AUTONOMOUS ROBOTIC CAR WITH OBSTACLE DETECTION AND AVOIDANCE

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Abstract

An autonomous robotic car that has the ability to control its direction on detecting an obstacle. This paper gives a report on design and construction of an autonomous robotic car that has the ability to control its direction when an obstacle is detected. The car has been designed and built typically using a PIC16F84A microcontroller, and ultrasonic sensors deployed for obstacle detection and avoidance. The robot gets its information from is immediate environment with the help of the sensor fixed robot. The input signal received via the sensor is transmitted to the microcontroller for interpretation and control. Change of direction is done by the robot by making 90˚or 180 ˚turn to look for a free space to avoid the obstacle and resume its normal direction is achieved by triggering the motors which are done through a motor driver. Ultrasonic sensor was chosen to be more appropriate for the obstacle detection function because of its high ranging capability. The Ultrasonic sensor is made up of two parts which are the emitter and the detector. The emitter produces 40KHz sound wave and detector detects 40KHz sound wave and emits frequency signals. When obstacle is detected, these signals are reflected back which serve as input to the microcontroller. The microcontroller controls in different direction either left, right or front based on the signal received from the ultrasonic sensor. The car has been built to sense obstacles within 400m range, and move in accordance with the code programmed on it, it would move in a straight direction and if it senses any obstacle in its way it would check for a free space and avoid the obstacle.

Keywords: autonomous, robot, ultrasonic sensor, obstacle detection, microcontroller.

Introduction

A robot is seen as a machine of the modern day with improved technological advancements and robotics is one of the subfields of mechatronics and artificial intelligence. It is a considered to be a mechanical/virtual artificial agent, usually a goal driven machine, an electro-mechanical machine that is being run based on series of computer programs or electronic circuitry. This work however, focuses on autonomous vehicles which belong to the class of mobile robots.

Mobile robots achieve obstacle detection using ultrasonic sensors. As the name indicates, ultrasonic sensors measure distance by using ultrasonic waves. The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. Ultrasonic Sensors measure the distance to the target by measuring the time between the emission and reception.

Unlike human beings, robots do not know fatigue and can work round the clock. Deployment of the kind of robot discussed in this paper in certain sectors such as agriculture, manufacturing industries and home care assistance can help a great deal to revamp the economy of our country Nigeria. The obstacle avoidance robot would be useful in the various places like the industrial area where less supervision is needed and prevent the risk of human being getting hurt at hazardous work sites.

Electronics have found their place into the development and the initiation of the first electronic autonomous robots produced in Bristol England by William Grey Walter in the year 1984, also the first digital and programmable robot was invented and named Unimate in the year 1954 by George Devol. Sumit Garethiya in his dissertation, "the first ever system to detect an obstacle was developed by Delco System operations, Goleta of California in 1988". The study was mainly a safe way to spot obstacles on the road and then inform the motorist.

As many believe, autonomous robotic cars are this new big change everyone is talking about, leading not only to high impact environment benefits such as the improvement of the economy (Payre et al., 2014), (Luettel et al., 2012), (Levin et al., 2015), (Harnish Jamson et al., 2013), (Merat et al., 2012), but also the reduction of required cars to only 15% of the current amount needed (Ross, 2014). This would save 20-30% fuel consumed and also lead to improvement in other social aspects such as immense productivity gains while commuting, decline on the accident and death tolls considered as the eight highest death cause worldwide in 2013 (World Health Organization,2013) and the decline of parking space up to ¼ of the current capacity (Alessadrim, et al., 2015). It would also, according to a study by Morgan Stanley (2013) lead to an average 38 hours reduction of commuting time per individual per year.

How Robotic Car Works

Human beings on a basic level are made of five major components:

A muscle system that can move the body structure, a body structure itself, a power source that can activate the muscles and sensors, a sensory system which can receive information about the body and the surrounding environment, and a brain system which can process sensory information and tell the muscles what to do.

