Development and Real-time Dynamic Positioning of an Unmanned Ground Vehicle

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Development and Real-time Dynamic Positioning of an Unmanned Ground Vehicle

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by

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Certificate

This is to certify that the thesis entitled *"Development and Real-time Dynamic Positioning of Unmanned Ground Vehicle"*, submitted to the National Institute of Technology, Rourkela by *KISHAN KUMAR PATEL, ROLL – 111EE0147* for the award of the degree of *Bachelor of Technology* in Department of *Electrical Engineering*. The candidate has fulfilled all the prescribed requirements. The thesis is based on candidate's own work, is not submitted elsewhere for the award of degree/diploma. In my opinion, the thesis is fulfilling all the standard requirements for the award of the degree of *Bachelor of Technology* in *Electrical Engineering*.

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ABSTRACT

Unmanned Ground Vehicles (UGVs) are the vehicles without any human present in the vehicle but the UGV may be controlled by human from a remote location or UGV may be operated autonomously depending on the advancement of the vehicle. For the operation of the UGV position of the vehicle is accurately determined and further the estimated current position is used for navigation of the vehicle. Navigation system for Unmanned Ground Vehicles must be effective and efficient in order to have a safer and tuned operation. In general GPS is used for the locating UGVs, but GPS signals are weak and not reliable everywhere, like underground mine areas and inner part of dense concrete buildings.

The objective of this project is to develop an Unmanned Ground Vehicle and to design a relative positioning method for navigation of unmanned ground vehicles (UGV) on a plane surface. A relative positioning method is developed to increase the reliability of the positioning of UGV. For this, a comparative study is performed to get effective sensor readings for the relative distance calculation and also deviation or orientation of the UGV is computed using angle measurement which is absolute without any fail. After getting data from the sensors the position of the UGV is estimated and path of the UGV is traced. Developed UGV is used to test the performance of the relative positioning using the sensors. The UGV can be controlled manually as well as can be operated automatically to navigate to destination location. The UGV is controlled by a Graphical User Interface (GUI) using a computer.

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Chapter 1

Introduction

1.1 Unmanned Ground Vehicle

An **unmanned ground vehicle** (**UGV**) is a vehicle that operates while in contact with the ground and without an on-board presence of human. UGVs can be used for many applications where it may be dangerous, difficult or impossible to have human operator present on vehicle. Generally, UGV is consisting of a set of sensors to observe the surroundings, and either autonomously makes decisions about its behaviour or pass the information to a human operator at a different location, who will control the vehicle through teleportation. An UGV is a fully automated intelligent robot, capable of self-learning **[1]** from its surrounding using artificial intelligent algorithms.

1.1.1 Classes of unmanned ground vehicles:

i. Remote-Operated:

   An UGV which can be remote-operated is a vehicle that is controlled by a human operator using a remote interfacing module. All movements are determined by the operator on the basic of either remote use of sensors such as digital video cameras or direct visual observation of the vehicle. One simplest example that uses the principle of remote-operation would be a remote controlled car.

ii. Autonomous Operation:

An autonomous UGV is essentially an autonomous robot or we can say an intelligent robot that operates without any human controller or human intervention on the UGV. Data collected from its sensors by the vehicle is used to develop some restricted understanding of its surrounding area, which is further used by control algorithms to determine the next movement to take in the perspective of a human provided task or objective. This can eliminate the requirement of any human to watch over the tedious task that the UGV is completing.

1.2 Real-time System

A real-time system or real-time computing is study of hardware and software which are restricted to some real-time operational deadlines from the start of the event to the system response time, whereas there is no deadline for a non-real-time system, even if the system response is fast and performance is very high. Real-time systems are required in the context of real-time operating systems, and synchronous system and programing languages, those provides frameworks on which real-time application software can be design. Real-time computation will fail to achieve its goal if there work is not completed before the given time interval, and this time interval or deadline is somehow relative to some event. So for a real-time system the tsk must be completed before the restricted time interval regardless of system any type of system load. One of the best examples of a real-time system is anti-lock braking system used in car and other vehicles. The real-time restriction of this type of system is that the brakes must be released, so that the locking of the wheel is prevented.

1.3 Motivation

Navigation of UGV plays an important role for its successful operation. Further the navigation system requires the exact location of the UGV at every instant of time. To locate UGV generally GPS is used. But the main problem with GPS are not reliable everywhere, at the same time error in positioning GPS is very high with respect to the size of the UGV. Hence I am highly motivated to design a relative positioning of UGV where GPS signal is weak and also to locate the UGV with respect to controller reference.

1.4 Objective

To build an Unmanned Ground Vehicle (UGV), that can navigate from one location to another without any human intervention.

The project leverages high-performance navigation operation with the help of high sensitive GPS module and other advanced sensors. Apart from sensor data processing more effective and efficient algorithms are used which gives high-end learning power to the autonomous robot.

The UGV will be combination of both, manual remote operation as well as autonomous.

- The starting command will be sent to the vehicle by remote operator
- Moving to the destination or completion of any other task by the robot solely.

