Jean-Louis Giavitto

Programming Interactive Musical Systems with Antescofo

(a story about cyber-temporal systems)

ircam
Centre Pompidou
cnrs
UPMC PARIS UNIVERSITAS
Inria

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Info

- **Antescofo on the IRCAM forum** (register, it's free):

  forumnet.ircam.fr
  - **user Forum page** (community/User Groups/Antescofo)
  - **download page** (Product/Antescofo)
    - **the antescofo~ object for PD** (Mac, Linux)**: free**
    - **the antescofo bundle for MAX/MSP:**
      object + examples + tutorials
      - **latest full forum release:**
      - **latest object:**

- **Documentation:**
  - **on-line: support.ircam.fr/docs/Antescofo/manuals**
  - **static HTML files:**
    support.ircam.fr/docs/AntescofoAntescofoDocHTML.zip

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Cyber-temporal systems: computing time in real-time

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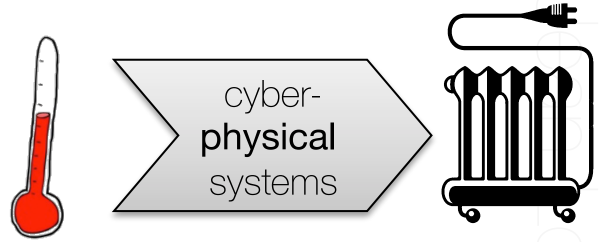

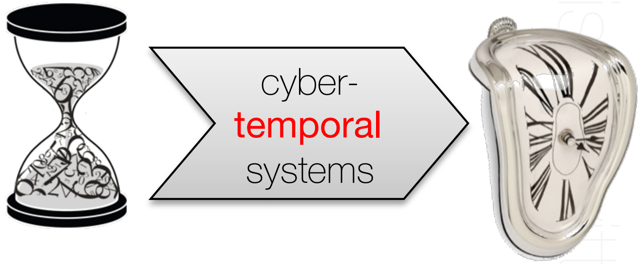

- *from:* physical entities
  monitored by algorithms
- *to:* temporal relationships
  sensed and produced by algorithms
- *example:* interactive music systems
  Antescofo
- notionS of TIME:
  - multiple times: deferred time, real-time
  - multiple models of time: event-driven, time-driven
  - multiple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

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An example of cyber-temporal systems : Automatic Accompaniment in *Antescofo*

Concerto pour main gauche, Ravel.
Performer: Jacques Comby
Orchestra: recording Orchestre de Paris *synchronized with* Antescofo *in real-time*

Tesla ou l'effet d'étrangeté Julia Blondeau (2014)

alto: Christophe Desjardins, real-time electronic: Antescofo

ODEI (performance Les Nuits Sonores, Lyon, 2014)

Odei

Improvised electronic music with Antescofo

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Real-time synchronization
of electronic actions
with the musicians performance

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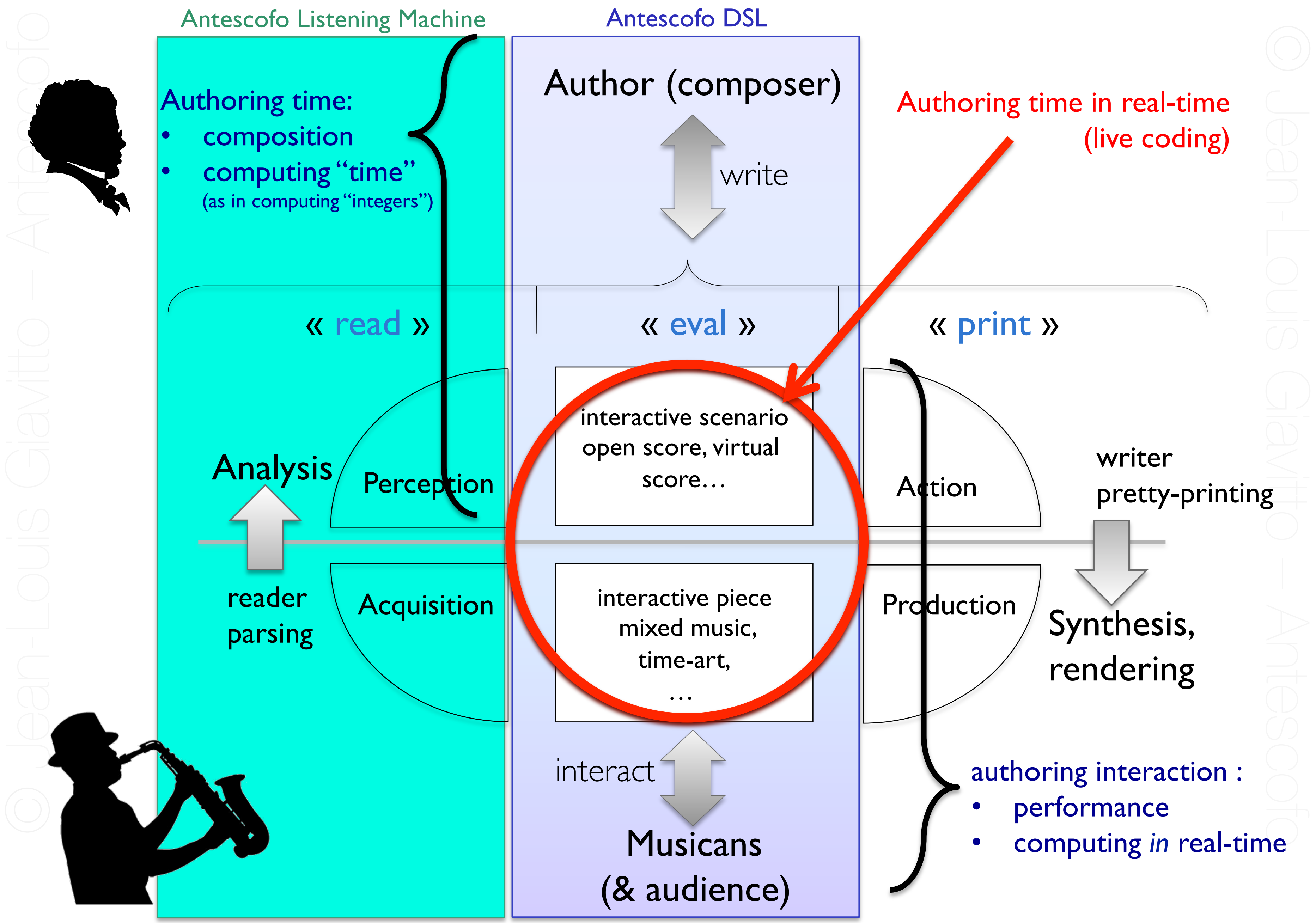
A “Language Approach” to IMS



Antescofo Listening Machine

Antescofo DSL

Authoring time:
- composition
- computing “time”
  (as in computing “integers”)

Author (composer)

write

Authoring time in real-time
(live coding)

« read »

« eval »

« print »

Analysis

Perception

interactive scenario
open score, virtual
score…

Action

writer
pretty-printing

reader
parsing

Acquisition

interactive piece
mixed music,
time-art,
…

Production

Synthesis,
rendering

interact

Musicans
(& audience)

authoring interaction :
- performance
- computing *in* real-time

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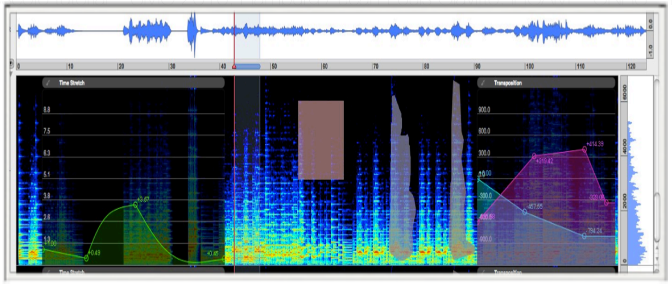
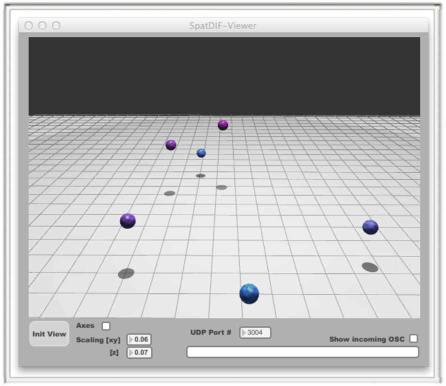


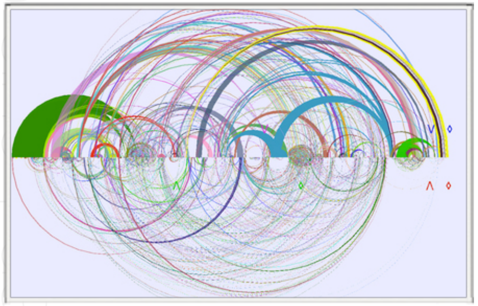
Audio Analysis/Synthesis

Gesture

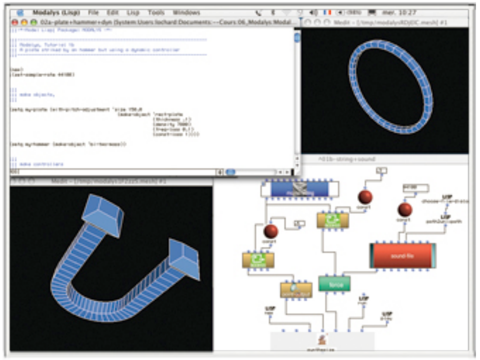


Spatialization

Antescofo



Improvisation



Physical Models

MIDI / Control

More than 100 Creations

New York Philharmonics, Chicago Symphony, Los Angeles Philharmonics, Berlin Philharmonics, BBC Orchestra...

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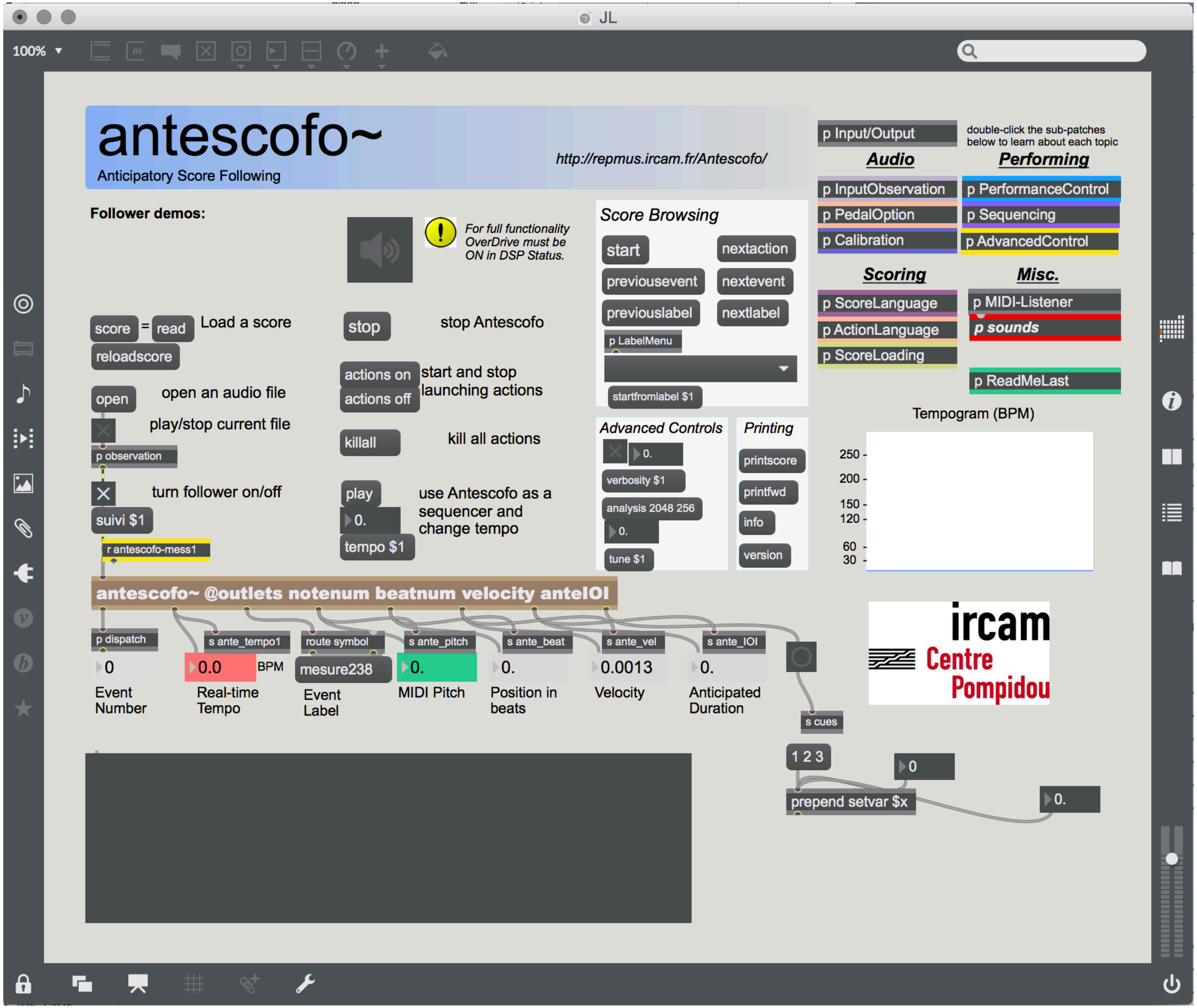
in Max/MSP



double-click the sub-patches below to learn about each topic

For full functionality OverDrive must be ON in DSP Status.

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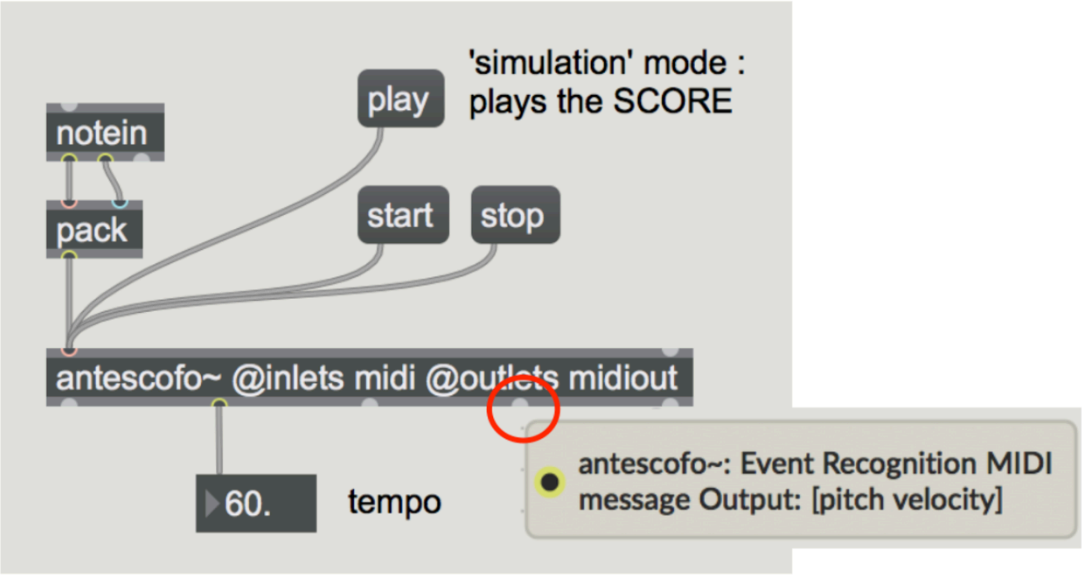
Simple patches

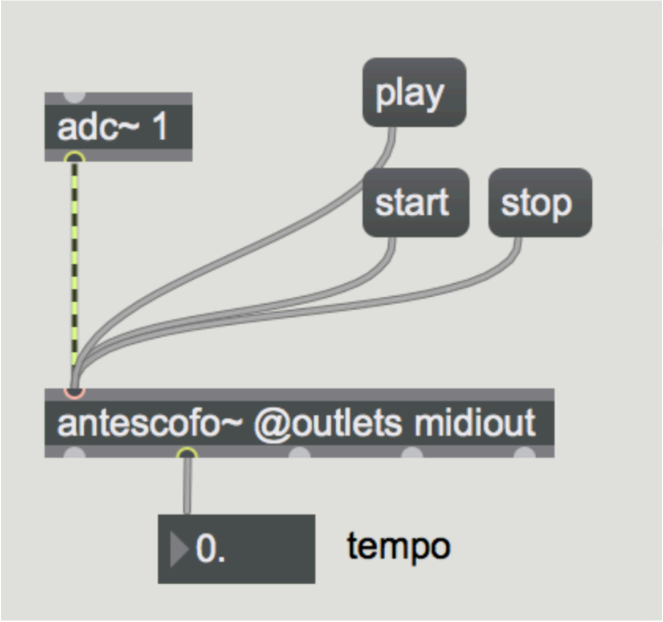
midi detection



'simulation' mode :
plays the SCORE

antescofo~: Event Recognition MIDI message Output: [pitch velocity]

audio detection



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Antescofo interacts with Max/PD through messages

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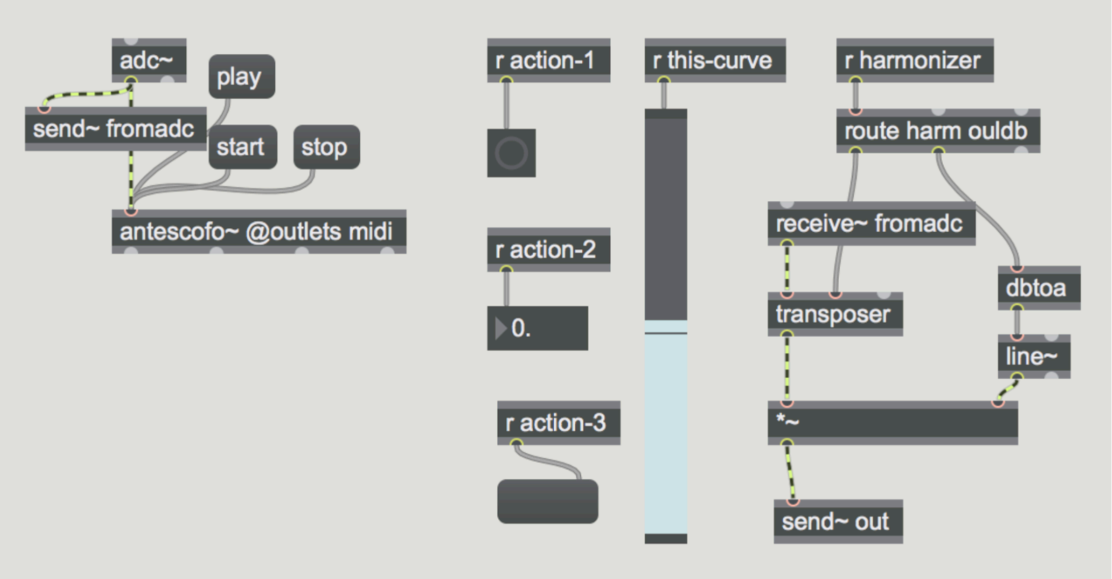

```
; ---------- measure 1 beat 0.00 ——

TRILL (7900 8000) 3 premiertrille

1 action-1 bang ; wait 1 beat to bang action-1
2/3 action-2 0.1 ; wait 2/3 beats after action-1 to trig action-2
1s action-3 hello ; wait 1 second
333ms action-3 hello ; wait 333 milliseconds
action-1 bang ; don't wait
NOTE 0 5/4

; ---------- measure 2 beat 4.00 ---------

NOTE Eb5 1/4 mesure2
     harmonizer harm -1200, outdb -3 ; set harmonizer on here.
     3/4 harmonizer outdb -96  ; … wait 3/4 beats and turn it off.

NOTE 62 1/4
NOTE 7100 1/4
MULTI (56->62) 1/1
```

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Antescofo tutorial – SMC 2016, Hamburg / Jean-Louis Giavitto, IRCAM – CNRS – INRIA MuTAnt

in PD

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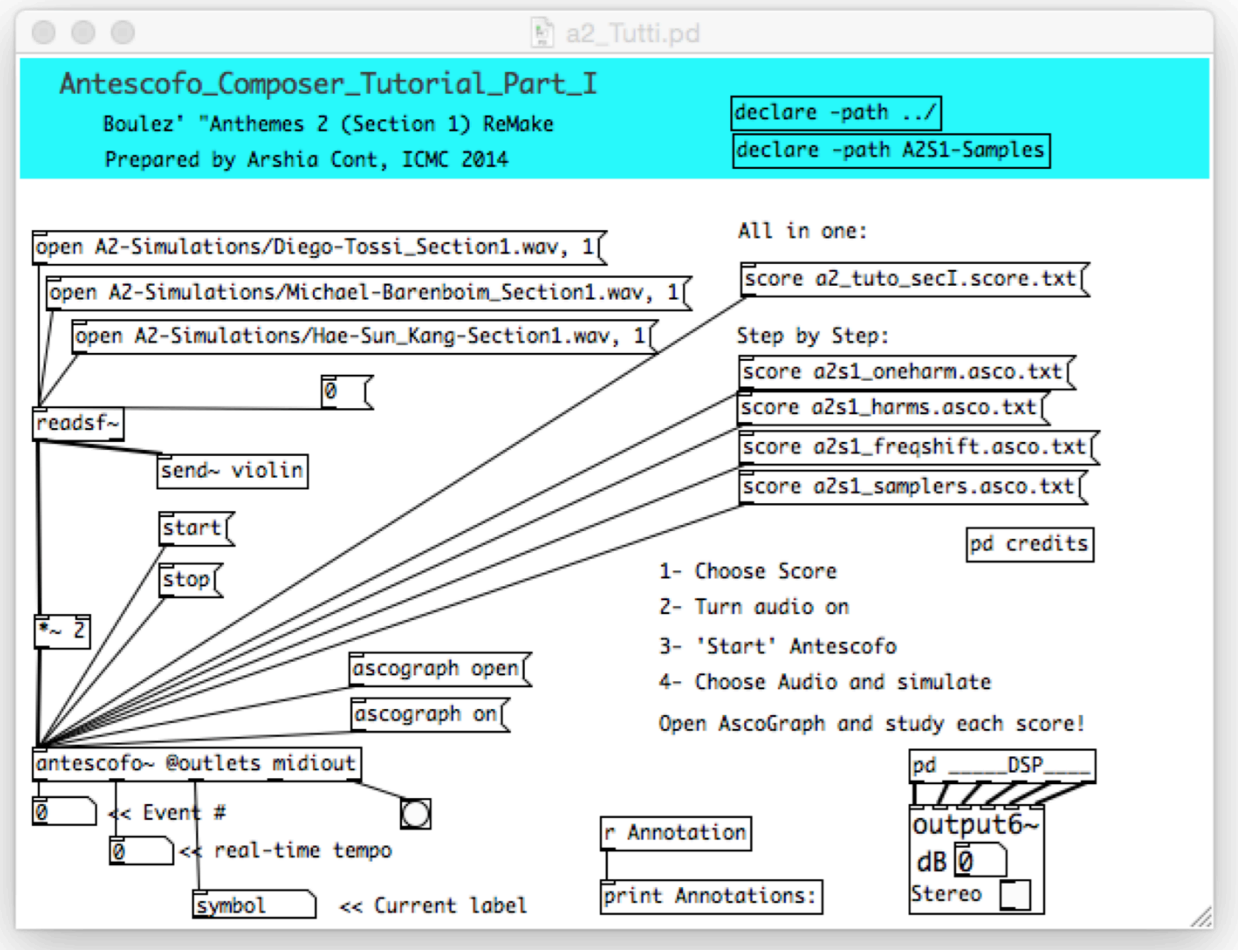

Antescofo_Composer_Tutorial_Part_I

Boulez' "Anthemes 2 (Section 1) ReMake

Prepared by Arshia Cont, ICMC 2014

```
declare -path ../
declare -path A2S1-Samples

open A2-Simulations/Diego-Tossi_Section1.wav, 1
open A2-Simulations/Michael-Barenboim_Section1.wav, 1
open A2-Simulations/Hae-Sun_Kang-Section1.wav, 1
0
readsf~
send~ violin
start
stop
*~ 2
ascograph open
ascograph on
antescofo~ @outlets midiout
0 << Event #
0 << real-time tempo
symbol << Current label
```

All in one:

```
score a2_tuto_secI.score.txt
```

Step by Step:

```
score a2s1_oneharm.asco.txt
score a2s1_harms.asco.txt
score a2s1_freqshift.asco.txt
score a2s1_samplers.asco.txt
pd credits
```

1- Choose Score

2- Turn audio on

3- 'Start' Antescofo

4- Choose Audio and simulate

Open AscoGraph and study each score!

```
r Annotation
print Annotations:
pd _____DSP____
output6~
dB 0
Stereo
```

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The Antescofo aproach (to mixed music)

- An *augmented score* is a real-time program
  - the composer is a programmer that specifies bith human and electronic parts
  - program evaluation is done jointly by <musician | machine>
  - the composer specifies the synchronization between human and electronic parts
- The listening machine provides the inputs to the machine

  <musician | *listening & recognition* | strongly timed program>
- **BUT music interpretation is not program evaluation**

  the gap between the score and its implementation is intentional
- **Time is a first class entity in the DSL**
  - time is not an operational property (e.g., a quality of service or a performance metric)
  - handling of events and duration
  - chronometric and relational time
  - computing dynamic timelines

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Community

BBC Symphony Orchestra

BERLINER PHILHARMONIKER

CONCERTGEBOUWORKEST
RCO ROYAL CONCERTGEBOUW ORCHESTRA AMSTERDAM

LA PHIL

CHICAGO SYMPHONY ORCHESTRA

orchestre philharmonique de radio france

NEW YORK PHILHARMONIC

ORCHESTRE DE PARIS

Antescofo:

- 100+ performances with ensembles around the world
- community of 150+ users with contributions from around the globe
- ~5K downloads since 2013
- teaching for musicians in Brasil, Seoul, Japan, Montreal, USA, Europe… .
- massive media coverage thanks to its users:

Le Monde
LE FIGARO
Télérama
La Recherche
Usbek & Rica EXPLORE LE FUTUR
Challenges
Les Echos
acn AGENCIA CUBANA DE NOTICIAS
BBC CULTURE
Shanghai Daily 上海日报
TEDx
BFM BUSINESS
LES FONDAMENTALES Le forum du CNRS GRENOBLE
The New York Times
MIF EXPO
LES OBJETS DE LA NOUVELLE FRANCE INDUSTRIELLE

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Programming temporal & Interactive Scenarios

Antescofo Quick Tour

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The Antescofo DSL

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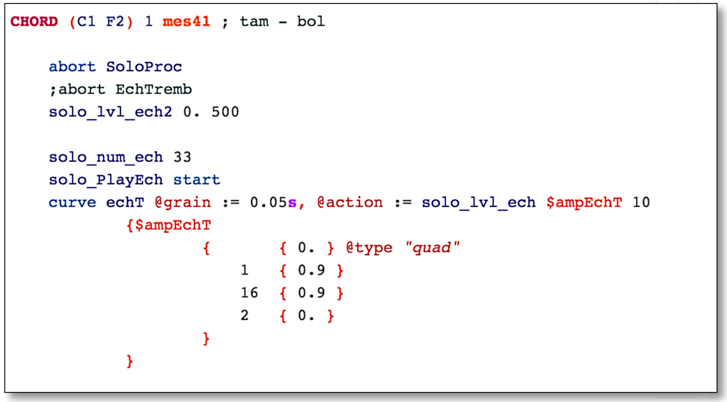
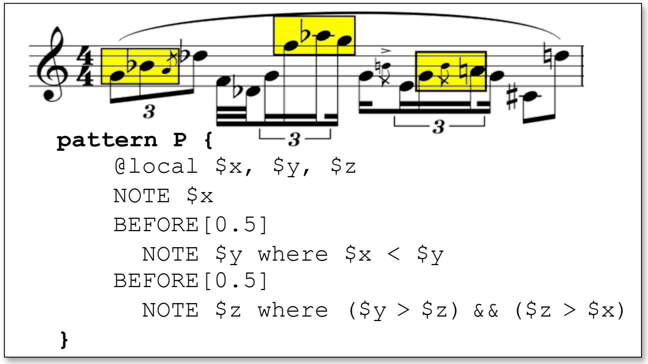
- Interleaving Musical Events and Electronic Actions
  - musical events specified by the composer and performed by the musician
  - electronic actions performed by the machines
  - the listening module ensure the coupling of the two
- Musical Events
  - basic note (pitch+duration)
  - containers
- Actions
  - Program constructions
    - group, forall, loop, if, whenever, curve
    - process, actors
    - pattern, track, …
    - continuations
  - Data Structures
    - int, float, string…
    - vector, map, nim
    - function, process, actor, coroutine



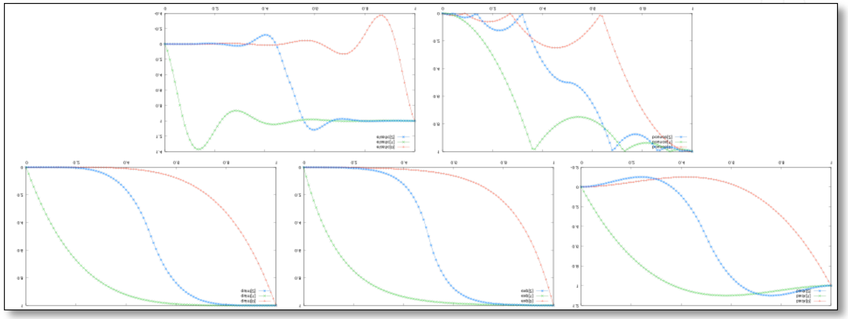
```
CHORD (C1 F2) 1 mes41 ; tam - bol

    abort SoloProc
    ;abort EchTremb
    solo_lvl_ech2 0. 500

    solo_num_ech 33
    solo_PlayEch start
    curve echT @grain := 0.05s, @action := solo_lvl_ech $ampEchT 10
            {$ampEchT
                    {       { 0. } @type "quad"
                        1   { 0.9 }
                        16  { 0.9 }
                        2   { 0. }
                    }
            }
```



```
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)
}
```



