Fuzzy control motion design for mobile robots in unknown environments

OUARDA HACHOUR
Department Of Electrical and Electronics Engineering
Faculty Of Engineering Sciences
Signal and System Laboratory
Boumerdes University
Boulevard de l'independence Boumerdes 35000
ALGERIA
E-mail: hachour_ouarda@yahoo.fr

Abstract: , we present an algorithm for path planning to a target for mobile robot in unknown environment. The proposed algorithm allows a mobile robot to navigate through static obstacles, and finding the path in order to reach the target without collision. This algorithm provides the robot the possibility to move from the initial position to the final position (target). The proposed path finding strategy is designed in a grid-map form of an unknown environment with static unknown obstacles. The robot moves within the unknown environment by sensing and avoiding the obstacles coming across its way towards the target. When the mission is executed, it is necessary to plan an optimal or feasible path for itself avoiding obstructions in its way and minimizing a cost such as time, energy, and distance. In order to get an intelligent component, the use of Fuzzy Logic In order to get an intelligent component, the use of Fuzzy Logic (FL), and Expert Systems (ES) is necessary to bring the behavior of Intelligent Autonomous Vehicles (IAV). To present a real intelligent task and to deal with autonomy requirements such as power and thermal, (FL), and Expert Systems (ES) is necessary to bring the behavior of Intelligent Autonomous Vehicles (IAV). The aim work must make the robot able to achieve these tasks: to avoid obstacles, and to make ones way toward its target by *ES_FL* system capturing the behavior of a human expert. The integration of ES and FL has proven to be a way to develop useful real-world applications, and hybrid systems involving robust adaptive control. The proposed approach has the advantage of being generic and can be changed at the user demand. The results are satisfactory to see the great number of environments treated. The results are satisfactory and promising.

Key-Words: - Expert System, Fuzzy Logic FL), Intelligent Autonomous Vehicles (IAV), navigation, Path planning.

1 Introduction

Autonomous robots which work without human operators are required in robotic fields. In order to achieve tasks, autonomous robots have to be intelligent and should decide their own action. When the autonomous robot decides its action, it is necessary to plan optimally depending on their tasks. More, it is necessary to plan a collision free path minimizing a cost such as time, energy and distance. When an autonomous robot moves from a point to a target point in its given environment, it is necessary to plan an optimal or feasible path avoiding obstacles in its way and answer to some criterion of autonomy requirements such as : thermal, energy, time, and safety for example. Therefore, the major main work for path planning for autonomous mobile robot is to search a collision free path. Many works on this topic have been carried out for the path planning of autonomous mobile robot.

Motion planning is one of the important tasks in intelligent control of an autonomous mobile robot . It is often decomposed into path planning and trajectory planning. Path planning is to generate a collision free path in an environment with obstacles and optimize it with respect to some criterion. Trajectory planning is to schedule the movement of a mobile robot along the planned path . Several approaches have been proposed to address the problem of motion planning of a mobile robot. If the environment is a known static terrain and it generates a path in advance it said to be off-line algorithm. It is said to be on-line if it is capable of producing a new path in response to environmental changes.

A robotic systems capable of some degree of self-sufficiency is the overall objective of an Autonomous Mobile Robot AMR and are required in many fields[1,5,7,8]. The focus is on the ability to move and on being self-sufficient to evolve in an unknown environment for example. Thus, the recent developments in autonomy requirements, intelligent components, multi-robot system, and massively parallel computer have made the AMR very used, notably in the planetary explorations, mine industry, and highways[12,13,14,15].

The ability to acquire these faculties to treat and transmit knowledge constitutes the key of a certain kind of intelligence. Building this kind of intelligence is, up to now, a human ambition in the design and development of intelligent vehicles. However, the mobile robot is an appropriate tool for investing optional artificial intelligence problems relating to world understanding and taking a suitable action, such as, planning missions, avoiding obstacles, and fusing data from many sources[4,5,6,7,10,11]

A robotic vehicle is an intelligent mobile machine capable of autonomous operations in structured and unstructured environment, it must be capable of sensing (perceiving its environment), thinking (planning and reasoning), and acting (moving and manipulating). But, the current mobile robots do relatively little that is recognizable as intelligent thinking, this is because :

1) Perception does not meet the necessary standards .
2) Much of the intelligence is tied up in task specific behavior and has more to do with particular devices and missions than with the mobile robots in general.
3) Much of the challenge of the mobile robots requires intelligence at subconscious level.

