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Sergey Y. Yurish



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Development of Single Place Multiple Obstacle Avoidable System for Guarded Tele-operated Trolley, a Service Robot Using Single Ultrasonic Sensor

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Abstract: This paper depicts the development of single place multiple obstacle avoidable system for a guarded tele-operated trolley-service robot. A guarded tele-operated mobile robot is that which must have the ability to sense and avoid obstacles but otherwise it will navigate as driven, like a robot under manual tele-operation. The configuration of the system consists of ultrasonic sensor, signal conditioning circuits, radio communication module, controller, and actuators. The Obstacle avoidance algorithm is developed based on physical realization of the requirement. The ultrasonic switch is designed to sense the front obstacle of the robot. An AT89C52 microcontroller is used in order to receive the sensor signal and generate the algorithm and control the movement of the mobile robot for obstacle avoidance. System implementation is briefly described to depict the system as a whole. Experimental results are presented to demonstrate and validate effectiveness of the technique used.
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Keywords: Guarded tele-operated mobile robotic system, Ultrasonic sensor, Automatic multiple obstacle avoidance, Human control mode.

1. Introduction

In the real world situation many condition occurs where man can see the environment where some useful service is needed but no one can go there due to some hazardas condition or some health restrictions or due to some security constrains. But a guarded tele-operated trolley can provide the service in the hospital ICU environment to the nuclear polluted environment area very smoothly. In human environment unwanted obstacles are common factor for any area of consideration. So the need

for unwanted obstacle avoidance is always significant for robot navigation system. To avoid them the system have to identify the obstacle first, then the system have to avoid the obstacle using some avoiding algorithm. So designing a system for avoiding the accident of obstacles such as the chair or any human equipment on the way is essential to make the trolley robot's safe working. Ultrasonic type of sensor has been widely used for environment detection and obstacle avoidance of autonomous mobile robots [1, 2]. There exists single sensor application [3] as well as multiple sensor application for better results [4, 5]. It has wide detection angle and offers a less expensive solution. However, the drawback of this type of sensor is that ultrasonic waves are transmitted through air and the reflex surface texture will affect the measurement. But we select ultrasonic sensor for it's wide surface measurement property & low cost. There exists many particular application based design & use of ultrasonic systems [6, 7]. The ultrasonic trans-receivers are used in different positions in mobile robot. They are may be in the front for front obstacle avoidance, may be in backside [8], may be in lateral position [9]. The work described in this paper is mainly concerned with the ultrasonic obstacle avoidance system based on RF+AT89C52 of the guarded tele-operated trolley, a service robot. The whole architecture, hardware and software design of the obstacle avoidance system will be discussed later.

2. The Whole Architecture of the System

The core of the guarded tele-operated trolley ultrasonic obstacle avoidance system is AT89C52 microprocessor; the modules which are connected with the processor are designed ultrasonic sensors, RF module, driver of the actuators and the actuators to control the motion of the trolley in the time of obstacle avoidance. Its main function is monitoring the obstacles within 36 cm in front of the trolley's way, helping the trolley to avoid multiple obstacles timely if there are obstacles. If obstacle is not there the system's main function is sending the actuator control signal information to the robot microcontroller via RF transmitter-Receiver module. The hardware schematic of the system is depicted in Fig. 1.

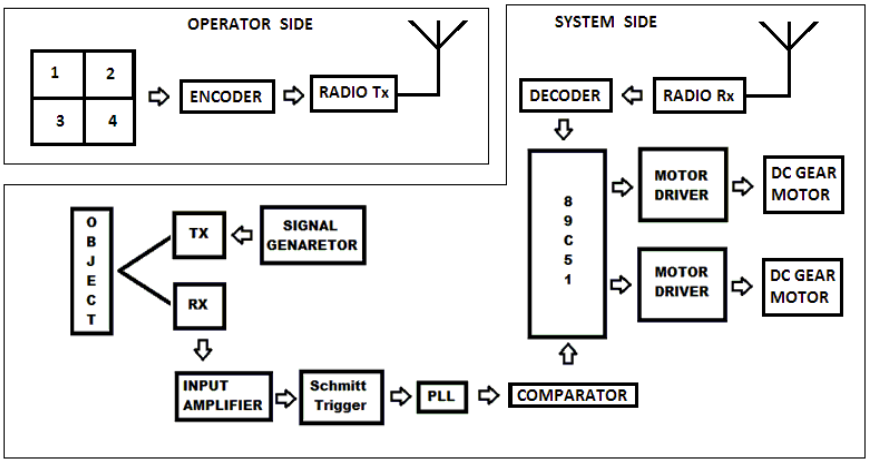


Fig. 1. System Block Diagram.

