NATIONAL UNIVERSITY OF SCIENCE & TECHNOLOGY

MILITARY COLLEGE OF SIGNALS

Design Simulation and Implementation of Reconnaissance and Surveillance UGV

FINAL REPORT

BACHELORS IN TELECOM ENGINEERING (BETE)

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ABSTRACT

The proposed project includes design, simulation and implementation of unmanned ground vehicle. Our Project is based on wireless communication between the controller and UGV. Vehicle is designed primarily for surveillance and reconnaissance purpose. We have done the hardware as well as software work for controlling our UGV. We have used Ardiuno boards for the design of both UGV and the controller which detects the command and accordingly move the UGV. Different sensors are used for different purposes for e.g. temperature, humidity, edge etc. Vehicle is powered by 6 batteries connected in series. These batteries can be charged by solar panel during the sunlight. DC motors are used for movement of vehicle. Vehicle is operated through laptop using GUI. 18V charger is used for charging batteries. Transceivers used are NRF that works in ISM band whose range is 2.4 GHz. These transceivers send an encrypted signal providing the security of the signal. The UGV will be able to move in all possible directions. UGV are used for various purposes these days we can change the primary purpose of UGV by making some alterations.

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ABBREVIATIONS

UGV: Unmanned Ground Vehicle

NTC: Negative temperature coefficient

MCU: Microcontroller Unit

I^2C: Inter integrated circuit

SPI: Serial Peripheral Interface

1. INTRODUCTION

1.1 PROJECT MOTIVATION

1.1.1 Previous Problems

Providing remote reconnaissance and surveillance while removing troops from excessive danger in today's ever-changing threat environment remains a key challenge for commanders and operators. Also the UGV's which we had seen in past could not be moved autonomously and to control them people would use remote controlled modules and big joysticks. It is difficult to use and carry big sized modules esp. in battle fields and remote areas.

1.1.2 Problem Solution

Keeping the above problem in our mind we try to introduce Reconnaissance UGV which is easy to control, smaller in size and user friendly. Our main goal is to design a UGV that can move autonomously and could also be controlled through control room.

1.2 PROJECT DESCRIPTION AND SALIENT FEATURES

1.2.1 Project Description

Our Project is based on wireless communication between the controller and UGV with a camera mounted on it. We have operated our UGV and camera through laptop using GUI. We have worked on making the hardware as well as software for controlling our UGV. We have used Arduino board for the design of both UGV and the controller which will identify the commands and accordingly move the UGV. The UGV will be able to move in all possible directions. The camera will be able to move 270 degrees on horizontal scale and 0-90 degree on vertical scale, and provides surveillance of the remote area.

1.2.2 Block Diagram

Figure 1: Block Diagram

1.2.3 Salient Features

Our UGV has got following salient features:

1. UGV is mechanical based and light weight. It is capable of moving in rough terrains.
2. Visual display of territory on laptop/computer through camera mounted on vehicle.
3. We have installed Arduino MEGA, Motors, and Batteries, RF Transmitter/Receiver and more.
4. Our UGV will move autonomously. We have done this by installing sensors for obstacle detection.
5. A controller is designed which can recognize the commands through laptop using Arduino MEGA board.
6. We have established wireless communication between the controller and the UGV using RF transmitter / receiver pair or RF transceivers. This enables the two Arduino boards to communicate serially.

1.3 SCOPE, OBJECTIVES, SPECIFICATIONS AND DELIVERABLES

1.3.1 Scope

The scope of the project is to develop an Unmanned Ground Vehicle for reconnaissance and surveillance purposes. The proposed project works on the following fronts:

1. Performance of some application-specific mission.
2. UGV for special cases such as hazardous environment, strength or endurance requirements, size limitation.
3. Encountering "long pole" technological challenges, in terms of functionality, performance, or cost, posed by the application.

4. Intended operating areas include indoor environments, anywhere indoors, outdoors on roads, general cross-country terrain, the deep seafloor, etc.
5. The vehicle's mode of locomotion (e.g., wheels, tracks, or legs).
6. Determination of path for the vehicle by control and navigation techniques.
7. This UGV can be used for defense purpose.
8. Autonomous mode in this UGV provides full control to UGV with ditch and obstacle detection and avoidance.

1.3.2 Objectives

The objectives of our proposed project autonomous as well as controlled RS-UGV include:

1. To design a UGV.
2. To make it autonomous.
3. To monitor the environment and get visual familiarization with the terrain of that place.
4. To establish wireless communication between the laptop and the UGV.
5. To move the camera mounted on the UGV to move in all directions.
6. To travel between waypoints without human navigation assistance.
7. To work for extended durations without human intervention.
8. To control it from the control room.

1.3.3Specifications

UGVs could be classified on the basis of their characteristics such as mode of locomotion, type of control system, and intended operating area. Proposed UGV mainly consists of the following specs:

1. **Terrain monitoring system:** Observing the environment of the place and get visually familiarize with the territory of that place. For more

precise data of the territory other sensors like temperature, humidity etc are included.

2. **Vehicle control system:** The level of autonomy and intelligence of the robot depends largely on its control systems, which range from classic algorithmic control to more sophisticated methods. DC motors are used for locomotion of vehicle. Highly configurable and mobile platforms are typically the best for unstructured terrain.
3. **Detection system:** We will use different sensor(s) in order to perceive its surrounding, and thus, permit controlled movement.
4. **Encrypted signal transmission system:** Communication is essential in the case of military robots, where both accuracy and secrecy of information exchange are crucial. This requires a communication link between the human and the vehicle. The NRF transceivers will be used which sends an encrypted signal ensuring the security of the signal. These transceivers works in ISM band whose range is 2.4 GHz.
5. **Powering system**: Vehicle is powered by batteries and also by solar panel.

1.3.4 Deliverables

Our project deliverables are:

1. To make the UGV that can move in difficult terrains.
2. Controlling the UGV through laptop using GUI Interface.
3. The UGV moves in four directions (forward, backward, left and right) at any angle the user wants.
4. UGV will provide observation with a camera mounted on top of it which can move in 270 degree in circle and 90 degree up and down and all these motions must be control by laptop.
5. A reliable, cost effective and fast link that will have ability to transmit data in real time and also cater to the threats of enemy interference and blockage of the link.

6. Establish a safe, hazard free and critical device in field of defense.
7. Encounter "long pole" technological challenges, in terms of functionality, performance or cost.

2.Literature Review

It was necessary to review the literature as then later on we might have problems regarding which module/equipment we have to use for specific purposes going through many different articles about different components that we will use in the project we summaries them and note all the main points that we think are useful in our project.

