A Fuzzy Approach to Performance Rules

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Abstract

The realization of the Stockholm KTH musical performance rules with fuzzy technique is thereby explained. The technique allows the formulation of rules in an evocative manner because it uses words rather than mathematics.

1 Introduction

Computer musical performance has always had the shortcoming of being excessively dull, that is to say of not introducing those microvariations which give musicality to the performance of a musician. To overcome this shortcoming Sundberg and his colleagues of the Royal Institute of Technology (KTH) of Stockholm have proposed performance rules [5,8], which allow a better performance than that obtained without the interpretation of the score. These rules introduce certain microvariations in the duration (DR), in the intensity level (L) of the tone, and in the duration of rest between notes (DRO). Microvariations are generally given in terms of functions and always in mathematical terms. Performance rules follow an additive formulation, i.e. microvariations proposed by the rules are added to one another. Almost each rule has a multiplying coefficient (*k*) defined as emphasis parameter. This parameter allows the amplification or attenuation of the effect of the corresponding rule.

The use of fuzzy sets as a way to express uncertainty in a structured manner is now spreading in engineerings [6,7]. Specific adjectives are associated to fuzzy sets so that linguistic deduction rules are obtained to establish adequate output values (from the fuzzy point of view). Numeric results can be obtained from these values so that a fuzzy controller can be build. Fuzzy methods allow the relatively easy implementation of communication aspects, typical of human reasoning where qualitative variables, unspecified concepts and subjective considerations play a fundamental role. Thus fuzzy logic leads to the creation of a controller able to “explain” its behaviour.

At Padua University we studied different approaches[1,2,4] to model performance rules, based on neural networks and many-sorted-logic. Supposedly a linguistic approach rather than a mathematical one enables to obtain a more effective model for the concepts at the basis of musical performance. From this point of view a fuzzy controller could be particularly useful for the expert in the field of musical interpretation who deals with the problems of computer musical performance. To test the opportunities given by the fuzzy approach we developed a fuzzy controller based on KTH rules. This reformulation has to be taken into account not only as way to establish the rules according to the fuzzy technique but also as a starting point towards a further development of the Sundberg rules which are at the basis of this work.

2 Fuzzy Rules

The KTH rules have been reformulated keeping the original additional aspect. First of all a choice has been made to eliminate the rules whose formulation was not apt to a fuzzy realization. In particular, the rules with costant or linear deviations have not been considered because their fuzzy realization is possible but it is not interesting. Table 1 shows the rules that have been realized. The descripition of fuzzy reasoning ought not to be too complex in order to obtain a better interpretation. It is advisable that input and output variables should not be divided into a too large number of membership functions and the number of inference rules must be as limited as possible. The aim is to obtain a controller consistent with the linguistic aspect of its behaviour, therefore a careful assessment of the adjectives to associate to membership functions is required so that meaningful inference rules can be achieved. It must be noted that to this aim the division into membership functions (and consequently the verbal characterization of an input set) must be identical for the same variables even though they are used in different rules. Although the formulation is still additional, the implementation of a rule is no longer indipendent from that of the others. In fact, implementing a rule with fuzzy method means choosing membership functions adequately and this choice will influence all the rules which use the same variable. The initial choice of membership functions has been made empirically; to obtain the final formulation a try and error procedure has been necessary, as it is for all fuzzy controllers. When building membership functions , it is better to analyse where output sensibility is greater : in this case it is better to thicken membership functions. In order to modify the controller behaviour, it is also possible to change membership functions shape. Figure 1 shows how we build fuzzy rules: from the central value of the input membership function we calculate the output value given by the KTH rules. The consequent of the fuzzy rule becomes the membership function "nearer"to this value. In order not to render the controller excessively complicated, with the introduction of a large number of membership functions, it is possible to use the following type of rules:

DDC 1: Durational Contrast	DPC 1B: High Loud	GMA 2A: Harmonic Charge	GMI 1A': Leap Articulation	GMI 1B: Leap Tone Duration

