Unmanned Ground Vehicle (UGV) With 5-DOF Robotic Arm

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Abstract- *The main purpose of this research is to design and develop complete system of a remote-operated multi-direction Unmanned Ground Vehicle (UGV). The development involved Arduino UNO Rev3 in remote-controller and UGV robot, HC-12 modules, brushless DC electric motor and night vision camera. This paper shows the study the movement of multidirectional UGV by using caterpillar track with differences drive configuration. The Arduino UNO Rev3 were used in the UGV's system that embed with HC-12 module through variable baud-rate value via UART protocol. Main features of this unmanned ground vehicle (UGV) is that it can move on various surfaces using caterpillar track, perform night time surveillance using a night vision camera and have ability to diffuse bomb using 5-Degree of Freedom(DOF) manipulator. Thus, the system provides high security for the life of the bomb diffusion squad. The proposed system is highly useful in the all areas that requires safety and it provides virtual reality in surveillance and diffusion.*

Keywords- Unmanned Ground Vehicle (UGV); HC-12; Remote-operated;Bomb diffusion; Surveillance

I. INTRODUCTION

Unmanned Ground vehicles (UGVs) are multipurpose remotely controlled vehicles, with the absence of any on-board human. UGV's have various applications in hostile environments where it can be dangerous for a human to work. A manipulator is a mechanical unit, designed to imitate the behaviour of human arm. It consists of various segments capable of moving in various directions. The end effecter of a manipulator is designed depending upon the required functionality, e.g. gripper, camera, gun mounts etc. Remote control of vehicle has become a popular technology due to the advantages it offers in terms of human safety and terrain accessibility [1]. UGV's have wide range of applications in various sectors. They provide assistance in civil service works like removal of debris and rescuing humans. UGVs are widely used nowadays in USAR (urban search and rescue) operations [2]. Besides their expanding role in domestic market, UGVs are also being used for surveillance, reconnaissance, bomb disposals, land-mine detection, IED's and other military purposes [3].

The Arduino UNO is designed for projects that require I/O lines, sketch memory and RAM. With 14 digital I/O pins,6 analog inputs and a sufficient space for sketch it is the recommended board for robotics projects. This gives our projects plenty of room and opportunities maintaining the simplicity and effectiveness of the Arduino platform.

The Arduino UNO is programmed using the Arduino Software (IDE), the Integrated Development Environment common to all Arduino boards and running both online and offline. Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them.

Different techniques have been developed to control this vehicle. Speech control [7] and PointCom [8] are common among them. However, Remote control is one of the most user friendly technique, and therefore, this paper is focused on the UGV control using remote controller.

II. COMPOSITION OF UGV AND ITSMANIPULATOR

In this section, we describe the detail of the system. The design consists of two major stages:

1. UGV mechanical design
2. 5-DOF manipulator mechanical design
3. The electronics design.

1. UGV mechanical design

The UGV's base has been built high quality 3-ply and 5-ply material. It is a differential wheeled robot [9]. Each track uses two motors which allows the vehicle to climb steep slopes easily by providing large torque.

The caterpillar track enables the UGV to move on rocky terrains and in hilly areas. Fig. 1 shows the UGV base. Specification of UGV is shown in Table. 1

Table 1. Specification of UGV.

Material	Ply-3,ply-5, aluminium, iron
Length	50cm
Width	26cm
Height	14cm
Drive type	Differential
Number of Motors	x4

2. 5-DOF manipulator mechanical design

The manipulator, shown in Fig 1, is manufactured to keep as light as possible without compromising its strength. DC motors are used for actuating links which are designed to carry a payload of 0.5kg. Specification of the manipulator is given in Table. 2.

