

Fuzzy Logic Based Trajectory Tracking Controller

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Abstract— *shape autopilot of ship has been proposed based totally on fluffy reason. A non-direct numerical version for oil tanker is taken for assessment of parameters which shift with profundity. The presentation of proposed controller has been tested as for course by way of the usage of normal AI fluffy framework just as ANFIS*

ANFIS based framework for designing autopilot of deliver has been proposed. A nonlinear medical model of an oil tanker is taken for assessment of parameters which shift with profundity. The presentation of proposed controller is to be tried for both converting and direction preserving mode

Index Terms— *Autopilot, controller, Fuzzy logic, ship, Trajectory Tracking*

I. INTRODUCTION

Mechanics of photo of ship constant non direct and shift with running situations, as an example, profundity of water and pace simply as outer, erratic additives like ocean flows and wind produced waves and circulation of winds. Nonlinear manage plans, for instance, yield complaint control, back venturing had been accounted for [1,2,3]. utilization of valid techniques are identified with the minute to be directed and again joined with hydrodynamics, precise model of marine car is difficult to determine. To defeat such troubles, fluffy cause and neural systems are helpful. Fluffy cause primarily based controllers have been advocated with the aid of severa scientists inclusive of Yang, et.al, Santos, et.al, Velagic, et.al[4,5,6]who proposed deliver autopilot for following via sugeno type fluffy framework Wu,y,et.al consolidated neural device and fluffy cause. essentially Di.move, et.al moreover displayed blend of both.

A large portion of the paintings mentioned did not receive profundity of water as a element furthermore, they proposed fluffy reason coordinated with exclusive systems. it is the purpose of this proposed to build up a fluffy motive controller working sturdy for numerous profundity of region [7].

Deliver factors

Mobility of marine automobiles is depicted via the factors which consist of both kinematics and energy. Kinematics are identified with precise pace wherein as electricity are identified with reaction while basic amounts are applied. The six degrees of opportunity are flood, influence, hurl, yaw, roll and pitch. The preliminary 3 directions and their time subsidiaries deliver the location and translational movement in x,y,z hub. the second one association of three

guidelines are identified with direction and rotational moment of the marine vehicle

Model of Tanker

$x = Ax + Bu$ $x=[u,v,r]$ is a state vector A is the system matrix, B is the input matrix and $u=[\delta r]$ is input component (rudder deflection)

Fuzzy Logic Controllers (FLC)

It should have proper values for any reference angles from $\pm 3^0$ to $\pm 45^0$. It should give agreeable outcomes for predefined direction by giving arrangement of heading points. The ship should follow the ideal heading with great exactness. Increasingly finished, the distinction between wanted heading and real heading ought not surpass ± 30 . The control sign ought not achieve the greatest estimation of ± 350

Inputs and outputs of control mechanism

States influenced by rudder minute which is identified with yaw and influence velocity. The wanted states are takes from second subsidiary and the fixed premiss is to decrease the mistake [difference among wanted and real states].

- Inputs: 1) Heading angle error (ψ_error).
2) Heading state error (r_error).

Output: Rudder deflection (δr)

Selection of ranges

Table 1. Universal sets for ranges of input

Input	Range
Heading_error	-3^0 to $+3^0$

Table 2. Output limits

Output	Range
Rudder deflection	-35^0 to $+35^0$

Starting from these values of range of I/O variables are obtained by trail and error (experience).

-ve to +ve => clock wise and anti clock wise => port to star board.

Universal sets of ranges of I/O variables

I/P Heading error (ψ_error) $\rightarrow -0.4^0$ to $+0.4^0$

Heading rate error (r_error) $\rightarrow -0.01^0$ to $+0.01^0$

O/P Rudder deflection $\delta r \rightarrow -0.8^0$ to $+0.8^0$

A Type of Membership Function

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$$\mu(x_{error}, a, b, c) = \begin{cases} 0 & x_{error} < a, x_{error} > c \\ \frac{x_{error} - a}{b - a} & a \leq x_{error} \leq b \\ \frac{c - x_{error}}{c - b} & b \leq x_{error} \leq c \end{cases}$$

Subsets BN-Big negative MN-Medium negative ZE-Zero SP-Small positive MP-Medium positive BP-Big positive

Fuzzy variables and subsets

- Heading error as a range -0.533 to +0.530
- Heading rate error as a range -0.13330 to +0.13330
- Rudder rate as a range -1.067 to +1.670

IF THEN Rules

- 1) IF → Antecedent THEN → Subsequent
The no.of rules depends on number of inputs, no. of subsets/membership functions [10] and number of output
 - 2) seven subsets 7X7=49 rules
Some of the rules are [7,8]
 - 1) IF heading rate error is BN AND heading error is BN THEN rudder is BN
 - 2) IF heading rate error is MN AND heading error is MN THEN rudder is MN
 - 3) IF heading rate error is SN AND heading error is SN THEN rudder is SN
 - 4) IF heading rate error is ZE AND heading error is ZE THEN rudder is ZE
 - 5) IF heading rate error is SP AND heading error is SP THEN rudder is SP
 - 6) IF heading rate error is MP AND heading error is MP THEN rudder is MP
- and so on

Defuzzification & RESULTS

$$u = \frac{\int \mu(z)zdz}{\int \mu(z)dz}$$

ANFIS is a combination of a neural networks and fuzzy logic in which fuzzy factors are adoptive. Neural networks have learning algorithms where as fuzzy system generates signals for controlling is through fixing of rule base this rule based is taken from previous data and is random the implication is that the output of the controller is also random which can present optimum results.

