EXTENDED WAVEFORM SEGMENT SYNTHESIS, A NONSTANDARD SYNTHESIS MODEL FOR MICROSOUND COMPOSITION

Nikolas Valsamakis
Technological Educational Institute of Crete
Department of Music Technology and Acoustics
E.Daskalaki, Perivolia, 74100 Rethymno, Greece
vals@stef.teicrete.gr

Eduardo Reck Miranda
University of Plymouth
Computer Music Research,
Drake Circus, Plymouth PL4 8AA, UK
eduardo.miranda@plymouth.ac.uk

ABSTRACT

This paper discusses a non-standard technique for time-domain waveform synthesis. In Extended Waveform Segment Synthesis sound is described as a structure of blocks of amplitude micro-fluctuations. These structures can be updated during synthesis or different structures can be combined generating dynamic evolving waveforms. This technique is intended to be: first, an extension of the existing linear segment synthesis techniques, second a generalized framework of various existing non-standard techniques - like stochastic waveform synthesis or pulsar synthesis - and third, the basis of new directions in composing the sound and in waveform transformation. The concept of a compositional structure that goes down to the microlevel is also presented.

1. INTRODUCTION

1.1. Non-standard Synthesis

The term non-standard synthesis is used to frame a collection of otherwise different approaches to sound design and differentiate them from other standard and commonly used approaches (FM, AM etc.). What is common to these techniques is that they do not refer to some acoustical theory or model but rather are based on rules and processes that explicitly define the relationships between sound samples [1]. These relationships determining the morphological properties of the emergent sounds. Under this approach compositional theory is applied down to the lowest possible synthesis level.

1.2. Waveform Segment Techniques

In waveform segment techniques wave fragments are assembled together to form sound waveforms. These techniques operate exclusively in the time domain and describe sound by referencing only to amplitude and time values. The time scale of the operations is near the threshold of auditory perception, placing the techniques in the territory of microsound. Basic waveform segment synthesis was introduced by Bernstein and Cooper [2]. Among composers that have designed systems taking a non-standard approach and based in segment synthesis are: G.M.Koenig in SSP [3], H.Brun in Sawdust [4], Paul Berg in PILE [5], I.Xenakis in GenDy [6] and A.Chandra in Wigout and Tricktracks [7].

2. EXTENDED WAVEFORM SEGMENT SYNTHESIS

In Extended Waveform Segment Synthesis (EWSS) a waveform is constructed by assembling blocks of amplitude fluctuations with very short durations (hundred microseconds). In EWSS each separate wavecycle of a waveform is composed by a *number of segments*. These segments are joined together in a *structure* to form a complete wavecycle. Therefore, the segment is the building unit of this synthesis technique. Each segment is defined by *amplitude*, *length* and *shape*. Both the amplitude and the total length of the structure are normalized, giving independent control to the final amplitude and frequency of the sound. To avoid unwanted discontinuities between neighboring segments, each segment's starting amplitude is the previous segment's ending amplitude. This amplitude transient lasts according to the segment's length. The segment shapes are stored in different lookup tables.

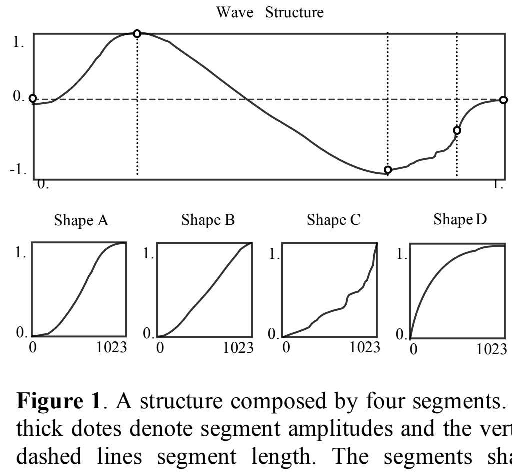

Figure 1. A structure composed by four segments. The thick dotes denote segment amplitudes and the vertical dashed lines segment length. The segments shapes stored in tables are displayed below.

The segment shapes can be produced by the application of mathematical functions, can be designed by the composer by hand or can be derived from recorded sounds. The shape of the segment affects the smoothness of the transient. The joining of succeeding segment shapes with their respective length ratios and amplitudes completes a structure. Shapes with abrupt changes or discontinuities usually produce higher frequency spectral components. Similar sound characteristics are encountered on succeeding segments with minimal length ratios and large amplitude differences. The data set of a structure can be updated during synthesis or different structures can be combined generating dynamic evolving waveforms.

