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Review Article

Obstacle Avoidance Robot using an ultrasonic Sensor with Arduino Uno

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Abstract

The first function of obstacle avoidance robots is to detect the presence of obstacles. When you power on the system with the help of the ON/OFF switch, the Arduino microcontroller will read the data. When the ultrasonic sensor detects the presence of an obstacle in the process of moving forward, the robot will move backward. If the robot does not sense any obstacle, that is, if the distance between an obstacle and it is wide, it will then move forward again until it senses an obstacle before it stops. Two LEDs are used in the research, one indicating the robot is moving forward and the other showing if the robot is moving backward. The third LED shows if the battery is fully charged. C programming is used for Arduino board applications to develop the program for the whole system's operation. There is also a power source unit that is used to charge the batteries used in the system.

Keywords: LEDs, Implementation, Arduino Uno, Ultrasonic Sensor, Obstacle Avoidance Robots, 5 volt DC Motor

I. Introduction

Robotic navigation research is beginning to gain momentum on its own. Robotics experts started to create various free routes finding algorithms. The navigation system is regarded as being of paramount importance since the robot must be able to be securely controlled from the starting point to the target (destination). To avoid impediments, or to put it another way, the robot must be able to avoid them. The first of two elements that serve as a guide is this. The robot must also continually make sure that it reaches its goal (target). Making a decision from the different travel possibilities is the challenging part. When making decisions, like in the example, a driver is frequently nevertheless troubled by uncertainty in reality above. It will be interesting to see how this is implemented in a mobile robot (autonomous robot). Simple problems like these can turn into more complex ones if they are applied to autonomous mobile robots that must avoid obstacles. It would be difficult for a mobile robot to identify obstacles and decide how to avoid them, not to mention that the main target (goal) can disappear from the camera's field of view. All of these calls for a very difficult computational process. The light intensity is a factor that must be taken into account because the sensor that will be used is a camera sensor. The aforementioned factors will make it difficult for the robot to get where it is going. Obstacle avoidance has been the subject of numerous studies, starting with the presentation of fuzzy algorithms for reactive navigation of mobile robots in challenging environments [1-61]. This study shows that fuzzy logic is reasonably efficient and reacts rapidly to problems. This study only considers static workplace obstructions; moving obstructions caused by moving objects are not included. This study only considered unexpectedly appearing static obstacles, although model-based predictive controller (MBPC) using neural networks and ultrasonic sensors is also utilized to guide mobile robots around unexpectedly appearing static obstacles in their environment [62]–[77]. The Dynamic Artificial Neural Network (DANN) approach is used for motion planning for mobile robot paths [78] through [80]. This research shows that on a flat surface, a mobile robot can be directed around both stationary and moving obstacles. In order to further enhance the robot's ability to overcome obstacle avoidance, generalized dynamic fuzzy neural networks (GDFNN), a blend of neural network and fuzzy approaches, were employed to construct real-time control autonomous mobile robots [81]. The experimental findings show that GDFNN outperforms conventional fuzzy logic control in terms of performance. The obstacle avoidance problem for mobile autonomous robots is also addressed by certain researchers using Reinforcement Learning with Neural Networks (RLNN) [82]. The simulation's results show that the robot can improve its capacity for learning and can complete the tasks assigned to it in a challenging setting [89–92]. By combining camera sensors with lasers, researchers are starting to invent new ways to identify obstructions instantly. These sensors are capable of precisely identifying both two- and three-dimensional objects [83]. Even in more recent studies, stereovision systems were developed using a combination of omnidirectional cameras and perspective cameras [84]. To estimate the locations of obstacles in three dimensions, this technique combines a wide field of view from a perspective camera with a 360°C field of view from an omnidirectional camera. Several vision system implementations based on color sensors [85], camera sensor Pixy 2 CMUcam5 [86], and thermal cameras [87] have been investigated in past studies. Excellent outcomes are obtained from the aforementioned trials, particularly with regard to real-time obstacle detection. The earlier experiments, however, did not use movable barriers. The goal of this project is to develop a method for avoiding moving obstacles. Based on prior research, this project will develop an autonomous mobile robot that can navigate by itself to avoid moving obstructions caused by environmental changes in the robot's working environment.

To recognize the environment, two webcams are used as stereo vision sensors. Because it is possible to detect pedestrians' upper bodies, they are used as impediments. Since the robot is operating in its genuine environment, this item was picked. The intelligence technique as a control system must be able to handle the issue of moving obstructions in the work area in order to send the robot to the objective (destination). The control system that is used to avoid obstacles is neurofuzzy. With the hope that it would be able to negotiate obstacles with ease and flexibility, a three-wheeled omnidirectional robot was deployed for this experiment. A robot behavior that can recognize the target object, recognize moving obstacles, and make flexible judgments to avoid them must be designed in order for the mobile robot to reach its predetermined target (goal). These actions will be used by the robot to navigate. With the help of stereo vision and the Neuro-Fuzzy algorithm, the robot is directed from its beginning point to its final location. In order to improve the robot's ability to adapt to changing environments, omnidirectional robotics and the Neuro-Fuzzy algorithm are employed to assist the robot in identifying obstacles and making decisions that the robot will avoid. The focus of this research is on robot navigation systems, which comprise locating the target (destination), which is assumed to always be in the robot's line of sight, spotting obstacles and avoiding them, and creating flexible and fluid movements. The impediment items employed are pedestrians, who are located via upper body detection. The robot's workstation consists of a corridor and an interior chamber that are each 4 meters long and 4 meters wide. This study is not focused on traveling the shortest distance because the robot does not walk along a path. To help omnidirectional mobile robots avoid obstacles, this research aims to develop a stereo vision-based navigation system. The proposed method employs the Neuro-Fuzzy algorithm to create a barrier-free path in real-time and to control the robot's movement in a flexible and fluid manner. To guide the mobile robot to a predetermined place, it is crucial to design a robot behavior that can recognize the target object, detect moving barriers, and make adaptive judgements to avoid them. This study aims to investigate the navigational behaviors of the robot. As shown, by using a stereo camera to detect a target and obstacles as input to ANFIS, this study advances the state-of-the-art in obstacle avoidance based on the visual sensor for robot navigation systems. The research technique for this work is divided into two primary sections. The first step is to create a technique for managing the angular and linear velocities of mobile autonomous robots [88].

II. How to Create a Robot That Avoids Obstacles Using Ultrasonic Sensors

Understanding the ultrasonic sensor's operation is crucial before beginning construction of the robot because it will be used to detect obstacles. The essential premise underpinning how an ultrasonic sensor operates is keeping track of how long it takes to broadcast ultrasonic beams and how long it takes to receive them after they have impacted a surface. The distance is then determined using the formula. Therefore, the trig pin of the HC-SR04 is raised for at least 10 us. Eight pulses at a frequency of 40 kHz are employed to transmit a sound beam. The signal is received by the HC-SR04 after it bounces off the surface and lands on the receiver echo pin. When the message was sent, the Echo pin had already risen significantly [94–95].

