Fuzzy Logic Controller For Wheeled Mobile Robots

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Abstract -In this paper, we propose a fuzzy logic controller forthe motion control of a wheeled mobile robot (WMR)in simulation environment. Algorithms for controlling robot formations have been inspired by biological and organizational systems. The main motivation for the use of fuzzy logic (FL) is that it is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems

Keywords – Mobile wheeled robot, fuzzy logic controller, leader- follower.

1. Introduction

In recent years there has been an increasing amount of research on the subject of mobile robotics. Mobile robots are increasingly used in industry, in service robotics, for domestic needs (vacuum cleaners, lawn mowers, pets), in difficult-to access or dangerous areas (space, army, nuclear-waste cleaning) and also for entertainment (robotic wars, robot soccer) [11].There are many robot navigation strategies , and in cases where operating environment map is known, approach with trajectory planning algorithms is commonly used. Here the term trajectory denotes the path that robot should traverse as a function of time. A trajectory can be generated in real-time on the basis of current sensor readings or generated in advance on the basis of operating environment map. In common in practical applications the wheeled mobile robots have the same kinematic model [2][5][8]. It is very important to find a control law that produces a smooth control signal. If this is not the case, the implementation on the dynamic model becomes impossible.

One of the important features of multiple mobile agent systems is team formation. It is inspired by swarming behavior of living beings, such as flocks of birds, schools of fish, herds of wildebeest, and colonies of bacteria. Formation control has been studied in robotics within different structures and approaches, such as, Differential Game approach [1][6][7], behavior-based structure [6][17], leader-follower structure [1][12][14][15], and virtual leader structure[10][11][25]. The formation control in the behavior-based structure is achieved by building up a group of formation related behaviors. It is suitable for uncertain environments, but lack of a rigorous theoretic analysis Tracking a mobile robot's position and orientation precisely is a challenging task. In trajectory tracking, the actual and reference position and orientation of mobile robot are moved all the time. Hence, stabilization in tracking is a problem. Several authors adopt a simple path planning approach which identifies only the target positionof the robot and passes the obstacle avoidance to the motion control using techniques such as model predictive control [3][9][13] ,PID, neural network,fuzzy logic and genetic algorithms[18]. The use of fuzzy logic in the design of navigation behaviors for a mobile robot is nowadays quite popular. Fuzzy logic has been applied to mobile robot and autonomous vehicle control significantly [17]-[27]. Fuzzy control has shown to be a very useful tool in the field of autonomous mobile robotics, characterized by a high uncertainty in the knowledge about the environment where the robot evolves

In this paper, we consider the leader-follower approach for the wheeled mobile robot. Our approach is to develop a control strategy for mobile robots using Fuzzy logic. We propose a motion control strategy based on fuzzy logic control so that WMR reached the desired position/location. We consider the leader-follower control problems revolving around a group of wheeled mobile robots. Here we state the control problem as following

A robot group, comprised of “n” wheeled mobile robots R_i (i=1, 2…n). As soon as leader robot changes it position the follower robots will also changer their position accordingly without colliding with the leaderrobot.

In the following, theoretical information about Fuzzy logic is given in Section II. Fuzzy logic control strategy is presented in Section III. The simulation results are provided in Section IV. Finally, conclusions andfuture work are given in Section V.

2. Fuzzy Logic

Fuzzy control is one of the intelligent control techniques that pertain to the realization of intelligent control systems. Fuzzy Logic was initiated in 1965 by Lotfi A. Zadeh , professor for computer science at the University of California in Berkeley. Basically, Fuzzy Logic (FL) is a multivalued logic, which allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. [26]. The use of Fuzzy Logic Systems (FLS) for control applications has increased since they became popular from 80's. After Mendel in 90's showed how uncertainty can be computed in order to achieve more robust systems, Type-2 Fuzzy Logic Systems (T2FLS) are in the focus of researchers and recently they became a new research topic [27]. Fuzzy logic poses the ability to mimic the human mind to effectively employ modes of reasoning that are approximate rather than exact. In traditional hard computing, decisions or actions are based on precision, certainty, and vigor. Precision and certainty carry a cost. In soft computing, tolerance and impression are explored in decision making. With FL, we can specify mapping rules in terms of words rather than numbers. Computing with the words explores imprecision and tolerance. Another basic concept in FL is the fuzzy if–then rule. Although rule-based systems have a long history of use in artificial intelligence, what is missing in such systems is machinery for dealing with fuzzy consequents or fuzzy antecedents. In most applications, an FL solution is a translation of a human solution. Thirdly, FL can model nonlinear functions of arbitrary complexity to a desired degree of accuracy. FL is a convenient way to map an input space to an output space. FL is one of the tools used to model a multi-input, multi-output system

