DESIGN OF ADAPTIVE FUZZY TRACKING CONTROLLER FOR ROBOT NAVIGATION USING PARTICLE SWARM OPTIMIZATION

Pallavi P. Lingawar^{*1}, K.K. Jajulwar²

^{*1} Dept of Communication Engineering, G.H.Raisoni College of Engineering & Technology, Nagpur, India Email: pplingawar@gmail.com;

² Dept of Communication Engineering, G .H.Raisoni College of Engineering & Technology, Nagpur, India Email: Kapil.jajulwar@raisoni.net;

***Corresponding Author: -**

Email: pplingawar@gmail.com;

Abstract: -

This paper proposes a methodology for mobile robot navigation using the concept of Fuzzy Tracking Controller. The objective is to Design adaptive fuzzy controller for x-direction and y-direction movement. Mostly it is used in Robot Localization, Obstacle avoidance, Mapping, recognizing people and objects & learn how to interact (e.g., grasp) with objects in Robot Navigation. It determines the safe path for the robot to transverse to its target location, while avoiding obstacles along the way. In this System it calculates the reference path and using Particle Swarm Optimization technique it will reduce Time required to reach the target. Fuzzy tracking controller will be used to direct the system to the destination which will help system to overcome the obstacles in the path and reach the accurate destination.

Keywords: - PSO (Particle Swarm Optimization), fuzzy logic controller, Navigation.

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I. INTRODUCTION

Navigation is a field of study that focuses on the process of monitoring and controlling the movement of a craft or vehicle from one place to another. The field of navigation includes the four basic categories such as aeronautic navigation, marine navigation, land navigation and space navigation. Locating the Navigator's position compared to known locations or patterns includes navigational techniques. Robot navigation means the robot's ability to determine its own position in its frame of reference and then to plan a path towards some goal location. Navigation can be defined as the combination of the three fundamental competences: Self-localization, Path planning, Map-building and map interpretation.

Robot navigation has long been a fundamental goal in both computer vision research and robotics. While the problem is largely solved for robots equipped with active range-finding devices, for a variety of reasons, the task still remains challenging for robots equipped only with vision sensors. Vision is an attractive sensor as it helps in the design of economically viable systems with simpler sensor limitations. Sensors like ultrasonic, IR, GPS, laser sensors etc are used in conventional robot navigation systems, utilizing traditional suffer several drawbacks related to either the physical limitations of the sensor. Vision sensing has emerged as a popular alternative where cameras can be used to minimize the overall cost and maintaining high degree of intelligence, robustness and flexibility.

"The world is only shades of gray but not black and white." Zadeh introduced fuzzy sets in 1965, sets with unsharp boundaries. Rather than black and white These sets are considered gray are a sin contrast to classical sets which form the basis of binary or Boolean logic.

In this paper, basic concepts of fuzzy logic are briefly presented. Its utility for synthesis of control systems is discussed in the context of an application to mobile robot motion control. In mobile robotics, a fuzzy logic-based control system has the advantage that it allows the intuitive nature of collision-free navigation to be easily modeled using linguistic terminology. Due to the relative computational simplicity of fuzzy rule-based systems, intelligent decisions can be made in real-time, thus allowing for uninterrupted robot motion. Moreover, accurate (expensive) sensors and detailed models of the environment are not absolutely necessary for autonomous navigation.

II. RELATED WORK

In some literature certain factor were taken in to consideration GA based & Particle Swarm Optimization based design approaches and two variants of hybrid design approaches for optimal controller design have been implemented for robot navigation in unknown environments. *Particle Swarm Optimization* based hybrid methodology is considered to be superior approach for this study.

Literature [1] proposes a method for vision based mobile robot navigation which uses stable fuzzy tracking controller design which is based on lyapunov theory and it also uses *Particle Swarm Optimization* hybrid methodology. Work has been done on two factors:

1. By using single camera-based vision sensor which captures images periodically.
2. Secondly it utilizes the method path planning to investigate reference path.

Literature [2] proposes scheme of situating mobile robots to move around in large complex or building for criminal or theft location detection prompt for some time. This study approaches to a mathematical model which helps in development of a scheme for an autonomous low-cost mobile robot system using visual SLAM (simultaneous localization & mapping) & *Particle Swarm Optimization* planner. The study could provide a cost-effective solution for problem in indoor mobile robot navigation.

