Session: Theme Human and Artificial Creativity (HAC)

Programming (Cyber-) Temporal Musical Systems

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[1]Equipe RepMus

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- Cyber-temporal vs. Cyber-physical systems
  - multiple times (defered time, real time), multiple models of time (event-driven, time-driven), multiple scale (audio to control), time programmability
- Inputs
  - evenemential inputs in OM (reactive-OM)
  - listening machine in Antescofo
- Temporal Scenarios
  - Antescofo augmented score
  - Open Score: temporal pattern and non-linear score
  - OM maquette
- Real-time scheduling
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  - ImproteK infrastructure
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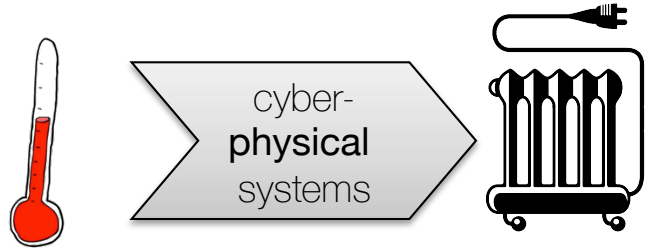
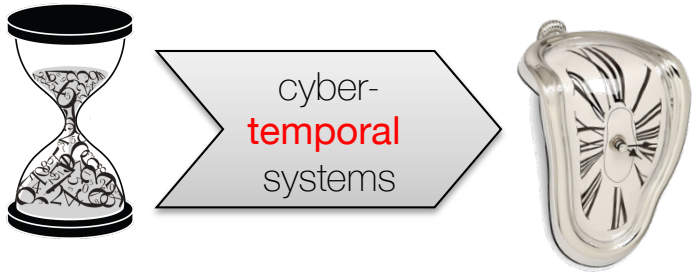
Notion of

CYBER-TEMPORAL SYSTEMS

Cyber-temporal systems:
computing time in real-time

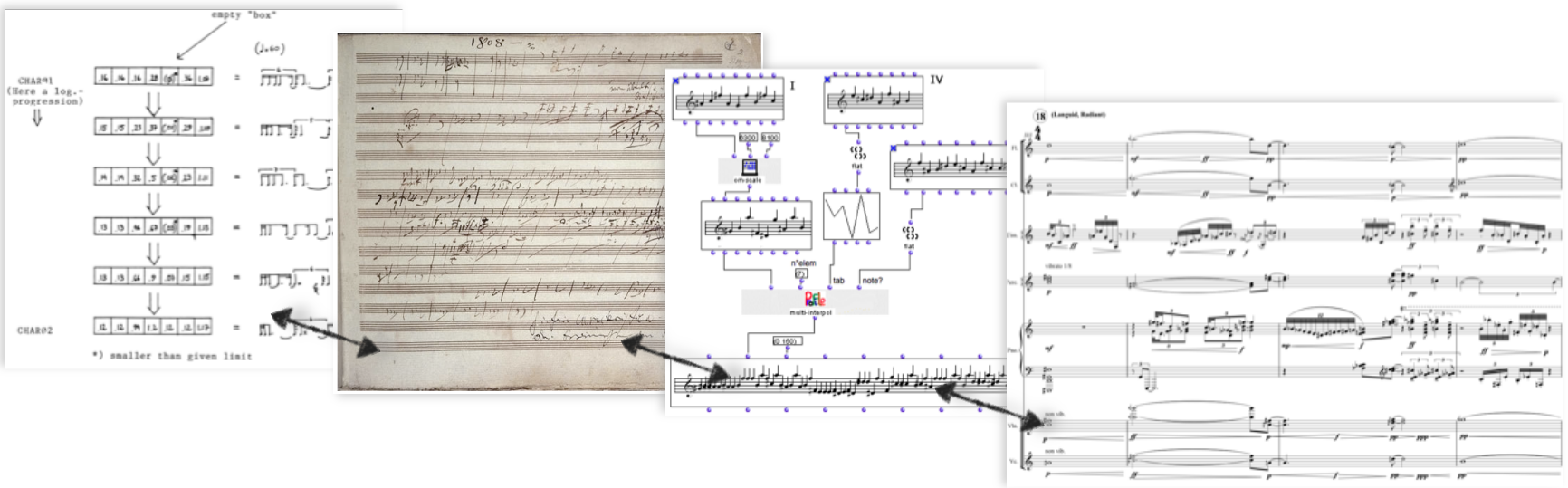
- *from:* physical entities monitored by algorithms
- *to:* temporal relationships sensed and produced by algorithms
- *example:* interactive music systems
  OpenMusic, Antescofo
- notionS of TIME:
  - multiple times: defered time, real-time
  - multiple models of time: event-driven, time-driven
  - multiple scales: from audio (0.02 ms) to control (hours)
  - time programmability: time is a denotable entity





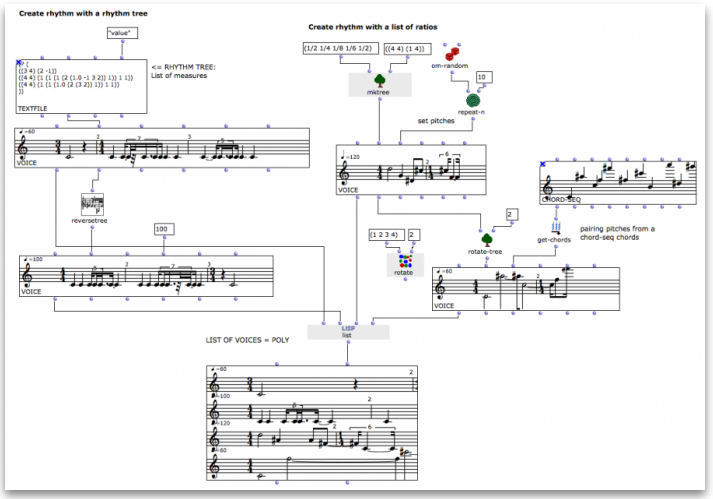
Visual Programming language + CAC environment

Open Music



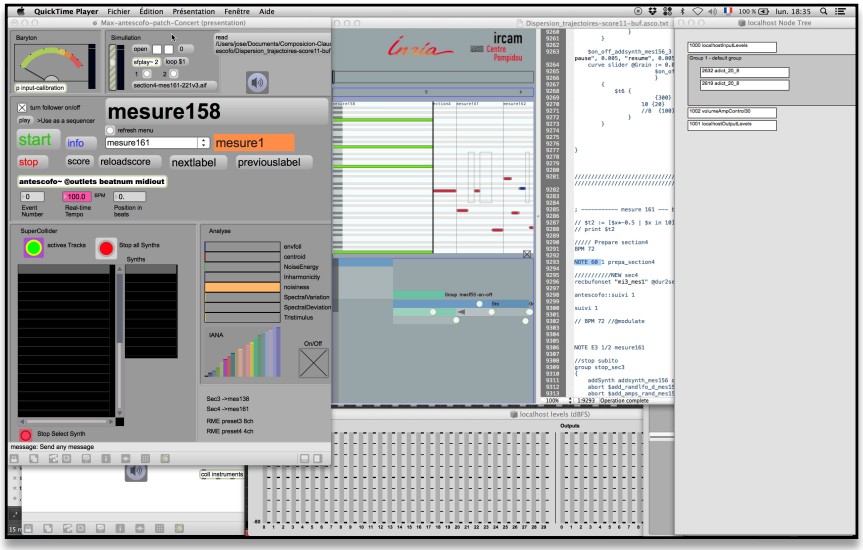
Formalization ⇆ Sketching ⇆ Implementation ⇆ Score

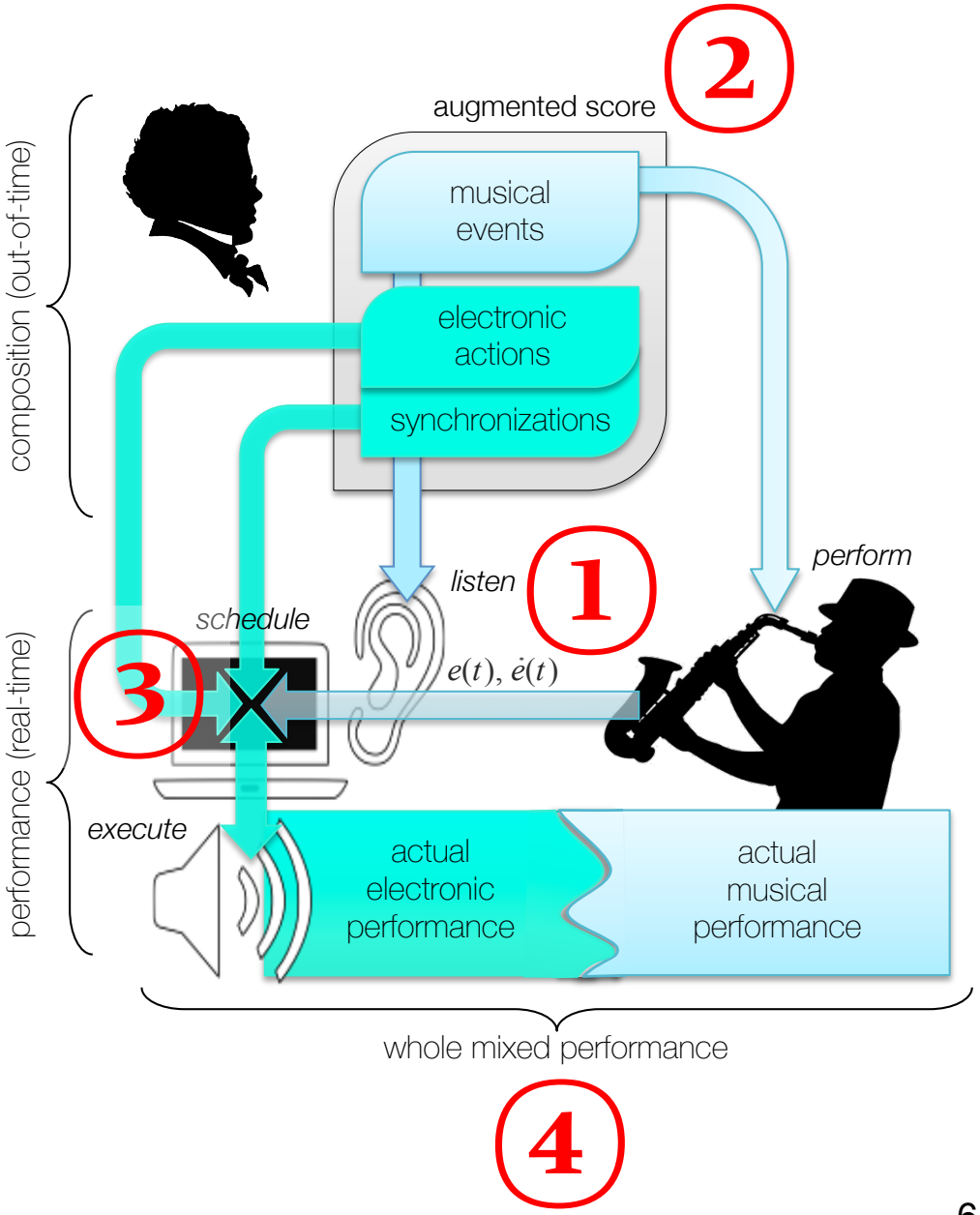
- OM Visual program = Symbolic Representation:
  - of a musical object/process,
  - of a compositional model.
- Describe intentions through a specific (computer) language.



