Comparing Neural Networks and Fuzzy Control Techniques

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Abstract.- This paper tries to show the way neural networks and fuzzy logic could be applied to control non linear systems. This is interesting to teaching. Non linear systems are good examples to apply several control techniques on them, from classical control to artificial intelligence. The capacities of the Neural Networks to learn non linear behaviour, and the Fuzzy systems to extrapolate the results, are here under test and comparison. Topologies and parameters have been tested, to differentiate possibilities and benefits from the both techniques. In this particular example, the goal is to control a process at different set-points with minimum error.

1.Introduction

Nowadays, programming and control techniques introduce artificial intelligence algorithms. Since actual PCs have capabilities in fast calculation, to set variables and set points to continuous real processes is possible, in on-line and real-time control is possible. In this work Fuzzy Logic and Neural Networks techniques are applied in order to control non linear system. Although these techniques are conceptually different, results and final behaviour are similar enough.

The system consists of by a DC. fan and a tilt plate who responds an angle depending on wind velocity . The angular velocity of DC. motor is proportional to V supply (Vs.) due to independent Field (I.F.) Non linearities come from wind turbulences, friction, dead zones, and systems who respond differently at different angle [1].

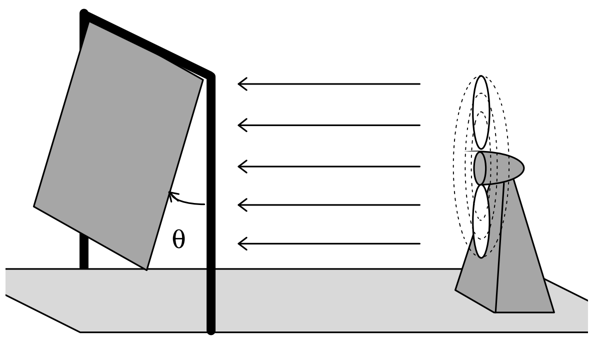

Fig. I. Non linear system.

Control system is a MISO system , two inputs, set-point angle and angle error, and a output , fan Vs. , that behaves differently depending upon the angle.

2.Dealing with Neural Networks

To determine behaviour and capability of the neural network, different analysis in design steps are characteristic : topology, typology, learning and disposition [2].

Topology determines capacity of the net to recognise different situations and to specify the number of outputs. This experiment requires three layers : first one with ten neurones, second one with fifteen, and the third with one, to obtain a network with one output. ("Fig. 3").

Typology settles the magnitude of data and interpolation between learned pattern, and the smoothness or linearity. In this subject case, tansigmoidal type neurone are used for the first two layers and pure linear neurone for the output layer.

Learning process establish data ordered into patterns to be learned and selects a corrective, reactive, predictive or governative behaviour depending on the learned patterns. To achieve representative situations, previous knowledge of process is required based on system response with different controllers keeping attention on redundant information. Different training methods allow the net to work at various learning speeds with a bounded error. Above, backpropagation training method is used with error bounded to 10e-2

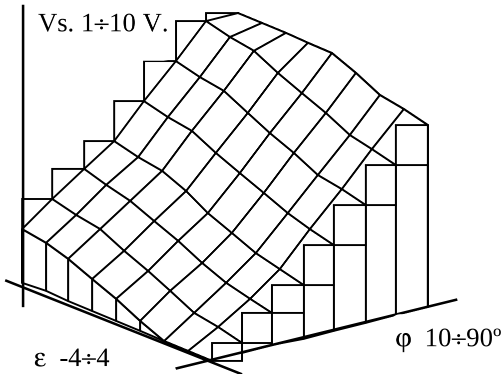

Fig 2.- Learned patterns

Disposition establishes the behaviour of the system because feedback loops allow temporal evolution and to recognise different dynamic situations. In this case, feedback is used to adjust the set points[3].

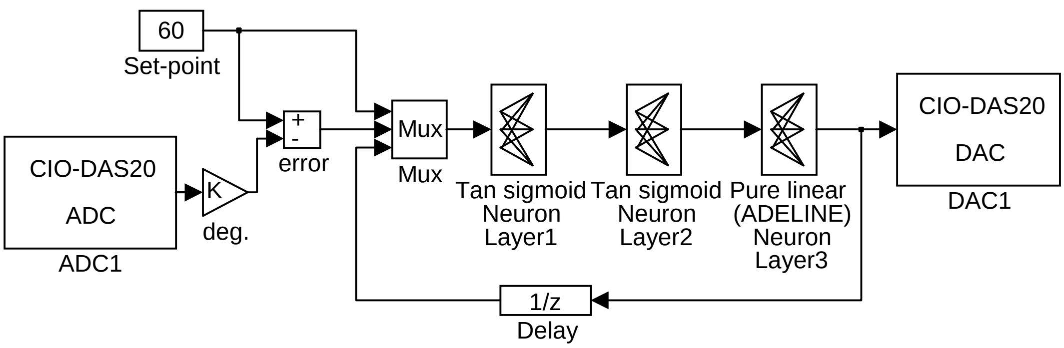

Fig 3.- Neural Network scheme

3.The fuzzy control

The structure of a Fuzzy Logic Controller (FLC) consists of a fuzzifier, an inference engine, a knowledge base (data base and rule base), and a deffuzzifier which transforms fuzzy sets into real numbers to provide control signals.

