

Fuzzy Control for Person Follower FPGA based Robotic System

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Abstract

Robotic systems perform various tasks using image processing techniques. This paper proposes a fuzzy logic controlled robotic system for person follower behavior in an indoor environment. The robot platform used here is from National Instruments which has 120 degree rotating ultrasonic sensor and a Single-Board Reconfigurable Input-Output (SBRIO). The board has a Field Programmable Gate Array (FPGA) device and real time controller which is interfaced to an Internet Protocol (IP) camera. The robot motion is controlled using a fuzzy logic based algorithm. Higher momentum and soft control are some benefits of using fuzzy logic controller when compared to binary logic, as it assigns variable speeds to wheels. The image captured from the camera is processed using Optical Character Recognition (OCR) method and the ultrasonic sensor is used to measure the distance, avoid the obstacles. The design is done using NI-LabVIEW and the experimental results of this approach shows fast response of the robot to follow a person in a smooth manner.

Keywords: FPGA, Fuzzy control, Robot, Ultrasonic sensor

1. Introduction

The problem of person following autonomous mobile robots using optimal paths through environments cluttered with obstacles has attracted much research interest. The use of Fuzzy control for smooth motion of mobile robot avoiding the erratic effects while taking intelligent decisions is a well known fact. Also the usage of image processing techniques for person following can be found in literature. The important capability that needs to be possessed by a service robot when required to complete some human-allied tasks is person following. The ability to automatically determine clash-free paths in the presence of obstacles is a vital one for a mobile robot.

The design a fuzzy logic system for an obstacle avoidance algorithm for a path planning in unknown environment for a mobile robot is proposed in², an angular velocity control for left and right wheels was implemented

by a fuzzy logic system. A binary logic OCR based person follower is proposed by¹. A fuzzy inference system is developed and used as a controller to provide decisions achieving smooth and safe person-following behavior using laser range finder¹⁰. A simple fuzzy logic controller is presented in⁴ which searches target and plans the path with obstacle avoidance. The robot following a target person robustly using a laser range finder is discussed in⁵. An algorithm for mobile robot path planning to move in a freely spaced self-service canteen environment is presented in⁶. To solve the robot navigation, a priority-based behavior fuzzy logic control was proposed by⁷. Vision-based person following with a mobile robot using the Binocular Sparse Feature Segmentation algorithm is presented in¹¹. A new reactive planning algorithm was proposed by⁸ for mobile robot navigation in unknown environments. For object based navigation a real time and robust recursive line extraction algorithm was introduced

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by⁹. The design and simulation of fuzzy-logic based algorithms for mobile robots for avoiding obstacles and reaching a pre-defined target point in an unknown environment is presented in³. The different methods were presented in¹² for mobile robot tracking and following of a fast-moving person in outdoor unstructured and possibly dynamic environment.

The major problem for the real-time hardware implementation of intelligent robots is the requirement of fast and complex computations. The alternative approach is using an ASIC implementation, which is very expensive and does not have reconfigurability feature. The introduction of the powerful Field Programmable Gate Array (FPGA) does have become alternative in some context. It proved to be an effective tool for real-time hardware implementation of complex tasks and played a key role in a variety of engineering fields such as image processing, control, signal processing, and the like¹³.

Robotic mapping in dynamic environments with regard to hardware-efficient schemes for autonomous robotic exploration and planning is discussed in¹⁴. The important issue for a robot exploring in unknown environments is active map learning. The learning of accurate map models in practical is limited by many factors. A fuzzy logic controller for mobile robot path control for shooting action of soccer robot was presented in¹⁵. A humanoid service robot for following people using the Continuous Real-time Partially Observable Monte-Carlo Planning method was proposed by¹⁶. An agent with full perceptual capability and limited auditory for human-human interaction along a given path is proposed by¹⁷. A computationally intelligent control algorithm proposed by¹⁸ in which the recognition methods use segmentation and classification of detected regions of interests with a thermal vision camera.

This paper proposes an algorithm on FPGA based fuzzy logic control for the person-following case in order to achieve smoothness in motion of the mobile robot. It uses a IP Camera mounted on a DaNI Robot platform to perceive the characters on the person's uniform and follow them in a smooth motion while keeping a safe distance from that person. The remainder of this paper is organized as follows: Section 2 gives an overview of the parts of the Robot platform and the fuzzy control based proposed algorithm. Section 3 presents the fuzzy membership functions. Test results carried out using NI-Embedded FPGA Robotic platform are described in Section 4. Conclusion is given in Section 5.