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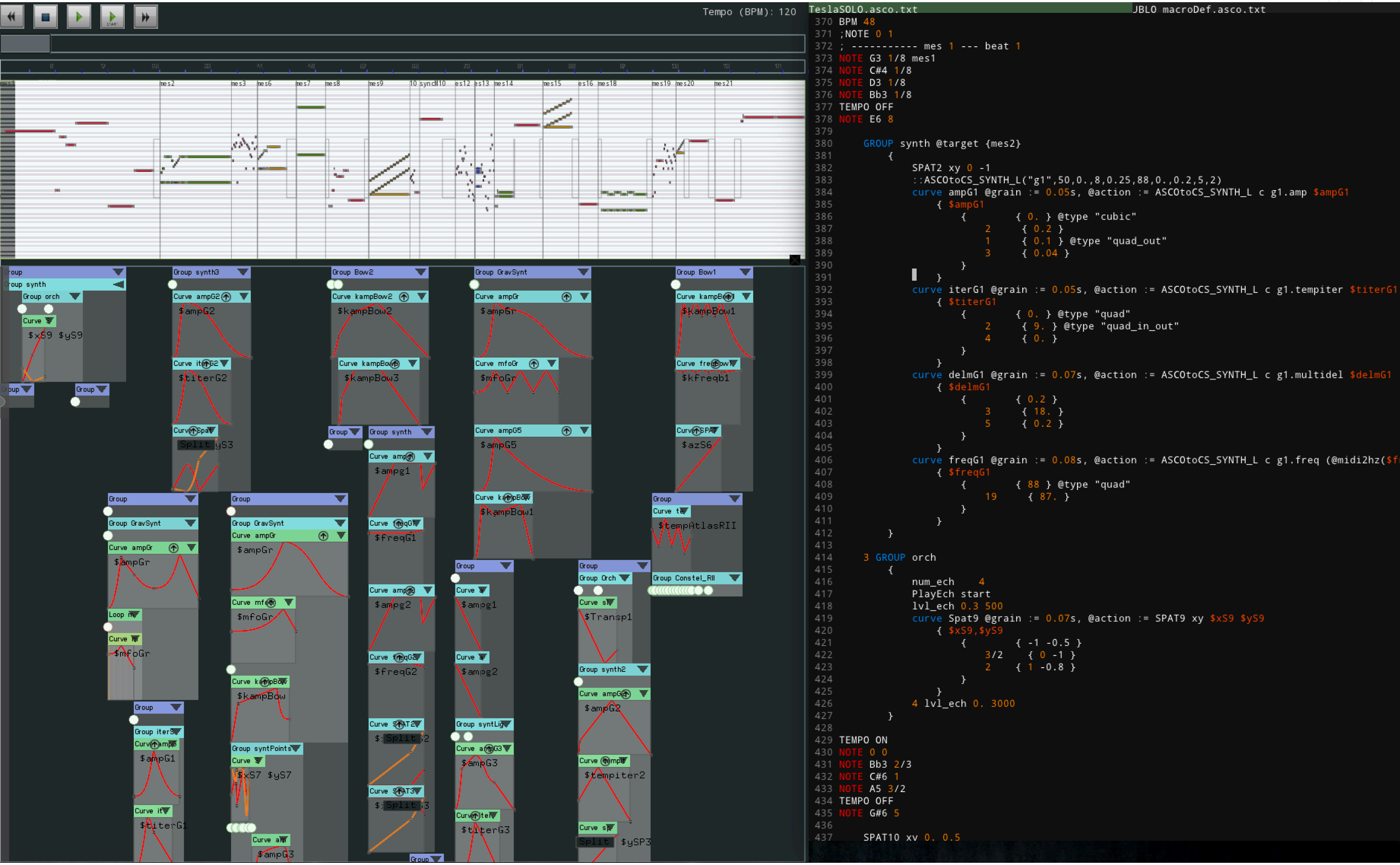
An augmented score in *Ascograph*

(Thomas Coffy, Grieg Burloiu)



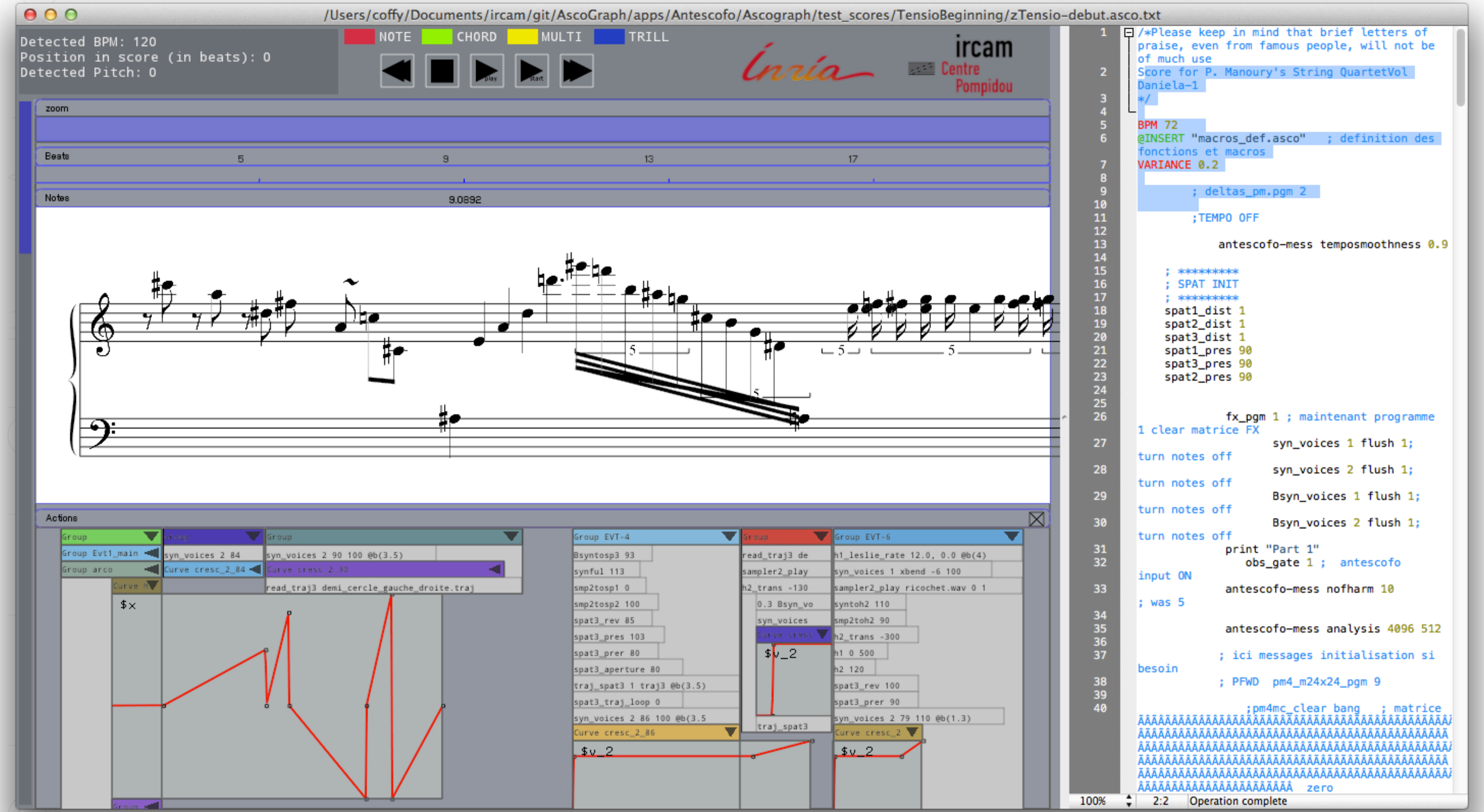
```
BPM 48
;NOTE 0 1
; ----------- mes 1 --- beat 1
NOTE G3 1/8 mes1
NOTE C#4 1/8
NOTE D3 1/8
NOTE Bb3 1/8
TEMPO OFF
NOTE E6 8

    GROUP synth @target {mes2}
        {
            SPAT2 xy 0 -1
            ::ASCOtoCS_SYNTH_L("g1",50,0.,8,0.25,88,0.,0.2,5,2)
            curve ampG1 @grain := 0.05s, @action := ASCOtoCS_SYNTH_L c g1.amp $ampG1
                { $ampG1
                    {           { 0. } @type "cubic"
                            2    { 0.2 }
                            1    { 0.1 } @type "quad_out"
                            3    { 0.04 }
                    }
                }
            curve iterG1 @grain := 0.05s, @action := ASCOtoCS_SYNTH_L c g1.tempiter $titerG1
                { $titerG1
                    {           { 0. } @type "quad"
                            2    { 9. } @type "quad_in_out"
                            4    { 0. }
                    }
                }
            curve delmG1 @grain := 0.07s, @action := ASCOtoCS_SYNTH_L c g1.multidel $delmG1
                { $delmG1
                    {           { 0.2 }
                            3    { 18. }
                            5    { 0.2 }
                    }
                }
            curve freqG1 @grain := 0.08s, @action := ASCOtoCS_SYNTH_L c g1.freq (@midi2hz($f
                { $freqG1
                    {           { 88 } @type "quad"
                            19    { 87. }
                    }
                }
        }

    3 GROUP orch
        {
            num_ech    4
            PlayEch start
            lvl_ech 0.3 500
            curve Spat9 @grain := 0.07s, @action := SPAT9 xy $xS9 $yS9
                { $xS9,$yS9
                    {           { -1 -0.5 }
                            3/2    { 0 -1 }
                            2    { 1 -0.8 }
                    }
                }
            4 lvl_ech 0. 3000
        }

TEMPO ON
NOTE 0 0
NOTE Bb3 2/3
NOTE C#6 1
NOTE A5 3/2
TEMPO OFF
NOTE G#6 5

    SPAT10 xv 0. 0.5
```



/Users/coffy/Documents/ircam/git/AscoGraph/apps/Antescofo/Ascograph/test_scores/TensioBeginning/zTensio-debut.asco.txt

```
Detected BPM: 120
Position in score (in beats): 0
Detected Pitch: 0
```

```
/*Please keep in mind that brief letters of praise, even from famous people, will not be of much use
Score for P. Manoury's String QuartetVol Daniela-1
*/

BPM 72
@INSERT "macros_def.asco"   ; definition des fonctions et macros
VARIANCE 0.2

        ; deltas_pm.pgm 2

        ;TEMPO OFF

            antescofo-mess temposmoothness 0.9

    ; *********
    ; SPAT INIT
    ; *********
    spat1_dist 1
    spat2_dist 1
    spat3_dist 1
    spat1_pres 90
    spat3_pres 90
    spat2_pres 90


             fx_pgm 1 ; maintenant programme 1 clear matrice FX
                   syn_voices 1 flush 1;  turn notes off
                   syn_voices 2 flush 1;  turn notes off
                   Bsyn_voices 1 flush 1;  turn notes off
                   Bsyn_voices 2 flush 1;  turn notes off
            print "Part 1"
               obs_gate 1 ;  antescofo input ON
            antescofo-mess nofharm 10  ; was 5

            antescofo-mess analysis 4096 512

           ; ici messages initialisation si besoin
           ; PFWD  pm4_m24x24_pgm 9

               ;pm4mc_clear bang   ; matrice ÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃÃ  zero
```

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Antescofo Quick Tour

EVENT SPECIFICATION

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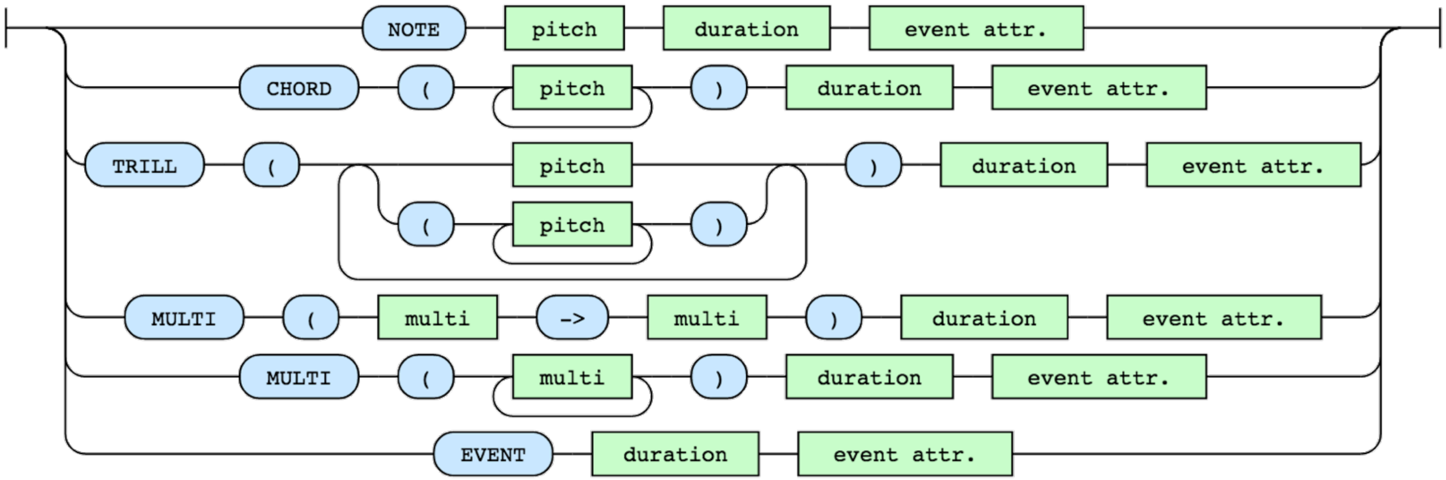
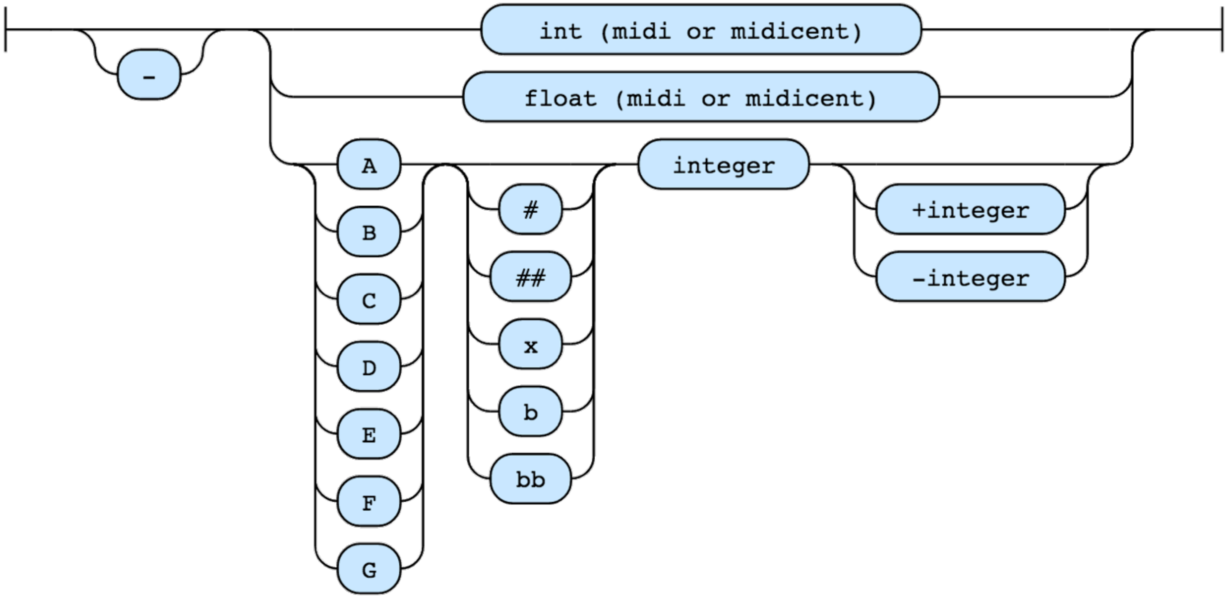
Event Specification



Pitch Specification



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Notes and event containers

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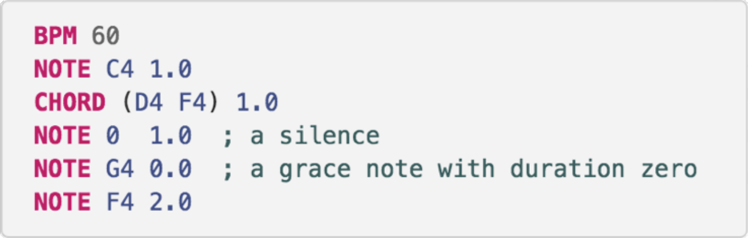
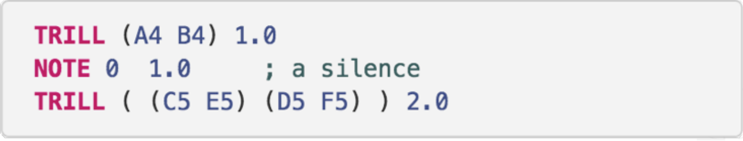
note
and chord



```
BPM 60
NOTE C4 1.0
CHORD (D4 F4) 1.0
NOTE 0  1.0  ; a silence
NOTE G4 0.0  ; a grace note with duration zero
NOTE F4 2.0
```

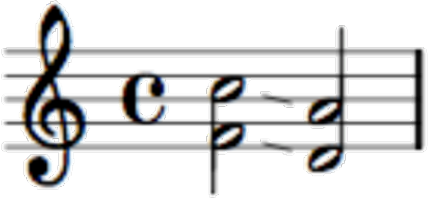
trill

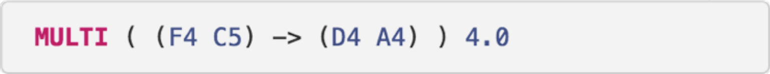


```
TRILL (A4 B4) 1.0
NOTE 0  1.0     ; a silence
TRILL ( (C5 E5) (D5 F5) ) 2.0
```

trill = set of notes to be played repetitively in any order

glissendo
of chords

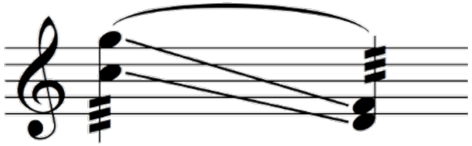




```
MULTI ( (F4 C5) -> (D4 A4) ) 4.0
```

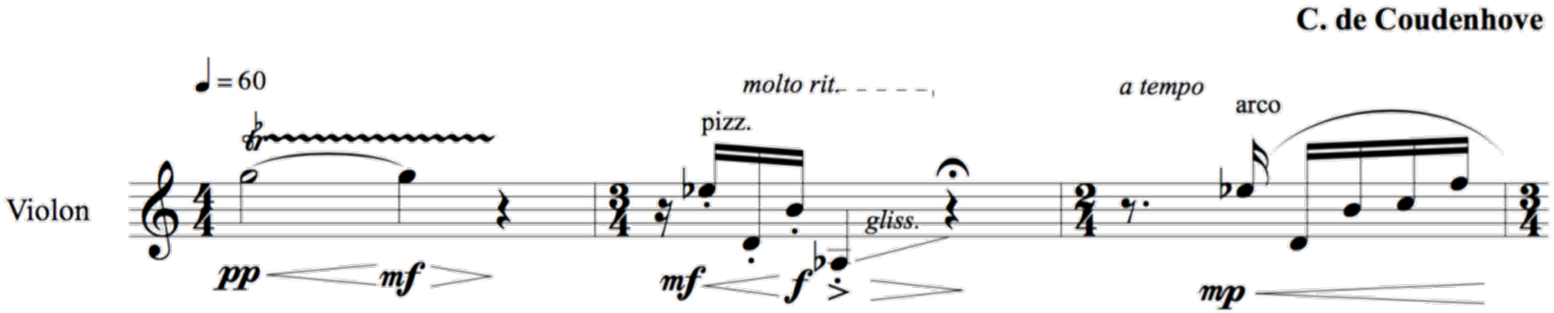
multi = sequence of events to be played in the given order

glissendo
of trills



```
MULTI ( (C5 G5)' -> (D4 F4)' ) 2.0
```

Event specification



import MusicXML file

- through Ascograph
- http://forumnet-dev.ircam.fr/antescofo-converter/

```
BPM 60.00 ; commentaire
NOTE 0 1 ; note 0 : a rest. A good advice is always to start with a rest.

; ---------- measure 1 beat 0.00 --------- this is a comment. importing XMLs in Ascograph allows
to print such comments at the beginning of each bar.


TRILL (7900 8000) 3 premiertrille ; a trill btw 2 notes – « premiertrille » is a label
NOTE 0 5/4 ; la durée du silence peut être notée aussi : 1.25

; ---------- measure 2 beat 4.00 ---------

NOTE Eb5 1/4 mesure2
NOTE 62 1/4 ; notes can be written in MIDI format
NOTE 7100 1/4 ; notes can be written in midi cents, for microtonality
MULTI (56->62) 1/1  ; multi is useful for glissandi

NOTE 0 7/4 @fermata ; @fermata is an attribute

; ---------- measure 3 beat 7.00 ---------

NOTE 7500 1/4  mesure3 @fermata
NOTE 6200 0.25
NOTE 7100 1/4
NOTE 7200 1/4
NOTE 7700 1/4
```

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Antescofo Quick Tour

ACTIONS

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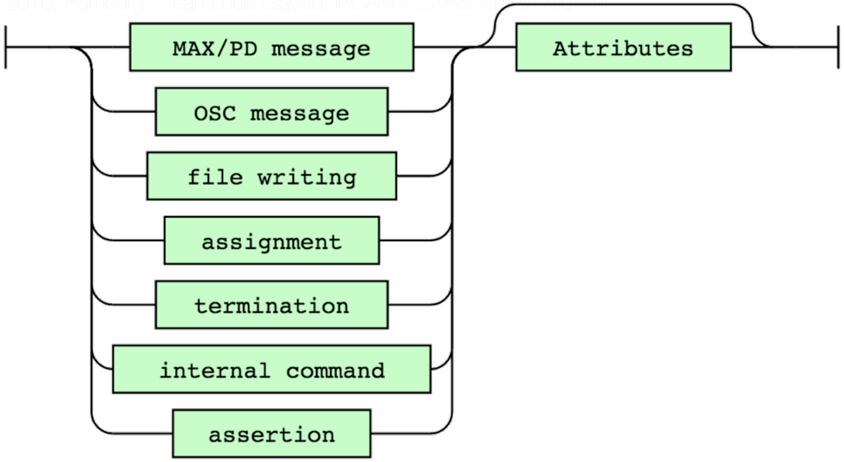
Atomic Actions

- assignment
- messages (Max/PD, OSC)
- command (e.g., abort)



Compound Actions

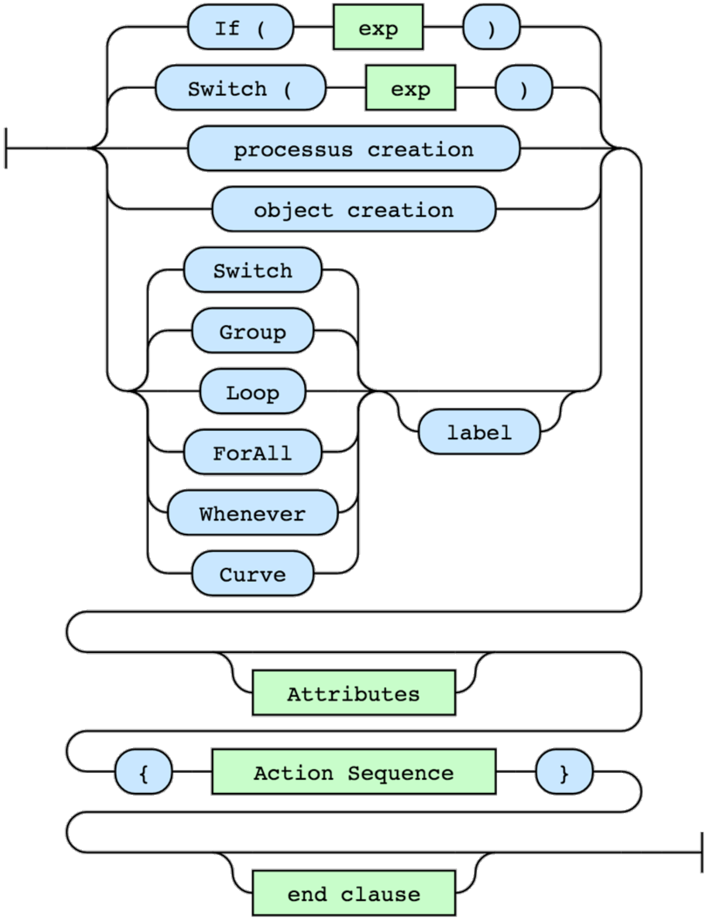
container for sequence of actions

```
group
{
        print hello
        print beautiful
    2.0 print world
}
```

```
curve
@grain 0.1s
@action draw $NOW $y
{
    $y   {  { 0.3 }  4s{ 2.4 } }
}
```

```
loop  3.0
{
    print "loop"
} during [6#]
```

```
whenever ( $y > 3.0 )
{
    print $y "greather than 3"
}
```



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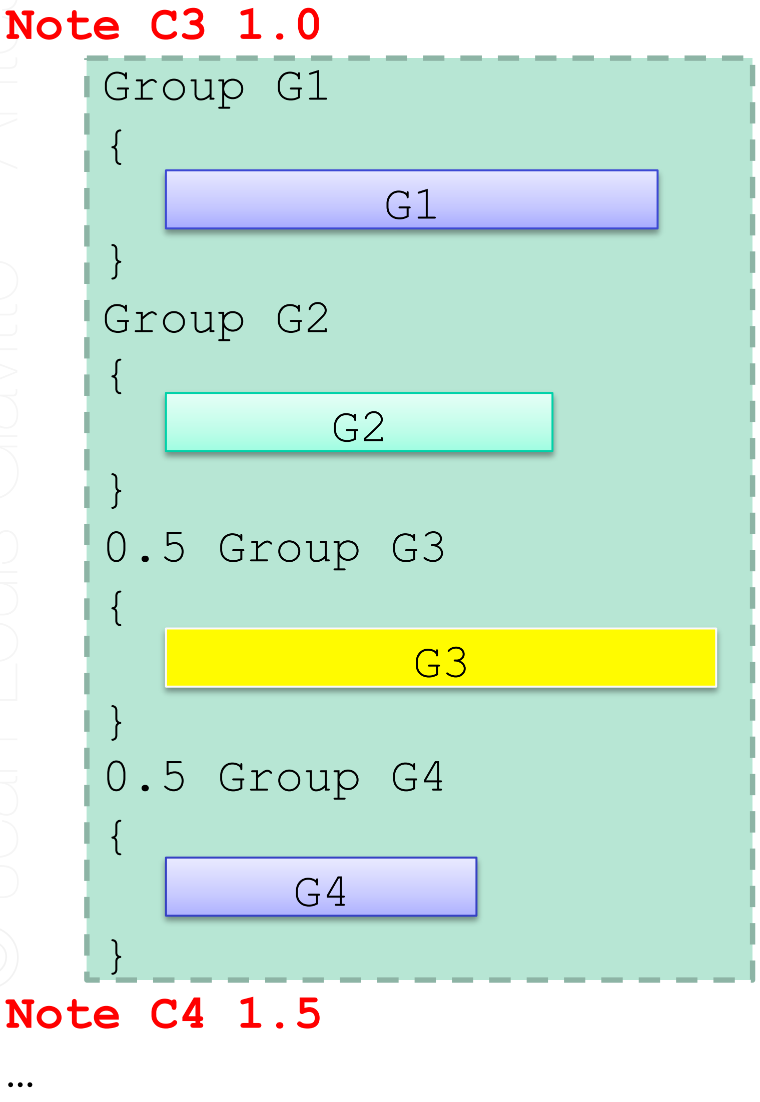
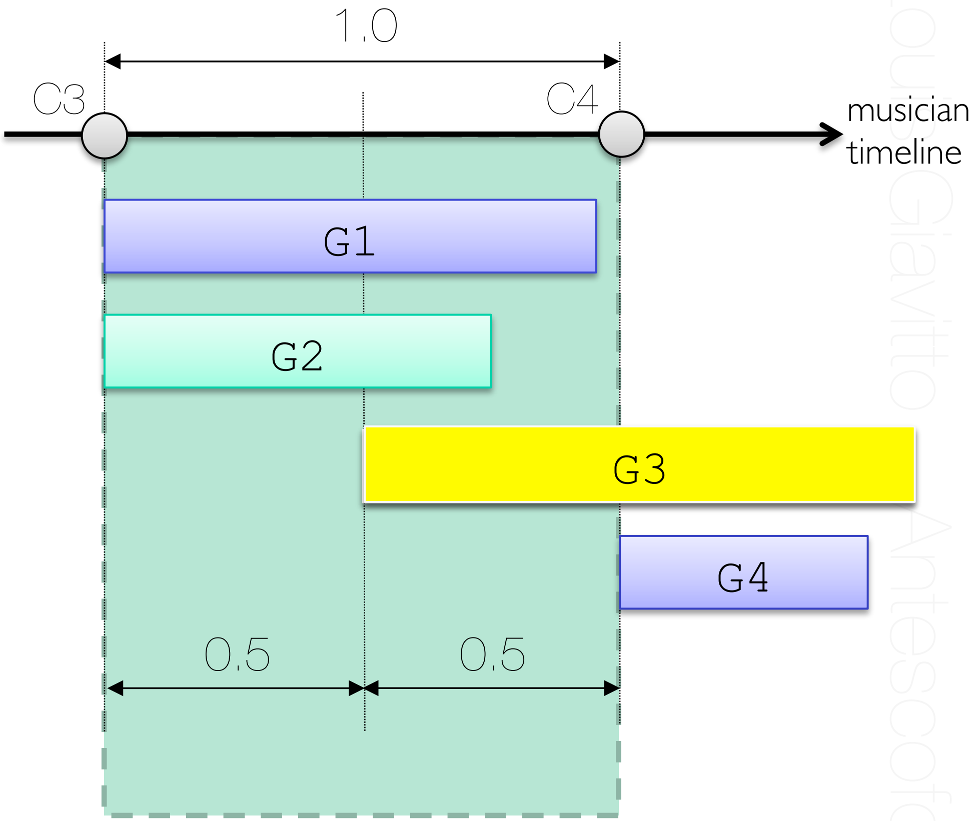
Group

- sequential autonomous thread of execution
- shares some resources (e.g., local variables)
- implemented efficiently by a coroutine
- corresponds to a timeline with a specific time
- passing of time defined wrt another timeline



```
Note C3 1.0
    Group G1
    {
        G1
    }
    Group G2
    {
        G2
    }
    0.5 Group G3
    {
        G3
    }
    0.5 Group G4
    {
        G4
    }
Note C4 1.5
...
```



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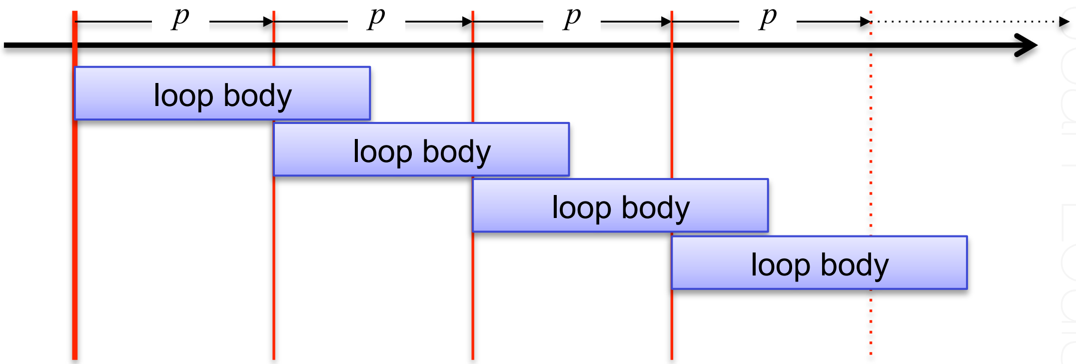
Loop: iteration of a group