The objective of intelligent mobile robots is to improve machine autonomy. This improvement concerns three (03) essential aspects. First, robots must perform efficiently some tasks like recognition, decision-making, and action which constitute the principal obstacle avoidance problems. They must also reduce the operator load by using natural language and common sense knowledge in order to allow easier decision making. Finally, they must operate at a human level with adaptation and learning capacities[1,2,3].

This paper deals with the intelligent navigation control of IAV in an unknown environment. The aim of this paper is to develop an IAV combining Expert Systems (ES) and Fuzzy Logic (FL) for the IAV stationary obstacle avoidance to provide them with more autonomy and intelligence. Artificial intelligence, including Fuzzy logic and Expert system, has been actively studied and applied to domains such as automatically control of complex systems like robot. In fact, recognition, learning, decision-making, and action constitute the principal obstacle avoidance problems, so it is interesting to replace the classical approaches by technical approaches based on intelligent computing technologies. These technologies ES, and FL are becoming useful as alternate approaches to the classical techniques one. The proposed approach can deal a wide number of environments. This system constitutes the knowledge bases of FL_ES *approach* allowing recognizing situation of the target localization and obstacle avoidance, respectively. This approach can be realized in efficient manner and has proved to be superior to combinatorial optimization techniques, due to the problem complexity. This approach FL_ES based on intelligent computing offers to the autonomous mobile system the ability to realize these factors: recognition, learning, decision-making, and action (the principle obstacle avoidance problems). The results are promising for nest development

2 The proposed fuzzy logic and motion design

Today, researchers have at their disposal, the required hardware, software, and sensor technologies to build IAV. More, they are also in possession of a computational tool such as FL and ES that are more effective in the design and development of IAV than the predicate logic based methods of traditional Artificial Intelligence. Fuzzy Logic FL and Expert System ES are well established as useful technologies that complement each other in powerful hybrid system. Hybrid intelligent systems are now part of the repertoire of computer systems developers and important research mechanisms in the study of Artificial Intelligent. The integration of ES and FL has proven to be a way to develop useful real-world applications, and hybrid systems involving robust adaptive[8].

2.1 Expert System

An ES is a computer program that functions, is in a narrow domain, dealing with specialized knowledge, generally possessed by human experts. ES is able to draw conclusions without seeing all possible information and capable of directing the acquisition of new information in an efficient manner

2.2 Fuzzy Logic

To build intelligent systems that are able to perform complex requiring massively parallel computation, a knowledge of the environment structure and interacting with it involves abstract appreciation of natural concepts related to, the proximity, degree of danger, etc. the implied natural language is represented through fuzzy sets involving classes with gradually varying transition boundaries. As human reasoning is not based on the classical two-valued logic, this process involves fuzzy truths, fuzzy deduction rules, etc. This is the reason why FL is closer to human thinking and natural language than classical logic[9]. The fuzzy model, treaded in this conception is presented in figure1

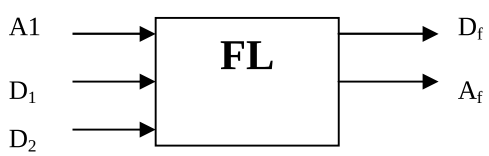

Figure 1: Fuzzy model

Where:

A_1 : the direction of the robot.D_1, D_2: intermediate distance between current position, intermediate position and visual point (see the figure2). The membership labels for distance D1 and D2, see the fig.4, are defined as: Cp: current position, Ip : intermediate position, Iv : intermediate visual position.,Vp : visual position, the membership functions of direction A_1 are presented in figure 5, where fuzzy labels are defined as:LDS :