3. System Hardware Design

The system hardware can be divided into three different parts. They are The Ultrasonic Transducer, The FSK Radio transmitter Module with control switch and The FSK Radio Receiver Module with Driver, Actuator & microcontroller. Now we will go through this parts one by one.

3.1. The Ultrasonic Transducer

The Ultrasonic transducer consists two basic circuits. They are Continuous Ultrasonic Transmitter Circuit and The Ultrasonic Receiver Circuit. Description of both is given below.

3.1.1. The Continuous Ultrasonic Transmitter Circuit

Transmitter circuit is a simple circuit, consisting of signal generator and an ultrasonic transmitter. IC 4047 functions as signal generator, producing 40 kHz electrical signal burst. We get this signal from pin no 10 & 11 of the IC & fed to two input pins of Ultrasonic Transmitter. This IC acts as an asteble multivibrator, and generates a squire wave such that there is constant voltage difference between two terminals of transmitter, while having oscillatory electrical input pulses. High voltage pulses excite the piezoelectric element in the ultrasonic transducer, causing this element to oscillate at 40 kHz frequency. This will cause the transducer to produce an oscillatory acoustic output, and thus ultrasonic sound waves are generated due to piezoelectric effect. Fig. 4 describes the circuit diagram.

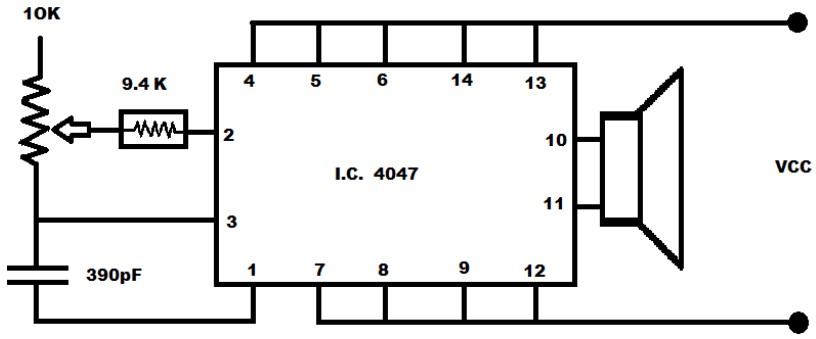


Fig. 2. Ultrasonic Transmitter module.

3.1.2. The Ultrasonic Receiver Circuit

The Fig. 3. Describes The Ultrasonic Receiver Circuit. The reflected sound waves are detected by the ultrasonic receiver. When an acoustic wave reaches the piezoelectric element; the element produces a voltage which is the sensor signal. This signal is generally of low amplitude, and less strength. This signal may also contain unwanted noise signals, which are generated from atmospheric sources. Those signals received from transducer are fed to FET Amplifier for amplification. The Amplifier is designed in such a way that it amplify with an overall gain of 100, in two stages. This amplifier is operated in inverting mode with negative feedback. Amplifier output is collected across 7^{th} pin and connected to 4 -input NAND gate, which functions as a Schmitt trigger. All the pins 1, 2, 4 and 5 are connected to the amplifier output, through a variable resistance of 10 kOhm. This variable resistance is used for Range and Sensitivity adjustment. Pin 3 of IC7413 is not connected, and output is collected at 6th pin of the Schmitt trigger IC. The output of Schmitt trigger is not an exact replica of 40 kHz input electrical signal but it's frequency is 40 kHz. This Schmitt trigger output is fed to input pin of PLL. The PLL circuit is designed such a way that, if it detects 40 kHz pulse in the input signal its output will become low. For any other frequencies, output is high. The PLL (LM567) acts as a tone decoder set to lock onto 40 kHz signal. The output of the tone decoder is HIGH when no echo is heard and swings LOW when an echo is detected. From pll we get 4 V output when obstacle is detected & we get 4.9 V when obstacle does not exists. This change is fed to a comparator whose output is 10.5 V when obstacle exists & 1.9 V when not. These voltages are made 4.7 V when obstacles exist & 0.85 V when not by proper voltage divider circuit (POT). Fig. 4 shows different Signals across transmitter & receiver

circuit.