There will be two stages of this project:

1. Testing of different sensors and modules through a robot and its wireless manual operation to reach the destination.
2. Implementation of the tested module in real time operation and complete autonomous navigation to the destination location.

1.5 Literature Review

Generally UGV are designed for war purpose starting from 1930s. In 930s, the USSR developed Trletanks[1], a machine gun-armed tank remotely controlled by radio from another tank. At that time robots are controlled manually, but now a day's UGV are not limited to war its concept is used extensively for autonomous transportation and navigation in every field.

First autonomous car was exhibited in the year 1939 at "New York World's Fair" sponsored by "General Motor"[2]. After that a lot of modifications have been considered to develop a fully automated vehicle [3,4].

Google has already developed its autonomous car automatic navigation from one location to another without any human intervention.

In April 2014, the Russian Army unveiled the Taifun-M UGV as a remote sentry to fuard RS-24 Yars and SS-27 Topol-M missile sites. The Taifun-M features laser targeting and one cannon to carry out reconnaissance and patrol mission, detect and destroy stationary or moving targets, and provide fire support for security personnel at guard facilities. They are currently remote operated but in near future they are planning to include an autonomous artificial intelligence system that will make this fully autonomous.

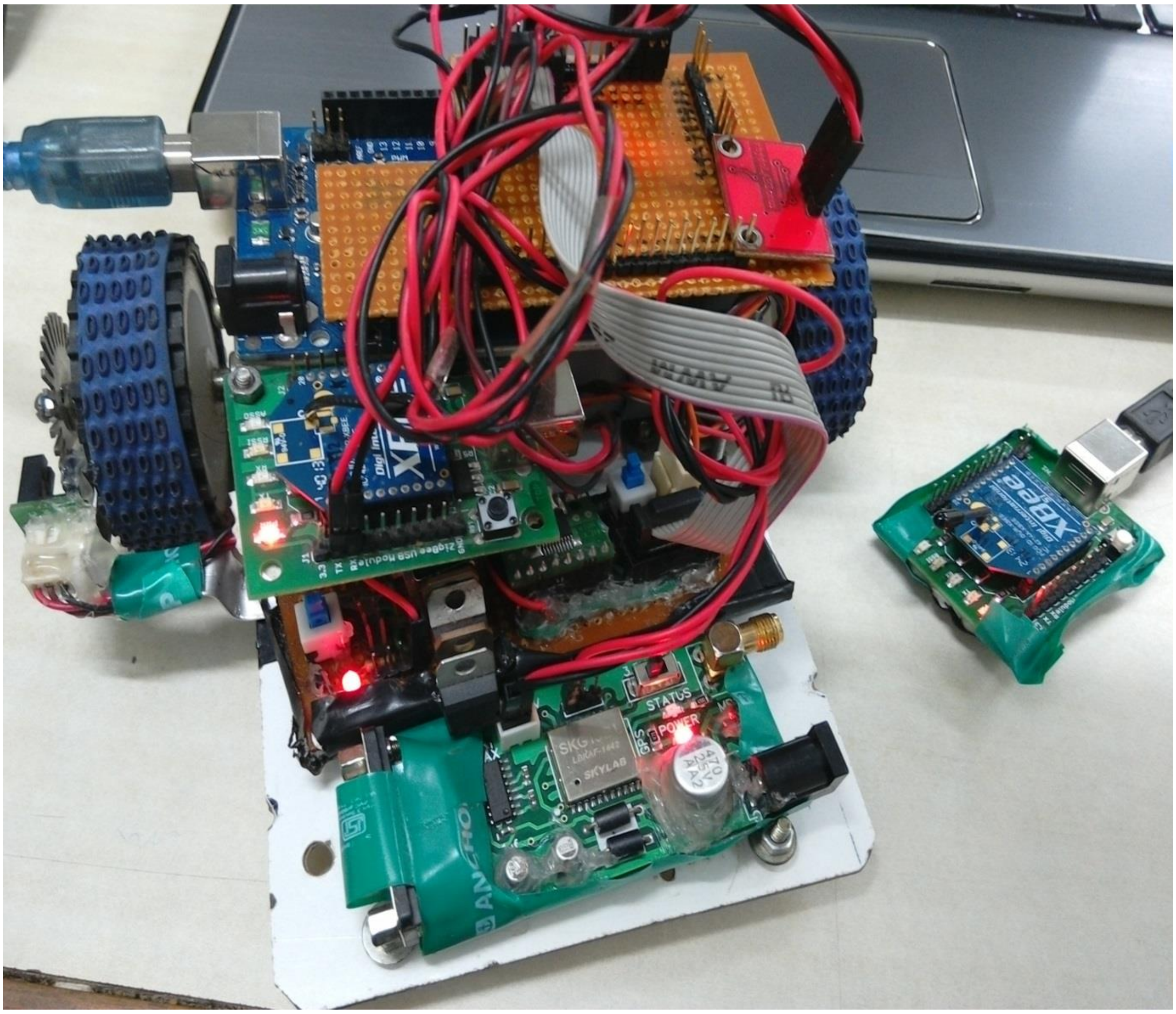


Figure – 14.1: Developed UGV for testing

Chapter 2

Hardware Implementation

2.1 Project Hardware Details

All sensor modules are integrated with a microcontroller. The microcontroller collect all the data and then process the data and send necessary command to the motor driver circuit which further drives the motor of the UGV for its locomotion. During the manual operation the controller will send the command to the UGV, through a wireless communication using a PC. The wireless communication is done by using two wireless trans-receiver XBee modules; one is connected to PC where as other one is connected to the robot.

