Inria's Junior Seminar

Model-Based Testing of an Interactive Music System

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UMR SMTS 9912

Mutant Team

Team leader: Arshia **Cont**

3 permanents and 3 Phd students

Realtime Recognition and Extraction of musical data from audio signals.

Realtime Synchronous Programming in Computer Music.

Publications http://repmus.ircam.fr/mutant/publications

UMR SMTS 9912

INEDIT project

Outline

Introduction

- Antescofo an Interactive Music System
- A Model-Based Testing application

A running method for testing

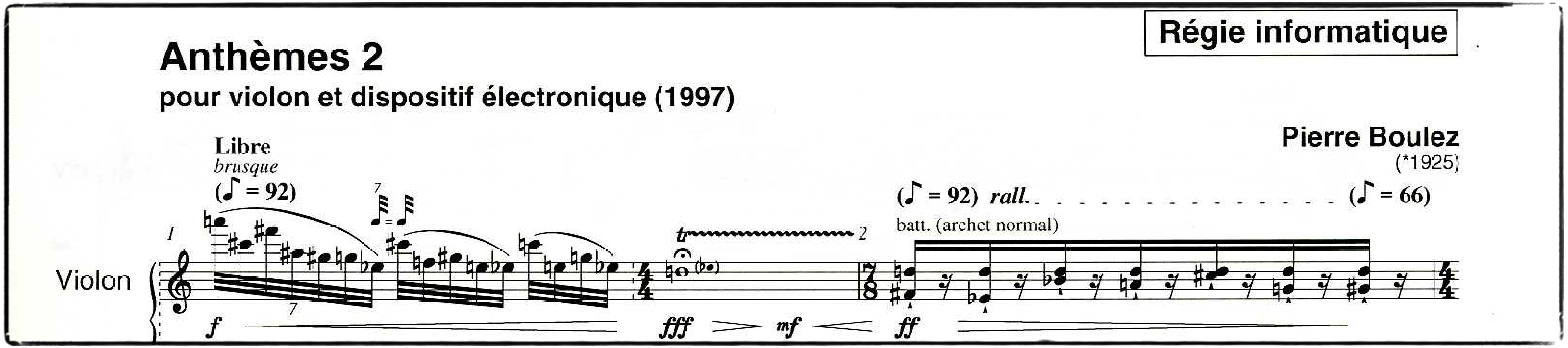
- Offline and Automatic timed conformance Testing
- An IMS Model: The Intermediate Representation

Conclusion

- Conclusion & Future works

Instrumental Music

A play between the composition and the performance time



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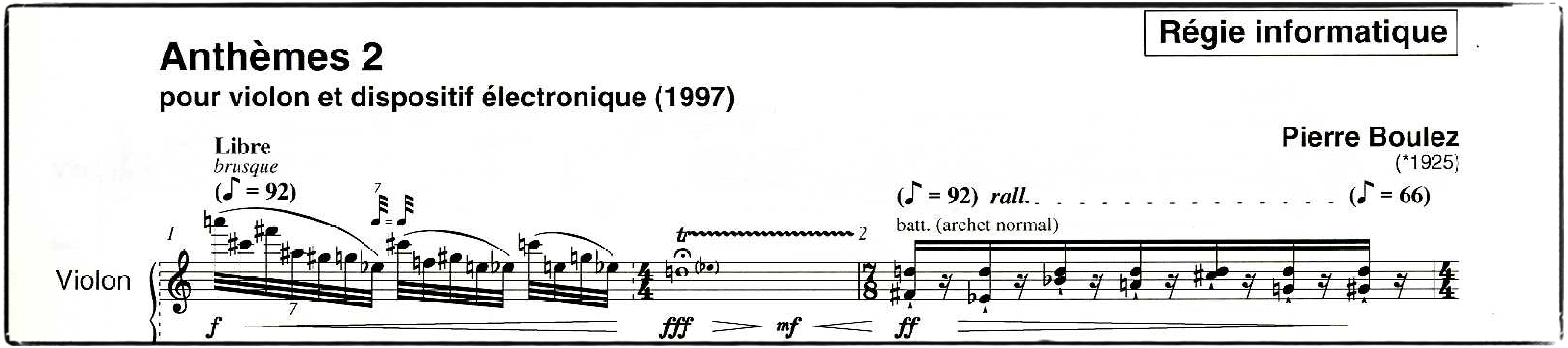
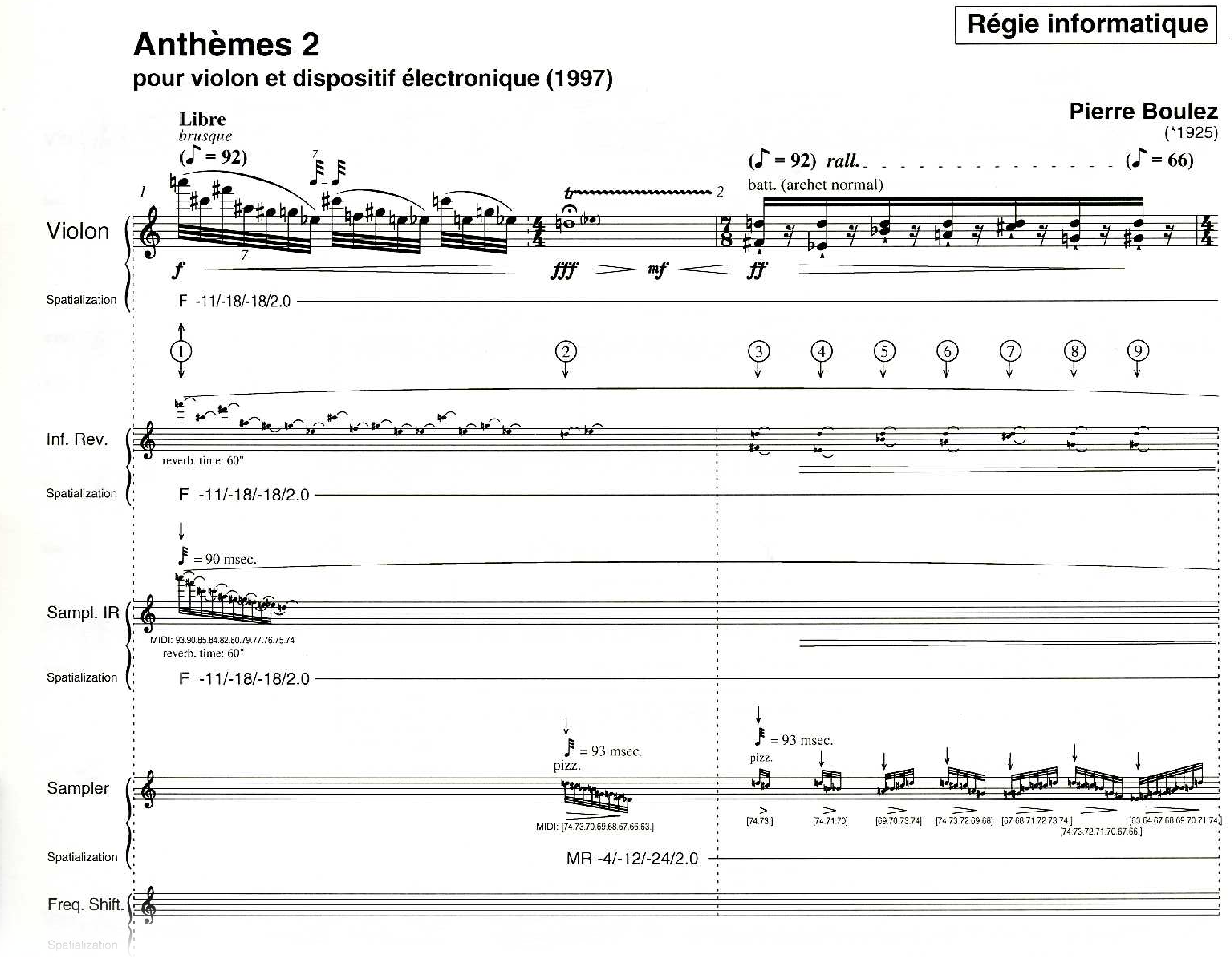
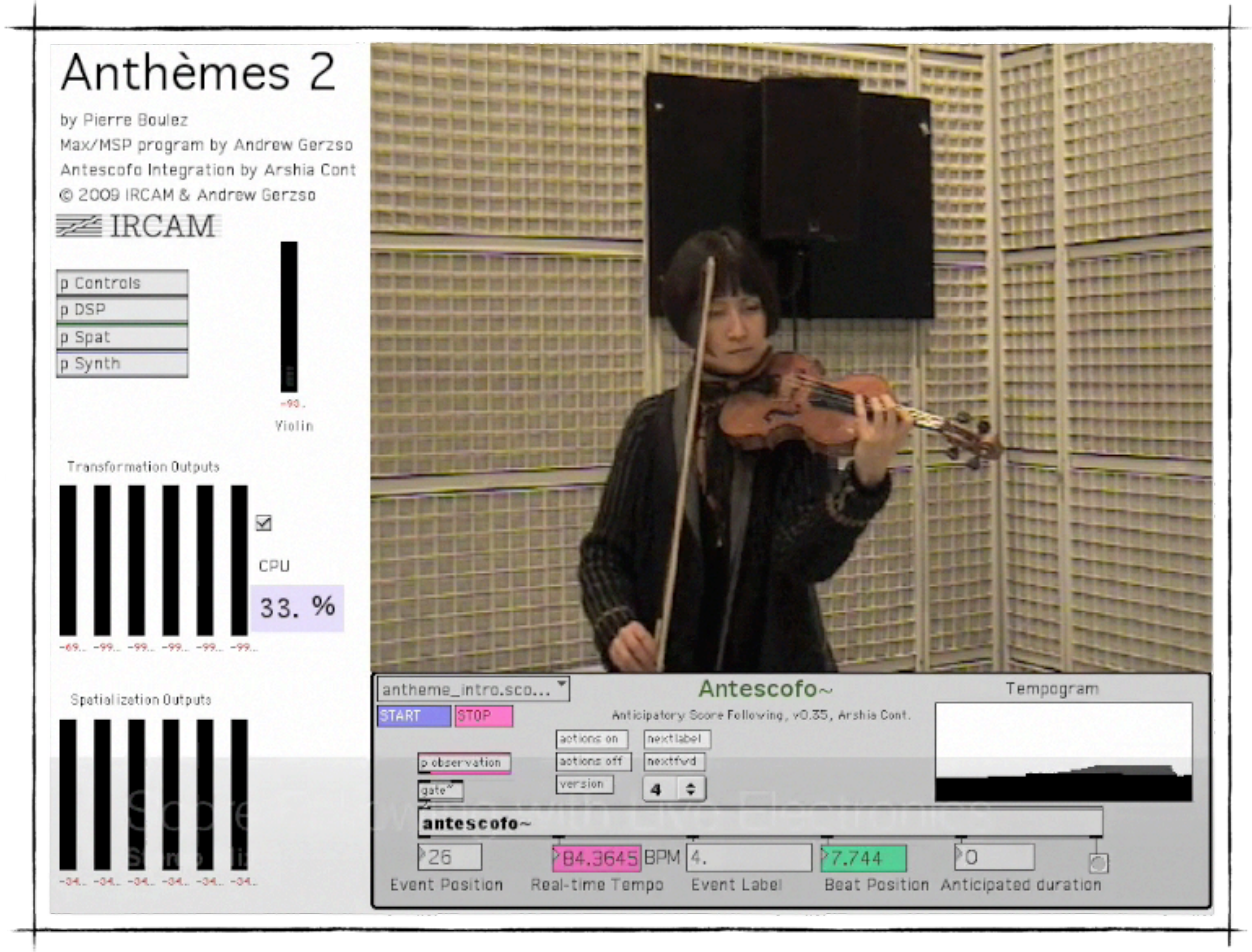


Mixed music

realtime interaction between acoustic and electronic instruments





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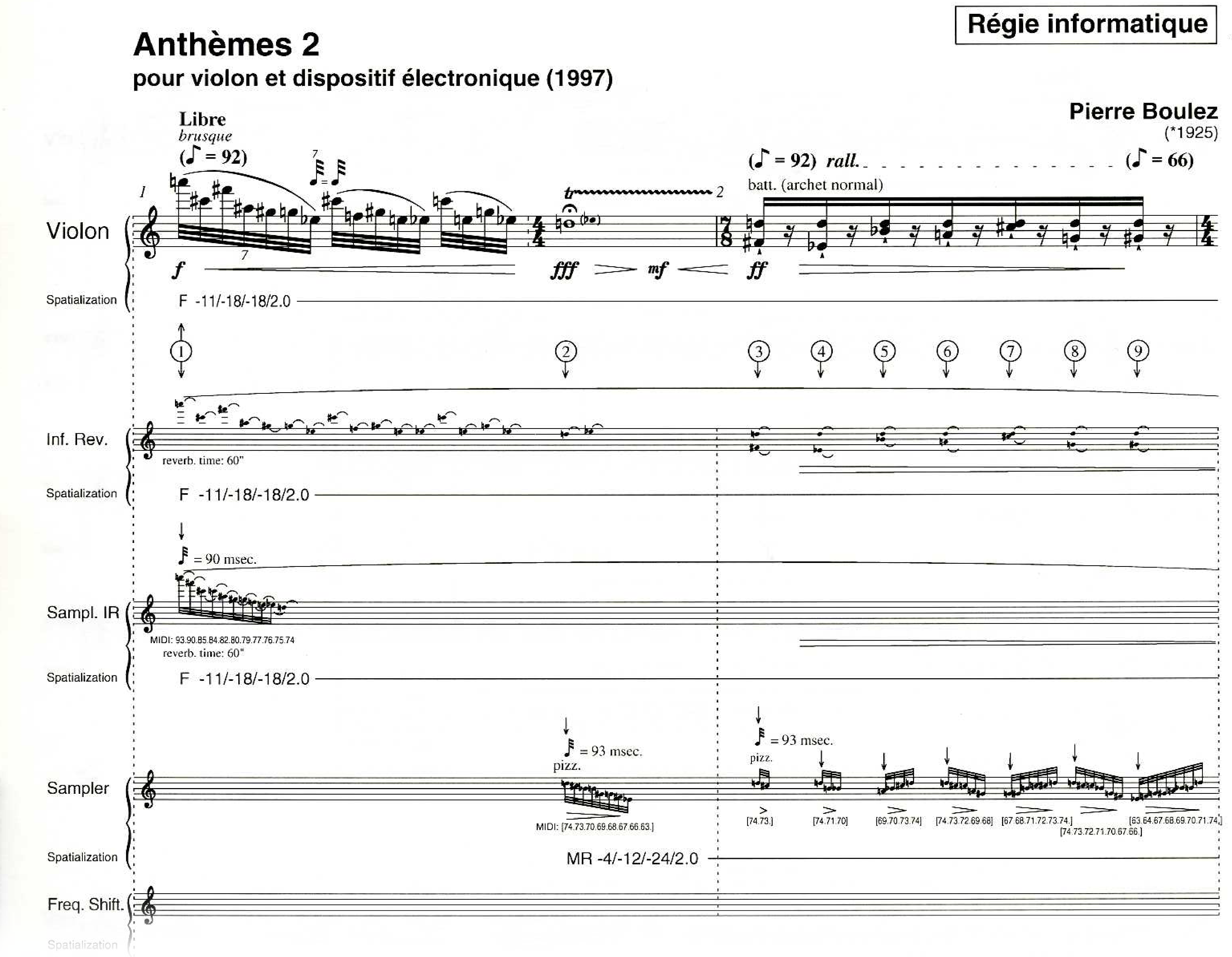
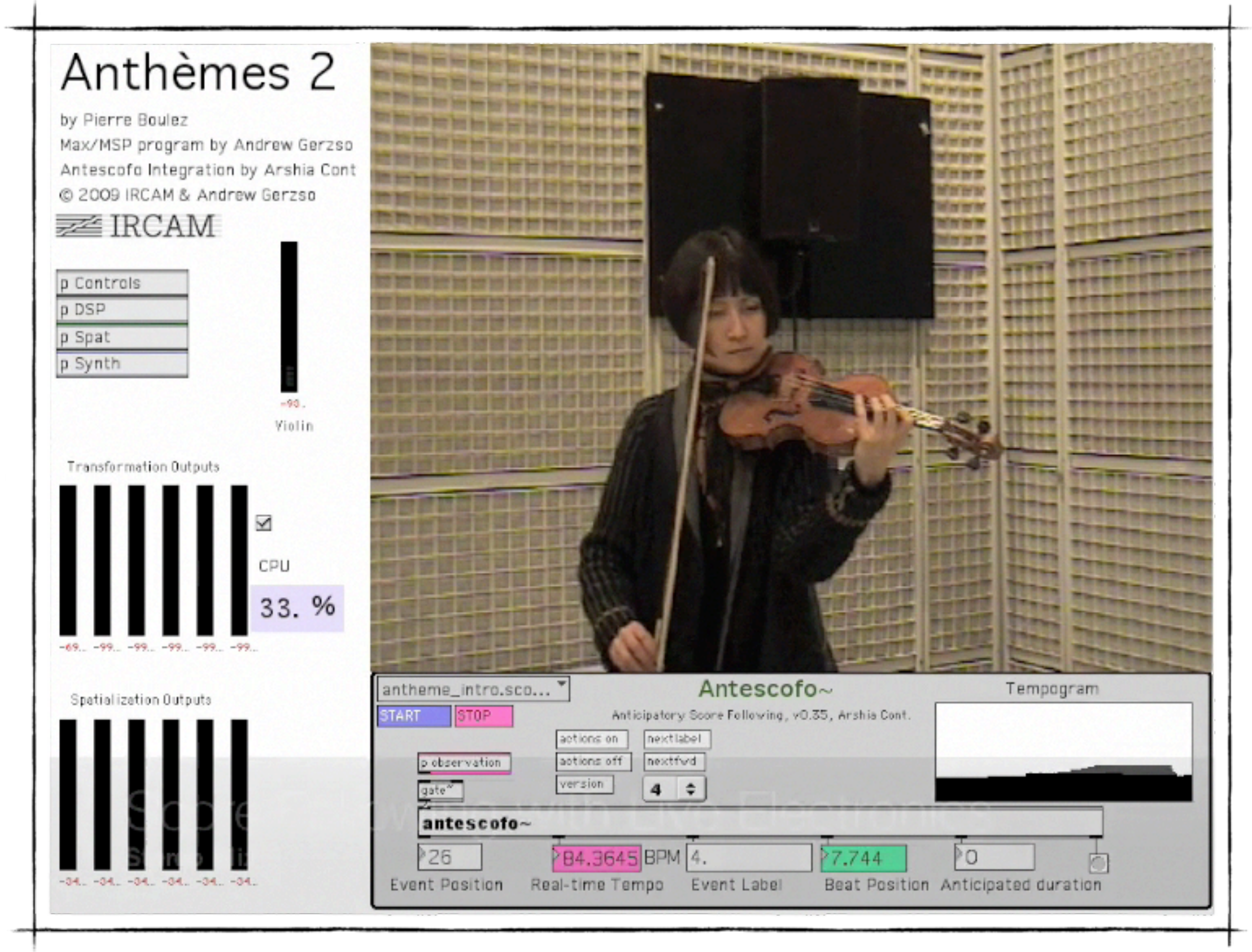
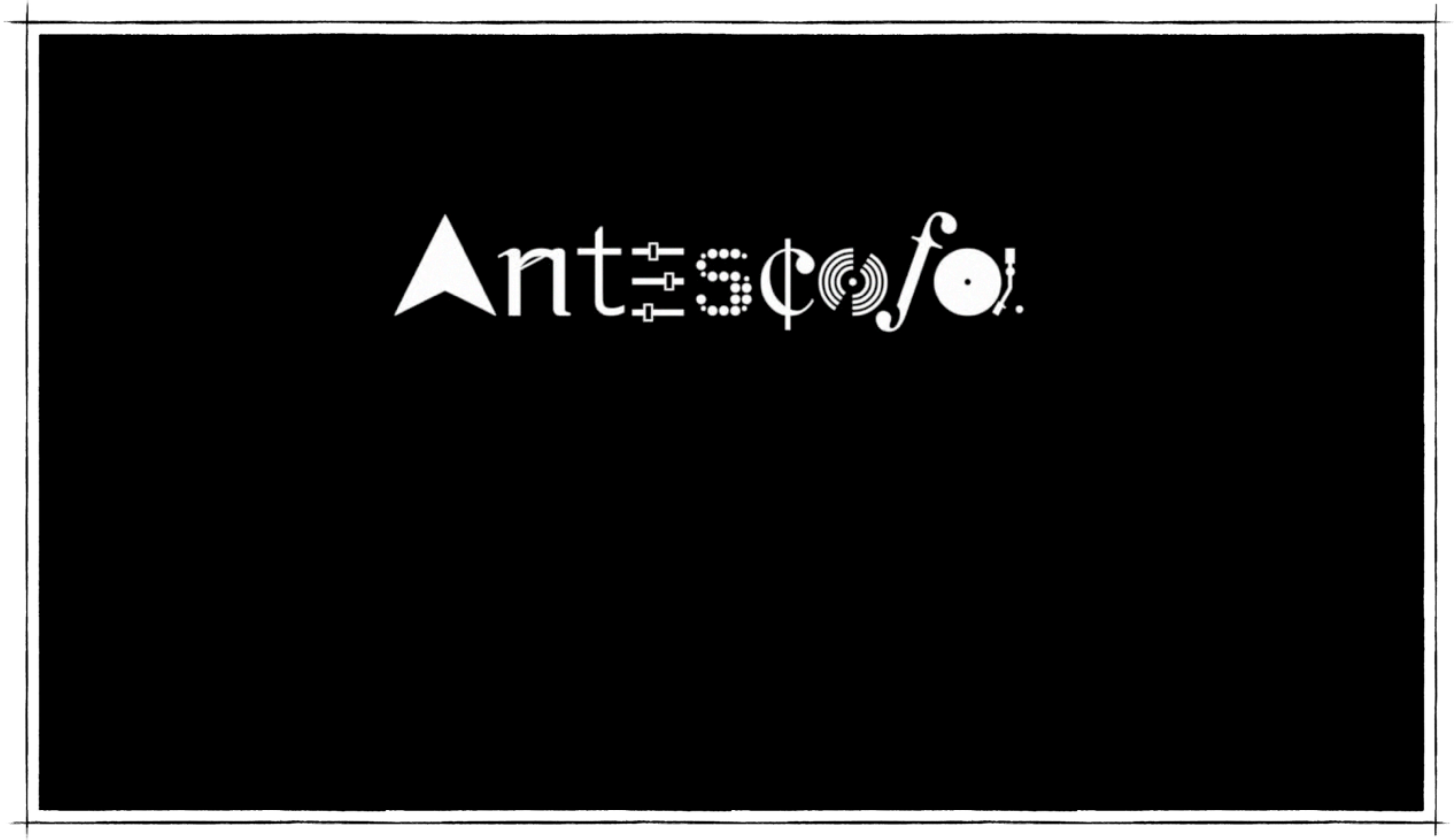




