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Obstacle avoidance based on fuzzy logic method for mobile robots in Cluttered Environment

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***Abstract*— this paper proposes approach based on fuzzy logic controller for the problem of obstacle avoidance of mobile robots in unknown environment. In particular, we are interested in determining the robot motion to reach the target while ensuring their own safety. To achieve these goals, we have adopted a fuzzy controller for navigation and avoidance obstacle static and dynamic (other robots), taking into account the changing nature of the environment. The proposed algorithm has been successfully tested in different configurations on simulation and experimentation.**

***Keywords*— Mobile Robots, Obstacle Avoidance, Fuzzy logic, ThymioII mobile robot.**

I. INTRODUCTION

The obstacle avoidance is an essential component to achieve successful navigation. Several trajectory tracking and path following algorithms have been proposed to steer the mobile robot along a path to a desired goal in order to prevent collisions with obstacles and other robots. Several research works have been reported in this area. The most well know are, the potential field method [1]., vector field histogram and the method of deformable virtual zone. The

first one was introduced by [2][3] imagines the virtual forces acting on the robot. This method assumes that the robot is driven by virtual forces that attract it towards the goal, or reject it away from the obstacles. The actual path is determined by the resultant of these virtual forces, the second method is introduced in [3] which corresponds to local occupancy grid, constructed from the sensors of the robot; this method was improved in [4], landmark learning [5], edge detection, graph-based methods [6], Limit-cycles method [7] and many others. However, relatively few of them are suitable for real.

This paper mainly deals the navigation control, static and dynamic obstacle avoidance for mobile robots. In this context, we propose a fast fuzzy controller system for navigating in real-time[8]. The fuzzy logic is certainly one of the most adopted approaches in industry. It addresses such applications perfectly as it resembles human decision making with an ability to generate precise solutions from certain or approximate information. It fills an important gap in engineering design methods left vacant by purely mathematical approaches (e.g. linear control design), and purely logic-based approaches (e.g. expert systems) in system design. The advantage of using fuzzy logic for navigation is that it allows for the easy combination of various behaviors outputs through a command fusion process. The navigation system in this case consists of three behaviors an obstacle avoidance static behavior, a goal seeking behavior and communication with other robots [9][10][11].

A set of experimentations is realized to demonstrate the feasibility of this approach for navigation, static and dynamic obstacles avoidance (other robots).

Beside this introduction, the structure of the paper is as follows: Section 2 gives the specification of the robot posture. Section 3 presents the control architecture based on inference fuzzy system. Section 4 is devoted to the description and analysis the simulation results. Conclusions and future work are given in Section 5.

II. ROBOT POSTURE

The circular shaped mobile robot has a differential steering system (figure 1). Two motors independently control two wheels on a common axis. The system consists of a total of three infrared range sensors. These sensors are arranged to cover the whole field around the robot. One forward facing range sensor is used for collision avoidance. Two lateral range sensors placed at a 60 angle relative to the forward moving direction (figure 1). In addition, this platform enables the robot to turn in place to ensure the collection at the global field side.

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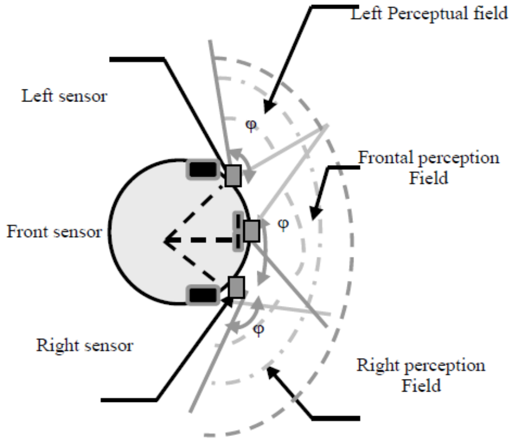


Fig. 1 Robot configuration in a Cartesian reference frame

The position of the robot at a given kinematic equations described by the following:

$$X(t) = X(t-1) + V(t) * \cos(\theta(t)) \quad (1)$$

$$Y(t) = Y(t-1) + V(t) * \sin(\theta(t)) \quad (2)$$

$$\theta(t) = \theta(t-1) + \Delta\theta(t) \quad (3)$$

$$V(t) = V(t-1) + \Delta\theta(t) \quad (4)$$

v And θ represent respectively the velocity and orientation of the robot.

