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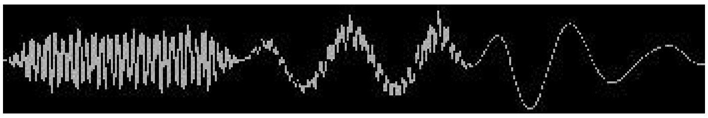
Chaosynth - A Cellular Automata-based Synthesiser

Granular Synthesis and Chaosynth

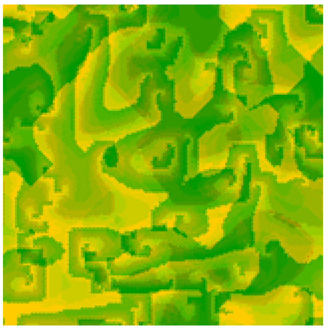
Granular synthesis works by generating a rapid succession of very short sound bursts called granules (e.g. 35 milliseconds long) that together form larger sound events.



A rapid succesion of tiny sounds form larger complex sounds.

The results tend to exhibit a great sense of movement and sound flow. This synthesis technique can be metaphorically compared with the functioning of a motion picture in which an impression of continuous movement is produced by displaying a sequence of slightly different images at a rate above the scanning capability of the eye. The composer Iannis Xenakis (France) is commonly cited as one of the mentors of granular synthesis. In the 1950s, Xenakis developed important theoretical writings where he laid down the principles of the technique. The first computer-based granular synthesis system did not appear, however, until Curtis Roads (USA) and Barry Truax (Canada) began systematically to investigate the potential of the technique in the 1970s. So far, most of these systems have used complex mathematical formulae (e.g. probabilities) to control the production of the granules; for example, to control the waveform and the duration of the individual granules. Chaosynth uses a different method: it uses a cellular automaton called ChaOs. ChaOs is much more efficient and flexible to use than most mathematical methods used by other granular synthesis systems so far. Chaosynth is an essential tool for ambient and electroacoustic music composers. Composers working with film or computer-game soundtracks will also find this program very useful. Chaosynth is aimed to produce sounds that cannot be found in the "real" acoustic world (e.g. science-fiction type effects), but its outcome may also resemble the sounds of flowing water, bird calls and insect-like noises. Moreover, Chaosynth also produces great visual images that can be used as the raw material to produce art work and animations.

The ChaOs cellular automaton

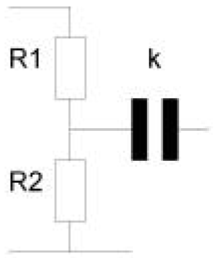


ChaOs is the cellular automaton that controls the formation of sound granules. - Click on the image to see the animation

ChaOs (an acronym for Chemical Oscillator) is a model of a neurophysiological phenomenon referred to as a neural reverbatory circuit . It is well known from neurophysiology that the neuronal activity of the nerve cells in the brain forms neuronal pathways. A large number of neuronal pathways are formed throughout the brain, branching and coalescing, and butting out abortive channels. An important feature in some of these neuronal pathways is the eventual formation of a reverbatory circuit in which the wave of neuronal information travels repeatedly around the same closed loop of nerve cells. Such a reverberation circuit presumably can maintain the excitation of the entire system of pathways for a certain period of time, suggesting a model for a possible memory mechanism of the brain.

ChaOs can be thought of as an array of identical electronic circuits called nerve cells. At a given moment, nerve cells can be in any one of the following conditions: quiescent, depolarised or burned. The automaton tends to evolve from an initial random distribution of cells in the grid towards an oscillatory cycle of patterns. The behaviour of ChaOs resembles the way in which most of the natural sounds produced by acoustic instruments evolve: they tend to converge from a wide distribution of their partials (for example, noise) to oscillatory patterns (for example, a sustained tone).