3. Fuzzy Controller Design

The simulation environmental model is expressed in a two-dimensional area,with x and y axis. The center position of the vehicle (x, y, θ) is expressed in the inertial coordinate frame. Here x and are position of the robot and θ is orientation of the robot with respect to inertial frame.As said above the robot group, comprised of “n” mobile robots R_i (i=1, 2…n). So the state of n robots is denoted as $R_i(x_i, y_i, \theta_i)$. The state of leader and follower robots will be (x_l, y_l, θ_l), (x_f, y_f, θ_f) respectively. Therobot can go Forward, Backward, Left or Right. The robots will do point to point tracking to reach the desired position.When the require number of robots is entered.The user will be asked to select the leader from the entered number of robots. Once the leader is selected user will select the required motion for the leader robot, whether it want the leader to move forward, backward,Left or Right. If forward or backward motion is selected then the following equation will be used for the distance(y_d) it has to move;

$$y_l = y_l \pm y_d \tag{1}$$

Here +ve signis used for forward motion & -ve sign is used for backward motion.

If Left or Right motion is selected then, the programmer will enter the required angle. Now the new angle for leader is calculated as;

$$\theta_l = \theta_l \pm \theta_d \tag{2}$$

Here +ve sign is used for right motion & - ve sign is used for left motion.

Distance(d_{12}) and angle12(θ_{12}) between leader and followers is calculated using equation given below;

$$\theta_{12} = \theta_f - \theta_d \tag{3}$$

If $\theta_{12} < 0$,then $\theta_{12} = 180 + \theta_{12}$ (4)

Else $\theta_{12} = 180 + (\theta_{12} / 2)$ (5)

$$d_{12} = \sqrt{(x_f - x_l)^2 + (y_f - y_l)^2} \qquad (6)$$

3.1 Fuzzy controller

The application of fuzzy logic control in robotics is to produce an intelligent robot with the ability of autonomous behaviour and decision. In this section, the problem of how to set the control parameter values for desired robot behaviour is solved.

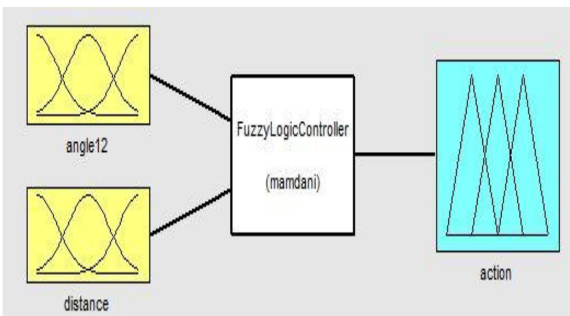

Fig. 1: Fuzzy Controller design.

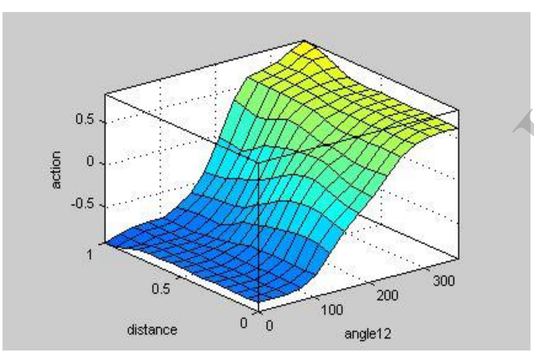

Fig. 2: The control surface

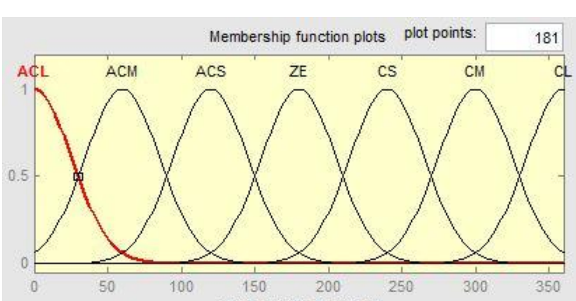

Fig. 3: input membership function of angle12.