The major source of information was the internet as it is the easiest source available for getting large amounts of relevant information just in few seconds.

2.1 Hardware Components

2.1.1 Arduino Mega

The Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

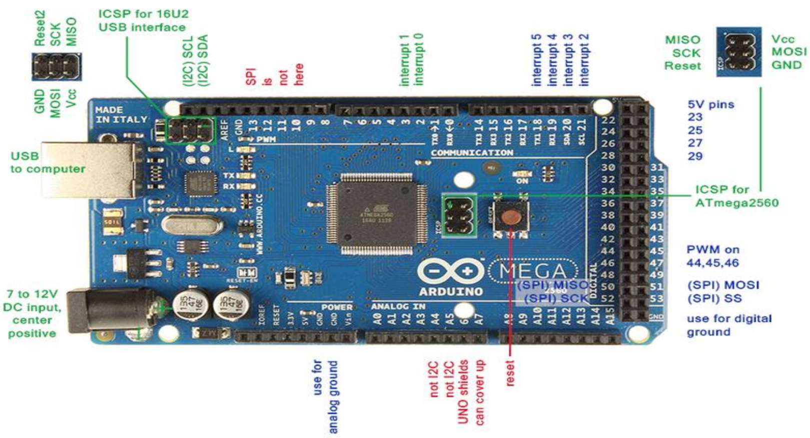

Figure 2: Arduino Mega

2.1.2 Transmitter/receiver pair:

We are using transmitter/receiver pairs. One will be attached to laptop and the second will be on the UGV. We are using this to establish wireless serial communication between the laptop and UGV.They send or receive data using radio waves. There corresponding frequency range varies between 30 kHz & 300 GHz.

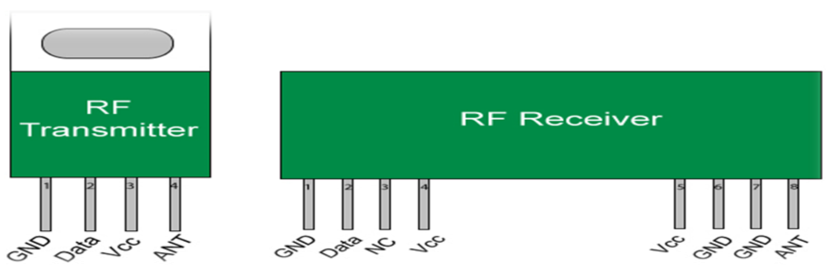

Figure 3: Transmitter/Receiver pair

2.1.3 Ultrasonic sensor:

We have decided to use ultrasonic sensor HC –SR04 which is located in the front of the UGV. We are using this sensor for obstacle detection. Whenever the sensor will detect an obstacle in front, it will change its direction.It offers excellent non-contact range detection with high accuracy and stable readings in an easy-to-use package. It ranges from 2cm to 400 cm or 1 to 13 feet.

Figure 4: Ultrasonic sensor

2.1.4Motor Driver (L298):

The L298 is an integrated monolithic circuit in a 15-lead Multi watt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. An additional supply input is provided so that the logic works at a lower voltage.

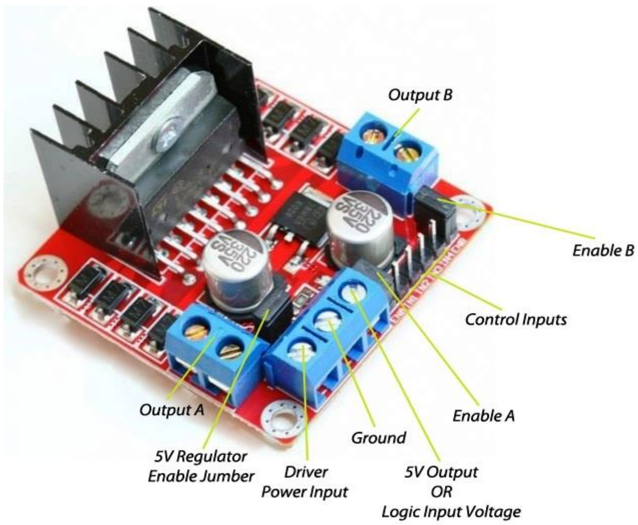

Figure 5: Motor driver(L298)

2.1.5IP Camera:

An Internet protocol camera, or IP camera, is a type of digital video camera commonly employed for surveillance, and which unlike analog closed circuit television (CCTV) cameras can send and receive data via a computer network and the Internet.

Figure 6: IP Camera

2.1.6KY-015 DHT11 Temperature Humidity Sensor Module:

The sensor module is including resistive humidity sensing component and NTC temperature testing the compatible digital temperature humidity sensor module is component and connected with 8-byte MCU.

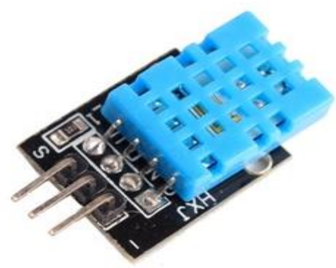

Figure 7: KY-015 DHT11 Temperature Humidity Sensor

2.1.7 LM 2596S Buck Module:

The LM2596 regulator is monolithic integrated circuit ideally suited for easy and convenient design of a step−down switching regulator (buck converter). It is capable of driving a 3.0 A load with excellent line and load regulation.Self protection features include switch cycle−by−cycle current limit for the output switch, as well as thermal shutdown for complete protection under fault conditions. It can convert 30 – 40 V to 5V.

Figure 8: LM 2596S Buck Module

2.2 Interfaces

2.2.1 Serial Communication

Serial communication is common method of transmitting data between a computer and a peripheral device such as a programmable instrument or even another computer. Serial communication transmits data one bit at a time, sequentially, over a single communication line to a receiver. This method is used when data transfer rates are very low or the data must be transferred over long distances and also where the costs of cable and synchronization difficulties make parallel communication impractical. Serial communication is popular because most computers have one or more serial ports, so no extra hardware is needed other than a cable to connect the instrument to the computer or two computers together.

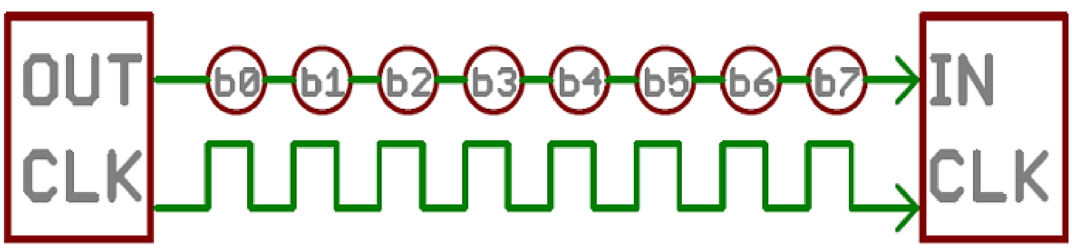

Figure 9: Serial communication

Keyboard and mouse cables and ports are almost invariably serial -- such as PS/2 port and Apple Desktop Bus and USB.

