Categorising Complex Dynamic Sounds

James Correa[1], Eduardo Miranda[1,2], Joe Wright[3]
(1) Laboratório de Música Eletroacústica de Santa Maria,
Orquestra Sinfônica da UFSM, Santa Maria - RS, Brazil (jcorrea1@ix.netcom.com)
(2) SONY Computer Science Laboratory Paris, 6 rue Amyot,
75005 Paris, France (miranda@csl.sony.fr)
(3) Nýr Sound, 8 Cringle Av., Bournemouth,
Dorset BH6 4HX, United Kingdom (joe@nyrsound.com)

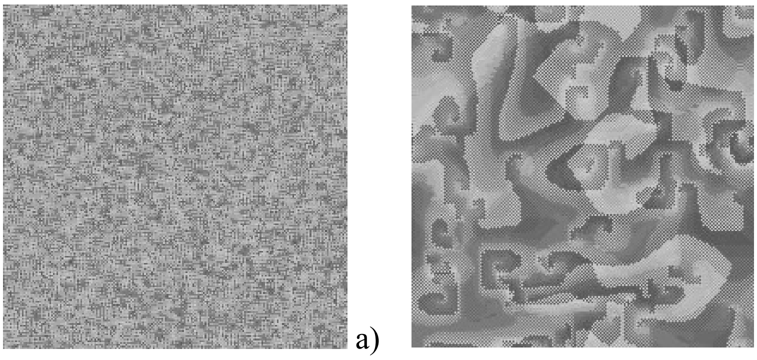
Abstract:
Chaosynth is a cellular automata-based granular synthesis system whose abilities to produce unusual complex dynamic sounds are limitless. However, due to its newness and flexibility, potential users have found it very hard to explore its possibilities as there is no clear referential framework to hold on when designing sounds. Standard software synthesis systems take this framework for granted by adopting a taxonomy for synthesis instruments that has been inherited from the acoustic musical instruments tradition: i.e. woodwind, brass, string, percussion, etc. Sadly, the most interesting synthesised sounds that these systems can produce are simply referred to as *effects*. This scheme clearly does not meet the demands of more innovative software synthesisers. In order to alleviate this problem, we propose an alternative taxonomy for *Chaosynth* timbres. The paper begins with a brief introduction to the basic functioning of *Chaosynth*. Then it presents our proposed taxonomy and ends with concluding comments.

1 Granular synthesis and cellular automata

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 (Gabor 1947; Miranda 1998). 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. 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. We devised a system called *Chaosynth* (Miranda 1995) which uses a different method: it uses cellular automata (Cood 1968).

In general, cellular automata (CA) are implemented as a grid of variables referred to as cells. Each cell may assume values from a finite set of integers and each value is normally associated with a colour. The functioning of a cellular automaton is displayed on the computer screen as a sequence of changing patterns of tiny coloured cells, like an animated film. At each frame, the values of all cells change simultaneously, according to a set of transition rules that takes into account the values of their neighbourhood. The CA used in *Chaosynth* is called ChaOs, an acronym for Chemical Oscillator. An in-depth understanding of the mathematics behind ChaOs is not necessary to operate *Chaosynth*. It suffices to know how the algorithm works and its general behaviour: from an initial random distribution of cells in the grid, the automaton tends to drive the cells towards an oscillatory cycle of patterns (Figure 1).

Figure 1:
ChaOs tends to evolve from (a) an initial random distribution of cells in the grid
(b) towards an oscillatory cycle of patterns.



a) b)

The behaviour of ChaOs resembles the way in which most of the natural sounds produced by some 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). ChaOs can be thought of as an array of simple identical electronic circuits called cells. At a given moment, cells can be in any one of the following conditions: *quiescent*, *depolarised* or *burned*. A cell interacts with its neighbours (4 or 8) through the flow of electric current between them. There are minimum (*Vmin*) and maximum (*Vmax*) threshold values which characterise the condition of a cell. If its internal voltage (*Vi*) is under *Vmin*, then the cell is quiescent (or polarised). If it is between *Vmin* (inclusive) and *Vmax* values, then the cell is being depolarised. Each cell has a potential divider which is aimed at maintaining *Vi* below *Vmin*. But when it fails (that is, if *Vi* reaches *Vmin*) the 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 cell fires and becomes burned. A burned cell at time t is automatically replaced by a new quiescent cell at time $t + 1$.

