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Minimization Of Fuzzy Rule Base By Using Fuzzy Switching Function

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Abstract

This paper present the general technique in a new application, it will be used to reduce the number of fuzzy rule base to reduce the time of applications and simplify its form.
This method will be applied for the controller of helicopter module.

الخلاصـــــــة

يبين هذا البحث طريقة جديدة لتطبيق التقنية العامة واستخدامها لتصغير قاعدة البيانات الغامضة لطائرة هليكوبتر وسوف تستخدم لقاعدة المروحية التي يكون لها مدخلات لكل مدخل تسع متغيرات لغوية.

المدخل الاول هو موقع الخطأ والمدخل الثاني هو السرعة والناتج سوف يكون الموقع الصحيح ، الطريقة اثنان وثمانون قاعدة وبعد استعمال قاعدة التقنية الجديدة سيكون العدد اثنا عشر ويعطي حلول قريبة جداً من الحالة الاصلية وهناك مقارنة لكيفية تنفيذ الحالتين.

Introduction:

In many applications the Fuzzy Rule Base for them are large, for example if the application has two inputs and each input has five or seven linguistics variables the Fuzzy rule base will be twenty five and forty nine respectively. So let's think about the large number of linguistics that will leads us to huge fuzzy rule base, but the big issue is the execution time of the fuzzy controller, if the fuzzy rule base has large number of rules so the execution time will be long.

The general technique, which presented in [1] was used to minimize the switching function. In this paper the same method will be used to minimize the fuzzy rule base.

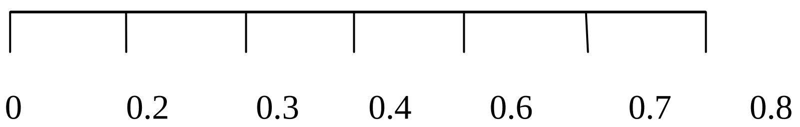
The application will be the Helicopter model which has two inputs each with nine linguistics variables, the first input is the error position and the other one is the velocity, the output will be the correct position. This application will have 82 fuzzy rule bases and after using this technique the rule base will minimize to 12 rules only and there will be a comparison to the execution time between the two cases.

Ordered Fuzzy table [1]:

The fuzzy truth table will be presented by the ordered table which is extracted from fuzzy table by replacing each fuzzy vale on the same input row by an ordered numbers where the smallest order is 1 and the largest order is 2N where N is the number of variables. The input take the same order of the input that is equal to or the same ordered of region of it.

Example 1:

X_1	$\bar{X}_1$	X_2	$\bar{X}_2$	X_3	$\bar{X}_3$	F_0
0.2	0.8	0.3	0.7	0.6	0.4	0.6
1	6	2	5	4	3	4



General Technique for the Minimization of Fuzzy Rule Base

The parameters of the fuzzy controller are optimized to maximum value of the membership. The parameters subject to optimization are: the shape and width of the membership functions, number of linguistic vales, defuzzification method and scaling factors.

Observations are made regarding influences of fuzzy controller parameters the general performance of the controller system.

The theory of fuzzy sets becomes a useful instrument for the control engineer as the complexity of the system increases and the ability to understand and predict its behavior in a precise and yet significant manner diminution.

Tuning and optimizing a fuzzy controller is a difficult and time-consuming task due to the lack of standard procedures. Attempts to blend the two AI techniques have made in the process of solving problems like fuzzy system identification based on input – output data and controller parameters tuning.

The purpose is to put together two artificial intelligence techniques to design an optimal fuzzy controller for the longitudinal channel of an autonomous helicopter model and to investigate influence of fuzzy controller parameters on the vehicle global performance. Several design requirements were formulated based on the time response of the controlled system and an evaluation index was built that captures the complex, constrained, multiple objective character of the problem.