reactive, strongly timed language + score following

Antescofo

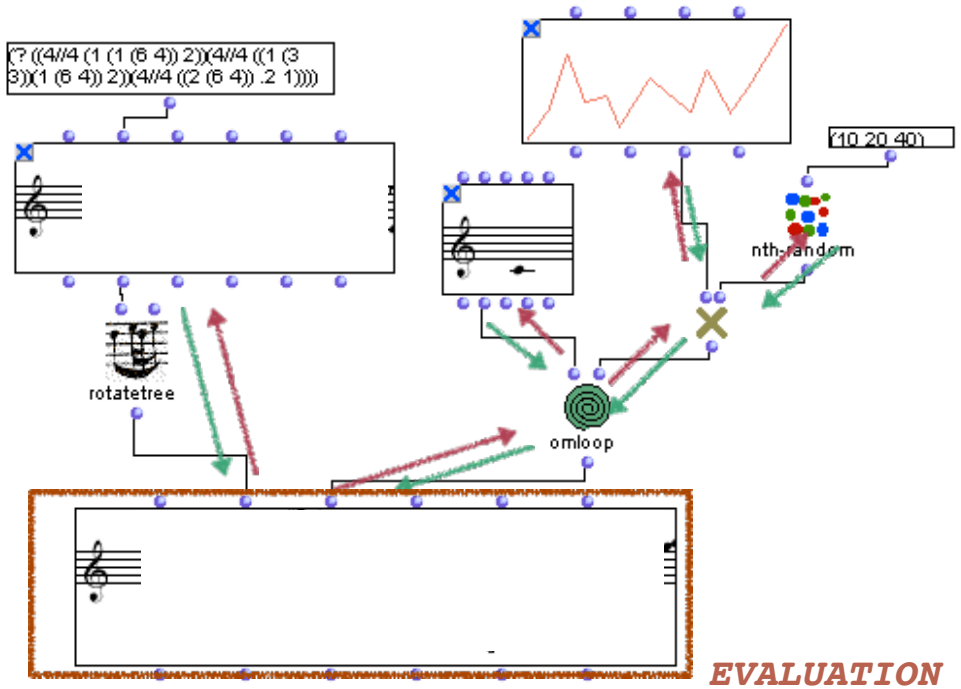




- taking events into account in OM
- formalization of temporal coherency of semi-Markov chains
- semi-Markov without prior information

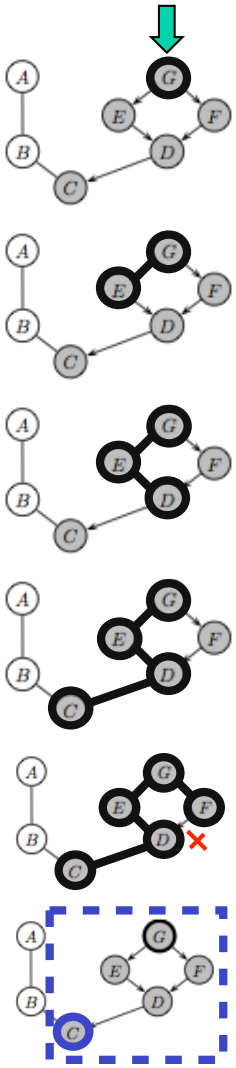
① SENSING

Subsuming the data-driven/event-driven dichotomy



demand-driven evaluation in OM

Subsuming the data-driven/event-driven dichotomy



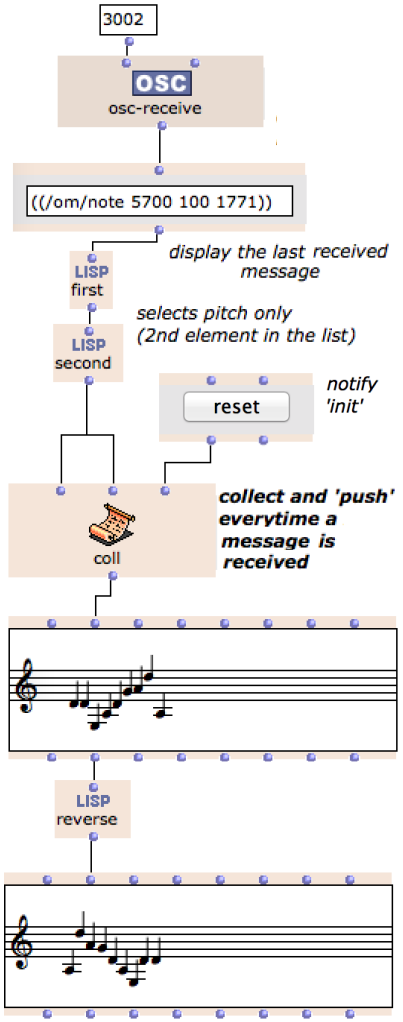
EVENT

propagation

End of propagation
(« end » box)

propagation

EVALUATION (update)



- Propagation of changes down the tree
- Immediate feedback
- Freeze
- Non-functional boxes

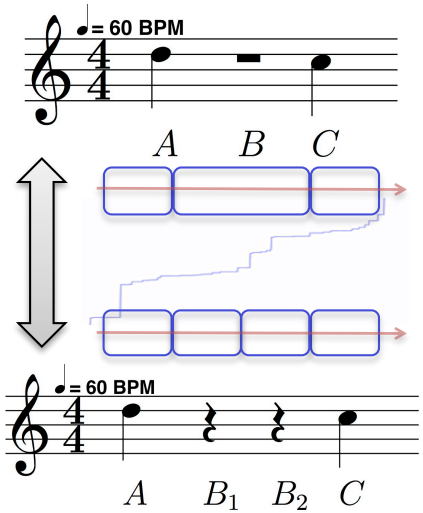
J.Bresson, J-L.Giavitto « A Reactive Extension of the OpenMusic Visual Programming Language », Journal of Visual Programming Languages and Computing, 2014

data-driven evaluation

Real-Time Machine Listening
1: temporal evolution

Score Following by Probabilistic Graphical Models
Temporal Coherency of Semi-Markov Chains

- How does the inference behave if the observation is non-informative?
- Is duration(A)+duration(B) probabilistically & inference-wise equivalent to duration(A+B)?
- What are sufficient conditions on probabilistic laws to satisfy time-coherency?



- Theoretical Results
  - Relation between semi-Markov chains & Lévy Processes
  - Formalization of an interesting sub-class of Lévy Processes (log-concavity, stochastic order, etc.) where certain properties are invariant to discretization
  - Formalization of *Hazard Rate* quantifying the conformance of models

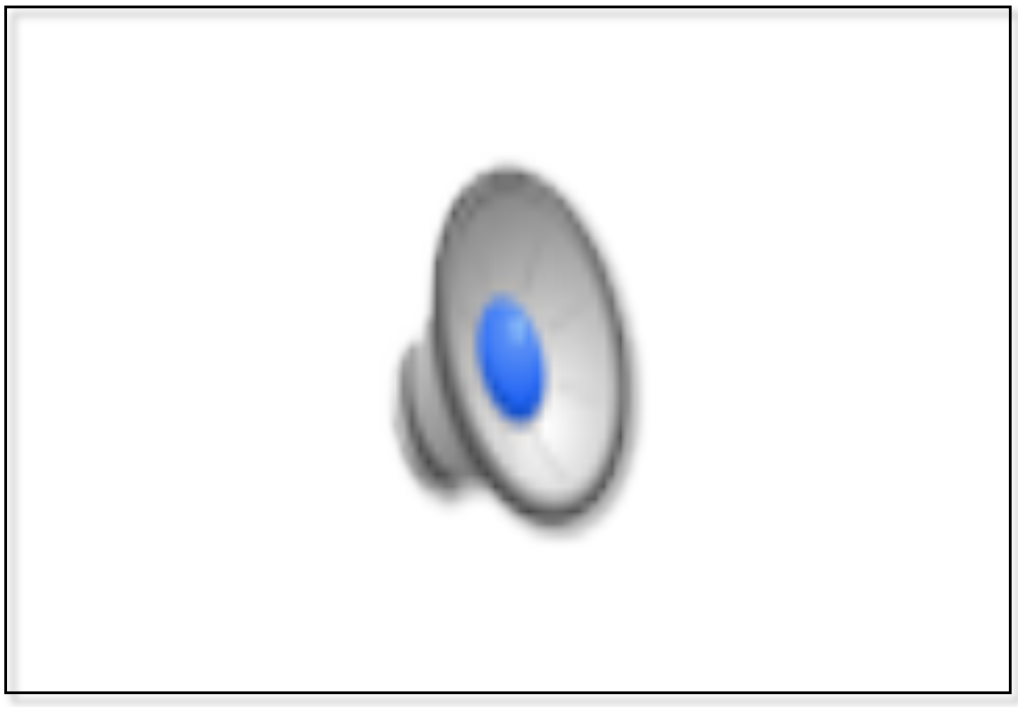
Philippe Cuvillier, Arshia Cont. Coherent Time Modeling of semi-Markov Models with Application to Real-Time Audio-to-Score Alignment. *MLSP 2014 - IEEE International Workshop on Machine Learning for Signal Processing 2014*.

Real-Time Machine Listening

2: instantaneous observation

Online Segmentation & Clustering of Audio Signals

- Following the same Semi-Markov hypothesis & formalization;
- Drop out the prior information (music score, pitch structure, duration, etc.)
- Online/Incremental learning of observation probabilities



