Jean-Louis Giavitto
http://www.repmus.ircam.fr/giavitto

hors-temps & temps-réel
l'écriture informatique du temps et de l'interaction en musique mixte

ircam
Centre Pompidou

cnrs

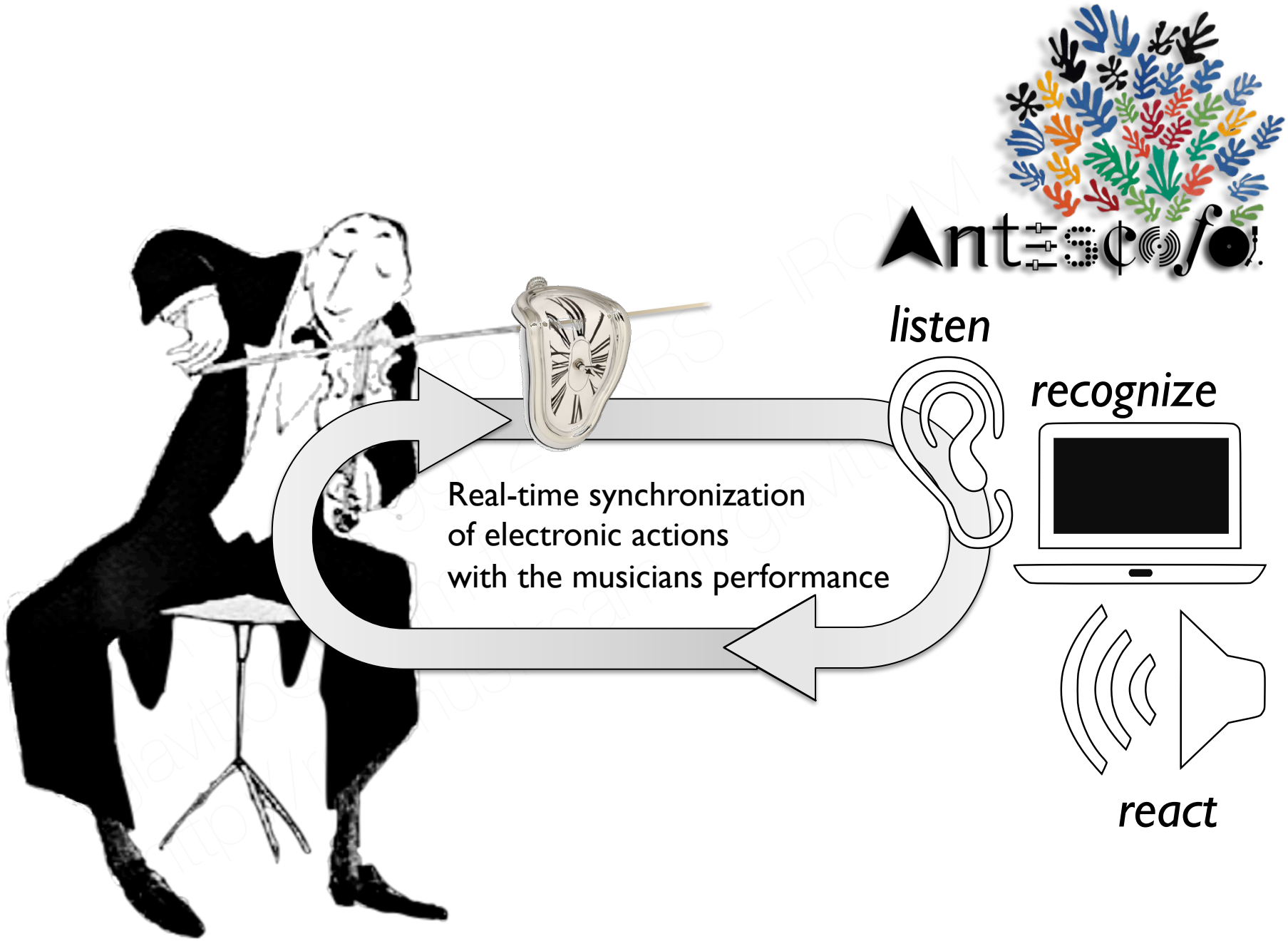
UPMC
PARIS UNIVERSITAS

Un ordinateur peut-il…

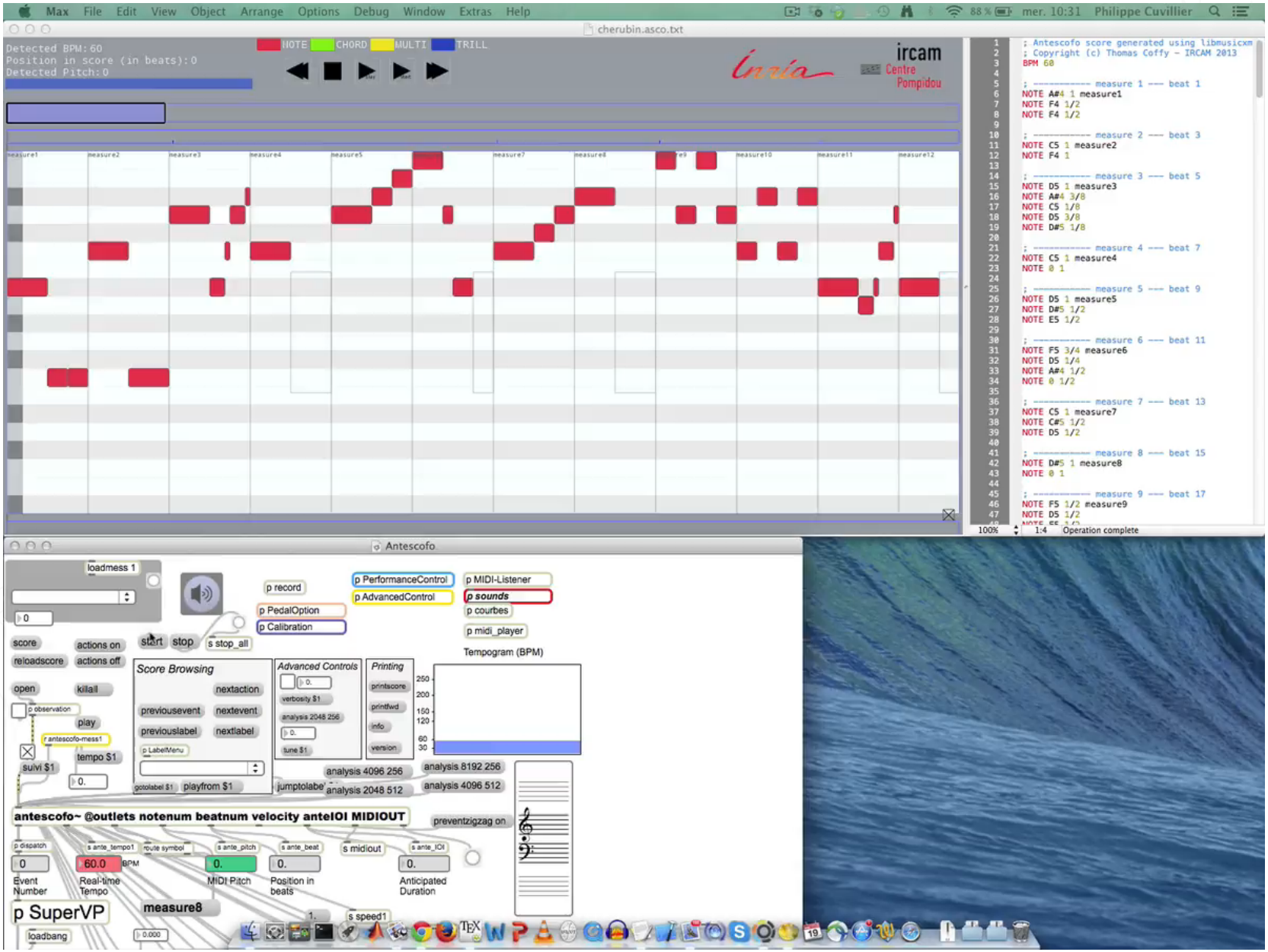
- jouer aux échecs
- effectuer des raisonnements logiques
- trouver un itinéraire sur une carte routière
- …
- reconnaître un sourire dans un visage
- marcher sur deux jambes
- …
- *jouer de la musique avec des musiciens ?*

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*


Antescofo
listen
recognize
Real-time synchronization
of electronic actions
with the musicians performance
react

Dealing with wide ranges of interpretation and errors



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

alto: Christophe Desjardins, real-time electronic: Antescofo

ODEI (performance Les Nuits Sonores, Lyon, 2014)

Outlines

Interactive Music Systems as interpreters (computer meaning of « interpretation »)

- time in a score
- score as program, performance as execution !?
- the interpretation problem

Times in Antescofo

- time in computer programing languages
- events and duration
- from triggers to synchronization strategy
- time-time diagrams
- tempo extraction
- temporal scope
- some metaphysical questions
  - why multiple times ?
  - fungible or incomparable times ?
  - time and causality ?

Some other artistic applications

- the Polyrhytmic Machine
- Marco Stroppa's Totem
- open score by Jason Freeman
- gesture-following by José-Miguel Fernandez

Final remarks

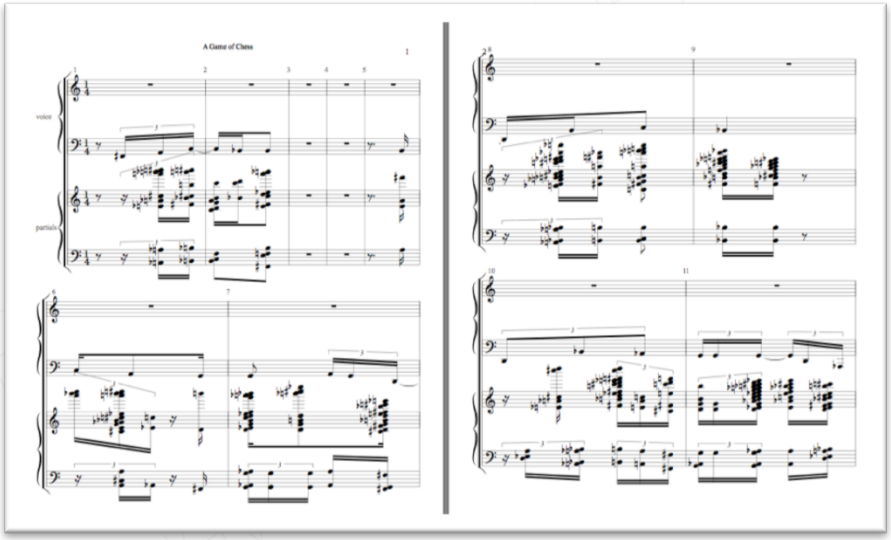
- from functions to interactions through processes
- sharing our time with machines

- temps discret et temps continu
- un temps construit à plusieurs
- une notation géométrique du temps
  = le hors-temps de la partition

QUEL TEMPS DANS UNE PARTITION ?

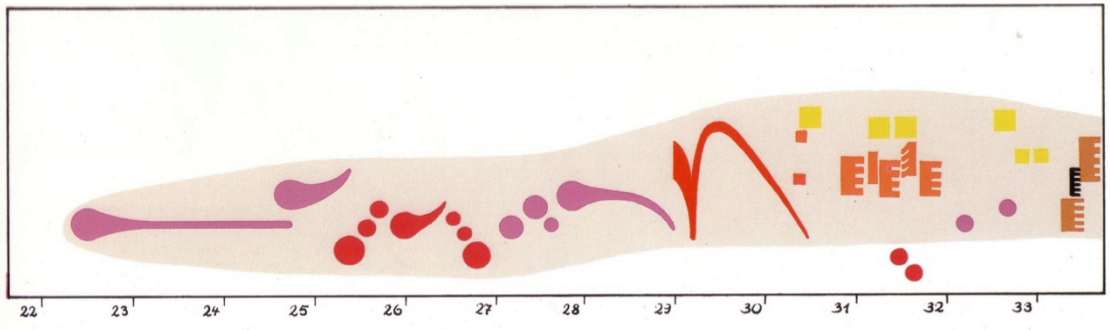
A Score

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

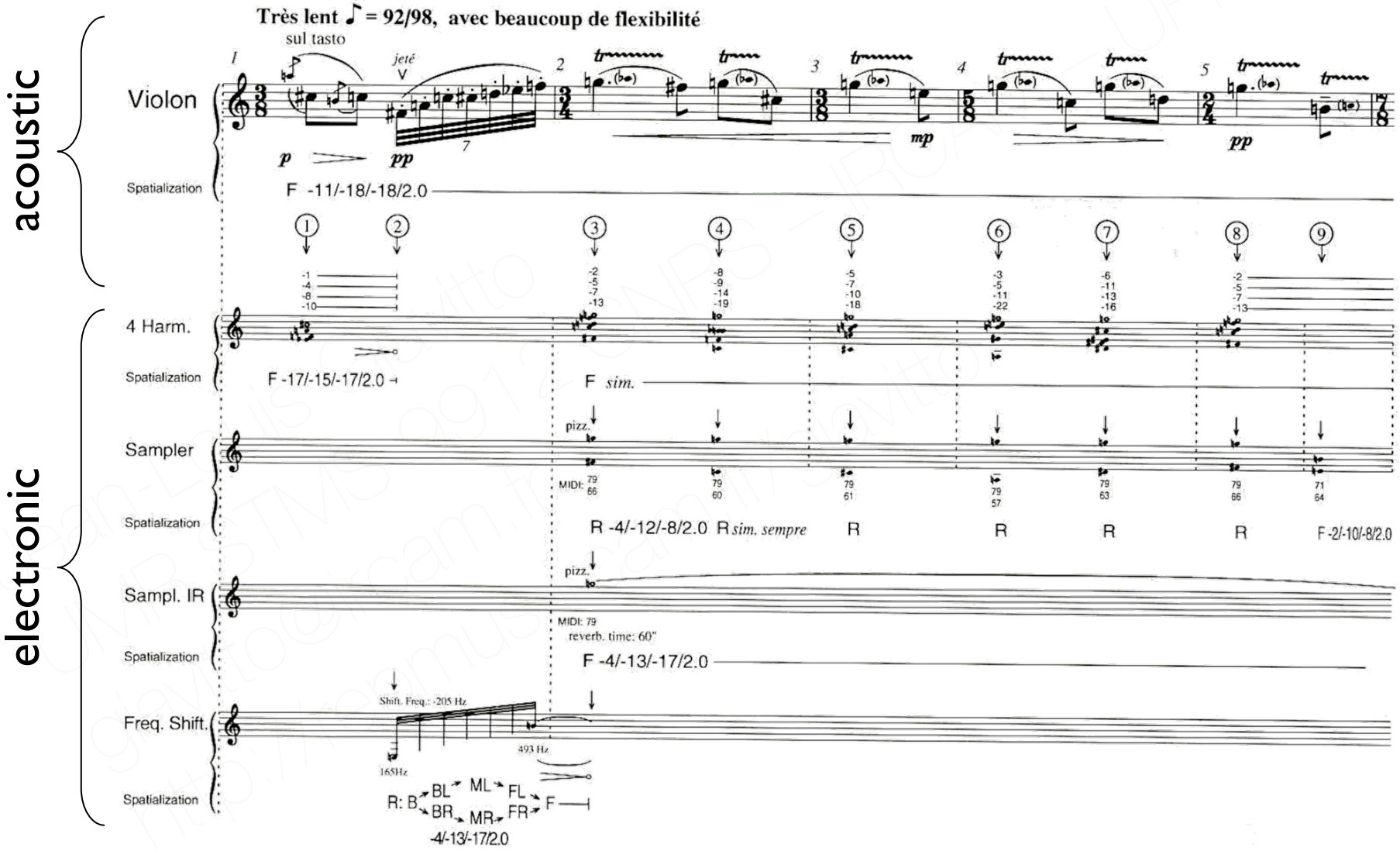


- events that last
  (duration of a note)

- continuous change of parameter (*movement*, *gesture*)
  - frequency
  - ambitus
  - sound localization
  - etc.

