A TECHNIQUE FOR CONTROLLING THE PROPORTION OF INFORMATION IN THE SONIFICATION OF COMPLEX TIME-SERIES DATA

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ABSTRACT

This paper presents a technique for controlling the proportion of information present in parameter mapping sonifications which use time-series data. It suggests treating parameter mapping sonification as the addition of a modulated, data bearing signal to a carrier signal and the use of a low pass filter on the time-series data to control the amount of information present in the final sonification. The advantage of this approach is that it allows the level of information present in the audible sonification to be turned up or down, while still representing relationships within the original time-series data.

1. PARAMATER MAPPING SONIFICATION AS THE MODULATION OF AUDITORY PARAMETERS

Parameter mapping sonification (PMSon) maps data to auditory parameters such as pitch, amplitude, duration or timbre in order to communicate some information about the original data to a listener [1]. We can also think of PMSon as the modulation of some given acoustic parameter, acting as a carrier signal, by the data, acting as a modulating signal. This is similar to how we process signals in the fields of RF communications and the related sound synthesis techniques of amplitude modulation and frequency modulation synthesis. Figure 1 outlines this basic concept. We can see from the figure that the output signal (top) results form the modulation of our carrier signal (bottom) with the modulation signal (middle).

$$PMSon_n = Pc_n + Pm_n X_n \quad (1)$$

We can formalise PMSon on the basis of this modulation model as outlined in formula 1 where $PMSon$ is the audbile parameter mapping sonification, Pc is the minimum carrier parameter (i.e. the lowest parameter value to which data is mapped), Pm is the range of parameter values modulated by the data and X_n is the data. Thus formalised, PMSon essentially involves choosing an auditory carrier parameter along which to represent data, deciding on the minimum value of that parameter (Pc) and then deciding on the range of values (Pm) to map your data (X) to.

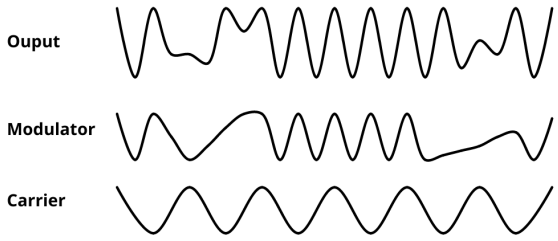

Figure 1: Example of the modulation of a carrier signal with a modulator.

2. THE PROBLEM

There is a distinction to be made here between data and information. The data in this context is the time-series data that we are mapping to some sonic parameter. Information, on the other hand, is extracted by the listener from the resulting PMSon. In order to control the amount of information a listener can extract from a PMSon we need to control how the data is mapped to sound. There are a number of strategies we could adopt here. One approach might be to re-scale Pm thereby, changing the mapping strategy so that the original data is linked to a greater or lesser range of parameter values. This is a common approach in PMSon and referred to across the literature as 'tuning' of the mapping strategy or mapping function [2]. This approach has its drawbacks when working with complex, high density time-series data. The rapidly varying components of the data can dominate the perceptual result and obscure any components of the data that might evolve at a slower or more intermediate pace. The listeners' attention is drawn to the rapid variation in sonic parameters ([3]. This problem cannot be solved by constraining the range of Pm. In fact it is compounded because as the overall range is reduced, the perceptual space allotted these slower trends is compressed and they become less audible. Expanding out the range is equally unlikely to help as the rapidly varying trends continue to obscure the result as discussed previously. This approach doesn't so much allow you to control the level of information in a sonification, but obscures the information instead.

This is generally dealt with by cleaning the data before it is re-scaled.

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3. THE SOLUTION

A more effective solution to this problem that retains the relationships in the original data regardless of the pace at which they vary, involves transforming our data before we map it to sound. Formula 2 describes a method for filtering the rapidly varying or high frequency content from our original data set. It divides the difference between our current input data value X_n and our previously filtered value Y_{n-1} by a smoothing variable α and adds the result to our previous filter value Y_{n-1} to compute our current filter output Y_n. This smoothes out our signal and reveals lower frequency content present in the original data.

$$Y_n = \left(Y_{n-1} + \frac{X_n - Y_{n-1}}{\alpha}\right) \quad 0 > \alpha \leq X_n - Y_{n-1} \tag{2}$$

