Visualizing *Pictor alpha*

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When Curtis Roads asked me to design a visualization of his piece *Pictor alpha,* I was delighted to have the opportunity to present this *microsonogram* in an artistic context. My visualization is based on an analysis of the sound signal of *Pictor alpha*.

Many sound analysis techniques exist. Each method of sound analysis is based on a specific model of the inner structure of sound. For example, some analysis techniques assume that every sound is a combination of sine waves, while others assume that every sound can be analyzed as filtered noise. Each method focuses our attention on some features, while obscuring others.

In the case of the commonly-used Fast Fourier Transform (FFT for short), the analysis model assumes that all sound is a sum of sine waves, whose frequencies are multiples of a fundamental frequency. This model was championed by the nineteenth-century acoustician Helmholtz, a pioneer of musical acoustics. Due to its compatibility with the harmonic nature of some Western music and musical instruments, this model has had far reaching ramifications in academic musical theory and pedagogy.

The FFT has several major drawbacks, however. First among these is the so-called time-frequency tradeoff. If we want more detail about the frequency content of a sound, we lose detail about when this content occurs. Conversely, when we use the technique to reveal information at a finer time scale, we lose resolution in the frequency plane. Another problem is that the Fourier domain is brittle: one cannot freely edit and rearrange the time-frequency energy without danger of clicks and other artefacts when it is resynthesized.

The visualization technique that I used for *Pictor alpha* is called the *Matching Pursuit* (MP) technique. MP represents musical sound along the lines of a theory proposed by the Nobel laureate physicist Dennis Gabor (1947). In Gabor's theory, all sound can be viewed as a collection of acoustical quanta or particles scattered in the two dimensions of frequency and time. MP is one of a class of analysis techniques, often called *granular decompositions,* which distill sound not into a choir of sine waves, but into a symphony of particles. The MP, originated by Stéphane Mallat and Zhifeng Zhang, matches the energy it analyzes in the sound with a large predetermined dictionary of particles. When a matching particle is found, it is removed from the input signal, and what is left over is matched to the dictionary again and again until a desired amount of energy or number of particles is found.

MP analysis requires extremely heavy computation. The analysis of *Pictor alpha* that you see in the visualization on this DVD represents 10 hours of calculation on a 1 GHz computer. Another drawback is that MP analysis can create energy at times where it does not exist, which is counterbalanced with another particle later that cancels out the extra energy. Several ways to deal with this are currently being researched.

The microsonogram

By visualizing sound as a collection of sound particles, we can enter into the molecular structure of a sound. This technique, *microsonography,* is a class of visualizations that graph sound as a collection of microsonic events. The visualization you see in the video represents this view of Curtis Roads's *Pictor alpha,* one that is pertinent to his musical technique.