Robots are made up of the same components as above. A typical autonomous robot has a sensory system, a movable physical structure, a power supply and a processor that controls all of these elements. Basically, robots are man-made versions of the animal life. They are machines that can replicate human and animal behavior.

The Actuator

All robots have a movable body (almost all). Some have motorized wheels only, while others may have a dozen of movable parts (that are typically made of plastic or metal). Like bones in a human body, the individual segments are connected together with the help of joints. Robots use actuators to spin wheels and jointed pivot. Some robots use solenoids and electric motors as actuators; some use a pneumatic system (a system driven by compressed gases); yet others use a hydraulic system. A robot may even use all of these actuator types together. Robots need a power source to be able to drive the actuators. Most robots have a battery or they are plugged into an electricity source.

Robot Learning

Robot learning is an intersecting research field between robotics and machine learning. It studies techniques that allow robots to acquire skills and adapt to its environment by learning various algorithms. Learning can take place either by self-exploration or through guidance (from a human teacher), like in robot learning that learns by imitation.

Autonomous Robot

Autonomous robots are independent of any controller and can act on their own. The robot is programmed to respond in a particular way to an outside stimulus. The bump-and-go robot is a good example. This robot uses bumper sensors to detect obstacle. When the robot is turned on, it moves in a straight direction and when it hits an obstacle, the crash triggers its bumper sensor. The robot uses a programming instruction that asks the robot to back up, turn to the right direction and move forward. This is its response to every bump. In this way, the robot can change direction every time, it encounters an obstacle.

Some mobile robots also use various ultrasound sensors or infrared to see obstacles. These sensors work in a similar fashion to animal echolocation. The robot sends out a beam of infrared light or a sound signal. It then detects the reflection of the signal. The robot locates this distance to the obstacles depending on how long it takes the signal to bounce back.

Materials and Method

The design of obstacle avoidance robotic car needs the integration of many components like the ultrasonic sensor, microcontroller, diodes, motor drivers IC, DC Motors etc. according to their task.

The autonomous robotic car was designed to operate in two modes; the manual mode and the automatic mode. One can switch through the different modes using a remote control that was designed to work with radio frequency, having control buttons labeled A,B,C,D. Long-pressing the C button in the remote-control switches between the manual mode and the automatic mode.

Manual Control Mode

When the car is powered, it is automatically in the manual mode. The A and D button represents the front control and back control while the B and the C button represents the right and left control. When A is pressed, the back motor is activated in the forward direction and when D is pressed the back motor is activated in the backward direction(anticlockwise). Motors have the ability to go in clockwise or anticlockwise based on the polarity. With this, we are able to get the forward and backward movement of the vehicle. The automatic changing of the polarities is done by a relay. When any of the buttons is pressed, the relay switches to the appropriate position causing change in polarity which in turn makes the motor to move either in clockwise or anticlockwise direction

Automatic Control Mode

In the automatic mode, the microcontroller and the two ultrasonic sensors mounted on the top of the car helps in making the decision for the forward, backward, left and right movement of the car. When the C button is long pressed, the system automatically switches to automatic mode. The ultrasonic sensor is activated immediately and with the help of the microcontroller, checks to know if there is any obstacle.

During the test of functionality, if there is obstacle at the front left and no obstacle at the back and front right, the car will decide to move left. If there is obstacle at the left and there is none at the right, it goes right. If there is obstacle at the two sides and there is no obstacle at the back, it goes back. If there is obstacle everywhere, the vehicles stay in a place and starts indicating with the buzzer. The ultrasonic sensors check the front-left, front-center, front-right, side-right, back-left, back-center, back-right and side-left.

The autonomous robotic car comprises the following units which include; the transmitter, receiver, power supply, microcontroller, obstacle detection, switching , and DC motor units.

The Transmitter Unit

The transmitter unit consists of the RF transmitter module, consisting of a 434MHz license-exempt Transmitter module and an encoder IC. It was designed to remotely switch simple appliances on and off. The RF part consists of a standard 434MHz transmitter module, which works at frequency of 433.92MHz and has a range of about 400m according to the manufacture. The transmitter module has four pins. Apart from “Data” and the “VCC” pin, there is a common ground (GND) for data and supply. Last is the RF output (ANT) pin.

