A DYNAMIC INTERMEDIATE MODEL BASED ON CELLULAR AUTOMATON « GAME OF LIFE »

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ABSTRACT

The decoupling between the instrumentalist's gesture and the output sound of electronic music instruments has led to a renewed consideration on the notion of music instrument [5] and to new practices of digital lutherie [1]. Particularly, the great diversity of available interfaces, the possibility of instantaneously reconfiguring the virtual instruments, and the symbolic computation at work in the instruments program lead to rethink and redesign these instruments on new bases.

The authors have developed modules coined "dynamic intermediate models" (DIM) that are to be inserted between the control interface and the synthesis device. The DIMs give to the instrumentalist a mental representation of a unique object (in the singular) instead of multiple parameters (in the plural) that are actually controlled.

Following the development of a few DIMs for sound synthesis control [8], the authors investigated a model based on the cellular-automaton known as the "Game of Life" [7] to handle the real-time manipulation of musical fragments at a longer time scale. Particularly, they made available the existing catalogue of more than 700 identified for live usage within the model.

Last, the real-time manipulation of this algorithm for performance purposes requires some ergonomics adapted to a musical usage, such as editing and triggering gestures, which will be detailed in this paper.

1. INTRODUCTION

1.1. OrJo Project

In the context of OrJo project[1], we are developing digital audio-graphic instruments meant for collective performance, and loadable in the software "Meta-Mallette"[2]. These instruments are based on the concept of Dynamic Intermediate Models.

A "Dynamic Intermediate Model" is an instrumental model that controls audio synthesis, graphical synthesis and/or electro-mechanical actions from the instrumentalist actions on an electronic device (e.g. MIDI keyboard, joystick, pen tablet, etc.) It fits in the mapping chain that ties values output by sensors to synthesis parameters, but differs from a simple "data conditioning" by its complex nature, both dynamic and non-linear.

Then it seems interesting to uncouple the relationships between the interface and the -virtual- behaviour model on the one hand, and between this behaviour model and the synthesis engine on the other hand. This way, the model is (relatively) in dependant from the kind of synthesis it controls, as far as their number. We hypothesize that it is possible to learn its behaviour (relatively) independently from the upstream controller and the downstream synthesis, by making up a mental image of the controlled model's kinematics.

Such an architecture also tries to favour implicit learning (which is mostly the case when learning is based on a controlled psycho-motor activity), while "usual" static mapping techniques would often lead to explicit learning.

With this DIM concept, we would also like to embrace a large scope of "musical gestures" : performance, composition, tuning, instrument making, listening … in a unified environment. These various types of "gestures" often blend in the musical creation process, and it appears quite essential to us to enable the navigation between these various fields. Playing the listening, composing gestures, tuning playing-modes … are real musical propositions, not mere figures of speech. Indeed, the musical processes that we would like to drive spread over a large timescale, from sound's micro-structure to large musical patterns lasting several seconds or minutes.

	gestes										sons								
			perception des durées								perception des hauteurs								
F			0,21	0,43	0,86	1,72	3,44	6,88	13,75	27,5	55	110	220	440	880	1760	3520	7040	14080
T	18,62	9,31	4,65	2,33	1,16	0,58	0,29	0,15	0,07										
S			𝅝	𝅗𝅥	♩	♪	𝅘𝅥𝅯	𝅘𝅥𝅰	𝅘𝅥𝅱	-	la1	la2	la3	la4	la5	la6	la7		

Figure 1. The time "continuum". F : frequency in Hz; T : time in seconds; S : corresponding musical symbols.

Dynamic intermediate models should therefore adapt to these various timescales, as well as the various gestures made by the musician. To this end, we decided to explore various families of dynamic models : physical models (simulating the behaviour of structures possibly described by physical laws), topological models (navigating in parameter spaces), generative (based on rules acting on models' evolution : birth, growth, death), etc.

At first we developed several intermediate models running at frequencies of a few Hertz, a timescale corresponding to timbre micro-rhythmic modulation. Developments led during this first stage have been

[1]OrJo – standing for "Joystick Orchestra" – is a project gathering Puce Muse, LAM (Jean Le Rond d'Alembert Institute), LIMSI, and company 3Dlized. It is funded by FEDER and the regional council of Ile-de-France.

[2]Meta-Mallette is a software built by Puce Muse with Max/MSP/Jitter meant for collective music practice. See [10] for a presentation.

presented in recent conferences (JIM 2011, SMC 2011, DAFx) [8] and we will not detail them further here.

