

Directions de recherche actuelles en composition assistée par ordinateur

Projet *EFFICAC(e)*

[*Extended Framework for In-time Computer-Aided Composition*]

Jean Bresson
UMR STMS - IRCAM



Participants :

- Jean Bresson (IRCAM - Représentaions Musicales)
- Diemo Schwartz (IRCAM - Interactions Musicales Temps Réel)
- Thibaut Carpentier (IRCAM - Espaces Acoustiques et Cognitifs)
- Florent Jacquemard (IRCAM - Représentaions Musicales/Mutant)
- Dimitri Bouche (PhD, IRCAM - Représentaions Musicales)
- John MacCallum (CNMAT / UC Berkeley)
- Rama Gottfried (UC Berkeley)

Thèmes abordés :

- Processus réactifs en CAO
- Structures temporelles dynamiques
- Interaction dans le contrôle de la synthèse et de la spatialisation
- Intégration de données et interfaces gestuelles
- ...

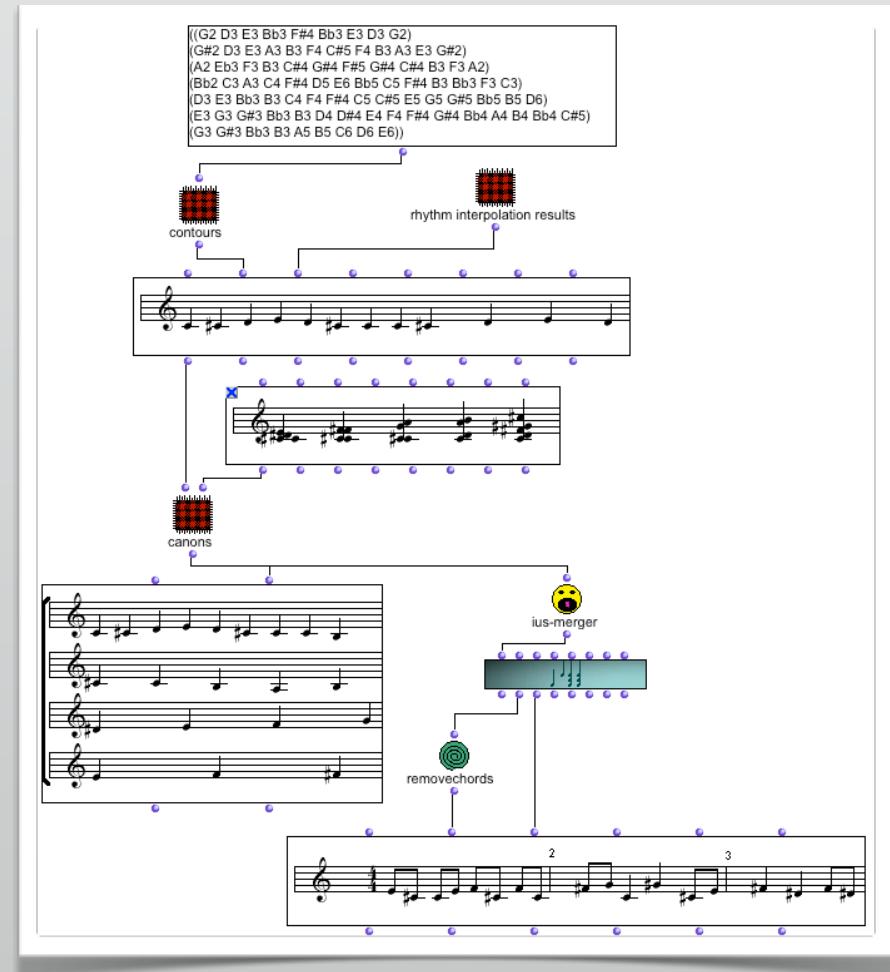
OpenMusic

Computer-Aided Composition environment Symbolic computation Musical data structures

G. Assayag, C. Rueda, M. Laurson, C. Agon, O. Delerue. "Computer Assisted Composition at Ircam: PatchWork & OpenMusic", Computer Music Journal, 23(3), 1999.

Visual programming language

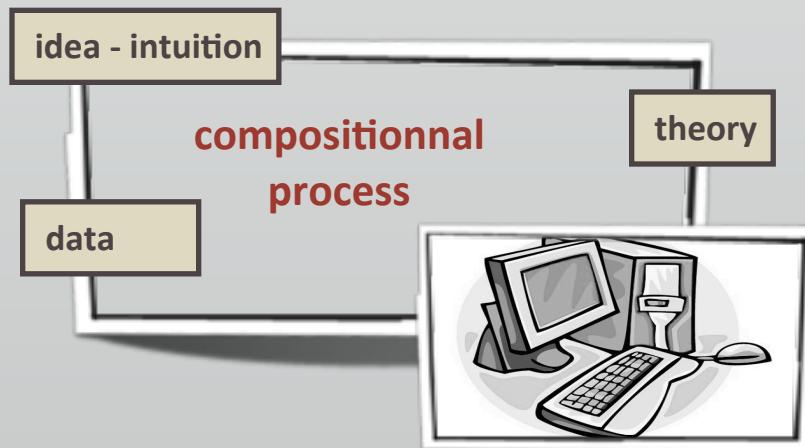
J. Bresson, C. Agon, G. Assayag. "Visual Lisp/CLOS Programming in OpenMusic"
Higher-Order and Symbolic Computation, 22(1), 2009.



<http://repmus.ircam.fr/openmusic/>

Specificity of the computer-aided composition approach

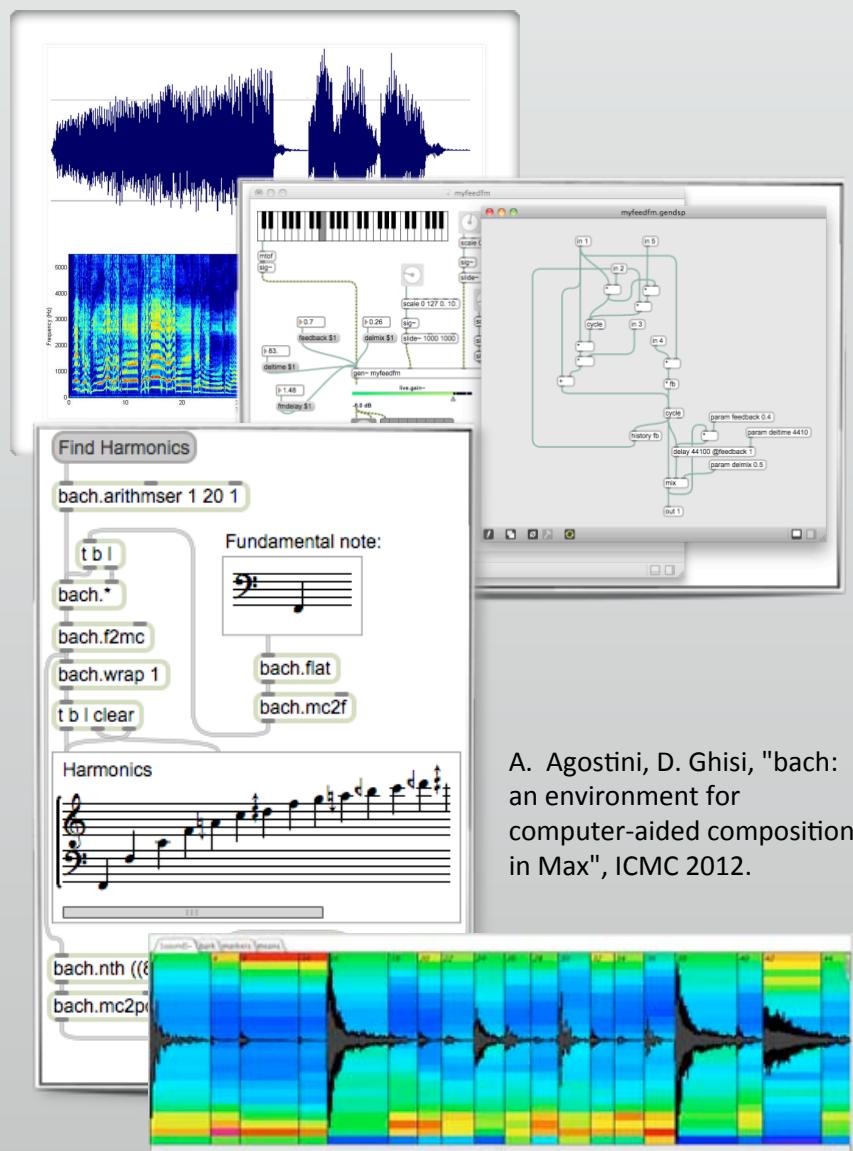
a.k.a. "what is the difference between OM and Max?"



"We conceive such an environment [of computer-aided composition] as a specialized computer language that composers will use to build their own musical universe. [...] This leads us to reflect on the various existing programming models, as well as on the interfaces [...] which make it possible to control this programming, and on the representations of the musical structures, which will be built and transformed using this programming."

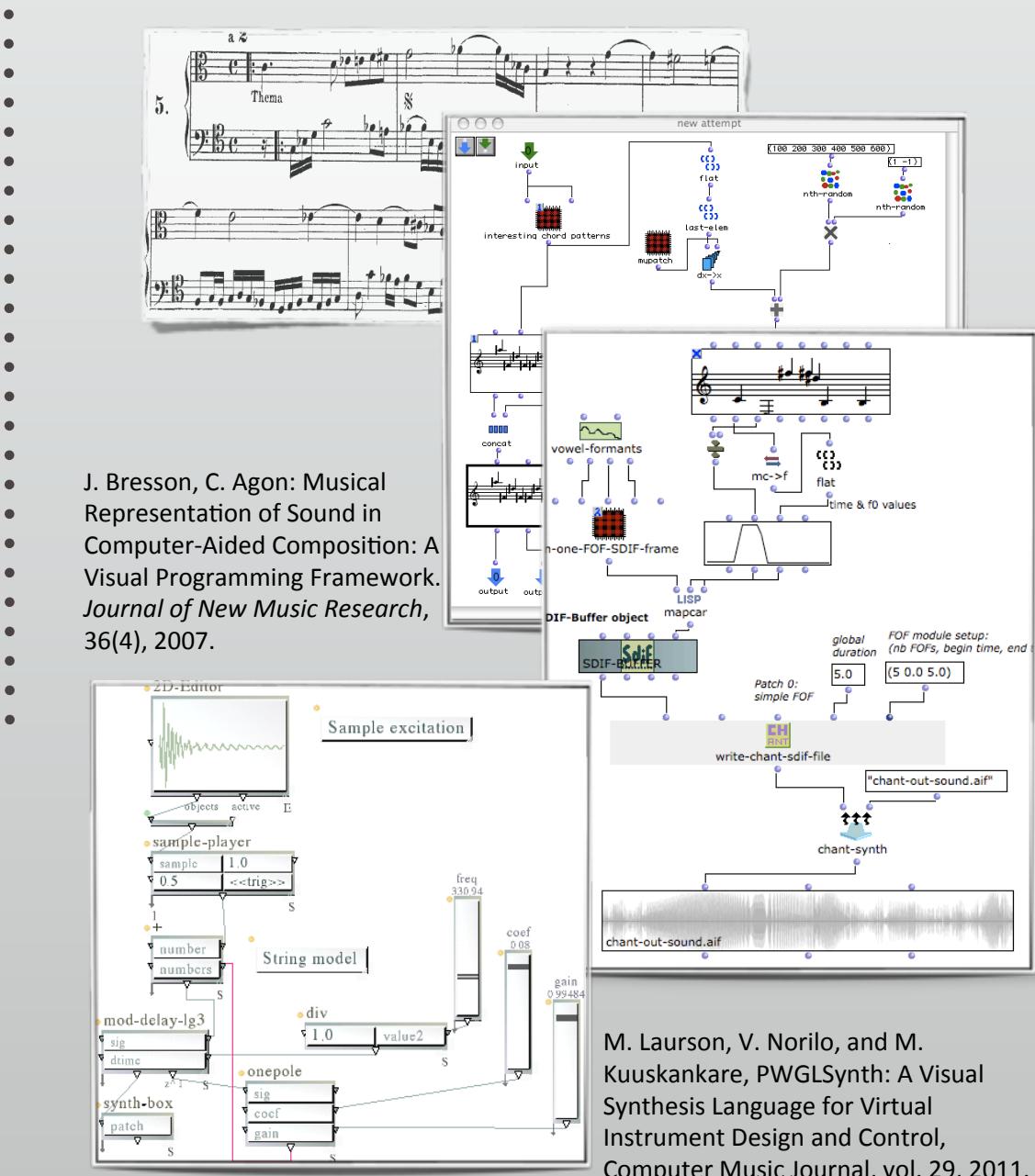
G. Assayag, Computer Assisted Composition Today (1998).