Note that, for the transmission of a unique signal, an encoder is crucial. For this, a renowned encoder ICHT12E from Holtek has been used. HT12E is capable of encoding information which consists of N address bits and 12N data bits. Each address/data input can be set to one of the two logic states. The programmed addresses/data are transmitted together with the header bits via an RF transmission medium upon receipt of a trigger signal. Solder bridges TJ1 and TJ2 are used to set the address and data bits.

The current consumption with a supply voltage of near 5.4V is about 10mA. Since the current consumption is very little, the power can also be provided by standard button cells. Recommended antenna length is 17cm for 433.92MHz, and a stiff wire can be used as the antenna.

The Receiver Unit

This circuit complements the RF transmitter built around the small 434MHz transmitter module. The receiver picks up the transmitted signals using the 434MHz receiver module. This integrated RF receiver module has been tuned to a frequency of 433.92MHz, exactly same as for the RF transmitter. The receiver module has eight (4+4) pins. Apart from three “ground (GND)” and two “VCC” pins, there are two pins (one for Digital Data & other for Linear Data) for data output. Last is the RF input (ANT) pin. The pins are labeled as follows;

1. Antenna, 2. Ground, 3. Ground, 4. VCC, 5. Linear Data (Normally NOT used),
6. Digital Data (Normally Used), 7. Ground.

The “coded” signal transmitted by the transmitter is processed at the receiver side by the decoder IC HT12F from Holtek.VR1 and R1 are used to tweak the oscillator frequency of the decoder to that of the transmitter. Any possible variations due to component tolerances and/or a different supply voltage can be compensated by this arrangement. HT12F is capable of decoding information that consist of N bits of address and 12N bits of data. HT12F decoder IC receives serial addresses and data from the HT12E encoder that are transmitted by the RF transmitter module. HT12 compare the serial input data three times continuously with the local addresses.

If no error or unmatched codes are found, the input data codes are decoded and then transferred to the output pins. The “Valid Transmission” (VT) pin also goes high to indicate a valid transmission.

For proper operation, a pair of HT12E/HT12F ICs with the same number of addresses and data format should be chosen. The data bits are setup using solder bridges RJ1 and RJ2. Output of the decoder is brought out on a pin header KI, making the logical signal available to circuits that need it. This output is also fed to the relay driver transistor T1. The RF Receiver circuit can be powered from a standard 5VDC supply. Just as for the RF Transmitter, the aerial (17cm for 433.92MHz) has to be mounted as close as possible to the RFIN (ANT) pin of the 434MHz RF receiver module.

Results and Discussion

The Power Supply Unit

The power supply unit is made up of a 12v rechargeable battery which supplies the precise electromotive force (emf) required to drive electrical current round the circuit. It is also made up of a 5v regulator circuit which supplies emf to the micro-controller.

The Microcontroller Unit

The microcontroller serves as the reasoning chamber of the system. The output of the microcontroller controls other parts of the circuit from a processed data received from its input section as shown in figure. 3.1.

