A WIRELESS CONTROLLED SEMI-AUTONOMOUS SENSOR BASED UNMANNED GROUND VEHICLE

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Abstract: *Engineering is rapidly moving towards unmanned robotic vehicles (UGVs). In this paper we have implemented a real time wireless sensor based semi autonomous unmanned ground surveillance vehicle that is adaptable to changes within its environment. The design and development of the physical prototype is 3.0 x 2.5 x 1.0 (l x w x h) feet in dimensions. Its combat proven reliability is non-matched and first time introduced in Pakistan. Obstacles avoidance is efficiently implemented using integrated two optimized precision SHARP 2Y0A710 IR (5.5m) range finders. Live video transmission is received using wireless CCTV (2.4GHz, FM) camera mounted on the UGV. It can easily enter dangerous areas with its four wheel chain drive chassis coupled with wiper motor operated at 24V (150rpms) producing torque of 5.44 Nm and can lift additional load. To reduce risk of collision, damage and enhance situational awareness we have implemented wrong command rejection algorithm.*

Key words: UGV, Semi-Autonomous, Wrong Command Rejection

1. INTRODUCTION

There are variety of potential applications of unmanned ground vehicle to land operations that can increase efficiency and safety. These include surveillance, reconnaissance, target engagement, runways and airport lounge security, mine detection, explosive disposal, security and operations in contaminated and hazardous environment. Unmanned ground vehicle (UGV) technology has wide applications in civilian and military purposes [1-2]. The UGV can serve in industries to reduce the labor and loss of valuable life. These vehicles have capability of replacing humans in hard situations and battle fields. Currently, a lot of research and development is done in UGVs for military and civil applications [3-4]. UGVs are of different sizes and capabilities depend upon the nature of their application. There most important applications are in the surveillance, reconnaissance and security service, control and monitoring situation, police department, natural disaster, law and enforcement, patrolling, etc. UGVs are not only saving lives and providing vital support capability in forces operations. UGVs work effectively in severe environments such as cold, heat, chemical, nuclear and contamination in the battlefield as compared to humans. UGVs are normally human supervisory controlled from an isolated location through a communications link usually RF or satellite link [5]. Direction-finding of Unmanned Ground Vehicles (UGVs) towards an identified target using wireless sensor algorithms has been proposed [6]. Operators can obtain and view critical information form UGVs in real time due to the multiple sensors installed, and provide access to areas that would be high risk before the operation [7-8]. Linear optimization for obstacle avoidance algorithm is proposed using the wrong command rejection module for remote control in order to guarantee strong and real time combat ability in UGVs [9]. Power efficiency of UGV drive axles causes the dynamics to become operationally coupled and affect vehicle mobility largely [10]. Remote tests are conducted multiple times to verify the effectiveness of our proposed system.

Target applications of this unmanned ground vehicle are

- Surveillance/ Reconnaissance
- Rescue Operation
- Route Clearance

Aim of this paper is to provide a platform for the upcoming researchers in the field of UGVs for implementing their research tasks and projects. Researchers have also developed speed control for non autonomous robotic vehicle in difficult surveillance conditions [11]. Today the first need of any country is to increase their defense. The primary function of this unmanned ground vehicle is to navigate in the narrow, hazardous environment for emergency situations and surveillance. This UGV can avoid obstacles and find a clear passage using its IR sensors.

The key features of designed UGV are:

- Chained wheels mobility in extreme areas.
- Mechanical design able to move on rough trains.
- Zero degree rotation on its own axis.
- Wireless controlling using RF control.
- Front mounted camera for image acquisition and Transmission.

In this paper Section 2 describes the development of the design for UGV. Section 3 explains hardware and electronics. Section 4 describes the implementation of obstacle avoidance using wrong command rejection 5 discussions and cost of UGV. Finally, the conclusion is presented in Section 6.

2. DESIGN AND IMPLEMENTATION

The wireless controlled unmanned vehicle is designed and implemented consisting of a human supervisory and semi-autonomous control system.

Figure 1 Designed UGV

This unmanned vehicle is mechatronically constructed from 5mm aluminum sheet and 15mm steel iron rod. The UGV is equipped with two IR sensors of 5.5m range for obstacle avoidance, a wireless CCTV camera for transmitting visual images to the operator, a high intensity SMD LED array for lighting at night, a custom made controller board designed for semi-autonomous mode and wrong command rejection signal generation. A 2.4GHz radio control four channel transmitter communicates with a receiver within the UGV that sends signals to mini rc hobbyist servos which move the control arm based on the position of joysticks on the transmitter.