With:

- x, y, θ : configuration state of the mobile robot
- v: Linear velocity of the robot.

III. PROPOSED OBSTACLE AVOIDANCE

This section describes the behavior control architecture for navigation, obstacle avoidance static and dynamic (other robots) and attraction to the target based on fuzzy logic method in unstructured environment.

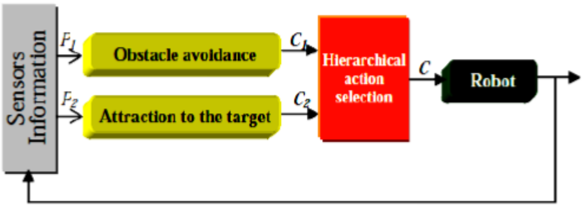


Fig 2. Control architecture for mobile robot navigation [13].

A. *Hierarchical action selection*

The proposed control architecture uses an action selection mechanism to manage the switch, between two or even more controllers, according to environment perception.

The desired output actions are then combined together by an arbitration mechanism. This way of letting behaviors be active simultaneously is desirable in many situations.

B. *Attraction to the target controller*

This section describes the behaviors for attraction to the target. The robot moves in the search space from its initial position to the target. The used method to achieve this behavior is the method "on-line". The robot must reach a given target radius Rc and center coordinates (xc,yc) expressed in the coordinate of the robot.

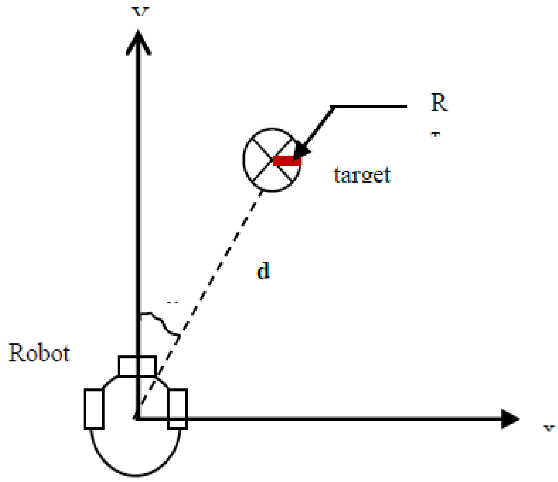


Fig. 3 Controller for attraction to target

C. *Obstacle avoidance controller*

A real-time obstacle avoidance approach for mobile robots has been developed and implemented. This approach permits to the mobile robot to avoid obstacles and going toward the target simultaneously.

The main objective of the proposed method is to reduce the robot orientation change in obstacle avoidance behavior, without affecting the efficiency and the safety of the avoidance.

The use of Fuzzy Logic has found application in the area of control system design, where human expert knowledge, rather than precise mathematical modeling, of a process or plant is used to model/implement the required controller. Uncertainty and ambiguity are evident in many engineering problems [9]. Fuzzy Logic Control (FLC) therefore provides a formal method of translating subjective and imprecise human knowledge into control strategies, thus facilitating better system performance through the exploitation and application of that knowledge.

In general, there are two approahes to the application of fuzzy logic in mobile robot navigation, namely, behavior-based approach and classical fuzzy rule based approach [14]. The overall control problem is decomposed into small behaviors, each one focusing on only a small portion in input space. The controller is given a path in some internal reference frame and it generates motor commands in order to follow it as closely as possible.