2.1. The Core Synthesis Algorithm

In the current implementation we used arrays to store the *amplitude*, *length ratio* and *shape index* of all the segments. The order in which these arrays are indexed forms a *structure*. The segment *shapes* are also stored in tables and are selected by the shape index. These tables can be of arbitrary length. The amplitude values of the segment shapes are normalized between [0. – 1.]. Usually, the first amplitude value is set to zero and the last amplitude value to one. The length ratio defines the duration of each segment proportional to the total length of the structure. The actual total length of each structure is determined by the set output frequency and the sampling rate:

$$StructureLength = SamplingFrequency / OutputFrequency \quad (1)$$

The total length multiplied by the segment's length ratio gives the actual length of each segment [n]:

$$SegmentLength[n] = LengthRatio[n] * StructureLength \quad (2)$$

A *phase index* pointer reads the amplitude values for each segment shape from its relevant table. By reaching the end of each table it skips to the next segment shape table. Because the length of each segment usually differs from the size of the shape table, the phase index pointer has a variable *index increment*. The index increment takes different values for every new segment:

$$Increment = TableSize[n] / SegmentLength[n] \quad (3)$$

Since the phase index usually takes a real value it interpolates linearly between the two neighboring table entries. The two values are weighted according to the floating part of the phase index.

2.2. Segmenting Sampled Waveforms

The EWSS algorithm can be extended from the application of user-defined segment shapes to the application of sampled sounds. This can be achieved by splitting a selected part of a recorded sound into segments. These segments are then normalized and stored in tables as different segment shapes. If these segment shapes are played sequentially in their initial order along with their respective amplitudes and lengths, then the original sampled waveform can be reproduced. Therefore, the continuity and smoothness of a structure depends on the nature of the derivate signal.

Up to the present stage of our research, we have devised a simple algorithm for segmenting a waveform. This algorithm searches for parts of the waveform that have upward or downward direction and lead to important amplitude peaks. The endpoints of the detected segment should take the minimum and maximum amplitude values for that waveform part. This direction is still under research.

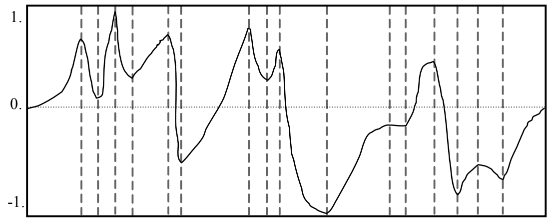

Figure 2. Segmented waveform of a recorded sound. Dashed lines denote different segments.

3. HIGHER-LEVEL ORGANIZATION

The real strength and interest of EWSS is revealed by the dynamic control of the core algorithm during synthesis. Apart from changing the output fundamental frequency and the total waveform amplitude, control can be applied to the amplitude, length ratio and shape of every different segment. The control and update of these parameters can be applied throughout synthesis down to every new wavecycle. Therefore, a sequence of new structures is produced where every structure is slight or grater variation of the previous one. This option opens new directions in waveform synthesis and transformation but requires a large number of parameters that have to be renewed each second. Therefore, it is necessary to provide some higher-level organization model or *scheme* for compositional purposes. The scheme is a set of rules, procedures and data that automatically creates, combines and connects new structures. This allows the composer to define fewer global parameters and automate the detailed control of complex EWSS.

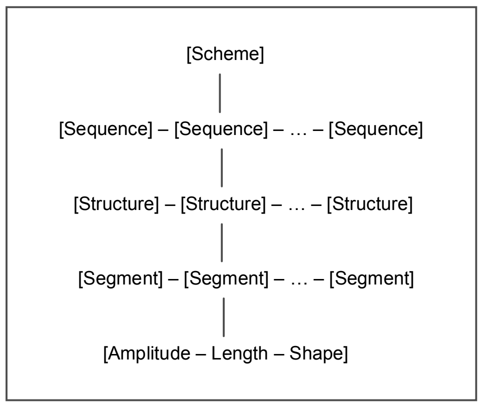

Figure 3. Compositional hierarchies in EWSS.

Schemes generate *sequences* of structures. A number of different structures is set in order form a sequence and can produce complex waveforms that exhibit change over time. Gradual transformation from one structure into the next is achieved by interpolating the amplitude, length and shape datasets of the segments over time. Therefore, a sequence can be defined as an array of structures along with their relevant interpolation times or *structure length*. If the structure length is set to zero then no interpolation occurs and the next structure follows directly. In general, any arbitrary interpolation function could determine the shape and speed of transformation. These functions can be calculated directly or stored in tables. Interpolation between structures can be conceived in a way similar to the interpolation between amplitude segment values occurring over a specific segment length and with a specific segment shape. Figure 3 illustrates the compositional hierarchies when composing exclusively with EWSS.

3.1. Structure Sequencing

The simplest form of implementing higher-level organization is when the composer defines the sequence of structures himself/herself. Although the concept of interpolation automates the transformation between structures, the composer has yet a lot of manual work, which makes the process cumbersome. A graphical user interface helps the composer to visualize and accelerate the compositional process enabling design sequences that are more complex.

