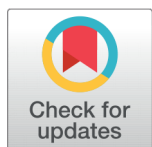


## RESEARCH ARTICLE



### OPEN ACCESS

**Received:** 07-07-2020

**Accepted:** 03-08-2020

**Published:** 27-08-2020

**Editor:** Dr. Natarajan Gajendran

**Citation:** Mahapatruni N, Ramana Rao KV, Velangini Sarat P, Bhaumik M (2020) Unmanned ground robot for diffusing explosives with surveillance. Indian Journal of Science and Technology 13(31): 3160-3175. <https://doi.org/10.17485/IJST/v13i31.1086>

\***Corresponding author.**

Tel: +91-9581155737  
[nagyie@gmail.com](mailto:nagyie@gmail.com)

**Funding:** None

**Competing Interests:** None

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Published By Indian Society for Education and Environment (iSee)

**ISSN**

Print: 0974-6846

Electronic: 0974-5645

## Unmanned ground robot for diffusing explosives with surveillance

**Nagendrababu Mahapatruni<sup>1\*</sup>, KV Ramana Rao<sup>2</sup>, P Velangini Sarat<sup>3</sup>, Munmun Bhaumik<sup>1</sup>**

**1** Associate Professor, Department of ME, Vignan's Institute of Engineering for Women, 530046, AP, India. Tel.: +91-9581155737

**2** Associate Professor, Department of ECE, Vignan's Institute of Engineering for Women, 530046, AP, India

**3** Assistant Professor, Department of EEE, Vignan's Institute of Engineering for Women, 530046, AP, India

## Abstract

**Background/Objectives:** In the worldwide scenario diffusing any explosive is the challenging task for any defense. This research aims to develop an unmanned ground robot for disusing such explosives with live surveillance.

**Methods/Statistical analysis:** Diffusing any explosive requires human effort adversely at risk. Incorporating a lightweight mobile robot consisting 4 DOF robotic arms which can do multiple operations with a tool armor. Also, a moving vehicle that can crawl lobes and travel to places where a human cannot reach while operating the robot with radio frequency which is difficult to hack in a short span along with live 360° video transmitting system.

**Findings:** Surveillance system developed can observe the motion tracking and visual identification to study the type of explosive. This wireless diffusion system prototype can be operated remotely within a range of 100 meters while surveillance and operating the robotic arms. This unmanned ground robot can stream live at 60Hz and can sense any motions in the vicinity of the camera with security alert of movements by artificial intelligence. In the context current robots run on IR transmitter, RF transmission used in the current unmanned ground robot can be operated even in the vicinity of signal jammers. **Novelty/Applications:** Unmanned ground robot is unique with its RF transmitter with 360° live streaming operating multiple interchangeable armors with artificial intelligence identifying the motions in the vicinity of the surveillance.

**Keywords:** Diffusing system; explosives; wireless robotic surveillance; video transmitting device; robotic arms; unmanned ground robot; 4 degree of freedom

## 1 Introduction

In the present scenario, every nation and every country in the entire world are focused on setting up a robust defense system with profound advancements in

robotics and mechatronics.<sup>(1)</sup> It has been very challenging for every country to control the terrorists who are using various plastic explosives. During the diffusion process many soldiers or experts lost their lives or severely injured. In this perspective, a wireless surveillance robot which can diffuse explosives with expert aid remotely has been designed and developed. One of such explosives like landmines and plastic explosives may cause damage by direct blast effect, by fragments that are thrown by the blast, or by both. In earlier days, the process of surveillance and diffusing of landmines was carried out by humans. Later sensors, metal detectors, mechanical probes and prodders were used to detect these landmines.<sup>(2)</sup> Many technologies like infrared imaging system, nuclear magnetic resonance, x – ray backscatter, electric impedance tomography, etc. were used to detect the landmines. These systems are used to detect the landmines, but they need human interference for diffusing. This may be harmful to the human which even puts the life of a person in danger.<sup>(3)</sup> Later surveillance process was even carried out using unmanned aerial vehicles (UAV) which may not put the life of a human in risk but the process of diffusion may not be carried out using this vehicle.<sup>(4)</sup>