The parameters of the fuzzy controller to be optimized are: the shape and width of the membership functions, number of linguistic values, defuzzification method and scaling factors. In this paper, the new parameter to be optimized is the number of fuzzy rule base to be minimized to the smallest number as it is possible by using the method of general technique these steps will be described in this method, which is based on the use of the general techniques (1) to minimize the number of fuzzy rule base. The following steps can specify this method:

Step (1): Convert the fuzzy rule base to the fuzzy truth table by the following:

1- Represent the linguistic variable with a certain number (the maximum value in the membership function).
2- Scaling the values (linguistic variables) to convert it to the fuzzy value.
3- Rewrite the fuzzy rule with replacing the linguistic variables by its fuzzy values
4- Write the fuzzy rule base as fuzzy truth table then convert it to its fuzzy ordered table.

Step (2): Sign all the rules that equal in their inputs (have the same ordered inputs).

Step (3): From the rules of step (2), Take only the rule with greater output from each group and put them in new table.

Step (4): This table represents the minimized ordered table (the minimized fuzzy rules).

Step (5): Convert the ordered table to its rules by taking the rules that represent ordered values.

5. Helicopter Model: The aircraft is a 35 Ib. X-CELL model helicopter of conventional configuration: two – bladed, clockwise rotating main rotor and tail rotor.

It features a Hiller control rotor providing pitch and roll rate lagged feedback as well as transitional velocity feedback. Only the decoupled dynamics in the vertical plane of symmetry are considered.

The command to the controlled system is the desired longitudinal position of the vehicle center of gravity. A PD controller is assumed; therefore position error and velocity are evaluated and used to generate the input to the plant.

Due to the nature and goals of the mission that the autonomous airvehicle has to accomplish, a number of design requirements were established, based on step time response:

1- Reduced overshoot-good obstacle avoidance characteristics.

2- Reduced settling time-quick response reduced oscillation.

3- Reduced time constant-quick response.

4- Smooth position response in the initial transient domain, no zero or negative velocity regions.

5- Limited maximum peak in the position response too wide gust-good wind disturbance rejection.

6- Reduced settling time in the position response to wind gust-good wind disturbance rejection.

F = the desired time in the position to wind gust-good wind disturbance rejection

X1 = position error

X2 = velocity

Table1. The rule for the fuzzy controller

X1 / X2	ELN	VLN	LN	N	O	P	LP	VLP	ELP
ELN	O	P	P	LP	LP	VLP	VLP	ELP	ELP
VLN	N	O	P	P	LP	LP	VLP	VLP	ELE
LN	N	N	O	P	P	LP	LP	VLP	VLP
N	LN	N	N	O	P	LP	LP	LP	VLP
O	LN	LN	N	N	O	P	P	LP	LP
P	VLN	LN	LN	N	N	O	P	P	LP
LP	VLN	VLN	LN	NLN	N	N	O	P	OP
VLP	ELN	VLN	VLN	LN	LN	N	N	O	P
ELP	ELN	ELN	VLN	VLN	LN	LN	N	N	O

