# Design and Development of a Semi-Autonomous Military Fighting Vehicle

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***ABSTRACT:*** *Flexibility of unmanned vehicles can be enhanced by inclusion of adaptive control which enables devices maintain intelligent decisions in slightly changing environments without human aid. This project designs and implements a MRAC-adaptive control system for unmanned ground vehicles (UGVs). It also implements a cost effective communication system for the vehicles. This effective combination of control and communication yields smart unmanned vehicles for society, government and military. The developed vehicle is equipped with an object avoidance algorithm which is programmed on a microcontroller unit. The unit receives information via a sensor set strategically on the chassis of the vehicle, makes its decision by the programmed algorithm and effect this decision by the adaptive algorithm linked with the actuators on board. Results show intelligent navigation and rapid avoidance of collision. The developed model was tested and transition time of less than 15ms was achieved.*

***Keywords –*** *MRAC- Model Reference adaptive control, Object avoidance, photosensitivity, Radio frequency, Unmanned Ground Vehicle, Semi-autonomous.*

## I. INTRODUCTION

Unmanned vehicles are becoming increasingly widespread in numerous applications such as space exploration, surveillance, firefighting, mine clearance, environment sensing, search and rescue and even military operations round the world today [1]. Whether remotely piloted or autonomous, such systems offer abundant advantages, most especially by sparing human soldiers from performing wearisome or dangerous tasks. They most often operate without any on-board operator or human intervention and are broadly used in tasks where it is near impossible for a human to be present. They are commonly equipped with controller and on-board sensors to observe the environment and autonomously make decisions or pass off the information to a remote operator through some means of communication. Computer processing Advances in computer processing procedures, image processing, communication techniques and compactness have led to quick advancement in the field of autonomous vehicles. UGVs are now able to sense their environment using a variety of sensors [2]. They are able to capture, represent and interpret their environment and autonomously combine and manipulate this information through a series of control actions. Currently existing UGVs are either totally autonomous or operate manually autonomous. In this research an autonomous UGV was designed with a manual override which makes it operable either in total autonomous mode or total manual mode [3]. This makes the UGV semi-autonomous and hence called the semi-autonomous unmanned vehicle.

This Semi-Autonomous Unmanned Vehicle (SMUV) model is equipped with a controller that utilizes Radio Frequency module to navigate the vehicle by a human and on-board sensors to observe the environment and autonomously make decisions according to the information relayed from sensors to the on-board microcontroller through some means of communication.

In this research, a model was developed to investigate the smart algorithms useable to achieve semi-autonomy of the vehicle. The model is electrically powered, carries an ultrasonic sensor, electric microphones and receives commands via remote control with signal modifiers as shown in Fig 1. One unique feature of the developed SAUV is the designed signal processor incorporated in the system that enables it distinguish gunshot sound from other sounds in the environment. The SAUV is designed to move outdoors, in normal roads with small bumps, offering sufficient range control and autonomy. Following these procedures, a chassis was got (not constructed) which addressed the issue of mechanical strength and availability of DC motors.

