Real-time Granular Sampling Using the IRCAM Signal Processing Workstation

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Running Title: **Real-time Granular Sampling**

Abstract

This paper describes research into granular sampling, including "time-stretching" techniques, and presents a musical application using the IRCAM Signal Processing Workstation in which granular sampling is controlled via turbulence algorithms and stochastic processes in a real-time compositional environment. Additionally, an important aspect of this work involves the control of granular techniques via the real-time detection and tracking of musical parameters of live instruments.

Key words

granular synthesis, granular sampling, Max, real-time processing, time-stretching, turbulence

Introduction

Techniques for producing granular synthesis, and compositional approaches for exploring these techniques, have been presented by various composers [Xenakis 1971; Roads 1978]. More recently, important compositional and technical results have been presented in the domain of real-time granular sampling [Truax 1987], which has proven to be a powerful technique for timbral transformation in real time. This paper gives a brief explanation of granular techniques, including earlier work by the author using "time-stretching" techniques [Jones & Parks 1988], and presents a musical application using the IRCAM Signal Processing Workstation (ISPW) [Lindemann, Starkier & Dechelle 1990] in which granular sampling is controlled via turbulence algorithms and stochastic processes in a real-time compositional environment [Truax 1988; Washka & Kurepa 1989; Di Scipio 1993]. Recent compositions by the author for instruments and live ISPW are referenced. An important aspect of these pieces involves the "expressive" control of granular techniques via the detection and tracking of musical parameters of live instruments in real time [Lippe & Puckette 1992; Wessel, Bristow & Settel 1992]. A user interface has been developed by the author using the program Max [Puckette 1988, 1991] running on the ISPW.

Description of Granular Techniques

Briefly described, the technique of granular synthesis involves the production of a multitude of short sounds (grains) consisting of a waveform, to which an amplitude envelope has been applied, at a specified frequency and amplitude. These grains of sound, produced at a high rate of speed, are usually overlapped with neighboring grains in order to produce a certain density and continuity of sound. A simple, standard description of a granular synthesis model includes the following constants: a sinusoidal waveform, a bell-shaped amplitude envelope with a duration of 20 milliseconds, and an overlap-time of 5 milliseconds between successive grains. In this model, the pitch and maximum amplitudes of individual grains may be considered as compositional variables. (See figure 1.)

The technique of granular sampling involves the application of the above-described technique to a stored sampled sound in which the waveform used in granular synthesis is replaced by a small chunk of sampled sound. Thus, for each grain, the onset time into the sampled sound becomes a compositional variable, along with the pitch and maximum amplitude. Furthermore, in a more detailed model of granular sound production, the waveform (or sampled sound), envelope description, grain duration, rate of grain production, overlap of grains, spatial location of each grain, etc., may all be considered as compositional variables.

With this large palette of parameters, it is clear that an immense quantity of data is required in choosing individual values for each grain of sound. Historically, compositional algorithms have often been employed to automate these choices. The practicality and necessity of automating control of granular techniques was obvious to Xenakis, who, prior to working with granular techniques in electronic music had already explored similar problems in the instrumental domain during the 1950s with works such as *Pithoprakta,* in which he employed techniques akin to a kind of "granular" conception of instrumental music.

Granular Sampling as Musique Concrète

While granular synthesis and granular sampling are variants of the same technique, their musical essences lie at opposite poles of the electronic music paradigm. One is immediately confronted, historically speaking, with the two main categories of electronic music: granular synthesis is *Elektronische Musik,* making use of purely synthetic sounds, while granular sampling is part of the world of *musique concrète* in which recorded sounds are manipulated and transformed. As the Canadian composer, Jean Piché, has suggested, granular sampling is an "input dependent" technique. Thus, using granular techniques on sampled sounds offers a level of musical implication which does not exist in granular synthesis: one is acting on and transforming a pre-existing sound object.