III. MATERIALS AND METHOD

3.1. The materials used in this research are shown in Table I below.

Table I: materials used in this research

S/N	Name of components	Number used
1	Arduino Uno	1
2	Ultrasonic sensor	1
3	5 Volt DC motor	2
4	LM298N Motor Driver Module	1
5	Wheels	4
6	LEDs	3

3.2. Method

The first function of obstacle avoidance robots is to detect the presence of obstacles. When you power on the system with the help of the ON/OFF switch, the Arduino microcontroller will read the data. When the ultrasonic sensor detects the presence of an obstacle in the process of moving forward, the robot will move backward. If the robot does not sense any obstacle, that is, if the distance between an obstacle and it is wide, it will then move forward again until it senses an obstacle before it stops. Two LEDs are used in the research, one indicating the robot is moving forward and the other showing if the robot is moving backward. The third LED shows if the battery is fully charged. C programming is used for Arduino board applications to develop the program for the whole system's operation. There is also a power source unit that is used to charge the batteries used in the system.

3.2.1. Arduino Uno with driver motor

This is the pin configuration of how the Arduino Uno is connected with the motor driver, which is used to turn on the motors. For driving DC and stepper motors, the L298N Motor Driver Module is a high-power motor driver module. An L298 motor driver IC and a 78M05 5V regulator make up this module. Up to 4 DC motors or 2 DC motors with speed and direction control can be managed by the L298N Module. The L298N Motor Driver module is made up of an integrated circuit that contains an L298 Motor Driver IC, a 78M05 voltage regulator, resistors, capacitors, a power LED, and a 5V jumper. Only when the jumper is in place will the 78M05 voltage regulator be activated. The internal circuitry will be powered by the voltage regulator when the power source is less than or equal to 12 volts, and the 5-volt pin can be utilized as an output pin to power the microcontroller. When the power source is more than 12 volts, the jumper should not be installed, and a separate 5 volts should be provided through the 5-volt terminal to power the internal circuitry. Motor A and Motor B's IN1, IN2, IN3, and IN4 pins regulate direction, while ENA and ENB pins control speed for each motor.

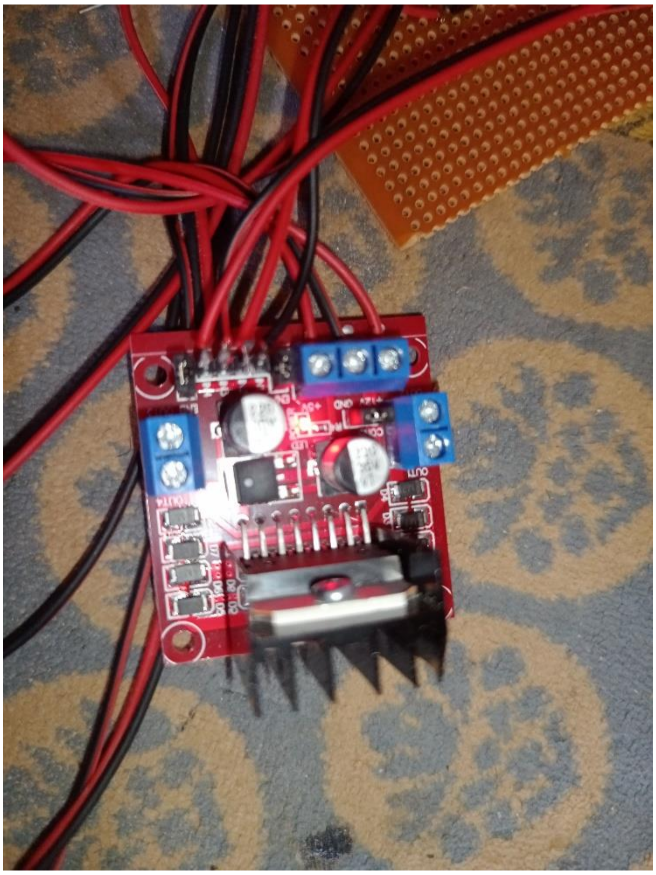

Figure 1: Pin configuration of the Arduino and driver motor

3.2.2. Pin configuration of the Arduino with servo motor

The below diagram shows how the Arduino Uno is connected to the 5-volt servo motor. The ultrasonic sensor is mounted on the servo motor. This motor helps rotate the sensor to detect obstacles. Any of a group of rotating electric motors that use direct current (DC) electricity to create mechanical energy is referred to as a DC motor. The majority of types rely on the magnetic field's forces. For a portion of the motor's current to occasionally shift direction, almost all types of DC motors contain an internal mechanism that is either electromechanical or electronic. Because they could be supplied by existing direct-current lighting power distribution networks, DC motors were the first type of motor that was widely employed. A DC motor's speed can be varied across a large range by varying the supply voltage or the amount of current flowing through its field windings [96].