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Left Danger Small, RDS: Right Danger Small, LDB: Left Danger Big., RDB: Right Danger Big, the membership labels of distance D_f are defined as (see the figure 6): Cp : current position, Id : intermediate danger, Vp Visual point . The membership functions of direction A_f are presented in figure 7, where fuzzy labels are defined as: RSS: Right Safety Small, RSB: Right Safety Big, LDS: Left Danger Small, RDS: Right Danger Small, LSS: Left Safety Small. LSB Left Safety Big., LDB: Left Danger Big. ,RDB: Right Danger Big. The direction A1 is calculated by：

$$A_1 = \tan^{-1}(Y_g - Y_i)/(X_g - X_i)$$

Where

The P_1(x1,y1), P_i(xi, yi), and P_g (xg, yg) are the coordinates of respectively to initial point , intermediate and visual point (we calculate point to point until the visual point become the target one). The vehicle must learn to decided A_f and D_f using FL from a fuzzy linguistic formulation of human expert knowledge. This FL is trained to capture the fuzzy linguistic formulation of this expert knowledge is used and a set of rules are then established in the fuzzy rule as shown in Table 1.

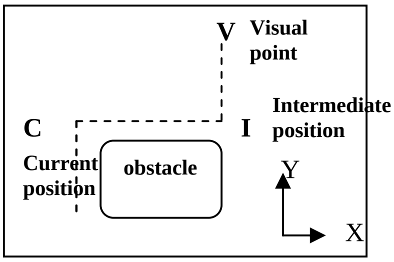

Figure2: Robot obstacle mode avoidance

Another example is presented in the figure 3 to find an optimal path to navigate intelligibly avoiding the obstacles. This example shows the way on which the scene of navigation is decomposed.

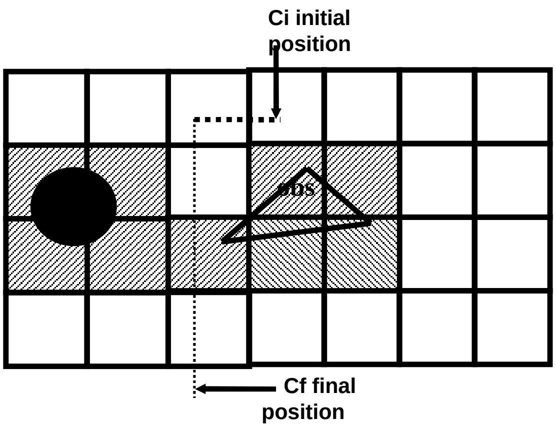

Fig. 3: example of the navigation finding an optimal path.