The EKF (extended Kalman filter) is well known choice for localization when a prior knowledge is well known. Literature [3] proposes develop adaptive Neuro-Fuzzy inference system for localization based EKF when a priori knowledge is incorrect. The propose system aims to start the system with incorrect knowledge of statistics on the basis of adaptive Neuro-Fuzzy inference system which tries to minimize the mis-matching between theoretical and actual values. this method is beneficial because of consistency in this approach is more than localization based EKF.

Literature [4] uses PID controller for autonomous mobile robot Navigation was implemented in PID controller using FPGA card. The PID controller was first simulated in simulink Then FPGA card was used to construct the PID controller in combination with stamp micro controller. Finally, performance of PID controller used to navigate robot.

III. PROBLEM DEFINITION

To search for an optimal path successfully, the model of an environment should be constructed first as shown in fig1. Environment Fig.1 shows the environment. It is a two-dimensional rectangular workspace where all the objects including robot, obstacles, source and destination point are located. *Mobile Robot* is defined as a Green square object which is represented by $C(C_x, C_y)$ in the 2D space.

Obstacles are unpredictable objects that the robot may encounter during the execution of the task. In general, obstacles can be of any shape and size with a representation of each point by $O(O_x, O_y)$. To avoid a safe region around obstacles, the obstacle is wrapped by a circle. The radius, R of the circle is chosen in accordance with the size of the obstacle. *Goal* is defined as a Red square object which is represented by $G(G_x, G_y)$ in the 2D space.

Figure:1 Indoor Environment for Mobile robot Navigation

A. Assumption

- The obstacles are detected by the Adaptive fuzzy Tracking controller So, the obstacles within the range, can be detected with reference to the coordinate system.
- The obstacles can be overlapping.
- The path planning program run until the goal has been returned.

B. Input

- Initial location of robot (Red square in bottom-left).
- Location of Destination (Green square in Fig. 1) and
- Position of the obstacles detected by sensor. (Cyan circles)

C. Outcome of each step

Next step of robot towards the feasible path by avoiding obstacle/s.

D. Final Output

A shortest pathway which is not crashed with the given obstacle/s.

IV. PROPOSED METHODOLOGY

Consider images stored in Database. One of the images is consider from the Database. It Is Difficult to Controller work on RGB level. Therefore, it is needed to convert in gray level image. Then that gray image is fed to controller. Working of controller as shown in below Flowchart. Robot is considered as X. After the controller find out destination then PSO will be applied on it to minimize the time delay.

FIGURE:2 FLOW CHART OF ADAPTIVE FUZZY CONTROLLER

V. APPROACH

A. Adaptive Fuzzy Tracking Controller

Fuzzy logic-based controllers are expert control systems that smoothly interpolate between rules. Rules fire to continuous degrees and the multiple resultant actions are combined into an interpolated result Processing of uncertain information

and savings of energy using common-sense rules and natural language statements are the bases for fuzzy logic control. Fuzzy controller rule-bases typically take the form of a set of if-then rules whose antecedents (“if” parts) and consequents (“then” parts) are propositions involving fuzzy membership functions. If X and Y are input and output universes of discourse of a fuzzy controller with a rule-base of size n , the usual if-then rule takes the following form

IF x is $\tilde{A}_i$ THEN y is $\tilde{B}_i$

Where, x and y represent input and output fuzzy linguistic variables, respectively, and $\tilde{A}_i \in X$ and $\tilde{B}_i \in Y$ ($1 \leq i \leq n$) are fuzzy sets representing linguistic values of x and y .

Figure:3 Fuzzy Logic Controller

Our purpose is to design a FLC able to guide a robot in its navigation in an environment from a start position to a goal zone. So, for this reason we adopted the following fuzzy logic system: In the Fuzzification, the inputs variables of our FLC are d_l , d_c , d_r , d_{lr} , d_{ll} and a ; where: d_l , d_c and d_r : are respectively the distances to the nearest obstacles in the left, the center and the right sides of the robot, d_{lr} , d_{ll} : are respectively the distances to the nearest obstacles in the lateral right and lateral left sides of the robot and a : is the angle value between the robot direction and the target position. The variation range of variables d_l , d_c and d_r is $[0, 2000]$ in millimeters; 0 mm means that the obstacle is very near and a collision may be happened, 2000 mm means that the obstacle is very far. Each of those three variables are represented by two trapezoidal Mfs: Near and Far. Whereas values of d_{lr} and d_{ll} are either 0 or 1 depending on the presence of obstacle or not. While the variation range of the input variable a is $[-180^\circ, 180^\circ]$ in which negative values refer to the left side robot and positive ones to the right side. Concerning the output variable of our FFLC we defined the angular velocity computed from the left and right robot's angular velocities values $V_{angular}$; the robot is supposed to have a fixed linear velocity equal to 100 mm/s. The range of variation of the output is $[-40, 40]$; it is represented by five singleton MFs: T.Left; to orders the robot to turn to its left side, T.L.left to turn little left, Zero to forward, T.L.Right to turn little to its right side and right to make the robot turning to the right side. Regarding the inference part, in our controller we elaborated rules in such a way the robot behavior mimics the human comportment in driving.