As mentioned above, in granular synthesis the parameters most often controlled algorithmically are the pitch and amplitude of grains. The ordering of grains in a coordinate space is calculated, giving some sort of density distribution, but the concept of grains in an ordinal sense remains somewhat abstract. The result of arbitrarily different orderings gives sounding variants which, although possibly very different in nature, remain abstract synthetic sounds. Since the synthetic waveform used in granular synthesis is replaced by a small portion of a stored sampled sound in granular sampling, an additional parameter exists: onset time into the stored sound. This additional parameter can be of primary importance in granular sampling. No longer a kind of "commutative" or arbitrary parameter, *grain order* may have important consequences, thus creating a hierarchy of parameters. In fact, this hierarchy may be considered implicit in the very nature of granular sampling. Using a piano note as the stored sound, if onset times descend in an ordinal fashion from high to low, while density distributions of all other parameters are randomly calculated, the sounding result will always be recognized as a piano note played backwards even though variants may sound quite different. Furthermore, the ability to "deconstruct" sounds via the manipulation of onset times in granular sampling, moving between the boundaries of recognizability and non-recognizability on a continuum, is one of the principle, musically interesting characteristics of granular sampling.

An ISPW User Interface for Granular Sampling

Using Max on the ISPW, I have constructed an interface for controlling granular sampling in real time. All the parameters mentioned above, including: onset time into the sampled sound, pitch, envelope description, maximum amplitude, grain duration, rate of grain production, overlap of grains, and spatial location of each grain are all controllable in real time for each grain that is calculated. Max also allows for real time switching from one sampled sound to another; either by reading elsewhere in memory, loading soundfiles from disk, or sampling anew (all of which can be done while the granular reading continues to take place). A control panel allows for the setting of parameter values via sliders and number boxes, and parameters can be independently changed over time via automation. Independent granular sampling tasks can run at the same time. Since the point of departure for this work in granular sampling grew out of experimentation with "time-stretching" of sampled sounds, each task originally produced a single stream of grains. Multiple, simultaneous grain attacks were a later development. (The number of tasks and the number of overlapping grains within a task are limited by real-time constraints.) A recent addition to the system allows for real-time mixing and sampling of the granular output of simultaneous tasks, which then may be reused as sample tables for other granular sampling tasks. This "recursive" approach offers exponential increases in densities, and a musically reflexive dimension (the ability to recall earlier musical material) which can be pertinent.

Time-Stretching of Sampled Sounds

Time-stretching of sampled sounds has been studied for altering speech signals for quite some time. Compositionally, this technique offers the possibility to separately control pitch and time in sample playback. Slowing down a sound without changing its pitch, or changing pitch without changing playback speed, have interested composers since the early days of electronic music. In the late 1940s, D. Gabor developed a type of time-stretching which is essentially a form of granular sampling. His technique was commercialized as the Springer tape-recorder, which gave composers an analog tool for experimentation [Roads 1991]. A simple digital model for granular time-stretching makes use of a small number of "sampler voices" which read a stored sound in the following way: each voice produces a grain with a duration of 50 milliseconds, with a 15 millisecond overlap between successive voices. This is repeated cyclically on a continuous basis, while a pitch is specified for each grain and a "precession" rate is defined.

The precession rate is a sliding window which moves or advances a group of sampler voices while they read through a sampled sound from beginning to end at a certain speed. Since the precession rate does not transpose the original sound, a slow precession rate can give a slowed-down playback at the original pitch, or the precession speed can be kept at the original playback speed while the pitch can be altered. With this technique, one can freeze the reading process in a single region by giving a precession time of zero, freely move forwards or backwards in a linear fashion, repeat short sections of the stored sound, and constantly vary the playback time and/or pitch independently. (Note that, essentially, this technique does not change the sequential order of onset times into the sampled sound.) After exploring the above-mentioned possibilities of time-stretching in my compositions *Music for Harp and Tape*, *Music for Guitar and Tape*, and the tape piece *Paraptra*; in which stored samples of harp and guitar sounds were transformed, it was a simple step to produce granular sampling by modifying time-stretching techniques in order to control the onset times into sample tables in a non-sequential fashion.

Initial Experiments in Granular Sampling

My initial experiments with granular sampling were extremely simple and employed a single stream of grains. The auditory result of randomly choosing onset times into a stored sound, while producing grains at the original pitch of the sound, is fairly statistical. Using phrases of clarinet music, one has the impression with certain phrases that, for example, an entire 10-second phrase is sounding simultaneously. This is not surprising, since any onset is just as possible as any other, and, since, in using 20 millisecond grain durations with overlaps of 5 milliseconds between successive grains, more than 60 grains are produced each second. (Increasing the overlap time between grains will greatly increase the density of grains per second.) One sampled clarinet phrase, in particular, made up of approximately 5 seconds of rapid short notes, and then a 5-second held note was noteworthy because of the omnipresence of the long note in this statistical sound mass. It was immediately obvious that the musical content of the stored sounds being operated on was not a trivial aspect of the procedure, and that mapping algorithmic calculations onto the stored sound might produce more successful results if the musical content of the sound was taken into account.

