Knowledge based evaluation of knowledge bases

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Resume

This paper shows an evaluation system of control knowledge bases in Fuzzy control systems. The key of the evaluation is a knowledge-based system that rates the behaviour of the controlled system. Too, the methodology used and several examples of control knowledge bases are included.

Keyword: Fuzzy logic controllers, knowledge-based system, knowledge evaluation.

1 INTRODUCTION

Among the applications of Fuzzy systems, we can stand out the process control. This type of applications, Fuzzy control systems, is structured in control system and system to be controlled. System control is composed of inferences engines and control knowledge base.

These system can be considered system based on knowledge[2]. The system knowledge is represented by means of the control knowledge bases, which consist of variables, membership functions and performance rules. The knowledge bases control the process behaviour.

In this type of systems, the excellence measure or the ***control knowledge base evaluation (CKBE)*** is very important. This evaluation means to mark the behaviour of the control knowledge base over the system to be controlled.

The scope of the CKBE application can include Fuzzy control systems and learning Fuzzy – genetic systems [4] based on the Pittsburgh approach. In the very first ones, they can check the correct working of the control system and can detect any changes in the system to be controlled. In the case of the learning systems, CKBE allows to evaluate the behaviour of the generate individuals, in a previous step (limbo [2][4]), before use them in a real system.

In this paper, an evaluation system of control knowledge base evaluation is described. In order to carry out the evaluation, a knowledge-based system is used. The following points show the methodology used to carry out the evaluation of the control knowledge base, examples of the obtained results, conclusion and the present working lines.

2 EVALUATION OF CONTROL KNOWLEDGE BASES

The aim of the control knowledge base evaluation is to measure the excellence of the behaviour of the control knowledge bases over a system to be controlled. The measure of the performance is provided by evaluation system that analyses the evolution of the controlled system.

2.1 EVALUATION SYSTEM.

Fig. 1 shows an integrated Fuzzy control system with an evaluation scheme.

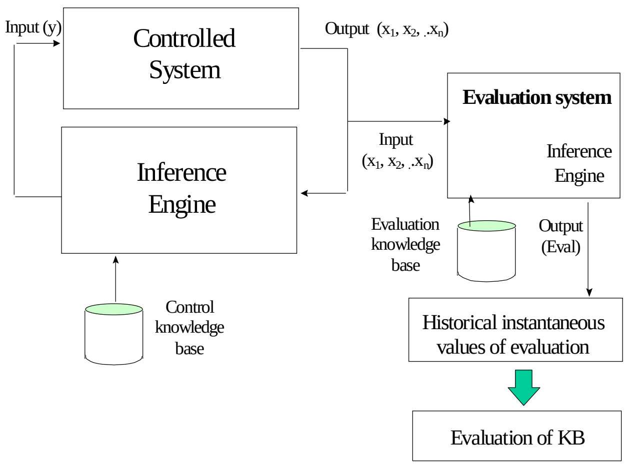

Figure 1: Integrated Fuzzy control system with evaluation system.

Fuzzy control system is structured in controlled system, inference engine and control knowledge base. The state of the system to be controlled is characterised by a set of variables (x_1, x_2, $x_{3,....}x_n$). Inferences engines infers Fuzzy control actions (output variable y) using control knowledge base and input variables (x_1, x_2, $x_{3,....}x_n$).

The system evaluation is designed as a knowledge-based system. It is structured in inferences engines and evaluation knowledge base. System evaluation input accords with the state of the controlled system and its output is the instantaneous evaluation of the actual state of the controlled system. This instantaneous evaluation is inferred using evaluation knowledge and the state of the controlled system.