For positioning of the UGV in a plane surface the distance travelled by the UGV and the orientation of the UGV must be known. So distance measuring sensors are used and a comparative study is performed to get the best sensor suitable for this purpose. To detect the orientation of the robot, an electronics compass is used. Electronics compass gives angle of deviation from the NORTH direction in clock-wise rotation. Further a sensitive GPS module is used to get the absolute position of the robot at the possible places and then take that position as the reference point and then relative positioning of the UGV can be estimated in near future. If GPS signal is not available then the UGV will consider its current location as the reference location and further positioning of the UGV is predicted.

The hardware used in the UGV is shown in the following figure along with their placement on the robot. This one is a prototype model used for the testing of the relative positioning of the UGV.

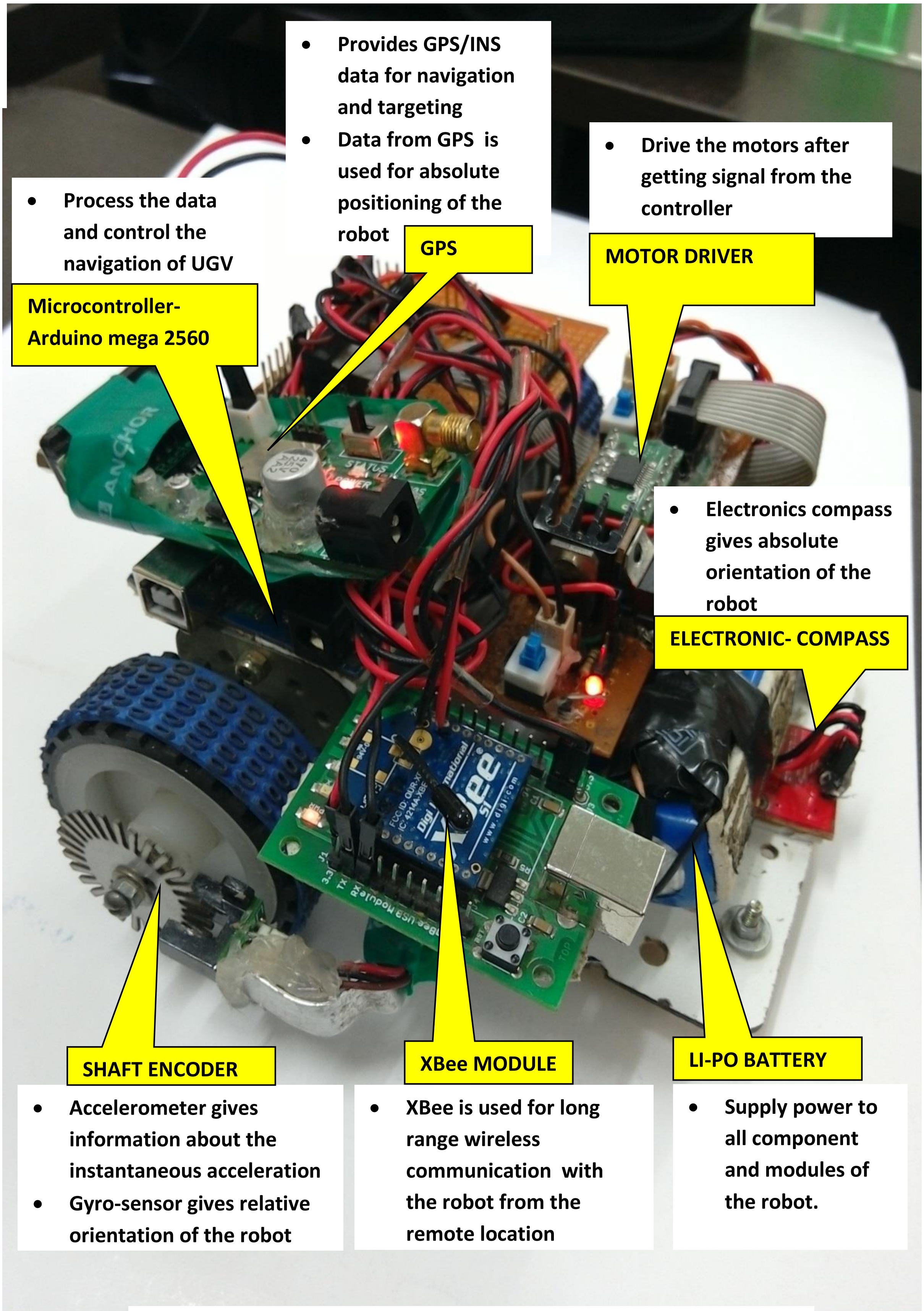


Figure – 2.1: Developed robot used for the testing of positioning

2.2 Component Details

List of components used during the development of the UGV are as follows:

i. GPS (Global Positioning System):
ii. Electric compass
iii. Shaft Encoder
iv. XBee module
v. interfacing base for XBee
vi. motor driver module
vii. microcontroller – Arduino mega 2560
viii. LI-PO battery