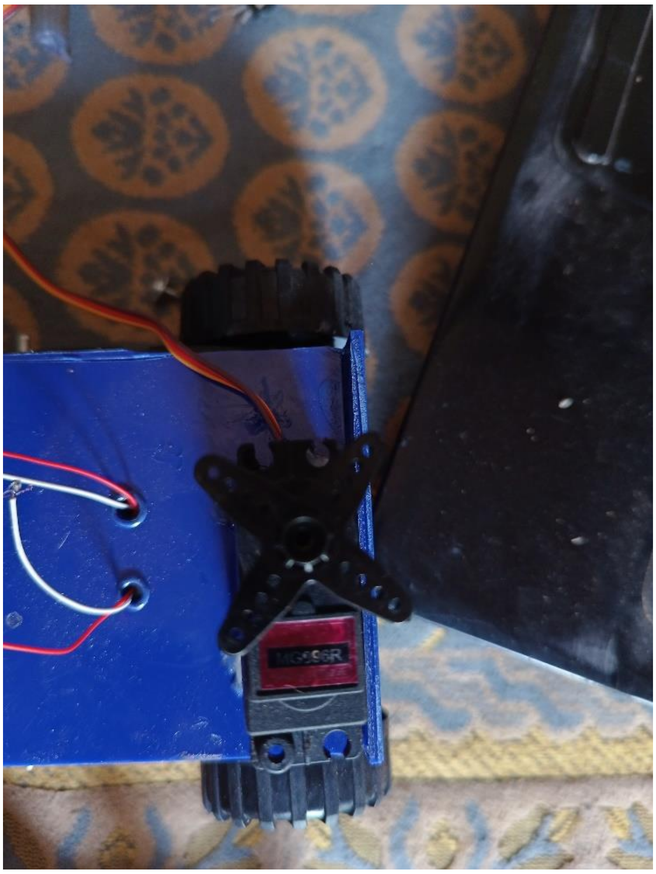

Figure 2: Pin configuration of the Arduino to 5v dc motor

3.2.3. Pin configuration of the Arduino to ultra sonic sensor

The image below shows how the pin of the Arduino Uno is connected to the ultrasonic sensor. This ultrasonic sensor is used to detect an obstacle that is in front of the robot. The 2cm to 400cm (about an inch to 13 feet) range of the HC-SR04 distance measuring sensor makes it an economical and simple device to use. There are two ultrasonic transducers in the sensor. The first is an ultrasonic sound pulse transmitter, while the second is an ultrasonic sound pulse receiver that searches for reflected waves. In essence, it is a sonar that submarines use to find items beneath the surface. When an object or obstacle gets in the way of the ultrasonic, which emits at 40 000 Hz and travels through the air, it will bounce back to the module. You can determine the distance by taking into account the sound's speed and travel time. We need to activate the Trig pin on high for 10 seconds in order to produce the ultrasound. This will emit an ultrasonic burst that lasts for eight cycles and moves at the speed of sound. After that 8-cycle ultrasonic burst is sent, the echo pin immediately goes high and begins listening for that wave to be reflected off a surface. The echo pin will time out after 38 ms and return to a low state if there is neither an object nor a reflected pulse. The echo pin will disappear earlier than those 38 milliseconds if we receive a reflected pulse. The distance the sound wave traveled, and consequently the distance from the sensor to the item, can be calculated based on how long the echo pin was on high. Actually, we are aware of both the values for time and speed. The speed is the sound speed, which is 340 m/s, and the period is the duration that the echo pin was high. We still have one more step to complete, which is to divide the result by 2, so that we can determine how long it takes for the sound wave to reach the object and then bounce back.

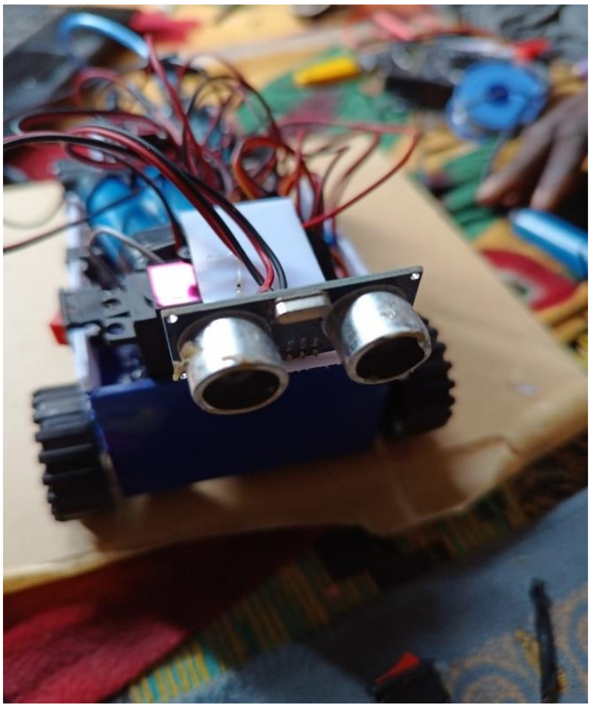

Figure 3: Pin configuration of the Arduino to the ultra-sonic sensor.

3.2.4. Arduino Uno

Is a board for an ATmega328P microprocessor. It has a 16 MHz ceramic resonator (CSTCE16M0V53-R0), 6 analog inputs, 14 digital input/output pins (of which 6 can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. It comes with everything required to support the microcontroller; to use it, just plug in a USB cable, an AC-to-DC adapter, or a battery to power it.

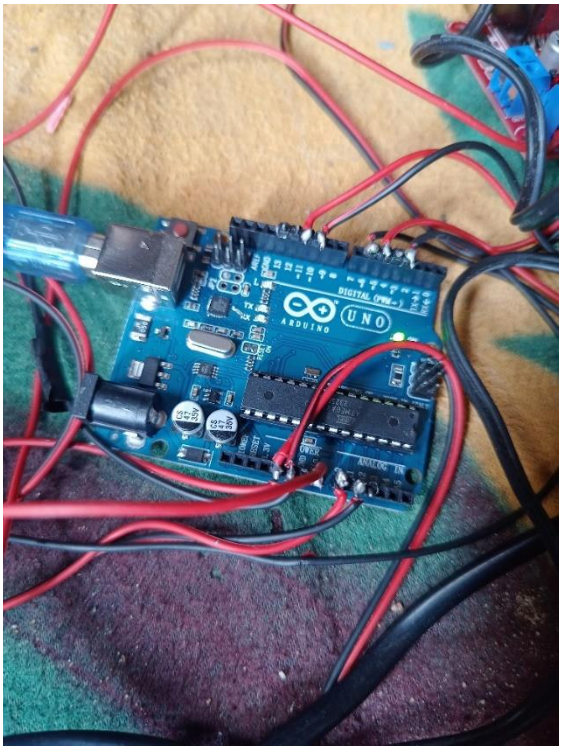

Figure 4: Pin configuration of the Arduino Uno of the whole system

3.2.5. Batteries

Batteries are made up of one or more cells, each of which produces a flow of electrons in a circuit as a result of chemical reactions. An anode (the "-" side of a battery), a cathode (the "+" side), and some type of electrolyte (a material that chemically reacts with the anode and cathode) make up all batteries. Below are the batteries used in the operation of the system.

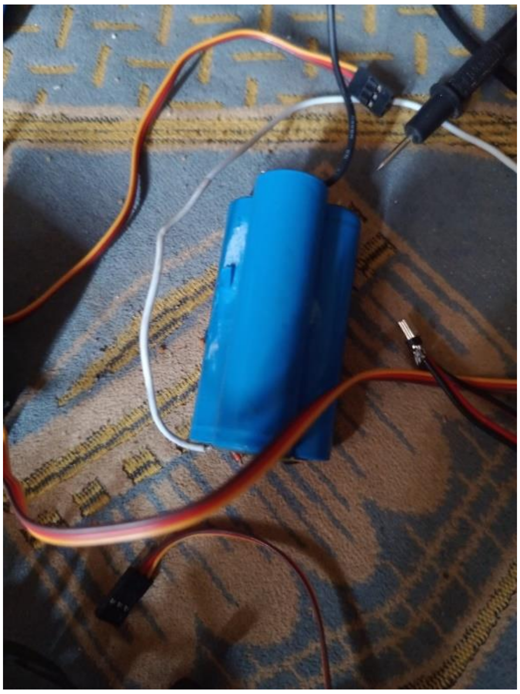

Figure 5: Three batteries are used to power the system

3.2.6. Wheels

A wheel is a rotatable circular component that rests on an axle bearing. One of the essential parts of the wheel and axle, one of the six fundamental machines, is the wheel. Wheels and axles work together to make it simple to move heavy items, whether they are used to support a load or do work in machines. Wheels can be used for a variety of other things, including steering wheels, flywheels, pottery wheels, and robotic wheels. The image below shows how the wheels are mounted.

