Optimization of a Reactive Control in a Mobile Robot using Evolutionary Algorithms and Fuzzy Logic

Abraham Meléndez, Oscar Castillo, and Arnulfo Alanis

Tijuana Institute of Technology,
Tijuana, Mexico
abraham.ms@gmail.com,ocastillo@hafsamx.org

Abstract. This paper describes an evolutionary algorithm applied to the optimization of a reactive controller applied to a mobile robot. The Genetic algorithm will optimize the Fuzzy Inference System's membership parameters and fuzzy rules.

Keywords: Mobile Robot, Fuzzy Logic, Evolutionary Algorithms.

1 Introduction

Robots are being more commonly used in many areas of research and a reason for this is that they are becoming more accessible economically for researchers. In this paper we consider the optimization of a fuzzy controller; that gives the ability of reaction to the robot. This may be too general so let's limit what in this paper will be described as ability of reaction, this is applied in the navigation concept, so what this means is that when the robot is moving and at some point of its journey it encounters an unexpected obstacle it will react to this stimulation avoiding and continuing on its path. The trajectory and path following are considered independent parts and are not consider on this paper [19].

There are many traditional techniques available to use in control, such as PD, PID and many more but we took a different approach in the Control of the robot, using an area of soft computing which is fuzzy logic that was introduced by Zadeh [1]. Later this idea was applied in the area of control by Mandami [2] where the concept of FLC (Fuzzy Logic Controller) originated. It's also important to mention that this is not the only area were the fuzzy concepts are applied but it's where the most work has been done, and were many people have contributed important ideas and methods like Takagi and Sugeno [2].

This paper is organized as follows: In section 2 we describe the mobile robot used in these experiments, section 3 describes the development of the evolutionary method. Section 4 shows the simulation results. Finally section 5 shows the Conclusions.

© G. Sidorov et al. (Eds.)
Advances in Soft Computing Algorithms
Research in Computing Science 49, 2010, pp. 3-10

2 Mobile Robot

In this section we describe the particular mobile robot considered in this work. The robot is based on the description of the the Simulation toolbox for mobile robots[22] assumes wheeled mobile robot consisting of one or two conventional, steered, unactuated and not-sensed wheels and two conventional, actuated, and sensed wheels (conventional wheel chair model). This type of chassis provides two DOF (degrees of freedom) locomotion by two actuated conventional non-steered wheels and one or two unactuated steered wheels. The Robot has two degrees of freedom (DOFs): y-translation and either x-translation or z-rotation [22], Fig. 1 shows the robots configuration, it will have 2 independent motors located on each side of the robot and one castor wheel for support located at the form of the robot.

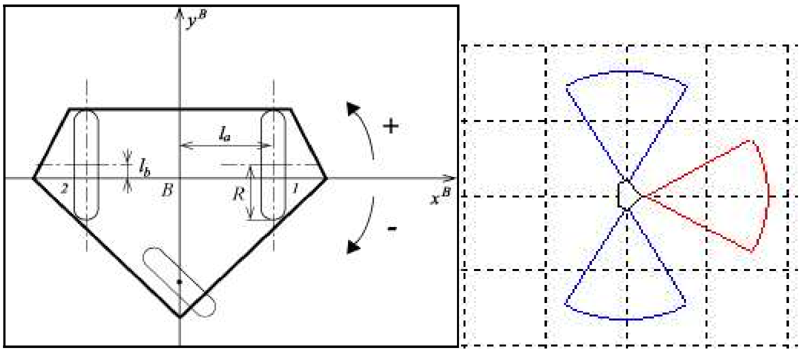

Fig. 1. Kinematic coordinate system assignments [22].

The kinematic equations of the mobile robot are as follows:
Equation 1 is the sensed forward velocity solution [22]

$$\begin{pmatrix} v_{Bx} \\ v_{By} \\ \omega_{Bz} \end{pmatrix} = \frac{R}{2l_a} \begin{pmatrix} -l_b & l_b \\ -l_a & -l_a \\ -1 & 1 \end{pmatrix} \begin{pmatrix} \omega_{W1} \\ \omega_{W2} \end{pmatrix} \quad (1)$$

Equation 2 is the Actuated Inverse Velocity Solution [22]

$$\begin{pmatrix} \omega_{W1} \\ \omega_{W2} \end{pmatrix} = \frac{1}{R(l_b^2+1)} \begin{pmatrix} -l_a l_b & -l_b^2-1 & -l_a \\ l_a l_b & -l_b^2-1 & l_a \end{pmatrix} \begin{pmatrix} v_{Bx} \\ v_{By} \\ \omega_{Bz} \end{pmatrix} \quad (2)$$

Where under the Metric system.