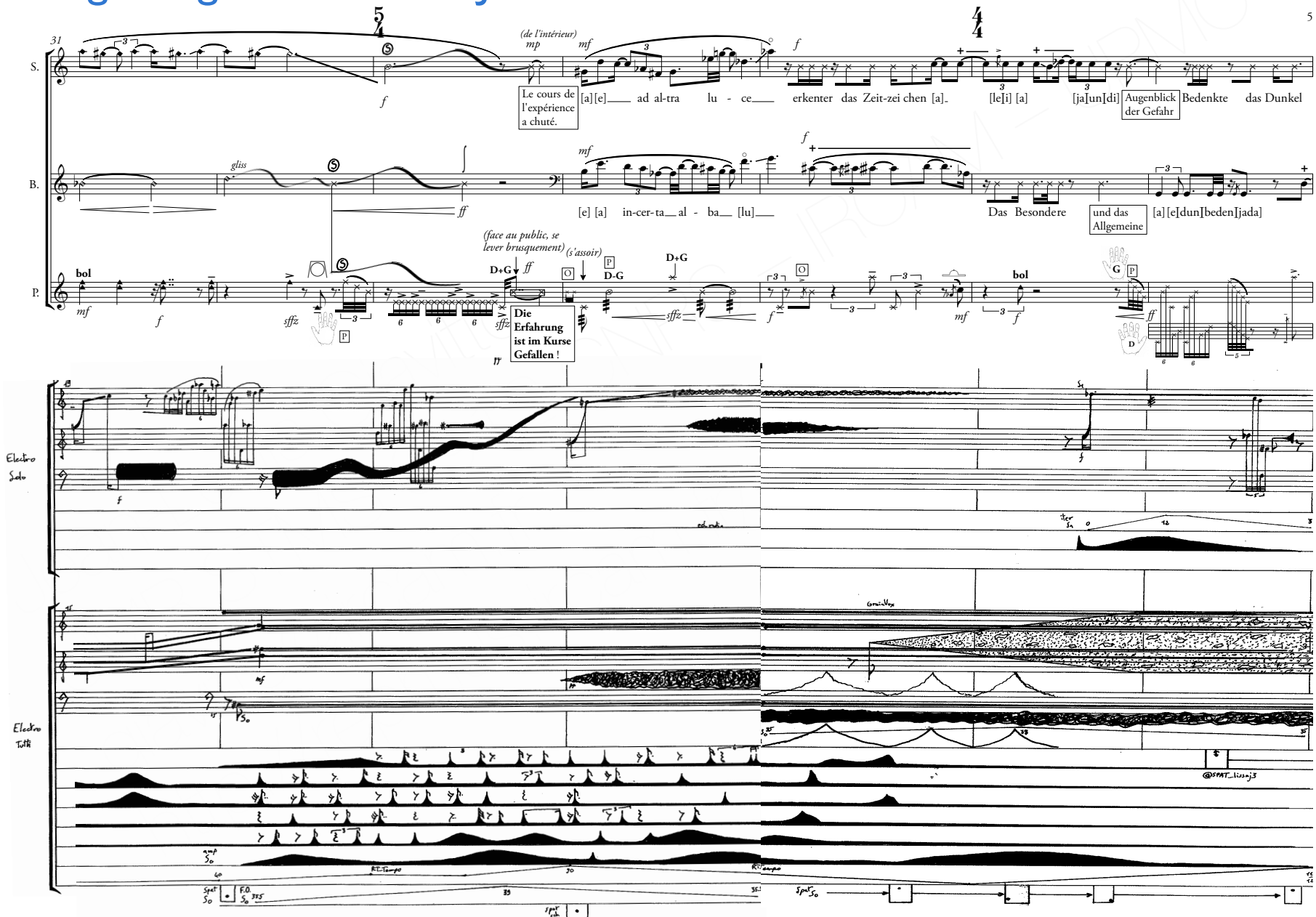


Beginning of Antheme2 score (P. Boulez)



Notice the difference with…

beginning of *Nachleben Julia Blondeau*



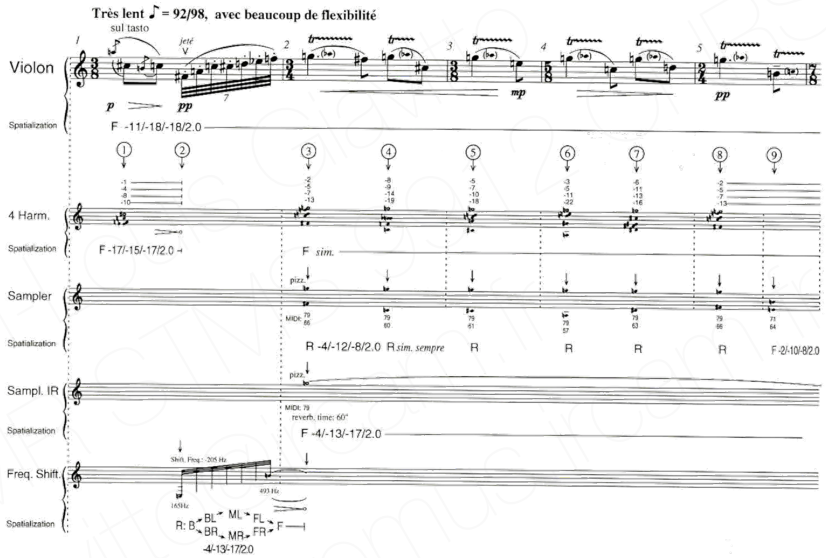
Notice the difference…

from trigger (event alignment)

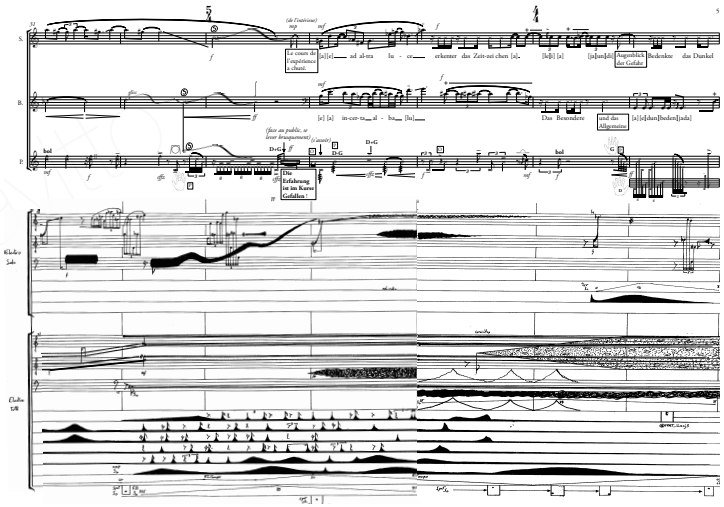
to synchronization (full timeline event + duration alignment)

electronic acoustic

Antheme2
Pierre Boulez

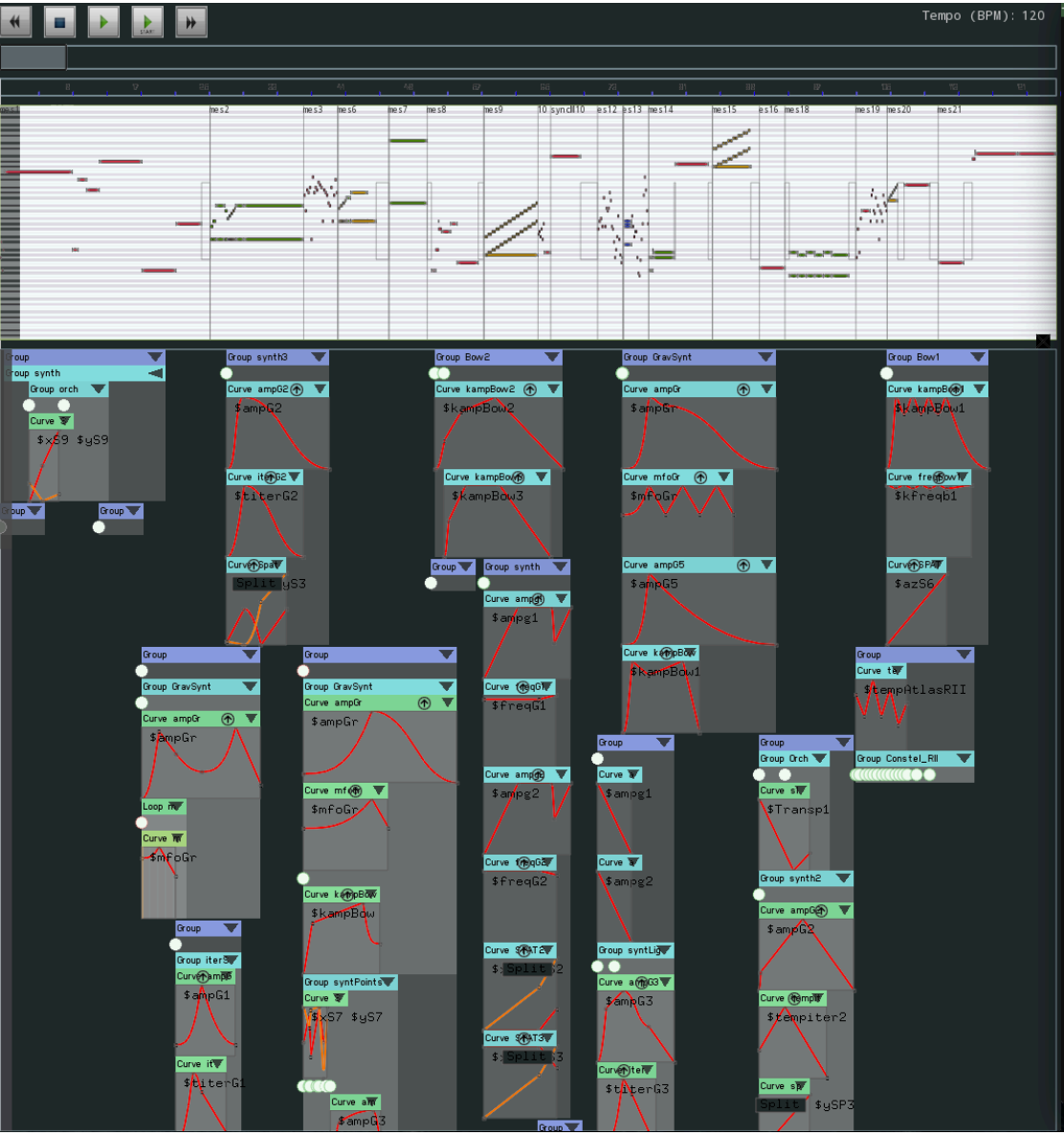


Nachleben
Julia Blondeau



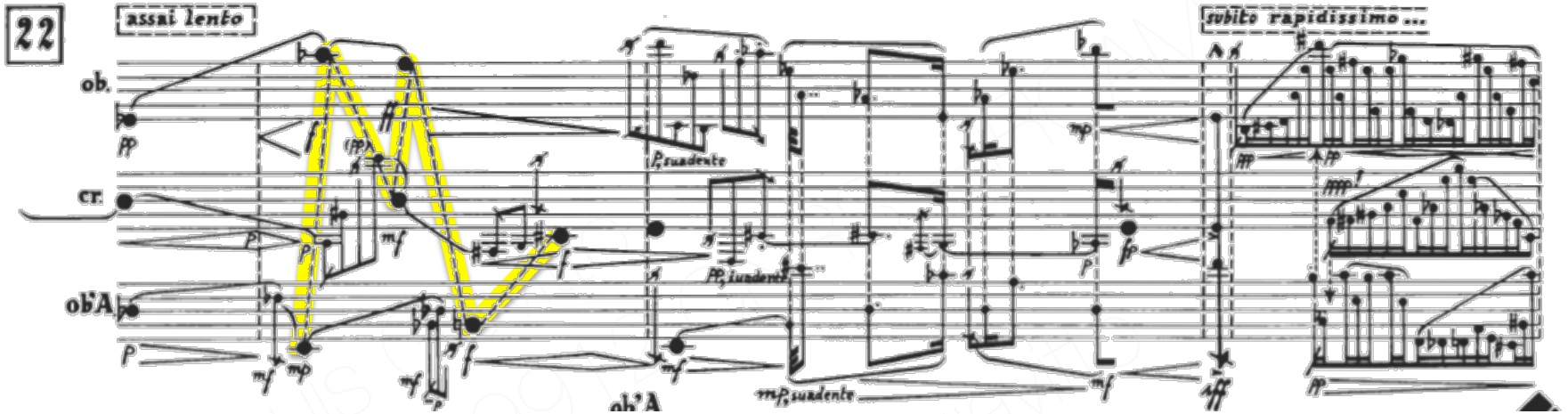
An augmented score in *Ascograph*

(Thomas Coffy, Grieg Burloiu)

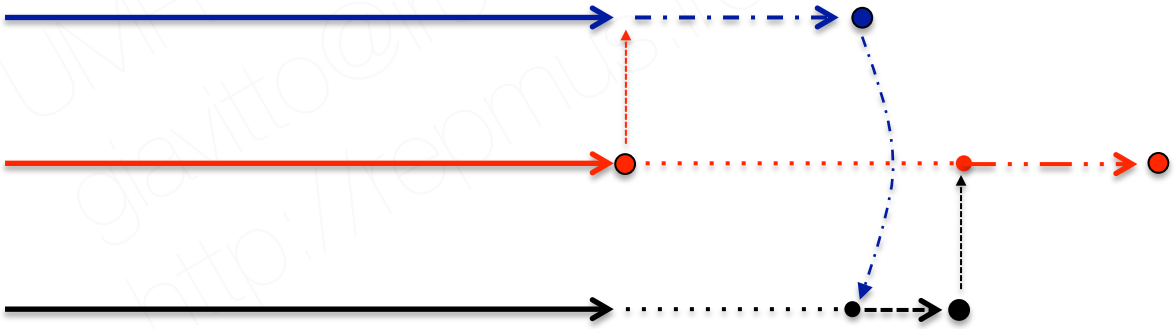



```
TeslaSOLO.asco.txt                                    JBLO macroDef.asco.txt
370 BPM 48
371 ;NOTE 0 1
372 ; ----------- mes 1 --- beat 1
373 NOTE G3 1/8 mes1
374 NOTE C#4 1/8
375 NOTE D3 1/8
376 NOTE Bb3 1/8
377 TEMPO OFF
378 NOTE E6 8
379
380     GROUP synth @target {mes2}
381         {
382             SPAT2 xy 0 -1
383             ::ASCOtoCS_SYNTH_L("g1",50,0.,8,0.25,88,0.,0.2,5,2)
384             curve ampG1 @grain := 0.05s, @action := ASCOtoCS_SYNTH_L c g1.amp $ampG1
385                 { $ampG1
386                     {       { 0. } @type "cubic"
387                         2     { 0.2 }
388                         1     { 0.1 } @type "quad_out"
389                         3     { 0.04 }
390                     }
391             }
392             curve iterG1 @grain := 0.05s, @action := ASCOtoCS_SYNTH_L c g1.tempiter $iterG1
393                 { $iterG1
394                     {       { 0. } @type "quad"
395                         2     { 9. } @type "quad_in_out"
396                         4     { 0. }
397                     }
398                 }
399             curve delmG1 @grain := 0.07s, @action := ASCOtoCS_SYNTH_L c g1.multidel $delmG1
400                 { $delmG1
401                     {       { 0.2 }
402                         3     { 18. }
403                         5     { 0.2 }
404                     }
405                 }
406             curve freqG1 @grain := 0.08s, @action := ASCOtoCS_SYNTH_L c g1.freq (@midi2hz($f
407                 { $freqG1
408                     {       { 88 } @type "quad"
409                         19      { 87. }
410                     }
411                 }
412         }
413
414     3 GROUP orch
415         {
416             num_ech    4
417             PlayEch start
418             lvl_ech 0.3 500
419             curve Spat9 @grain := 0.07s, @action := SPAT9 xy $xS9 $yS9
420                 { $xS9,$yS9
421                     {       { -1 -0.5 }
422                         3/2     { 0 -1 }
423                         2     { 1 -0.8 }
424                     }
425                 }
426             4 lvl_ech 0. 3000
427         }
428
429 TEMPO ON
430 NOTE 0 0
431 NOTE Bb3 2/3
432 NOTE C#6 1
433 NOTE A5 3/2
434 TEMPO OFF
435 NOTE G#6 5
436
437     SPAT10 xy 0. 0.5
```

Un temps construit à plusieurs (de manière distribuée)



Stockhausen, *Gruppen*



waiting an event

waiting a duration

Le “hors temps” de la partition

Quand le compositeur organise du temps dans une partition :

- le temps qui s’écoule pour lui n’est pas celui qu’il note
- le temps noté est un temps « spatialisé »: tous les instants sont accessibles et ont le même statut