ANFIS makes the guidelines primarily based completely choice more adaptive to the state of affairs which utilises the Neural Networks through decrease back propagation for reinforcing the overall performance. The residences of fuzzy good judgment in approximating a non-linear system via if then hints is used in the modelling. In ANFIS crisp signs are converted into fuzzy inputs thru membership features and these are fed to neural network block .

Back Propagation is used for neural community in right selection of rule based definitely. as quickly as education is finished right tips may be generated and hired via NN to feed most dependable output. Linguistics output of NN is converted to crisp output through defuzzification. The nodal outputs are combined to the crisp outputs that is in comparison with favored price and errors is comments precept of ANFIS

In ANFIS(Adaptive Neuro-Fuzzy inference system) policies are developed all through education this is information primarily based absolutely FIS (Fuzzy inference gadget) has membership derived from schooling examples. There are forms of FIS and Sugeno. In Mamdani type, output membership is triangular or and sugeno is linear or consistent. Sugeno is pc powerful where as mamdani is much less effective depending on expert information.

Architecture

- If input are X and Y
- Rule 1: If X=A1, Y=B1 then f1=p1X+q1Y+r1
- Rule 2: If X=A2, Y=B2 then f2=p2X+q2Y+r2

Here A1 and B1 are Fuzzy sets, f1 is the output. Design parameters determined by training process p, q, r

Layers

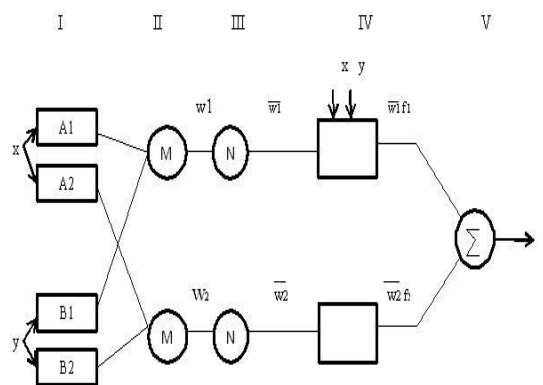


Fig.1. Layered structure of ANFIS

O_i^j o/p of ith node, jth layer

Layer 1: O_i¹ = μA_i(X)

i=1, 2

A_i is linguistic label such as cold hot

Layer 2: Each node determines firing strength of a rule by multiplicative

O_i² = w₂ = μA_i(X) x μA_i(Y)

i=1, 2

Layer 3: Firing strengths are normalized to distinguish between the firing strength strengths of each rule for the total furry strength of total rules.

O_i³ = w₁ = w_i / (w₁+w₂) i=1, 2

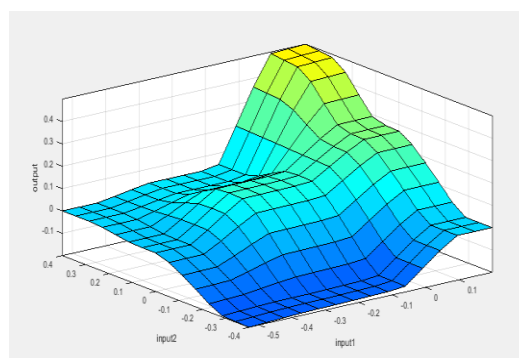


Fig.2. 3D Surface view of ANFIS



Input 1 as heading rate error and input 2 as heading error
 output as rudder deflection
 ANFIS info: WITH NORMAL MODE
 nodes: 35
 linear parameters: 27
 nonlinear parameters: 24
 Total parameters: 51
 training data pairs: 7
 checking data pairs: 0
 fuzzy rules: 9

