Intelligent Fuzzy Model Conception in unknown environments

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Abstract—In this present work, we present an algorithm for path planning to a target for mobile robot in unknown environment based on the principle of fuzzification. 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. In this context, our 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 System (IAS). The results are satisfactory to see the great number of environments treated. The results are satisfactory and promising for next developments and more design.

Keywords— Autonomous Mobile Robot (AMR), optimal path, Fuzzy logic (FL),Expert system (ES), fuzzy reasoning.

I. INTRODUCTION

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. A wide variety of approaches have been considered, but these can broadly be categorized into on-line and off-line techniques. However, few algorithms have been developed for on-line motion planning in a time-varying or unknown [9].

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)[3]. 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.

A robotic system capable of some degree of self-sufficiency is the overall objective of an autonomous mobile robot and are required in many fields . 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 systems, and massively parallel computer have made the autonomous mobile robot very used, notably in the planetary explorations, mine industry, and highways [4].

Intelligent autonomous systems designers search to create dynamic systems o navigate and perform purposeful behaviours like human in real environments where conditions are laborious. However, the environment complexity is a specific problem to solve since the environments can be imprecise, vast, dynamical, and partially or not structured. Then, intelligent autonomous Systems must then be able to understand the structure of these environments. To reach the target without collisions, intelligent autonomous systems must be endowed with recognition, learning, decision-making, and actions capabilities.

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.

Recent research on intelligent autonomous systems has pointed out a promising direction for future research in mobile robotics where real-time, autonomy and intelligence have received considerably more weight then, for instance, optimality and completeness. Many navigation approaches have dropped the explicit knowledge representation for an implicit one based on acquisitions of intelligent behaviours that enable the robot to interact effectively with its environment, they have to orient themselves, explore their environments autonomously, recover from failure, and perform whole families of tasks in real-time.

A robot is a "device" that responds to sensory input by running a program automatically without human intervention. Typically, a robot is endowed with some artificial intelligence so that it can react to different situations it may encounter. The robot is referred to be all bodies that are modeled geometrically and are controllable via a motion plan.\q robotic vehicle is an intelligent ;mobile machine capable of autonomous operations in structured and unstructured environment. It must be capable of sensing thinking and acting.

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The goal of the navigation process of mobile robots is to move the robot to a named place in a known, unknown or partially known environment. In most practical situations, the mobile robot can not take the most direct path from the start to the goal point. So , path planning techniques must be used in this situation, and the simplified kinds of planning mission involve going from the start point to the goal point while minimizing some cost such as time spent, chance of detection, or fuel consumption [1,2,3,4,5].

Moreover, when a robot moves in a specific space, it is necessary to select a most reasonable path so as to avoid collisions with obstacles. Several approaches for path planning exist for mobile robots, whose suitability depends on a particular problem in an application. For example, behavior-based reactive methods are good choice for robust collision avoidance. Path planning in spatial representation often requires the integration of several approaches. This can provide efficient, accurate, and consistent navigation of a mobile robot.

The major task for path-planning for single mobile robot is to search a collision –free path. The work in path planning has led into issues of map representation for a real world. Therefore, this problem considered as one of challenges in the field of mobile robots because of its direct effect for having a simple and computationally efficient path planning strategy. For path planning areas, it is sufficient for the robot to use a topological map that represents only the different areas without details such as office rooms.

The possibility to use topological maps with different abstraction levels helps to save processing time. The static aspect of topological maps enables rather the creation of paths without information that is relevant at runtime. The created schedule, which is based on a topological map, holds nothing about objects which occupy the path. In that case it is not possible to perform the schedule. To get further actual information, the schedule should be enriched by the use of more up-to date plans like egocentric maps.