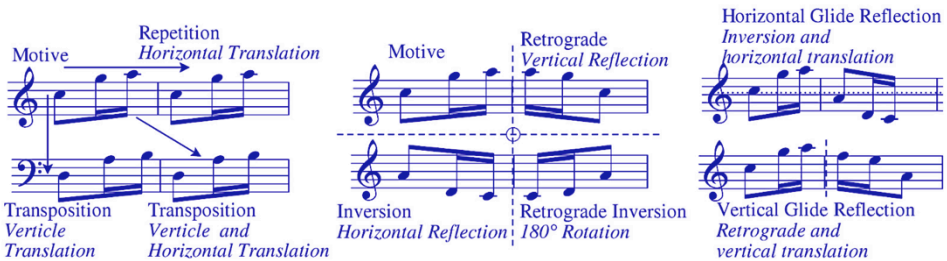
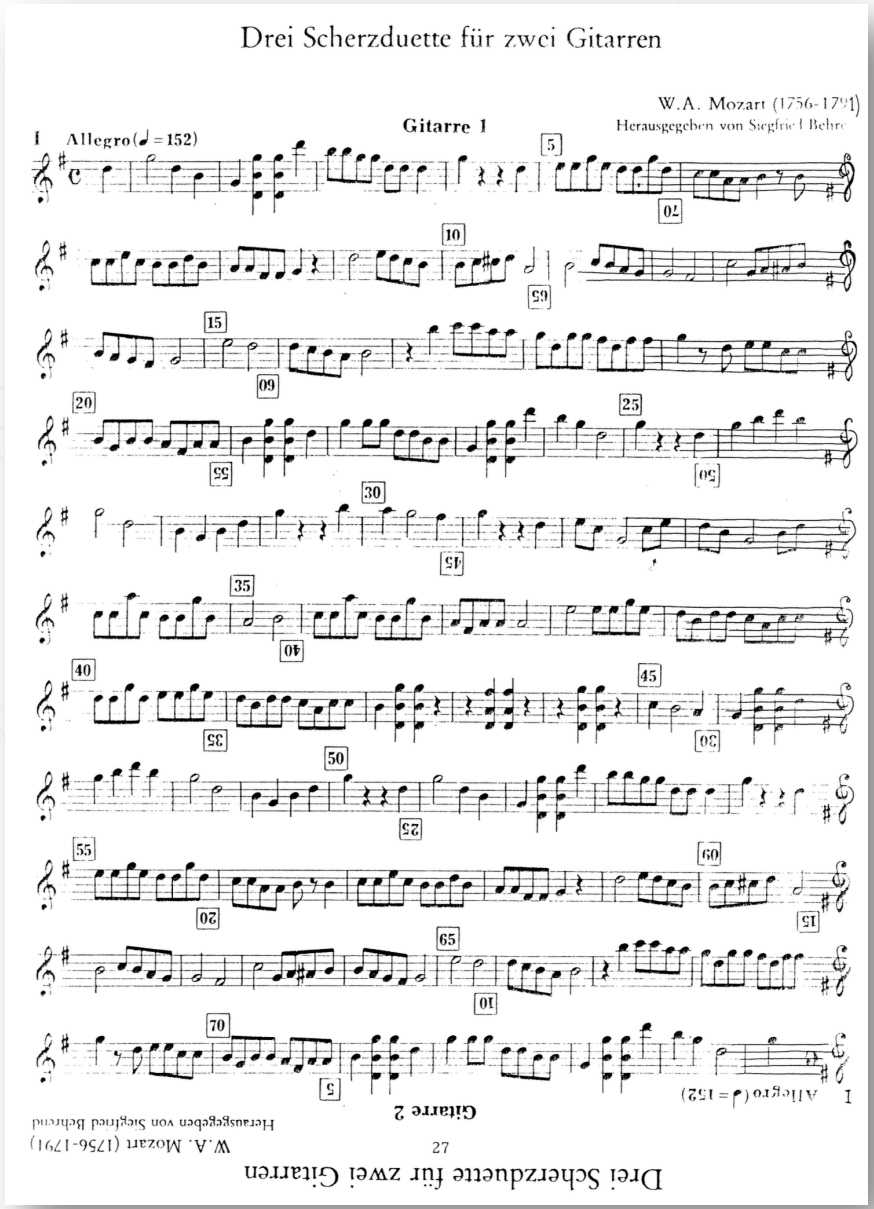
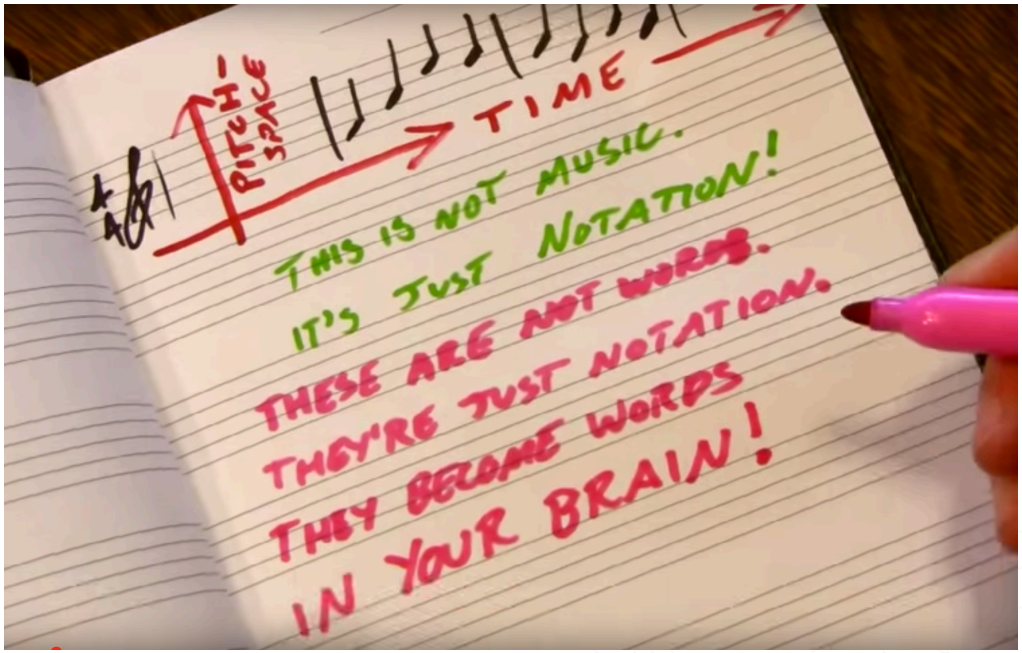
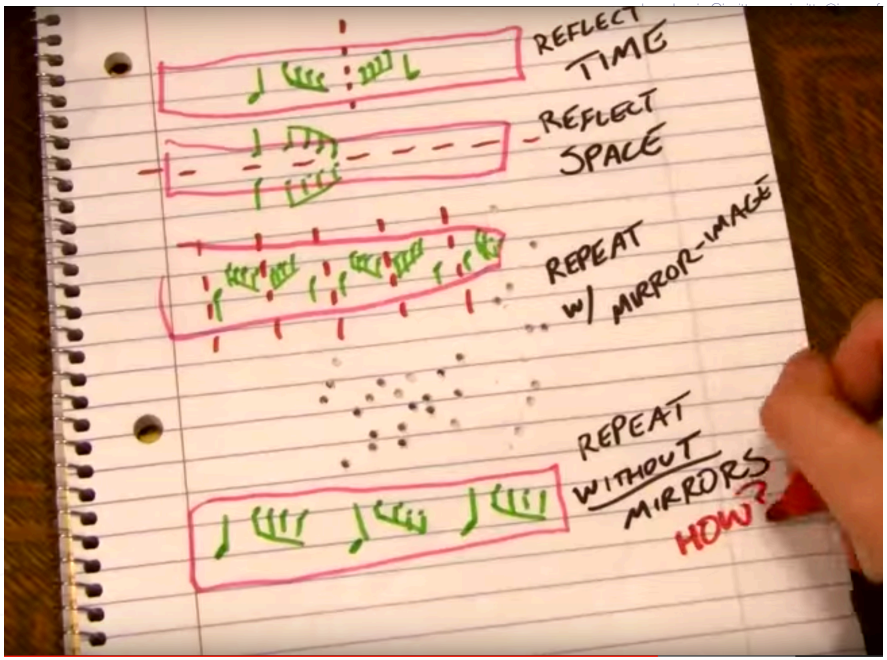


Figure 1: *All Eight Isometric Transformations in Musical Space*



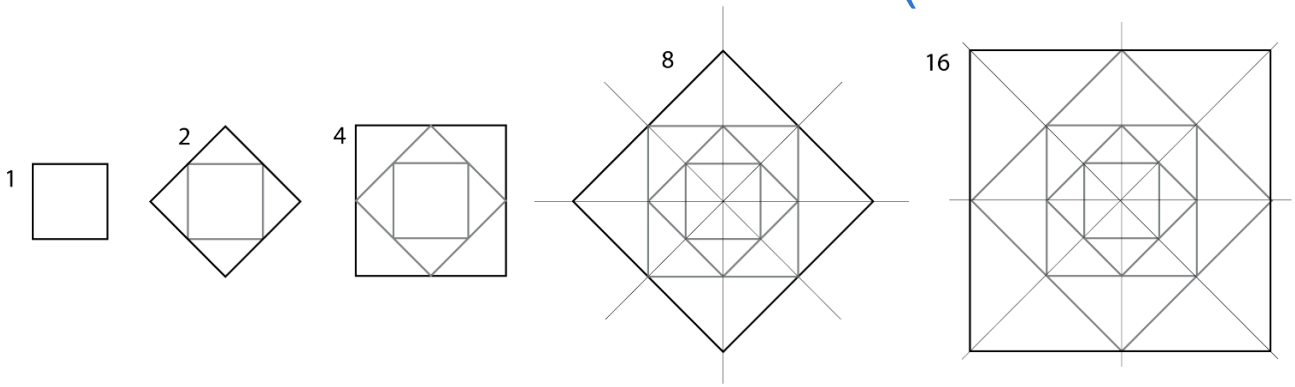


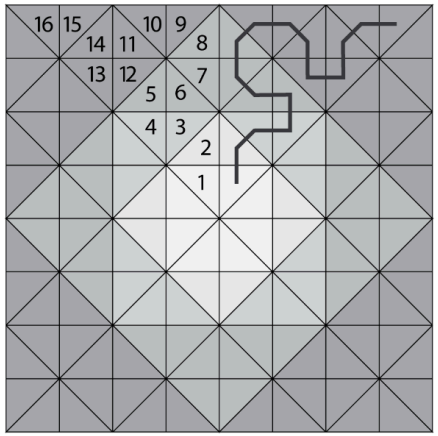


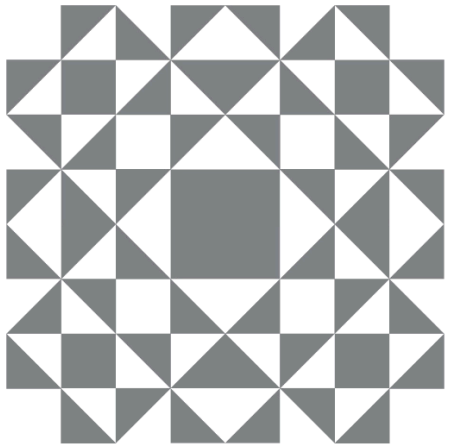
Vi Hart

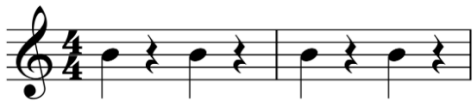
http://vihart.com/

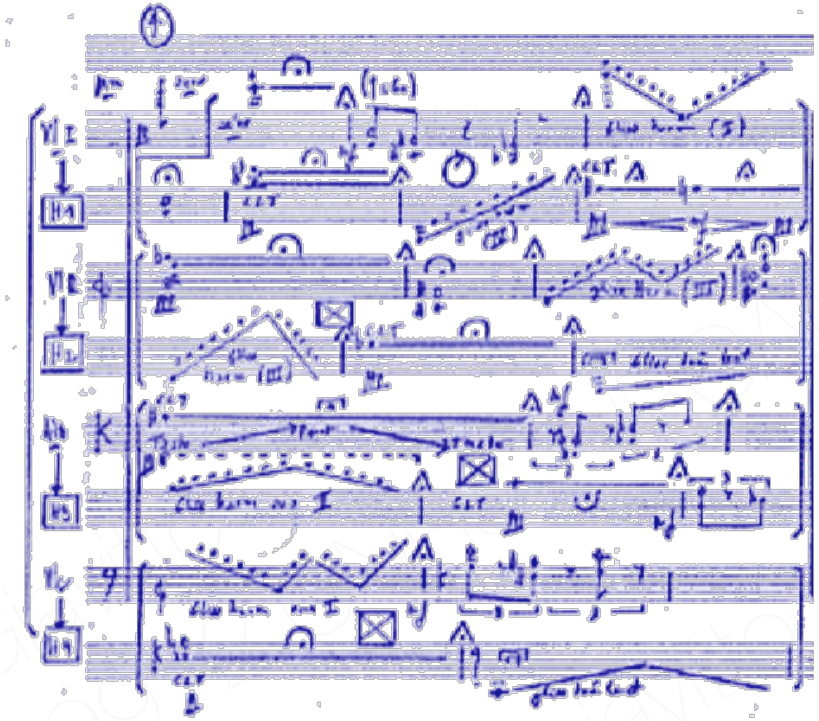
Lee Westwood & Sama Mara (www.musicalforms.com)











LA PARTITION COMME PROGRAMME
LA PERFORMANCE COMME EXECUTION !?

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

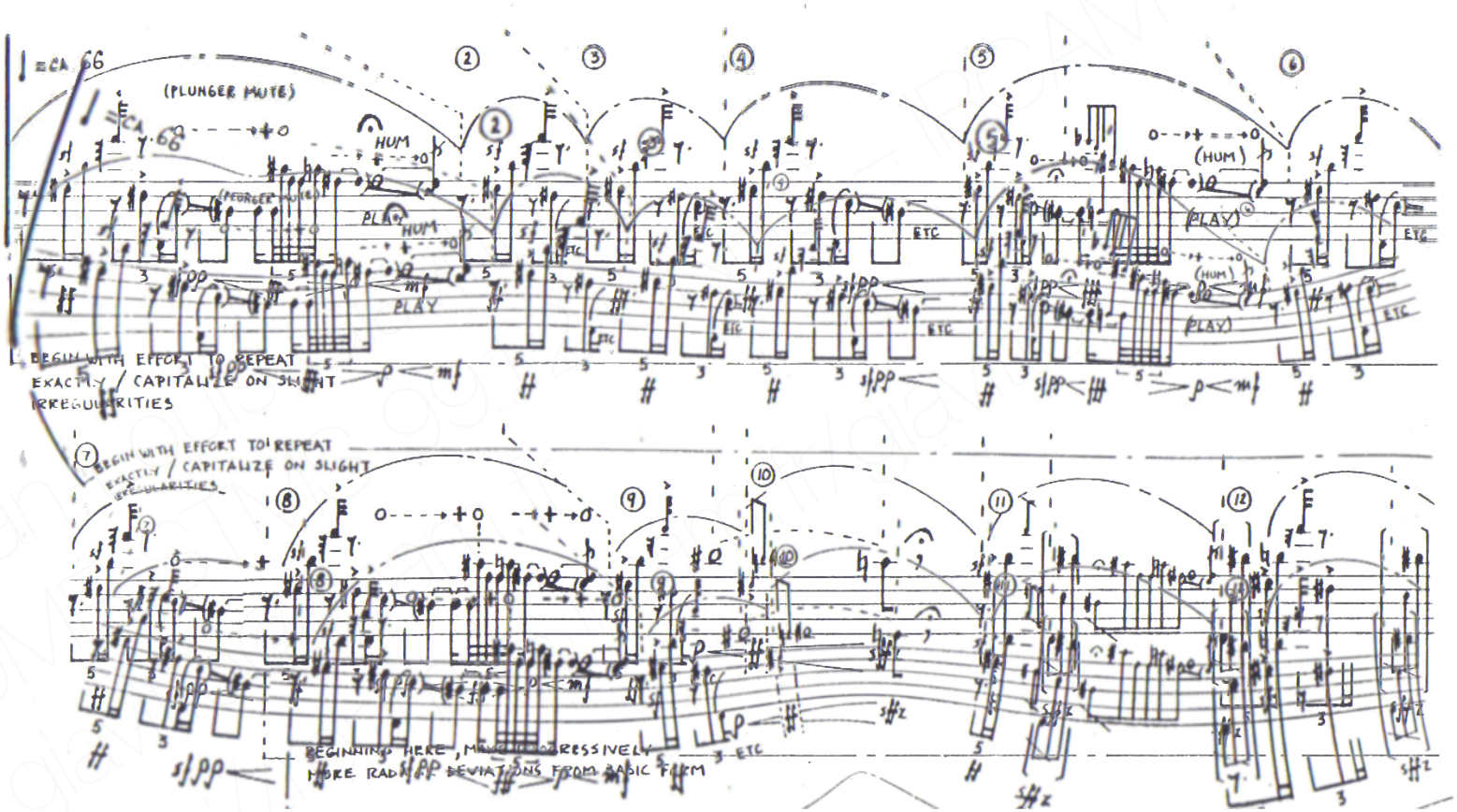
Musicans
(& audience)

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

The Antescofo aproach (to mixed music)

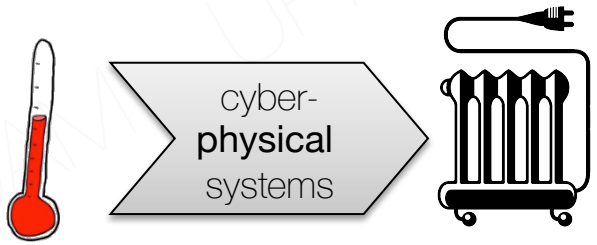
- An *augmented score* is a real-time program
  - the composer is a programmer that specifies bith human and electronic parts
  - program evaluation is done jointly by <musician | machine>
  - the composer specifies the synchronization between human and electronic parts
- The listening machine provides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

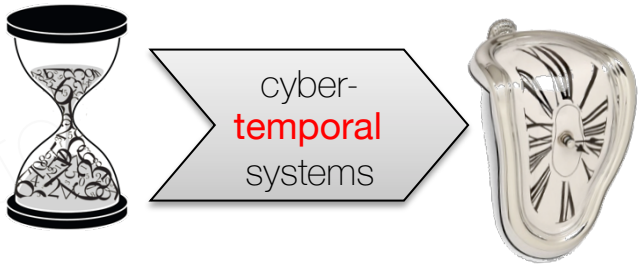
La déformation de la partition à l'interprétation



Cyber-temporal systems: computing time in real-time

- *from:* physical entities monitored by algorithms
- *to:* temporal relationships sensed and organized 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

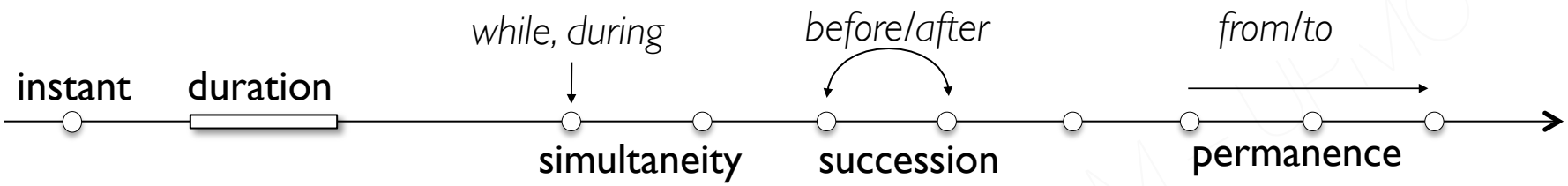
Times in Antescofo

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

times in Antescofo

MULTIPLE TIMES

Instant and Duration: Simultaneity, Succession & Permanence



process algebra

non-simultaneity

non-permanence

succession

synchronous languages

non-permanence

simultaneity

non-succession

temporized systems

non-simultaneity

its not simultaneous to something

and

its not before nor after

➔ so, its lasts

permanence

non-succession

Can we deal with *instants* only?