Loop p
{
loop body
}



Period:

- dynamic (may changes in time)
- relative (in beat) or absolute (second)

Optional loop termination:

apply also for each compound action

- logical condition
  - until ($x > 10.33)
  - while ($x <= 10.33)

- duration
  - during [3] **(duration in beat)**
  - during [3s] **(duration in second)**
  - during [3#] **(logical duration = 3 times)**

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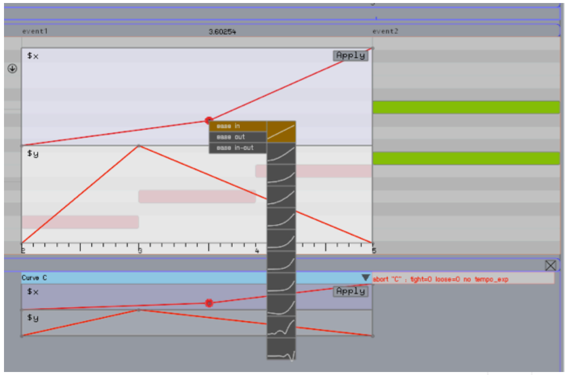
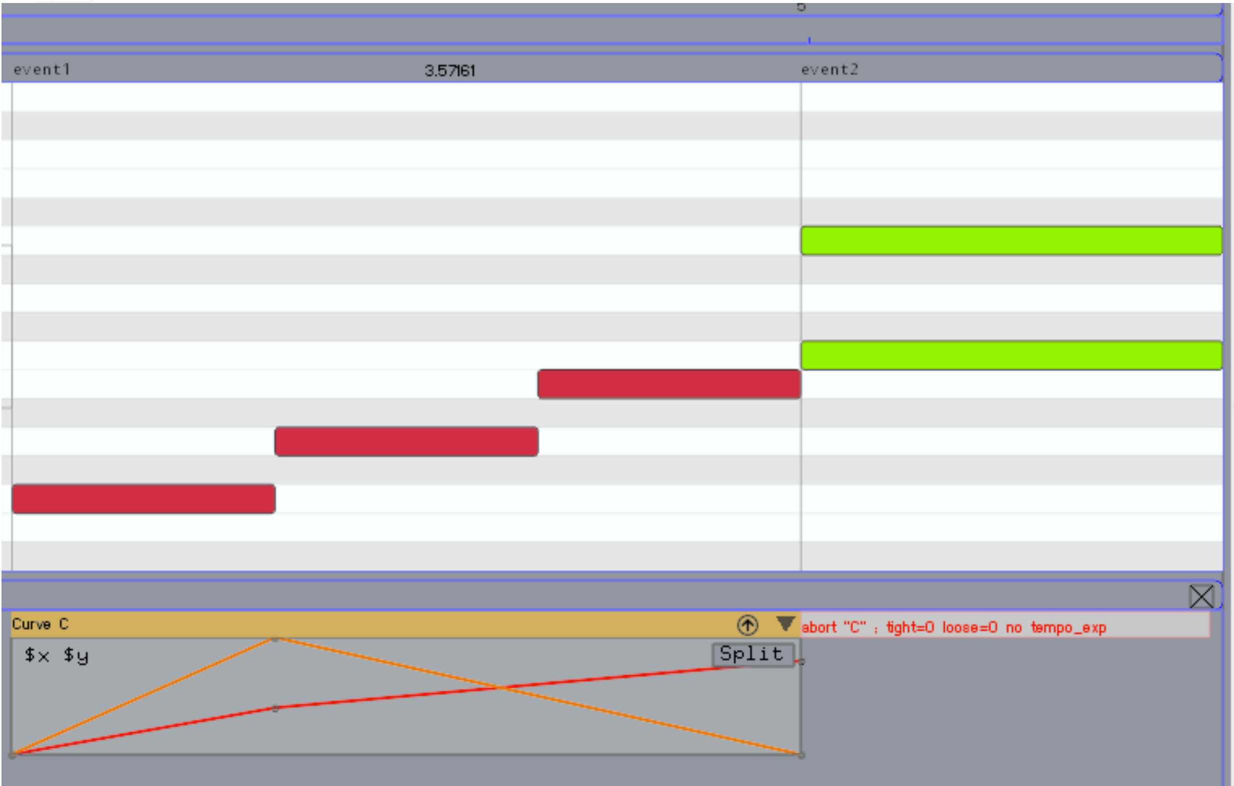
Curve

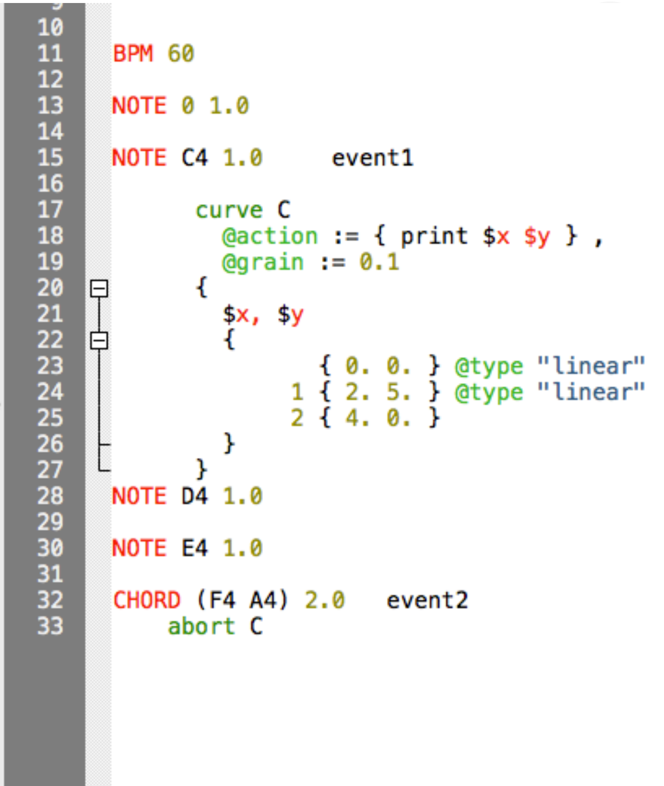
- scalar/vectorial
- Action to do at each sampling point: @action
- Action to do if killed: @abort
  apply also for each compound action
- Sampling: @grain:
  - dynamic (may changes in time)
  - relative (in beat) or absolute (second)



graphical edition in *Ascograph*



abort "C" ; tight=0 loose=0 no tempo_exp



```
BPM 60

NOTE 0 1.0

NOTE C4 1.0      event1

        curve C
          @action := { print $x $y } ,
          @grain := 0.1
        {
          $x, $y
          {
                 { 0. 0. } @type "linear"
               1 { 2. 5. } @type "linear"
               2 { 4. 0. }
          }
        }
NOTE D4 1.0

NOTE E4 1.0

CHORD (F4 A4) 2.0    event2
     abort C
```

Example of abort handler

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```
Curve C
   @grain := 0.5
   @action := { print "curve: " $x }
   @abort := {
        print "Curve C aborted at " $x
        Curve AH
           @grain := 0.3
           @action := { print "handler curve: " $x }
        {
          $x { { $x } 1 { 0.0 } }
        }
   }
{
  $x { { 0.0 } 10 { 10.0 } 10 { 0.0 } }
}
```

```
print: curve:  0.
print: curve:  0.5
print: curve:  1.
print: curve:  1.5
print: Curve Aborted at  1.5
print: handler curve:  1.5
print: handler curve:  1.2
print: handler curve:  0.9
print: handler curve:  0.6
print: handler curve:  0.3
print: handler curve:  0.
```

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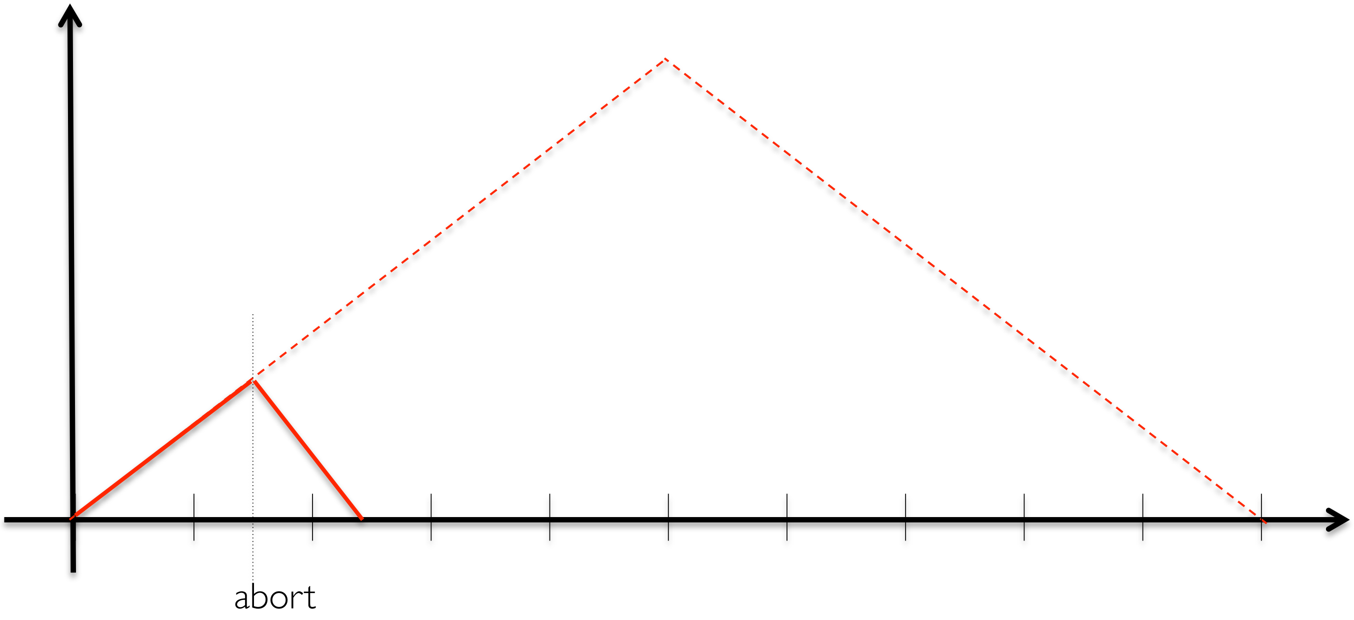

Interpolation types… tweeners

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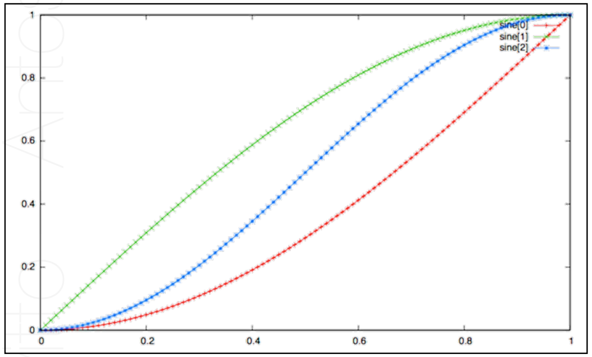
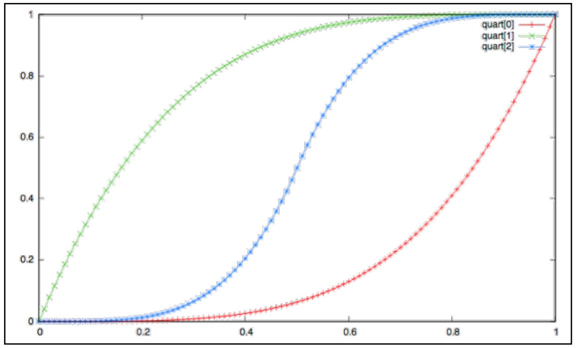
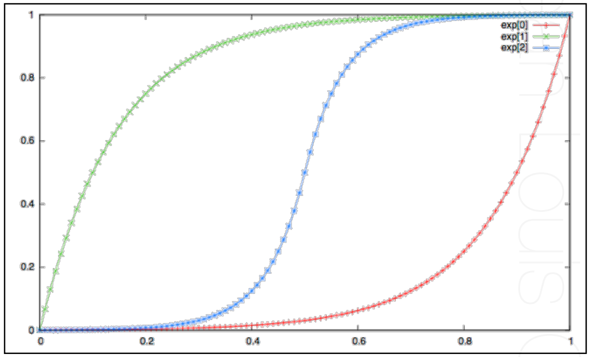
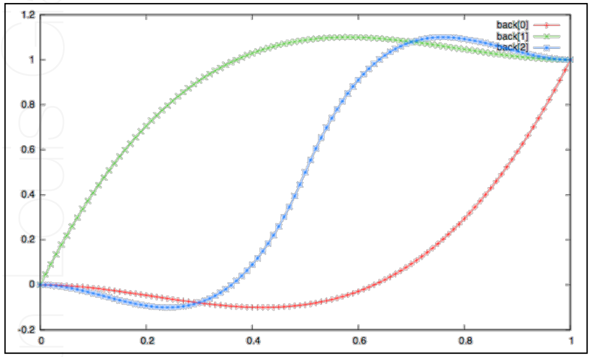
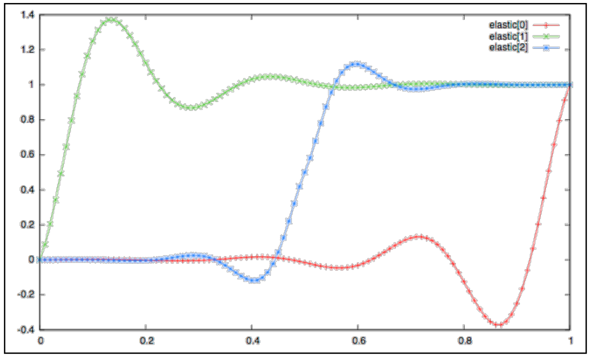
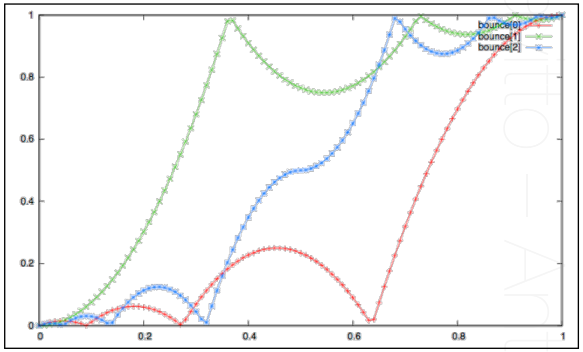






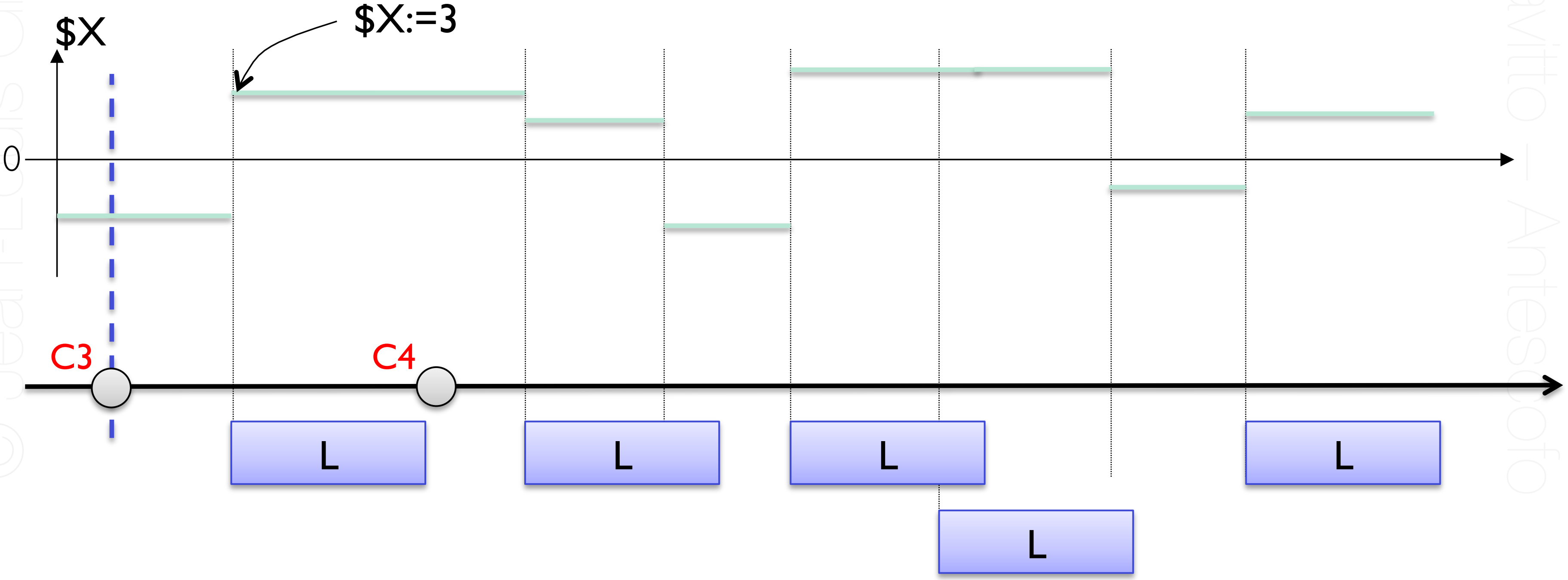






Whenever:
performing a group each time a logical condition is true

```
Note C3  2/3
        whenever ($X > 0)
        {
                L
        }
Note C4 1.5
…
```



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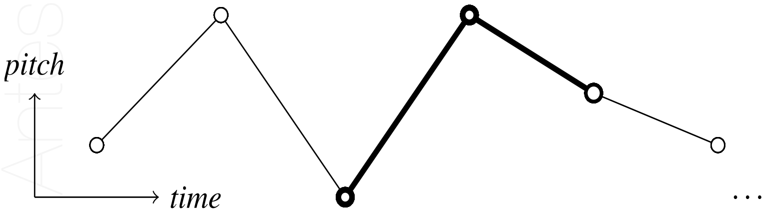
react to
“temporal regular expressions”

TEMPORAL PATTERN

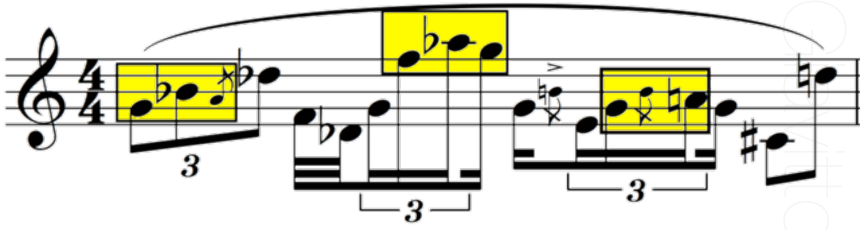
Real-Time Matching a Temporal Pattern

Real-Time Matching of Antescofo Temporal Patterns,
J.-L. Giavitto, J. Echeveste,
ACM PPDP 2014, 2014.



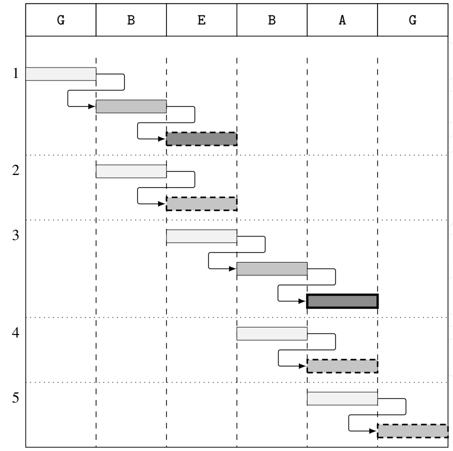
```
pattern P
{
   @local $x , $y , $z
   NOTE $x
   before [0.5]
   NOTE $y where $x < $y
   before [0.5]
   NOTE $z where ($y>$z) & ($z>$x)
}
```

compilation & on-the-fly matching



```
whenever ($PITCH) {
  @local $x
  $x := $PITCH
  whenever ($PITCH > $x) {
    @local $y
    $y := $PITCH
    whenever ($PITCH<$y & $PITCH>$x) {
      @local $z
      $z := $PITCH
      a
    } during [1#]
  } during[1#]
}
```

temporal patterns



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3 versions of the « gong example »
interleaving recognized events and actions

```
;A classic midi to hz convertor
@FUN_DEF midicent2hz($X)  {
                    440.0* @exp( ( ($X/100.0)-69.0) * @log(2.0)/12)
}


@MACRO_DEF Gong($NAME,  $F0,  $DECAY )
{
    print gong1 $RNOW
    $NAME @midicent2hz($F0) @exp(-0.2*1.0) $DECAY (@midicent2hz($F0)+5) @exp(-0.2*1.0) $DECAY (@midicent2hz($F0)*2.54) @exp(-0.2*2.0) ($DECAY*2.0) (@midicent2hz($F0)*5.57)
@exp(-0.2*3.0) ($DECAY*3.0) (@midicent2hz($F0)*5.9) @exp(-0.2*3.0) ($DECAY*3.0) (@midicent2hz($F0)*8.5) @exp(-0.2*3.0) ($DECAY*3.0) (@midicent2hz($F0)*8.9) @exp(-0.2*4.0)
($DECAY*4.0) (@midicent2hz($F0)*12.7) @exp(-0.2*4.0) ($DECAY*4.0) (@midicent2hz($F0)*14.57) @exp(-0.2*4.0) ($DECAY*4.0) (@midicent2hz($F0)*17.4) @exp(-0.2*5.0) ($DECAY*5.0)
(@midicent2hz($F0)*21.11) @exp(-0.2*5.0) ($DECAY*5.0), 0.25
}


NOTE 0 1.0
NOTE 70 0.125                    Measure1
NOTE 72 0.125
NOTE 70 1.0
                    @Gong(ds_1, $PITCH-2400, 1.0)

NOTE 70 0.125
NOTE 72 0.125
NOTE 70 1.625
                    @Gong(ds_1, $PITCH-2400, 1.0)
```

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3 versions of the « gong example »

whenever analysing the output of the listening machine

```
@pattern_def pattern::motif
{
            @local $x, $y, $z
            NOTE $x
            NOTE $y where $x < $y
            NOTE $z where $z < $y
}


whenever pattern::motif
{
            @Gong(ds_1, $PITCH-2400, 1.0)
}

NOTE 0 1.0
NOTE 70 0.125               Measure1
NOTE 72 0.125

NOTE 70 1.0
NOTE 70 0.125

NOTE 72 0.125
NOTE 70 1.625
NOTE 69 0.125
```

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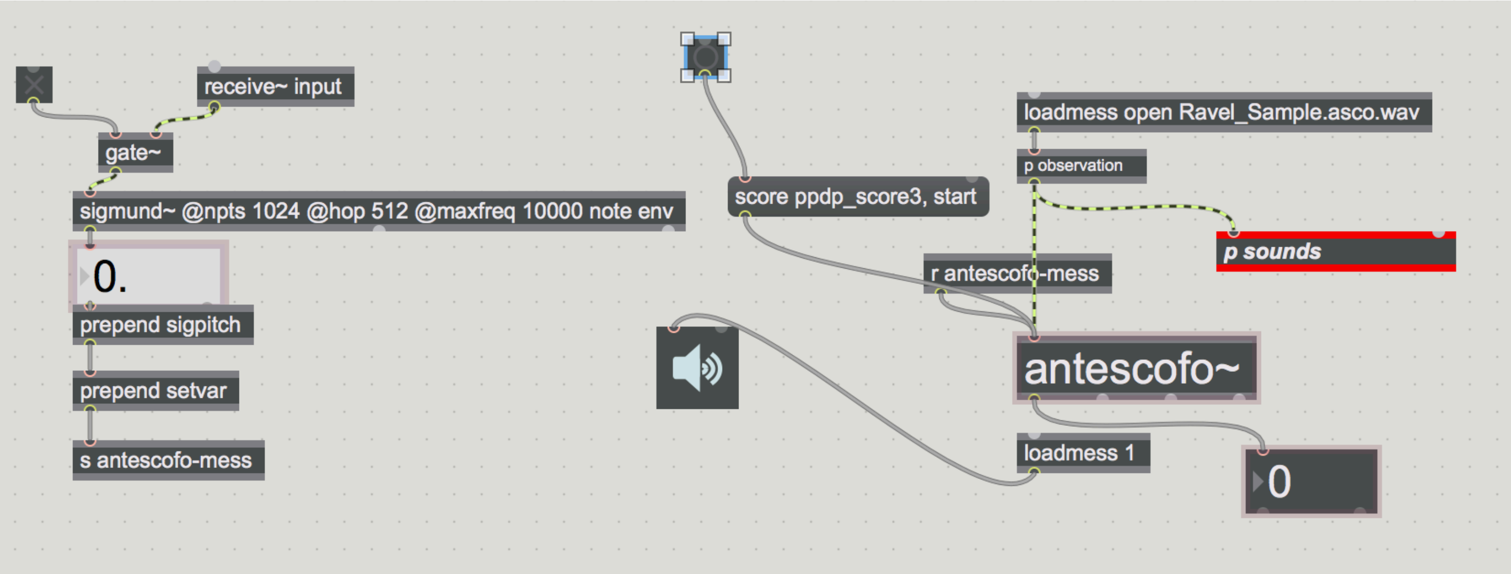
3 versions of the « gong example »
whenever analysing an external signal (sigmund~)

```
@pattern_def pattern::motif
{
        @local $x, $y, $z
        event $sigpitch value $x
        event $sigpitch value $y where $x < $y
        event $sigpitch value $z where $z < $y
}

whenever pattern::motif
{
        @Gong(ds_1, ($sigpitch*100)-2400, 1.0)
}
```



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back to the language

EXPRESSIONS

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Expressions

- Values
  `int, float, bool, string, symbol…`
  `tab, map, continuous symbolic curve…`
  `functions, processes, actors… (first-order values)`

- Operators and predefined functions (more than 190)
  `@sin(),@exp(),@random(),@score()...`

- Imperative Variables
  - system variables: `$RT_TEMPO $NOW $RNOW $TEMPO $PITCH,` *etc.*
  - history
    `[3#]:$x`
    `[3]:$x`
    `[3s]:$x`
  - `@date([3#]:$x)`
    `@rdate([3#]:$x)`

$v	*undef*	43	52	53	49
timestamps in beats	0.0	1.0	2.5	4.0	5.5
timestamps in sec	0.0	2.3	4.2	5.9	7.5

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Structuring Computations

- **Macros**
  textual substitution (before parsing)
- **Functions**
  instantaneous evaluation
- **Processes**
  parameterized sequence of actions
- **Actors (~ concurrent object)**
  - encapsulates a state
  - methods (both actions and expressions)
  - reactions
  - broadcast
- **Functions, Process definition, Actors definition, running processes and running Actors** ***are first class values***
  they can be argument of a function/method/process call or an actor instantiation

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Functions

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```
@fun_def @rational($x)   {  @rational0($x, 2)  }

@fun_def @rational0($x, $i)
{
    @local $n_x, $r_x
    $n_x := @floor($x)
    $r_x := $x - $n_x

    if ($r_x < 0.125) { return [$n_x, 1] }
    else
    {
        $ir_x := 1.0 / $r_x
        if ($i == 0)
        {
            $nir_x := @round($ir_x)
            return [$n_x * $nir_x + 1,  $nir_x]
        }
        else
        {
            $y := @rational0($ir_x, $i-1)
            return [$y[1] + $n_x * $y[0],  $y[0]]
        }
    }
}
```

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Process

abstraction

```
@Proc_def ::Tic($x) {
   $x print TIC
}
@proc_def ::Toc($x) {
   $x print TOC
}
@proc_def ::Clock($p, $q) {
   :: $p(1)
   :: $q(2)
   3 ::Clock($q, $p)
}

Clock(::Tic, ::Toc)
```

computed call
higher-order process,
genericity

recursive call
there there is no
terminal case but a delay

argument passing

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generative process “à la P. Manoury” in “real-time”

LINDENMAYER SYSTEMS

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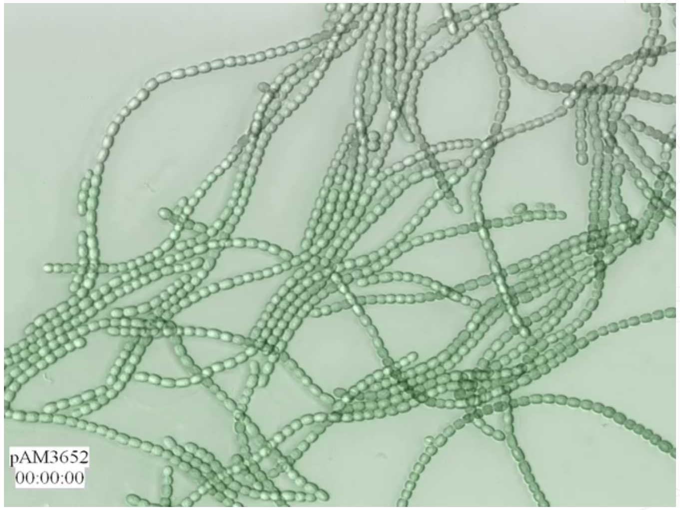
Antescofo tutorial – SMC 2016, Hamburg / Jean-Louis Giavitto, IRCAM – CNRS – INRIA MuTAnt

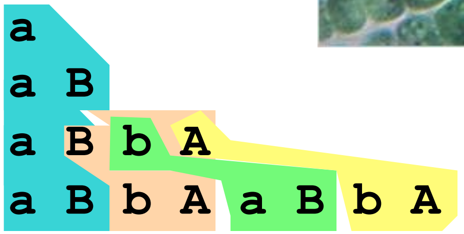
Grammatical model of Morphogenesis

Growth of ***Anabaena Catenula***

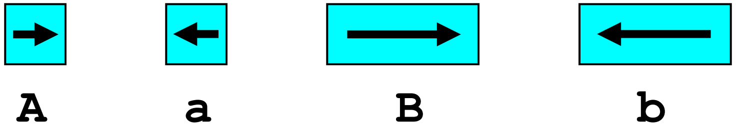
- Asymétric division: one cell is smaller than the other
- Cell are polarized (left or right orientation)

```
a -> aB
A -> bA
b -> aB
B -> bA
```





```
a
a B
a B b A
a B b A a B b A
a B b A a B b A a B b A a B b A
…
```



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Codage d'une plante

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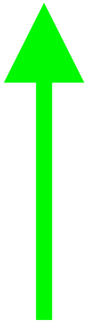
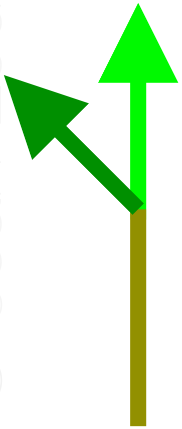
I

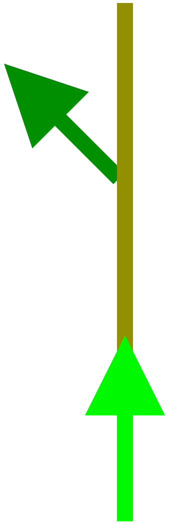


A

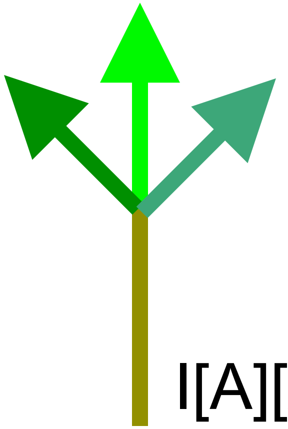
- On peut coder une plante par une chaîne de symboles parenthésés.
- Un symbole représente une partie élémentaire de la plante (entre-noeud, méristème, feuille, inflorescence)
- Les parties entre parenthèses représentent un sous-arbre (*au sens informatique*) = une sous-structure
- Conventions particulières pour représenter l'axe principal, etc.