Systems that control the navigation of a mobile robot are based on several paradigms. Biologically motivated applications, for example, adopt the assumed behavior of animals. Geometric representations use geometrical elements like rectangles, polygons, and cylinders for the modeling of an environment. Also, systems for mobile robot exist that do not use a representation of their environment. The behavior of the robot is determined by the sensor data actually taken. Further approaches were introduced which use icons to represent the environment. One of the specific characteristics of mobile robots is the complexity of their environment, therefore, one of the critical problem for the mobile robots is path planning. Several approaches for path planning exist for mobile robots, whose suitability depends on a particular problem in an application. For example, behavior-based reactive methods are good choice for robust collision avoidance. Path planning in spatial representation often requires the integration of several approaches.

This can provide efficient, accurate, and consist navigation of a mobile robot. It is sufficient for the robot to use a topological map that represents only the areas of navigation (free areas, occupied areas of obstacles). It is essential the robot has the ability to build and uses models of its environment that enable it to understand the environment’s structure. This is necessary to understand orders, plan and execute paths.

To deal with a one of largely studying area of research which is now used in computer graphics in design and manufacture computer-assisted, we present the linear parametric curves for the path planning. Several approaches have been addressed to the use of the parametric curves for path planning. A path without collision is presented as a sequence of curves connecting the initial points to the target in the workspace. The control points connected determine the form of the path for which the problem of optimal trajectory calculation is posed. In this regard, we present an algorithm for the path planning using only one point of control from which we can obtain the remaining points constituting the trajectory[6,7,8,9].

For the path planning we suppose that the environment workspace is real and known, i.e., the system is equipped by vision sensors that able to provide information concerning the obstacles. These obstacles can have any complex or simple shape. Our conception treats the problem of moving of an autonomous mobile robot without collisions with any object in the workspace taking into consideration the dimension of that

robot.
A key ability needed by an autonomous, mobile robot is the possibility to navigate through the space. The problem can basically be decomposed into positioning and path planning.

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[10,11,12,13,14].

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.

II. The Proposed Approach

The robot navigates on a grid (see Figure 6) which regularly divides the ground into square grids that are identified with Cartesian Coordinates. As mentioned earlier, the robot starts out from a predefined position (e.g. the centre of grid 0,0) and orientation (e.g. North, which means looking up the y-axis).
It is sufficient that the full grid is rectangular and all grids are the same size. It is not required that the robot knows the dimension (n,m) of the grid. It is satisfactory to only request navigation to grids that really exist.

A. 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.

B. 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]. The fuzzy model, treaded in this conception is presented in figure1
Where:
A_1: the direction of the robot.D_1, D_2: intermediate distance between initial position, intermediate position and desired point (see the figure2) D3: is the distance between the initial position and the desired point. The membership labels for distance D1 and D2 and D3, see the fig.4, are defined as: AP: actual position, MP : medium position, IV : intermediate visual position ,DP : desired position, see the figure3. The membership functions of direction A_1 are presented in figure 4, where fuzzy labels are defined as: LCP Left Current Position ,RCP Right Current Position, LDP : left Desired Position, RDP :Right Desired Position, LIP: Left Intermediate Position, RIP : Right Intermediate Position. The rule inferences of this system are presented in th figure 5, where decision table written with productions rules and then avoidance direction vector are shown.

