal detectors work on the principle of transmitting a magnetic field and analyzing a return signal from the target and environment. The transmitted magnetic field varies in time, usually at rates of fairly high-pitched audio signals. The magnetic transmitter is in the form of a transmit coil with a varying electric current fl owing through it produced by transmit electronics. The receiver is in the form of a receive coil connected to receive and signal processing electronics. The transmit coil and receive coil are sometimes the same coil. The coils are within a coil housing which is usually simply called "the coil," and all the electronics are within the electronics housing attached to the coil via an electric cable and commonly called the "control box". This changing transmitted magnetic field causes electric currents to flow in metal targets. These electric currents are called eddy currents, which in turn generate a weak magnetic field, but their generated magnetic field is different from the transmitted magnetic field in shape and strength. It is the altered shape of this regenerated magnetic field that metal detectors use to detect metal targets. (The different "shape" may be in the form of a time delay.)
The regenerated magnetic field from the eddy currents causes an alternating voltage signal at the receive coil. This is amplified by the electronics because relatively deeply buried targets produce signals in the receive coil which can be millions of times weaker than the signal in the transmit coil, and thus need to be amplified to a reasonable level for the electronics to be able to process.

3.6 Gas Detection Subsystem

A Typical human nose has 400 types of scent receptors enabling us to smell about 1 trillion different odors. But still many of us do not have the capacity to identify the type or concentration of gas present in our atmosphere. This is where Sensors comes in, there are many types of sensors to measure different parameters and a gas sensor is one which comes handy in applications where we have to detect the variation in the concentration of flammable/toxic gases in order to maintain the system safe and avoid/caution any unexpected threats. There are various gas sensors to detect gases like oxygen, Carbon Dioxide, Nitrogen, methane etc. They can also be commonly found in devices that are used to detect the leakage of the flammable gases, monitor the air quality in industries and offices etc. A gas sensor is a device that senses the atmosphere's presence or concentration of gases. The sensor creates a corresponding potential difference depending on the concentration of the gas by adjusting the resistance of the material within the sensor, which can be determined as the output voltage. The type and concentration of the gas can be calculated based on this voltage value.

3.7 Control Subsystem and Surveillance Subsystem

Here, the control sub-system hardware is basically the ESP32 CAM board, which is a micro-controller on its own. This micro-controller consists of 16 pins and each of its pins performs a particular function. In the general control of the system processes, the program which controls the system is embedded in to the micro controller using the Arduino IDE. Various tests and analysis were carried out to ensure proper functioning of the system.

Fig 3.2 ESP32-CAM Module

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 7.047 ⫶ Vol. 10, Issue 3, March 2022

DOI: 10.17148/IJIREEICE.2022.10309

ESP32-CAM is a very small camera module with the ESP32-S chip. The ESP32-CAM is a full-featured microcontroller that also has an integrated video camera and micro SD card socket. It's inexpensive and easy to use, and is perfect for IoT devices requiring a camera with advanced functions like image tracking and recognition. It also features a square white LED on the top of the module, this can act as a "flash" for illuminating the subject you are trying to view with the camera. This camera is integrated with remote configuration, remote viewing, and remote playback. It is a new generation of intelligent technology application that can conveniently send a live video feed over a local network. The control subsystem majorly consists of a single-board microcontroller based on the ESP32 chip. ESP32 is a single 2.4GHz Wi-Fi and Bluetooth combo chip designed with the TSMC ultra-low-power 40 nm technology. It is designed to achieve the best power and RF performance, showing robustness, versatility and reliability in a wide variety of applications and power scenarios.

The various steps involved in setting up the micro-controller before use are as follows:

1. Get the Hardware: which is the ESP32 CAM board.
2. Download and study the Data sheet for the ESP32 CAM board.
3. Generate an Arduino program (.ino) that will control the system
4. Use the Arduino IDE to burn the program into the microcontroller.
5. Interface the microcontroller with the components sensors and modules.
6. The control sub-system is ready to be integrated with other subsystems.