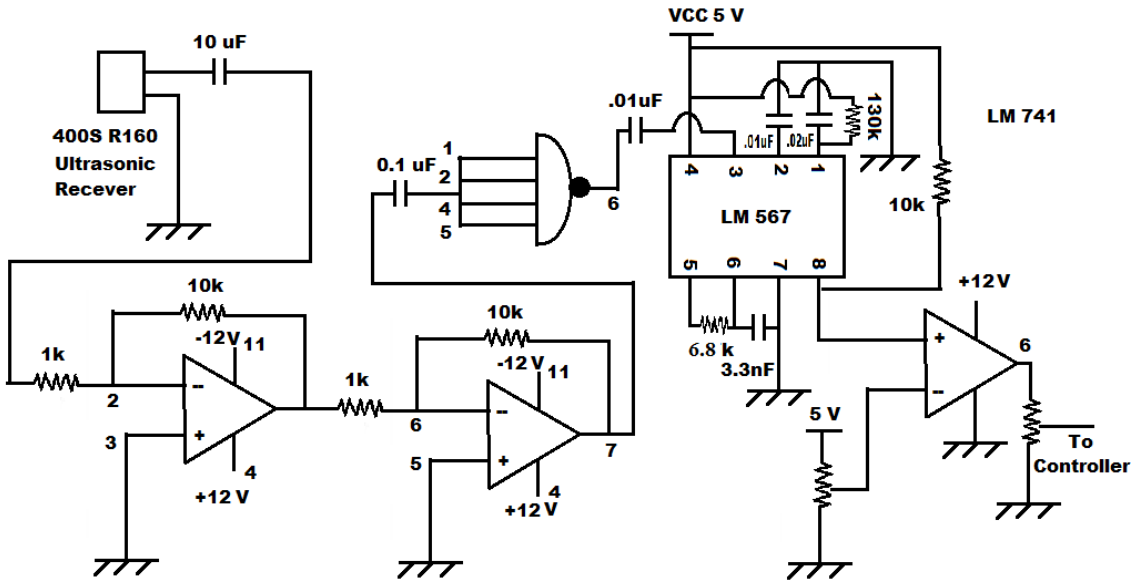
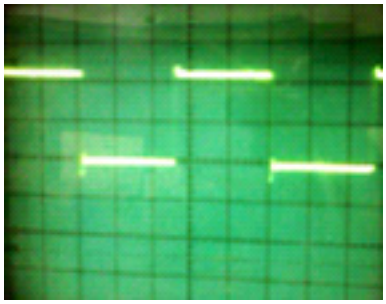
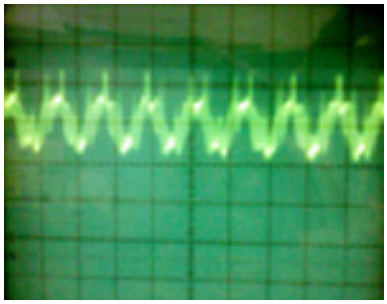


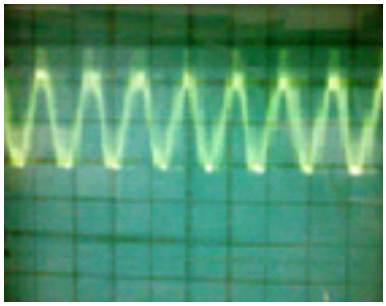
Fig. 3. Ultrasonic Receiver Module.



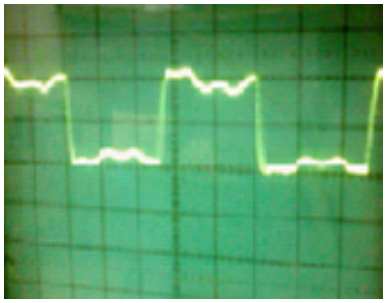
(a) Signal of 40 kHz Burst from IC 4047



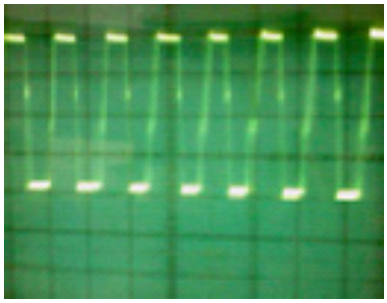
(b) Signal before amplifier



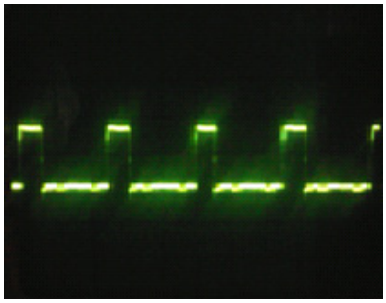
(c) Signal after capacitor



(d) Signal with ultrasonic loading



(e) Signal after amplifier



(f) Signal after Schmitt Trigger

Fig. 4. Signals across transmitter & receiver circuit.

3.2. The FSK Radio Transmitter Module with Control Switch

Transmitter circuit is a simple circuit, consisting of HT-12E encoder which encodes the switching signals and send it to the FSK transmitter module which sends the signal to the robot through a 10 Ohm antenna. When power is on the circuit is able to control the trolley's motion with a human

navigator by four switches sw1 for forward, sw2 for backward, sw3 for rotate right, sw4 for rotate left. The switches are connected through pull-up & pin 1 to 9 of HT-12E connected to ground to get the logic 'ground to on' in this circuit. The resistor 760 kΩ connected to in built crystal pin 15&16. We will get all connections details in Fig. 5.

