FUZZY LOGIC ALGORITHM FOR MOBILE ROBOT CONTROL

Viorel Stoian and Cristina Pana
University of Craiova, Mechatronics Department, Decebal Street No. 107, Craiova, Romania

Keywords: Fuzzy logic algorithm, mobile robots, obstacole avoidance, trajectory controller.

Abstract: This paper presents a fuzzy control algorithm for mobile robots which are moving next to the obstacle boundaries, avoiding the collisions with them. Four motion cycles (programs) depending on the proximity levels and followed by the mobile robot on the trajectory (P1, P2, P3, and P4) are shown. The directions of the movements corresponding to every cycle, for every reached proximity level are presented. The sequence of the programs depending on the reached proximity levels is indicated. The motion control algorithm is presented by a flowchart showing the evolution of the functional cycles (programs). The fuzzy rules for evolution (transition) of the programs and for the motion on X-axis and Y-axis respectively are described. Finally, some simulations are presented.

1 INTRODUCTION

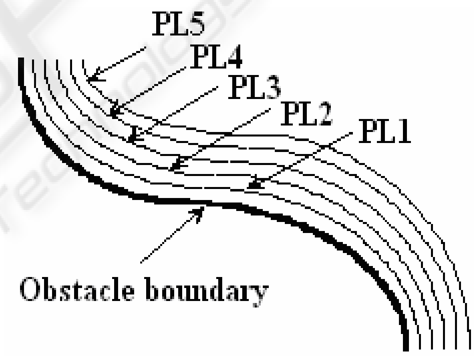
Fuzzy set theory, originally developed by Lotfi Zadeh in the 1960's, has become a popular tool for control applications in recent years (Zadeh, 1965).

Fuzzy control has been used extensively in applications such as servomotor and process control. One of its main benefits is that it can incorporate a human being's expert knowledge about how to control a system, without that a person need to have a mathematical description of the problem.

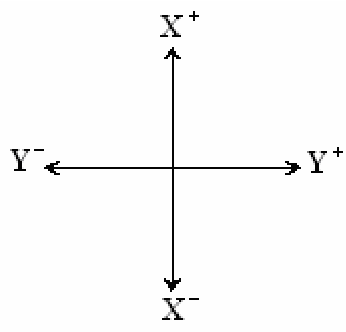
Many robots in the literature have used fuzzy logic (Song, 1992, Khatib, 1986, Yan, Ryan, Power, 1989 …). Computer simulations by Ishikawa feature a mobile robot that navigates using a planned path and fuzzy logic. Fuzzy logic is used to keep the robot on the path, except when the danger of collision arises. In this case, a fuzzy controller for obstacle avoidance takes over.

Konolige, et al. use fuzzy control in conjunction with modeling and planning techniques to provide reactive guidance of their robot. Sonar is used by robot to construct a cellular map of its environment.

Sugeno developed a fuzzy control system for a model car capable of driving inside a fenced-in track. Ultrasonic sensors mounted on a pivoting frame measured the car's orientation and distance to the fences. Fuzzy rules were used to guide the car parallel to the fence and turn corners (Sugeno et al., 1989).



a) The proximity levels.



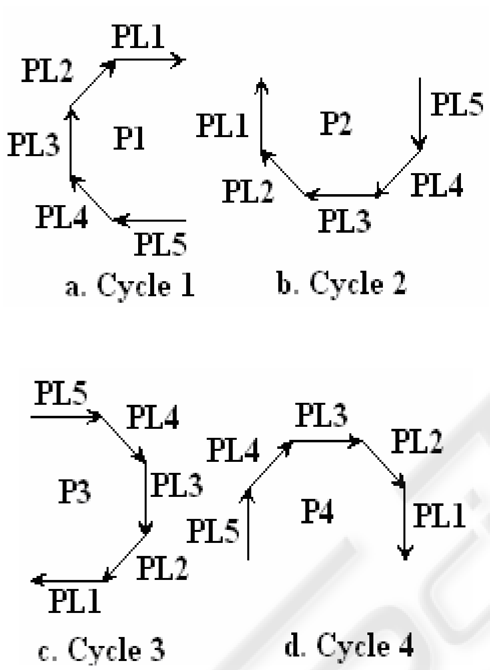
b) The two degrees of freedom of the locomotion system of the mobile robot.