Table 1 Size of UGV

Full Length Diameter	914.4mm
Wide Base	762.0mm
Total Height	304.8mm
Lifter Length	274.3mm

We used the general dimensions for designing this UGV given in the international rules of combat events such as robo-wars. These are typically 3 x 3 x 3 (l x w x h) with maximum 60Kg weight. Our designed structure was stable because of its four wheel chain drive. Moreover using local material for making and fabricating was very cheap than importing parts for UGV. Its total weight is 25Kgs without payload carry which ideal for serving as unmanned ground vehicle.

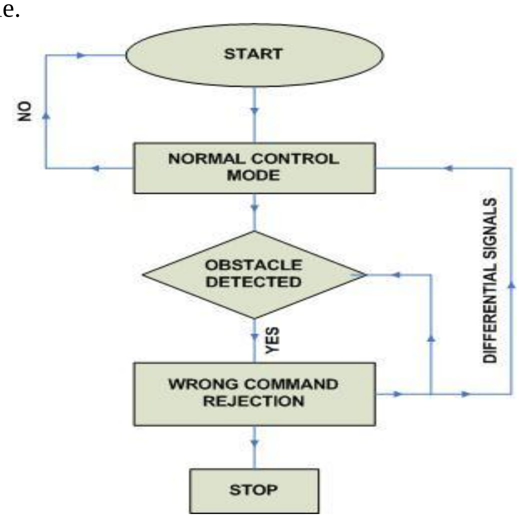


Figure 2 Flow Diagram of Designed Control System

This flow control in figure 2 has been implemented using 5.5m IR based Range Finders. The specified safe range of 1.2m has been preset in the algorithm. Whenever an obstacle enters within this range the sensors send the differential signals to the controller board and it generates reverse corresponding signals.

3. ONBOARD MECHATRONIC AND DEVICES

3.1 Battery specification

For powering our UGV, three rechargeable lead acid batteries are used operated on 12Volts and 4.5AH. Two are used in series for 24 volts DC viper motors (WM6061) consuming 60Watt and 12Volts for DC power window motor of 48Watt for lifting. Being low cost makes it attractive for use in motor vehicles to provide the high current required by automobile starter motors.

3.2 Switching Module

We have used servo motors and limiting switches operated on 12 volts 10 Amps for mechanical switching of electronic circuits from control signal received using a transmitter and receiver. Tower Pro SG90 Mini Gear Micro Servo 9g was selected. Total of 3 RC servo motor in the UGV along with twelve limit switches been used in this module.

3.3 Wireless Control

We used an FMS four channel radio, which operates on 2.4GHz bandwidth spectrum operating on Direct Sequence Spread Spectrum (DSSS) modulation. This technique involves the transmitter and receiver staying within a fixed part of the 2.4GHz spectrum.

3.4 Base and Lift Motor Driver

H –bridge is used for dc gear motors. It is made by using the relays operated on 12 volts. Maximum current of current of 10 amps can be passed. Two dc motors are used in our robot. Speed of DC motor is 150 rpms operated on 24 volts. The drive mechanism and load specifications determine the type of motor to use. We had used automobile DC viper Motors model (WM6061) 24volts operated at 150 rpms. For lifting we have used auto car power window worm gear dc motor operate on 12 volts operated at 90 rpms. It can carry load up to 5kg. We maneuvered the UGV without and with carrying load testing its performance and mobility as shown below in figure 3.

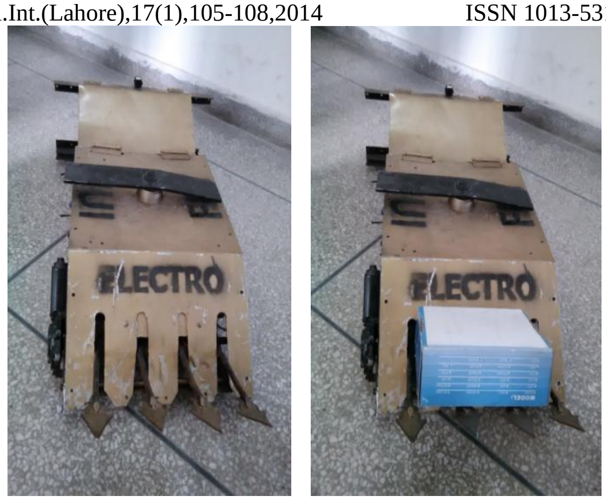
3.5 Sensor Linearization

IR Range Finder gives us a non-linear analog output voltage from 0.5v-3.1v at output as the distance to the object decreases. The non-linear output is not suitable to be directly used so we had to linearize as is shown in figure 3.