In a second step, we developed intermediate models dealing with larger timescales, by investigating genetic growth algorithms. In particular, we tried to use cellular automaton such as the “Game of Life” by John Horton Conway [7].

2. A DIM BASED ON CELLULAR AUTOMATON “GAME OF LIFE”

2.1. Game of Life's features

The “Game of Life” is a very simple yet very fertile cellular automaton. Numerous articles are covering its history, its specifics, as well as its usage in computer music [4], and we will leave the reader refer to them for further details, solely reminding the two simple rules :

- A dead cell with exactly three neighbouring cells becomes alive.
- A living cell with two or three neighbouring cells stays alive, otherwise it dies.

Although the “Game of Life” universe is possibly infinite, it is convenient (and frequent) to use a finite unbounded universe, by wrapping a plane on itself to make a torus. This technique allows to get rid of the computational problems arising with unlimited grids, and get the cells evolving in a matrix with known dimensions. Also, the Game of Life is essentially a discrete process time and space-wise, but its mode of proliferation by neighbourhood gives it continuity when using large canvas.

Several studies have shown how the “Game of Life” could be used to generate musical patterns, but it has seldom be considered as part of an “instrument”, that is in a context of real-time performance. From a theoretical point of view, using cellular automaton to build a “music instrument” is quite unusual, as the relation to energy and limits differs from the “physical models” we are used to with acoustic instruments.

However, such automaton are extremely interesting for handling morphological generation and transformation of patterns at various space and time scales. Besides, the impressive catalogue of emerging patterns that has been compiled for the last 40 years has not been, to our knowledge, acknowledged as what it really is : an inventory of several hundreds of patterns described and sorted in terms of type, period, size, speed, etc.

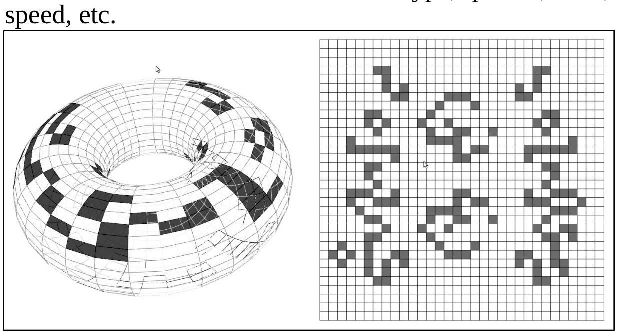

Figure 2. :The “diuresis” oscillator represented in a looped surface (tore) and unrolled to a plane.

2.2. Intervention modes

We assume that composition, among other tasks, consists in producing musical patterns on one hand, and to arrange them time-wise on the other hand. To envisage composition as an instrumental “musical gesture” means to consider the production and arrangement of such patterns during the performance itself. However, while a top-down process is suitable for designing DIMs, drawing up a list of “composition gestures” needs beforehand to prepare the ground by an empirical “bottom-up” method. This we tried to find what “gestures” were most ergonomic to manipulate this model efficiently in a performing context.

The “Game of Life” deploying in a 2D space is particularly well suited for control surfaces such as pen tablet or the now widely-used multi-touch screens. Nonetheless, when addressing the use of such a model for a music instrument, the ergonomics of data manipulation becomes crucial. For live performance, several functionalities seemed useful to us :

- editing the canvas at multiple position at a time
- copying / cutting / pasting parts of the grid
- selecting chosen areas to modify them without altering the rest of the canvas
- pre-visualising one’s selection, and triggering it only at the right moment
- returning to previously saved state
- inserting loops
- inserting patterns with known behaviours

We particularly attached importance to this last point, acknowledging the huge collection that has been identified by researchers in the field of cellular automatons and by “Game of Life” enthusiasts.

2.3. Using the pattern library

Indeed, cellular automatons in general and the “Game of Life” in particular have been extensively studied since the 1970’s, and remain a very active field of research and development[3]. To date, there is a growing “bestiary” of more than 700 patterns identified in the “Game of Life”. However, despite the considerable amount of research on music generation through cellular automaton (cf. bibliography in [3]), the importance of this inventory seems to be relatively ignored. This inventory is yet the basic tool of a rich programming with this Turing-complete language that allows for highly complex constructions.

This classification also has the educational value of being easily remembered, thanks to the picturesque names that have been given to the identified patterns (“Glider”, “Boat”, “Mathematician”, “Mould”, etc.). Also, a number of properties and quantitative magnitudes of the figures were named: bounding box, period, speed, number of cells, heat, type of figure, volatility.