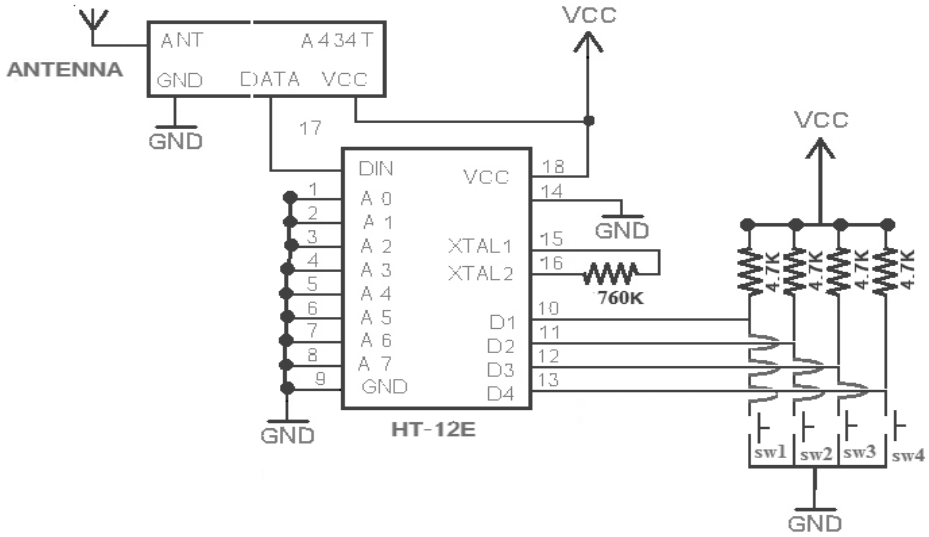


Fig. 5. Human control module.

3.3. The FSK Radio Receiver Module with Driver, Actuator & Microcontroller

The receiver circuit also is a simple circuit, consisting of a 10 Ohm RF antenna which catches the transmitted signals with the help of receiver module and send it to the HT-12D decoder which decodes the receiving signals and fed it to the microcontroller.

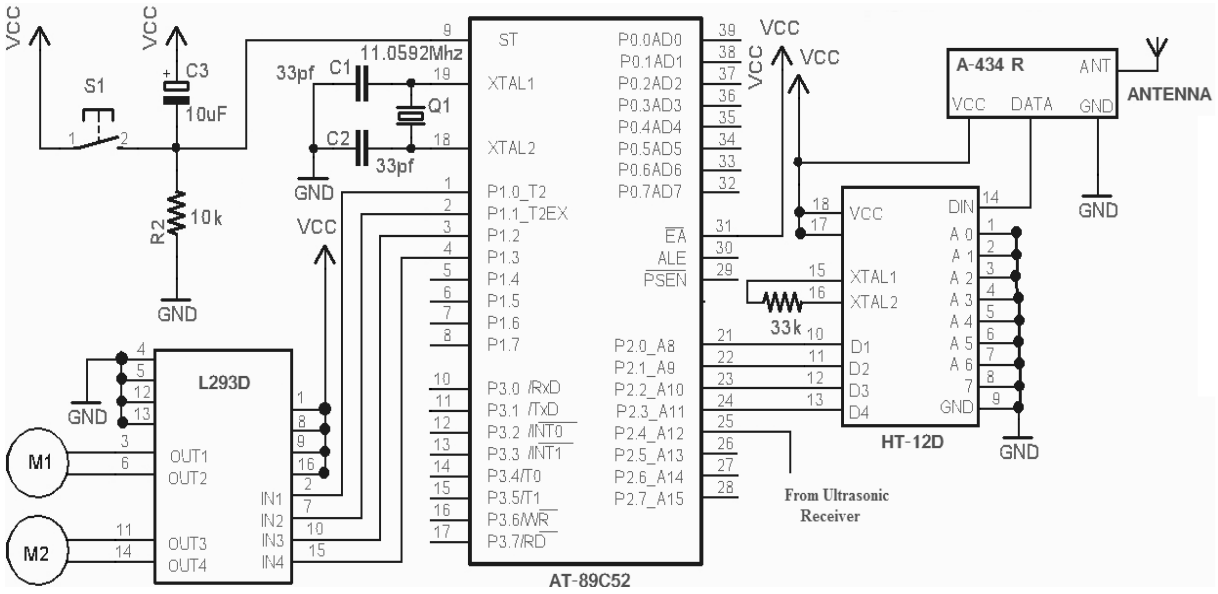


Fig. 6. Mobile Robot Circuit.

The microcontroller receives the control signal from the pins P2.0, P2.1, P2.3 & P2.4 and controls the left and right motor's forward or reverse movements to control the trolley movement via pins P1.0,

P1.1, P1.3 & P1.4 which are connected to the driver IC-L293D. The sonar data is fed to the microcontroller pin P2.5. The microcontroller monitors these pins all time. The details of circuit diagram are shown in the fig.6 & fig.7 shows the pictorial representation of the robot.