B. Particle Swarm Optimization

Particle Swarm Optimization (PSO) was introduced by Eberhart and Kennedy in 1995. This technique was inspired by bird flocking's social behavior. Where it was observed that the motion of each bird is influenced by the motion of the nearest bird to it. PSO was used successfully in several applications. The algorithm initializes the population with random solutions and updates the generation to found an optima. A swarm consists of N particles in a M -dimensional search space. In PSO each individual or particle has a position and a velocity expressed by a position change which means the flying direction of the particle. It successively adjusts its position based on two factors: the best position of its neighbors (pbest) and the best position visited by the whole swarm (gbest). The best solution is determined using a defined fitness function. Each particle is represented by its instantaneous current position x and position change $_v(x)$ or also named velocity, which are generally calculated as below:

$$v[] = c_0 * v[] + c_1 * \text{rand}() * (pbest[] - \text{present}[]) + c_2 * \text{rand}() * (gbest[] - \text{present}[])$$

&

$$\text{present}[] = \text{present}[] + v[]$$

Where w indicates the inertia weight, t is the t^{th} iteration, $\text{rand}()$ is a random function in $[0, 1]$, $gbest$ is the global best of the whole swarm, $pbest_i$ is the local best of the i^{th} particle and c_1 ; c_2 are cognitive and social parameters. The swarm size is assumed to be D .

In the algorithm the position change of each particle is limited by a maximum value $_v(x)_{\text{max}}$.

Figure:4 Description of particle's position in PSO

The overall steps of the algorithm are as follow:

Step1: Initialization of the swarm.

Step2: Evaluation of the fitness value for each particle, evaluation of the particle's best position and the global best position of the swarm. Updating the particle's velocity and position using equation.

Step3: If one of the stopping criteria is achieved, then stop, or else go to step 2. Step4: Optimal solution (latest gbest) is generated.

Fig.4 illustrates the schematic view of updating position of particle in two successive iterations.

VI. SIMULATION RESULT

The starting direction is found from the start point and the end point. The inputs are three sensors for detection of obstacle which fuzzified on the basis of far, close or very close and the output is the navigation i.e. straight, soft right, hard right, soft left, hard left. The distance of the obstacle is sensed from the sensor and depends on the current position and orientation of the moving robot.

Figure:5 Indoor Environment consist of source and destination with obstacle

The environment where controller work shown in following figure. Figure:5 consist of source goal along with obstacle, Figure:6 Shows possible path here only three possible paths considered out of which one is shortest one shown in

Figure:6 Indoor Environment Possible paths

Figure:7 Final collision free path

Table:1

Sr. No.	Indoor Environment Possible Path	No. Of Obstacle in Given path
1	X1	1
2	X2	2
3	X3	1

Table:1 shows the Possible Path and Path with No. of obstacle. Whereas table2 Shows Movement of Robot and Obstacle Position.

Here Distance between Source and Destination considered 10 units then it is divided into 3 parts according to the Ranges As for very close, close and far. Three sensor are considered in Left, Right and Straight direction respectively. Depending upon the distance and direction membership function has been calculated.

Table:2 Position of Right Sensor

Figure:8 Movement of Robot in Right Direction				
Sr. No	Decision by Robot	Sensor Right	Sensor Straight	Sensor Left
1	Straight	F	F	F
2	Soft Right	F	F	C
3		F	C	F
4		F	C	C
5	Hard Right	F	F	VC
6		F	C	VC
7	Soft Left	C	F	F
8	Left	C	C	F
9	Hard Left	VC	F	F

Where; F-Far, C-Close, VC-Very Close

Figure: 9 Relation between degree of membership function and direction

All above figure shows relationship between membership function and distance.

CONCLUSION

In This paper we Proposed Adaptive fuzzy logic controller for finding out the collision free smooth path. Whereas simulation result shows the how the controller will find out the target.

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