Digital signal processing vs. symbolic music processing ?



A. Agostini, D. Ghisi, "bach: an environment for computer-aided composition in Max", ICMC 2012.

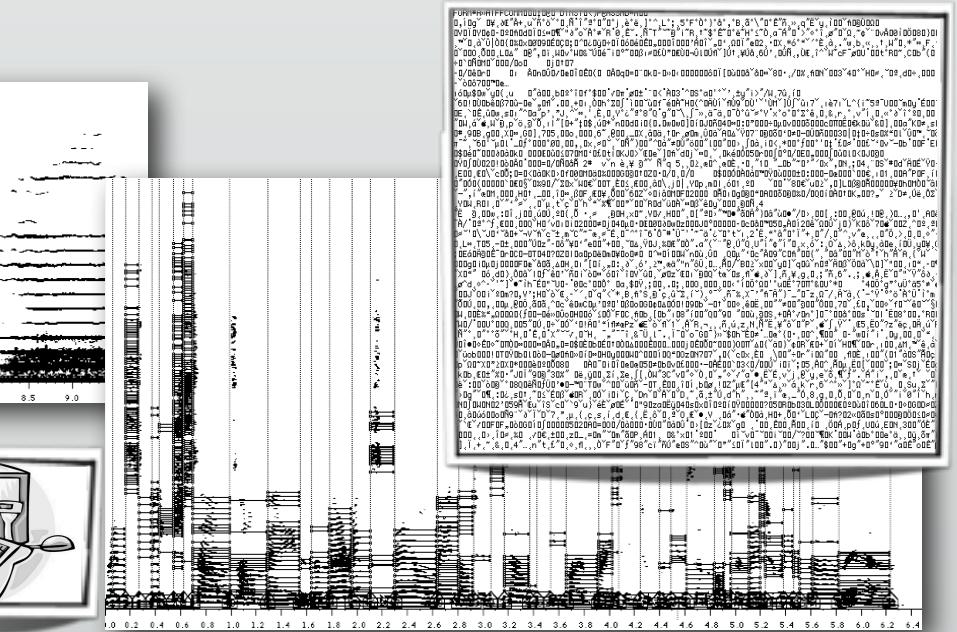
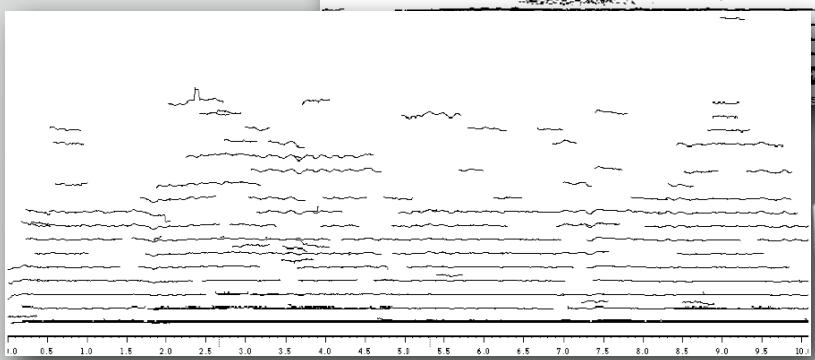
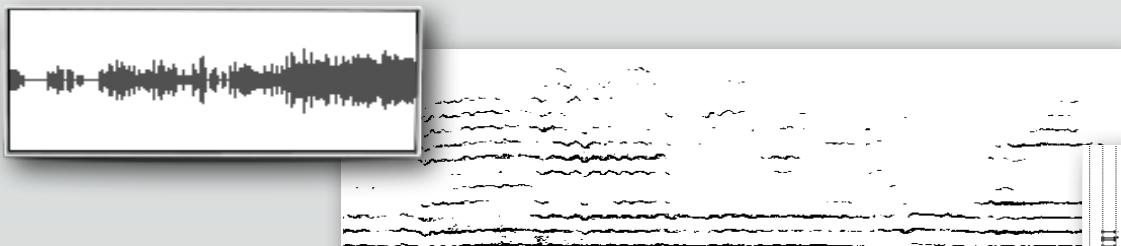
N. Schnell et al. "MuBu & Friends - Assembling Tools for Content Based Real-Time Interactive Audio Processing in Max/MSP." ICMC 2009.



J. Bresson, C. Agon: Musical Representation of Sound in Computer-Aided Composition: A Visual Programming Framework. *Journal of New Music Research*, 36(4), 2007.

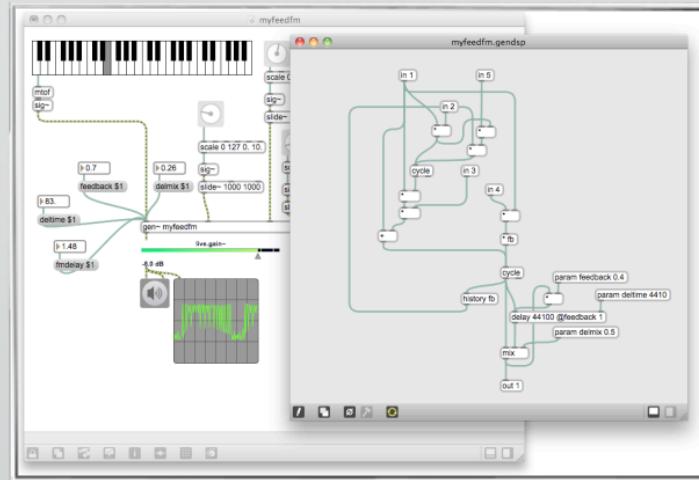
M. Laurson, V. Norilo, and M. Kuuskankare, PWGLSynth: A Visual Synthesis Language for Virtual Instrument Design and Control, Computer Music Journal, vol. 29, 2011.

Computer-aided composition at the origins

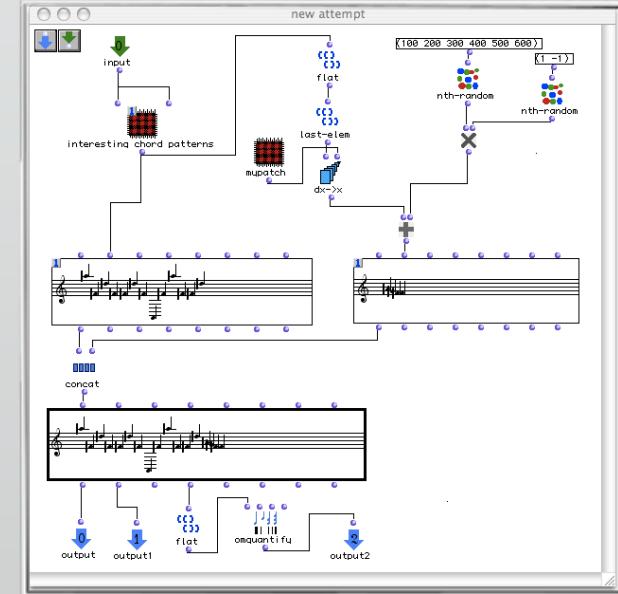


Computer assistance in the exploration, processing and rendering of musical material

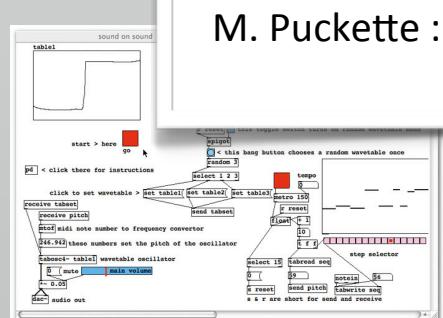
Digital signal processing performance



Symbolic music processing composition



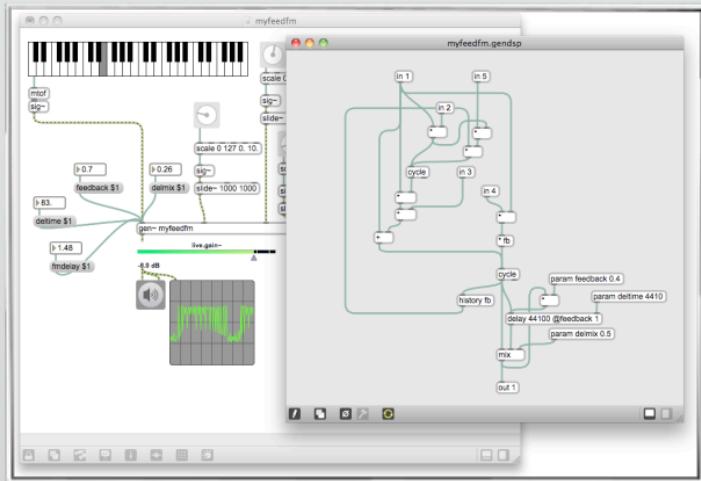
M. Puckette : *A divide between 'compositional' and 'performative' aspects of Pd*,
1st Pd Convention, Graz, 2004.



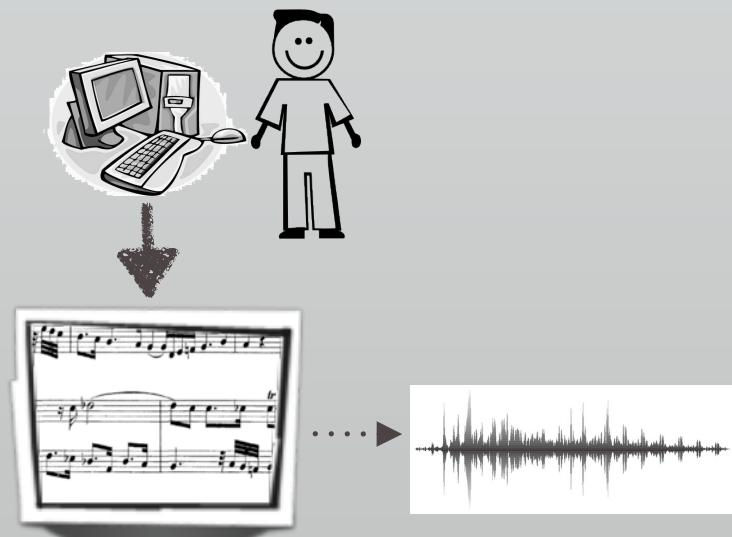
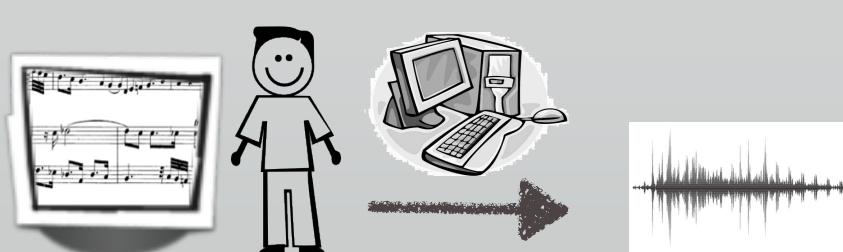
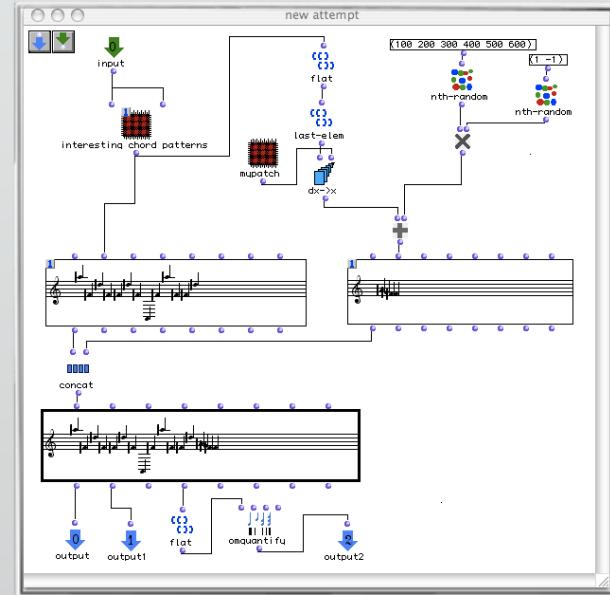
Processes

