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An Rf-Based Control System for Limiting Vehicular Speed in Populated Area

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ABSTRACT

Many vehicle drivers violate the approved speed limit given by road traffic regulatory agency in populated areas and this has caused accidents leading to loss of lives and property. This paper presents the design and development of a control system that automatically reduces a vehicle's speed that has exceeded the approved speed limit in a given region. The system works with Radio Frequency communication between Radio Frequency Identification (RFID) cards that are coded with the approved speed limits and installed at different regions along the road, and an RFID card reader installed in the vehicle and connected to a microcontroller that controls the operation of the Electronic Control Unit (ECU) responsible for causing acceleration and deceleration of the vehicle. When a vehicle comes in contact with an RFID card, the RFID card reader decodes the coded speed limit and sends to the microcontroller to process. The developed system was installed in a robotic vehicle and when tested, the vehicle speed was maintained when it was lower than the approved speed limit. When it exceeded the limit, the ECU automatically reduced the vehicle speed to the approved limit.

1. INTRODUCTION

Over speeding is the major cause of many road accidents. In fact, the World Health Organization (WHO) has identified over speeding as a key factor in road traffic crashes, influencing both the risk of a crash as well as the severity of the injuries that result from crashes (Federal Road Safety Corps, 2014). To cut down road fatalities, WHO and the Global Road Safety Partnership recommended that speed limiters be introduced as part of the global strategy to cut down road fatalities (Global Road Safety Partnership, 2008) and this has since been used by developed countries as a means of eliminating road traffic crashes.

Over speeding occurs when a driver is travelling above the legal and permissible speed limit given by road traffic regulatory agency on any road (Akande, 2011), while inappropriate speed is defined as driving at a speed improper for the prevailing road and traffic conditions. Over speeding and inappropriate speed are the main causes of

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the high proportion of mortality and morbidity that result from crashes on the road (Federal Road Safety Corps, 2014). Over speeding reduces drivers' response time and ability to manoeuvre safely on the road, and extends the distance necessary to stop a vehicle. The higher the speed of a vehicle, the longer it would take for the driver to bring the vehicle to a stop in order to avoid a crash.

However, some drivers fail to admit that over speeding is also poor driving despite the fact that this is a contributory factor to hundreds of deaths and thousands of injuries every year. From the Federal Road Safety Corps (FRSC) Road Traffic Crashes (RTC) Data of the year 2012 in Nigeria, there was a total of 14,783 road traffic crashes involving 22,071 vehicles in 2012 that killed 6,573 people and injured 40,683 of which speed violation accounted for the highest causative factor of 35 percent, followed by loss of control and dangerous driving at 17 percent each (Federal Road Safety Corps, 2012). Similarly in 2013, analysis of the probable causative factor of Road Traffic Crashes recorded by FRSC revealed that speed violation (SPV) accounted for 32 percent of the total causes.

To reduce the growing trend of speed consequences which have dominated the country's RTC data, FRSC introduced the use of speed governors/limiters for all commercial vehicles.

1.1 Review of Existing Methods

Several methods have been employed both in road construction and vehicle design to limit the speed of vehicles on the road. On roads, speed bumps are constructed and sign boards indicating speed limit in a particular region are installed along the roadside. However, poor construction and lack of sign boards ahead of speed bumps have caused many road traffic accidents and crashes (Vanguard Newspaper, 2017; Payal, 2020).

In the area of vehicle design, the Adaptive cruise control system (Wang & Rajamani, 2004), Radar based Technology (Sivakumar & Mangalam, 2014), Infrared Technology (Gopal et al, 2014), GSM/GPRS Technology (Devikiruba, 2014) and RF transmitter/receiver system (Fatema et al, 2015) are used for speed control but these systems require human intervention to control the speed of the vehicle and are also affected by weather, line of sight, speed data, congestion and interference from nearby vehicles.

The RFID technology presented in this paper requires no human intervention to automatically control the vehicle speed and is not affected by weather, line of sight, speed data, congestion and interference from nearby vehicles.

2. METHODOLOGY

The proposed system controls the speed of a vehicle by automatically braking the vehicle to the required speed in that region. To achieve this, various technologies and principles were applied.

2.1 Electronic Throttle Control System (ETCS)

The electronic throttle control has no cable connection between the pedal and the throttle of the vehicle, it uses electronic signal to control the throttle. The system has three important parts: throttle pedal, throttle valve, and control module (Tim, 2020). The throttle body is fitted with an electronic servomotor and a throttle position sensor (TPS) (Benjamin, 2018).