No.	X1	X1	X2	X2	F	P.I.
1	0.1	0.9	0.1	0.9	0.5	0101
2	0.1	0.9	0.2	0.8	0.4	0101
3	0.1	0.9	0.3	0.7	0.4	0101
4	0.1	0.9	0.4	0.6	0.3	0111
5	0.1	0.9	0.5	0.5	0.3	0111
6	0.1	0.9	0.6	0.4	0.2	0111
7	0.1	0.9	0.7	0.3	0.2	0111
8	0.1	0.9	0.8	0.2	0.2	0111
9	0.1	0.9	0.9	0.1	0.1	1111
10	0.2	0.8	0.1	0.9	0.1	1111
11	0.2	0.8	0.2	0.8	0.6	0101
12	0.2	0.8	0.3	0.7	0.5	0101
13	0.2	0.8	0.4	0.6	0.4	0111
14	0.2	0.8	0.5	0.5	0.4	0111
15	0.2	0.8	0.6	0.4	0.3	0111
16	0.2	0.8	0.7	0.3	0.3	0111
17	0.2	0.8	0.8	0.2	0.2	0110
18	0.2	0.8	0.9	0.1	0.2	1110
19	0.3	0.7	0.1	0.9	0.1	1101
20	0.3	0.7	0.2	0.8	0.6	0101
21	0.3	0.7	0.3	0.7	0.6	0101
22	0.3	0.7	0.4	0.6	0.5	0101
23	0.3	0.7	0.5	0.5	0.4	0111
24	0.3	0.7	0.6	0.4	0.4	0111
25	0.3	0.7	0.7	0.3	0.3	1111
26	0.3	0.7	0.8	0.2	0.3	1110
27	0.3	0.7	0.9	0.1	0.2	1110
28	0.4	0.6	0.1	0.9	0.2	1101
29	0.4	0.6	0.2	0.8	0.7	0001
30	0.4	0.6	0.3	0.7	0.6	0101
31	0.4	0.6	0.4	0.6	0.6	0101
32	0.4	0.6	0.5	0.5	0.5	0111
33	0.4	0.6	0.6	0.4	0.4	0110
34	0.4	0.6	0.7	0.3	0.4	1110
35	0.4	0.6	0.8	0.2	0.3	1110
36	0.4	0.6	0.9	0.1	0.3	1101
37	0.5	0.5	0.1	0.9	0.2	1101
38	0.5	0.5	0.2	0.8	0.7	0001
39	0.5	0.5	0.3	0.7	0.7	0001
40	0.5	0.5	0.4	0.6	0.6	0001
41	0.5	0.5	0.5	0.5	0.6	1111
42	0.5	0.5	0.6	0.4	0.5	1110

Table 2. Fuzzy Truth Table

No.	X1	$\overline{X1}$	X2	$\overline{X2}$	F3	P.I.
43	0.5	0.5	0.7	0.3	0.4	1110
44	0.5	0.5	0.8	0.2	0.4	1110
45	0.5	0.5	0.9	0.1	0.3	1110
46	0.6	0.4	0.1	0.9	0.8	1001
47	0.6	0.4	0.2	0.8	0.7	1001
48	0.6	0.4	0.3	0.7	0.7	1001
49	0.6	0.4	0.4	0.6	0.6	1001
50	0.6	0.4	0.5	0.5	0.6	1000
51	0.6	0.4	0.6	0.4	0.5	1010
52	0.6	0.4	0.7	0.3	0.4	1110
53	0.6	0.4	0.8	0.2	0.4	1110
54	0.6	0.4	0.9	0.1	0.3	1110
55	0.7	0.3	0.1	0.9	0.8	0001
56	0.7	0.3	0.2	0.8	0.8	0001
57	0.7	0.3	0.3	0.7	0.7	1001
58	0.7	0.3	0.4	0.6	0.7	1001
59	0.7	0.3	0.5	0.5	0.6	1000
60	0.7	0.3	0.6	0.4	0.6	1010
61	0.7	0.3	0.7	0.3	0.5	1010
62	0.7	0.3	0.8	0.2	0.4	1010
63	0.7	0.3	0.9	0.1	0.4	1010
64	0.8	0.2	0.1	0.9	0.9	0001
65	0.8	0.2	0.2	0.8	0.8	1001
66	0.8	0.2	0.3	0.7	0.8	1000
67	0.8	0.2	0.4	0.6	0.7	1000
68	0.8	0.2	0.5	0.5	0.7	1000
69	0.8	0.2	0.6	0.4	0.6	1010
70	0.8	0.2	0.7	0.3	0.6	1010
71	0.8	0.2	0.8	0.2	0.5	1010
72	0.8	0.2	0.9	0.1	0.4	1010
73	0.9	0.1	0.1	0.9	0.1	1111
74	0.9	0.1	0.2	0.8	0.9	1000
75	0.9	0.1	0.3	0.7	0.8	1000
76	0.9	0.1	0.4	0.6	0.8	1000
77	0.9	0.1	0.5	0.5	0.7	1000
78	0.9	0.1	0.6	0.4	0.7	1000
79	0.9	0.1	0.7	0.3	0.6	1010
80	0.9	0.1	0.8	0.2	0.6	1010
81	0.9	0.1	0.9	0.1	0.5	1010

