An integrated granular approach to algorithmic composition for instruments and electronics

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1. Introduction

The domain of instrumental electroacoustic music is a treacherous one. On the level of coordination between the electronic medium (tape, hard disk, real time system) and live musicians, there are many difficulties, primarily of timing. On the level of sonority, the spectral and dynamic content of electroacoustic sounds have the possibility to be far removed from standard instrumental sonorities. In addition, the balance between a live musician and amplified sounds is difficult to achieve in such a way that the live sound is not overwhelmed by either the volume or the 'presence' of what could be extremely rich, evocative, or dramatic sounds, processed or recorded.

In trying to develop a compositional approach to the mixed domain of instruments and electronics, a number of considerations must be taken into account. In the author's work, which has been oriented toward the development of compositional algorithms, a solution to the problem of integrating instruments with electronic sounds has been adopted based on the principles of granular synthesis. This paper will discuss two compositions which exemplify different treatments of the relationship between the live performer and the electroacoustic component. Both were realized in the instrument-and-tape format, but it is conceivable now that interactive versions could be developed.

2. Adaptation of Granular Synthesis

As is well-known, granular synthesis developed out of a paradigm at odds with the Fourier conception of sound. If a signal is defined as a packet of sonic 'grains,' then certain consequences result. For one thing, it is more amenable to a statistical description. From the point of view of the composer, the granular model provides new possibilities for creating rich sonorities. A sonic texture can be generated by defining the range and density of the grains, along with the parametrical details of the grains themselves. It is a relatively simple matter to create algorithms to generate such textures, as evidenced in the pioneering work of Barry Truax and Curtis Roads, among others. Extensions of the technique into formant synthesis such as FOF (Xavier Rodet) and VOSIM (Werner Kaegi) have provided means for modeling vocal and instrumental sonorities that have proved useful for mixed-media compositions. The granulation of sampled sounds has also proven to be a fruitful method for integrating instrumental and digital sonorities. Barry Truax and Horatio Vaggione have been particularly successful in this area. Work in the real-time domain based on "windowing," a related technique, has been carried out by Cort Lippe and Zack Settel using the different generations/versions of MAX.

In seeking to integrate instrumental music with synthesized sonorities, an extension of the principles of granular synthesis was sought such that the instrumental part could be generated in a similar way. By extending the durations of the grains and widening the ambitus of the "grain fields," the same generative procedures can be applied to both elements. In this way, an integrated approach can be developed, while leaving contraints as to the specific nature of the sonic material as open as possible.

3. *Per Foramen Acus Transire*

In 1986, a first attempt was embarked upon in the direction of creating an integrated compositional approach based on granular principles. The resulting composition, *Per Foramen Acus Transire* for flute/bass flute and tape, was completed in 1987. The electronic sounds were created on the UPIC at CEMAMu.

The first step in the compositional procedure was to define a structural framework for the work. In reflecting the title, "through the eye of the needle," the overall design aimed to unveil a wide-band texture and then gradually tighten it in around a central point, to occur more or less halfway through the piece, and then to allow the music to open out again into a transformed soundworld (the flutist switching at that point to bass flute). Using a generative process based on a permutational procedure adapted from group theory processes, a double series of "focal pitches" were designated, one for each channel of the audio material, the temporal placement being generated by similar means. Having thus defined a harmonic-temporal framework, parallel processes were implemented for the detailed composition of the flute and the tape parts.

The ‘program’ for the flute part was to gradually increase the density of the music at the same time as the range within which the pitches could be generated was being decreased. The aim was to portray the psychological tension of a person undergoing the spiritual process described in the title. To that end, as each focal pitch is reached, a new layer of material is launched. These layers, created according to an algorithm similar to that used to generate the focal pitches, are subject to the narrowing-bandwidth filtering process. Eventually, then, as the flute part reaches its maximum density, a conglomeration of several layers of material, the pitch range within which the notes can be placed is reduced to its most constrained, a single pitch. This, obviously, is the "eye of the needle." The additive process by which the several layers of music are combined for the single performer to play acts to cancel out the original durations of the sequences of notes, leaving only the attacks. The flute, then, ends up playing music of such density that it approaches a granular texture. That the score ends up on a single pitch at its point of maximal density only serves to underscore the parallel with this method of synthesis.

The electronic material follows a parallel process linked to the focal pitches. Around each of these, a "block" of a certain ambitus and duration is defined. It is then filled with "grains" of sound, ranging in length from tenths of a second to tens of seconds. The "pitch-space" is not filled indiscriminately, but is defined in terms of quarter-tone intervals moving out higher and lower from the central pitch. A separate process determines the degree of density for each of these pitch levels within the block, generally decreasing in density the farther the pitch level is from the center. The aim was to create a band of sound around each of the focal pitches, the duration of each block overlapping the next (the two channels being generated independently).

The waveforms used for these electronic ‘grains’ were extracted from a flute sample, and they were organized according to the number of cycles in each (and, by necessity, degree of complexity), from one up to eleven. These were combined with seven families of envelopes, each containing five degrees of amplitude modification. There were, then, 385 different sonic entities to choose from for the ‘grains.’ The choice of harmonically related waveforms (according to the number of cycles filling the wavetable) had the result of creating a timbrally varying sonority, overall, on the basis of grains of fixed spectrum.