A nerve cell interacts with its 8 neighbours through the flow of electric current between them. There are minimum (*Vmin*) and maximum (Vmax) threshold values which characterise the condition of a nerve cell. If its internal voltage (*Vi*) is under Vmin, then the nerve cell is



Each nerve cell of ChaOs can be thought of as an electronic circuit.

quiescent (or polarised). If it is between *Vmin* (inclusive) and *Vmax* values, then the cell is being depolarised. Each nerve cell has a potential divider which is aimed at maintaining *Vi* below *Vmin*. But when it fails (that is, if *Vi* reaches *Vmin*) then the nerve cell becomes depolarised. There is also an electric capacitor which regulates the rate of depolarisation. The tendency, however, is to become increasingly depolarised with time. When *Vi* reaches *Vmax*, the nerve cell fires and becomes burned . A burned nerve cell at time *t* is automatically replaced by a new quiescent cell at time $t + 1$.

The bahaviour of ChaOs is specified by setting up a number of parameters:
the number *n* of cell values (i.e., colours), such that $n >= 3$ the resistances *R*1 and *R*2 for the potential divider the capacitance *k* of the electric capacitor the dimension of the grid.

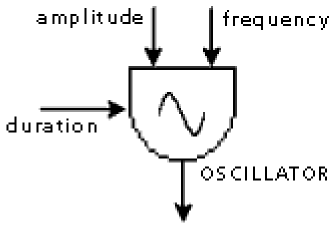
The algorithm

The condition of a nerve cell is represented by a number between 0 and $n - 1$ (*n* = amount of different conditions). A value equal to 0 corresponds to a quiescent condition, whilst a value equal to $n - 1$ corresponds to a burned condition. All values in between exhibit a degree of depolarisation. The closer the value gets to $n - 1$ then the more depolarised the cell becomes. The global transition function is defined by three rules simultaneously applied to each nerve cell, selected according to its current condition: quiescent, burned or depolarised. The rules are as follows:

- **if quiescent**: the cell may or may not become depolarised at the next tick of the clock ($t + 1$). This depends upon the number of polarised nerve cells in its neighbourhood, the number of burned nerve cells in its neighbourhood and the resistance of the nerve cell to being burned.
- **if depolarised**: the tendency is to become more depolarised as the clock *t* moves forward.
- **if burned**: a burned cell at time *t* generates a new quiescent cell at time $t + 1$.

The mapping technique

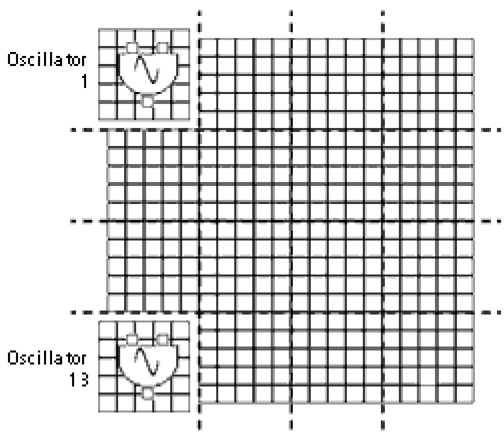
Each sound granule produced by Chaosynth is composed of several components. Each component is a waveform produced by a digital oscillator which needs three parameters to function: frequency, amplitude and duration (in milliseconds) of the signal.