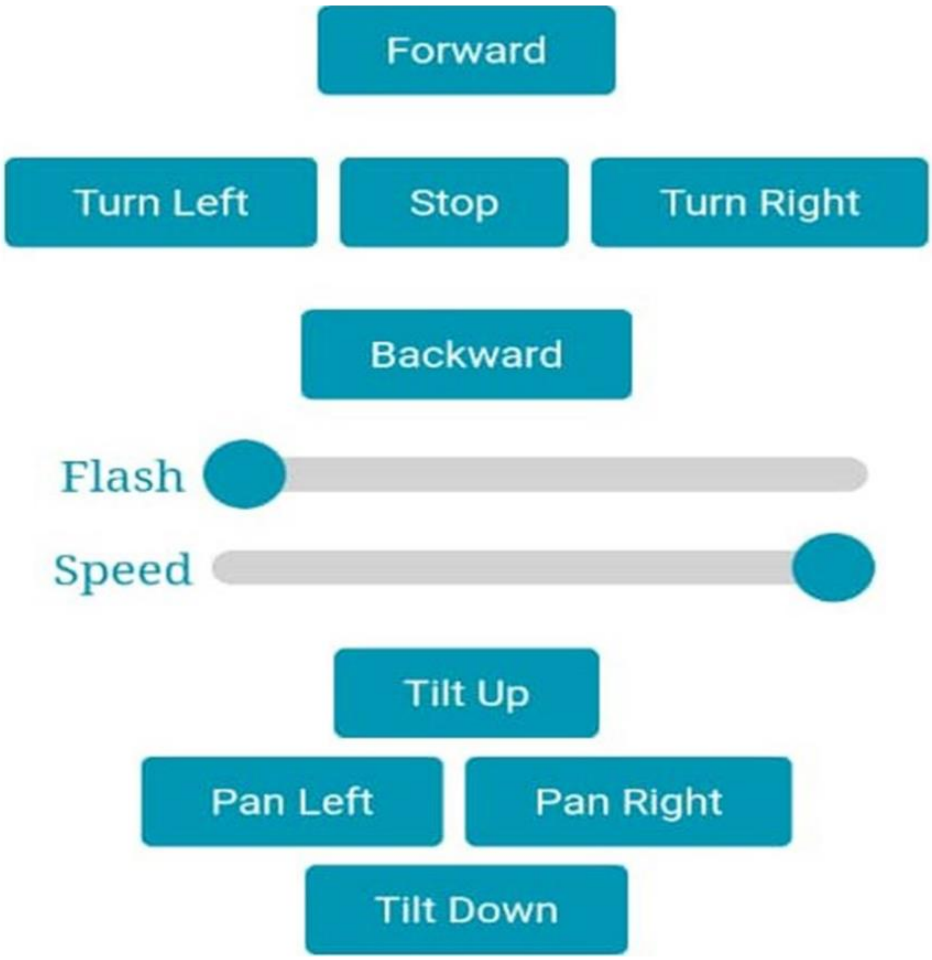

Fig 3.3 Graphical user Controller interface at remote location (Laptop, Phones, I-Pad etc)

The smart bomb detector is mounted on a customized plastic chassis with tracks. From a mobility perspective, tracked vehicles offer the best solution for a versatile platform that is required to operate over diverse terrain, including extremely difficult ground. Where wheels get bogged down, tracks with their increased surface area and drive provide a better solution. The ability to turn on the spot greatly increases tracked vehicles' off-road performance.

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Fig 3.4 Side view of finished bomb detector Robot with all specifications interfaced

3.8 Testing and Result Analysis

A number of tests were done to check the operations of the system. During our final result analysis of the project, the following parameters necessary for the proper functioning of the UGV for bomb detection were recorded in order ascertain the necessary conditions needed for the optimum performance of the system.

The recorded parameters are as follows:

1The sensitivity of the metal detector using the buzzer sound intensity and the distance of the metal from the surface of the detector.

2The image quality of the video feedback from the live-cam against the distance of the vehicle from the remote operator.

3The battery voltage against the sensitivity of the metal detector.

4The various gases that can be detected by our system

Here we take a critical look at the results obtained with different variables being measured and their graphical representations to fully demonstrate the behavior of the device in when it is under use.

This helps to ascertain the best condition for optimum performance of the robot.
the Gas detector is more efficient at detecting flammable gases within the range of 0 - 5 cm from the sensor
The following tests were carried out on the gas detection unit to find out the gases that can be detected by our system. The tests and results are listed as follows;

Major uses of potassium nitrate are in fertilizers production, tree stump removal, rocket propellants and fireworks. It is one of the major constituents of gunpowder (black powder). Igniting gunpowder produces nitrogen and carbon dioxide gas that propels the bullet by the reaction:
2KNO3(s)+18S8(s)+3C(s)→K2S(s)+N2(g)+3CO2(g)2KNO3(s)+18S8(s)+3C(s)→K2S(s)+N2(g)+3CO2(g)
We ignited potassium nitrate [gun powder] to produce Nitrogen gas and carbon dioxide gas. On bringing the gas close to sensor we observed a loud buzzer sound and flashing red led to indicate the presence of nitrogen gas

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Fig 3.5 Acetylene gas test being tested and good results obtained

Secondly, Ammonia (NH3), colorless, pungent gas composed of nitrogen and hydrogen. It is the simplest stable compound of these elements and serves as a starting material for the production of many commercially important nitrogen compounds. Ammonia is also used in the manufacture of commercial explosives (e.g., trinitrotoluene [TNT], nitroglycerin, and nitrocellulose). We purchased some ammonia and on bringing the gas close to sensor we observed a loud buzzer sound and flashing red led to indicate the presence of nitrogen gas.
Since efficiency is an important part of the system's operation, corresponding measurements were carried out.