Figure 1: The proximity levels and the degrees of freedom of the robot motion.

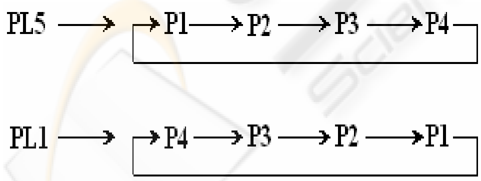
Stoian V. and Pana C. (2007).
FUZZY LOGIC ALGORITHM FOR MOBILE ROBOT CONTROL.
In *Proceedings of the Fourth International Conference on Informatics in Control, Automation and Robotics*, pages 244-247
DOI: 10.5220/0001633002440247

2 CONTROL ALGORITHM

The mobile robot is equipped with a sensorial system to measure the distance between the robot and object that permits to detect 5 proximity levels (PL): PL1, PL2, PL3, PL4, and PL5. Figure 1a presents the obstacle (object) boundary and the five proximity levels and Figure 1b presents the two degrees of freedom of the locomotion system of the mobile robot. This can move either on the two rectangular directions or on the diagonals (if the two degrees of freedom work instantaneous).



2.1) Motion cycles (programs)



2.2) The sequence of the programs

Figure 2: The sequences of the motion.

The goal of the proposed control algorithm is to move the robot near the object boundary with collision avoidance. Figure 2a shows four motion cycles (programs) which are followed by the mobile robot on the trajectory (P1, P2, P3, and P4). Inside every cycle are presented the directions of the movements (with arrows) for every reached proximity level. For example, if the mobile robot is moving inside first motion cycle (cycle 1 or program P1) and is reached PL3, the direction is on Y-axis (sense plus) (see Figure 1b, too). In Figure 2b we can see the sequence of the programs.

One program is changed when are reached the proximity levels PL1 or PL5. If PL5 is reached the order of changing is: P1→P2→P3→P4→ P1→

If PL1 is reached the sequence of changing becomes: P4→P3→P2→P1→ P4→

The motion control algorithm is presented in Figure 3 by a flowchart of the evolution of the functional cycles (programs). We can see that if inside a program the proximity levels PL2, PL3 or PL4 are reached, the program is not changed. If PL1 or PL5 proximity levels are reached, the program is changed. The flowchart is built on the base of the rules presented in Figure 2.1 and Figure 2.2.

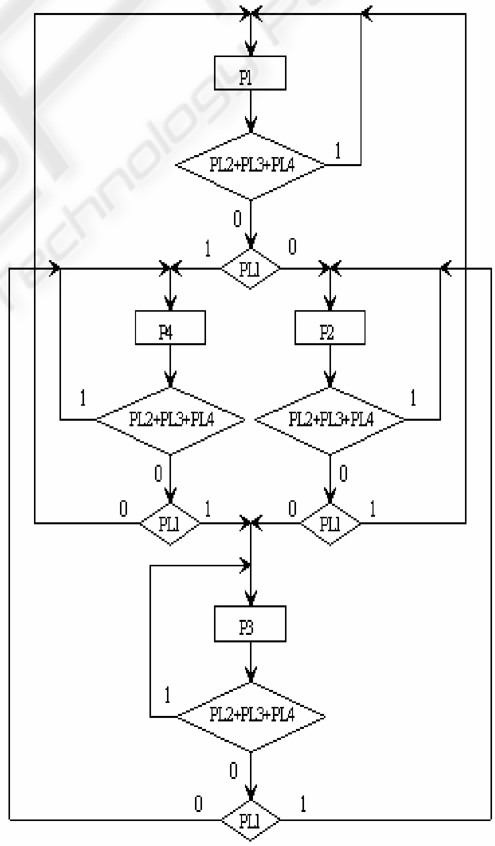
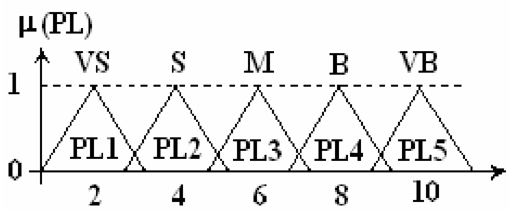