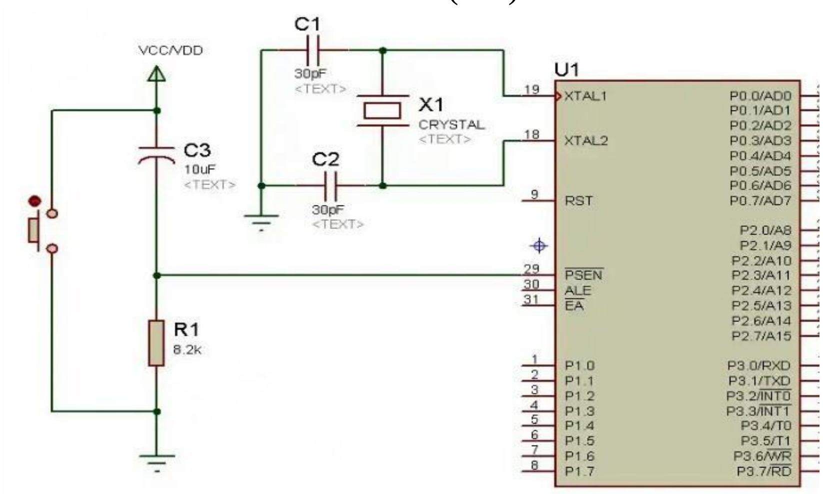

Figure 3.1 Configuration of the microcontroller

The Obstacle Detection Unit

The obstacle detection unit is achieved using an ultrasonic sensor. As the name indicates, ultrasonic sensors measure distance by using ultrasonic waves.

The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. Ultrasonic Sensors measure the distance to the target by measuring the time between the emission and reception.

Detection Principle

An optical sensor has a transmitter and receiver, whereas an ultrasonic sensor uses a single ultrasonic element for both emission and reception. In a reflective model ultrasonic sensor, a single oscillator emits and receives ultrasonic waves alternately. This enables miniaturization of the sensor head.

Distance Calculation

The distance can be calculated with the following formula: Distance $L = 1/2 \times T \times C$

Where L is the distance, T is the time between the emission and reception, and C is the sonic speed. (The value is multiplied by ½ because T is the time for go-and-return distance.).

The following list shows typical characteristics enabled by the detection system.

- **Transparent object detectable**

Since ultrasonic waves can reflect off a glass or liquid surface and return to the sensor head, even transparent targets can be detected.

- **Resistant to mist and dirt**

Detection is not affected by accumulation of dust or dirt.

- **Complex shaped objects detectable**

Presence detection is stable even for targets such as mesh trays or springs.

The Switching Unit

This comprises of transistor and relay logic which serves as a switch to ON/OFF the DC motor. It uses BC547 transistor to boast the signal from the microcontroller. The transistor in this section serves as both amplifier and a switch because it amplifies the voltage that switches the relay on.

Relay

Relays are the switches which aim at closing and opening the circuits electronically as well as electromechanically. Relays are switches that open and close circuits electromechanically or electronically. Relay control one electrical circuit by opening and closing contacts in another circuit. When a relay contact is normally open (NO), there is an open contact, when a relay contact is Normally Closed (NC), there is a closed contact This is applicable when the relay is not energized. In either case, applying electrical current to the contacts will change their state.

Relays are generally used to switch smaller currents in a control circuit and do not usually control power consuming devices except for small motors and Solenoids that draw low amps. Nonetheless, relays can "control" larger voltages and amperes by having an amplifying effect because a small voltage applied to a relays coil can result in a large voltage being switched by the contacts.

Protective relays can prevent equipment damage by detecting electrical abnormalities, including over current, undercurrent, overloads and reverse currents. In addition, relays are also widely used to switch starting coils, heating elements, pilot lights and audible alarms.

The relay is made up of the following parts:

1. The coil
2. The common
3. The normally closed
4. The normally open.

When the coil of a relay is energized, the common moves from the normally closed to the normally open, putting the relay to its ON state

DC Motor

Generally, an electric motor is a machine that converts electrical energy into mechanical energy, and uses the electricity generated to produce rotational motion and thereby to do work.

While there are many different types of motors, this work focuses on use of DC motors, which are electric motors driven by direct current (DC).

DC motors are used in a wide variety of different devices and appliances that play a part in our lives.