Automatic Accompaniment

polyphonic score following and audio accompaniment



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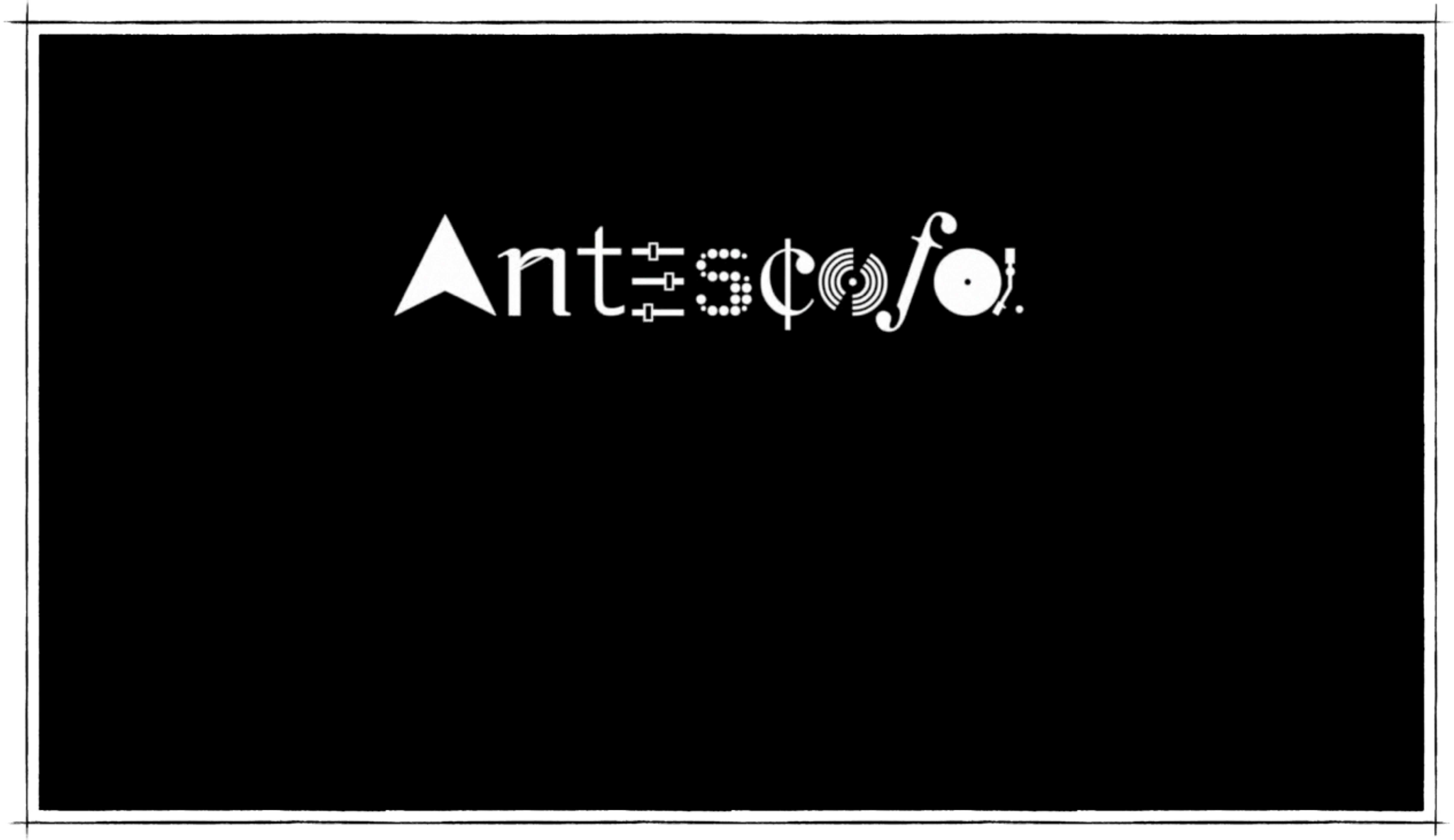
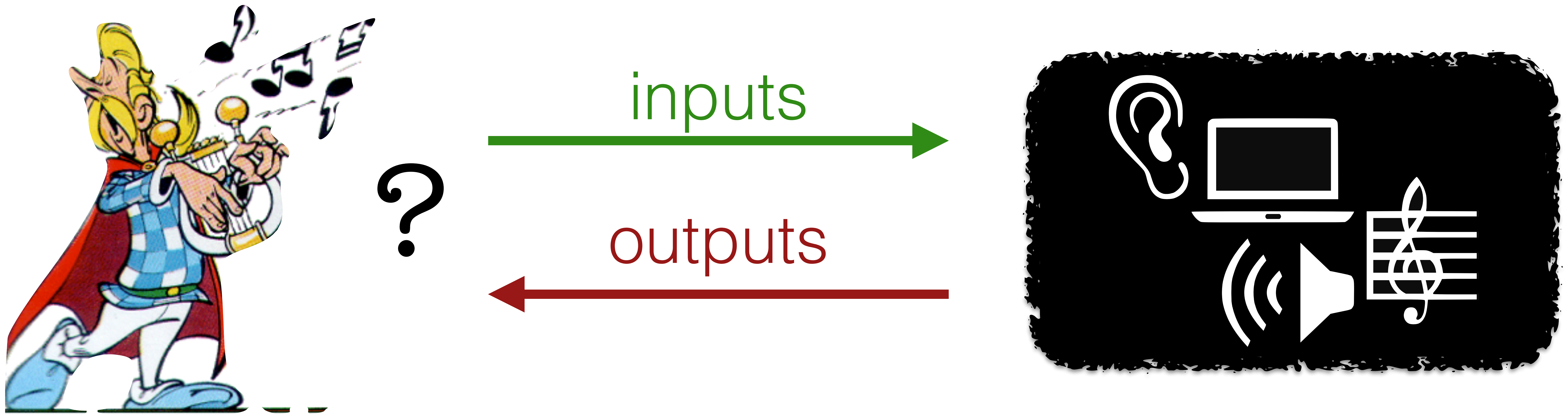


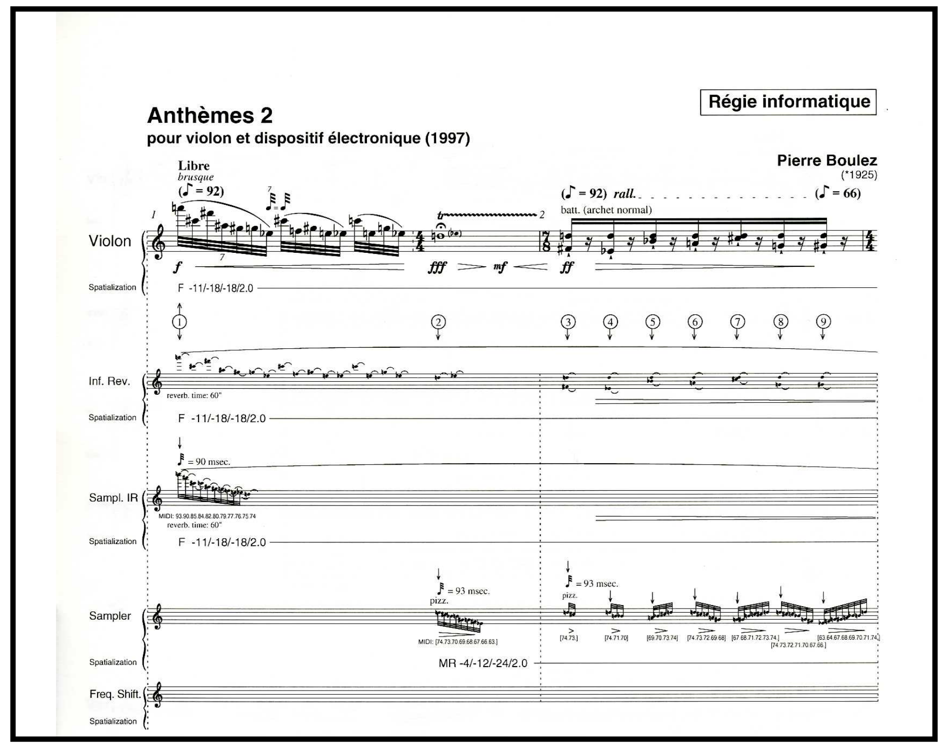
IMS

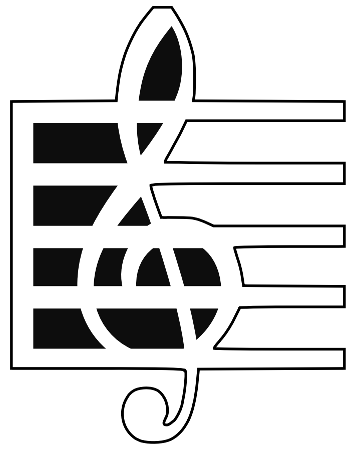
Unpredictable inputs



Hardly Timed reactions

Antescofo an Interactive Music System





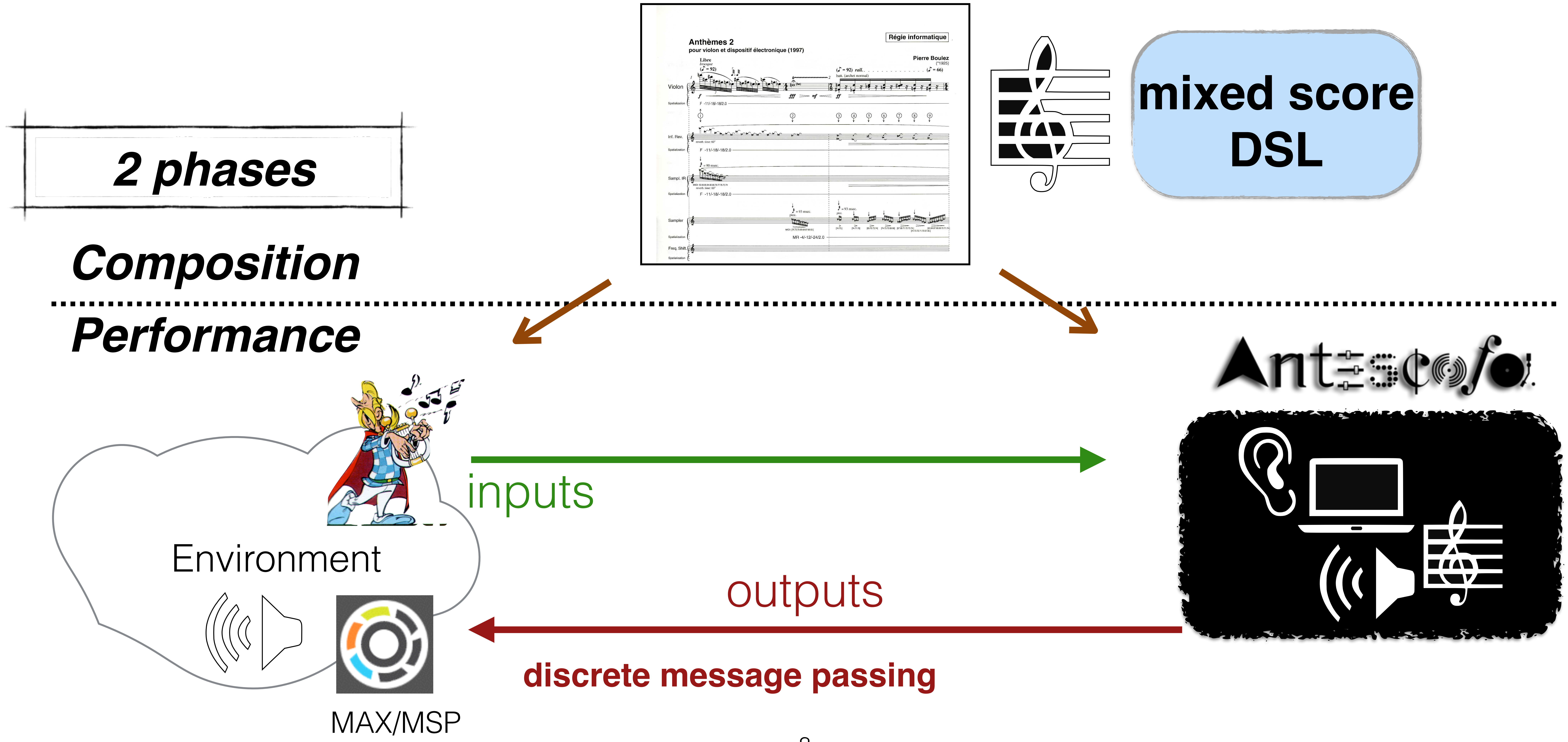
mixed score DSL

2 phases

Composition

Performance

Antescofo an Interactive Music System



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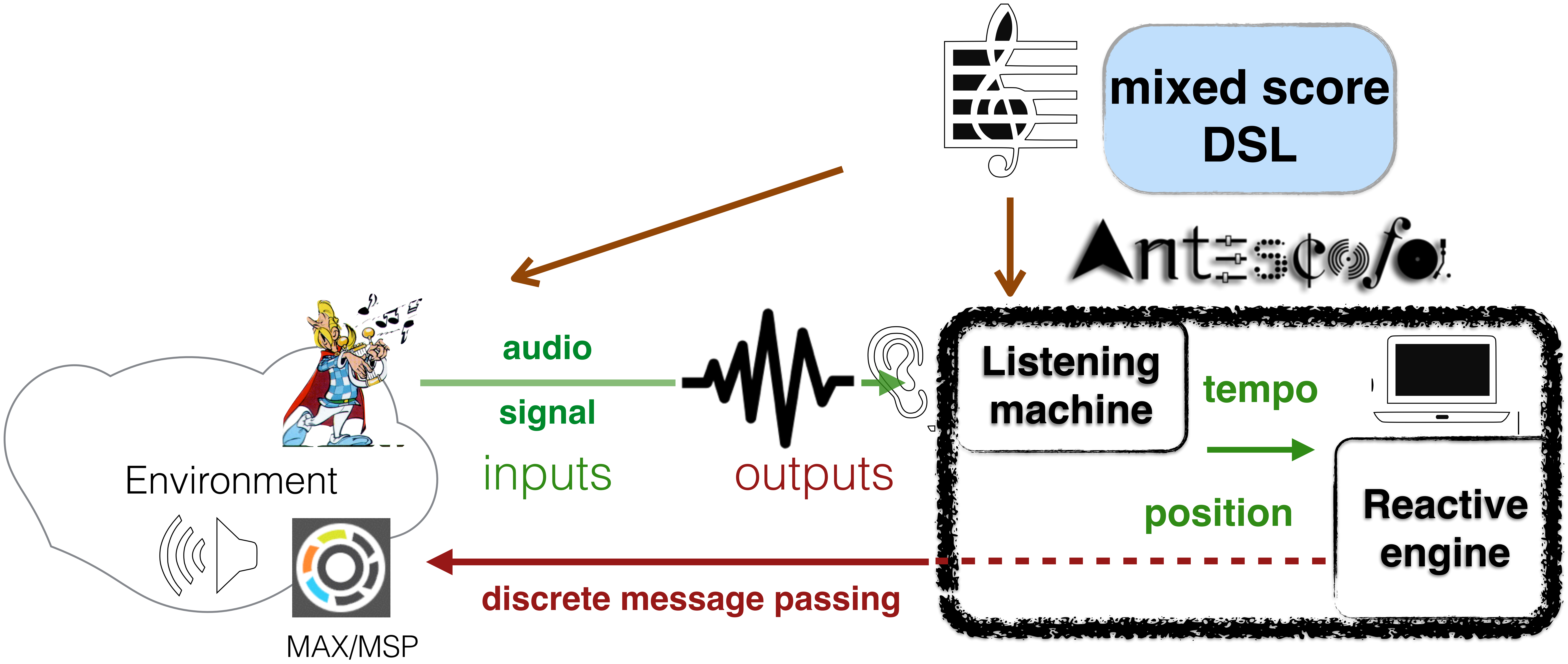
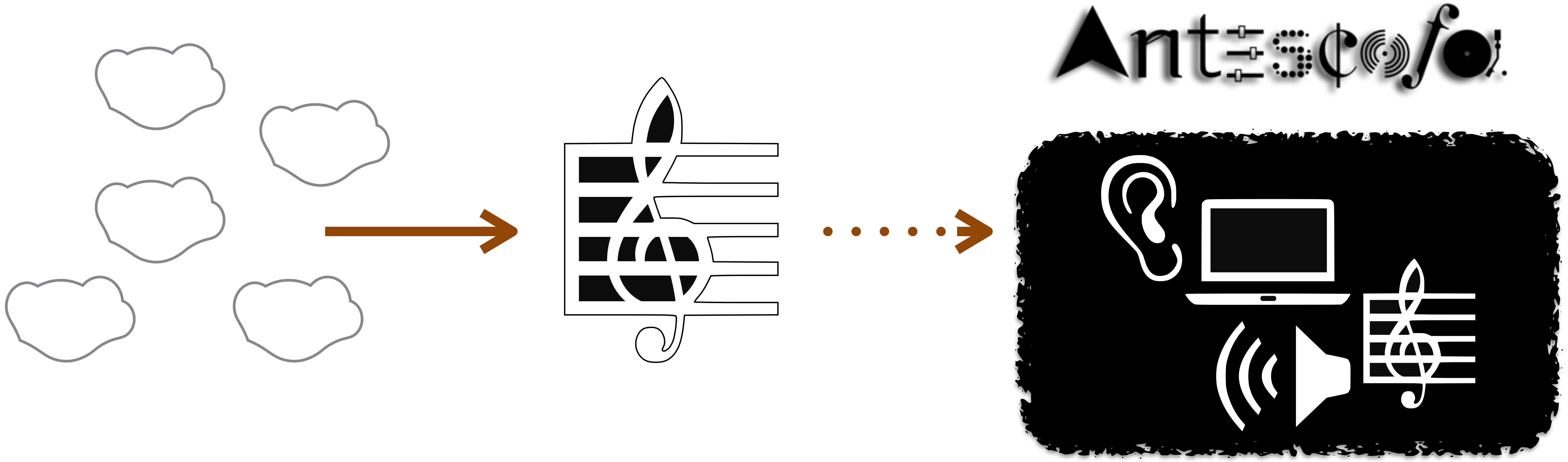


Piece creation



Ideas

Score

…

Concert ?

Testing a piece

Prepare the IMS for a concert

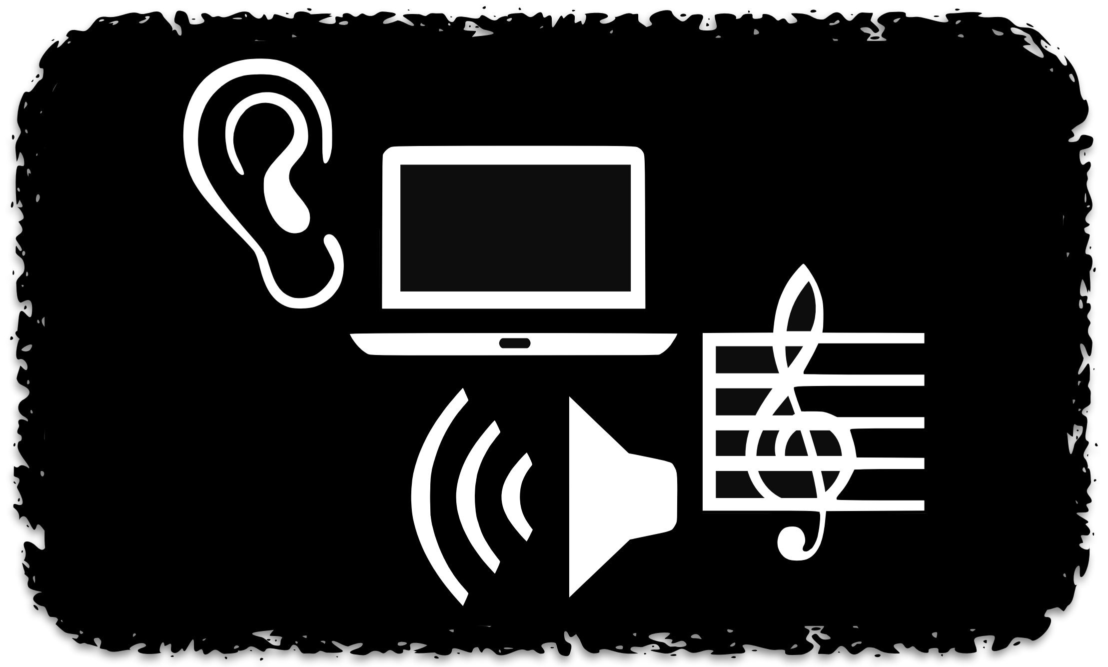
realtime

interpretation

rehearsal

human checking
of outcome

Antescofo



no time for debugging!