Statistical and Nonlinear Algorithmic Mapping to Control Parameters

The next attempt at controlling granular sampling was simply to choose grains within defined "tendency masks" (constantly moving windows with varying sizes). For instance, a window with the size of a single grain which expands to the size of a full 10 second sample table over a specified time produces a sound which begins untransformed and, over time, becomes a statistical sound mass. These tendency masks of constantly moving window sizes and window locations can be used to read through sounds quite freely in a kind of statistical "scrubbing" fashion, creating more or less recognizable playback of the original sounds with a rich amount of timbral variation. Random walks through the sound can be calculated and combined with control over the numerous other parameters available: pitch, amplitude, sample table, envelope description, grain duration, rate of grain production, overlap of grains, and spatial location of each grain, giving one a vast amount of transformational flexibility. My composition *Music for Clarinet and ISPW* employs variants of time-stretching and granular sampling, making use of tendency masks to control virtually all the parameters of granular sampling. In a composition in progress, numerous algorithms have been tried for controlling different parameters using chaotic equations. The fact that these algorithms can be predictively and easily controlled, enabling smooth transitions from the seemingly random towards stability, makes them quite attractive.

Mapping Performer Expression to Control Parameters

Due to the large number of parameters and the much larger number of values needed for each parameter in granular techniques, it is obvious that algorithmic mappings can be extremely useful, if not necessary. Several of the pieces mentioned above involve the use of live performers. Since the ISPW offers tools for real-time audio signal analysis of acoustic instruments for the extraction of musical parameters, another level of control over the granular sampling comes directly from the performers, giving musicians a degree of expressive control over the electronic transformations. In *Music for Clarinet and ISPW* the sampled sounds used for granular sampling are taken directly from the performed score, either sampled on-the-fly during performance, or prerecorded and loaded into memory during performance. Continuous pitch and amplitude tracking of a performance offers musically relevant data which can be used to control aspects of an electronic score, and perceptually create coherence between the instrument and electronics. In the clarinet piece, continuous pitch data taken from the clarinet is often used to control the pitch of grains, and continuous amplitude data controls the windowing of the tendency masks of certain parameters. In an ensemble piece in progress, additional control of parameters is being attempted via spectral analysis, thus allowing for timbral control of the sampling by way of instrumental color changes. (See figure 2.)

Conclusion

Granular sampling is a powerful tool for transforming sampled sounds. Control of granular sampling via non-linear processes in a real-time compositional context, and via continuous control signals made available by the detection and tracking of musical parameters of live instruments in real time, offer composers and performers a rich palette of possibilities. In addition, sampling of the output of a performer in a real time environment, while allowing the performer a certain degree of control over the granular sampling of this same material, can ultimately provide an instrumentalist with a high degree of intimate expressive control over an electronic score.

Acknowledgements

I would like to thank Miller Puckette, Jean Piché, and Agostino Di Scipio for their invaluable technical and musical insights.

