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Implementation of Target-Reaching and Obstacles-Avoiding Behaviors for a Mobile Robot

Cristina Popescu, Otilia Cangea

Petroleum – Gas University of Ploieşti, 39 Bucureşti Blvd., Ploieşti, ROMÂNIA
e-mail: cristinap@upg-ploiesti.ro, ocangea@upg-ploiesti.ro

Abstract

A mobile robot is usually used as an experimental platform for the validation of fuzzy and neuro-fuzzy controllers. The complexity of these types of controllers increases when a robot has many sensors and actuators and when a complex behavior is required. In this paper the authors proposed a neuro-fuzzy controller structure that realizes the performance of target- reaching behavior and obstacles-avoiding behavior. The results for implementation of these behaviors are obtained by simulation.

Key words: *mobile robot, neural network, neuro-fuzzy control.*

Introduction

The primary advantage of fuzzy control is the possibility of implementing human expert knowledge as linguistic if-then rules. Furthermore, it offers methods to control non-linear plants known to be difficult to model.

Artificial neural networks can be applied for control tasks like fuzzy controllers. Both have the capacity to learn from examples, have similar and are highly parametric structures [1].

Fuzzy control succeeded in the industrial world and similarly neuro-fuzzy controllers are promising for practical applications. For this, it is important to show the capabilities of these techniques on real-world applications and mostly researchers have been trying to demonstrate their concepts only on simulation.

The authors implemented in present work a neuro-fuzzy control structure on the mobile robot Khepera III which realizes the obstacle avoidance behavior. The implementation was a success, but in the same time can appear the “dead cycle” problem. To avoid this problem the authors proposed in this paper a neuro-fuzzy algorithm for implement target-reaching and obstacle-avoiding behaviors. The results are obtained by simulation, because the robot Khepera III hasn’t the necessary sensorial system for implement target-reaching behavior. Because of this it can be use a simple optical sensor with a rotate mirror or a global positioning system (GPS). In addition the robot has to be equipped with a speed sensor to measure the current speed of the robot. This problem was studied by Zhu and Yang [3] who proposed an algorithm for robot navigation with target-reaching and “dead cycle” avoiding. The authors adapted this algorithm for the mobile robot Khepera III.

Khepera III configuration

The results for our work are obtained by simulation in Matlab® high level computer language on Khepera III mobile robot. It is cylindrical in shape, measuring 130 mm in diameter and 70 mm in height and its weight is 690 g. Some details of Khepera III are presented in next figure.

Fig.1. Details of Khepera III mobile robot.

The sensory/motor board includes two DC motors with incremental encoders, 9 infra-red proximity sensors for line following applications and 5 ultrasonic sensors with range 20 cm to 4 meters.

Target-reaching behavior can be implement by equip the robot with an orientation optical sensor or a global positioning system (GPS). Moreover, the robot must be equipped with a speed sensor to measure the robot current speed. The robot movement is control by adjusting two motor wheels accelerations. Because of these, we choose the Matlab® language to simulate the implementation of neuro-fuzzy control structure.

Neuro-fuzzy control structure

The inputs of the fuzzy controller are the signals of the multisensory system referred to the *distances from the obstacles* which are obtained by the left, front and right sensors group, the *robot speed* and *target direction*. The outputs are *left* and *right wheels accelerations*.

The parameters adaptation for membership function is based on learning algorithm with neural networks, to eliminate redundant rules being use a separate algorithm. In various situations under the proposed control structure, the mobile robot can generate reasonable trajectories to the target without "dead cycle" problem.

For Khepera III mobile robot control, the input of the controller are represented by sensorial information D_s, D_f, D_d and also the target direction θ_d (the angle between movement direction of the robot and the line which connect the center of the robot with the target) and the robot current speed v_s. The output of the controller are represented by the two motor wheels accelerations a_s and a_d.

The linguistic variables associated to the inputs are: for distances to the obstacles – *far* and *near*, for robot speed – *fast* and *slow*, for direction – *left*, *center*, *right*. The linguistic variables associated to the outputs (motor wheels accelerations) are: *big positive*, *small positive*, *zero*, *small negative*, *big negative* [2].

The proposed fuzzy controller structure is shown in figure 2.