V_{Bx}, V_{By} Translational velocities [$\frac{m}{s}$],

ω_{B_z} Robot z-rotational velocity [$\frac{rad}{s}$],

ω_{W_1}, ω_{W_2} Wheel rotational velocities [$\frac{rad}{s}$],

R Actuated wheel radius[m],

l_a , l_b Distances of wheels from robot's axes [m].

3 Evolutionary Method Description

In this section we will cover the Genetic Algorithm applied to our problem of finding the best fuzzy reactive controller for a mobile robot.

The purpose of using a evolutionary method, is to obtained the best reactive control possible, for the robot, but also taking into consideration other desirable characteristics on the robot that we want to improve making this a multi objective [17] problem, for this we will take advantage of the HGA (Hierarchy Genetic Algorithm) intrinsic characteristic to solve multi objective problems, now let us state the main goal of our HGA.

The main goal is to optimize the Reactive Control taken in to consideration the following:

- Fine tune the Fuzzy Memberships,
- Optimize the FIS if then fuzzy rules,
- The mobile robot Power Usage.

In Fig. 4, we show the global cycle process of the GA, under the Evaluation of the each individual, is where we are going, to measure the goodness of each of the FIS (Fuzzy Inference System) represent by each Individual chromosome, in our test area, that will take place in a unknown environment (Maze [19]) to the robot where the robot´s objective will be find the exit, avoiding hitting the walls and any other obstacle present.

Our criteria to measure the FIS global performance will take into consideration the following:

- Cover Distance,
- Time use to cover distance,
- Battery life.

All of these variables are the inputs of the Evaluation FIS that we will use to obtain the fitness value of each chromosome.

The FIS that we optimize is a Mamdani type fuzzy system, consisting of 3 inputs that are the distances obtain by the robots sensors describe on section 2, and 2 outputs that control de velocity of the servo motors on the robot, all this information is encoded on each chromosome.

The chromosome architecture, shown on Fig. 4, where we have encoded the membership functions type and parameters, we have set a maximum number of 5 membership functions for each of the outputs and input and output variables.

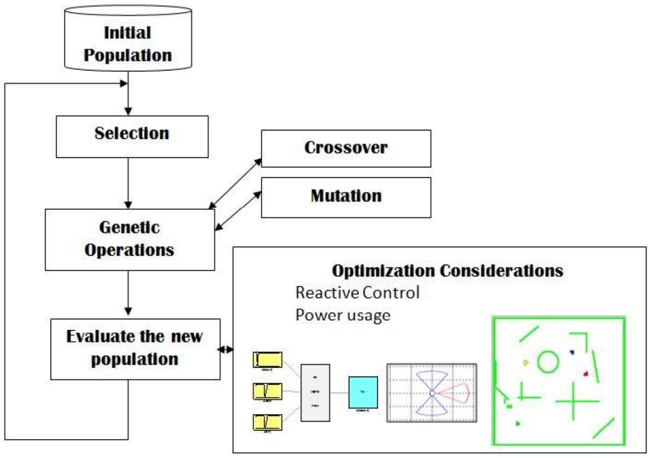

Fig. 2. Genetic Algorithm process.

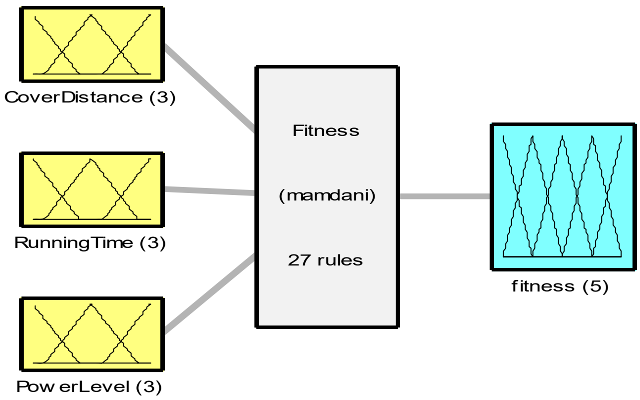

Fig. 3. Fitness FIS.

