TOWARDS A FUZZY LOGIC APPROACH TO DRUM PATTERN HUMANISATION

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ABSTRACT

A fuzzy logic-based approach can be used to simulate human agents in many control situations. Numerous authors have noted that this methodology has advantages for a variety of tasks within the realm of computer music. In this paper, a review of such projects is conducted and a rudimentary example application of fuzzy logic techniques is presented. This automatically achieves a basic level of 'humanisation' of a drum pattern through strike velocity modification. Such a tool could significantly reduce the time spent on editing individual drum hits in a music production environment and has potential applications for rhythmic composition and performance.

1. INTRODUCTION

Drum machines and computer-based music sequencing packages allow rhythmic patterns to be programmed, stored, modified and performed. In music production scenarios, the drum track may be programmed manually for aesthetic effect and/or due to restricted project resources. The common 'piano roll' sequencer view has many benefits in this case;- editing tools such as 'cut-and-paste' speed the arrangement of short patterns into larger structures, hits may be quantised to correct timing problems, etc. The strength/ loudness of each drum note is primarily controlled by setting the associated velocity value and a set of tools is commonly provided to automate this process to some degree. However, the music producer/ engineer often needs to modify drum note velocities individually by hand in order to mimic the variation in hit strengths of a real drummer. Such local changes typically rely on the experience of the rhythm programmer and can be quite time intensive if an expressive, 'human-like' performance is to be recreated. This process of 'humanising' or 'adding groove' to programmed drums actually involves modifying both the levels and onset times of the note hits, as a real drummer will not perform with the precise timing of an electronic sequencer.

An automated velocity assignment process would reduce editing time and would also have other applications in composition and performance situations. A number of tools exist that attempt to automate the process of modifying a large number of note velocities simultaneously. In an industry standard production environment [1] a logical editor can operate on as many notes as are selected. However this type of tool is restricted to simple arithmetic and logical operations and cannot generally be used to automatically express the type of variation seen in real drumming performances. A number of commercial software tools exist that can add a humanising effect to programmed drums based on templates of drumming styles [2], [3]. These are plug-ins or standalone programs that can process MIDI files. Some include models to implement the physiological limitations and skills of the virtual drummer [4]. The project under discussion here intends to provide a free alternative to these tools that is open-source and applies fuzzy logic techniques to the problem of automatic drum humanization.

As this project is a first step towards a complete automatic humaniser, discussion in this paper will be restricted to the generation of velocity values for a programmed MIDI drum part. Modification of drum hit onset times has been previously discussed in an effort to produce expressive performances using electronic drum machines [5]. Algorithms to extract the deviations of hit times from performances have then facilitated the application of a model of these deviations to scored drum parts. The technique met with good qualitative success in listening tests, sounding more natural than other techniques such as the introduction of random timing deviations.

The remainder of this paper takes the following form. Section 2 introduces fuzzy logic theory and describes some of the attempts to use such techniques in artistic scenarios. Section 3 outlines the development of an example system that uses fuzzy logic to implement a drum humanising tool. Section 4 offers a brief discussion of the output of the basic humaniser prototype while section 5 looks at the potential for future work on this project.

2. FUZZY LOGIC

Systems based on fuzzy set theory and fuzzy logic can use expert knowledge in the form of a rule base to make decisions [6], [7]. Traditional 'crisp' set theory uses an absolute value of truth for any statement. Typically, any given element in the universe of discourse will either be fully included or excluded from a specific set. Fuzzy set theory allows an element to have partial membership of a set such that the element's membership grade in that set falls between 0 and 1. This more closely resembles how humans think, allowing system variables to be expressed using linguistic labels that are articulated in simple language. For example, the loudness of a sound may be expressed as *quiet*, *average* or *loud* and the full range of possible sound levels may be expressed as falling partially within any pair of these fuzzy subsets e.g. *a little bit loud* or *very quiet.* An input to such a system has its membership grade within the fuzzy subsets evaluated by means of membership functions; - as shown in figure 1, an input loudness level of 59 will have a membership grade of 0.22 in *quiet* and 0.78 in *average*.

This process of fuzzification means that rules contained in the system rule-based can be fired to a partial degree through a fuzzy inference engine. Using *if-then-else* statements results in the conditions involved being met to some degree. The result of rule firing is then de-fuzzified to produce a crisp value that serves as the controller output.