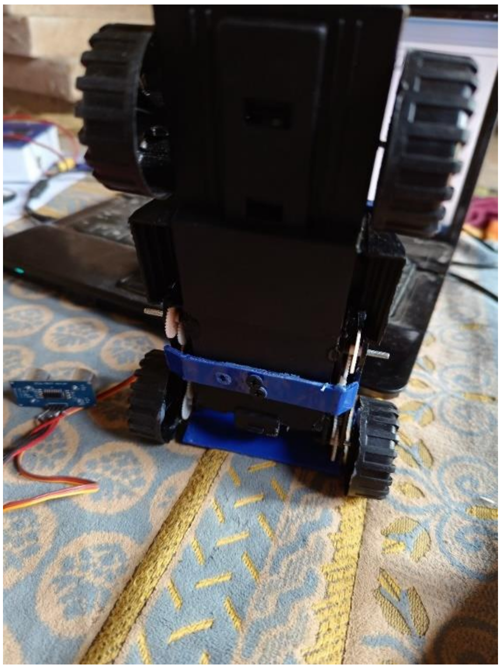

Figure 6: Four wheels are used to move the robot

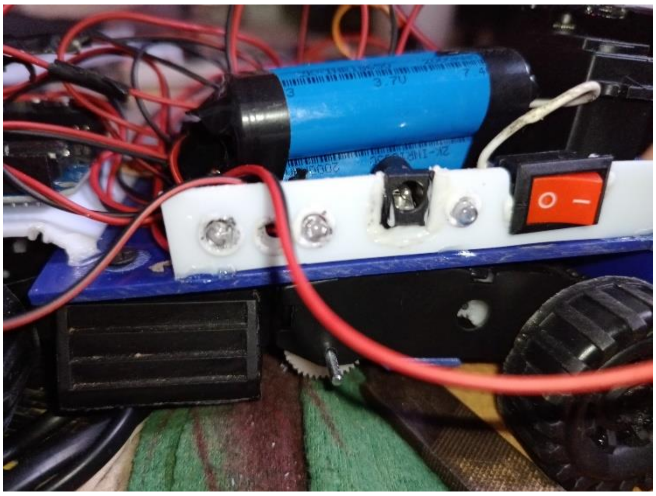

Figure 7: The three LEDs that are used in the system

IV. RESULT

The implementation results are generated, and they also show how the entire robot's circuit is put into practice. The software was created using the Arduino IDE integrated development environment and then converted from the C language into machine code (a hex file) for debugging. The PROTEUS ISIS expert then puts it to the test and runs simulations of it. The case was made from plastic rubber based on a dimension, and the components were joined using gum rubber.

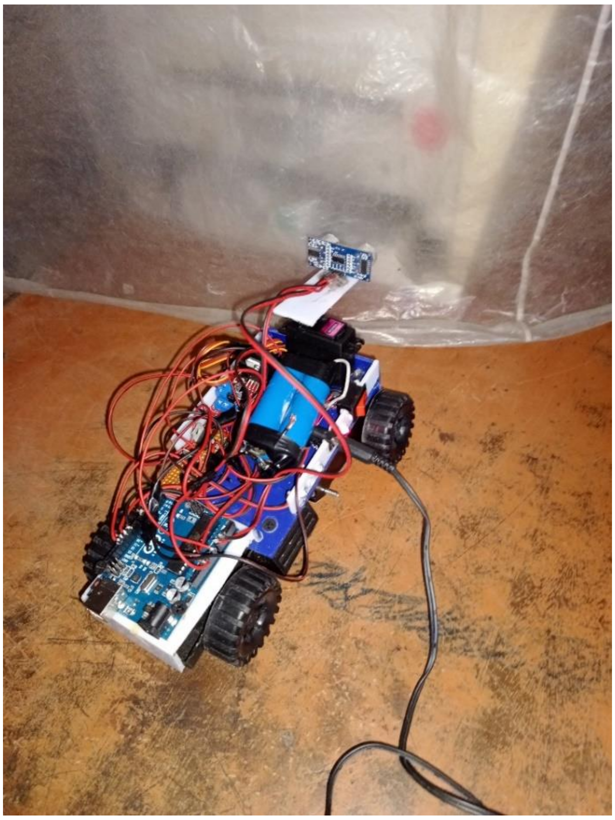

Figure 7: Implementation of the whole system

V. CONCLUSION

This study has been successfully finished and put to the test [98]. To detect the existence of an obstruction, the obstacle avoidance robot underwent testing. This robot will travel backward until it is distant from any obstacles it detects, then it will advance once more in the direction of those obstacles. This tool is practical and has a variety of uses in daily life.