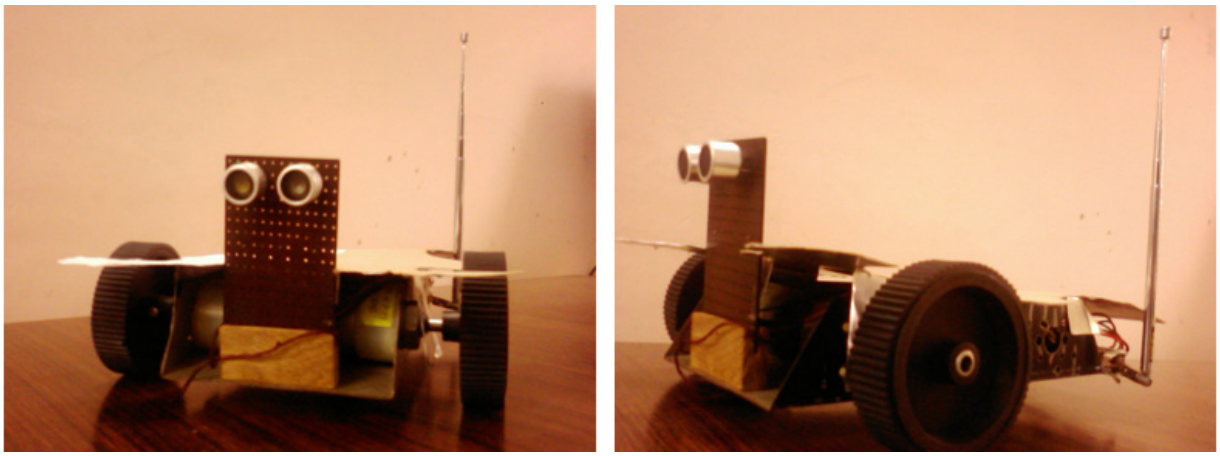


Fig.7. Pictorial view of Robot.

4. The Design Formula

4.1. Astable Mode Design Formula

In the astable mode operation on time that is T_{on} and OFF time that is T_{off} is given by,

$$T_{on} = -RC \ln (V_{tr} / V_{dd} + V_{tr})$$

Typically this is,

$$T_{on} = 1.1 RC$$

$$T_{off} = = -RC \ln (V_{dd} – V_{tr} / 2 V_{dd} + V_{tr})$$

Typically this is also,

$$T_{off} = 1.1 RC$$

So Time period,

$$T = T_{on} + T_{off} \text{ [in terminal 13]}$$

And Time period

$$T' = 2(T_{on} + T_{off}) \text{ [in terminal 10]}$$

4.2. Op-Amp Gain Formula

In the negative feedback mode of operation, operational amplifier gain is given by,

$$AV = R_f / R1$$

4.3. PLL Centre Frequency

In PLL tone detector, the free-running frequency of the current controlled oscillator in the absence of an input signal, is known as centre frequency, which is given by,

$$f_O = 1 / (1.1\ R1\ C1)$$

4.4. PLL Detection Bandwidth

The frequency range, centered about f_O, within which an input signal above the threshold voltage (typically 20 mVRMS) will cause a logical zero state on the output. The detection bandwidth corresponds to the loop capture range.

$$BW\ (\text{in \% of } f_O) = 1070\ V1 / (f_O\ C1)$$

5. The Software System

5.1. Algorithm Development

1. Start the program.
2. Initialize direction value by left.
3. If obstacle exists enter the avoidance program else go for computer command.
4. Initialize degree value by '0' degree.
5. If obstacle exists in front of the vehicle swap direction value left to right or right to left & increment degree value by 45 degree if not go for recovery program i.e., go forward for two delay, rotate vehicle by degree value in the direction of direction value, again go forward for two delay, again rotate vehicle by degree value in the direction of direction value and again go forward for two delay and rotate vehicle by degree value in the direction of negative of direction value and achieve the axis.
6. Rotate the vehicle by degree value in the direction of direction value looking for free space.
7. Until direction value is180 degree goes to the 5th line.
8. If the degree value is 180 degree & still obstacle exists rotate the vehicle left by 90 degree i.e., turn back the vehicle & go to the 1st line if not also go to the start.

This algorithm can be realized by the Fig. 8.