I[A]A



AI[A]I



I[A][A]A

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A good example of **declarative** formalism: Lindenmayer systems

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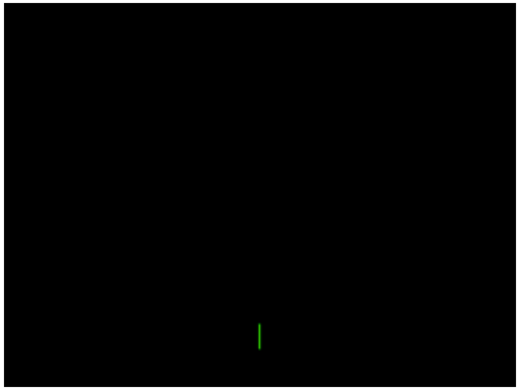

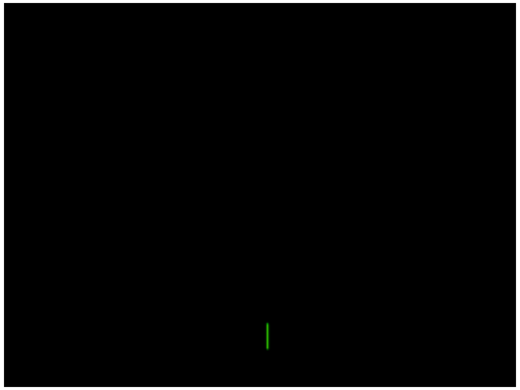

P. Prusinkiewicz

- The structure of a tree can be coded by a string of parenthetised symbols
- A symbol is an elementary part of the plant
- The symbol between [and] represents a sub-tree
- Additional conventions are used to represent main axis, orientation, depth, etc.
- A rule

  $$s_0 \longrightarrow s_1\ s_2\ s_3 \ldots$$

  represents the evolution of s_0

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Process as token, process call as derivation

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```
/*
      a → Ab
      A → ba
      b → B
      B → aB

a
Ab
ba Ab
B Ab ba B

 a = bang(0.1) 0.2 A(0.3) 0.2 b(0.1) bang(0.1)
 A = bang(0.1) 0.1 b(0.3) bang(0.1) a(0.3)

 b = 0.3 bang(0.1) B(0.5) bang(0.1)
 B = 0.25 bang(0.1) a(0.25) B(0.4)

*/
```

```
@proc_def ::a($depth, $duration, $note)
{
        if ($depth > 0)
        {
              @local $dur
              $dur := $duration/10.

              mnote1 $note 120 $dur
              (3 * $dur)
              ::A($depth - 1, 3*$dur, $note)
              (5 * $dur)
              ::b($depth - 1, $dur, $note)
              $dur
              mnote1 $note 120 $dur
        }
}
```

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Process as token, process call as derivation

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```
print "ON Y VA"

  ::a(5, 4.5, 56)
+=>
  print DONE



// Create 20 such processes with random arguments

   _ := [ ::a(2+@rand_int(3), 2+@rand_int(5), 54+@rand_int(6)) | (20) ]
```

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A glimpse into Yan Maresz

POLYRHYTHMIC MACHINE

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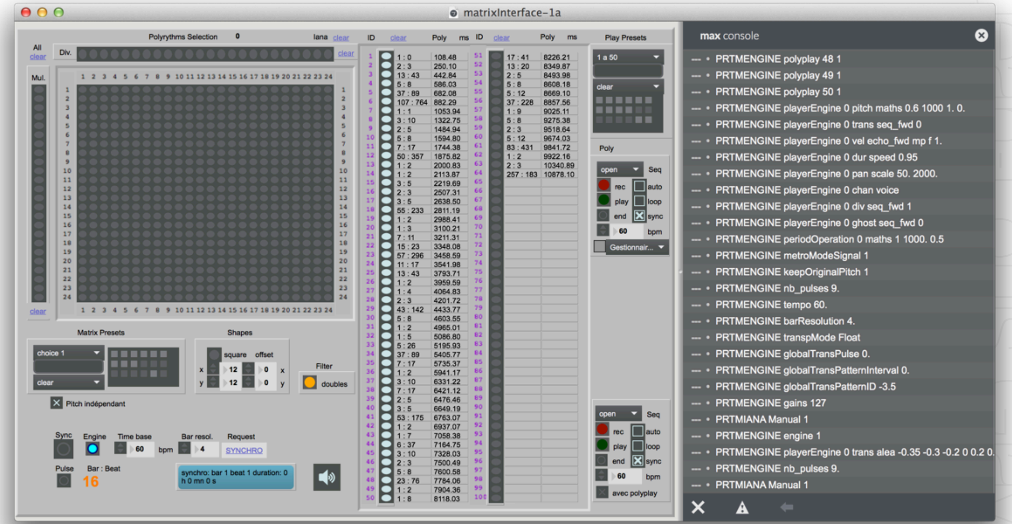
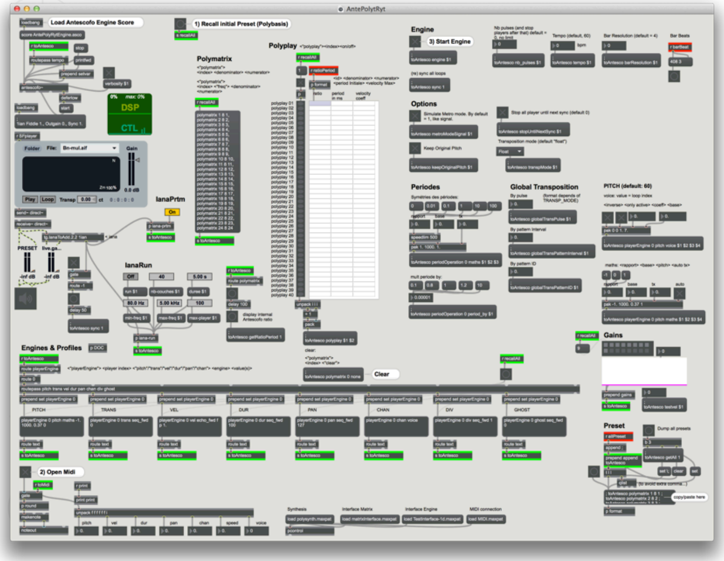
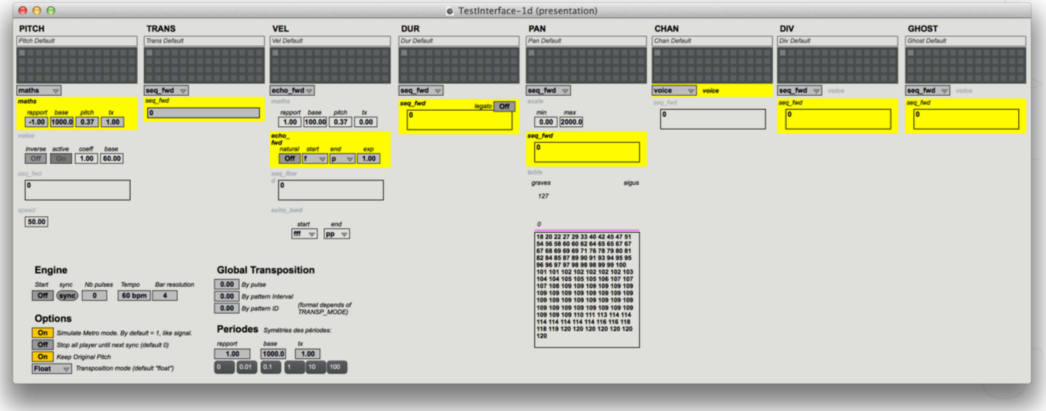
Yan Maresz *Polyrhythmic machine* in Antescofo



```
— • PRTMENGINE polyplay 48 1
— • PRTMENGINE polyplay 49 1
— • PRTMENGINE polyplay 50 1
— • PRTMENGINE playerEngine 0 pitch maths 0.6 1000 1. 0.
— • PRTMENGINE playerEngine 0 trans seq_fwd 0
— • PRTMENGINE playerEngine 0 vel echo_fwd mp f 1.
— • PRTMENGINE playerEngine 0 dur speed 0.95
— • PRTMENGINE playerEngine 0 pan scale 50. 2000.
— • PRTMENGINE playerEngine 0 chan voice
— • PRTMENGINE playerEngine 0 div seq_fwd 1
— • PRTMENGINE playerEngine 0 ghost seq_fwd 0
— • PRTMENGINE periodOperation 0 maths 1 1000. 0.5
— • PRTMENGINE metroModeSignal 1
— • PRTMENGINE keepOriginalPitch 1
— • PRTMENGINE nb_pulses 9.
— • PRTMENGINE tempo 60.
— • PRTMENGINE barResolution 4.
— • PRTMENGINE transpMode Float
— • PRTMENGINE globalTransPulse 0.
— • PRTMENGINE globalTransPatternInterval 0.
— • PRTMENGINE globalTransPatternID -3.5
— • PRTMENGINE gains 127
— • PRTMIANA Manual 1
— • PRTMENGINE engine 1
— • PRTMENGINE playerEngine 0 trans alea -0.35 -0.3 -0.2 0 0.2 0.
— • PRTMENGINE nb_pulses 9.
— • PRTMIANA Manual 1
```





An polyR object

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```
@obj_def polyR($period, $subperiod)
{
        @local ...
        @init { … }
        @broadcast sync_all_loop() { … }
        @proc_def change_period($np) { … }
        @whenever ($fire)
        {
                Loop $period
                {
                        Loop ($period/$subperiod)  { … }
                }
        }
        @init { … }
}
```

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An polyR object

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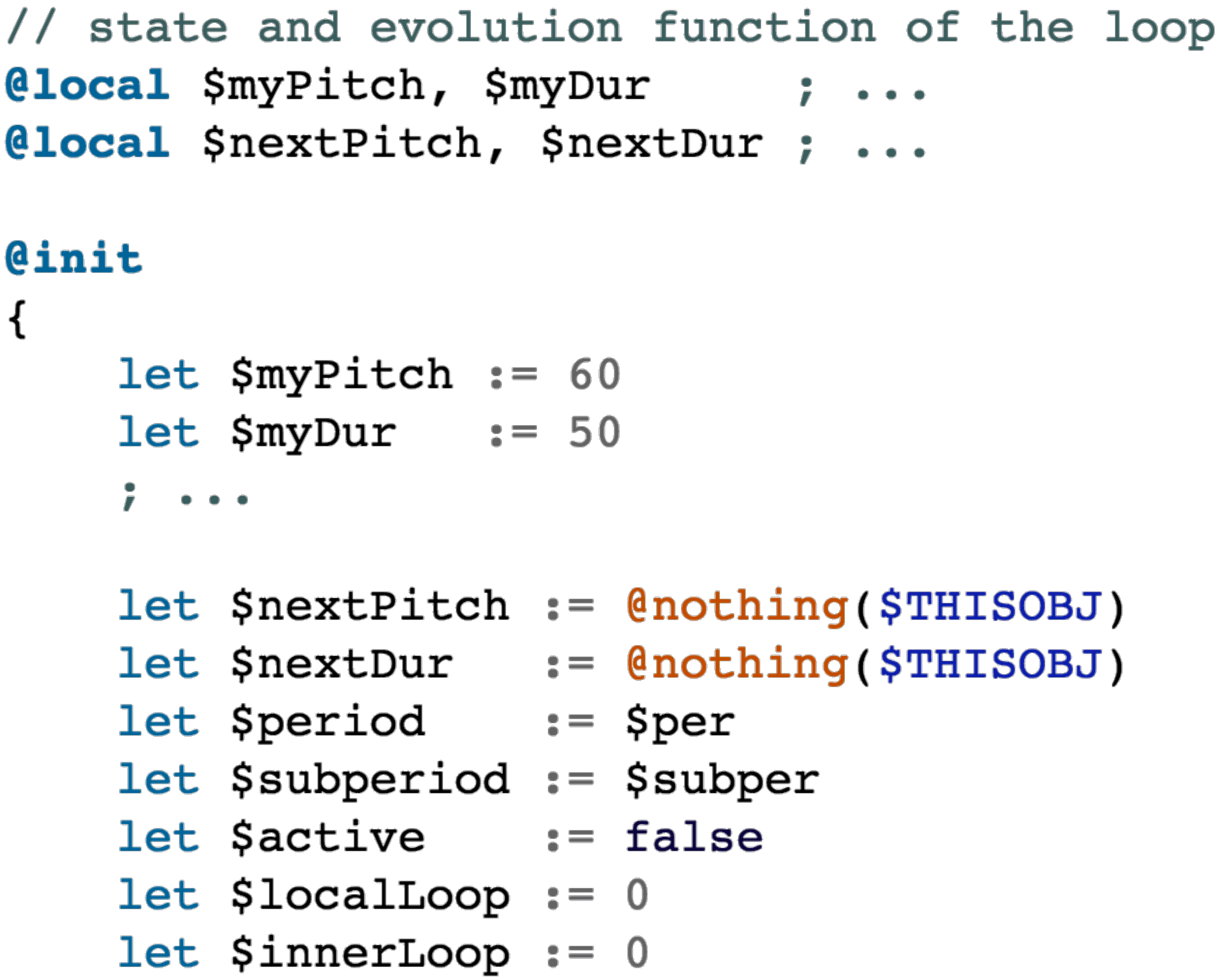

```
// state and evolution function of the loop
@local $myPitch, $myDur     ; ...
@local $nextPitch, $nextDur ; ...

@init
{
    let $myPitch := 60
    let $myDur   := 50
    ; ...

    let $nextPitch := @nothing($THISOBJ)
    let $nextDur   := @nothing($THISOBJ)
    let $period    := $per
    let $subperiod := $subper
    let $active    := false
    let $localLoop := 0
    let $innerLoop := 0
```

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An polyR object

```
@whenever ($fire)
{
    $cpt := 0
    $subcpt := 0
    abort $localLoop

    $localLoop := {
        Loop $period
        {
            $start_body := $NOW
            $cpt := $cpt + 1
            if ($active)
            {
                abort $innerLoop
                print "start L" $NOW
                $innerLoop := {
                    Loop ($period/$subperiod)
                    {
                        $subcpt := $subcpt + 1
                        let $myPitch := $nextPitch($myPitch)
                        let $myDur   := $nextDur($myDur)
                        ; ...
                        toMidi $myPitch $myDur $NOW ; ...
                    }
                }
            }
        }

    }
}
```

```
@init {
   print start $THISOBJ $NOW
   let $fire := true
}
```

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An polyR object

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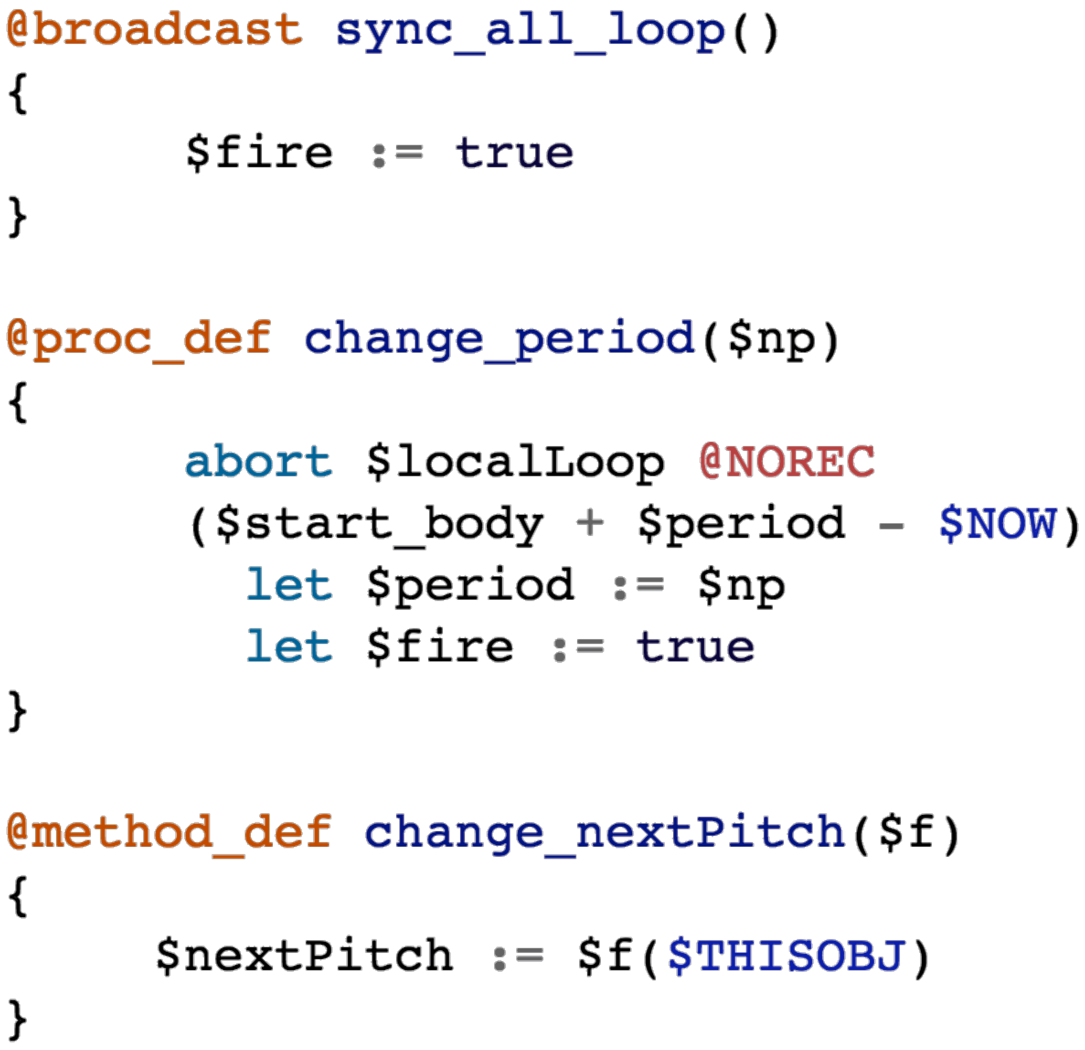

```
@broadcast sync_all_loop()
{
        $fire := true
}

@proc_def change_period($np)
{
        abort $localLoop @NOREC
        ($start_body + $period - $NOW)
          let $period := $np
          let $fire := true
}

@method_def change_nextPitch($f)
{
       $nextPitch := $f($THISOBJ)
}
```

An polyR object

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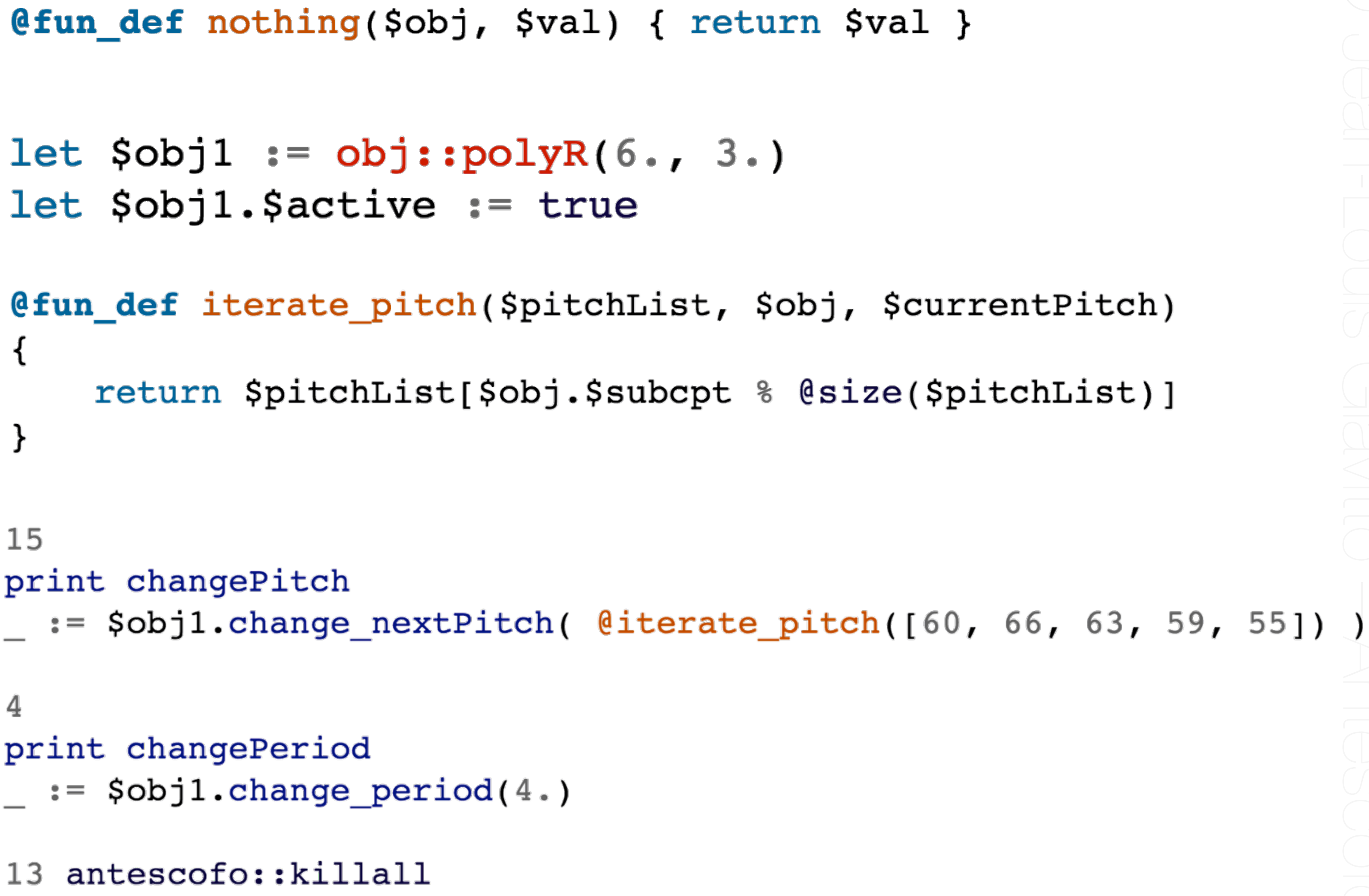

```
@fun_def nothing($obj, $val) { return $val }


let $obj1 := obj::polyR(6., 3.)
let $obj1.$active := true

@fun_def iterate_pitch($pitchList, $obj, $currentPitch)
{
    return $pitchList[$obj.$subcpt % @size($pitchList)]
}


15
print changePitch
_ := $obj1.change_nextPitch( @iterate_pitch([60, 66, 63, 59, 55]) )

4
print changePeriod
_ := $obj1.change_period(4.)

13 antescofo::killall
```

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Trace of a program execution

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```
print start `4 0.0
print "start L" 6.0
toMidi 60 50 6.0
toMidi 60 50 8.0
toMidi 60 50 10.0
print "start L" 12.0
toMidi 60 50 12.0
toMidi 60 50 14.0
print changePitch
toMidi 66 50 16.0
print "start L" 18.0
toMidi 63 50 18.0
print changePeriod
toMidi 59 50 20.0
toMidi 55 50 22.0
print "start L" 24.0
toMidi 66 50 24.0
toMidi 63 50 25.3333
toMidi 59 50 26.6667
print "start L" 28
toMidi 55 50 28
toMidi 60 50 29.3333
toMidi 66 50 30.6667
…
```

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Time<u>s</u> in Antescofo

- multiple time(s)
- tempo extraction
- from triggers to synchronization
- the interpretation problem
- time-time diagrams

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times in Antescofo

MULTIPLE TIMES

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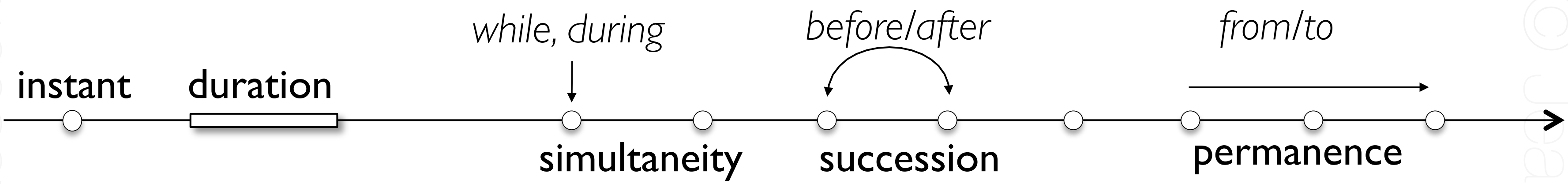
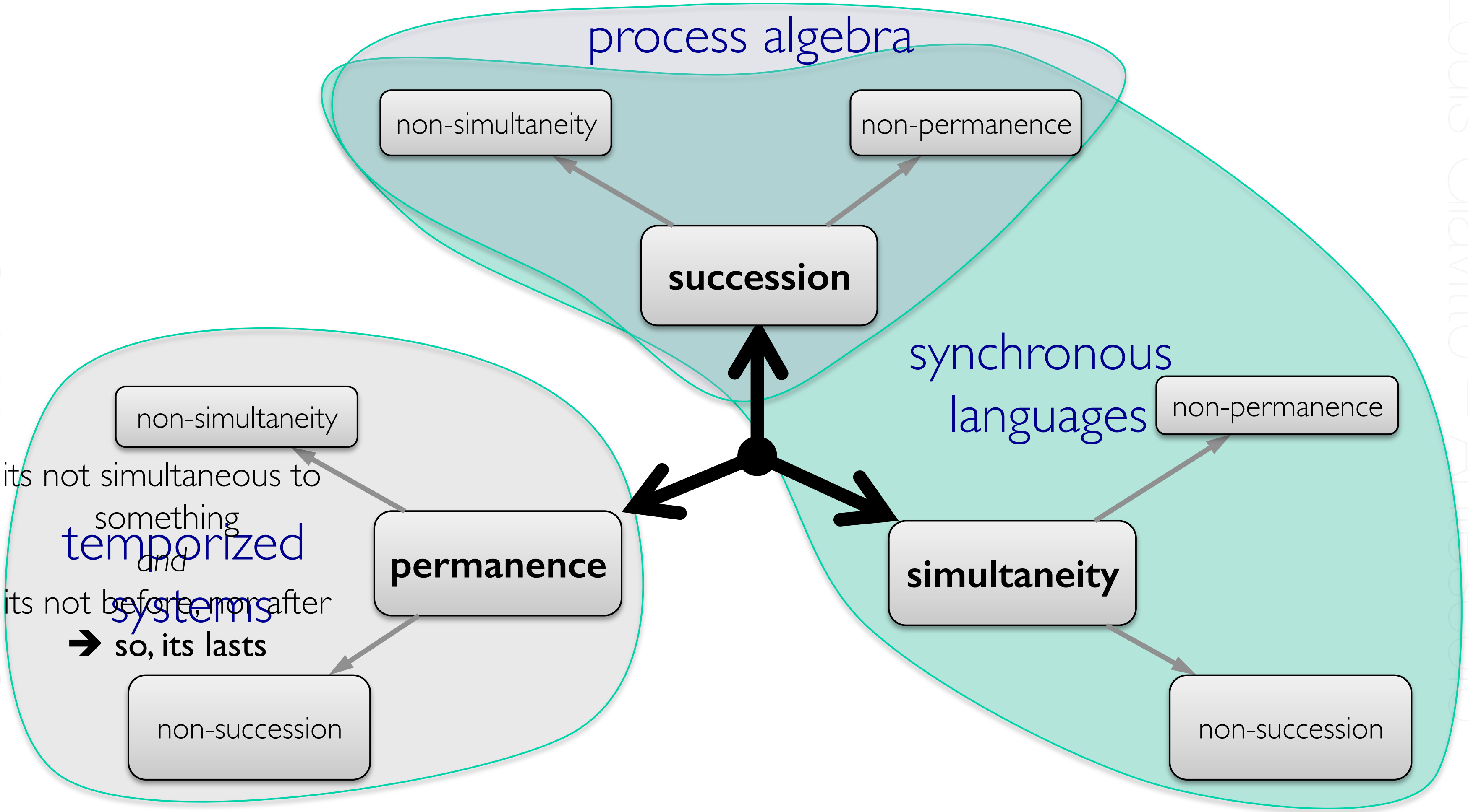
Instant and Duration: Simultaneity, Succession & Permanence





its not simultaneous to something

and

its not before nor after

➔ so, its lasts

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A Score

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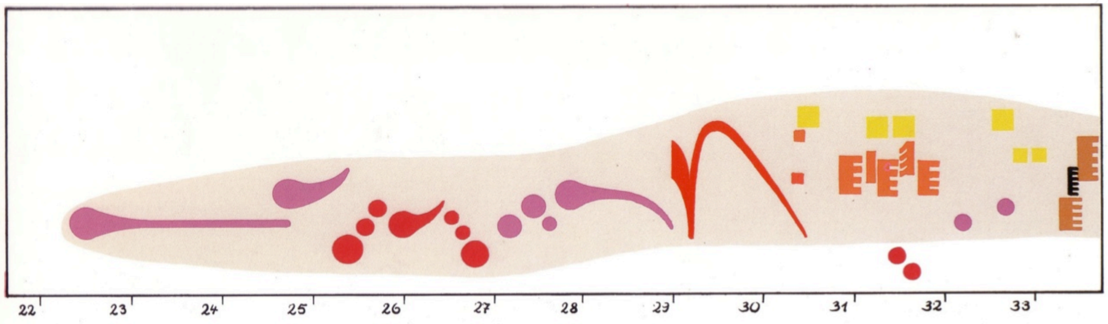
- instantaneous events
  (e.g. the onset of a note)

- events that last
  (duration of a note)
- continuous change of parameter (*movement*, *gesture*)
  - frequency
  - ambitus
  - sound localization
  - etc.