References

1. T. E. Mora and E. N. Sanchez, “Fuzzy logic-based real-time navigation controller for a mobile robot,” in Proceedings. 1998 IEEE/RSJ International Conference on Intelligent Robots and Systems. Innovations in Theory, Practice and Applications (Cat. No.98CH36190), vol. 1, pp. 612–617, 1998, doi: 10.1109/IROS.1998.724686.
2. L. M. Waghmare, P. Tallapragada, and N. Bidwai, “Reactive Navigation of Autonomous Vehicle using Neuro-Fuzzy Controller,” in 2006 IEEE International Conference on Industrial Technology, pp. 2681–2685, 2006, doi: 10.1109/ICIT.2006.372675.
3. S. Seghour and M. Tadjine, “Consensus-based approach and reactive fuzzy navigation for multiple no-holonomic mobile robots,” in 2017 6th International Conference on Systems and Control (ICSC), pp. 492– 497, 2017, doi: 10.1109/ICoSC.2017.7958658.
4. T. Shen and J. Zhai, “Reactive Obstacle Avoidance Strategy Based on Fuzzy Neural Network and Arc Trajectory,” in 2019 Chinese Automation Congress (CAC), pp. 4792–4796, 2019, doi: 10.1109/CAC48633.2019.8996374.
5. Y. Wang and Y. Yuan, “A dynamic reactive power compensation method for high-power and high-voltage electronic motors based on self-adaptive fuzzy PID control,” in 2016 IEEE Chinese Guidance, Navigation and Control Conference (CGNCC), pp. 10–15, 2016, doi: 10.1109/CGNCC.2016.7828749.
6. E. Ruiz, R. Acuña, P. Véélez, and G. Fernández-López, “Hybrid Deliberative Reactive Navigation System for Mobile Robots Using ROS and Fuzzy Logic Control,” in 2015 12th Latin American Robotics Symposium and 2015 3rd Brazilian Symposium on Robotics (LARSSBR), pp. 67–72, 2015, doi: 10.1109/LARS-SBR.2015.24.
7. P. Chand, “Fuzzy reactive control for wheeled mobile robots,” in 2015 6th International Conference on Automation, Robotics and Applications (ICARA), pp. 167–172, 2015, doi: 10.1109/ICARA.2015.7081142.
8. H. Zerfa and W. Nouibat, “Fuzzy reactive navigation for autonomous mobile robot with an offline adaptive neuro fuzzy system,” in 3rd International Conference on Systems and Control, pp. 950–955, 2013, doi: 10.1109/ICoSC.2013.6750971.
9. Melendez and O. Castillo, “Optimization of type-2 fuzzy reactive controllers for an autonomous mobile robot,” in 2012 Fourth World Congress on Nature and Biologically Inspired Computing (NaBIC), pp. 207–211, 2012, doi: 10.1109/NaBIC.2012.6402263.
10. E. Baklouti, M. Jallouli, N. Ben Amor, S. Titi, and A. Nafti, “Autonomous mobile robot navigation coupling fuzzy logic and reactive DVZ 3D obstacle avoidance control,” in 2015 International Symposium on Innovations in Intelligent Systems and Applications (INISTA), pp. 1–6, 2015, doi: 10.1109/INISTA.2015.7276748.
11. Y. Lv and P. Jiang, “The Design of Indoor Mobile Robot Navigation System Based on UWB Location,” in 2018 Eighth International Conference on Instrumentation & Measurement, Computer, Communication and Control (IMCCC), pp. 334–338, 2018, doi: 10.1109/IMCCC.2018.00077.
12. Itta, G. Attolico, and A. Distante, “Combining reactive behaviors using a hierarchy of fuzzy controllers,” in Ninth IEEE International Conference on Fuzzy Systems. FUZZ- IEEE 2000 (Cat. No.00CH37063), vol. 2, pp. 1041–1044, 2000, doi: 10.1109/FUZZY.2000.839194.
13. M. A. O. Mendez and J. A. F. Madrigal, “Fuzzy Logic User Adaptive Navigation Control System For Mobile Robots In Unknown Environments,” in 2007 IEEE International Symposium on Intelligent Signal Processing, pp. 1–6, 2007, doi: 10.1109/WISP.2007.4447633.
14. I. Ismail and M. F. Nordin, “Reactive navigation of autonomous guided vehicle using fuzzy logic,” in Student Conference on Research and Development, pp. 153–156, 2002, doi: 10.1109/SCORED.2002.1033080.
15. N. Zhang, D. Beetner, D. C. Wunsch, B. Hemmelman, and A. Hasan, “An Embedded Real-Time Neuro-Fuzzy Controller for Mobile Robot Navigation,” in The 14th IEEE International Conference on Fuzzy Systems, 2005. FUZZ "05., pp. 319–324, 2005, doi: 10.1109/FUZZY.2005.1452413.
16. G. Castellano, G. Attolico, E. Stella, and A. Distante, “Reactive navigation by fuzzy control,” in Proceedings of IEEE 5th International Fuzzy Systems, vol. 3, pp. 2143–2149, 1996, doi: 10.1109/FUZZY.1996.552796.
17. W. L. Xu and S. K. Tso, “Sensor-based fuzzy reactive navigation of a mobile robot through local target switching,” IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), vol. 29, no. 3, pp. 451–459, 1999, doi: 10.1109/5326.777079.
18. M. M. Joshi and M. A. Zaveri, “Fuzzy Based Autonomous Robot Navigation System,” in 2009 Annual IEEE India Conference, pp. 1–4, 2009, doi: 10.1109/INDCON.2009.5409419.
19. M. Alwan, P. Y. K. Cheung, A. Saleh, and N. E. C. Obeid, “Combining goal-directed, reactive and reflexive navigation in autonomous mobile robots,” in 1996 Australian New Zealand Conference on Intelligent Information Systems. Proceedings. ANZIIS 96, pp. 346–349, 1996, doi: 10.1109/ANZIIS.1996.573982.
20. A. S. Al-Jumaily and S. H. M. Amin, “Fuzzy logic-based behaviors blending for intelligent reactive navigation of walking robot,” in ISSPA "99. Proceedings of the Fifth International Symposium on Signal Processing and its Applications (IEEE Cat. No.99EX359), vol. 1, pp. 155–158, 1999, doi: 10.1109/ISSPA.1999.818136.
21. M. Skubic, S. Graves, and J. Mollenhauer, “Design of a two-level fuzzy controller for a reactive miniature mobile robot,” in Third International Conference on Industrial Fuzzy Control and Intelligent Systems, pp. 224–227, 1993, doi: 10.1109/IFIS.1993.324183.

