DESIGN AND IMPLEMENTATION OF A SOLAR UNMANNED GROUND VEHICLE

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Abstract

The paper presents the design and development of Solar Unmanned Ground Vehicle. Mounted on the UGV is a wireless camera that translate audio/video signal from the field to the control unit which is used to navigate the vehicle in different directions and a GPS receiver that gives the geographical coordinates of the vehicle in longitude and latitude. The vehicle is powered by solar panel which provides adequate power for 10hours when there is sunshine and a battery which compliment in the absence of sunshine. The exact location of the UGV in terms of its longitude and latitude (i.e. Lat: 1036.8637N, Lon: 00722.4956E.) is given by the gps receiver. Open circuit Voltage (V_{OC}) from the solar panel was measured to be 12.24V. Finally the coverage distance for which the constructed UGV was able to communicate with the control unit was 1000m, above this distance there was loss of communication between the ugv and the control unit.

Keywords: UGV, Solar panel, GPS, sensors, communication.

1.0 INTRODUCTION

Unmanned Ground Vehicle (UGV) is a vehicle that operates in contact with no on-onboard human presence (Gavhane 2013). It is a robotic platform used as an extension of human capability. It is generally capable of operating indoor, outdoor and over a wide variety of terrain, it can move to any area so desired and perform all sort of work requiring manipulation of different tools. It is being used by both military and civilian to perform dirty and hazardous work. To observe the environment and gather information UGVs have sensors incorporated to them. The information received to either make decisions autonomously about this behavior (Heonyoung, 2009) or pass the information to a different location that will control the vehicle through tele-operation (Mehta et al, 2006). Hence there are two types of UGV; Tele – operated and Autonomous (Jun, 2012).

Rohini B. and J. Sreekantha Reddy (2008), presented an overview of sensors normally deployed in unmanned tracked vehicles. Robotic vehicles are designed, constructed and integrated with sensors, actuating mechanisms and computers. Sensors allow gathering of information about certain physical parameters. These devices can be grouped into various categories in tune with the application and the purpose. Several sensors are used for tele operated and autonomous ground vehicles. It is important to integrate a number of sensors to make an intelligent system that works efficiently in various kinds of environment.

For a tele-operated UGV that is controlled by a human operator at a remote location via a communication link, all cognitive processes are provided by the operator based upon sensory feedback from either line of sight visual observation or remote sensory input such as video cameras. An autonomous UGV is essentially a self sufficient robot that operates without the need for a human controller. A fully autonomous robot has the ability to gain information about the environment, work for long period of time without human intervention, travel from one place to the other and detect objects of interest.

A lot of work has been done in the field of surveillance with the intention of achieving an efficient and very reliable ways of surveillance (Singh, 2009; Motus, 2009). UGVs are also used for mine detection (Yagmil, 2009), and rescue and search operations (Ko, 2009). Zikidis K., et al. (2014) designed a UGV prototype operating on electrical power and receiving commands via remote control software from a computer, featuring a surveillance IP camera. It was based on a simple tricycle chassis and powered by a high capacity automotive battery, which provides adequate power for few hours of use only. Binoy B. N, et. al (2010), designed a remotely operated versatile UGV mounted with a robotic manipulator. The robustness, range and security of the communication link between the remote base station and the robot, obstacle avoidance and the real time control of the robot are some of the major issues that were said to be encountered by the authors while deploying the robots in the given scenarios. The design made use of the already existing GSM mobile telephony network to establish a long range, secure, fast and reliable connection with the remote base station. When a robot is equipped with IR sensors and camera, it can be used for obstacle detection and avoidance. The camera can also be used to send visual information back to the base station in real-time, allowing accurate control and monitoring. The distance covered will be determined by the type of communication link used.

An energy source is required to power the vehicle. Most UGVs use non-renewable energy. In today's world, non-renewable energy are going to get exhausted (Wamborikar, 2011). Solar UGV is a step in saving these non-renewable sources of energy. The advantage of solar UGV is that they are pollution free and eco-friendly. Also the UGV will require less maintenance.

This paper aims to design and implement a tele operated solar UGV system that is powered by renewable energy. The photo voltaic cells are used to charge battery bank during the day time as a result of power from the sun, while the energy stored in the battery is used to power the UGV. A gps receiver is also incorporated to help give the exact location (coordinates) of the UGV.