2 Rendering sounds from ChaOs

Each sound granule produced by *Chaosynth* is composed of several spectral components. Each component is a waveform produced by a digital oscillator (i.e., a lookup sampling table containing one cycle of a waveform) which needs three parameters to function: frequency, amplitude and duration (in milliseconds) of the signal. 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 via *Chaosynth*'s Oscillators panel (Figure 2), but the actual frequency content of the spectrum is controlled by ChaOs.

The values (i.e., the colours) of the cells are associated to frequencies (these values are set via *Chaosynth*'s Frequency panel); and oscillators are associated with a number of 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 cells associated with the respective oscillators. Suppose, for example, that an oscillator is associated with 9 cells and that at a certain time t, 3 cells correspond to 110 Hz, 2 to 220 Hz and the other 4 correspond to 880 Hz. In this case, the mean frequency value for this oscillator at time t will be 476.66 Hz. An example of a grid of 400 cells allocated to 16 oscillators of 25 cells each is shown in Figure 3. The user can also specify the dimension of the grid, the amount of oscillators, the allocation of cells to oscillators, the allocation of frequencies to CA values, and various other CA-related parameters. 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 millisecond particles results in a sound event of 3.5 seconds of duration.

Figure 2:
A sample screen shot of *Chaosynth* featuring the Oscillators panel.
Each column on the main window controls the amplitude for a table lookup oscillator.

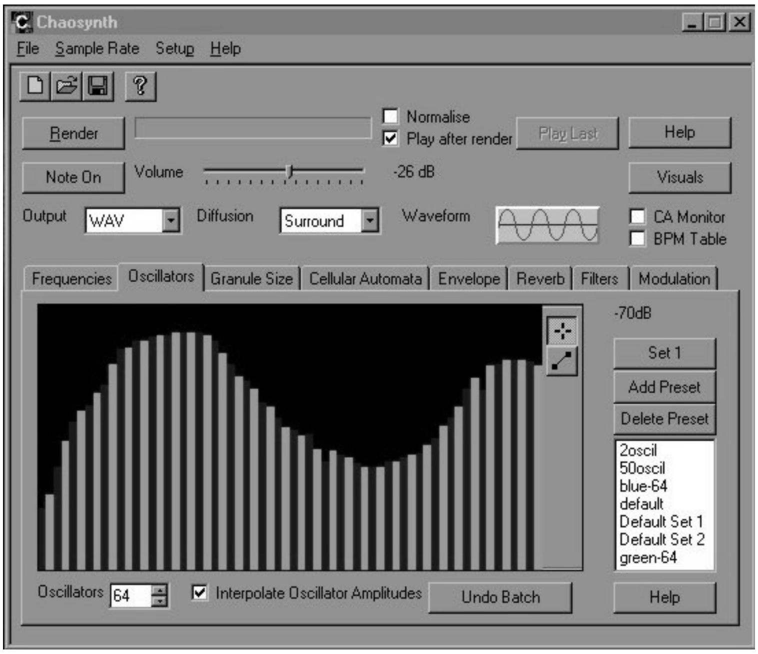
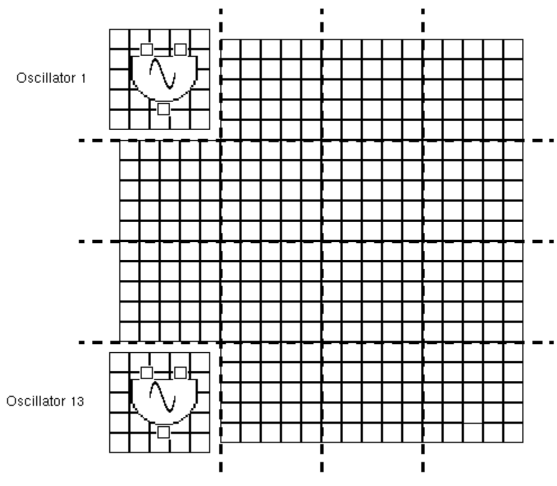


