iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 Issue: VI Month of publication: June 2016

DOI:

www.ijraset.com
IC Value: 13.98
Volume 4 Issue VI, June 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Fuzzy Based Motion Planning of Mobile Robot

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***Abstract*— In this paper, We have developed fuzzy rules for Dynamic Motion Planning of Mobile Robots. Motion planning becomes more complex when the configuration and position of obstacle are not known priori for such system Soft Computing Techniques are popularly used. Due to the dynamic uncertainties posed by the vary nature of the problem use of Fuzzy Approach makes the handling the task easier. In this paper a solution is proposed for dynamic motion planning of Mobile Robot with and without obstacle. A Fuzzy Logic Controller is design as a solution to the problem.**
***Keywords*—Fuzzy Logic System. Preference – Based Fuzzy Behavior Control System, Motion Planning**

I. INTRODUCTION

Today Robot Systems are becoming more and more significant in various aspects of human life, for example in industrial, commercial and scientific applications. As a result of scientific achievements and industrial development, the number of Robots currently being used in industrial projects is increasing fast. However, Robotics have been evolving in the last years and there has been an increasing interest in developing Mobile Robot systems, capable of performing robust cooperative work.

Control and communication methods for Mobile Robot systems have been investigated by various researchers. Problems such as motion planning and coordination of Mobile Robot systems are generally approached with a centralized controller in mind. Moreover, most of the work in obstacle avoidance and motion planning has been developed on a single Mobile Robot interacting with its environment.

This work is part of the relatively new interest in interaction between Autonomous Mobile Robots. Such systems bring in the problems of both multiple Robot coordination and autonomous navigation. However, due to the complexity in developing a complete system, this paper will focus on a specific task: Preference – Based Fuzzy Behavior Control System and Dynamic Motion Planning for obstacle avoidance. This task appears to be very difficult when an environment also affect the motion of Mobile Robot.

Since the cooperation in the system will be based upon the interchange of information relating to position and force sensing of the Mobile Robots, the operative systems must integrate several characteristics to make this communication easier, besides, the force feedback must come from a reliable source, so the sensor should be robust enough to provide this information.

The problem of motion planning in dynamic environments is quite different from navigating static environments. Motion planning in static environments guarantees a solution if there exists one whereas motion planning in dynamic environments in intractable. Hence, the objective of motion planning in dynamic environments is to avoid collisions and minimizing motion time as much as possible [9, 10].

Robots are going to play a vital role in upcoming generation of human being. They will be having major impact on our life, Science and Technology. Robotics is the field where almost every branch of Technology has got merged like Mechanical, Electrical and Electronics & Computer Science [7].

The key difference between Mobile Robot and Human navigation is the quantum difference in perceptual capabilities. Human can detect, classify and identify the environmental features under widely varying environment condition, independent orientation and distance. Current Mobile Robots, while being able to detect stationary obstacles before they start run into them, have very limited perceptual and decision making capabilities.

Navigation in dynamic environment is most important and necessary constraint for Mobile Robot to work - well. Robot need to recognize their position and pose in known environment as well as unknown environment. In the future, the Mobile Robot will be human friendly, that are able to coexist with humans in dynamic space [4]. Motion planning of Mobile Robot included several restrictions which arise due to dynamic nature of obstacle. It is desirable for a Mobile Robot to take decision in such varying environment. Set of rules of Fuzzy Logic Controller (FLC) which Mobile Robot use for Dynamic Motion Planning (DMP). Fuzzy approach is important tool to handle uncertainties of environment. Uncertainty - There are a number of uncertainty factors that contribute to Mobile Robot navigation problem [8]. First and foremost, Mobile Robot environments are the factors because of their unpredictable. Mobile Robot navigation problem is full of uncertainties which can be easily handled by fuzzy approach.