2.0 METHODOLOGY

Figure 2.1 is a block diagram of the UGV system, showing the different sections of the work. Energy from the sun is converted into electrical signal by the photovoltaic cells. The voltage signal from the photovoltaic cells is then used to charge the batteries continuously. An electric motor powered by the batteries moves the UGV quietly and efficiently, while the vehicle motion is controlled from the control unit through commands sent wirelessly. The combination of a common 12 Volt battery and the electric motor provides a reliable and relatively low cost solution to the UGV mobility issue, minimizing maintenance requirements. For the movement control of the vehicle, a special code in C was created and loaded on the main microcontroller, and keypads are used for sending navigation control to the UGV.

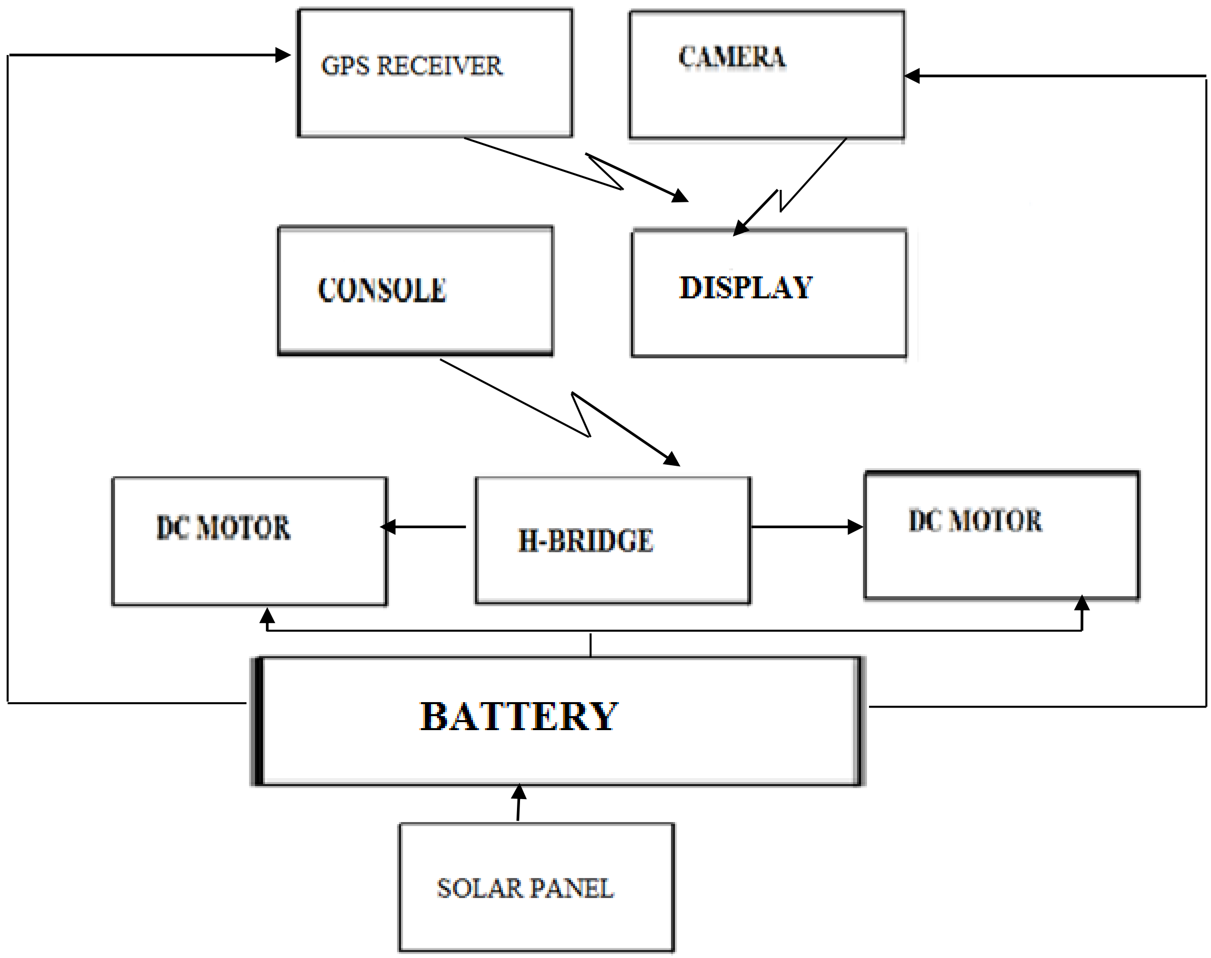

Fig 1: Block diagram of proto-type UGV

The UGV is mounted with a wireless camera that observes the environment, obtains and sends the audio/video signal to the display unit. The GPS receiver sends the geographical coordinates of the vehicle which is used in translating the vehicles particular location at a time. The operator at the control unit now sees the images sent from the wireless camera and sends the basic navigational instructions for the control of the UGV through the consoles. The console receives the signal and decodes the instruction for the control circuit (H-Bridge) to drive the load (DC Motors) in different directions.