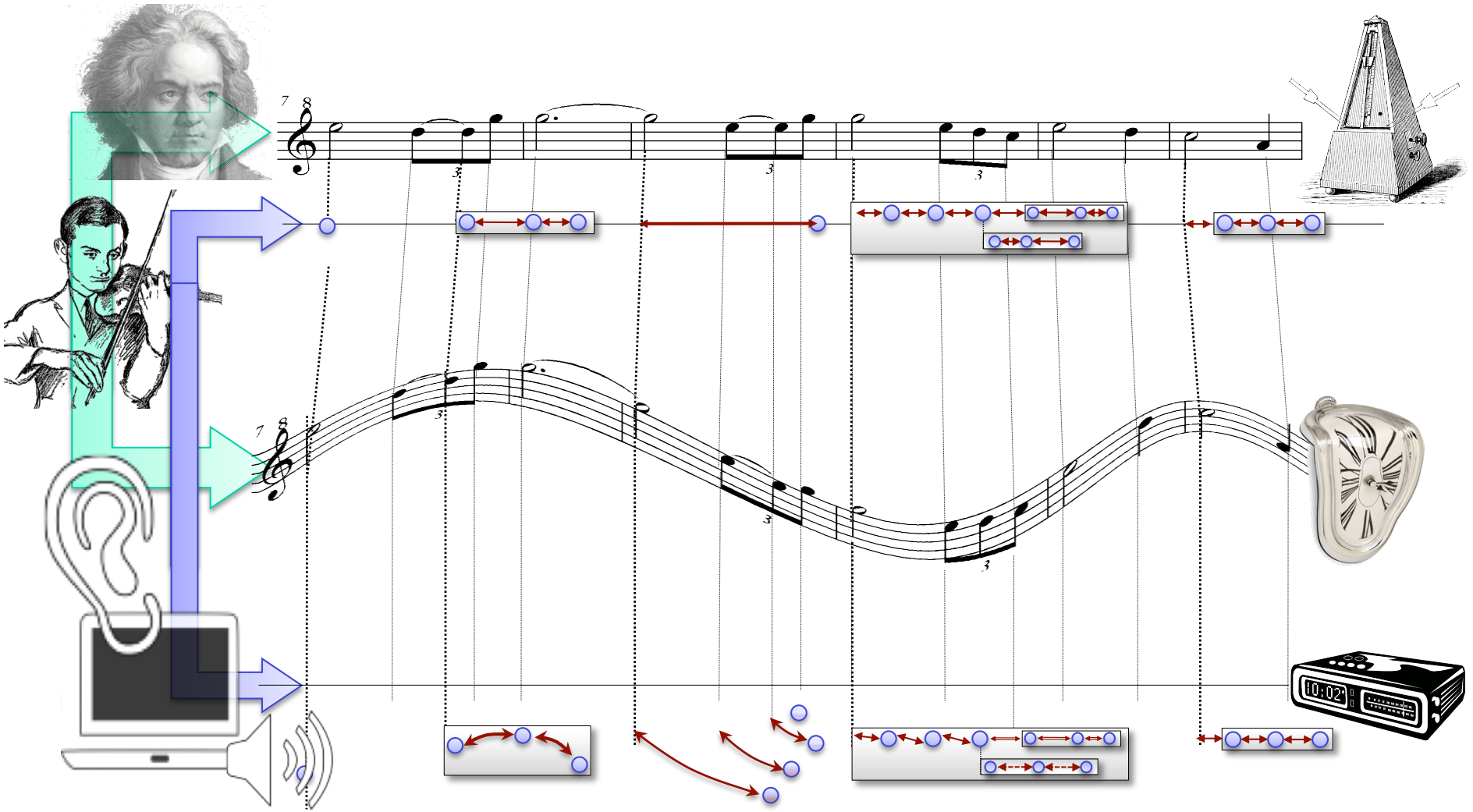
- Unsupervised
- Beaten up State-of-the-art Supervised Methods on Drum Classification
- Going towards Auditory Scene Analysis
- In collaboration with SIERRA

Alberto Bietti, Francis Bach, Arshia Cont. An online EM algorithm in hidden (semi-)Markov models for audio segmentation and clustering. *ICASSP 2015 - 40th IEEE International Conference on Acoustics, Speech and Signal Processing*, Apr 2015, Brisbane, Australia. 2015. **(Best Student Paper Award)**

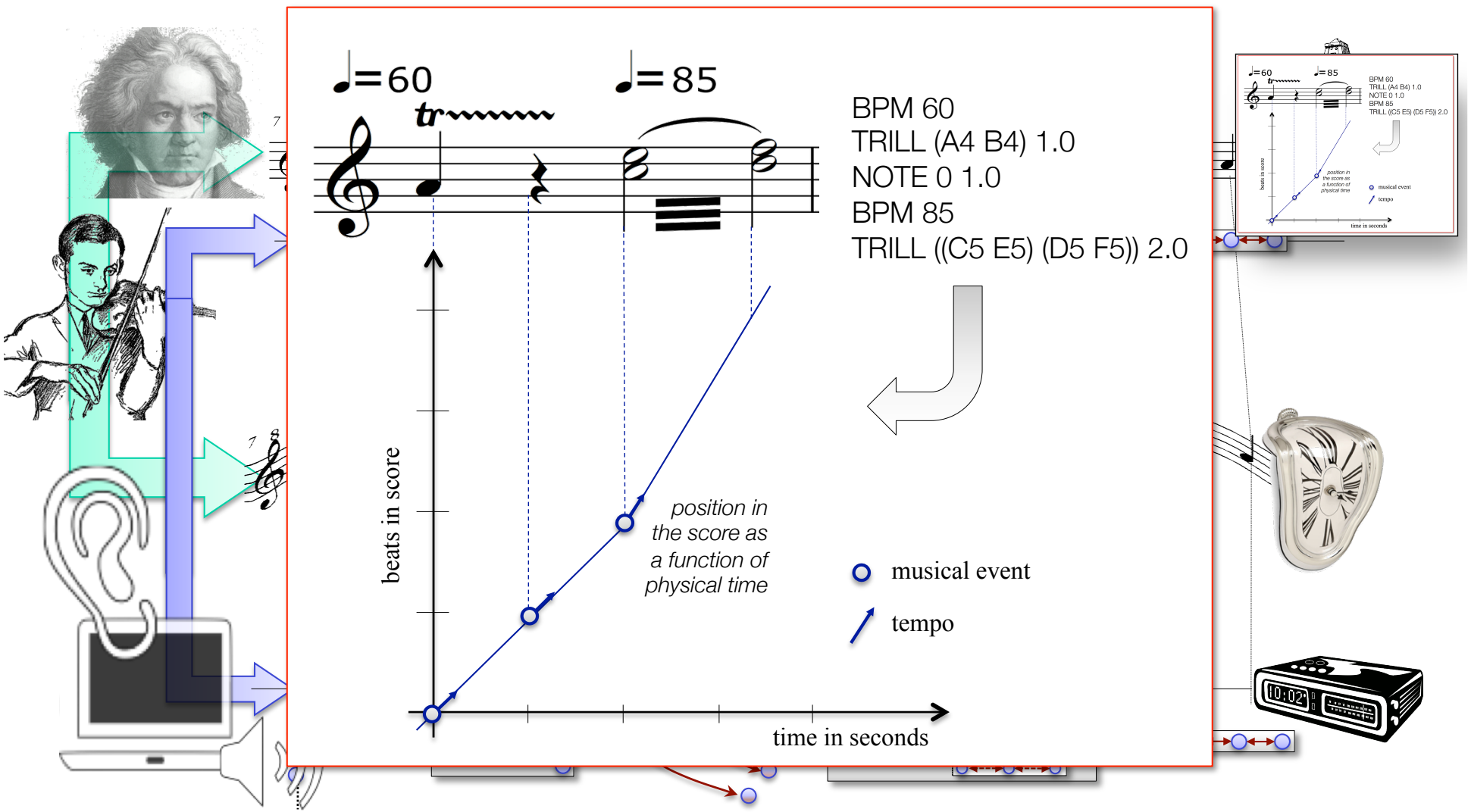
Programming

② TEMPORAL SCENARIOS

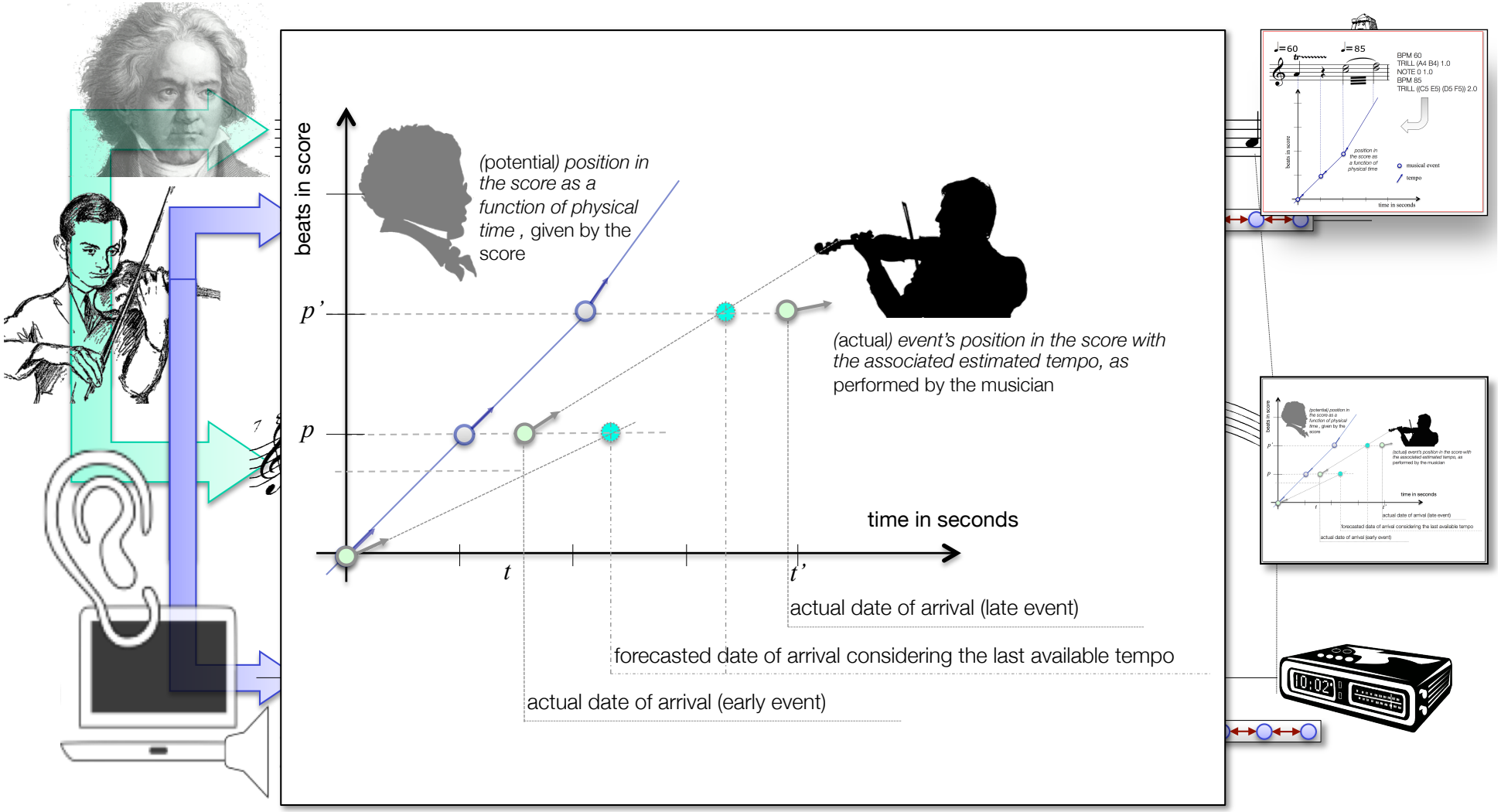
The Multiples Times of Temporal Scenarios