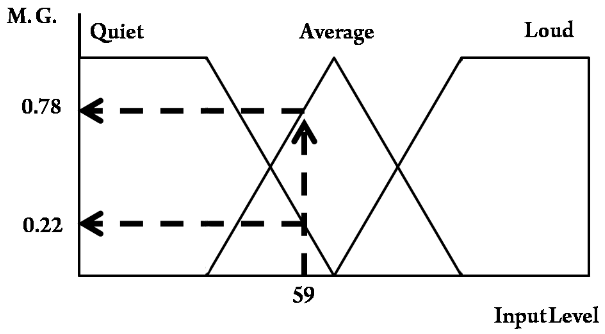

Figure 1: *Determination of fuzzy membership grades (M.G.) of an input of 59 using membership functions.*

Fuzzy systems provide benefits in many control situations, including those where the underlying process is too complex to model or where the system is non-linear [6]**.** Of primary interest for this project is the ability of a fuzzy system to act like a human control agent using a set of rules specified in terms of simple language and determined using human observation. As a fuzzy controller can incorporate qualitative knowledge, it seems obvious that this should provide a useful method for approaching projects where the expert data comes from an artistic or a creative contributor. The next section briefly reviews a number of projects that have used fuzzy logic methods in just such a manner for creative endeavor.

2.1. Fuzzy Logic in the Creative Arts

The flexibility of the fuzzy logic framework has produced solutions to many engineering problems and has even been applied in such 'soft-science' fields as sociology, medicine and finance. The possibility of extending its use to the arts has also been explored in a broad review of such attempts [8], but adoption of the technique is not widespread as yet.

An early example of the use of fuzzy techniques for generation of musical note pitches was outlined as a series of example patches for the Max MSP environment [9]. A more recent conference publication highlighted the prospect of using a general fuzzy framework for similar computer-aided music arrangement tasks and gave a particular example for the automatic generation of musical counterpoint [10]. The general technique presented in that research may be extended to other musical undertakings, such as improvisation and composition, through the inclusion of more expert knowledge taken from the corpus of music theory.

Fuzzy logic has been used to drive expressive music performance systems. In one such project, input camera data was analysed using a fuzzy logic system in order to classify the control signal using 'emotional' labels [11]. Musical output was then modified to reflect this high-level abstraction of the input, resulting in a type of 'emotional control'. The project showed the potential of using linguistic variables to incorporate qualitative expert knowledge into a musical controller, contrasting with other data-driven soft-computing approaches such as Neural Networks and Hidden Markov Models.

Audiovisual composition has used a fuzzy logic based mapping layer to relate the aural and visual realms [12].

Generative systems have been used for many years in artistic domains and a series of systems has been developed that explore the production of musical pieces using a combination of techniques [13]. These systems attempt to foster an organized approach to the production of complex musical variation as distinct from the purely stochastic works generated by the use of constrained random processes. A hierarchical model is used in one system where a 'composer' unit specifies large-scale musical parameters to a set of improvisational 'dumb player' agents that generate the low-level variation in emergent percussive patterns. Fuzzy logic is used to control the amount of variation between subsequent compositions through the modification of their durations, tempo, time signatures and the arrangement of instruments based on desired timbre groupings [14]. Later versions of the system were modified in order to manage the tradeoff between the potential for novel output and the production of music falling within a more tightly-defined aesthetic. In version 2, control was effectively limited to an overall note density parameter which was communicated to participating agents by the composer unit. A fuzzy system was used to decide if the density was within a specified range and agents would play more or less notes in order to produce the desired overall effect. The actions of agents were also determined by fuzzy logic methods which produced decisions that were scaled by specified internal traits. For example a 'fuzzy counter' determined when an agent should start playing after receiving a 'go' from the composer unit [15].

A number of software libraries and tools have recently been developed to allow experimentation with fuzzy logic techniques in the computer music realm [16]. Although some of these seem to be unmaintained, a recent implementation now available online [17] is for the graphical audio-visual development environment Max5 [18].