2.2 EVALUATION KNOWLEDGE

Evaluation knowledge is defined in its knowledge base, which consist on variables, membership functions and performance rules. Evaluation rules provides a relationship between a set of antecedents and a consequent as it is showed at (1)

$$R_n : \text{if } x_1 \text{ is } A_{1n} \text{ and } \ldots \text{ and } x_m \text{ is } A_{mn} \text{ then Eval is } B_n \quad (1)$$

where x_i are input variables, A_{ij} are Fuzzy set relates to input variables, Eval is the output variable, and B_i are Fuzzy set related to output variables.

All the possible states of the controlled system are defined to obtain the evaluation knowledge. For each state a rate is established. The maximum value of the qualification corresponds to the final goal of the control. In this way, a set of evaluation rules is identified.

An important aspect is the evaluation knowledge mark. This knowledge, from the willing states of the controlled system, is known a priori. Evaluating with a correct evaluation knowledge base, results are successful. In other case, results are erroneous.

Furthermore it is possible the implementation of an evolutionary schemes based in genetic algorithm to get an optimum evaluation knowledge base.

2.3 EVALUATION

2.3.1 Instantaneous evaluation

When the control system is working, the inference engines result in new states of the controlled system. Each state gets an instantaneous evaluation $Eval_p[i]$ as (2)

$$Eval_p[i] = f\left(x_i[i], x_2[i], x_3[i] \ldots x_n[i]\right) \qquad (2)$$

Where i is inference number, ($x_1[i]$, $x_2[i]$, $x_3[i]_{,\ldots\ldots}x_n[i]$) controlled system state at inference i, f ($x_1[i]$, $x_2[i]$, $x_3[i]_{,\ldots\ldots}x_n[i]$) is the instantaneous evaluation, and p is the starting point (i=0) defined by ($x_1[0]$, $x_2[0]$, $x_3[0]_{,\ldots\ldots}x_n[0]$).

2.3.2 Evaluation from a starting point

Evolution of the instantaneous evaluation $Eval_p[i]$ is registered in an historical record. This record is processed to evaluate the behaviour of the control knowledge base from a starting point p.

The qualification is computed accounting several parameters: average value of the instant evaluation, oscillations existence, state of the starting and final system, time up to reaching and keeping a threshold value. Actually, the evaluation from a starting point $Eval_p$ is computed using (3).

$$Eval_p = \frac{\sum_{i=0}^{I} Eval_p[i]}{I} \qquad (3)$$

Where $Eval_p$ [i] is the instantaneous evaluation, and I is the inferences number.

$Eval_p$ is a parameter that measures the behaviour of the control knowledge base from a starting point. This behaviour is considered to be accurate over a threshold value G defined for each controlled system.

2.3.3 Control knowledge base Evaluation.

The evaluation of the control knowledge base needs an analysis of the behaviour control system from several starting points because it is possible that the control knowledge base performs an accurate behaviour for particular starting points, and works in a poor way for another starting points.

Then, it is necessary the proof of the completeness of the control knowledge base through the analysis of the control knowledge base from selected starting points.

Control knowledge base evaluation is obtained using (4) for established starting points.

$$EvalKB = \left(\beta \left(\frac{\sum_{p=1}^{P} Eval_p}{P} \right) + (1-\beta)K \right) \qquad (4)$$

where $Eval_p$ is the evaluation from a starting point p, P is the number of starting points, ß is the evaluation weight[3] (for this results a value of 0,8 is used), and K is the completeness constant defined in (5)

$$K = 1 \Leftrightarrow \forall p \quad Eval_p \geq G \tag{5}$$

$$K = 0 \Leftrightarrow \in p \,/\, Eval_p < G$$

where G is the threshold value defined for each controlled system.

3. RESULTS ON THE PARTICULAR APPLICATION OF THE INVERTED PENDULUM

As application of the evaluation system, two tests for the classical control system of the inverted pendulum are included. It consists in an inverted pendulum over a vehicle. The system uses six context variables (angle, position, lineal velocity, angular velocity, lineal acceleration, and angular acceleration) and an operation variable (force).