All the results obtain will get persisted on a Data Base, were we will store each step on the genetic cycle, keeping track of the genealogy of each chromosome, and with this we can examine each of the top individuals and can back track the behavior of the genetic algorithm.

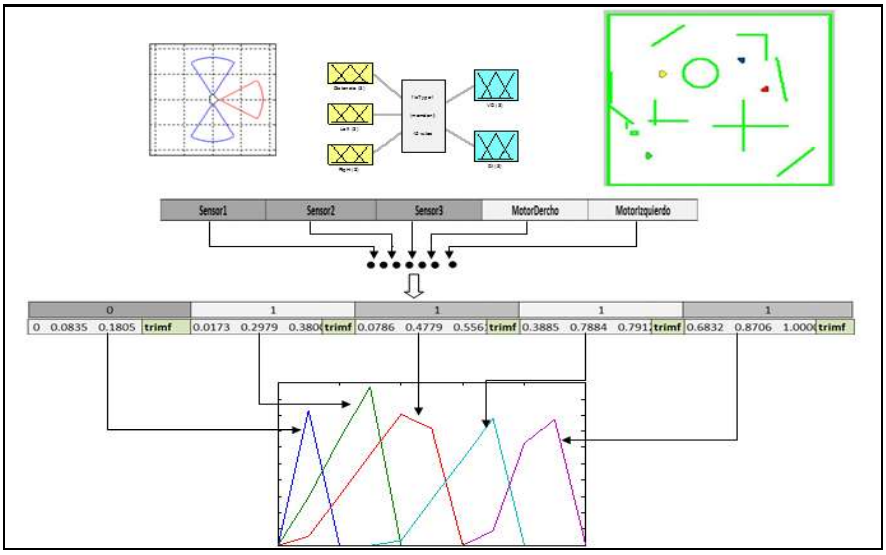

Fig. 4. Chromosome Architecture.

4 Simulation Results

We have worked on the reactive control for a mobile robot before, where we use a particular maze problem to test the effectiveness of each of the reactive controls, and we did not use any optimization strategy to fine tune the controllers as it was a manually process, and from that experience is that we decided to apply GA to this problem. On the Fig. 5 and Table 1 you can see the results we obtained in our prior experiments.

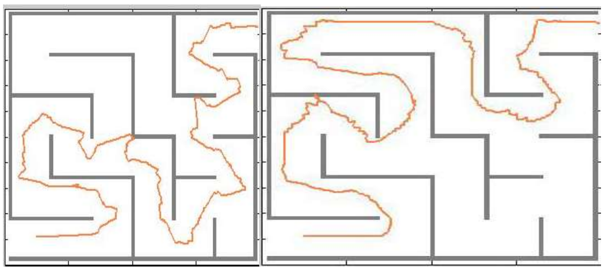

Fig. 5. Chromosome Architecture.

Table 1. Reactive Control Non Optimized Results.

Experiment	LAS	RAS	Time	FE
27 Rules FIS				
9	38.26	38.46	60.34	Yes
10	40.42	40.64	59.50	Yes
12	40.06	40.12	60.70	Yes
Average	*39.58*	*39.74*	*60.18*	
Standard Deviation	*1.16*	*1.14*	*0.62*	
10 Rules FIS				
1	31.51	47.43	55.75	Yes
2	35.55	54.33	51.80	Yes
3	36.66	53.68	55.40	Yes
4	36.66	53.68	54.10	Yes
5	36.91	54.18	49.95	Yes
6	35.44	52.51	46.65	Yes
7	36.14	51.66	49.85	Yes
8	33.48	49.58	51.76	Yes
9	37.61	51.51	55.15	Yes
Average	*35.55*	*52.06*	*52.27*	
Standard Deviation	*1.92*	*2.32*	*3.10*	

*LAS=Left Motor Average Speed
*RAS= Right Motor Average Speed
*FE= Found Exit

5 Conclusions

At the stage of this paper we are on the experimenting phase, our first result show promising data were we expect that the HGA will improve the overall performance of the mobile robot, and improve the results obtained previously. We will test our best reactive controller obtained with the HGA under the same maze problem this in order to establish a comparison between the controllers.

Acknowledgment. We would like to express our gratitude to the CONACYT, and Tijuana Institute of Technology for the facilities and resources granted for the development of this research.

