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FUZZY LOGIC BASED BEHAVIORS BLENDING FOR INTELLIGENT REACTIVE NAVIGATION OF WALKING ROBOT

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ABSTRACT

The reaction of autonomous mobile robot to the dynamic, uncertain, and changeable environment is one of most difficult issue in control of the intelligent autonomous robot movement. Fuzzy control appears as a very useful tool for handling the intelligent reactive navigation. Present work deals with building of fuzzy behavior based reactive navigation of goal achieving, obstacle avoidance, and propose new method to blend and coordinate multi behaviors in the same time. This method using fuzzy technique and fix priority value reflect the importantly of the behavior. We build our simulation and animation programs that can reflect on-line the robot movement using graphical user interface (GUI).

1 INTRODUCTION

Controlling the movement through dynamic environments is one of the major issues in mobile robotics. Navigation is a basic function and important component for intelligent autonomous system that allows for an independent execution, guiding the robot safely in a smoother movement.

The classical AI methods depends on SMPA (Sense, Model, Plan, Act) with the performance of robots in dealing with the real world, and concerned that the complexity of run-time modeling of the world was getting out of hand. The main drawbacks of them are computational effort and computer memory requirement. Both increase with environment complexity and frequently algorithms seek a reasonable compromise between accuracy and computations time [1], since it is usually difficult to obtain an accurate model of a dynamic environment. This lead to development of theories and algorithms needed for robots to process information and interact with the environment [2]. These methods react to the environment changes. The independent decision making processes of reactive approach is called behaviors [3]. The basic idea behind most behavior approaches is to break down sequential top down programs into a set of simple, distributed, and decentralized processes that have direct access to sensors and motors of the robot [4].

Reactive navigation utilizes the information provided by sensory data and executes the path reactive to this data. Reactivity provides immediate response to unpredicted environmental situations by giving up the idea of reasoning about future consequences of actions, reasoning about future consequence [5].

Behavior-based robotics, a field of robotics that is guided by principles from nature and aims to develop methods for synthesizing artificial systems, ranging from physical robots to autonomous software agents, and use robotics to model and analyze natural systems, ranging from insects to humans [6].

Reactive systems can be seen as specialized robot programming languages [7], so behaviors are unable to handle environments which the initial programmer did not foresee. Additional to that, most reactive control systems do not utilize sets of behaviors; instead, they rely on a single type of behavior to guide the system [8]. But the language and programming, that used, is so complex to interact the behaviors, so, the researchers move to use fuzzy logic-based behaviors.

Fuzzy logic does not need the mathematical description of how the output functionally depends on the input. It is relatively easy to implement a system that deals with many situations without defining an analytical model of environment, by representing relations between inputs and outputs in an if-then manner and constructing a knowledge base, and it is reactive because there is no planning stage [9].

Fuzzy logic controllers provide a means of transforming linguistic control strategy based on expert knowledge into an automatic control strategy. It appears to be very useful for handling problems that are too complex to be analyzed by conventional quantitative techniques or when the available sources of information provide qualitative, approximate, or uncertain data [10]. Reactive navigation of a mobile robot falls into this class of problems that fuzzy control system copes well. Fuzzy logic is suitable for multi-sensor fusion and integration [11].

The main idea is to incorporate fuzzy logic control with behavior based control such that fuzzy rules and fuzzy reasoning to coordinate conflicts and competition among different formulate types of reactive behavior. We have built simulation and animation programs that can reflect on-line the robot movement using graphical user interface (GUI). We designed the GUI windows to implement the fuzzy control behaviors to enable the robot to move on-line through the environment.

This paper is organized as follows: section 2 described the behaviors blending and our suggest method. The described the model of the robot and sensor features and its distribution in section3. The fuzzy reactive behavior controller presented in section 4. Section 5 described the simulation the animation for the navigation control. Section 5 comes to the conclusion.

2 BEHAVIORS BLENDING

Behaviors are normally intended as the basic elementary skills of the agent, from which more complex skills may be built. Early behavior-based architectures allow to active just one behavior influence the operation of the robot at each moment. This relied on a fixed priority. Later proposals relied on dynamic policies.