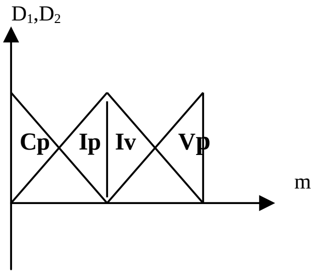

Figure 4: Memberships function of distance D_1 and D_2

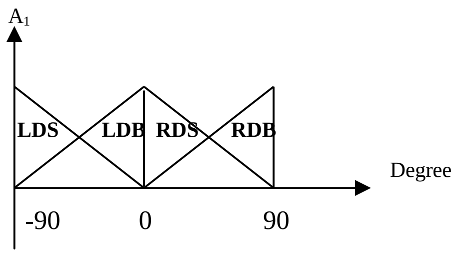

Figure 5: Memberships function of direction A_1

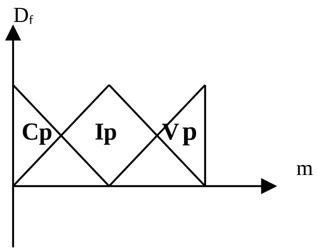

Figure 6: Memberships function of distance D_f

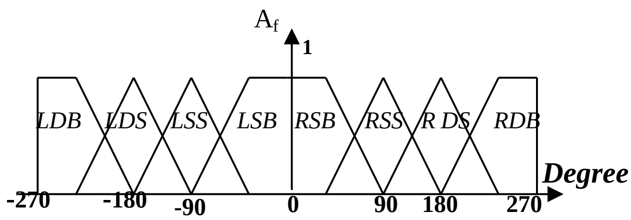

Figure 7: Memberships function of distance A_f

If ((A1 is LDS)and(D1is Cp)) **then** ((df is Cp) and (Ad is Cd))
If ((A1 is Cd)and(D1is Cp)) **then** ((df is Cp) and (Ad is Cd))
If ((A1 is Cd)and(D1is Cp)) **then** ((df is Cp) and (Ad is Cd))
If ((A1 is Cd)and(D1is Cp)) **then** ((df is Cp) and (Ad is Cd))

Table 1: Rule inference

G = (the sum of (u_i * g_i) / the sum of (u_i))

The final decision (defuzzification) is achieved to give the output of fuzzy controls and to converts the fuzzy given by:

Where : 1<=i<=m, m : number of rule, g: centroid of the backend membership function correspond for each rule. U: factor of membership correspond for each rule.

3 Simulation results

We denote that the configuration grid is a representation of the configuration space. In the configuration grid starting from any location to attend another one, cells are thus belonging to reachable or unreachable path. Note that the set of reachable cells is a subset of the set of free configuration cells, the set of unreachable cell is a subset of the set of occupied configuration cells. By selecting a goal that lies within reachable space, we ensure that it will not be in collision and it exists some "feasible fuzzy path" such that the goal is reached in the environment. Having determined the reachability space, the algorithm works and operates on the reachability grid .This one specifies at the end the target area.To maintain the idea ; we have created several environments which contain many obstacles. The search area (environment) is divided into square grids. Each item in the array represents one of the squares on the grid, and its status is recorded as walkable or unwalkable area (obstacle). The robot starts from any position then using fuzzy logic learning must move and attends its target. The trajectory is designed in form of a grid-map, when it moves it must verify the adjacent case by avoiding the obstacle that can meet to reach the target at the same line.

As an example : the environment set up is shown in the figure 8. The path is found by figuring all the fuzzy squares. Once the path is found, the robot moves from one square to the next until the target is reached, once we have simplified our search area into a convenient number of sub positions , as we have done with the grid design, the next step is to conduct a search to find the path. We do this by starting point, checking the adjacent squares, and training fuzzy model outward until we find our target. We start the search by the following steps: we have selected the starting position, it moves fuzzily forward as shown above in figure 9.The robot meets an obstacle, it moves a step down then back until it meets another obstacle. The robot keeps navigation in this manner until the target is found, as shown in figure 10 , figure 11, figure 12, figure 13 . The figure 14 shows the robot close to the target.

For unwalkable space, we compute the total size of freecells around danger (obstacle) area. This total may be at least greater or equal than to the length of architecture of robot. This is ensure the safety to our robot to not be in collision with the obstacle, and that the path P has enough security SE to attend it target where it is given by P$\pm$SE (S is size of security). For walkable space the robot reaches its target with the following steps illustrated in this algorithm :

Algorithm Of Work :

Begin
    Start set up environment
    Initialisation
    Move
    IF {*the target is Reached*? } DO End task
        ELSE
            Begin
            L1 : If {*the obstacle is detected?*} DO
                Begin
                Change the direction.
                Move.
                Target is attended.
                End task.
                ElSE GOTO L1.
            End
End.

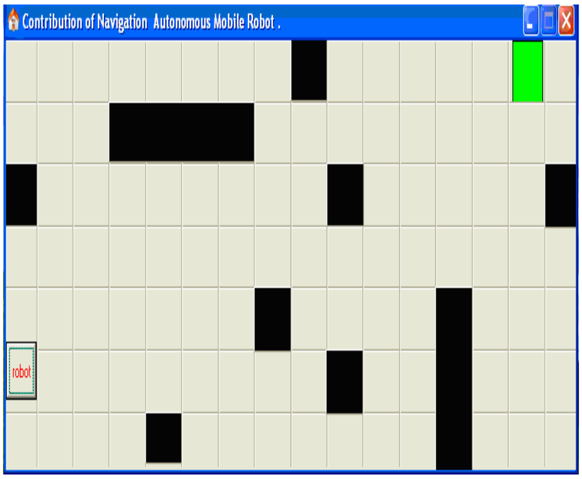

Figure 8 : assumed initial environment set up.