When the pedal is depressed or released, the TPS measures how far the pedal is from its original position and sends electric signals to the engine management system (EMS). The EMS sends the information to the servomotor which adjusts the position of the throttle by opening or closing it according to the instruction from the servomotor. The throttle body controls the amount of air and fuel that flows into the engine which is indicated by how far the driver depresses or releases the pedal (Tim, 2020).

The ETCS does not only read input from the driver's foot on the pedal, but also examines input from the wheels, steering system and brakes helping to balance several factors that affect a car's speed and direction (Jamie, 2020).

2.2 Throttle Position Sensor (TPS)

The throttle position sensor (TPS) is equipped with two potentiometers each having its own power supply from the engine control unit (ECU). The potentiometer contains a carbon track which is connected to the power supply at one end and ground at the other. A slider connected mechanically to the throttle pedal slides over the carbon track picking the sensor voltage.

The TPS is fixed to the throttle body and connected to the ECU. It monitors the position of the throttle pedal and converts it into electronic signal which then initiates the opening and closing of the throttle valve. If the valve is wide opened, large amount of air is supplied to the engine and the output given by this sensor and other sensors is transmitted to the engine control unit which decides the amount of fuel to be injected into the engine.

2.3 Engine Control Unit (ECU)

Engine control unit is a form of electronic control unit, an embedded system that employs software to regulate series of actuators on an indoor combustion engine to guarantee best engine performance. It does this by reading information from different sensors within the engine, interpreting the information using multidimensional performance records, and regulating the engine actuators accordingly.

2.4 Radio Frequency Identification (RFID) Technology

Radio frequency identification (RFID) is a wireless radio communication technology that is used to uniquely identify tagged objects or people. There are three basic components of an RFID system: (i) A tag which is composed of a semiconductor chip, an antenna, and sometimes a battery. (ii) An interrogator (reader) which is composed of an antenna, an RF electronics module, and a control electronics module. (iii) A controller which takes the form of a personal computer (PC) or workstation running database and control software (Daniel, Albert, & Mike, 2007).

The tag and the interrogator transfer information between one another via radio waves. When a tagged object enters the read zone of an interrogator, the interrogator signals the tag to transmit its stored data. Tags can hold many kinds of information including serial numbers, time stamps, and configuration instruction. Once the interrogator has received the tag's data, the information is relayed back to the controller via a standard network interface, such as an Ethernet LAN or even the internet. The controller then uses the information for variety of purposes. A single interrogator can connect with more than one tag simultaneously.

Radio Frequency Identification technology can be used in various applications such as logistics, medical science, security, access control (Eswaramoorthy & Arunkumar, 2014). The benefit of RFID is its low cost for tags and can be attached to the traffic signals easily.

2.5 Pulse Width Modulation (PWM)

Pulse width modulation (PWM) is the simplest method used in many DC motor controlling applications (Nandkishor & Ajay, 2012). The speed of the motor depends on the value (which is usually between 0 and 255) passed to the analog WRITE function of the microcontroller. If 0 is passed, the motor stops and if 255 is passed, the motor will run at full speed. If a value between 1 and 254 is passed, the speed of the motor will vary accordingly (Fatema et al, 2015).

PWM involves the generation of binary signals which have two (2) periods-HIGH and LOW. The width (W) of each pulse varies between 0 and period (T). The main principle is control of power by varying the duty cycle thereby controlling the conduction time to the load (Fatema et al, 2015). If time t_1 is the input voltage across the load (i.e., ON) and time t_2 is the voltage across the load (i.e., OFF), then.

$$\text{The average voltage output (Va)} = \text{Vmax x Ia} \quad (1)$$

Where V_{max} = Maximum output voltage, I_a = average load current

$$\text{The average load current Ia} = \frac{\text{Va}}{\text{R}} = \frac{\text{kVs}}{\text{R}} \quad (2)$$

Where R = resistance, V_s = supply voltage

$$\text{Total time period (T)} = \text{t1} + \text{t2} \quad (3)$$

Where t_1 = Time period for pulse ON, t_2 = Time period for pulse OFF

$$\text{Duty cycle, (k)} = \frac{\text{t1}}{\text{T}} \quad (4)$$

The duty cycle (k) can be varied from 0 to 1 by varying t_1, T or frequency (f). Hence, the output voltage (V_o) can be varied from 0V to the supply voltage by controlling k. As time t_1 changes, the width of the pulse varies and this type of control is called pulse width modulation (Fatema et al, 2015).