22. L. Overholt, G. R. Hudas, and K. C. Cheok, “A modular neural-fuzzy controller for autonomous reactive navigation,” in NAFIPS 2005 -2005 Annual Meeting of the North American Fuzzy Information Processing Society, pp. 121–126, 2005, doi: 10.1109/NAFIPS.2005.1548519.
23. W. Li, “Fuzzy logic-based robot navigation in uncertain environments by multisensor integration,” in Proceedings of 1994 IEEE International Conference on MFI "94. Multisensor Fusion and Integration for Intelligent Systems, pp. 259–264, 1994, doi: 10.1109/MFI.1994.398444.
24. N. Melik and N. Slimane, “Autonomous navigation with obstacle avoidance of tricycle mobile robot based on fuzzy controller,” in 2015 4th International Conference on Electrical Engineering (ICEE), pp. 1– 4, 2015, doi: 10.1109/INTEE.2015.7416799.
25. O. Aycard, F. Charpillet, and J.-P. Haton, “A new approach to design fuzzy controllers for mobile robots' navigation,” in Proceedings 1997 IEEE International Symposium on Computational Intelligence in Robotics and Automation CIRA"97. „Towards New Computational Principles for Robotics and Automation, " pp. 68–73, 1997, doi: 10.1109/CIRA.1997.613840.
26. B. C. Arrue, F. Cuesta, R. Braunstingl, and A. Ollero, “Fuzzy behaviors combination to control a nonholonomic mobile robot using virtual perception memory,” in Proceedings of 6th International Fuzzy Systems Conference, vol. 3. pp. 1239–1244, 1997, doi: 10.1109/FUZZY.1997.619465.
27. W. Li and X. Feng, “Behavior fusion for robot navigation in uncertain environments using fuzzy logic,” in Proceedings of IEEE International Conference on Systems, Man and Cybernetics, vol. 2, pp. 1790–1796, 1994, doi: 10.1109/ICSMC.1994.400110.
28. A. S. Al-Jumaily and S. H. M. Amin, “Behaviors blending for intelligent reactive navigation of climbing robot,” in 2000 26th Annual Conference of the IEEE Industrial Electronics Society. IECON 2000. 2000 IEEE International Conference on Industrial Electronics, Control and Instrumentation. 21st Century Technologies, vol. 2, pp. 795–799, 2000, doi: 10.1109/IECON.2000.972224.
29. X. Yang, M. Moallem, and R. V Patel, “A fuzzy logic-based reactive navigation algorithm for mobile robots,” in Proceedings of 2005 IEEE Conference on Control Applications, 2005. CCA 2005., pp. 197–202, 2005, doi: 10.1109/CCA.2005.1507124.
30. Y. Duan and Xin-Hexu, “Fuzzy reinforcement learning and its application in robot navigation,” in 2005 International Conference on Machine Learning and Cybernetics, vol. 2, pp. 899-904, 2005, doi: 10.1109/ICMLC.2005.1527071.
31. W. L. Xu, S. K. Tso, and Y. H. Fung, “Sensor-based reactive navigation of a mobile robot through local target switching,” in 1997 8th International Conference on Advanced Robotics. Proceedings. ICAR"97, pp. 361–366, 1997, doi: 10.1109/ICAR.1997.620207.
32. M. Anvar, “Intelligent navigation process for autonomous underwater vehicles (AUVs) using time-based fuzzy temporal reasoning,” in 10th International Symposium on Temporal Representation and Reasoning, 2003 and Fourth International Conference on Temporal Logic. Proceedings., pp. 56–61, 2003, doi: 10.1109/TIME.2003.1214880.
33. H. Maaref and C. Barret, “Fuzzy help in mobile robot navigation,” in Proceedings IEEE Conference on Industrial Automation and Control Emerging Technology Applications, pp. 387–390, 1995, doi: 10.1109/IACET.1995.527593.
34. C. Barret, M. Benreguieg, and H. Maaref, “Fuzzy agents for reactive navigation of a mobile robot,” in Proceedings of 1st International Conference on Conventional and Knowledge Based Intelligent Electronic Systems. KES "97, vol. 2, pp. 649–658, 1997, Doi: 10.1109/KES.1997.619449.
35. A. S. Al-Jumaily, S. H. M. Amin, and M. Khalil, “A fuzzy multi-behavior reactive obstacle avoidance navigation for a climbing mobile robot,” in Proceedings of IEEE International Conference on Intelligent Engineering Systems, pp. 147–152, 1997, Doi: 10.1109/INES.1997.632408.
36. W. Li, “A hybrid neuro-fuzzy system for sensor-based robot navigation in unknown environments,” in Proceedings of 1995 American Control Conference - ACC"95, vol. 4, pp. 2749–2753, 1995, doi: 10.1109/ACC.1995.532349.
37. G. Mester, “Obstacle Avoidance of Mobile Robots in Unknown Environments,” in 2007 5th International Symposium on Intelligent Systems and Informatics, pp. 123–127, 2007, Doi: 10.1109/SISY.2007.4342637.
38. M. Benreguieg, H. Maaref, and C. Barret, “Fusion of fuzzy agents for the reactive navigation of a mobile robot,” in Proceedings of the 1997 IEEE/RSJ International Conference on Intelligent Robot and Systems. Innovative Robotics for Real-World Applications. IROS "97, vol. 1, pp. 388–394, 1997, doi: 10.1109/IROS.1997.649091.
39. M. Dupre and S. X. Yang, “Two-Stage Fuzzy Logic-Based Controller for Mobile Robot Navigation,” in 2006 International Conference on Mechatronics and Automation, pp. 745–750, 2006, doi: 10.1109/ICMA.2006.257683.
40. Jayasiri, G. K. I. Mann, and R. G. Gosine, “Supervisory control of Fuzzy Discrete Event Systems and its application to mobile robot navigation,” in 2009 Canadian Conference on Electrical and Computer Engineering, pp. 1147–1151, 2009, doi: 10.1109/CCECE.2009.5090305.
41. D. Shi, M. F. Selekwa, E. G. Collins, and C. A. Moore, “Fuzzy behavior navigation for an unmanned helicopter in unknown environments,” in 2005 IEEE International Conference on Systems, Man and Cybernetics, vol. 4, pp. 3897-3902. 2005, doi: 10.1109/ICSMC.2005.1571754.
42. G. Mondelli, G. Castellano, G. Attolico, E. Stella, and A. Distante, “Self-tuning fuzzy logic controller for reactive navigation,” in Proceedings of Conference on Intelligent Vehicles, pp. 87–92, 1996, doi: 10.1109/IVS.1996.566358.