Table 1

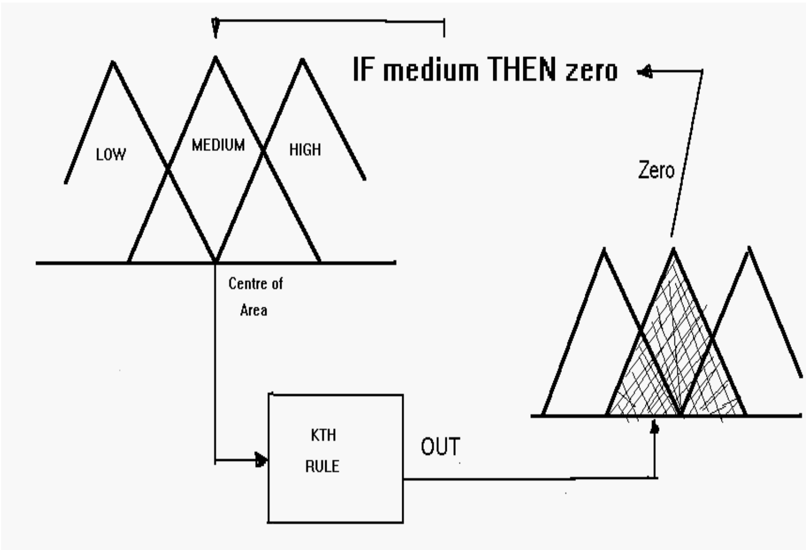

Figure 1

IF (DURATION **IS** "*long*") **THEN** (DRO **IS** "*very short*" **OR** DRO **IS** "*short*")

these rules allow to obtain an intermediate result without introducing another membership function so that the interpretation of the controller is easier. From a logical point of view these rules imply that for a given input there are several correct output values (fuzzy values are meant here).

We must remember that fuzzy rules have to be significant, i.e. they should have a linguistic meaning. So we must choice accuratly our adjective. The inference method known as MAX-MIN resulted the most suited for our fuzzy controller. The evaluation of the defuzzied value is obtained through the Center of Area method. Figure 2 shows membership functions that are used for input/output variables (for the meaning of abbreviations see Table 2). Table 3 shows the inference rules developed.

DR:Duration	N:Semitone Number (N=60 for C_4)	L:Loudness Level	HC:Harmonic Charge	DRO: Off-time Duration	
Z:Zero	MS:Medium Short	M:Medium	ML:Medium Long	Ln:Long	
Lo:Low	H:High	Ne:Negative	SN:Small Negative	SP:Small Positive	P:Positiv

Table 2 Abbreviations

3 An Example: Leap Tone Duration

An example is useful to explain how the controller works. Rule GMI 1B is here implemented; the rule modifies the duration of the tone according to the leap interval in semitones (ΔN). The entity of the duration variation is given by the following formula:

$$\Delta DR = 4.2\sqrt{\Delta N} \cdot k$$

As shown by Table 3 the formulation of the rule given in the example has a linguistic aspect and is therefore self-explicative. For instance the first column of the table represents the fuzzy rule:

IF (LEAP_INTERVAL **IS** "*zero*") **THEN** (DELTA_DURA9TION **IS** "*zero*")

For each leap interval value the five fuzzy rules are evaluated in parallel producing a fuzzy subset expressing the deviation of duration. This subset is defuzzified to obtain a crisp value. As shows Figure 2, an interval equal to 7 is medium with fit value 0.3 and medium-long with fit value 0.7. As imply the rule base (Table 3) ΔDR is medium with fit value 0.3 and medium long with fit value 0.7. Figure 3 shows how we obtain a crisp value from the output's fuzzy set.

