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Obstacle Avoiding Robot Using Karnaugh Map

Priyanshi Agrahari[1], **Amandeep Kaur**[2], **Harjit Kaur Dhanoa**[3] and **Gurjot Singh**[4]

[1,2,3]B.Tech (Hons.) students, Dept. of ECE, Lovely Professional University, Phagwara, Punjab, India
Email: agraharipriya.16@gmail.com[1], amanbrar8394@gmail.com[2], harjit28893@gmail.com[3]
[4]Asst. Professor, Dept. of ECE, Lovely Professional University, Phagwara, Punjab, India
Email: gurjot.17023@lpu.co.in[4]

ABSTRACT

This paper proposes a new method to make an obstacle avoiding robot which avoids unexpected obstacles in its way and follows a light source which is an additional feature in it. It is based on logic gates and it uses the infrared sensors for detection of an obstacle while finding the brightest light source using light dependent resistor. Karnaugh map is used for the simplification and minimization of Boolean functions to design the circuit. The usage of logic gates instead of microcontroller greatly reduces the cost of the robot, lowers the demand of the power supply and takes negligible access time as combinational circuits are memory-less. Working principle of sensors, obstacle avoiding algorithm, light detecting module and its implementation are discussed in this paper.

Keywords: Obstacle avoiding, light following, Karnaugh map, logic gate.

1. INTRODUCTION

Today robots are widely used in industries for manufacturing appliances and for serving in hazardous places where human intervention is not possible, for example in dark caves, fire affected areas, nuclear factories etc. The ability to detect and avoid obstacles is of vital importance for any autonomous robot. A lot of research has been done in this field and a number of promising methods have been formulated for the same [5]. The proposed solution focuses on digital logic using Karnaugh map and the use of Boolean algebra adds to the simplicity, reduces the data error, requires low power and is more accurate as compared to the analog counterparts.

Designing of any robot needs incorporation of multiple sensors to accomplish its proposed task effectively. The task of the proposed obstacle avoider robot is to avoid the obstacles coming in its way while following a light source. Sensors commonly used for obstacle avoiding are infrared sensor, bump sensor, sonar sensor, laser range finder and ultrasonic sensor. For obstacle detection CCD web cam and various other devices can be used [1]. This robot will use three infrared sensors mounted at the front side, left side and right side of the robot. The good ranging capability of IR sensor improves its level of performance and its low cost as compared to other obstacle avoidance sensors makes it comparatively more reliable to use[1]. Vacuum photocells, photoresistors, photodiodes and light dependent resistor (LDR) are used for detecting the light source. Light is an electromagnetic wave that consists of waves in the visible range (wavelengths 400-800 nm), near infrared range (wavelengths 800-1400 nm) and near ultra-violet range (wavelengths 320-400 nm) regions. While choosing, it is important to be aware about the sensitivity of the light sensor as it varies with wavelength and it may not respond to all the wavelengths in the range specified above.

Engineering students are fascinated by robots but the belief that it requires a lot of skills and infrastructure to build even a simple robot holds them back. The new method described in this paper would rather be easygoing as it uses the basic logic gates and doesn't require any prior knowledge of programming to build an innovative and inexpensive robot.

2. SENSORS

Two types of sensors are used in the proposed project, one is infrared sensor for detection of an obstacle and the other is light dependent resistor (LDR) for sensing the light source. The sensors opted for obstacle detection are IR sensors because IR sensors are low cost as compared to other sensors. IR sensor is divided into two parts: IR Transmitter and IR Receiver. Transmitter consists of an IR LED and receiver consists of a photodiode. Transmitter continuously sends the IR signals and the signal is reflected back as the IR signal strikes any object which comes in the way. The reflected signal is then received by the IR receiver. This increases the voltage drop across the photodiode and the voltage drop can be detected using an op-amp. Thus, the output gives logic one when voltage drop at cathode of photodiode drops under a certain voltage. So, the sensor module gives the logic high in case the obstacle is detected and logic low in case no obstacle is detected. IR sensors have a sensing range of approximately 2cm to 8cm. User can adjust the sensing range using potentiometer present in the sensor module as per the application. LED can be used as an indicator which turns on when signal is received at the IR sensor thus indicating the detection of an obstacle.[3]