43. M. F. Selekwa, D. D. Dunlap, and E. G. Collins, “Implementation of Multi-valued Fuzzy Behavior Control for Robot Navigation in Cluttered Environments,” in Proceedings of the 2005 IEEE International Conference on Robotics and Automation, pp. 3688–3695, 2005, doi: 10.1109/ROBOT.2005.1570682.
44. B. B. K. Reddy, B. Kimiaghalam, and A. Homaifar, “Reactive real time behavior for mobile robots in unknown environments,” in 2004 IEEE International Symposium on Industrial Electronics, vol. 1, pp. 693– 697, 2004, doi: 10.1109/ISIE.2004.1571890.
45. S. Kundu and D. R. Parhi, “Behavior-based navigation of multiple robotic agents using hybrid-fuzzy controller,” in 2010 International Conference on Computer and Communication Technology (ICCCT), pp. 706–711, 2010, doi: 10.1109/ICCCT.2010.5640437.
46. Safiotti, “Fuzzy logic in autonomous robotics: behavior coordination,” in Proceedings of 6th International Fuzzy Systems Conference, vol. 1, pp. 573–578, 1997, doi: 10.1109/FUZZY.1997.616430.
47. H. Maaref and C. Barret, “Progressive optimization of a fuzzy inference system,” in Proceedings Joint 9th IFSA World Congress and 20th NAFIPS International Conference (Cat. No. 01TH8569), vol. 1, pp. 47–52, 2001, doi: 10.1109/NAFIPS.2001.944225.
48. C. Vega Oliver and P. F. Huamaní Navarrete, “Fuzzy control to simulate 4 autonomous navigation behaviors in a differential-drive mobile robot,” in 2017 IEEE International Conference on Aerospace and Signals (INCAS), pp. 1–4, 2017, doi: 10.1109/INCAS.2017.8123498.
49. J. Yung-Jen Hsu, D.-C. Lo, and S.-C. Hsu, “Fuzzy control for behaviorbased mobile robots,” in NAFIPS/IFIS/NASA "94. Proceedings of the First International Joint Conference of The North American Fuzzy Information Processing Society Biannual Conference. The Industrial Fuzzy Control and Intelligent, pp. 209–213, 1994, doi: 10.1109/IJCF.1994.375097.
50. Zhu and S. X. Yang, “A goal-oriented fuzzy reactive control for mobile robots with automatic rule optimization,” in 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 3688– 3693, 2010, doi: 10.1109/IROS.2010.5651799.
51. Zhu and S. X. Yang, “A fuzzy logic approach to reactive navigation of behavior-based mobile robots,” in IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA "04. 2004, vol. 5, pp. 5045-5050, 2004, doi: 10.1109/ROBOT.2004.1302517.
52. S. Kundu and D. R. Parhi, “Fuzzy based reactive navigational strategy for mobile agent,” in 2010 International Conference on Industrial Electronics, Control and Robotics, pp. 12–17, 2010, doi: 10.1109/IECR.2010.5720149.
53. S. G. Goodridge and R. C. Luo, “Fuzzy behavior fusion for reactive control of an autonomous mobile robot: MARGE,” in Proceedings of the 1994 IEEE International Conference on Robotics and Automation, vol. 2, pp. 1622–1627, 1994, doi: 10.1109/ROBOT.1994.351358.
54. C. Tan, K. K. Tan, T. H. Lee, S. Zhao, and Y. J. Chen, “Autonomous robot navigation based on fuzzy sensor fusion and reinforcement learning,” in Proceedings of the IEEE International Symposium on Intelligent Control, pp. 182–187, 2002, doi: 10.1109/ISIC.2002.1157759.
55. A. Sotelo et al., “Vehicle fuzzy driving based on DGPS and vision,” in Proceedings Joint 9th IFSA World Congress and 20th NAFIPS International Conference (Cat. No. 01TH8569), vol. 3, pp. 1472–1477, 2001, doi: 10.1109/NAFIPS.2001.943766.
56. Howard, B. Werger, and H. Seraji, “Integrating terrain maps into a reactive navigation strategy,” in 2003 IEEE International Conference on Robotics and Automation (Cat. No.03CH37422), vol. 2, pp. 2012– 2017, 2003, doi: 10.1109/ROBOT.2003.1241889.
57. H. Liu, P. Hu, Y. Luo, and C. Li, “A goal-oriented fuzzy reactive control method for mobile robot navigation in unknown environment,” in 2009 IEEE International Symposium on Industrial Electronics, pp. 1950–1955, 2009, doi: 10.1109/ISIE.2009.5219773.
58. H. A. Hagras, “A hierarchical type-2 fuzzy logic control architecture for autonomous mobile robots,” IEEE Transactions on Fuzzy Systems, vol. 12, no. 4, pp. 524–539, 2004, doi: 10.1109/TFUZZ.2004.832538.
59. S. Kundu and R. P. Dayal, “A fuzzy approach towards behavioral strategy for navigation of mobile agent,” in INTERACT-2010, pp. 292– 297, 2010, doi: 10.1109/INTERACT.2010.5706164.
60. B.-K. Shim, J.-H. Kim, I.-M. Park, and S.-H. Han, “An intelligent control of non-holonomic mobile robot based on fuzzy perception,” in ICCAS 2010, pp. 2111–2114, 2010, doi: 10.1109/ICCAS.2010.5670182.
61. A. S. Al-Jumaily and S. H. M. Amin, “Blending multi-behaviors of intelligent reactive navigation for legged walking robot in unstructured environment,” in 2000 TENCON Proceedings. Intelligent Systems and Technologies for the New Millennium (Cat. No.00CH37119), vol. 2, pp. 297–302, 2000, doi: 10.1109/TENCON.2000.888751.
62. J. G. Ortega and E. F. Camacho, “Mobile robot navigation in a partially structured static environment, using neural predictive control,” Control Eng Pract, vol. 4, no. 12, pp. 1669–1679, 1996, doi: https://doi.org/10.1016/S0967-0661(96)00184-0.
63. L. E. Zarate, M. Becker, B. D. M. Garrido, and H. S. C. Rocha, “An artificial neural network structure able to obstacle avoidance behavior used in mobile robots,” in IEEE 2002 28th Annual Conference of the Industrial Electronics Society. IECON 02, vol. 3, pp. 2457–2461, 2002, doi: 10.1109/IECON.2002.1185358.

64. Gamal, X. Cai, and H. Roth, “Learning from Fuzzy System Demonstration: Autonomous Navigation of Mobile Robot in Static Indoor Environment using Multimodal Deep Learning,” in 2020 24th International Conference on System Theory, Control and Computing (ICSTCC), pp. 218–225, 2020, doi: 10.1109/ICSTCC50638.2020.9259786.
65. S. Lafmejani, S. Berman, and G. Fainekos, “NMPC-LBF: Nonlinear MPC with Learned Barrier Function for Decentralized Safe Navigation of Multiple Robots in Unknown Environments,” 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 10297-10303, 2022, doi: 10.1109/IROS47612.2022.9981177.
66. G. Chen et al., "Robot Navigation with Map-Based Deep Reinforcement Learning," 2020 IEEE International Conference on Networking, Sensing and Control (ICNSC), pp. 1-6, 2020, doi: 10.1109/ICNSC48988.2020.9238090.
67. Y. Pan and J. Wang, “A neurodynamic optimization approach to nonlinear model predictive control,” in 2010 IEEE International Conference on Systems, Man and Cybernetics, pp. 1597–1602, 2010, doi: 10.1109/ICSMC.2010.5642367.
68. Hirose, F. Xia, R. Martín-Martín, A. Sadeghian, and S. Savarese, “Deep Visual MPC-Policy Learning for Navigation,” IEEE Robot Autom Lett, vol. 4, no. 4, pp. 3184–3191, 2019, doi: 10.1109/LRA.2019.2925731.
69. T. Ono and T. Kanamaru, “Prediction of pedestrian trajectory based on long short-term memory of data,” in 2021 21st International Conference on Control, Automation and Systems (ICCAS), pp. 1676– 1679, 2021, doi: 10.23919/ICCAS52745.2021.9649937.
70. T. Kim, H. Lee, S. Hong, and W. Lee, “TOAST: Trajectory Optimization and Simultaneous Tracking Using Shared Neural Network Dynamics,” IEEE Robot Autom Lett, vol. 7, no. 4, pp. 9747– 9754, 2022, doi: 10.1109/LRA.2022.3184769.
71. Y. Guo, R. Jena, D. Hughes, M. Lewis, and K. Sycara, “Transfer Learning for Human Navigation and Triage Strategies Prediction in a Simulated Urban Search and Rescue Task,” in 2021 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN), pp. 784–791, 2021, doi: 10.1109/ROMAN50785.2021.9515526.
72. A. Polevoy, C. Knuth, K. M. Popek, and K. D. Katyal, “Complex Terrain Navigation via Model Error Prediction,” 2022 International Conference on Robotics and Automation (ICRA), pp. 9411-9417, 2022, doi: 10.1109/ICRA46639.2022.9811644.
73. S. Lai, M. Lan, and B. M. Chen, “Model Predictive Local Motion Planning with Boundary State Constrained Primitives,” IEEE Robot Autom Lett, vol. 4, no. 4, pp. 3577–3584, 2019, doi: 10.1109/LRA.2019.2928255.
74. F. Gauthier-Clerc, A. Hill, J. Laneurit, R. Lenain, and É. Lucet, “Online velocity fluctuation of off-road wheeled mobile robots: A reinforcement learning approach,” in 2021 IEEE International Conference on Robotics and Automation (ICRA), pp. 2421–2427, 2021, doi: 10.1109/ICRA48506.2021.9560816.
75. E. P. Ferreira and V. M. Miranda, “Development of static neural networks as full predictors or controllers for multiarticulated mobile robots in backward movements - new models and tools,” in 2011 9th IEEE International Conference on Control and Automation (ICCA), pp. 985–990, 2011, doi: 10.1109/ICCA.2011.6138028.
76. N. D. Weerakkodi Mudalige et al., “DogTouch: CNN-based Recognition of Surface Textures by Quadruped Robot with High Density Tactile Sensors,” in 2022 IEEE 95th Vehicular Technology Conference: (VTC2022-Spring), pp. 1–5, 2022, doi: 10.1109/VTC2022-Spring54318.2022.9860815.
77. X. Zou, B. Sun, D. Zhao, Z. Zhu, J. Zhao, and Y. He, “Multi-Modal Pedestrian Trajectory Prediction for Edge Agents Based on Spatial Temporal Graph,” IEEE Access, vol. 8, pp. 83321–83332, 2020, doi: 10.1109/ACCESS.2020.2991435.
78. I. Engedy and G. Horvath, “Artificial neural network based mobile robot navigation,” in 2009 IEEE International Symposium on Intelligent Signal Processing, pp. 241–246, 2009, doi: 10.1109/WISP.2009.5286557.
79. M. K. Bugeja, S. G. Fabri, and L. Camilleri, “Dual Adaptive Dynamic Control of Mobile Robots Using Neural Networks,” IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), vol. 39, no. 1, pp. 129–141, 2009, doi: 10.1109/TSMCB.2008.2002851.
80. J. Yuan, H. Wang, C. Lin, D. Liu, and D. Yu, “A Novel GRU-RNN Network Model for Dynamic Path Planning of Mobile Robot,” IEEE Access, vol. 7, pp. 15140–15151, 2019, doi: 10.1109/ACCESS.2019.2894626.
81. M. J. Er, T. P. Tan, and S. Y. Loh, “Control of a mobile robot using generalized dynamic fuzzy neural networks,” Microprocess Microsyst, vol. 28, no. 9, pp. 491–498, 2004, doi: https://doi.org/10.1016/j.micpro.2004.04.002.
82. B.-Q. Huang, G.-Y. Cao, and M. Guo, “Reinforcement Learning Neural Network to the Problem of Autonomous Mobile Robot Obstacle Avoidance,” in 2005 International Conference on Machine Learning and Cybernetics, pp. 85–89, 2005, doi: 10.1109/ICMLC.2005.1526924.
83. S. Soumare, A. Ohya, and S. Yuta, “Real-time obstacle avoidance by an autonomous mobile robot using an active vision sensor and a vertically emitted laser slit,” In Intelligent Autonomous Systems, vol. 7, pp. 301-308, 2002.
84. M. Lauer, M. Schönbein, S. Lange, and S. Welker, “3D-objecttracking with a mixed omnidirectional stereo camera system,” Mechatronics, vol. 21, pp. 390–398, 2011.
85. M. Tahmasebi, M. Gohari, and A. Emami, “An Autonomous Pesticide Sprayer Robot with a Color-based Vision System,” International Journal of Robotics and Control Systems, vol. 2, no. 1, pp. 115–123, Feb. 2022, doi: 10.31763/ijrcs.v2i1.480.