Testing a piece

Prepare the IMS for a concert

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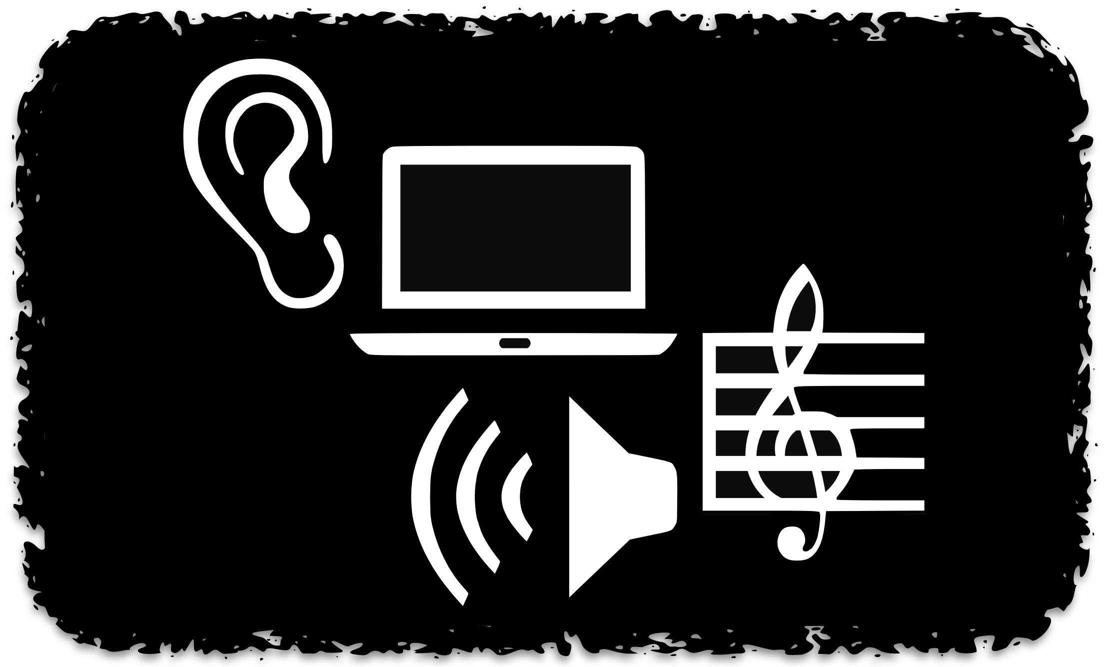


Manual method

Test for one performance

Tedious (perform the whole piece)

Not precise

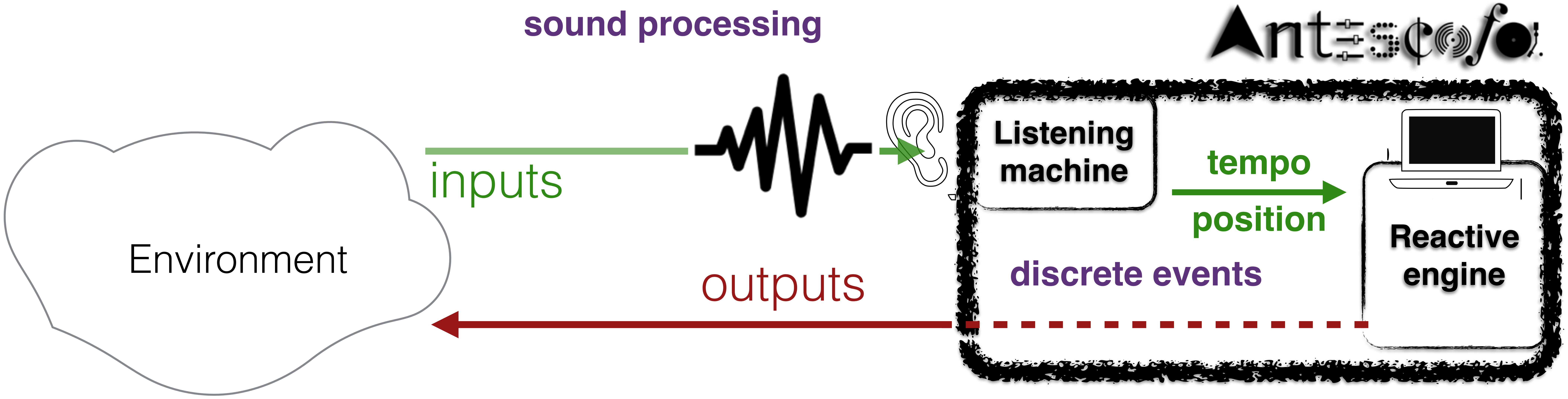
Model Based Testing

Covering generation

Automatic and Virtual Clock

Formal (accurate and informative)

Model Based Testing Antescofo



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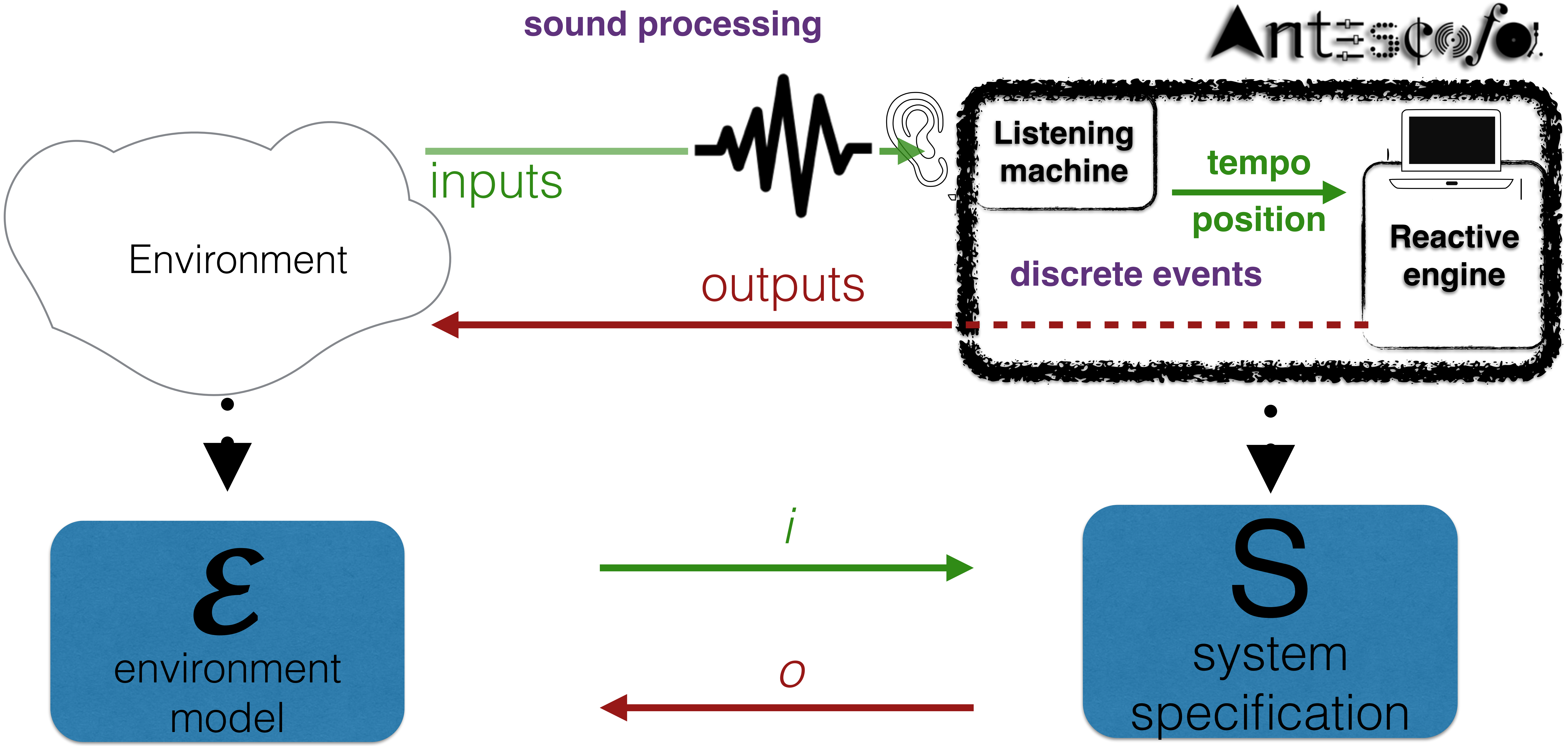

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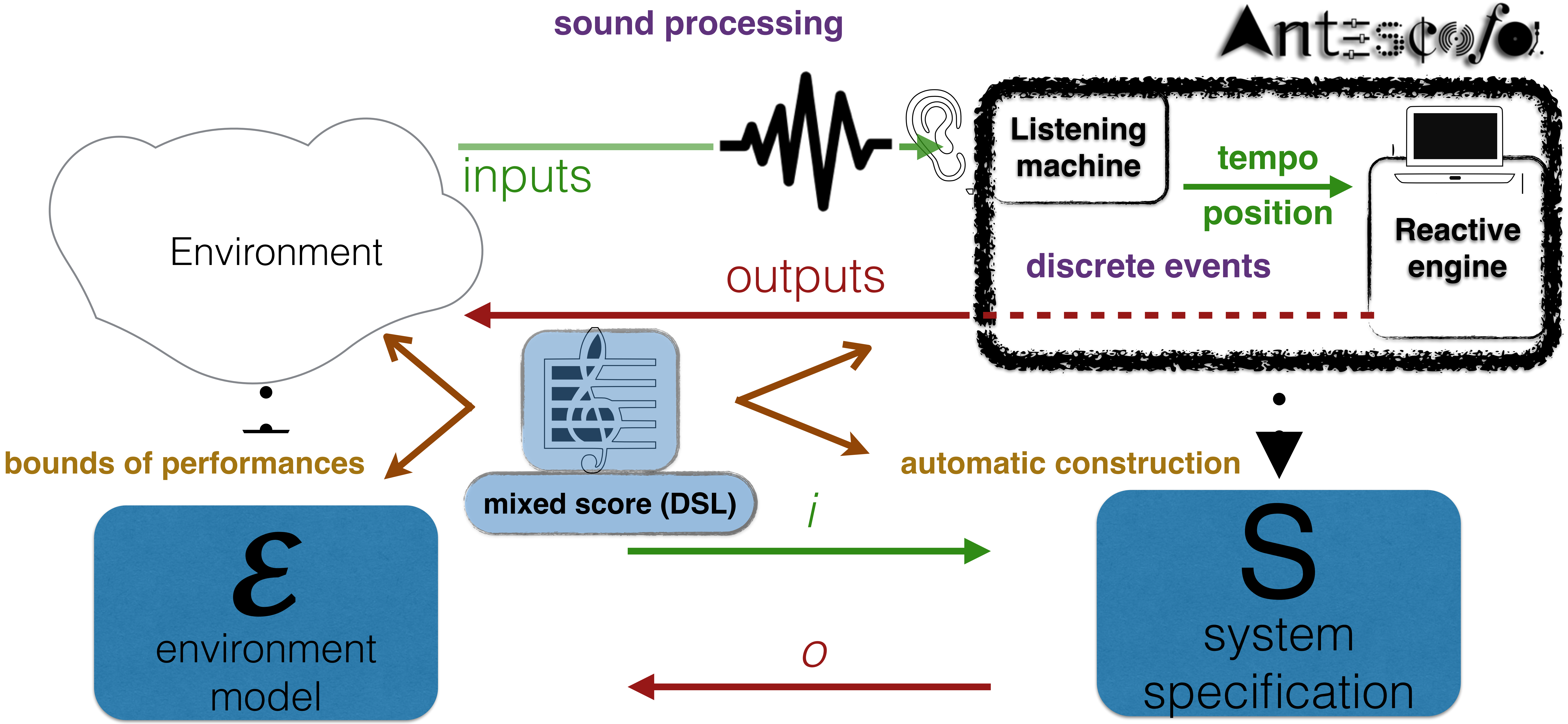

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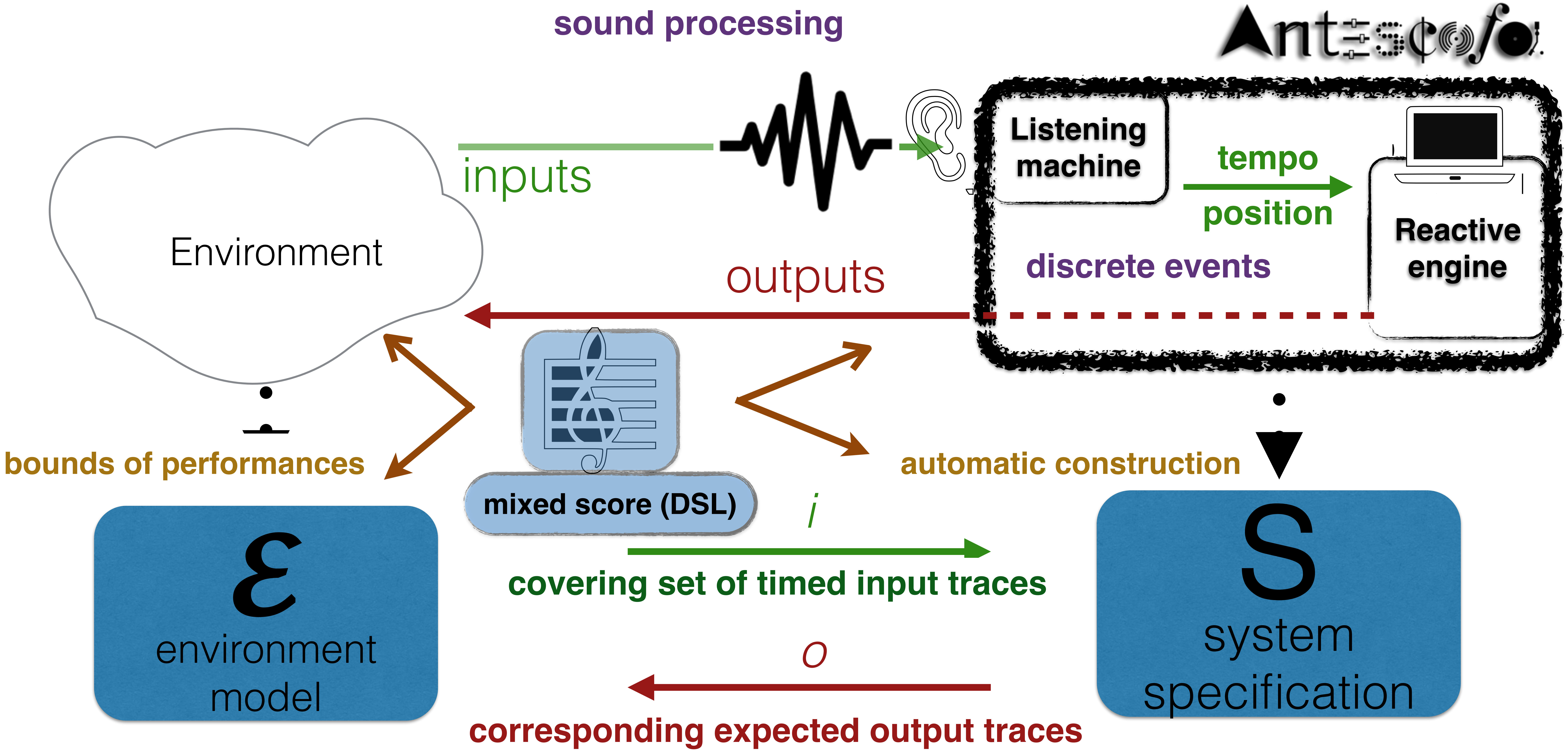

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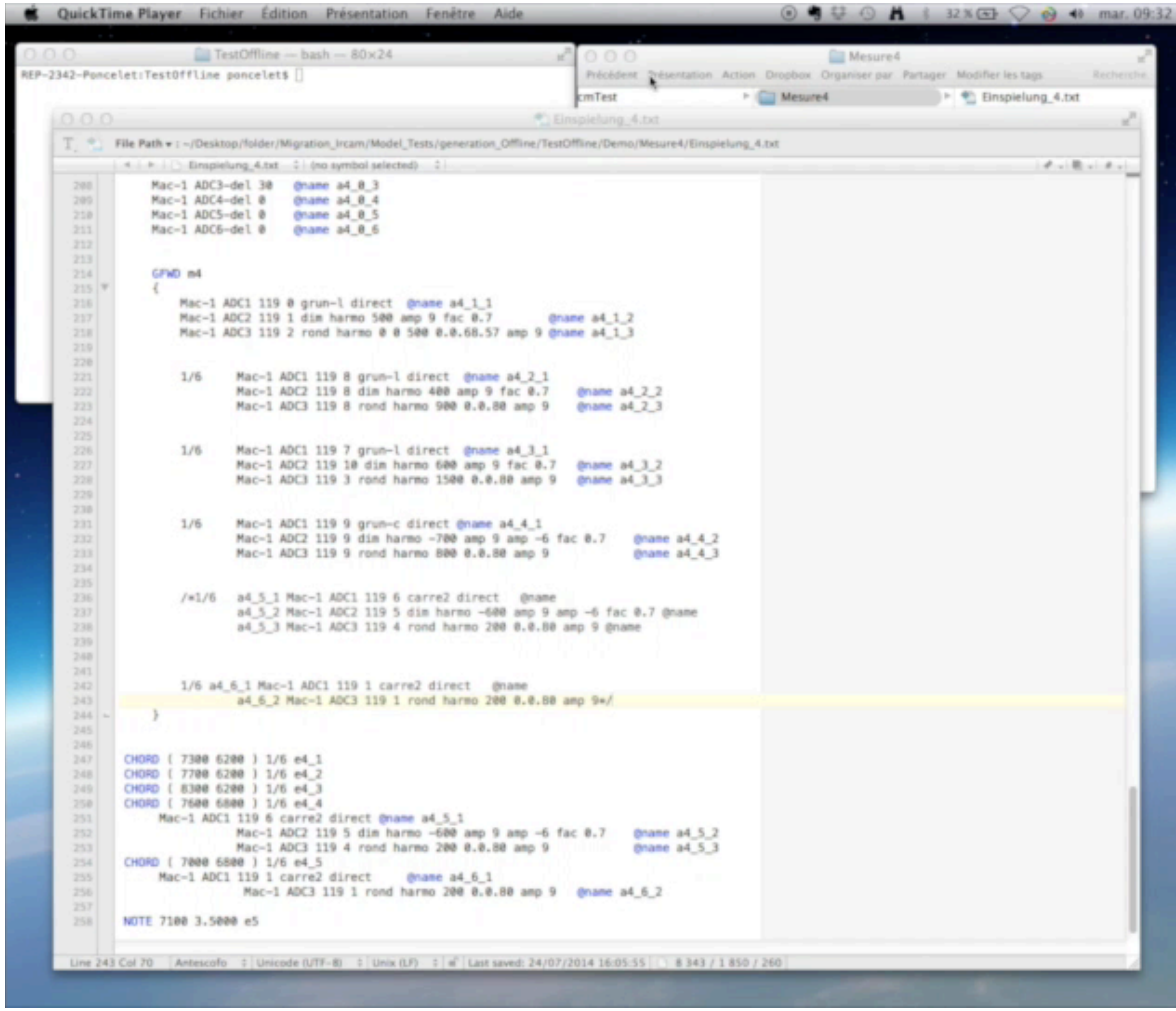
Test Workflow

Design of a running method to test using existing MBT tools

Mixed Score



__Timed traces:__ $\langle a, t \rangle$ with $a \in \Sigma_{\text{in}} \cup \Sigma_{\text{out}}$ and $t \in \mathbb{R}^+$

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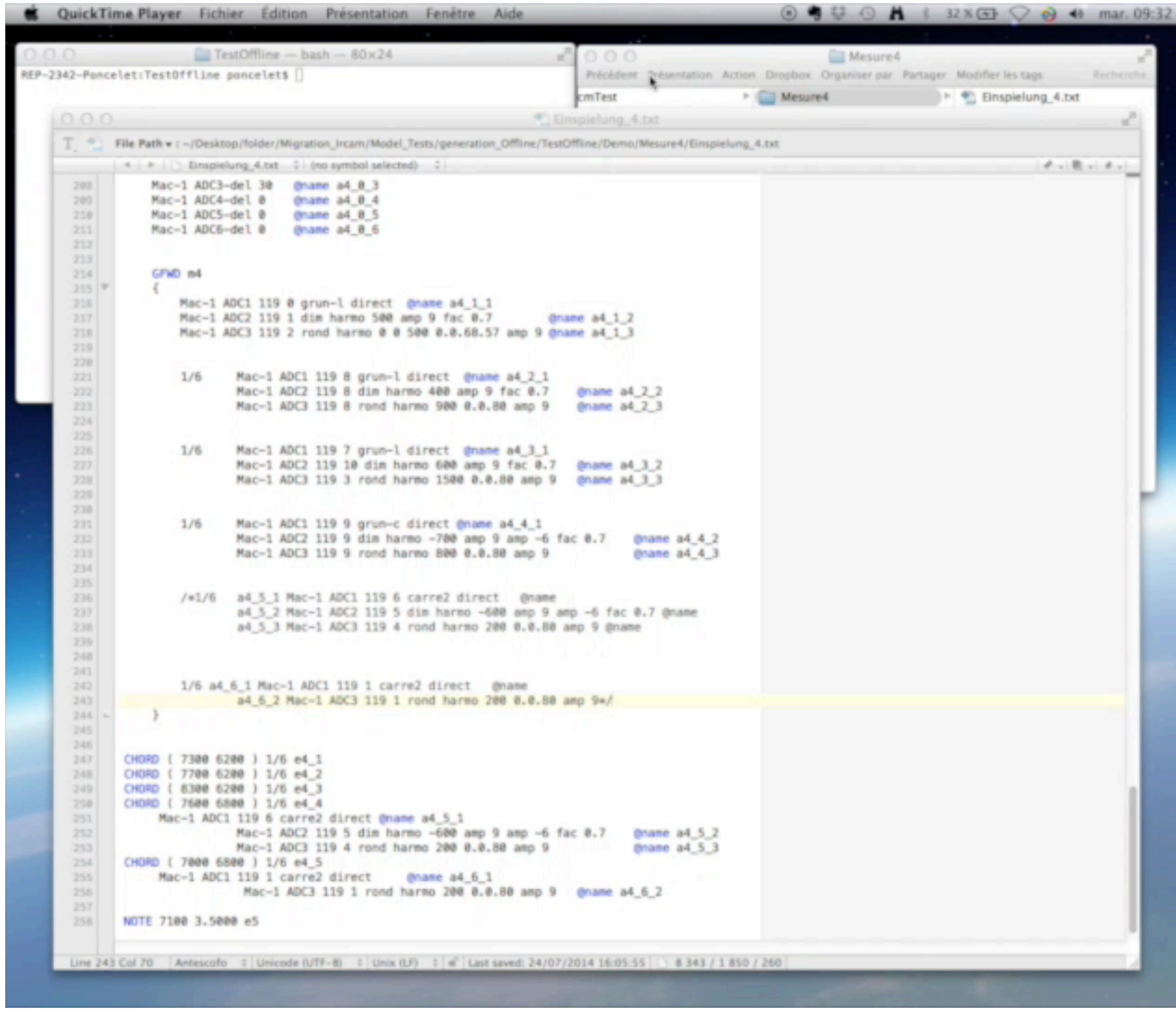

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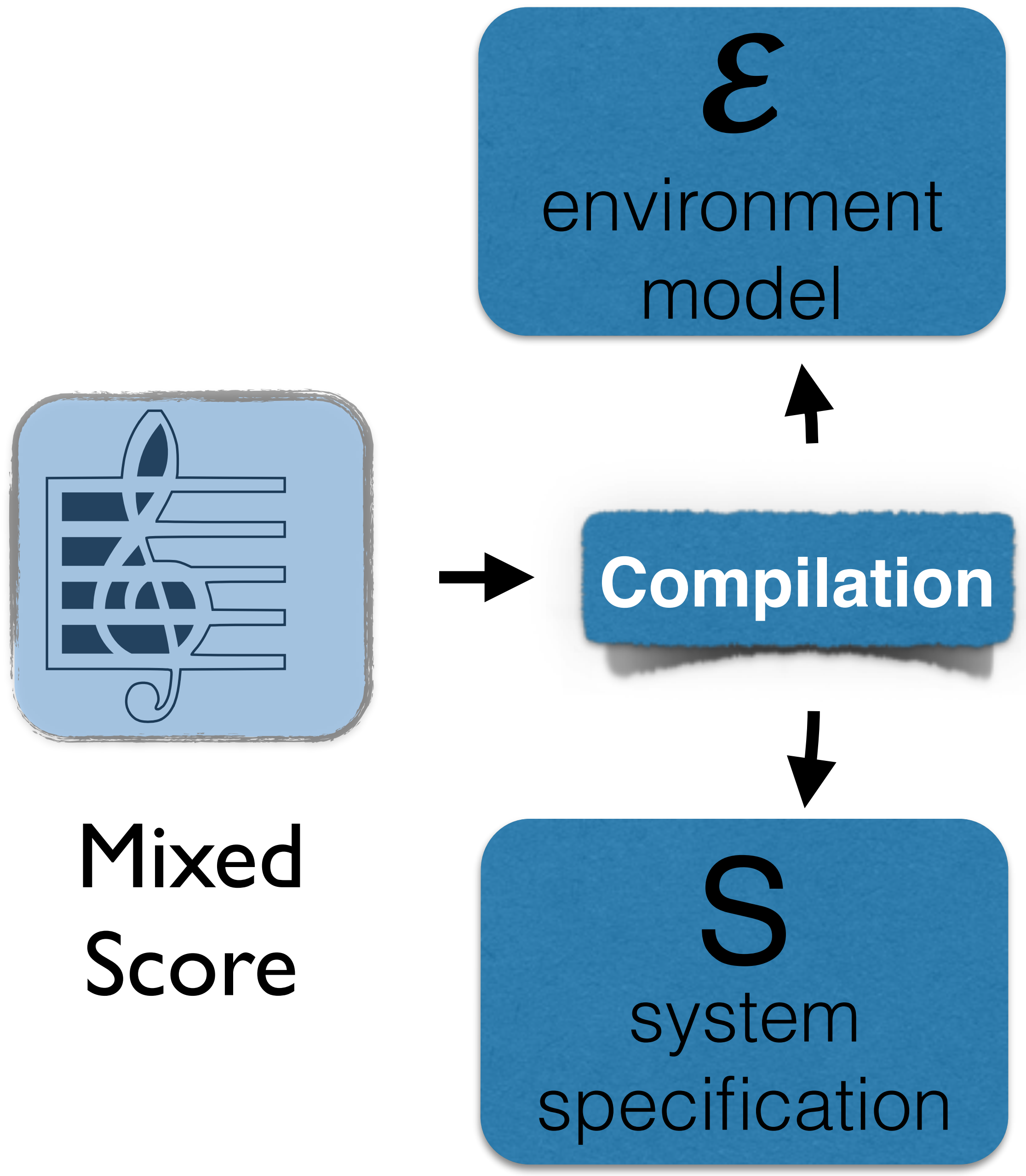