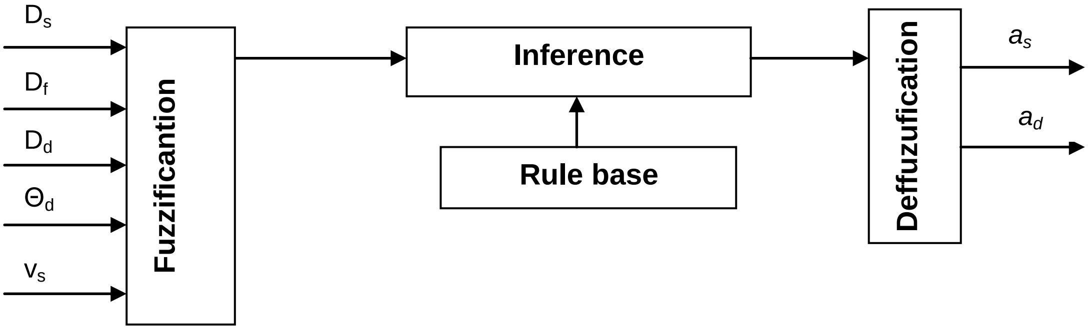
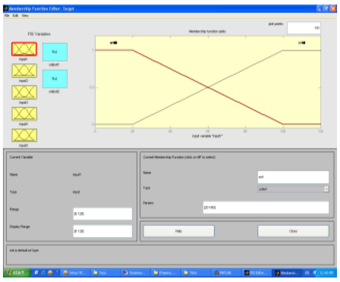


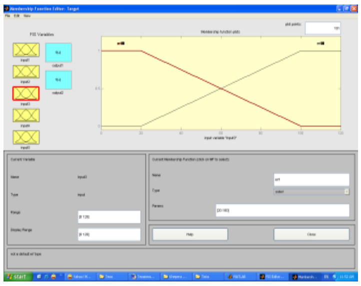
Fig.2. Structure of fuzzy controller.

The design methodology of fuzzy controller follows the known stages: fuzzification, inference mechanism and defuzzification.

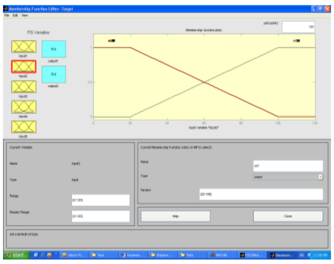
The defuzzification procedure transforms the real input values in fuzzy linguistic terms with values between 0 and 1. In this paper the authors proposed and defined in Matlab language some membership functions for the inputs and add of these to predefine list. The choose functions are triangular, S type and Z type functions, which was adapted for existing situations. Graphical representation of these in Matlab® language is illustrated in figure 3.



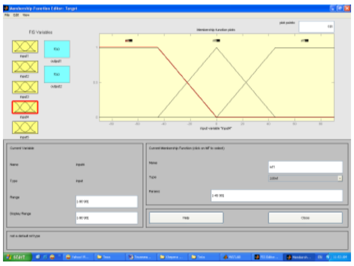
a) Distance to the left D_s



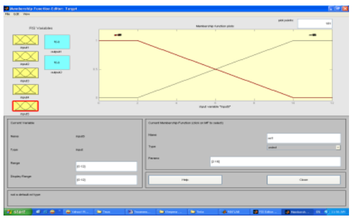
b) Distance to the front D_f



c) Distance to the right D_d



d) Distance to the target θ_d



e) Robot current speed v_s

Fig.3. Membership functions associated to the inputs.

The membership functions of the outputs are functions with constant values, like singleton, and linguistic values associated with inputs and outputs are presented in tables 1, 2, 3 and 4.

Table1. Linguistic values of distances

Linguistic value	Notation	Function type	Center and dispersion of membership function
Near	N	Z	[20 160]
Far	F	S	[100 160]

Table2. Linguistic values of angle between robot and target

Linguistic value	Notation	Function type	Center and dispersion of membership function
Left	L	Z	[-45 90]
Center	C	Triangular	[0 90]
Right	R	S	[45 90]

Table3. Linguistic values of speeds

Linguistic value	Notation	Function type	Center and dispersion of membership function
Slow	SL	Z	[2 16]
Fast	FS	S	[10 16]

Table4. Linguistic values of accelerations

Linguistic value	Notation	Center of membership function
Negative big	NB	-10
Negative small	NS	-5
Zero	Z	0
Positive small	PS	5
Positive big	PB	10

The inference mechanism is responsible with decisions in fuzzy controllers, the inference rules being the one describe in follow:

If

distance to the left from obstacle (D_s) is *near* and
distance to the front from obstacle (D_f) is *far* and
distance to the right from obstacle (D_d) is *far* and
direction to the target (θ_d) is *right* and
robot current speed (v_s) is *slow*

Then

left wheel acceleration (a_s) is *positive big* and
right wheel acceleration (a_d) is *positive small*.

To realize the two behaviors, target-reaching and obstacles-avoiding, the authors formulated 48 rules, ten of these being presented in table 5.