86. S. D. Perkasa, P. Megantoro, and H. A. Winarno, “Implementation of a camera sensor pixy 2 cmucam5 to a two wheeled robot to follow colored object,” Journal of Robotics and Control (JRC), vol. 2, no. 6, pp. 496–501, Nov. 2021, doi: 10.18196/jrc.26128.
87. M. I. Rusydi et al., “Autonomous Movement Control of Coaxial Mobile Robot based on Aspect Ratio of Human Face for Public Relation Activity Using Stereo Thermal Camera,” Journal of Robotics and Control (JRC), vol. 3, no. 3, pp. 361–373, May 2022, doi: 10.18196/jrc.v3i3.14750.
88. F. Umam, M. Fuad, I. Suwarno, A. Ma'arif, and W. Caesarendra,” Obstacle Avoidance Based on Stereo Vision Navigation System for Omni-directional Robot”, Journal of Robotics and Control (JRC) Volume 4, Issue 2, March 2023 ISSN: 2715-5072, DOI: 10.18196/jrc.v4i2.17977.
89. M. A. Baballe, A. I. Adamu, A. S. Bari, A. Ibrahim, “Principal Operation of a Line Follower Robot”, Global Journal of Research in Engineering & Computer Sciences ISSN: 2583-2727 (Online) Volume 03| Issue 03 | May-June | 2023 Journal homepage: https://gjrpublication.com/gjrecs/.
90. M. Çavaş, and M. B. Ahmad, “A REVIEW ON SPIDER ROBOTIC SYSTEM”, International Journal of New Computer Architectures and their Applications (IJNCAA) vol. 9, no. 1 pp. 19-24, The Society of Digital Information and Wireless Communications, 2019.
91. M. B. Ahmad, and A. S. Muhammad,” A general review on advancement in the robotic system”, Artificial & Computational Intelligence, pp. 1-7, Mar 2020, http://acors.org/ijacoi/VOL1_ISSUE2_04.pdf.
92. M. A. Baballe, M. I. Bello, A. Hussaini, U. S. Musa, “Pipeline Inspection Robot Monitoring System”, Journal of Advancement in Robotics, Volume 9, Issue 2, 2022, DOI (Journal): 10.37591/JoARB.
93. M. B. Ahmad et al., “The Various Types of sensors used in the Security Alarm system”, International Journal of New Computer Architectures and their Applications (IJNCAA) 9(2): 50-59 The Society of Digital Information and Wireless Communications, 2019.
94. https://circuitdigest.com/microcontroller-projects/arduino-obstacle-avoding-robot.
95. I. Adamu, A. S. Bari, A. Ibrahim, and M. A. Baballe,” The Several uses for Obstacle-Avoidance Robots”, Global Journal of Research in Engineering & Computer Sciences ISSN: 2583-2727 (Online) Volume 03| Issue 03 | MayJune | 2023 Journal homepage: https://gjrpublication.com/gjrecs/.
96. M. A. Baballe et al.,” A Look at the Different Types of Servo Motors and Their Applications”, Global Journal of Research in Engineering & Computer Sciences ISSN: 2583-2727 (Online) Volume 02| Issue 03 | May-June | 2022 Journal homepage: https://gjrpublication.com/gjrecs/.
97. Abdulkadir S. B, Muhammad A. F, Amina I., Mukhtar I. B, & M. A. Baballe. (2023). Elements needed to implement the Obstacle-Avoidance Robots. Global Journal of Research in Engineering & Computer Sciences, 3(3), 18–27. https://doi.org/10.5281/zenodo.8051131.
98. Mukhtar I. B., & M. A. Baballe. (2023). Simulation of Obstacle Avoidance Robots. Global Journal of Research in Engineering & Computer Sciences, 3(5), 1–9. https://doi.org/10.5281/zenodo.8408537

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