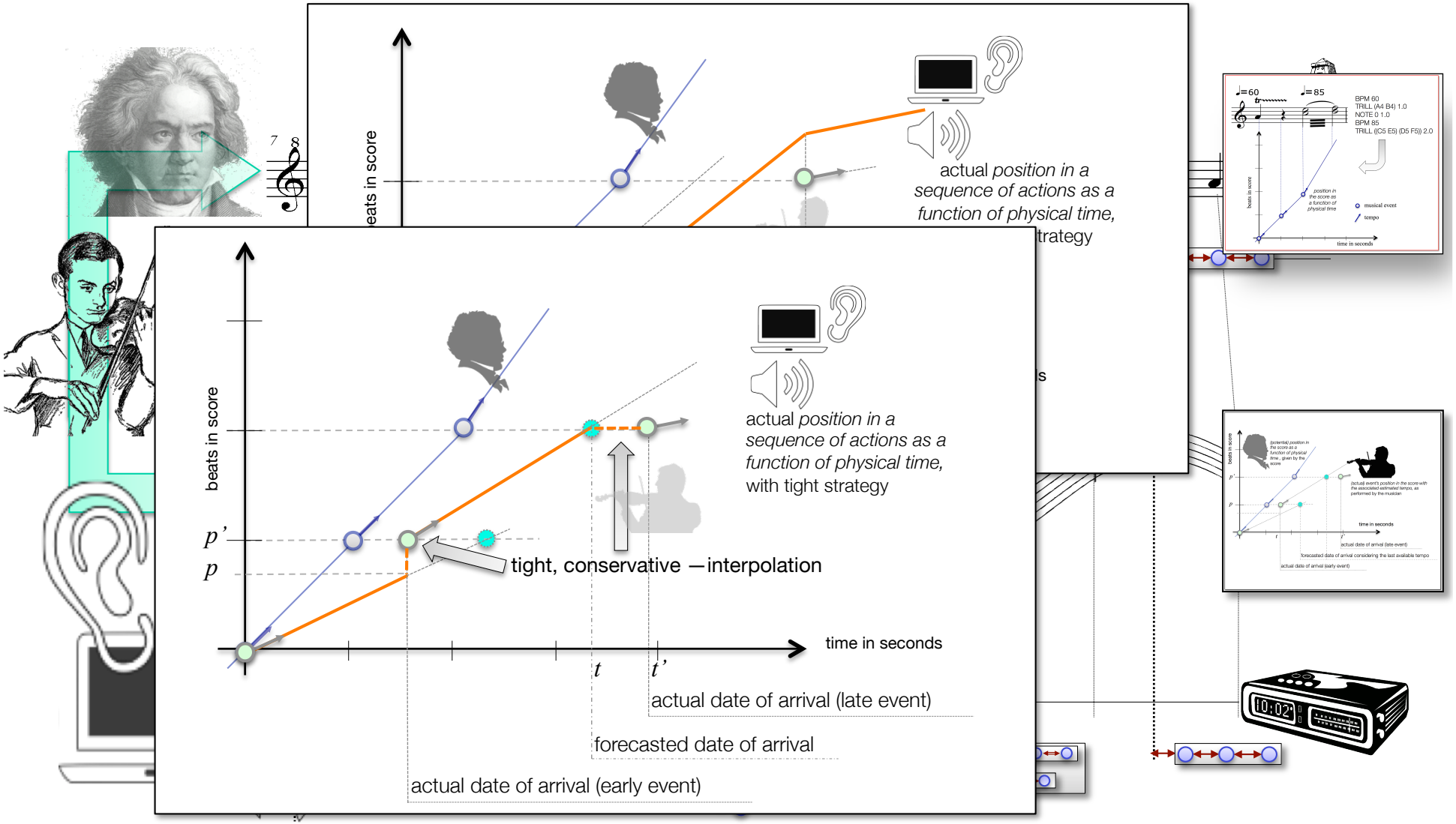
Time-time diagrams



Time-time diagrams

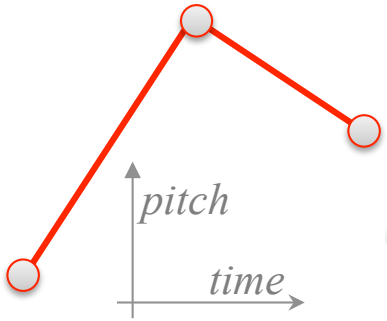


Time-time diagrams



Open Score in Antescofo

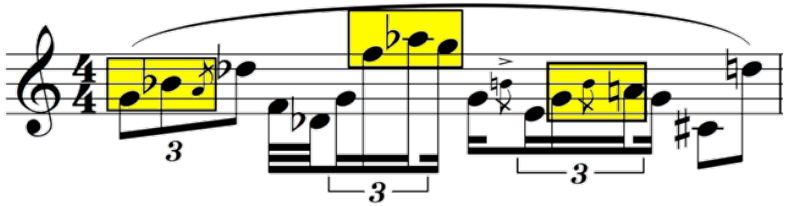
- real-time matching of temporal pattern



specification
(including durational properties)

```
pattern P
{
   @local $x , $y , $z
   NOTE $x
   before [0.5]
   NOTE $y where $x < $y
   before [0.5]
   NOTE $z where ($y>$z) & ($z>$x)
}
```

compilation
&
on-the-fly matching



Real-Time Matching of Antescofo Temporal Patterns, Jean-Louis Giavitto, José Echeveste, ACM PPDP 2014, 2014.

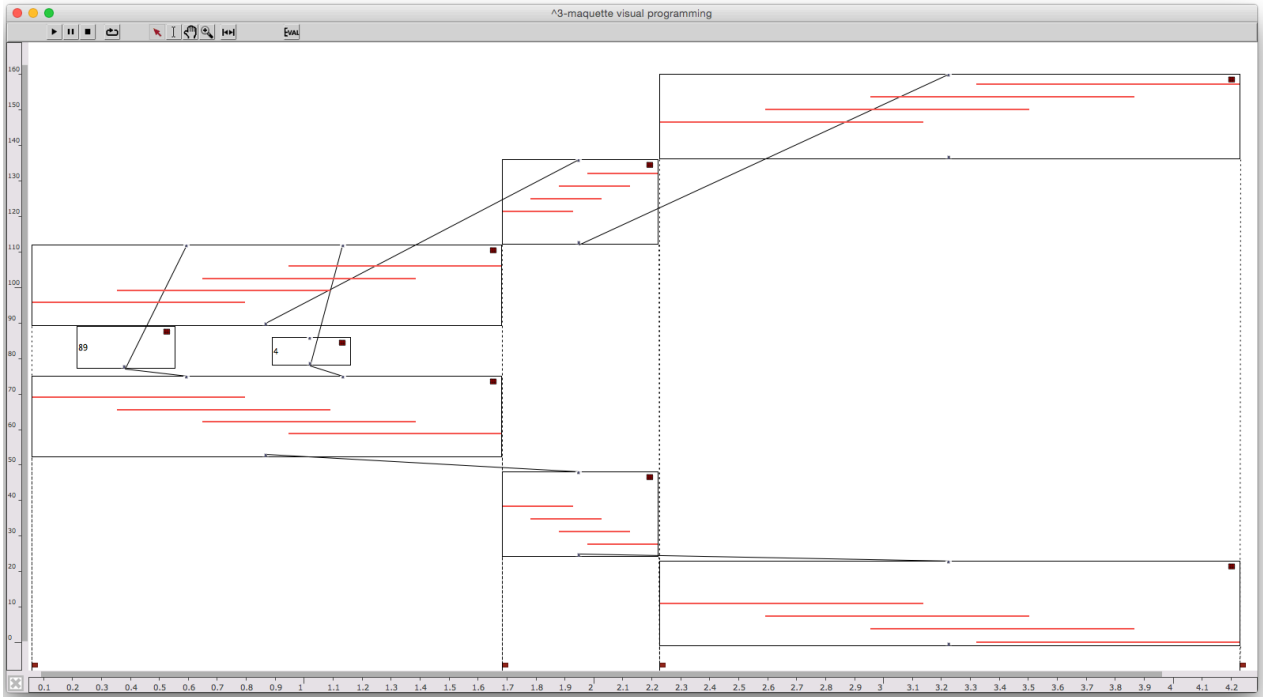
- dynamic non-deterministic score

Jason Freeman (GeorgiaTech) *Shadows,* 2015.

Maquette in OM

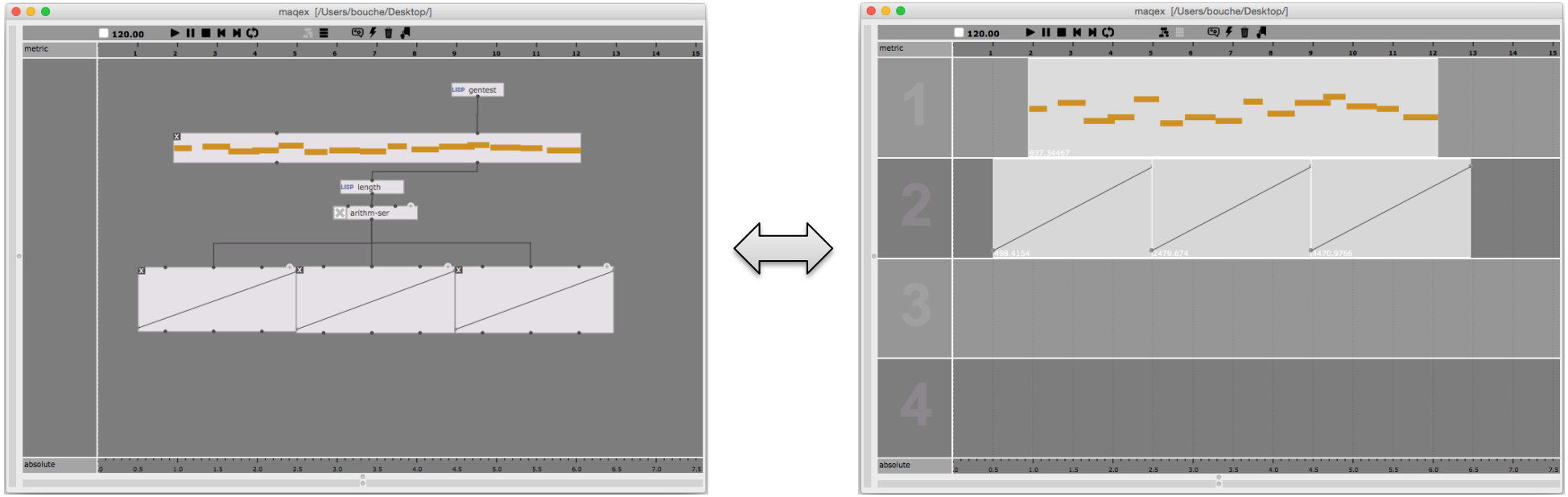
"Temporal Container" for objects and a visual program

- Connect objects together,
- Locate them in time them using their time onset (x-axis)
- Handle dependencies: their y-position and their connections,
- Compute (flatten & schedule) the maquette using the "synthesis patch"



New Maquette in OM

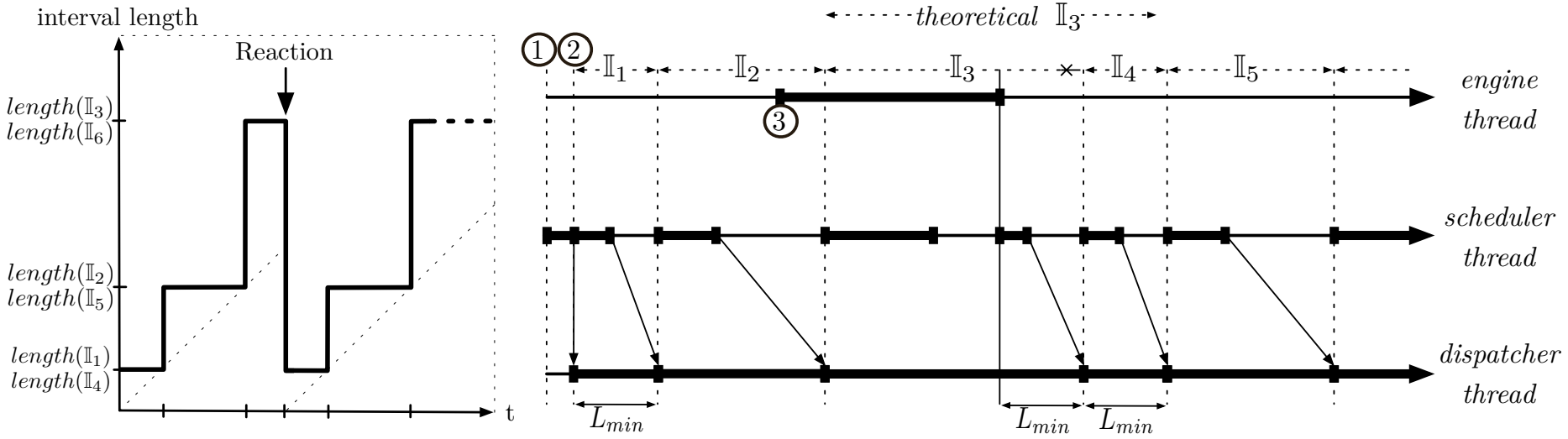
- Synthesis Patch ⟹“Control Patch”
  to control the maquette content in real-time:
  - Using OM-reactive and incoming external messages,
  - Using internal objects such as Clocks, Break Point Functions with custom action etc.
- Can embed “frozen” visual programs that will be evaluated in real-time:
  - A maquette becomes a running evolving program
    that changes a temporal scenario being rendered.