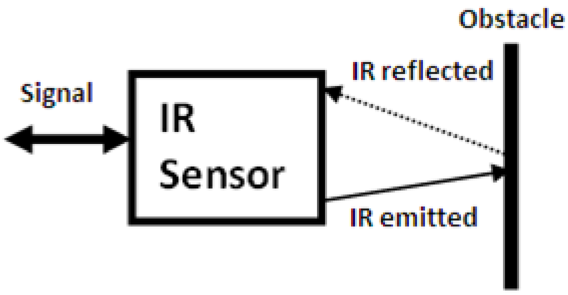


Figure 1. IR Sensor

The second sensor used is the LDR which is made up of high resistance semiconductor material. When it is dark, LDR has high resistance which makes the voltage at the base of transistor very low to turn it on. As the light falls on the LDR, its resistance starts to decrease which causes the base bias voltage to increase. At a certain instant, the base bias voltage becomes high enough to turn on the transistor. The potentiometer in series is used to set the threshold level. Variable resistance can be adjusted in such a way that in the absence of light base emitter voltage is less than 0.5 volts. With the increase in light intensity, this voltage would increase and LED glows with full intensity when voltage becomes greater than 0.8 volts.

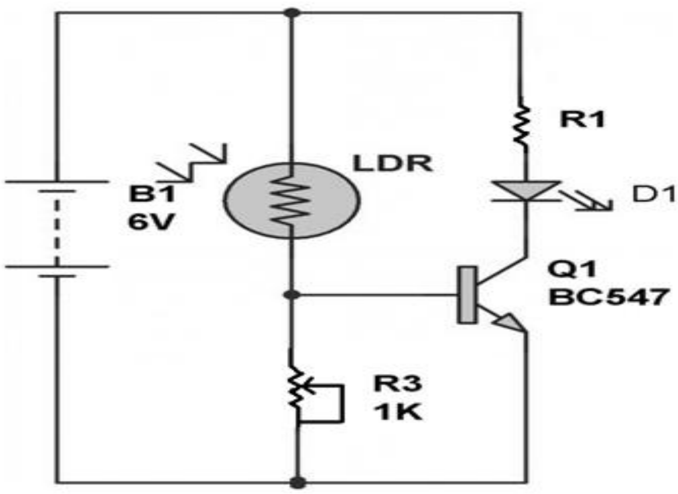


Figure 2. Circuit diagram of LDR

3. IMPLEMENTATION

Implementation of the obstacle avoider robot that follows light involves variety of hardware components. Figure depicts the detailed block diagram of the robot. Firstly, LDR is used as the light detector so that when light is made to fall on the LDR using a light source, robot moves into the direction of light. When there is no input from light source, robot stops. In the proposed project, LDR detects the brightest light source based on the threshold value that is set using the potentiometer such that the robot does not detect and follow ambient light. Secondly, three IR sensors are mounted at the front side, left side and right side of the robot. IR sensors are used for avoiding any kind of obstacles that comes in the way.

During the operation of robot, it continuously takes the input from the three IR sensors. Input is compared in the LM358 comparator inbuilt in IR sensor. Output of the comparator decides the IR sensor output to be logic one or logic zero. Thus, output from all the four sensors that are light detector, front obstacle sensor, left obstacle sensor and right obstacle sensor decides that in which direction the robot should turn in order to avoid obstacles in the path. A digital logic for this scenario is designed in which all possible cases corresponding to the output from the four sensors are considered. Two dc motors are used for left and right wheel and a castor wheel is used in the front to support the robot in its movement. Output given by the digital logic circuit is passed as an input to the motor driver L293D which further amplifies the signal and provides the motors the required voltage for operation.