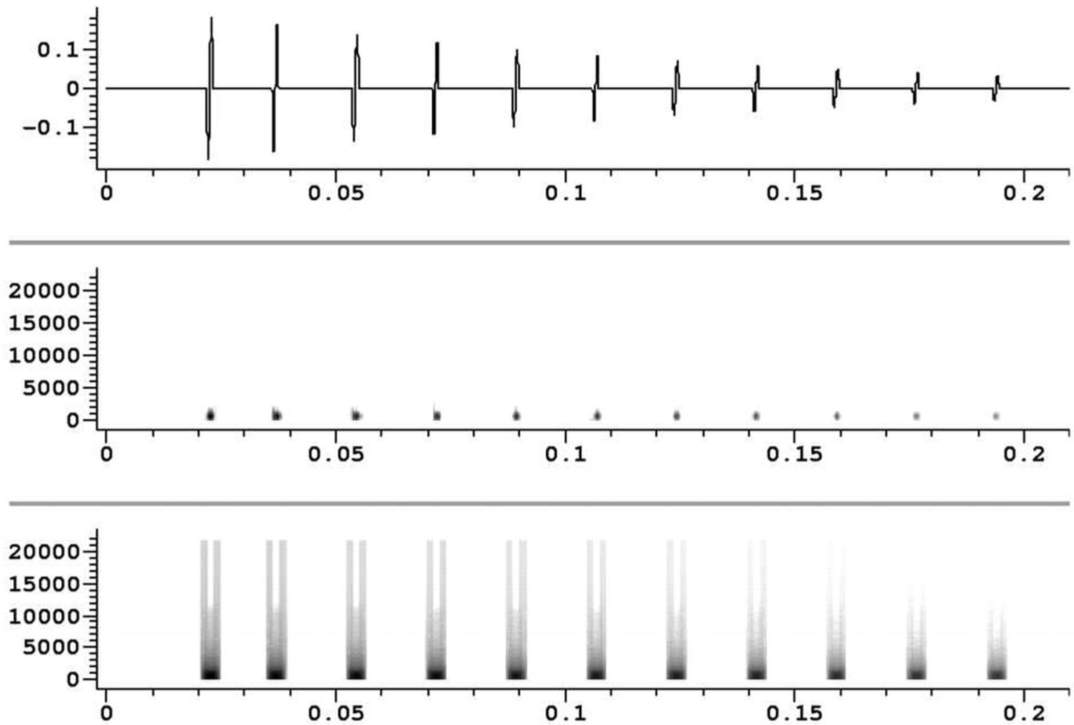

Figure 1 (a) A pulsar train excerpted from *Pictor alpha.* (b) The microsonogram of the first 100 particles found with a MP. (c) A 256 point short-time Fourier transform with a Hamming window.

One can clearly see the differences between sound analysis techniques by comparing their respective visualizations. Figure 1(a) is the signal plot of a pulsar train from *Pictor alpha,* 1(b) is a plot of the first 100 particles MP analysis of the signal in a microsonogram, and 1(c) is a plot of a 256-point Fourier transform with a Hamming window. The FFT is visualized by graphing the intensities of each sine wave in a time-frequency grid by color, darkness indicating strength. MP data is graphed in a similar way, with the spectral energy of each particle composited together, though not in discrete time-frequency "bins" like the FFT. We can easily see how the FFT smears energy of each pulsar across the time and frequency planes, while MP reveals a more localized events. The detail (Figure 2) amplifies this difference.

Another important difference between the traditional sonogram and the microsonogram is illustrated in Figure 3. Here we see (a) an excerpt from *Pictor alpha,* composed of grains with a sharp transient, (b) a microsonogram of the first 100 particles found in an MP analysis, (c) a 256 point STFT with a Hamming window. Note how the FFT (c), while recovering the main pitched component in rough form, dissolves the transient across time and frequency. The microsonogram (b) represents the transient well, as well as better showing the amplitude variation of the pitched component.

The application of the microsonogram to *Pictor alpha* gives us a picture of the inner life of

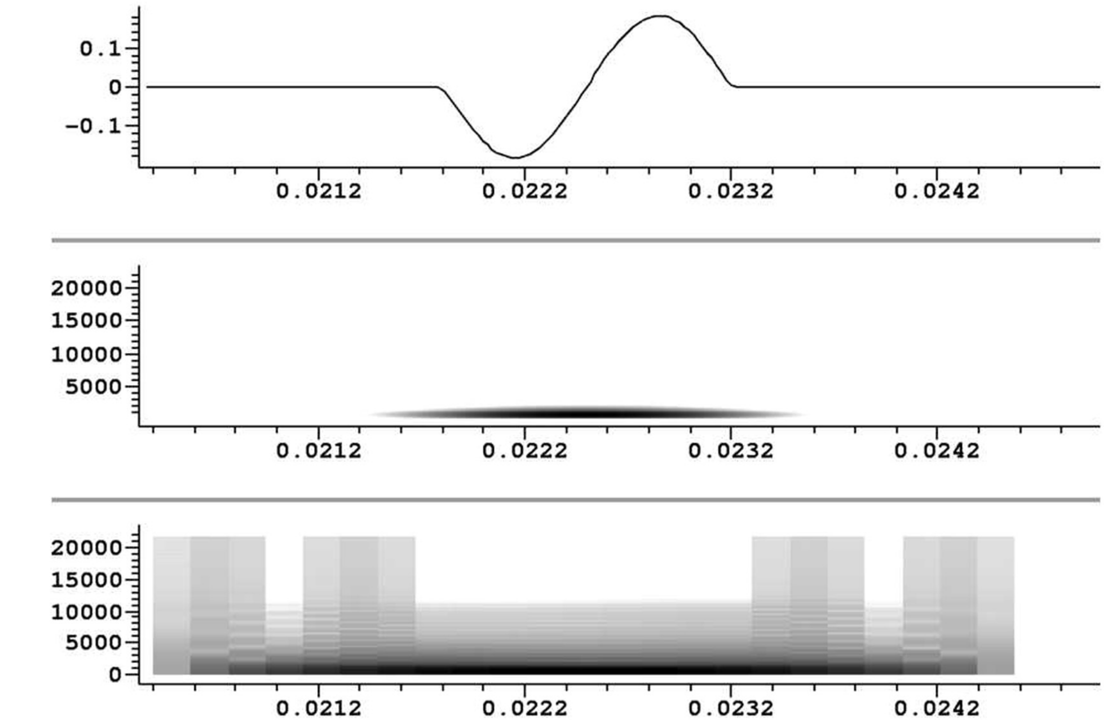

Figure 2. Detail of Figure 1. Note the time and frequency smearing in the short-time Fourier transform representation (c).