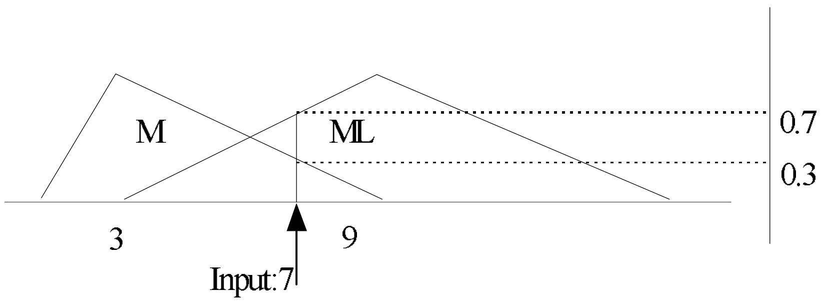

Figure 3

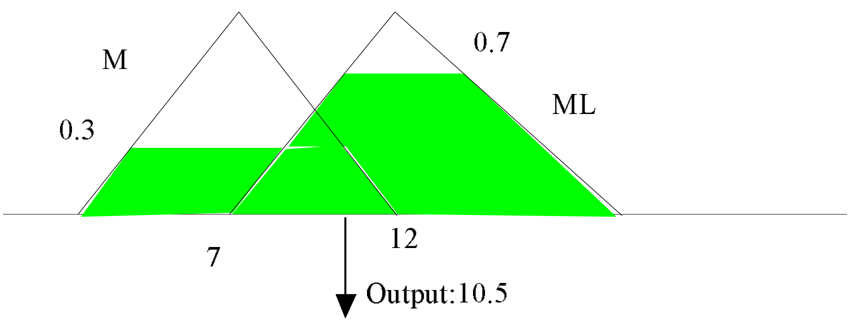

Figure 4

Figure 4 shows a comparison between variations suggested by KTH rules (solid line) and those obtained with the fuzzy controller (dotted line). Fuzzy technique can implement KTH rules. An example is provided by Figures 6a, 6b and 6c which show a comparison between the variations obtained by applying the rules to Träumerei of R. Schumann. Rules were applied with k=1. If we want to considered the quantity factor k of each rule in a fuzzy way we have to add a new input value to each rule and thus a new dimension to each table. In this case the number of fuzzy rules increase notably. A simple solution is to apply the quantity factor after the computation of the defuzzified output deviation.

Table 4. Rule Base

DR
ΔDR

DR | Z
ΔL | Z

ΔN
ΔDR

HC
ΔD

GMI 1A' (DRO)					
	DR				
ΔN	Z	MS	M	ML	Ln
Z	Z	Z	Z	Z	Z
MS	Z	Z & MS	Z & MS	Z & M S	MS
M	Z	MS	MS	MS & M	M
ML	Z	M & ML	ML	ML & L	Ln
Ln	Z	M & ML	ML	ML & L	Ln

GMI 1B. Leap Tone Duration.

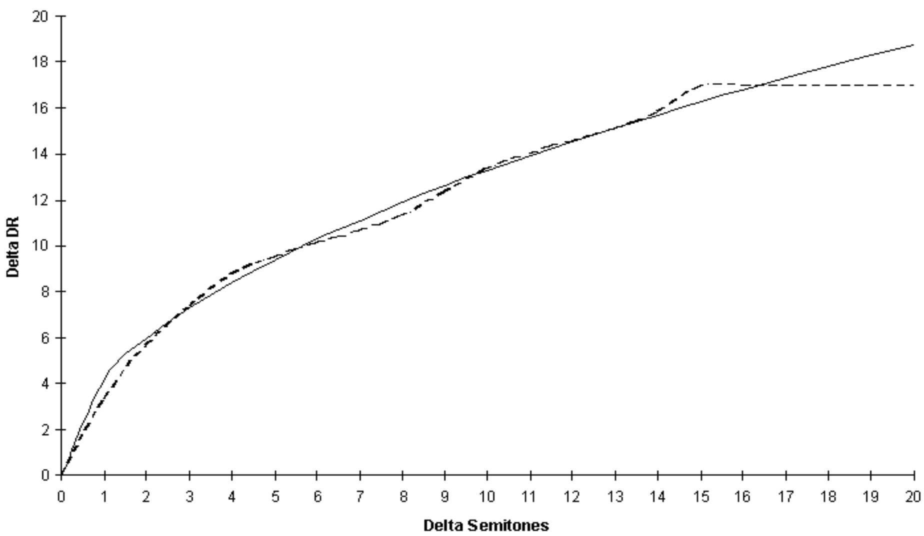

Figure 5. GMI 1B