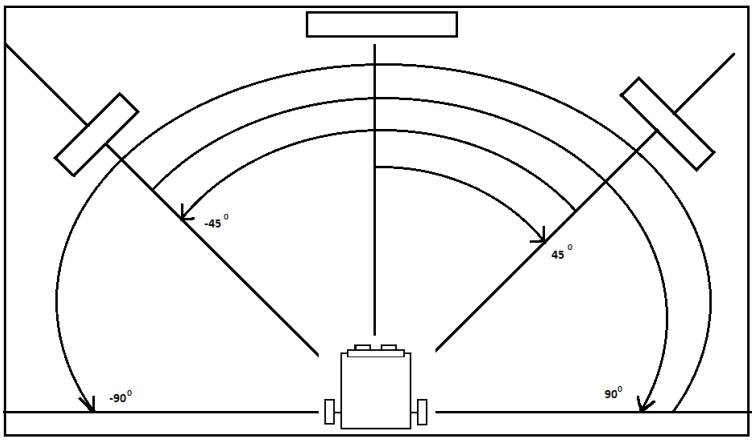


Fig. 8. Realization of the algorithm.

5.2. Flow Chart

The program of this work had done in Keil uVision4 software. In the program the timer of the microcontroller is used to generate the required time delay of 1.68 s. which is required to rotate the robot 45degree each time. The microcontroller monitors the sonar data all time. If the sonar data is 1 microcontroller executes the avoiding algorithm and after successful avoidance it recovers the direction displacement and acquires the axis of navigation. Fig. 9 depicts the flowchart.

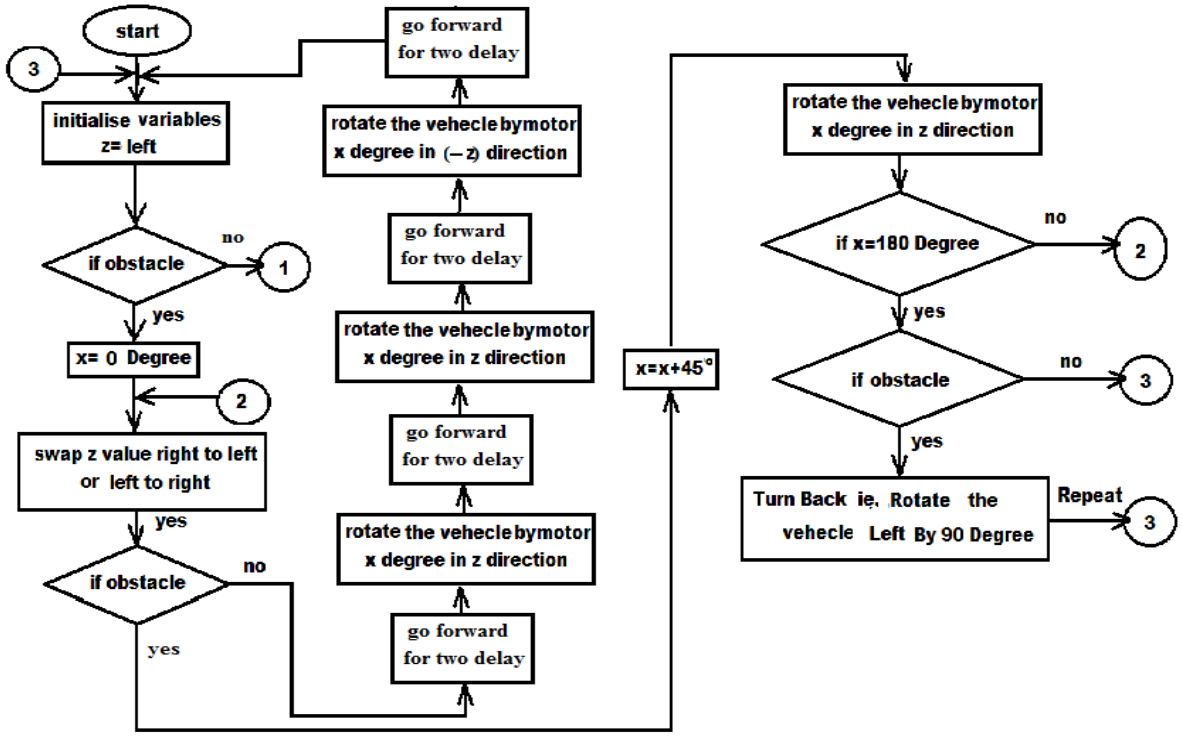


Fig. 9. Obstacle avoidance & axis recovery flowchart.

Now when the obstacle is not exists in front of the trolley the microcontroller controls the motion of the robot according to the four pins of port 2. Fig. 10 describes the whole thing. Fig. 11 describes the real experimental situation of robot obstacle avoidance.