Schematic Diagram

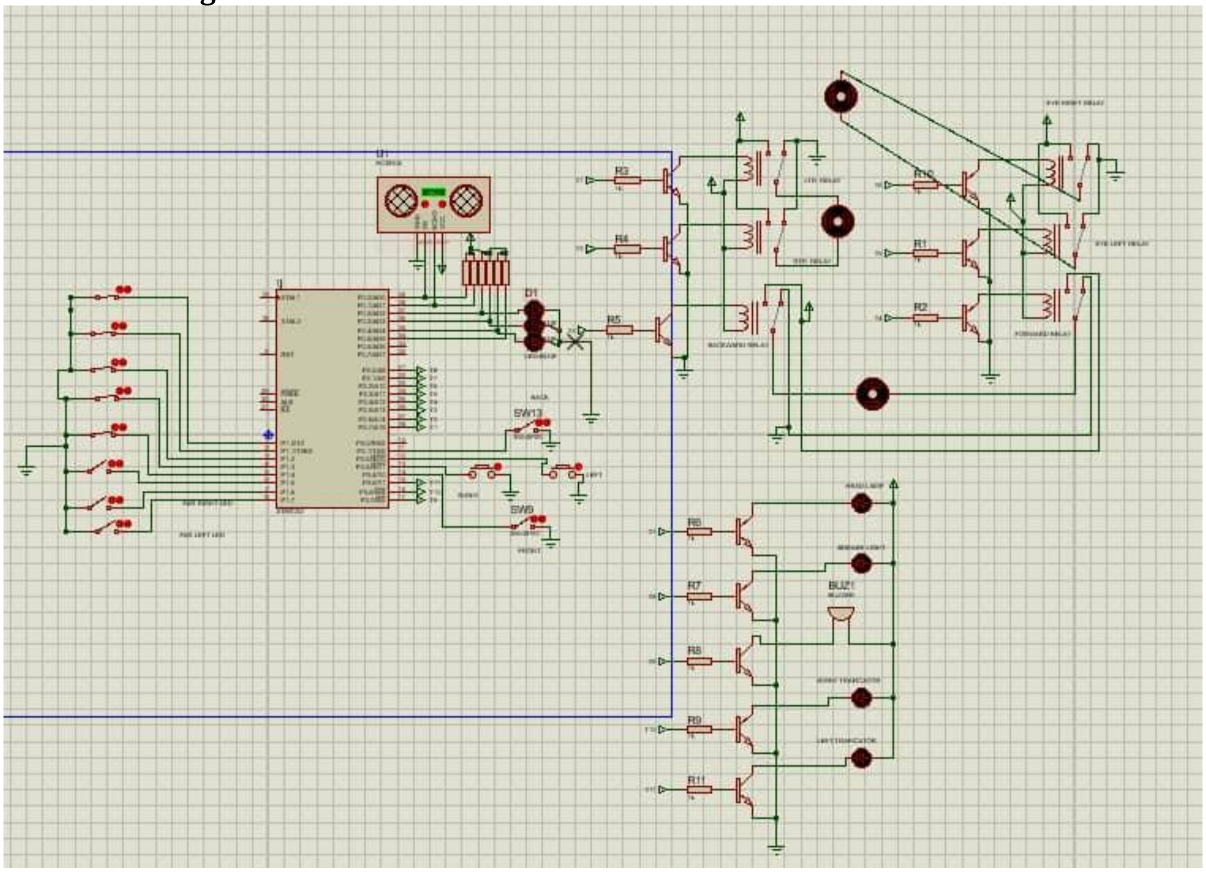

Figure 3.2 Circuit diagram of autonomous robotic car with obstacle detection and avoidance

This circuit in figure 3.2 contains two ultrasonic sensors, the front motor and the back motor, microcontroller, trafficator lights, alarm system, etc. The two ultrasonic sensors are connected together in parallel and then connected to the port 0.0 and port 0.1 of the microcontroller. The positive pin of U1 and U2 were sent to +5v while the negative pin of U1 and U2 were connected together and sent to the ground. Push buttons were connected to P3.1, P3.2, P3.3 and P3.4. These buttons signify the forward movement, backward movement, left movement and right movement. Relay RL10 and RL2 controls the left and right turning of the ultrasonic sensor while the transistor Q10 activates RL10 through resistor R10. R10 is connected to the P2.0 of the microcontroller while R1 is connected to P2.1 of the microcontroller and this powers Q1 which in turn powers RL1. When signal is sent to the P2.1, the signal is sent to the RL1 through R1 and this powers RL1 leaving RL10 low. Also, when signal is sent to the P2,0, the signal is sent to the RL10 through R10 leaving RL1 low.