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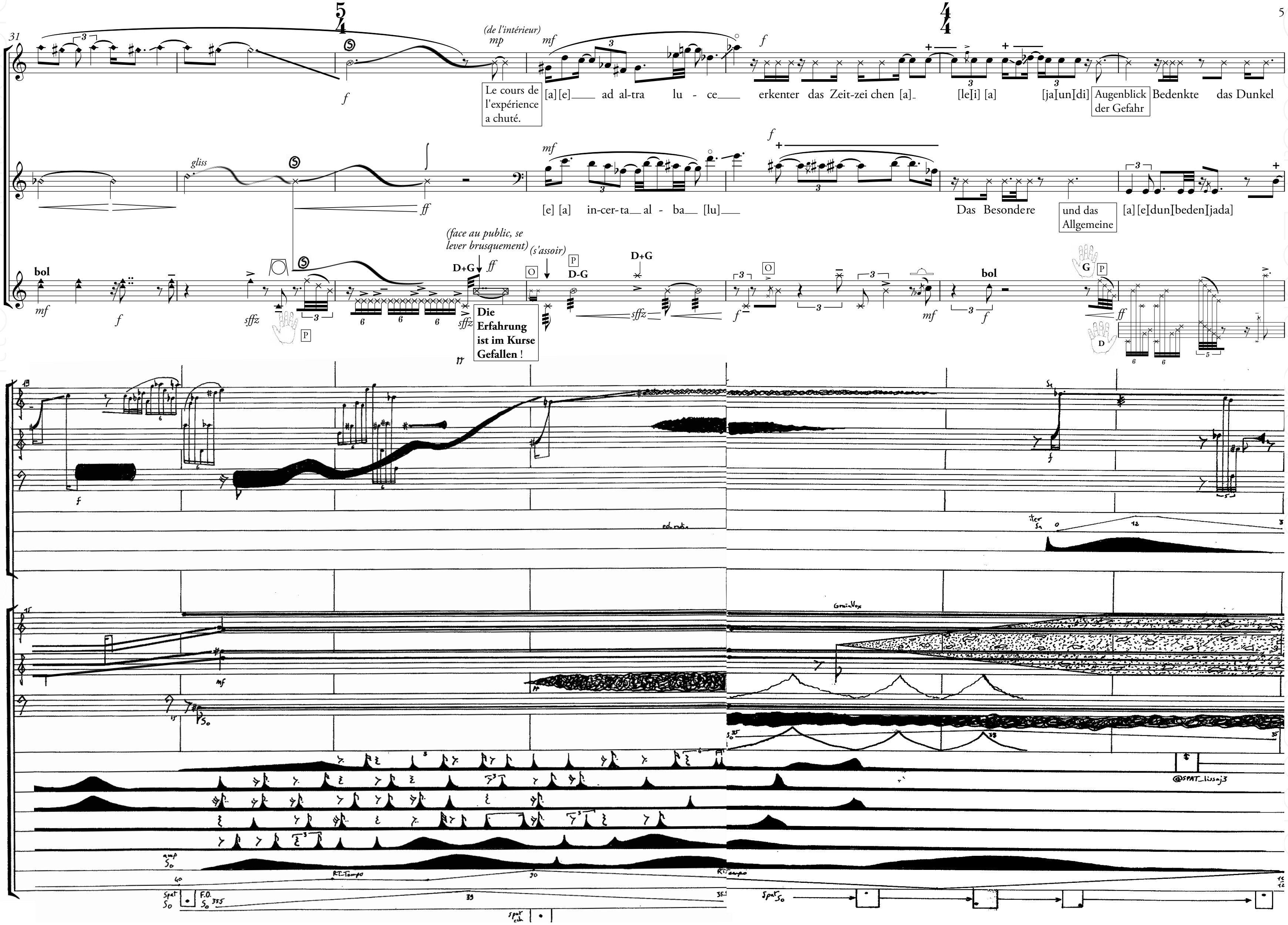
Nachleben Julia Blondeau (2014)



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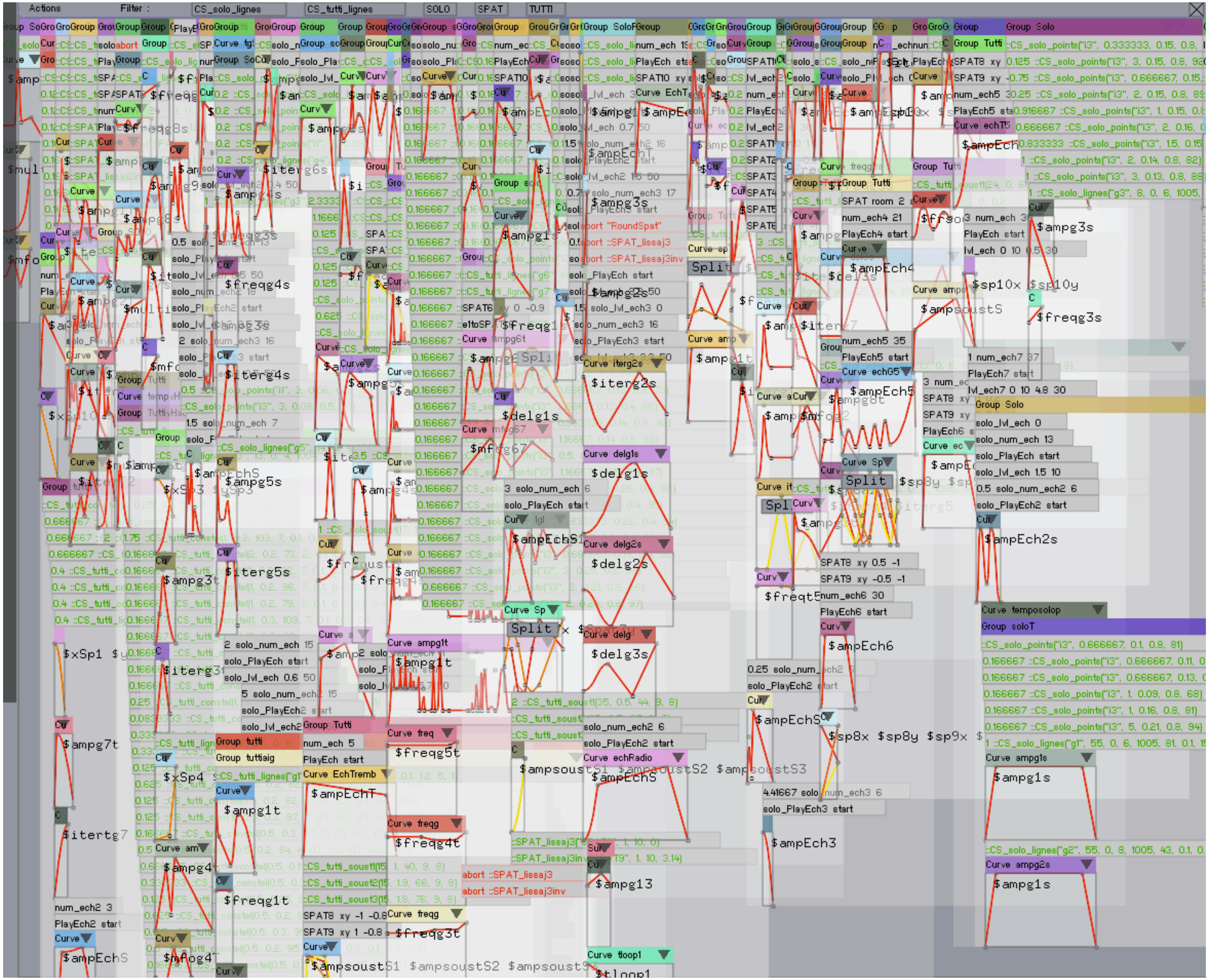
Nachleben, Julia Blondeau (8'30)



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Can we deal with *instants* only?

➔ duration as a set of contiguous instants

- evenemential-time

versus

- the fluxion: continuous passage of time
  - going twice faster
  - finishing together
  - accelerando
  - rubato
  - tempo
  - etc…

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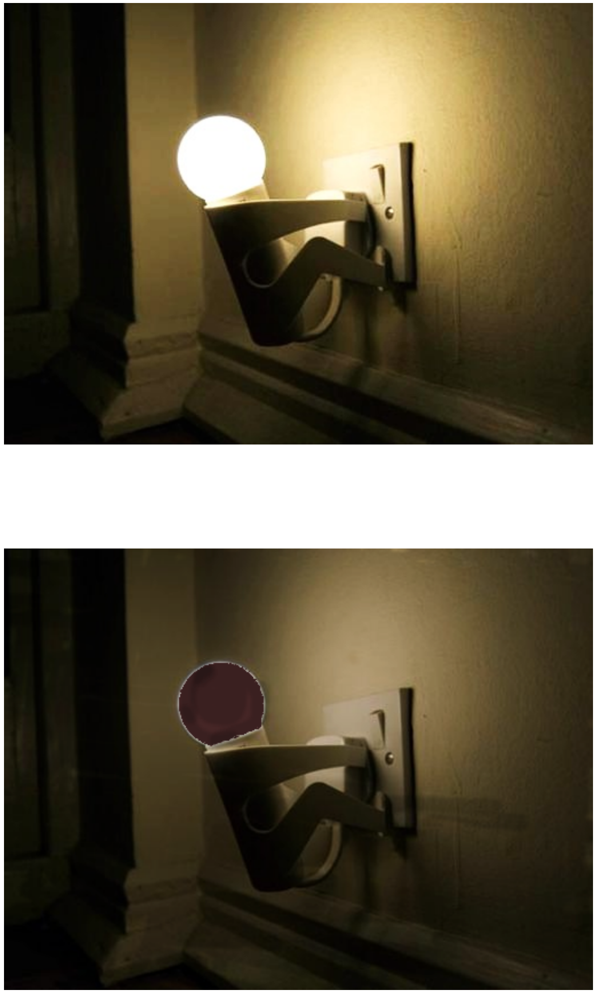
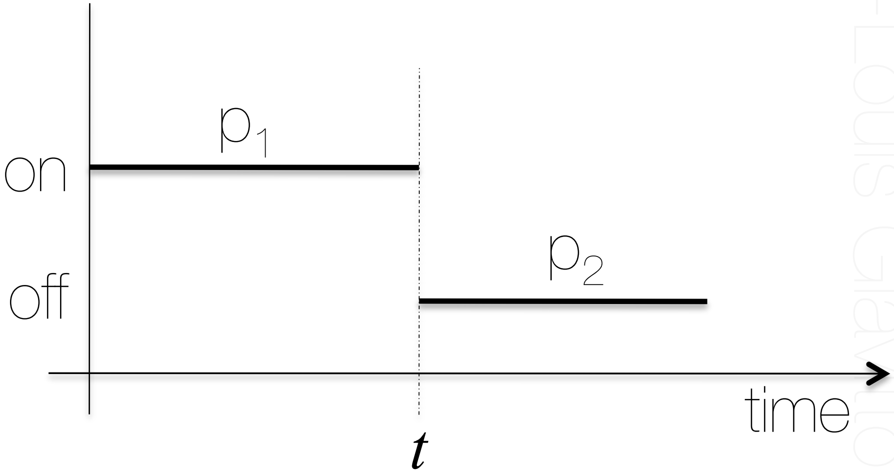
Can duration be reduced to instant?
(in temporal logic)





doing real analysis and topology

or

making instant and duration primitive notions

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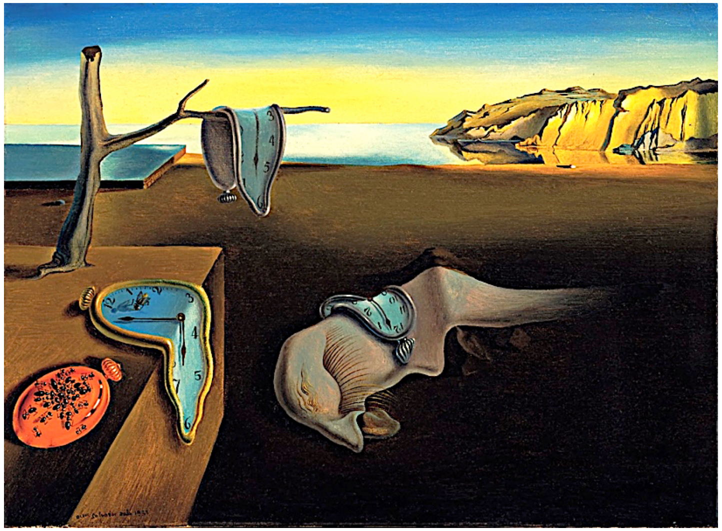
Multiples (ways of denoting/managing/handling) times

- A unique time : an external, observable, privileged *clock*
  - events occurs ***in*** time
  - Newton: *fongibles* temporal unit
  - (partially-)shared, prescriptive, normative time
- multiple time<u>s</u> : co-dependant plurality of times
  - events ***define*** time
    (Bluedorn: epochal time is defined by events)
  - Leibniz: relationnal time
  - Examples :
    - « time layer » in a score
    - relationships between the score and its performance
    - co-construction during the performance by the ensemble of musicians



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Example of relational (event-specified) time
Roman notions of summer hours and winter hours

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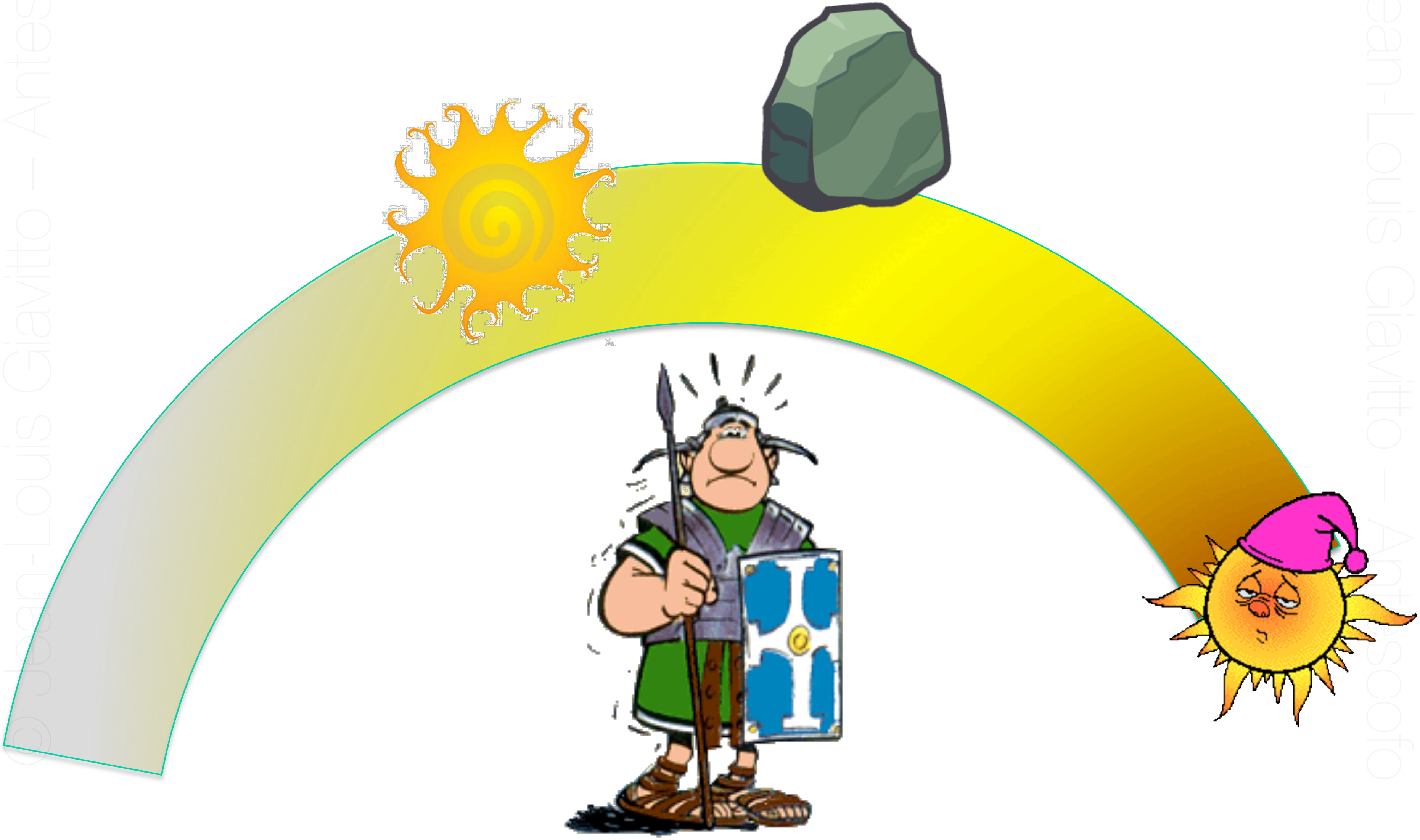

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times in Antescofo

FROM TRIGGER TO SYNCHRONIZATION

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Tackling the interpretation problem in mixed music

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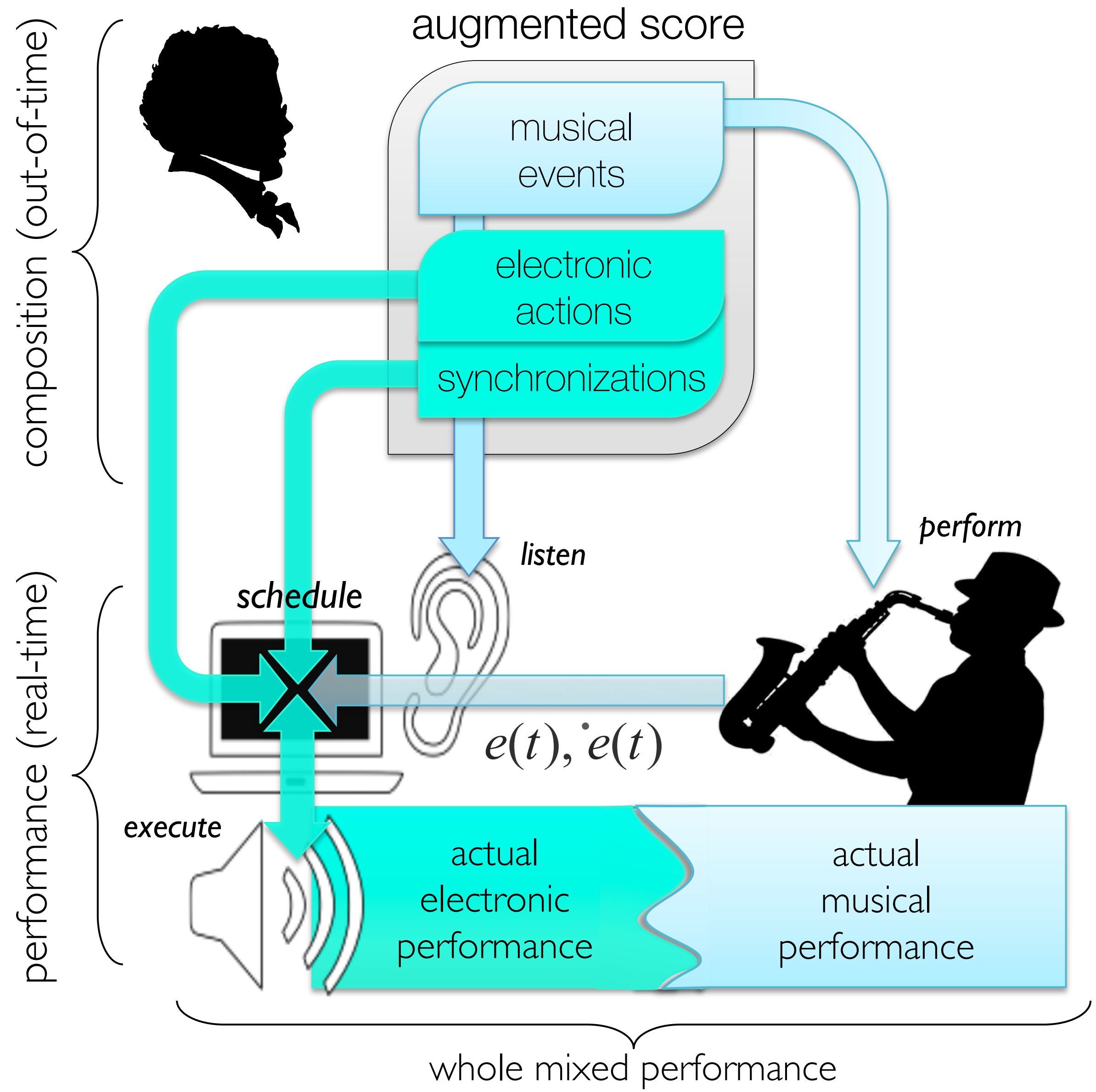

augmented score

musical events

electronic actions

synchronizations

composition (out-of-time)

performance (real-time)

listen

perform

schedule

execute

$e(t), \dot{e}(t)$

actual electronic performance

actual musical performance

whole mixed performance

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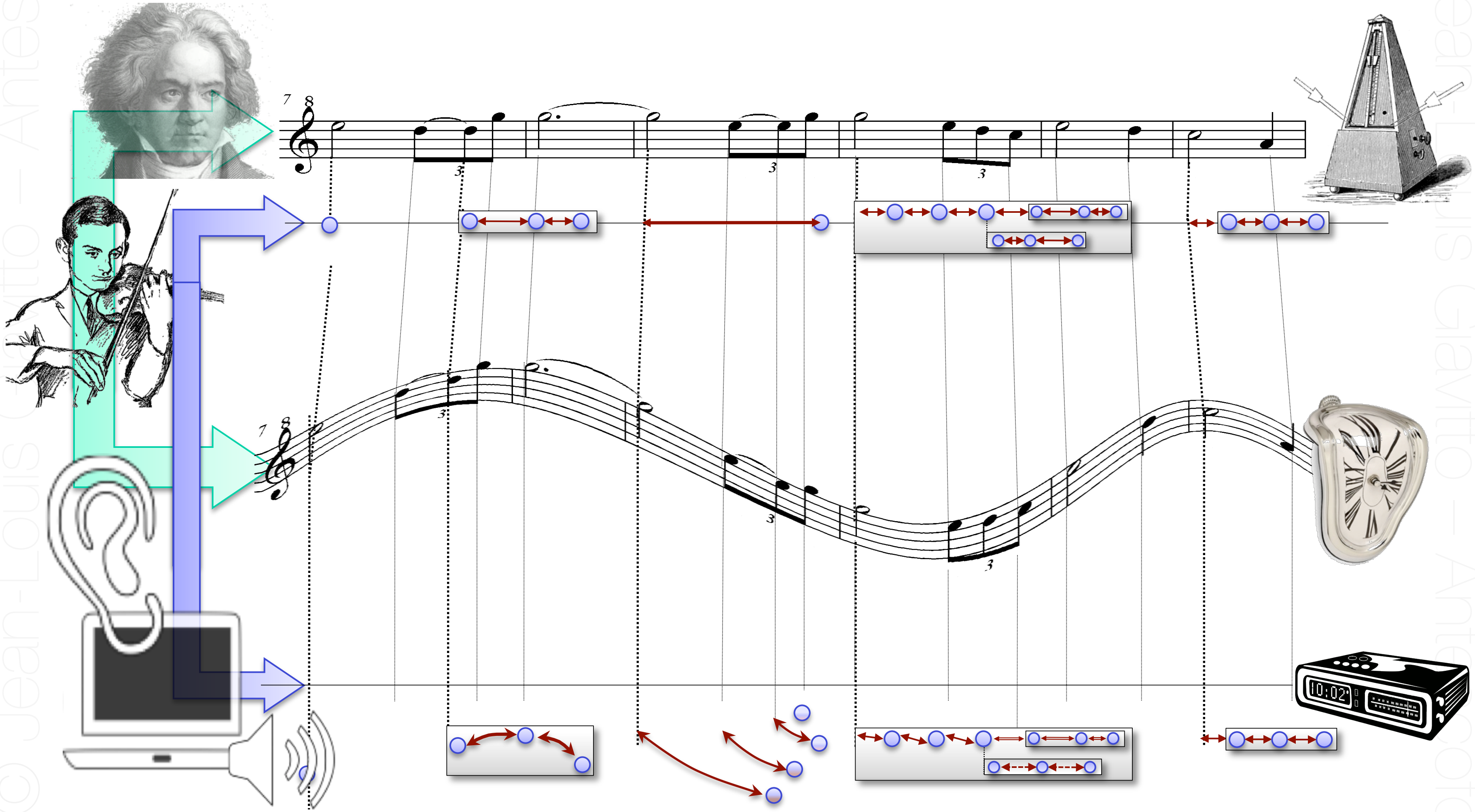
The Multiples Times of Temporal Scenarios



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Notice the difference with…

beginning of *Antheme2* score, P. Boulez

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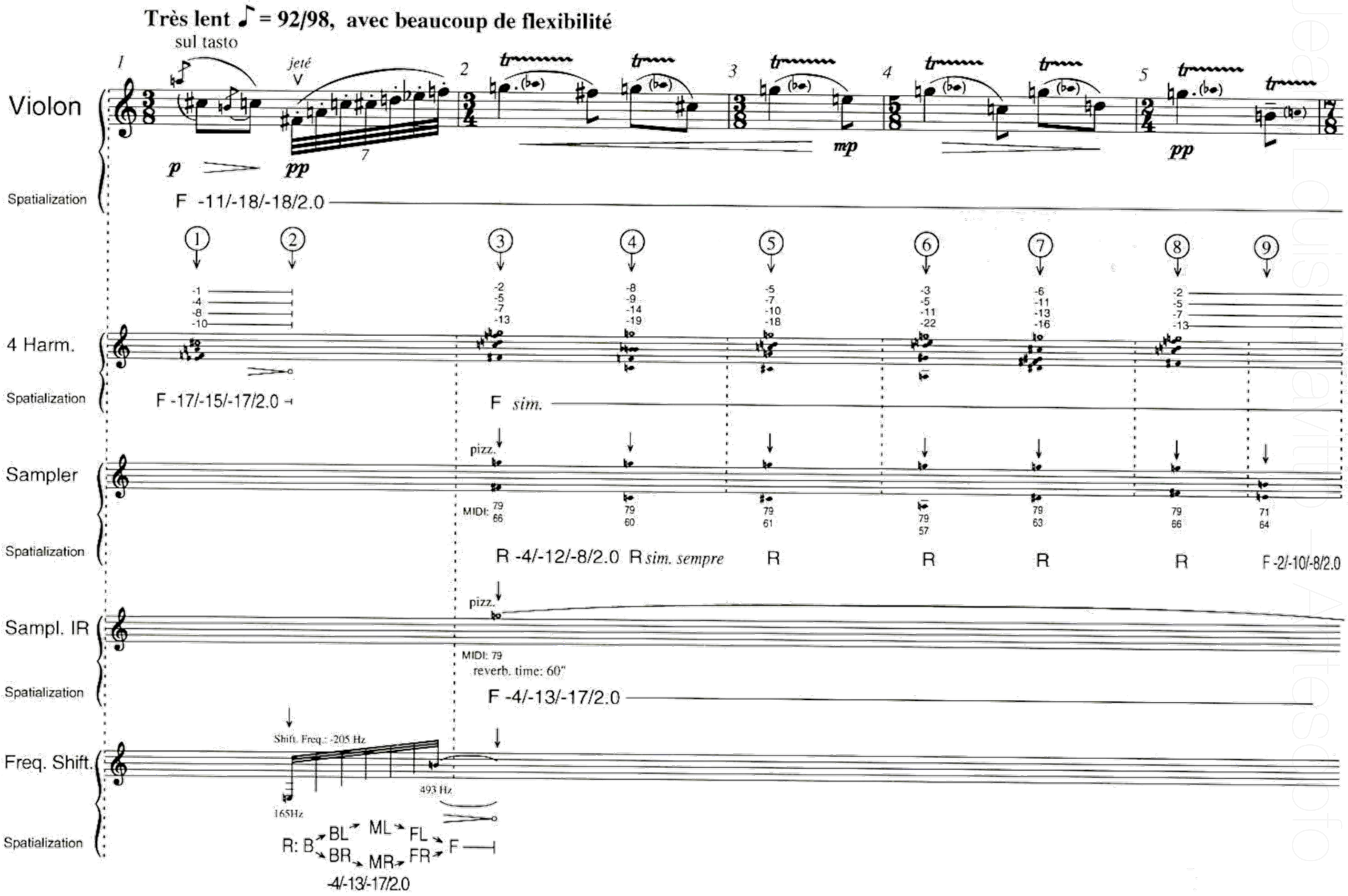
acoustic

electronic



Notice the difference with…

beginning of *Nachleben Julia Blondeau*

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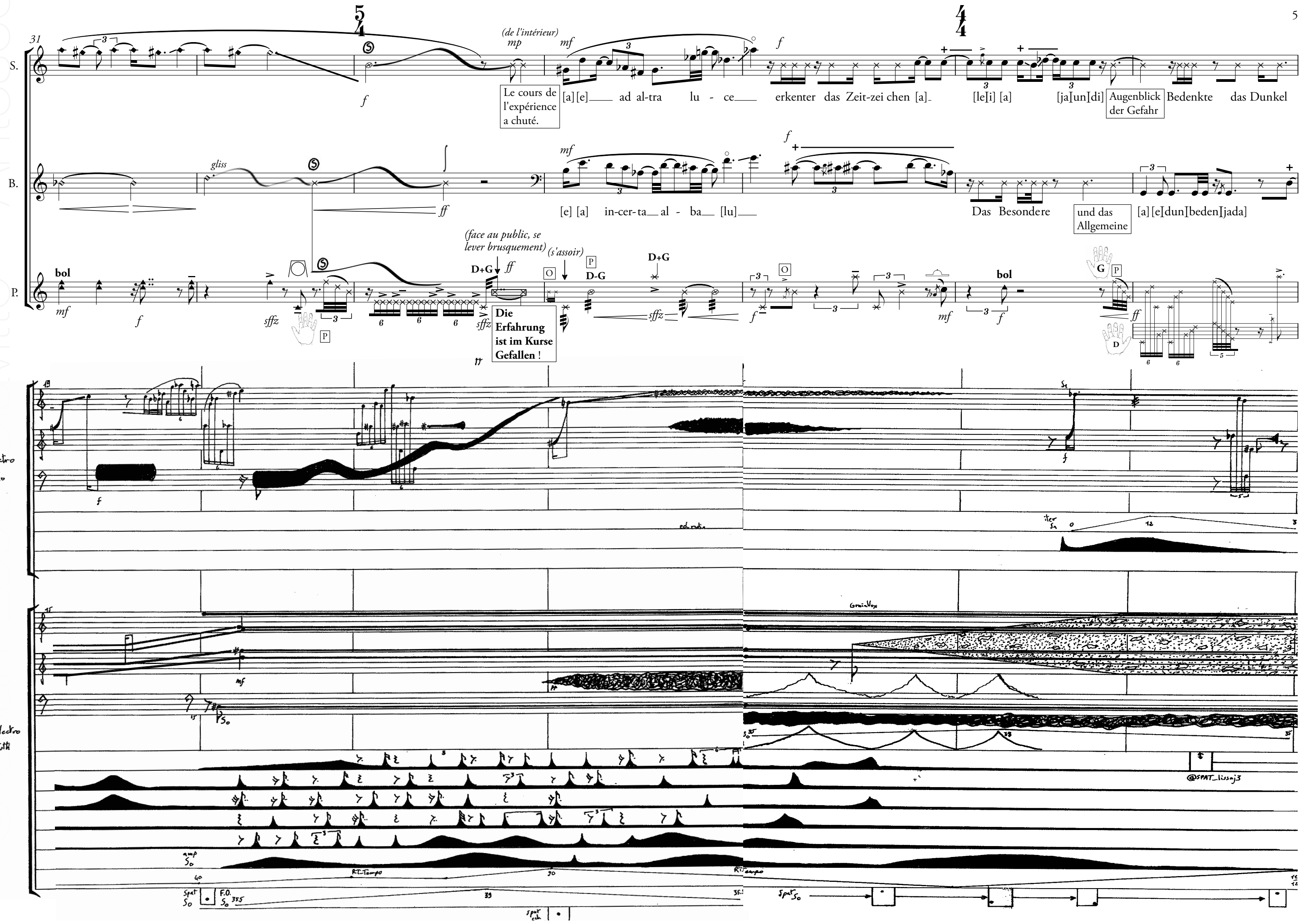