1) *Description of the architecture of fuzzy control system*

The reflex action of the robot is derived from the analysis of data according to the three sides of the robot (dG, dF dD: the obstacles distances) and polar coordinates of the end point in

the coordinate system of the robot (the orientation of the target denoted γ, and the distance to the target denoted d).
The robot acquires information from the environment across its sensors then the local planning system (fuzzy controller) may determine and direct the action and movement to perform to achieve the goal or avoid an obstacle.

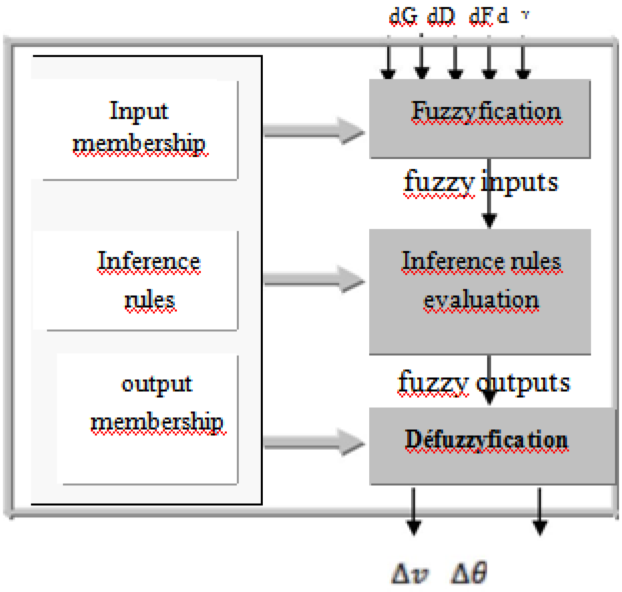


Fig. 4. Fuzzy controller configuration

Based on the specifications of the robot, the design of fuzzy controller is proposed by defining the functional and operational below:

- **Membership functions**

The membership functions of the input variables and output are explained in the following figures.

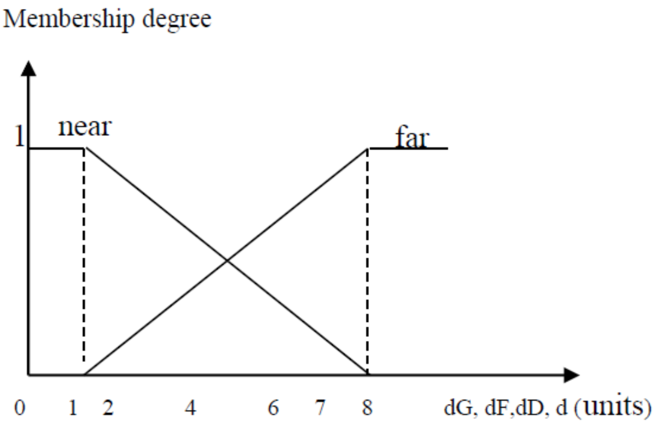


Fig 5. Representation fuzzy sets in the distance

This figure shows the membership functions of the distances dG, dF, and dd are evaluated against two fuzzy subsets P and L, which correspond to Far and Near.

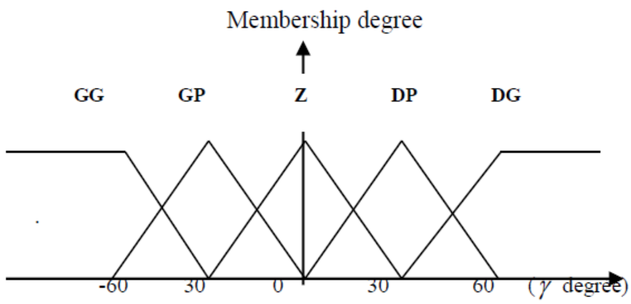


Fig 6.Representation of the fuzzy sets of input

This figure shows the membership functions of the angle of orientation of the target relative to the robot γ is represented by five fuzzy intervals: GG (great left), GP (left small), Z (zero), DP (right small), DG (right large) covering the front half of the space robot.