The cables that carry digital video are almost invariably serial -- such as coax cable plugged into a HD-SDI port, a webcam plugged into a USB port, Ethernet cable connecting an IP camera to a Power over Ethernet port, etc.

2.2.2 Asynchronous serial communication

Asynchronous serial communication is a form of serial communication in which the communicating endpoints' interfaces are not continuously synchronized by a common clock signal. Instead of a common synchronization signal, the data stream contains synchronization information in form of start and stop signals, before and after each unit of transmission, respectively. The start signal prepares the receiver for arrival of data and the stop signal resets its state to enable triggering of a new sequence.

Figure 10: Asynchronous Serial Frame

2.2.3 Universal Asynchronous Receiver/Transmitter

The Universal Asynchronous Receiver/Transmitter (UART) controller is the key component of the serial communications subsystem of a computer. The UART takes bytes of data and transmits the individual bits in a sequential fashion. At the destination, a second UART re-assembles the bits into complete bytes.

Bit number	1	2	3	4	5	6	7	8	9	10	11
	Start bit	5–8 data bits								Stop bit(s)	
	Start	Data 0	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7	Stop	

Figure 11: Data Frame for UART

Each character is sent as a logic low start bit, a configurable number of data bits (usually 8, but users can choose 5 to 8 or 9 bits depending on which UART is in use), an optional parity bit if the number of bits per character chosen is not 9 bits, and one or more logic high stop bits.
The start bit signals the receiver that a new character is coming. The next five to nine bits, depending on the code set employed, represent the character. If a parity bit is used, it would be placed after all of the data bits. The next one or two bits are always in the mark (logic high, i.e., '1') condition and called the stop bit(s). They signal the receiver that the character is completed. Since the start bit is logic low (0) and the stop bit is logic high (1) there are always at least two guaranteed signal changes between characters.
Communication may be simplex (in one direction only, with no provision for the receiving device to send information back to the transmitting device), full duplex (both devices send and receive at the same time) or half duplex (devices take turns transmitting and receiving).

2.2.4 OSI Layer

2.2.4.1. Data Link Layer

Asynchronous communication at the data link layer or higher protocol layers is known as statistical multiplexing, for example asynchronous transfer mode (ATM). In this case the asynchronously transferred blocks are called data packets, for example ATM cells.
The packets may be encapsulated in a data frame, with a frame synchronization bit sequence indicating the start of the frame, and sometimes also a bit synchronization bit sequence, typically 01010101, for identification of the bit transition times.

2.2.4.2. Physical Layer

The physical layer consists of the basic networking hardware transmission technologies of a network. It is a fundamental layer underlying the logical data structures of the higher level functions in a network.

The physical layer translates logical communications requests from the data link layer into hardware-specific operations to affect transmission or reception of electronic signals. The major function performed by the physical layer in our project is Start-stop signaling and flow control in asynchronous serial communication.

2.2.5 I²C

I²C is a multi-master protocol that uses 2 signal lines. The two I²C signals are called ‘serial data’ (SDA) and ‘serial clock’ (SCL). There is no need of chip select (slave select) or arbitration logic. Virtually any number of slaves and any number of masters can be connected onto these 2 signal lines and communicate between each other using protocols. Arduino pins 4 (SDA) and 5 (SCL) support I²C.

2.2.6 SPI

Serial Peripheral Interface (SPI) is an interface bus commonly used to send data between microcontrollers and small peripherals such as shift registers, sensors, and SD cards. It uses separate clock and data lines, along with a select line to communicate. Arduino pins that support SPI are 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).

3. DESIGN AND DEVELOPMENT

3.1 MODULES OF DESIGN

Our project consists of following modules.

1. Unmaned Ground Vehicle (UGV)
2. Laptop for Visual Display
3. Ultrasonic sensor (Obstacles Avoidance)
4. Temperature and Humidity sensor (Precision of environmental conditions)
5. Buck Module (Voltage Regulation)
6. Wireless IP Camera (Real Time Video Transmission)

3.2 DESIGN TECHNIQUES

Following design techniques are required in our project:

- Arduino IDE
- Proteus/Virtual Breadboard
- Matlab
- Visual Studio
- Eagle Cad Designing
- Tennis Search Tool