Fig 1: PCB design of signal modification unit

## II. RESEARCH METHOD

The system was modelled with an electronic circuit which was designed to operate in a manual mode and an autonomous mode. The overall model was designed atomistically with smaller units linked up together to form the vehicle. The units include the communication system, the human machine interface (HMI), the obstacle avoidance algorithm, the sound tracking system, the light tracking system. Amplitude shift keying modulation scheme was used for communication which enables the model send relevant data based on its position and kinematics. Human machine interaction was only designed in the manual mode. A remote controller, comprising of an RF module operating at a frequency of 433MHz and has a range of about 400m was integrated into the game pad (with the transmitter module on the remote while receiver is on-board the vehicle) as a means of communication between remote and vehicle was used to achieve this purpose. The remote controller is used to enable manual mode driving on the system by implementing the algorithm shown in Fig 2. An RF module is a small electronic device used to transmit and/or receive radio signals wirelessly between two devices [4]. Object avoidance was implemented via an ultrasonic sensor mounted at the top of the vehicle. The ultrasonic sensors evaluate attributes of an object by interpreting echoes from sound waves, measuring the time interval between sending the signal and receiving the echo to determine the distance of an object. The system typically uses a transducer which generates sound waves in the ultrasonic range, above 20 kHz, by turning electrical energy into sound, then upon receiving the echo, turn the sound waves into electrical energy which can be measured and utilized by the system for its object avoidance function [5]. The output of the ultrasonic sensor is fed into the microcontroller. A threshold distance of 0.60m (determined in the code for the vehicle microcontroller unit) is fed to the micro controller and when the sensor senses the threshold distance the SAUV is made to turn or deviate from the obstacle depending on its position. The circuit design is shown in Fig 1. Three electret microphones mounted on the front and sides of the vehicle detect sound and amplify the sound. These form the input of the sound tracking unit. Three signal levels are set on the microcontroller: 0V, 1.5V and 3V. The three microphones are in the 0V state when there is no sound. When there is a sound source, the three microphones could sense it but not all amplify it to the same level. A comparator was designed for the microcontroller in the code written for it. The microphone that produces a full 3V output is taken as the direction of the sound source and hence the vehicle moves in that direction. Variable filters were added to the sound tracking algorithm to enable them track various specific sounds and an automatic light detector was added to the circuitry for navigating dark times and courses effectively.

## III. COMMUNICATION SYSTEM DESIGN

The communication system was designed, modelled and simulated before deploying the system for the control of the vehicle. An RF module was used for the communication. The RF module makes use of the Amplitude Shift Keying (ASK) or On and Off Shift Keying (OOK) modulation technique. The RF module was selected for its simplicity and its proven insusceptibility to noise for data rates below 100bits/s [6]. In addition, the module has a transmitting power of 25mW which is convenient for our design.

## IV. CONTROL SYSTEM DESIGN

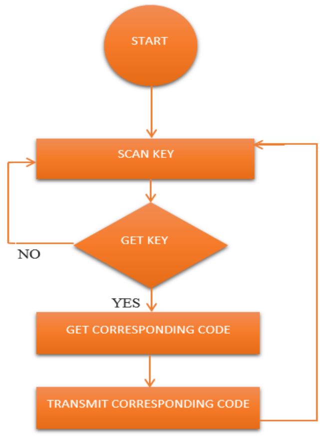


Fig 2: Control system algorithm for manual mode control.

For the control system, the vehicle was designed to operate in manual mode via a remote control and in an autonomous mode. In manual mode, A PIC16F876A microcontroller was programmed with some lines of instructions using the following algorithm and program flow chart for proper functioning. The unit starts the remote, scan the remote for any input, and get the entry from the control joystick, if no entry then it scans again but, if there is entry then it converts the entry into corresponding code, transmits the corresponding code and then rescans. In the autonomous control mode, The aim of this mode is to enable autonomous functioning and implementation of only a set of basic functions (which include sound detection, object avoidance and the LDR environment sensing/ switching system) of the SAMFV without human supervision on detection and continuous detection of the sound. To accomplish this, operation navigation technology such as, ultrasonic sensor, LDR/ light sensor and sound sensor (mic) is used to provide the on-board system (the PIC 16F877A microcontroller) enough data to operate as a self-navigating system. The ultrasonic sensors technology is used in this prototype to provide functional obstacle avoiding capabilities which augment the autonomous operation. The major tasks of the self-control mode are to:

1. Enable the vehicle to travel from point A to point B without any human navigation commands.
2. Adjust strategies based on surroundings using path planning and obstacle detection algorithms.

In other to ensure fast self-regulating movement, which implies self-calibration of the compensators for the control system, an adaptive controller was designed for servo motors which are the actuators used in the vehicle. The Matlab/Simulink model for the MRAC control is shown in Fig 3.

## V. OVERALL SYSTEM ARCHITECTURE

The SAMFV is built with the microcontroller (PIC16f877) as the main module and controller of the entire system (Fig 4). The microcontroller which is the brain of the vehicle is program to function in response to input from the remote and also to respond to the impulse sound source from its environment.