Data structures

performance



composition



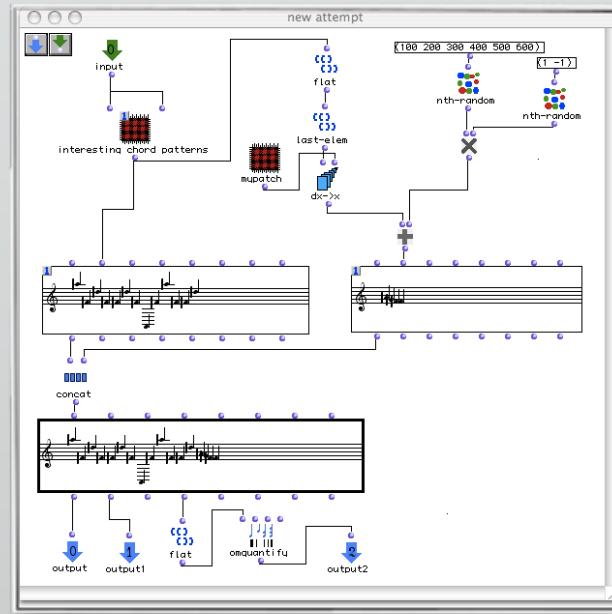
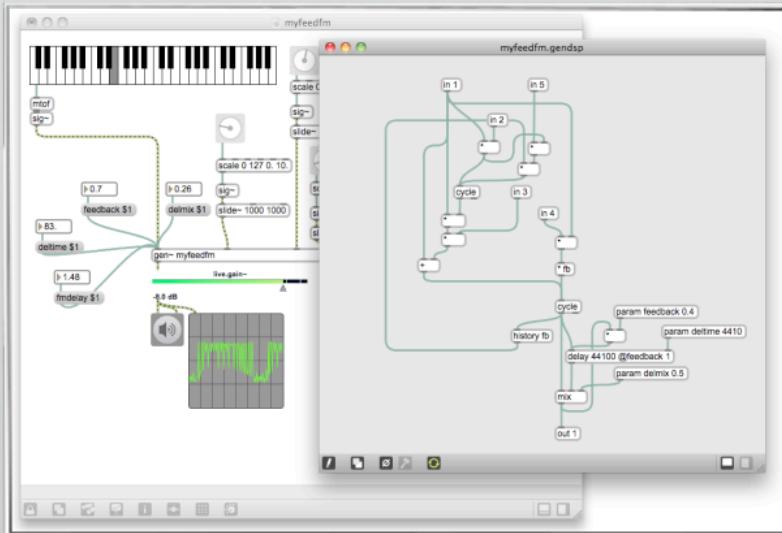
Programming / computation models

Real-time (DSP-oriented) systems:

- imperative dataflow
- continuous input/output (signal, events)

Computer-Aided Composition:

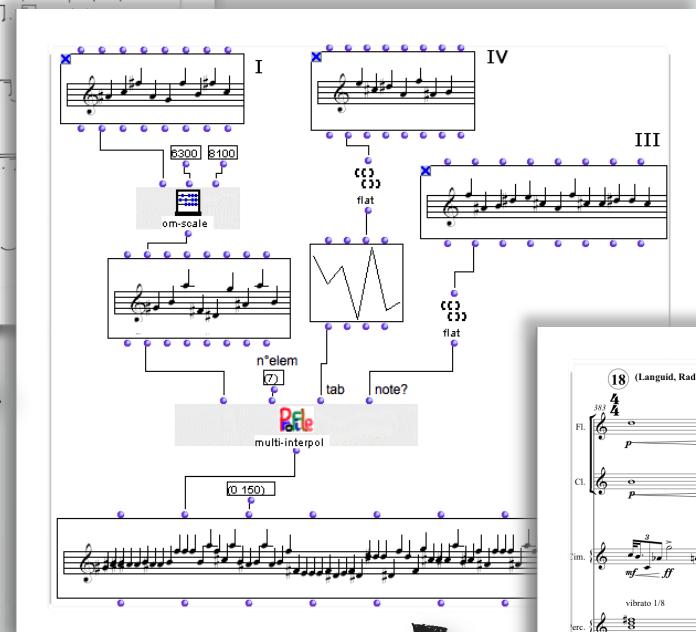
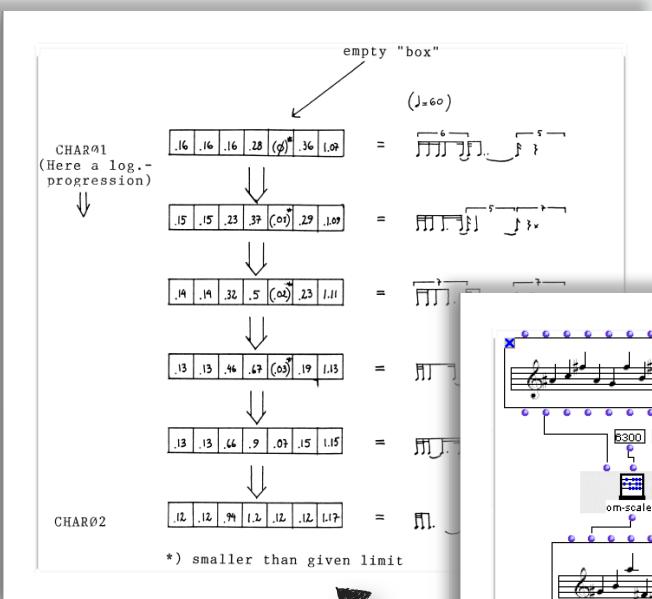
- functional / declarative style
- “out-of-time” calculus - static inputs/outputs



D. Harel, A. Pnueli, “On the Development of Reactive Systems”,
Logics and Models of Concurrent Systems, 1985.

REACTIVE

TRANSFORMATIONAL



Computer-Aided Composition: *FORMALIZATION* $\Leftarrow\Rightarrow$ *IMPLEMENTATION* $\Leftarrow\Rightarrow$ *SCORE*

Musical score for orchestra and piano, page 18. The score includes parts for Flute, Clarinet, Trombone, Percussion, Piano, Violin, and Cello. The instrumentation is as follows:

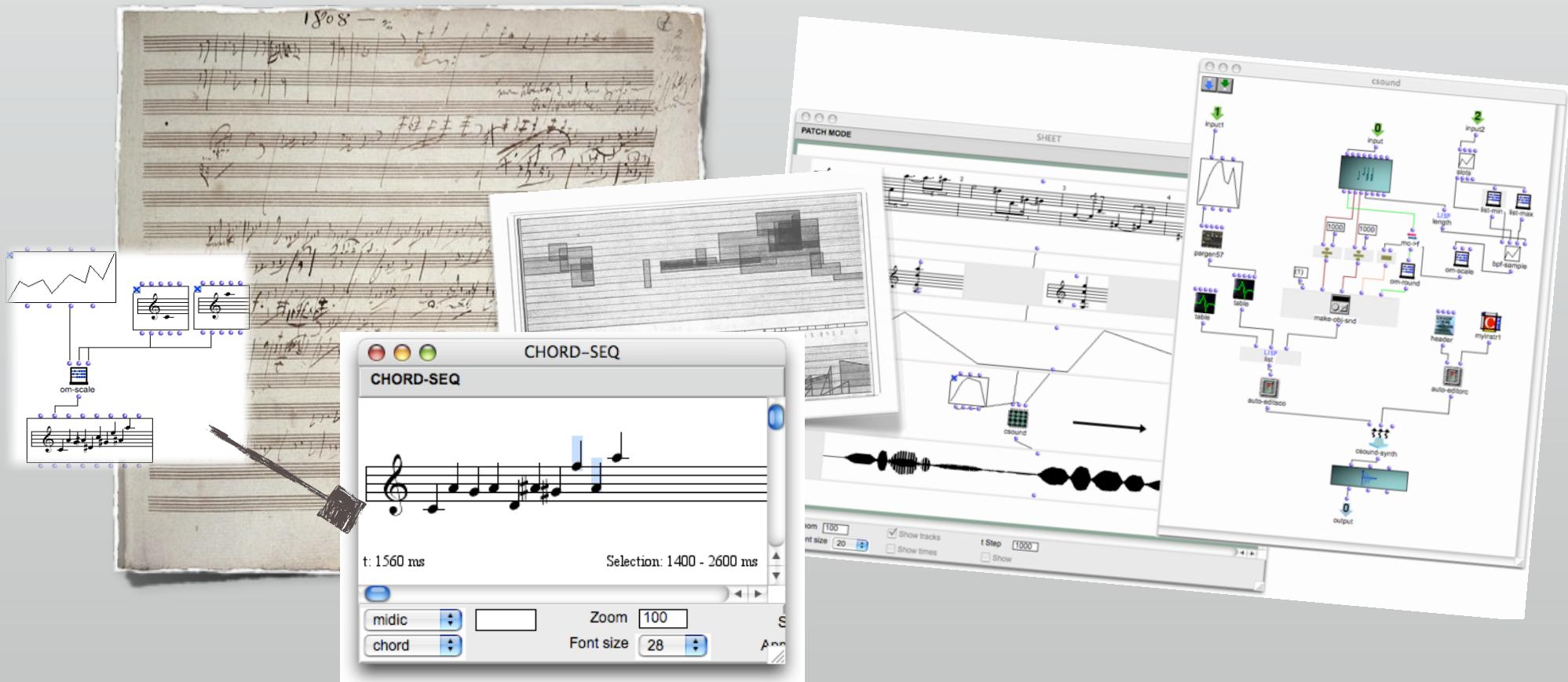
- Flute:** Dynamics: p , mf , ff , pp , p , pp . Articulation: $\text{d} \cdot$.
- Clarinet:** Dynamics: p , mf , ff , pp . Articulation: $\text{d} \cdot$.
- Trombone:** Dynamics: mf , ff , f . Articulation: $\text{d} \cdot$, vibrato 1/8 .
- Percussion:** Dynamics: p , pp . Articulation: rhythm 3 , rhythm 3 , rhythm 3 , rhythm 3 .
- Piano:** Dynamics: mf , f , mp , ff , p . Articulation: rhythm 3 , rhythm 3 , rhythm 3 , rhythm 3 .
- Violin:** Dynamics: p , ff , p , f , pp , ppp , p . Articulation: non vib. , $\text{d} \cdot$, non vib. , $\text{d} \cdot$.
- Cello:** Dynamics: p , ff , p , f , pp , ppp , p . Articulation: $\text{d} \cdot$, $\text{d} \cdot$.

The score indicates measures 18-19, with measure 18 starting at $4/4$ and measure 19 starting at $2/2$. Measure 19 includes a dynamic instruction ff and a tempo marking f .

OM visual program = symbolic representation...

- of a musical object/process
- of a compositional model

Describe intentions through a (computer) language



Time of computation vs. Time of music

[...] the major characteristic of *Formes* constitutes its weakness from our point of view; we think indeed that continuous and irreversible time, necessary for sound synthesis, is not the better paradigm for music composition in general.
G. Assayag, Computer assisted composition today, 1998.