A further controlling element for the electronic sounds is the orientation of each grain towards the central 'eye' pitch at the end of the first section of the piece. Thus, all of the 'arcs' were calculated on an angle radiating from that point. At first, the 'glissandi' are not noticeable, as the angle of the arc is calculated over a temporal distance of eight minutes. As the piece progresses, however, and as the grains become closer to the central pitch, the glissandi become more pronounced (for the longer grains, in any case). While the live flute is gradually narrowing in on the 'eye of the needle,' so too are the electronic sounds, by means of glissandi (the focal pitches on the tape continue to be placed across the full gamut of the original pitch-space, rather than being gradually constrained in terms of registral placement. The angles of the arcs become more and more pronounced as the temporal location draws nearer to the central point.

Upon reaching that central 'eye' of the piece, at the eight-minute mark, the music is subjected to a radical transformation. The tape part contains a lengthy (ca. 1 minute) passage or block of material limited to this central pitch. Variation is found in the layering of different waveforms and envelopes, creating a rich timbral evolution, highlighted by the addition of a pre-recorded bell, tuned to approximately the same fundamental. The flutist switches to the bass flute, joining the two pre-recorded bass flutes on the tape. Once the electronic sounds and bells play themselves out, the rest of the piece consists of a trio for bass flutes. Structurally, the music is formed from the remaining strands of material left over from the first half of the piece. As each strand begins at the same time as one of the focal pitches, placed in temporal succession throughout the first section, the texture in the second section gradually thins out as each strand plays itself out. The material is distributed between the live bass flute and the two pre-recorded on the two channels of the tape. An additional element is added to the pre-recorded parts; long whistle-tones that take the place of the rests assigned to the live part. Eventually, this sonority is the dominant one, with long breaks separating the final few notes or phrases of the live performer.

In conclusion, *Per Foramen Acus Transire* represents an attempt to create an integrated compositional approach to the medium of live instrument and electronics. In this case, the electronic part takes the form of a pre-recorded tape, which is made up of both flute sounds and electronic sounds created on the UPIC on the basis of a flute sample. The conception of the piece in terms of 'grains' or discrete elements enabled parallel, closely related processes to be developed for both the flute part and the tape.

4. *Night-flowering … not even sand*

In 1989, a different approach to the medium of live instrument and tape was implemented on the basis of compositional software written in C, and the direct digital synthesis environment of Csound. This project centered around a piece for bassoon and tape (a piece for tape alone was also created on the basis of the same materials, and the compositional software has been used for several works since). *Night-flowering … not even sand* - I was conceived for microtonal specialist, Johnny Reinhard, and explores the domain of 31-tone equal temperament. It was completed in 1990. It would now be possible to generate the tape part in real time.

The tape part was designed to act as a 'sonic environment,' presenting a continuous texture based on the 31-tone temperament. The primary sonority is a plucked-string sound, designed on the basis of the Karplus-Strong algorithm (implemented in Csound as the 'pluck' unit generator). While the conception is granular, in this case, the attacks of each grain are not intended to be masked in order to create a smooth texture. The attacks are distinctly perceivable, the result being more like a 'hyper-harp.' There is also a sustained bass sonority, generated according to the same principles, but with smoother envelopes and longer durations.

The compositional algorithm is built around a 'chaotic' function, the logistic difference equation. The nonlinear output of this simple data generator is analyzed across a limited range of values, and the statistical ordering of values within that range is made use of as a governing feature of the compositional process. In the case of both the tape part and the live bassoon part, the array of values was reordered so as to privilege particular intervals around a central pitch (which changes over the course of the piece according to a separate process built from the same algorithm). In this piece, the smallest interval appears with the greatest statistical frequency, followed by the 'pure' 5th and the 'neutral' 3rd. In this way, there is a degree of intervallic coherence built into both the texture on tape and the succession of notes in the live bassoon part.

As noted, the focal pitches for this intervallic structure are organized according to a parallel process built from the same chaotic algorithm. The two channels of the tape and the bassoon part proceed in parallel fashion, the 'bandwidth' of possible pitches also changing according to a similar process. The density of 'grains' fluctuates in like fashion (the variables being: mean density, range, degree of temporal variability).

There are other elements that are unique to each part (the elements of the synthesis algorithms, the dynamics, the articulatory and extended-sonority capabilities of the bassoon), but the same generative algorithm is used to produce all the elements of the piece. The live performer, in this case, is not tied precisely to particular events on the tape, allowing a degree of interpretative freedom that is unusual for the medium.

5. Conclusion

Granular synthesis is intended to be an alternative approach to sound synthesis (and analysis). As has been demonstrated, the principles of this method can also be adapted to the compositional process and applied to higher-level domains. The advantage of an algorithmic approach built on a granular conception of music is that different media (e.g., instruments, electronic sounds) can be unified on the basis of the underlying identity of design applied to each. Given the difficulties in coordinating the instrumental domain with the electronic domain, in terms of sonority and presentation, this approach is one way of overcoming the problems inherent to the medium of instrumental electroacoustics.

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