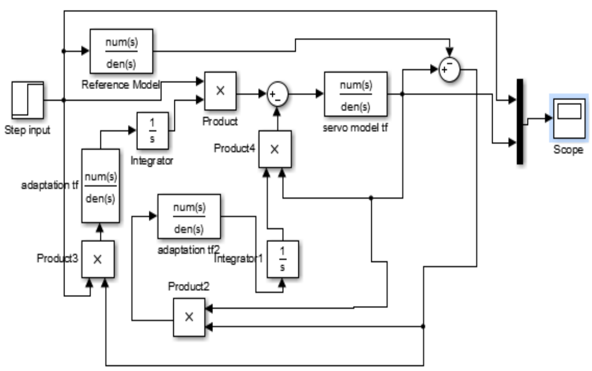


Fig 3: Matlab/Simulink MRAC model

The control diagram below illustrate the basic major component and their interconnectivity for the achievement of desired design specification

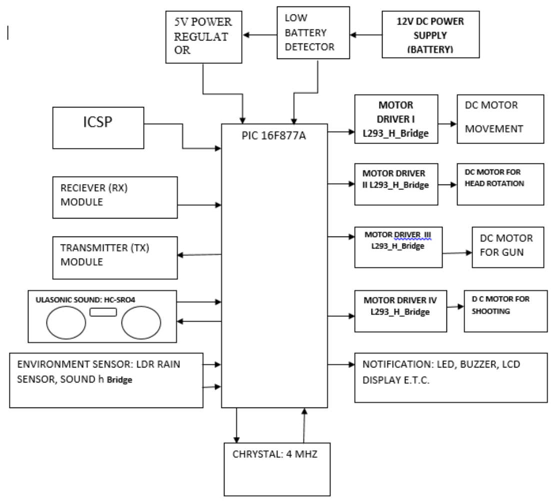


Fig 4: Overall system architecture for the vehicle

## VI. RESULT AND DISCUSSION

The systems were represented in Proteus Professional 8.1 and analyzed as shown in Figure 5 and Fig 6. This is necessary to ensure that the code written for the implementation of the hardware works as intended. The joystick of the remote controller was represented using voltage sources. The joystick which is used to give commands to the SAUV inputs three signal levels to the microcontroller which then determines what the vehicle's response is. The three voltage levels are 0V, 2.5V and 5V. Centre-pressing one of the joysticks is for switching modes from manual to autonomous or vice versa while center-pressing the other is for shooting.

The adaptive control compensator was observed to achieve a time response of 15ms (Fig 7) and this implies almost instantaneous tracking of the input command by the joystick.

The Light Emitting Diodes on the upper side of the microcontroller are used to represent the different motor movements of the wheels of the vehicle, main gun and turret. The lower LEDs are used to indicate a switch of mode from manual to autonomous mode. D5 and D7 staying on indicates to the human operator that the system is in manual mode while D4 and D6 being lighted means the system is operating in the autonomous mode.

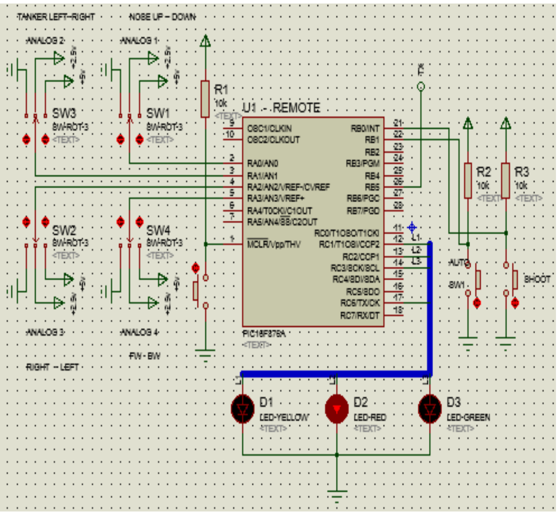


Fig 5: Simulation of manual mode remote controller

The voltage sources to the left of the microcontroller are used to represent the sound detecting circuit, as the output of the circuit has been found to be between 0V and 3V. A voltmeter is connected to the voltage source to indicate the output voltage. A buzzer is also integrated to provide an audio indication of a switch of modes. The shooting function of the system is represented by an LED that is placed on the hull and lights up when the 'shoot' button is pressed. The microphones are set to three signal levels: 0V, 1.5V and 3V. The initial state of each is the OV. The system will only move in the direction of the microphone with the signal level of 3V (the other two microphones will have 1.5V) as this signifies where the sound is coming from. This is so because if there is a sound source, all three microphones may sense the signal. But then how the system knows which of the sound sources to respond to is implemented in the code where a comparator is employed.