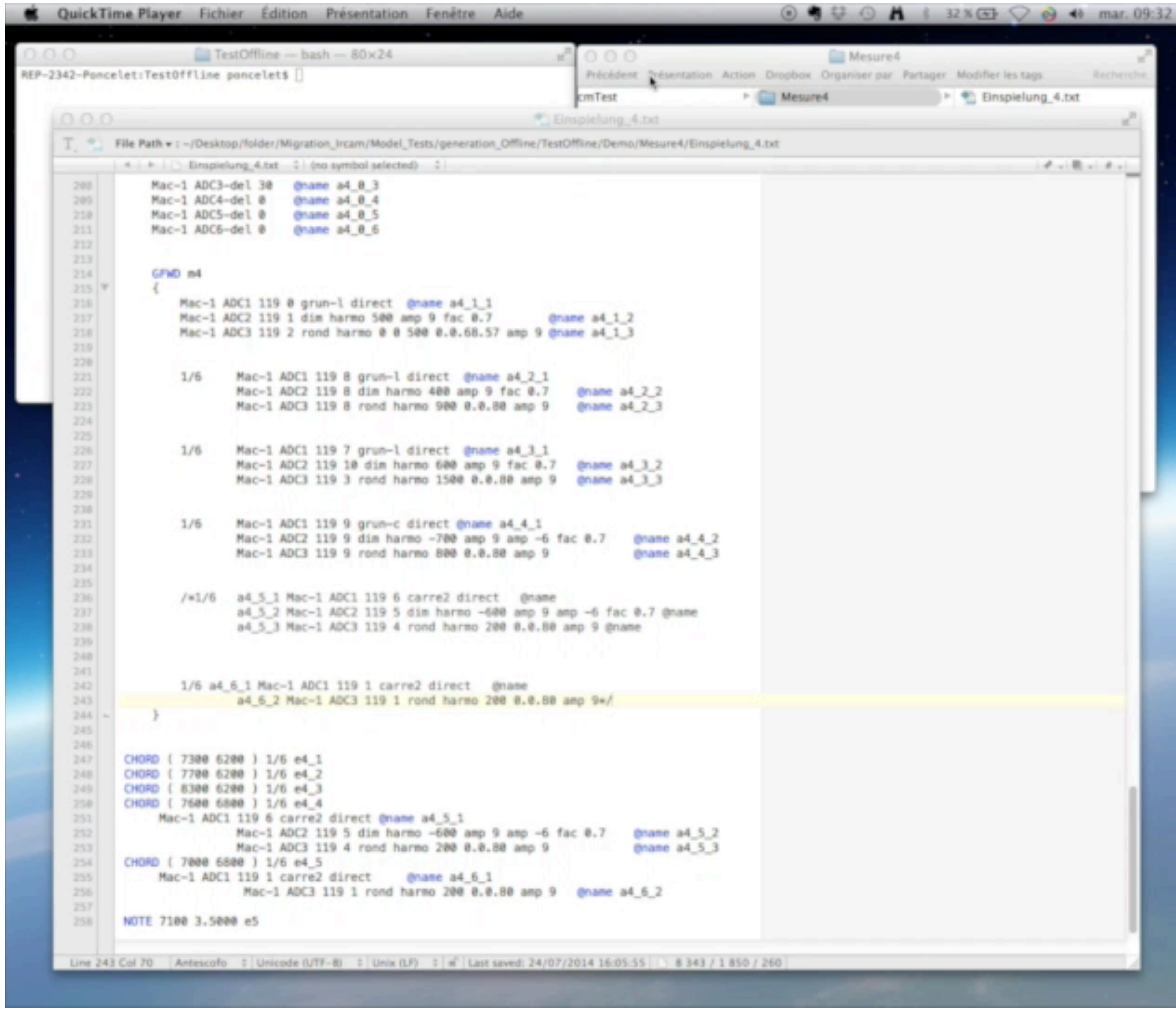

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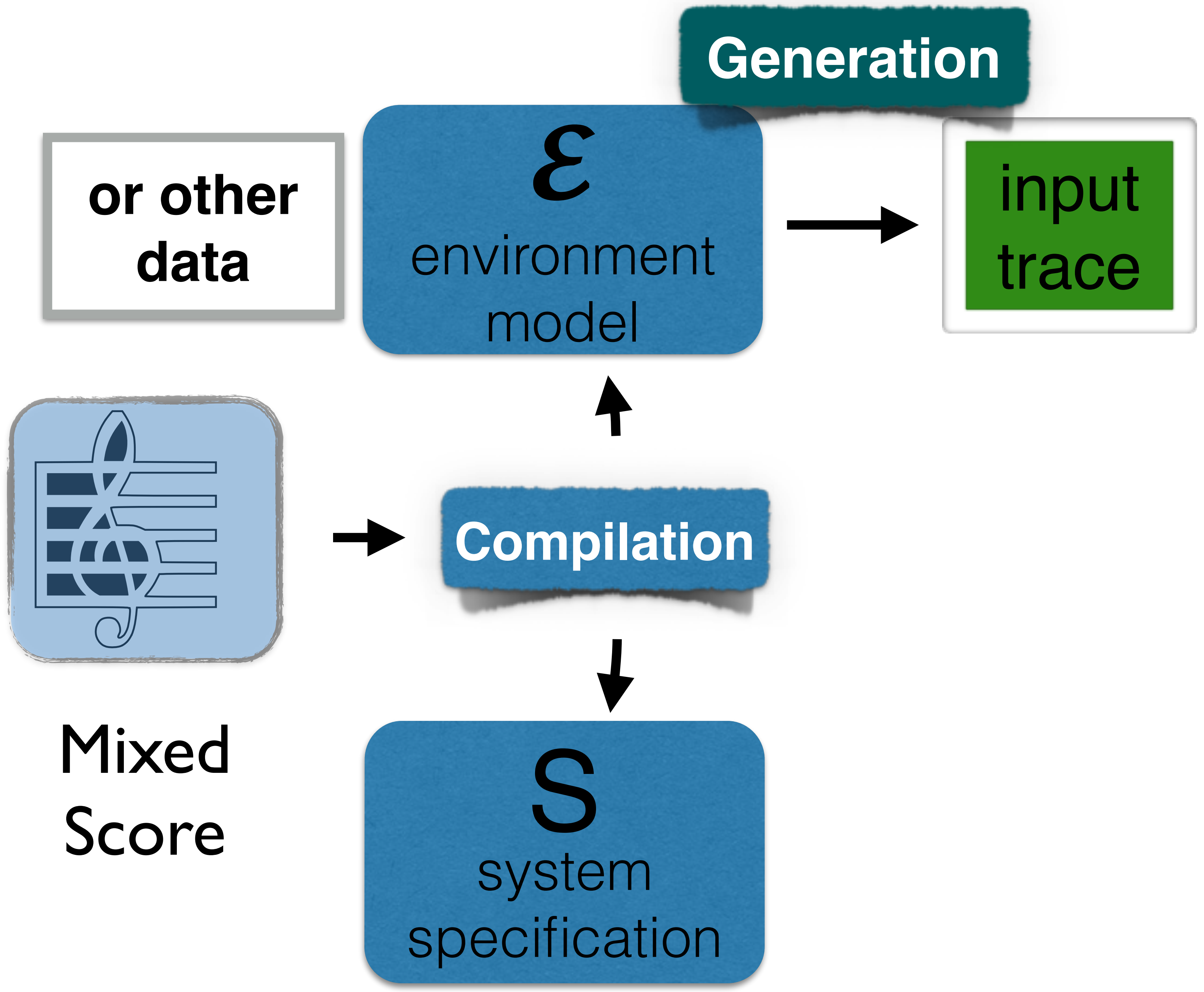

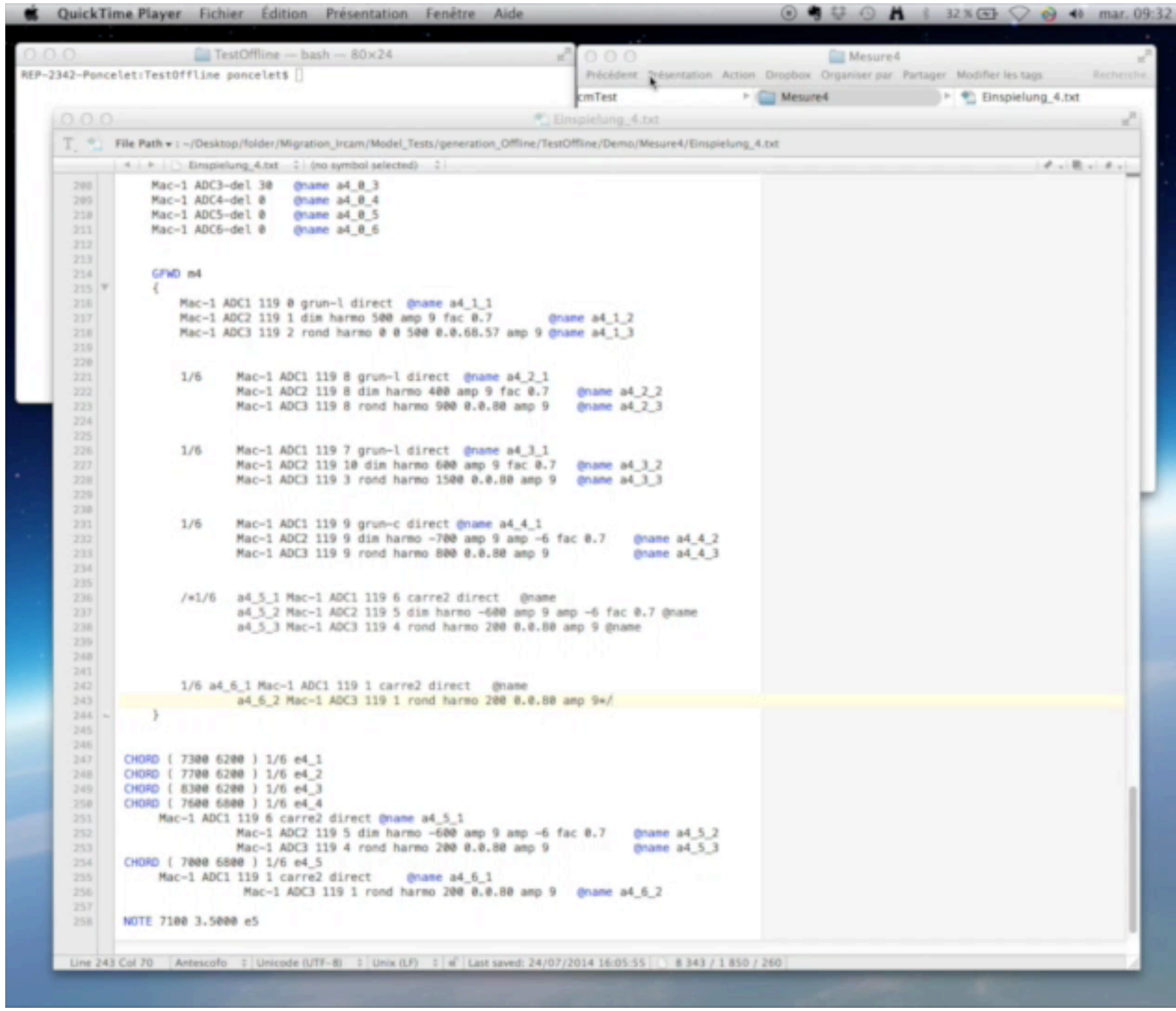

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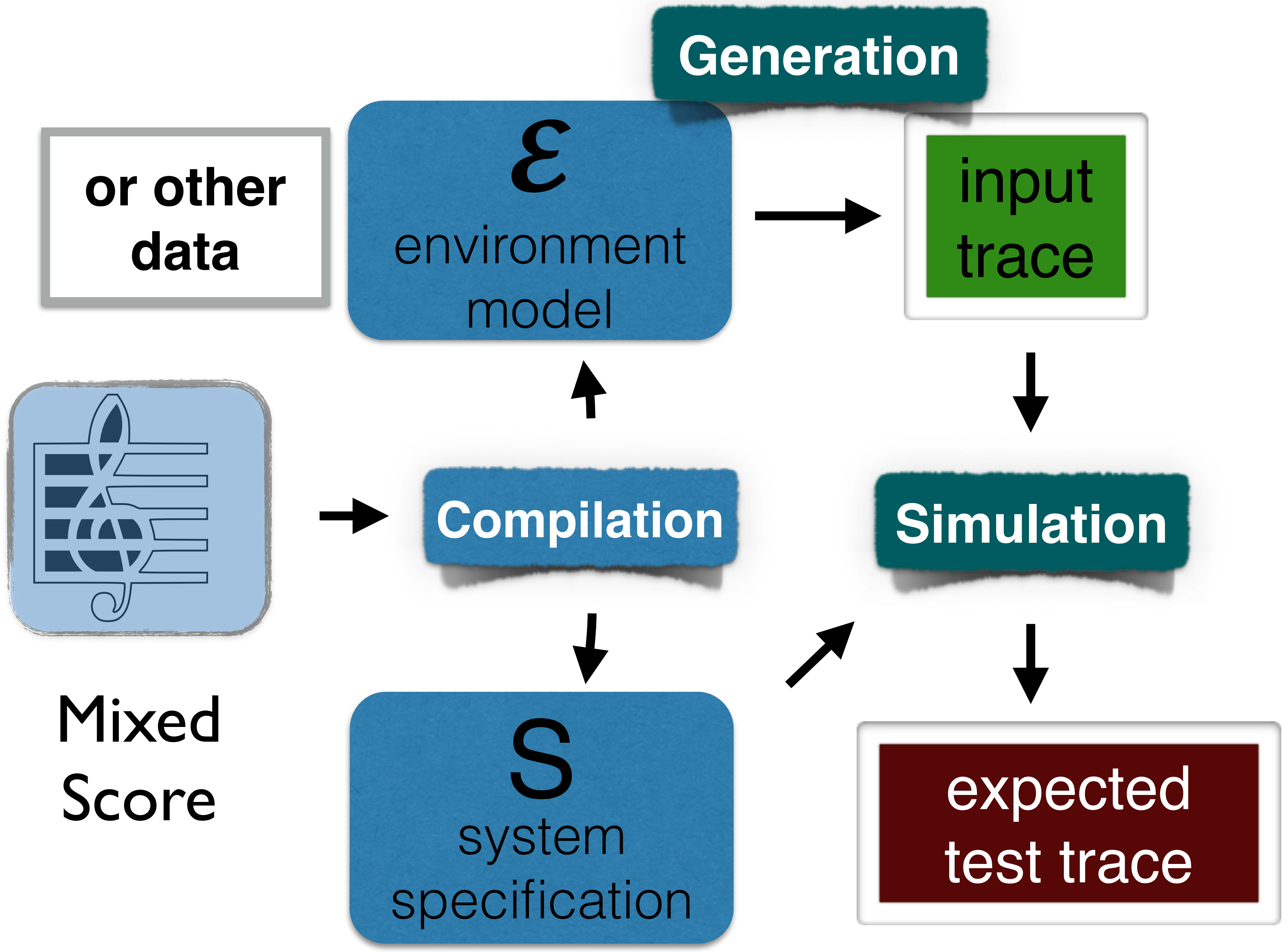

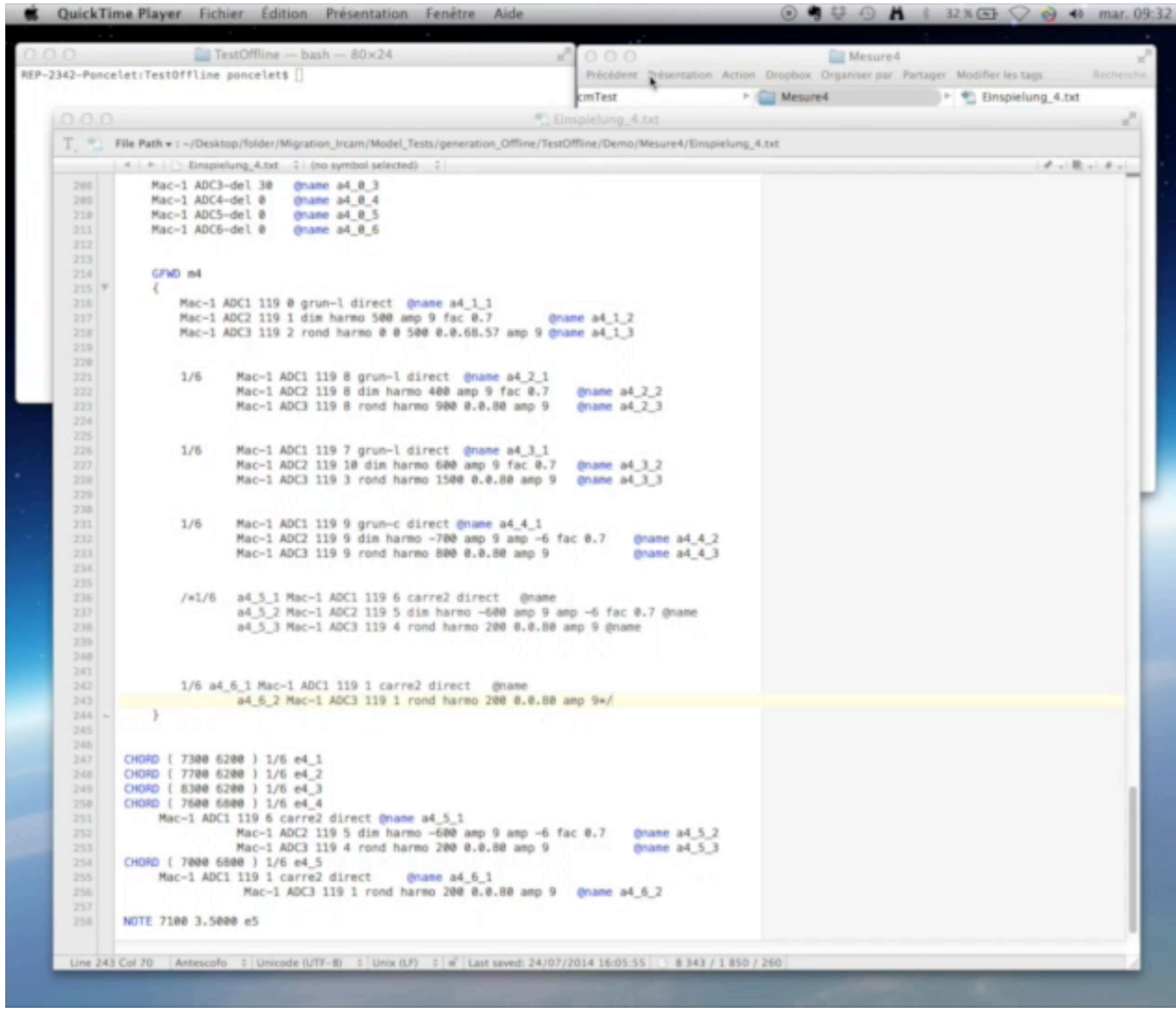

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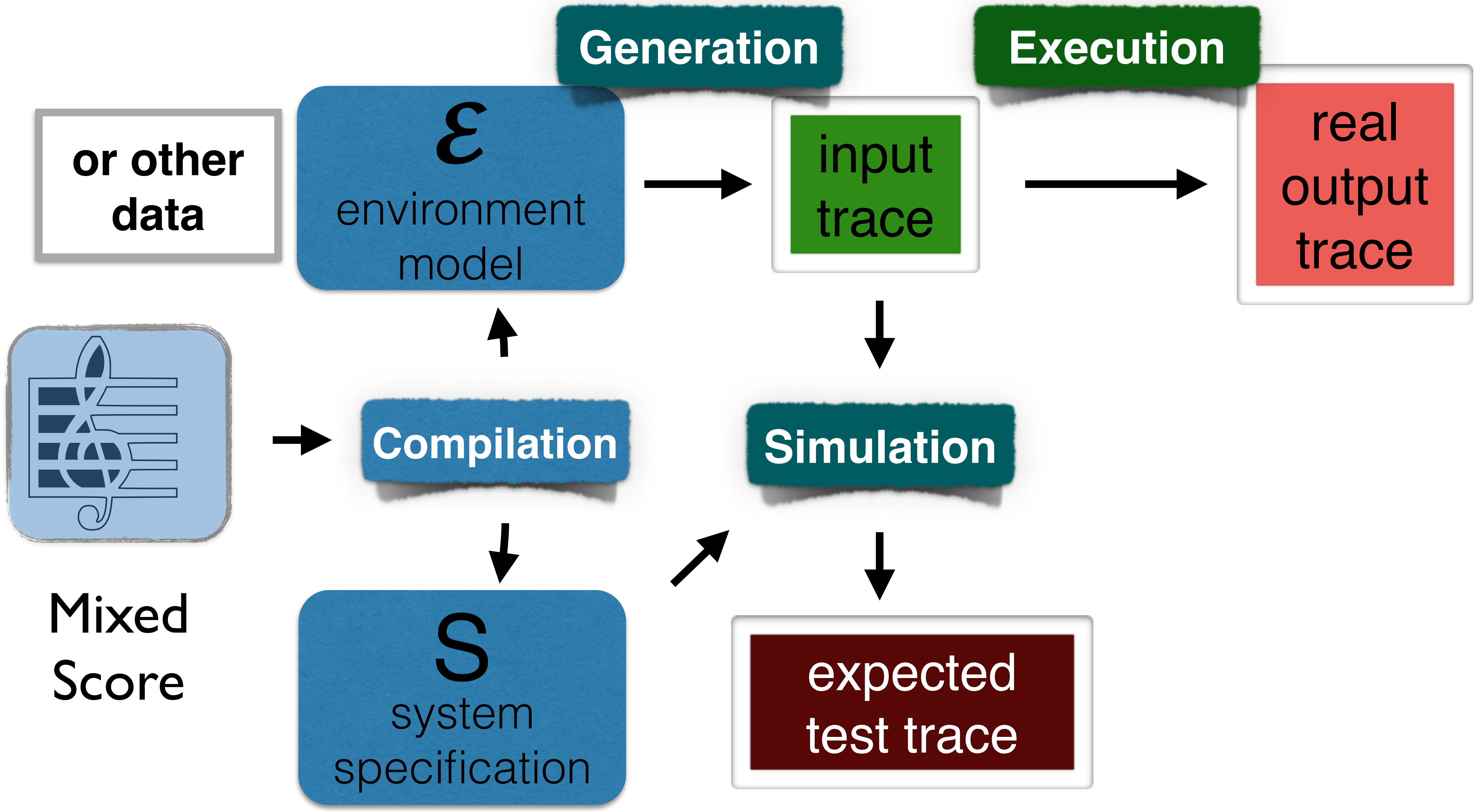