Robots developed for location can do surveillance with movement,<sup>(5)</sup> whereas they are unable to crawl over the stones or unbiased surfaces. Hence, a system which fulfills the process of surveillance and diffusing is created which can be operated from a minimum safest distance which can crawl over unbiased surfaces.<sup>(6)</sup> This assemblage of wireless video transmitting device which fulfills surveillance process and a robotic arm which fulfills diffusing process is standardized on the chassis of an RF based vehicle which is used to move the system to the desired location.<sup>(7)</sup>

It is always challenging to design and develop a prototype for sensitive operations like to diffuse any explosive.<sup>(8)</sup> In this investigation, a prototype of mobile surveillance robot has been developed to build an automatic surveillance and live monitoring using radio frequency signals which cannot be interpreted by any individual.<sup>(9)</sup> In order to identify remotely and diffuse any type of explosives such as landmines remotely by operating the robotic arms without any risk to human.<sup>(10)</sup> Haptic arms developed will not be suitable to unmanned ground robots, as they cannot lift the loads, wire cutting and other extraction operations.<sup>(11)</sup> These operations have been completed with the help of live 360 degree monitoring/surveillance system, crawler and a 4 DOF robotic arm (whereas using this design it be applied to 8 DOF robotic arm also).<sup>(12)</sup> This wireless robot can fulfill other applications such as motion detection, material handling, processing operations, assembly, inspection, loading and unloading operations, etc.

## 2 Design and Development

### 2.1 RF based vehicle

Radio frequencies (RF) are electromagnetic wave frequencies ranges from 3-300 GHz which are not visible to the human eye. Radio frequency usually denotes electrical rather than mechanical oscillations. Radio frequency module is a small electronic device which is used to transmit and receive radio signals between two devices. In an embedded system it is often desirable to communicate with another device wirelessly. This wireless communication may be accomplished through optical communication or through radio frequency. RF communications incorporate a transmitter and a receiver.<sup>(13)</sup> They are various types and ranges where some can transmit up to 500 feet. RF modules are widely used in electronic designs. Owing to the difficulty of designing radio circuitry, RF modules are most often used in medium and low volume products. These are sometimes used to replace older infrared communication designs.

Nowadays, the Radio Frequencies are mostly used in vehicles because of the following advantages:

- Cost of the system is very less compared with its applications.
- Helps the passengers to cross the road safely without facing any danger from high speed vehicles.
- This system helps to avoid the rash driving of the drivers.

[ Figure 1 ] shows the RF based vehicle used for surveillance and diffusing system. This RF Based vehicle was geared with 6 servo motors to drive the wheels and one servo to steer the crawler. A base plate was attached to the chassis so that the space required for standardizing the wireless video transmitting device and robotic arm was obtained.<sup>(14)</sup>



**Fig 1.** RF based vehicle

## **2.2 Wireless video transmitting device**



**Fig 2.** Wireless video transmitting device

This wireless video transmitting device is used for the surveillance and motion tracking in the diffusing system for live monitoring while diffusing the explosives. This device is clamped on the RF Vehicle which is moved to the desired location using radio frequencies<sup>(15)</sup>. The operation is observed through the mobile phone connected to the device. The range of the device is limited to the wifi range which is about 50m. [ Figure 2 ] shows wireless video transmitting device used in the surveillance and diffusing system.

### 2.2.1 Specifications

- Rotation of about 180 degrees in vertical motion above ground level is possible.
- Rotation of about 360 degrees in horizontal motion is possible.
- Range: 100m
- Input: 5V DC
- Operates on WPS secured wifi line.

When the RF Vehicle is moved towards the desired location, this device is used for identifying the presence of any unusual object.<sup>(16)</sup> This helps in knowing the desired information of the unusual object in order to adopt specific diffusing process. This device is capable of identifying all the unusual objects regardless of the material used and type of object.

### 2.3 Arduino board

Arduino board uses a variety of microprocessors and controllers. These boards are equipped with sets of digital and analog input/output pins (14 digital pins and 6 analog pins) that may be interfaced to various expansion boards or breadboards and other circuits. The boards feature serial communication interfaces which are used for loading programs from personal computers<sup>(17)</sup>. The microcontrollers can be programmed using C and C++ programming languages using Arduino IDE software. It can be powered through a USB cable or by an external battery with an input voltage ranging from 7 to 20 volts. [ Figure 3] depicts the Arduino board used for surveillance and diffusing system.