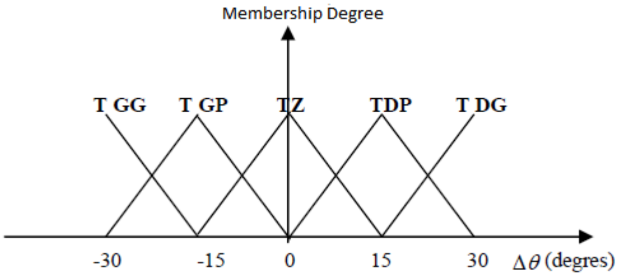


Fig 7. Representation of the fuzzy sets of the output

The output variable (the angle of the robot) is represented by five fuzzy sets: TGG (theta great left), TGP (theta little left), TZ (theta zero), TDP (right small theta) , TDG (theta right large).

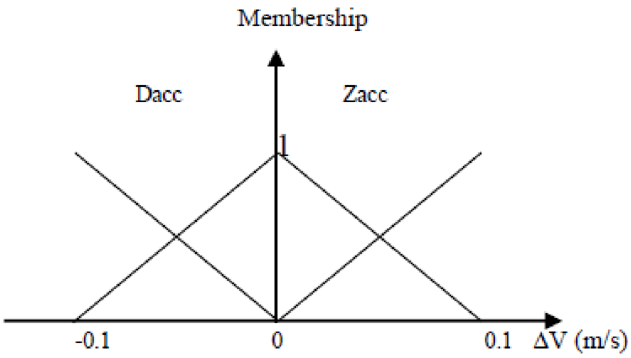


Fig 8. Representation of the fuzzy sets of the output Δv

The speed variation is described by three subsets: DACC (lower speeds), Zacc (no shift) and Acce (increase speed).

- **Inference Rules**

This step concerns the development of rules to define the expected behavior of the robot according to its intrinsic para parameters. For each combination of values of the input variables, an action on the output variables associated with it. In all you get 80 fuzzy rules. The following table summarizes the rules for the detection of a frontal obstacle:

TABLE 1 SITUATION (AVOID NEAR FRONT)

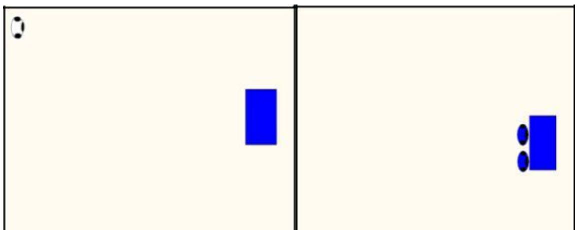
	dG	dF	dD	d	γ		Δθ	Δν
SI	L	P	L	L	GG	alors	TGG	ZAC
	L	P	L	L	GP		TGP	ZAC
	L	P	L	L	Z		TGP	ZAC
	L	P	L	L	DP		TDP	ZAC
	L	P	L	L	DG		TDG	ZAC
	L	P	L	P	GG		TGG	DEC
	L	P	L	P	GP		TGP	DEC
	L	P	L	P	Z		TGP	DEC
	L	P	L	P	DP		TDP	DEC
	L	P	L	P	DG		TDG	DEC

- METHOD DEFUZZIFICATION

Having put in place the membership functions and inference rules established defining the behavior of the controller, we choose a method of defuzzification. The latter allows transforming the values of fuzzy control domain to the real domain (physical variables). We opted for the defuzzification method called "center of gravity method discreet." This choice is usually conditioned by a compromise between ease of implementation and computational performance.