Driving the brushed DC motor in both directions by reversing the current through it can be achieved using the full-bridge circuit (Nandkishor & Ajay, 2012). It consists of four switches in an arrangement that resembles a H. By controlling different switches in the H-bridge, a positive, negative, or zero potential can be placed across a load which corresponds to forward, reverse and off for a motor (Gopinath & Arikesh, 2013).

The four switches in the H-bridge correspond to HIGH side left, HIGH side right, LOW side left, LOW side right. Table

1 shows the four possible positions that can be used to obtain potential across the load. For any other position, the power would be short to ground causing damage to the device or draining the power supply.

The switches used to implement the H-Bridge can be mechanical component or solid-state transistors. Implementing the circuit using only N-Channel MOSFETs lowers the ON resistance resulting in reduced power loss but this will require FET drivers because to turn ON a HIGH side, you need a voltage higher than the switching voltage. This difficulty is often overcome by driver circuits capable of charging an external capacitor to create additional potential (Gopinath & Arikesh, 2013).

Table 1: Valid H-Bridge Switching States

High Side Right	High Side Left	Low Side Right	Low Side Left	Potential Across Load
OFF	ON	ON	OFF	Positive
ON	OFF	OFF	ON	Negative
ON	ON	OFF	OFF	Zero Potential
OFF	OFF	ON	ON	Zero Potential

2.6 Implementation

The block diagram of the RF-based control system for limiting vehicular speed is shown in Figure 1. The system is implemented using a robotic vehicle. RFID cards or identification tags are coded with the approved speed limits and installed at different regions along the road.

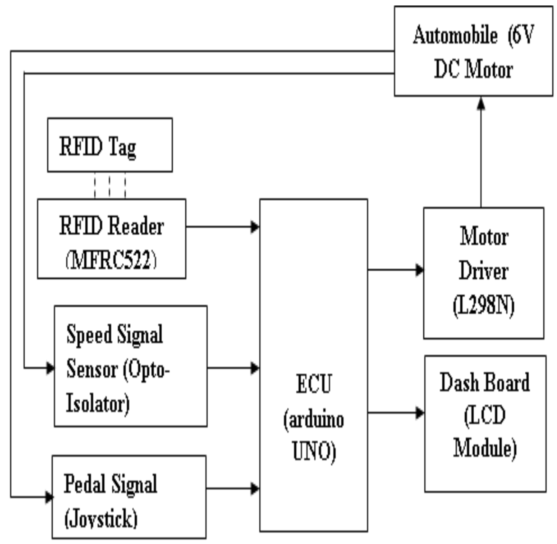

Figure 1: Block diagram of the RF-based control system for limiting vehicular speed

Figure 2 shows the RFID cards used. An RFID card reader is installed in the vehicle and connected to an Arduino Uno microcontroller that controls the operation of the Electronic Control Unit (ECU) responsible for causing acceleration and deceleration of the vehicle. When the vehicle comes in contact with an RFID card, the RFID card reader decodes the coded speed limit and sends to the microcontroller to process.

Figure 2: RFID Cards

The speed of the automobile is varied according to the accelerator's pedal position (joystick position). The variation in the pedal position is fed to the ECU. The ECU determines the position of the throttle based on the accelerator's pedal position and the inputs received from the other sensors.