The design comprises of two sections which are:

2.1 Hardware section

The hardware section enables two way communication from the control unit to the UGV and also a reverse communication from the UGV to the control unit that is used for control and video/audio transmission. The control unit has a visual display unit and a keypad for receiving visual information from the UGV and for controlling the movement of the UGV. The components used in the design include: microcontrollers (AT89C2051 and DS80C310), data transceivers (KYL 500S), DC motors, wireless camera (8107JM4), GPS receiver (ME2530A), crystal oscillator, and H-Bridge circuit. This paper aims to control a DC motor wirelessly using radio frequency link and indicate the location of the UGV using GPS receiver. The project uses Wi – Fi (IEEE802.11) wireless camera, RF modules, GPS receiver and microcontrollers. The power supply unit consists of two 6W/12V solar panels, used to charge a 9V battery to give the required voltage of 9V to the DC motor and 5V to the GPS receiver, Microcontrollers and transceiver after being regulated by a regulator IC 7805 and 7809. A 100µF capacitor is connected to the output of the regulators to remove unwanted spikes/noise as shown in figure 2.2. A diode is connected in series with the panels. When the sun shines and as long as the voltage produced by the panels is greater than that of the battery, charging will take place. The diode is used to block the reverse flow of current in the absence of sun shine to produce the required voltage for the solar panels hence stopping the discharge of the battery.

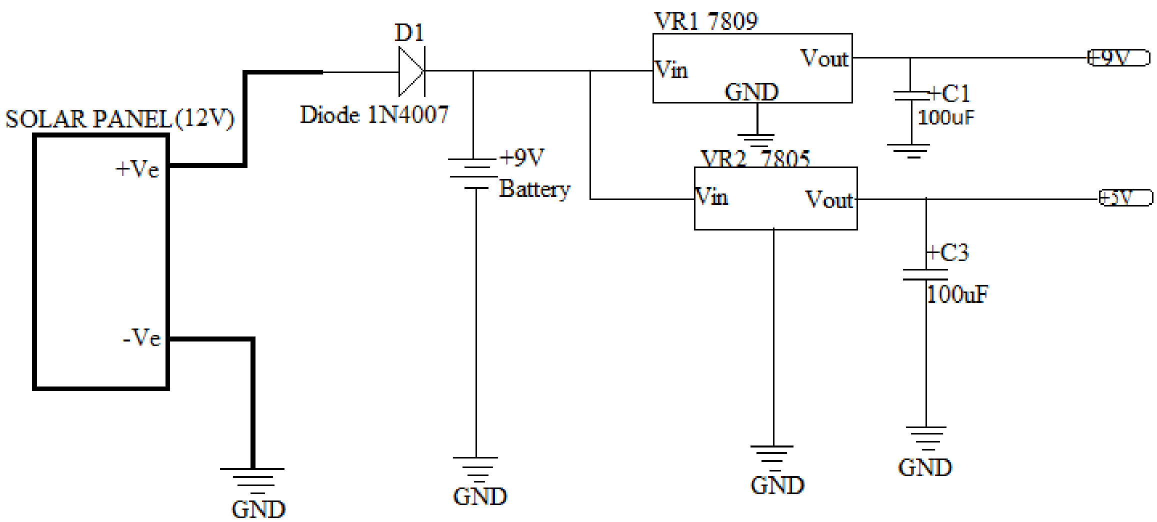

Fig 2: Power supply unit

The total power required by the circuit is as computed in table1 which forms the basis for the selection of the solar panel. The specifications for the different components that make up the circuit are obtained from the data sheets.

Table 1: Power consumption of each component of the circuit

Components	Voltage (V)	Current (I)	Power(VI)
Data transceiver	5v	60mA	0.3W
GPS Receiver	5V	34mA	0.17W
DS80C310µC	5V	30mA	0.15W
AT89C2051µC	5V	5mA	0.025W
DC Motor	9V	115mA	1.035W
Wireless camera	5V	0.3A	1.5W