To keep behaviors simple, there are some mechanism to combine behaviors for more complicated situations. One of them is to allow several behaviors to operate at the same time, and merge their control outputs so that all of the behavior goals are satisfied, at least to some extent, this called behavior blending.

Fuzzy logic provides the basis for the basic mechanism to compose control structures into complex control regimes. Using the mechanisms of fuzzy logic can smoothly blend behaviors induced by many simultaneous goals.

Fuzzy behavior is similar to the conventional fuzzy logic control in that it performs an inference mapping from some input space to some output space. The concept of a fuzzy behavior has been developed using the fuzzy membership to determine the most appropriate behavior to adopt. Under these systems a number of behaviors are continually competing, relative membership value of each of the behaviors is then used to determine which behavior is dominant at that time. Blending, that can create complex behaviors, basic behaviors using the context dependent blending of desirability functions. More complex behaviors that perform goal directed actions be used to guide the reactive behaviors.

Each fuzzy rules, of the form IF context THEN behavior, meaning that behavior should be activated with a strength given by the truth value of context, this own context applicability. Correspondingly, the impact of the control actions suggested by each behavior is weighted according to that behavior's degree of applicability to the current situation associates each situation with the fuzzy set of control values characterized by the membership function. The outputs of all the rules in a rule-set are fed to the defuzzification module for computing one single control value, the defuzzification module converts the resulting tradeoff applicability into one crisp control decision. This has been used in one flat rule-base for each behavior and used for group of behaviors in hierarchical fuzzy control.
We present new method that implement both the fuzzy blend with fix priorities for the behaviors depending on the movement analysis that used to build behaviors. Our rule form is IF context THEN p behavior, where p is the Degree of importantly (DOI) and take fix value from (0 to 1) reflect the behavior importantly, like the actions proposed by the obstacle avoidance behavior should receive higher priority when there is a danger of collision.

3 ROBOT AND SENSORS

The robot is a four leg walking robot with body width 30cm and needs 40 cm form each side for free movement, It has two types of sensors, ultrasonic sensors, distributed on front, left and right sides to detect the distance of the robot from the obstacles. The second type is a heat detector sensor to detect the goal, as illustrated in Figure 1. The fuzzy control architecture for the robot is illustrated in Figure. 2. The sensors discover the environment and send the information to the fuzzy control navigator. Fuzzy control contains three main steps: **encoder** (Fuzzification) that fuzzify the information depending on its membership, **Inference** that applied the rules in its knowledge base, and **decoder** (Defuzzification) that change fuzzy values to crisp values that make the robot move.

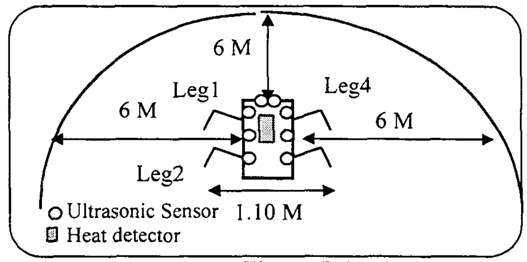

Figure 1. Walking Robot

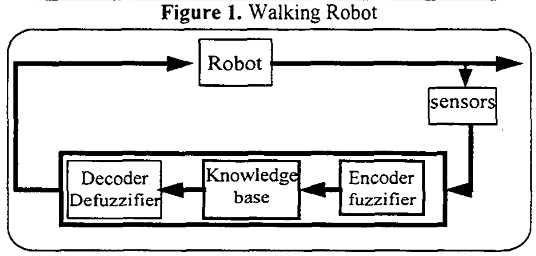

Figure 2. Fuzzy Control Architecture

4 REACTIVE BEHAVIORS

Behavior is the independent decision making processes. Each behavior receives sensor data relevant to its decision-making needs and produces a control output based on its desired action. We use fuzzy logic to directly orient dynamic environment, improve real-time response and reliability by building a set of fuzzy variables and rules that take expert decision in planning the action needed to solve the problems and improve navigational planning. The aim of our work is not to build a map of the environment from sensory information, but to obtain some immediate indication about the robot environment by matching the current robot state through the sensor reading. Fuzzy algorithms are able to activate the behaviors needed to dynamically navigate. In order to fulfill a movement of the robot in unknown environment the following types of reactive navigation behavior was built, Move behavior, Stop behavior, Goal Reaching behavior and its own sub-behaviors, and Obstacle avoidance behavior and its own sub-behaviors as shown in Figure 3. Our behaviors Degree of importantly (DOI) are stop behavior take 1, obstacle avoidance behaviors 0.9, goal reach take 0.7, and move take 0.6.