Table 3.1 Metal detector Sensitivity

Distance (mm)	35	31	27	23	19	15	0
Sound Intensity(dB	79	81	83	85	88	90	90

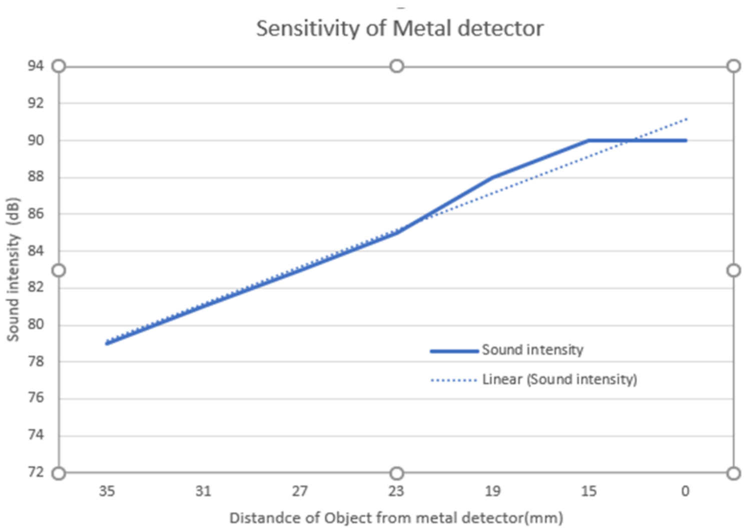

Fig 3.6 Sensitivity of metal detector

It can be clearly seen from the results above that the sensitivity of the metal detector has a maximum range of 35mm beyond which the metal detector cannot detect any metals within its surroundings despite us setting the potentiometer at the best level for which the metal detector can pick up the signals from its surrounding. Conclusion from this result is that the robot has to go as close to at least 35mm from the object to be detected in order to pick signal of a metal presence.

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From the results seen above, since our work was limited to using local server-side communication in communicating with the UGV instead of the planned IoT, the issue of distance of the device from the remote operator becomes imperative to analyze, this, of course would not have been a problem with the IoT. Therefore, the image quality drops the further the operator moves away from the device in which the signal strength is purely dependent on the maximum range of the Wi-Fi module and that of the Hotspot of the operating device.

Table 3.2 Detector Sensitivity with respect to Battery voltage

Voltage (v)	3.7	3.6	3.4	3.0	2.8	2.5
Sound (dB)	90	88	80	65	0	0
Distance	15	15	15	15	15	15

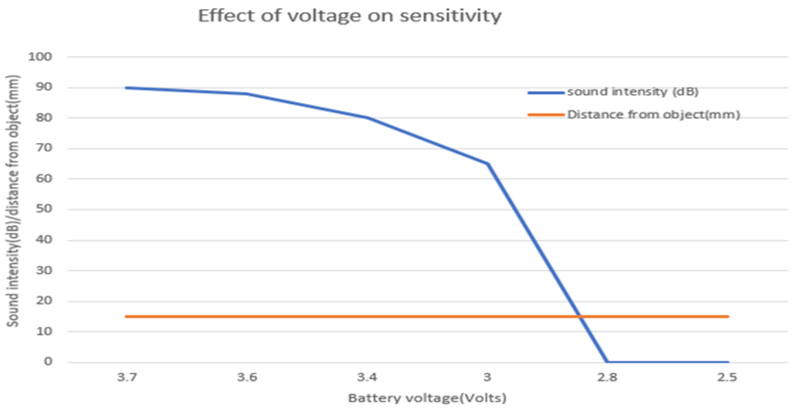

Figure 3.7 Effect of voltage on sensitivity

In order for us to accurately gather the above data, we had to perform our testing in a perfectly serene environment to avoid noise pollution distorting our results. We also had to run down the battery voltages at different time intervals using our digital multi-meter to read the voltage values of the battery. We had to equally keep this distance of the metal detector from the metal constant so that the issue of varying distances would not have to interfere with our results. From the above results, it is very clear that the performance of the UGV and the sensitivity of the coil is greatly affected by the operating battery voltage. Hence, while in operation, the operator must make sure that the battery is well charged before use.

4.1 CONCLUSION

The goal of this paper "bomb detection robot" is to provide an effective and reliable means of detecting improvised explosive devices (IEDs) especially the main components used in bomb making such as ammonia and calcium carbide. This work uses a wireless network interface and a surveillance camera which makes it possible for remote monitoring of the environment and getting live feed from the system.

This work, bomb detection robot can be used in schools, churches, market places, mostly at the entrance to check individuals, vehicles possessing improvised explosive devices especially now that our country is facing serious security challenges .

This project is a prototype work of a defense system when fully developed can be used to combat terrorism in full scale. From the work, it was discovered that for the system to be more accurate it requires many sensors due to the nature of improvised explosive devices and also incorporating many sensors will make the system bulky and not cost effective.
. For future improvement, there are several suggestions stated below:

Firstly, The prototype has a limited-range of detection, and therefore future and more research on improvements should be conducted, so as to increase the detection range and make the device more-efficient.
Secondly, An essential goal for future would be the integration of artificial intelligence algorithms used for object identification to better detect explosives Thirdly, The next steps include noise suppressors in the modification of the robotic subsystem to reduce the noise output of the robotic system during operations..

ISSN (O) 2321-2004, ISSN (P) 2321-5526

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