

Supervisory Control for a robot manipulators using fuzzy interval

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Abstract—In this paper, we present a supervision approach to control a mobile robot that follows a moving target in a medium that contains obstacles. The mobile robot is controlled through three different controllers: attraction to a moving target, Overcome obstacles and get back on track and the supervision controller. The role of a supervisor is to coordinate interactions between other controllers according to the global Information of the system. The proposed hybrid controller was designed using fuzzy intervals that manages the combination of two controllers according to the mobile robot linear and angular velocities.

Keywords—Supervisor, aggregation operators, fuzzy intervals, mobile robot.

I. INTRODUCTION

Our goal in this work is to design a fuzzy supervisor that determines a weighting factor α , which gives the participation rate of each control signal then we apply it to the control of a moving robot that is controlled by two controllers: target tracking and obstacle avoiding[1]–[4].

Thus, an approach based on aggregation mechanisms (aggregation by fuzzy rules and aggregation by mathematical operators) is developed to develop the weighting factor α of the supervisor[5].

In this case, the supervisor's action consists of giving more weight to the obstacle avoidance controller in the event of an obstacle in the path. Then it gives more weight to the target tracking controller in the normal case [2], [6], [7].

In the summary of the supervisor, we base on the importance of the form of representation of objectives. For this, we propose

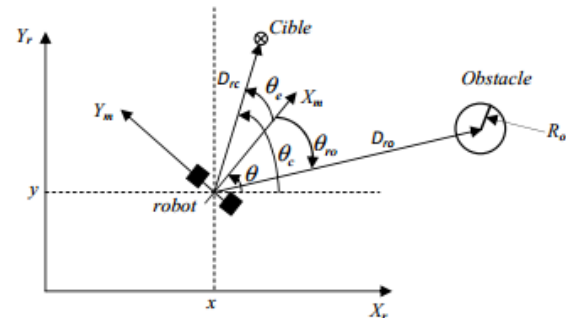


Figure 1graphic representation of a mobile robot with differential wheels

a representation based on intervals (fuzzy and fuzzy intervals)[5], [8].

Finally, we compared the simulation results that we obtained by using the supervisor based on fuzzy intervals with the results obtained from the simulation using the Fuzzy supervisor [2].

II. MODEL SYSTEM

We represent by figure (1) a kinematic modeling of a mobile robot. Indeed, a mobile robot can be considered as an autonomous wheeled vehicle capable of performing missions in known or unknown environments[9].

Hence the following kinematic model:

$$dx / dt = v \cdot \cos(\theta)$$

$$dy / dt = v \cdot \sin(\theta)$$

$$d\theta / dt = \omega$$

Where θ , v and ω are respectively the robot orientation, linear and angular velocities.

From Figure (1) We define the position errors as :

$$e_x = (x_T - x) = D_{RT} \cos(\theta_{RT})$$

$$e_y = (y_T - y) = D_{RT} \sin(\theta_{RT})$$

Where DRT corresponds to the current distance between the robot and the dynamic target T, which is expressed by

$$D_{RT} = \sqrt{e_x^2 + e_y^2}$$

Similarly, the current angle of the robot according to the target, noted θ_{RT} , is computed as :

$$\theta_{RT} = \alpha \tan 2(e_y, e_x)$$

The angle error is given by

$$\theta_e = (\theta_{RT} - \theta)$$

III. FUZZY CONTROL DESIGN

A. tracking controller

The fuzzy controller has two inputs: distance between the robot and the dynamic target (DRT) and the angle of the robot according to the target θ_{RT} .

Two output variables: linear velocity (v) and angular velocity (ω).

For the first input and output, the distance (Drc), we define three membership functions characterizing the linguistic values (P: small, M: average, G: large) and five fuzzy sets for the second input and output, the orientation error (θ_e), (NG: large negative, NM: medium negative, N: zero, PM: medium positive, PG: large positive). See figure (2).

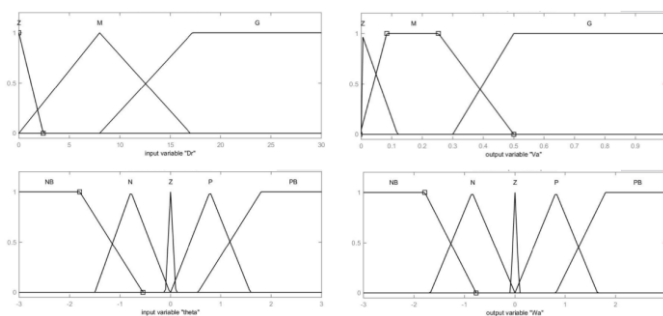


Figure 2 membership function shapes of the FLC input/output variables

Table (1) shows the decision table of the considered fuzzy controller.