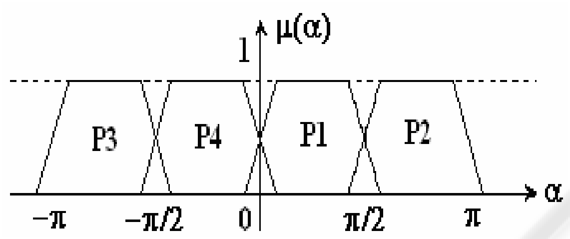
Figure 3: The flowchart of the evolution of the functional cycles (programs).

Figure 4: The inputs and outputs of the fuzzy algorithm.

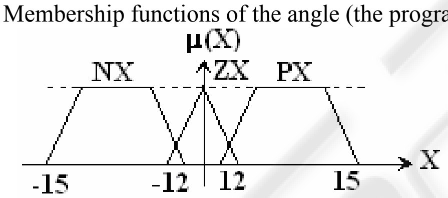
3 FUZZY ALGORITHM



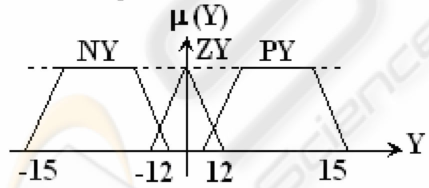
a) Membership functions of the proximity levels (distance) measured with the sensors



b) Membership functions of the angle (the programs)



c) Membership functions of the X comands



d) Membership functions of the Y comands

Figure 5: Membership functions of the I/O variables.

The fuzzy controller for the mobile robots based on the algorithm presented above is simple. Most fuzzy control applications, such as servo controllers, feature only two or three inputs to the rule base. This makes the control surface simple enough for the programmer to define explicitly with the fuzzy rules.

The above robot example uses this principle, in order to explore the feasibility of using fuzzy control for its tasks. Figure 4 presents the inputs (distance-proximity levels and the program on k step) and the outputs (movement on X and Y-axes and the program on k+1 step) of the fuzzy algorithm.

For the linguistic variable "distance proximity level" we establish to follow five linguistic terms: "VS-very small", "S-small", "M-medium", "B-big", and "VB-very big". Figure 5a shows the membership functions of the proximity levels (distance) measured with the sensors and Figure 5b shows the membership functions of the angle (the programs). If the object is like a circle every program is proper for a quarter of the circle.

Figure 5c and Figure 5d present the membership functions of the X, respectively Y commands (linguistic variables). The linguistic terms are: NX-negative X, ZX-zero X, PX-positive X, and NY, ZY, PY respectively.

Table 1: Fuzzy rules for evolution of the programs.

	VS	S	M	B	VB
P1	P4	P1	P1	P1	P2
P2	P1	P2	P2	P2	P3
P3	P2	P3	P3	P3	P4
P4	P3	P4	P4	P4	P1

Table 2: Fuzzy rules for the motion on X-axis.

	VS	S	M	B	VB
P1	PX	PX	ZX	NX	NX
P2	ZX	NX	NX	NX	ZX
P3	NX	NX	ZX	PX	PX
P4	ZX	PX	PX	PX	ZX

Table 3: Fuzzy rules for the motion on Y-axis.

	VS	S	M	B	VB
P1	ZY	PY	PY	PY	ZY
P2	PY	PY	ZY	NY	NY
P3	ZY	NY	NY	NY	ZY
P4	NY	NY	ZY	PY	PY

Table 1 describes the fuzzy rules for evolution (transition) of the programs and Table 2 and Table 3 describe the fuzzy rules for the motion on X-axis and Y-axis, respectively. Table 1 implements the sequence of the programs (see Figure 2.2 and Figure 3) and Table 2 and Table 3 implement the motion cycles (see Figure 2.1 and Figure 3).