In-time / out-of-time

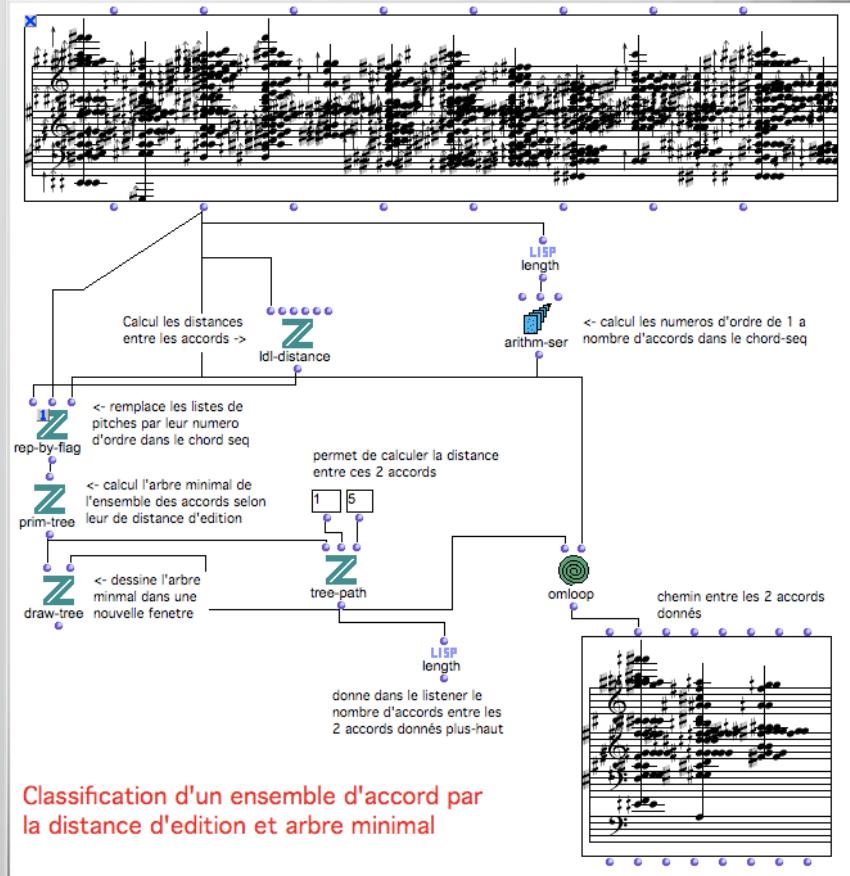
I. Xenakis. *Formalized music: thought and mathematics in composition* (1971)

A-series vs B-series

J. McTaggart. *The Unreality of Time* (1908)

J.-L. Giavitto. "Du temps écrit au temps produit en informatique musicale"
(to appear)

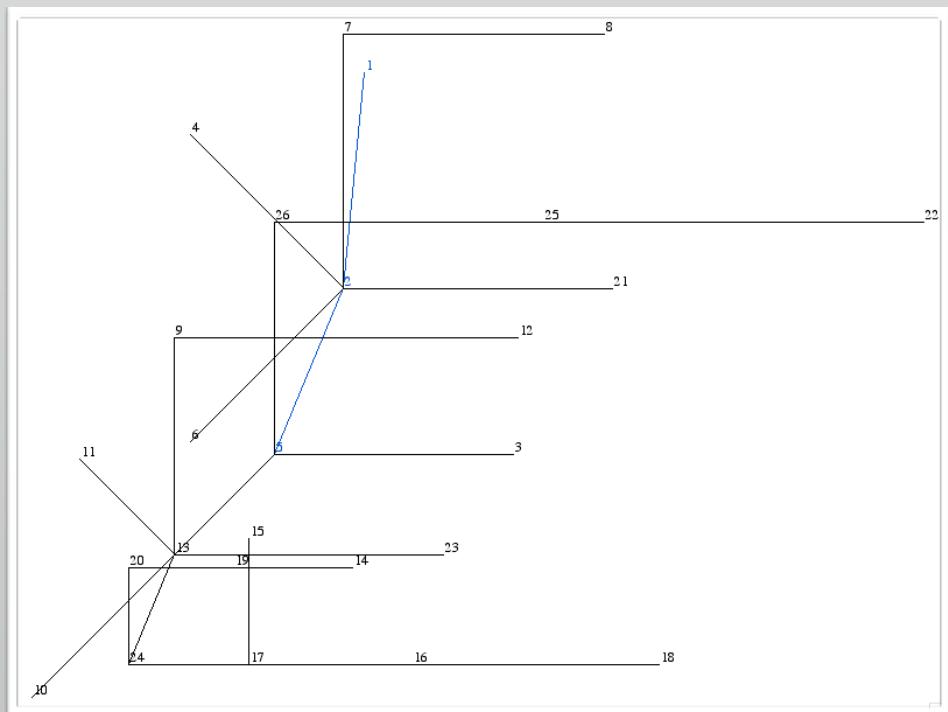
Construction of temporal forms : A few examples of CAC (from *The OM Composer's Book*)



combinatorial optimization problems

Ph. Leroux
VOI(DEX) (2002)

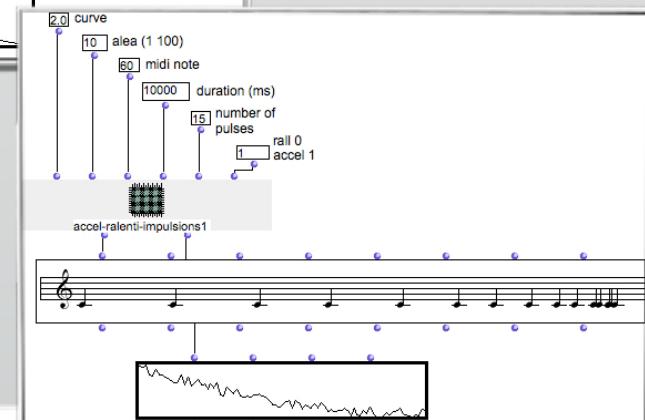
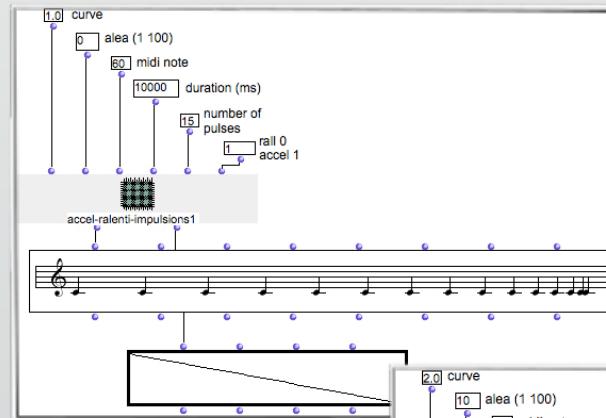
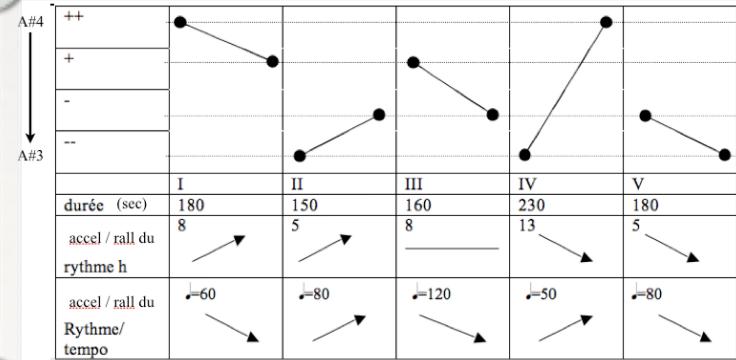
Minimum Weight Spanning Tree
= optimal arrangement of the chords
following a given classification criteria



G. Lorieux

Langage de l'ombre

(2006)



Pattern to slow down

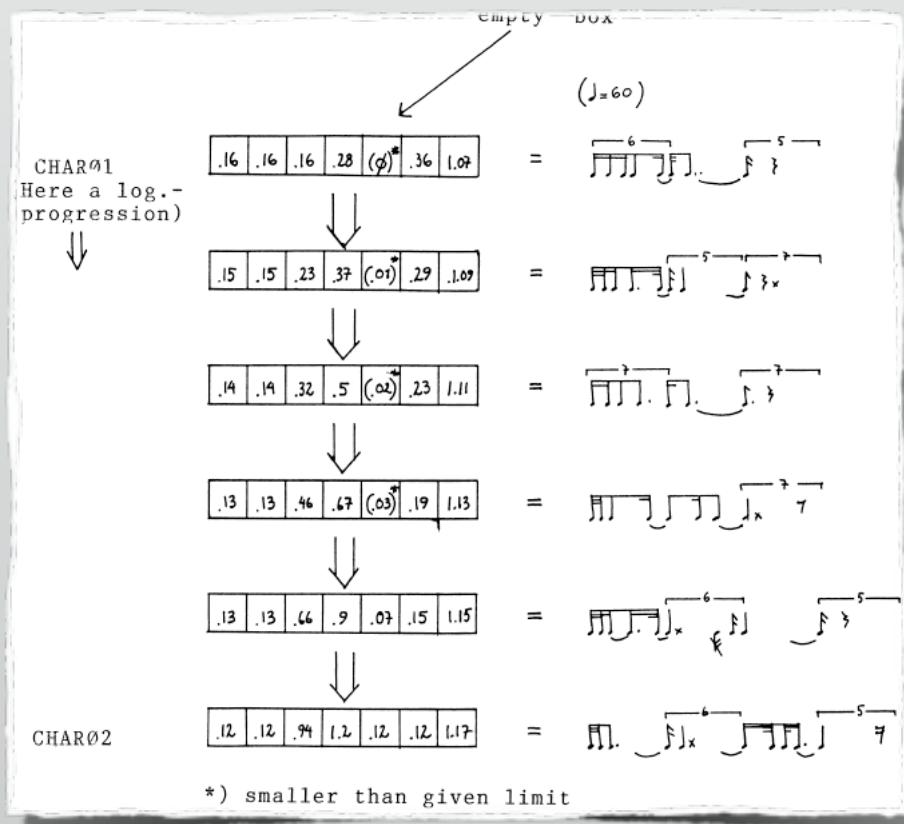


Simple pulses

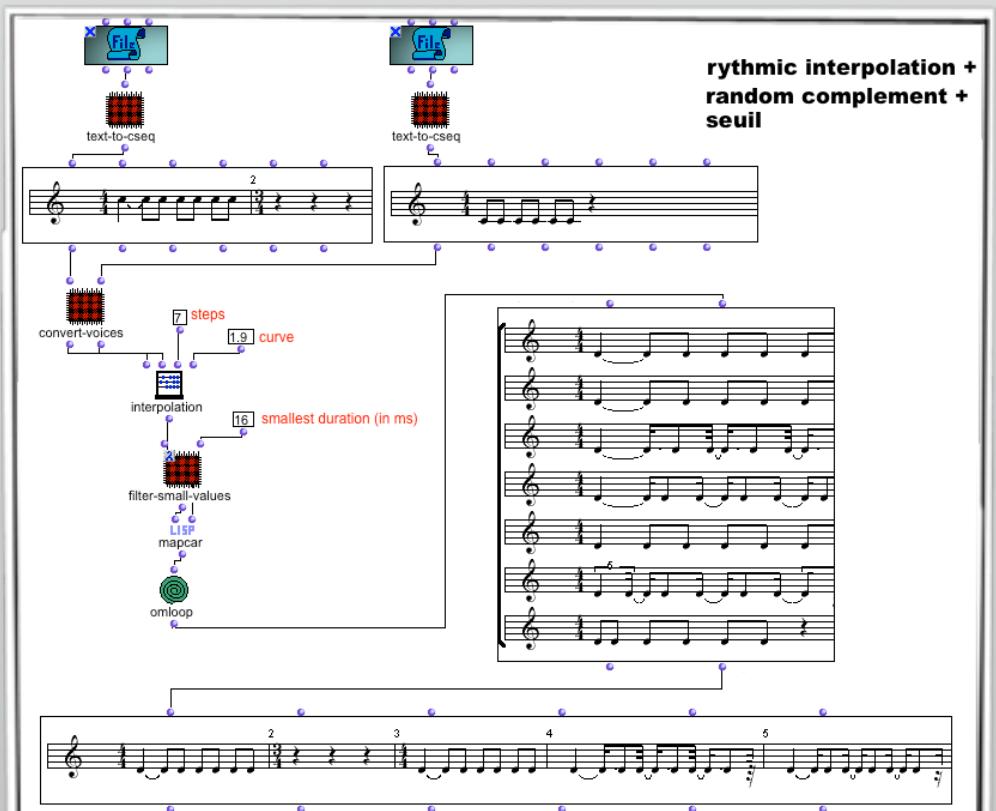


Result





A. Schaathun *Double Portrait* (2006)



Ph. Hurel / E. Daubresse
Hors-Jeu (2006)

The image displays a complex musical score and its generation process.

Musical Score: The top half shows a multi-part musical score for various instruments, including a woodwind part with six staves and a glockenspiel part at the bottom.