Therefore the Total power consumed by the load is calculated using equation 3.1

$$P_t = P_1 + P_2 + P_3 + \text{------} + P_6 \quad (1)$$

$P_t = 3.18W$

2.1.1 Sizing of the PV system

The PV modules sizing was carried out such that the power output of the PV panels and the storage capacity of the batteries should be within the required value given the formula for sizing of PV module as shown in equation 2: (Ref)

$$P_{pv} = P_t(T_N + K_2T_D) / K_1K_2T_D \quad (2)$$

Where P_t = Total power, T_N & T_D = Time of night period and Time of day period, K_1= Direct energy transfer path efficiency and K_2= Stored energy transfer path efficiency. Assuming operation time of 24hrs since it is a surveillance vehicle that needs to be functional all day through,

$P_t = 3.18W$, T_D= 9hrs (Number of hrs sunshine), $T_N = 15hrs$, (K_1= 1 & K_2= 0.75)

Substituting in equation 2

$$P_{pv} = 11.66W$$

Two available 6W/12V mono-crystalline solar panels connected in parallel mode were used to give the 12W at 12V.

2.1.2 Sizing of battery bank

The battery bank was sized to be able to store power for 24hrs surveillance. The battery size is determined from the following analysis

The total circuit power was calculated to be 3.18W, Therefore, for 24hrs operation time. Load energy (EL) = 3.18 x 24 = 76.32 Watt hr.

$$WH = NcEL / (DOD \times \eta_b \eta_s \quad (3)$$

Where, EL is the Load energy, DOD = Depth of discharge (0.75%) $\eta_{b.}$=Battery efficiency (0.85%) η_s=System efficiency (0.85%), N_C = Load factor

$WH = (1 \times 76.32) / 0.75 \times 0.85 \times 0.85$

$WH = 140.84Wh$

$AH = 140.84/12$

$AH = 11.73Ah$

Although, the sizing result of the battery bank gives 11.73Ah, in this work 6 pieces of the available lithium ion battery with storage capacity of 4.8Ah connected in series/parallel mode was used to achieve the required current and voltage.

2.1.3 AT89C2051 Microcontroller

The AT89C2051 is a low-voltage, high-performance CMOS 8-bit microcomputer with 2K bytes of Flash programmable and erasable read-only memory. A crystal oscillator is connected to AT89C2051. An 11.0592MHz crystal oscillator was selected for use in this project work based on recommendation from the data sheets. For this design the values of C1= C3 = C6 = C7 = 22pF. The microcontroller is used in this work to control data from the transceiver, UGV movement and direction by the set of instruction written on it.

2.1.4 GPS Receiver Selection

ME2530A GPS Receiver with Antenna is used in this work because of its high performance, low noise amplifier and built-in regulators. It uses the universal asynchronous receiver/transmitter (UART) for communication at a baud rate of 9600. A UART is usually an individual (or part of an) integrated circuit used for serial communications over a computer or peripheral device serial port. UARTs are now commonly included in microcontrollers. The GPS receiver takes information transmitted from the satellites and uses triangulation to compute the exact location in longitude and latitude of the prototype vehicle. When the GPS receiver is first turned on, it downloads orbits information from all the satellites. This process takes about 12minutes for the first time but once the information is downloaded it is stored in the receiver's memory for future use.

2.1.5 RF Transceiver Selection

KYL-500S Mini-size RF transceiver is used for the radio frequency module. It is usually used for restricted space application. With TTL interface, it is widely used for micro-controller wireless communication and other TTL level port communication systems. It has high reliability and good performance.

2.1.6 **Wireless camera Selection**

The wireless camera mounted on the UGV is used for the video/audio transmission. It uses Wi-Fi wireless technology with auto IR-LED illumination for night vision, 2.4GHz external Omni-directional antenna. The transmission system adopted is the IEEE 802.11b standard, Wi-Fi wireless communication protocol because of its advantage of long range, high data rate and normalized energy consumption.

2.1.7 H-Bridge circuit

H-Bridge is an electronic circuit that enables a voltage to be applied across a load (motor) in either direction i.e. drive a motor clockwise and anticlockwise. They are often used in Robotics and other applications to allow DC motors to run forward and backward. To reverse a motor, the supply must be reversed and this is what the H-Bridge does. An H-Bridge can be implemented with switches, relays, transistors or Mosfets. Power transistors TIP41 NPN and TIP42 PNP are used in this project work for the H-Bridge. These transistors have just enough power needed to move the UGV. Figure 2.3 shows an H-bridge circuit and the connections of the H-Bridge to the microcontroller.