Using MATLAB we have linearized the output to as a constantly increasing output as the distance increases

$$y = m * x + b \qquad (1)$$

where y is the horizontal linear range. Substituting this linearization function from above for y and substituting V for x, the equation (1) becomes



(a) (b)

Figure 3 No load and carrying load on UGV

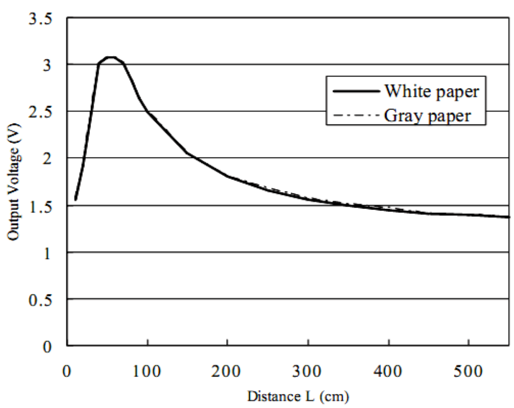


Figure 4 IR Sensor Output

$$1 / (R + k) = m * V + b \quad (2)$$

$$R = (1 / (m * V + b)) – k \quad (3)$$

$$R = (m' / (V + b')) – k \quad (4)$$

where m' = 1/m and b' = b/m .

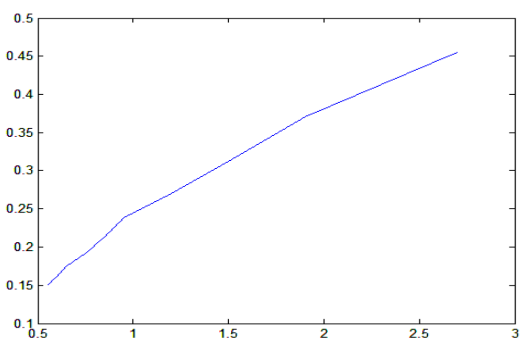


Figure 5 Linearized Output

4. WRONG COMMAND REJECTION

This algorithm has been implemented using two precise 5.5m IR Range Finders. A distance of 1.2 m is set as the safe range in the programming of the microcontroller. We have integrated it with PIC18F452 microcontroller using its 10 bit built in Analog to Digital Convertor with fast sampling rate. When obstacle is near the sensor output voltage linearly decreases also showing on LCD, indicating controller to generate reverse differential signals.

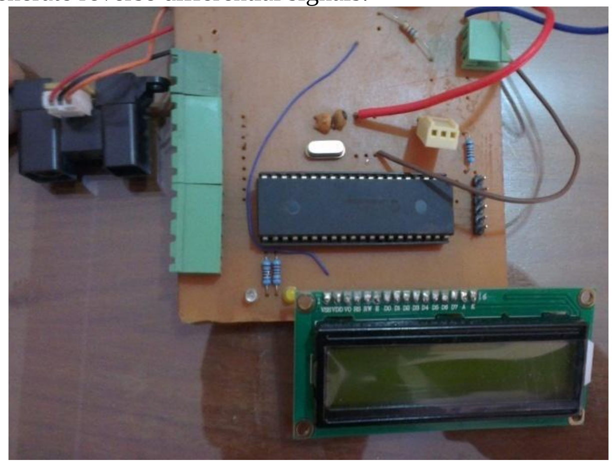


Figure 6 Sensor and Controller interfacing

One sensor controller interfacing is shown above in figure 6.