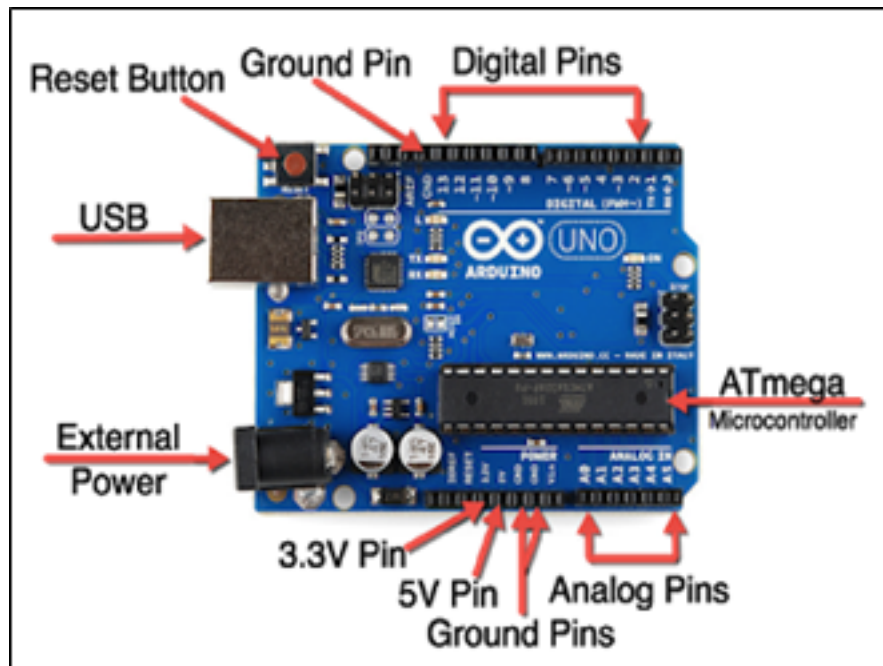


Fig 3. Arduino board

## 2.4 Arduino connections

The Arduino was connected to the PCB and IR module using jumper wires and IR receiver.

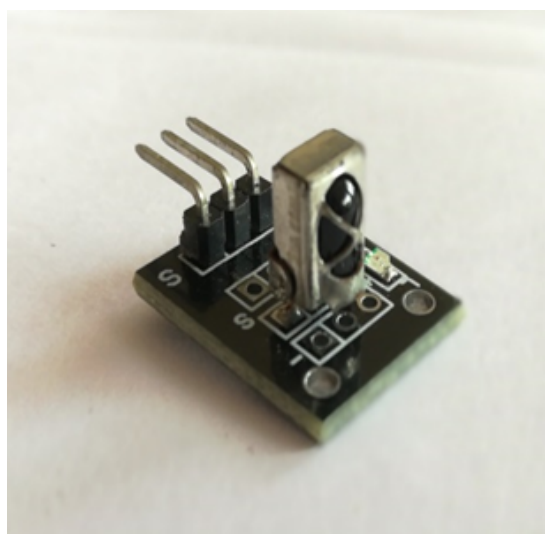
### 2.4.1 Jumper wires

Jumper wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools in order to make it easy to change a circuit as needed. [ [Figure 4](#) ] Jumper wires typically come in three versions: male-to-male, male-to-female and female-to-female.



**Fig 4.** Jumper wires

### 2.4.2 IR receiver



**Fig 5.** IR Receiver



An infrared (IR) receiver [ [Figure 5](#)] is a hardware that sends information from an infrared remote control to another device by receiving and decoding signals. In general, receiver outputs a code to uniquely identify the infrared signal that it receives. When an infrared remote is used on the IR receiver, the device translates the signal and broadcasts it over RF [ [Figure 6](#)]. The paired unit then receives that signal, decodes it and transmits an IR signal. IR transmitter and receiver devices can also be used with some computers.