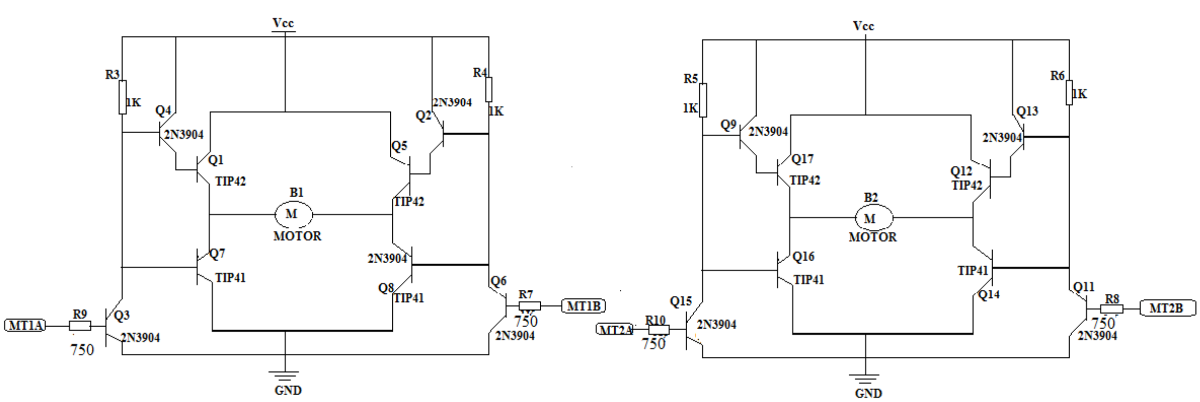

Fig 3: H-Bridge Circuit

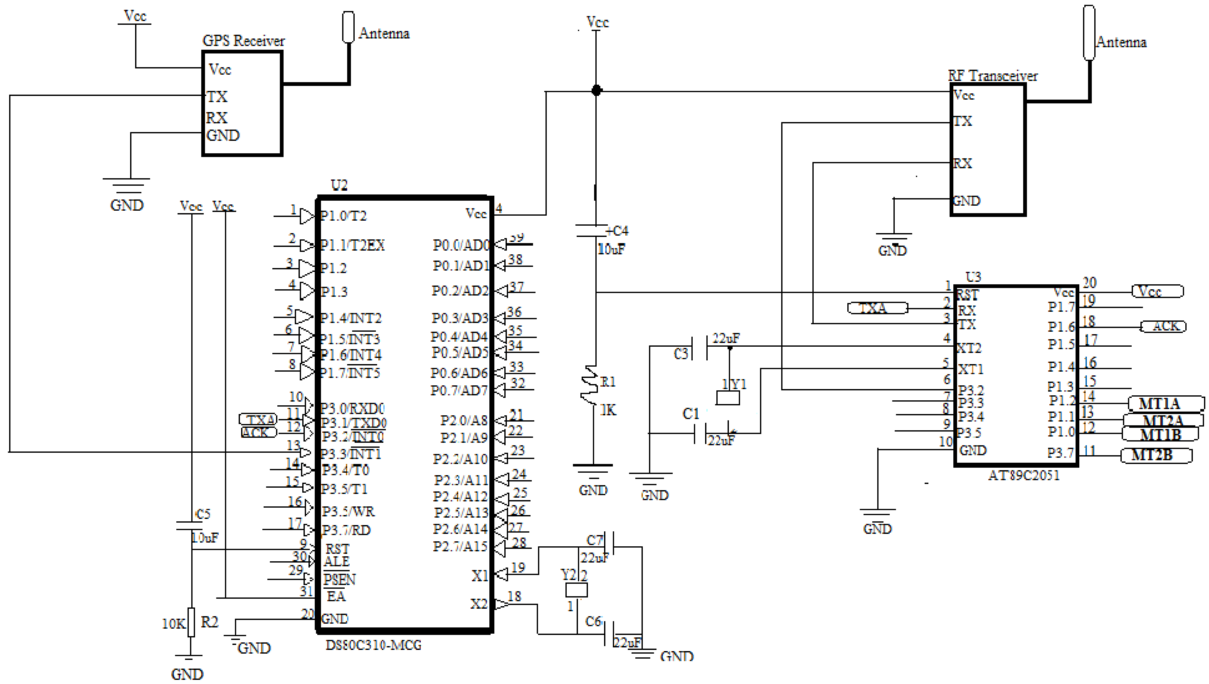

Figure 2. 3 Schematic diagram showing H-Bridge and Microcontoller Circuit on UGV

The gps receiver extract the coordinate data from the satellite and wirelessly transmit it to the display unit, at the same time the audio/video signal from the wireless camera is also sent to the UGV which enable the vehicle control in different directions.