2. Proposed Algorithm-Robot Platform

2.1 Main Thoughts

The Single-Board Reconfigurable Input-Output (SBRIO-9632) based robot is equipped with one steering ultrasonic sensor in the frontend without affecting echo errors from multiple obstacles, like reflection of floor and top of the indoor environment. The mobile robot motion is assumed to be in an indoor environment. Ultrasonic sensor is used since they have a cone-shaped beam angle of approximately 22° .

An Axis made IP camera is placed in appropriate manner at a suitable height on the Robot front as shown in Figure 1 and is connected to a wireless router. The camera captures the lower side real time images of the person to be followed, sends to the SBRIO, also to a laptop through the wireless router. The captured image pattern is matched with the standard images using OCR and the output character string is sent to the controller unit designed for navigation of Robot. A minimum distance is kept between the mobile robot and the person to be followed.

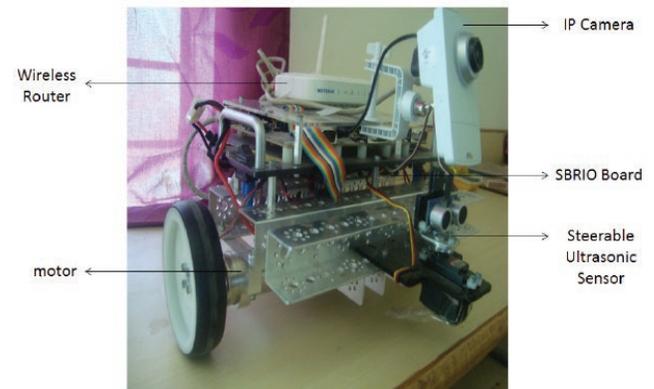


Figure 1. IP camera interfaced DaNI Robot platform.

The mobile robot periodically explores the environment starting from image pattern detection, following the person based on the commands from the FPGA and also checks the status of the sensor if any obstacle is detected. The hardware implementation of robotic exploration is done in the FPGA. The template characters which are on the person's uniform are 'HL', 'L', 'R'. The template HL is used for forward movement, L for turning left and R for turning right.

2.2 Flowchart

The algorithmic flow chart of person follower behavior is shown in Figure 2. A fuzzy control based approach for autonomous robot follower is developed and implemented on NI's SBRIO which is a two wheel differential drive mobile robot. The ultrasonic sensor mounted on a servomotor which can sweep through a 120° frontal area, can sense the obstacles up to a maximum distance of 3m.

The images captured from camera on Robot are compared with the character images stored in the memory using OCR. The Robot follows the person if the image 'HL' is detected. The speed control is based on the input and output fuzzy sets discussed in section 3. If the person takes right direction, then right template 'R' is matched, the robot takes a right turn based on fuzzy sets. And if the person takes left direction, then left template 'L' is matched, the robot moves forward for the minimum distance and the wheel rotates left as per fuzzy rules.

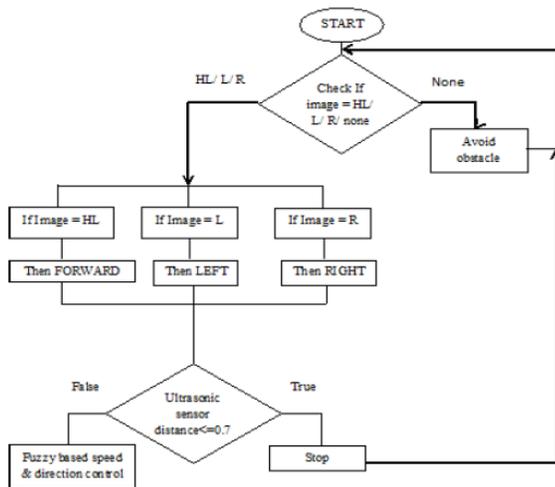


Figure 2. Algorithmic Flow chart.

3. Fuzzy Control

The main problem in robot navigation is the need to handle with the large amount of improbability. The advantage of fuzzy is its ability to use the common sense reasoning to describe complex systems. The response of a very complex system in a simple manner can be instinctively described by creating a range of fuzzy sets for input-output variables and generating a simple rule based matrix by using fuzzy logic.