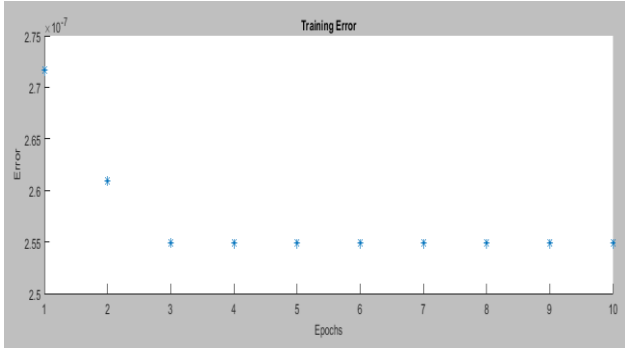


Fig.3. Training error for 10 epochs

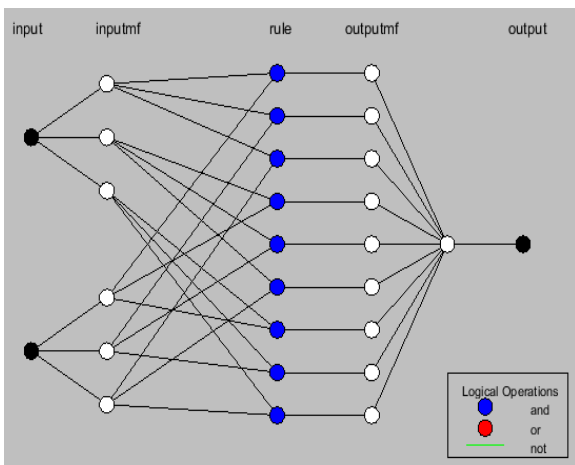


Fig.4. Structure of ANFIS

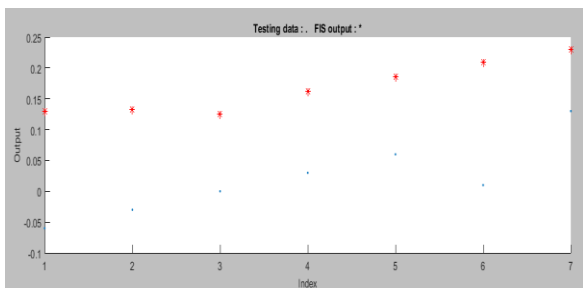


Fig.5. Anfis Using Fuzzy Output

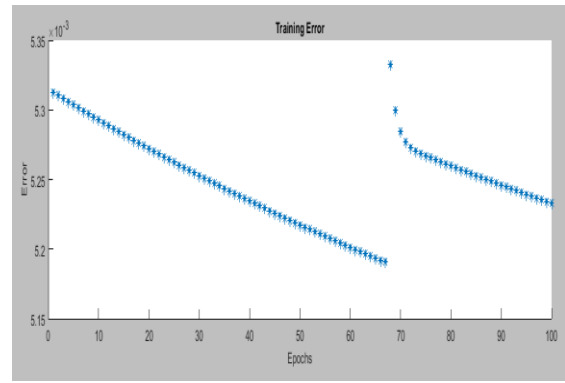


Fig.6. Training error for 100 epochs

ANFIS info: with RMSE USING BACK PROPAGATION METHOD

nodes: 35
 linear parameters: 27
 nonlinear parameters: 24
 Total parameters: 51
 training data pairs: 7
 checking data pairs: 7

fuzzy rules: 9
 Minimal training RMSE = 0.001022
 Minimal checking RMSE = 0.00102177
 Epoch 100 error = -0.00523

Final outputs

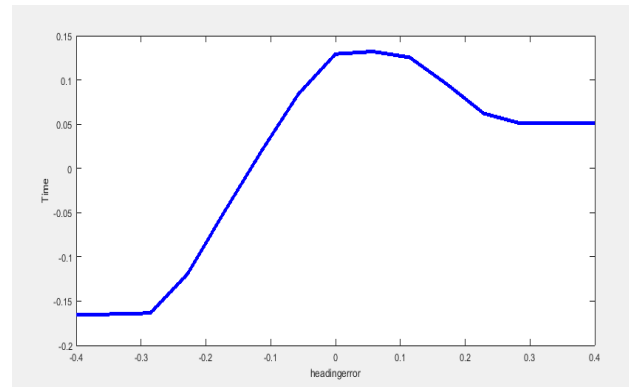


Fig.7. Heading error

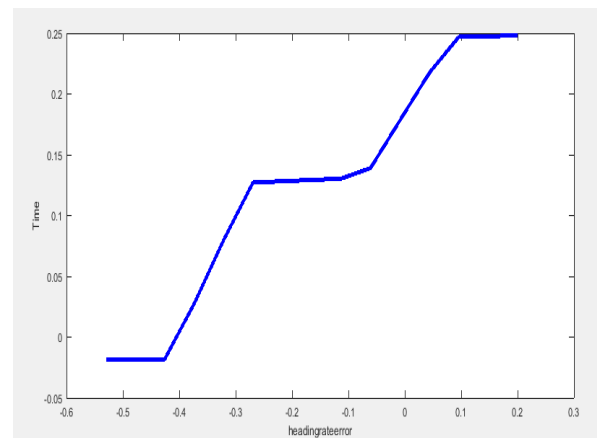


Fig.8. Heading_rate error

TABLE 3. Comparison between AI, ANFIS, RMSE

Method	AI	ANFIS	RMSE
Back propagation	0.01	0.025	2.54943e-07
Hybrid	0.09 100 Epoch	0.0001 100 Epoch	9.19762e-07
	0.093 200 Epoch	0.003077 200 Epoch	0.00307744

CONCLUSION:

The conventional FIS is an ANFIS are the guideline systems which can be proposed and thought about for settling on a green technique for format og autopilot. the capacity of ANFIS is obvious to be the fundamental motivation behind inclination while effortlessness is the power of the customary fluffy method

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