Table 2. Specification of the manipulator

Payload	0.5Kg
DOF	5
Material	Ply, 3-ply, Aluminium, Acrylic,iron
Max. horizontal reach	45cm
Max. vertical reach	30cm
Number of Motors	X5

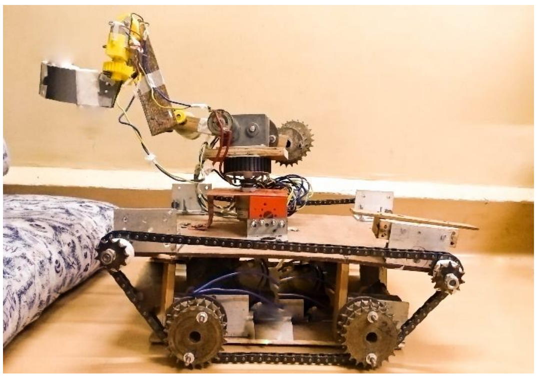

Figure 1 Unmanned Ground Vehicle with Manipulator

3. The Electronic Design

The figure 2 and figure 3 gives an illustration of UGV's electronic hardware architecture of Arduino UNO Rev3 and its connections with different electronic components ofUGV.

Figure 2 Connections on Remote controller(Basic)

We have used Arduino UNO which have 14 digital pins from which we'll use 10 digital pins as an Input signal for 5DC motors(for robotic arm) and 4 digital pins for four DC motors(to control movement of robot). We have assigned a Character to each digital pin. Each digital pin is connected to a DPDT Momentary push button switch which takes input from user. Depending upon the switch pressed by the user, that particular pin to which switchis connected turnsHIGH and transmits a designated Character assigned to it, via HC-12 Transreceiver moduleto the receiver circuit.

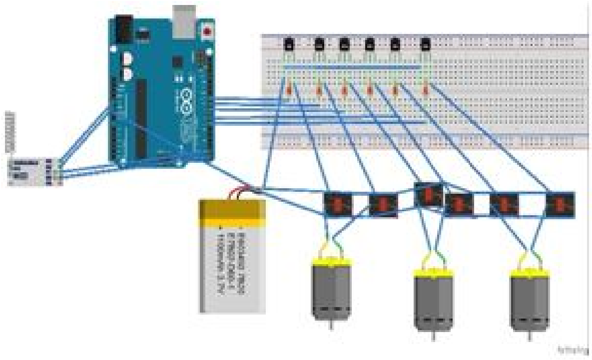

Figure 3 Connections on UGV system(Basic)

At receiving end we have connected HC-12 Transreceiver module toArduino UNO to receive Characters transmitted via transmitter circuit. The characters received decides which function is to be performed. We have connected 5 DC motorsmotors(which will control movement of robotic arm) to 5Digital pins and 4 DC motors(which will control movement of robot) are connected to 4 digital pins of Arduino UNO via relay circuit. We are using relays to isolate the input and output power, as Arduino cannot drive a DC motor so we are using a relay circuit to drive the motor at higher power.

III. DEVELOPMENT OF KINEMATIC MODEL OF UGV

Development of any control on a mobile system requires a kinematic model. Since a differential drive robot resembles a UGV, its model is used as an equivalent for UGV [16], as given in Figure4.

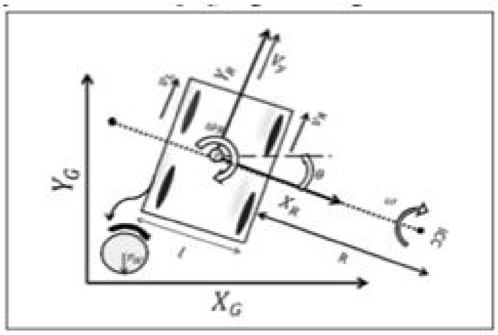

Figure4 UGV Equivalent Model

The linear and rotational velocities with respect to global frame of reference are functions

$$f(l, \theta, r_W, \omega_{RW} \omega_{LW})$$

Where l is the length between UGV tracks (left and right), θ is the UGV's angle of rotation, r_ω is the UGV wheel's radius, ω_{LW} is the rotational velocity of left track/wheel and, ω_{RW} is the rotational velocity of right track/wheel. R is radius of rotation of vehicle about rotational centre at that instant. ω is the rotational velocity of vehicle about its instantaneous centre (IC) of rotation.