2.2 Software

After the hardware implementation is completed, a program was developed for the hardware to perform its required task. The software development was divided into two stages i.e. the graphic user interface (GUI) and the embedded system. The GUI and the embedded system were implemented using C programming language. The flow chart for the UGV system is shown in figures 2.4.

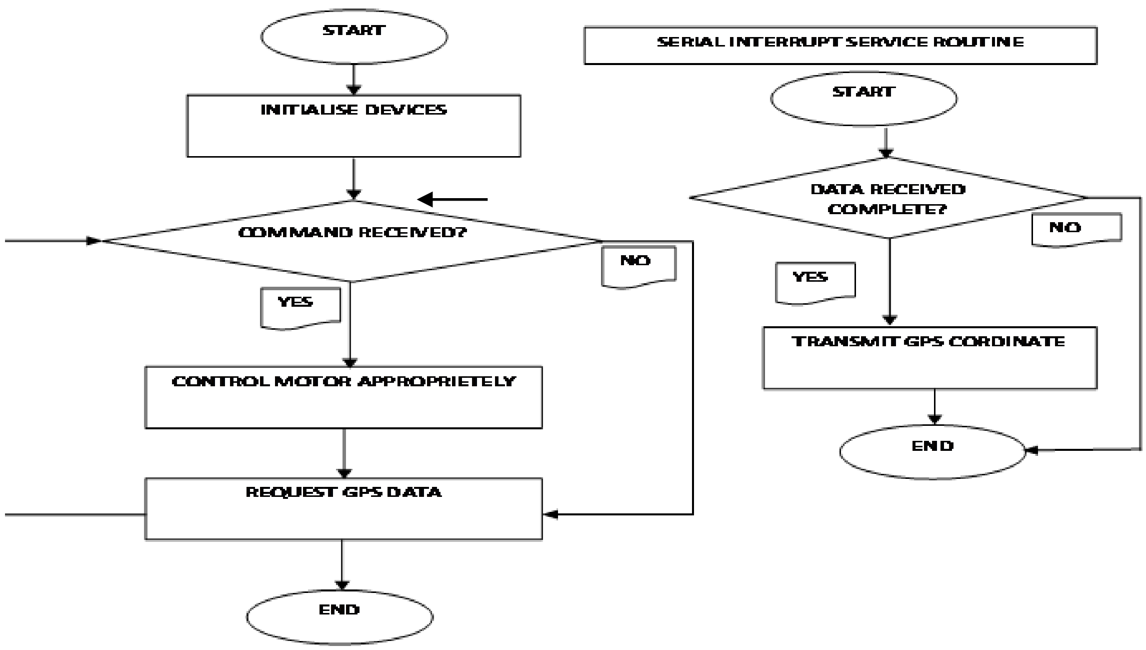

Figure 2.4 Flow Chart of UGV

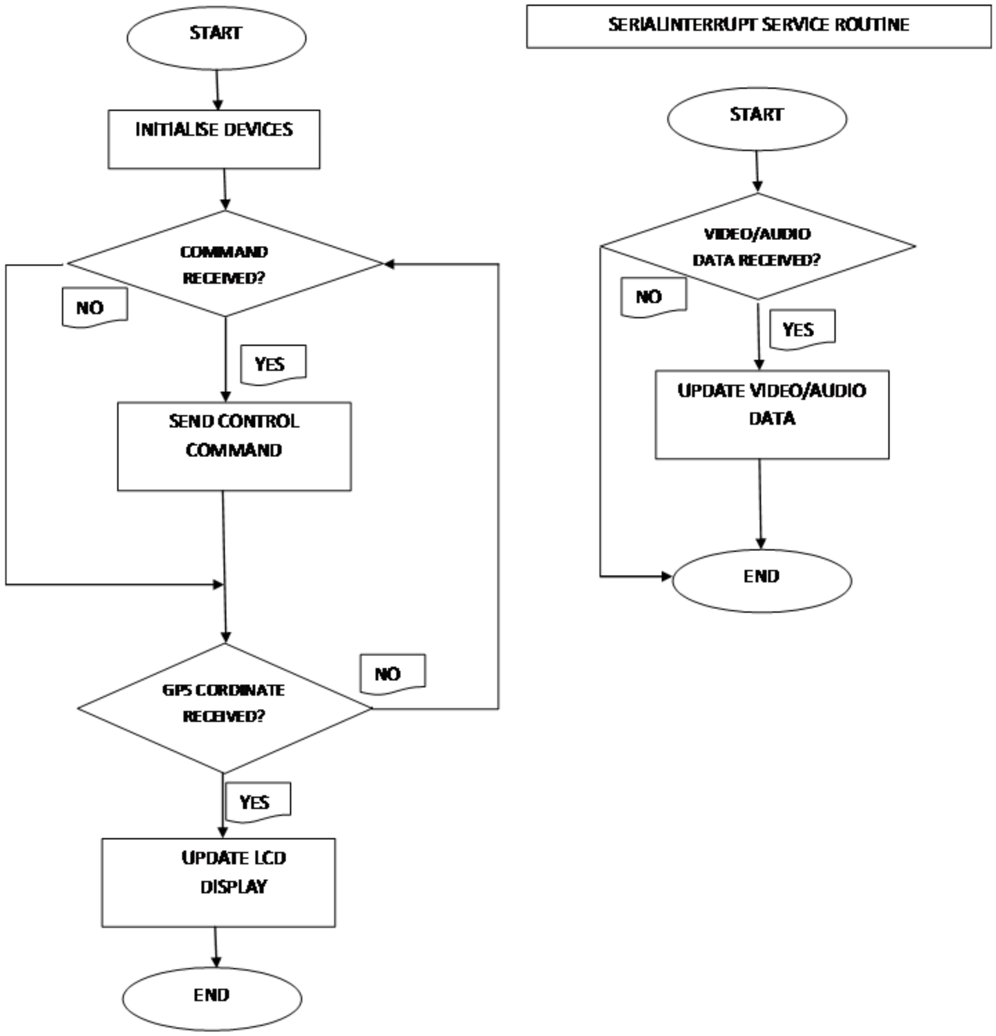

Figure 2.5 Flow Chart of Control Unit

3.0 RESULTS AND DISCUSSION

Figure 3.1 shows snap shots of the constructed system, while Figure 3,2 shows set-up for some measurements