3.3 SYSTEM MODEL

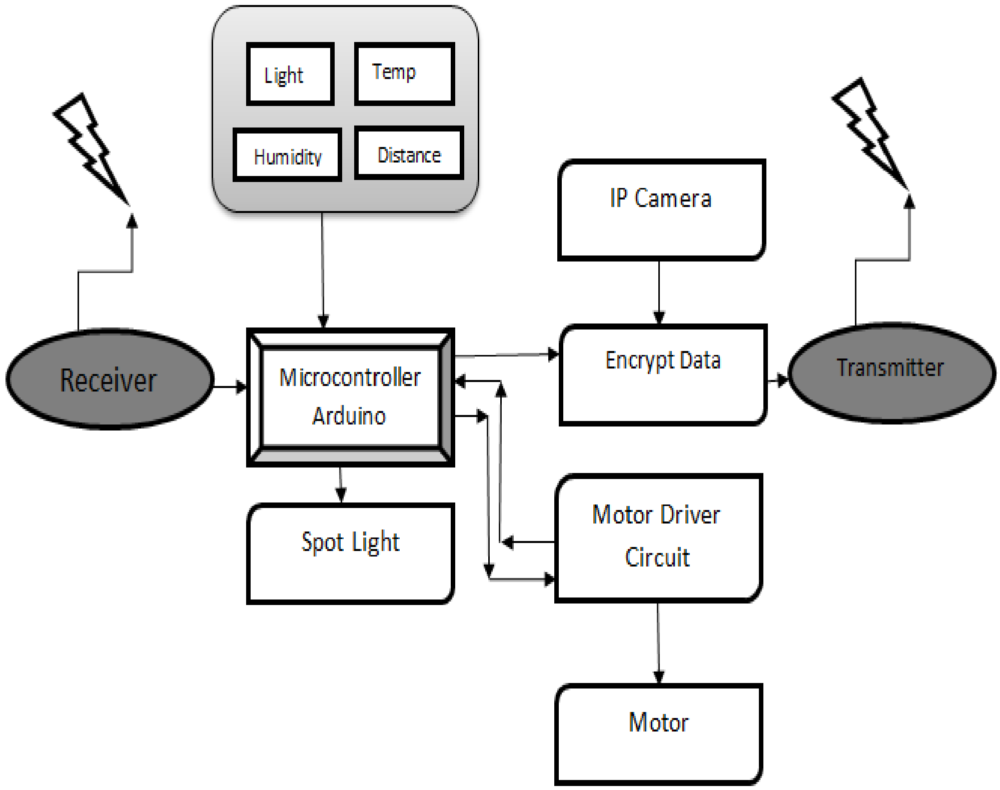

Figure 12: System Model For UGV

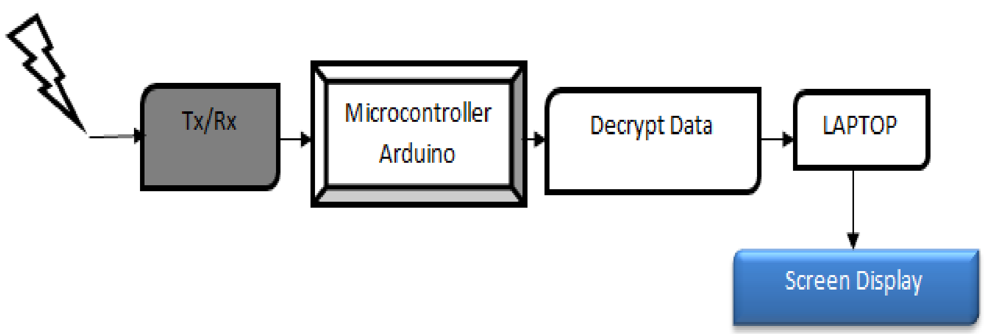

Figure 13: System Model For Laptop Connection

3.4UGV Manager& Data Acceptor Design and Development

This is the figure of the receiver that we have designed. Its each component is explained below with pictures. This receiver is used to give commands & receive data from the designed UGV which will move autonomously and manually.

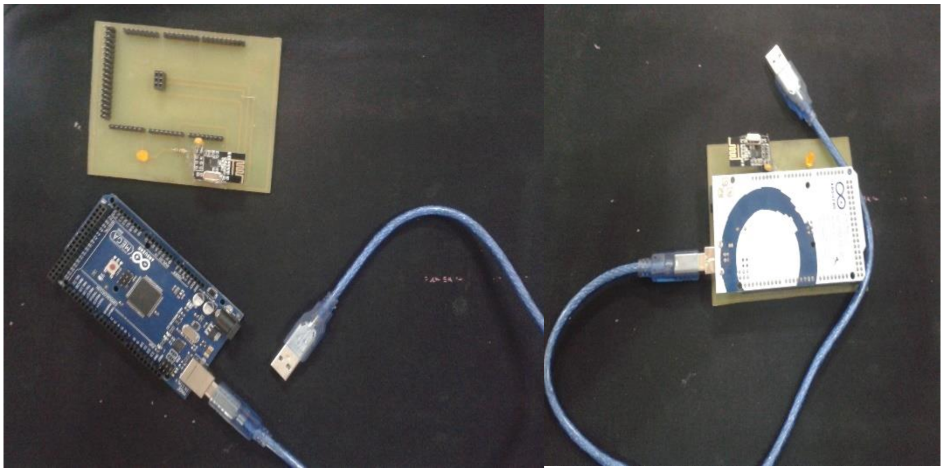

Figure 14: UGV Manager& Data Acceptor

3.4.1 ARDUINO MEGA

The Arduino Mega is a microcontroller board based on the ATmega1280 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

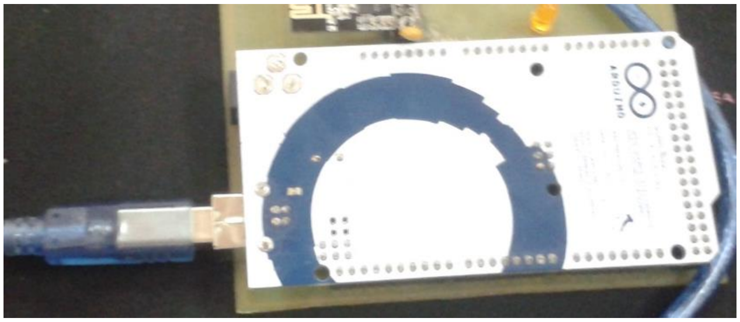

Figure 15: Arduino Mega

3.4.2 NRF24L01 Transceiver:

We are using nRF24L01 transceiver to establish wireless serial communication between laptop and the UGV. The nRF24L01 is a highly integrated, ultra-low power (ULP) 2Mbps RF transceiver IC for the 2.4GHz ISM band. It has a built-in Antenna. Its base module consists of voltage regulator and bypass capacitors for stability. We are using an external antenna for longer range.

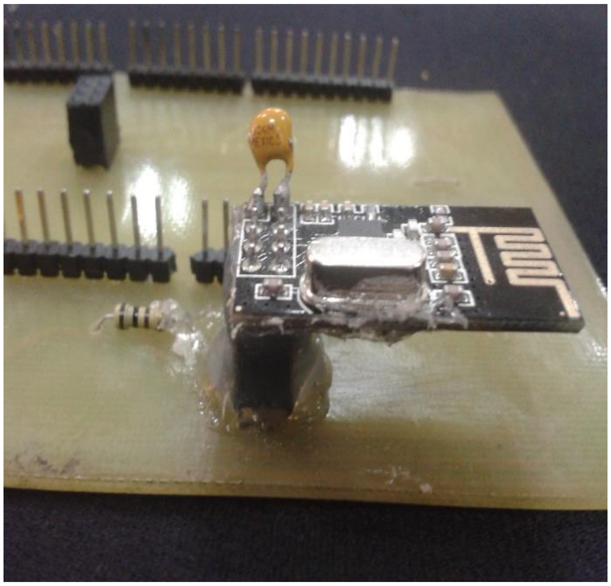

Figure 16: NRF24L01 Transceiver

3.5 UGV Design and Development

3.5.1 External View

This is the complete picture of our designed UGV. Its different components will be described below.

Figure 17: External View of UGV

3.5.1.1 Mechanical Part:

This is designed using acrylic sheets base to mount all the circuitry and wiring of the our UGV. It has got batters, h-bridges and motors on it.