Table 1 fuzzy rule sets of the attraction to the dynamic target flc

θ_e					
Drc					
P	NG	NM	N	PM	PG
M	N/GG	M/GM	N/D	N/DM	N/DG
G	N/GG	M/GG	G/D	M/DG	N/DG

B. obstacle avoidance controller

The obstacle avoidance controller that we used has two input variables: distance and robot obstacle angle (D_{ro} and θ_{ro}) respectively, (see figure1), two output variables: linear and angular speed. The distribution of the discourse universes of these variables are shown below figure (3).

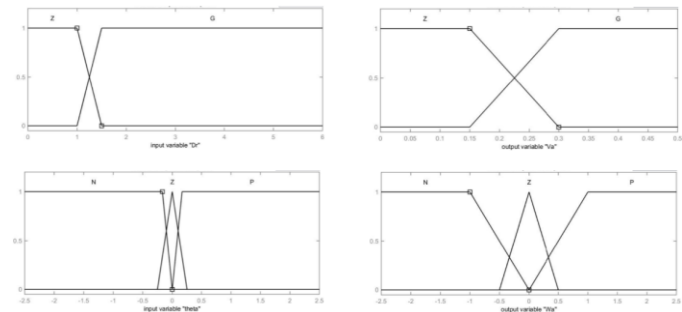


Figure 3 membership function of the FLC input/output variable

The rule base for this controller is generated according to the table (Tab 2).

TABLE 2 fuzzy rules set of the obstacle avoidance FLC

θ_{ro}			
Dro			
P	N	Z	P
G	P/G	P/D	P/D
	G/N	G/N	G/N

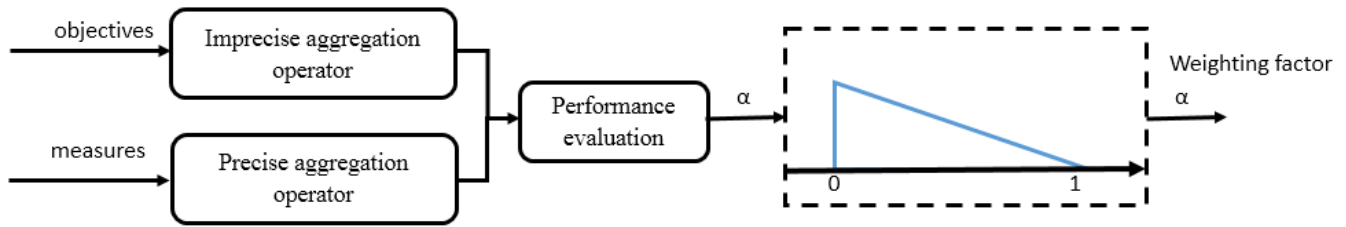


Figure 4 the supervision structure

C. Supervision controller

The supervision structure shown in figure (4) consists of coordinating the local controllers in order to reach a satisfactory compromise between the global objectives. The global objectives, denoted P_{obj} , are represented by fuzzy intervals.

1) Objectives representation

In this study, we used only triangular fuzzy intervals to represent the objectives. The tolerance intervals of the indicators are chosen as follows

Linear velocity (v) = p_1 and angular velocity (ω) = p_2 .

$$P_1^{obj}(\alpha) = [(P1_{obj}(g)^-), (P_1^{obj}(g)^+)] = [(-1 + g), (1 - g)]$$

$$P_1^{obj}(\alpha) = [0 \ 1 \ 1 \ 2].$$

$$P_2^{obj}(\alpha) = [(P2_{obj}(g)^-), (P_2^{obj}(g)^+)] = [(-1 + g), (1 - g)]$$

$$P_2^{obj}(\alpha) = [2 \ 0 \ 0 \ 2].$$

Thus, an approach based on aggregation mechanisms (aggregation by fuzzy rules and aggregation by mathematical operators) will be developed to develop the supervisor's weighting factor α as shown in figure (4).