ANFIS tool from MATLAB converts the trained Neural Network points to rules and fuzzy sets , [4][5] nine rules are sufficient to assign non linear behaviour to fuzzy controller "Table 1".

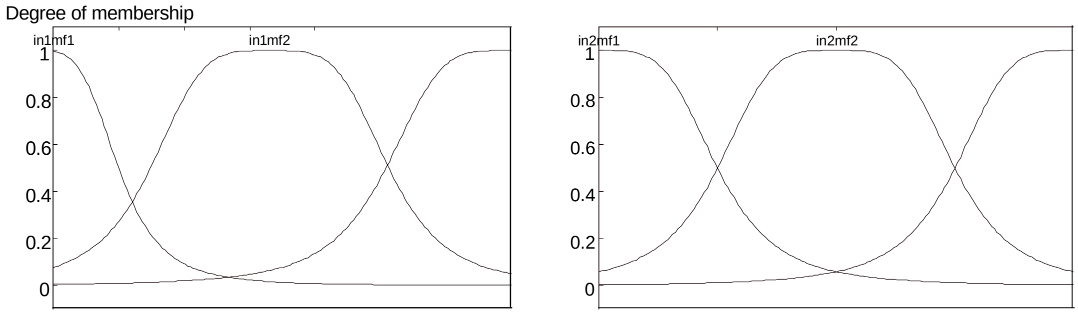

Fig.4 Membership functions of linguistic values of a)Set-Points and b)Error

1. If (input1 is in1mf1)	and (input2 is in2mf1)	then (output is out1mf1) (1)
2. If (input1 is in1mf1)	and (input2 is in2mf2)	then (output is out1mf2) (1)
3. If (input1 is in1mf1)	and (input2 is in2mf3)	then (output is out1mf3) (1)
4. If (input1 is in1mf2)	and (input2 is in2mf1)	then (output is out1mf4) (1)
5. If (input1 is in1mf2)	and (input2 is in2mf2)	then (output is out1mf5) (1)
6. If (input1 is in1mf2)	and (input2 is in2mf3)	then (output is out1mf6) (1)
7. If (input1 is in1mf3)	and (input2 is in2mf1)	then (output is out1mf7) (1)
8. If (input1 is in1mf3)	and (input2 is in2mf2)	then (output is out1mf8) (1)
9. If (input1 is in1mf3)	and (input2 is in2mf3)	then (output is out1mf9) (1)

Table I. Rule base for FLC

With these rules, the control velocity is mapped into 3 fuzzy sets and 9 ruled-zones on which the action control takes different values. Membership functions generated are non symmetric dispositions to track the set-points

According to Sugeno's survey, singleton functions are used for consequent terms in order to obtain an easiest process of reasoning. The inference result, given by the weighted average method, calculates the centre of gravity of the aggregated consequent fuzzy sets.

All this FLC structure is implemented in MATLAB/SIMULINK as follows:

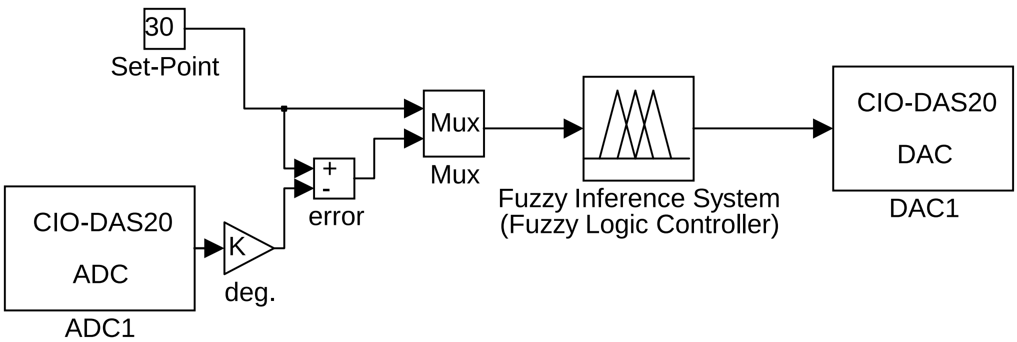

Fig. 5 - Fuzzy Logic Control block

4.Results

The system requires accurate adjustment in a certain set-point , to avoid oscillations. That coerces a fine retunning of the controller , in a whole range of set points.