The design of fuzzy controller uses four input variables for rotation and speed control of motors as shown

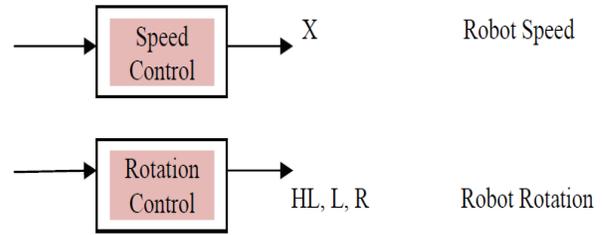


Figure 3. Fuzzy controller.

in Figure 3. Here X is the distance from the sensor and HL/L/R are the discrete value inputs. These inputs and outputs variable fuzzy membership functions are given in Figure 4.

The input values on x-axis for L /R /HL are normalized to the range of -10 to 10 and 0 to 3 for the ultrasonic sensor. Similarly the output values on x-axis are normalized in the range of -10 to 10 for the direction of rotation of

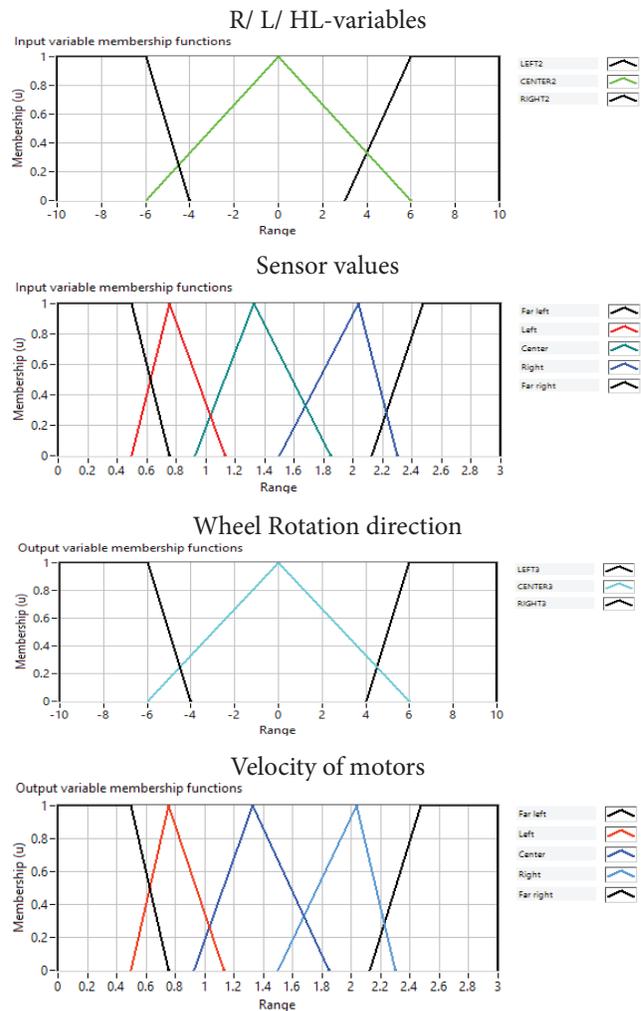


Figure 4. Input/Output membership functions.

wheels and 0 to 3 for the speed of motors. The figure 6 shows the graphical design developed in LabVIEW using various modules.

The graphical design shown in Figure 6 is first simulated in LabVIEW and then implemented on FPGA. The image capturing is set using live feed from camera. The initialization of image references is done using the loaded OCR character set and is stored in the memory.

The Fuzzy Rules set are shown in Figure 5.

