Fuzzy Logic Control and Optimization for Indoor Navigation of Mobile Robots

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***Abstract*— Autonomous mobile robots have many applications in indoor unstructured environment, wherein optimal movement of the robot is needed. The robot therefore needs to navigate in unknown and dynamic environments. This paper proposes design and implementation of fuzzy logic controller for navigation of mobile robot in an unknown dynamically cluttered environment. Fuzzy logic controller is used here as it is capable of making inferences even under uncertainties. It helps in rule generation and decision making process in order to reach the goal position under various situations. Sensor readings from the robot and the desired direction of motion are inputs to the fuzzy logic controllers and the acceleration of the respective wheels are the output of the controller. Hence, the mobile robot avoids obstacles and reaches the goal position.**

Keywords: Fuzzy Logic Controller, Defuzzification, Genetic Algorithm, PSO

I. INTRODUCTION

Autonomous navigation systems have distinct approaches to trajectory generation, path planning, control and required computation to execute the tasks for self-driving vehicles and mobile robotic platforms. Unlike self-driving vehicles, autonomous mobile robots for indoor as well as outdoor applications do not have a specific road-like path to maintain while moving ahead, thereby having the independence to plan and track any feasible and easy path to the target location while avoiding obstacles and satisfying other dynamic constraints.

Over the years, several control techniques have been deployed for efficient performance of these mobile robotic platforms. These techniques range from classical methods like PID control, trajectory control and position control to sophisticated methods like Model Predictive Control and Fuzzy Logic Controller [1], [2]. PID Control technique is the easiest of all, but suffers from issues of tuning and robustness; the major deterrent to its use in any real-time high fidelity demanding problem, like mobile robot platforms. Other techniques like trajectory and position control work in environments without disturbances and/or unprecedented possibilities. However, Receding Horizon-Model Predictive Control shows promising results but it is mathematically quite expensive, making the implementation tough.

To accommodate such limitations, we propose using the Fuzzy Logic Controller [3], [4] for navigation of a mobile robot platform while using techniques like Genetic Algorithm and Particle-Swarm Optimization techniques to tune the same, if time permits. A fuzzy control system runs on fuzzy logic (no hard decisions) by considering analog inputs as continuous logical variables ranging between 0 and 1 instead of strictly 0 or strictly 1. It essentially means asserting conditions to be "partially true/false" instead of "true/false".

A. Motivation

Mobile robot navigation in indoor as well as outdoor scenarios has been a topic of intricate research over the years. Given the discord in transfer of the latest state-of-the-art technologies for self-driving vehicles to these mobile robots, we focus our project to develop and refine techniques specifically applicable to the latter systems. Though the use of fuzzy logic control has been long in use, the methods of tuning and further exploration into refining the technique is still sought after. We propose this topic to explore how optimization techniques combined with fuzzy control to enhance performance in static as well as dynamic environments.

B. Literature Survey

Fuzzy Logic controller has been used many times for control of mobile robots. In [5] both the navigation and obstacle avoidance approaches are used. The method is applied on a non-holonomic mobile robot. In the paper [6] the authors have used fuzzy logic controllers with various types of inputs like sonar, camera and stored map. An application of fuzzy logic controller is proposed for indoor navigation in the paper [7]. In this paper wheeled mobile robots(WMR) are used. Another application of the fuzzy logic controller for indoor navigation is presented in the paper [8].In this paper visual sensors are used to guide the robot to the target, but they do not use FLC for obstacle avoidance.

II. PROBLEM STATEMENT

To design a Fuzzy Logic Controller(FLC) for a mobile robot navigation in an unknown indoor environment using the Tracking FLC and Obstacle Avoidance FLC.

III. PRELIMINARIES

In this section, we describe our initial thoughts into solving the proposed problem. The section is divided into subsections - subsection A discusses the approach to fuzzy control and optimization algorithm while subsection B, C and D explain about the proposed experimental setup, namely, the simulator platforms and the choice of robots.

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A. Fuzzy Control Approach

Fuzzy logic theory is a solution to control mobile robots. The basic structure of a fuzzy logic controller is composed of three steps. The first step is fuzzification which transforms real values inputs and outputs into grade membership for fuzzy control terms. The second step is the inference which combines the facts acquired from the fuzzification step and conducts a reasoning process. The basic fuzzy rules depend on the information acquired which is then reasoned using the 'If-antecedents-then-conclusion' rule. The last step is the defuzzification which transforms the subsets of the outputs which are calculated by the inference step.

We use a combination of two fuzzy logic controllers to complete our task. For navigation a Tracking Fuzzy Logic Controller (TFLC) would be used and an Obstacle Avoiding Fuzzy Logic Controller(OAFLC) would be used for avoiding unknown obstacles in the cluttered environment. The lack of information of the environment makes it a challenging problem to navigate. The TFLC and OAFLC are combined to navigate the robot to the target along a collision free path. The algorithm starts with TFLC and whenever there is an obstacle in the path, it switches to OAFLC. The output of this algorithm is the left and right velocities of each wheel.

TLFC helps to move the robot to the target smoothly by taking the distance and the angle between the robot and the target as its inputs. OAFLC is used to generate a control signal in order to avoid obstacles. The inputs to the OAFLC are the left, right and front distances of the robot from the obstacles.These distances are acquired from the The velocities of the left and right wheels are calculated using the defuzzification step.