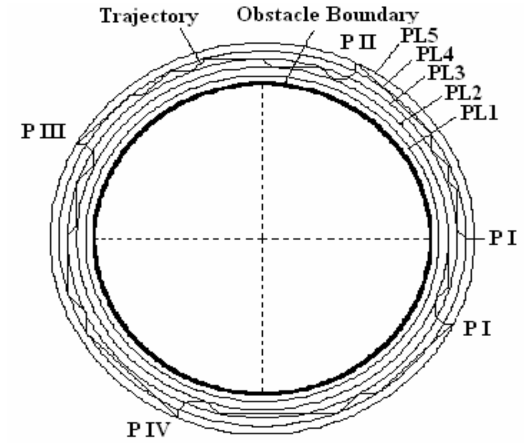


Figure 6: The trajectory of the mobile robot around a circular obstacle.

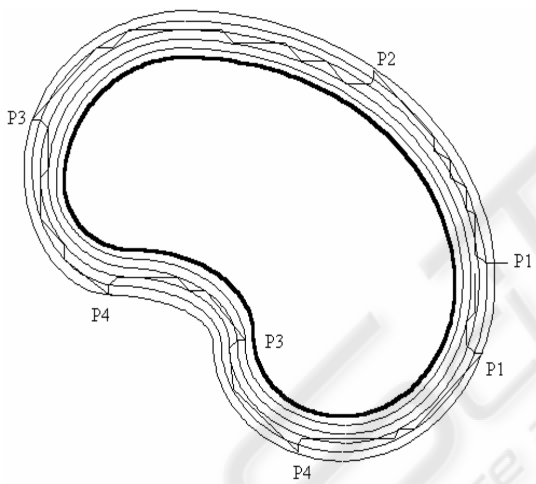


Figure 7: The trajectory of the mobile robot around a irregular obstacle.

4 SIMULATIONS

In the simulations can be seen the mobile robot trajectory around an obstacle (object) with circular boundaries (Figure 6) and around an obstacle (object) with irregular boundaries (Figure 7). One program is changed when are reached the proximity levels PL1 or PL5. If PL5 is reached the order of changing becomes as follows: P1→P2→P3→P4→... If PL1 is reached the order of changing is becomes follows: P4→P3→P2→P1→ P4→ ……

5 CONCLUSIONS

This paper presents a fuzzy control algorithm for mobile robots which are moving next to the obstacle boundaries, avoiding the collisions with them. Four motion cycles (programs) depending on the proximity levels and followed by the mobile robot on the trajectory (P1, P2, P3, and P4) are shown. The directions of the movements corresponding to every cycle, for every reached proximity level are presented. The sequence of the programs depending on the reached proximity levels is indicated. The motion control algorithm is presented by a flowchart showing the evolution of the functional cycles (programs). The fuzzy rules for evolution (transition) of the programs and for the motion on X-axis and Y-axis respectively are described**.** The fuzzy controller for the mobile robots based on the algorithm presented above is simple. Finally, some simulations are presented**.** If the object is like a circle, every program is proper for a quarter of the circle.

REFERENCES

Zadeh, L. A., 1965. Fuzzy Sets, *Information and Control*, No 8, pp. 338-353.

Sugeno, M., Murofushi, T., Mori, T., Tatematasu, T., and Tanaka, J., 1989. Fuzzy Algorithmic Control of a Model Car by Oral Instructions, *Fuzzy Sets and Systems,* No. 32, pp. 207-219.

Song, K.Y. and Tai, J. C., 1992. Fuzzy Navigation of a Mobile Robot, *Proceedings of the 1992 IEEE/RSJ Intern. Conference on Intelligent Robots and Systems*, Raleigh, North Carolina.

Khatib, O., 1986. Real-Time Obstacle Avoidance for Manipulators and Mobile Robots, *International Journal of Robotics Research*, Vol. 5, No.1, pp. 90-98.

Boreinstein, J. and Koren, Y., 1989. Real-time Obstacle Avoidance for Fast Mobile Robots, *IEEE Transactions on Systems, Man., and Cybernetics*, Vol. 19, No. 5, Sept/Oct. pp. 1179-1187.

Jamshidi, M., Vadiee, N. and Ross, T. J., 1993. *Fuzzy Logic and Control. Software and Hardware Applications*, PTR, Prentice Hall, New Jersey, USA.

Yan, J., Ryan, M., and Power, J., 1994. *Using Fuzzy Logic. Towards intelligent systems*, Prentice Hall, New York.