Fuzzy logic control system for a underwater unmanned vehicle

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Abstract- **In some scenario of underwater activity, it is too dangerous for human participating in underwater vehicle. At this circumstance, underwater unmanned vehicle (UUV) is needed. To maintain the stable movement of the UUV, a robust control system is specifically needed. One of the most mature control system for UUV uses PID control as feedback control. PID control is an autonomous control method, it provide robust control against disturbance. However, PID control is not optimal for UUV, since it's a passive control method. Thus, fuzzy logic inference system (FIS) will be introduced in the feedback system for UUV as controller. Fuzzy logic control system is an expert system. Based on preset rules, it can provide well planned solution according to real time input as parameters. For FIS system, input data is derived from available state space models while output data is given. These data is used in Adaptive Network Fuzzy Inference System (ANFIS) to train the FIS system. After training, FIS performed a stable controller behavior.**

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I. Introduction

To set up the simulation model for a simple UUV, state space model is introduced according to paper from Javier etc. This model uses rudder angle, stern angle and bow angle as input and gives yaw angle, yaw rate, pitch angle, pitch rate, depth and heave velocity etc. as output. Part of the out of this model is introduced in simulation model as the feedback data to create input data for FIS. These data is fuzzificated, and is coded into membership functions thus to create FIS system. Sugeno type FIS is created for ANFIS training. Program is written to give optimal output according to the understanding of the FIS input data. Given both input and output. ANFIS system can train the FIS by setting up its rules and repeated learning from given data and adjusting rules. After training, simulation model is created. Trained FIS is tested in this model, and data is adjusted to give optimal output.

This project deals with a system which experiences very high nonlinear changes in its Environment. Also, these Nonlinear Changes cannot be interpreted as a mathematical function and hence designing a controller to control the movement of UUV in its desired way is very tough. An ANFIS makes it simple to design the controller by exploiting the concept of neural networks. ANFIS initially trains the FIS system with the existing data so that rules and membership function were created automatically accounting for all the nonlinear changes in the environment.

II. MODELS

A. Plant model

Under assumptions of constant surge velocity and deeply submerging etc. Linear model is obtained in paper by Javier etc.

(linear model equations)

where A is a 8 × 8 matrix representing: , B is an 8 × 3 matrix representing hydrodynamics coefficients, and u(t) is the input matrix for UUV plant.x(t) is the time variable state matrix.

(x(t) equation)

where r(t) is yaw rate, phi(t) is yaw Euler angle, w(t) is heave velocity, q(t) is pitch rate, theta(t) is pitch Euler angle and z(t) is depth.

B is an 8 × 3 matrix representing^.

B. Simulation model

Number citations consecutively in square brackets [1]. Punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]. Use "Ref. [3]" or Reference [3]" at the beginning of a sentence: "Reference [3] was the first …"

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the reference list. Use letters for table footnotes (see Table I). *IEEE Transactions* no longer use a journal prefix before the volume number. For example, use "IEEE *Trans. Magn*., vol. 25," not "vol. MAG-25.

Give all authors' names; use "et al." if there are six authors or more. Papers that have not been published, even if they have been submitted for publication, should be cited as "unpublished" [4]. Papers that have been accepted for publication should be cited as "in press" [5]. In a paper title, capitalize the first word and all other words except for conjunctions, prepositions less than seven letters, and prepositional phrases.

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III. FIS CONTROLLER

A. Fuzzy inference systems

MATLAB ANFIS toolbox accept one output for each FIS only. To train the data, three FISes separately control rudder angle, stern angle and bow angle are created, providing one output each. First FIS is used to control rudder angle. It requires two inputs, one is difference between desired and actual yaw angle, and the other is current yaw rate. The second FIS is used to control stern angle. It requires two inputs, one is difference between desired and actual pitch angle, and the other is pitch rate. The third FIS is used to control the bow angle. It requires two inputs, one the difference between desired and actual depth, and the other is heave velocity. The third FIS is applied with Mamdani type, and is not trained in ANFIS. Three FISes are shown in Fig.X