The ability to include qualitative knowledge in the form of linguistic variables, membership functions and an associated rule base is seen as a major advantage of fuzzy logic systems applied to the computer music realm. The next section outlines a practical example of a Max5 patch developed to automatically add 'groove' to an electronic drum pattern.

3. SYSTEM IMPLEMENTATION

The first step in the development of the system involved deriving knowledge of how the velocities of the hits vary for a real drum performance. As stated previously, an advantage of fuzzy logic-based systems is that they may often first be described in very simple language; - layers of sophistication may be added successively until the system performs as desired. As such, no formal mathematical analysis of the sample recordings was entered into (such as that mentioned previously [5]**)**. Instead, intuitive observations were made by looking at the velocity data retrieved from a drum recording of a real drummer using a commercial plug-in with audio-to-midi conversion capability [19]**.** Once the MIDI file had been extracted, the drum hits were quantized to the nearest beat to simplify later analysis with the automatically generated velocities. An example of the qualitative analysis of a section of the kick drum recording is shown in figure 3. The downbeats are indicated by arrows and it can be seen that these are generally stronger than the hits occurring off the beat. There is a trend for velocities to dip towards the middle of the recorded section. The drum fill signaling the end of the section sees a crescendo. Starting from such intuitive rules facilitated the prototyping of the fuzzy system in Max5 using the FuzzyLib set of JavaScript objects. Development of the velocity controller was broken down into several steps as suggested in established literature [6] and the build process for the system involved the following:

1) *Identification of system inputs and outputs.* These included the position of the percussive hit in the musical section *(time)* and whether the current beat was on a down-beat *(beat)*. The output was the amount of velocity attenuation to be applied to the hit *(dip)*.
2) *Definition of membership functions using linguistic labels.* These functions measured the membership grade of an input or output within a fuzzy subset. Figure 2 shows the membership functions used for the kick drum part implemented in a Max5 patch.
3) *Rule compilation.* A system of rules was compiled that captured the qualitative knowledge gleaned from the simple analysis of the drum recordings. Examples of these rules for the kick drum part are given in Table 1.
4) *Inference.* The amount of rule firing was determined through experimentation with various fuzzy inference systems in order to produce results that mimicked the general trends observed in the recordings of the real drummer.

4. ANALYSIS

A MIDI file containing a drum pattern with beat positions matching the recorded kick drum part was run through the fuzzy humaniser patch. The velocities generated are shown in figure 4. The general trends observed in the recorded drum part are seen in the output of the fuzzy logic system. It is notable that the stress for down-beat hits is less pronounced than that seen in the recorded file. This is a matter of tuning aspects of the system such as the membership functions and the inference and normalisation methods used. As this prototype was manually adjusted using trial and error the system is far from optimised. Acknowledging this and considering the small number of ad-hoc rules used as the expert knowledge base, the potential of this fuzzy logic-based approach is very promising. Comparison with other systems such as neural networks, Bayesian probability methods and Hidden Markov Models is yet to be explored.

5. CONCLUSIONS

As noted earlier, an advantage of using a fuzzy system is the potential for fast prototyping. Greater refinement is achievable through the addition of more rules and the tuning of membership functions; - the simple tool presented here will be further developed in order to produce better results. In order to extend the expert database, a deeper analysis of a greater number of drum recordings will be undertaken. These could incorporate different styles, players of differing abilities, varied musical goals and a myriad of other considerations. A training process using neural nets or other techniques could also be used to tune the system to produce particular output. This will allow the extension of the application to full rhythmic sections including a more complete set of percussion instruments.

The set of software tools associated with this project and numerous audio examples will be made available at: http://www.mee.tcd.ie/~lmosulli/fuzzy

6. ACKNOWLEDGMENTS

This work has been supported by the Irish Research Council for Science, Engineering and Technology.