Software Interface: The bottom left contains a software interface titled "BPF-LIB". It includes:

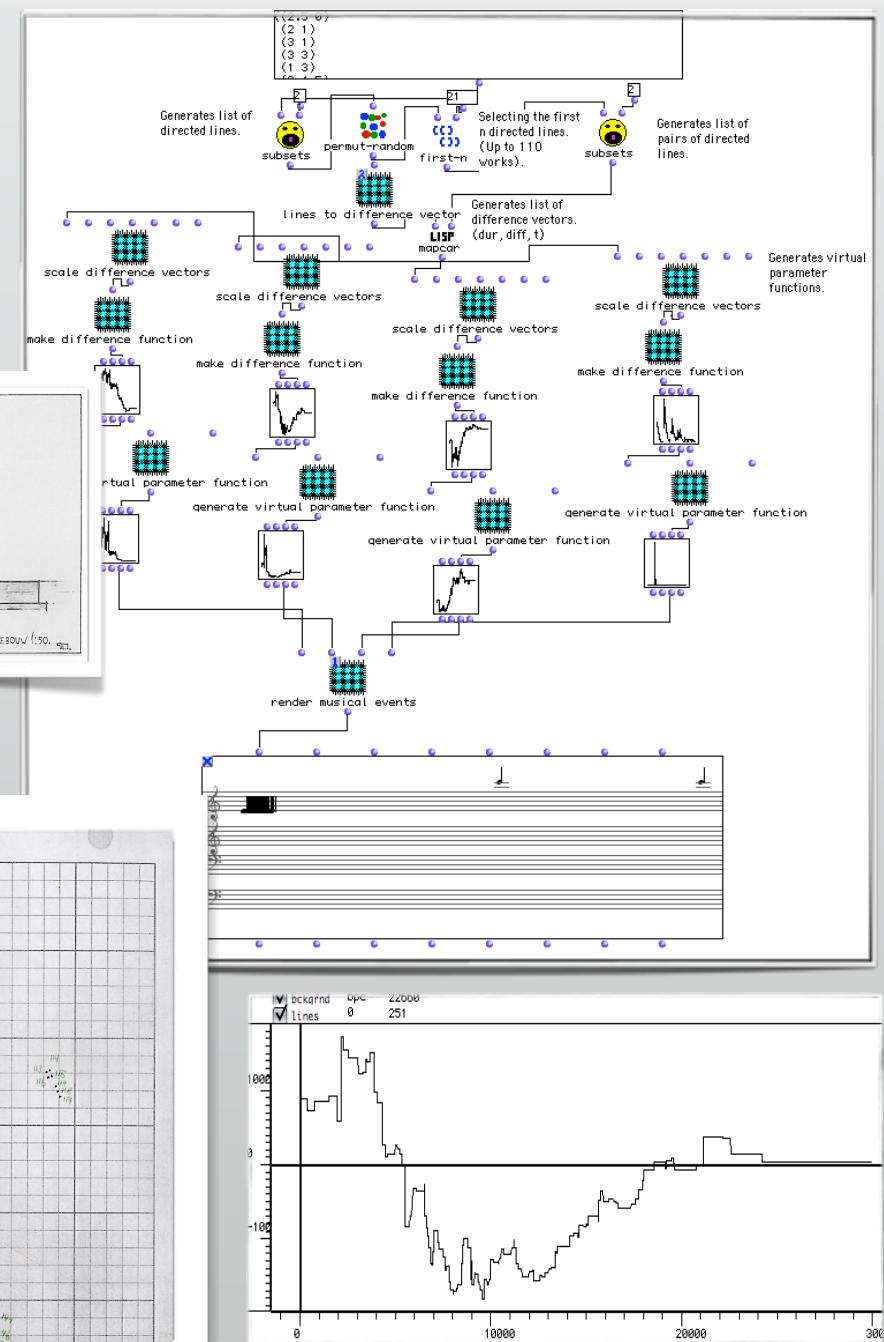
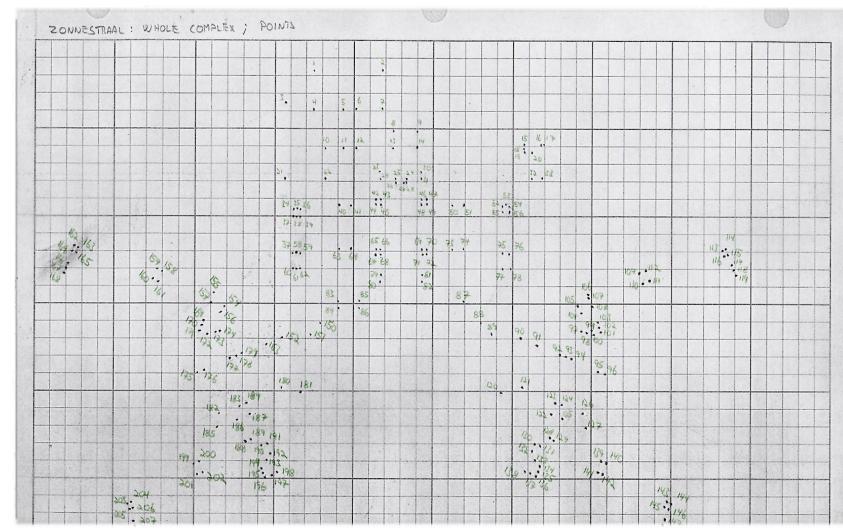
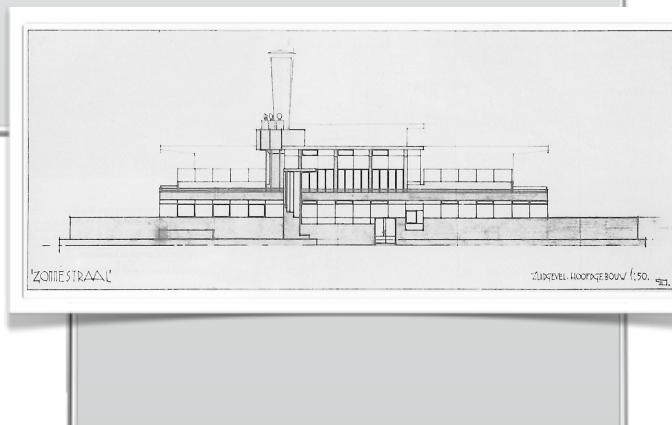
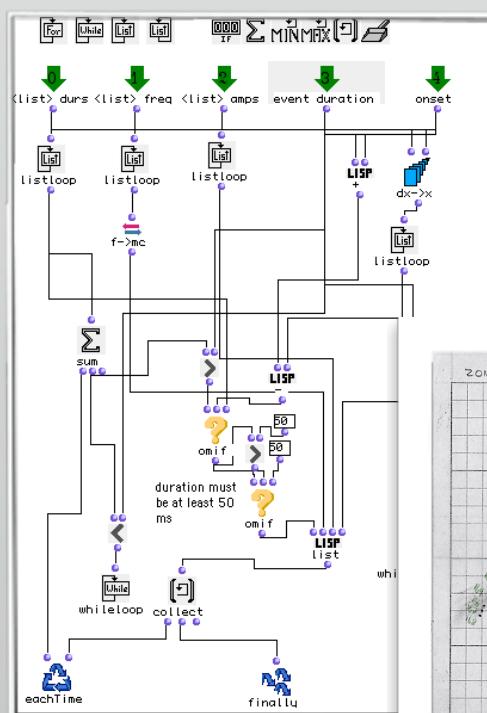
- A "pattern de départ" section with two diagrams: one showing a jagged waveform and another showing a straight diagonal line.
- A "pattern d'arrivée" section with a diagram showing a straight diagonal line.
- A "nombre de patterns supplémentaires à la fin" section with a dropdown menu set to "0".
- A central graph titled "BPF-LIB" showing a fluctuating waveform over time (0 to 110).
- A "bpf-interpolx" section with a small red icon.
- A "visualisation" section showing a waveform visualization.
- A "Glockenspiel" section at the bottom with musical notation.

Waveform Analysis: A large waveform visualization is overlaid on the musical score, showing amplitude over time across multiple staves.

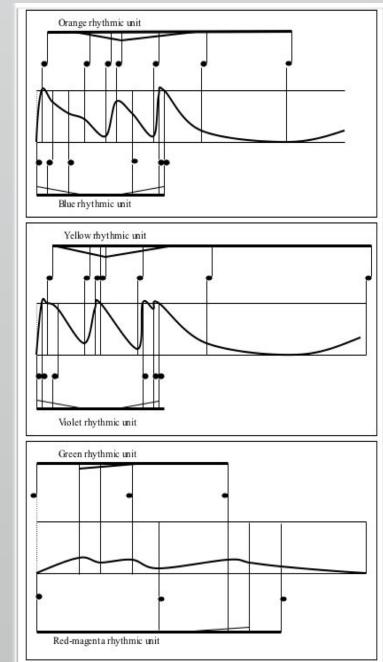
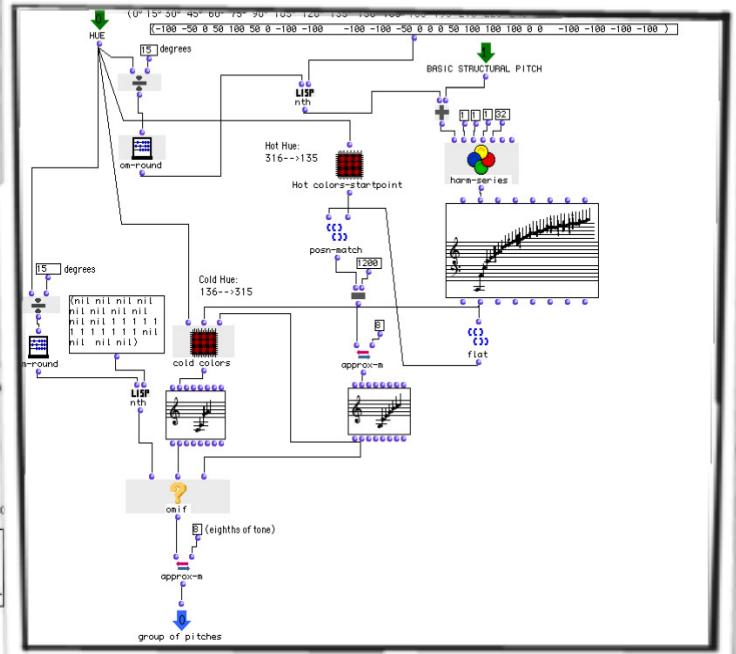
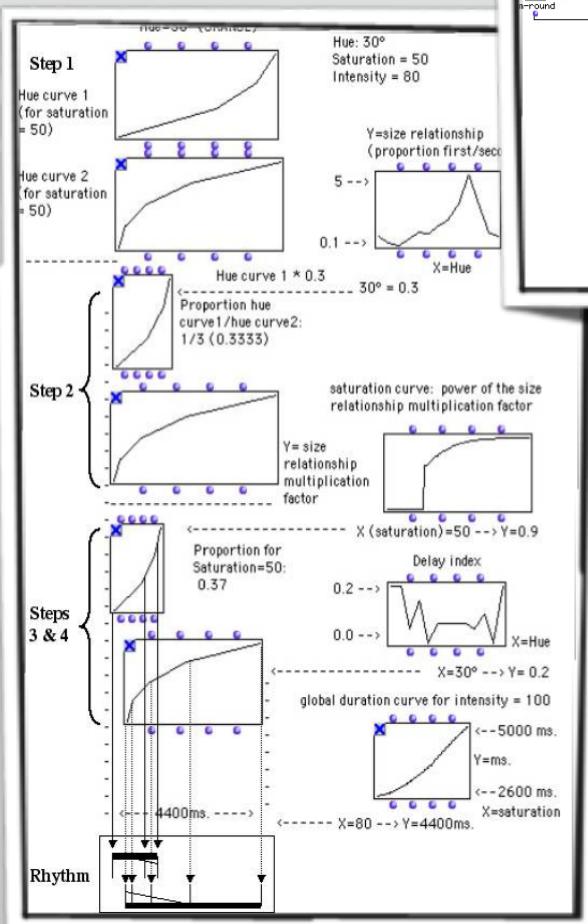
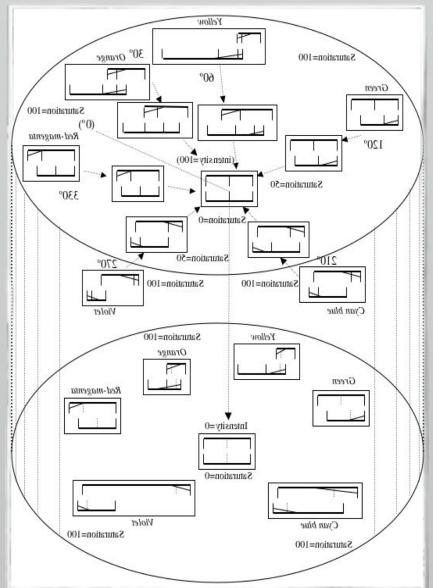
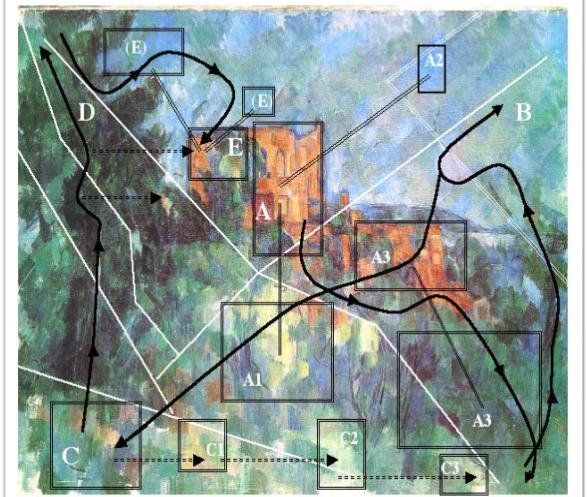
C. Jaksjo