Linguistic variables for inputs membership function angle12 are denoted as, Anticlockwise Large (ACL), Anticlockwise Middle (ACM), Anticlockwise Small(ACS), Zero (ZE), Clockwise Small(CS), Clockwise Middle(CM), Clockwise Large(CL).

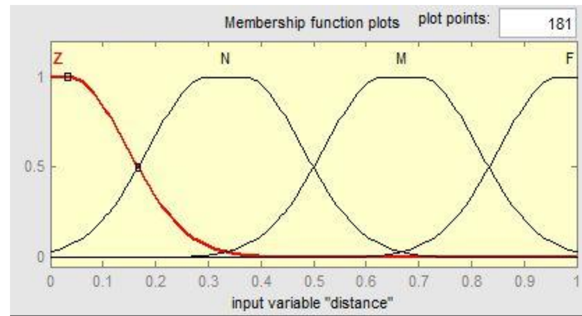

Fig. 4:Input membership function of distance.

Linguistic variables for inputs membership function distance are denoted as, Zero (Z), Near (N), Medium (M), Far (F).

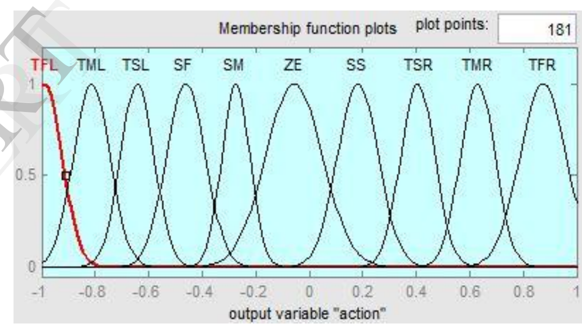

Fig. 5: Output membership function action

Linguistic variables for output membership function action are denoted as, Turn medium left(TML), Turn medium right (TMR), Turn fast left (TFL), Turn fast right (TFR), Turn slow left (TSL), Turn, Slow right (TSR), Straight slow(SS), Straight medium (SM), Straight fast (SF)

3.2 Fuzzy rules

The robot motion is controlled by total 28 rules.

1. *If (angle12 is ACL) and (distance is Z) then (action is TML)*
2. *If (angle12 is ACL) and (distance is N) then (action is TML)*
3. *If (angle12 is ACL) and (distance is M) then (action is TML)*
4. *If (angle12 is ACL) and (distance is F) then (action is TFL)*
5. *If (angle12 is ACM) and (distance is Z) then (action is TML)*
6. *If (angle12 is ACM) and (distance is N) then (action is TML)*
7. *If (angle12 is ACM) and (distance is M) then (action is TML)*
8. *If (angle12 is ACM) and (distance is F) then (action is TML)*
9. *If (angle12 is ACS) and (distance is Z) then (action is TSL)*
10. *If (angle12 is ACS) and (distance is N) then (action is TSL)*
11. *If (angle12 is ACS) and (distance is M) then (action is TML)*
12. *If (angle12 is ACS) and (distance is F) then (action is TML)*
13. *If (angle12 is ZE) and (distance is Z) then (action is ZE)*
14. *If (angle12 is ZE) and (distance is N) then (action is SS)*
15. *If (angle12 is ZE) and (distance is M) then (action is SM)*
16. *If (angle12 is ZE) and (distance is F) then (action is SF)*
17. *If (angle12 is CS) and (distance is Z) then (action is TSR)*
18. *If (angle12 is CS) and (distance is N) then (action is TSR)*
19. *If (angle12 is CS) and (distance is M) then (action is TMR)*
20. *If (angle12 is CS) and (distance is F) then (action is TMR)*
21. *If (angle12 is CM) and (distance is Z) then (action is TMR)*
22. *If (angle12 is CM) and (distance is N) then (action is TMR)*
23. *If (angle12 is CM) and (distance is M) then (action is TMR)*
24. *If (angle12 is CM) and (distance is F) then (action is TMR)*
25. *If (angle12 is CL) and (distance is Z) then (action is TMR)*
26. *If (angle12 is CL) and (distance is N) then (action is TMR)*
27. *If (angle12 is CL) and (distance is M) then (action is TMR)*
28. *If (angle12 is) and (distance is F) then (action is TFR)*

4. Simulation Result

The effectiveness of the fuzzy controller is demonstrated by selecting 5 robots out of which one is selected as leader. The overall system is designed and implemented within Matlab environment. At first user will be asked to enter the number of robots, then out of those one will be selected as leader robot. Initially the robot will at any random position. Once the leader robot moves to the desired position the follower robots will change their position accordingly. The system output is shown as below.In the output the leader is shown in red color while the followers are shown in green color.