The angle measures the pendulum deviation over the vertical axis. Its space is divided in three triangular Fuzzy sets (LEFT, CENTRE, and RIGHT). The position shows the location of the vehicle. Its space is similar divided in three triangular Fuzzy sets (LEFT, CENTRE, and RIGHT).

The goal of the control system is to maintain the vehicle in a centred spatial position, keeping the pendulum over the vertical axis (POSITION = CENTRE and ANGLE = CENTRE).

Evaluation knowledge base (fig. 2) uses two context variables (angle and position), and an operation variable (Eval). The space of Eval variable is homogeneously divided in nine triangular Fuzzy sets (ONE to NINE).

R1: if ANG is Left and	POS is Left	then EVAL is One
R2: if ANG is Left and	POS is Centre	then EVAL is Four
R3: if ANG is Left and	POS is Right	then EVAL is Seven
R4: if ANG is Centre and	POS is Left	then EVAL is Five
R5: if ANG is Centre and	POS is Centre	then EVAL is Nine
R6: if ANG is Centre and	POS is Right	then EVAL is Five
R7: if ANG is Right and	POS is Left	then EVAL is Seven
R8: if ANG is Right and	POS is Centre	then EVAL is Four
R9: if ANG is Right and	POS is Right	then EVAL is One

Figure 2: Rules of Evaluation knowledge base.

The number of the inferences used in the evaluation for each starting point is I=1000, the number of starting points is P=16,and the threshold value of accurate behaviour is G=0,5.

3.1 EVALUATION OF KB nº6

Knowledge base nº6 uses two context variables (Angle and position) and an operation variable (force). Force variable indicates the control interaction over the vehicle to get the final goal, with a homogeneous divided space of nine triangular Fuzzy sets (-4 to +4)

R1: if ANG is Left and	POS is Left	then FORC is - 3
R2: if ANG is Left and	POS is Centre	then FORC is - 2
R3: if ANG is Left and	POS is Right	then FORC is - 1
R4: if ANG is Centre and	POS is Left	then FORC is - 3
R5: if ANG is Centre and	POS is Centre	then FORC is 0
R6: if ANG is Centre and	POS is Right	then FORC is +3
R7: if ANG is Right and	POS is Left	then FORC is +1
R8: if ANG is Right and	POS is Centre	then FORC is +2
R9: if ANG is Right and	POS is Right	then FORC is +3

Figure 3: Rules of control knowledge base nº6.

Fig. 4 shows evolutions of position, angle and $Eval_p[i]$ for a particular starting point. The system starts from a initial point with a low mark (extreme situation of angle and position = left) and develops without oscillations towards the willing state (angle and position = centre). The value of evaluation is $Eval_p = 0,580$.

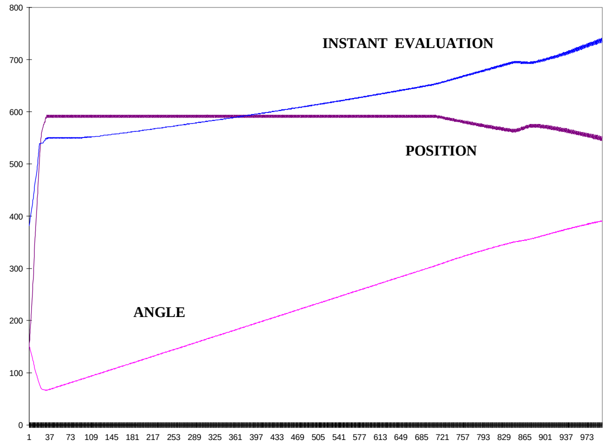

Figure 4: Evaluation from a starting point.

Fig. 5 shows instant evaluations $Eval_p[i]$ for the sixteen starting points. The system always reaches the goal.