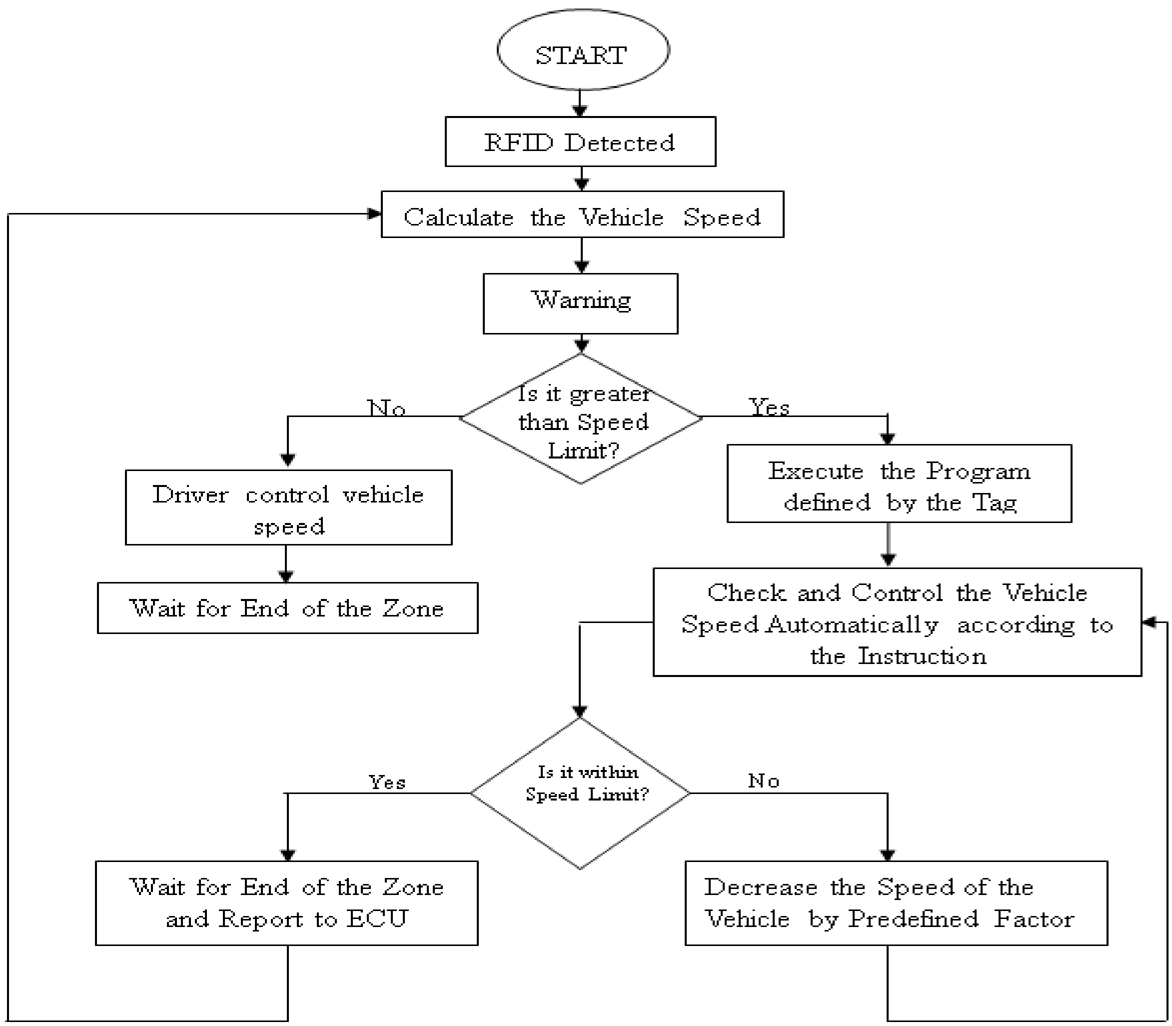

Figure 3: Program flowchart

Adjustment of throttle position causes the change in the vehicle's speed. The microcontroller reads the speed of the vehicle from the potentiometer (speedometer sensor) and compares it to reference speed in the Arduino code. If the vehicle exceeds the speed limit specified in the RFID card, the microcontroller activates the ECU which automatically adjusts the throttle position in order to force the speed of the vehicle to reduce. The vehicle starts to decelerate until the vehicle speed is equal to the reference speed. Each time the accelerator pedal is engaged to increase the speed, the microcontroller calculates the speed that would be reached on the new pedal position. If the speed is greater than the maximum speed limit, then it denies excess speed and gives appropriate signal to the ECU to keep the speed within limits. The program flowchart is shown in Figure 3.

The circuit diagram of the RF-based control system for limiting vehicular speed is shown in Figure 4.