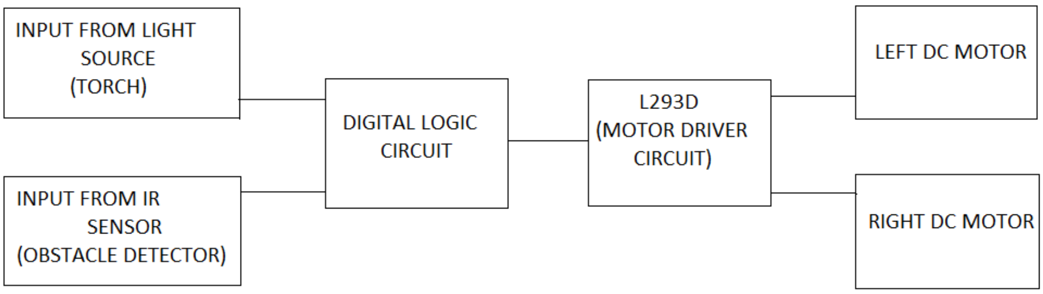


Figure 3. Block diagram of robot

4. ALGORITHM

Taking into consideration Binary logic, IR sensors give logic 1 when obstacle is detected and LDR gives logic 1 when Light is sensed. The algorithm discusses different cases on the basis of input logic from the sensors. Since three IR sensors are used, they are named as FS (front sensor), LS (left sensor) and RS (right sensor) used for detecting obstacles at front , left and right directions respectively and LDR used for detecting light is named as LD (light detector) for simplicity. Similar to the sensors, motors are named as LM (left motor) and RM (right motor). The different cases depending on different inputs from the sensors and the corresponding output are discussed as follows:

1. Case 1 {Robot moves Forward (RM=1, LM=1)}: If there are no obstacles sensed by any of the IR sensors (LS=0, RS=0, FS=0) and light is detected (LD=1), robot moves forward. Apart from this if there is obstacle at left and right side but not at front (LS=1, RS=1, FS=0) and light is detected (LD=1), still the robot would move forward.
2. Case 2 {Robot moves Right (RM=1, LM=0)}: If there is obstacle sensed at left but not at front and right side (LS=1, RS=0, FS=0) and light is detected (LD=1), robot moves right. Apart from this if there is obstacle at left and front

side but not at right side (LS=1, RS=0, FS=1) and light is detected (LD=1), still the robot would move right.

3. Case 3 {Robot moves Left (RM=0, LM=1)}: If there is obstacle sensed at right but not at front and left side (LS=0, RS=1, FS=0) and light is detected (LD=1), robot moves left. Apart from this if there is obstacle at front and right side but not at left side (LS=0, RS=1, FS=1) and light is detected (LD=1), still the robot would move left.
4. Case 4 {Robot stops (RM=0, LM=0)}: If there are obstacles sensed by all of the IR sensors (LS=1, RS=1, FS=1), then even if light is detected (LD=1), robot stops moving. Apart from this if there is obstacle at front side but not at left and right side (LS=0, RS=0, FS=1) and light is detected (LD=1), still the robot would stop moving. The latter case is special case, here the robot could have moved either in left or right side detecting no obstacle at both the sides but that would require the intelligence to take a decision of its own to decide which direction the robot should move in, hence this case is termed as special case.

Considering all the above cases, it is clear that input from the light detector (LD) acts as an enable that is the robot would move if and only if light is detected (LD=1). If no light is detected (LD=0), robot would not move even if there are no obstacles present at any of the sides (RS=0, LS=0, FS=0). All the cases discussed above can be visualized using the flowchart as follows:

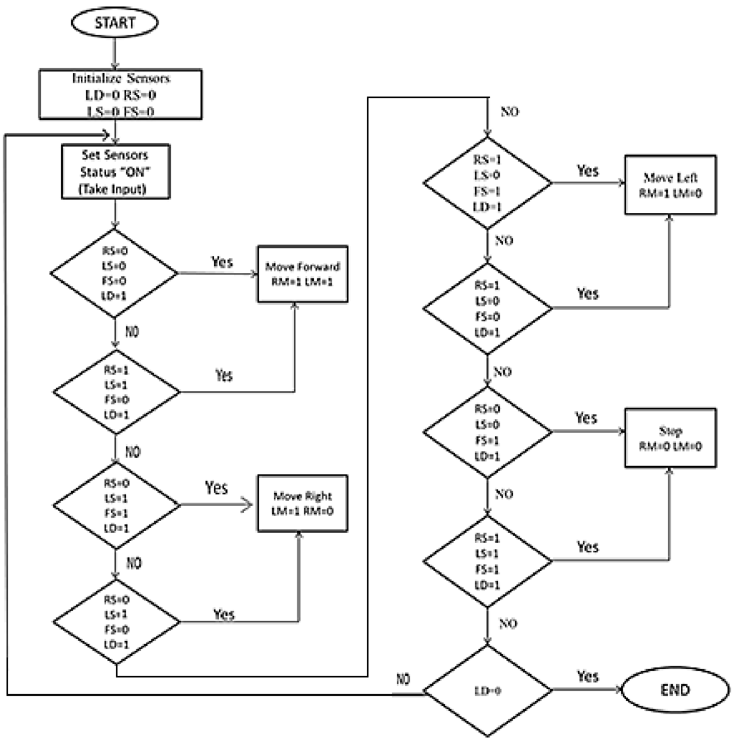


Figure 4. Obstacle Avoiding AlgorithmFlowchart

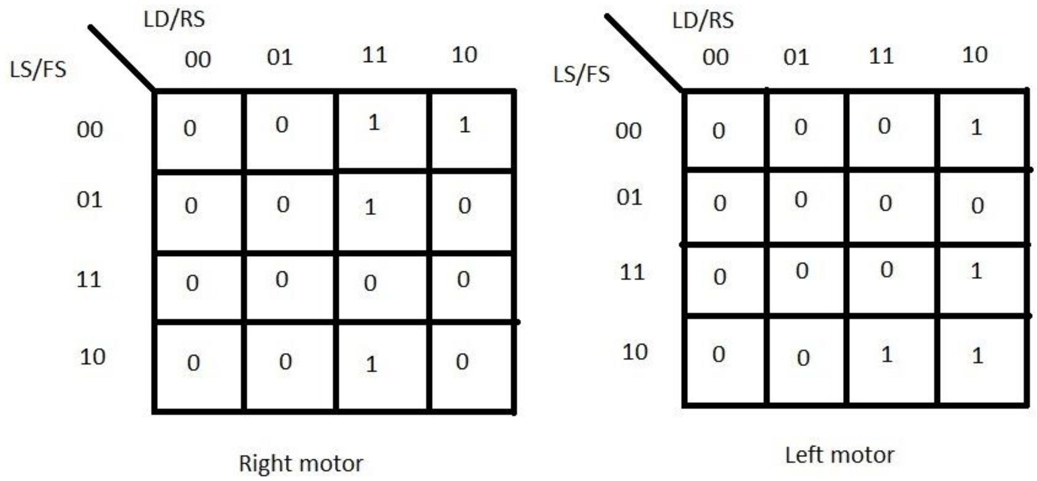
5. DEVELOPING DIGITAL LOGIC USING K-MAP

Digital logic for the circuit is implemented using the three basic gates that is AND, OR and NOT gates. Digital equation for motors can be developed depending on input from the sensors using the following truth table:

Table 1: Truth Table for the design

LD (ENABLE)	RS	LS	FS	RM	LM
1	0	0	0	1	1
1	1	1	0	1	1
1	0	1	1	0	1
1	0	1	0	0	1
1	1	0	0	1	0
1	1	0	1	1	0
1	0	0	1	0	0
1	1	1	1	0	0

From the truth table, K-MAP is drawn for developing equations for the right motor (RM) and left motor (LM) using which we can implement digital logic circuit.



$$RM = (LD)(\overline{FS})(RS) + (LD)(\overline{FS})(\overline{LS}) + (LD)(RS)(\overline{LS})$$

$$LM = (LD)(\overline{RS})(\overline{FS}) + (LD)(\overline{RS})(LS) + (LD)(\overline{FS})(LS)$$

Figure 5. K- Map for developing digital equation for motors

Using the equations for the motors, the digital logic circuit can be developed accordingly using basic gates. So depending on the various inputs from different input sensors as described in the truth table, the movement of motors is determined. The use of digital logic makes circuit design easier to implement.

The digital equation developed using K-Map is used to design the circuit diagram. The proposed design is tested using “Proteus 8 Professional” Software tool which is a single application with different service modules providing many functionalities such as PCB layout, Graphic Design, Schematic Capture, etc.