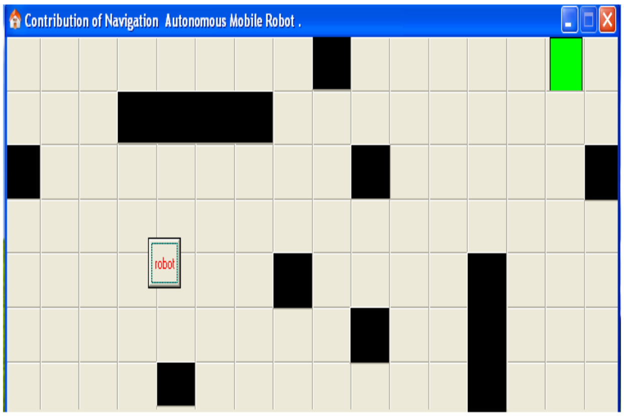

Figure 9 : intermediate position : robot moves

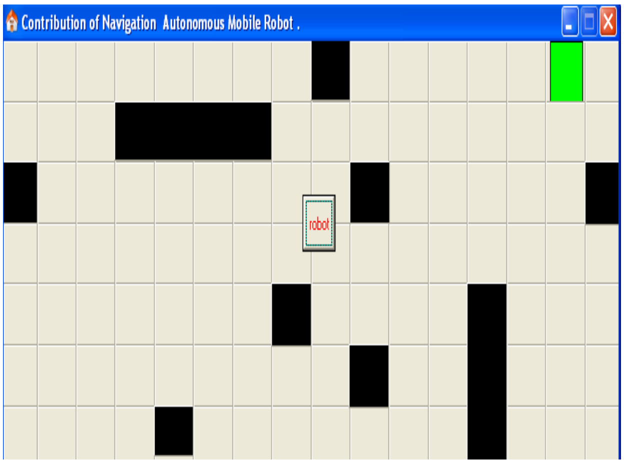

Figure 10 : intermediate position: robot in half way

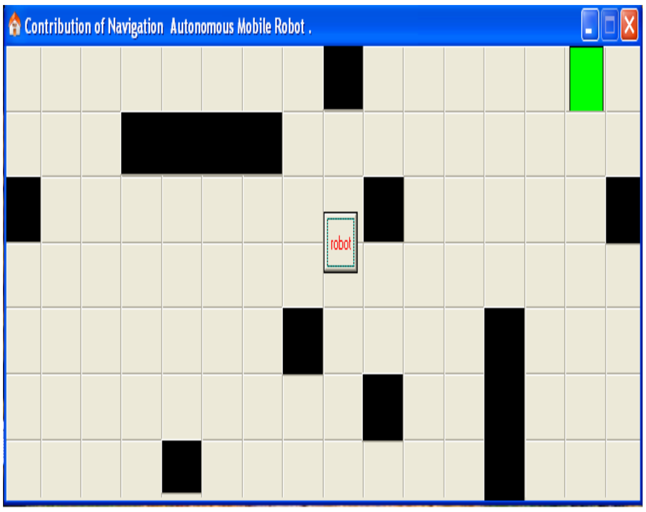

Figure 11 : robot recognizes the obstacle (robot must avoids this obstacle)

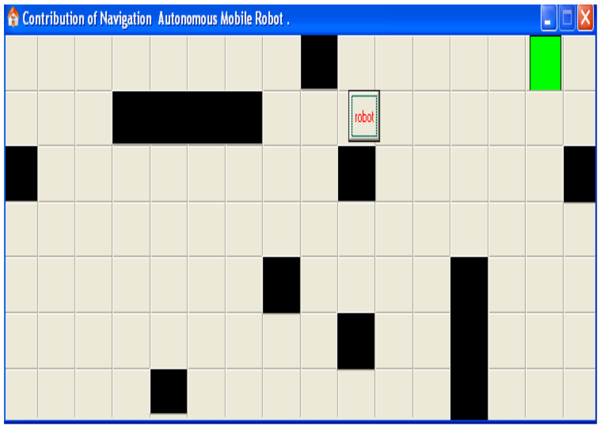

Figure 12 : the task fuzzy reasoning and inference : robot avoids the obstacle .