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times in Antescofo

TIME-TIME DIAGRAM

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Time-time diagrams

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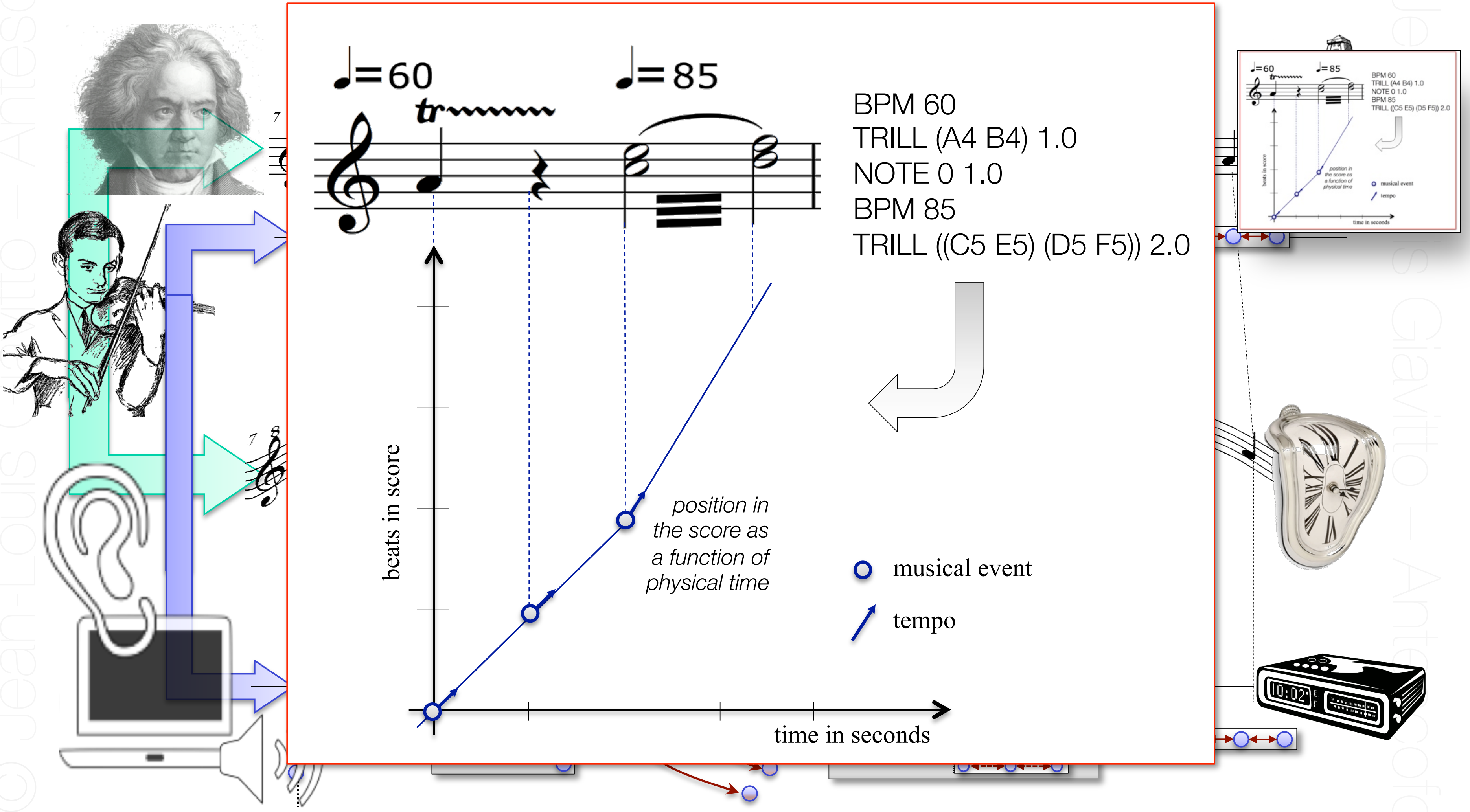

```
BPM 60
TRILL (A4 B4) 1.0
NOTE 0 1.0
BPM 85
TRILL ((C5 E5) (D5 F5)) 2.0
```

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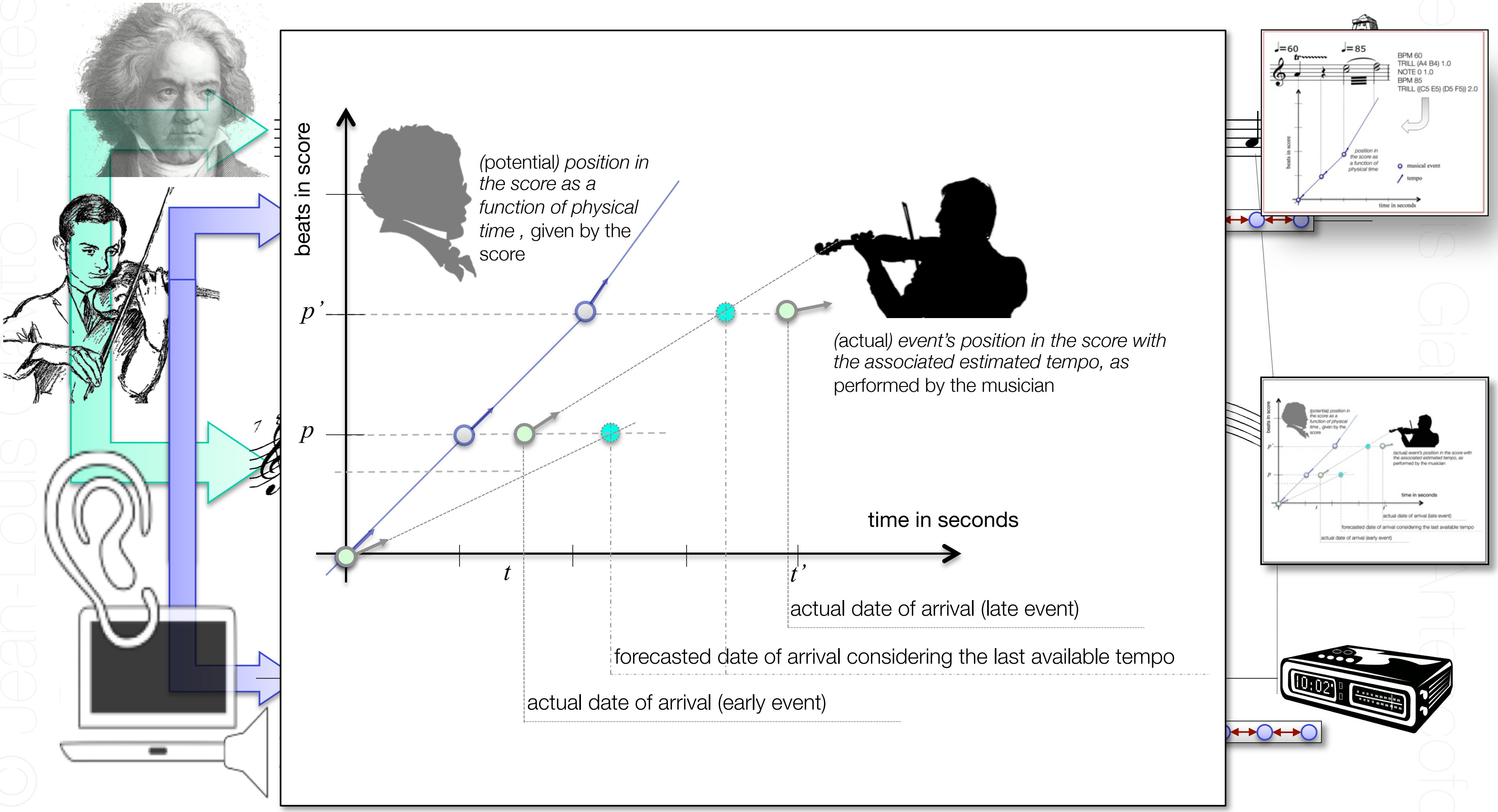
Time-time diagrams



(potential) *position in the score as a function of physical time* , given by the score

(actual) *event's position in the score with the associated estimated tempo, as* performed by the musician

actual date of arrival (late event)

forecasted date of arrival considering the last available tempo

actual date of arrival (early event)

```
BPM 60
TRILL (A4 B4) 1.0
NOTE 0 1.0
BPM 85
TRILL ((C5 E5) (D5 F5)) 2.0
```

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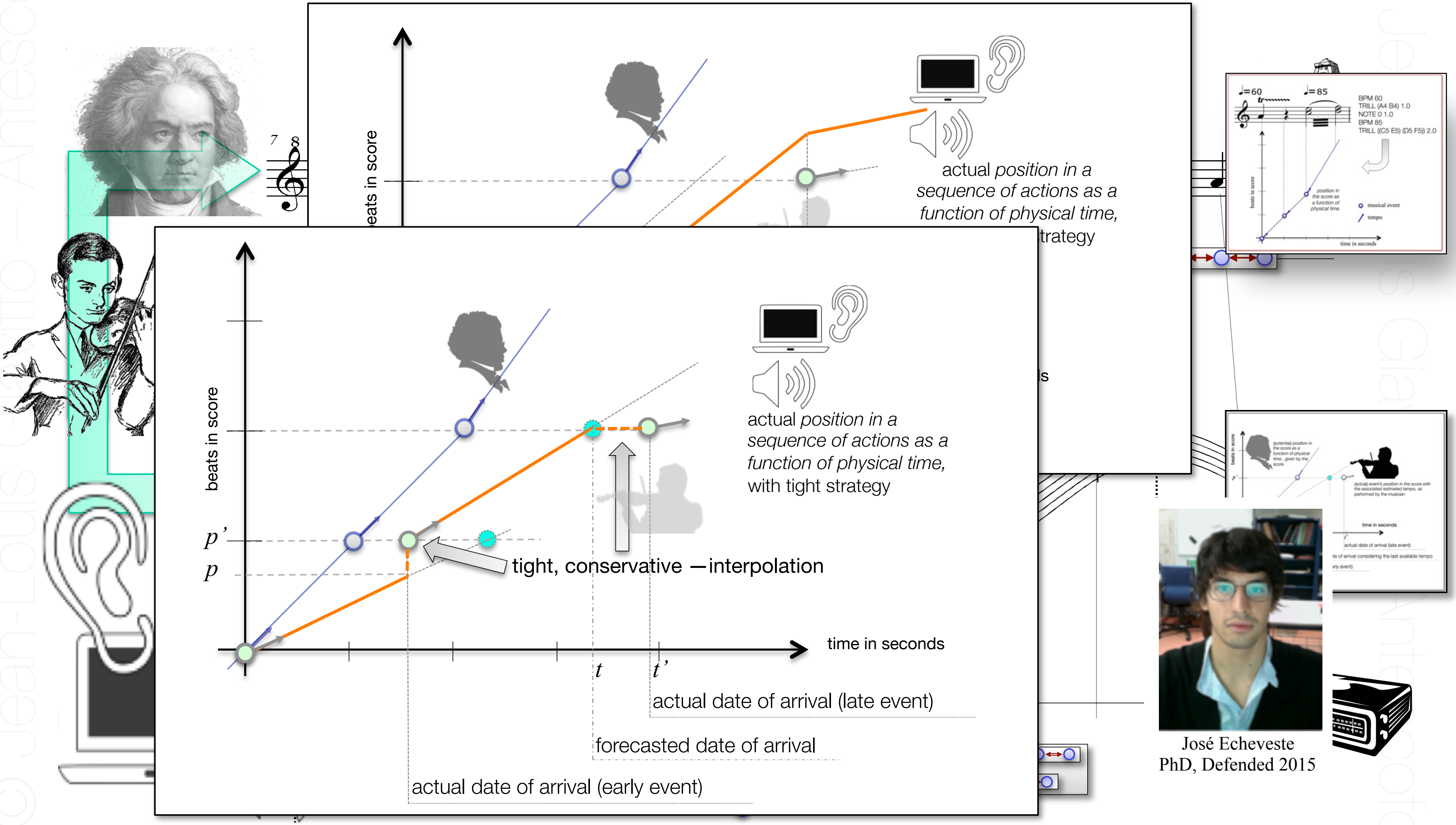
Time-time diagrams



José Echeveste
PhD, Defended 2015

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aligning (*aka* synchronizing) timelines

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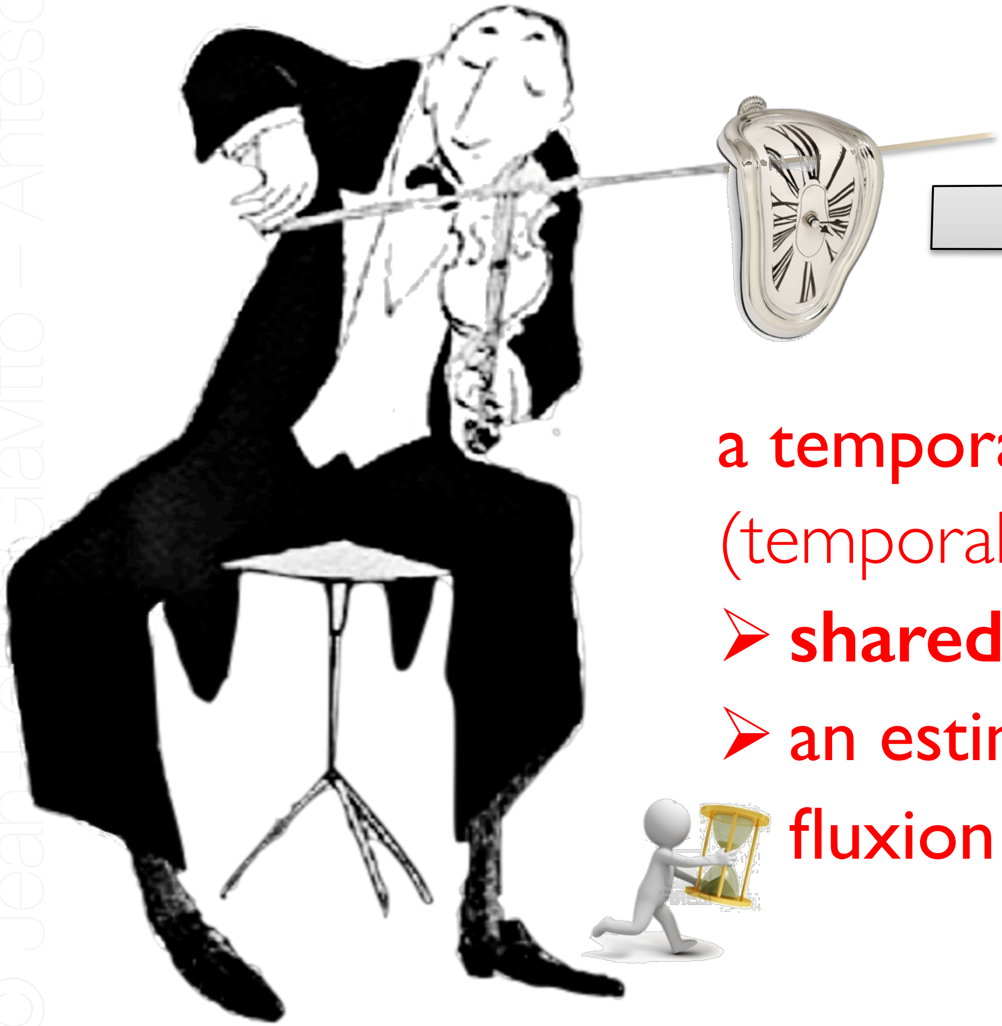

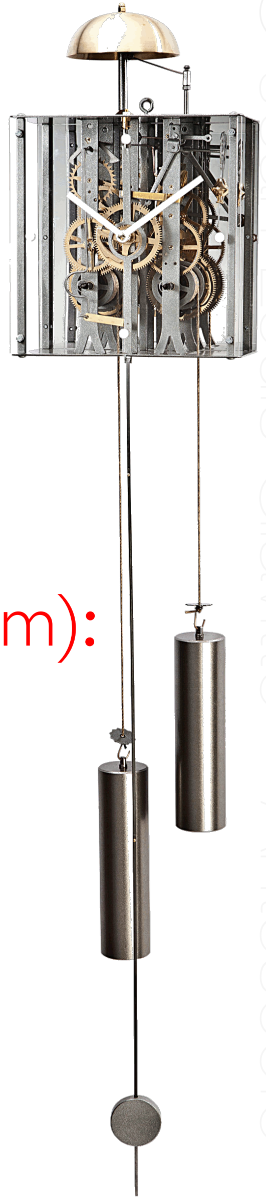

a temporal scope

(temporal coordinate system):

- **shared events**
- an estimation of the fluxion of time (**tempo**)

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times in Antescofo

TEMPO EXTRACTION

(Large’s algorithm)

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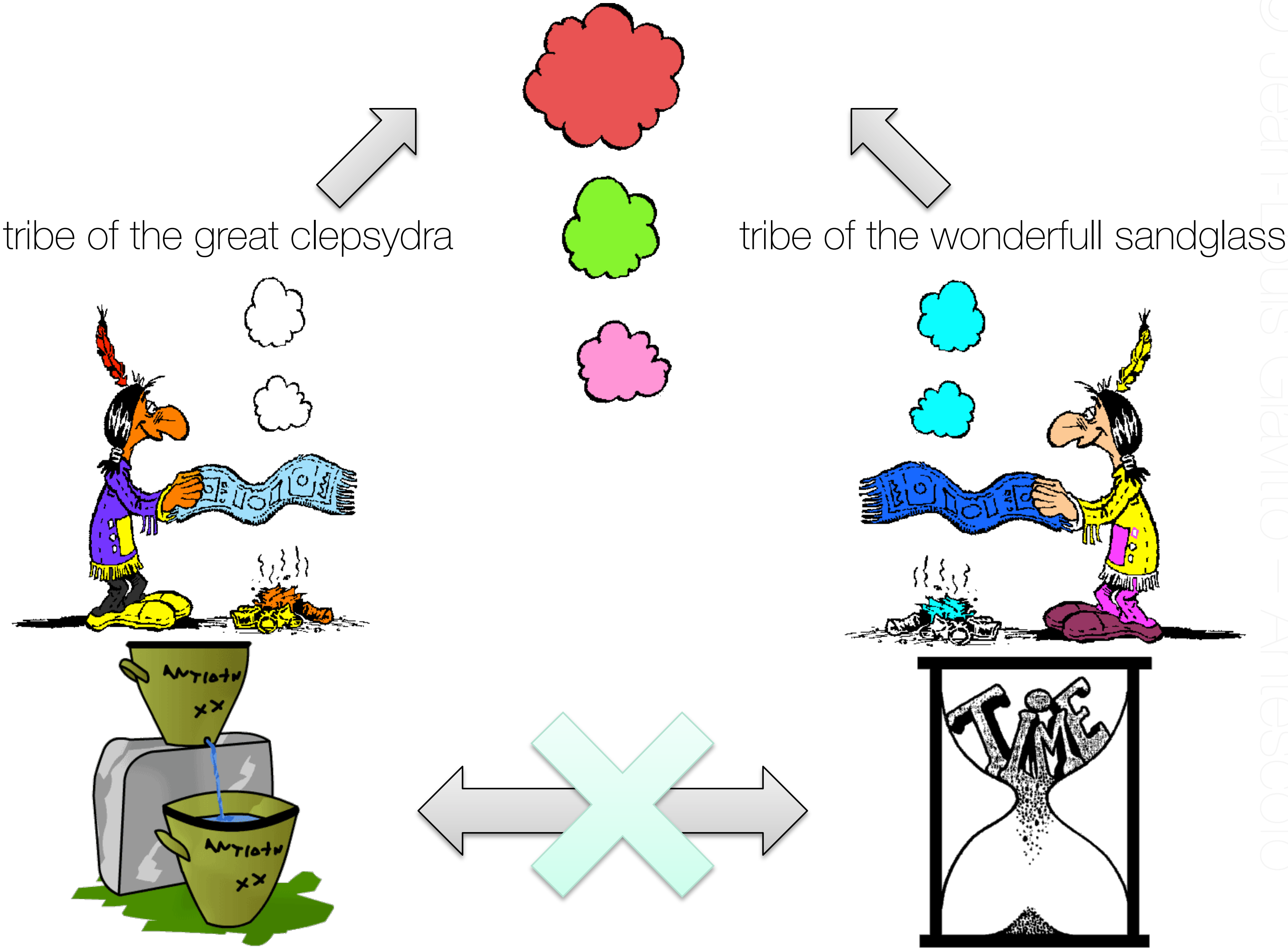
Building a shared time



tribe of the great clepsydra

tribe of the wonderfull sandglass

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Building a shared time

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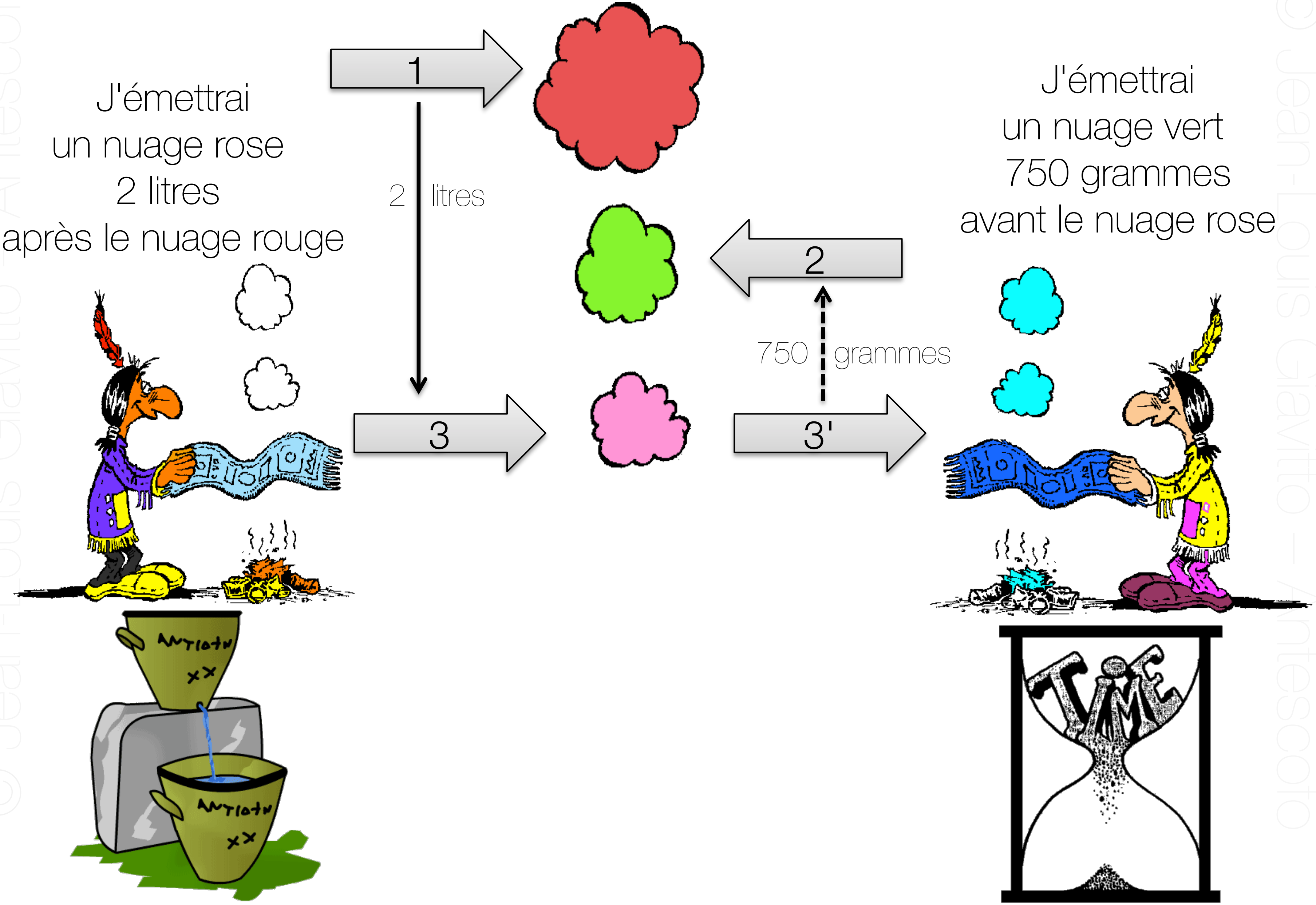

J'émettrai
un nuage rose
2 litres
après le nuage rouge

J'émettrai
un nuage vert
750 grammes
avant le nuage rose

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Building a shared time

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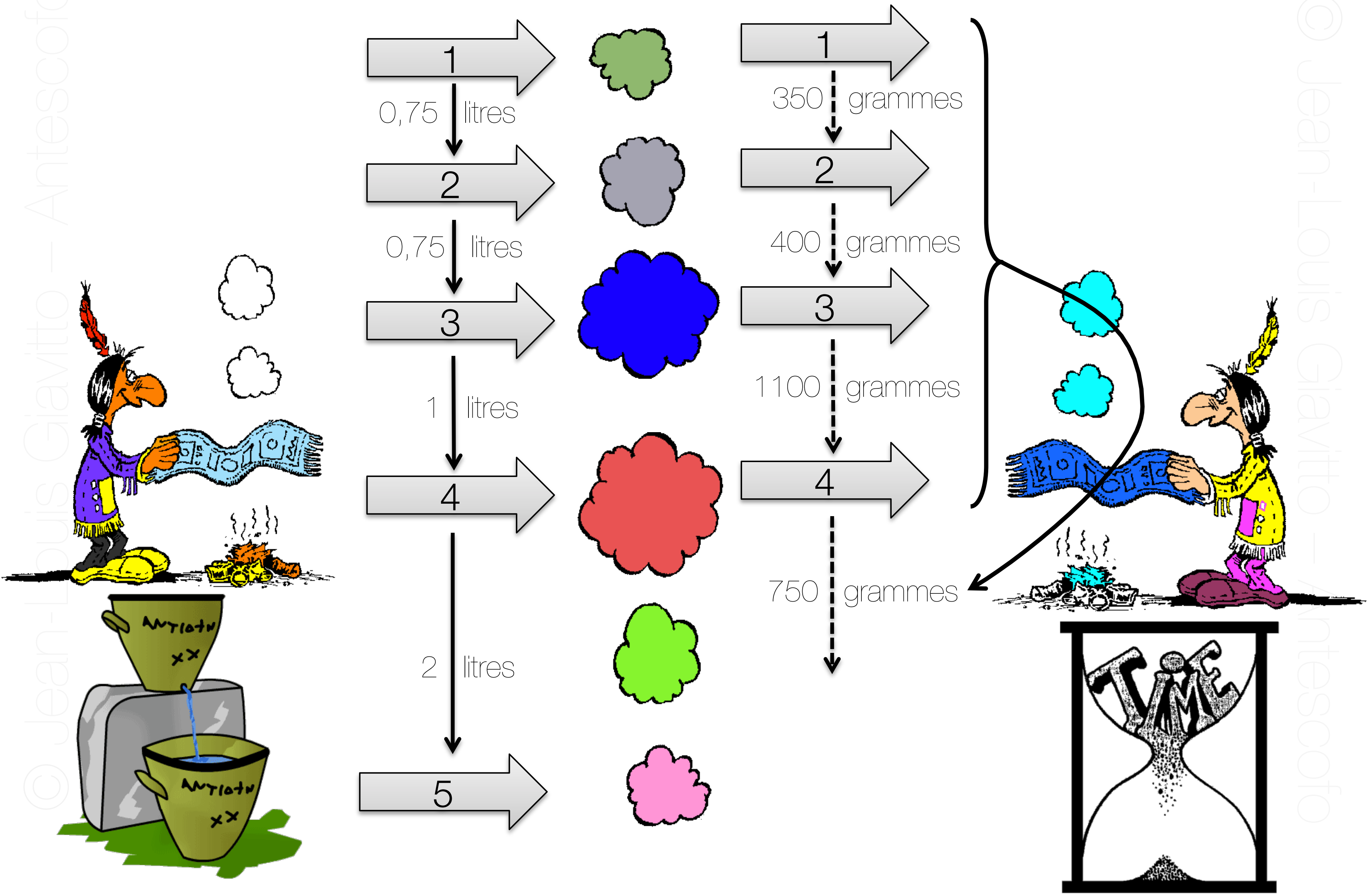

1
0,75 litres
2
0,75 litres
3
1 litres
4
2 litres
5

1
350 grammes
2
400 grammes
3
1100 grammes
4
750 grammes

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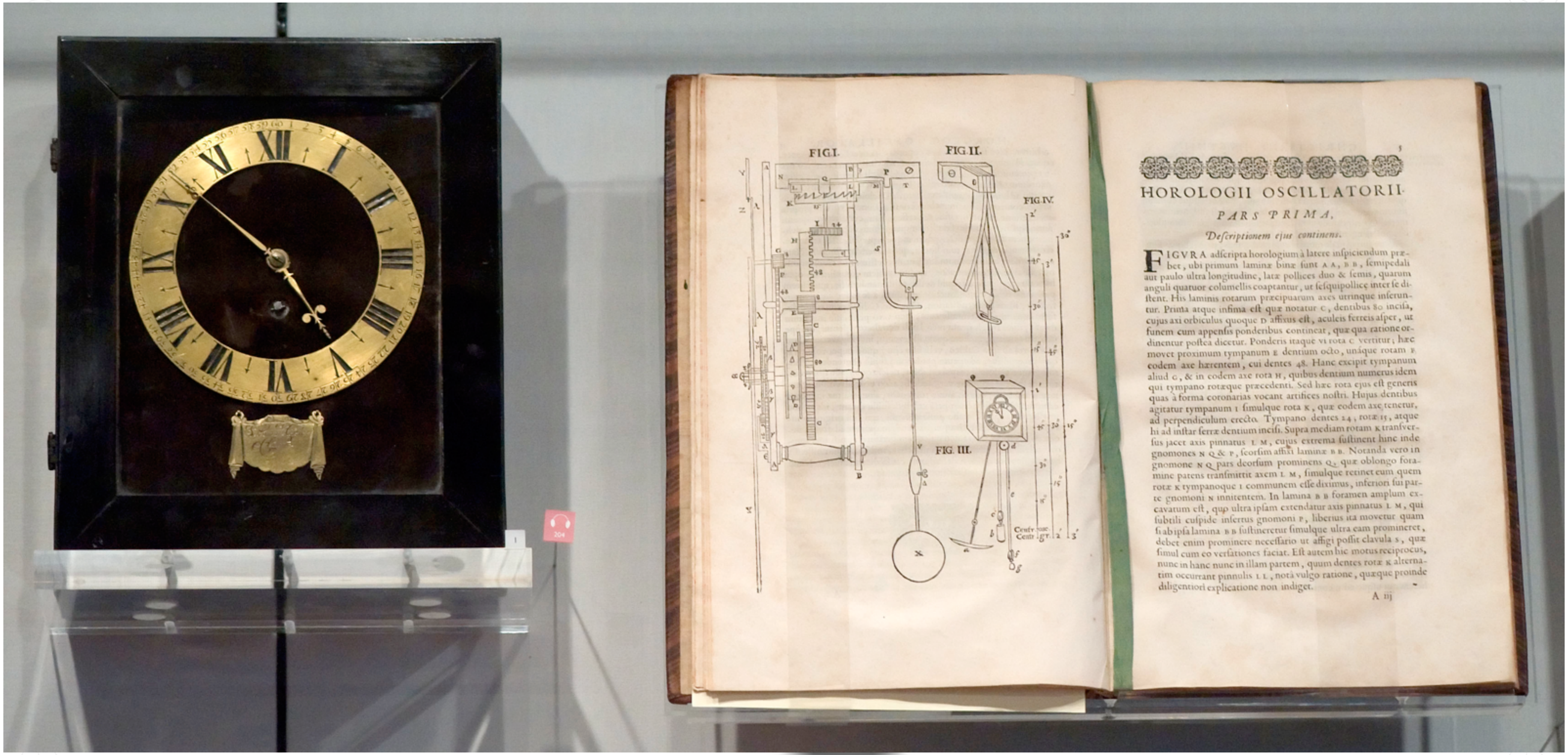
Tempo inference and odd sympathy



5

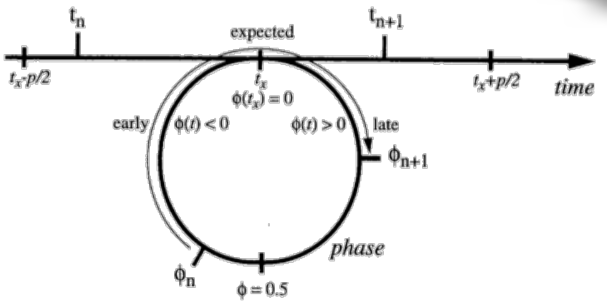
HOROLOGII OSCILLATORII.