Convert this table to the ordered fuzzy table:

No.	X1	$\overline{X1}$	X2	$\overline{X2}$	F
1	1	3	2	4	3
2	1	4	2	3	2
3	1	4	2	3	3
4	1	4	2	3	2
5	1	4	2	3	3
6	1	4	3	2	2
7	1	4	3	2	2
8	1	4	3	2	2
9	2	4	4	1	1
10	2	3	1	4	1
11	2	3	1	4	3
12	1	3	2	3	3
13	1	4	2	3	2
14	1	4	2	3	3
15	1	4	3	2	2
16	1	4	3	2	2
17	1	4	3	2	2
18	2	4	4	1	2
19	2	3	1	4	1
20	2	3	1	4	3
21	2	3	1	4	3
22	1	4	2	3	3
23	1	4	2	3	3
24	1	4	2	3	3
25	1	4	3	2	2
26	1	4	3	2	2
27	2	3	4	2	2
28	2	3	4	2	2
29	2	3	1	2	2
30	2	3	1	4	4
31	2	3	1	3	3
32	2	3	1	4	4
33	1	4	2	3	3
34	1	3	4	2	2
35	2	3	4	2	2
36	2	3	4	2	2
37	2	3	4	2	2
38	2	3	1	1	1
39	2	3	1	4	4
40	2	3	1	4	4
41	2	3	1	4	4

Table 3. Fuzzy Ordered Table

No.	X1	X1	X2	X2	F
42	1	2	3	4	4
43	2	3	4	1	3
44	2	3	4	1	3
45	2	3	4	1	3
46	3	2	4	1	2
47	3	2	1	4	4
48	3	2	1	4	4
49	3	2	1	4	4
50	3	2	1	4	4
51	4	1	2	3	4
52	3	1	4	2	3
53	3	2	4	1	2
54	3	2	4	1	2
55	3	2	4	1	2
56	3	2	1	4	4
57	3	2	1	4	4
58	3	2	1	4	4
59	4	1	2	3	4
60	4	1	2	3	4
61	4	1	3	2	3
62	3	2	4	1	2
63	3	2	4	1	2
64	3	2	1	4	4
65	3	2	1	4	4
66	4	1	2	3	4
67	4	1	2	3	4
68	4	1	2	3	4
69	4	1	3	2	3
70	4	1	3	2	3
71	4	1	3	2	3
72	3	2	4	1	2
73	4	1	2	3	2
74	4	1	2	3	4
75	4	1	2	3	4
76	4	1	2	3	4
77	4	1	2	3	4
78	4	1	3	2	4
79	4	1	3	2	3
80	4	1	3	2	3
81	4	1	3	2	3

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From the group, these have the same input rule taking only the greatest outputs table result will be as below:

Table 4. The minimized Fuzzy ordered Table

No.	**X1**	$\overline{\textbf{X1}}$	**X2**	$\overline{\textbf{X2}}$	**F**
1	1	4	3	2	1
2	2	3	4	1	3
3	2	3	1	4	4
4	1	4	2	3	3
5	1	3	4	2	2
6	1	2	3	4	4
7	3	2	1	4	4
8	4	1	2	3	4
9	3	1	4	2	3
10	3	2	4	1	2
11	4	1	3	2	3
12	3	1	2	4	2

Anyone from the above orders comes from many rules, because these rules have the same order inputs, so they give the same output. Therefore they can be represented by any of the original rules these come from.

The following rules are coming out from the minimized table, by taking the rule representing each order statement:

Table 5. Minimized Fuzzy Rule Base

X1 / X2	**ELN**	**VLN**	**LN**	**N**	**O**	**P**	**LP**	**VLP**	**ELP**
ELN									
VLN	**ELN**					**VLP**			
LN		**O**							
N									
O					**O**				
P	**VLN**					**O**			
LP				**N**		**N**			**O**
VLP									
ELP		**ELN**							

The frequency response of the minimized fuzzy rule base is shown in Fig.2, and the comparison between it and the original rule base. The minimized rules give a closed response from the original one but with much minimized rules number this provide a short time at the execution.