2.2.1 GPS (Global Positioning System) module

GPS module provides a string of data consisting of longitude, latitude, altitude and many more data related to the position of the module. Here only longitude and latitude values are collected and processed in the micro-controller and further used for relative positioning.

Figure – 2.2.1: GPS module

2.2.2 Electronic Compass module

Electronics compass provide the absolute angle of deviation of the robot in degree from NORTH direction. The angle of deviation is measured in clockwise direction from the NORTH direction. Performance is high due to integration of solid-state magnetic sensor.

It uses I2C – two wire serial communications with the controller for transmitting angle of deviation.

Figure – 2.2.2: Electronics Compass Module

2.2.3 Shaft Encoder

Shaft encoder helps in measuring distance covered by the vehicle to calculate the relative positioning from the starting reference point. It will add more accuracy to the GPS result. It works on the principle of counting the number of interruption occurred in IR-receiver sensor.

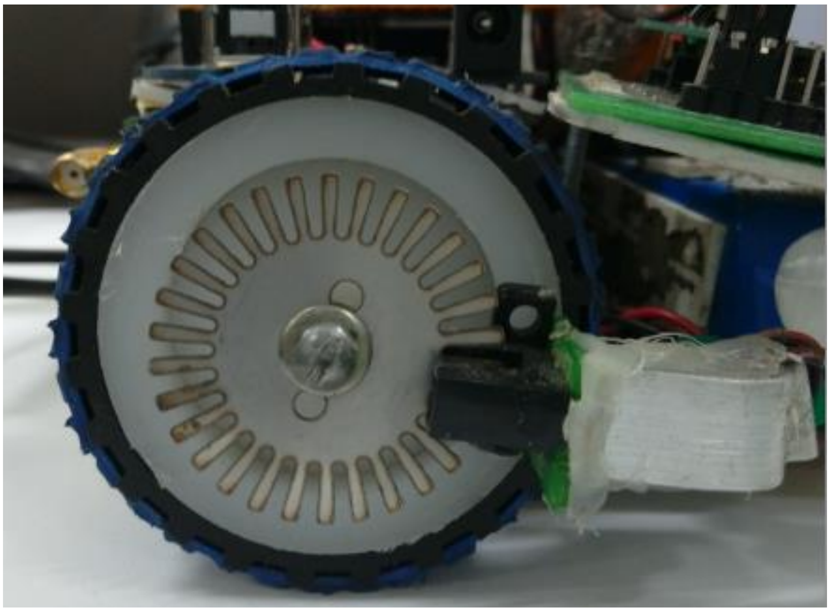


Figure – 2.2.3: Shaft Encoder module

2.2.4 XBee wireless trans- receiver module

XBee is used for the short range and small local area wireless communication between the robot and the remote controller or computer, during manual operation as well as configuration of the UGV required for autonomous mode operation. Indoor range of the XBee is 30m whereas outdoor range is around 90m to 100m. Generally XBee are operated at a frequency of 2.4 GHz.

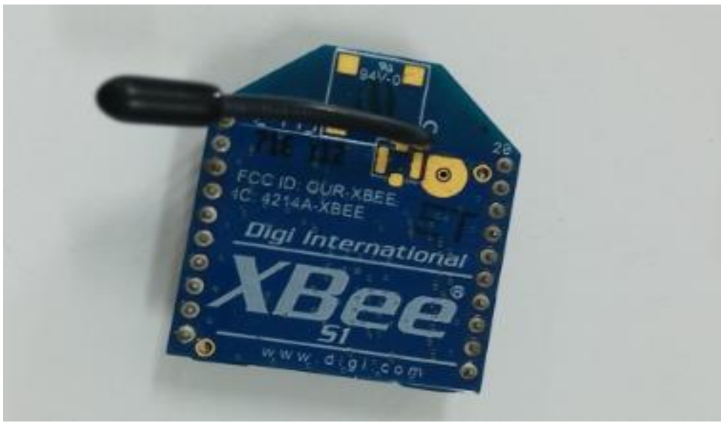


Figure – 2.2.4: XBee Trans-receiver Module

2.2.5 Interfacing base for XBee

Interfacing base is used to interface the XBee module with the controller via serial communication. Also we can configure XBee module for different mode of wireless communications.