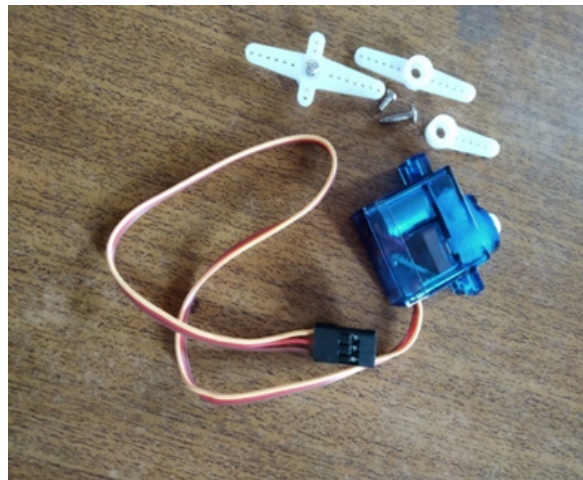
#### 2.4.3 IR remote

IR remote control is a wireless device used to operate audio, video and other electronic equipment within a room using light signals in the infrared (IR) range. [ [Figure 6](#)] Infrared light requires line of sight to its destination. Low-end remotes use only one transmitter at the end of the unit and have to be aimed directly at the equipment. High-quality remotes have three or four powerful IR transmitters set at different angles to shower the room with signals.



**Fig 6.** IR Transmitter remote

#### 2.4.4 Servo motors

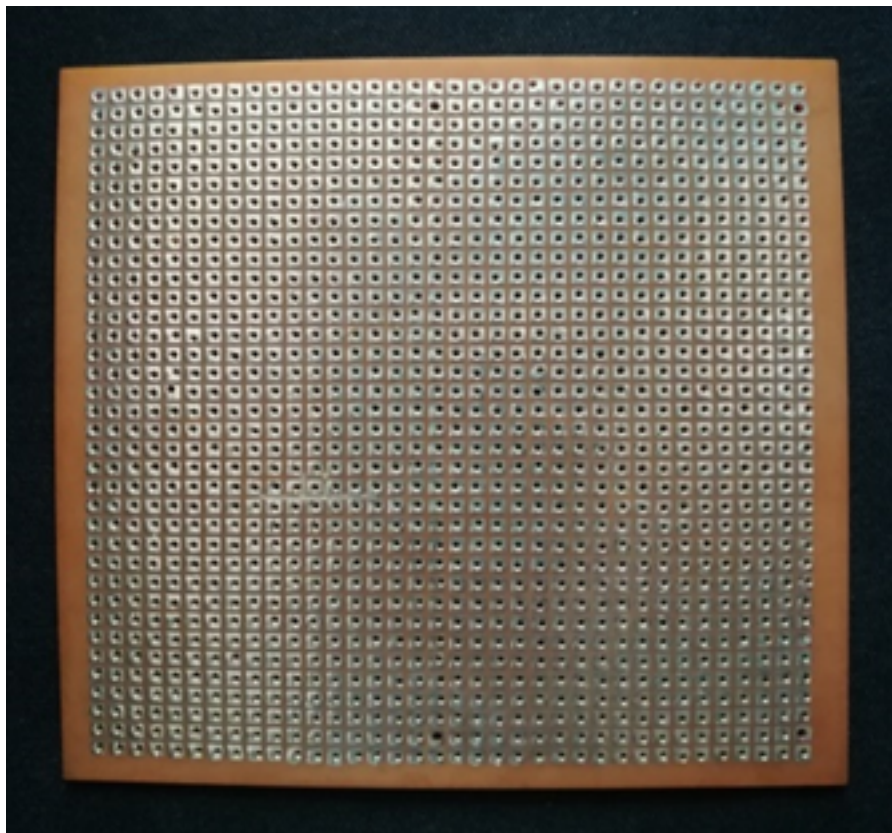


**Fig 7.** Servo motors

A servomotor allows precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. A servomotor is a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is a signal (either analogue or digital) representing the position commanded for the output shaft [ Figure 7].

#### 2.4.5 Printed Circuit Board (PCB)

Printed circuit Board (PCB) [ Figure 8] is a thin board made of fiberglass, composite epoxy, or other laminate material. Conductive pathways are printed onto board, connecting different components on the PCB such as transistors, resistors, and integrated circuits. Perfboard is a material for prototyping electronic circuits (also called DOT PCB). It is a thin, rigid sheet with holes pre-drilled at standard intervals across a grid, usually a square grid of 0.1 inches (2.54 mm) spacing. These holes are ringed by round or square copper pads, though bare boards are also available.