Figure 3.1 Snap shot of Control Unit, Solar Panels and UGV System

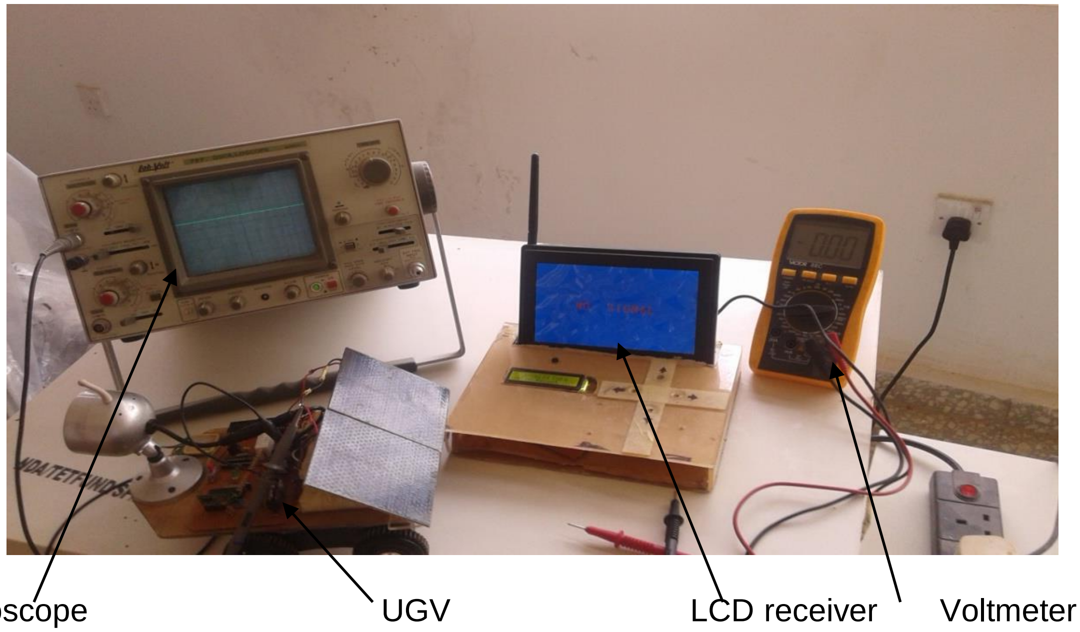

Fig3.2: Test set up showing the different sections of the work

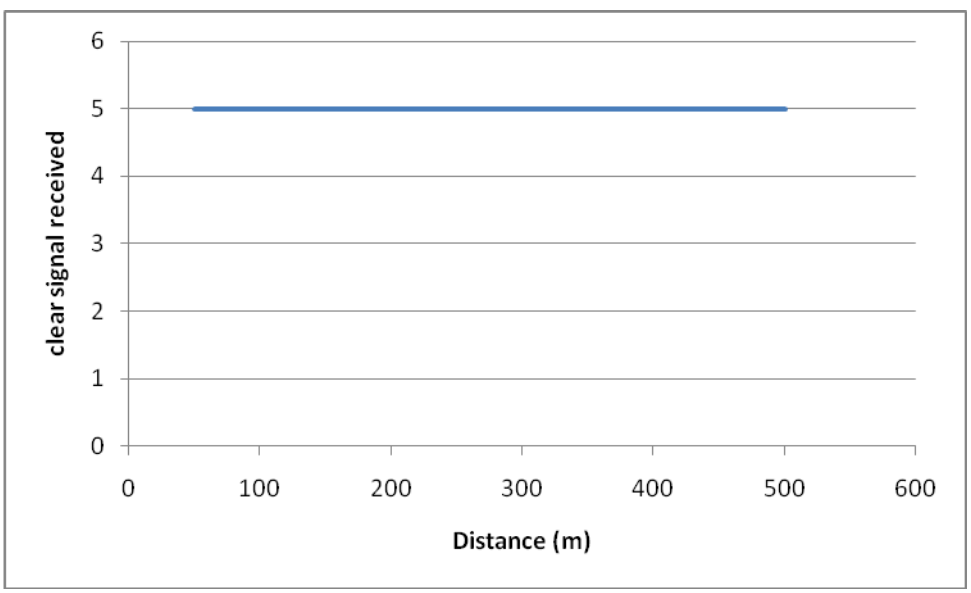

Fig 3.3: A graph of clear signal received against Distance covered

The keys on the key pad are numbered A1 to A4, they were used for sending navigational signals to the UGV and the results obtained are in Table 3.1

A_1 controls the vehicle to move forward.

A_2 for backward movement

A_3 for movement to the left direction

A_4 for movement to the right direction

Table 3.1: Result of UGV Movement using Control unit

A_1	A_2	A_3	A_4	Operation
0	0	0	0	Stop
1	0	0	0	Forward
0	1	0	0	Backward
1	0	1	0	Forward Left
1	0	0	1	Forward Right
0	1	1	0	Backward Left
0	1	0	1	Backward Right

Another test that was carried out on the designed UGV is the distance and clear signal reception. The UGV was controlled to move some distance and a clear signal reception was observed over distance as shown in the following figures.

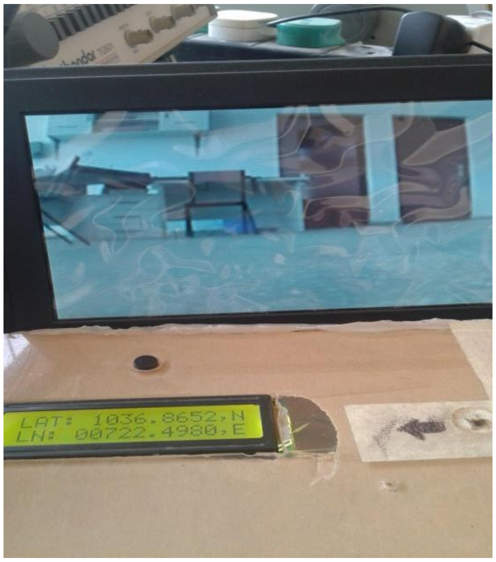

Fig 3.4: UGV image at a distance of 10m   Fig 3.5: UGV image at a distance of 30m

Showing coordinates

Figure 3.4 and 3,5 show images captured by the UGV and translated to the control unit at a distances of 10m and 30m together with the coorinates.

Table 3,2 shows measured voltages from the solar panel at different times of the day.

Table 2: Measured voltages at one hour interval

Time	Voltages (V)
08:00	11.69
09:00	11.76
10:00	11.82
11:00	11.77
12:00	11.75
13:00	11.62
14:00	11.40

15:00	11.35

Covered distance and clear signal reception test was conducted on the constructed UGV to ascertain the range of distance the vehicle can cover with clear signal reception and it was observed that it can cover a distance of 1000m with clear signal and command response. Figure 3.3 shows a graph of clear signal receive against distance. The voltage reading of the solar panel was also measured at an hour interval for 7hours (between 8am -7pm) with the panel exposed to sunshine and it was observed that it ranges from 11.35 to 11.82 which is used to charge a 9v battery.

4.0 Conclusion

The research demonstrated that an unmanned ground vehicle can be used for surveillance purposes in places with high security risk there by reducing the number of life lost by personnel involved and also providing a first-hand security information of the coverage area. This will go a long way in combating crime.

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