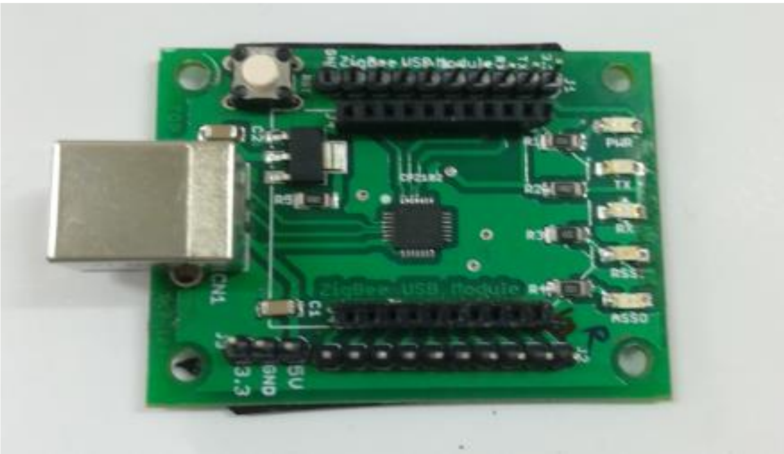


Figure – 2.2.5: XBee Interfacing base Module

2.2.6 Motor Driver module

Motor driver module is used to drive motors of the UGV. Micro-controller can't operate the motors directly as the current rating of motors are very high, whereas controller can handle very less amount of current. So motor driver is used which bypass the current drawn by motors, directly to the main power supply. By giving PWM signal of different duty-cycle to motor driver the speed of the motors can be varied.

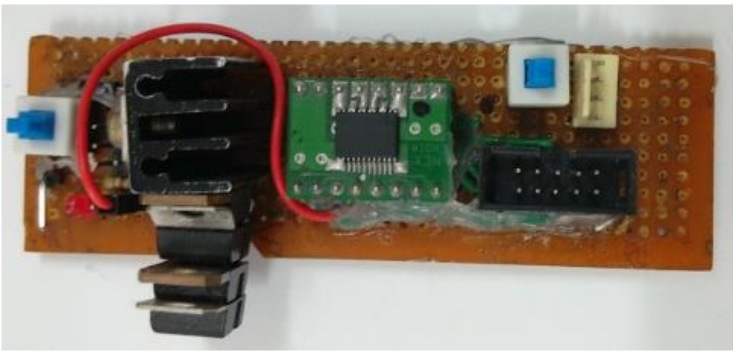


Figure – 2.2.6: Motor Driver Module

2.2.7 Microcontroller – Arduino mega 2560

ATmega2560 microcontroller is used in the Arduino mega 2560 development board. There are 54 digital input and output pins among which, 15 can be used for generation of PWM output signal. Apart from this another 16-analog input pin are available along with 4-USART, hardware serial pin. It operates at a frequency of 16 MHz. Arduino mega must be programed, according to the task to be performed by the controller during its operation.

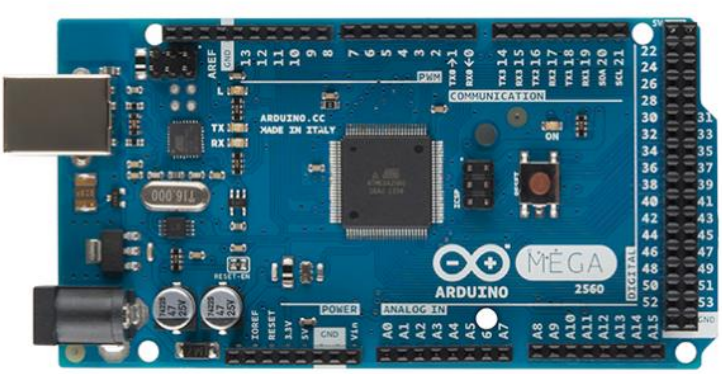


Figure – 2.2.7: Arduino Mega- 2560

2.2.8 LI-PO battery

Li-Po Battery is the rechargeable and efficient portable power supply for small electrical system. Its weight is very less as compared to other type of battery which has same rating. Hence this is the most suitable powering unit for the UGV.

Figure – 2.2.8: Li-Po Battery

Chapter 3

Software Implementation

3.1 Project Software Details

The software part of this project has further two types of sub parts, controller programing and programing required for the development of Graphical User Interface (GUI). The UGV is controlled by a micro-controller; hence before the start of UGV, controller must be programmed. To control the UGV, a GUI is designed in visual studio using C# programing language.