References

1. Aceves, A., Aguilar, J.: A Simplified Version of Mamdani's Fuzzy Controller: The Natural Logic Controller. IEEE Transactions on Fuzzy Systems, Vol. 14, No 1, 16-30 (2006)
2. Astudillo, L., Castillo, O., Aguilar L.T.: Intelligent Control of an Autonomous Mobile Robot Using Type-2 Fuzzy Logic. Journal of Nonlinear Studies, Vol. 14, No. 1., 37-48
3. Astudillo L., Castillo O., Aguilar L.: Control Difuso de Robots Autónomos Móviles en Ambientes Inciertos usando Lógica Difusa. Tesis, División de Estudios y Posgrados e Investigación, ITT, México (2006).
4. Campion G., Bastin G., D'Andrea-Novel B.: Structural Properties and Clasification of Kinematic and Dynamic Models of Wheeled Mobile Robots. IEEE Trans. On Robotics and Automation, Vol. 12, No 1, 47-62 (1996)
5. Cardenas S., Castillo O., Aguilar L.: Controlador de Seguimiento para un Robot Móvil empleando Lógica Difusa. Tesis, División de Estudios y Posgrados e Investigación, ITT, México (2005).
6. Conde Bento L., Nunes Urbano, Mendes A., Parent M.: Path-Tracking Controller of a bi-steerable Cybernetic Car using Fuzzy Logic. In: Proceedings of ICAR 2003, The 11th International Conference on Advanced Robotics. pp. 1556-1561 (2003)
7. Cupertino, F., Giordano, V., Naso, D., Delfine, L.: Fuzzy control of a mobile robot. Robotics & Automation Magazine, IEEE, pp. 74-81.
8. Erkkinen, T.: Embedded Coder Robot NXT. http://www.mathworks.com/matlabcentral/fileexchange/loadFile.do?objectId=13399.
9. Erkkinen, T.: Embedded Coder Robot for LEGO® Mindstorms® NXT Rev. 3.03. http://www.mathworks.com/matlabcentral/fileexchange/loadFile.do?objectId=13399.
10. Ishikawa S.: A Method of Indoor Mobile Robot Navigation by Fuzzy Control. In: Proc. Int. Conf. Intell. Robot. Syst., Osaka, Japan, pp. 1013-1018 (1991)
11. Thomson, A., Baltes, J.: A path following system for autonomous robots with minimal computing power. University of Auckland. Private Bag 92019. Auckland, New Zealand. Technical Report (2001)
12. Jang, J.-S. R., Sun, C.-T., Mizutani, E.: Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence. Prentice Hall Chapter (1997)

14 Kulkarni A.: Computer Vision and Fuzzy-Neural Systems. Prentice Hall PTR (2001)

15 Leyden, M, Toal D., Flanagan, C.: A Fuzzy Logic Based Navigation System for a Mobile Robot. In: Proceedings of Automatisierungs Symposium, Wismar, Germany (1999)

16 Macek, K., Petrovic, I., Siegwart, R.: A control method for stable and smooth path following of mobile robots. In: Proceedings of the 2nd European Conference on Mobile Robots - ECMR 2005, Ancona, Italy, pp. 128-133 (2005)

17 Man. K. F.: Genetic Algorithms Concepts and Designs (Advanced Textbooks in Control and Signal Processing). Springer, Corrected edition (1999)

18 Martínez R., Castillo O., Aguilar L.: Control Inteligente de Robots Autónomos Móviles Bajo Pares Perturbados Usando Lógica Difusa Tipo-2. Tesis, División de Estudios y Posgrados e Investigación, ITT, México (2008)

19 Meléndez, A., Castillo, O., Soria, J.: Reactive Control of a Mobile Robot in a Distributed Environment Using Fuzzy Logic. In: Fuzzy Information Processing Society, NAFIPS 2008. Annual Meeting of the North American Vol. 19-22, pp. 1-5 (2008)

20 Payton, D.W., Rosenblatt, J.K., Keirsey, D.M.: Plan guided reaction. IEEE Transactions on Systems, Man and Cybernetics, Volume 20, Issue 6, pp. 1370–1382

21 Peri, V.M., Simon, D.: Fuzzy logic control for an autonomous robot. In: NAFIPS 2005. Annual Meeting of the North American Fuzzy Information Processing Society, pp. 337-342 (2005)

22 Pishkenari H. N., Mahboobi S. H., Meghdari A.: On the Optimum Design of Fuzzy Logic Controller for Trajectory Tracking Using Evolutionary Algorithms. In: IEEE Conference on Cybernetics and Intelligent Systems, vol. 1, pp.660-665 (2004)