③ REAL-TIME SCHEDULING

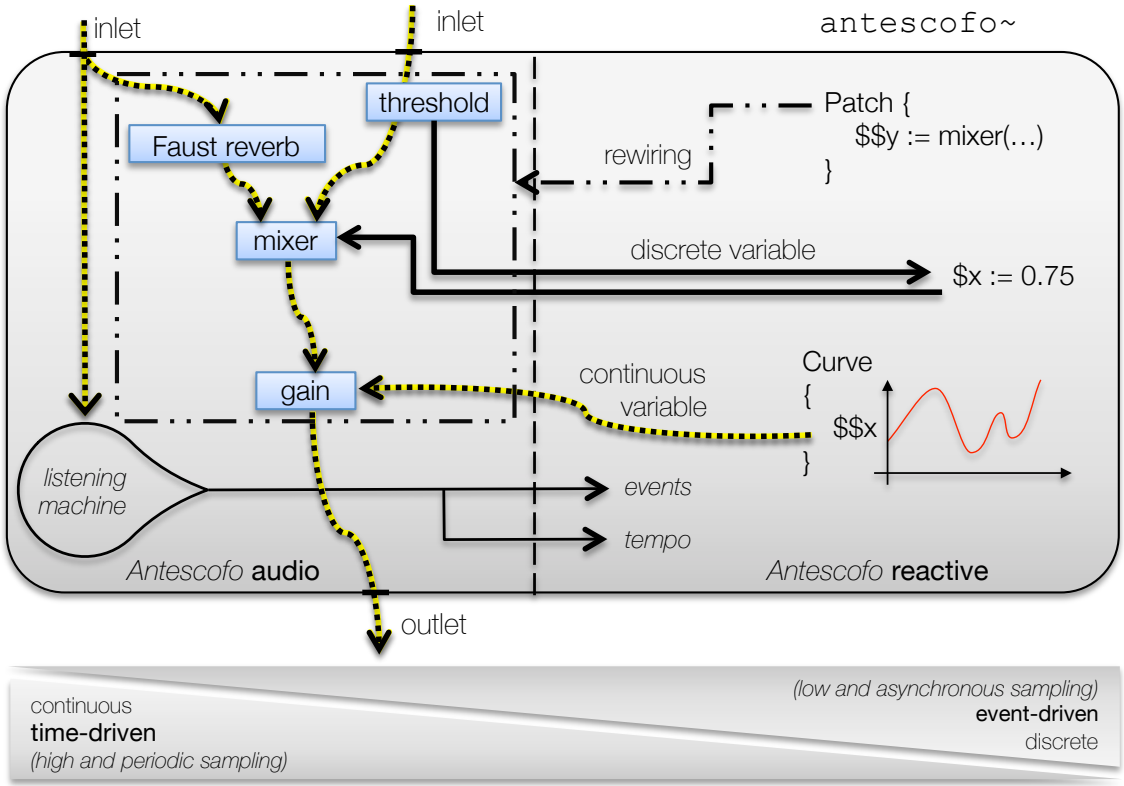
From defered to real-time in OM

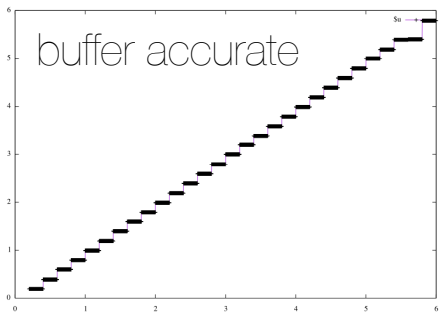
- Render and compute concurrently => modeled as a scheduling problem
- In most cases, the duration of scheduling operations is a monotonous function of the requested plan time interval:
  - Re-scheduling an object induces a latency proportional to its duration
- Dynamically control the scheduling time boundaries allows to:
  - Control the system latency,
  - Choose between static and dynamic scheduling strategies
  - Compensate scheduling duration (monitoring + dynamic behavioral changes)

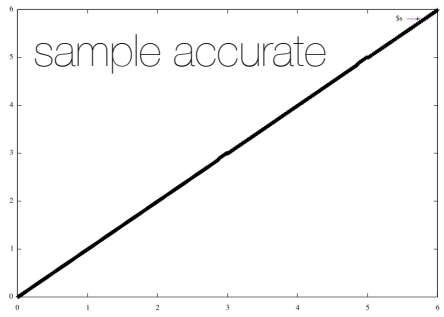


Embedding audio in Antescofo

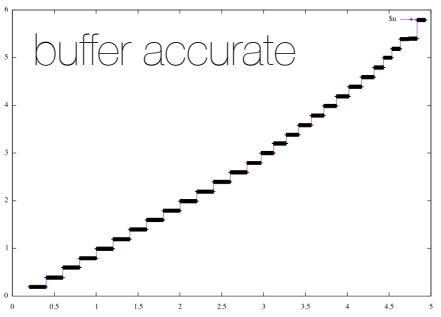
- audio effects written in FAUST
- compiled on-the-fly
- 40% cpu improvement on the remake of *Antheme2*
- new hybrid scheduling
- sample accurate for curve → audio
- sample accurate for audio → control
- buffer accurate elsewhere

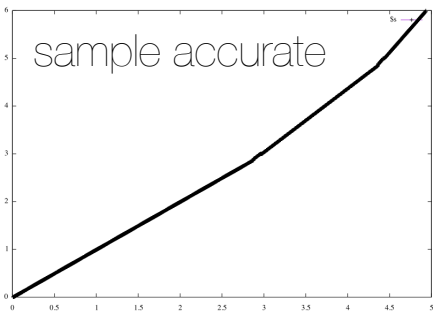






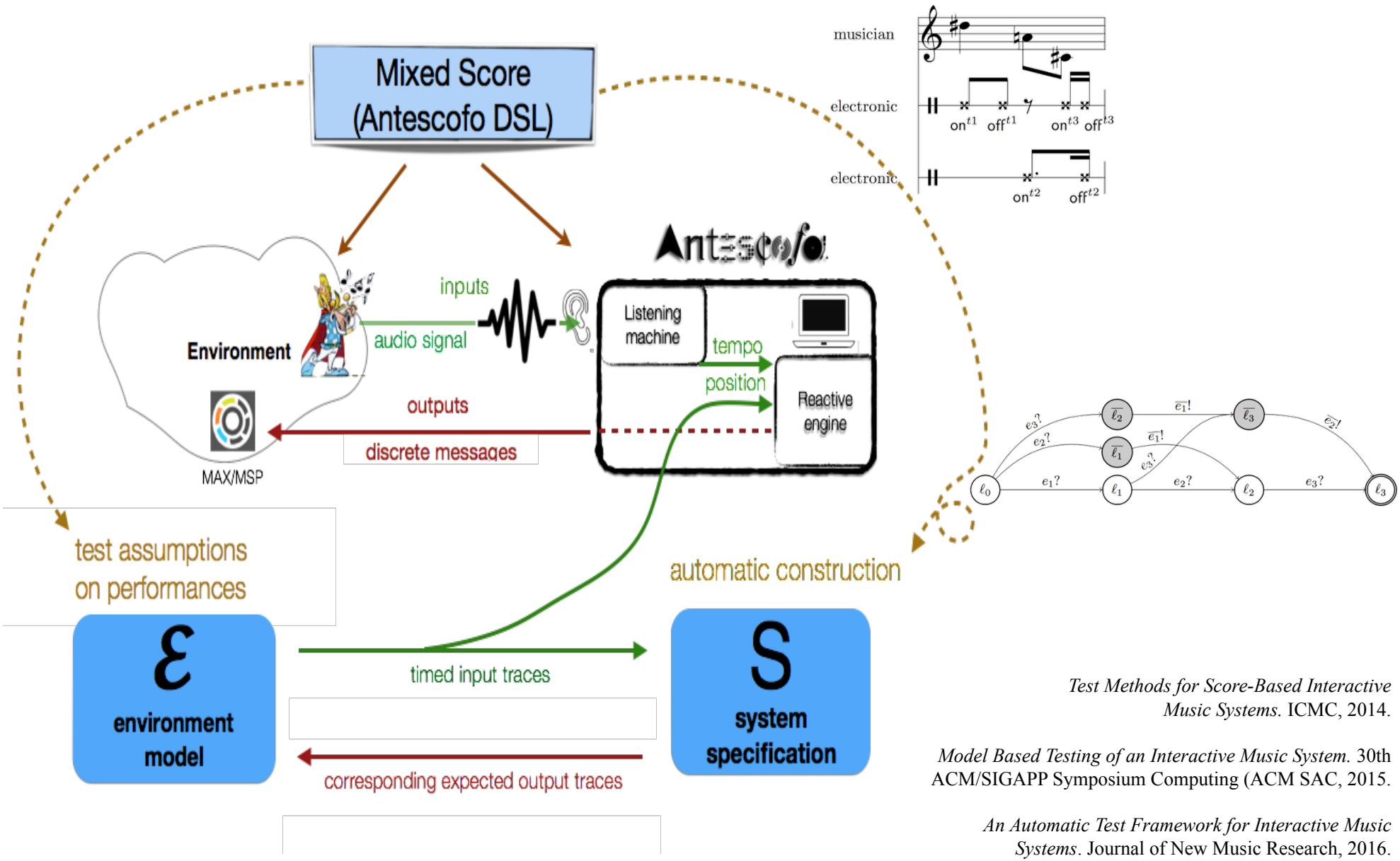
relative time





physical time

Model-Based Conformance Testing



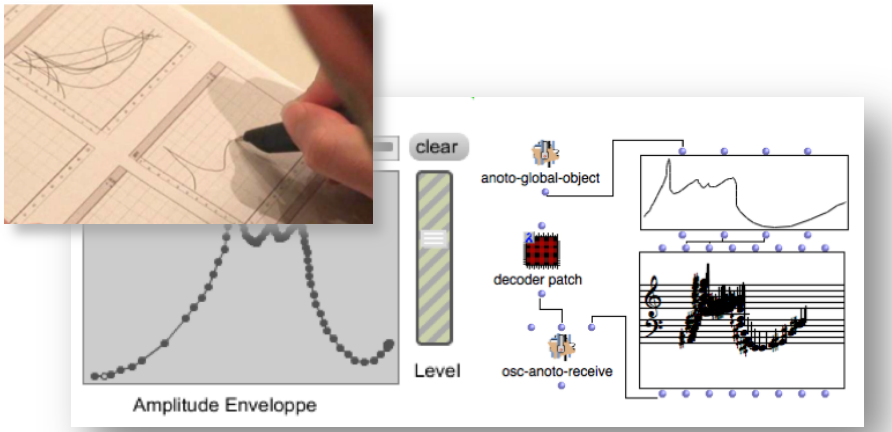
Test Methods for Score-Based Interactive Music Systems. ICMC, 2014.