Both controllers make smoother non linearities of the system, and good response is obtained in a wide set-points range. Zero error is stabilised in some periods, in a different set points, due the error signal is treated consequently to the system behaviour .

Results obtained at different Set-points ,with Neural Networks and Fuzzy controllers:

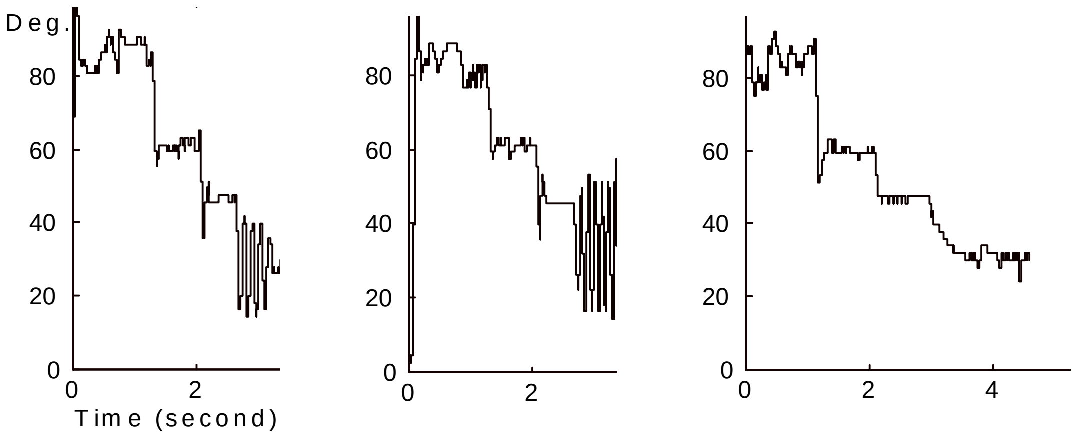

Fig5. Results : a)Neural Network,b) Fuzzy, and, c) Feedback Neural Network.

This graphs represents the behaviour of system to establish at 90º, 60º, 45º, 30º. Fuzzy controller have non linearities smoother, due to approximation to desired points , otherwise Neural force controller at learned pattern, obtaining fines differences in some set-points.

At 30º the system makes oscillations , a feedback Neural Network can stabilise, controlling the evolution of signal around Set-point. This form have a cost in time, .5 seconds are necessary to set the system at new set-point, possible solution in zones with great gains, and unstabilities.

Differences between the controllers are seen when the Neural Network use the capability to reproduce temporal series, who permits to catch the set-point smoothly. Control signal evolution are adequate to force a progressive approximation to set point [3] , and avoid oscillations. Feedback schemes permit to control the signal evolution.

5.Implementation

The implementation phase obliges to readjust the controller several times: first a linear controller is obtained, then a non linear behaviour is contemplated, to control the system in all operating points. Basic structure of controller is updated in measure the requirements grow.

Deep knowledge of the system permits the adaptation of the controller to the real system. The readjustment on process can became tedious, due to unmodelled process dynamics you came across.

The procedure to adapt the FLC to data, makes the system robuster ,to external disturbances , and impredictable situations , desirable in partially known systems.

Generated rules from ANFIS help to know a qualitative behaviour of the system. These rules are the basic set of rules to modify to achieve the desired results.

6.Conclusions

Different type actuation are necessary to obtain good response in a whole range of operating points.

-In a non linear system is necessary a non linear actuation in a set-points set.

-Non linear process of signal error to avoid oscillations around set-point is done.

-Different treatment of error in set-point function is taken into account.

-Progressive control evolution in determinate set-points is programmed.

-Oscillation detection and cancellation is possible.

This actuation is possible with Neural Networks, using feedback, delays, and learning characteristic patterns. Fuzzy does not permit to develop temporal series, due the uncertainty of the output signal.

6.References :

[1] Widmann G. González J. “A force Commanded Impedance Control Scheme for Robots with Hard Nonlinearities , Control Systems Technology, 389 :408, 1995

[2] Bart Kosko. Neural Networks and Fuzzy systems. Prentice Hall.1992.

[3] Hornik K.M., Stinchocombe M. White H. “Multilayer Feedforward Networks are Universal Aproximators” ,Neural Networks, 2 :359-366,1989.

[4] Abe S. Lan M. “Fuzzy rules Extraction Directly from Numerical Data for Function Aproximation”, Systems, Man, and Cybernetics, 119 :129,1995.

[5] Fuzzy Logic Toolbox User’s Guide. Math Works Inc. 1995.