It is essentially a low pass filter on our input data that smoothes out the high frequency (rapidly varying) components while leaving the lower frequency relationships intact in accordance with the smoothing factor α.

$$PMSon_n = Pc_n + Pm_n Y_n \tag{3}$$

To map this to sound we simply need rewrite our original equation describing $PMSon$ with our new filter variable Y_n as demonstrated in formula 3 above. By controlling α we can determine how much of the data in our data-set becomes information in our sonification with higher values for α revealing lower frequency relationships that evolve more slowly and higher values revealing those trends which vary more quickly. In this way we can present an overview of the major trends in a given data set by selecting a large value for $alpha$ and filtering out all but the most slowly varying trends, or we can choose a higher value that allows more of the detailed high frequency content to emerge.

4. IMPLEMENTATION AND DATA TO SOUND MAPPINGS

The output data Y_n can be mapped to any auditory parameter. It can be mapped to control a simple auditory dimension like, pitch or a more complex parameter such as perceived distance of a given sound source.

4.1. Pitch Based PMSon

The technique can be easily implemented in a range of audio programming and signal processing environments. Figure 2 presents a live implementation in Max 8. The advantage of a live implementation is that it gives the listener control over the data allowing them to choose a representation that is suited to the task they are trying to complete. For example, if they're interested in broader overall trends a lower value for α would be preferable as it will expose the slowly varying trends over time, while a higher value reveals more of the moment to moment fluctuations in the data.

This implementation maps data to the frequency of a sine wave. The data is a series of pseudo random values between 0 and 1 produced by a drunk walk algorithm (step size = .1). It produces 50 new values every second. The filter outputs are computed sample by sample on the input data in accordance with the $alpha$ provided. The result is multiplied by 220 to give us our modulation range from 0-220hz.This is in turn added to our carrier minimum of 220hz and the result is mapped to the frequency of a single sine wave generator.

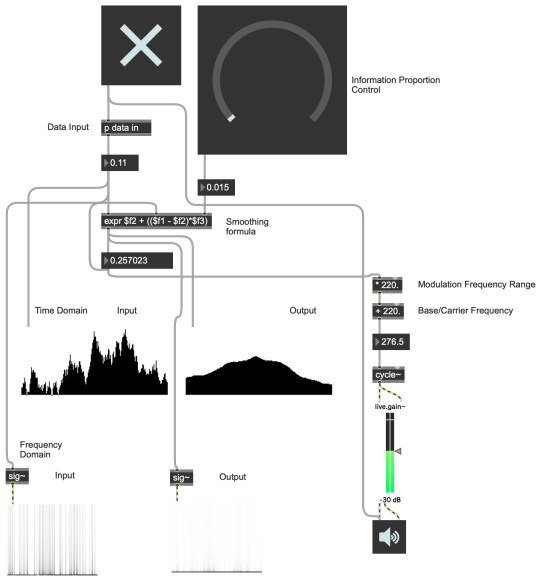

Figure 2: Example implementation in Max 8.

5. DISCUSSION AND FUTURE WORK

A key advantage of this approach is that it can allow the listener to control the proportion of information provided in the signal, filtering out highly changeable data relations to focus on slowly evolving trends that represent the overall shape of the data or zoom in to hear each of the individual value changes in the data-set.

A key difference in this approach is that filtering of the data in a sonification context often happens outside of real-time and is carried out by the designer rather than the user. The general approach involves cleaning and scaling the data before passing it to the mapping transform. Giving the user the ability to choose the level of filtering applied to the data signal may open up new sonification applications.

5.1. Piggy-Backing, Complex Mapping and Testing

The next step of this project will develop a prototype that uses the piggybacking technique introduced by Fitch and Kramer [4]. This is a variant on the many-to-one approach to mapping and it in involves mapping multiple streams of data to different audible parameters within a single audible sound. This is extended in the authors previous work [5][6].

A third prototype in which a single data stream sampled at differing levels of filtration is mapped with the piggy-baking technique to control a range of sonic elements within a fully realised soundscape sonification context will also be created. Each of the three prototypes will then be tested for their efficacy in a series of listening tests that will involve both expert and non-expert listeners and the results thereof will be incorporated into the further development of the prototypes.

6. REFERENCES

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