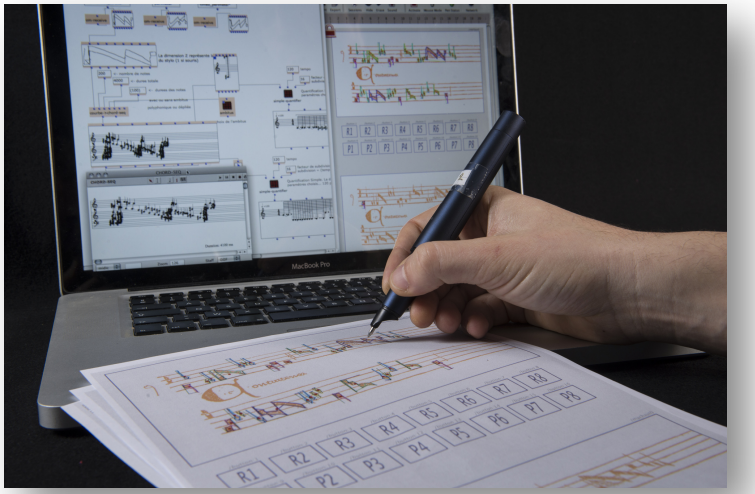
Model Based Testing of an Interactive Music System. 30th ACM/SIGAPP Symposium Computing (ACM SAC, 2015.

An Automatic Test Framework for Interactive Music Systems. Journal of New Music Research, 2016.

④ ARTISTIC APPLICATIONS

OM-reactive: *augmented paper interactions*





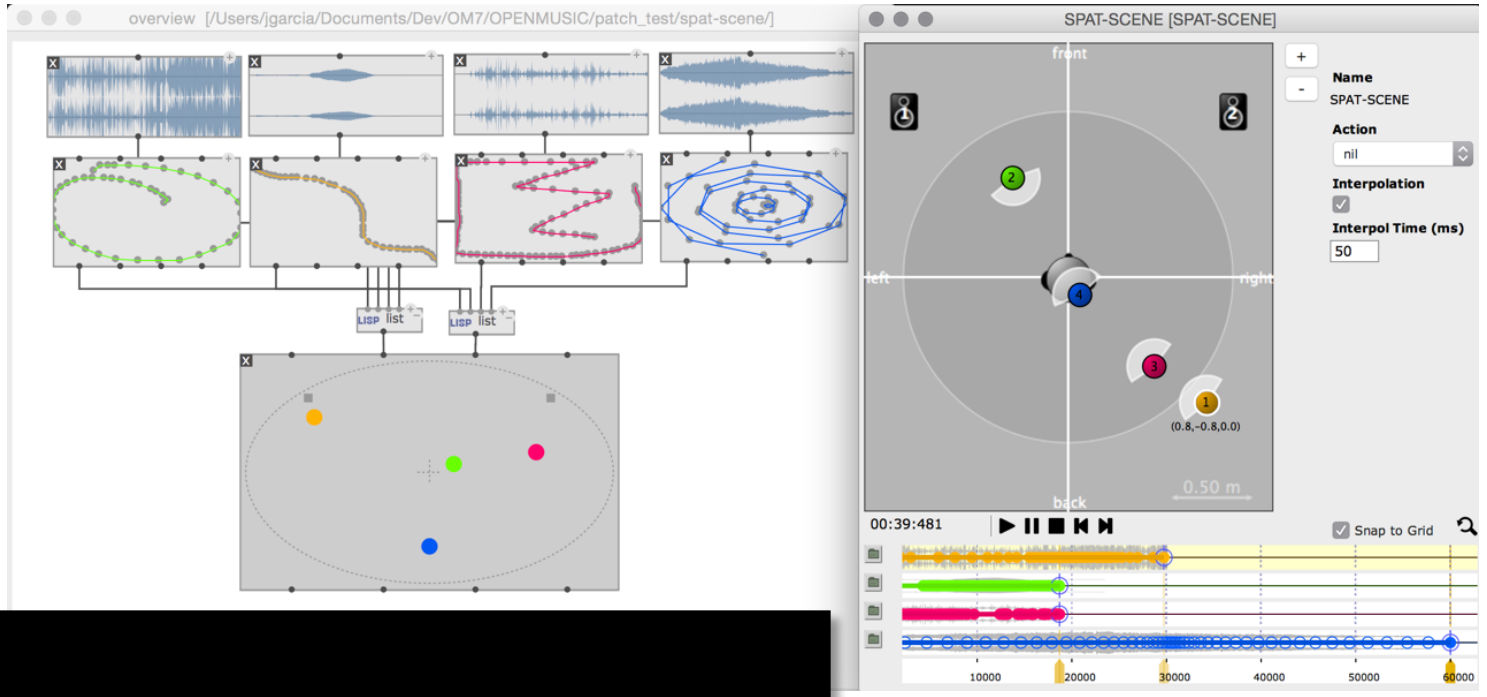
http://www.dailymotion.com/video/x258fs1_images-d-une-oeuvre-n-1 8-quid-sit-musicus-de-philippe-leroux_music

[vers 7'35]

Integration of sensors and devices for composition

J. Garcia, P. Leroux, J. Bresson (2014) pOM: Linking Pen Gestures to Computer-Aided Composition Processes. Proc. International Computer Music Conference, Athens, Greece.

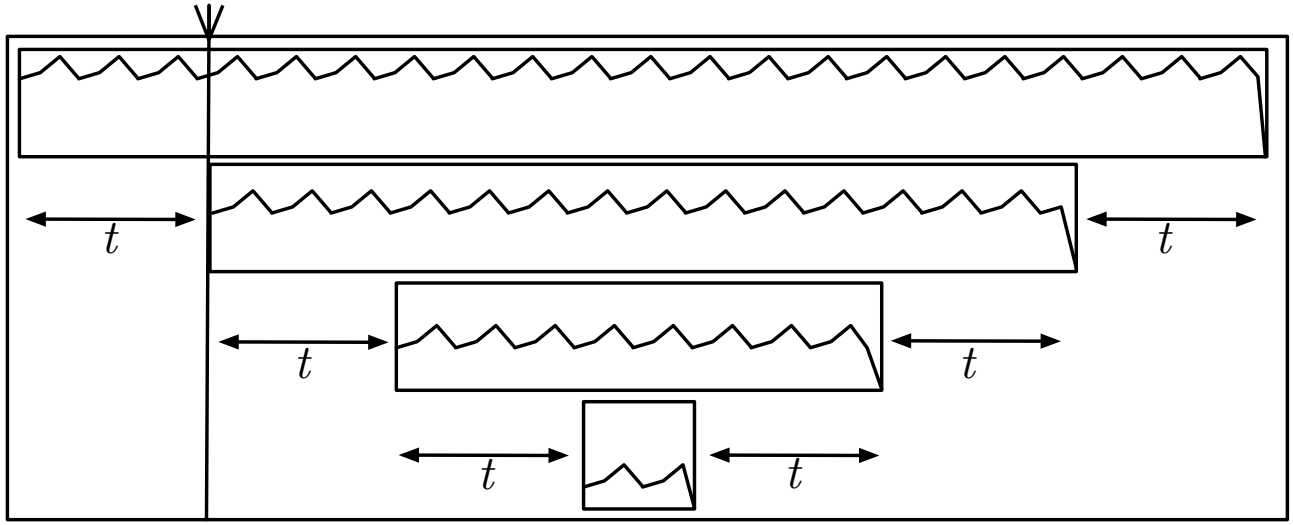
Spat control in OM



Interactive Composition and Authoring of Spatialisation

J. Garcia, J. Bresson and T. Carpentier (2015): "Towards Interactive Authoring Tools for Controlling Spatialisation", In *IEEE 10th Symposium on 3D User Interfaces*

Synthesis control in OM

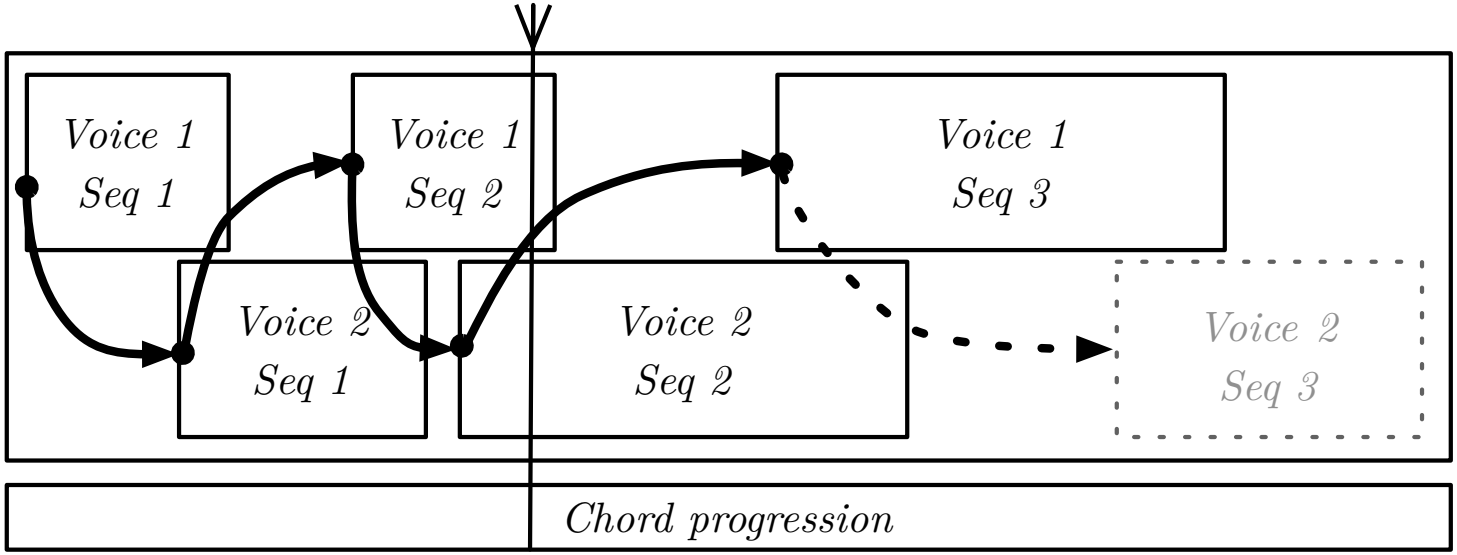


Composition for evoking auditory distortion products, sounds generated within the listener's ears from acoustic primary tone combinations.

A. Chechile (2015): "Creating spatial depth using distortion product otoacoustic emissions in music composition", In *International Conference on Auditory Display*, Graz, Austria.