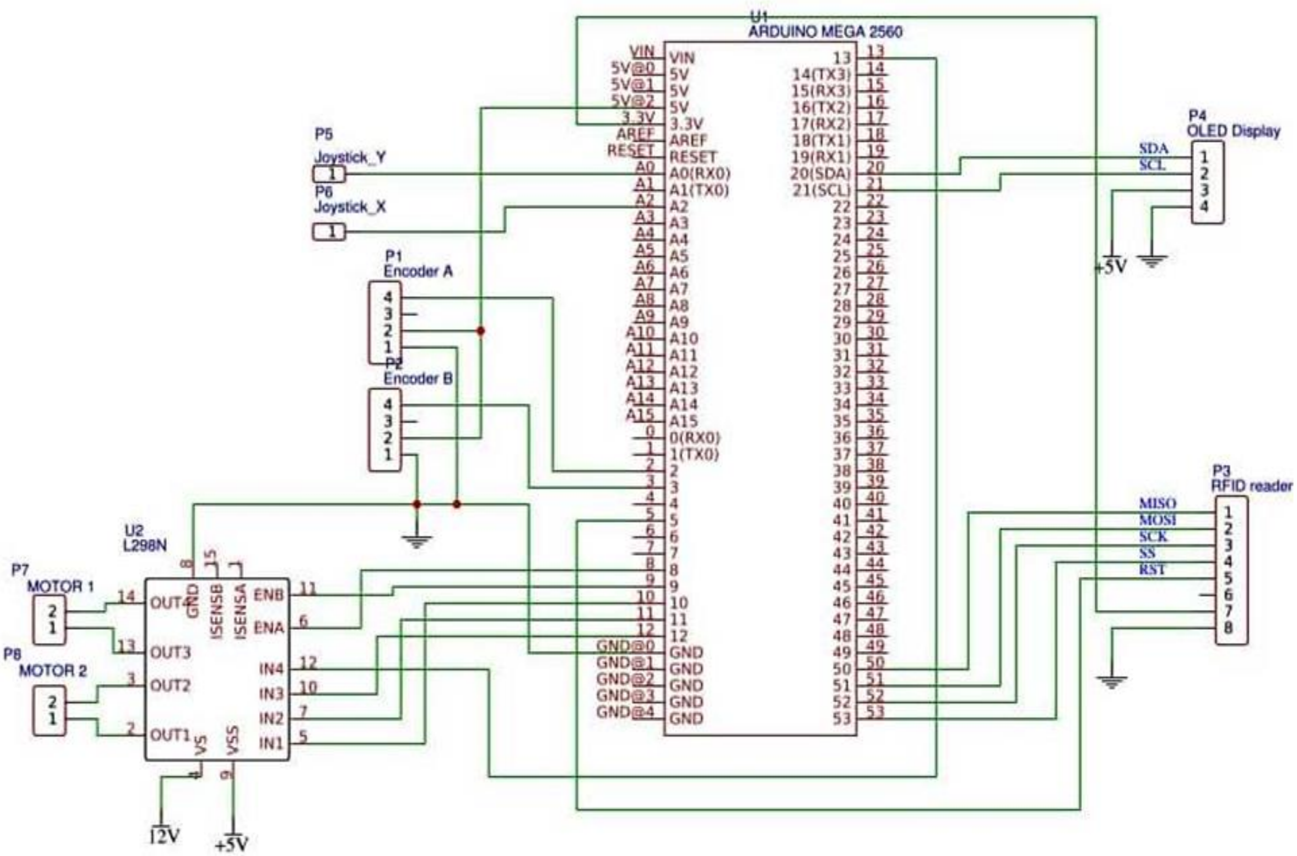

Figure 4: Circuit diagram of the RF-based control system for limiting vehicular speed

3. TESTS AND RESULTS

Figure 5 illustrates how the programmed RFID tags are placed on the robot car path while Table 2 shows the results and observations during implementation. We used 0.28 m/s on the laboratory floor to represent 1 km/h on the actual road.

Figure 6 shows the result displayed when there is speed violation (driver driving at 99 km/h while the speed zone is 30 km/h). The warning messages “Critical area” and “Slow down” together with the vehicle speed were displayed until the vehicle speed is reduced to within the speed limit. During this period, the joystick was interrupted, and the speed of the robot car could not be increased manually until the speed becomes less than 30 km/h.