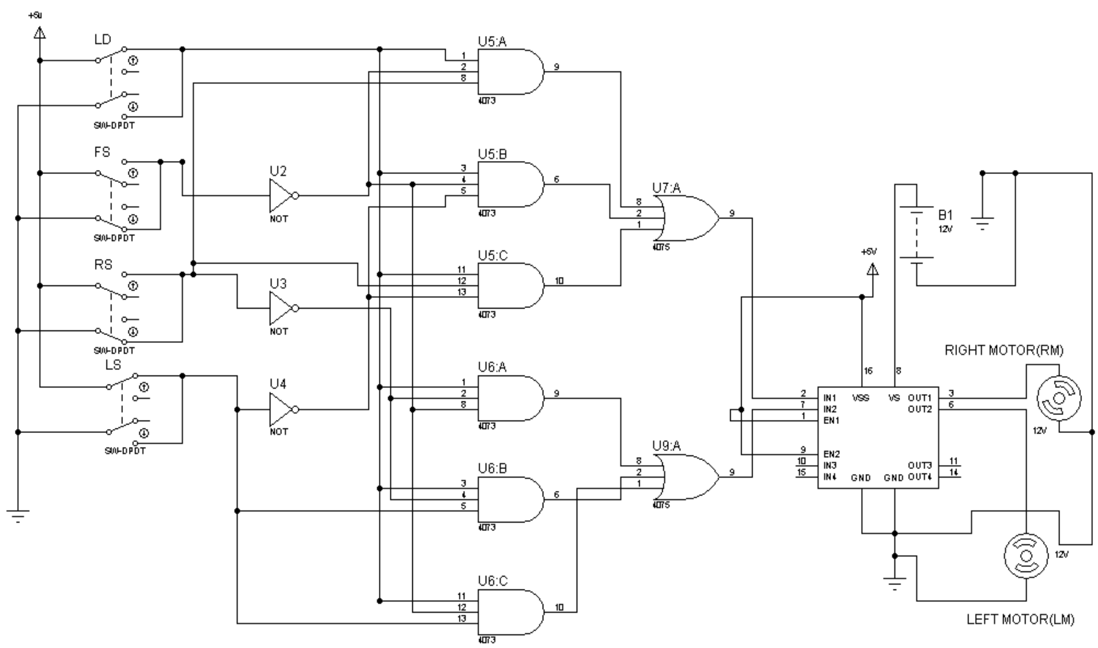


Figure 6. Circuit Diagram of the proposed Robot

6. CONCLUSION

Building is not the only purpose of an engineer, keeping his design simple and low cost is of utmost importance. The use of digital logic makes the circuit simple and low cost. This robot is built without using microcontroller that is used for the intelligence system of most of the robots. Logic gates are used for taking the decision for the movement of this robot. The implementation of logic gates instead of microcontroller lowers the power supply demand of the robot and reduces its cost. The memory-less feature of combinational circuit increases the response time of the robot. As robots help to bring theoretical concepts into practice, so this robot is an instance of the most simple obstacle avoiding cum light following robot.

Adding more to the features of the design, the robot can be used for emergency rescue and as a path finder in dark places such as caves. Robot can be of help to find path in places which are dangerous or even impossible for humans to reach. The robot would follow the path from where light is coming at a dark place avoiding any obstacles in the path. The idea of following light may be applied to a fire caught place and implemented in the design of a fire fighting robot. Moreover, in the design of any navigational robot, the idea of obstacle detection is of extreme importance and can be of use in scientific exploration as well as in various indoor applications.

7. FUTURE SCOPE

Robot has been successfully designed to detect and follow light, avoiding any kind of obstacles in the path. But the IR sensors used for obstacle detection have the limitation that obstacle may not be detected in case it is of black or dark color as these colors are good absorbent of light, and thus light may not be reflected back from these colors. Also IR sensors have short range, ultrasonic sensors can be used for detecting obstacles at up to 6m [4]. The special case of robot coming to halt state on detecting obstacle at front as discussed in algorithm (case 4) has further scope of improvement. In case robot is made to move towards any side according to our choice (say left side) on confronting an obstacle in front, it may result in vicious cyclic behaviour.

8. REFERENCES

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