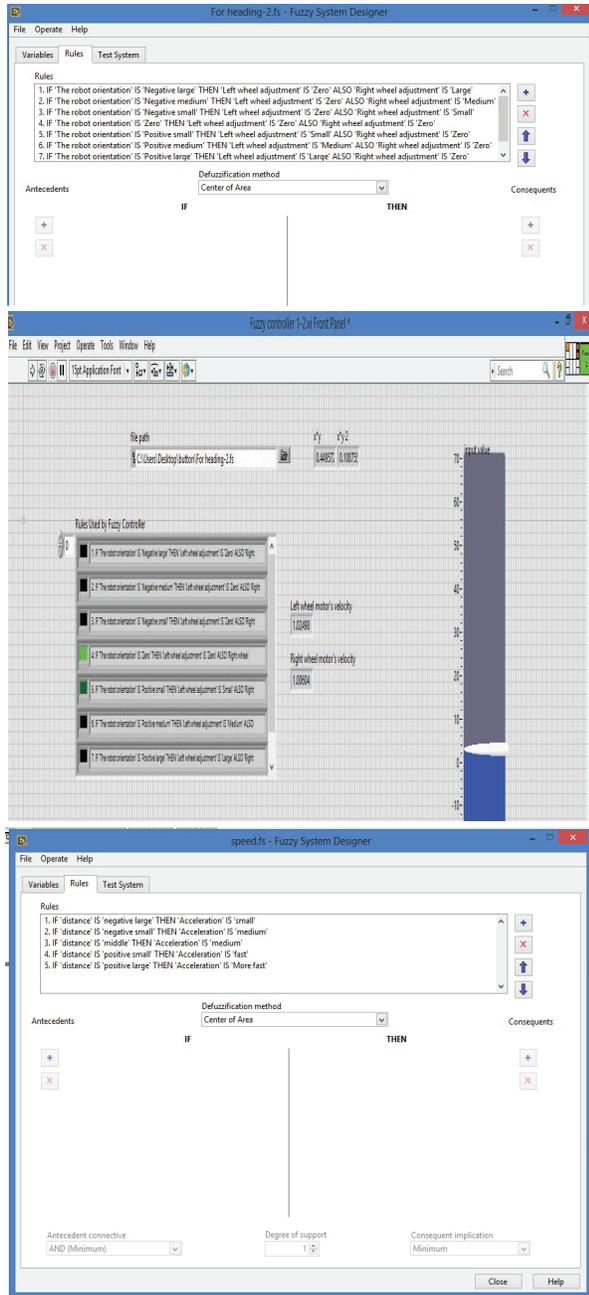


Figure 5. Fuzzy rule sets.

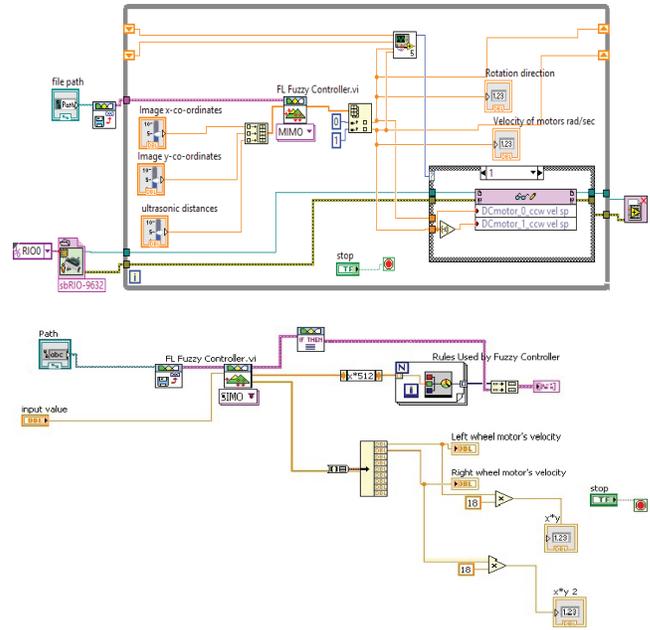


Figure 6. Graphical Design in Labview for Fuzzy controllers.



Figure 7. Start position and OCR output, Robot takes a Right turn for 'R' and then following 'HL'.

4. Test Results

The test results are shown as sequence of snapshots taken during the experiment in Figure 7. They represent the movement and the directions of the robot. Here the person to be followed is considered as a patient. The Figure 7 shows the initial position of the robot and once the OCR string 'HL' is detected, it follows the person. It takes a right turn based on the fuzzy rule set, when 'R' is detected. The wheel rotation is smoother when fuzzy control is used. Thus it follows the person avoiding obstacles using the ultrasonic sensor which rotates +60 to -60 degrees.

5. Conclusion

The lower processing time is achieved using the developed fuzzy logic based algorithm for person following and is intelligent in processing sensor data, matching the character in image using OCR. The fuzzy controller

does parallel processing in terms of collision avoidance and template recognition. The mobile robot avoids jerky effects when fuzzy logic is used. The experiments conducted shows that the soft control and higher momentum are the benefits of fuzzy logic when compared to binary logic.