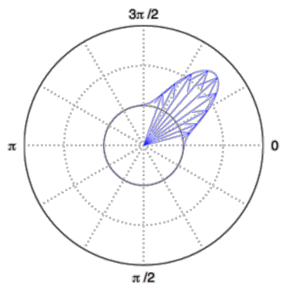
PARS PRIMA,

Deſcriptionem ejus continens.

FIGVRA adſcripta horologium à latere inſpiciendum præbet, ubi primum laminæ binæ ſunt A A, B B, ſemipedali aut paulo ultra longitudine, latæ pollices duo & ſemis, quarum anguli quatuor columellis coaptantur, ut ſeſquipollice inter ſe diſtent. His laminis rotarum præcipuarum axes utrinque inſeruntur. Prima atque infima eſt quæ notatur C, dentibus 80 inciſa, cujus axi orbiculus quoque D affixus eſt, aculeis ferreis aſper, ut funem cum appenſis ponderibus contineat, quæ qua ratione ordinentur poſtea dicetur. Ponderis itaque vi rota C vertitur; hæc movet proximum tympanum E dentium octo, unáque rotam F eodem axe hærentem, cui dentes 48. Hanc excipit tympanum aliud G, & in eodem axe rota H, quibus dentium numerus idem qui tympano rotæque præcedenti. Sed hæc rota ejus eſt generis quas à forma coronarias vocant artifices noſtri. Hujus dentibus agitatur tympanum I ſimulque rota K, quæ eodem axe tenetur, ad perpendiculum erecto. Tympano dentes 24, rotæ 15, atque hi ad inſtar ferræ dentium inciſi. Supra mediam rotam K tranſverſus jacet axis pinnatus L M, cujus extrema ſuſtinent hinc inde gnomones N Q & P, ſeorſim affixi laminæ B B. Notanda vero in gnomone N Q pars deorſum prominens Q, quæ oblongo foramine patens tranſmittit axem L M, ſimulque retinet eum quem rotæ K tympanoque I communem eſſe diximus, inferiori ſui parte gnomoni N innitentem. In lamina B B foramen amplum excavatum eſt, quo ultra ipſam extendatur axis pinnatus L M, qui ſubtili cuſpide inſertus gnomoni P, liberius ita movetur quam ſi ab ipſa lamina B B ſuſtineretur ſimulque ultra eam prominerer, debet enim prominere neceſſario ut affigi poſſit clavula S, quæ ſimul cum eo verſationes faciat. Eſt autem hic motus reciprocus, nunc in hanc nunc in illam partem, quum dentes rotæ K alternatim occurrant pinnulis L L, notâ vulgo ratione, quæque proinde diligentiori explicatione non indiget.

A iij





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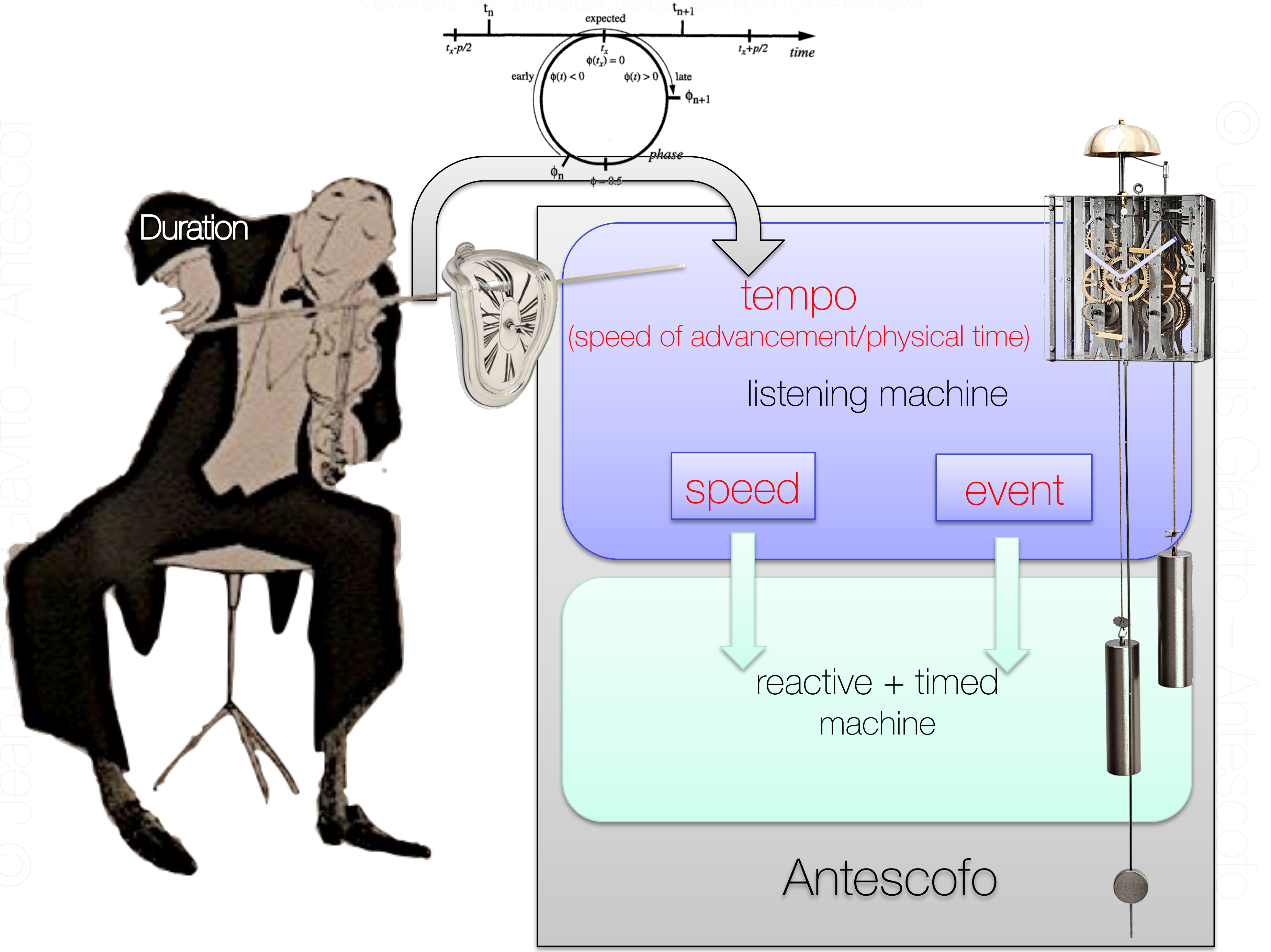

Duration

tempo

(speed of advancement/physical time)

listening machine

speed

event

reactive + timed machine

Antescofo

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times in Antescofo

TEMPORAL SCOPE IN ANTESCOFO

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Temporal objects and relationships handled in Antescofo

- Instant
  synchrony hypothesis = atomic computations are instantaneous
- Duration
  delay, period, sample
- Different ways of denoting time
  - event/ chronometric
  - absolute / relative
  - continuous / discrete
  - controle / audio
- Various scales
  - audio (1/44 ms)
  - control (2 ms -> 1 h)
  - human perception of sound simultaneity ~ 20ms

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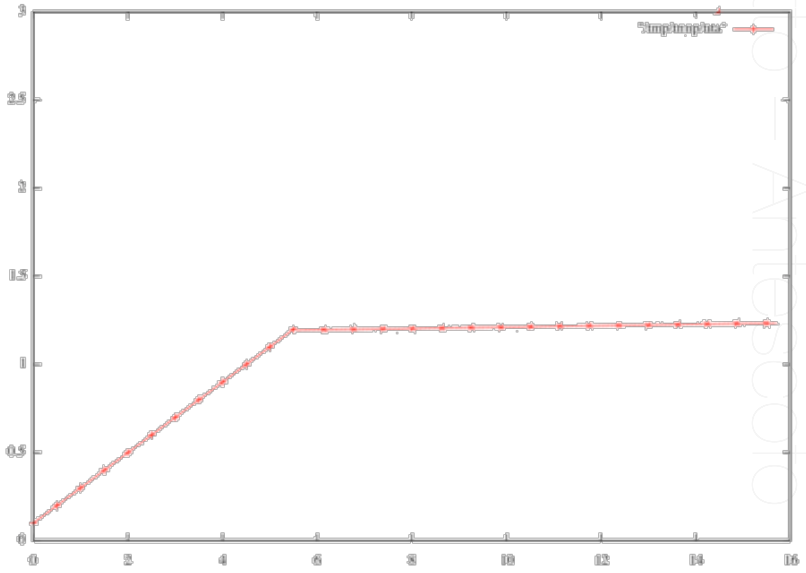
Strongly timed

- **event-driven system**
  - events from the listening machine
  - logical events
    - predicates on variables
    - begining or end of a computation (continuation)
  - introspective events
- **time-driven: computing with duration**
  - delay
  - continuous actions
  - relative time (dynamic) tempo
  - synchronization: tempo + event
- **time-controled concurrency**
  - all actions are *in parallel*
  - **no** lock/mutex/threads…



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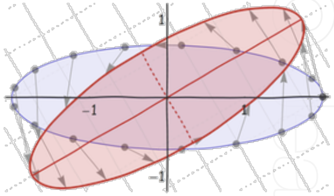
Strongly timed



- time transformations are for Antescofo
  what changes of coordinates are for postscript…
- BUT
  - time is only spent in real-time
  - time is causal
    (I don't know the transformation in the future)
  - the transformation comes from the environment
    (synchronization)
  - transformations are not necessarily *newtonian*
    (when human is in-the-loop position $\neq \int$ tempo)

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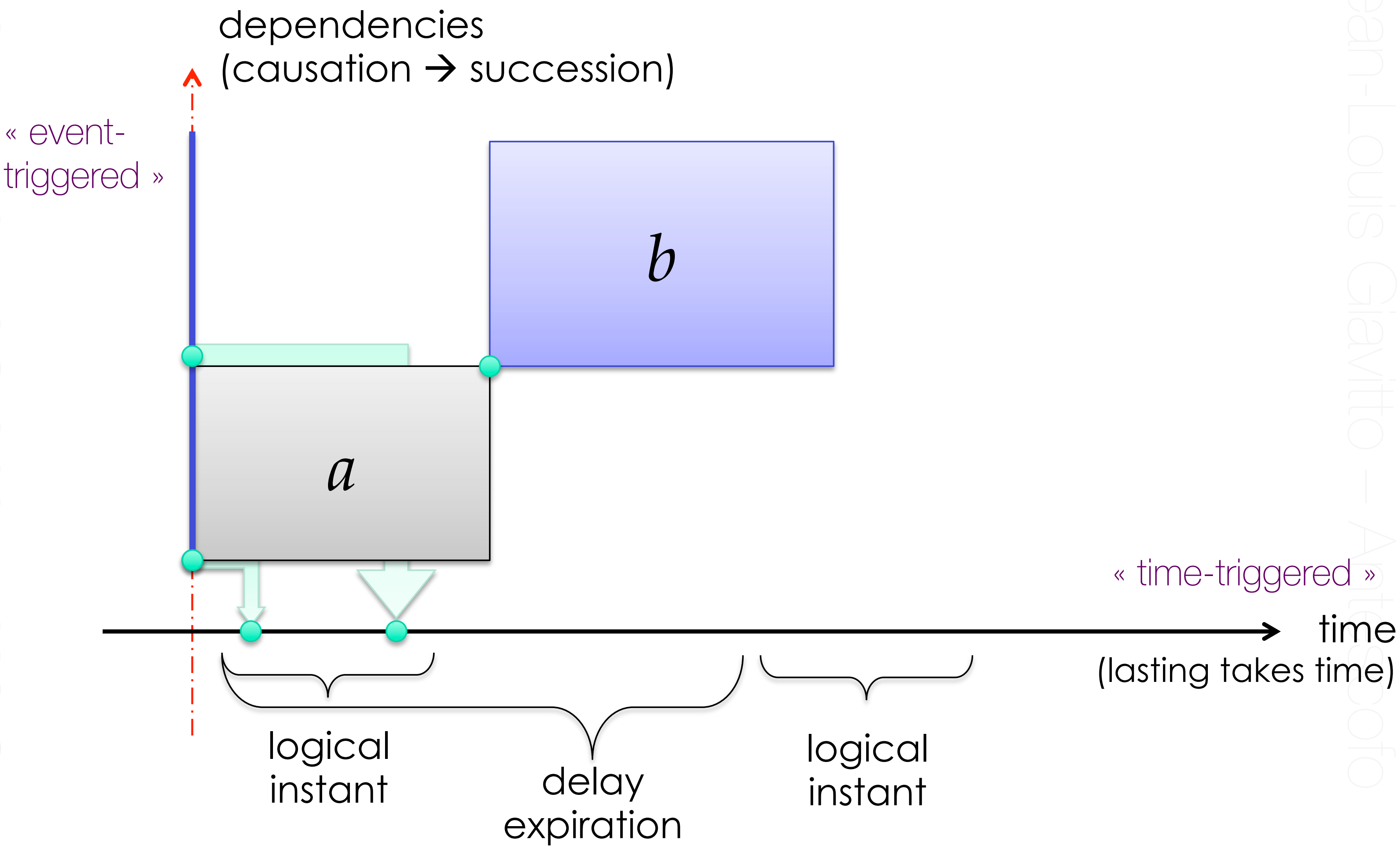
The passing of time: causality & duration



dependencies
(causation → succession)

« event-triggered »

« time-triggered »

time
(lasting takes time)

logical instant

delay expiration

logical instant

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Temporal Scope

- each sequence of actions has a temporal scope
- a temporal scope defines *how time passes* with respect to another temporal scope (synchronization)
- the passing of time may takes into account
  - the occurrence of events
  - the tempo of he followed temporal scope (how time passes between events)
  - what to do if the two information disagree
- primitive temporal scopes
  - the musician
  - the physical time (no event, except the beginning of time)
  - any process using tempovar to specify events and tempo

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Tempo inheritance

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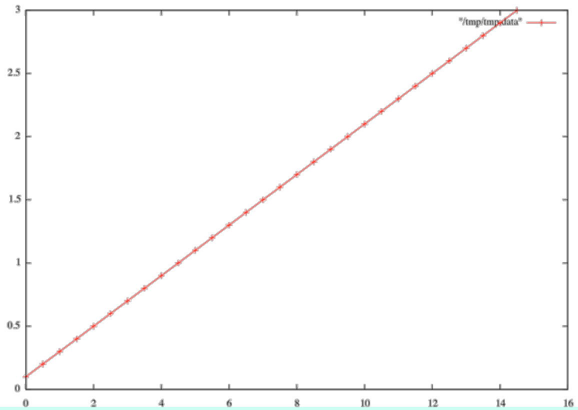
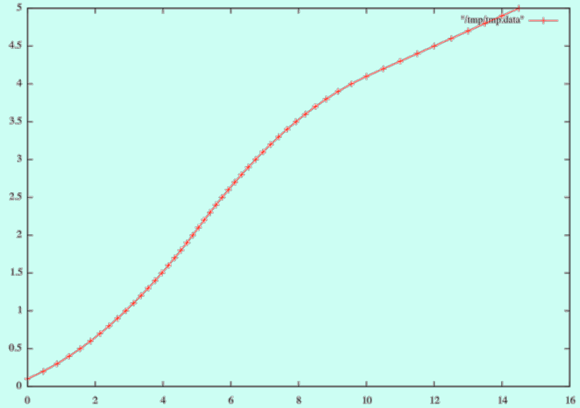
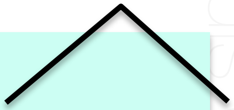


```
@proc_def ::Trace()  {
          @local $x
          $x := 0
          Loop L 0.1 {
                    $x := $x + 0.1
                    plot $NOW " " $x "\n"
          }
}
$trace1 := ::Trace()
```

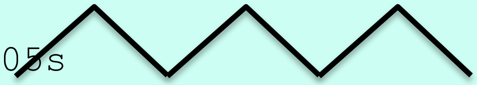


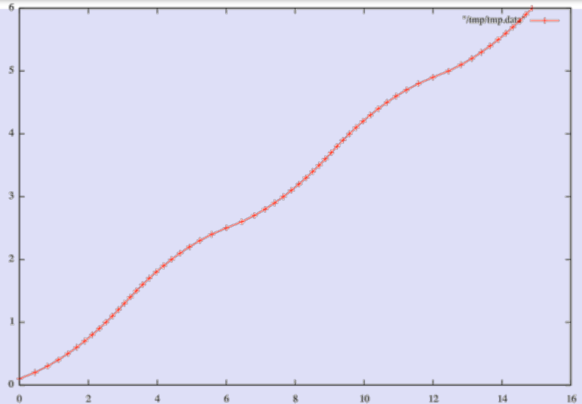


```
Curve C1 @grain 0.05s
{  $t1 { {60} 5 {180} 5 {60} } }

Group G1 @tempo := $t1
{
          $trace2 := ::Trace()

          Curve C2 @grain 0.05s
          { $t2 {  {60} 3 {180} 3 {60} 3 {180}
            }      {60} 3 {180} 3 {60} }
     }
```





```
          Group G3 @tempo := $t2
          {
                    $trace3 := ::Trace()
          }
}
```

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Striated time and smooth time

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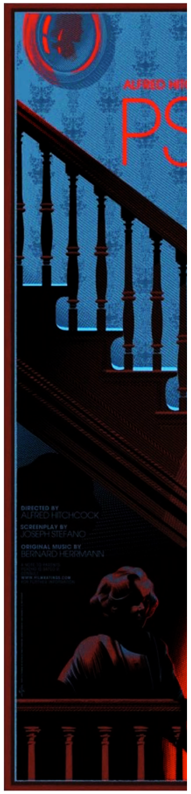
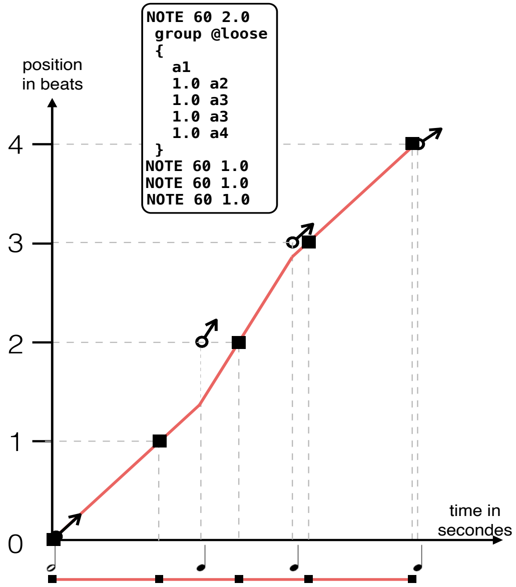
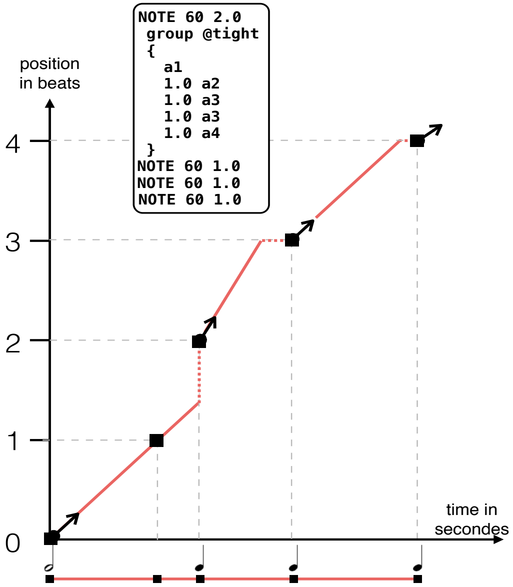
Bernard Herr



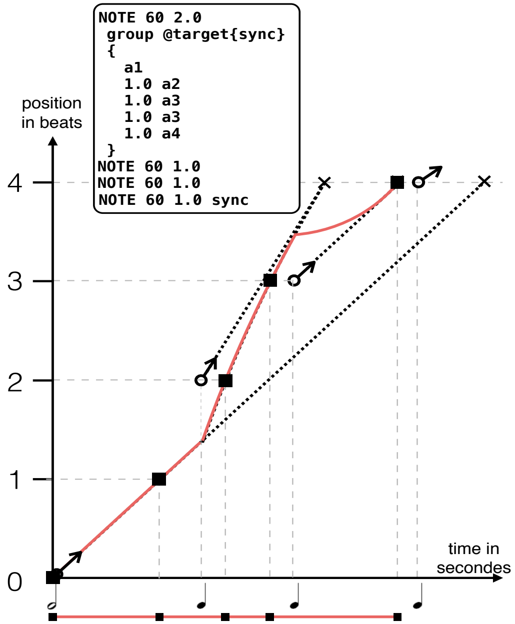


```
NOTE 60 2.0
 group @loose
 {
   a1
   1.0 a2
   1.0 a3
   1.0 a3
   1.0 a4
 }
NOTE 60 1.0
NOTE 60 1.0
NOTE 60 1.0
```

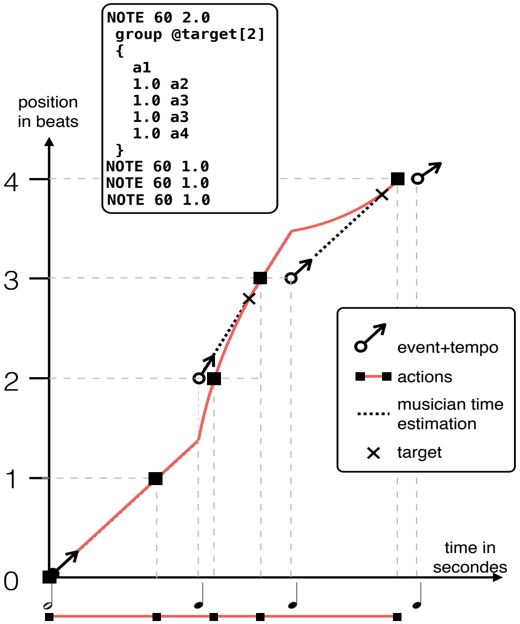


```
NOTE 60 2.0
 group @tight
 {
   a1
   1.0 a2
   1.0 a3
   1.0 a3
   1.0 a4
 }
NOTE 60 1.0
NOTE 60 1.0
NOTE 60 1.0
```

ano (1967)



```
NOTE 60 2.0
 group @target{sync}
 {
   a1
   1.0 a2
   1.0 a3
   1.0 a3
   1.0 a4
 }
NOTE 60 1.0
NOTE 60 1.0
NOTE 60 1.0 sync
```



```
NOTE 60 2.0
 group @target[2]
 {
   a1
   1.0 a2
   1.0 a3
   1.0 a3
   1.0 a4
 }
NOTE 60 1.0
NOTE 60 1.0
NOTE 60 1.0
```

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Dynamic Target

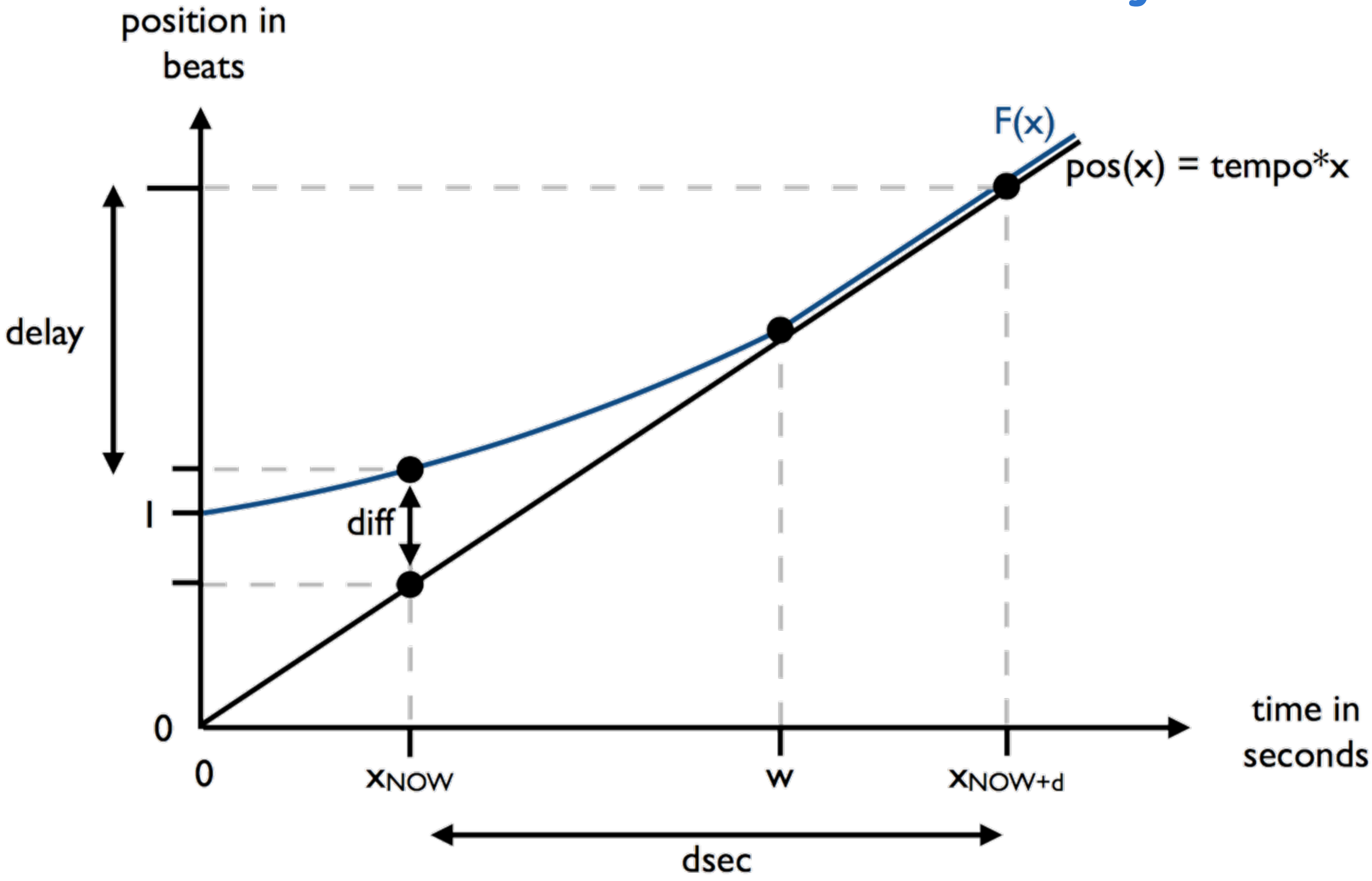

Fig. 10. Method used to compute a duration *dsec* in seconds corresponding to a delay *delay* in beats with a dynamic target $[w]$ and with a initial difference of position $diff = \tau.beatPos - position$. Function F represents the position in τ as a function of time x. It is made of two parts: a part G where the $\tau.tempo$ changes linearly until it becomes equal to *tempo*. From this time, F evolve as *pos*, with $\tau.tempo = tempo$ (a constant). Function G is the part of the parabola that goes from $x = 0$ to $x = w$. Because the origin is translated w.r.t. the origin of the physical time, the date x_{NOW} of the current instant is localized on the X axis by looking at the point which achieve the current difference *diff*.