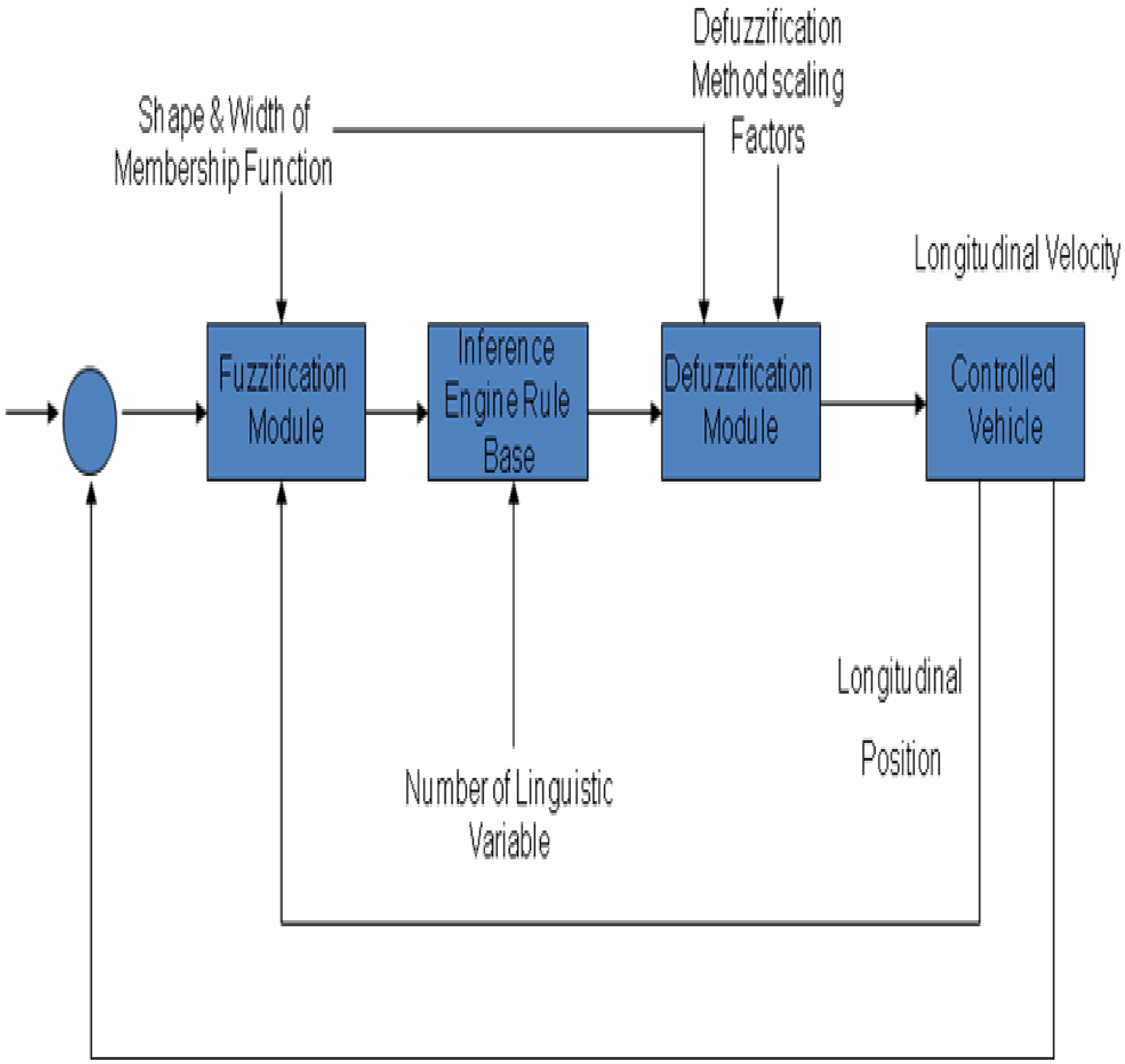

Figure 1 The Block diagram of the helicopter model

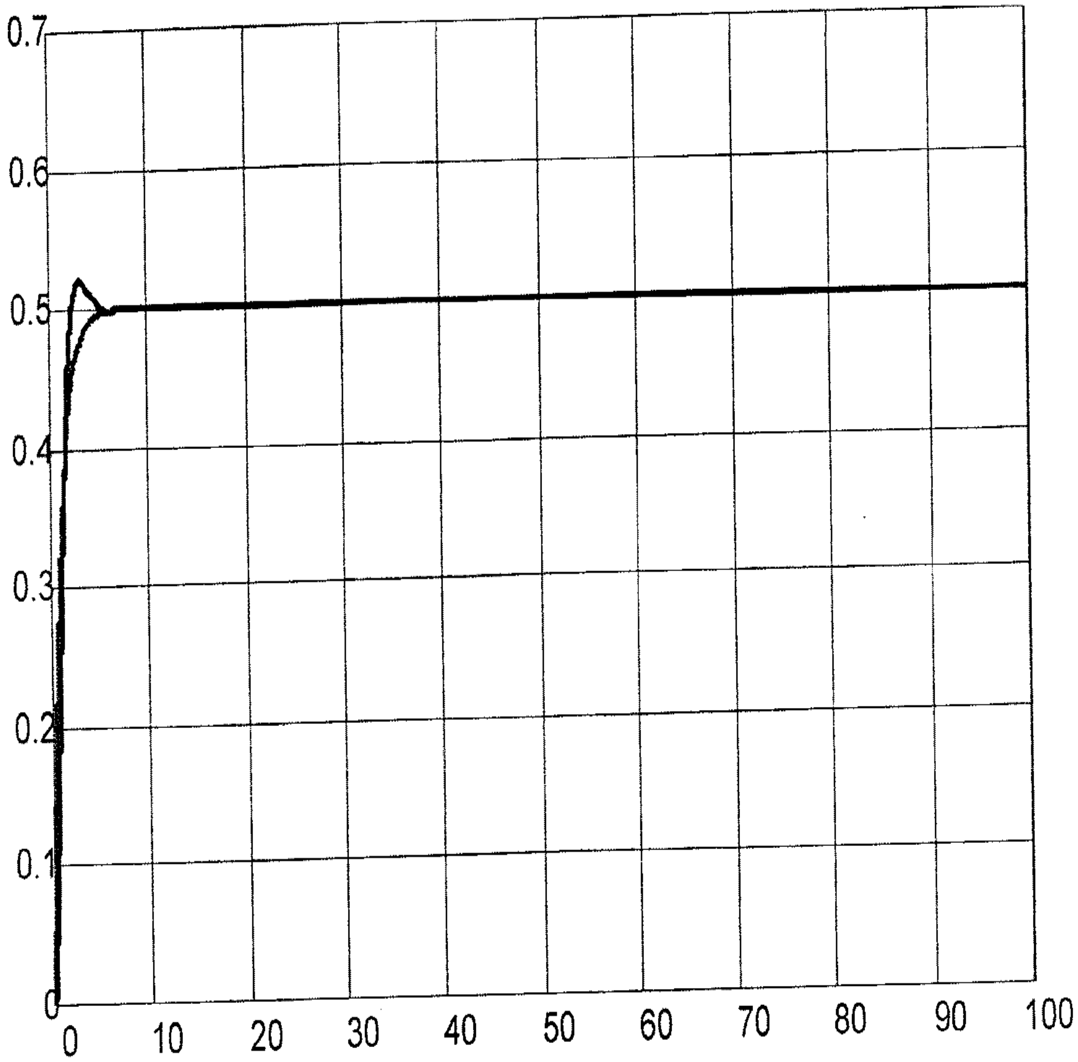

Figure 2 Time Response

Conclusions:

The conclusions from this theory :

1- The general method is a very simple fast theory can be used to minimize the fuzzy rule base with a large number of rules to a very small number of rules.

2- The frequency response of the minimized rule is very closed to the original one.

3-The execution time of the minimzed rules is much less than the original one.

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