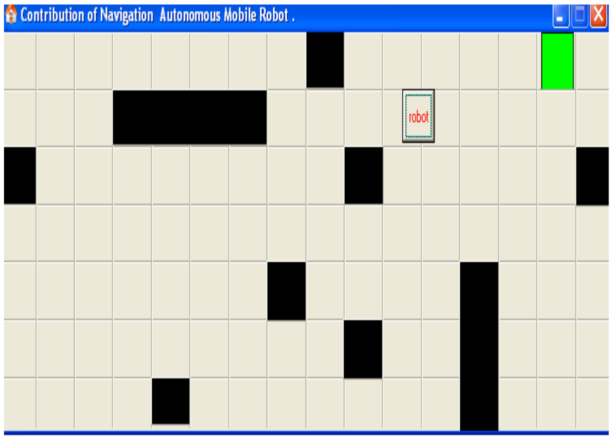

Figure 13 : robot in security self : far from obstacle

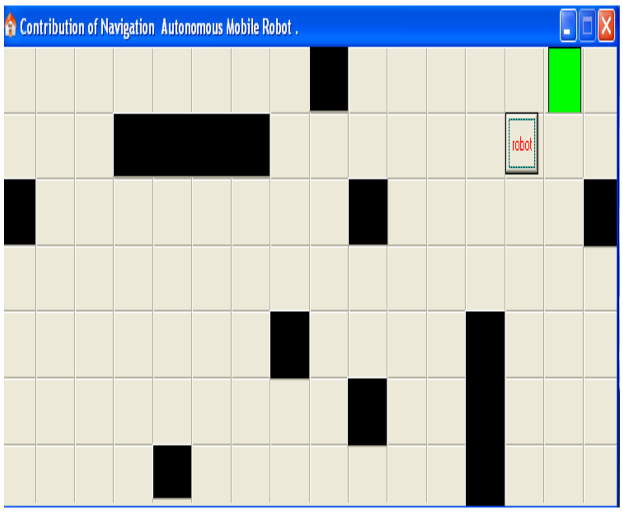

Figure 14 : Final position: robot approaches target .

4 Conclusion

the theory and practice of IAV are currently among the most intensively studied and promising areas in computer science and engineering which will certainly play a primary goal role in future. These theories and applications provide a source linking all fields in which intelligent control plays a dominant role. Cognition, perception, action, and learning are essential components of such-systems and their use is tending extensively towards challenging applications (service robots, micro-robots, bio-robots, guard robots, warehousing robots).In this paper, we have presented a fuzzy logic implementation of navigation approach of an autonomous mobile robot in an unknown environment using hybrid intelligent. Indeed, the main feature of FL combined with ES is the task fuzzy reasoning and inference capturing human expert knowledge to decide about the best avoidance direction getting a big safety of obstacle danger**.** Besides, the proposed approach can deal a wide number of environments. This system constitutes the knowledge bases of our *approach* allowing recognizing situation of the target localization and obstacle avoidance, respectively. Also, the aim work has demonstrated the basic features of navigation of an autonomous mobile robot simulation .We have run our simulation in several environments where the robot succeeds to reach its target in each situation and avoids the obstacles capturing the behaviour of intelligent expert system. The proposed approach can deal a wide number of environments. This navigation approach has an advantage of adaptivity such that the IAV approach works perfectly even if an environment is unknown. This proposed approach has made the robot able to achieve these tasks : avoid obstacles, deciding, perception, recognition and to attend the target which are the main factors to be realized of autonomy requirements. Hence; the results are promising for next future work of this domain.

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