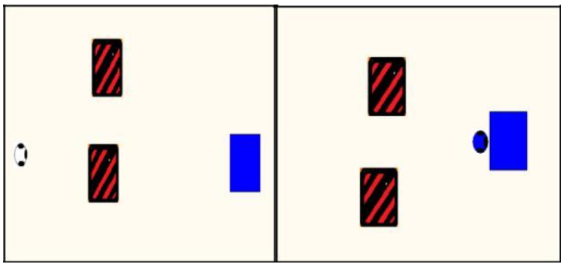
IV. SIMULATION RESULTS

To confirm the relevance of the proposed control architecture, it is proposed to simulate a mobile robot navigation to reach a target in presence of obstacles for different robots configurations and different environment.



(a) Before (b) After

Fig 9 Scenario of navigation1



(a) Before (b) After

Fig 10 **Scenario of navigation 2**

V. EXPERIMENTATION RESULT

In this section, we evaluate the proposed approach efficiency by a set of experimentations on Thymio II robots. Thymio II is an affordable educational robot. It provides three main features: a large amount of low-cost sensors and actuators,a specific interactivity based on light and touch, aimed at increasing the understanding of the robot functionalities and a very efficient programming environment based on Aseba (https://aseba.wikidot.com/en:start). Its interactivity is based on several functionalities: capacitive touch buttons,color of the body (full RGB spectrum) and LED associated with each robot functionality (https://aseba.wikidot.com/fr:thymioprogram).

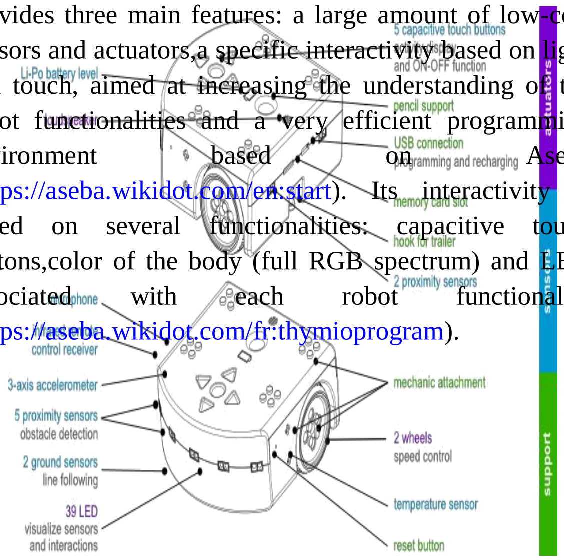
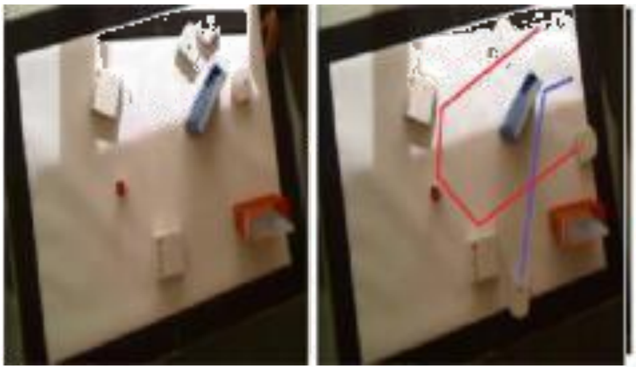


Fig11. The ThymioII robot Platform and its structural component (https://aseba.wikidot.com/en:thymio)

The experimentation scenes are timed and filmed by several cameras. In figures 12 -13, we show several cases of environments simples and complexes to validate the proposed approach. The bold line represents the trajectory of the robot.



(a) First position (b) Final position
Fig 12. avoidance obstacle in the environment 1

(a) First position (b) Final position
Fig 13. Avoidance obstacle in the environment 2

VI. CONCLUSION

In this article, a proposed solution has been presented to the problem of navigation, obstacle avoidance, by developing a fuzzy navigation controller. The experimental and simulation results are satisfactory and validate the proposed approach. The robot navigates autonomously and safe despite the complexity of the environment.

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