Automatic routing submarine robots using fuzzy logic

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Abstract—It is known that the fuzzy control rules for a control system is always built by designers with trial and error and based on their experience or some experiments. This paper introduces a Genetic Algorithm (GA) based method to generate a satisfactory fuzzy rule base spontaneously. With the specific structure of the chromosome, the special mutation operation and the adequate fitness function, the proposed method with GA produces a fuzzy rule base with small number of rules, suitable placement of the premise's fuzzy sets and proper location of the consequent singletons. The generated fuzzy rule base can be the controller to achieve some control objective or can be a fuzzy model to approximate an unknown nonlinear system. [1]

Keywords- Genetic algorithms, fuzzy controller, fuzzy

I. INTRODUCTION

The fuzzy logic has been applied successfully in several of fields. The fuzzy control has become an effective method in industry applications because it has the ability to solve difficult nonlinear control problems without the extract model of the controlled plant. Trial-and-error always exists in building a satisfactory fuzzy rule base for controlling a nonlinear system or an un-modeled system. Designers usually cannot guarantee that the fuzzy control system designed with trial-and-error has a good performance. To avoid trial-and-error method and/or complex calculation, a number of papers have proposed some kinds of methods to build the fuzzy rule base by using GA or neural networks. Obviously, GA has successfully been used in searching proper fuzzy rule bases with an assumed structure. But it is not well suited for evolving fuzzy rule base without any prior assumption. The reason is that two different structure rules will be inefficient in the crossover procedure of GA.

II. FUZZY IF-THEN RULE BASE

Even though fuzzy sets were introduced in their modern form by Zadeh in 1965, the idea of a multi-valued logic in order to deal with vagueness has been around from the beginning of the century. Fuzzy set theory generalizes classical set theory in that the membership degree of an object to a set is not restricted to the integers 0 and 1, but may take on any value in [0,1].By elaborating on the notion of fuzzy sets and fuzzy relations we can define fuzzy logic systems (FLS). FLSs are rule-based systems in which an input is first *fuzzified* (i.e.,converted from a crisp number to a fuzzy set) and subsequently processed by an inference engine that retrieves knowledge in the form of fuzzy rules contained in a rule-base. The fuzzy sets computed by the fuzzy inference as the output of each rule are then composed and *defuzzified* (i.e., converted from a fuzzy set to a crisp number)[2,6]. A fuzzy logic system is a nonlinear mapping from the input to the output space. In Fuzzy Logic Controller (FLC) design, we do not need to model the. Instead of system modeling. FLC collects experts' knowledge in a linguistic form. Fuzzy controller translates, directly, from external performance specifications and observations of plant behavior to a rule-based linguistic control strategy.

III. SUBMARINE ROBOT

This robot has been considered to be able to move by two motors and also being controlled. These motors are able to move the robot forward. The length of the robot is one meter. It can dive and rise up through two mounted wings. It has four wings which two of them are mounted front and two of them are mounted rear. You can see the designed robot in fig.1. Due to the mounting form of motors, the mentioned robot will have four degrees of freedom (linear movement and rotating around the X and Y axis). In order to simplify the equations and its dynamic rules, we consider its movement just in one specified depth and we consider the issue only bi-dimensional. So, the freedom degrees would be limited to move in X and rotate in Z axis. [7-8]

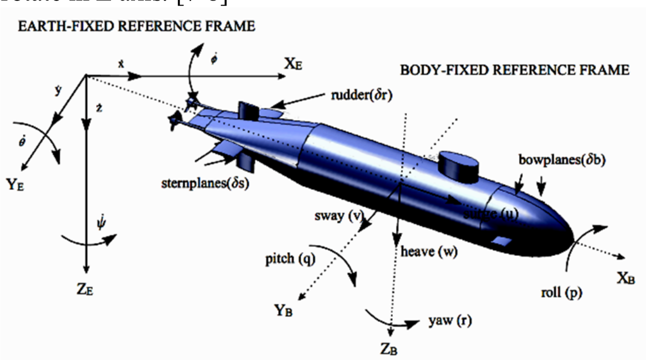

Figure1. The designed submarine robot and its freedom degrees

IV. Problem formulation and some preliminary

In this paper, we are going to introduce a new GA-based method to generate a satisfactory fuzzy rule base to control a nonlinear system. This method can be also applied to the work of fuzzy modeling to approach a nonlinear unknown system.