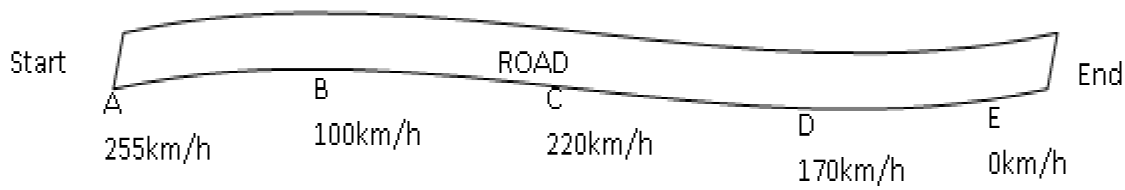

Figure 5: Robot car path with RFID tags at different location

Table 2: Results/Observation at different zones

Zone	Speed limit Km/h	Observation	
		With joystick (Manual)	With Arduino (Automatic)
A	255	We were able to vary the robotic car speed between zero and full speed until we arrived at zone B.	No action
B	100	We were able to reduce the speed from 255km/h to 100km/h and beyond but could not increase the speed above 100km/h until we get to zone C.	30s after the warning message, the robot car speed reduced from 255km/h to 100km/h without using the joystick.
C	220	We were able to increase the speed from 100km/h to 220km/h but not above it.	No action
D	170	We were able to reduce the speed from 220km/h to 170km/h and beyond but could not increase the speed above 170km/h even when the joystick was pushed to the far end.	30s after the warning message, the robot car speed reduced from 220km/h to 170km/h without using the joystick.
E	0	We were able to reduce the speed to 0km/h but unable to move the vehicle.	30s after the warning message, the robot car speed reduced from 170km/h to 0km/h without using the joystick.

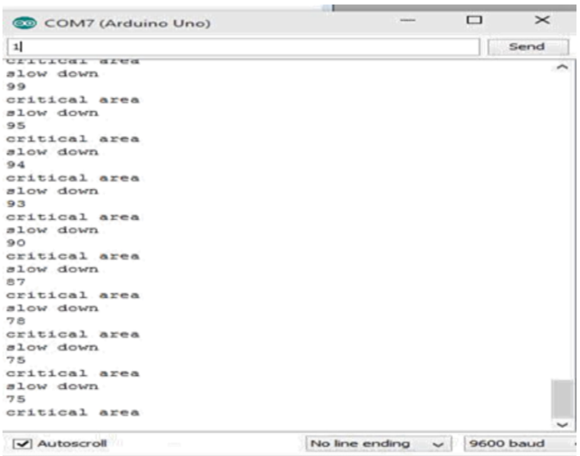

Figure 6: Result displayed when there is speed violation.

Figure 7 shows the test result when there is no speed violation (driver driving at 28 km/h while the speed zone is 30 km/h). The vehicle speed and the message "Speed Controlled" were displayed.

Figure 7: Result displayed when there is no speed violation

The pictorial view of the developed robotic vehicle is shown in Figure 8.

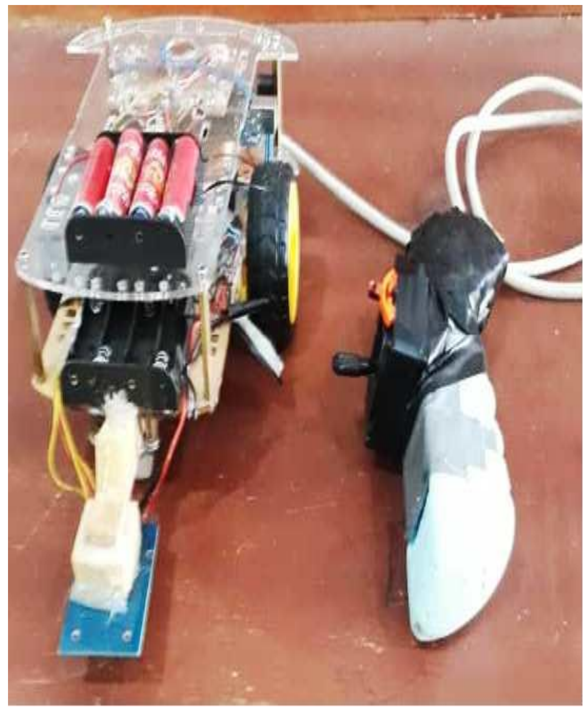

Figure 8: Pictorial view of the developed robotic vehicle

4. CONCLUSION

This research work focuses on the design and development of a control system that automatically reduces a vehicle's speed that has exceeded the approved speed limit in a given region. From the results obtained as presented in Table 2 and Figures 6 and 7, the developed RF-based control system was able to achieve the desired aim of automatically reducing the speed of a moving vehicle to the approved limit when the vehicle exceeds the speed limit. When properly implemented, this system will help to reduce incidences of road traffic crashes that are caused by speed violation.

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