B. Optimization Techniques

We propose using techniques like Genetic algorithm and particle-swarm to improve the performance of our system. Genetic algorithm is an evolutionary algorithm that uses biological operators like mutation, crossovers, elitism and culling. The algorithm tunes the fuzzy control rules and tries to make the system resemble an ideal control system. The tuning method fits the fuzzy rules' membership functions with the FIS (Fuzzy Inference System) and the defuzzification process. In the end, the method extracts best membership functions for the process. Particle-swarm optimization technique is another similar iterative evolutionary algorithm that improves a candidate solution by making it "fly" through the problem space following the current best solution.

C. Simulation Platforms

Implementation and visualization of the environment with the mobile robot requires a powerful physics simulator. Here, we discuss the characteristics and plausible features of our current two best choices for the simulator.

1) V-REP: Our first choice is V-REP (Virtual Robot Experimentation Platform). VREP is a robotics environment simulator with an IDE for simulating pre-defined and custom-made robot models and environment scenes. By virtue of its distributed control architecture, it allows for individual control of the entities. It is capable of running motion planning algorithms, forward/inverse kinematics, minimum distance calculation and sensor simulation and supports many other functionalities. The proposed Summit XL mobile platform is pre-defined in V-REP, thereby easing the process of initial setup.

Powered by multiple physics engines, it can simulate real-life interactions like collisions and manipulation between robots. It provides multiple control options like embedded script, ROS nodes, remote API clients or custom plugin with support for languages like Lua, Python, C++ and MATLAB. Its sheer ease of use, gradual learning curve and cross-platform support makes VREP our preferred choice. We take advantage of the Python Remote API client to define control logic for the robot.

2) Gazebo: Our second choice for simulator is Gazebo, an apt-platform to rapidly test algorithms, design robots, perform regression testing, and train AI system using realistic scenarios. Gazebo is an advanced robotic simulator developed by the Open Source Robotics Foundation providing inherent support for ROS in Python as well as C++. Given the availability of our two choices of robotic platforms (Husky and SummitXL) in ROS, Gazebo gives us an edge over V-REP due to ease of initial setup.

We look forward to exploring implementation on both the above platforms and then decide the most apt one. We shall update our final choice within the first few weeks of start of our work.

IV. RESULTS SO FAR

Work done so far mainly consists of setting up of the simulation environment for testing the control algorithm. Two simulation environments which can be used for the project are Gazebo simulator and V-REP Robot Simulator. We plan to use either of them with multiple robots available in both. We have selected the following robots :

1) Husky Robot (Gazebo) - The UGV by Clearpath Robotics
2) Summit XL (V-REP) - The mobile robot platform by Robotnik

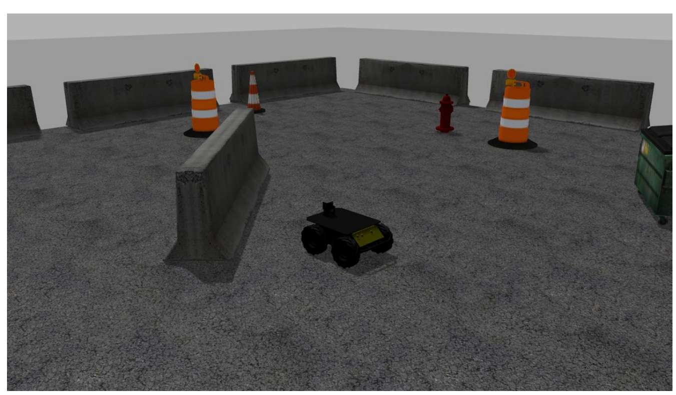

Fig. 1. Husky Robot in Gazebo simulator

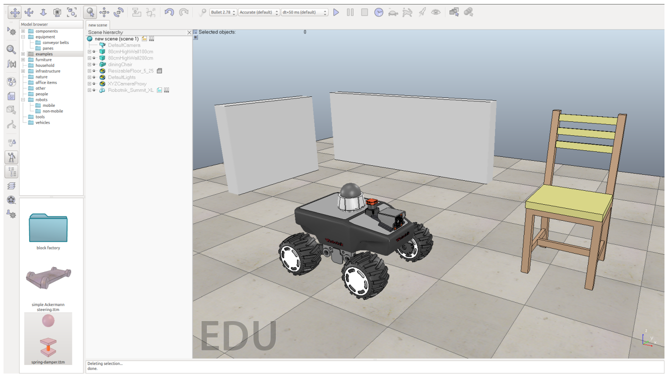

Fig. 2. Summit XL in V-REP simulator

V. GOALS

The project is defined to accomplish some Reachable goals, and if time permits, to extend the research in an effort to reach some Desired goals.

A. Reachable Goals

We would start the Fuzzy Logic control implementation using one of the robots mentioned above. We would start with navigation in a static environment and then move towards introducing dynamic components in the environment. The dynamic components here can be other robots or humans moving in the room where our subject of interest i.e. the robot will navigate towards the goal. Once we achieve these goals, we will try for some of desired goals in order to improve our research related to the topic.

B. Desired Goals

Depending on our progress and time, we would try tuning and optimization of out Fuzzy Logic Control algorithm using Genetic Algorithm or Particle Swarm Optimization techniques.

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