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AI Based Navigation of Mobile Robot in Unknown Environment

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ABSTRACT

With the advent of a new technical era, mobile robot finds its application in aerospace industries, defence, medical institute and research laboratories for study purpose. The most important feature of a mobile robot is that it reaches the goal position without touching obstacles present in the ernvironment. To find desired target inside an environment, mobile robot must navigate safely as well as not collide with surrounding objects. Therefore, this paper provides an AI based control algorithm using integrated system which creates collision free navigation inside an environment. To figure out fast and smother navigation for mobile robot, AI based integrated systems are combined with some other techniques. Integrated system responses like different types of sensors, simulation technique, optical encoder, odometer, rule based technique, etc. are analyzed here. Also, different types of processes (sensor integration, combination of statements, map updating, etc.) combined data from different type of sources to build a map and improve navigation system of mobile robot are studied here. Further, Matlab software is used to validate the simulation result before implementation inside the realistic world. Finally, all simulation results show that robot is being able to complete the task by avoiding the obstacle in efficient manner.

Key Words: Fuzzy Logic, Navigation, Localization, Path Planning.

1. INTRODUCTION

In a universal aspect, “Mobile Robot” may be defined as a combination of automated based control structure with the sensing element, intelligence, and mobility. On the other hand, cognition, perception, action (using actuator), localization, and learning are essential gears of the autonomous mobile robot. The robots are mostly planned to switch humans in monotonous, hazardous and tedious processes. On the other hand, for all the talk of machines flattering intelligent getting a sophisticated robot to do any complex task still requires countless hours of careful, patient programming. Today, factories increasingly use mobile robots for jobs that require localization speed, precision, strength and endurance. These are the advantages of mobile robot compared to a simple robot. At the end to 2014, industries around the world wanted advanced mobile robots in an attempt to help the country to continue its massive manufacturing. At present, new skills and AI algorithms allow mobile robots to learn different technique more rapidly in the desired manner. Moreover, the new inclination observed in 2015 for sharing the acumen with other robots, which could accelerate the learning procedure. In future, these thoughts can replace the human tendency at maximum level with a mobile robot for an operational platform. Based on data provided by International Federation of Robotics [1], almost a 1.2 million robots were in operation around the world in 2014 and expected this number to reach 1.6 million by the end of 2018.

Elementary problems with the mobile robots are related to navigation and localization due to presence of different obstacles on its path. Accordingly, we have categorized the navigation problem as follow:

- Steering Control
- Control over wheel speed

Now, success rate of steering control can be achieved using four behaviours: -

- Avoidance of Front Obstacle
- Avoidance of Right Obstacle
- Avoidance of Left Obstacle
- Target Tracking Behaviour

Another, control of wheel speed which can use control of two behaviours as

- Obstacle tracking by sensory module
- Over Turning situation

Both of these two behaviors are most significant when we build an intelligent mobile robot, which can perform their task during navigation inside specified environment.

Based on changes in position and direction, the mobile robots have been operated as holonomic and non-holonomic. Holonomic robots can change each component of their position and direction without any restrictions. Also, they are capable to steer on same place and move in any direction irrespective of orientation. On another side, non-holonomic mobile robots can’t freely operate in a similar manner. Therefore, they can only move in some degree of directions and it depends upon their positioning capability. Non-holonomic mobile robots only change its direction when the position of the robot has been modified. Currently, the majority of mobile robots are non-holonomic, and there is a drive with different control strategies.

Another problem with the mobile robot is localization, and it is due to present of different obstruction in surrounding environment. Although, the work of many researchers towards developments of mobile robot localization algorithm can’t be neglected. But somewhere the localization problem is not yet solved for navigation in cluttered environment. Mobile localization in a recognized environment govern on reference benchmarks guidance [1] and dead estimate. Further, location supervision depends upon an earlier information of location to estimate robot position [2]. The working platform of the mobile robot is separated into either indoor [3] or outdoor platform [4]. Based on these two scenarios, set of environmental challenges and the necessities we have designed software and hardware.