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II. PREFERENCE BASED FUZZY BEHAVIOR CONTROL SYSTEM

Preference – based fuzzy behavior control system can be apply in variety of control application. A preference -based structure consists of a finite set of parallel running behavior, and a centralized control command unit. A set of possible control commands is kept by this command unit and is also known by each behavior. The behavior responds to their respective stimuli by expressing their preference levels a_i to each of the available command alternatives i through rules of the form

IF (Stimulus has particular values)….
THEN (Command 1 has preference a_1)…
AND (Command 2 has preference a_2)…
AND (Command 3 has preference a_n)…

The central control command unit augments the preferences that each command receives from the behaviors and selects the command that gets the highest score. The behaviors are treated as advisors to the central control command unit; they together form an advisory block. Since each behavior has to express its relative preference to each of the available command alternatives, it respond by firing multiple signals, one corresponding to each of the available command alternatives. Fig.1 shows the basic structure of preference –based fuzzy behavior system. In a preference –based fuzzy behavior system each behavior is a fuzzy system and the preference levels are expressed as fuzzy sets. The preference based fuzzy behavior system is inspired by the result of [1, 11, 12]. The work of [11] served to firmly establish a rigorous generalized framework for the development of similar method to their navigational algorithm first demonstrated in [12]. The Distributed Architecture for Mobile Navigation (DAMN) and

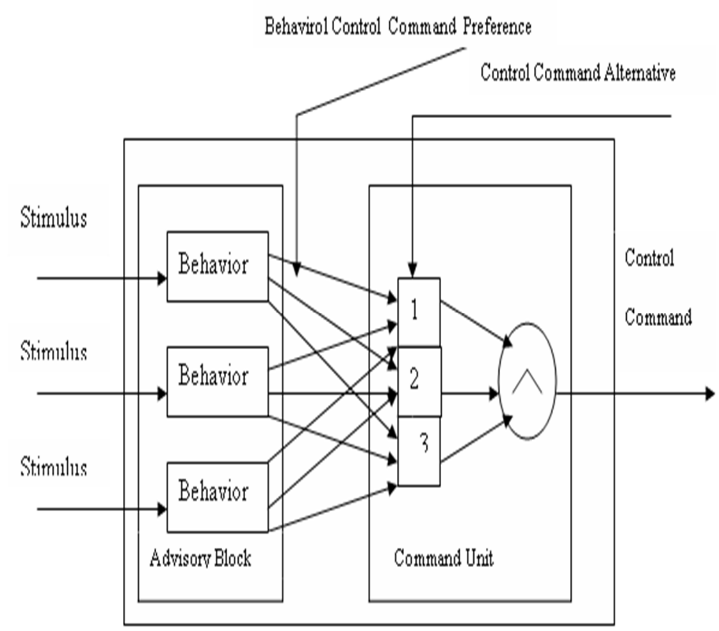

Figure 1: Preference – based fuzzy behavior control system

its predecessor, the fine grained behavior system of [13], used crisp behaviors that express their preference through voting (positive, negative, or neural) for each command. The preference levels or votes from all behaviors to each command that had the highest sum was selected as the system command. A natural drawback of all crisp behavior system is the lack of continuity in the commands, where each command is allowed to only have discrete values and intermediate values are not executed. Fuzzy behaviors inherently eliminate this problem, which helps provide smooth motion.

III. THE PROPOSED CONTROL SYSTEM BY PREFERENCE BASED FUZZY BEHAVIORS

The proposed model of preference – based fuzzy behavior control system is based on the point kinematics [3] of the Robot, if we represent Mobile Robot in x-y plane

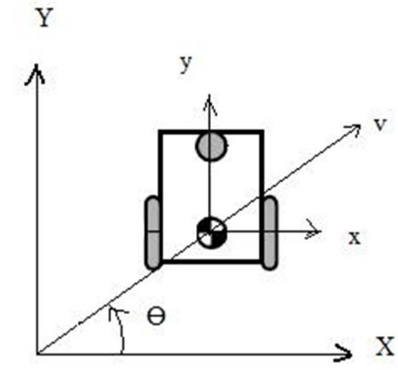

Figure 2: Mobile Robot aligned with a global axis

(1) $$\frac{dx}{dt} = v\cos(\Theta)$$

(2) $$\frac{dy}{dt} = v\sin(\Theta)$$

where v is the Mobile Robot speed, Θ is heading direction relative to the x- axis, the x-y position of the Mobile Robot at instant k can be computed as

$$x(k+1) = x(k) + \tau_s v_k \cos(\Theta_k), \quad (3)$$
$$y(k+1) = y(k) + \tau_s v_k \sin(\Theta_k), \quad (4)$$

where τ_s is the sample interval. Hence, the dynamic motion planning of Mobile Robot can be divided into two control action: heading control for determining Θ_k (The head focuses on the closest object to it), and speed control for determining v_k. The heading control is achieved using four behaviors: (1) front obstacle avoidance, (2) right obstacle avoidance, (3) left obstacle avoidance, and (4) goal seeking. The speed control uses two behaviors only: (1) obstacle avoidance and (2) overturning avoidance [1]..