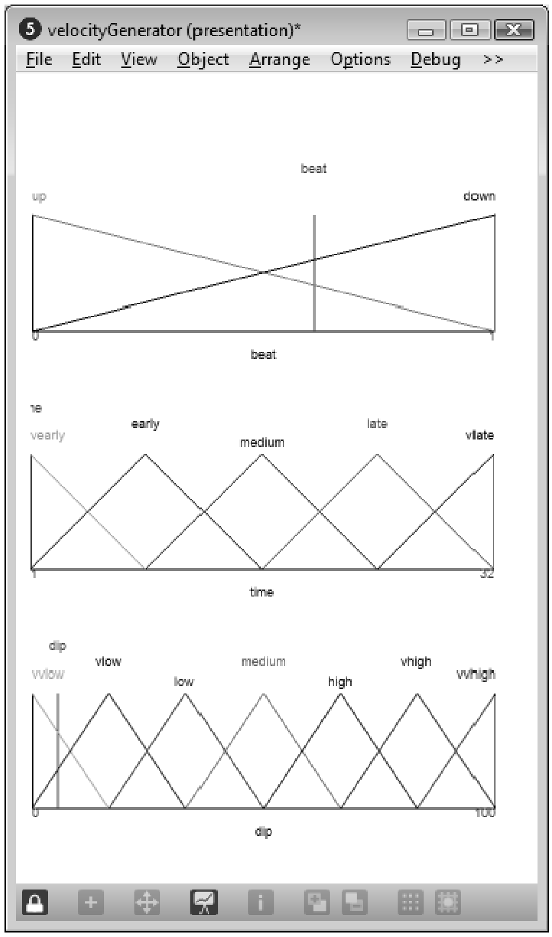

Figure 2: *Membership functions used to fuzzify the inputs* **beat** *(top) and* **time** *(middle) in Max5. The output of the fuzzy controller is the amount of velocity attenuation,* **dip** *(bottom).*

Table 1: *Sample rules used as the expert knowledge base in the fuzzy velocity humaniser system.*

If-Then-Else Rules
if (time is vearly) then (dip is vvlow)
if (time is early) then (dip is medium)
if (time is medium) then (dip is high)
if (time is late) then (dip is medium)
if (time is vlate) then (dip is low)
if (beat is down) then (dip is vvlow)

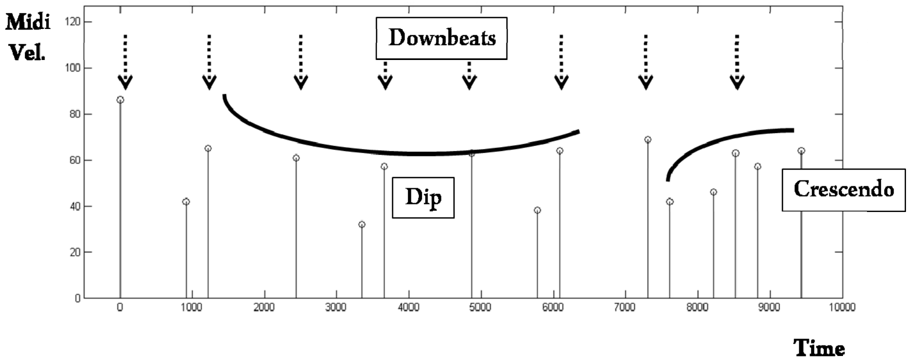

Figure 3: *Qualitative analysis of MIDI velocity of a section of kick drum over time.*

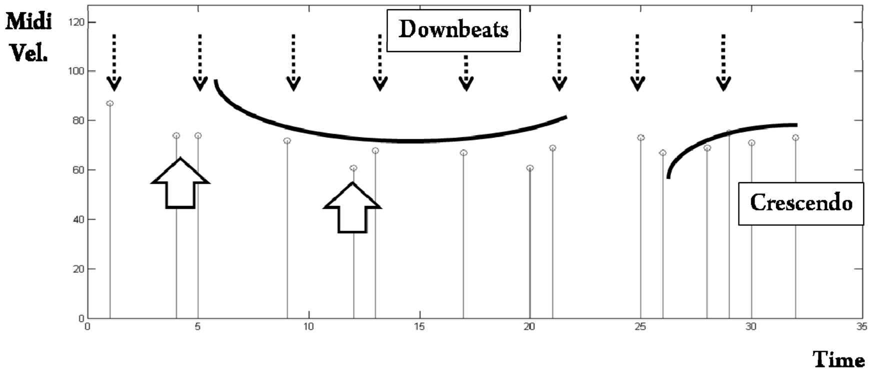

Figure 4: *Qualitative analysis of the output of the fuzzy logic drum pattern humaniser.*

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