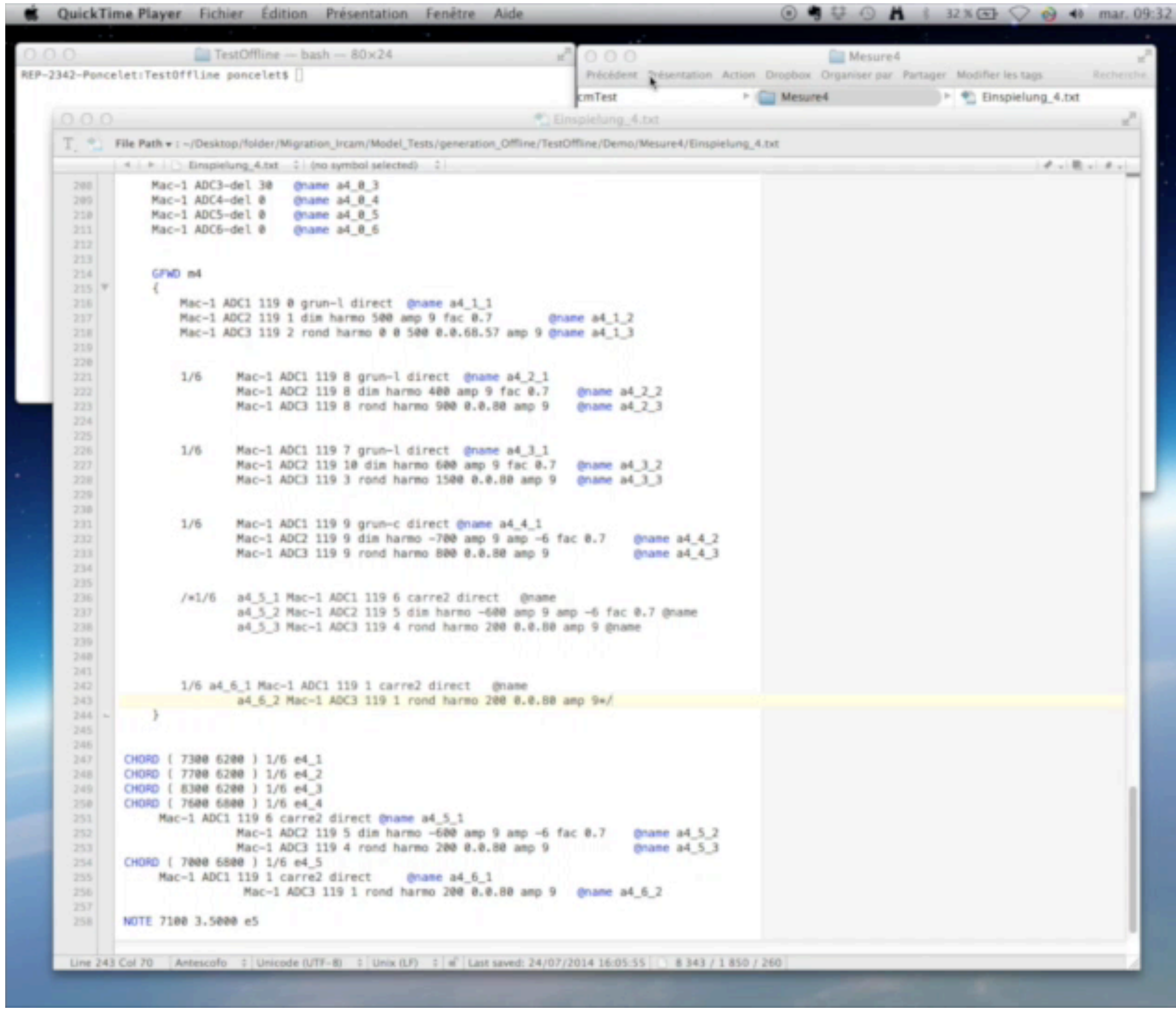

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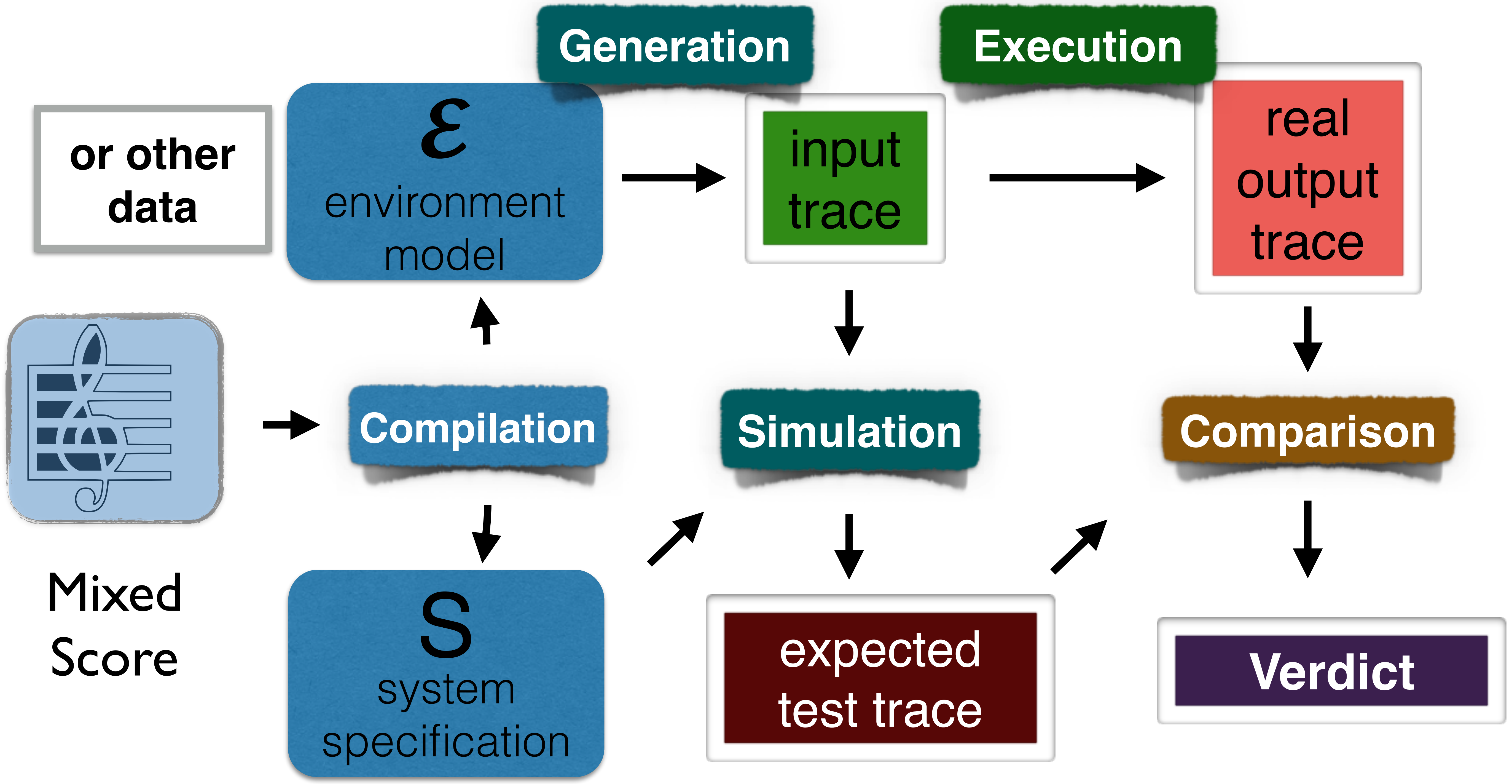

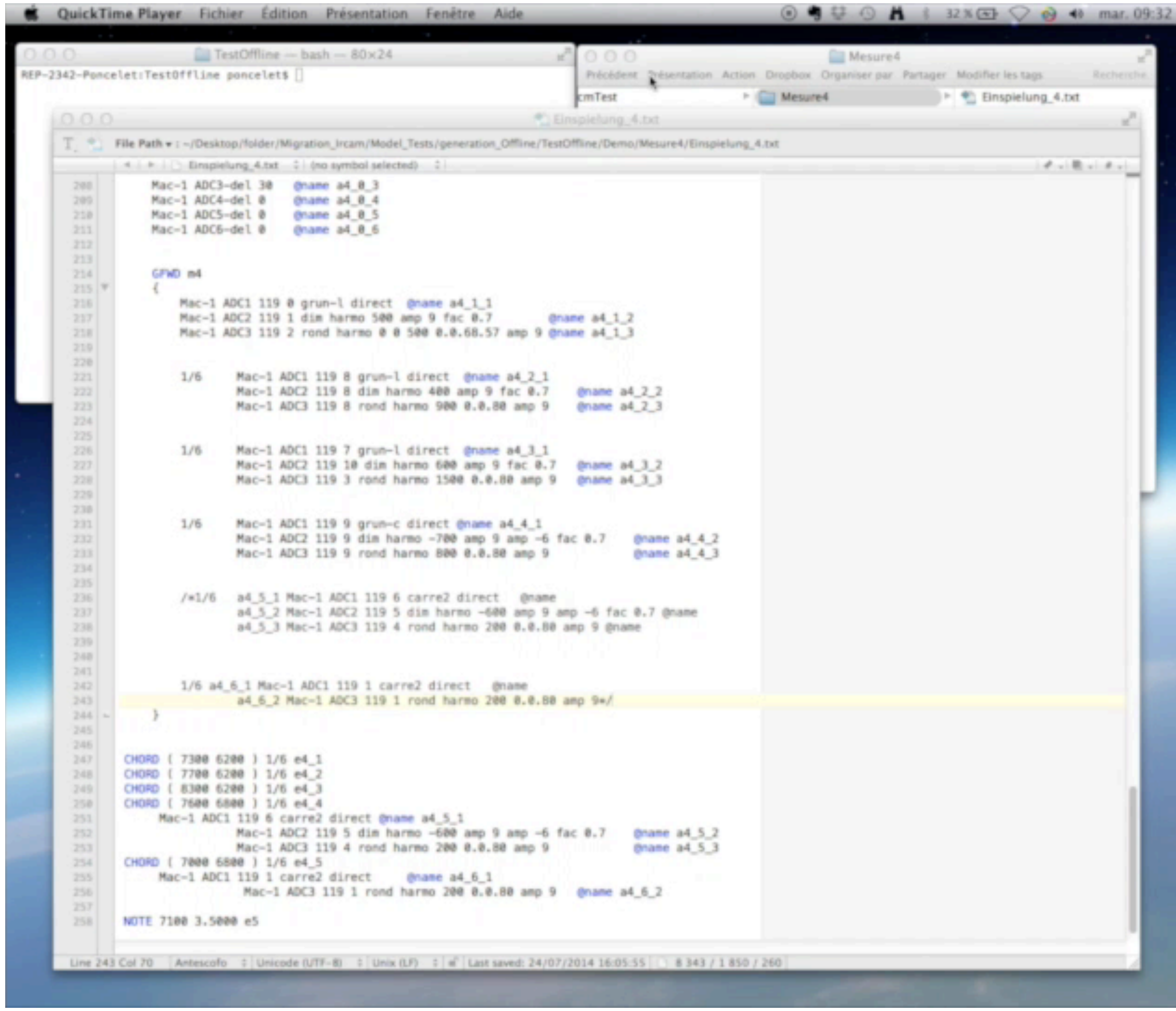

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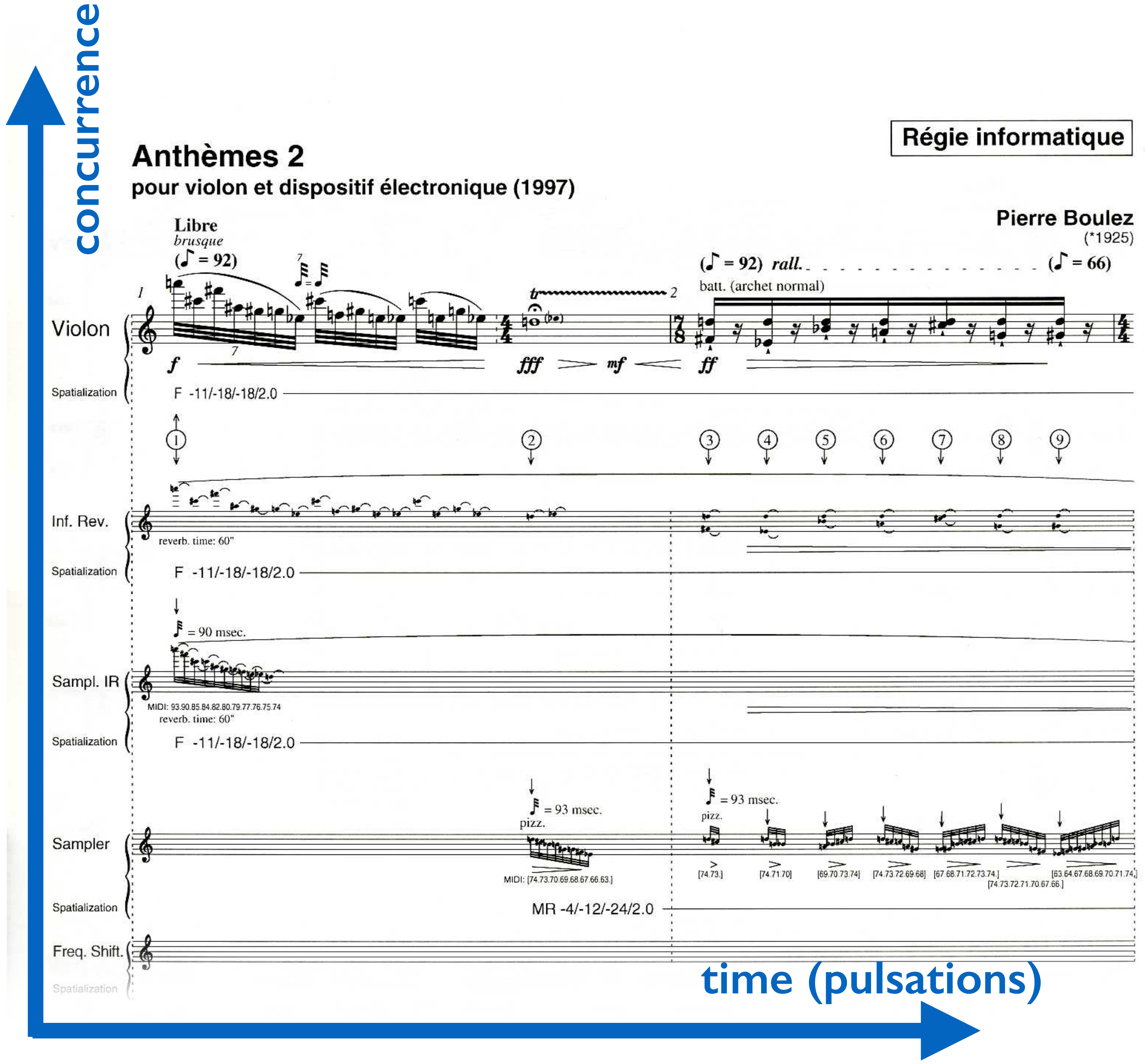
An IMS Specification

Antescofo Domain Specific Language




```
; Antheme 2 INTRO
BPM 92   ; tempo a la croche attention

[…]

;    PFWD 0.1 s1-t1-trait2 bang

; BPM 46 ;

TEMPO OFF
TRILL ( 7400 7500 )   8.0 Q2   ;second_trait ; old_e2; Trill_1
cue_nb 2;
ir2-param reverb tr0 25
A2_samples_in    74   120  15
0.1  A2_samples_in    73   120  15
0.1  A2_samples_in    70   120  15
0.1  A2_samples_in    69   120  15
0.1  A2_samples_in    68   120  15
0.1  A2_samples_in    67   120  15
0.1  A2_samples_in    66   120  15
0.1  A2_samples_in    63   120  15
fd_1_del 25;
fd_1_fre -347;
fd_1_db 0;
ir1 99 500;  start decrescendo reverb inf 1
```

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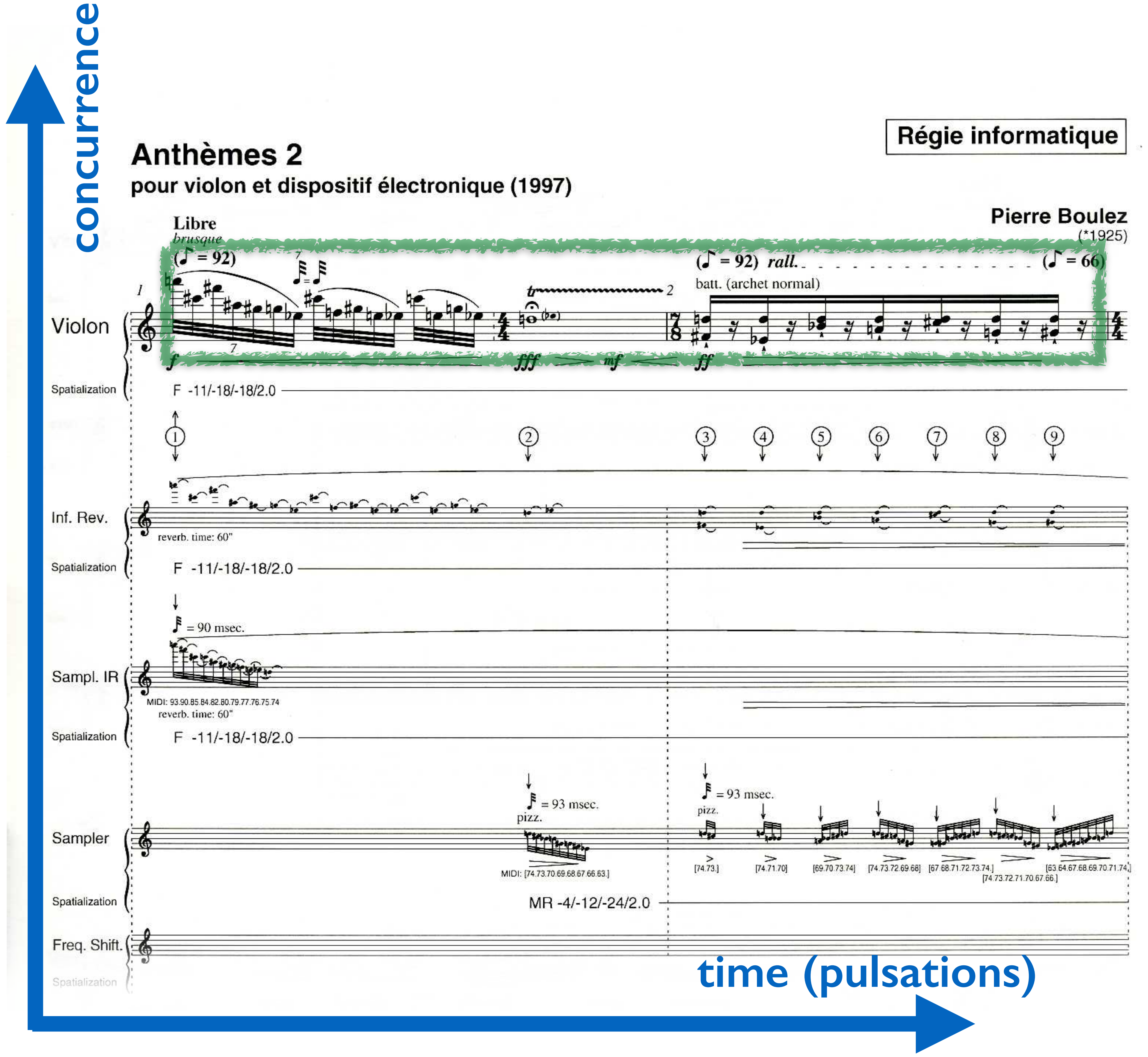