Enter number of Robots:5
Enter the Leader Number:3
Follower Robot 1, X:175.00, Y:153.00, Angle:41.16
Follower Robot 2, X:306.00, Y:318.00, Angle:46.10
Leader Robot 3, X:75.00, Y:196.00, Angle:69.06
Follower Robot 4, X:178.00, Y:259.00, Angle:55.50
Follower Robot 5, X:284.00, Y:302.00, Angle:46.76

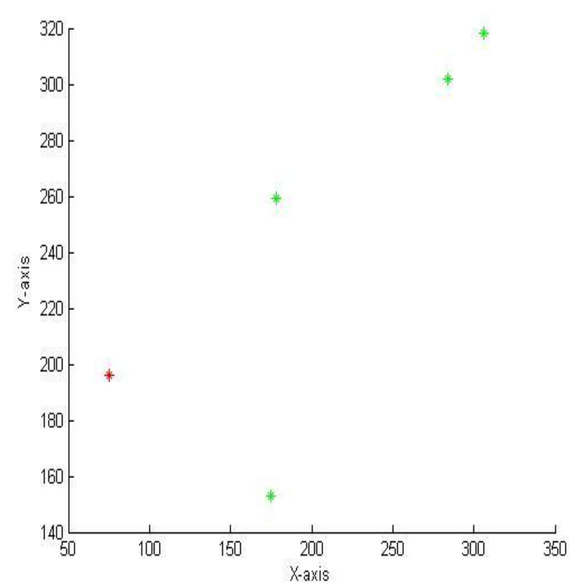

Fig. 6: Initial position of robots with leader shown in red and followers are shown in green color.

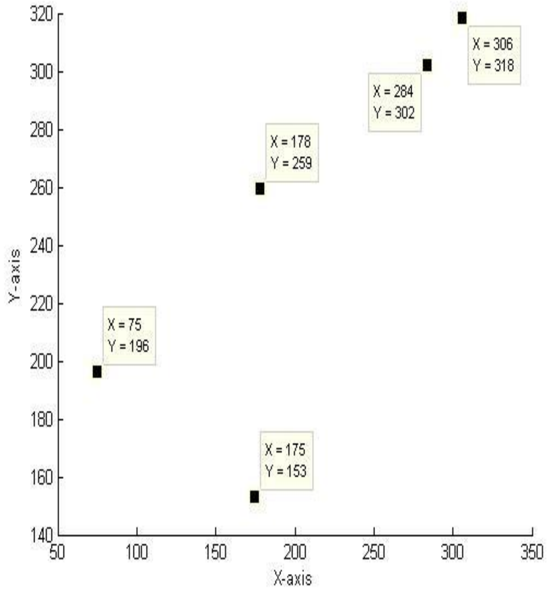

Fig. 7: Initial position of robots with X,Y co-ordinates of leader and followers.

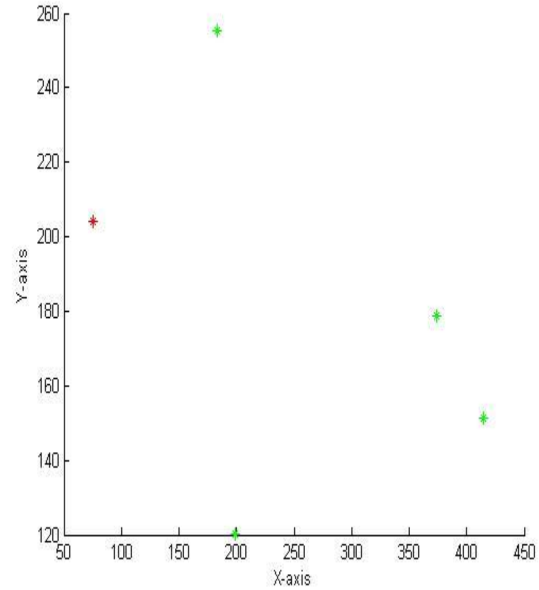

Fig. 7: final position of robots with leader shown in red and followers are shown in green color.