4.1 Proposed Pseudocode

The pseudocode for wrong command is as follows:

do Human- Supervisory-Control (Remote Signal)
start
Forward = Control_1
Backward = Control_2
Right = Control_3
Left = Control_4
while
{
if Control_1 is clear
Continue Moving Forward
else
Jump to Control_2
if Control_2 is clear
Continue Moving Backward
else
Jump to Control_1
if Control_3 is clear
Continue moving Right
else
Jump to Control_4
if Control_4 is clear
Continue Moving Left
else
Jump to Control_3
}
end do

5. DISCUSSION AND COST

This project has demonstrated its viability as starting platforms for commercial unmanned ground vehicles. The low cost and high production volume make it extremely affordable for military and civil purposes. Total weight of our UGV is 25Kgs producing torque of 5.44 Nm. It can also lift and carry additional load up to 5 kg.

Table 2: Itemized Cost for Single UGV

Base Structure and Assembly	$350
DC Motors (WM6061)	$50
Rechargeable Batteries	$25
IR SHARP Sensor 2Y0A710	$60
CCTV 2.4 GHz Camera	$20
FMS 4 Channel RC	$42
Controller Board	$10
Tower Pro SG90 Mini Servo 9g	$40
Limit Switches and Relays 12 Volts	$15
Total Cost	$612

The low cost of a single UGV, it is not only affordable but it replaces a complete human life in warfare and hazardous situations. Mass production can further reduce its cost significantly.

6. CONCLUSION

The designed and proposed UGV with dimensions 3 x 2.5 x 1 (l x w x h) feet prove to be very reliable. The UGV is capable of avoiding collisions and provides vision surveillance. IR range detectors serve as major sensing units for obstacles. The stable design resulted in highly safe and stable system. Its active lifter can carry additional load up to 5 kg. This UGV will help in inspection of specific areas with real time video transmission. It can be used to find the people in collapsed mines, buildings, and forest. Also maneuvering in congested and narrow places can be approached and monitored easily.

REFERENCES

1. V. Sezer, C. Dikilita, Z. Ercan, H. Heceoglu, A. bner, A. Apak, M. Gokasan and A. Mugan, Conversion of a conventional electric automobile into an unmanned ground vehicle (UGV), *IEEE International Conference on Mechatronics*, 564-569, **(2012)**
2. A. Bouhraoua, N. Merah, M. AlDajani and M. ElShafei, Design and Implementation of an Unmanned Ground Vehicle for Security Applications, *7th International Symposium on Mechatronics and its Applications*, 1-6, **(2010)**
3. A. Cadena, Development of a low cost Autonomous Underwater Vehicle for Antarctic exploration, *IEEE Conference on Technologies for Practical Robot Applications*, 76-81, **(2011)**
4. M. Yagimli and H. S. Varol, Mine Detecting GPS-Based Unmanned Ground Vehicle, *International Conference on Recent Advances in Space Technologies*, 303-306, **(2009)**
5. G. Zhang, C. Duncan, J. Kanno and R. Selmic, Unmanned Ground Vehicle Navigation in Coordinate-Free and Localization-Free Wireless Sensor and Acutuator Networks, *IEEE International Conference on Control Applications*, 428-433, **(2010)**
6. G. Zhang, C. A. Duncan, J. Kanno, and R. R. Selmic, Unmanned Ground Vehicle Navigation in Coordinate-Free and Localization-Free Wireless Sensor and Actuator Networks, *Journal of Intelligent & Robotic Systems*, **74(3)**, 869-891, **(2014)***and Technology*, **4(17)**, 2879-2886 **(2012)**
7. A. Ko and H. Y. K. Lau, Robot Assisted Emergency Search and Rescue System With a Wireless Sensor Network, *International Journal of Advanced Science and Technology*, **6(1)**, 121-128, **(2009)**
8. A. L. Rankin and L. H. Matthies, Passive sensor evaluation for unmanned ground vehicle mud detection, *Journal of Field Robotics*, **27(4)**, 473-490, **(2010)**
9. M. Ahsan, K. Abbas, A. Zahid, A. Farooq and S. M. Mashhood, Modification of a toy helicopter into a highly cost effective, semi-autonomous, reconnaissance unmanned aerial vehicle, *International Conference on Robotics and Artificial Intelligence*, 49-54, **(2012)**
10. V. Vantsevich, J. Gray, and D. Murphy, Fused Dynamics of Unmanned Ground Vehicle Systems, *SAE Int. J. Commer. Veh.* **7(2)**, 406-413, **(2014)**
11. K. Sailan and K. D. kuhnert, Speed Control of Unmanned Ground Vehicle for Non Autonomous Operation, *International Journal of materials Science and Engineering*, **3(1)**, 44-48, **(2015)**