**Fig 8.** PCB

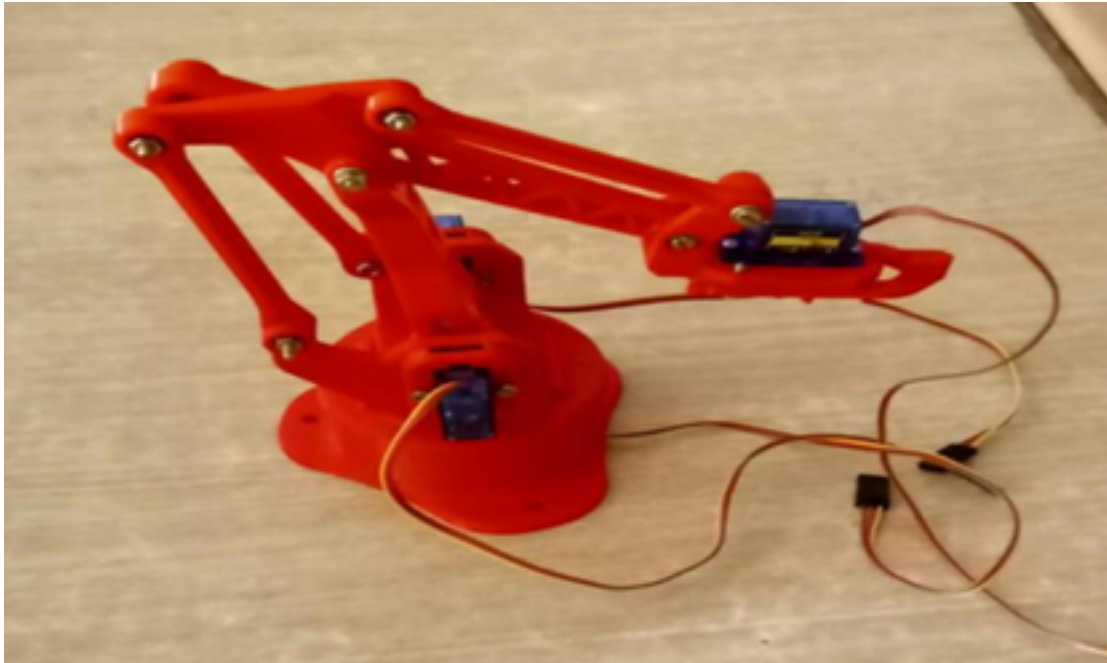
#### 2.4.6 Breadboard

The purpose of a breadboard is to make quick electrical connections between components like resistor, LED, capacitors, etc. so that one can test the circuit before permanently soldering it together. Certain parts of the breadboard are wired together so that electricity can flow from component to component in orderly rows.

#### 2.4.7 Degree of freedom (DOF) of robotic arm

A robotic arm is a type of mechanical arm, usually programmable, with similar functions to a human arm. This robotic arm may be the total sum of the mechanism. A robotic arm made up of Polylactic Acid (PLA) is used as a 4

DOF Robotic Arm. The PLA 3D printed plastic parts are assembled together with servo motors which constitute a 4 DOF Robotic Arm [ Figure 9].



**Fig 9.** 4 DOF Robotic arm with 3D printed frames and base

#### **1<sup>st</sup> Axis**

This axis, located at the robotic arm base, allows the robot to rotate from left to right. This axis allows the robot to spin up to a full 180 degree range from the center point.

#### **2<sup>nd</sup> Axis**

This axis allows the lower arm of the robotic arm to extend forward and backward. It is the axis powering the movement of the entire lower arm.

#### **3<sup>rd</sup> Axis**

This axis extends the robotic arm vertical reach. It allows the upper arm to raise and lower.

#### **4<sup>th</sup> Axis**

This axis of the robotic arm is used for the gripper action as it moves for holding the objects which helps it to lift and drop any object when desired.

### **3 Working of surveillance and diffusing system**

This surveillance and diffusing system for explosives like landmines is designed to identify and diffuse the explosives without human risk.