$$A_{(i,h)}(C_{(i,h)}; x_i) = \begin{cases} \frac{(C_{(i,h)}-C_{(i,l)})-(C_{(i,h)}-x_i)}{C_{(i,h)}-C_{(i,l)}}, & C_{(i,l)} \le x_i \le C_{(i,h)} \\ \frac{(C_{(i,r)}-C_{(i,l)})-(x_i-C_{(i,h)})}{C_{(i,r)}-C_{(i,h)}}, & C_{(i,h)} \le x_i \le C_{(i,r)} \\ 0 & others \end{cases} \quad (1)$$

where $c(i, h)$ is the center of fuzzy set $A(i, h)$, h , l , and r are some integers belonging to j_i . Hence, the shape of the membership function associated with the fuzzy set $A(i, k)$ is determined by only one parameter $c(i, h)$. In this paper, each terminal of a fuzzy set is a center of the adjacent one, in other words, two adjacent fuzzy sets are overlapping in a half as shown in Fig.2. Except the beginning and final points of the universal set, the other $(k - 2)$ points are set to be the centers of the other $(k - 2)$ fuzzy sets, respectively.

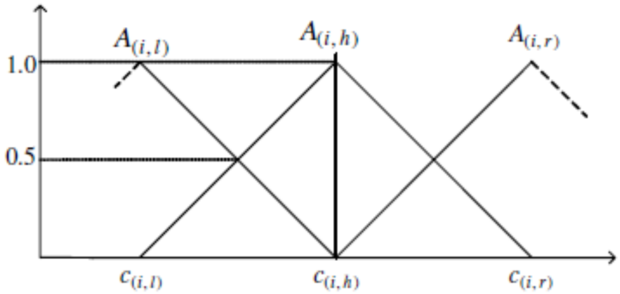

Figure2. Fuzzy sets $A(i, h)$, $A(i, r)$ and $A(i, l)$.

For a rule base, a product inference engine and any defuzzification are chosen. We take the weighted average defuzzification to calculate the inference output value y as follows.

$$y = \frac{\sum_{j_1=1}^{k}\sum_{j_2=1}^{k}\cdots\sum_{j_{i=1}}^{k}\omega(j_1, j_2, \cdots, j_i)\cdot B(j_1, j_2, \cdots, j_i)}{\sum_{j_1=1}^{k}\sum_{j_2=1}^{k}\cdots\sum_{j_{i=1}}^{k}\omega(j_1, j_2, \cdots, j_i)} \quad (2)$$

where

$$\omega(j_1, j_2, \cdots, j_i) = \prod_{i=1}^{q} A_{(i,j_i)}(x_1) \quad (3)$$

The main task of this paper is as follows. Finding a GA based fuzzy rule base as the controller of a closed loop control system (as Fig. 3) to achieve some desired control objective. In Fig. 2, u is the output y of (2). By the way, applying the same method to build a fuzzy model for a nonlinear unknown system will be considered also. By using the given training data, we can establish a fuzzy model as (2) to approach the behavior of an unknown system.

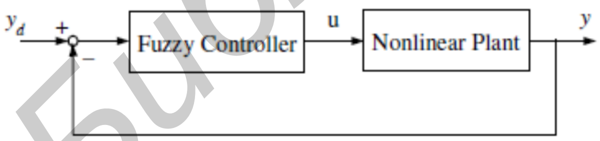

Figure3. A closed loop system with fuzzy controller.

Manipulating fuzzy path finding and controlling the submarine has been considered in this article. Using the classic controllers to control all the movements in intelligent equipments needs complete knowledge from all the forces and the momentums applied on the body. These forces and momentums are needed to be able to achieve differential equations in linear and rotating movements and to achieve them also needs to solve complicated relations and a lot of time or it needs performing many tests to achieve various coefficients of drag such as water tunnel, wind tunnel and etc.[8-11] In this article, instead of using the above mentioned tests on a real model or simplifying the tests which will minimize the accuracy, the fuzzy controller was used. The advantage of this controller is that the input to the system controls the system only through the output data without considering the system itself. Here, the fuzzy controller of the submarine was mounted through a neural network called "Back Propagation" in three layers which its path finding has been shown in Fig.4.

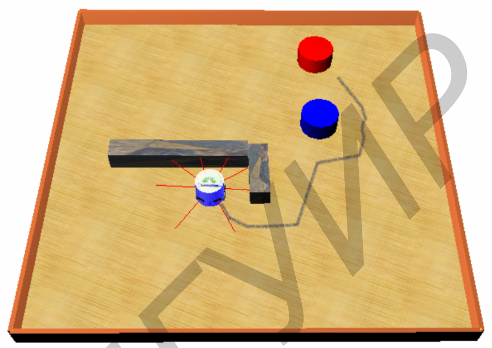

Figure4. The movement path of the robot toward the target

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