Programming Mixed Music in ReactiveML

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Mixed Music and Antescofo

[Cont 2008]

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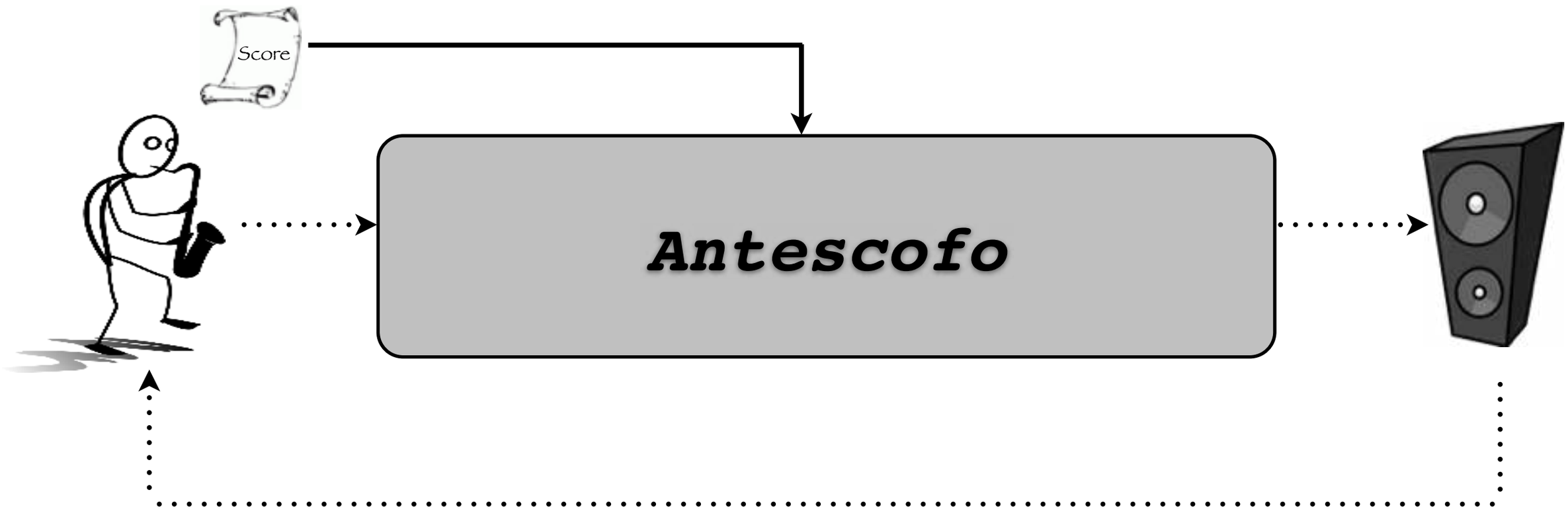
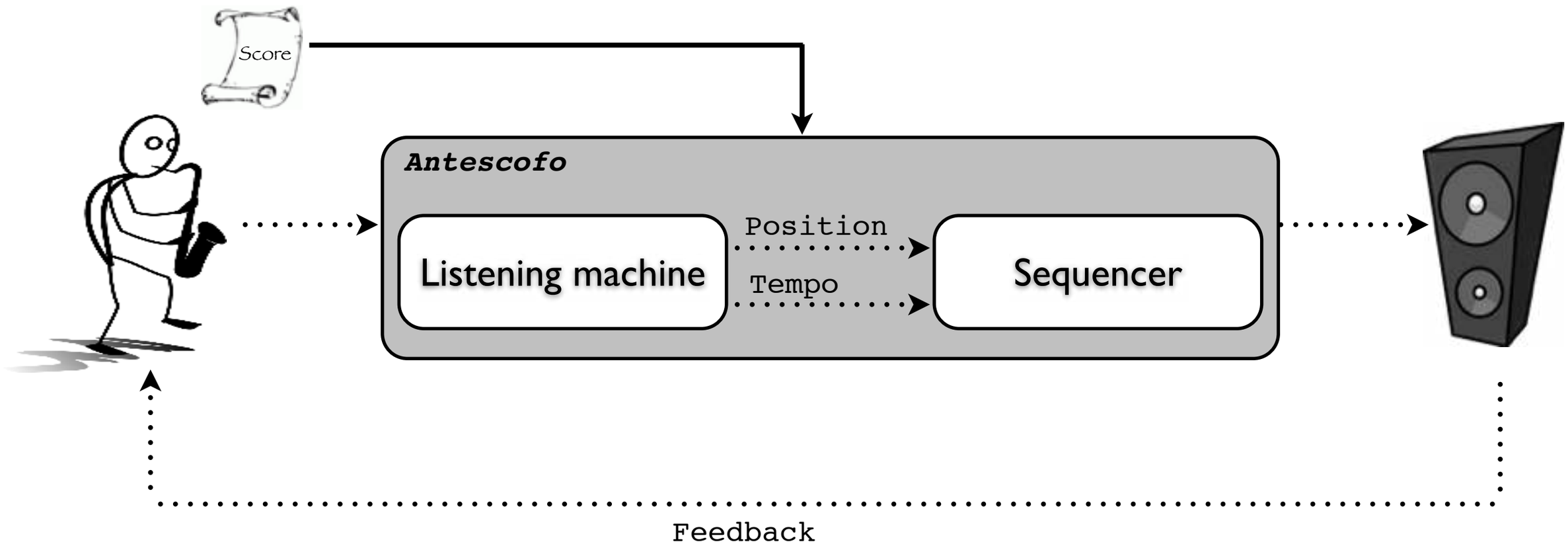