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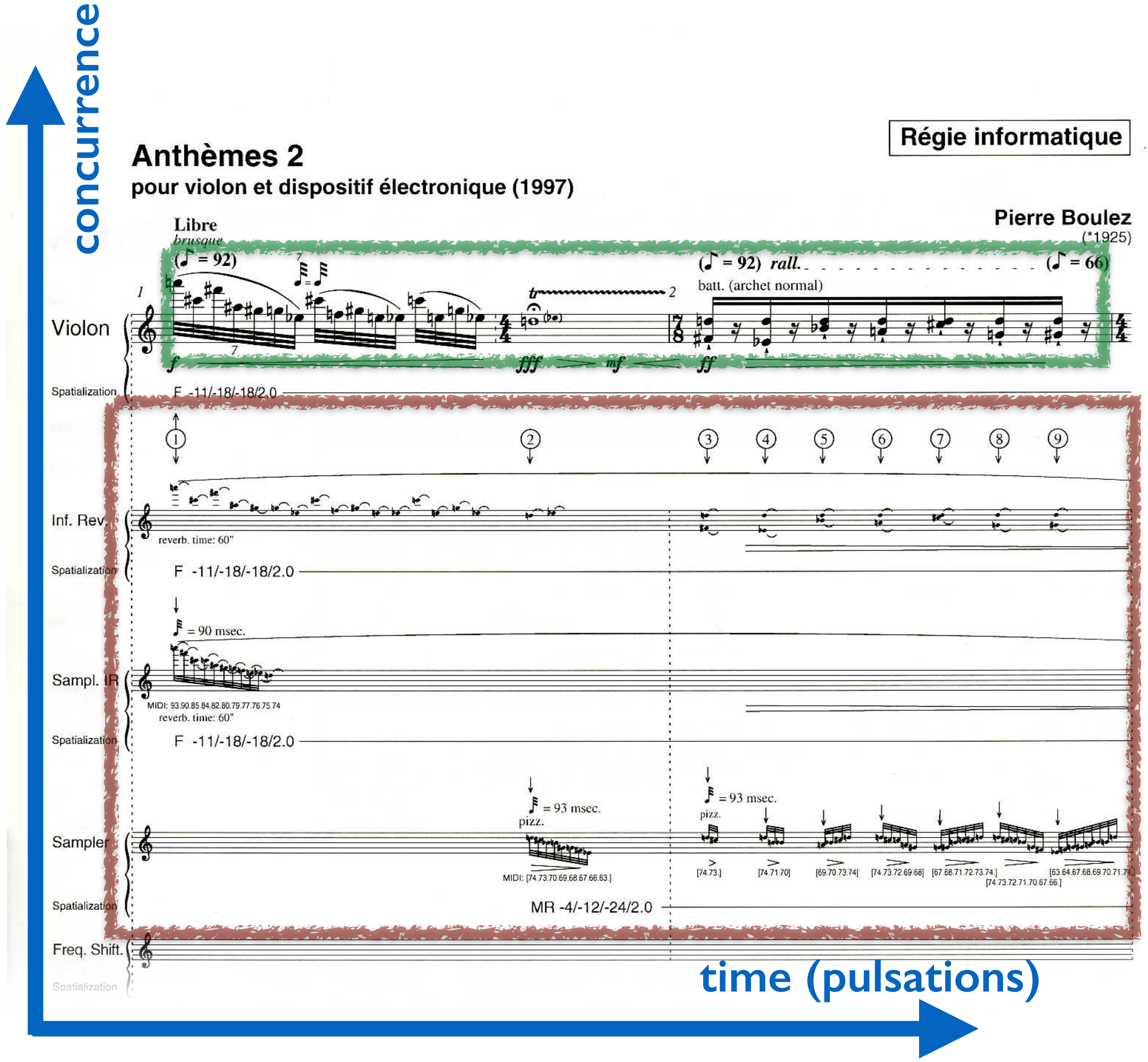

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output actions
triggered by events
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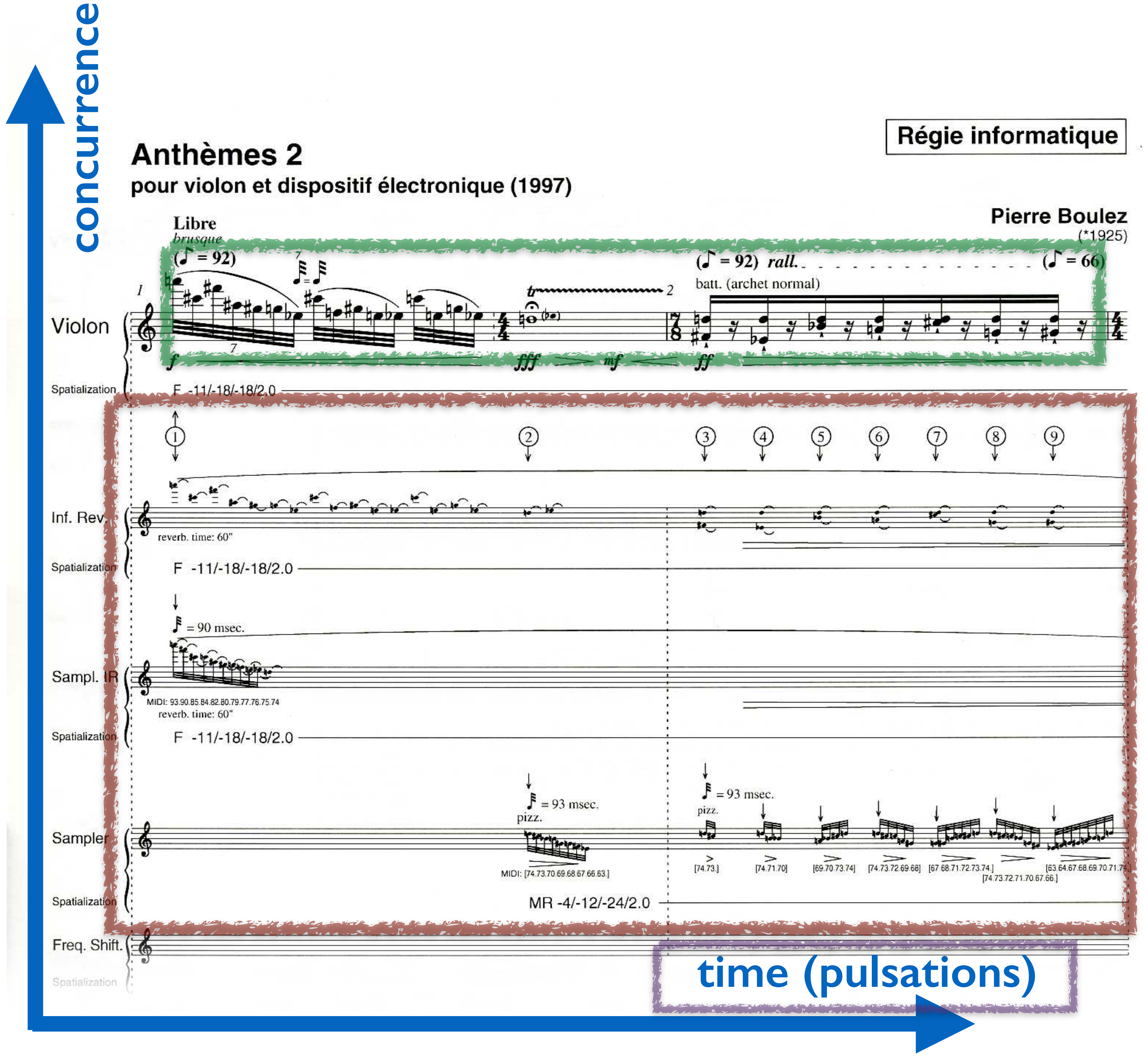

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durations \ delays
beats of tempo \ beats

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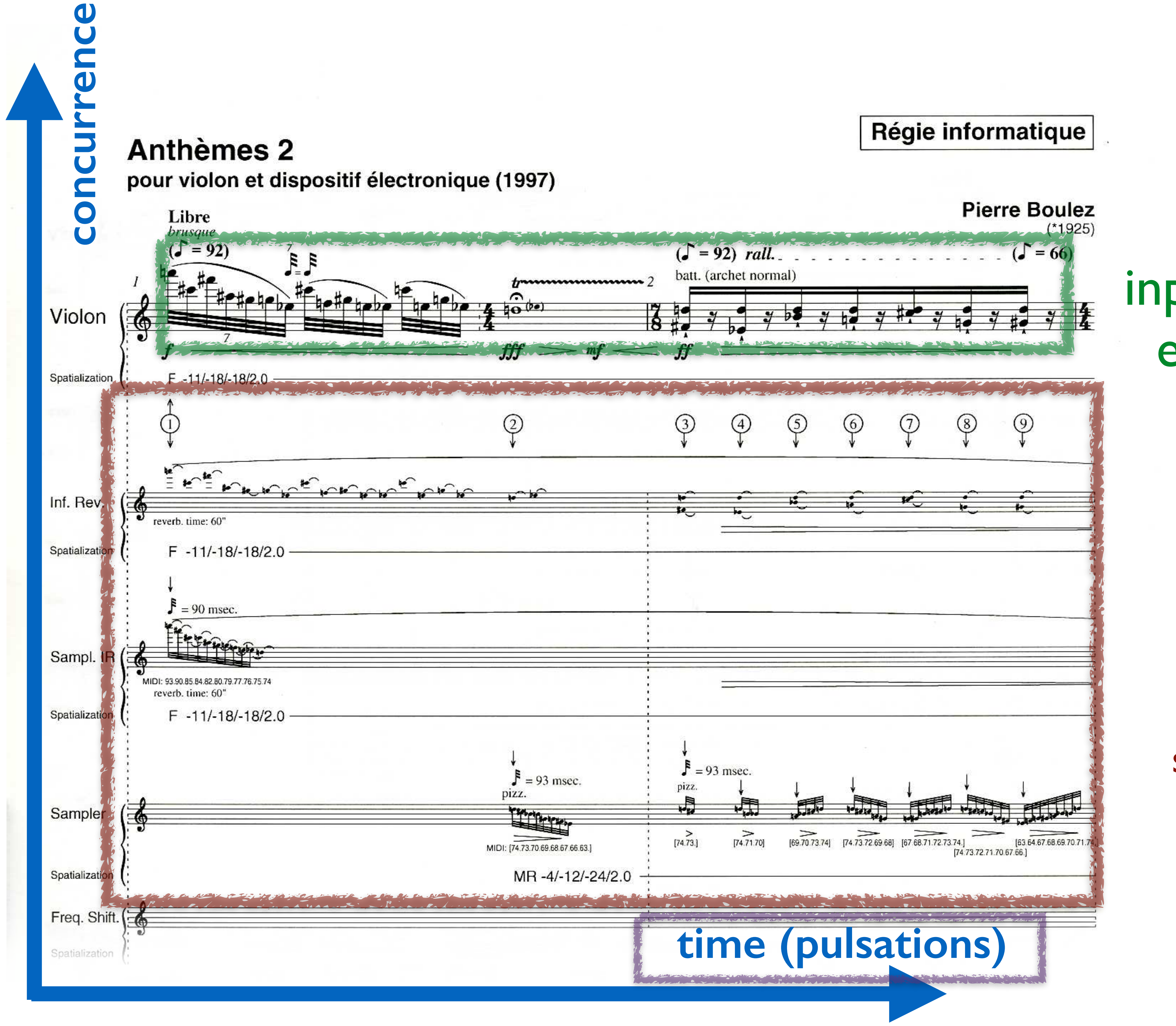

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durations \ delays
beats of tempo \ beats

+ High level features: Synchronisation, error management dynamic processes …

Intermediate Representation

the syntax

symbols $\Sigma = \Sigma_{\text{in}} \uplus \Sigma_{\text{out}} \uplus \Sigma_{\text{sig}}$

input events	Σ_{in}
output messages	Σ_{out}
internal signals	Σ_{sig}

Representable with **Finite State Machine** + variables & time

Intermediate Representation

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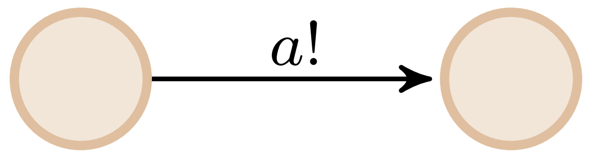
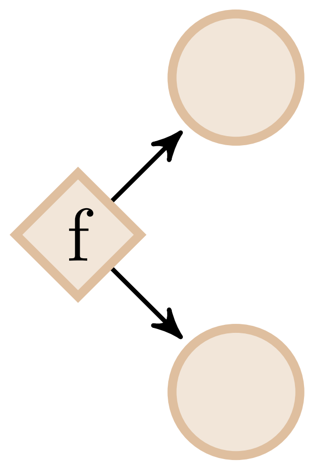
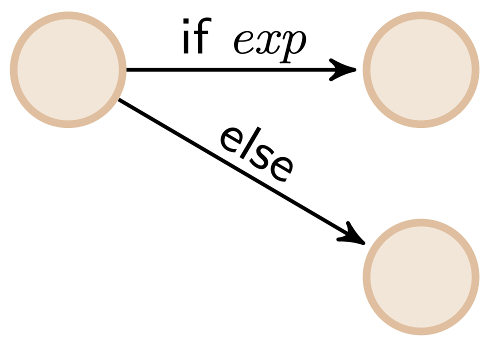
Synchronous transitions set (instantaneous)

Representable with **Finite State Machine** + variables & time

emit 

fork 

$a \in \Sigma_{\text{out}} \cup \Sigma_{\text{sig}}$

conditional 

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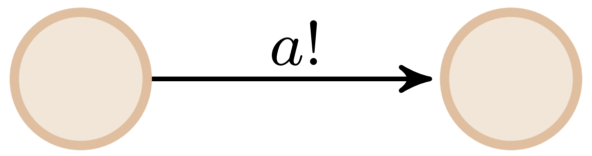
Synchronous transitions set (instantaneous)

Representable with **Finite State Machine** + variables & time

Asynchronous transitions set (delaying)

emit



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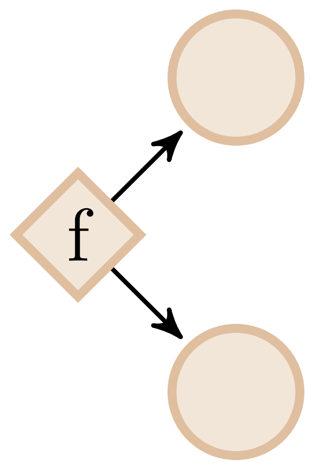

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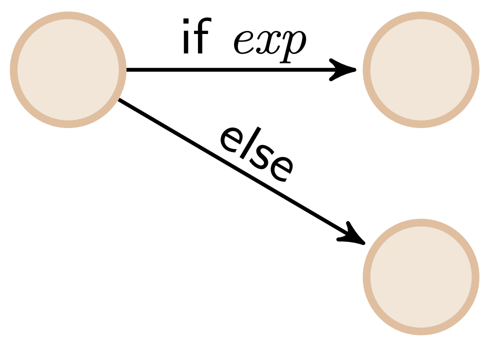
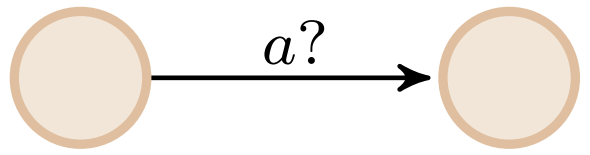
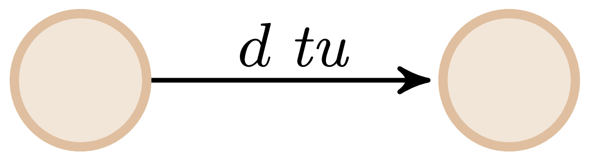


$a \in \Sigma_{\text{out}} \cup \Sigma_{\text{sig}}$

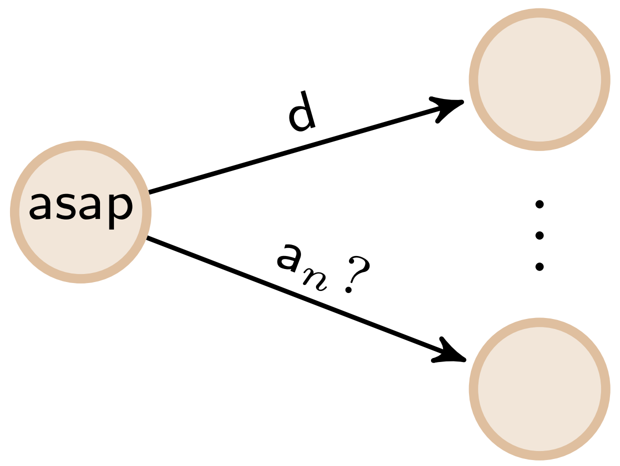
receive



delay



asap concurrency



$b \in \Sigma_{in} \cup \Sigma_{sig}$

tu is a time unit

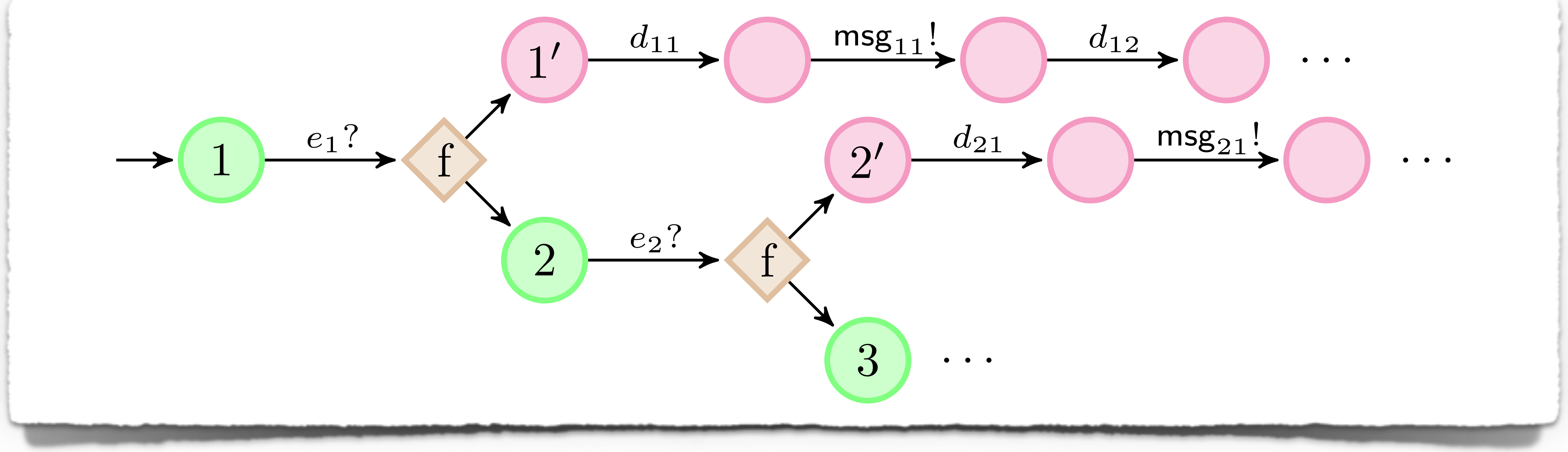
Intermediate Representation

the semantics with example

```
NOTE e1 d1
    d11 msg11
    d12 msg12
      ...
NOTE e2 d2
    d21 msg21
      ...
   ...
```

Antescofo score

Executable bytecode



IR representation

Intermediate Representation

the semantics with example

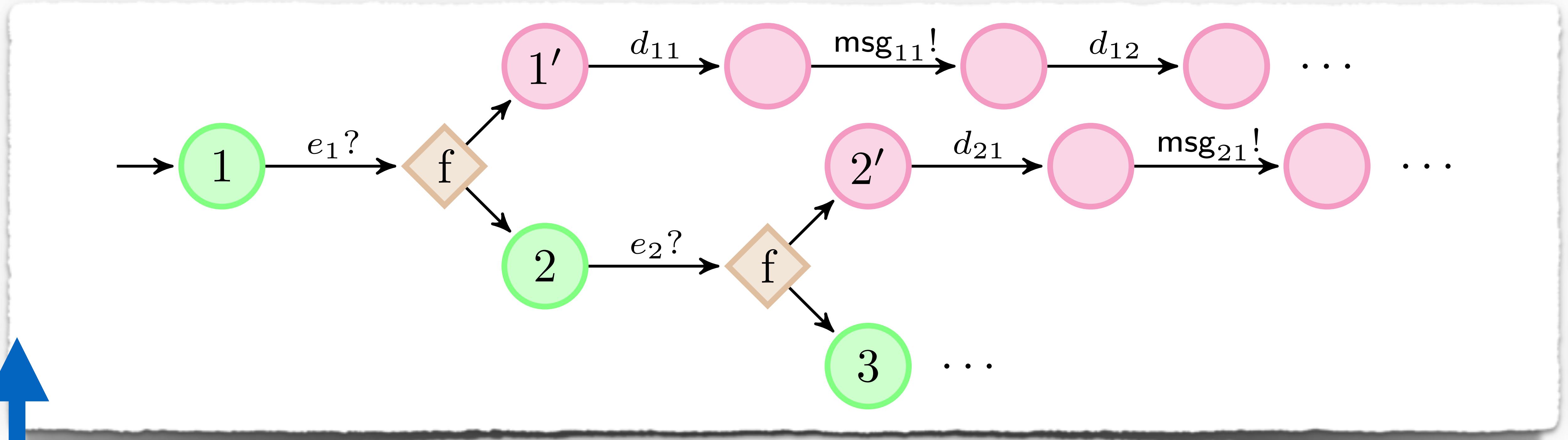
```
NOTE e1 d1
   d11 msg11
   d12 msg12
      ...
NOTE e2 d2
   d21 msg21
      ...
```

...