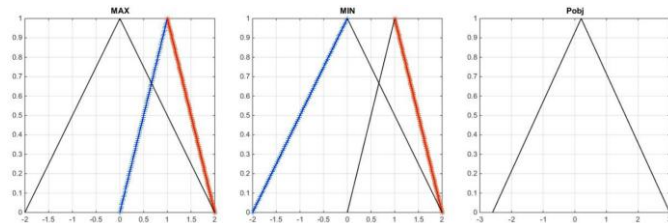


Figure 5 aggregated fuzzy intervals

To calculate the aggregate value of P_1 and P_2 we used the analytical expression of the MIN and MAX operators

$$MIN(A,B)(z) = \text{Sup}_{z=\min(x,y)} \min(A(x), B(y)).$$

$$MAX(A,B)(z) = \text{Sup}_{z=\max(x,y)} \min(A(x), B(y)).$$

IV. SIMULATION RESULTS

To perceive the effectiveness of the control scheme proposed in this paper. We have simulated it in matlab. This robot should reach a dynamic target, moving on direct robot path. Or with sinusoidal movement

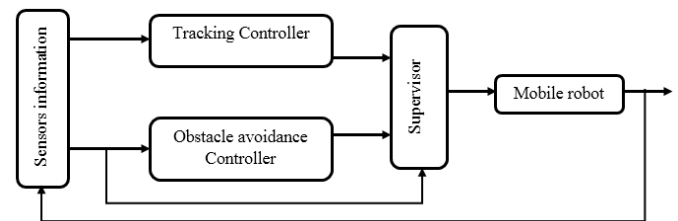


Figure 6 the proposed control scheme

We have compared the results obtained from simulations of control by fuzzy intervals with fuzzy controller Which has the same characteristics and settings as the fuzzy interval controller. The result was as shown in figures (7,8,9,10).