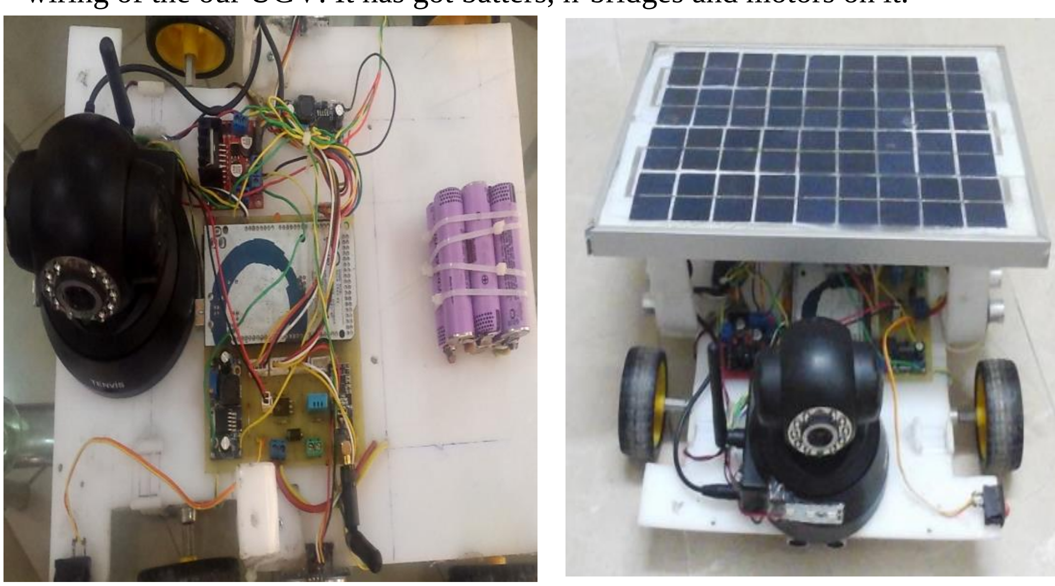

Figure 18: Mechanical Part

3.5.1.2 Jeep Type Structure:

The UGV's movement is based on jeep type structure. We have connected motors to all the wheels. They are controlled through Arduino Mega and motor drivers.

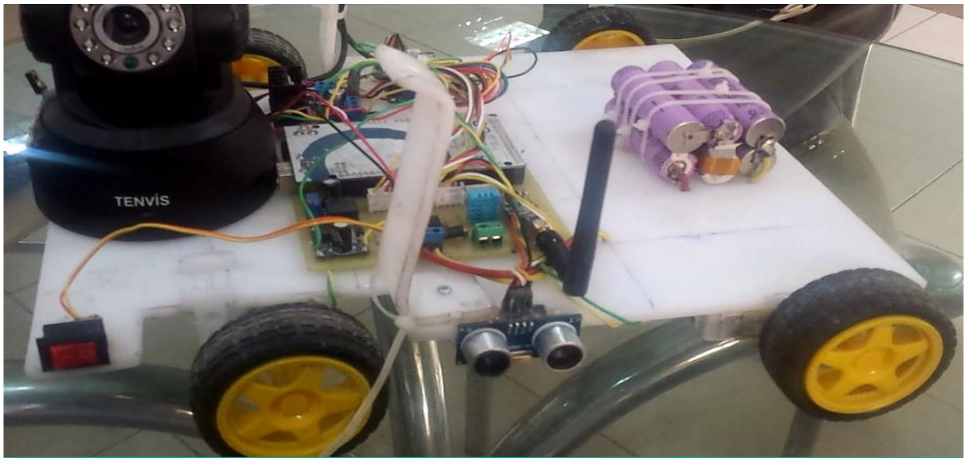

Figure 19: Jeep Type Structure

3.5.2 Internal View

3.5.2.1 Arduino Mega:

It is a microcontroller board based on the ATmega1280. The board consists of 54 digital input/output pins. Other components include16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. All the motors and modules are connected with Arduino and it gives commands to them.

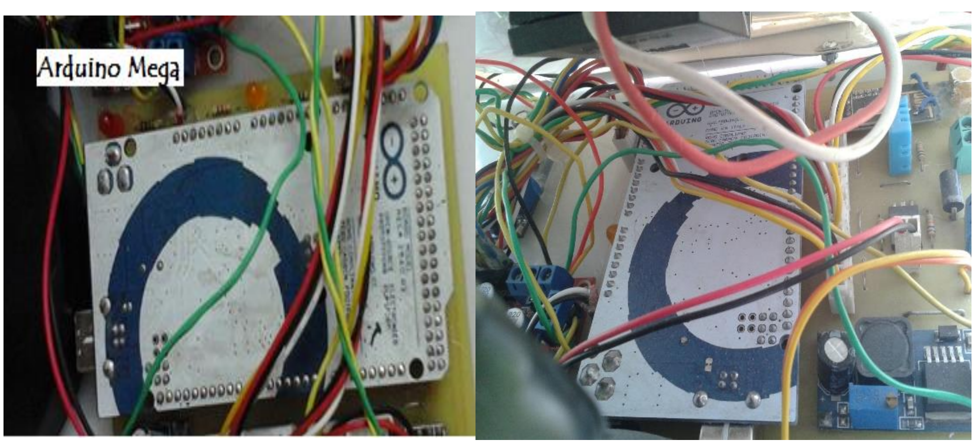

Figure 20: Arduino Mega

3.5.2.2 RF24L01 Transceiver:

We are using two transmitter/receiver pairs. We are using this to establish wireless serial communication between the Headset and the UGV. It is a 2.4G Wireless Transceiver.

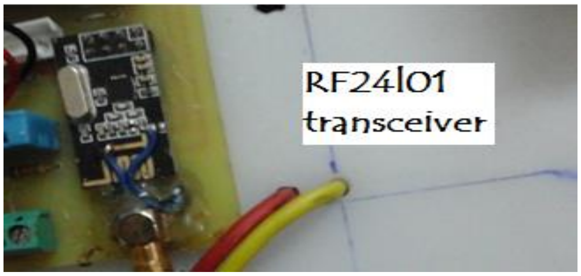

Figure 21: RF24L01 Transceiver

3.5.2.3 Motor Driver:

These are the drivers for the motors. They are used to control the UGV movement.