IV. RECOGNITION OF OBSTACLE

In the dynamic nature of the environment we cannot predict the nature of obstacle and it becomes more difficult to handle the motion of the Mobile Robot when we do not having the knowledge of obstacle in advance. The Very near (VN), Near (N) and Far (F) obstacle avoidance behaviors use range sensor measurements to determine the preference for the possible movements. Its design is such that these behaviors become effective when an obstacle is observed in some neighborhood of the Mobile Robot. The fuzzy rules for these behaviors can be expressed as

IF (Range sensor readings)
THEN ($a_{i,}$ 1 and a_i, 2 and $a_{i,}$ 3)

where *i* represent corresponding to the behavior with *i* =1, *i* =2, and *i* =3 represents the VN, N and F respectively. For example we have assigned fuzzy preference $a_{i,}$ 1 and a_i, 2 and $a_{i,}$ 3 to avoid the Very near (VN), Near (N) and Far (F) obstacle with help of sensor. Sensor gives the information about static and dynamic obstacle to the Mobile Robot [6]. Any obstacle whose image is becoming larger and smaller can be treated as coming toward and going away from Mobile Robot respectively, Mobile Robot make decision for only those obstacle which is coming toward and obstacle which is in the path of Mobile Robot.

V. FUZZY APPROACH

Problem in the real world quite often turn out to be complex owing to an element of uncertainty either in the parameter which define the problem in the situations in which the problem occur, Dynamic Mobile Robot navigation problem is one of them in which all parameter are having full of uncertainties.

It is in such situations that fuzzy set theory exhibits immense potential for effective solving of the uncertainty in the problem [5]. Soft computing techniques enable handling of imprecision and uncertainty often encountered in practical problems dynamic motion planning of Mobile Robot. There is natural connection between dynamic motion planning (DMP) problem of Mobile Robot and a fuzzy logic approach.

The purpose of the DMP (dynamic motion planning) problem of a Robot is to find obstacle –free path which takes a Robot from a starting point (S) to a goal point (G) with minimum time [2]. These are basically two important part of the problem.

Learn to find any path from point S to G that avoid all obstacle; and

Learn to choose that obstacle –free path which takes the Robot in a minimum possible time.

The DMP problem of Mobile Robot can be solved by many approaches but Fuzzy approach give optimum solution of the DMP problem of the Mobile Robot.

We state the assumptions made about the DMP problem

The Mobile Robot is considered to be single point.

No kinematics constraint limits the motion of the Mobile Robot. The motions are only constrained by moving obstacles.

Each obstacle is represented by its boundary circle, although this is a not rigid limitation.

The obstacles are disjoint, that is, no two obstacles are allowed to overlap at any time.

Thus, the fuzzy logic technique helps in quickly determining imprecise yet obstacle –free paths and the use of an algorithm helps in learning an optimal set of rules that a Mobile Robot should use while navigating in presence of moving obstacle.

VI. REPRESENTATION OF A SOLUTION

A solution to the DMP problem is represented by a set of rules which a Mobile Robot will use to navigate point S to Point G. Each rule has three conditions - *Distance*, *Angle*, and *Movement.*

A. Distance

The distance of the nearest obstacle forward from the Robot. Three fuzzy values for distance are Very near (VN), Near (N), and Far (F).

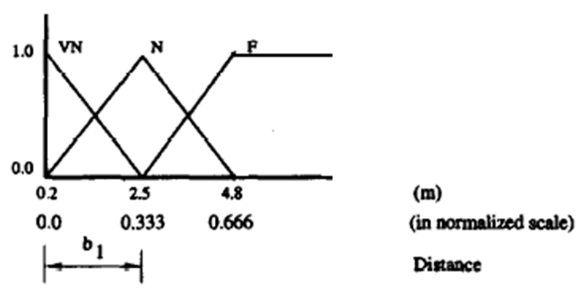

Figure 3: Membership function of distance used in fuzzy approach

B. Angle

The angle between the path joining the Robot and the target point and the path to the nearest obstacle forward. The corresponding five fuzzy values for the angle are Left (L), Ahead left (AL), Ahead (A), Ahead right (AR), Right (R).