A reactive navigation system based fuzzy control, as shown in Figure 4, is used for our robot. The inputs are the data (signals) provided by sensors in frontal, left, right obstacle's range, and the reach of the goal. The outputs are crisp values (commands) of the speed and the orientation of the robot reacting with the changing of the environment.

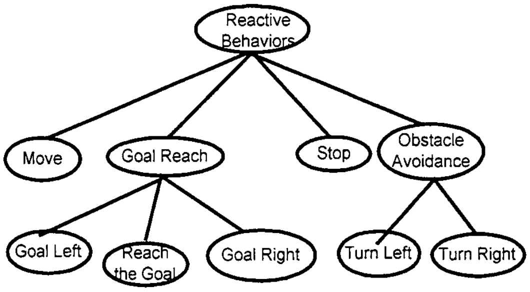

Figure 3. Fuzzy Behaviors

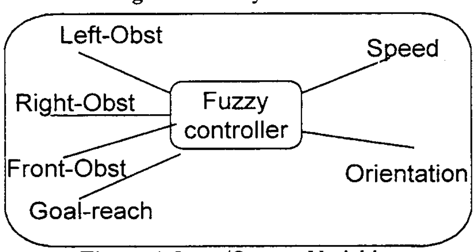

Figure 4. Input/Out put Variables

Our robot is for fire fighting, so, we choose the ultrasonic sensors with range 6 meter that cover the front and sides of the robot to discover the obstacles. The goal-reach sensor is heat or fire detector. Our membership functions are Trapezoidal membership functions are used to represent the possible inputs and output values. The front-obstacle, right- obstacle, and left- obstacle memberships take the terms of very near, close, near far, and very far that utilize the ultrasonic sensors. The goal-reach membership function take the terms if the goal on the front, the goal on the right and the goal on the left of the robot position and it deal with heat sensors data. The orientation function signs refer to turn right if it is positive and turn left if it is negative and it takes the terms of big left, normal left, small left, center, small right, normal right and big right. The speed function takes the terms of stop, very slow, slow, medium and fast. The safety distance of right and left sides is not less than 20 centimeters. For the front obstacle, the safety distance is about one mete. The rules of all behaviors, in one flat inference database, were fired at the same time that allow us to blend the behaviors and weight through defuzzification method and DOI. We used Min-Max inference algorithm and the centroid defuzzification method.

5 SYSTEM SIMULATION

The simulation model computes the location of the goal and obstacles, simulate the sensory data, finds the distance from the obstacles and feed this information to the fuzzy controller that make the movement decision (speed and orientation). The robot will move depending on the fuzzy control decision to new position. The simulation of the fuzzy based reactive navigation behaviors model is shown in Figure 5.

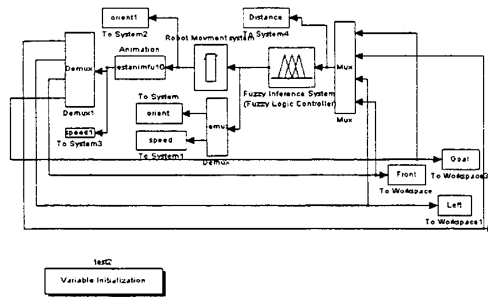

Figure 5. Simulation Model

We considered the "world" layout that reflects the environment of the robot to move in. We choose environment with different distribution of objects to test our system. The robot begin to move from a start point (x, y, θ) and takes its decision to move and generates the path using the behaviors until it reaches the goal as detected by the heat (fire) sensor. We made the robot start with different directions. As shown in figure. 6, the robot heads toward east (right) and began its movement until reaches the boundary of the environment, then change its direction until reaching the goal. While figure 7 is start the movement to east (right) but different position. Figure. 8 the robot head is toward the west (left).