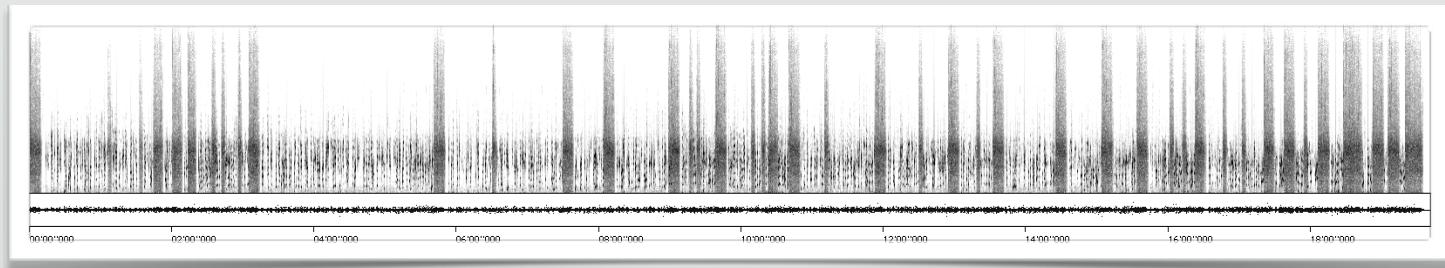
Undergrounded [Zoonestraal] I (2002)

Zoonestraal (2008)

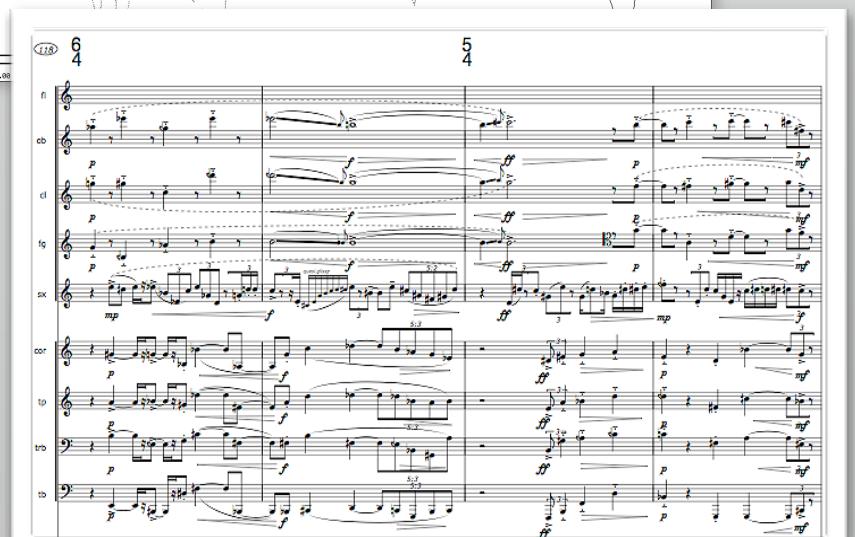
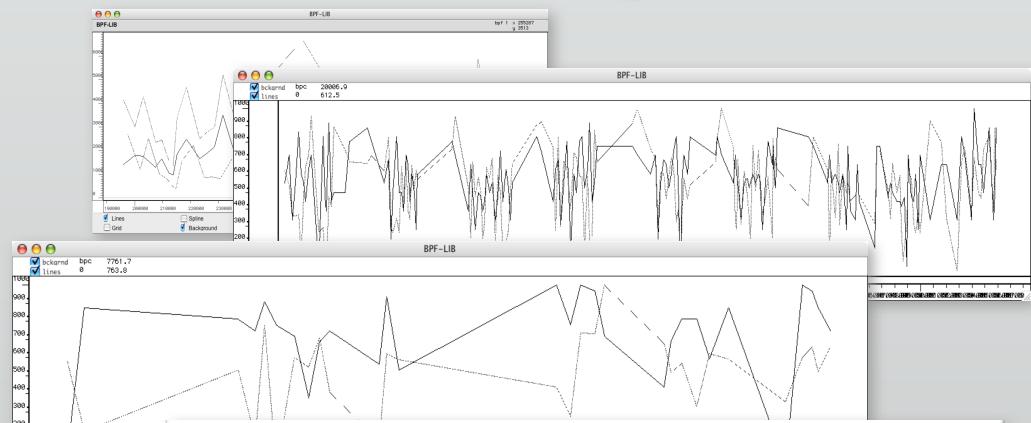
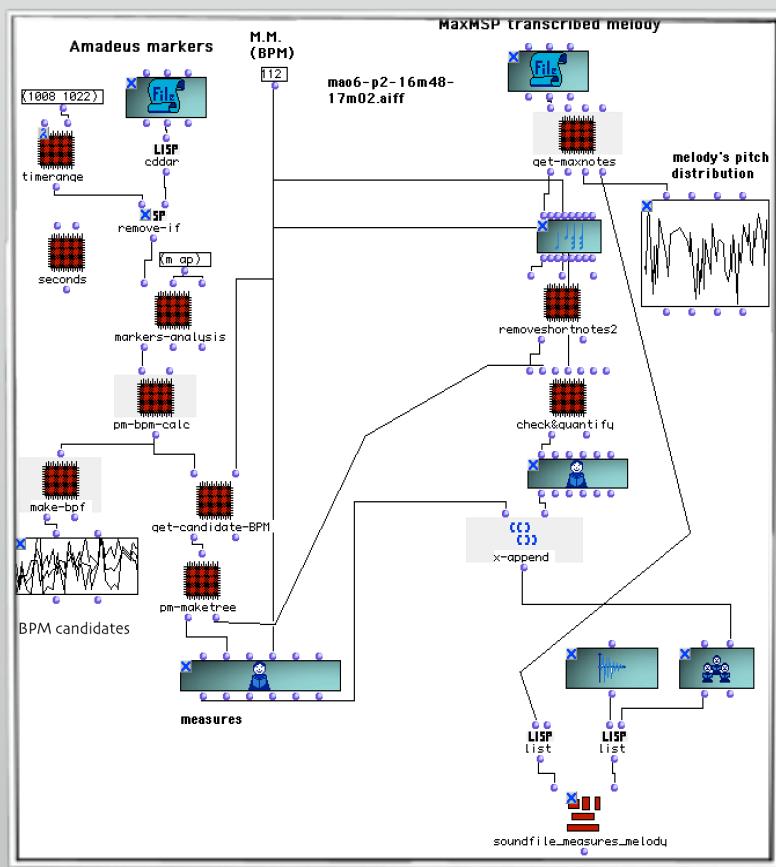


H. Parra
Strette (2006)



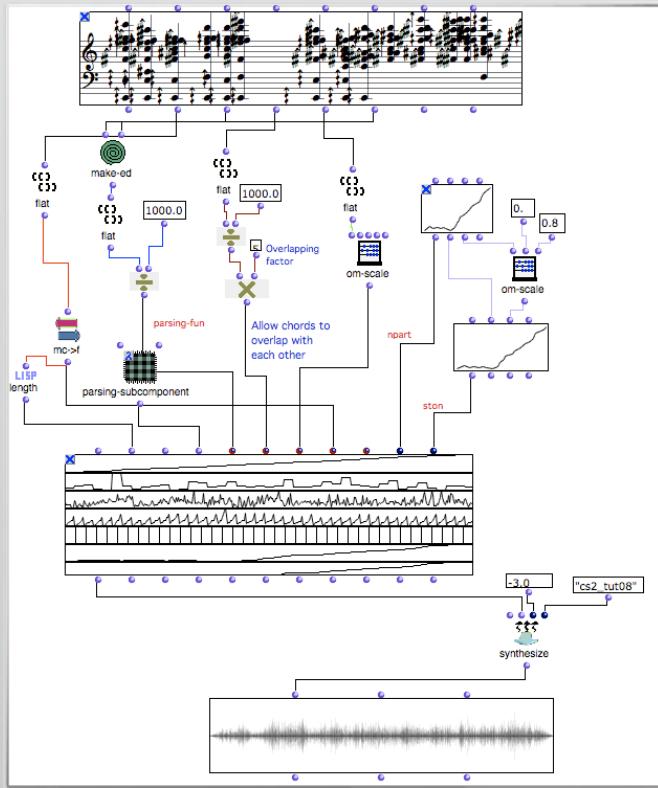


P. Linborg
TreeTorika
(2006)

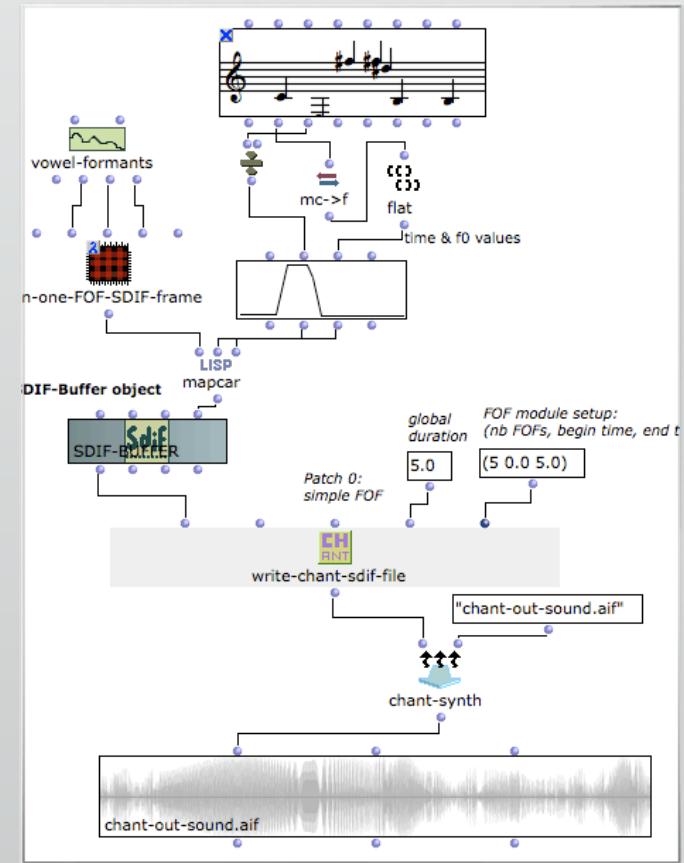


... construction of large-scale temporal forms

Applies in the sound processing domain too:



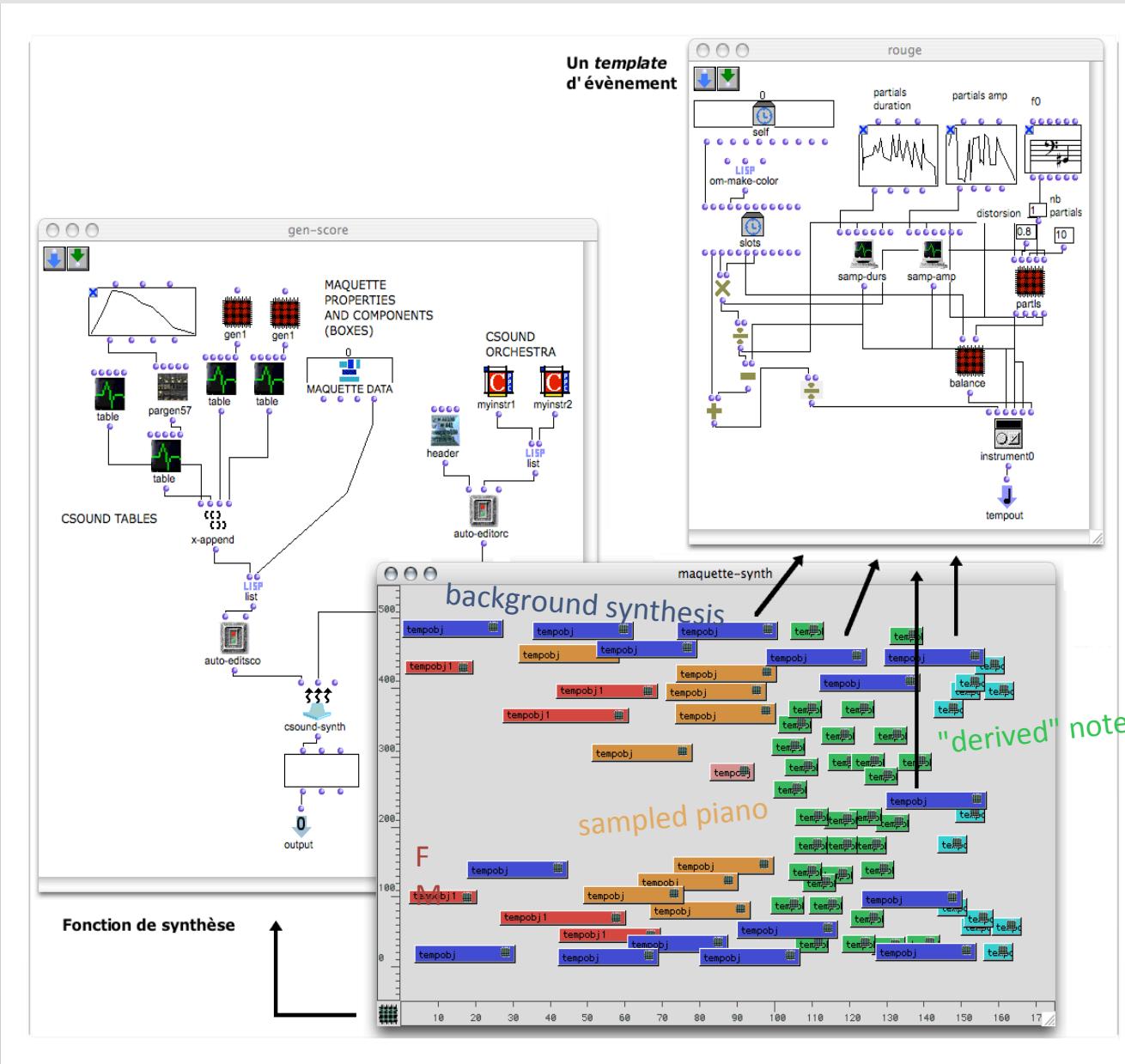
J. Bresson, M. Stroppa, C. Agon :
Generation and Representation of Data and Events for the Control of Sound Synthesis, Proc. Sound and Music Computing Conference, Lefkada, Greece, 2007.



J. Bresson, R. Foulon, M. Stroppa, *Reduction as a Transition Controller for Sound Synthesis Events*. Workshop on Functional Art, Music, Modeling and Design, Boston, MA, USA, 2013.

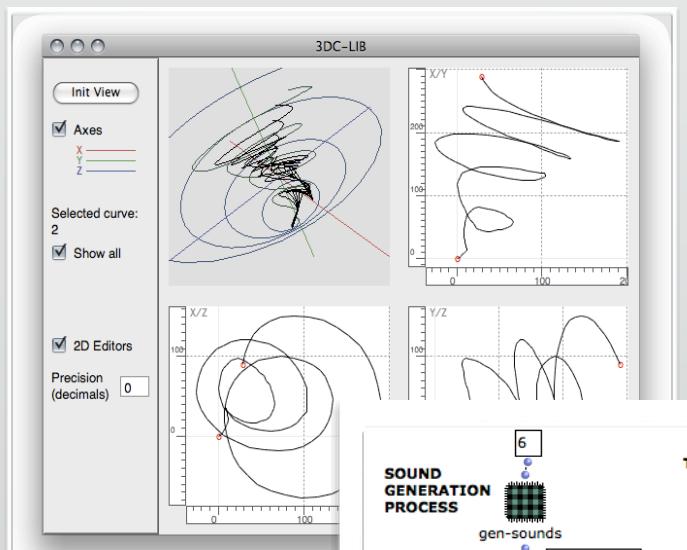
- => Implementation of the compositional electroacoustic models and processes
- Symbolic approach/representation of sounds
- Musical sound formalisation

... construction of large-scale temporal forms (+ sound synthesis)

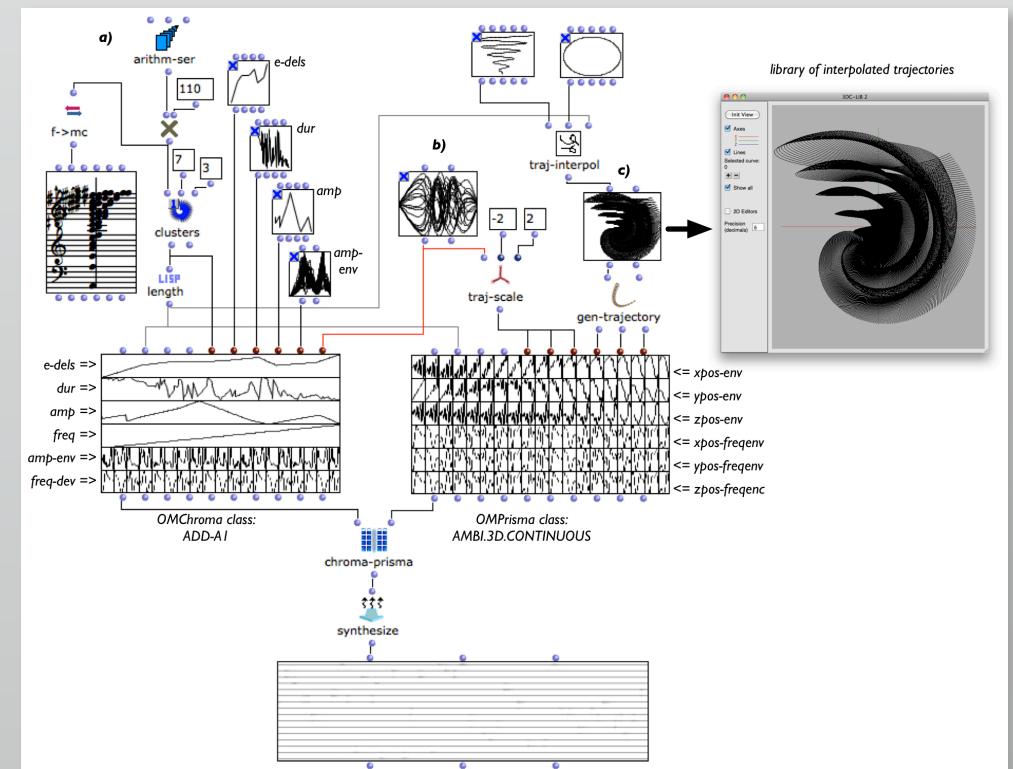
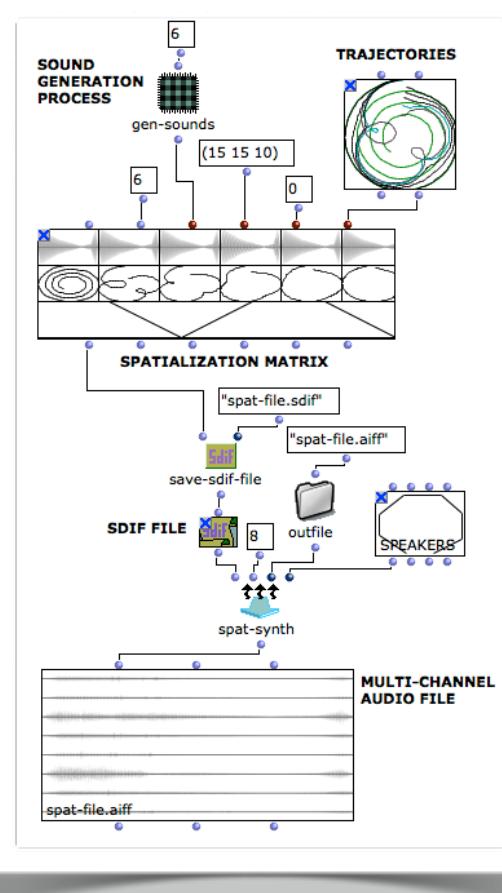


[0'35"]

[... and sound spatialization]



J. Bresson, "Spatial Structures Programming for Music". AAMAS'12
Spatial Computing Workshop, Valencia, 2012.

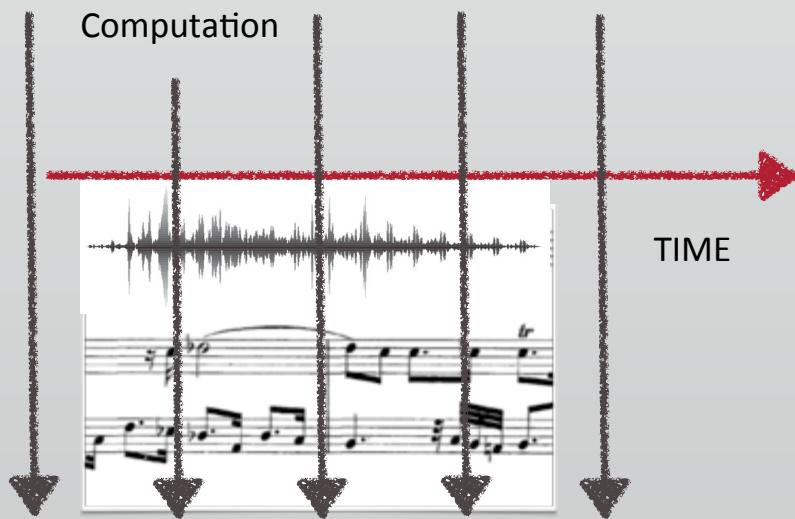


M. Schumacher, J. Bresson (2010) Spatial Sound Synthesis in Computer-Aided Composition. Organised Sound, 15(3).

Time of computation vs. Time of music

(reactive) real-time systems

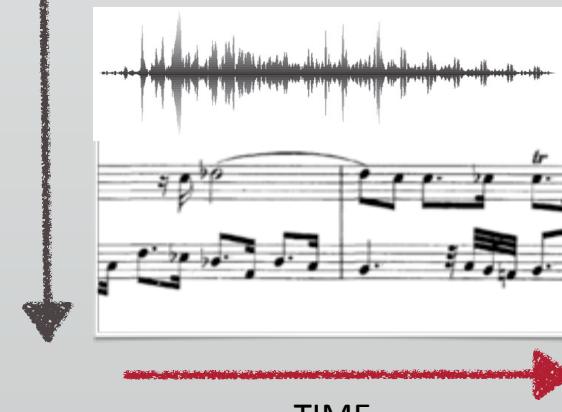
[Max]



(transformational)
computer-aided composition

[OM]

Computation
(Best effort)



where the distinction gets blurred...