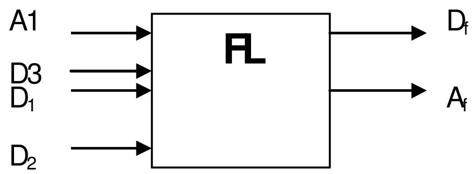

Fig. 1 Fuzzy Model

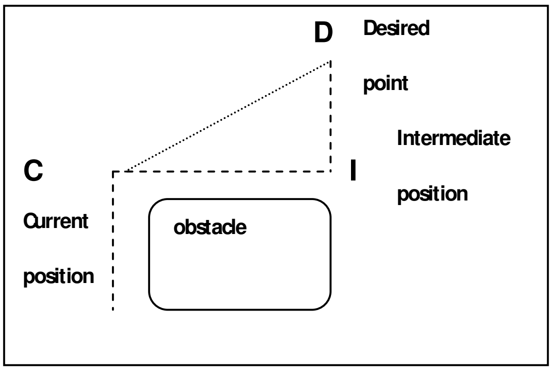

Fig. 2 Robot obstacle mode avoidance

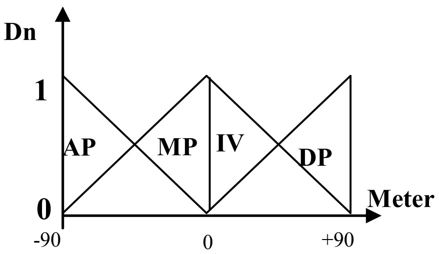

Fig. 3 Membership functions of distance D_n

IF (A1s LCP and D is AP) Then (**C_f** is LCP and DF is AP)
IF (A1s LIP and D is AP) Then (**C_f** is LIP and DF is AP)
IF (A1s LDP and D is AP) Then (**C_f** is LDP and DF is AP)
IF (A1s LCP and D is MP) Then (**C_f** is LCP and DF is MP)
IF (A1s LIP and D is MP) Then (**C_f** is LCP and DF is MP)
IF (A1s LDP and D is MP) Then (**C_f** is LIP and DF is MP)
IF (A1s LCP and D is IV) Then (**C_f** is LCP and DF is IV)
IF (A1s LIP and D is IV) Then (**C_f** is LCP and DF is IV)
IF (A1s LDP and D is IM) Then (**C_f** is LIP and DF is IV)
IF (A1s LCP and D is DP) Then (**C_f** is LCP and DF is DP)
IF (A1s LIP and D is DP) Then (**C_f** is LCP and DF is DP)
IF (A1s LDP and D is DP) Then (**C_f** is LIP and DF is DP

Fig. 5 Rule Inference

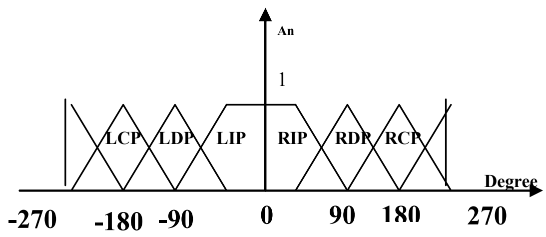

Fig. 4 Membership functions of the direction

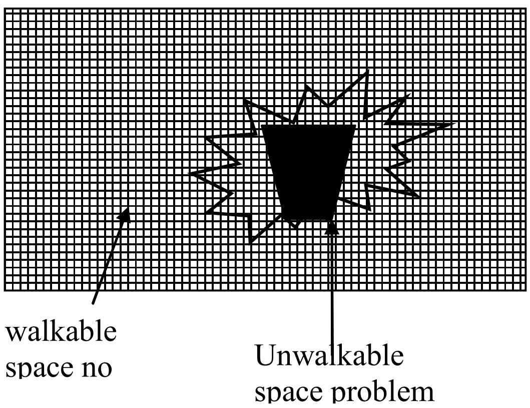

Fig. 6 an example of walkable space and walkable space

To determine the nature of space of navigation, and as we have illustrated before, cells are marked as either free or occupied ; otherwise unknown. We can therefore divide our search area into free and occupied area . note that all free space cells represent the walkable space and unwalkable in occupied space. Each free cell is able of lying all the neighbor free cell within a certain distance “d”. this distance “d” is usually set to a value greater than or equal to the size of cell. Note that the set of free cells is a subset of the of free cells, which is in turn a subset of the set of free occupancy cells. Thus, by selecting a goal that lies within free space , we ensure that the free sub-path will not be in collision with the environment, and that there exists some sub-paths to get the target. Note that , we determine the free resultant cells within free space to get a feasible path during navigation . for unwalkable space (occupied space) we just develop a procedure of avoiding danger.

For unwalkable space, we compute the total size of free cells 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). In principle, we generate a plan for reaching safety area for every neighboring danger area. The safety distance is generated to construct the safety area building to the navigation process, to be near without collision within this one.