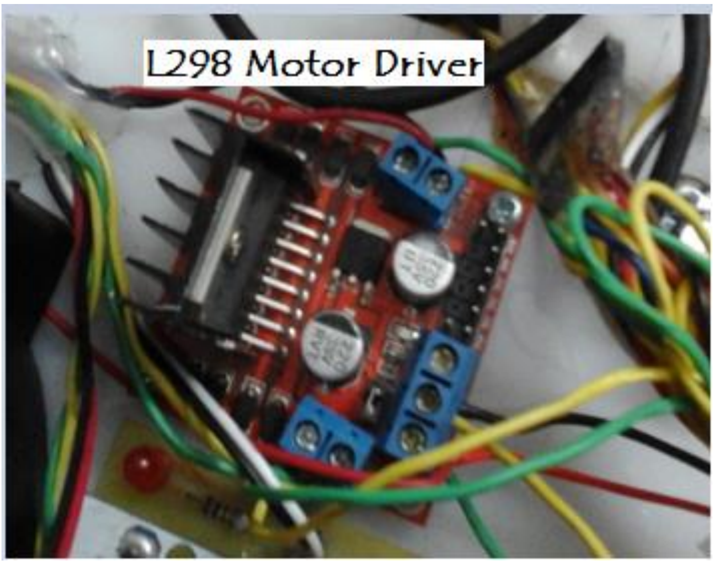

Figure 22: L298 Motor Driver

3.5.2.4 Batteries:

These are rechargeable batteries. They are charged either by solar panel in day light or by charger.

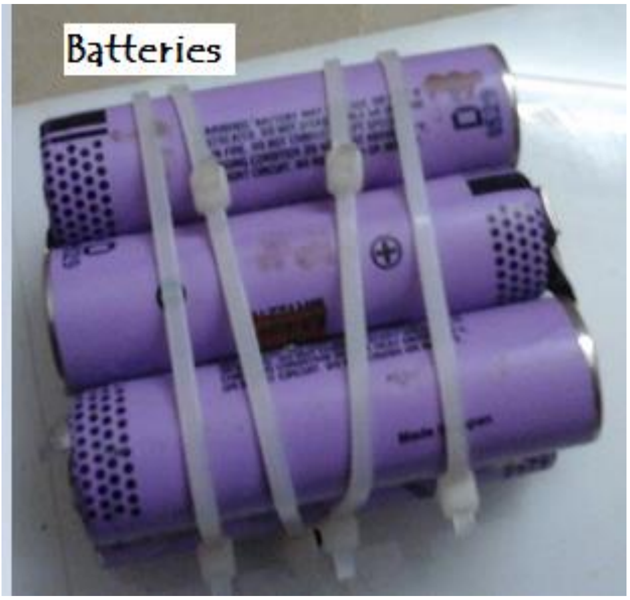

Figure 23:Batteries

3.5.2.5 Ultrasonic sensor:

Two ultrasonic sensors are planted at the front of the UGV body. Their work is to detect any obstacle present in the path when the UGV is working in autonomous mode.

Figure 24: Ultrasonic sensor

3.5.2.6 Buck Module:

It is used to convert higher voltage of 30 – 40 V to 5 V. Two buck modules are used in our UGV.

Figure 25 : Buck Module

3.5.2.7 DC Motors:

We are using 4 motors in our UGV side. 2 DC motors are used to control the UGV front wheels and 2 for back wheels.

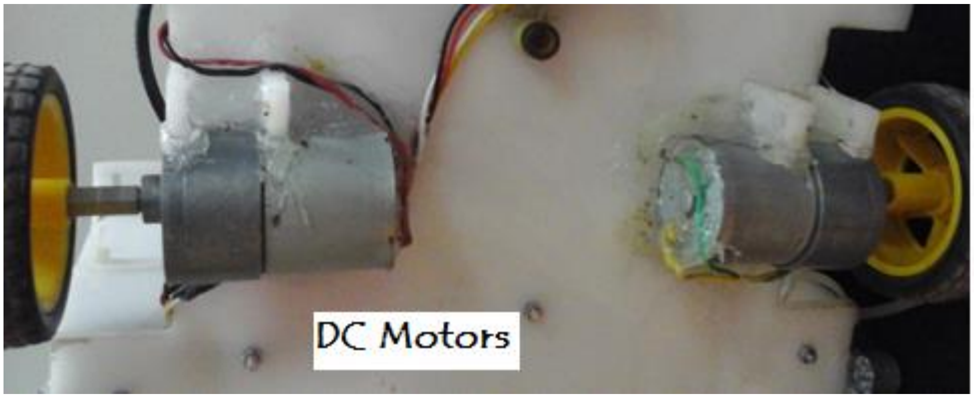

Figure 26: DC Motors

3.5.2.8 IP Camera:

An Internet protocol camera, or IP camera, is a type of digital video camera commonly employed for surveillance. There are flexible in a way that IP cameras are able to function on a wireless network. We are using this to provide remote accessibility; live video from the camera, mounted on the UGV, can be viewed from the laptop.

Figure 27:IP Camera

3.6 Visual Studio Implementation:

We have the real time video transmission and display of all the values of sensors in discrete form as well as in a graphical display.