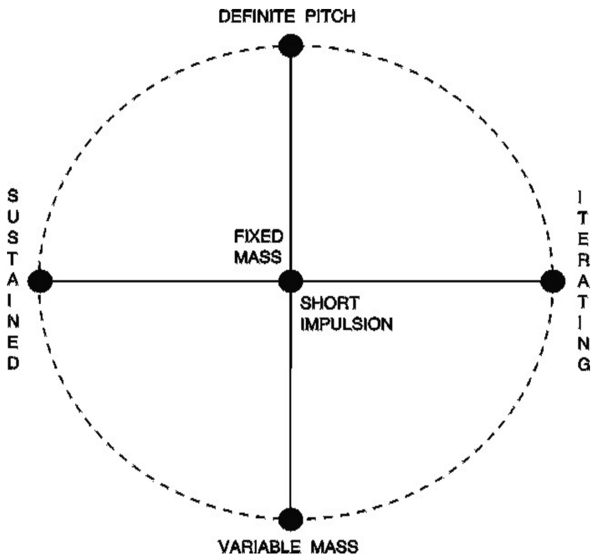
Figure 3:
An example of a grid of 400 cells allocated to 16 digital oscillators.



3 *Chaosynth* and sound design

Chaosynth has proved to be a incredibly powerful synthesiser, whose abilities to produce unusual sounds are limitless. The main criticism that we have received from its potential users, however, is that due to its newness and flexibility, it has been very hard to explore its potential: users other than *Chaosynth*'s makers themselves do not have a clear reference to begin the sound design process. The problem is that standard software synthesis systems take for granted a taxonomy for synthesis instruments that is inherited from the acoustic musical instruments tradition: i.e. woodwind, brass, string, percussion, etc. Sadly, the most interesting synthesised sounds that these systems can produce are simply referred to as *effects*. This scheme clearly does not meet the demands of more innovative software synthesisers. In order to alleviate this problem, we propose an alternative taxonomy for *Chaosynth* timbres. This new taxonomy departs from a framework for sound categorisation (Figure 4) inspired by Pierre Schaeffer's (1966) concept of sound maintenance and to some extent by an article written by Jean-Claude Risset in the book *Le timbre, métaphore pour la composition* (1991). We assume that the most important characteristic of the sounds produced by *Chaosynth*, and granular synthesis in general, is their spectral evolution in time (Miranda 1998). Our proposed taxonomy is introduced below. Note that we will use the term "instrument" to refer to specific *Chaosynth* setups that produce the sounds of the respective categories.

Figure 4:
A framework for sound categorisation.



4 The proposed taxonomy

The general structure of the proposed taxonomy is portrayed in Table 1. We have defined five general classes: Fixed Mass, Flow, Chaotic, Explosive and General Textures.

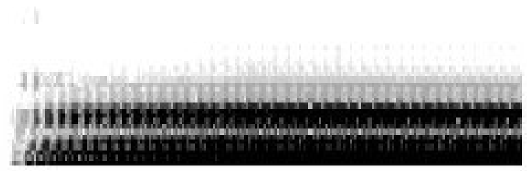
Table 1:
The five main classes of our taxonomy and some sub-classes.

