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a cura di
Luigi Fiparelli e Fabio Regazzi

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A.I.M.I. Associazione di Informatica Musicale Italiana
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Dipartimento di Musica e Spettacolo, Università di Bologna
Progetto MusicaDuemila - Dipartimento dello Spettacolo
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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 engineering [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 constant 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 description 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.

<table>
<thead>
<tr>
<th>DDC 1:</th>
<th>DPC 1B:</th>
<th>GMA 2A:</th>
<th>GMI 1A:</th>
<th>GMI 1B:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>High</td>
<td>Loud</td>
<td>Harmonic</td>
<td>Leap</td>
</tr>
<tr>
<td>Contrast</td>
<td>Charge</td>
<td>Articulation</td>
<td>Duration</td>
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</tbody>
</table>

Table 1

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 independent 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:

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 choose accurately our adjective. The inference method known as MAX-MIN resulted the most suited for our fuzzy controller. The evaluation of the defuzzized value is obtained through the Center of Area method.

3 A Global Fuzzy Controller

Until now we described a fuzzy controller that considers rules one by one: final deviations are obtained adding deviations of each rule. Our previous experience with neural nets [2] showed that, using one global function of all the inputs instead that an additive formulation, a better model could be obtained. As showed in [3], it is possible to represent the KTH rules system with the following equation:

\[ y_n = \sum_{i=1}^{N} k_i f_i(x_n) \]

where the meaning of each parameter is the following:

\( y_n \) deviation of time or of loudness

\( f_i() \) function that represents the i-th KTH rule determined in an heuristic way

\( x_n \) represent the vector of the parameters used by the KTH rules applied at the n-th note

\( k_i \) constant used to emphasize the deviation due to each i-th rule

The CSC model could be written in the following form:

\[ y_n = \text{net}(K, x_n) \]

where the meaning of each parameter is the following:

\( y_n \) deviations of time or of loudness

\( \text{net}(\cdot) \) Neural Net, non linear function that computes the deviations
As a result of these considerations we developed a new fuzzy formulation of the model of CSC. The result is a fuzzy global controller (FGC). In the previous paragraphs we choose rules that contain some uncertainty (i.e. rules that are good for fuzzy realization); so we avoid linear or deterministic rules. For the GFC point of view, however, we choose also linear or deterministic rules if their output is very meaningful. For the choice criteria we referred to [2]. Table 2 shows the rules taken into account.

From Table 2 is possible to observe that we need also information about the structure of the piece of music. For this reason, the FGC must also decide when a rule is to be applied. This task was not performed by the controller described in the previous paragraphs. Figure 2 shows the difference between the KTH model and the GFC. Each output variable is described by a non-linear function:

\[
\begin{align*}
\text{DRO} & = f_{\text{DRO}}(\text{DR}, \Delta N, \text{PR}, \text{AR}) \\
\Delta \text{DR} & = f_{\Delta \text{DR}}(\text{DR}, \Delta N, \text{PR}, \text{MC}) \\
\Delta L & = f_{\Delta L}(\text{DR}, \text{N}, \text{MC})
\end{align*}
\]

where the meaning of each parameter is the following:

- \text{DR} \quad \text{duration in ms}
- \Delta N \quad \text{leap interval in semitones}
- \text{PR} \quad \text{end of phrase flag}
- \text{AR} \quad \text{articulation of repetition flag}
- \text{N} \quad \text{number of semitone (N=60 for C4)}
- \text{MC} \quad \text{melodic charge}

To obtain these functions we used the standard value of KTH rules, i.e. we used rules with \(k=1\). These functions are not obtained by adding rules of Table 2 because some saturation are inserted. Figures 3, 4 and 5 show a comparison between deviations obtained by applying KTH rules and those obtained with the GFC. The score is Sonata K284 of W.A. Mozart. Generally, deviations given by the GFC follow correctly the deviations proposed by the KTH rules; the error obtained from the difference between the two performance is generally under the JND. It should be noticed that GFC would require others input value to manage the quantity factor. This will increase the complexity of the controller as previous discussed. For the GFC there are two way to insert quantity factor. The simpler is to multiply final value, in this case all effects that affect the same output are amplified at the same manner. If we don't want this we must insert quantity factor "inside" the controller.

Another choice is to not insert any quantity factor. In this case when we want apply the GFC to a piece with other values of \(k\) parameter, we must rebuild the controller (like neural nets where we must train another-time the net). This method take a lot of time but in this case the controller is simpler.

Also the tempo parameter affect the quality of performance. When tempo is very fast or very slow using, like us, absolute output value could determine some mistakes. For a further develop is possible to consider variables with their relative value instead with the absolute one. In this case we avoid the necessity of rebuild rules when we want to perform scores with different tempo but is more difficult to consider rules (like Phrase) where deviations depending only by structure of score.

### 4 Conclusion

It has been shown that a fuzzy controller can quite accurately approximate the KTH performance rules both with the additive formulation then the global formulation. By examining (we could also say "reading") the controller it is possible to quickly understand its functioning together with the reasons for the control action. In this sense fuzzy realization can be considered as a linguistic reformulation of the musical performance rules. However what is all the more useful is that it is possible to associate an algorithm that can be used on computer. The most important aspect of a linguistic formulation is that it is comprehensible to everyone, it will be particularly useful as the basis for the cooperation with music expert in order to integrate or revise KTH rules.
References