[3]Cf. the development of software like Golly (http://golly.sourceforge.net), and websites like http://conwaylife.com or http://pentadecathlon.com

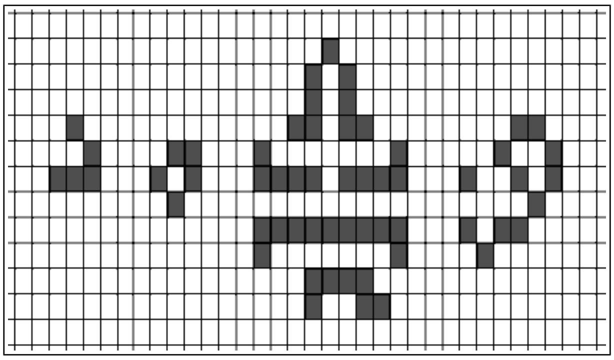

Figure 3. Glider, Boat, Mathematician, Mould

2.3.1. *Oscillators*

Oscillators are patterns returning to their original state, at the same location and with same orientation, after a finite number of generation so called the “period” of the oscillators.

By temporally "unrolling" an oscillator, we obtain a kind of score that helps capture at a glance the features of a particular oscillator such as:

- The internal rhythms of each cell relative to the overall pace
- The relative independence of each cell’s own rhythm
- The symmetries of the oscillator
- The volatility of the oscillator (i.e. the proportion of cell that actually oscillates compared to cells remaining fixed)
- Heat of the oscillator (i.e. the amount of cells that changes after each generation)

Considering live performance aspects, the time-wise deployment of an oscillator also allows to select it at a particular time of its cycle (its phase) to insert it into a "Game of Life" grid. Put in more musical terms, this means you can insert a rhythmic loop starting upbeat.

2.3.2. *Spaceships*

A spaceship is a special form of oscillator. Its period lead it to its original shape, but offset with respect to its original position. The consequence is that this oscillator moves, hence its name “spaceship”. This type of pattern also has a period which is the number of generations after which it is found with an identical shape. It also possesses speed, expressed as the ratio c / N where c represents the speed limit of displacement, i.e. 1 cell per generation, and N is an integer. Finally it has a direction of displacement: diagonal or orthogonal.

Each ship has its own way of moving. The result is a characteristic iso-rhythmic pattern, consisting in progressions and setbacks. On a canvas polarized using a range of heights, it translates to an arpeggiated form.

Another capacity of the spaceships is to go modify the canvas at another location, reacting in contact with other cells.

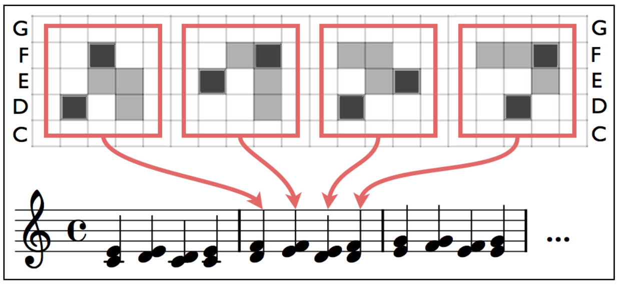

Figure 4. Iso-chromaticism caused by the progression of Glider. The scores reflects a vertically polarized space with C-scale degrees. This representation does not necessarily represent the notes of the scale, but events associated with a row index.

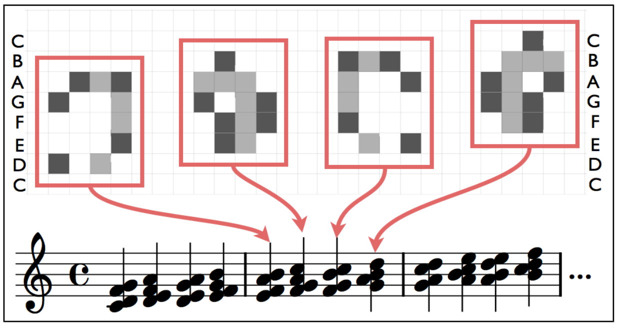

Figure 5. Iso-chromaticism generated by the progression of "Light Weight Space Ship" (LWSS) represented with the same modality as in the previous figure.

2.3.3. *Other patterns*

There are patterns whose unstable behaviour is also interesting in a musical perspective. The “Methuselahs” are explosive : starting with a small number of initial cells, they spread quickly into more complex forms, before stabilizing or even disappear completely.