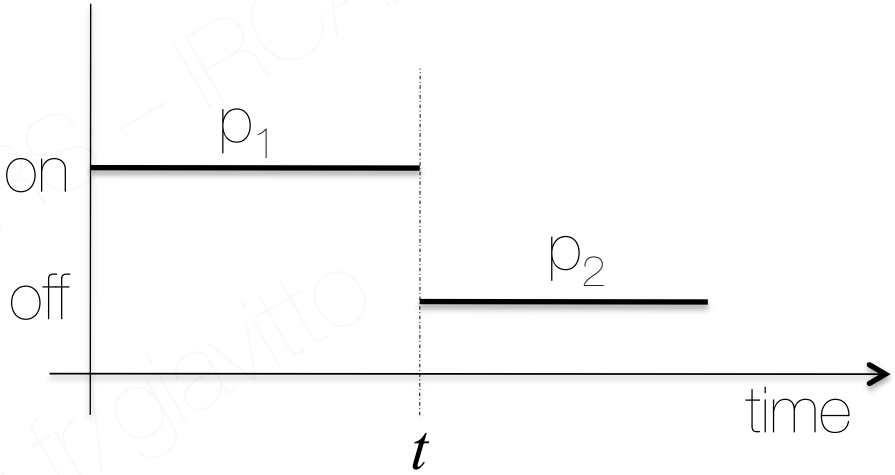
➔ duration as a set of contiguous instants

- evenemential-time

versus

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

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



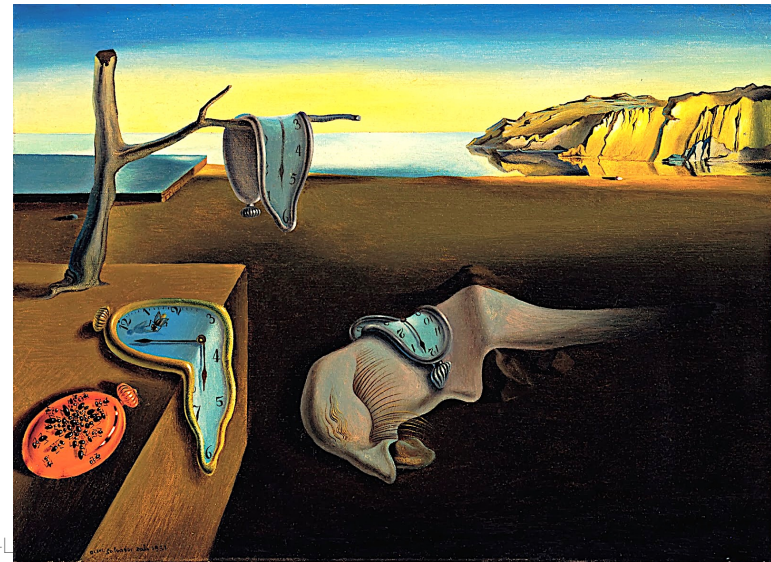
doing real analysis and topology

or

making instant and duration primitive notions

Du temps unique aux temps multiples

- temps unique : *une horloge externe objective*
  - les événements arrivent *dans* le temps
  - temps newtonien, unités temporelles fongibles
  - un temps partagé prescriptif
    (qui n'est éventuellement que partiellement connu)
- temps multiples : *pluralités co-dépendantes*
  - les événements définissent le temps
    (Bluedorn: epochal time is defined by events)
  - Temps leibnizien, relationnel
  - Exemples :
    - partition : couches temporelles
    - relation partition / performance
    - co-construction lors de la performance

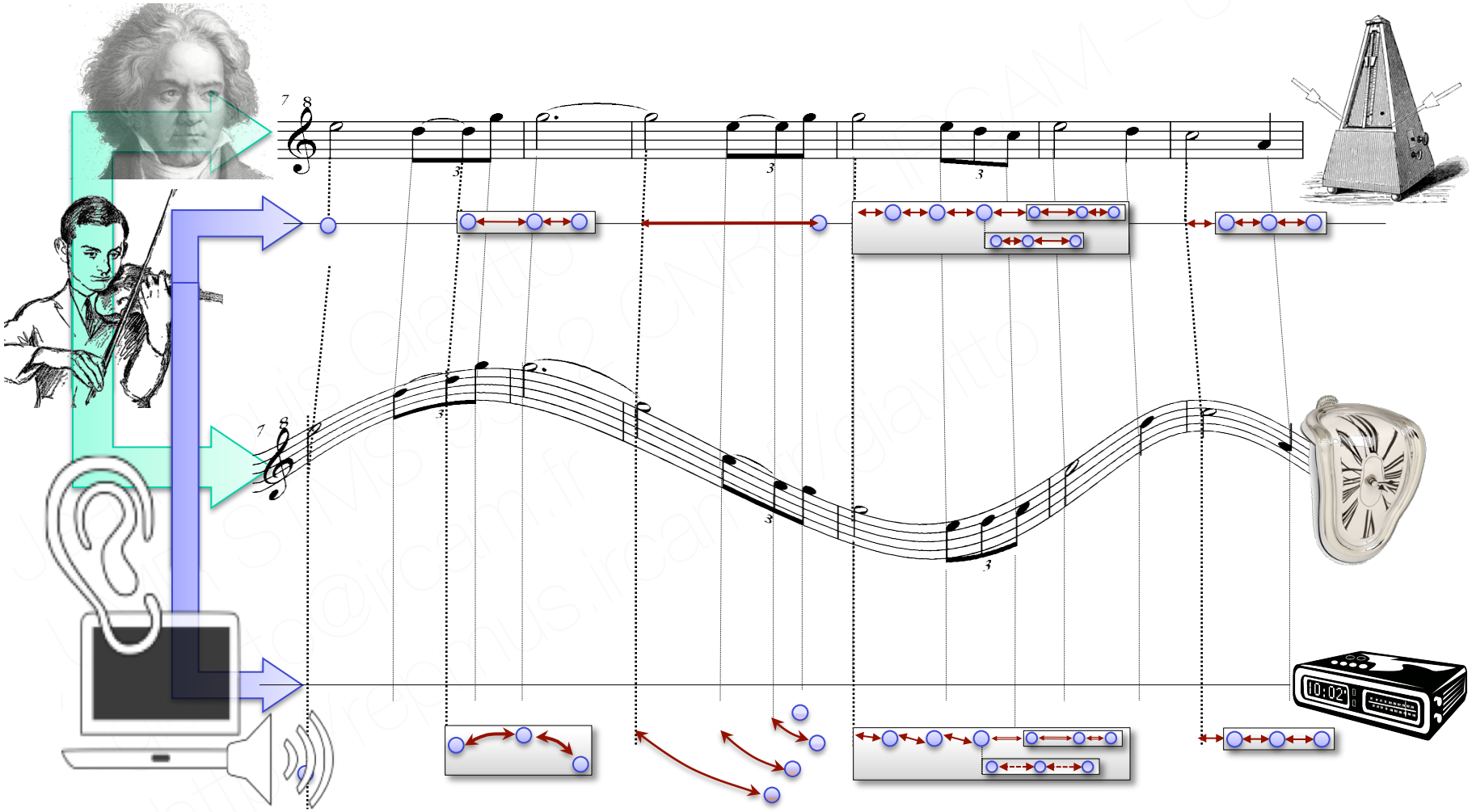


Example of relational (event-specified) time
Roman notions of summer hours and winter hours

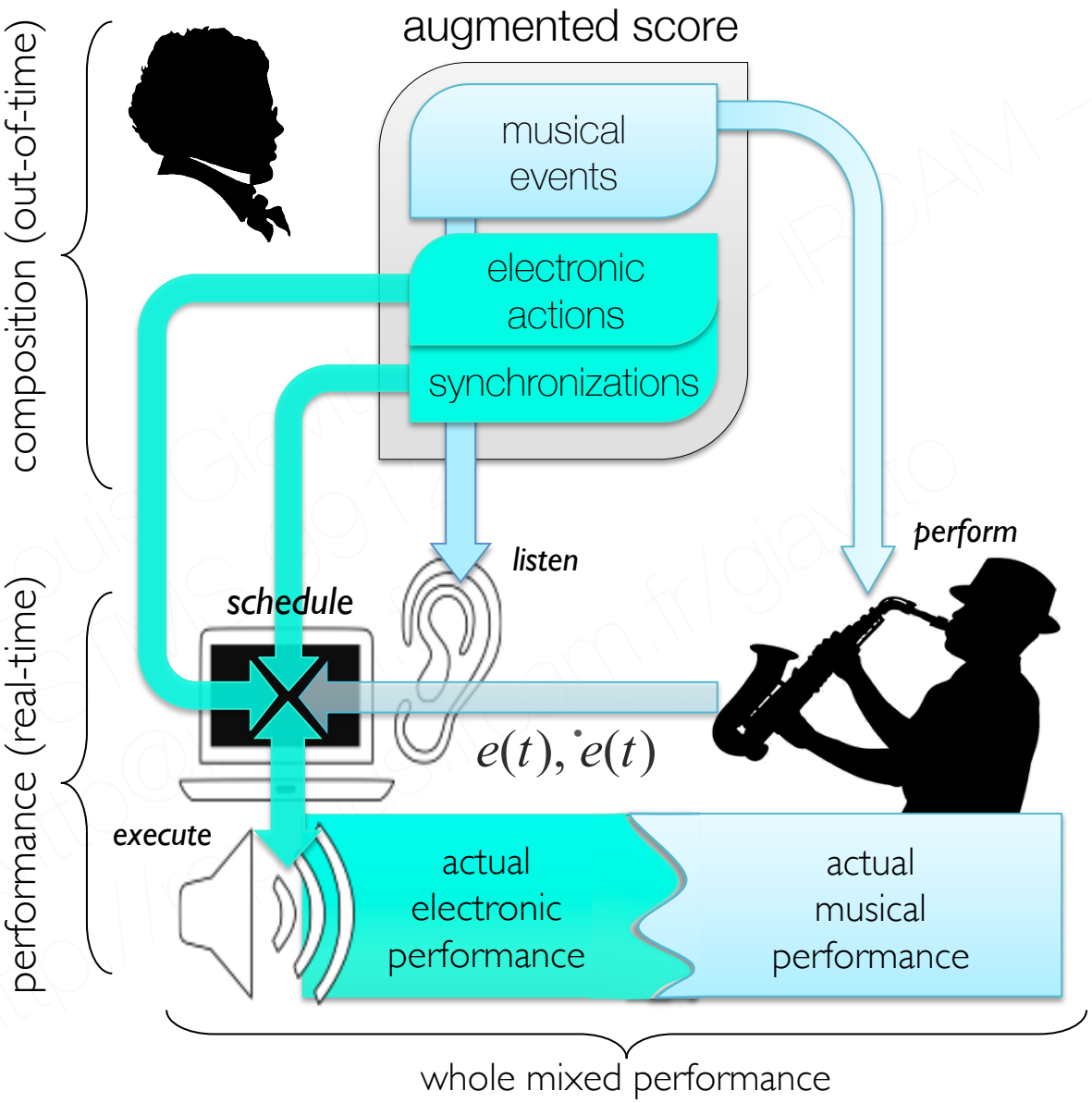
times in Antescofo

FROM TRIGGER TO SYNCHRONIZATION

The Multiples Times of Temporal Scenarios



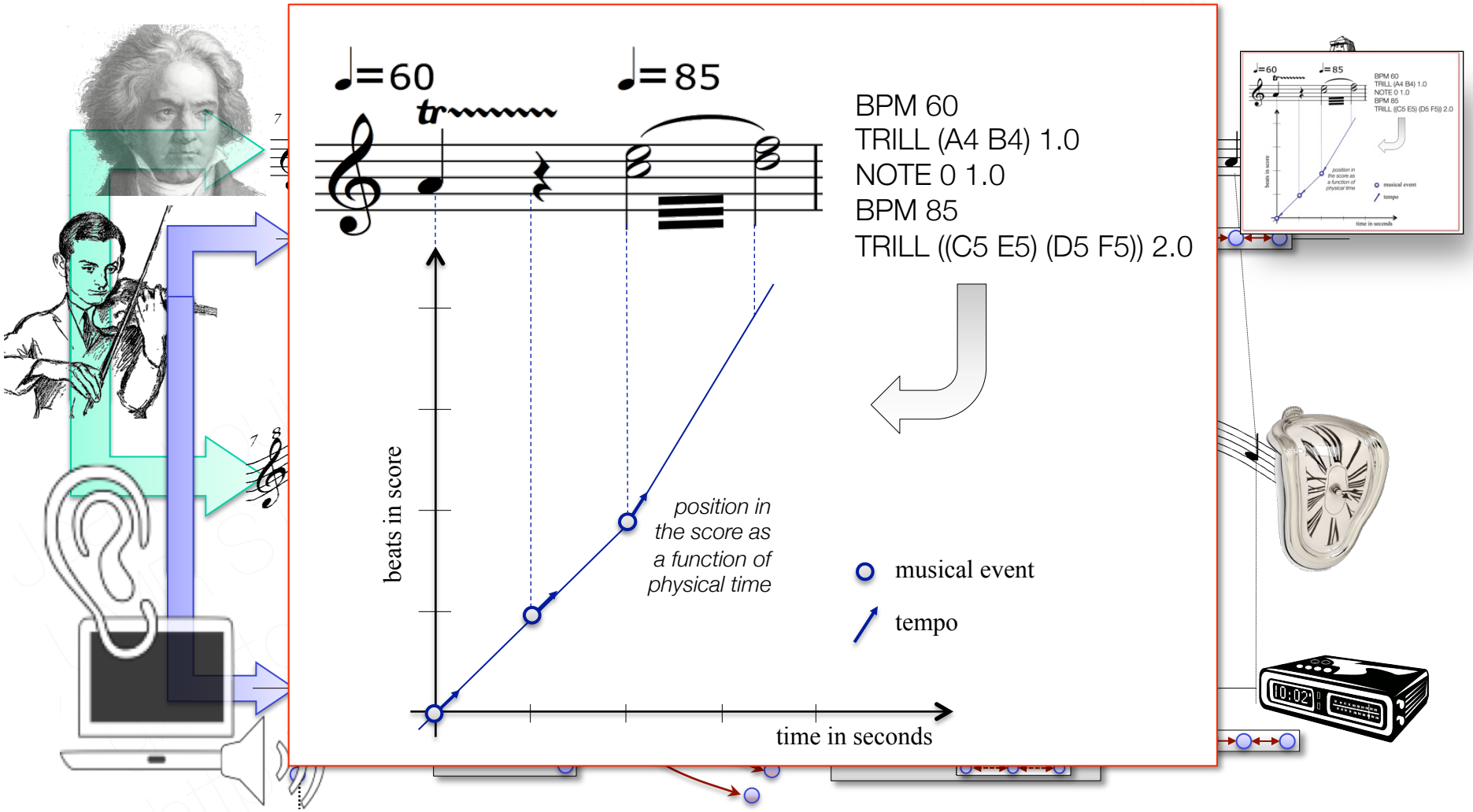
Tackling the interpretation problem in mixed music