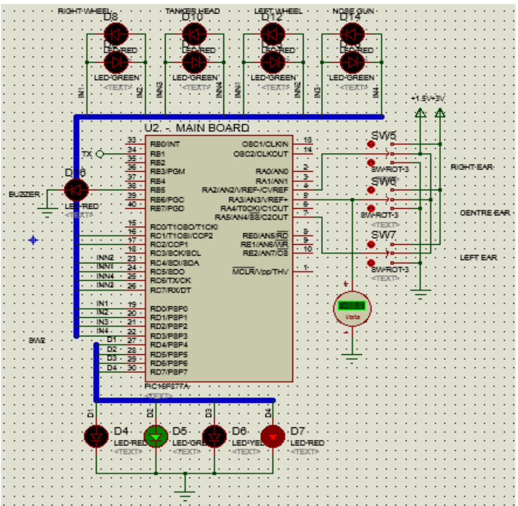


Fig 6: Simulation of microcontroller unit

The microphone circuit with the highest amplification level is the sound source. Figure 4 shows the SAUV operation while in autonomous mode. The voltmeter attached to the front microphone indicates a voltage level of 3V. This shows that the sound source is at the front of the SAUV. As can be seen, two green LEDs representing two wheels (right and left) are on which indicated that the SAUV is moving in the forward direction because the LEDs are forward biased. The complete SAUV is shown in Fig 8.

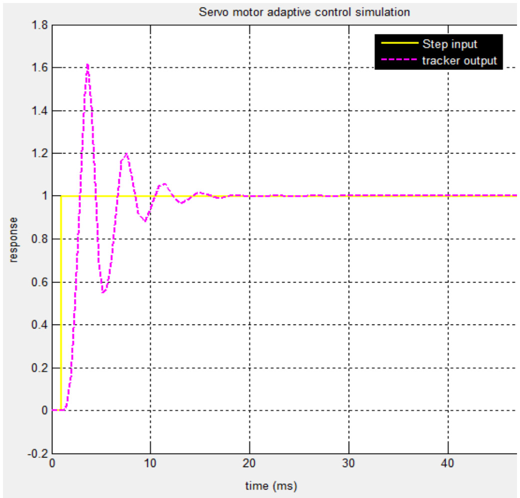


Fig 7: Simulation of MRAC showing response time

Fig 8: Fully developed vehicle during operation

## VII. CONCLUSION

This research presented the autonomous and manual operations of a Semi-Autonomous Unmanned Vehicle. It included intelligence such as object avoidance, sound detection, photo sensitivity, wireless communication and adaptive control. Additionally, new technologies could be investigated to improve mobility of the vehicle in unstructured and complex environments using better locomotion means and intelligent control systems.

## REFERENCES

[1] John Capp & Bakhtiar Litkouhi, "The Crash-Proof Car," IEEE Spectrum, 14 April 2014.

[2] D. Emery, "MoD lifts lid on unmanned combat plane prototype," BBC News, 2010.

[3] S. Mithileysh, " Unmanned Ground Vehicles" , Thesis at Visvesvaraya Technological University, 2011

[4] B. Pollet, Power Ultrasound in Electrochemistry: From Versatile Laboratory Tool to Engineering Solution, John Wiley & Sons, 2012.

[5] S. P. A.S. Peshkovsky, "Acoustic Cavitation Theory and Equipment Design Principles for Industrial Applications of High-Intensity Ultrasound," Hauppauge, NY, Nova Science Publishers, 2010.

[6] Sanjay, S. (2012). *Communication Systems (Analog and Digital).* New Delhi: Katson Books.