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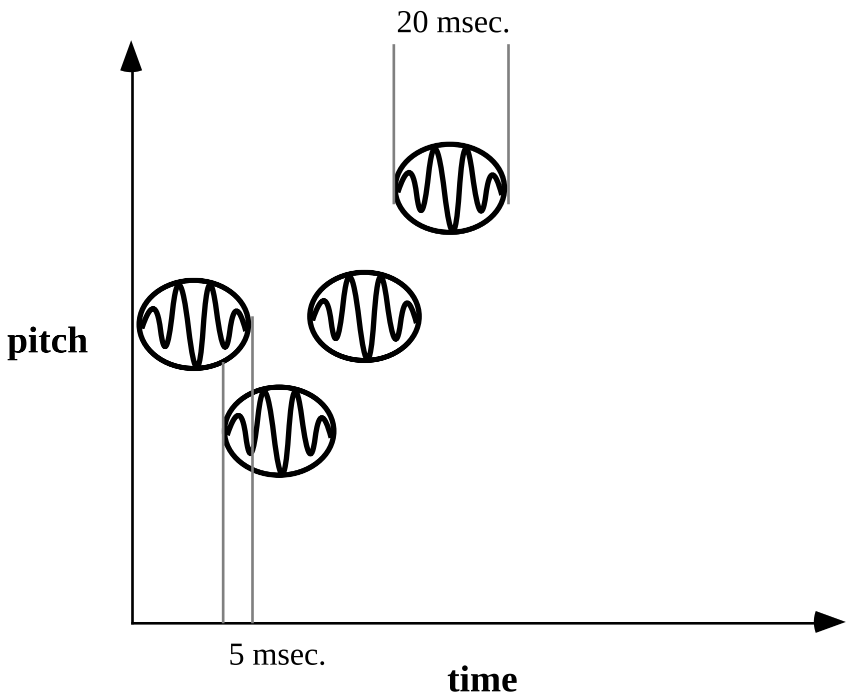

figure 1. Granular synthesis model

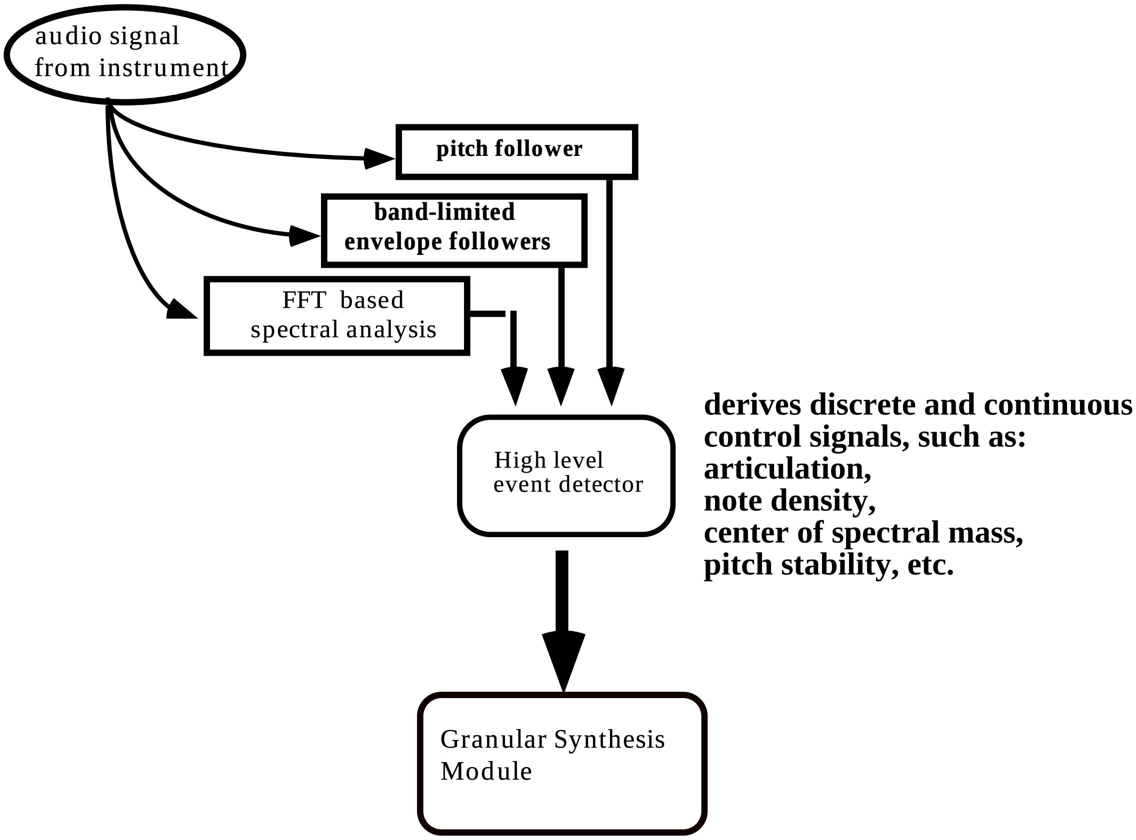

figure 2. Mapping performer expression