Obstacle Detection and Aviodance Algorithm

The algorithm for obstacle detection and avoidance is outlined as follows;

Step one:

The automatic mode is activated by the remote control

If (C button is long-pressed) {
Automatic mode is activated;
} Else {
Continue with manual mode;}
Step two:
Ultrasonic sensor checks for obstacle by turning 360
If (obstacle at the front = 0)
Move forward;

Else if (obstacle at the back = 0)
Move backward;
Check 360 for obstacle;

Else if (obstacle at left = 0)
Move left;
Else if (obstacle at right = 0)
Move right;
Else (Activate Buzzer);

Repeat Step two

The first thing in the program is that the car automatically enters the manual mode when it is powered. The manual mode is when the car is being controlled with a remote control to go left, right, front and back. The car keeps checking for the signal to activate the automatic mode. If no signal is sent, the car continues to be in the manual mode. But when a signal is sent by long-pressing the C button on the remote control, the car automatically switches to automatic mode.

The next step is that the ultrasonic sensor turns 180 degrees to check for obstacle. There are two ultrasonic sensors connected back-to-back so that the ultrasonic sensors will be able to cover 360° of its view after which the ultrasonic sensors move back into position and then makes decision.

The next step is the decision-making process. The first step in decision-making is to check based on the data gathered when the ultrasonic sensor was turning around to check for obstacle whether there is obstacle at the front. If the data gathered shows that there is no obstacle at the front then the car continues moving forward. If the result shows that there was actually obstacle at the front then the car check if there was an obstacle at the back. If there was obstacle at the back the car does not go backwards instead it checks if the was obstacle at the left but if there was no obstacle at the back the car goes backwards for three seconds and then recheck again that is turned 360 again to check for obstacle and then make decision again but that is if there was no obstacle at the back. If there was an obstacle at the back then it checks the gotten data if there was obstacle at the left and goes left if there is none but if there is it finally checked right still on the data gotten when the ultrasonic sensor was moving 360 now checking right round seeing that there is obstacle everywhere the car does not move at all instead it sounds an alarm to simulate the horn of the car that there is obstacle everywhere.

After this, the microcontroller restarts the whole operation again but it is a point to note that when the car is going forward it keeps turning left and right only that is watching the left front and the right front as it goes forward.

Packaging

After the construction and final testing of the autonomous robotic car, choice of packaging was made with due consideration to cost and durability. Perspex material was used to build the wind screens while plastic and soft wood materials were used to fabricate the body of the car as shown in figure 3.3.

Figure 3.3: Snapshot of the Autonomous Robotic Car (Nwokolo C.P. and Nwankwo V.I. 2022)

Several running tests were made to verify the capability of the robot. The first test run was done by drawing strips of black line and the robot could follow the line. In these contests of autonomous path finder obstacle e.g. encountering a block in the path, the robot avoids them by choosing an appropriate path and reach their final destination from initial destination easily. It was found that the robot satisfactorily detected the block. The third test run was done by placing an obstacle e.g., a block. It was found that the robot satisfactorily detected the block. The fourth test run was done and moving the robot towards the edge which it detected and hence changed its route.

Conclusion

As was demonstrated in this work, many different obstacle avoidance techniques were examined, and a unique approach based loosely on other people's work was adopted based on carefully chosen algorithm to successfully design and build the autonomous robotic car. In order to improve on this algorithm more testing in the field needs to be done. More testing would allow one to try different exit angles from the path and different return angles to the path, finding the optimal solution. More testing would also demonstrate the robustness of the algorithm. The obstacle filter, which was a novel approach to combining global and local obstacle avoidance, can be improved to try and take out spurious data. Some improvements could be pattern recognition; examining the filter map and determining if a cluster of cells is dust (spurious data) or an actual obstacle. This avoidance algorithm could also be used in other autonomous vehicle research, such as the omni-directional vehicles being developed by Utah State University. The algorithm would have to be adapted to the specific robot function, but the basis for the algorithm stays the same.

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