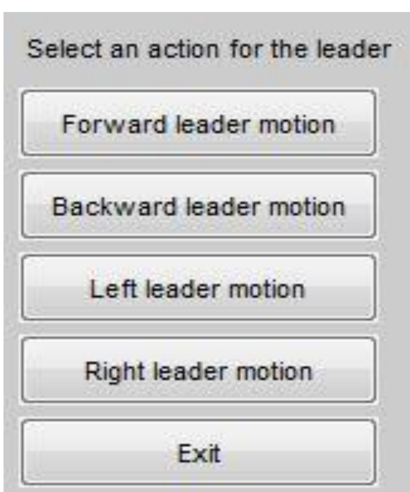

Fig. 8: menu for selecting the desired motion for leader robot.

We have selected forward motion for the leader robot. For forward we will also tell the robot how much distance it should move. In our case we selected 8 moves for the leader robot. The result is shown as below.

Enter the forward distance to move:8
Follower Robot 1, X:198.84, Y:120.39, Angle:41.16
Follower Robot 2, X:414.50, Y:151.50, Angle:46.10
Leader Robot 3, X:75.00, Y:204.00, Angle:69.81
Follower Robot 4, X:183.41, Y:255.20, Angle:55.50
Follower Robot 5, X:374.00, Y:178.84, Angle:46.76

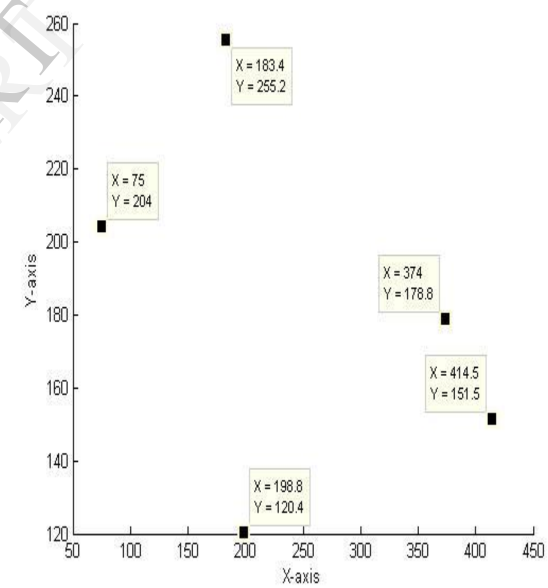

Fig. 8: final position of robots with X,Y co-ordinates of leaders and followers.

5. Conclusion and Future Work

In this paper, we show the effectiveness of fuzzy controller on tasks like point to point tracking by multiple mobile robots verified by simulation results. The controller is based on simple *if* and *then* rules.

The future research work will focus on extending the simulation results to more general applications such as employing real time continuous path tracking and maintaining formation between leader and follower robots taking into consideration of robot dynamics, model uncertainties and noise.

Reference

[1] Dongbing Gu, "A Differential Game Approach to Formation Control" IEEE Transactions On Control Systems Technology, Vol. 16, No. 1, January 2008

[2] Miˇsel Brezak, Ivan Petrovi´c and Nedjeljko Peri´c,"Experimental Comparison of Trajectory Tracking Algorithms for Nonholonomic Mobile Robots", Industrial Electronics, IECON '09. 35th Annual Conference of IEEE, 2009.

[3] E. Camponogara, D. Jia, B. Krogh, and S. Talukdar, "Distributed model predictive control," *IEEE Control Syst. Mag.*, vol. 22, no. 1, pp. 44–52, Feb. 2002

[4] T. Balch and R. Arkin, "Behavior-based formation control for multirobot systems," *IEEE Trans. Robot. Autom.*, vol. 14, no. 2, pp. 926–939, 1998

[5] Altamiro Veríssimo da Silveira Júnior, Elder Moreira Hemerly ,"Kinematic Control Of The Magellan-Isr Mobile Robot" ABCM Symposium series in mechanics-Vol. 1-pp.48-57, 2004

[6] T. Basar and G. Olsder, Dynamic Noncooperative Game Theory. Warrendale, PA: SIAM, 1995.

[7] J. C. Engwerda, LQ Dynamic Optimization and Differential Games. New York: Wiley, 2005

[8] Shamsi F.*, Abdollahi F.*, Nikravesh K.Y.*,"Time varying Formation Control Using Differential Game Approach",18th IFAC World Congress Milano (Italy) August 28 - September 2, 2011

[9] J. Shinar and V. Glizer, "Application of receding horizon control strategy to pursuit-evasion problems," Opt. Control Appl. Methods,vol. 16, no. 2, pp. 127–142, 1995.