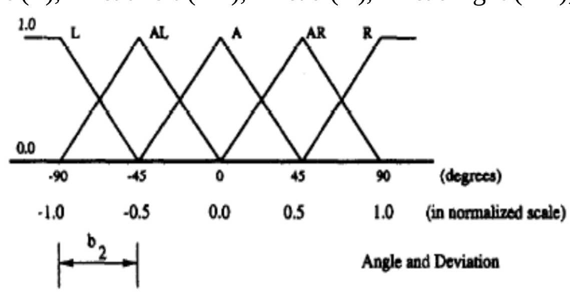

Figure 4: Membership function of angle used in fuzzy approach

C. Movement

Movement is the relative velocity vector of the nearest obstacle forward with respect to the Mobile Robot. Here, in each condition we assumed to take a triangular membership function.

It enables us to use an incremental approach, where the Mobile Robot locates all obstacles at the end of a small time step. This makes the approach practical to be used in real scenario. The action variable is movement of the Mobile Robot from its path towards the target. This variable is considered to have five fuzzy values: Left (L), Ahead Left (AL), Ahead (A), Ahead Right (AR), Right (R), Here, The membership function is same as angle. A set of rules can be expressed as

IF (distance is VN and angle is A)

THEN (movement is AL)

In our solution we have three choices for distance and five choices for angle, so possible set of rule could be 3 x 5 or 15 combinations of two different conditions possible. For each of these 15 combinations, these could be one value for action variable. Thus there are total of 15 x 5 or 75 different rules possible, but an arbitrary set from these 75 rules cannot be used to constitute a valid rule base, this is because for two rules having identical combination of condition variables, there should be unique value of action variable, thus the maximum number of rules that may present in a rule base is 15, which can be used for the movement of the Mobile Robot.

TABLE 1 SET OF RULE

distance \ angle	L	AL	A	AR	R
VN	A	AR	AL	AL	A
N	AL	A	AL	A	AR
F	AL	A	AL	A	AR

We have assigned a particular value of the action variable for each combination of condition variable based on intuition. An obstacle is very near and straight ahead, the robot deviated towards ahead left. However, when the obstacle is very near but on the left of the Mobile Robot, the Mobile Robot goes ahead. As the critical obstacle is away from the Mobile Robot, it has a tendency to move ahead. This set of rule is pretty good and we shall see later that an FLC with this rule base can navigate well in certain scenarios. However, currently we are also extending the –fuzzy approach to adaptively find the best action variable for a particular combination of condition variable, thereby eliminating the need for such a user – defined rule base.

It is important to note that not all 15 rules are necessary for the Mobile Robot to use during obstacle avoidance. One of the tasks in this study is to find which (and how many) rules should be there in the rule base for the Mobile Robot to find the shortest path between two point. We represent the presence of the rule by a 1 and the absence of the rule by a 0. Thus, a complete solution will have a 15-bit length string of 1 and 0. The value of the i^{th} position along the string marks the presence or absence of the i^{th} rule in the rule base. Thus, the following 15-bit string represents the sixth rules, as shown in table 2

10011 01010 00010

TABLE 2 MINIMUM SET OF RULES

distance \ angle	L	AL	A	AR	R
VN	A			AL	A
N		A		A	
F				A	

We have simulated our solution of DMP problem in the MATLAB environment. Fuzzy approach is based on the membership function of the fuzzy variable. In our solution, we have eliminated set of rule of previous approach in [2], by not considering the VF fuzzy variable as shown in Fig.5, and we can still maintain the sensitivity of the sensor with the help of membership function. Membership function plays major role in this case. We need to increase the range of each membership function of distance. The proposed solution of DMP outperforms the previous approach in [2].

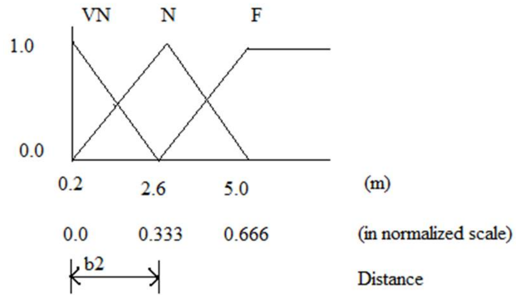

Figure 5: Membership function of distance used in fuzzy approach

VII. CONCLUSIONS

In this paper, obstacle recognition and avoidance method for a Mobile Robot with range sensor is proposed for both moving and stable object. We proposed fuzzy approach for DMP problem of Mobile Robot for smooth navigation.