The main problem of this approach is that does not encounter several obstacles at the same time and does not take into account the obstacles sizes. The static danger degree A and safety degree B are given by :

$$\mathbf{A_n = \tan^{-1} ((Y_i\text{-}Y_1)/ (X_i\text{-}X_1))\ldots.(1)}$$
$$\mathbf{B_n = \tan^{-1} ((Y_g\text{-}Y_1)/ (X_g\text{-}X_1))\ldots.(2)}$$

Where : the points P_1 (X_1,Y_1), P_i (X_i,Y_i) and $P_g(X_g,Y_g)$ are the co-ordinate of respectively to current point, intermediate point and desired point (we calculate point to point until the visual point becomes the target one.

The final decision is given by:
G = (the sum of $(u_i * g_i)$ / the sum of (u_i))

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

III. Simulation Results

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. Furthermore, to build machines that are able to perform complex task requiring massively parallel computation, knowledge of the environment structure and interacting with it involves abstract appreciation of natural concepts related to, the proximity, degree of dangers, etc. Also, FL can be viewed as an attempt to bring together conventional precise mathematics and human-like decision-making concepts.

To reflect the vehicle behaviors acquired by learning and to demonstrate generalization and adaptation abilities of our approach, vehicle is simulated in different static environments. In this context, we have created N unknown environments containing static obstacles; (complexity order of theses creations is limited at the last environment one, until now we have tested 95 environments), we start with no obstacle until the complexity order is done.

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.

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).

As there is no information at advance, this creation can give another configurations of environments, that means that, the user of this concept can change the positions of all objects as he want in the scene and can change the shapes of obstacle(big, small, different sizes,…), this have no effect since the environment is unknown, the robot success, in satisfactory manner, to avoid suitably the static obstacles while it makes one’s way toward its target, we can give different infinite environment complexity, in order to achieve the desired task.

Tested in different unknown environments with static obstacles, we present simulation results which provides the most preferable path between another one treated. As it is illustrated In the Figure 7,8 and 9 where S: Robot and B:

Target, the vehicle succeeds to avoid obstacles and reaches its target. In this case, we present virtually the best optimum path, e.g. the robot doesn't endanger itself or other objects in the environment.

At advance, the robot navigates virtually to structure the environment, and one or more camera are used for the perception which can guarantee to deliver acceptably accurate information all of the time. Also, the redundancy is useful (sensor data fusion), the robot receives a good deal of attention and recognizes all elements of the scene of navigation and learned where are situated the safety section to evolve and where the danger sections to avoid. After learning, the final decision is given as guide of steering vector. In this case, the robot is supposed not as square , it is replaced by point material and the path is a set of positions of all points of navigation .

The user can change the shape (body) of robot to execute the final path by gravity center (but the size of the vehicle is taken into account). We replace the body of vehicle by gravity center (material point) to execute the path truly. Before, the optimum path has been calculated and the accurate avoidance direction is known, so now the robot knows at advance how to evolve and where is situated from the target. The final decision is taken and the best path to execute is selected, the robot can evolve without risk. These results display the ability making IAS able to intelligently avoid obstacles with different architectures.

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.

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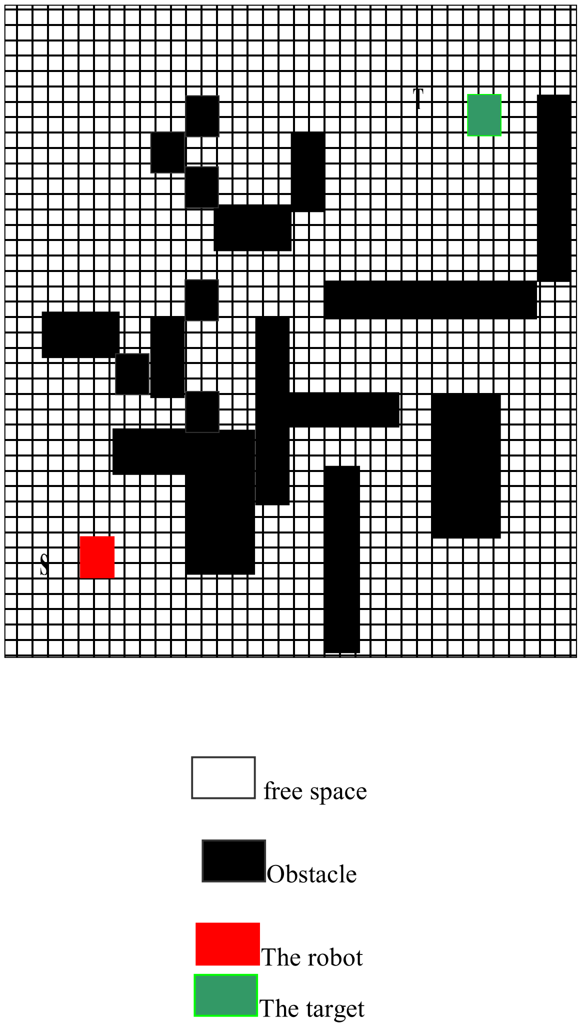