[10] Sunil Surve, Thesis on "Coordination Control And Synchronization Of Multi-Agent System", VJTI Nov-2010

[11] Gregor Klanˇcar_, Igor ˇ Skrjanc, "Tracking-error model-based predictive control for mobile robots in real time", ScienceDirect,Robotics and Autonomous Systems 55,page 460–469 (2007)

[12] Jian CHEN[1] , Dong SUN [2] and Jie YANG[3] "A Receding-Horizon Formation Tracking Controller With Leader-Follower Strategies" Proceedings of the 17th World Congress The International Federation of Automatic Control Seoul, Korea, July 6-11, 2008

[13] Zachary Lamb thesis on "Model Predictive Control of a Wheeled Mobile Robot with Nonlinear, Parametric Model of Wheel Slip" Robotics Institute Carnegie Mellon University Pittsburgh, Pennsylvania, August 2011.

[14] Yanyan Dai, Viet-Hong Tran, Zhiguang Xu, and Suk-Gyu Lee "Leader-Follower Formation Control of Multi-robots by Using a Stable Tracking Control Method" ICSI 2010, Part II, LNCS 6146, pp. 291–298, 2010

[15] Dongbing Gu∗ and Huosheng Hu "A model predictive controller for robots to follow a virtual leader" Cambridge University Press, Robotica: page 1 of 9, 2009

[16] Xiaohai LI and Jizhong XIAO "Robot Formation Control in Leader-Follower Motion Using Direct Lyapunov Method",International Journal Of Intelligent Control And Systems, Vol. 10, No. 3, September 2005

[17] Seung-IkLee,Sung-BaeCho "Emergent Behaviors of a Fuzzy Sensory-Motor controller Evolved by Genetic Algorithm", Journals & Magazines, Volume: 31 , Issue: 6, Dec 2001.

[18] Ching-Chang Wong, Hoi-Yi Wang, Shih-An Li, and Chi-Tai Cheng "Fuzzy Controller Designed by GA for Two-wheeled Mobile Robots",International Journal of Fuzzy Systems, Vol. 9, No. 1, March 2007

[19] Oscar Castillo, Luis T. Aguilar, and S´elene C´ardenas"Fuzzy Logic Tracking Control for Unicycle Mobile Robots" Engineering Letters, 13:2, EL_13_2_4 (Advance online publication: 4 August 2006).

[20] ZenonHendzel "Fuzzy Reactive Control O Fwheeled Mobile Robot"JOURNALOFTHEORETICAL AND APPLIEDMECHANICS 42, 3,pp.503-517,Warsaw 2004

[21] O. Ob e, I. Dumitrache"Adaptive Neuro-Fuzzy Controler With Genetic Training For Mobile Robot

Control" Int. J. of Computers, Communications & Control, ISSN 1841-9836, E-ISSN 1841-9844 Vol. VII (2012), No. 1 (March), pp. 135-146

[22] Rajeev Kumar Sharma and M.K Muju "Methodology For Kinematics Modeling Of Articulated Rovers, Enhanced With Fuzzy Logic System",XXXII NATIONAL SYSTEMS CONFERENCE, NSC 2008, December 17-19, 2008

[23] Siti Nurmaini , Anggina Primanita "Modeling of Mobile Robot System with Control Strategy Based on Type-2 Fuzzy Logic"International Journal of Information and Communication Technology Research, Volume 2 No. 3, March 2012.

[24] Sourav Dutta "Obstacle Avoidance of mobile robot using PSO based Neuro Fuzzy Technique" International Jour nal on Computer Science and Engineering Vol. 02, No. 02, 2010, 301-304

[25] M. Mucientes* D.L. Moreno, A. Bugarı´n, S. Barro"Design of a fuzzy controller in mobile robotics using genetic algorithms",Applied Soft Computing 7 (2007)

[26] M. Hellmann "Fuzzy Logic Introduction" ,Epsilon Nought Radar Remote Sensing Tutorials, 2001.

[27] Fuzzy Logic - Algorithms, Techniques and Implementations Edited by Elmer P. Dadios, ISBN 978-953-51-0393-6, Hard cover, 294 pages, Publisher: InTech, Published: March 28, 2012