Table5. A part of rules base

Rule	Input					Output		Behavior
	D_s	D_f	D_d	θ_d	v_s	a_s	a_d	
1	far	far	far	left	small	positive small	positive big	target reaching
2	far	far	far	left	fast	negative small	Zero	target reaching
3	far	far	far	center	slow	positive big	positive big	target reaching
4	far	far	far	center	fast	zero	zero	target reaching
5	far	far	far	right	slow	positive big	positive small	target reaching
6	far	far	far	right	fast	zero	negative small	target reaching
7	far	far	near	left	slow	zero	positive small	target reaching
8	far	far	near	left	slow	negative small	zero	target reaching
9	far	far	near	center	slow	zero	positive small	obstacles avoiding
10	far	far	near	center	fast	negative small	zero	obstacles avoiding

For example, corresponding with inference mechanism presented earlier, if are respected the rules eight and nine in the same time, the robot could realize the two behaviors, target reaching and obstacles avoiding.

The proposed defuzzification method is the gravity center method. The values of the output variables a_s and a_d are given by [4]:

$$a_s = \frac{\sum_{k=1}^{48} v_{k,1} q_k}{\sum_{k=1}^{48} q_k}$$

$$a_d = \frac{\sum_{k=1}^{48} v_{k,2} q_k}{\sum_{k=1}^{48} q_k} \tag{1}$$

where $q_k = min\{p_{1k1}, p_{2k2}, p_{3k3}, p_{4k4}, p_{5k5}\}$;

$v_{k,1}$and $v_{k,2}$ – estimated values of the output which are made by k rule, in respect with membership functions centers of output variables;

k – rule numbers;

p_{iki} – membership range for i input corresponding to k rule;

i – number of input values.

Based on the tuning parameters algorithm and deletion of redundant rules algorithm it was obtained a minimal number of rules for the base rules, which are expedient for the base rules with thousands or hundreds rules.

By simulation in Matlab® language it was observed that the robot gets to learn the two behaviors, target reaching and obstacles avoiding, the final error value being very small, about 0,079, like in figure 4.

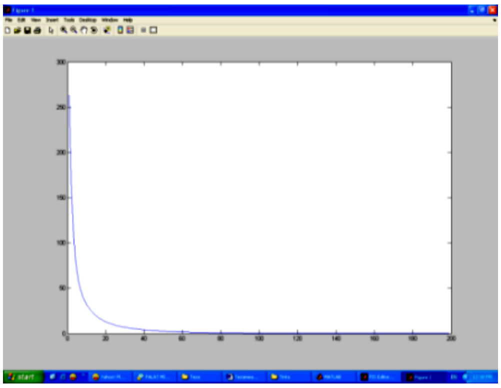


Fig.4. Error evolution in learning process.

Conclusions

In present, for simultaneous navigation of robots, are analyze the investigation techniques based on rules and neuro-fuzzy techniques based on rules. Because the main target of the robots is to realize some predefine objects, the authors proposed a neuro-fuzzy control structure which implements obstacles-avoiding and target-reaching behaviors. With the proposed rules base it was observed a good attitude of the robot in navigation process with target-reaching behavior, the main contributions of the authors being the implementation in Matlab® language of the membership functions associated to the neuro-fuzzy controller inputs. These functions were introduced in fuzzy inference system existing in fuzzy toolbox of Matlab® language.

References

1. Godjevac J. – *Neuro-Fuzzy Controllers Design and Application*. Presses Polytechniques et Universitaires Romandes, Laussane, 1997.
2. Popescu C. – *Neuro-Fuzzy Control for Mobile Robot*. PhD Thesis, Ploiesti, 2008.
3. Zhu, A., Yang, X.S. – *Neuro-Fuzzy Based Approach to Mobil Robot Navigation in Unknown Envinronments*. IEEE Transactions on Systems, Men and Cybernetics – Part C, Applications and Reviews, vol. 37, no.4, July 2007.
4. Wang, L.X. – *Adaptive Fuzzy Systems and Control Design and Stability Analysis.* Prentice Hall, 1994.

Implementarea comportamentelor de atingere a unei ţinte şi de ocolire a obstacolelor pe un robot mobil

Rezumat

Deoarece misiunea principală a roboţilor este să realizeze anumite sarcini predefinite, în această lucrare a fost propusă o structură de regulator neuro-fuzzy care nu numai că implementează comportamentul de evitare a obstacolelor, dar şi ajută robotul să urmărească o ţintă dorită. Cu baza de reguli propusă, alcătuită din 48 de reguli, a fost observată o bună comportare a robotului în cadrul procesului de navigare şi atingere a unei ţinte. Rezultatele au fost obţinute prin simulare în limbajul Matlab®.