Fixed Mass	Flow	Chaotic	Explosive	General Textures
Lighten	Cascade	Insects	Metallic	Textures
Darken	Landing	Melos	Woody	Effects
Dull	Raising	Boiler	Glassy	
Elastic	Lift	Windy	Blower	
Melted	Crossing	Noises	Drum	
	Drift			

4.1 Fixed Mass

This class comprises those instruments that produce sounds formed by a large amount of small grains. The overall outcome from these instruments is perceived as sustained sounds with a high degree of internal redundancy, that is, fixed mass. Notice here that by fixed mass we do not mean fixed pitch, but rather a stable and steady spectrum where the frequencies of the grains are kept within a fixed band; see spectrogram in Figure 5. Sometimes this creates a sense of pitch, but this phenomenon is not a mandatory condition. We have defined five sub-classes for this class: whilst *Lighten* are bright instruments that produce sounds rich in high frequencies, *Darken* are those instruments that produce sounds rich in low frequencies; *Dull* instruments produce muffled sounds, and finally *Elastic* and *Melted* were named after the psychoacoustic sensation they create. Figure 5 shows a sonogram of a typical fixed mass sound, or instrument, in our nomenclature.

Figure 5:
A *Fixed Mass* sound is perceived as sustained with a high degree of internal redundancy.



4.2 Flow

These are instruments whose outcome gives a clear sensation of movement due to a continuous change of the fundamental frequencies of the grains. These sounds are said to have a variable mass, but not an unpredictable one as the frequencies of the grains tend to move collectively in one direction. Six sub-classes for this class were defined according to the direction of the spectral movement: *Cascade* and *Landing*, both comprise instruments whose outcome is of a descending direction, with the difference that the movement of the former is smooth and light, whereas in the latter it is fast and vigorous. Conversely, there are *Raising* and *Lift* instruments, where the movement is ascending. The *Crossing* instruments produce sounds that display a cross movement between two groups of frequencies, one group going upwards and the other going downwards. Finally, the sub-class *Drift*, produces sounds whose sense of direction is not entirely clear; there is some flow but frequencies of the grains tend to drift up or down. Figure 6 portrays the sonogram of a Cascade-type of sound.

Figure 6:
The sonogram of a *Cascade*-type of sound whereby the frequencies of the grains are of a descending nature.

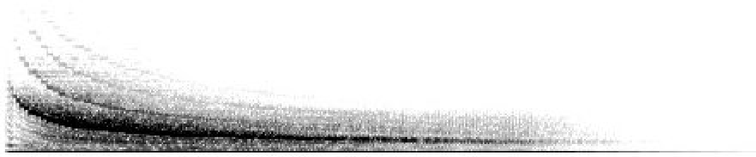
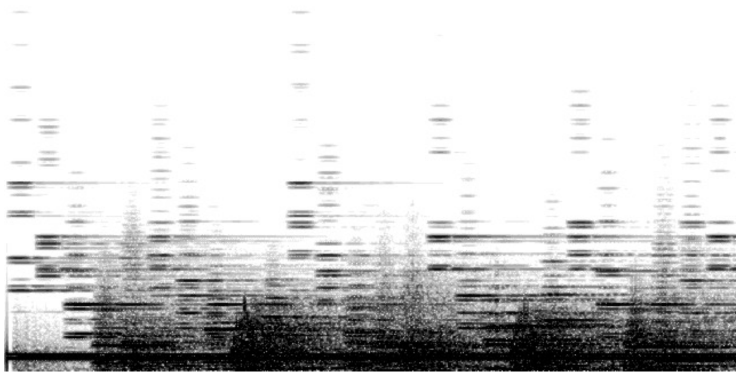


Figure 7:
The sonogram of a *Melos* sound.