2. Mobile Robot Wheel Arrangement

For current theoretical analysis, a theoretical model of three-wheeled mobile robot has been used. Current robot is employed with three wheels i.e. two rear wheels follow by one caster wheel. The configurations of two rear wheels are arranged in a manner to drive independently in working platform (Figure 1). Further, the speed of the rear wheels can be controlled independently using control algorithm. The caster wheel used as a follower for two rare wheels. To initiate navigation (in working platform) in an environment a mobile robot has the capability to read or recognize its surroundings securely. To understand or recognize its surroundings AI techniques combined with sensors situated on the robot body. Further, a collision-free navigation is obtained using local sensor reading.

$$X_{n+1} = X_n + Cos(\theta) \quad (1)$$

$$Y_{n+1} = Y_n + Sin(\theta) \quad (2)$$

$$\theta = Tan^{-1}\left[\frac{T_y - Y_{n+1}}{T_x - X_{n+1}}\right] \qquad (3)$$

Where, n = 0, 1, 2, 4, 5, 6 . . .

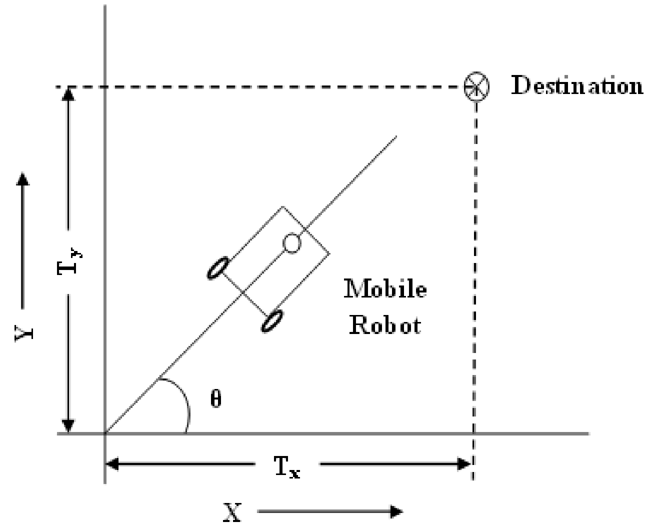

Figure 1 Mobile robot wheel arrangement

In equation. (3), 'θ' is a turning angle (either left or right) and depends upon navigation occurred towards the target point. Whereas, T_x and T_y are the range of the goal in X and Y plane respectively. Reading of X_n provides the current position in X plane whereas X_{n+1} readings provided the next position in an environment and given by equation (1). Similarly, Y_n provides the current position of Y plane, and Y_{n+1} readings provide the next position in an environment given by equation (2).

3. Fuzzy Logic Control Technique

Fuzzy is the smart control technique to solve navigational problems of a mobile robot in complex environment. Avoidance of obstacles is the principal necessity of any mobile robot. Accordingly, the required data for the robot about working environment is given by position of the robot, position of the obstacle, consecutive distance between robot and obstacle, and the goal. If obstacles are found along robot navigational path at that time, fuzzy control algorithm has been activated to avoid obstacles. To perform the successive obstacles avoidance and goal seeking behaviour robot must have to change its heading angle preciously as well as control the speed of wheels autonomously. Therefore, fuzzy control technique has been implemented with the robot control system to perform these tasks for collision free navigation. To handle the vagueness existing in the environment, we have to characterized and implement different linguistic rules (based on human perception) to manipulate the navigational strategies. In general, the fuzzy control algorithm has been built by formatting the different fuzzy rules and membership functions with expert learning knowledge. Table. 1 depicted some of the fuzzy rules and has been used by the robot at the time of navigation.

3.1 PROPOSED FUZZY CONTROLLER

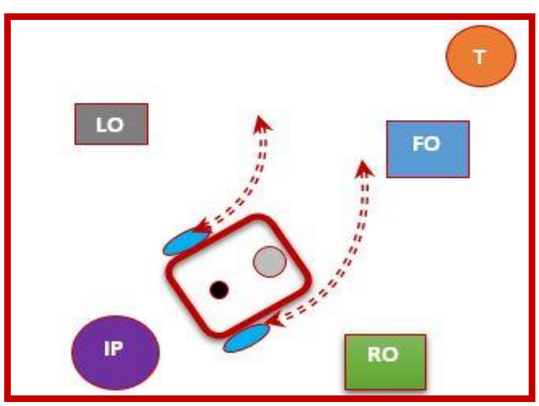

Figure 2 The robot environment

Figure 3 represents the proposed fuzzy controller. In which distance and angle are given as input quantity. Further, output is generated in the form of velocity for left and right wheel. Therefore, the angle of steering is totally depending upon these two quantity. Changes in velocity of the acting wheels is obtaining concerning the horizontal axis, target and obstacle position. Accordingly, path of the has been generated using environment data which is taken by sensory module. The sensory modules collect the environmental data for input as the obstacle distance from local robot position and given as front obstacle distance (FOD), left obstacle distance (LOD), and right obstacle distance respectively Figure 2.