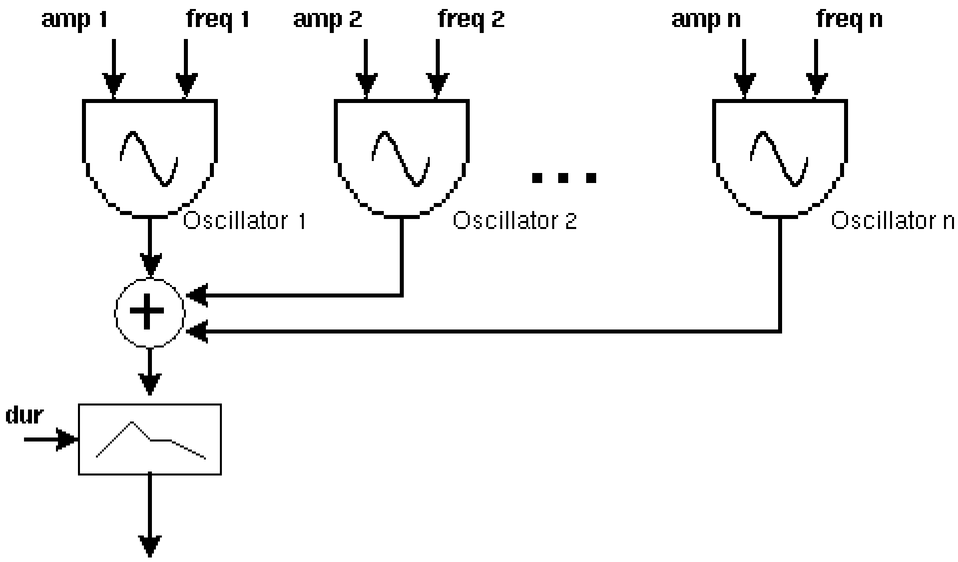
Each component of the spectrum of a granule is generated by a different digital oscillator.

ChaOs controls the frequency and duration values of each granule, but the amplitude values are set up by the user beforehand. That is, the spectral contours of the granules are established before hand, but the actual frequency content of the spectrum is controlled by ChaOs. The values of the nerve cells are associated to frequencies; and oscillators are associated to a number of nerve cells. The frequencies of the components of a granule at time t are established by the arithmetic mean of the frequencies associated with the values of the nerve cells associated with the respective oscillators. An example of a grid of 400 cells allocated to 16 oscillators of 25 cells each is shown below.

The user can also specify the dimension of the grid, the amount of oscillators, the allocation of nerve cells to oscillators, the allocation of frequencies to CA values, the resistances of the potential divider (i.e. *R*1 and *R*2) and the capacitance (i.e. *k*) of cells. Each granule is in fact the product of additive synthesis: at each iteration of ChaOs, all oscillators simultaneously produce waveforms (e.g. sinewaves, square waves, etc.), whose frequencies are determined by the arithmetic mean over the frequency values of their corresponding nerve cells.



An example of a grid of 400 nerve cells



al oscillators.

The additive synthesis of waveforms.

The duration of a whole sound event is determined by the number of CA iterations and the duration of the particles; for example, 100 iterations of 35 milliseconds particles results in a sound event of 3.5 seconds of duration. This mapping method is interesting because it explores the behaviour of ChaOs in order to produce sounds in a way which resembles the functioning of some acoustic instruments. The random initialisation of cells in the grid produces an initial wide distribution of frequency values, which tends to settle to an oscillatory cycle. This behaviour resembles the way in which the sounds produced by most acoustic instruments evolve during their production: their harmonics converge from a wide distribution (as in the noise attack time of a vocal sound, for example) to oscillatory patterns (the characteristic of a sustained tone). Variations in tone colour are achieved by varying the frequency values, the amplitudes of the oscillators and the number of nerve cells per oscillator. Different rates of transition, from noise to oscillatory patterns, are obtained by changing the values of $R1$, $R2$ and k.

Sound examples

Example 1 [Click to hear]
Example 2 [Click to hear]
Example 3 [Click to hear]
Example 4 [Click to hear]
Example 5 [Click to hear]
Example 6 [Click to hear]
Example 7 [Click to hear]
Example 8 [Click to hear]
Example 9 [Click to hear]
Example 10 [Click to hear]

Further information

Chaosynth is commercially available from Nyr Sound. There are versions of Macintosh and PC. Demo versions are freely available from Nyr Sound. An earlier version for Unix systems can be found here. Click here to download the Linux version.
This version generates score files for a Csound implementation of Chaosynth. (Csound is a programming language for sound synthesis.)