The “Guns” are oscillators producing “Spaceships”, “Puffers” are “Spaceships” that leave debris behind their passage and “Breeders” are “Spaceships” producing “Guns”. The “Wicks” are linear patterns which "burn" in a configurable number of generations and allow the introduction of such delays in the chaining of different patterns. The “Gardens of Eden” are figures who had no predecessor.

Finally, there are a number of patterns that have not much life of their own, but that will play a particular role when inserted in a more complex ensemble of interlinked patterns ("tag-along", "sidecar", "fuse ", etc.).

2.3.4. *Patterns bank*

The existing pattern catalogs are a useful tool, but they were seldom designed in a musical perspective. It therefore seemed useful to us to provide this catalog in a format more suitable to the use of figures for the real-time composition.

We have thus developed a RLE-file[4] reader. This module can access a catalog of over 700 recorded patterns available on the Internet[5], directly in Max environment.

Analysis tools are then used to deduce the period and size of patterns, and to unroll them temporally. Then the bank let us sort the patterns with respect to their various features (name, size, period, etc.). Finally, spatial transformation tools allows for rotating and flipping patterns as one wish before inserting them in the running canvas.

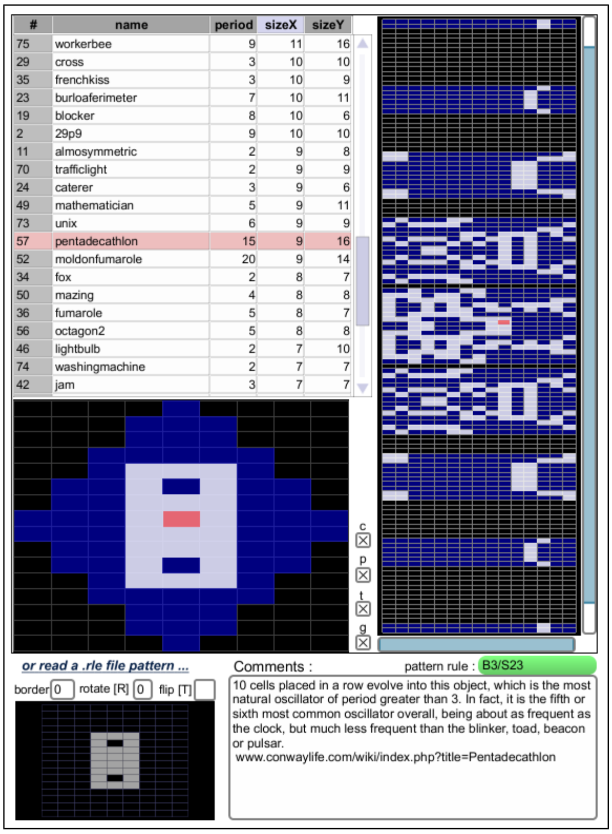

Figure 6. Top left : the table allows to sort the figures according to their characteristics. Below it: the pattern in a particular phase. Top right : the "score". In white: the figure at one moment of its phase. In blue: the area covered by the figure during its revolution. In red: a slider that allows to move synchronously in two spatial and temporal representations.

3. INTERACTION WITH SYNTHESIS

3.1. Several possible strategies

The output of the “Game of Life” is essentially a matrix. Various ways to “sonify” the canvas of the game of life were tested [2] : computation of statistical values, reading the matrix as a wave or look-up table, or using of polar coordinates [9].

The use of DIM based on the “Game of Life” in a modular programming environment such as Meta-Mallette gives us the opportunity to experiment with each of these methods, to invent another, or even to insert the game of life inside a more complex network of intermediate models.

In order to control the parameters of macro-forms such as the generation of musical phrases, we have forsaken the techniques based on an interpretation of the matrix as an audio signal and mainly experimented with a “triggered event” logic.

3.2. Triggers grid

To “sonify” the model of the game of life, we developed a topological intermediate model downstream consisting in a grid of triggers. This model allows positioning triggers on a matrix that acts as a sieve by operating an intersection with the matrix to be sonified. In our case, the triggers will be active when a cell of the game of life changes of state.