Linear velocity

Ignoring configuration of tracks, linear and rotational velocities of both tracks at any instant is derived mathematically;

Right track's linear velocity' v_R 'is given as under,

$$v_R = r_W \times \omega_{RW} \quad (1)$$
$$v_R = R \times \omega$$

Left track's linear velocity' v_L'is given as under,

$$v_L = r_\omega \times \omega_{LW} \quad (2)$$
$$v_L = (R + l) \times \omega$$

Since motors can only deliver motions to UGV along the y axis [17], so the point P (given in Fig. 5), which is situated at the centre of robot would have an average velocity only along y-axis. Due to fixed wheels, UGV has no linear motion along the x-axis.

$$v_y = \frac{v_R + v_L}{2} = \frac{r_\omega(\omega_{RW} + \omega_{LW})}{2} \quad (3)$$

Where 'v_y' is the mean velocity of point P along y axis with respect to vehicle's global frame of reference.

Rotational velocity

$$\omega_R = \frac{2(v_L - v_R)}{l}$$

$$\omega_R = \frac{2r_\omega(\omega_{LW} - \omega_{RW})}{l} \quad (4)$$

Where ω_R represents UGV's rotational velocity about the point P.

Instantaneous centre

The system has a pure rotation around the point of instantaneous centre situated on the axis of rotation and a zero velocity at this point [18]. By using the above equations, radius of IC can be determined as:

$$R = l\left(\frac{v_R}{v_L - v_R}\right) \quad (5)$$

IV. METHODOLOGY

Compact Arduino UNO Rev3 controller with various electronic components collaborates to form a system so as to enable the operator to operate UGV from a remote place. Remote Controller sends signals to the UGV wirelessly. An Open Loop Control is developed through which a human operator controls the forward/reverse movement and turning of the UGV via remote controller. Video feedback is provided from the cameras installed in UGV to control it, when it is not in visibility range of operator, as shown in Fig. 5

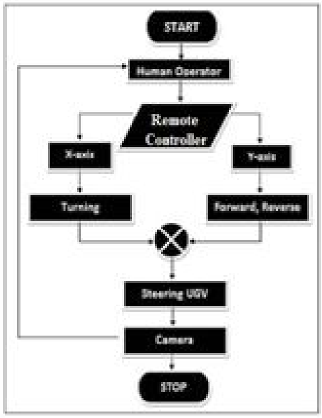

Figure5 UGV control flow diagram

V. CONCLUSION

An Arduino UNO based UGV was developed for moving on various surface which consists of a 5 DOF manipulator and a night vision camera, which are controlled via remote controller while operating from a remote location using wireless communication. Arduino software(IDE) has been used as a programming platform. The UGV manipulator equipped with onboard camera which has been used for providing real time video feedback over the wireless communication. This video feedback can be seen on a user mobile phone also. The movements of the UGV and manipulator have been controlled through the remote controller which offers a very smooth and easy operation. It makes this piece of equipment very useful to be used by the

USAR teams and military soldiers for carrying out surveillance in the natural calamity area or against enemies.

VI. FUTURE WORKS

The UGV has been tested on versatile terrains however the proposed control still holds a lot of flexibility in terms of advancement and innovation. A closed loop PID control can be developed by incorporating different sensors like Encoders, GPS and IMU for feedback making the vehicle semiautonomous. Implementation of different techniques of mobile robotics and motion planning can help evolve the current UGV control to a full autonomous UGV control.

The UGV can be made semi-autonomous so that in case of wireless module malfunction or in some critical situation UGV can take decision of its own, like returning back to base. Using feedback from the digital compass and wheel encoders a closed loop system can be implemented which will increase performance and reliability of the vehicle.

VII. ACKNOWLEDGMENT

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