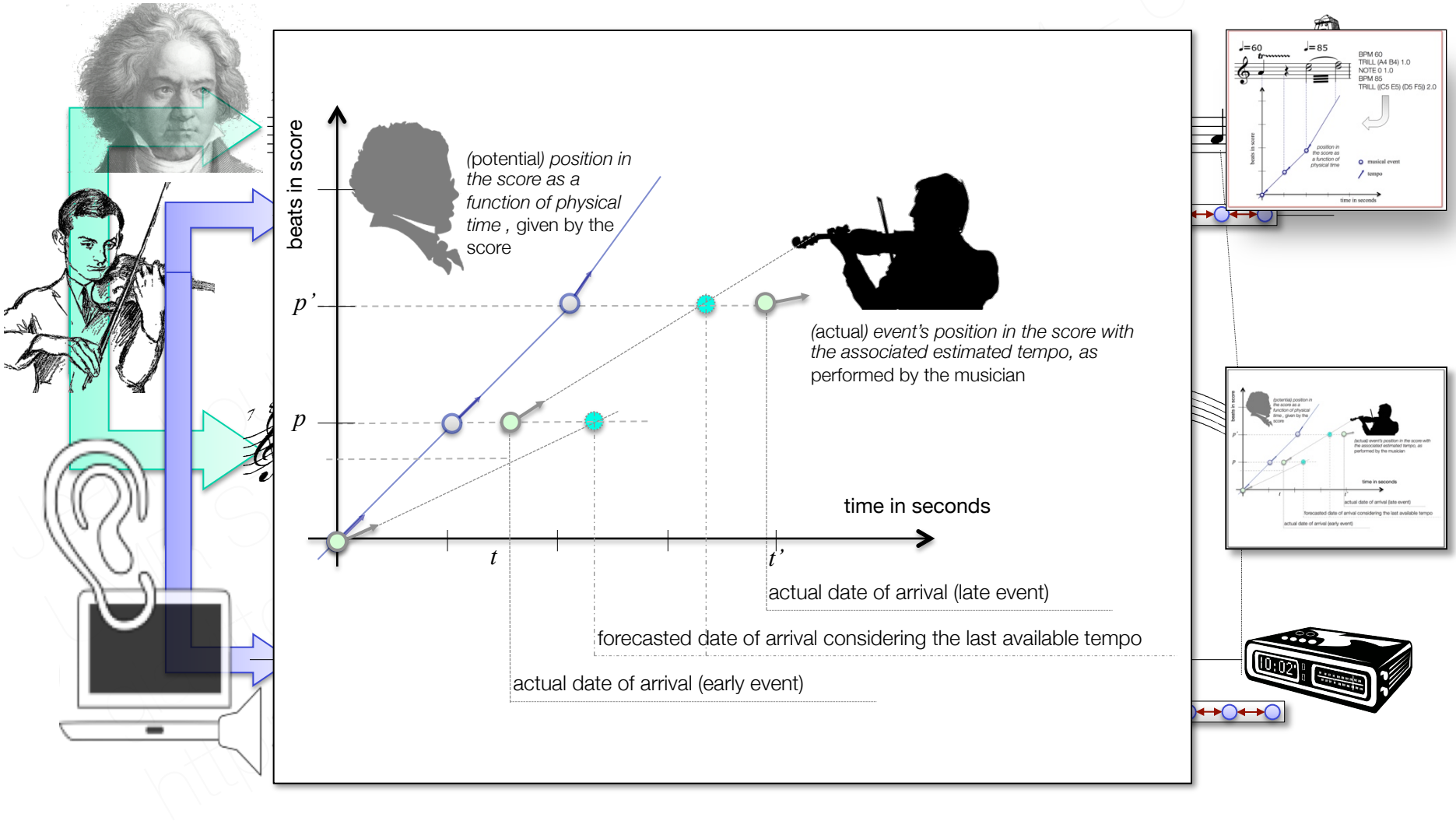
times in Antescofo

TIME-TIME DIAGRAM

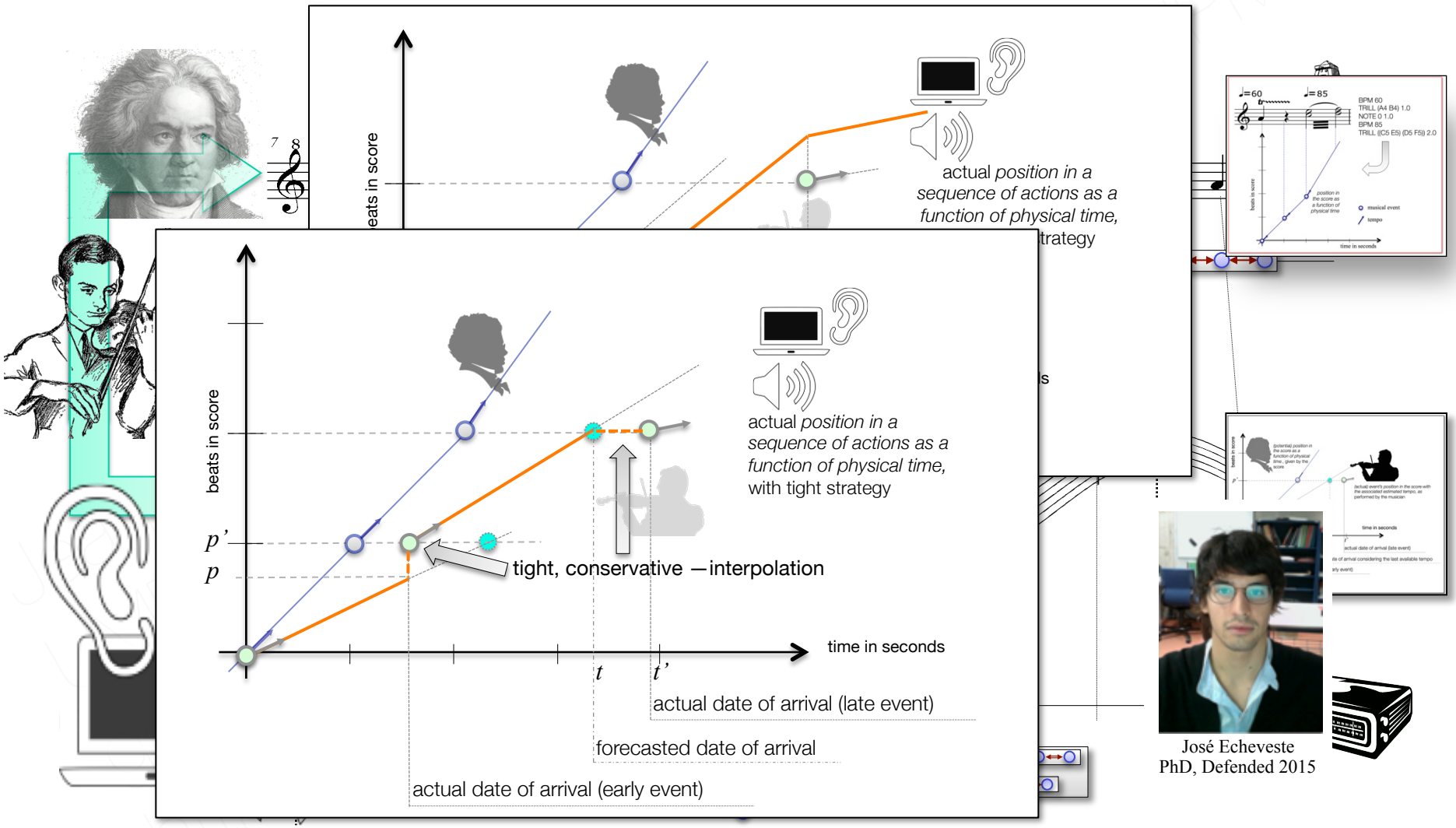
Time-time diagrams



Time-time diagrams

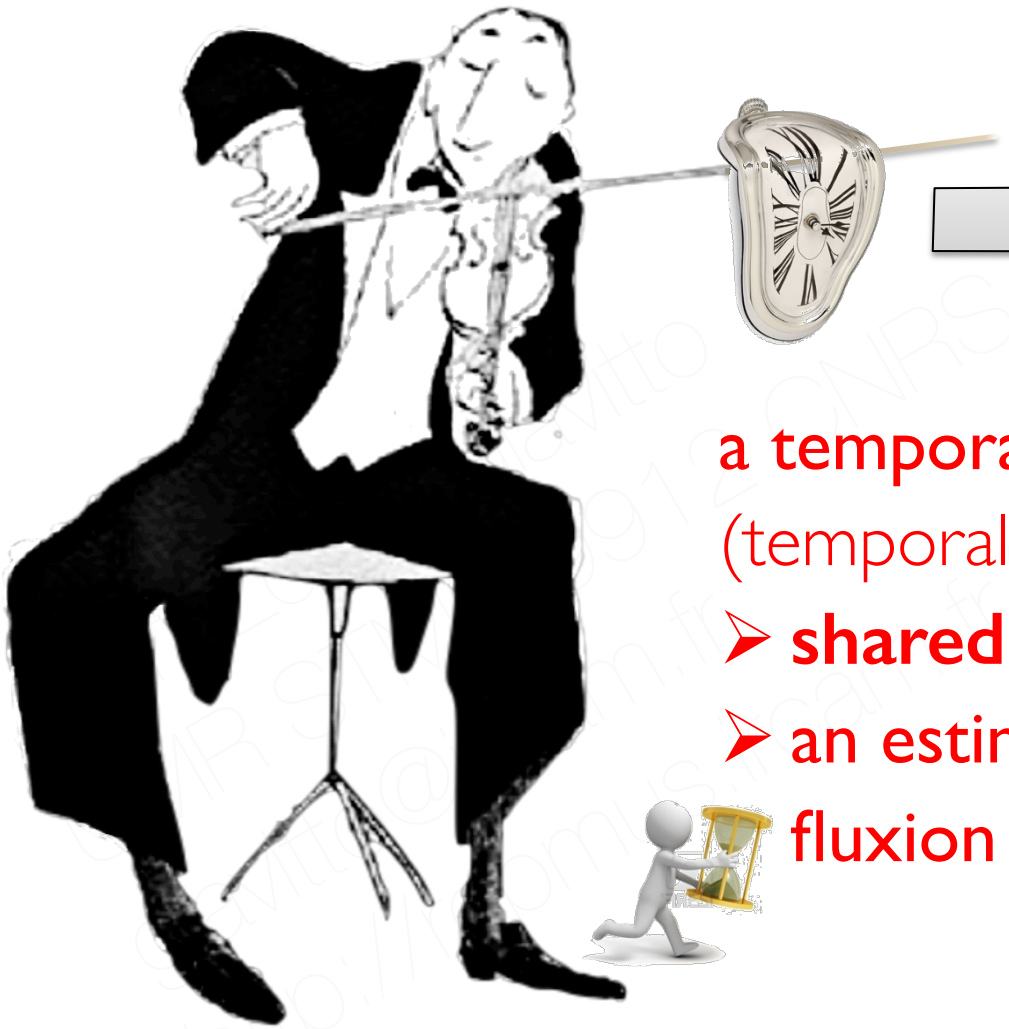


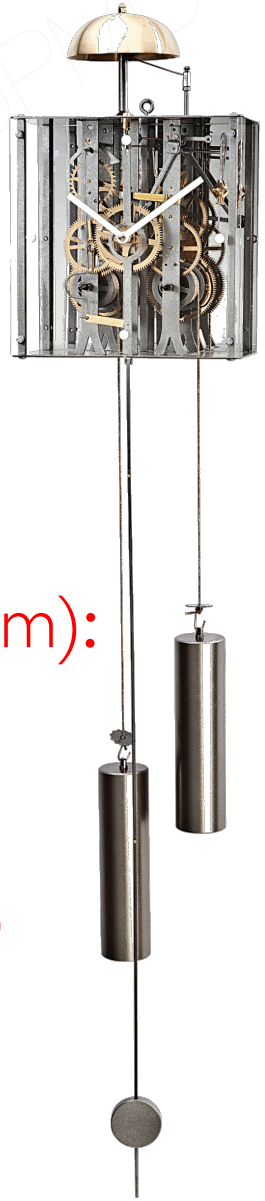
Time-time diagrams



José Echeveste
PhD, Defended 2015

aligning (*aka* synchronizing) timelines



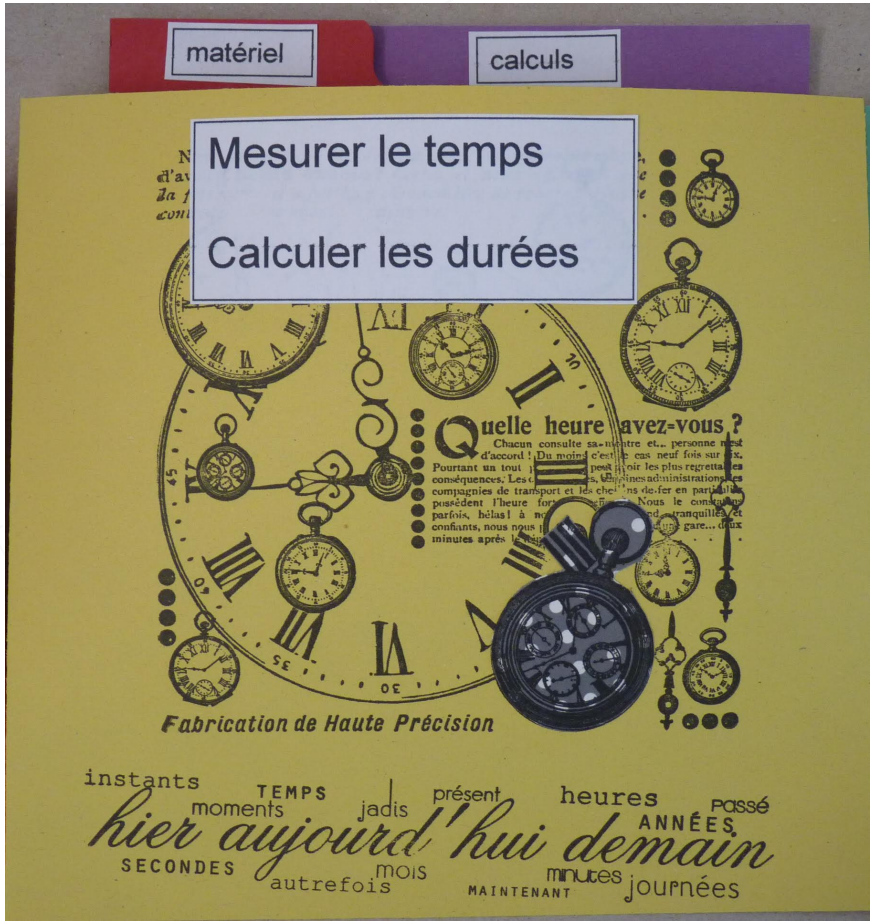


a temporal scope
(temporal coordinate system):

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

times in Antescofo

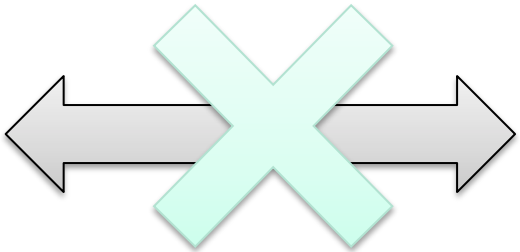
TEMPO EXTRACTION
(Large's algorithm)

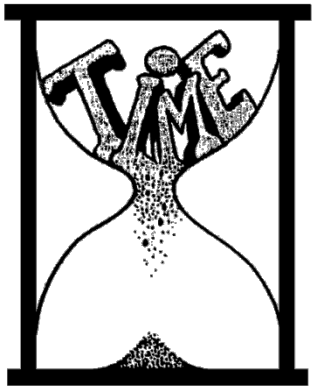


Building a shared time

tribe of the great clepsydra

tribe of the wonderfull sandglass





Building a shared time

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

1

2 litres

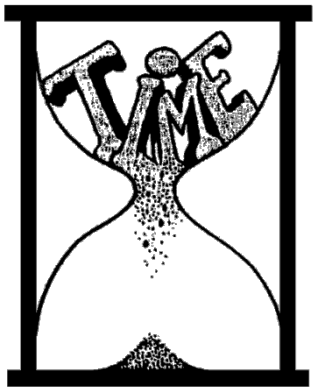
3

2

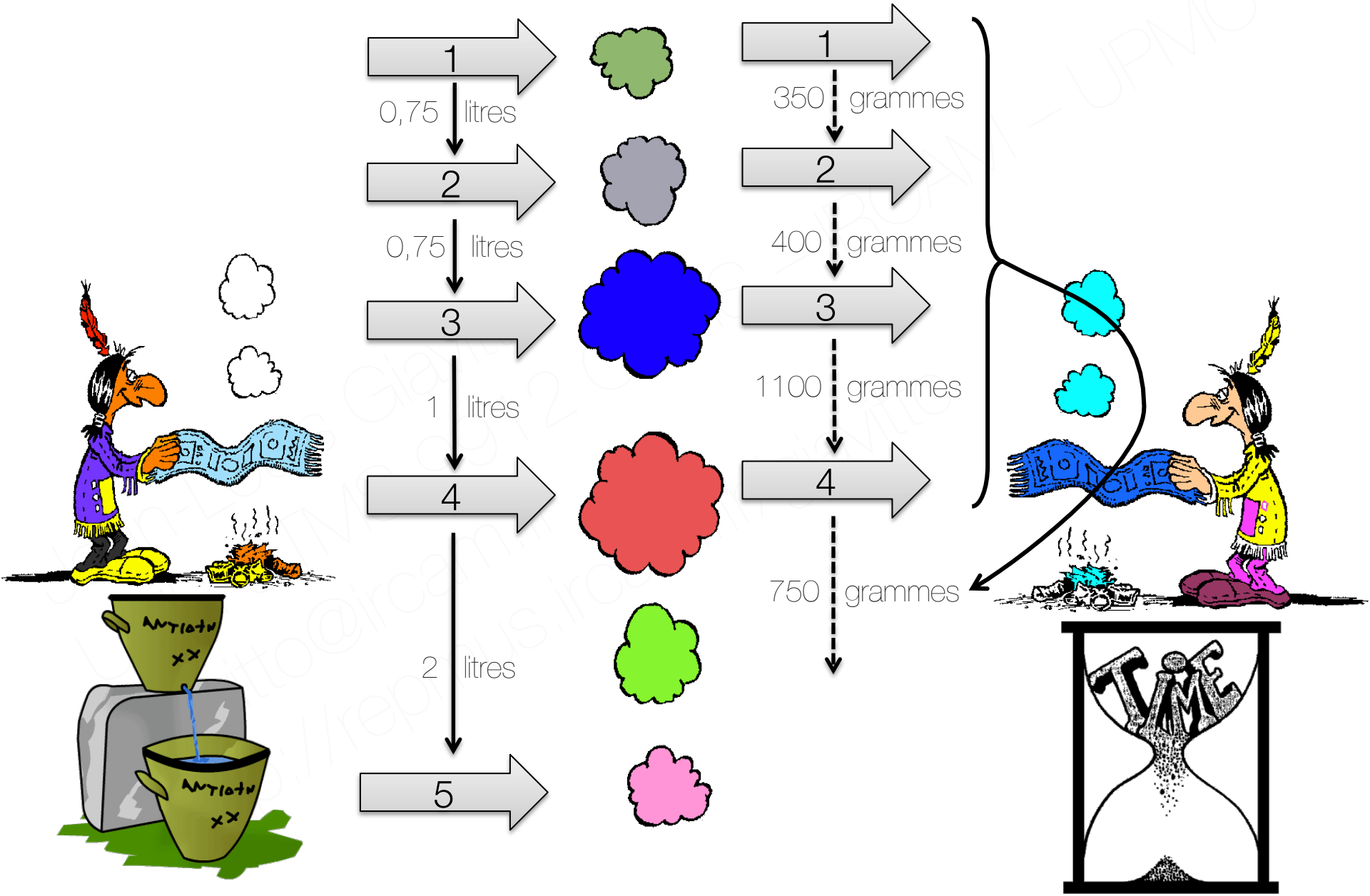
750 grammes

3'