Live coding

```

line-player
(declare (beat inst)
  (let ((dur (random (.cons .8 1/8) (.cons .1 8) (.cons .1 1))))))
    (play inst (random 30 75) (random 10 70) (* .8 dur)))
    (setf *angle* (random 360))
    (cond ((> dur 1)
           (change-over-time beat (* dur .8) 1/4 (random 10 90) (random 10 90)
                           change-inst *sm2:xf1:cutoff* 100
                           (random 4) (random 4) (random 4))
           (change-over-time beat (* dur .8) 1/4 (random 30 80) (random 30 80)
                           change-inst *sd2:vc1:cutoff* 100
                           (random 4) (random 4) (random 4)))
           (change-over-time beat (* dur .8) 1/4 (random -48 48) (random -48 48)
                           change-inst *sd2:xf1:freqoffset* 48
                           (random 4) (random 4) (random 4)))
           (callback (*metro* (+ beat (* .95 dur))) 'player (+ beat dur) inst)))
    )
  )
  (player (*metro* 'get-beat 4) zeb1)
)

```

Impromptu

Computer improvisation systems



0Max

Score following



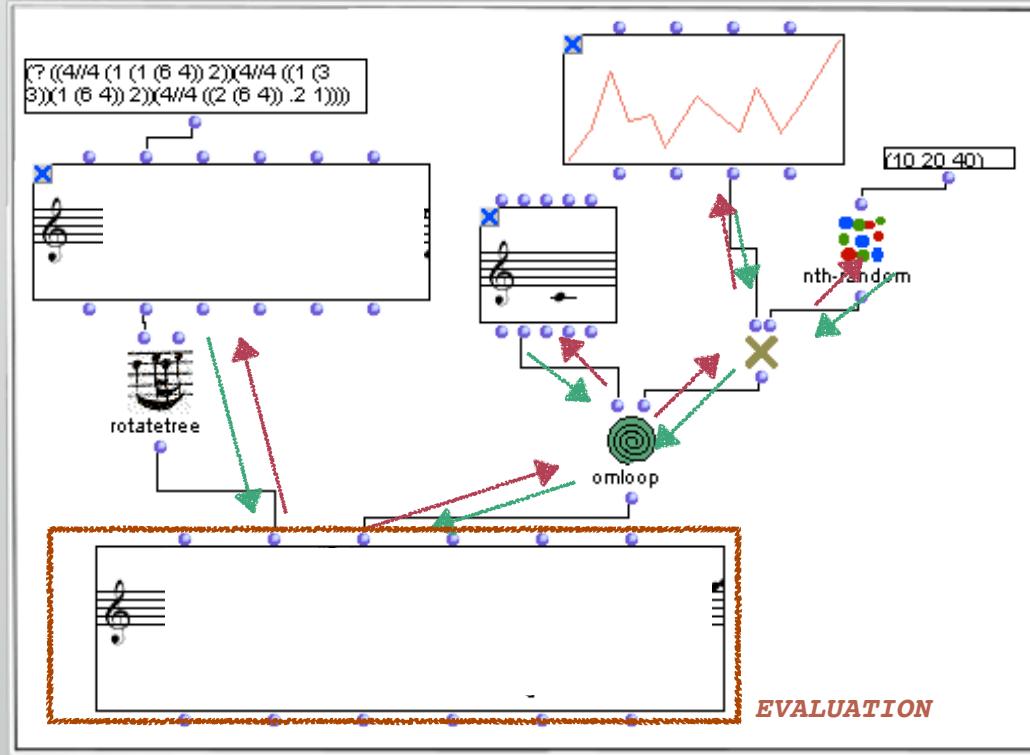
Antescofo

Toward a reactive computation model in OM

“demand-driven”

reactive

=> DEMO OM REACTIF



→ control

→ data flow

J. Bresson, C. Agon, G. Assayag. “Visual Lisp/CLOS Programming in OpenMusic”
Higher-Order and Symbolic Computation, 22(1), 2009.

Toward a reactive computation model in OM

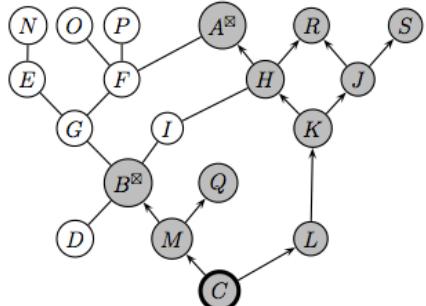


Figure 3: Call graph of the evaluation of C in Fig. 1.

Staggered Evaluation. The previous framework leads to a *staggered evaluation*

$$[\cdot]^t(\cdot) : \mathcal{B} \times \mathbb{N} \rightarrow \mathcal{V},$$

where only the values of the boxes required to compute the outputs of r^t are updated:

$$[\![b]\!]^t(k) = \begin{cases} * & \text{if } b \notin \mathcal{B}^t \\ e^t(b, k) & \text{if } \text{flag}^t(b) = \square \\ [\![b]\!]^{t-1}(k) & \text{if } \text{flag}^t(b) = \boxtimes \\ u & \text{if } \text{flag}^t(b) = \triangle \\ [\![b]\!]_k(v_1, \dots, v_{in(b)}) & \text{if } b \in \uparrow\{r^t\} \\ [\![b]\!]^{t-1}(k) & \text{otherwise} \end{cases}$$

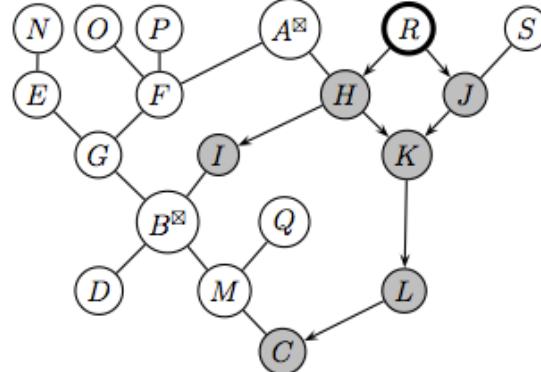
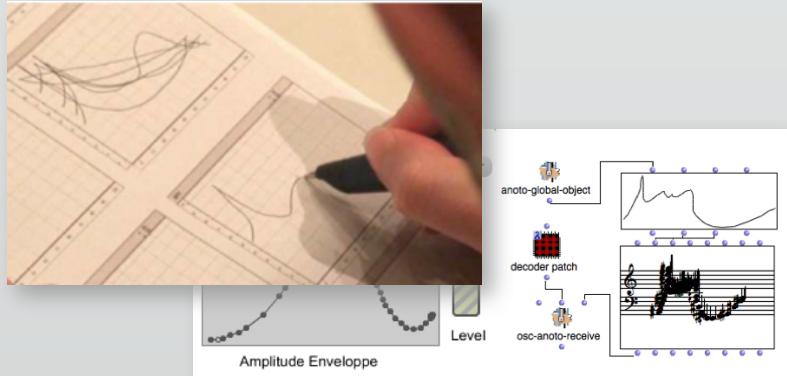
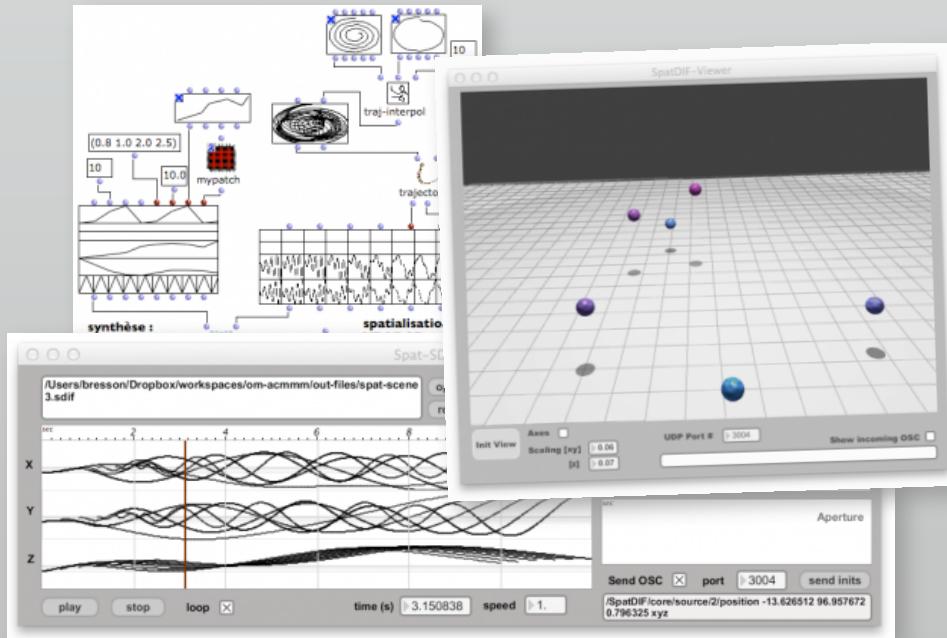


Figure 4: Propagation of event $\{R\}$ in the *reactive* patch from Fig. 1. We suppose that all boxes are active. Notice that $R \notin \downarrow\{R\}$: the values associated to R are obtained by edition, not by evaluation.

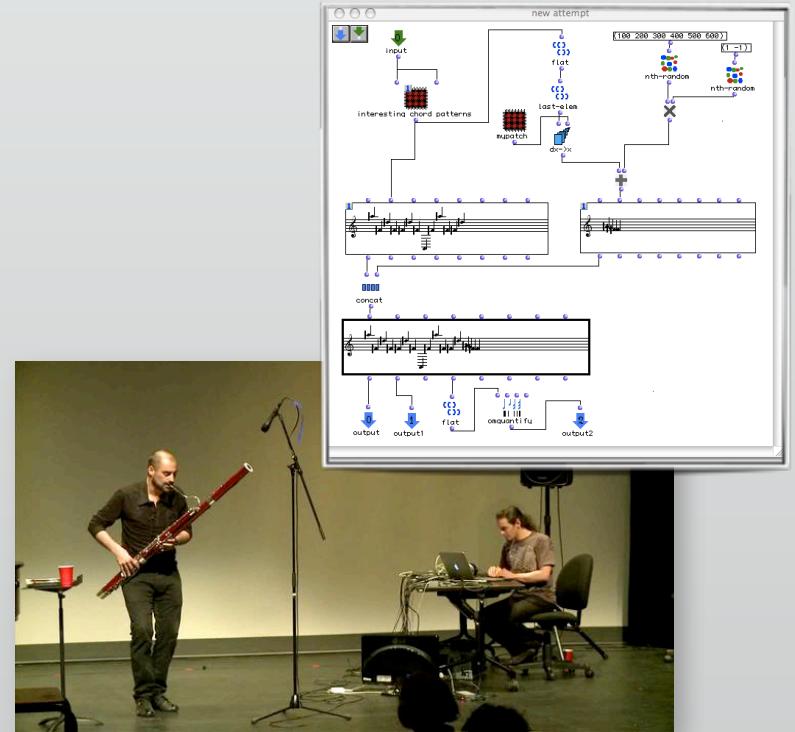
applications / perspectives



Gesture devices and integration
(J. Garcia, D. Schwartz)

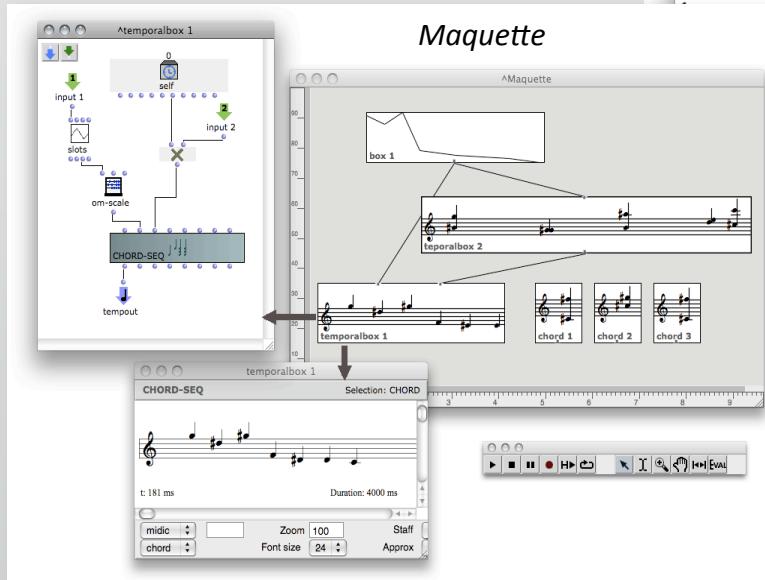


Control prcesses for granular sounds and spatialization (T. Carpentier, R. Gottfried, D. Schwartz)



Controlled improvisation systems
(J. Nika / Improtex)

applications / perspectives



Interaction in larger-scale time structures / dynamic scheduling
(D. Bouche)

Dynamic/interactive control of tempo and rhythmic structures
(J. MacCallum, F. Jacquemard)