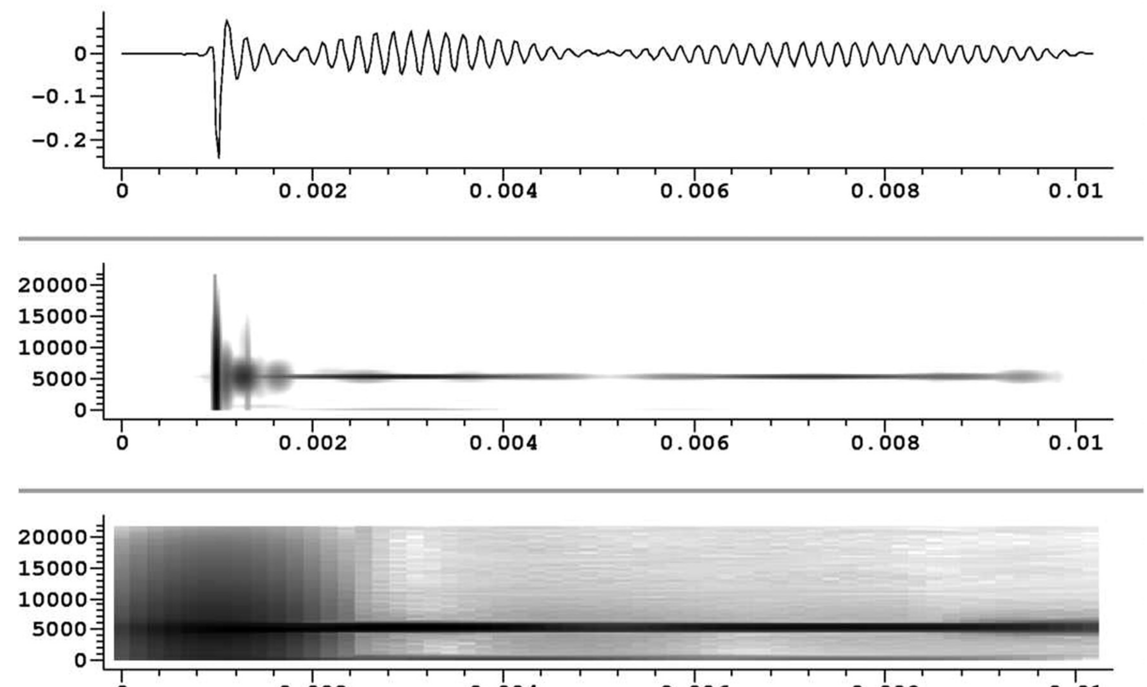

Figure 3. (a) An excerpt from *Pictor alpha* containing a sum of grains, including a sharp transient. (b) The microsonogram of the first 1000 particles found with a MP. (c) A 256 point short-time Fourier transform with a Hamming window. Compare the smearing of the transient in (c) to the clear representation in (b).

sound as particles. Where we once saw the blurred harmonic strata of the FFT, we now see clusters and constellations of grains in a field of open space. The MP representation shows us the analytical counterpart to granular synthesis.

The future of granular decomposition

The time-frequency resolution of the MP is perhaps the most interesting characteristic of the analysis data. Energy is more concentrated where it occurs, and can be more clearly visualized than the FFT. This data in a granular decomposition is organized in a more musically useful fashion. Transients are now distinct elements, rather than the by-product of complex phase interaction. Pitched events are more discretely located in the spectrum.

Techniques such as MP open up a new realm for transformations that were difficult if not impossible with the FFT. Transformations such as coalescence or disintegration, which were tediously applied with a tracking phase vocoder, are a simple operation in the domain of granular decomposition. The crude techniques of time-domain granulation can now be applied inside a sound, rather than on their surface. Rather than specifying clouds of particles, clouds can be borrowed from existing sources, sheared, and sprayed across the speakers of a performance space.

Just as the application of the FFT to computer music yielded numerous techniques for the manipulation of sound, granular decompositions promise to deliver us a menu of transformations with as yet unheard possibilities. Further work is needed, and is being carried out, to bring this domain under the eager fingertips of the computer musician.

Further resources

Bacry, E., et al. 1997-2003. LastWave, software and documentation. Internet: www.cmap.polytechnique.fr/~bacry/LastWave/index.html

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