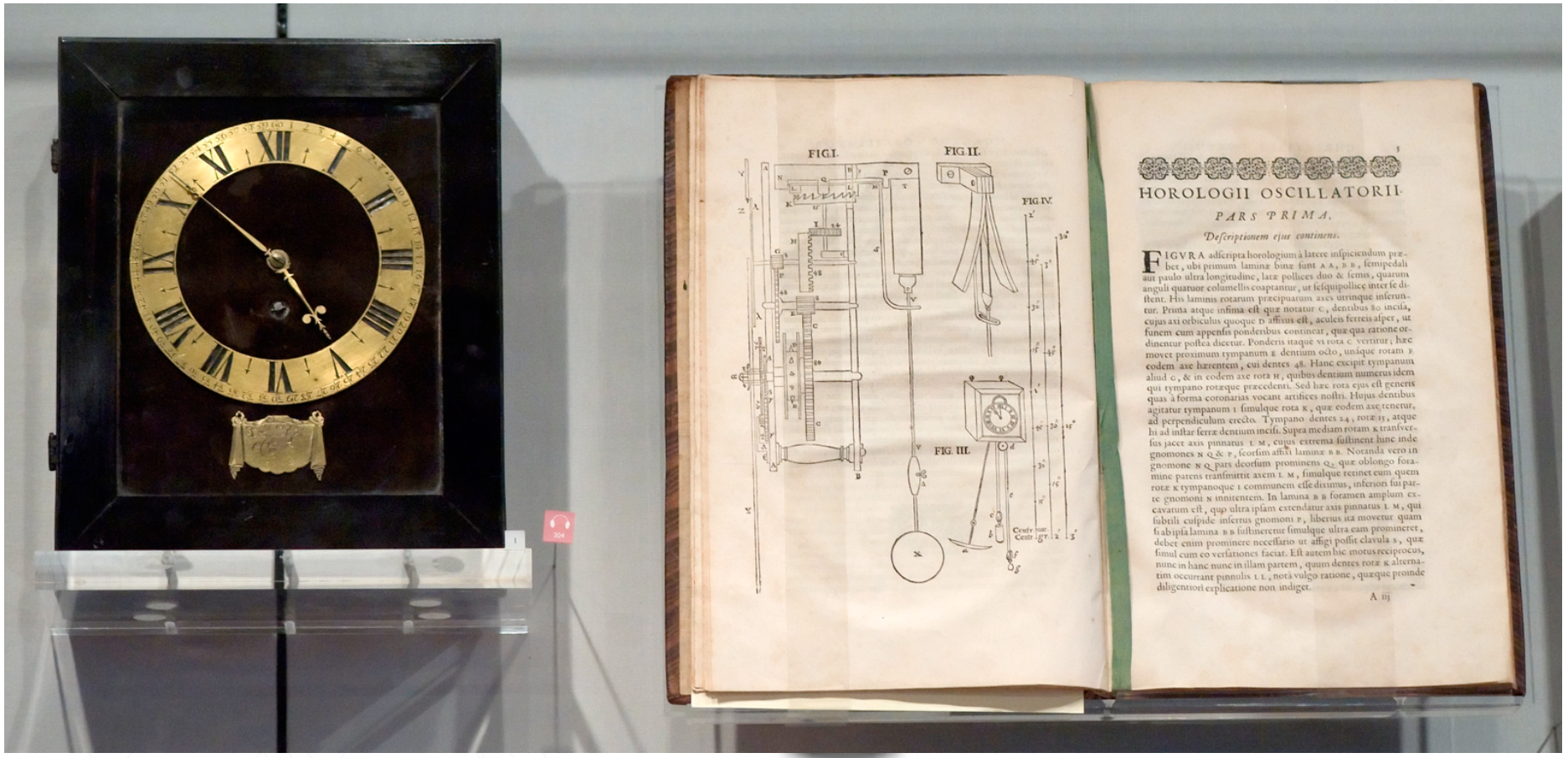
J'émettrai
un nuage vert
750 grammes
avant le nuage rose

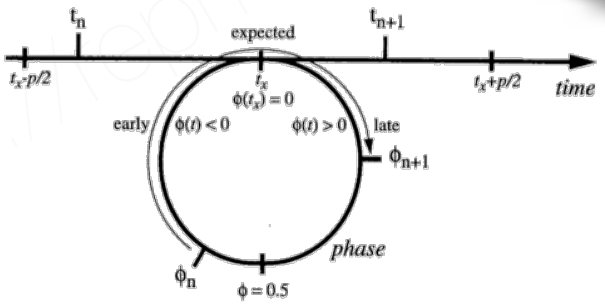


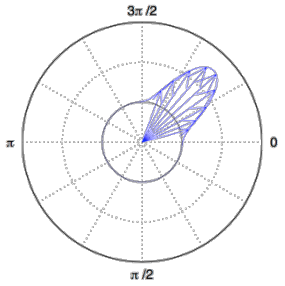
Building a shared time



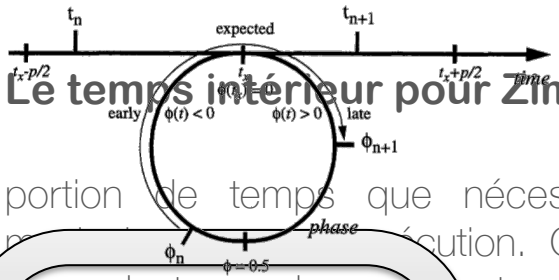
Tempo inference and odd sympathy



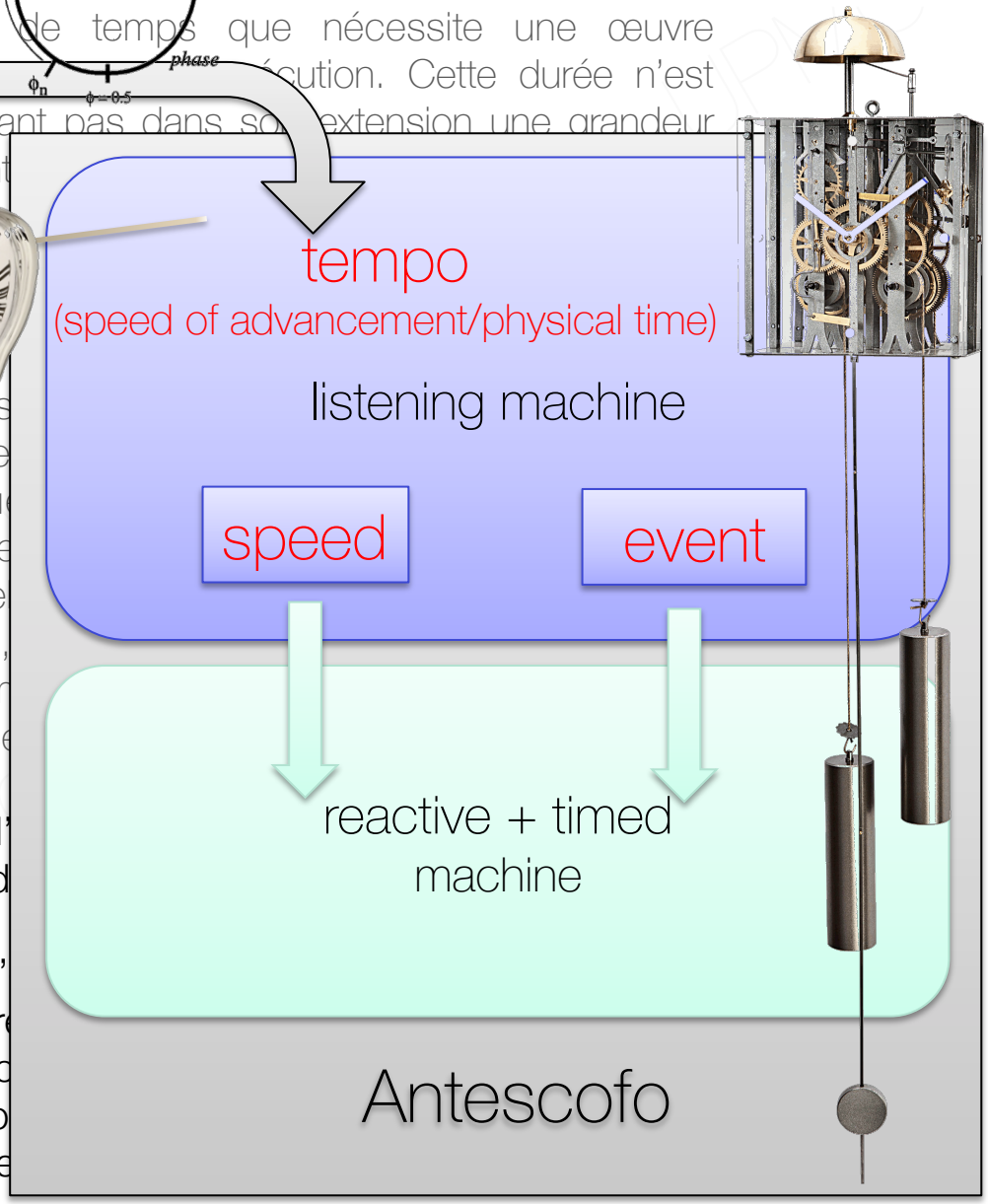




Le temps intérieur pour Zimmermann



portion de temps que nécessite une œuvre
écution. Cette durée n'est
cependant pas dans so extension une grandeur
constant
va
contraire
métriqu
demeure
tempore
manière,
doublem
d'une ce
fonction
choix d'
qui ord
Temps.
bien qu'
intérieur
sens, nc
de l'exp
musique



times in Antescofo

TEMPORAL SCOPES = EVENT + TEMPO

Temporal objects and relationships handled in Antescofo

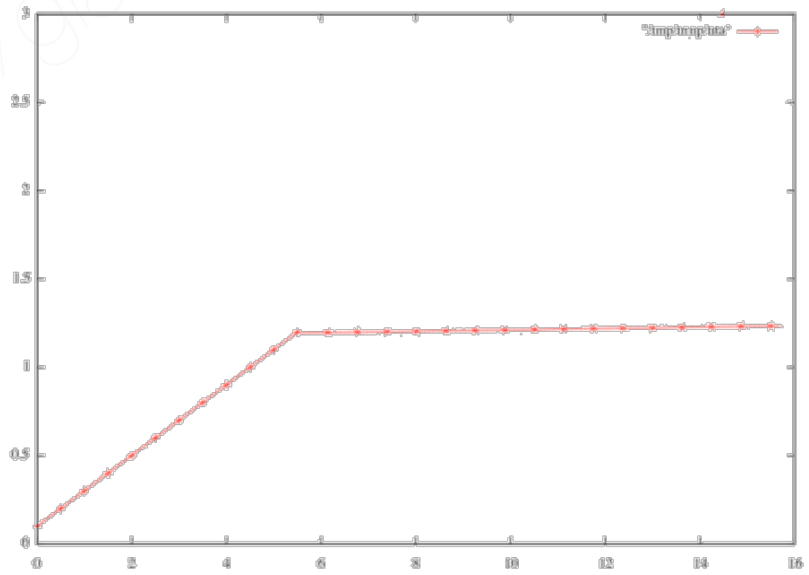
- Instant
  synchrony hypothesis = atomic computations are instantaneous
- Duration
  delay, period, sample
- Different ways of denoting time
  - event/ chronometric
  - absolute / relative
  - continuous / discrete
  - control / audio
- Various scales
  - audio (1/44 ms)
  - control (2 ms -> 1 h)
 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

Temporal Scope

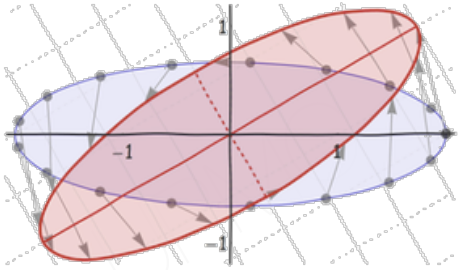
- each sequence of actions has a temporal scope
- a temporal scope defines *how time passes* with respect to another temporal scope (synchronization)
- the passing of time may takes into account
  - the occurrence of events
  - the tempo of the followed temporal scope (how time passes between events)
  - 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

Strongly timed

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

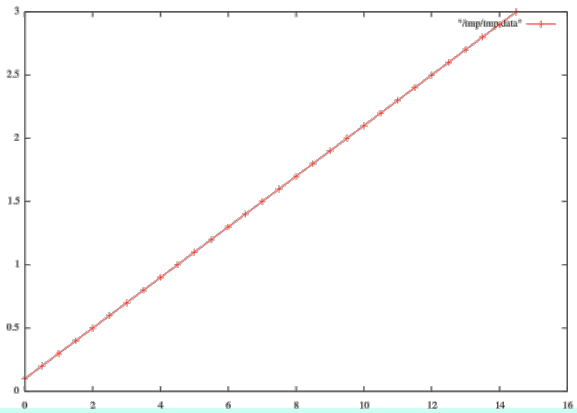


Strongly timed

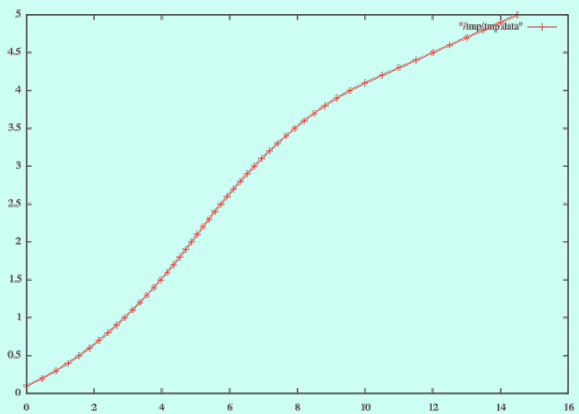


- time transformations are for *Antescofo* what changes of coordinates are for postscript…
- **BUT**
  - time is only spent in real-time
  - time is evenmential and durative
  - time is causal
    (I don't know the transformation in the future)
  - the transformation comes from the environment
    (synchronization)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

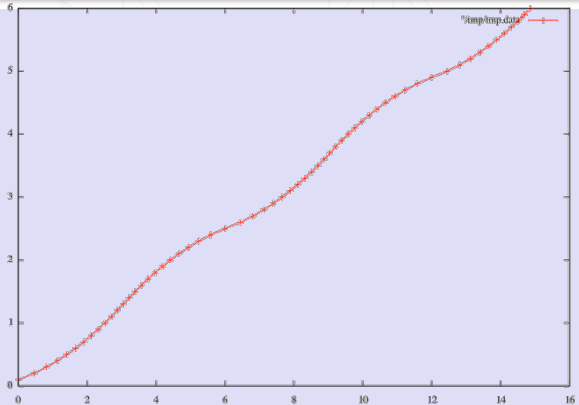
Tempo inheritance



```
@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}
           3     {60} 3 {180} 3 {60} } }
}
```

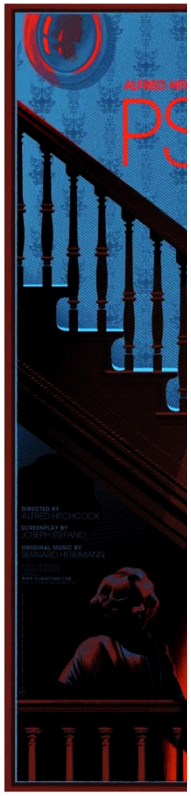


```
        Group G3 @tempo := $t2
        {
                $trace3 := ::Trace()
        }
}
```

POURQUOI UNE MULTIPLICITÉ DE TEMPS EN MUSIQUE?

Striated time and smooth time

Bernard Her



position in beats

time in secondes

```
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
```

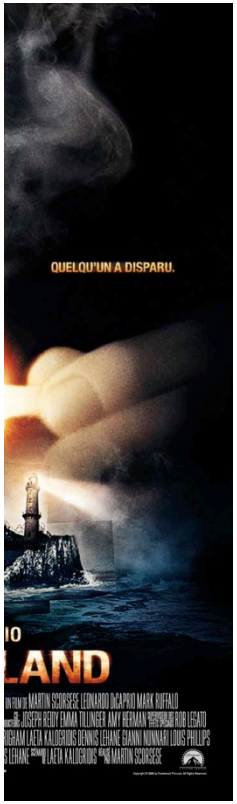
```
NOTE 60 2.0
 group @tight
 {
   a1
   1.0 a2
   1.0 a3
   1.0 a3
   1.0 a4
 }
NOTE 60 1.0
NOTE 60 1.0
NOTE 60 1.0
```

```
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
```

event+tempo
actions
musician time estimation
target

ano (1967)