6. References

- Sanjay D, Savithri TS, Kumar PR. Person follower Robotic system. 2014 IEEE-International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT); 2014 Jul. p. 1324–7.
- Li X, Choi Byung-Jae. Design of obstacle avoidance system for mobile robot using fuzzy logic systems. *International Journal of Smart Home*. 2013 May; 7(3):321–8.
- Mysorewala M, Alshehri K, Alkhatay E, Al-Ghusain A, Al-Yagoub O. Design and implementation of fuzzy-logic based obstacle-avoidance and target-reaching algorithms on NI's embedded-FPGA robotic platform. *IEEE Symposium on Computational Intelligence in Control and Automation (CICA)*. 2013 Apr; 168(173):16–9.
- Benbouabdallah K, Qi-dan Z. A Fuzzy logic behavior architecture controller for a mobile robot path planning in multi-obstacles environment. *Research Journal of Applied Sciences, Engineering and Technology*. 2013; 5(14):3835–42.
- Hiroi Y, Matsunaka S, Ito A. A mobile robot system with semi-autonomous navigation using simple and robust person following behavior. *Journal of Man, Machine and Technology (JMMT)*. 2012 Dec; 1(1).
- Chinnaiah MC, Sanjay D, Kumar PR, Savithri TS. A Novel approach and Implementation of Robot path planning using Parallel processing algorithm. *International Conference on Communications, Devices and Intelligent Systems (CODIS)*; 2012 28–29 Dec. p. 345–8.
- Dongshu W, Yusheng Z, Wenjie S. Behavior-Based Hierarchical Fuzzy Control for Mobile Robot Navigation in Dynamic Environment. 2011 IEEE Chinese Control and Decision Conference (CCDC); 2011. p. 2419–24.
- Velagic J, Lacevic B, Osmic N. Efficient Path Planning Algorithm for Mobile Robot Navigation with a Local Minima Problem Solving. 2006 IEEE International Conference on Industrial Technology; 2006. p. 2325–30.
- Norouzi M, Karambakhsh A, Namazifar M, Savkovic B. 2009 IEEE International conference on Object Based Navigation of Mobile Robot with Obstacle Avoidance using Fuzzy Controller; 2009. p.169–74.
- Shaker S, Saade JJ, Asmar D. Person-following using Fuzzy interference. *ACACOS'08 Proceedings of the 7th WSEAS International Conference on Applied Computer and Applied Computational Science*; 2008 6 Apr. p.19–25.
- Chen Z, Birchfield ST. Person following with a mobile robot using binocular feature-based tracking. *IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2007*; 2007 29 Oct–2 Nov. p. 815–20.
- Kobilarov M, Sukhatme G, Hyams J, Batavia P. People tracking and following with mobile robot using an omnidirectional camera and a laser. *IEEE International Conference on Robotics and Automation, ICRA 2006. Proceedings 2006*; 2006 15–19 May. p. 557–62.
- Rodriguez-Andina JJ, Moure MJ, Valdes MD. Features, Design Tools, and Application Domains of FPGAs. *IEEE Transactions on Industrial Electronics*. 2007 Aug; 54(4):1810–23.
- Kumar PR, Sridharan K. VLSI-Efficient Scheme and FPGA Realization for Robotic Mapping in a Dynamic Environment. *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*. 2007 Jan; 15(1):118–23.
- Min BC, Lee Moon-Su, Kim D. Fuzzy logic path planner and motion controller by evolutionary programming for mobile robots. *International Journal of Fuzzy Systems*. 2009 Sep; 11(3):154–63.
- Goldhoorn A, Garrell A, Alquezar R, Sanfeliu A. Continuous real time POMCP to find-and-follow people by a humanoid service robot. 14th IEEE-RAS International Conference on Humanoid Robots (Humanoids); 2014 18–20 Nov. p.741–7.
- Ranasinghe A, Sornkarn N, Dasgupta P, Althoefer K, Penders J, Nanayakkara T. Salient Feature of Haptic-Based Guidance of People in Low Visibility Environments Using Hard Reins. *IEEE Transactions on Cybernetics*. 2015 11 Jun; 99:1.
- Ciric I, Cojbasic Z, Nikolic V, Antic D. Computationally intelligent system for thermal vision people detection and tracking in robotic applications. 11th International Conference on Telecommunication in Modern Satellite, Cable and Broadcasting Services (TELSIKS). 2013 16–19 Oct; 2:587–90.