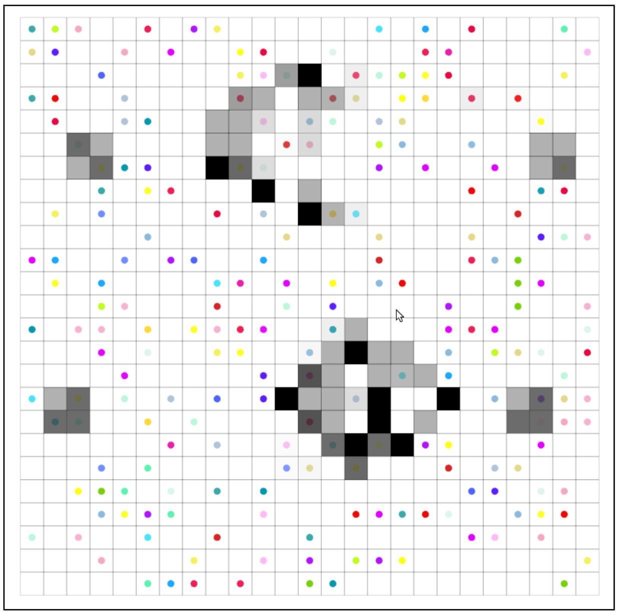

Figure 7. Two out-of-phase "Queen Bee Shuttles" in action on a canvas filled with coloured triggers. The highlights indicates the triggers that have been activated.

As an example, triggers can generate MIDI notes, but more generally any type of message, such as a change of tempo, a transposition, and even modifications in the trigger matrix itself or in the “Game of Life” ’s canvas.

This flexibility and its recursion opens a vast space of possibilities. Its apprehension varies between a proactive and thoughtful construction, and the observation of a semi-chaotic emergence.

To give a simple example of such logic, one can imagine using an oscillator such as "pentadecathlon" (of period 15) to play a melody of notes, and assign a particular cell an event which transposes a fifth higher wrapped in an octave.

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[4] RLE is a compressed but human-readable format in which most of the Gamed of Life patterns are encoded.

[5] A great collection is notably available on the web site : http://conwaylife.com/wiki/

Using a combination of self-recursive sieves and a lexicon of patterns with known periods makes it possible to reach a real-time control of music synthesis by high-level parameters. Without controlling each note or rhythm, it is possible to compose topologies with several scales, each of which operates according to a degree of probability, to favour certain rhythms, acting on very localized events, or conversely, of general influence.

4. PERSPECTIVES

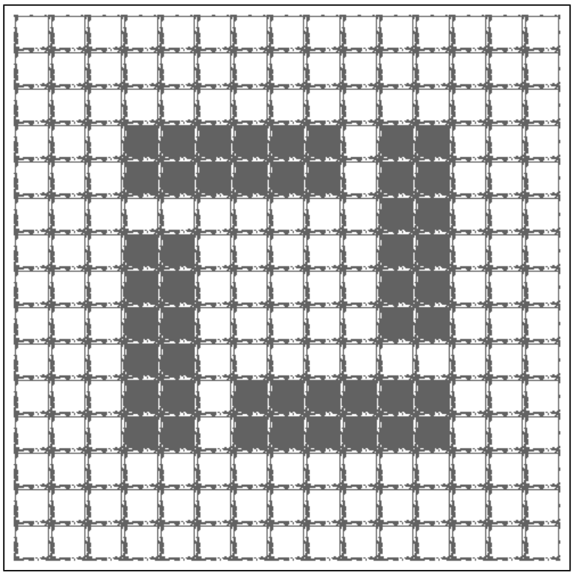

Figure 8. A "meta-oscillator" counting more than 7 million cells in Golly. Each active "meta-cell" is composed of about 65,000 cells.

Using the game of life opens a huge space in which the choices will probably be refined empirically. Many things remain to be invented on the ergonomics of a real-time manipulation of this model, and possible connections with the musical synthesis downstream. The relations between the data coming from the sensors and the synthesis parameters are complex [12] and, to be designed, they need an expertise which is more than a simple "validation test" [6]. In this perspective, it is hoped that the integration of Dynamic Intermediate Models in the Meta-Mallette and its practical use by a wider audience yield interesting results. In particular, one can imagine that typical shapes will emerge in the grids of triggers, in a similar way to the patterns library.

Limited performance of the implementation of the game of life in Max/MSP also deprives us of the use of hyper-complex figures, such as those that can run in optimized softwares as Golly [11]. Singular phenomena emerge in populations of several million cells, and it does not seem impossible to apprehend such figures, as some are purely built by assembling simple elements.

The leap between a software and a usable instrument is somehow similar to the leap between a plain string stretched above a wooden plate and a violin! It takes a long time to set up an instrument that can be played by others musicians. But like traditional instruments can be classified into several families, depending on how sound is produced, we envisage developing different instruments based on the same models.

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