The Navigation is one of the major problem of autonomous Mobile Robot due to uncertainties of environment. The Mobile Robot can handle such dynamic uncertainties with the help of fuzzy approach. In further research, proposed approach can be used to minimize the DMP problem of Mobile Robot with the fuzzy rule set.

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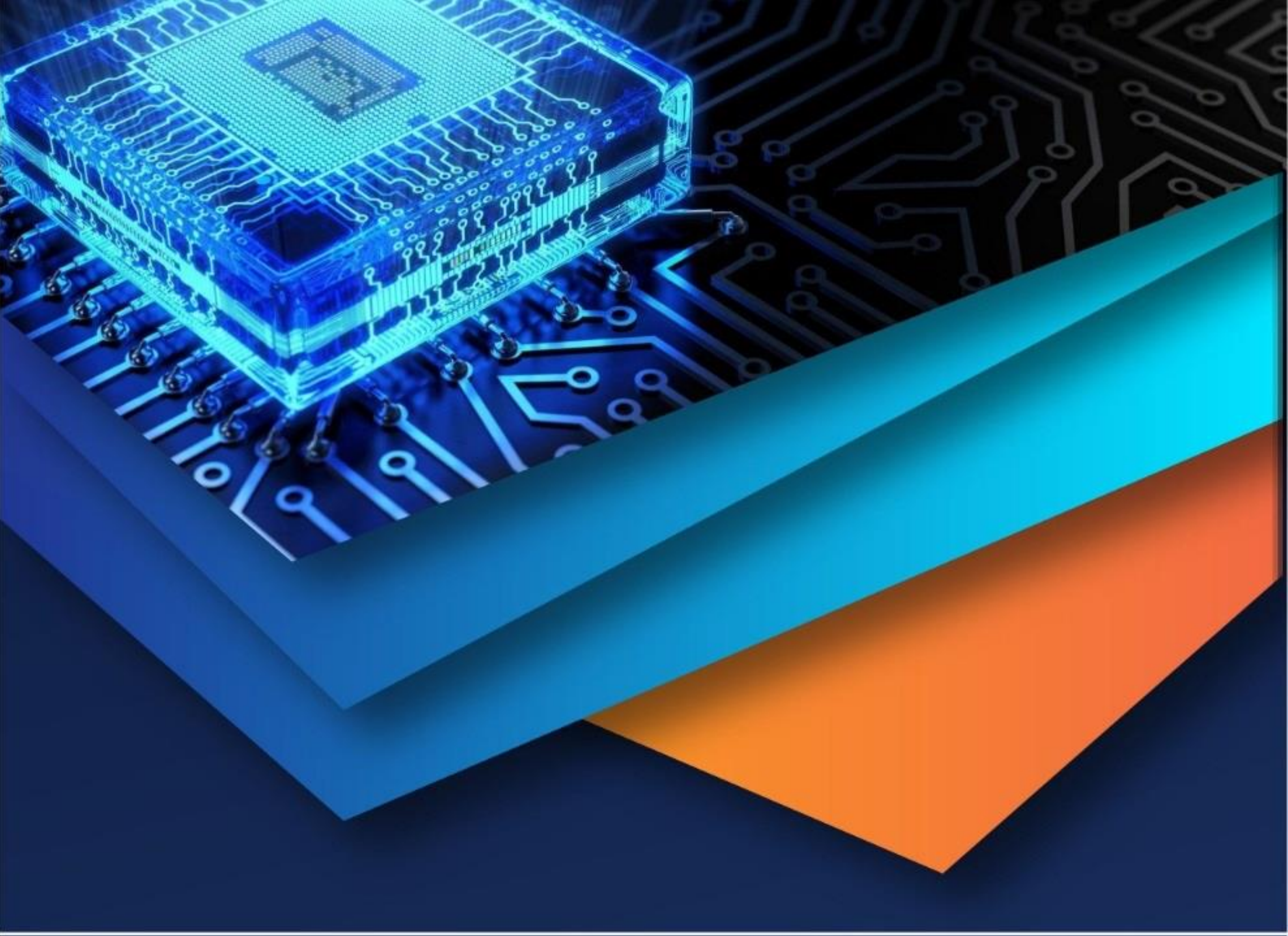

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