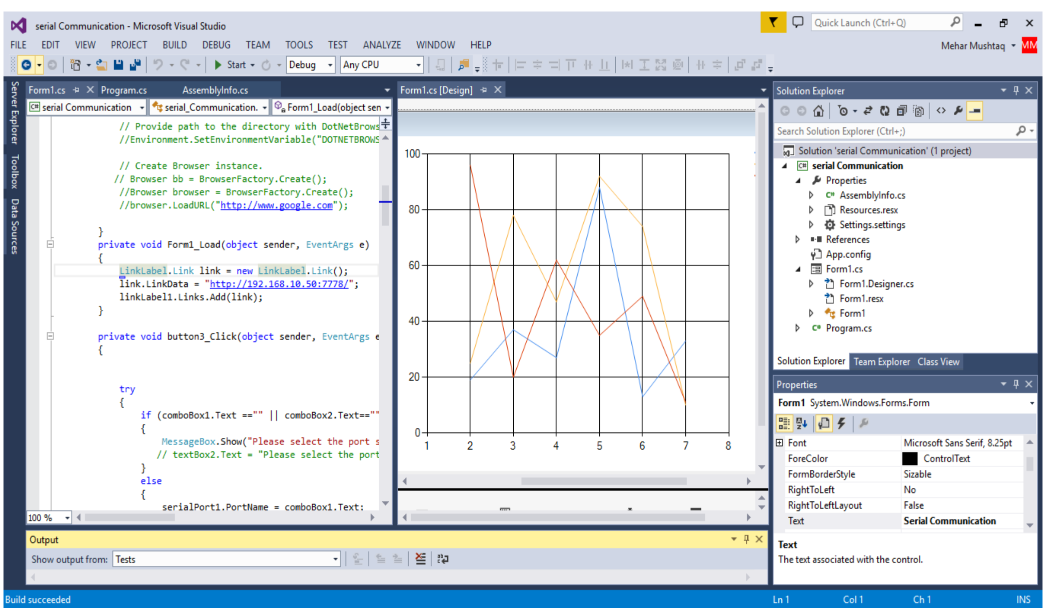

Figure 28: Visual Studio Implementation

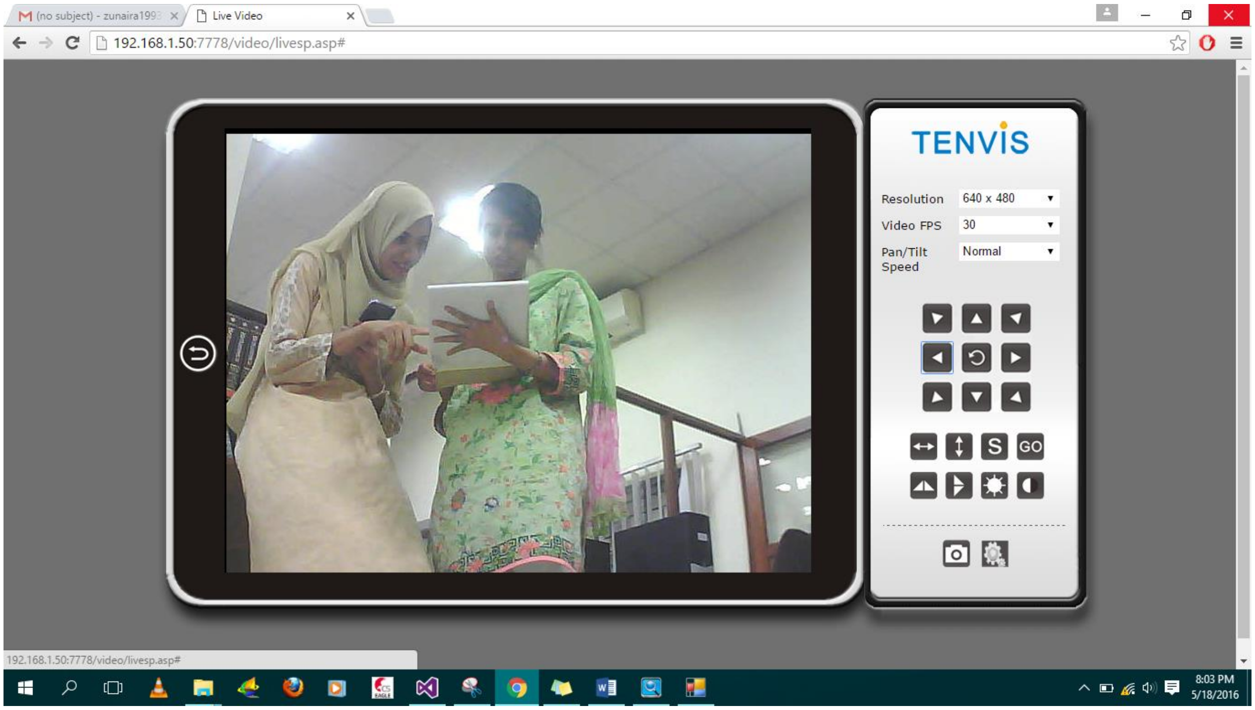

Figure 29: IP Camera Display

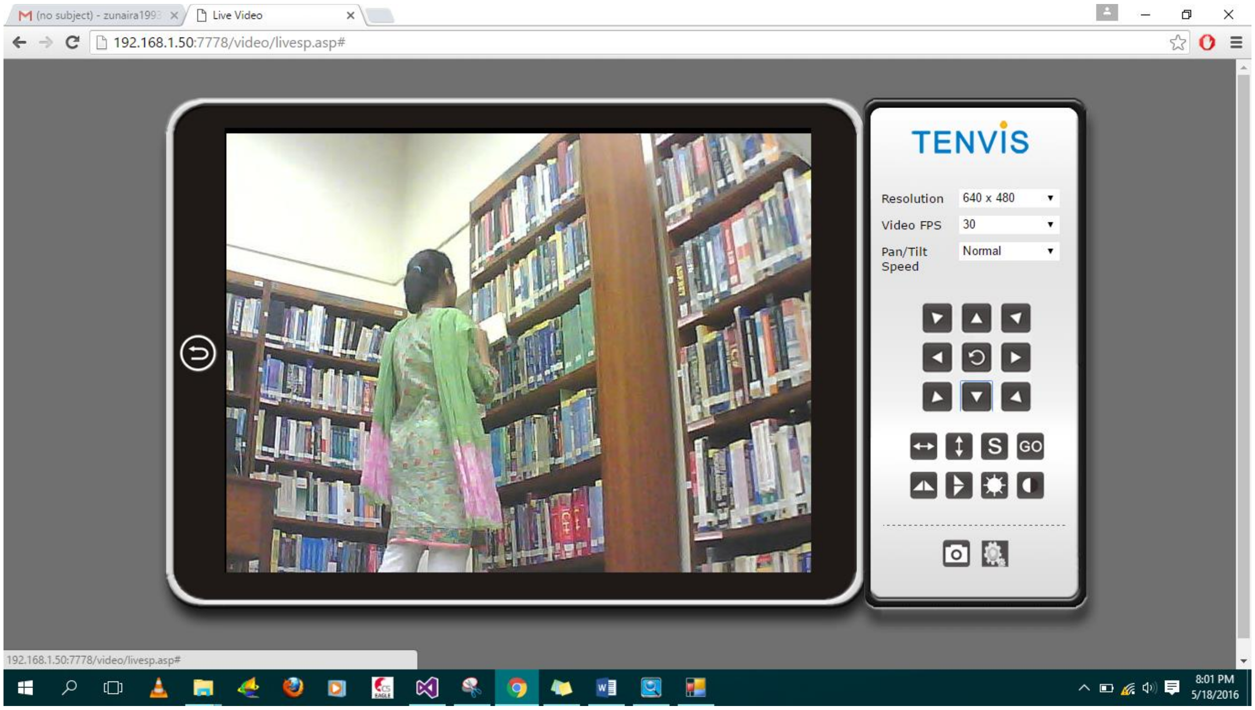

Figure 30: IP Camera Display

4.PROJECT ANALYSIS AND EVALUATION

We have checked out project and it is working perfectly. As it is hardware based project so its output will be shown in the demo. Coming to analysis we can say:

1. Our designed UGV can move in all four directions.
2. Movement of the UGV is autonomous and manual.
3. The IP Camera mounted on UGV can rotate 270 degrees on horizontal scale and 90 degrees on vertical scale
4. The humidity, light and temperature sensors display their values on the visual studio.
5. UGV avoids obstacles when anything comes in its way.
6. The way our project has come to the final stages is shown below.