Antescofo score

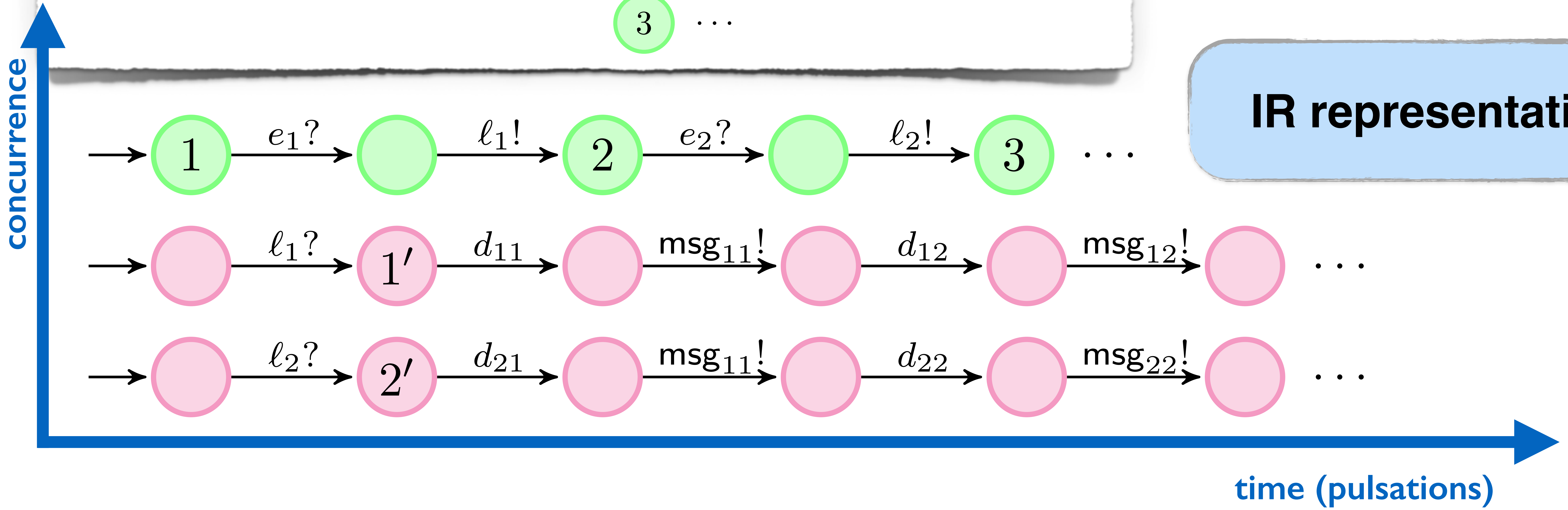
Network of parallelized machines

Executable bytecode



Before and after unfolding

IR representation



Intermediate Representation

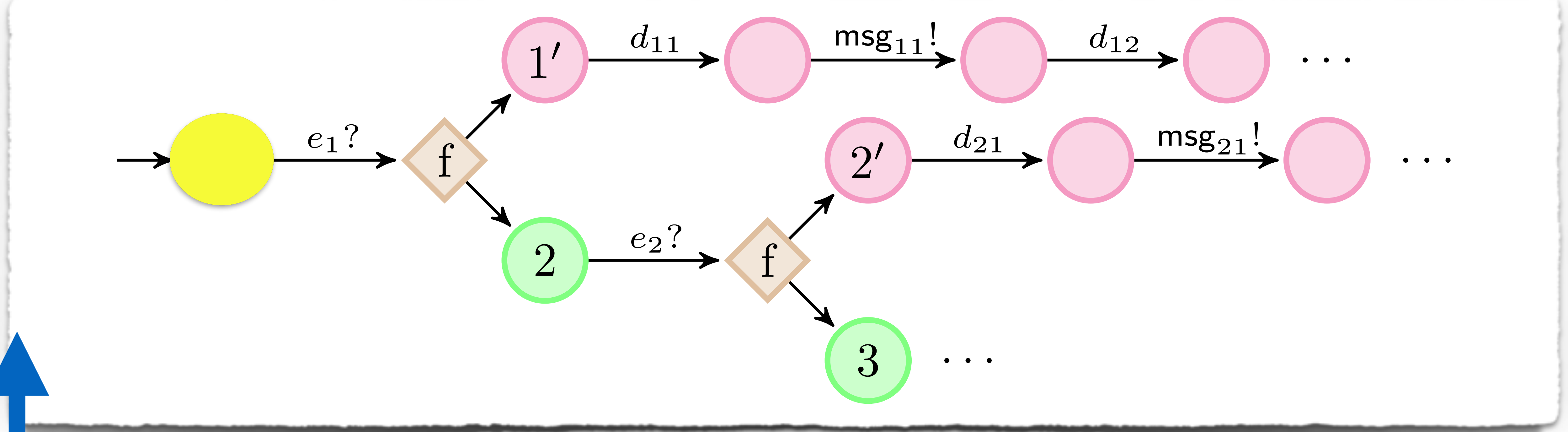
the semantics with example

```
NOTE e1 d1
   d11 msg11
   d12 msg12
      ...
NOTE e2 d2
   d21 msg21
      ...
    ...
```

Antescofo score

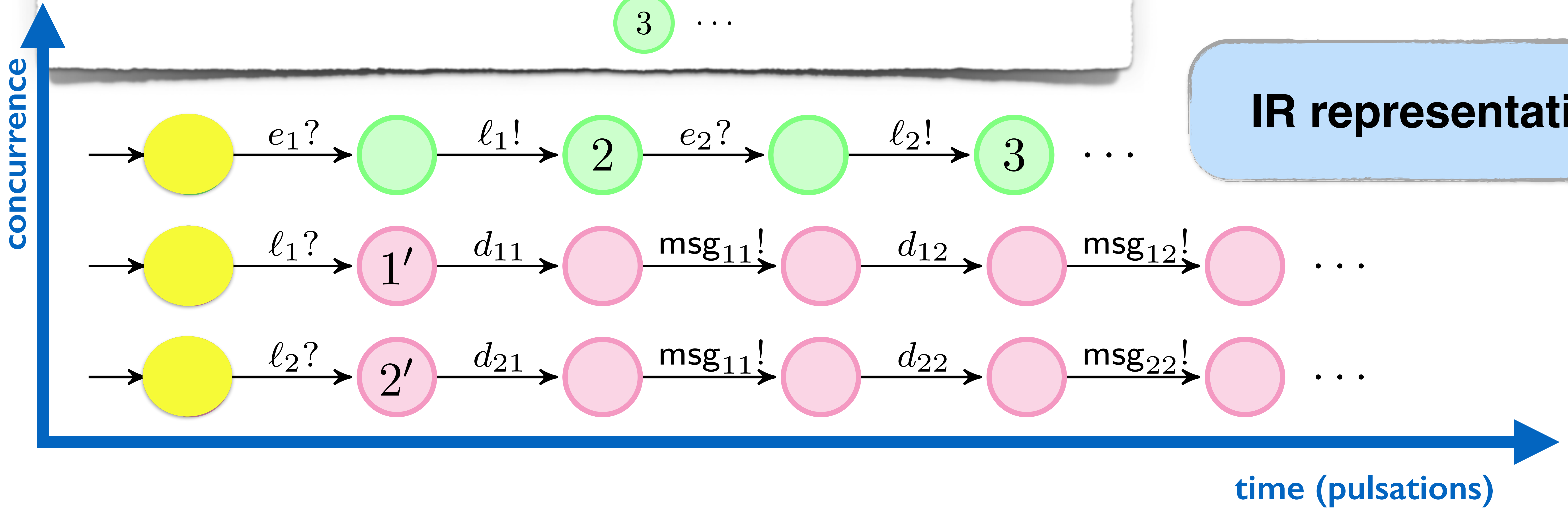
Network of parallelized machines

Executable bytecode



Before and after unfolding

IR representation



Intermediate Representation

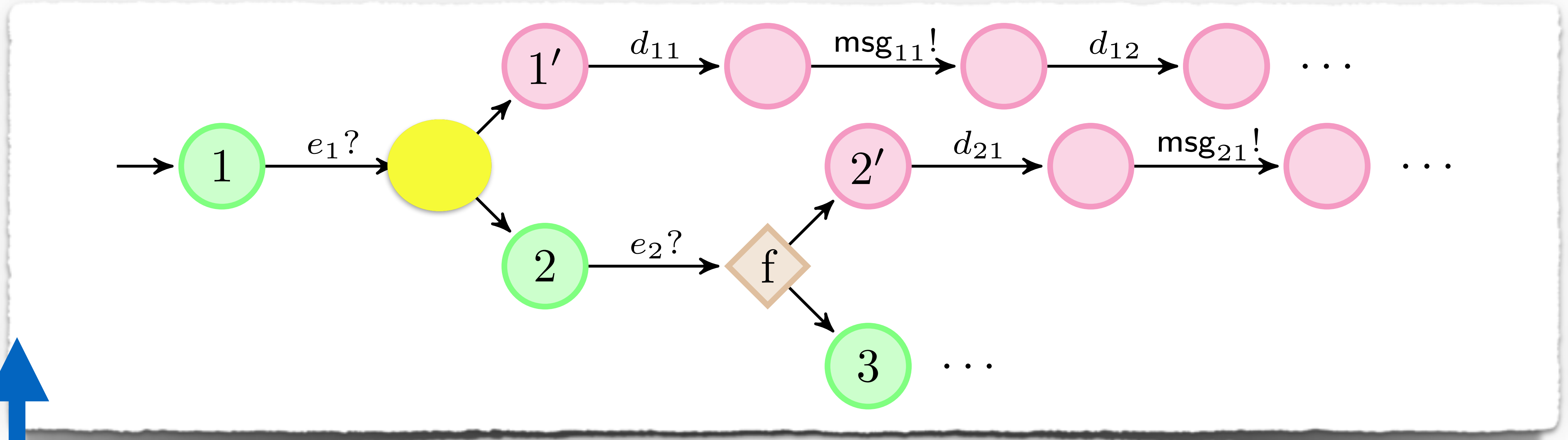
the semantics with example

```
NOTE e1 d1
    d11 msg11
    d12 msg12
        ...
NOTE e2 d2
    d21 msg21
        ...
      ...
```

Antescofo score

Network of parallelized machines

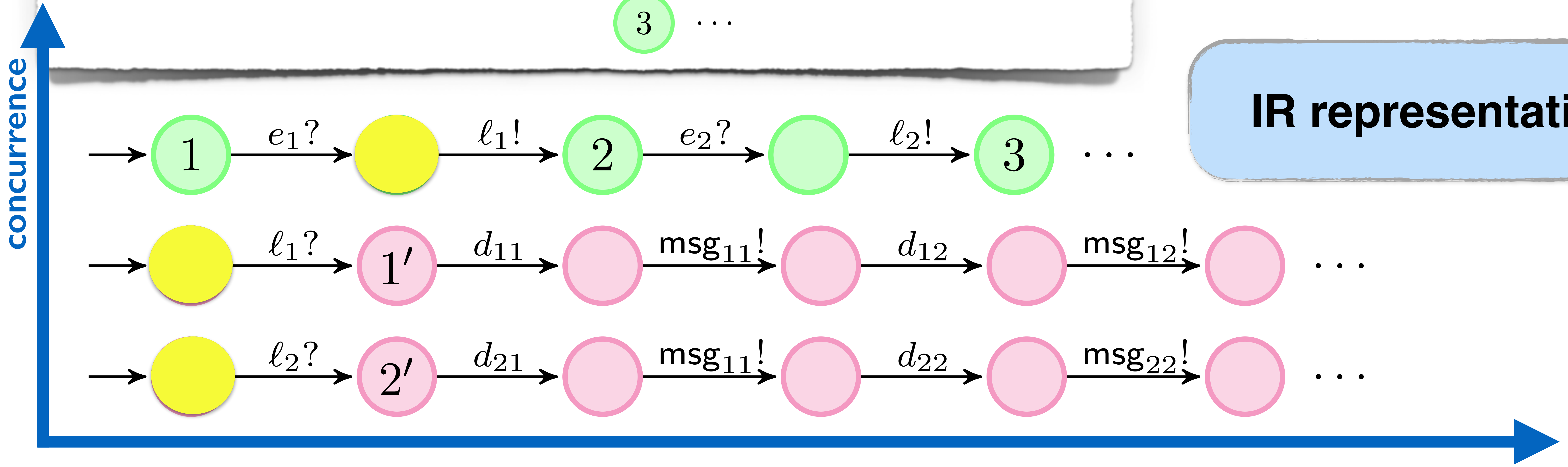
Executable bytecode



e1

Before and after unfolding

IR representation



time (pulsations)

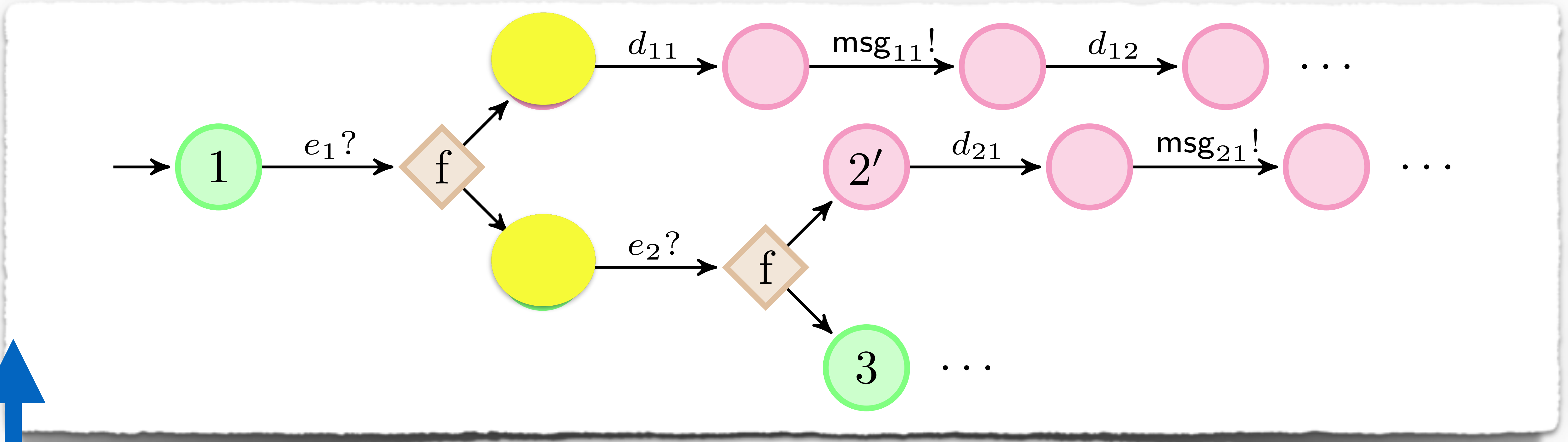
Intermediate Representation

the semantics with example

```
NOTE e1 d1
    d11 msg11
    d12 msg12
      ...
NOTE e2 d2
    d21 msg21
      ...
     ...
```

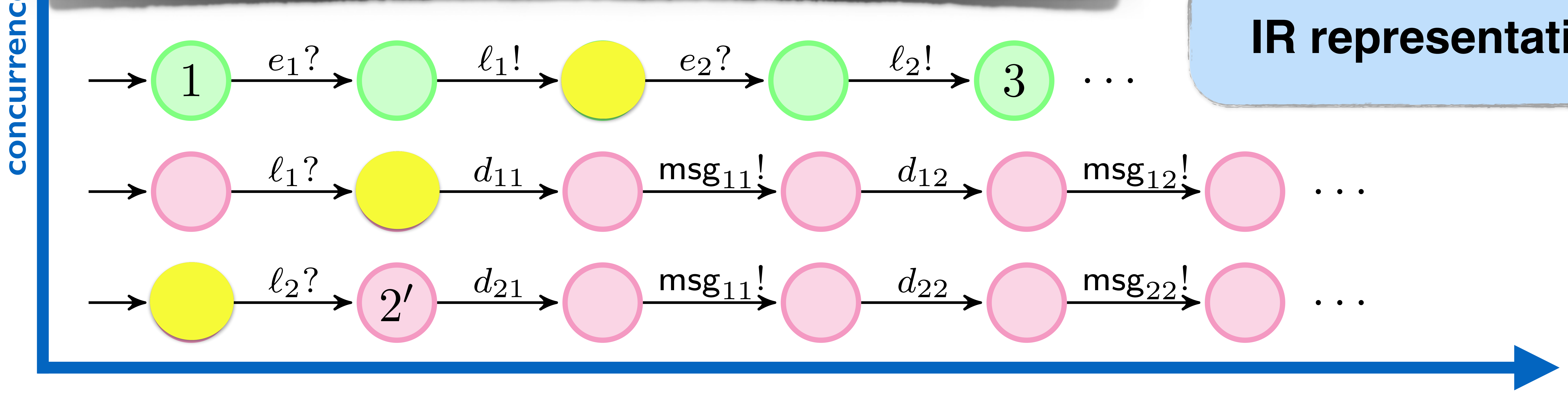
Antescofo score

Executable bytecode



Before and after unfolding

IR representation



Network of parallelized machines

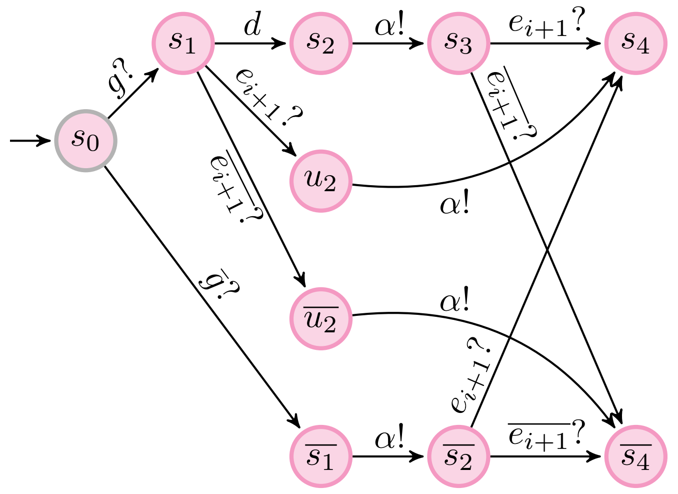
Intermediate Representation

Automatic construction

Mixed Score (AntescofoDSL)

```
NOTE e1 d1
    d11 msg11
    d12 msg12
      ...
NOTE e2 d2
    d21 msg21
      ...
   ...
```

Intermediate Representation



Inference rules

$$\frac{\vdash_{\mathsf{env}} sc : \mathcal{E} \qquad \vdash_{\mathsf{proxy}} sc : \mathcal{P} \qquad \vdash_{\mathsf{evt}} \langle [\,], sc\rangle : \mathcal{G}}{\vdash_{\mathsf{all}} sc : \mathcal{M}}\ \text{ALL}$$

$$\frac{}{\vdash_{\mathsf{all}} \emptyset : \mathcal{A}_{\emptyset}}\ \text{EMPTY}$$

$$\frac{\vdash_{\mathsf{evt}} \langle sc{::}ev, sc'\rangle : \mathcal{G}}{\vdash_{\mathsf{evt}} \langle sc, ev{::}sc'\rangle : \mathcal{G}}\ \text{TOP}$$

$$\frac{acc + d, sc, \tilde{e} \vdash_{al} sa : \mathcal{G}_{sa} \qquad acc + d, sc, \tilde{e} \vdash_{al'} sa' : \mathcal{G}'_{sa}}{acc, sc, e \vdash_{al} \mathsf{act}(d, sa', al'){::}sa : \tilde{\mathcal{G}} + \mathcal{G}_{sa} \parallel \mathcal{T}(g') + \mathcal{G}'_{sa}}\ \text{GRP}$$

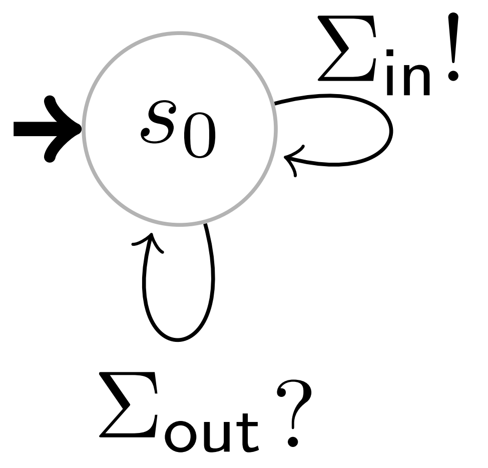
$$\frac{\vdash_{\mathsf{evt}} \langle sc{::}ev, sc'\rangle : \mathcal{G} \qquad 0, ev{::}sc', \tilde{e} \vdash_{\mathsf{top}} sa : \mathcal{G}_{sa}}{\vdash_{\mathsf{evt}} \langle sc, ev{::}sc'\rangle : \mathcal{G} \parallel \mathcal{T}_e + \mathcal{G}_{sa} + \mathcal{F}_i}\ \text{TOP}$$

$$\frac{acc + d, sc, closest(acc + d, sc) \vdash_{al} sa : \mathcal{G}_{sa}}{acc, sc, e \vdash_{al} \mathsf{act}(d, a, al'){::}sa : \mathcal{G}(a, d, al, sc, e) + \mathcal{G}_{sa}}\ \text{MSG}$$

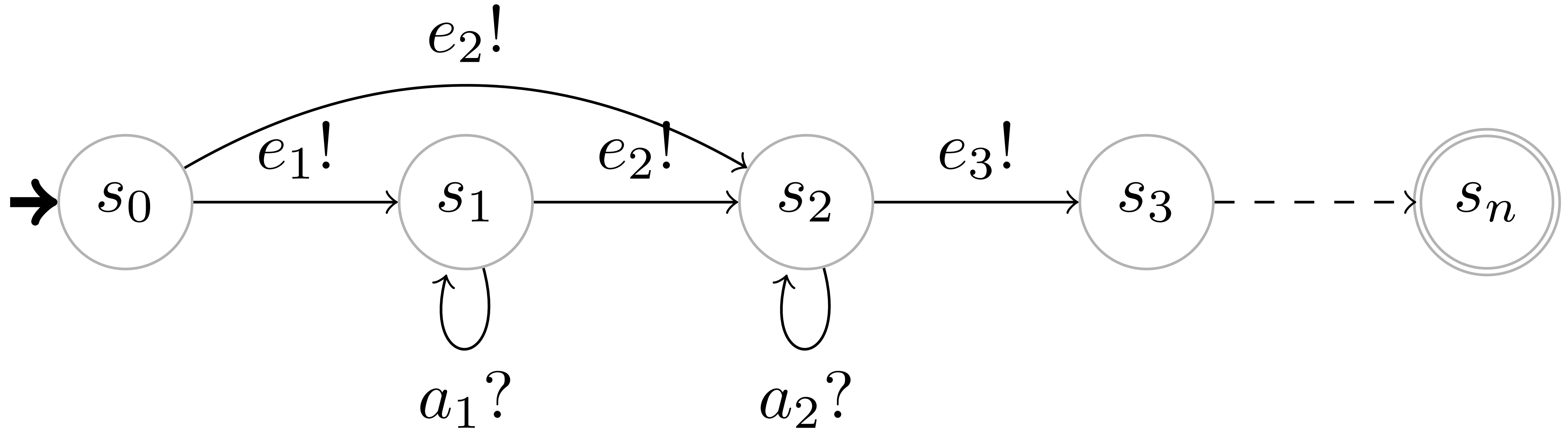
$$\mathcal{G}(\tau, d, [\mathsf{loose}, \mathsf{local}], sc, e) \ = \ 1\ \ell \xrightarrow{\ d\ } \ell_i \xrightarrow{\ \tau!\ } \ell'\ 1$$

$\mathcal{E}$

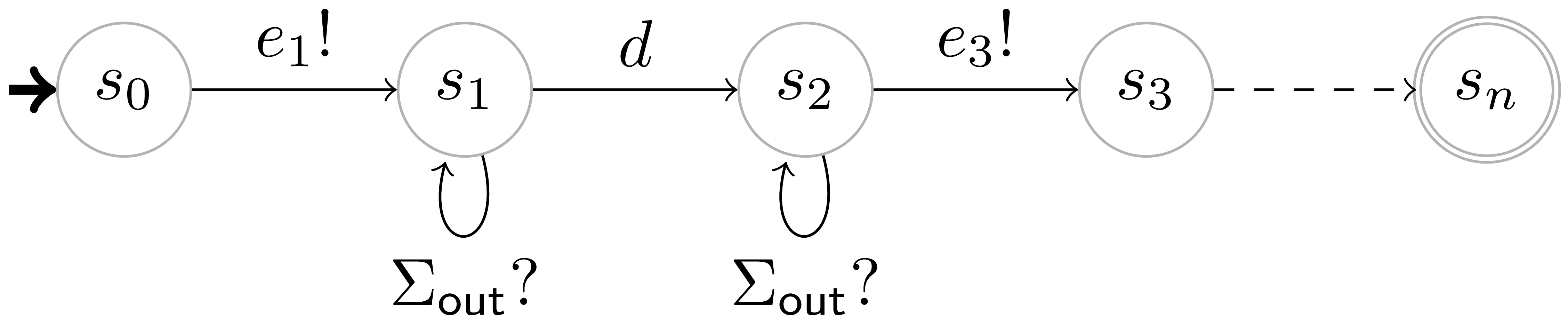
Environment model



Universal environment



Environment that can miss e_l



Environment modeling an interpretation

Conclusion & Perspectives

Conclusion

Model-Based Testing an IMS with automatic model construction
Automatic generation of test cases with CoVer and alternative methods

Future Works

Visualisation for IR (Assistance for composition)