Dynamic Target

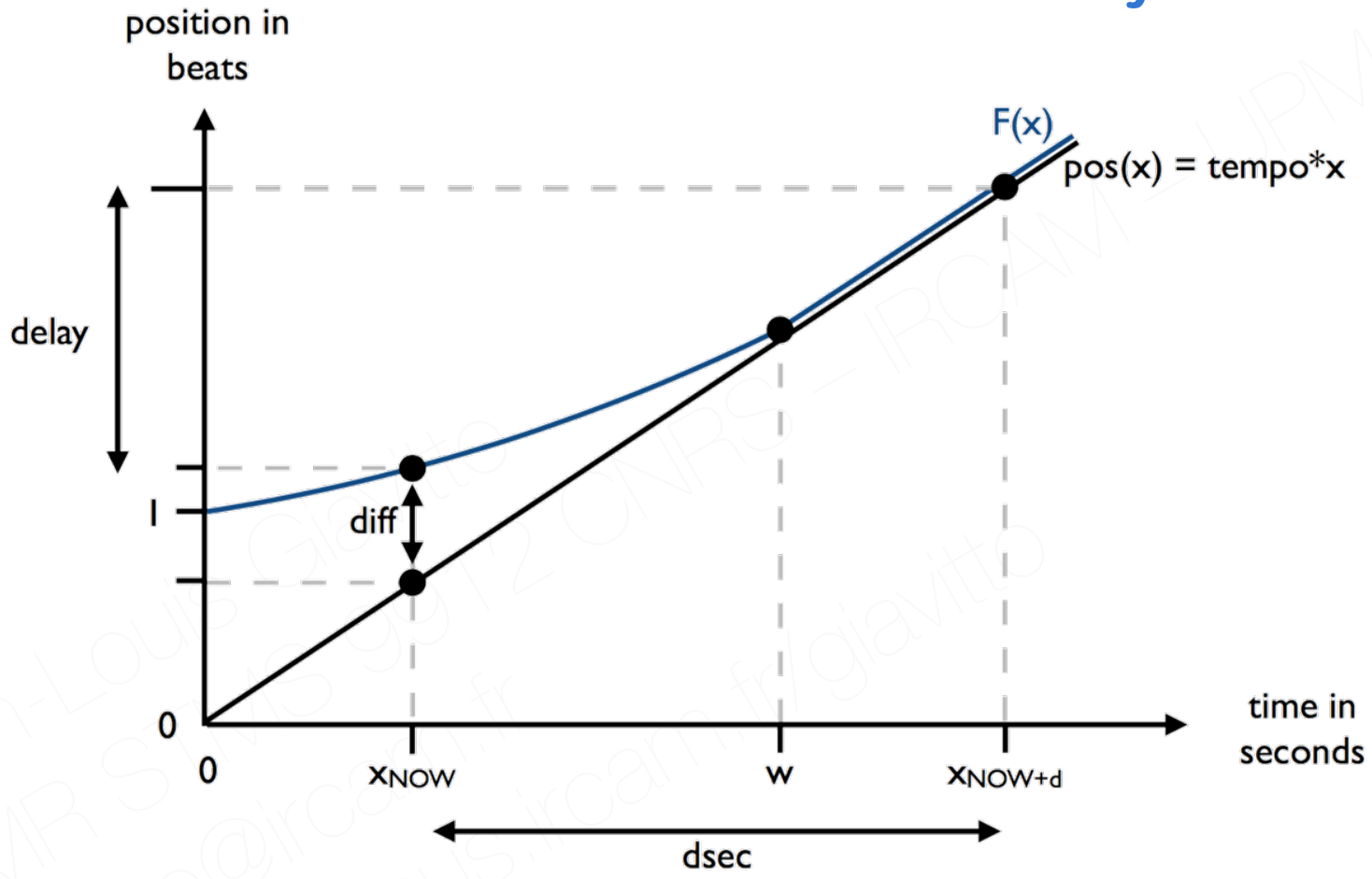
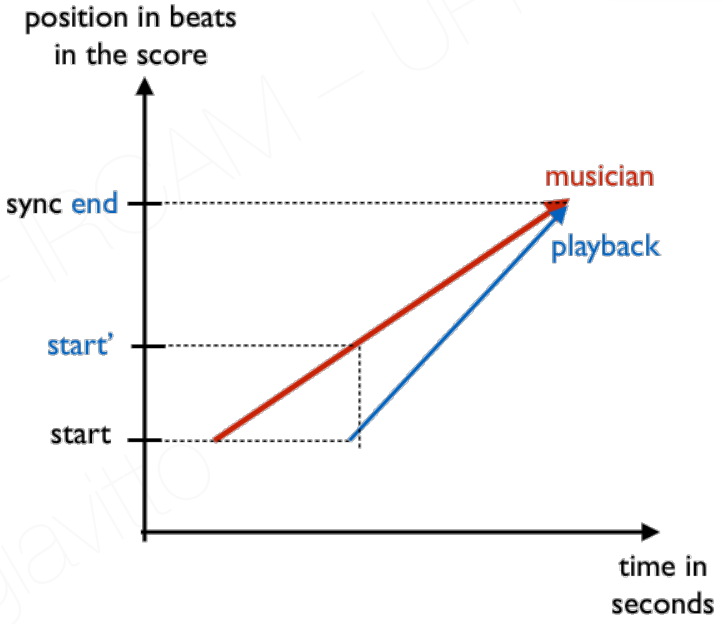
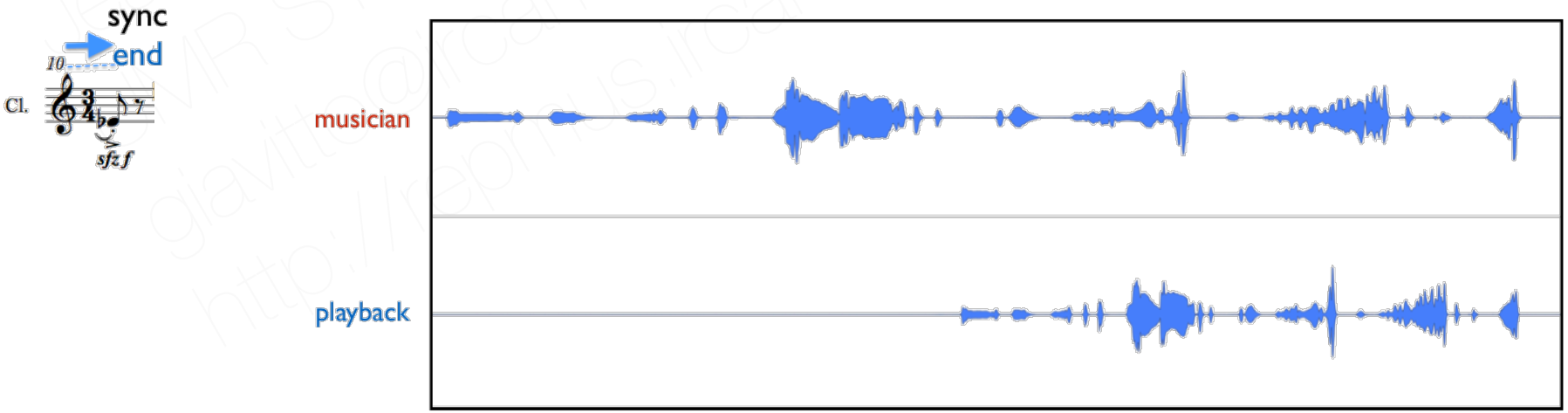


Fig. 10. Method used to compute a duration $dsec$ in seconds corresponding to a delay $delay$ in beats with a dynamic target $[w]$ and with a initial difference of position $diff = \tau.beatPos - position$. Function F represents the position in τ as a function of time x. It is made of two parts: a part 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 $diff$.

Christopher Trapani

real-time rythmic canon à la Nancarow





Christopher Trapani

real-time rythmic canon à la Nancarow

SCORE in C

3 DEC

Sketch — ~~7 Nov~~ 2012

CHRISTOPHER TRAPANI

X markers to be placed by Antescofo

X possible convergence points

1 -> A 3/5

ca. ♩ = 108

Clarinet in B♭

gliss.

'pizz.'

1B

1B -> A

point d'entrée défini

3 -> D 7/11

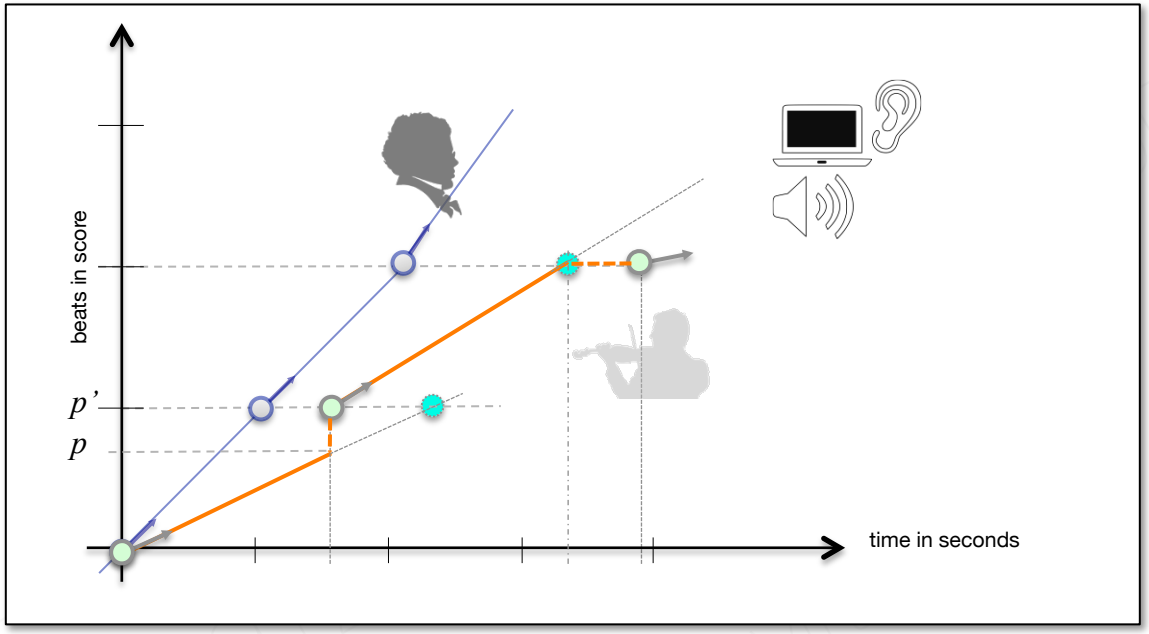
2 -> B point d'entrée défini

1B -> A point d'entrée défini

tongue -slap

gliss.

Cl.



FUNGIBLE TIMES
OR
INCOMPARABLE TIMES ?

One second per second

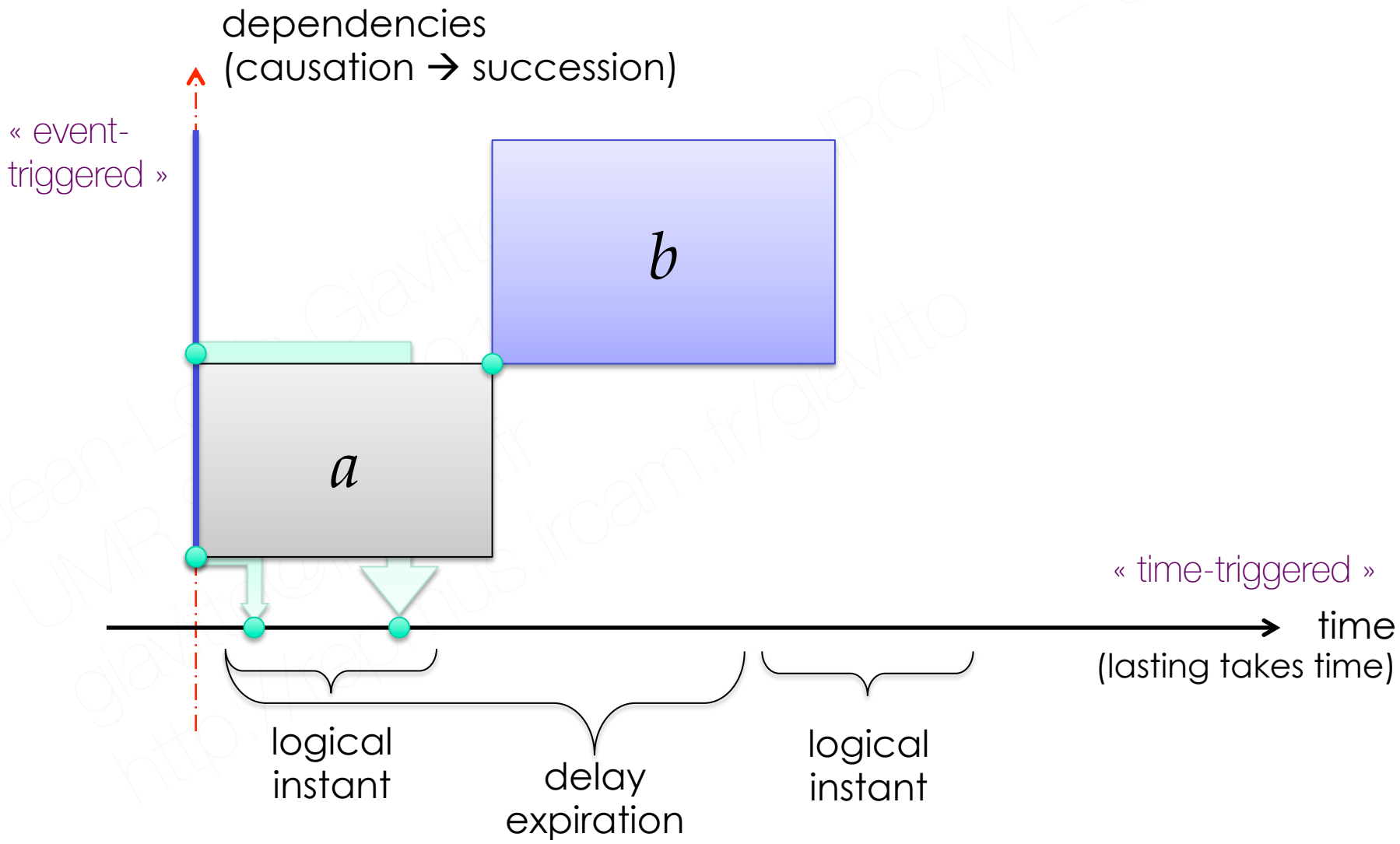
€ $

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

- shared events are not enough:
  duration is not reducible to instants
  - halving a duration
  - accelerando
  - *phrasé* (ex. rubato)
- the "conversion rate" changes in time and is known "after". The conversion rate is *established with the weaving of time itself*.
  - A-series et B-series,
  - "out of time" ("deferred 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

PASSAGE DU TEMPS ET CAUSALITÉ

The passing of time: causality & duration

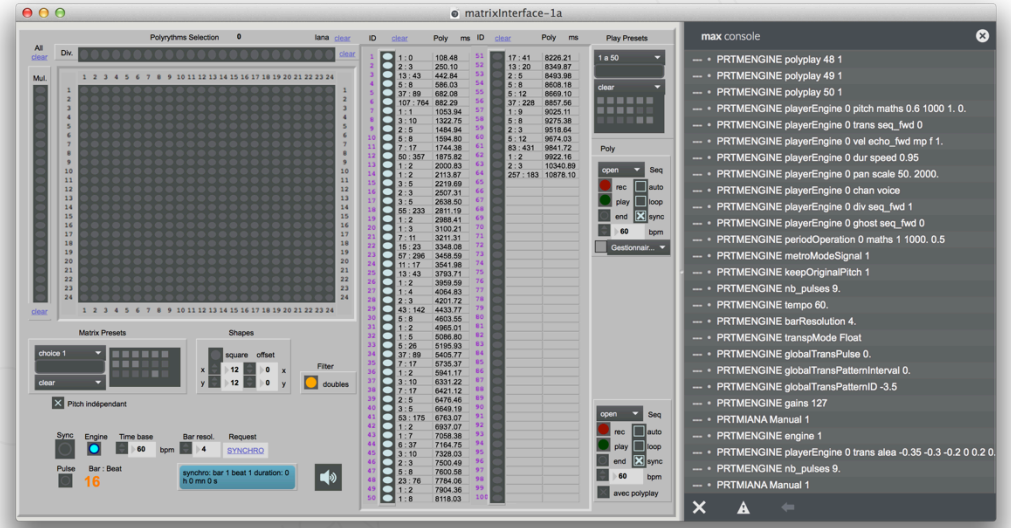


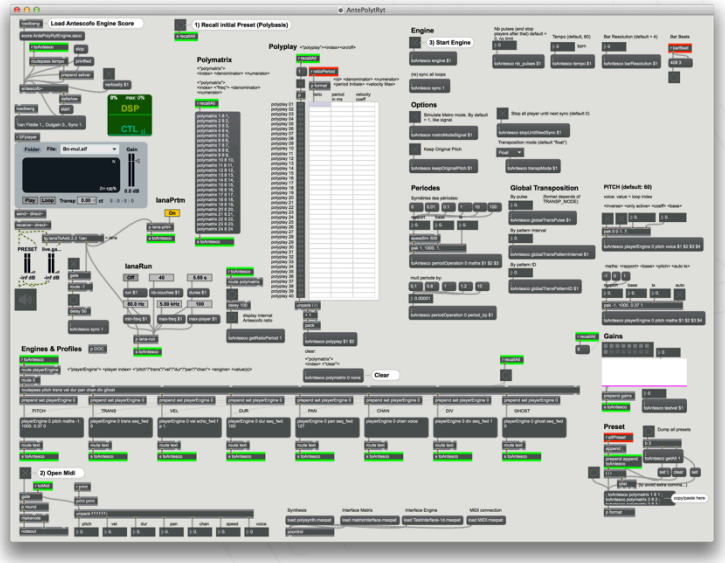
Some other Artistic Applications

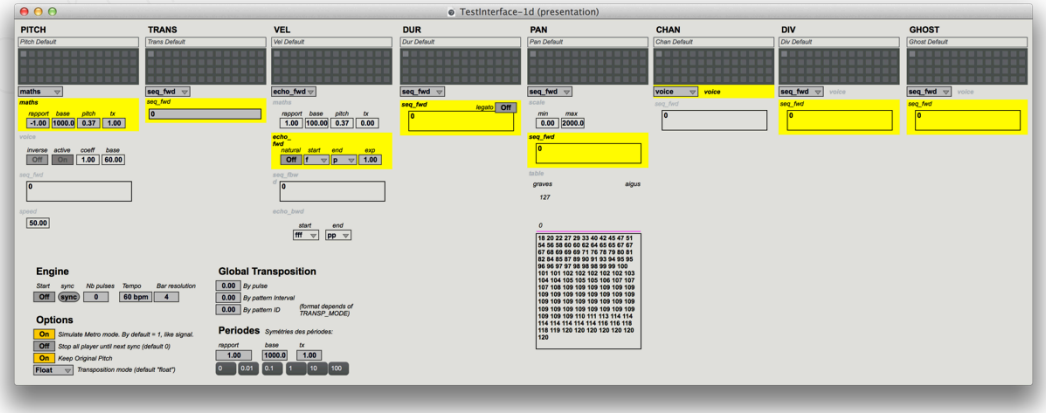
A glimpse into Yan Maresz

POLYRHYTHMIC MACHINE

Yan Maresz *Polyrhythmic machine* in Antescofo







An polyR object

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

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
}
```

An polyR object

```
@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

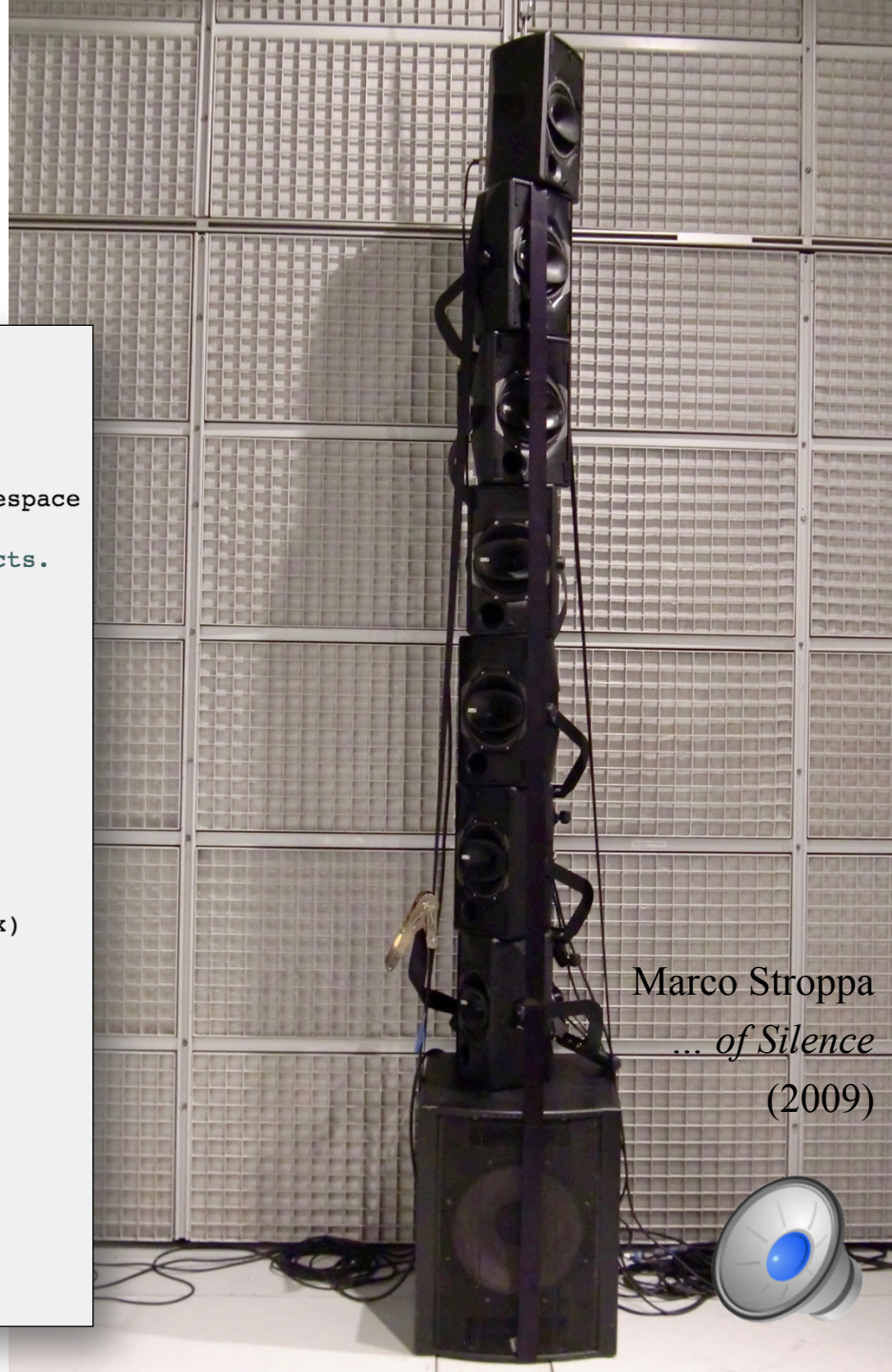
```
@fun_def nothing($obj, $val) { return $val }


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
```