#### **3.1 Surveillance process**

- The system is moved to the desired location using the RF Based Vehicle by controlling it with RF controller.
- The location where it was sent was monitored through an android mobile by connecting this android mobile to the wireless video transmitting device.
- While monitoring the location, the presence of any unusual object was identified.
- By moving the vehicle and rotating the wireless video transmitting device, we can examine the unusual object.



- If the unusual object which was found was turned out to be a landmine or a wired bomb, the complete information of the situation was examined in order to diffuse it.

### 3.2 Diffusing process

- When a landmine or a wired bomb is identified, using the rotations of the wireless video transmitting device, one can examine the situation like its location, connections, etc.
- The complete information of the landmine or wired bomb was collected so that we can adopt the specific diffusion process.
- Using the 4 DOF robotic arm, the process of diffusion is carried out like cutting the wires or diffusing the switches, etc.

### 3.3 Code for Arduino

The Arduino was programmed using 'Arduino Integrated Development Environment' software. In order to make the robotic arm working, the arduino was programmed with the below program.

```
#include <IRremote.h>
int RECV_PIN = 7;
IRrecv irrecv(RECV_PIN);
decode_results results;
void setup()
{
  Serial.begin(9600);
  Serial.println("Enabling IRin");
  irrecv.enableIRIn(); // Start the receiver
  Serial.println("Enabled IRin");
}
void loop() {
  if (irrecv.decode(&results)) {
    Serial.println(results.value, HEX);
    irrecv.resume(); // Receive the next value
  }
  delay(100);
}
```

HEX codes were imported for each button of the remote. These HEX codes for the remote represent the particular operation of the buttons.

#### 3.3.1 Base code

By using this code, a single motor can be attached to the arduino. This motor can be operated using the buttons in the remote whose HEX codes have been included.

```
#include <IRremote.h>
#include <Servo.h>
#define base1 0xFF18E7
#define base2 0xFF4AB5
int RECV_PIN = 7;
Servo servo;
int val;
bool cwRotation, ccwRotation;
```

```
IRrecv irrecv(RECV_PIN);
decode_results results;
void setup()
{
  Serial.begin(9600);
  irrecv.enableIRIn();
  servo.attach(3);
}
void loop()
{
  if (irrecv.decode(&results)) {
    Serial.println(results.value, HEX);
    irrecv.resume();
    if (results.value == basel)
    {
      cwRotation = !cwRotation;
      ccwRotation = false;
    }
    if (results.value == baser)
    {
      ccwRotation = !ccwRotation;
      cwRotation = false;
    }
    if (cwRotation && (val != 175)) {
      val++;
    }
    if (ccwRotation && (val != 0)) {
      val--;
    }
    servo.write(val);
    delay(20);
  }
}
```