The three-dimensional action control surface of the system output is shown in figure 9, which generated by plotting inputs with output variables, can give idea about the system behavior. In first plot, the high spots on the plot are the orientation degrees (z-axis) related to the goal-reach (y-axis) and front obstacles distance (x-axis). The degree of the changing of the robot orientation depends on the distance from obstacles. The high spots on the last two plots are the speed values related to the other variables. We can see the speed becomes zero when the goal is reached (on x-axis). If the robot does not reach the goal and there is no close by obstacle sensed in the right side, the action is to move in the different values of the speed depending on the distance of the obstacles. Similarly, the variations in the distances of obstacle at front and right are manifested in the control surfaces as shown in the other plots.

6 CONCLUSION

Reactive navigation for autonomous walking robot resembles the logic humans use to walk through busy city sidewalks, when the obstacles' motions are uncertain. It is an open system that is dependent on a simple unit known as behavior. But it is it hard to formulate reactive behavior quantitatively and the designers are forced to think in advance all possible situations. In order to overcome the above problem, fuzzy logic has been employed. We present our fuzzy logic based reactive system, our built behaviors, our method to blend and coordinate more than one behavior in the same time, and our simulation and animation, that include GUI, to test our system. Some promising results have been obtained.

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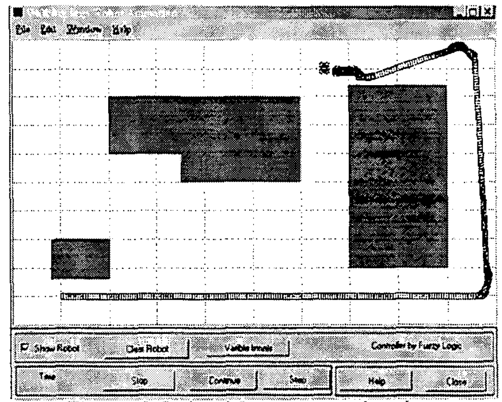

Figure 6. Robot Movement Animation

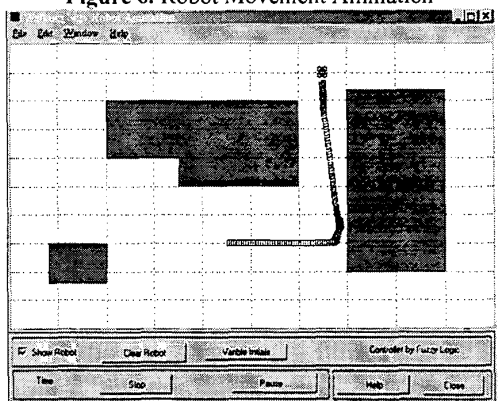

Figure 7. Robot Movement Animation

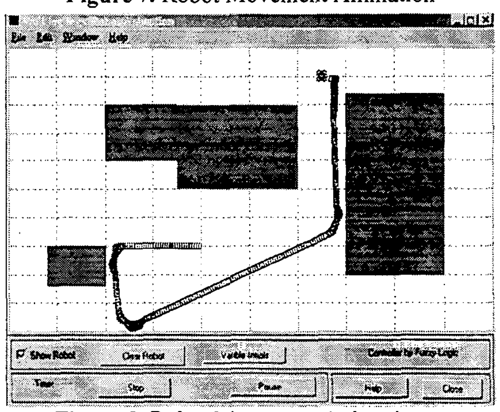

Figure 8. Robot Movement Animation

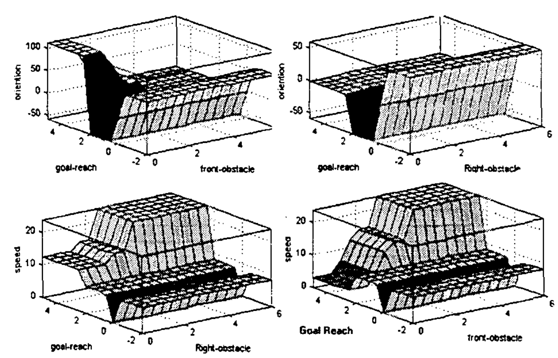

Figure 9. Action Control surfaces