Trace of a program execution

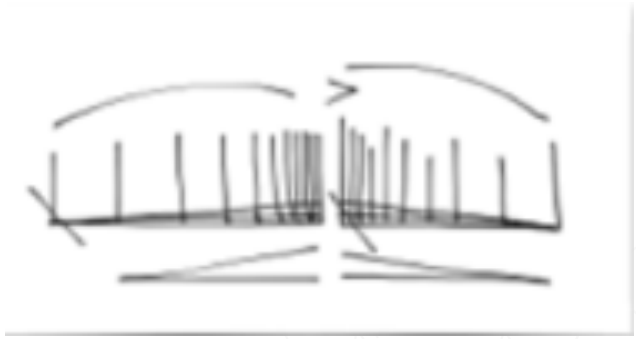
```
print start `4 0.0
print "start L" 6.0
toMidi 60 50 6.0
toMidi 60 50 8.0
toMidi 60 50 10.0
print "start L" 12.0
toMidi 60 50 12.0
toMidi 60 50 14.0
print changePitch
toMidi 66 50 16.0
print "start L" 18.0
toMidi 63 50 18.0
print changePeriod
toMidi 59 50 20.0
toMidi 55 50 22.0
print "start L" 24.0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

Marco Stroppa
Antescofo library for Totem control

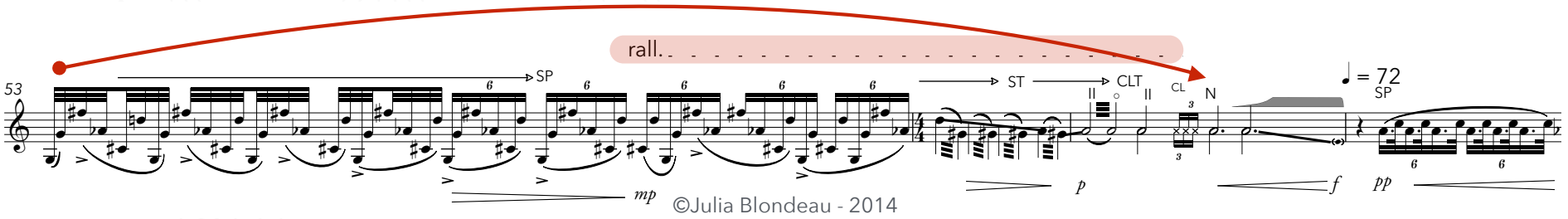
```
; SOURCE Object Definition

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



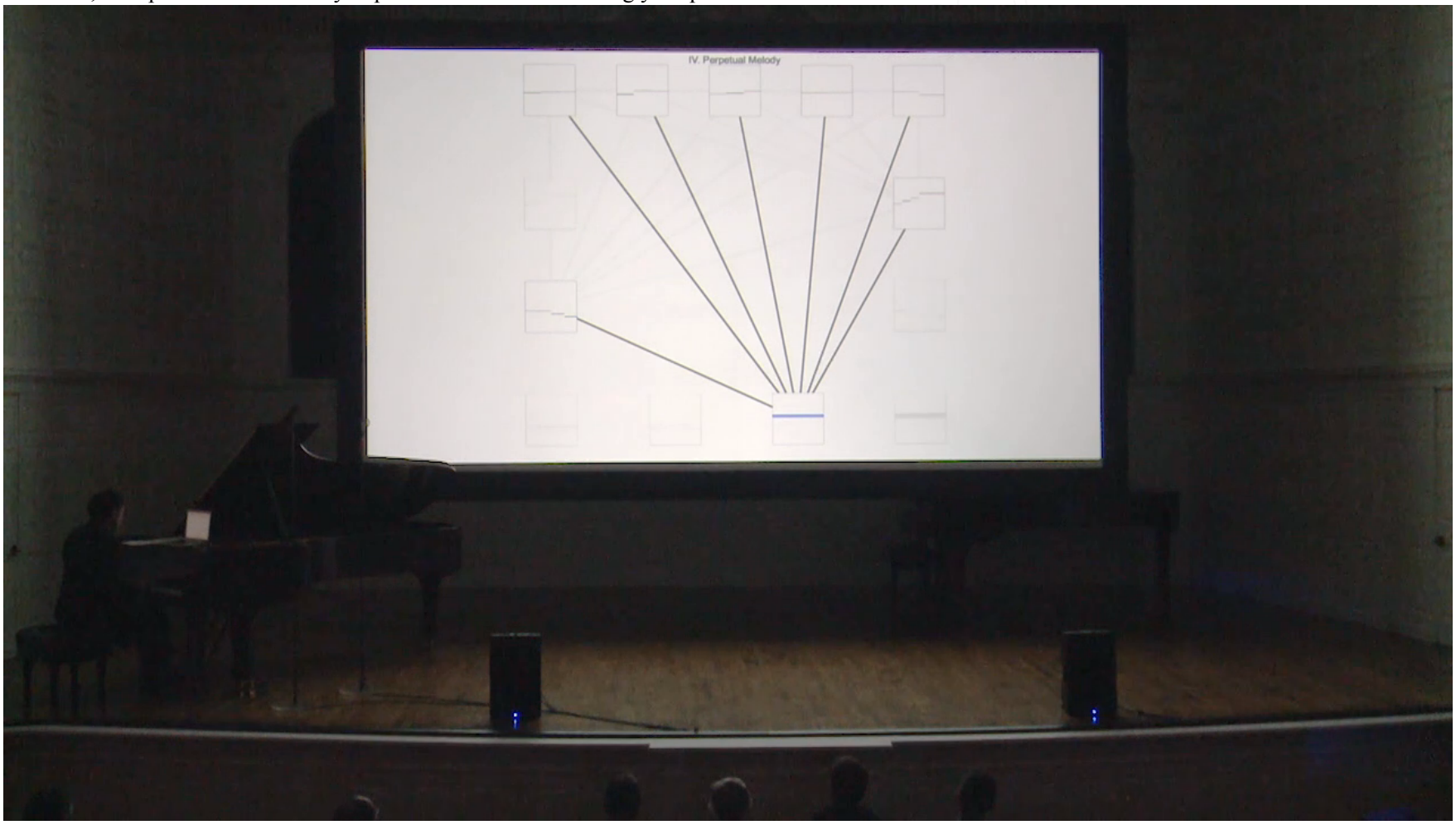
Jason Freeman (GeorgiaTech)

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.



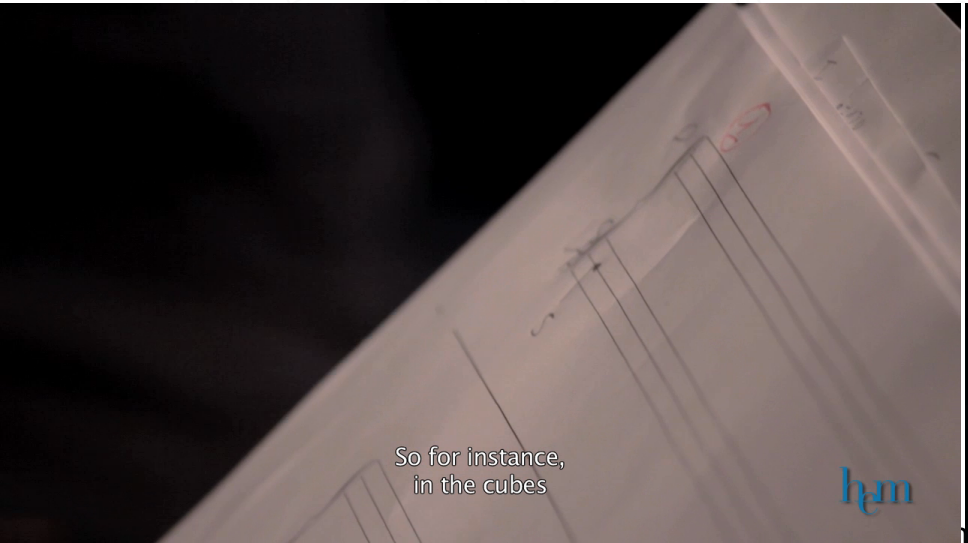
José-Miguel Fernandez
gesture-driven synthesis

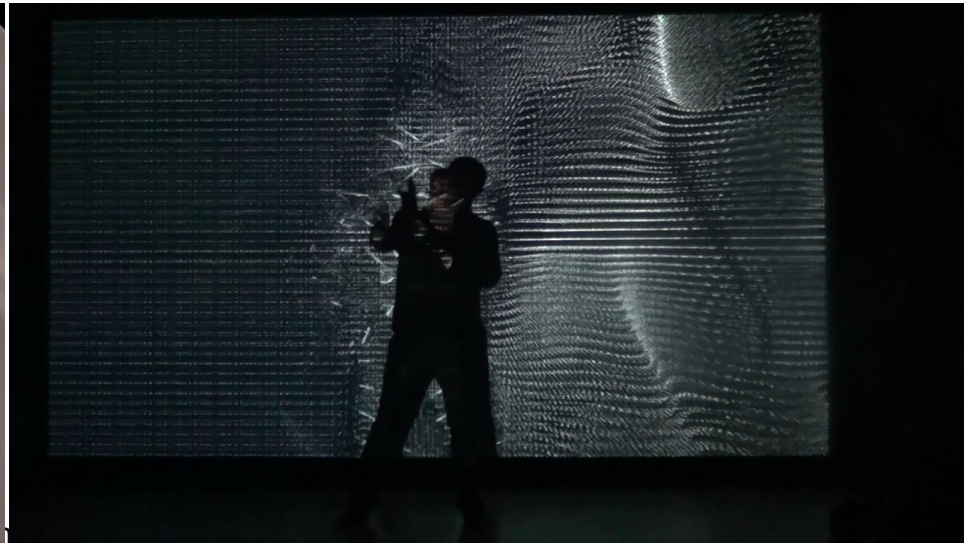
OSC *or* setvar

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

Haute école de musique Genève

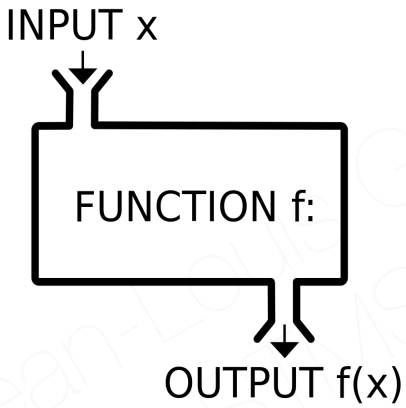
Hypersphère, Jose Miguel Fernandez,
séance de travail IRCAM 26/2/16

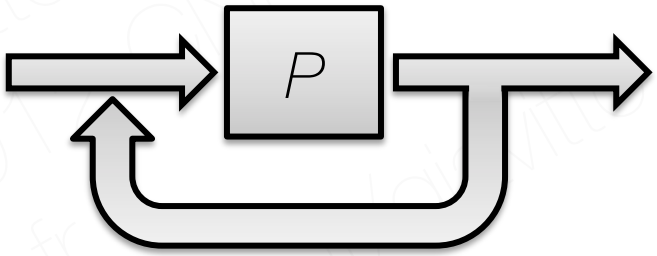




FINAL REMARKS

Computation:
function, process, *interaction*





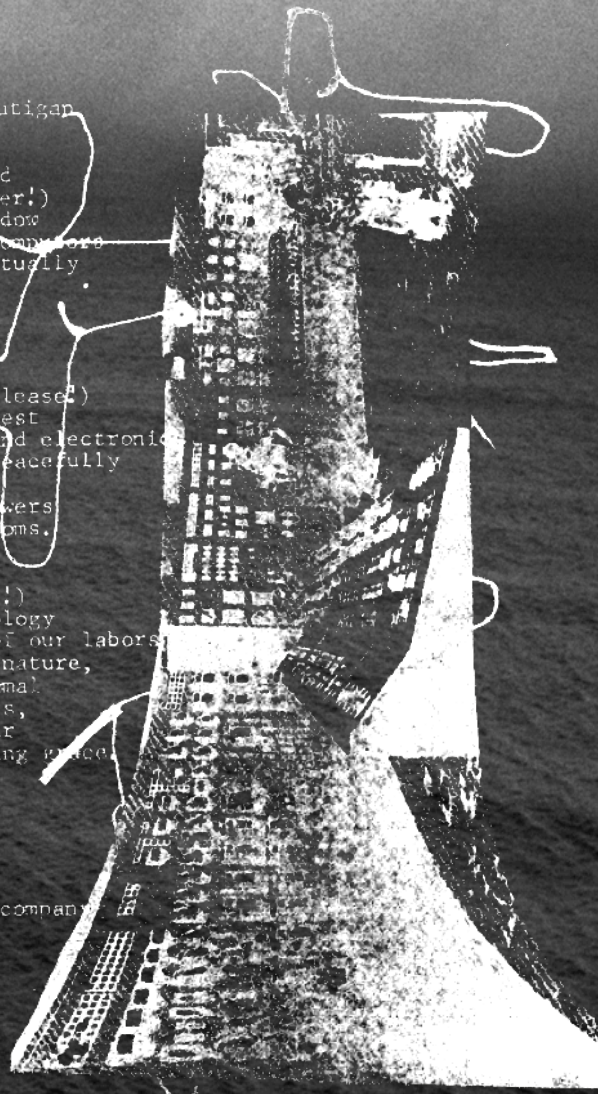
All Watched Over By Machines of Loving Grace

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.

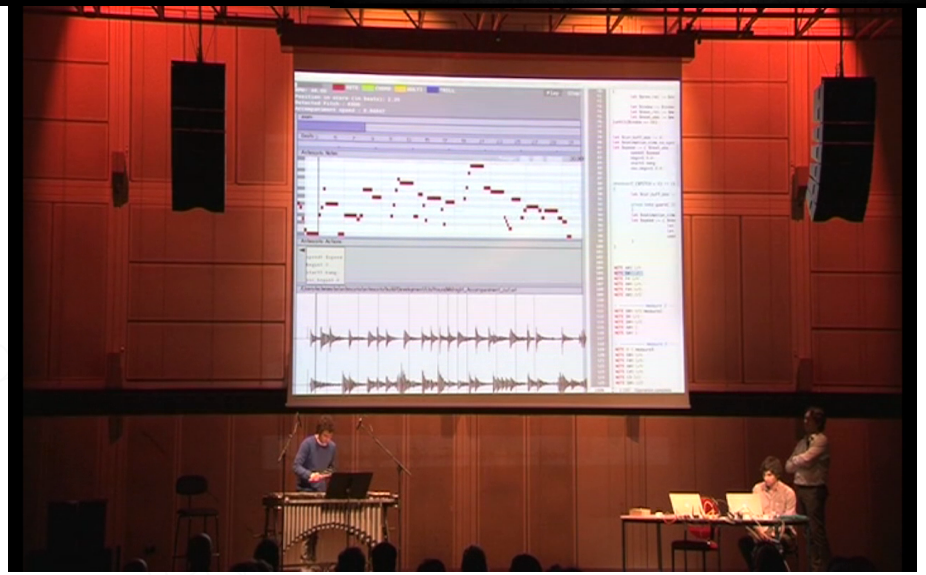
I like to think
(right now, please!)
of a cybernetic forest
filled with pines and electronics
where deer stroll peacefully
past computors
as if they were flowers
with spinning blossoms.

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

Towards Greater Public



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

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- GRAME (Lyon) ...
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