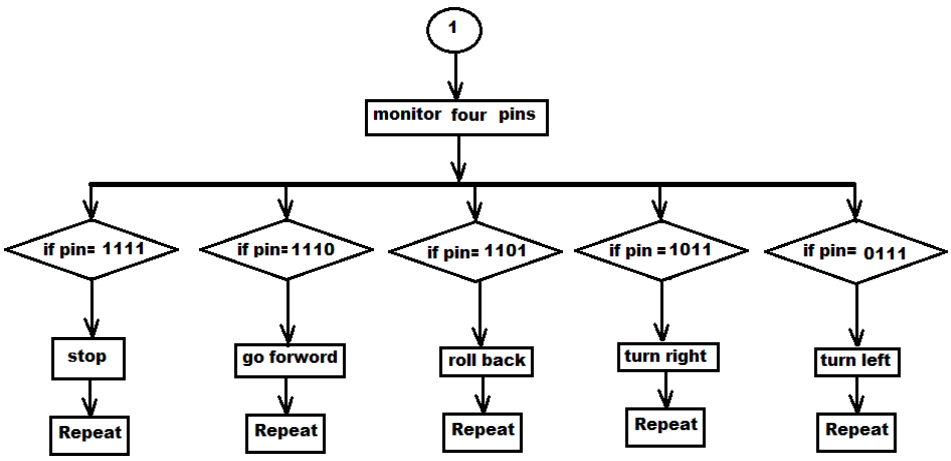


Fig. 10. Human control flowchart.

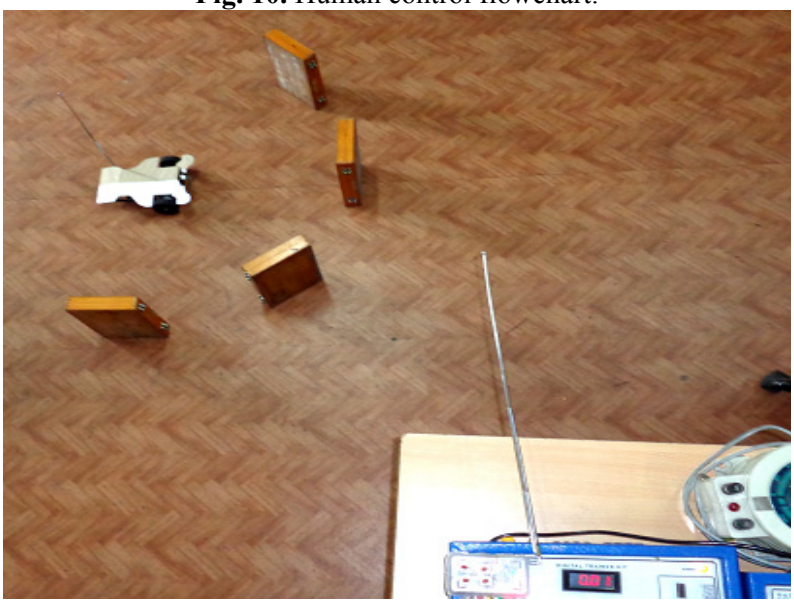


Fig. 11. Real Situation.

6. The Results

6.1. Robot Simulation Results for Multiple Obstacle Avoidance

Fig 12 represents the five scenarios of Obstacle Avoidance. In these all experiments less than one degree error occurs during ninety degree movement of the robot. This movement error can be minimized by stepper motor actuator.