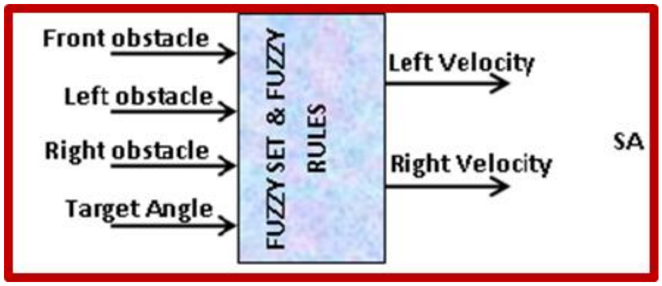

Figure 3 Proposed Fuzzy Controller

Some of the rules have been given as follow for control of mobile robot. *If front obstacle distance is 'F' and left obstacle distance is 'L' and right obstacle distance is 'R' and target angle is 'T' then steering angle is 'E'. Further, steering angle is either left steered or right steered, or zero depends upon obstacle position and target.* The linguistic terms are taken for distance of mobile robot from the different obstacle position (Figure 4) is given by Near (N), Medium (M), Far (F), Very Far (VF), & Very-Very Far (VVF). Similarly, the linguistic term (Fig. 5 and 6) VN (Very negative), N (Negative), Z (Zero), P (Positive), and VP (Very Positive) have been taken for and change in steering angle (either left, right and front) due to obstacle position.

3.2 Fuzzy Membership Function

The membership function in current analysis for front, left, right obstacle distance and target angle is measured as triangular (Figure 4,5) whereas for steering angle it is considered as Gaussian (Figure 6). Further, these three terms (i.e. front, left, and right obstacle distance) defines the inputs behaviour for obstacles avoidance. These terms provide the consecutive distance for any close obstacles in corresponding direction. In similar way, the fuzzy rules provide the steering angle as output for mobile robot and represents the further directional movement. Some of the rules for this analysis are shown below.

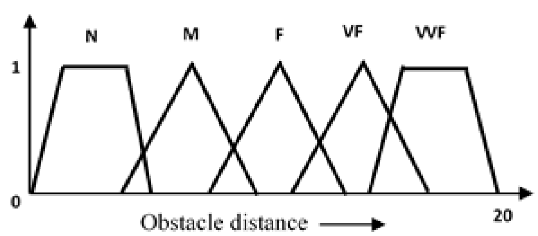

Figure 4 FMF for obstacle distance

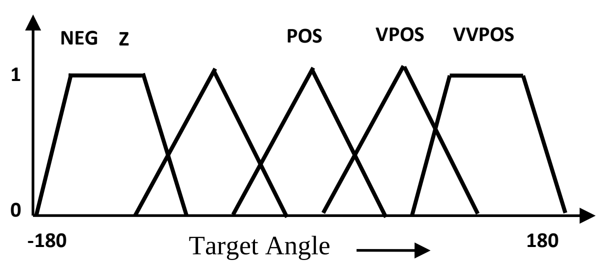

Figure 5 FMF for Target Angle

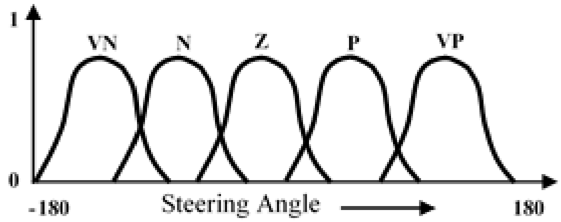

Figure 6 FMF for Steering Angle

- *IF FOD is N, LOD is VN; ROD is VVF and TA is P then SA is P.*
- *IF FOD is VN, LOD is VF; ROD is VN and TA is P then SA is P.*
- *IF FOD is N, LOD is VF; ROD is VF and TA is N then SA is VN.*
- *IF FOD is VN, LOD is F; ROD is VF and TA is VN then SA is N.*

Table 1 Fuzzy Rules for OA and TS Behavior

FO	LO	RO	TA	SA
N	VN	F	VP	P
M	M	VF	P	VP
F	F	M	VN	VN
N	VF	VF	VN	N
VN	VN	F	VP	VP
N	VN	VF	P	VP
VN	F	VN	N	VN
N	VVF	M	VN	VN
F	F	VF	P	P
VF	F	VN	Z	Z
F	VN	N	Z	Z
VF	F	F	P	P
F	VF	VF	N	N
VF	F	F	Z	Z
F	VF	VVF	VN	VN
VF	VN	M	Z	Z
M	M	N	Z	VP
M	VN	VF	VN	P
N	N	F	Z	VP
N	M	N	Z	VN

The fuzzy set for target tracking (TT) activities proceeds angle between the current position of the robot and the position of the target as input, which carries a heading angle towards robot through which it can succeed towards its goal. Some of the rules are given below for target tracking behaviour. If there is no obstacle between robot and target, these types of rules are activated.