### 3.3.2 Final code

Once the motors has been checked individually using the base code, overall program has to be dumped. This program runs the 4 motors together at a time. The rotation of each motor and its direction can be controlled with the help of IR remote by specifying the HEX codes in the program.

```
#include <IRremote.h>
#include <Servo.h>
#define basel 0xFF10EF
#define baser 0xFF5AA5
#define arm1u 0xFF18E7
#define arm1d 0xFF4AB5
#define arm2u 0xFF6897
#define arm2d 0xFFB04F
#define holdo 0xFF9867
```

```
#define holdc 0xFFA857
int RECV_PIN = 7;
Servo baseservo;
int val1;
bool cwRotation, ccwRotation;
Servo arm1servo;
int val2;
bool cwRotation2, ccwRotation2;
Servo arm2servo;
int val3;
bool cwRotation3, ccwRotation3;
Servo holdservo;
int val4;
bool cwRotation4, ccwRotation4;
IRrecv irrecv(RECV_PIN);
decode_results results;
void setup()
{
  Serial.begin(9600);
  irrecv.enableIRIn();
  baseservo.attach(4);
  Serial.begin(9600);
  irrecv.enableIRIn();
  arm1servo.attach(6);
  Serial.begin(9600);
  irrecv.enableIRIn();
  arm2servo.attach(8);
  Serial.begin(9600);
  irrecv.enableIRIn();
  holdservo.attach(9);
}
void loop()
{
  if (irrecv.decode(&results)) {
    Serial.println(results.value, HEX);
    irrecv.resume(); // Receive the next value
    if (results.value == basel)
    {
      cwRotation = !cwRotation;
      ccwRotation = false;
    }
    if (results.value == baser)
    {
      ccwRotation = !ccwRotation;
      cwRotation = false;
    }
  }
}
```

```
if (cwRotation && (val1 != 175)) {
  val1++;
}
if (ccwRotation && (val1 != 0)) {
  val1--;
}
baseservo.write(val1);
//General speed
if (irrecv.decode(&results)) {
  Serial.println(results.value, HEX);
  irrecv.resume();
  if (results.value == arm1u)
  {
    cwRotation2 = !cwRotation2;
    ccwRotation2 = false;
  }
  if (results.value == arm1d)
  {
    ccwRotation2 = !ccwRotation2;
    cwRotation2 = false;
  }
}
if (cwRotation2 && (val2 != 45)) {
  val2++;
}
if (ccwRotation2 && (val2 != 0)) {
  val2--;
}
arm1servo.write(val2);
//General speed
if (irrecv.decode(&results)) {
  Serial.println(results.value, HEX);
  irrecv.resume(); // Receive the next value
  if (results.value == arm2u)
  {
    cwRotation3 = !cwRotation3;
    ccwRotation3 = false;
  }
  if (results.value == arm2d)
  {
    ccwRotation3 = !ccwRotation3;
    cwRotation3 = false;
  }
}
if (cwRotation3 && (val3 != 45)) {
  val3++;
}
```

```
if (ccwRotation3 && (val3 != 0)) {  
  val3--;  
}  
arm2servo.write(val3);  
//General speed  
if (irrecv.decode(&results)) {  
  Serial.println(results.value, HEX);  
  irrecv.resume();  
  if (results.value == holdo)  
  {  
    cwRotation4 = !cwRotation4;  
    ccwRotation4 = false;  
  }  
  if (results.value == holdc)  
  {  
    ccwRotation4 = !ccwRotation4;  
    cwRotation4 = false;  
  }  
}  
if (cwRotation4 && (val4 != 45)) {  
  val4++;  
}  
if (ccwRotation4 && (val4 != 0)) {  
  val4--;  
}  
holdservo.write(val4);  
delay(20);  
}
```

### 3.4 Process of development

The development of surveillance and diffusing system includes technologies like RF Based Vehicle, Wireless Video Transmitting device, Arduino Board and a Robotic Arm. These technologies are assembled in such a way that they resemble to be a single unit.

#### Step – 1

The RF based vehicle was disassembled and examined. The suspension system of the vehicle was inspected and found it up to 30mm. Hence this RF based vehicle was used for moving the system to any desired location using the RF controller.

#### Step – 2

A base plate of required dimensions was mounted on the chassis of the RF based vehicle which acts as a base for other components. [ [Figure 10](#) ]





**Fig 10.** Connections between systems for arm and arduino for execution

**Step – 3**

A wireless video transmitting device was standardized on the base plate so that live monitoring was possible during the complete operation.

**Step – 4**

Connections were given to the arduino board and PCB using jumper wires according to the circuit diagram. [ [Figure 11](#) ]



**Fig 11.** Surveillance unit assembly along with vehicle

**Step – 5**

The robotic arm was assembled which has 4 DOF and it can perform the desired operations.

**Step – 6**

The Arduino board connections were connected to the robotic arm so that we operate it using the IR remote.

**Step – 7**

The complete assemblage of robotic arm and Arduino board were standardized on the base plate of the RF Based Vehicle.

## 4 Conclusions

Developed Unmanned Ground robot is unique with its features that enables artificial intelligence based surveillance. Hence a surveillance system that is very difficult to get hacked in short time and a unique diffusing system has been developed by assembling various components like RF crawler, Wireless Video Transmitting device and a 4 DOF robotic arm. This system can detect the explosives landmines or any other unusual objects with the help of the live monitoring system with artificial intelligence. After detecting these landmines, with the help of the 4 DOF Robotic arm any defense expert can operate the system and diffuse these explosives remotely without risk and in a secured WPS line.

The surveillance process is achieved by Wireless Video Transmitting Device. In order to detect the explosives like mines which are under the ground, a metal detector or other sensors can be attached to the system. This is a prototype for the conceptualization with execution strategy and in order to use it for real-time challenges, one should use the technologies with greater ranges.

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