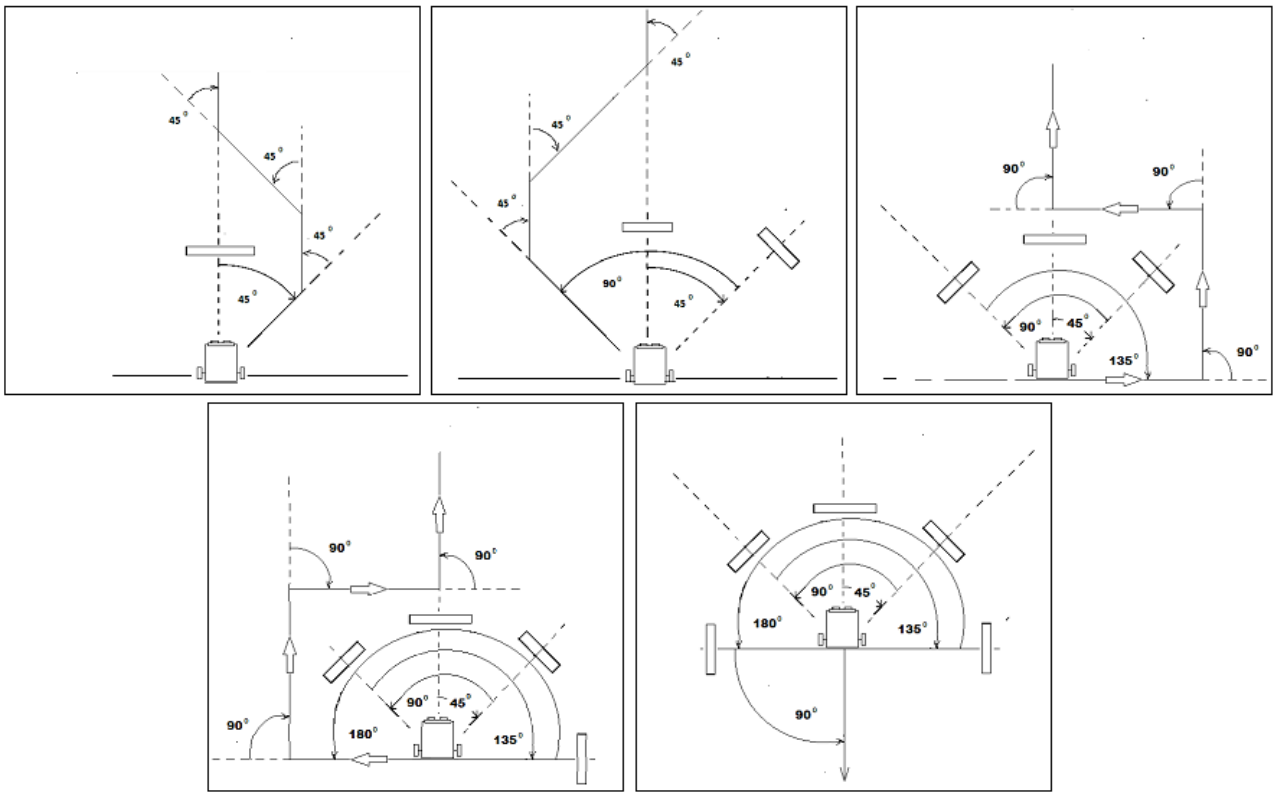


Fig. 12. Five scenarios of Multiple Obstacle Avoidance.

7. Conclusion

The objective of this project is to design and implement Ultrasonic Obstruction Detection intelligence for a guarded tele-operated trolley-service robot. As described in this report a system is developed that can detect objects up to a distance of 2.5 to 3 feet and depending upon that sensors intelligence the micro controller can take navigating command from human or from obstacle avoidance algorithm. This system gives satisfactory result as requirement. With respect to the requirements for an ultrasonic switch & the system the following can be concluded.

- The system is able to generate 40 KHz continuous burst.
- The system is able to detect objects within the sensing range.
- This system has the capability to acquire its axis & direction after obstacle avoidance.
- This trolley can navigate by human command through RF communication.
- This system can also communicate with PC through printer port. A human can give command via P.C.

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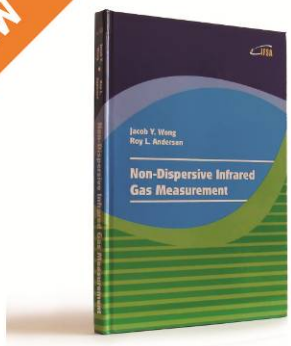
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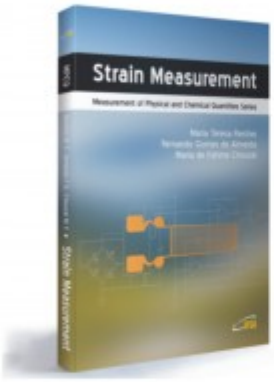
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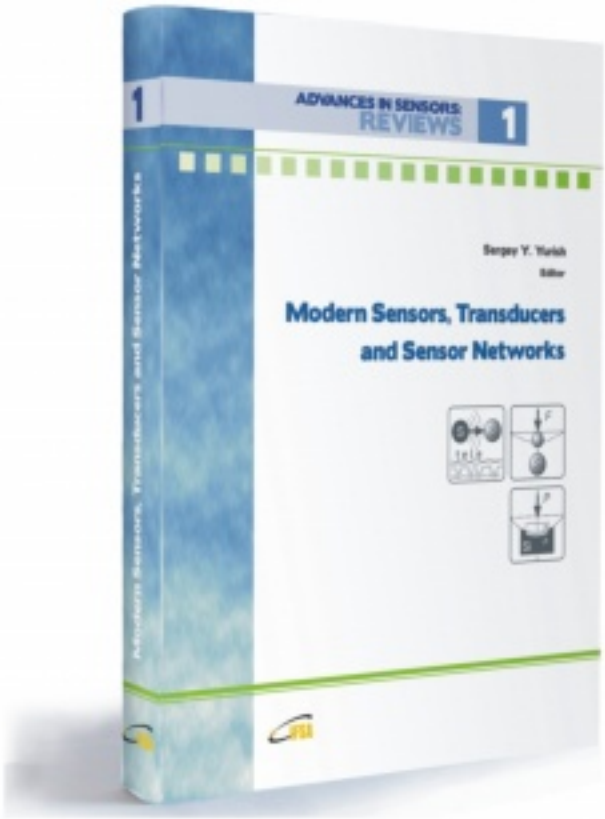
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