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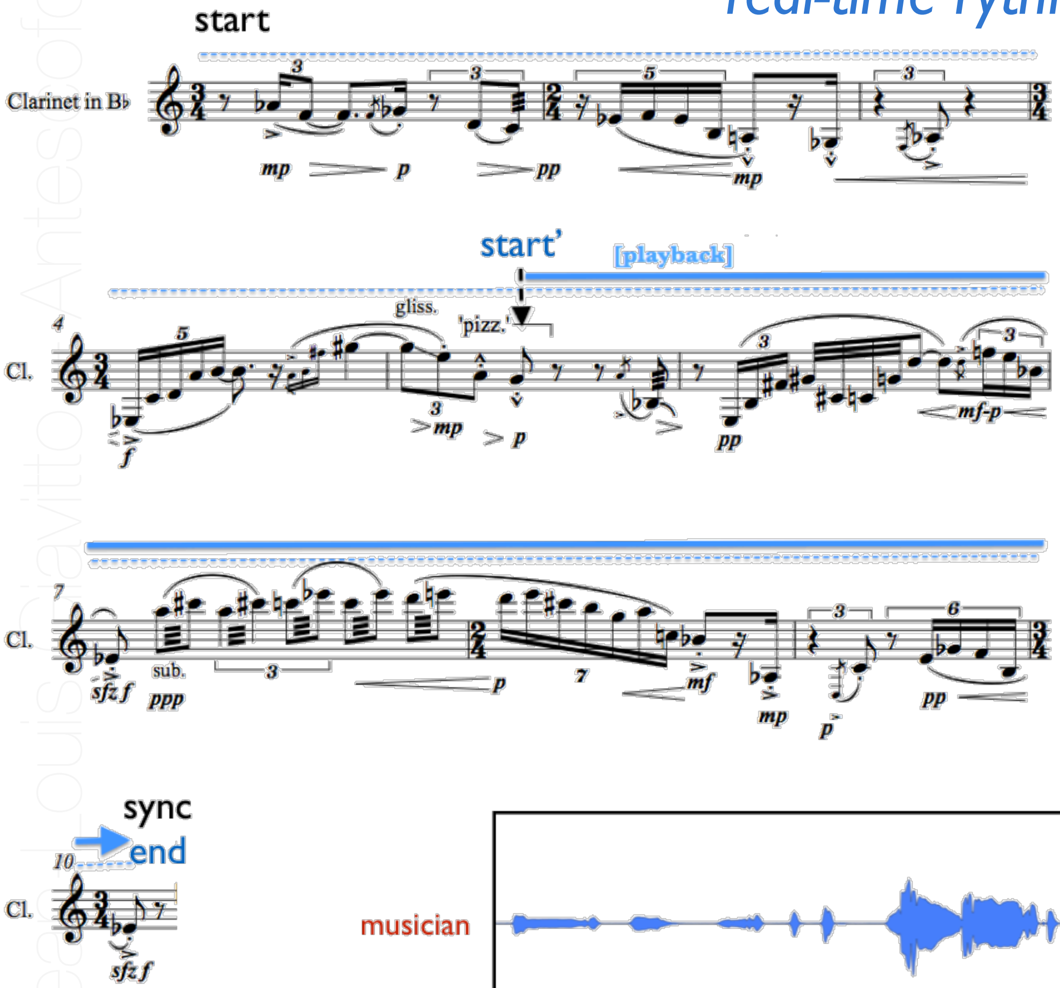
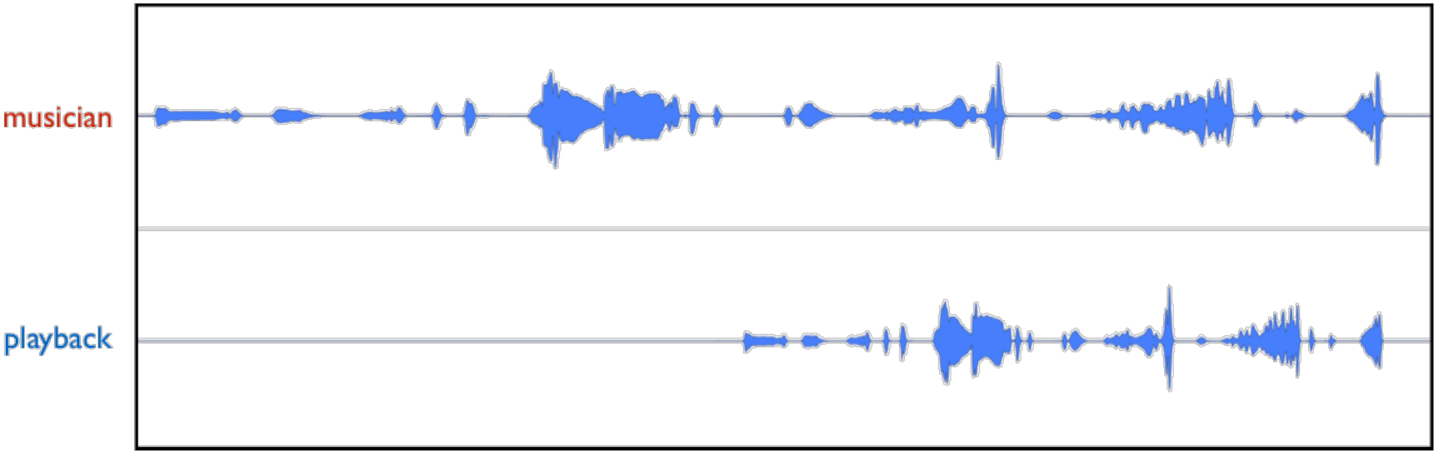
Antescofo tutorial – SMC 2016, Hamburg / Jean-Louis Giavitto, IRCAM – CNRS – INRIA MuTAnt

Christopher Trapani

real-time rythmic canon à la Nancarow





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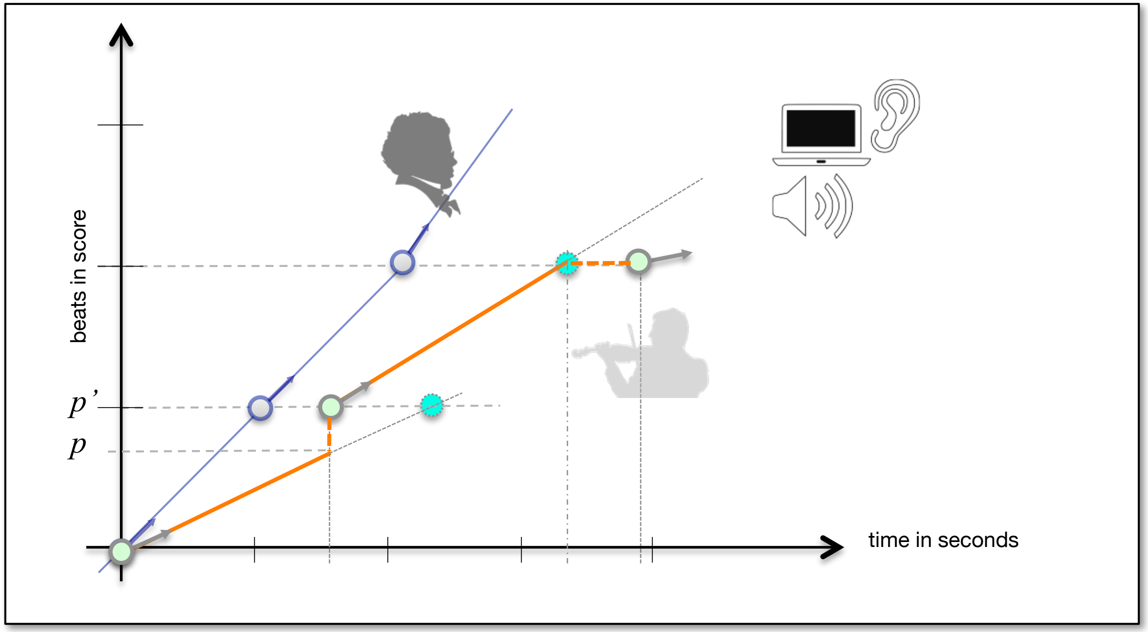

Fungible times

or

incomparable times ?

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One second per second

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Subordination of the objective time to the subjective ones and *not the reverse*!

- shared events are not enough:
  duration is not reductible to instants
  - halving a duration
  - accelerando
  - *phrasé* (ex. rubato)
- the "conversion rate" changes in time and is known "after". The conversion arte is established with the weaving of time itself.
  - A-series et B-series,
  - "out of time of the composition
    versus the real-time of the performance
- Subjective time is useful: the score refers to this subjective time, not to physical time in second
- *In fine*, it enables a effective musical interaction between the performer and the computer

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Some other
Artistic Applications

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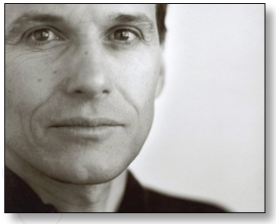


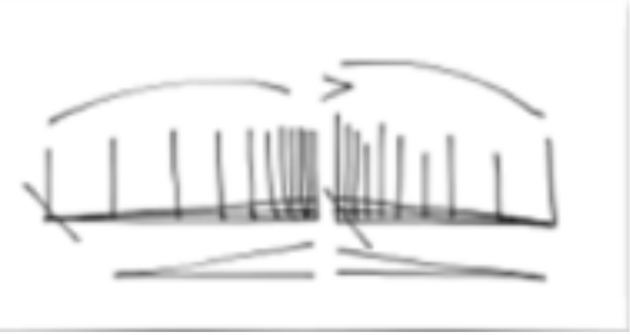
Marco Stroppa
Antescofo library for Totem control

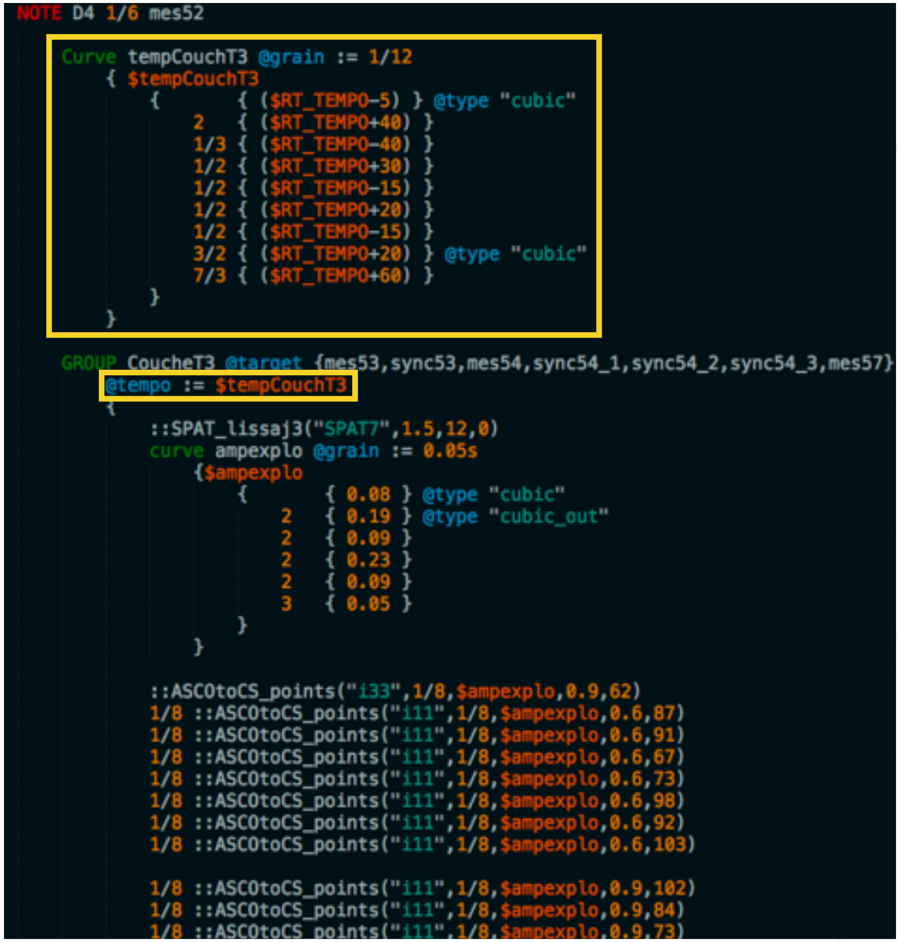
```
; SOURCE Object Definition

@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)) }
            }
        }
    }

    // …
}
```

Marco Stroppa
… of Silence
(2009)

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)
            1/8 ::ASCOtoCS_points("i11",1/8,$ampexplo,0.9,73)
```

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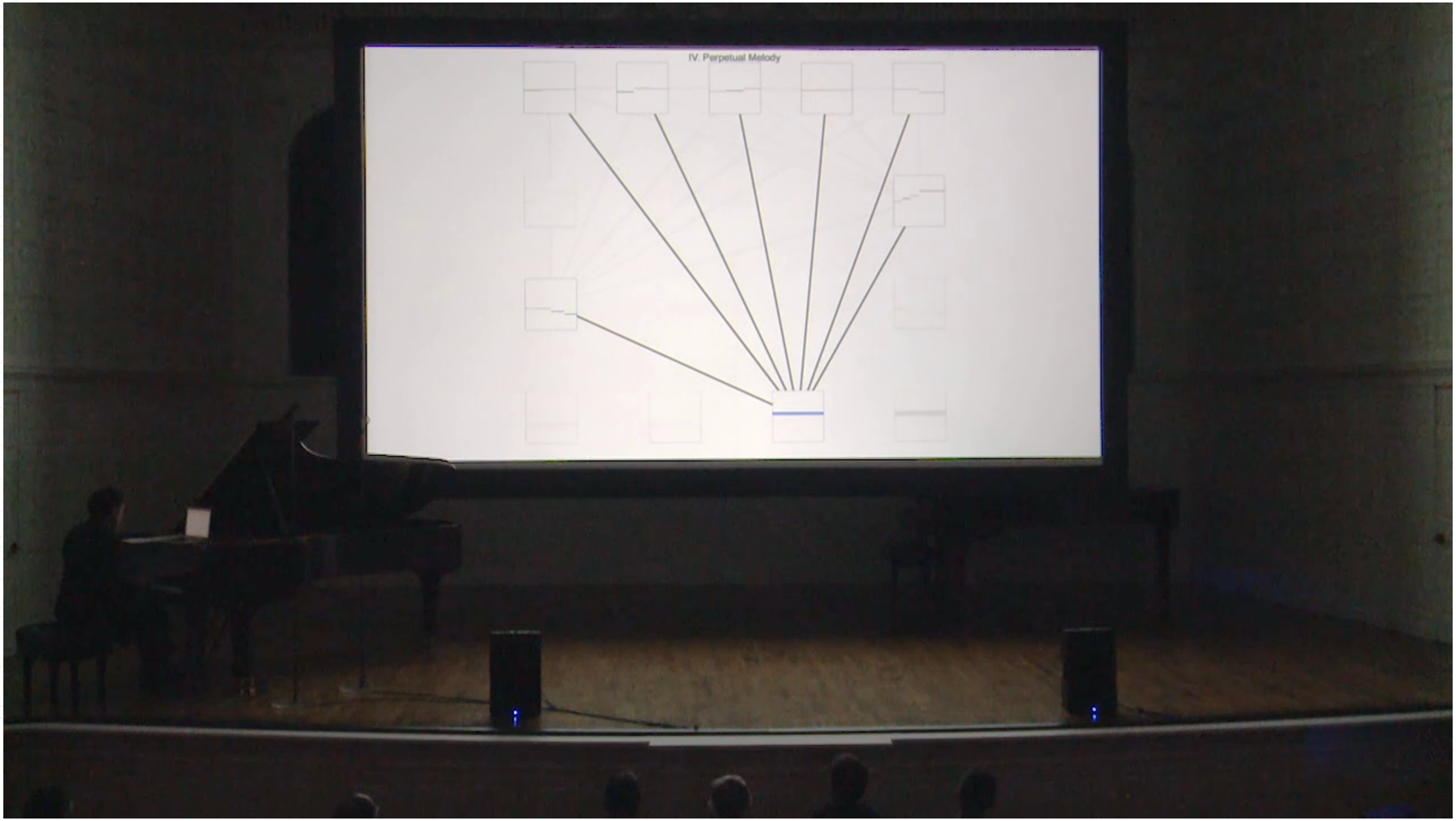
Jason Freeman (GeorgiaTech)

Shadows, 2015 dynamic non-deterministic score

(*excerpt from the score, Jason Freeman*)

The computer tracks the choices you make about which fragments to play and how long you play each one. It always highlights the fragment you are currently playing in blue and draws thick black lines to the fragment(s) you can choose to play next.

During your performance, the computer will vary how many choices it gives you about what to play next, as well as how it determines your options. It bases these decisions on which fragments you have played recently and for how long you have played each. At some points in the performance, the computer will push you towards repeating and alternating between the fragments you have played most often. At other points, it will push you to play fragments you have not played recently. Some aspects of the computer's algorithm, such as how many choices to give you and when to change sections, are updated automatically at predetermined times during your performance.



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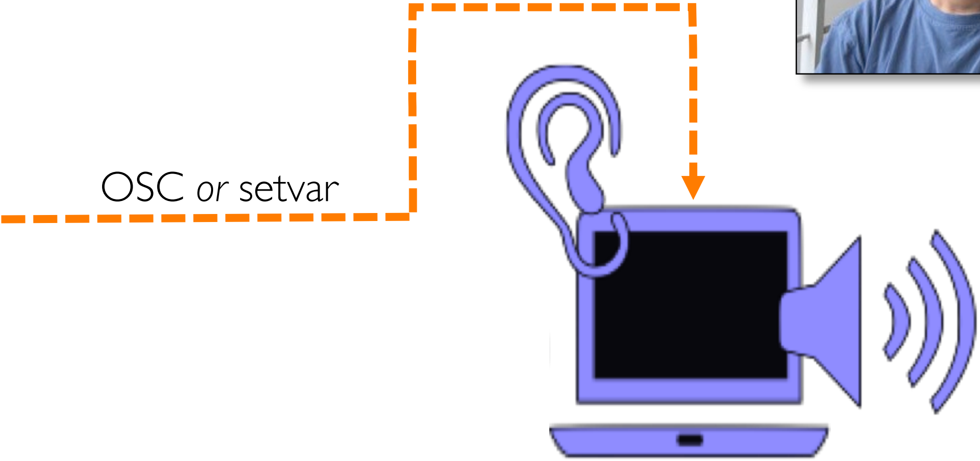
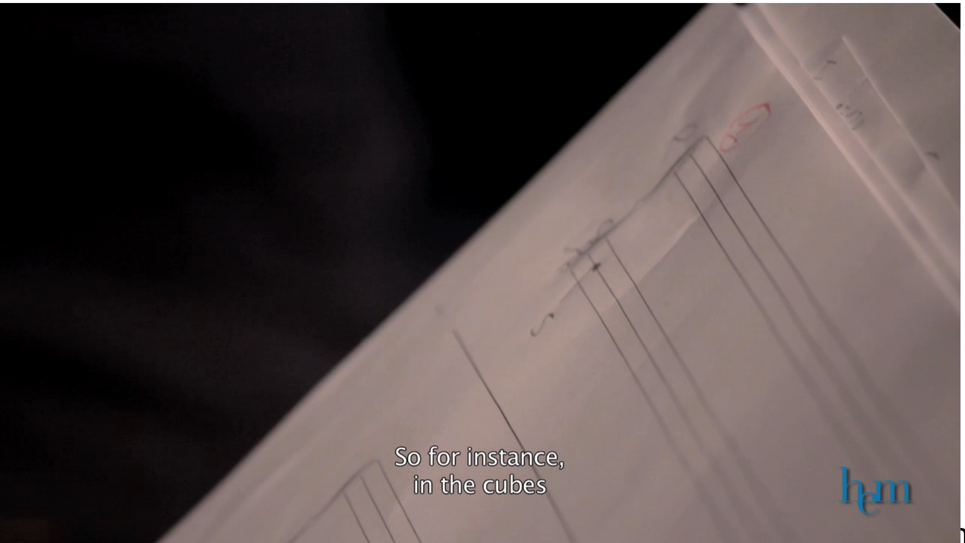
José-Miguel Fernandez
gesture-driven synthesis

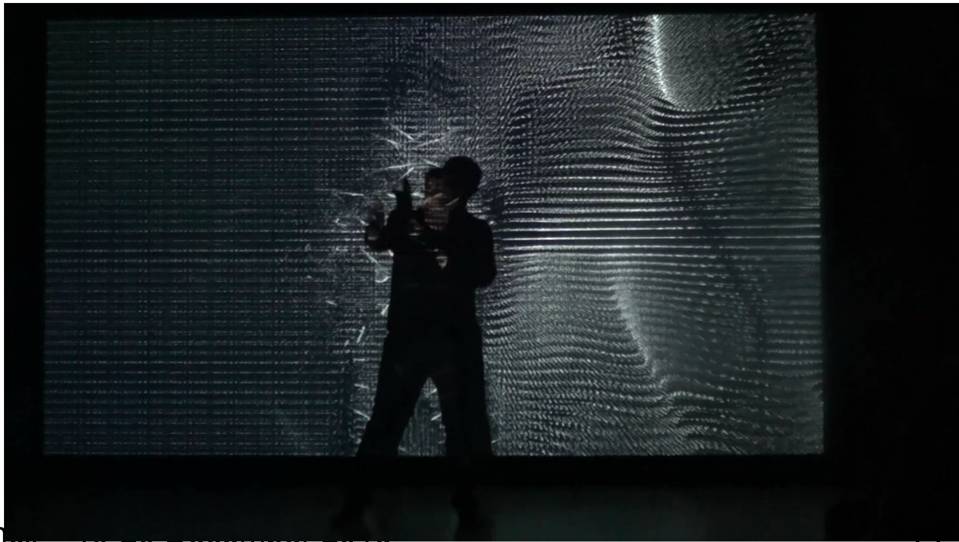


GeKiPe (Gest Kinect Percussion),
Philippe Spiesser (percu),
Alexander Vert (composition),
Jose Miguel Fernandez (RIM)

hem
Haute école de musique
Genève

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





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Future work

- **pedagogy and non-professional application**
- **embeding audio-processing**
  (at ICMC next month)
- **abstraction, compartmentalization, reuse**
- **alternative notations**
  - composer-specifiable syntax
  - idiosyncrasy
  - performance oriented syntax (~James bean)

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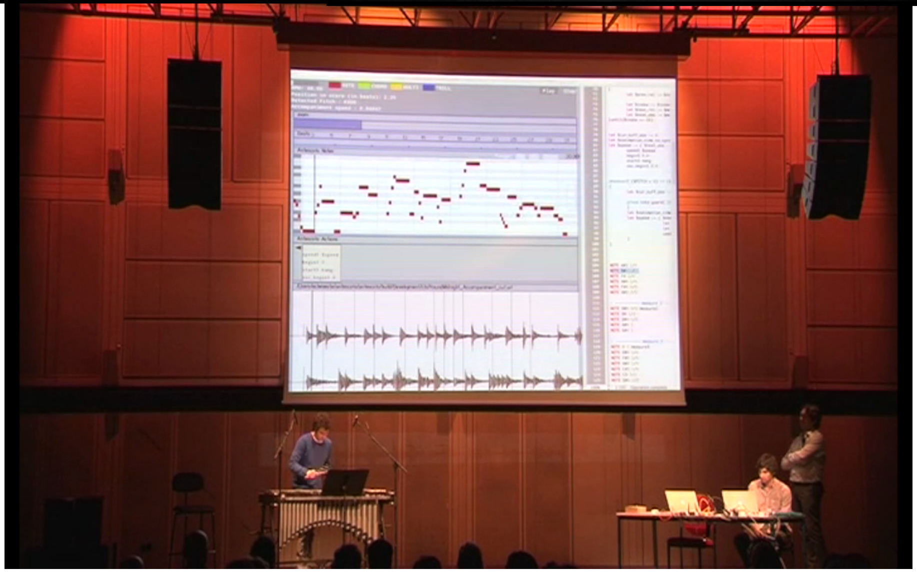
Towards Greater Public



Videos at **http://repmus.ircam.fr/antescofo/videos**

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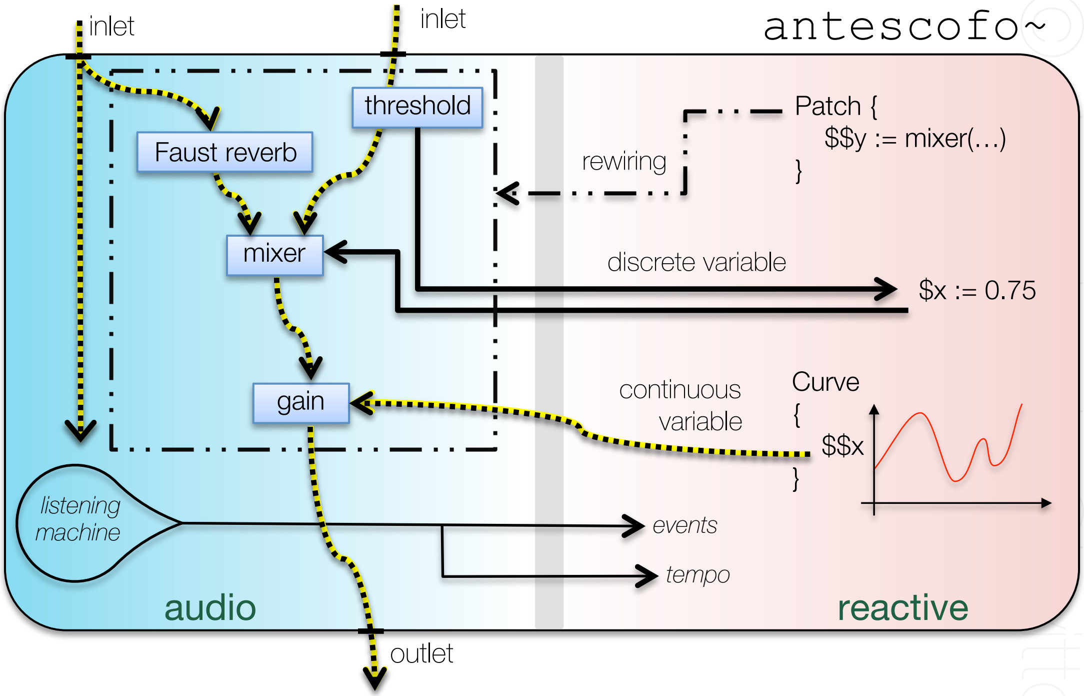
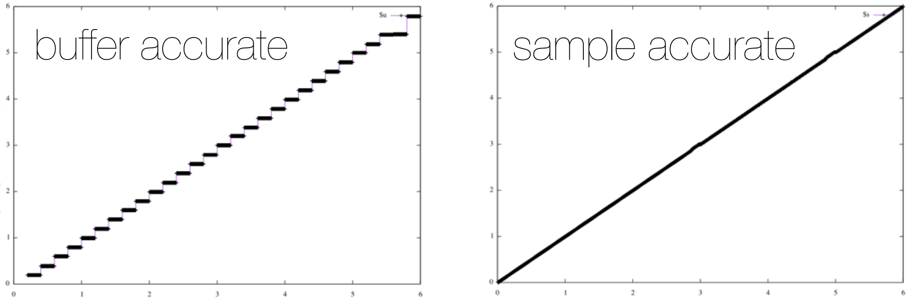
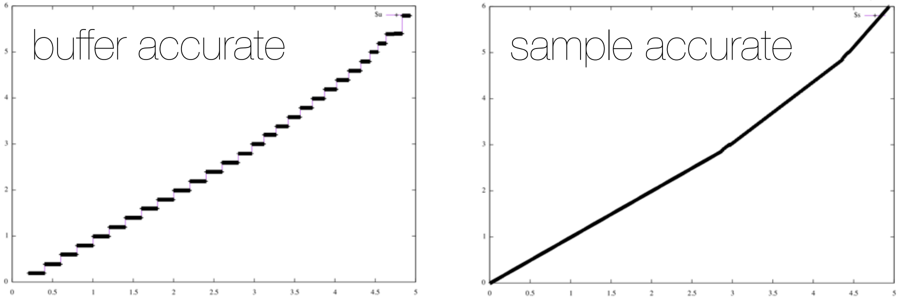
Embedding audio in Antescofo (next month at ICMC)

- audio effects written in FAUST + specifics (FFT)
- 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

Digital preservation of mixed music

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Perspectives

The Augmented Score

- temporal scope as denotable value
- musical gesture
- embedding composer specific languages
- abstraction
- durative *vs* continuous computations

Next Generation of IMS

- offline and online score analysis
- offline and online score scheduling
- real-time score execution at sample accuracy
- extensible-, distributed-architectures for interactive music systems (ex.: VST, RTAS, audio plugins)

Digital Preservation

- compilation

Beyond Music

- cyber-temporal systems: exploring other highly timed interactive scenarios (Robotics, Domotics)
- Programming with Perceptual Concepts
- Other listening machines / sensing devices
- Small embedded systems (Udoo, RasperyPi)

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FINAL REMARKS

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Credits

Arshia Cont

PhD students

J. Blondeau, P. Cuvillier, J. Echeveste, C. Poncelet

Scientific Collaborations

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

Composers (and their assistants !)

P. Manoury, M. Stroppa, J. Freeman, C. Trapani, J.-M. Fernandez, J. Blondeau, G. Nouno, Y. Maresz, O. Neuwirth, L. Morciano, … T. Goepfer, G. Beller, G. Lorieux... and many more

http://www.antescofo.com/

José Echeveste
PhD, Defended 2015

Philippe Cuvillier
(UPMC, Since 2012)

Julia Blondeau
(UPMC, Since 2014)

Clément Poncelet
(DGA/Inria, Since 2012)

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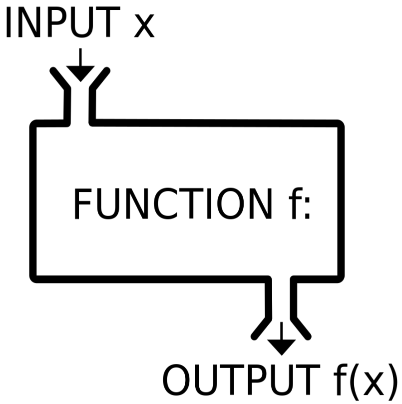
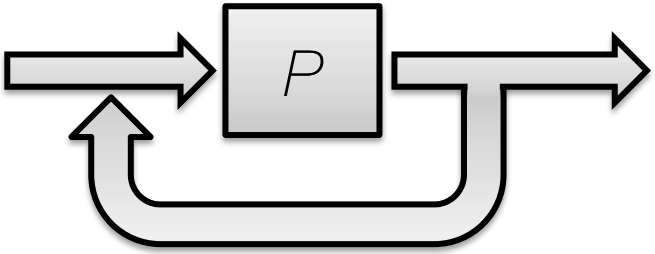
Computation:
function, process, *interaction*





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ALL WATCHED OVER BY MACHINES OF LOVING GRACE

by Richard Brautigan

I like to think (and
the sooner the better!)
of a cybernetic meadow
where mammals and computers
live together in mutually
programming harmony
like pure water
touching clear sky.

I like to think
(right now, please!)
of a cybernetic forest
filled with pines and electronics
where deer stroll peacefully
past computors
as if they were flowers
with spinning blossoms.

I like to think
(it has to be!)
of a cybernetic ecology
where we are free of our labors
and joined back to nature,
returned to our mammal
brothers and sisters,
and all watched over
by machines of loving grace.

communication company

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José Echeveste, Jean-Louis Giavitto,
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