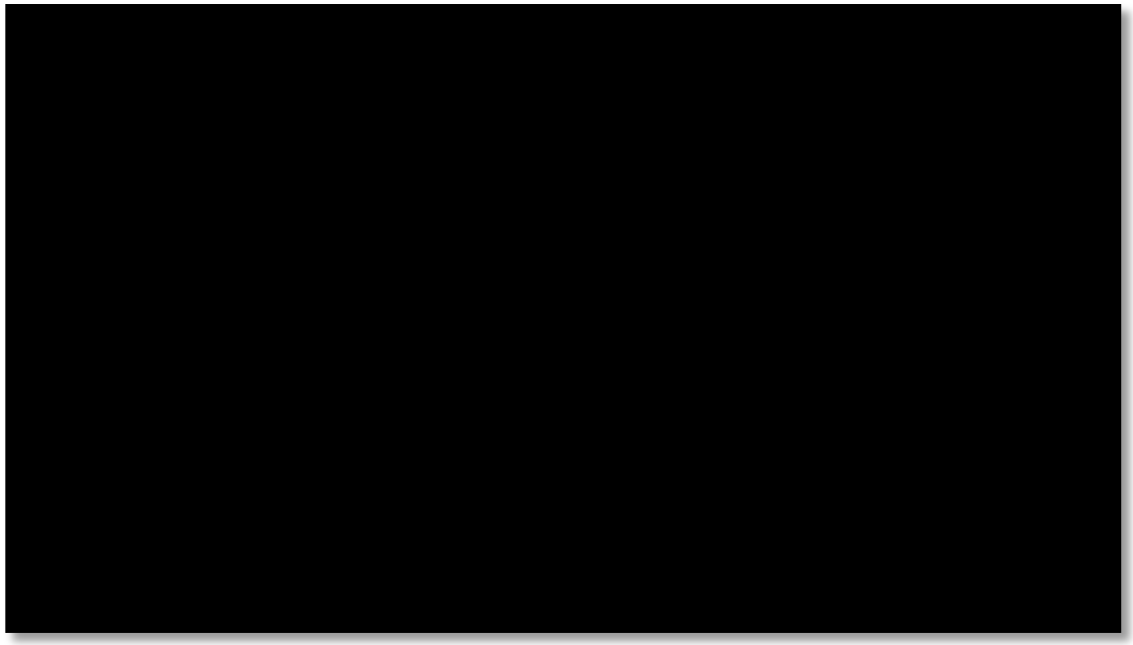
Meta-composition with ImproteK

OM & Antescofo

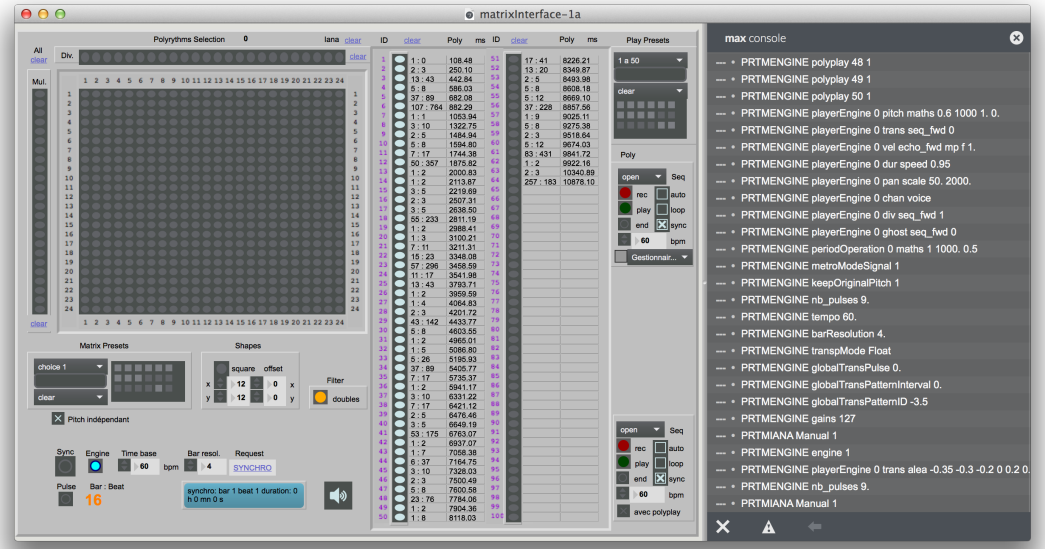


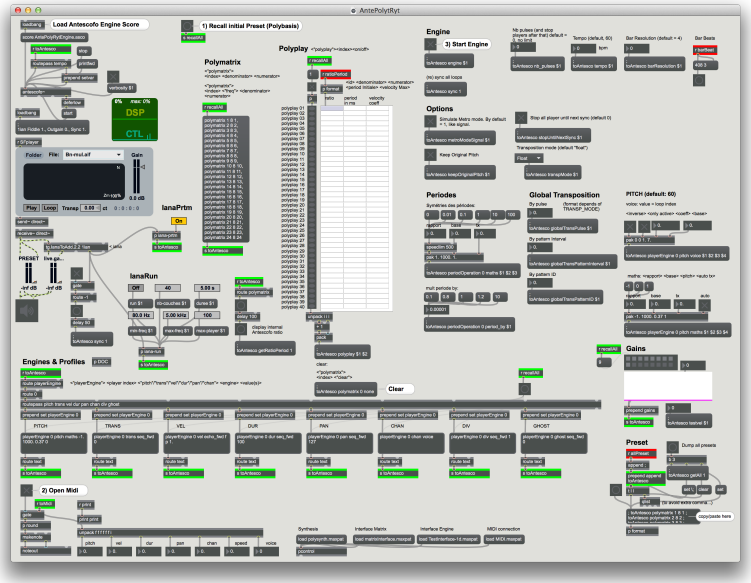
Illustrative example for controlling and automating dynamic calls to an offline generative model

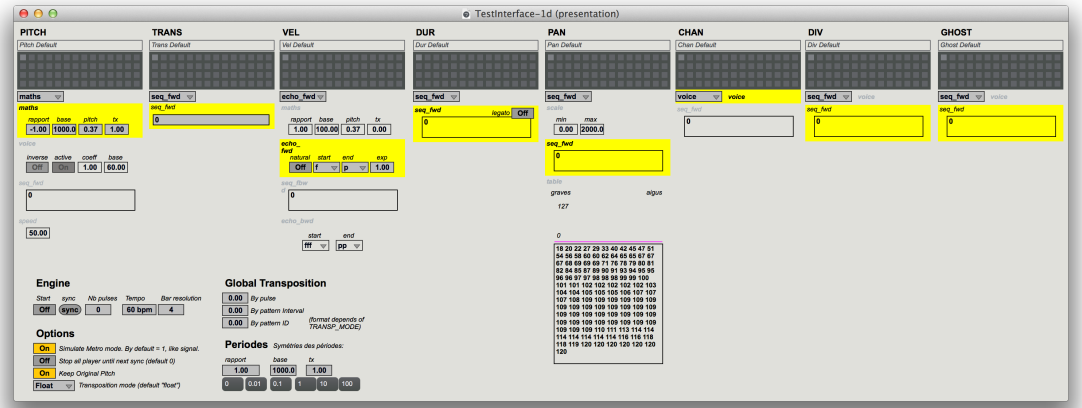
D. Bouche, J. Nika, A. Chechile and J. Bresson (2016) : "Computer aided composition of musical processes", In *Journal of New Music Research*. **[submitted]**

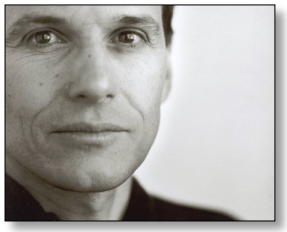


Yan Maresz *Polyrythmic machine* in Antescofo









Marco Stroppa
Antescofo library for totem control

```
; SOURCE Object Definition

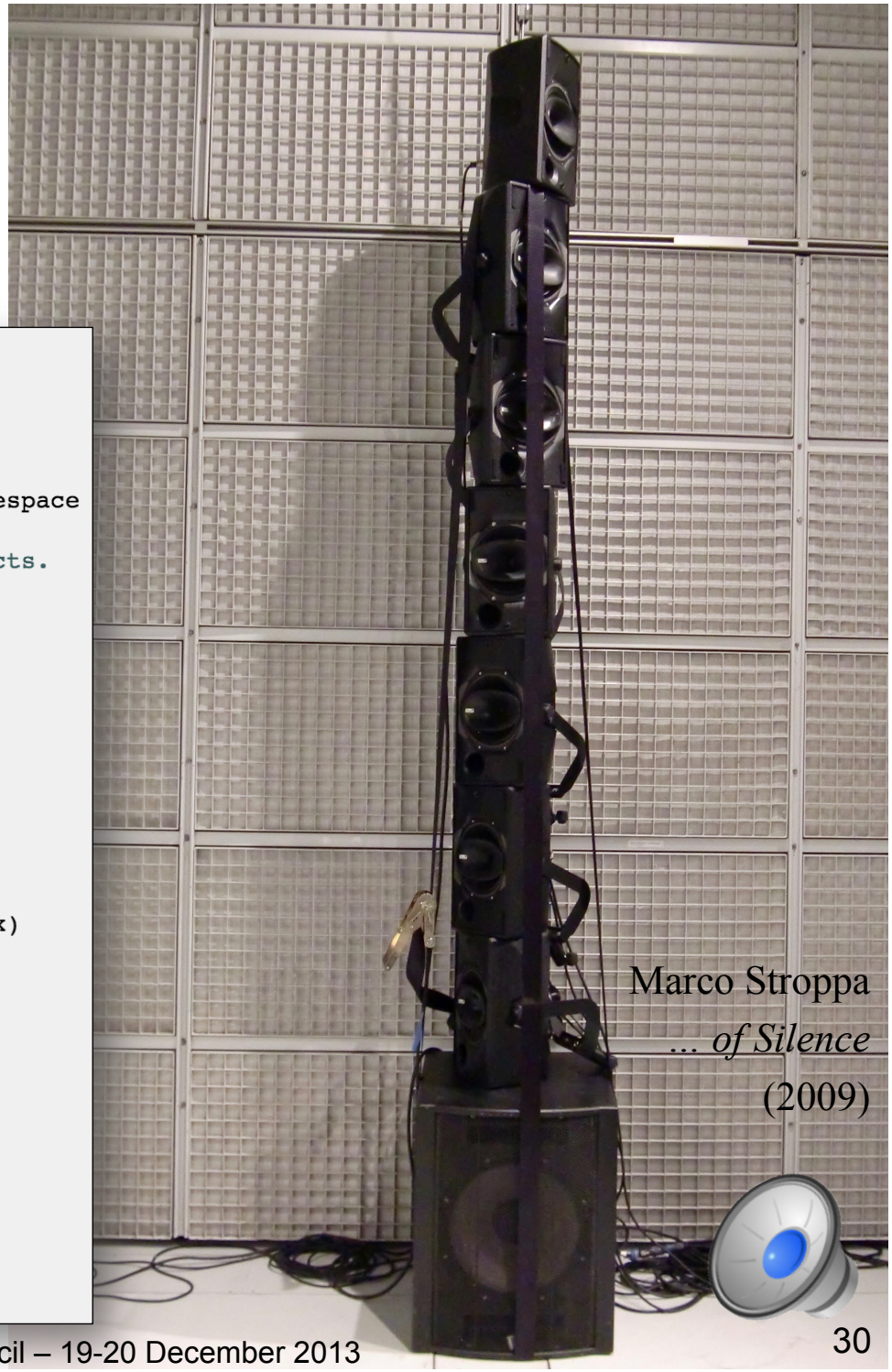
@obj_def source($idn, $npoints, $namespace)
{
    ; local state
    @local $coordinates, $idnum, $last_action, $prefix_namespace

    ; A broadcasted signal to all instances of source objects.
    @broadcast reset()  { abort $last_action }

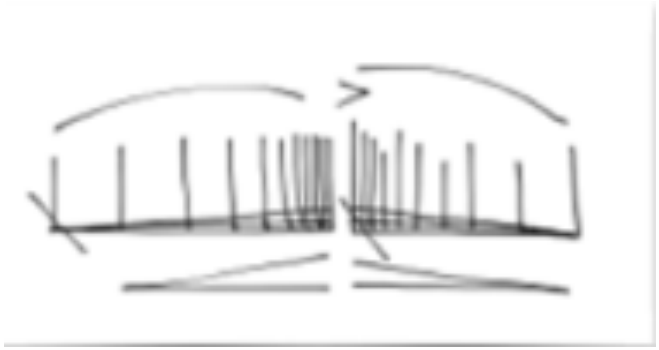
    // …

    ; igoto method will create a curve that goes
    ; from $coordinates to $destination in $dur time
    @proc_def igoto($destination, $dur, $itp)
    {
        curve FlyingEngine   @Grain := 0.05s,
          @Action := {
             $coordinates := $x
             @command($prefix_namespace+$idnum+"-spat") ($x)
          }
        {
            $x
            {
                        { ($coordinates) } @type $itp
                 $dur   { ($initlevels($destination)) }
            }
        }
    }

    // …
}
```