3.1.1 UGV Microcontroller Programming

The microcontroller is programed to receive command from the remote area computer via wireless communication. At the same time it collects data from the encoder, compass and GPS module and then sends these data to the computer. When UGV receives command from the computer, it first checks the mode of operation the controller wants to implement, i.e. manual mode or autonomous mode of operation. After completion of this task UGV complete its objective.

```
Serial.print("selected mode :");
do{
  while(!(Serial1.available()));  //CHECK FOR AVAILABLITY OF DATA
  r= rec();
} while((r!='M')&&(r!='A'));      //'M' = MANUAL MODE & 'A' = AUTONOMOUS MODE
while(Serial1.available()) Serial1.read(); //EMPTY THE RECEIVE BUFFER
Serial.println(r);
```

Figure – 3.1: Part of the code that used to receive command from the GUI

In the above figure- 3.1, the code is used to receive data from the GUI and accordingly select the mode of operation, i.e. MANUAL MODE or AUTONOMOUS MODE.

```
if(r == 'M')        //manual mode operation
{
  Serial.print("manual mode");
  cc=0;
  fend = 1;
  while(fend){
     while(Serial1.available()>0)
      {

        r=rec();

               if(r=='w') forward(ssp);
          else if(r=='a') left(ssp);
          else if(r=='d') right(ssp);
          else if(r=='s') backward(ssp);
          else if(r=='p') fend = 0;
          else            STOP();
          delay(10);
          f=1;
        }

     if(f == 1)
     {
           f=0;
           digitalWrite(pin, state);
           ///////////////////// READING GPS DATA  ///////////////////////////////////////////////////////////////
           Receive_GPS_Data();                                         //READ GPS VALUE
           SERIAL_PIN.println("");
           SERIAL_PIN.print("lat = "); SERIAL_PIN.print(lat);     SERIAL_PIN.print("\tlg ="); SERIAL_PIN.print(lg);
           //////////////////////////////////////////////////////////////
           SERIAL_PIN.print("\tencoder = "); SERIAL_PIN.print(cc);
           read_angle();                                               //READ COMPASS VALUE
           SERIAL_PIN.print("\tangle = "); SERIAL_PIN.println(reading);
           transmitBuffer = "$%e"+(String)cc+"%a"+(String)reading+"#";   //DATA PACKET TO BE SENT TO THE GUI
           i=0;
           while(transmitBuffer[i] != '\0') trans(transmitBuffer[i++]);  //STRANSMITTING DATA CHARACTER-WISE
      }
  }
}
```

Figure – 3.2: Part of the UGV microcontroller code for manual operation

3.3.2 Graphical User Interface Designing and programming

The GUI is designed to interface the UGV from a remote location. The GUI first connects to the COM PORT of the computer. Then via COM PORT it communicates with the UGV.

There is a provision for selecting MANUAL MODE or AUTONOMOUS MODE of operation. Further the sensor data like encoder value, compass value and GPS data can be checked by the GUI continuously. Apart from all these the path traversed by the UGV is traced on a panel in the GUI. Figure – 3.3 shows a view of the GUI used for the control of the UGV.

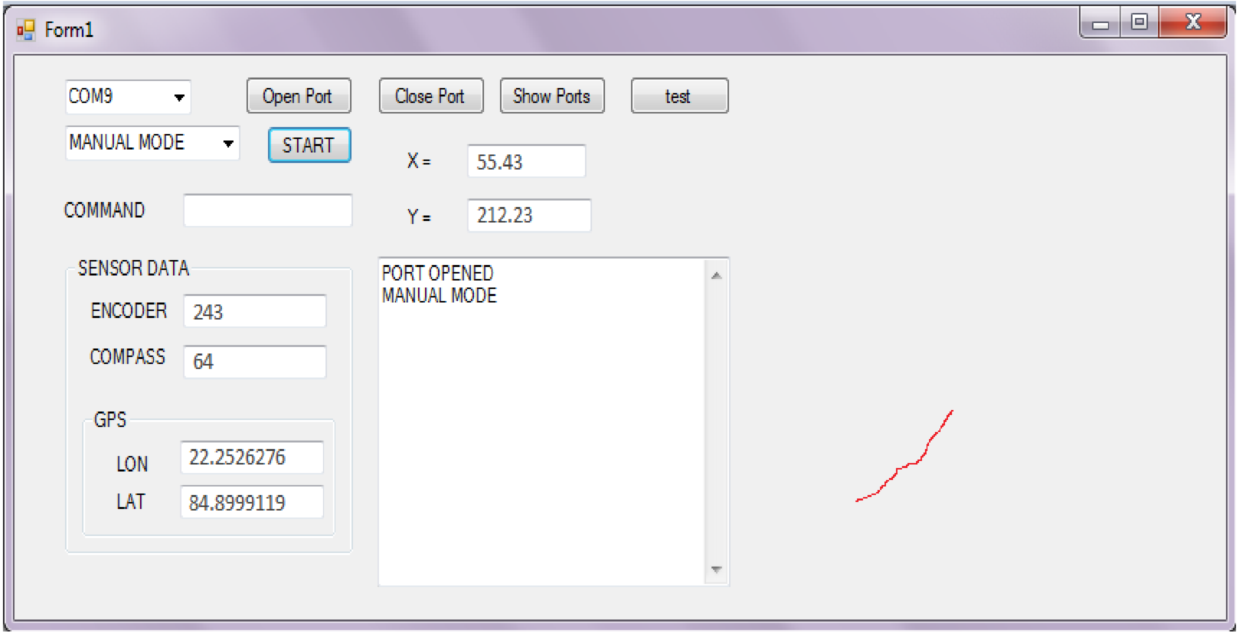


Figure – 3.3: Graphical User Interface (GUI) for UGV

Chapter 4
Work Done

4.1 Working Principle

A robot is designed and used as an UGV to test the positioning technique [6]. Computer collects all the data from sensors and then processes those data to trace the path of the UGV during its real-time operation. At each small time interval it measures the change in distance or distance travelled in a small time interval from its previous position. Along with the distance travelled the angle of deviation with respect to the NORTH direction is measured using the electronic compass. After getting the distance travelled and the angle of deviation we get a relative coordinate in polar notation. This polar form of relative coordinate is converted to Cartesian coordinate system by using appropriate conversion formula. After getting the relative Cartesian coordinate, this can be added to the previous absolute coordinate of the UGV to get the final position.