- *IF FOD is F, LOD is VF; ROD is VF and TA is Z then SA is Z.*
- *IF FOD is F, LOD is F; ROD is VF and TA is P then SA is P.*
- *IF FOD is F, LOD is VF; ROD is M and TA is VN then SA is VN.*
- *IF FOD is VF, LOD is M; ROD is F and TA is P then SA is P.*

4. OBSTACLE AVOIDANCE STRATEGY

Obstacle evasion strategy is the main condition follow by any mobile robot if searching goal inside an environment. Therefore, firstly we have to categorised the position, direction, and distance of the obstacle in arena. Once the robot recognized the position and direction of the overcome obstacles, robots can create its collision-free path. Figure 7 represents the obstacle avoidance strategy for the wheeled mobile robot, which is moving from start to its end position. When the robot started tracing of its environment, it is expected to catch proper responses from its surroundings and which is decided by its sensory module automatically. As a result, collision-free path for the particular environment created by the robot. The develop fuzzy control algorithm is used for both navigation and obstacle avoidance. Distance from the obstacle situated throughout the robot surrounding is categorised as left obstacle distance (LOD), right obstacle distance (ROD), front obstacle distance (FOD). Therefore, heading angle has been calculated using FLC. Figure 7 represent the all strategies opted throughout navigation and path planning unit.

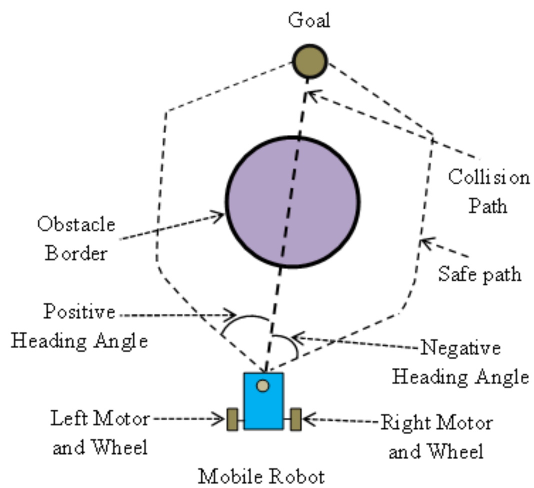

Figure 7 Mobile robot avoiding obstacle

The simulation experiment represents, the proposed fuzzy logic controller (FLC) has accomplish navigational and path planning task in a precious manner. The trajectory of the mobile robot navigation in unknown environment has been shown by Figure 8. Further, twenty number of obstacle has been situated inside environment. The simulation results offer an outstanding alternate based on navigation techniques with a fraction of the dealing out requirement. In this research, we accomplish a robot navigation strategy based on FLC approach and avoid obstacles and drives robot smoothly and robustly form initial point to the target point. Based upon fuzzy logic rules, we have established simulation environment to test the robot trajectory for moderately known environment. Based on experiment we have set the number of obstacles at different position which has been avoided by robot when its starts navigation. Further, the initial condition for the robot is that when the robot is near to the obstacle (in threshold rang) than firstly avoid the obstacle and secondly change the heading angle referring to target. In the Figure 8, a robot is controlled by FLC algorithm and change its heading angle according to the position of the target. In this experiments given that the robot navigates inside environment without striking any obstacle.