Julia Blondeau
Phrasé



```
NOTE D4 1/6 mes52

Curve tempCouchT3 @grain := 1/12
    { $tempCouchT3
        {       { ($RT_TEMPO-5) } @type "cubic"
            2   { ($RT_TEMPO+40) }
            1/3 { ($RT_TEMPO-40) }
            1/2 { ($RT_TEMPO+30) }
            1/2 { ($RT_TEMPO-15) }
            1/2 { ($RT_TEMPO+20) }
            1/2 { ($RT_TEMPO-15) }
            3/2 { ($RT_TEMPO+20) } @type "cubic"
            7/3 { ($RT_TEMPO+60) }
        }
    }

GROUP CoucheT3 @target {mes53,sync53,mes54,sync54_1,sync54_2,sync54_3,mes57}
    @tempo := $tempCouchT3
    {
        ::SPAT_lissaj3("SPAT7",1.5,12,0)
        curve ampexplo @grain := 0.05s
            {$ampexplo
                {       { 0.08 } @type "cubic"
                    2   { 0.19 } @type "cubic_out"
                    2   { 0.09 }
                    2   { 0.23 }
                    2   { 0.09 }
                    3   { 0.05 }
                }
            }

        ::ASCOtoCS_points("i33",1/8,$ampexplo,0.9,62)
        1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.6,87)
        1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.6,91)
        1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.6,67)
        1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.6,73)
        1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.6,98)
        1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.6,92)
        1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.6,103)

        1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.9,102)
        1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.9,84)
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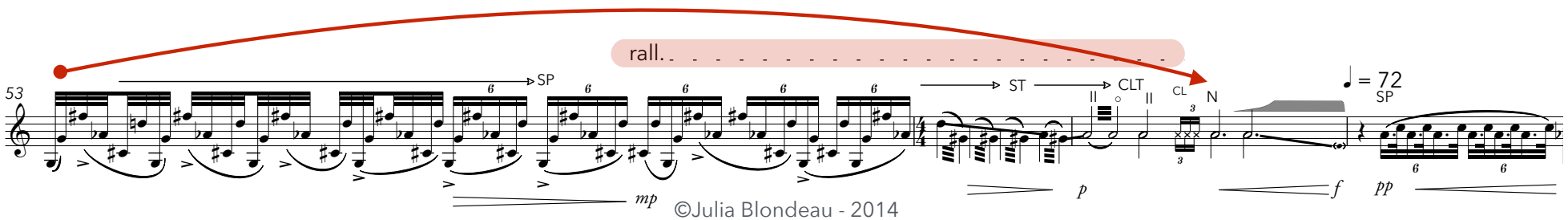
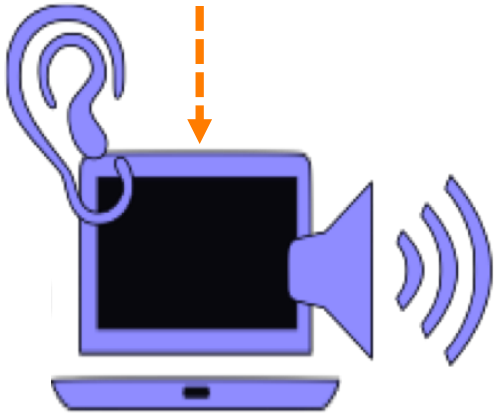


José-Miguel Fernandez
gesture-driven synthesis

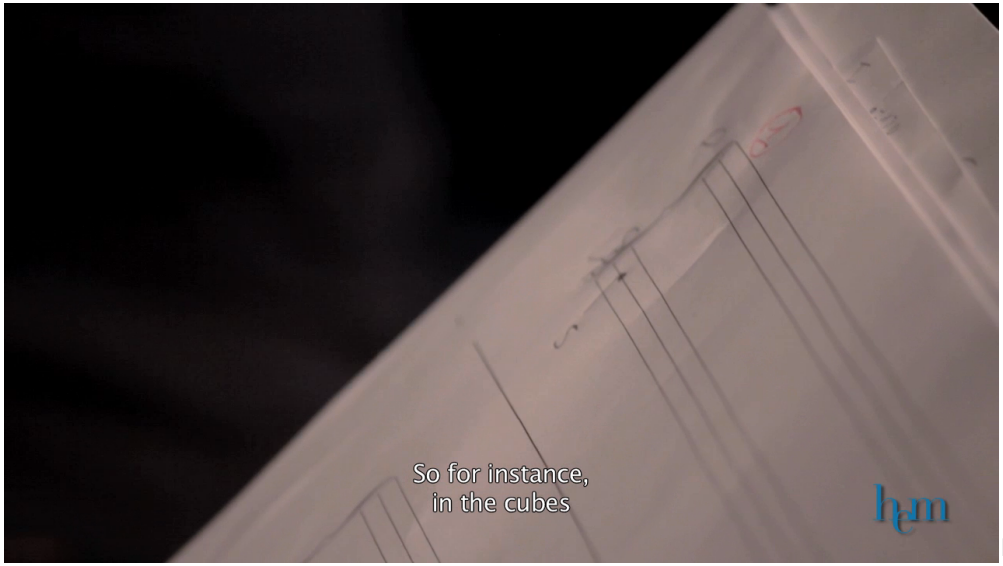
setvar

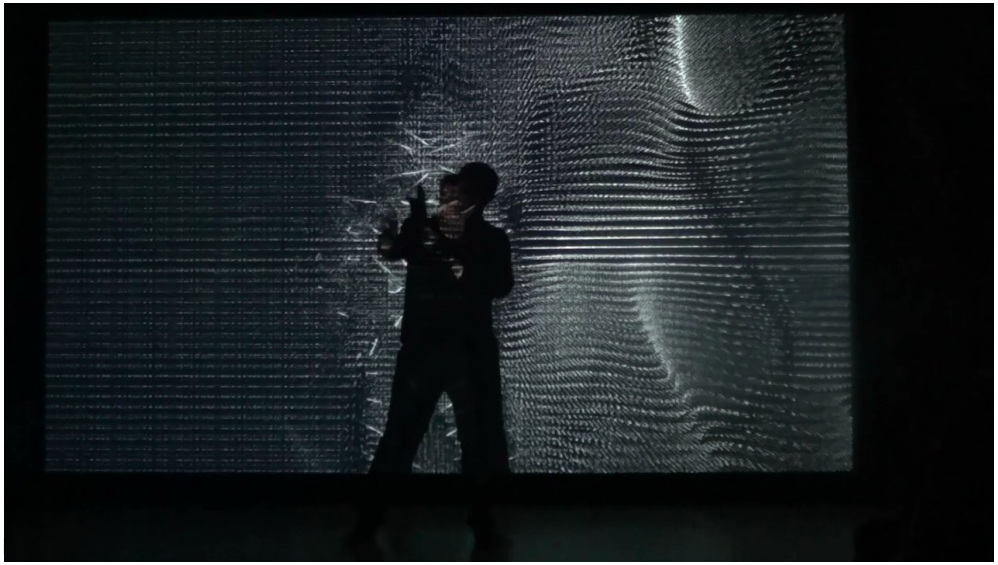


GeKiPe (Gest Kinect Percussion),
Philippe Spiesser (percu),
Alexander Vert (composition),
Jose Miguel Fernandez (RIM)

Haute école de musique Genève

Hypersphère, Jose Miguel Fernandez,
séance de travail IRCAM 26/2/16





PERSPECTIVES

Perspectives

The Augmented Score

- Maquette
  - Single threaded/synchronous model for offline interactive composition,
  - WIP : no rendering in the maquette, only a real time computation engine to display an evolving piece to a human performer,
  - Well define the boundaries of offered capabilities
  - WIP : Computations timing monitoring to perform empirical verification on scores
  - Focus on interfaces and high level tool to offer control over the flexible scheduling system
- Mixed score
  - temporal scope as denotable value
  - musical gesture
  - embedding composer specific languages

Symbolic Music Information Retrieval

- Representation, analysis and mining of music scores
  encoded in common Western notation
- Applications to Digital Humanities
  (computational musicology),
  Digital music libraries management, score editors

Next Generation of IMS

- offline and online score analysis techniques
- offline and online score compilation and scheduling
- real-time score execution at sample accuracy
- extensible-, distributed-, dynamic–architectures for interactive music systems

Beyond Music

- cyber-temporal systems: exploring other highly timed interactive scenarios (Robotics, Domotics)
- Programming with Perceptual Concepts
- other sensing devices

Fundings, Collaborations, Awards, Community

PhD students… thanks !

Julia Blondeau, Dimitri Bouche, Philippe Cuvillier, José Echeveste, Clement Poncelet, Jérome Nika, Maxime Sirbu, Pierre Talbot, …

Grants

- ANR INEDIT (2012-2015) with Grame (Lyon), LABRI (Bordeaux)
- ANR JC EFFICACE (2013-2016) (J. Bresson)
- PERSU Sorbonnes-University (2015) (A. Cont)
- PHC LETITBE (2015-16) Exchange Program with Ch. Kirsch (U. Salzburg)
- bourse Fullbright (2016) (J. Bresson)
- France-Stanford CIS (2015) (D. Bouche)

Industrial

- Contract with Qwant (2012)
- Collaborations with MakeMusic (US), Weezic (FR), AllegroIQ (China)
- **Start-up** creation by A. Cont based on Antescofo technology
  March 2016. Target: Music Entertainment and Education Industries

Scientific Collaborations

- SIERRA & PARKAS (ENS), FLOWERS & POSET (Bordeaux), Inria Chile, GRAME (Lyon) ... and many more
- International: UC Berkeley, UCSD, Tokyo U., Nagoya U. Salzburg U., Twente U., …

Community

- Antescofo: ~5K downloads since 2013
- OM: ~30K downloads

Awards

IEEE ICASSP Best Student Paper Award in MLSP, 2015; CMR, Best Student Paper Award 2015; Acoustical Society of America Best Paper Award 2014; ICMC, Best Presentation Award 2014; French Minister of Industry's prize for Antescofo, 2013 (ONFI)