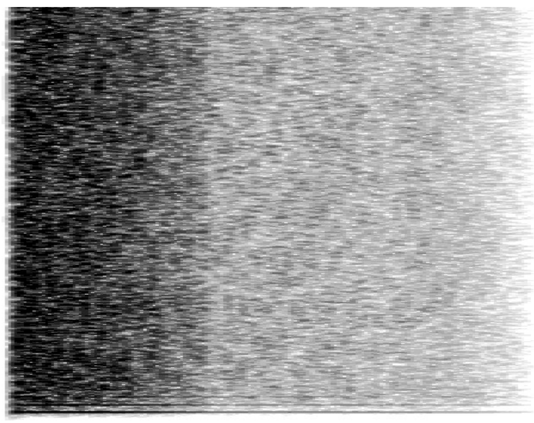
4.3 Chaotic

This class of instruments produce sounds with a very large degree of spectral movement. These sounds are of highly variable mass, the movement of the grain frequencies is unpredictable and they do not have an overall direction. We have defined five sub-classes of chaotic instruments: *Insects*, are those instruments whose outcome resemble the noises produced by insects. These sounds have more activity in the high frequencies. *Melos* produce sounds whereby the individual grains can be perceived as individual notes as if they were fast melodic fragments (Figure 7), whereas the sounds from a *Boiler* instrument resembles the sound of boiling liquids. *Windy* and *Noises* produce sounds that resemble or are derived from white-noises: the former produces an auditory sensation of blowing air, whereas the latter produces noise similar to an AM radio off station.

4.4 Explosive

This class resembles traditional acoustic percussion instruments. The sounds here are of short duration, fast attack, practically no sustain and short decay; in general terms, these sounds have a short impulsion and are either of a fixed or variable mass (Figure 8). This class comprises five sub-classes, organised according to the resemblance of their sound to those from real percussive materials: *Metallic*, *Woody*, *Glassy*, *Blower* and *Drum*. *Blower* instruments produce explosion-like sounds with a fast and very high energy. In the *Drum* class we include those instruments whose sounds are very similar to membrane-type drums.

Figure 8:
The sonogram of a *Explosive Metallic* timbre.



4.5 General Textures

These are instruments that produce what we refer to as *musical gestures*. They are divided into two sub-classes: *Textures* and *Effects*. The outcome of *Textures* is clouds of sounds with long duration and a variable mass. The classic example here is the typical bubbly and cloudy-like stereotype texture that is normally associated with standard granular synthesis methods. The second sub-class, the *Effects* generate sounds that resemble some musical instrument techniques, such as a cello glissando, or metaphorical sounds such as the noise of a steam train, a helicopter or a Klingon phaser.

5 Conclusion

The development of the proposed taxonomy is the result of massive experimentation with *Chaosynth*. There are still some inconsistencies to be addressed. We feel, for example, that the *General Textures* class still is too vague in comparison with the others. We are currently devising a large catalogue of instruments classified according to this taxonomy to distribute to *Chaosynth* users. Our aim is to gather as much feedback as possible from the users in order to implement further improvements.

Chaosynth is available for Windows and Macintosh computers. For more information please refer to the Internet site: <http://www.nyrsound.com>. Further information about the the underlying principles of the system can be found at Lamesm's Web site: <http://www.geocities.com/SilliconValley/Network/6537/>.

References:

Cood, E.F., *Cellular Automata*, London (UK): Academic Press, 1968.
Gabor, D., "Acoustical Quanta and the Theory of Hearing", *Nature*, Nr. 1044, pp. 591-594, 1947.
Miranda, E. R., "Granular Synthesis of Sounds by Means of a Cellular Automaton", *Leonardo*, Vol. 28, No. 4., pp. 297-300, 1995.
Miranda, E. R., *Computer Sound Synthesis for the Electronic Musician*, Oxford (UK): Focal Press, 1998.
Risset, J.-C., "Timbre et synthèse des sons", *Le timbre: métaphore pour la composition*, J.-B. Barrière (Ed.), IRCAM: Christian Bourgois Editeur, 1991.
Schaeffer, P., *Traité des objets musicaux*, Paris: Editions du Seuil, 1966.