Fig. 6 Robot initial position

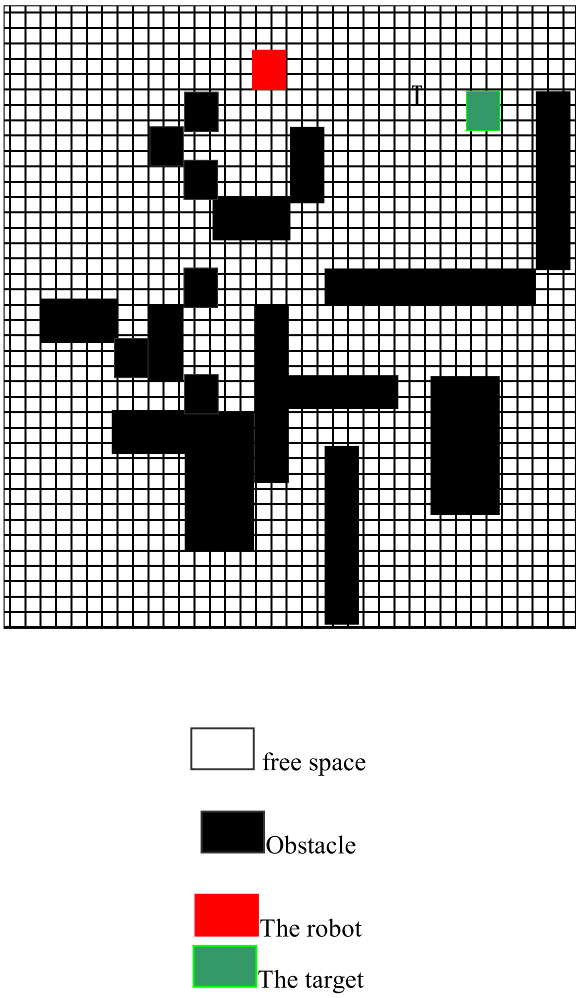

Fig. 7 Robot in hallway

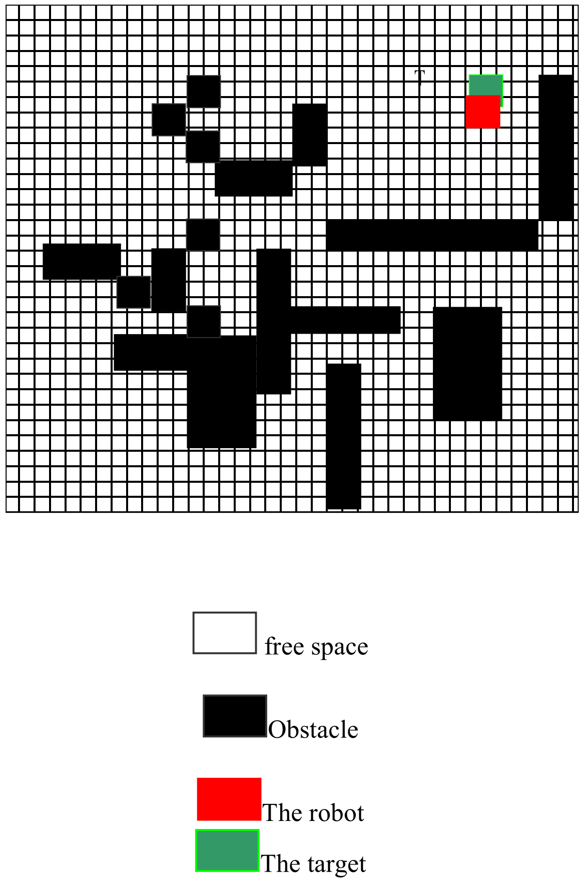

Fig. 8 Robot Approaching the Target

IV. CONCLUSION

We studied the path planning problem of an autonomous robot operating in a 2-dimentional surface with obstacles. A complete path planning algorithm guarantees that the robot can reach the target if possible, or returns a message that indicates that there is no free path when the target cannot be reached.

There also a very crucial performance consideration, i.e., the trajectory was smoothed. Furthermore, the returned path is optimal, i.e. this path is the shortest path from the possible free trajectories. This optimality is ensured by using the simulated annealing technique Actually the algorithm can deal with any shape obstacles but for the circular obstacles they be surrounded by a polygon with maximum number of edges, in the simulation we supposed to be eight edges. In addition, one of the assumptions in this part was that the dimensions of the robot are not taken in consideration, i.e., the robot is considered as material point.

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.

REFERENCES

[1] O. Hachour AND N. Mastorakis Behaviour of intelligent autonomous ROBOTIC IAR", *IASME transaction*, issue1, vol 1, ISSN 1790-031x WSEAS, January 2004,pp 76-86.

[2] Ihn Namgung and Joseph Duffy, "Two dimensional collision-free path planning using linear parametric curve", *Journal of Robotic Systems*, 1998.

[3] S.Florczyk, *Robot Vision Video-based Indoor Exploration with Autonomous and Mobile Robots*, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2005.

[4] O. Hachour and N. Mastorakis, IAV : A VHDL methodology for FPGA implementation, *WSEAS transaction on circuits and systems,* Issue5, Vol 3,ISSN 1109-2734, 2004,pp.1091-1096.