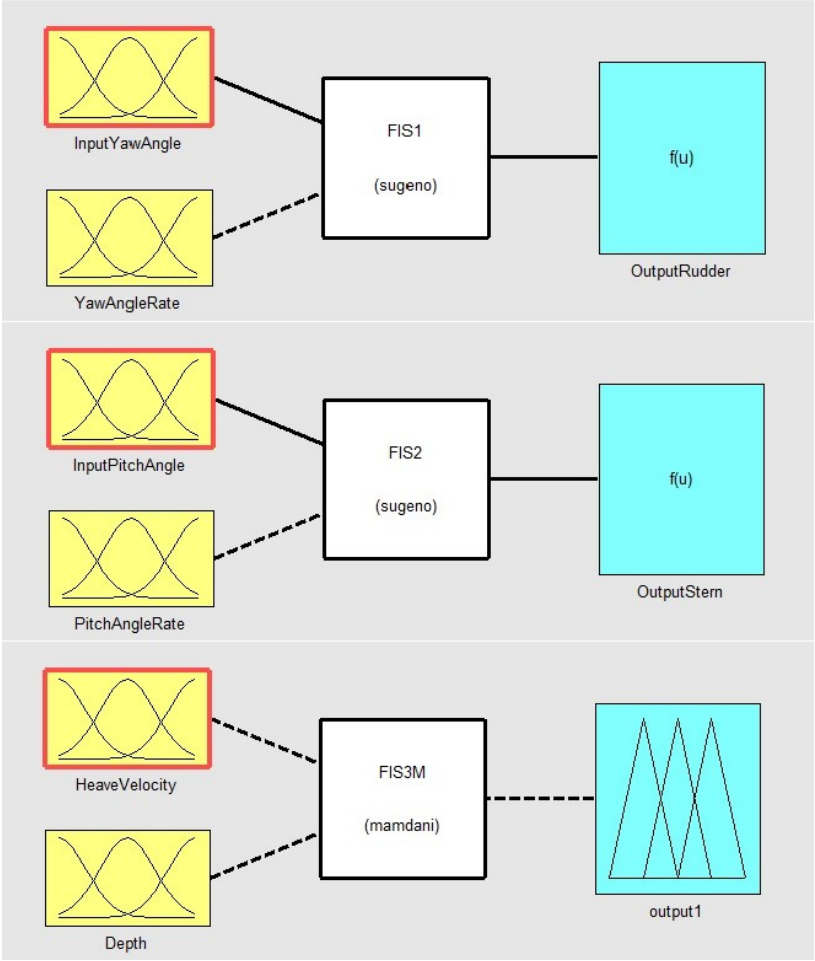

Figure X. Three FIS controllers

According to the state space model, the range of plant output is defined. Since state space model is confined within certain maximum rudder, stern and bow output shown in Table.X, any desired plant output more than a maximum value will be given an input of these maximum values.

TABLE.X PLANT OUTPUT RANGE

OUTPUTS OF PLANT	***Range***
Rudder Angle	-75° ~ +75°
Stern Angle	-35° ~ +35°
Bow Angle	-35° ~ +35°

To initial the input and output data, membership functions for FIS1 and FIS2 input are defined. Initial output for these two FISes are assigned.

B. ANFIS

IV. RESULT

The word “data” is plural, not singular. The subscript for the permeability of vacuum $_0$ is zero, not a lowercase letter “o.” In American English, periods and commas are within quotation marks, like “this period.” A parenthetical statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical *sentence* is punctuated within the parentheses.) A graph within a graph is an “inset,” not an “insert.” The word alternatively is preferred to the word “alternately” (unless you mean something that alternates). Do not use the word “essentially” to mean “approximately” or “effectively.” Be aware of the different meanings of the homophones “affect” and “effect,” “complement” and “compliment,” “discreet” and “discrete,” “principal” and “principle.” Do not confuse “imply” and “infer.” The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen. There is no period after the “et” in the Latin abbreviation “et al.” The abbreviation “i.e.” means “that is,” and the abbreviation “e.g.” means “for example.” An excellent style manual for science writers is [7].

IV. ANALYSIS

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IV. FUTURE WORK

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ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g.” Try to avoid the stilted expression, “One of us (R. B. G.) thanks …” Instead, try “R.B.G. thanks …” Put sponsor acknowledgments in the unnumbered footnote on the first page.

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