During MANUAL MODE and AUTONOMOUS MODE of operation the destination of the UGV is first estimated then the navigation starts. The processor checks at each small interval of time whether the set destination is reached or not. If destination is not reached then it continues its motion else it stops its navigation process and completes the task. In the following sections block diagram of the UGV and flow-chart of the working model is shown for better understanding about the project.

4.2 Block Diagram of the UGV and Controller

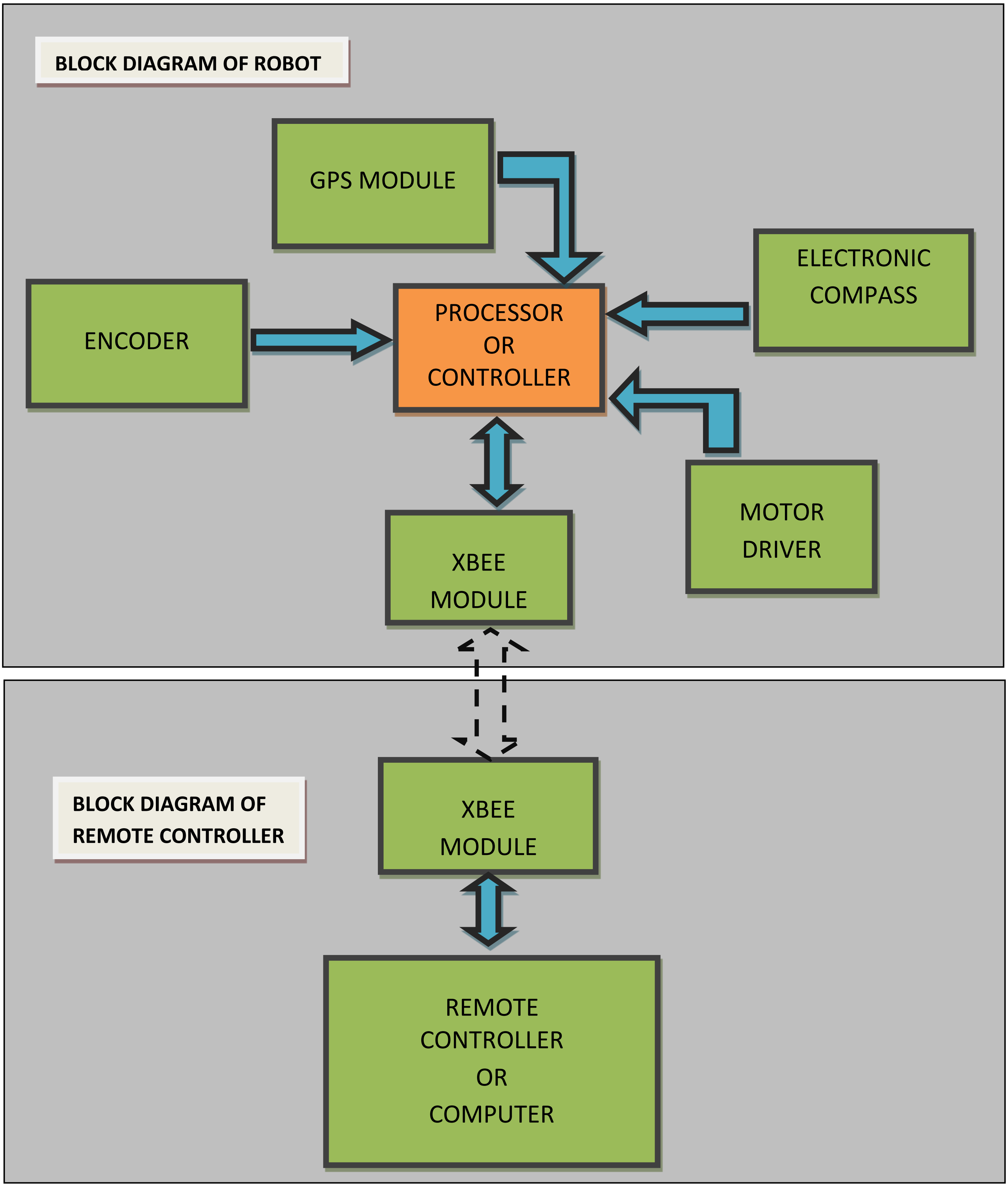
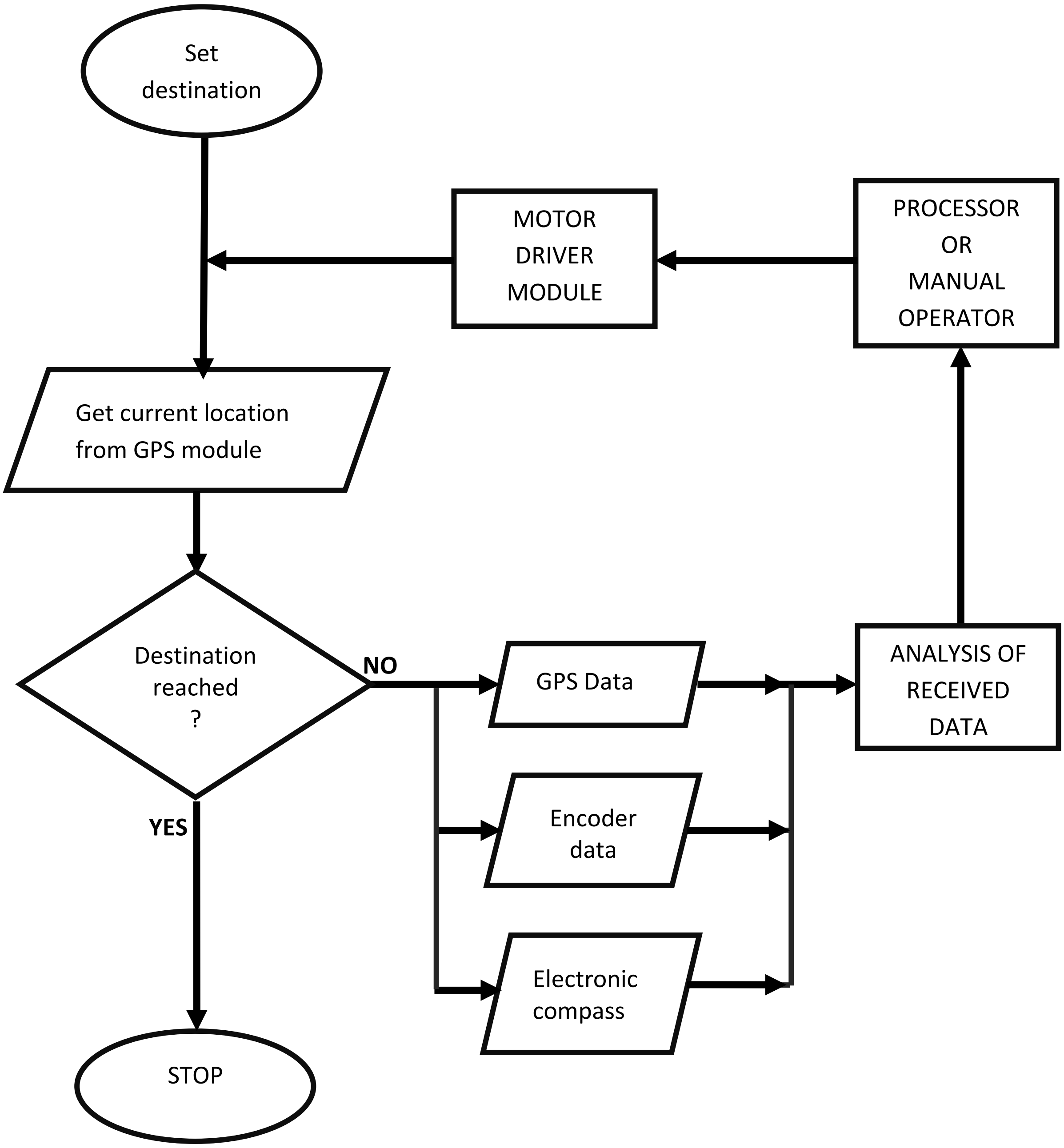


Figure – 4.1: Block Diagram of the UGV and its Control unit

4.3 Flow-chart Describing UGV’s Working Model



Chapter 5

Conclusion

4.1 Result and Observation

The UGV is designed successfully and its relative position is estimated and also traced on the GUI. A comparative study is performed during sensor selection for the distance measurement and it has been found that encoder gives more accurate data regarding the distance travelled by the UGV as compared to the distance measured using accelerometer. Hence encoder is preferred over accelerometer for distance measurement.

Since the electronic compass is highly sensitive to magnetic field, compass module must be placed away from other modules which has magnetic materials; for better and effective angle measurement.

Finally the relative positioning of the UGV is estimated with very less error which can be neglected and still the UGV can navigate safely without any fail.

4.2 Future Possibilities

The distance measurement can be more accurate and efficient if both encoder and accelerometer sensor data are combined together using some good algorithm or any possible technique. The UGV can be integrated with obstacle detection sensors or Kinect sensor [7] to detect obstacles and avoid them during its navigation process.

Also the traced path can be saved and used for future navigation at the same location or nearby surrounding for better and efficient navigation. Further learning algorithm can be used to increase efficiency of the navigation.

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