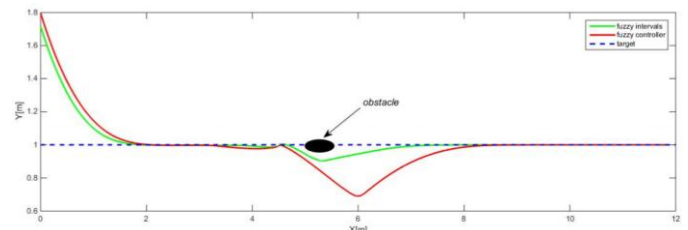


Figure 7 avoiding an obstacle while tracking a direct robot path

The evolution of the fusion gain for fuzzy intervals and fuzzy controller

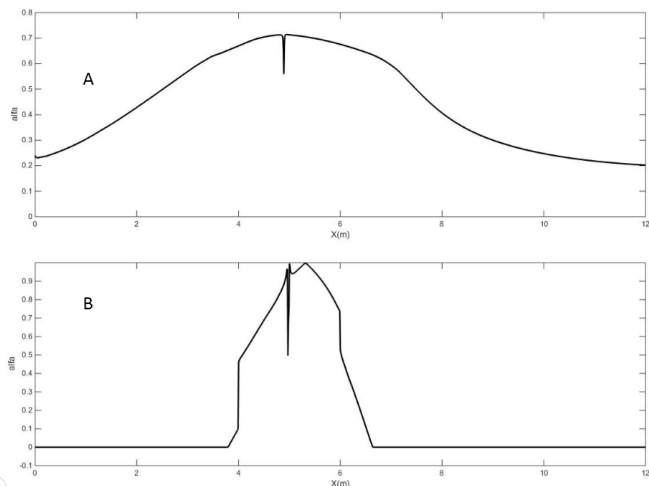


Figure 8 (A) fuzzy interval , (B) fuzzy controller

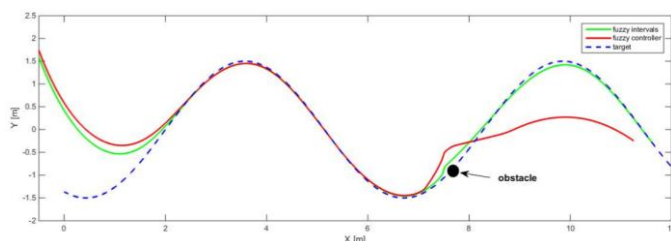


Figure 9 obstacle avoidance while tracking a sinusoidal movement

The evolution of the fusion gain for fuzzy intervals and fuzzy controller

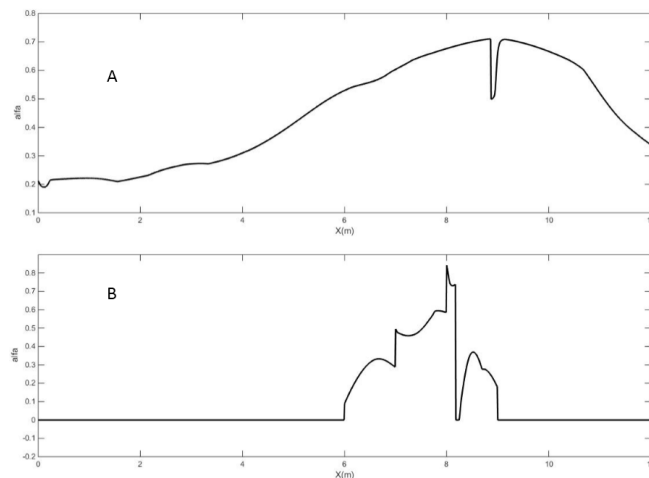


Figure 10 (A) fuzzy interval, (B) fuzzy controller

V. RESULTS INTERPRETATION

Overall, the trend of the different results illustrates comparable performance with that obtained with supervision based on fuzzy controller. However, the results obtained with the fuzzy intervals are more refined and more stable. This is in particular due to the replacement of free commutations by soft commutations through the representation by fuzzy intervals.

VI. CONCLUSION

In this work, we have developed a hybrid robust controller for a class of nonlinear and disturbed systems. The main idea is the use of a fuzzy supervisor to manage efficiently the action of two controllers, such that the system remains stable and robust despite the plant switching from one mode to a new one.

Furthermore, this structure allows us to take advantage of both controllers and to efficiently eliminate their drawbacks.

Simulation results showed the efficiency and the design simplicity of the proposed approach.

REFERENCES

- [1] M. Taher, H. E. Ibrahim, S. Mahmoud, et E. Mostafa, Tracking of a Moving Target by Improved Potential Field Controller in Cluttered Environments. .
- [2] M. Ider et B. Mendil, « Type-2 fuzzy logic control for a mobile robot tracking a moving target », *Mediterr. J. Model. Simul.*, vol. 3, no 1, p. 057- 065, mars 2015.
- [3] T.-H. S. Li, S.-J. Chang, et W. Tong, « Fuzzy target tracking control of autonomous mobile robots by using infrared sensors », *IEEE Trans. Fuzzy Syst.*, vol. 12, no 4, p. 491- 501, août 2004, doi: 10.1109/TFUZZ.2004.832526.
- [4] A. Al-Mayyahi et W. Wang, « Fuzzy inference approach for autonomous ground vehicle navigation in dynamic environment », in 2014 IEEE International Conference on Control System, Computing and Engineering (ICCSCE 2014), nov. 2014, p. 29 - 34, doi: 10.1109/ICCSCE.2014.7072684.
- [5] « MIN and MAX operators for trapezoidal fuzzy intervals | Emerald Insight ». <https://www.emerald.com/insight/content/doi/10.1108/17563781011028541/full/html> (consulté le sept. 17, 2021).
- [6] « Synthesis of switching controllers: A fuzzy supervisor approach - ScienceDirect ». <https://www.sciencedirect.com/science/article/abs/pii/S0362546X06000472> (consulté le sept. 17, 2021).
- [7] R. A. Hilhorst, J. van Amerongen, P. Lohnberg, et H. J. A. F. Tulleken, « A supervisor for control of mode-switch processes », *Automatica*, vol. 30, no 8, p. 1319- 1331, août 1994, doi: 10.1016/0005-1098(94)90111-2.
- [8] R. Boukezzoula, S. Galichet, et L. Foulloy, « MIN and MAX Operators for Fuzzy Intervals and Their Potential Use in Aggregation Operators », *IEEE Trans. Fuzzy Syst.*, vol. 15, no 6, p. 1135- 1144, déc. 2007, doi: 10.1109/TFUZZ.2006.890685.
- [9] P. K. Padhy, T. Sasaki, S. Nakamura, et H. Hashimoto, « Modeling and position control of mobile robot », in 2010 11th IEEE International Workshop on Advanced Motion Control (AMC), mars 2010, p. 100- 105, doi: 10.1109/AMC.2010.5464018.