[5] D. F. Rogers and J. A. Adams, « Mathematical Elements for Computer Graphics », 2nd ed., *McGraw-Hill*, New York, 1990.

[6] Bezier, P., 1972, "Numerical Control-Mathematics and Application, A. R. Forrest and A. F. Pankhurst, Trans., John Wiley & Sons, New York, 1972.

[7] V. J. Lumelsky, "Effect of kinematics on motion planning for planar robots arms moving amidst unknown obstacles", *IEEE J. of Robotics and Automation*, RA-3(3), 1987,pp207-223,.

[8] I. D. Faux et M. J. Pratt, *« Computational Geometry for Design and Manufacture"*, Jhon Wiley & Sons, New York, 1979.

[9] S. M. LaValle, "*Planning Algorithms*" , Published by Cambridge University Press, 2006.

[10] O.Hachour, "The Proposed Genetic FPGA Implementation For Path Planning of Autonomous Mobile Robot", *International Journal of Circuits , Systems and Signal Processing,* Issue 2, vol2 ,2008,pp151-167.

[11] O. Hachour AND N. Mastorakis, Avoiding obstacles using FPGA –a new solution and application *,5th WSEAS international conference on automation & information (ICAI 2004) , WSEAS transaction on systems* , issue9 ,vol 3 , Venice , Italy , , ISSN 1109-2777, November 2004, pp2827-2834

[12] O.Hachour, the proposed hybrid intelligent system for path planning of Intelligent Autonomous Systems, International journal of mathematics and computers in simulation,Issue 3, Volume 3, 2009, Pages 133-145.

[13] O. Hachour, ,"path planning of Autonomous Mobile Robot", *International Journal of Systems Applications, Engineering & Development*, Issue4, vol.2, 2008, pp178-190.

[14] O.Hachour, "The Proposed Genetic FPGA Implementation For Path Planning of Autonomous Mobile Robot", *International Journal of Circuits , Systems and Signal Processing,* Issue 2, vol2 ,2008,pp151-167.