Using Ascograph, Ptolemy, SpaceEx

IR

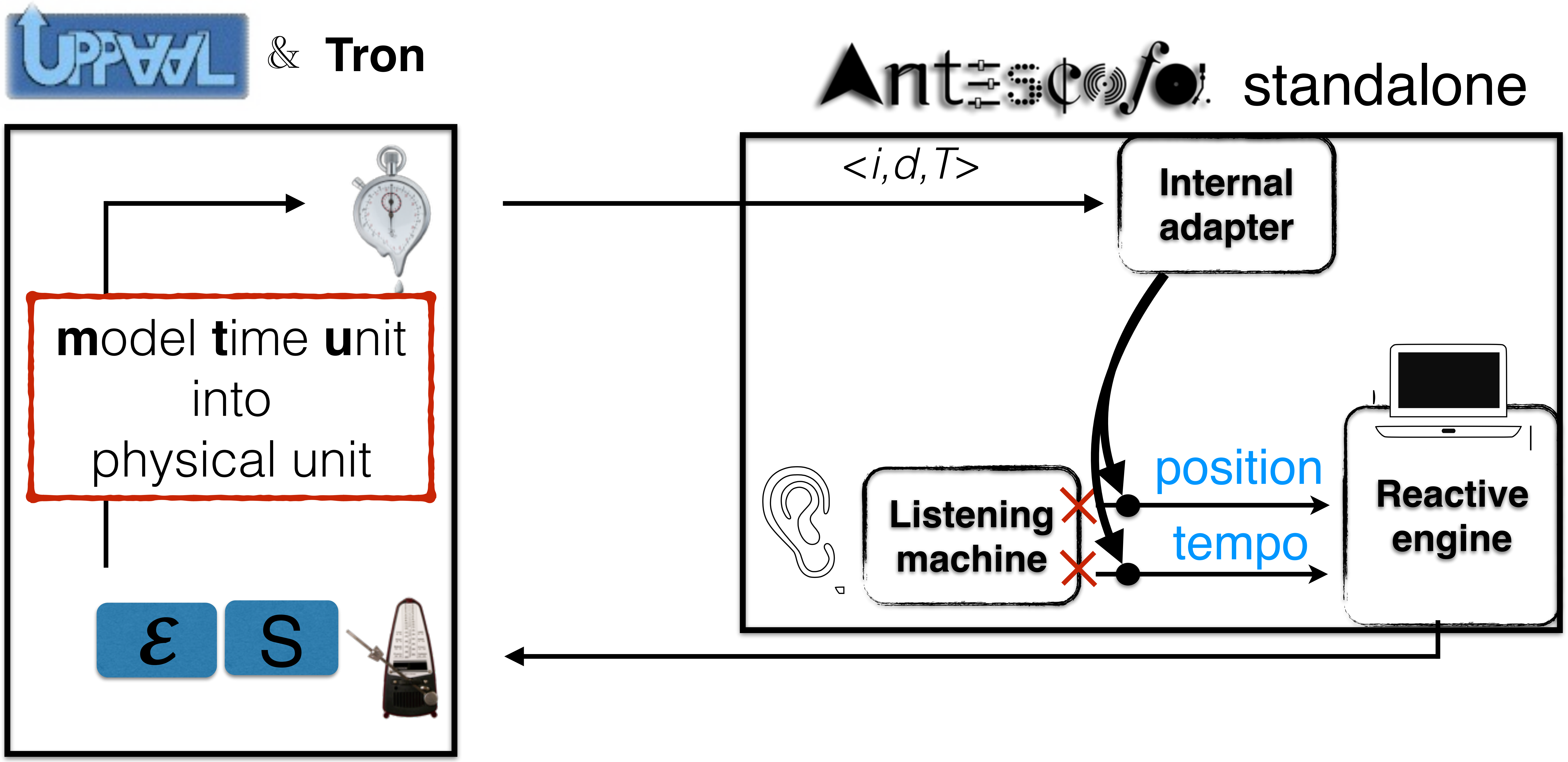
VM = IR interpreter.
Analyse robustness, race conditions, time safety…

Online

TRON-like framework: On-the-fly test suite generation

Online Testing

Uppaal/Tron [Larsen, Mikucionis, Nielsen 04]



[David, Larsen, Li, Mikucionis, Nielsen12] **Testing Real-Time Systems under Uncertainty.** *2012*

[Blom, Hessel, Jonsson, Peterson 04] **Specifying and Generating Test Cases Using Observer Automata.** *2004*

[Hessel, Larsen, Mikucionis, Nielsen,Pettersson, Skou08] **Testing Real-Time Systems Using Uppaal.** *2008*

[Dannenberg 97] **Abstract Time Warping of Compound Events and Signals.** *Computer Music Journal 1997*

[Honing01] **From time to time: The Representation of timing and tempo.** *Computer Music Journal 2001*

[Larsen, Mikucionis, Nielsen 04] **Online Testing of Real-time Systems Using Uppaal.** *2004*

Automatic construction of models

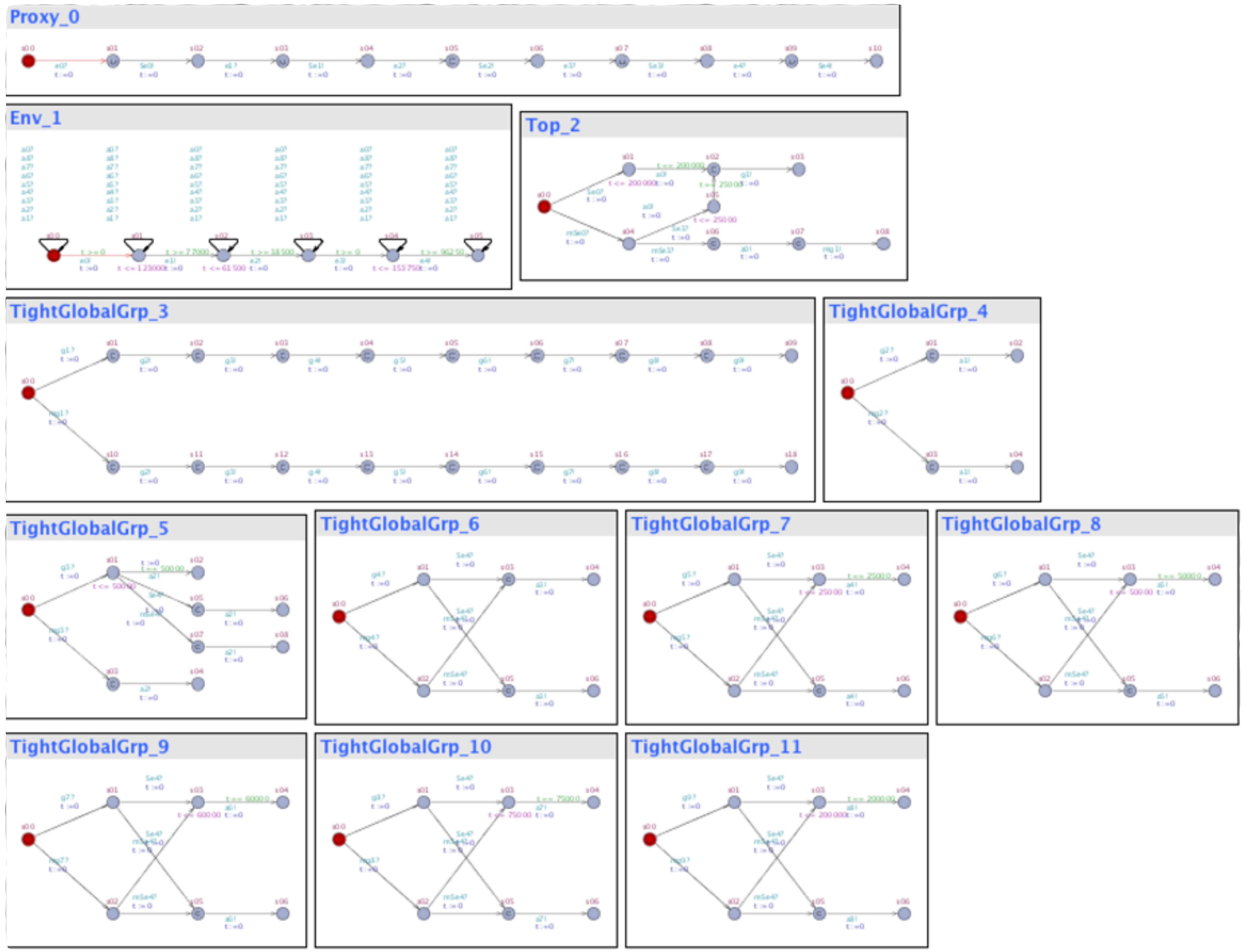
Mixed Score (AntescofoDSL)

↓

Intermediate Representation

↓ **Under restrictions**

Timed Automata



Generation of Input traces

Goal: create a test case (t_{in}, t_{out}) where t_{in} in $\mathcal{E}$ and t_{out} in $S(t_{in})$

$\mathcal{E}$
environment model

S
system specification

1) UPPAAL & **CoVer**

2) **Fuzzing**

3) **Audio files**

input trace(s)

expected test trace

Generation with UPPAAL & CoVer

Uppaal extension for Offline generation [Blom, Hessel, Jonsson, Peterson 04]

User defined coverage criterion on model items

$\mathcal{E}$ environment model

S system specification

→

Generation

- *observers* = FSA motoring the simulation
- exploration of the symbolic state set
- keep the trace with maximal number of Observer's final states

→

input traces

exhaustive

Conclusion Cover

\+ Well suited for debugging

\- Shortest delays → tempo explosion

\- Scalability problem (small scores/extracts)

Fuzzing the ideal trace

Performance Models (aka fuzz) [Dannenberg 97, Honing02]

Mixed score
(ideal trace)

→

Generation

Timing function (TIF)

$$\mathbf{f} \equiv \langle \mathsf{f}^{\mathsf{shift}}, \mathsf{f}^{\mathsf{tempo}} \rangle$$

time shifting for individual events

tempo curve

→

input traces

<u>Conclusion Fuzzing ideal trace</u>

+ Scalable
+ Preparation of concerts
- Lack of coverage criteria

From recorded audio file

Conclusion User File

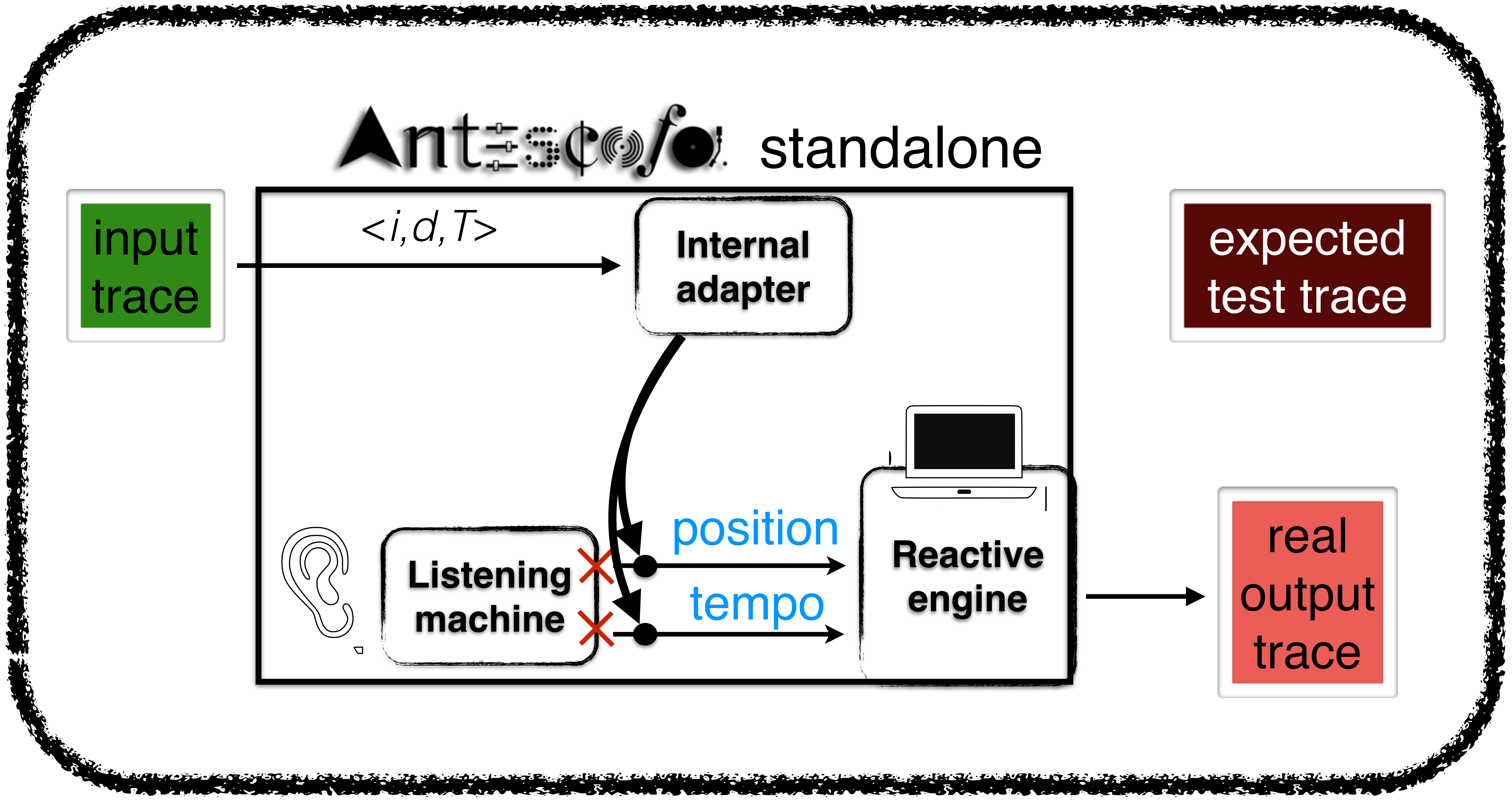
+ Well suited for Composition assistance
- Input score specifiable

Black-Box execution

3 Scenarios

bounds:

reactive machine

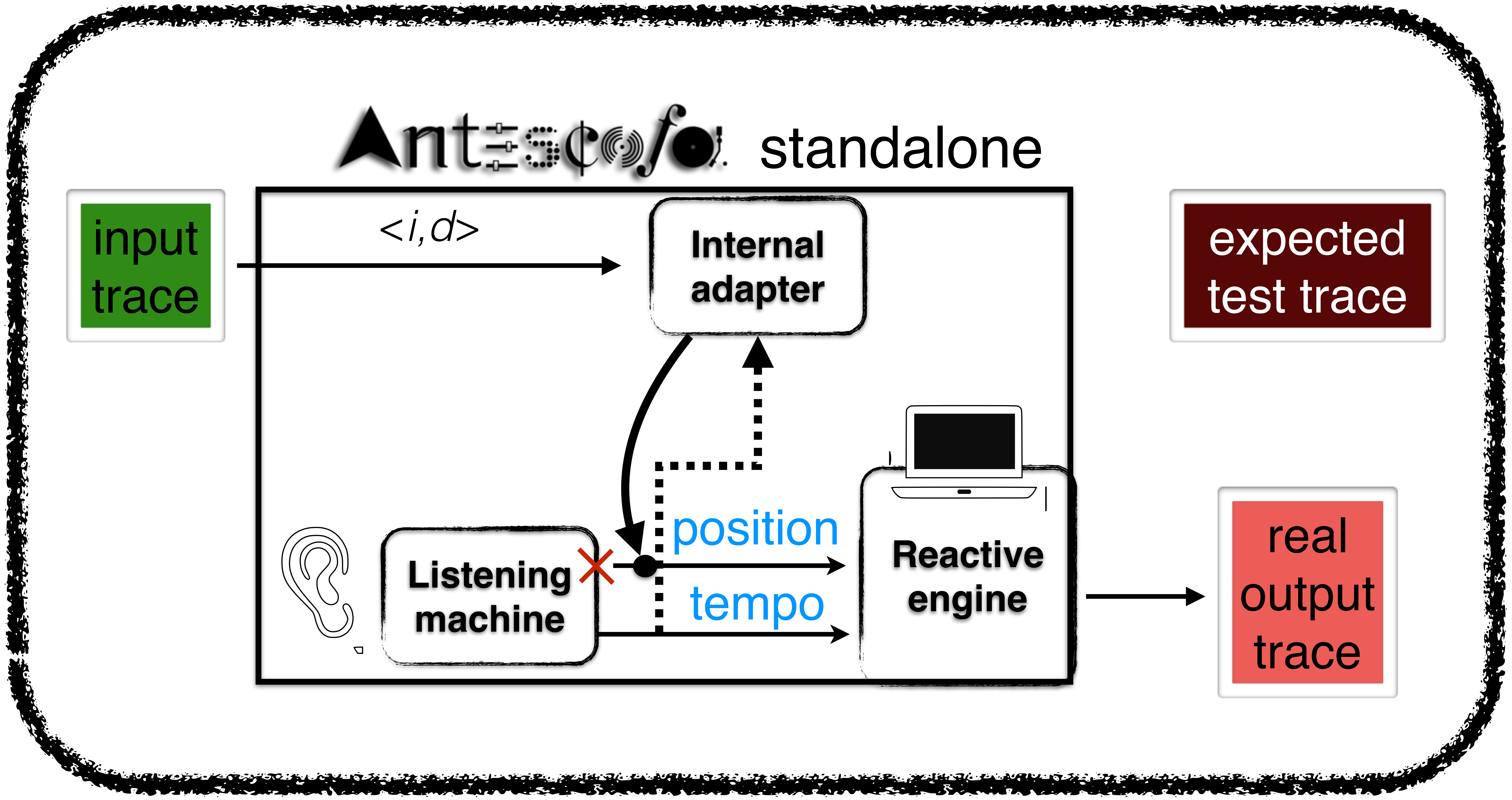


Black-Box execution

3 Scenarios

bounds:

reactive machine
+ tempo management



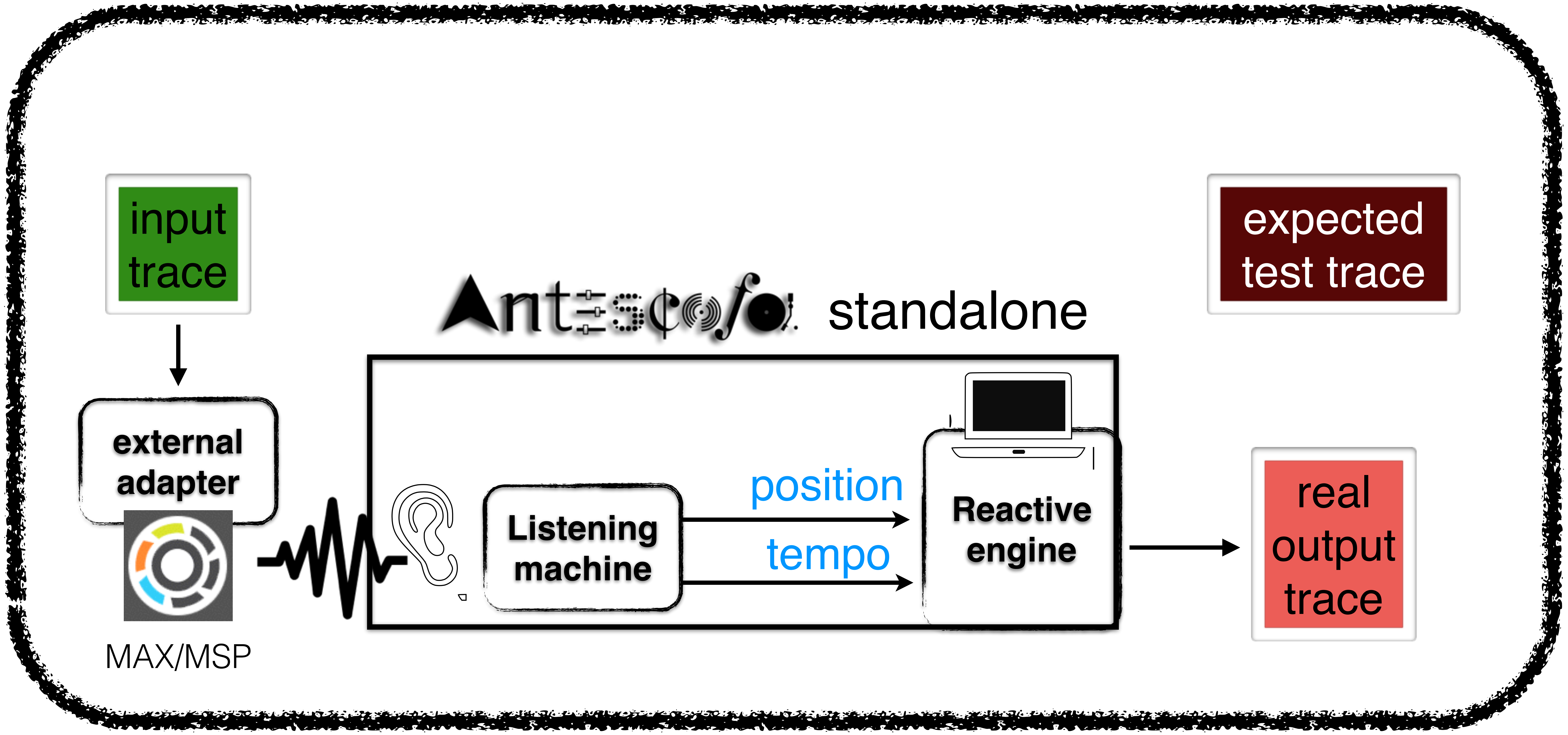
Black-Box execution

3 Scenarios

audio signal

bounds:

whole Antescofo



Timed conformance

rtioco$_e$

Relativized **t**imed **co**nformance **i**nput/**o**utput **r**elation

Testing Real-Time Systems Using Uppaal
[Hessel, Larsen, Mikucionis, Nielsen, Pettersson, Skou08]

real output trace

expected test trace

```
start of tests
note0 --> 0.77 --> note1_1.00 --> 0.385 --> note2_1.50 --> 0.1925 --> note3_1.75 --> 0
_________________________________________________________________
|-        Antescofo Trace                     Expected Trace        -|
|-     TimeStamp      [Estimate Beat]   TimeStamp       [Beat]      -|
|------------------------------------------------------------------|
         a0         0 [    0]           a0         0 [    0]
*     note0         0 [    0]           e0         0 [    0]          * T: 60 BPM
         a1       0.5 [ 0.5]           a1       0.5 [ 0.5]
         a2      0.77 [0.77]           a2      0.77 [0.77]
*note1_1.00      0.77 [0.824]           e1      0.77 [0.77]          * T: 64.2 BPM
         a3     0.887 [0.95]           a3     0.887 [1.02]
*note2_1.50 0.95047 [1.21]           e2 0.95047 [1.16]           * T: 128 BPM
         a4      0.99 [1.29]           a4      0.95 [1.16]          x delta: 0.04
         a5      1.02 [1.35]           a5     0.985 [1.25]          x delta: 0.0321
         a6      1.02 [1.35]           a6      1.02 [1.35]
*note3_1.75  1.0174 [ 1.4]           e3   1.0174 [1.35]          * T: 173 BPM
*note4_1.75  1.0174 [ 1.4]           e4   1.0174 [1.35]          * T: 203 BPM
         a7      1.28 [ 2.3]           a7      1.28 [2.31]
*       END  1.2831 [2.38]           e5   1.2831 [2.31]          * T: 220 BPM
|------------------------------------------------------------------|
Error :: Test KO
finito. ||
```

conformed iff ∀ test cases verdict OK