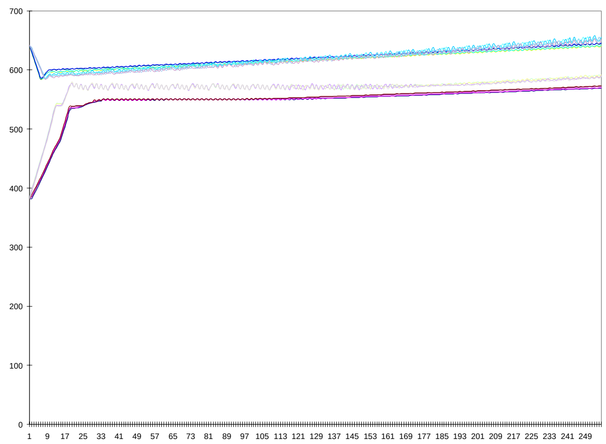

Figure 5: Instant evaluations from different starting points

Evaluation $Eval_p$, for each starting point is specified in table I.

Table 1: $Eval_p$ at KB nº 6.

Starting point					$Eval_p$
Nº	POS	VEL	ANG	VANG	
1	0,15	0,15	0,15	0,15	0,580
2	0,15	0,15	0,15	0,85	0,581
3	0,15	0,15	0,85	0,15	0,721
4	0,15	0,15	0,85	0,85	0,724
5	0,15	0,85	0,15	0,15	0,585
6	0,15	0,85	0,15	0,85	0,587
7	0,15	0,85	0,85	0,15	0,727
8	0,15	0,85	0,85	0,85	0,730
9	0,85	0,15	0,15	0,15	0,736
10	0,85	0,15	0,15	0,85	0,733
11	0,85	0,15	0,85	0,15	0,589
12	0,85	0,15	0,85	0,85	0,588
13	0,85	0,85	0,15	0,15	0,730
14	0,85	0,85	0,15	0,85	0,726
15	0,85	0,85	0,85	0,15	0,584
16	0,85	0,85	0,85	0,85	0,583

As it can be seen, the behaviour of the control knowledge base is accurate from all starting points (K=1). The value of the control knowledge evaluation is **EvalKB = 0,725**.

3.2 EVALUATION KB BASE nº4

Knowledge base nº4 uses three context variables (Angle, position and angular velocity) and an operation variable (force), using a set of ten rules.

R1: if ANG is Left and	VANG is -	then FORC is - 4
R2: if ANG is Left and	VANG is 0	then FORC is - 3
R3: if ANG is Left and	VANG is +	then FORC is - 2
R4: if ANG is Centre		then FORC is 0
R5: if ANG is Right and	VANG is -	then FORC is +2
R6: if ANG is Right and	VANG is 0	then FORC is +3
R7: if ANG is Right and	VANG is +	then FORC is +4
R8: if POS is left		then FORC is -4
R9: if POS is Centre		then FORC is 0
R10: if POS is Right		then FORC is +4

Figure 6: Rules of control knowledge base nº4

Control base obtains rates $Eval_p$ 0,567, 0,568, 0, 0, 0,571, 0,572, 0, 0, 0, 0, 0,574, 0,573, 0, 0, 0,570, 0,569. (0 value indicates the fall of the pendulum).

Evaluations $Eval_p$, indicate that the desired final state is obtained for eight starting points and drops for the rest. In this case K=0 and **EvalKB = 0,228**.

4 CONCLUSIONS

The knowledge evaluation is a very important aspect in intelligent system. For this purpose it is possible the use of knowledge-based system.

The presented system evaluation rates the control knowledge in Fuzzy control system and permits the analysis of new individuals in learning Fuzzy genetic systems.

All the possible states of the space are to be taken into account for the evaluation of the control knowledge, qualifying its behaviour from selected starting points.

An important aspect is the evaluation knowledge mark. It is possible the implementation of an evolutionary schemes based in genetic algorithm to get an optimum evaluation.

Actual working lines are: the study of evaluation function $Eval_p$, the generation of control knowledge through individuals evaluation in learning Fuzzy genetic systems, and the use of CKBE in real process.

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