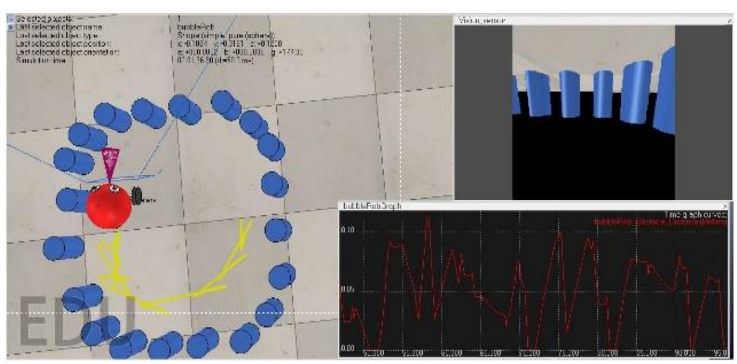

Figure 8 Overall simulation strategies including obstacle avoidance using FLC

5. RESULTS AND DISCUSSION

The simulation experiment using FLC illustrates the effectiveness of the control algorithm during mobile robot navigation in a cluttered environment (Fig. 8). In this experiment, the mobile robot accomplished different tasks such as navigation, path planning and obstacle avoidance. The navigational strategies of a mobile robot in an unknown environment have provided with twenty obstacles given by 'fig. 8'. Also, 'fig. 8' demonstrated different environmental elements such as circular obstacles and mobile robot including vision sensor image and time graph curve. Further, details of all environmental elements are provided by Figure 9 and 10.

The yellow line represents the simulated path covered by a mobile robot (Fig. 8) whereas, fig. 9 represents the distance from the obstacle (black line) during navigation. Other than this, fig. 10 represents the different strategies completed by an object (mobile robot) such as calculation of object position, orientation with heading angle and velocity. Further, in fig. 8 the time graph curve for every movement of the robot which considers the distance from an object and obstacles included dynamic index (heading angle) has been calculated. The proposed simulation offers a unique alternative based on navigation approaches.

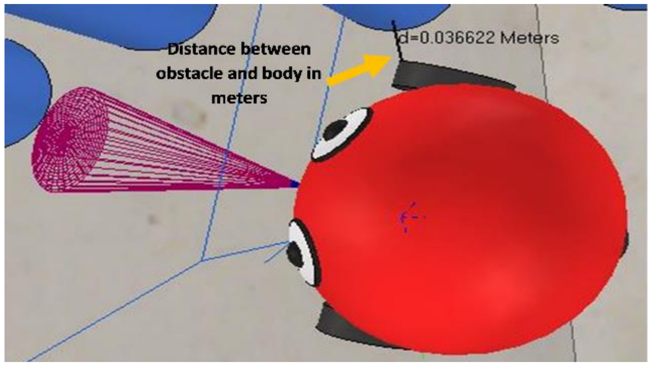

Figure 9 Distance from the obstacle (here right obstacle distance provided) is calculated (in meters)at every local search time

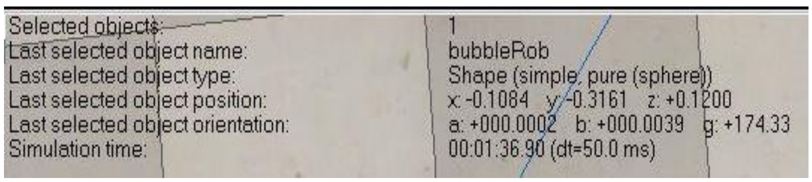

Figure 10 Position, Orientation, Simulation Time and Velocity provided at every navigation step

In this paper, we conclude and provides a mobile robot navigation strategy based on the Fuzzy approach. To process path planning as well as carry out obstacle avoidance task during navigation, it uses online sensory reading (i.e. distance from an obstacle, heading angle and position). Further, based on these calculated data time graph between the distance from an obstacle and dynamic index has been plotted (Fig. 8). The principle behind the viewpoint is that when the robot is near to an obstacle, then first it must adjust its heading angle to escape obstacle. In the fig. 8, a robot has been controlled by Fuzzy control algorithm to adjust its heading angle and avoids obstacles which obstruct path. In Fig. 8, robot moves from a start position and avoid obstacles placed in its path. Finally, the simulation results show that robot creates a collision-free path (Figure 8 yellow line) in the environment without striking an obstacle.

6. CONCLUSION

Fuzzy control algorithm is one of the advanced optimization algorithms and based on the linguistic variables draw together with different rules. In this proposed work Fuzzy approach is demonstrated to navigate the robot safely in an environment. To attain the optimum value of position readings (localization) and dynamic index (heading angle) during navigation, AI approach (FLC) is coined with the sensory module. Our simulation experiment shows that FLC approach is a fast and capable learning methodology to discover navigational path and avoid the obstacle. The proposed methodology has involved a minimum set of input data to find a route from source to target. Further, the problem is framed-up as a varied path planning (such as in known and cluttered environments), local navigation optimization, and localization which constitutes both continuous and discrete control structures. The dynamic index during robot's movement is calculated online using the position of the obstacles. To expand the effectiveness of fuzzy algorithm, the modification with its variables (such as LOD, ROD, FOD and HA) will be adapted using online tuning of sensory module. Further, experimental results show the effectiveness of the proposed Fuzzy technique over other AI technique.

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