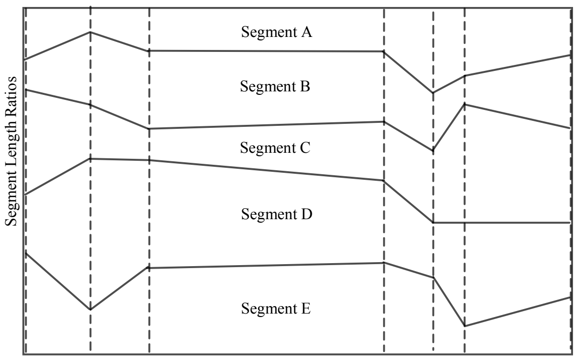

Figure 3. Graphical sequencing. The graph shows an example of linear interpolation between the *segment length ratios* of 7 structures. Each structure is comprised of 5 segments. The dashed lines denote the placement of the structures in time.

3.2. Schemes for other synthesis techniques

One of the objectives of EWSS is the construction of a common framework whereby other nonstandard synthesis techniques can be represented. Depending on the scheme set by the composer various techniques can be achieved

3.2.1. Pulsar Synthesis

In Pulsar Synthesis, proposed by C.Roads [8], a wavecycle consists of an arbitrary waveform or pulsaret followed by a silent time interval. Both of these quantities are continuously variable during synthesis, forming a pulsar train. In EWSS the pulsaret part is represented by a combination of segments either designed by the composer or taken with segmentation from a sampled sound. The last segment having the amplitude values always set to zero represents the silent part. Varying the segment length ratios over time produces an evolving pulsar train.

3.2.2. Stochastic Waveform Synthesis

In Stochastic Waveform Synthesis, proposed by I.Xenakis [6], a sound is represented as a polygon whose endpoints are subjected, irrespective of amplitude and length, to the action of two layers of bounded random walks. Every new wavecycle is a deformed version of the previous one. In EWSS this can be represented by using a scheme that models the operation of the two bounded random walks for the segment amplitude as well as for the length ratio. For this purpose only one linear segment shape is used. The scheme produces structures with zero length and generates a sequence of stochastically deformed structures.

4. RESULTS

As mentioned above, the strength of EWSS lies on the higher-order organization scheme. The spectral characteristics of a sound produced by EWSS depends on the number of segments, the amplitude differences between neighboring segments, the length of the segments and, the shape of the segments. EWSS proved capable of creating different families of idiomatic musical structures: from single impulses and rhythmic structures to various continuous sounds and modulated noises.

Experimentation with synthesized segment shapes has shown that the sound materials have a tendency towards raw and spectrally rich waveforms. This proved especially strong in the case of abrupt amplitude changes either because of discontinueties in the segment's shape or because of the combination of very short segment length and large amplitude differences.

Experimentation with segmented sampled sounds produced more warm and natural sounding sonorities. Test were carried out both with samples of musical instruments and with soundscape recordings. We believe that further research in this direction will provide further interesting results.

Our attempt to represent other techniques with EWSS proved also very successful. For this purpose we researched the options of Pulsar Synthesis and Stochastic Waveform Synthesis. Pulsar Synthesis was very easily represented by EWSS and yielded the various characteristic pulsar trains of the method. Stochastic Waveform Synthesis required a more complex scheme. Although only its core algorithm was constructed and only one stochastic distribution was tested, successful results were also derived.

5. CONCLUSIONS

This paper presented EWSS as a nonstandard model for microsound composition. In our experimentations, we obtained a broad sonic palette of various idiomatic but musically interesting sounds. We strongly believe that the compositional hierarchy of EWSS can serve as the generalized conceptual framework for approaching many nonstandard synthesis techniques. Furthermore, the core EWSS algorithm provides the basis for the development of various higher-level organization schemes.

In this direction our current research is focused on cellular automata and particle system. These systems are capable of producing complex and evolving structures, which we believe can give interesting musical results. Research is also being carried out on algorithms for splitting recorded sounds into segments.

6. REFERENCES

[1] Holtzmann, S.R. "An automated Digital Sound Instrumet", *Computer Music Journal*, 3(2):53-61.

[2] Bernstein, A., and Cooper, E. "The Piecewise Linear technique of Electronic Music Synthesis", *Journal of the audio Engineering Society,* vol 24, 446-454.

[3] Berg, P., Rowe R. and Theriault, D. "SSP and Sound Description", *Computer Music Journal*, 4(1):25-35.

[4] Grossman, G. "Instruments, Cybernetics and Computer Music", *Proceedings of the 1987 International Computer Music Conference*, San Francisco: ICMC, pp. 212-219.

[5] Berg P. "PILE – A Language for Sound Synthesis", *Computer Music Journal*, 3(1):30-41.

[6] Serra, M-H., "Stochastic Composition and Stochastic Timbre: GENDY3 by Iannis Xenakis", *Perspectives of New Music,* 31(1):236-257.

[7] Chandra, A. "The Linear Change of Waveform Segments Causing Non-linear Changes of Timbral Presence", *Contemporary Music Review* 10(2): 157–69.

[8] Roads, C. *Microsound*. MIT Press, Cambridge, Massachusetts, 2001.