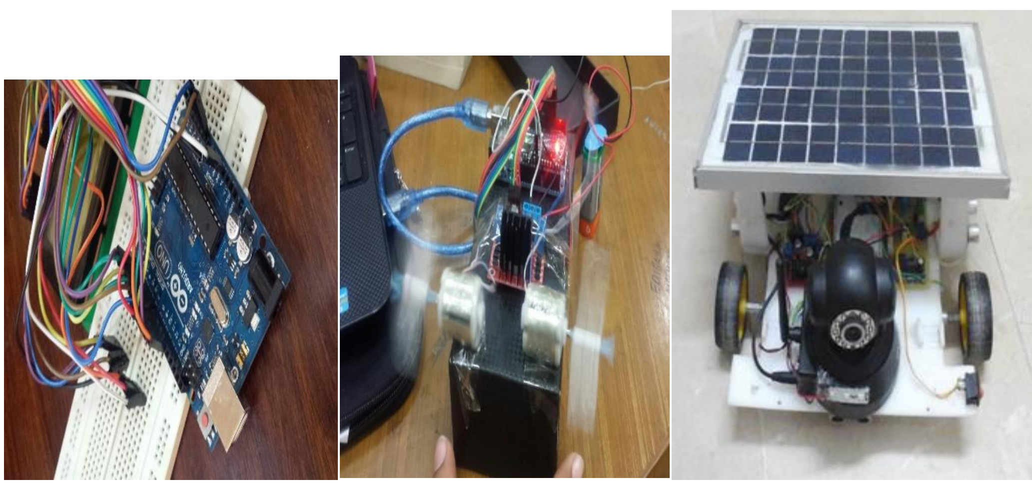

Figure 31: Milestones

Figure 32: UGV in the Field

5. RECOMMENDATIONS FOR FUTURE WORK

1. The UGV speed can be increased by using heavy motors.
2. The wireless communication range can be increased by using high power RF Transmitter/Receiver.
3. Encryption of signals received and transmitted by a UGV can also be done.
4. Introduction of topography maps in a UGV.
5. Ditch detection sensors can be added.

6. CONCLUSION

6.1 Overview

Our Project is based on wireless communication between the controller and UGV with a camera mounted on it. We have operated our UGV and camera through laptop using GUI. We have worked on making the hardware as well as software for controlling our UGV. We have used Arduino board for the design of both UGV and the controller which will identify the commands and accordingly move the UGV. The UGV will be able to move in all possible directions. The camera will be able to move 270 degrees on horizontal scale and 0-90 degree on vertical scale, and provides surveillance of the remote area.

6.2ACHIEVEMENTS

1. Successfully Learned Arduino board programming.
2. Successfully Learned Eagle Cad Designing.
3. Successfully Learned Microsoft Visual Studio C# Serial Communication.
4. Successfully Implemented wireless Interface between two Arduinos using 433 MHz Rf Transmitter Receiver
5. We have completed our designing of UGV.
6. We can control the motion of IP Camera using laptop.
7. We have mounted a camera on the top of UGV.
8. Successfully implemented the autonomous and manual mode of UGV by ultrasonic sensors and Arduino mega.
9. We have got precise values of data for the environment atmosphere.

7. REFERENCES

1) http://arc.engin.umich.edu/grrc/techreports/200901_ReliabilityUGV.pdf
2) http://www.dtic.mil/dtic/tr/fulltext/u2/a422845.pdf
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12) https://www.arduino.cc/en/Reference/Serial
13) https://en.wikipedia.org/wiki/Universal_asynchronous_receiver/transmitter

Appendix-A

Project Proposal

Extended Title: **Design, Simulation and Implementation of Reconnaissance and Surveillance Unmanned Ground Vehicle**

Brief Description of the Project / Thesis with Salient Specs:

The vehicle will monitor the environment of the place and get visually familiarize with the terrain of that place.The unmanned vehicle will have different sensors which will be interfaced with microprocessor. These sensors will monitor temperature, humidity, distance, vibration, metal etc. The vehicle will be powered through solar panels which will be connected to battery so that the vehicle is operated through both battery and direct supply. There will be a metal detector mounted on the vehicle which can detect metal objects in its path. Camera will be interfaced with microprocessor and its video will be recorded on the laptop which is operating the surveillance vehicle. For the purpose of transference of data a wireless link is required. Depending upon the availability and efficiency, any of the open-standards wireless radio technology can be employed. The connection between the vehicle and the laptop will be established through a radio link with the ability to transmit to at least 1-2 km. Further improvement in greater distance coverage can be made after positive result of the proposed project. Motors will be used for the movement of the vehicle and cameras inserted.

Scope of Work:

- Establishing an efficient state-of-the-art prototype model of unmanned reconnaissance and surveillance vehicle that has potential of transforming into a safe, hazard free and critical device in field of defense.
- Establishment of a reliable, cost effective and fast link that will have ability to transmit data in real time and also cater to the threats of enemy interference and blockage of the link. The project will work to establish a safe wireless link that will be noise free and will have potential to survive interference attacks.
- It will embody a sophisticated set of control systems that will be essential in determination of path and helpful in other navigation techniques. The control system designed will meet out all the possible logical scenarios and remote control of device in case of enemy attack.
- A powerful magnetic imaging device for the purpose of detection of metallic objects will help in timely and accurate detection of embedded bombs or other metallic objects.
- The project will also encounter "long pole" technological challenges, in terms of functionality, performance or cost.

Previous Work Done on The Subject:

Object tracking unmanned ground (august, 2011)
Vision based target recognition through unmanned ground vehicle (july, 2012)
Unmanned ground vehicle controlled by head movement (may, 2015)

Appendix-B

Timeline

ACTIVITY	SEPTEMBER/ OCTOBER 2015	NOVEMBER 2015	DECEMBER 2015	JANUARY 2016	FEBRUARY 2016	MARCH/ APRIL 2016
Collection of literature						
Study of literature						
Designing						
Analysis of literature &						
proteus implementation						
Preparation & impementation						
Analysis of Programing						
Result formation						
Final Report						

Appendix-C

Cost Breakdown

ITEMS	Price
2 Arduino Mega	5,000
4 Motors	3,200
1 Humidity Sensor	400
2 Rf Module and Antenna	3,000
4 Ultrasonic sensors	1,600
2 Buck Module	800
1 Acrylic Sheet	1,000
1 Solar Panel	1,500
1 Camera	7,500
2 Motor Drivers	1,200
Fiber PCB	500
Total	25,700