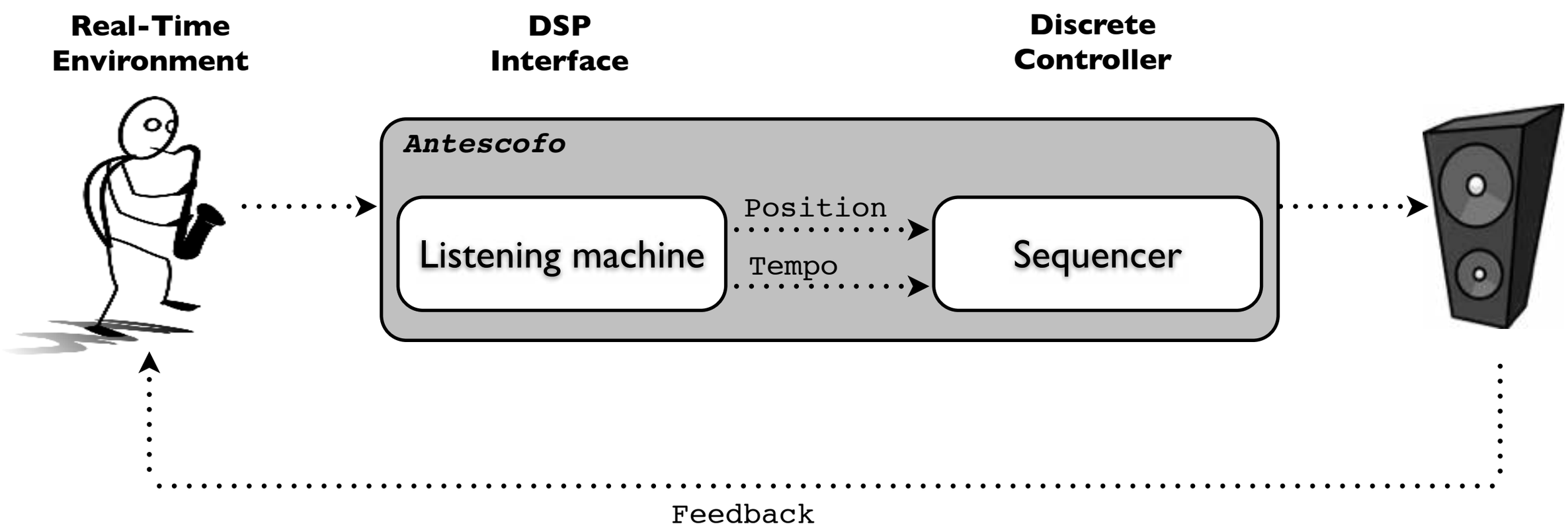
Antescofo Architecture

[Cont 2008]



Antescofo Architecture

[Cont 2008]



Antescofo Architecture

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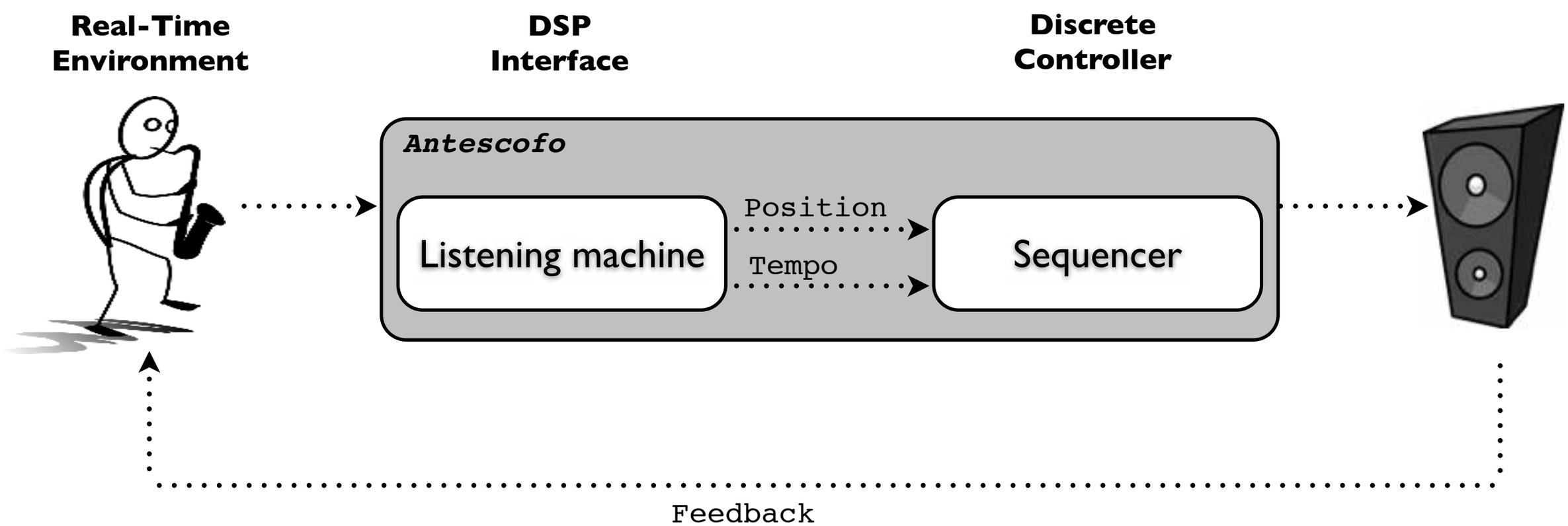
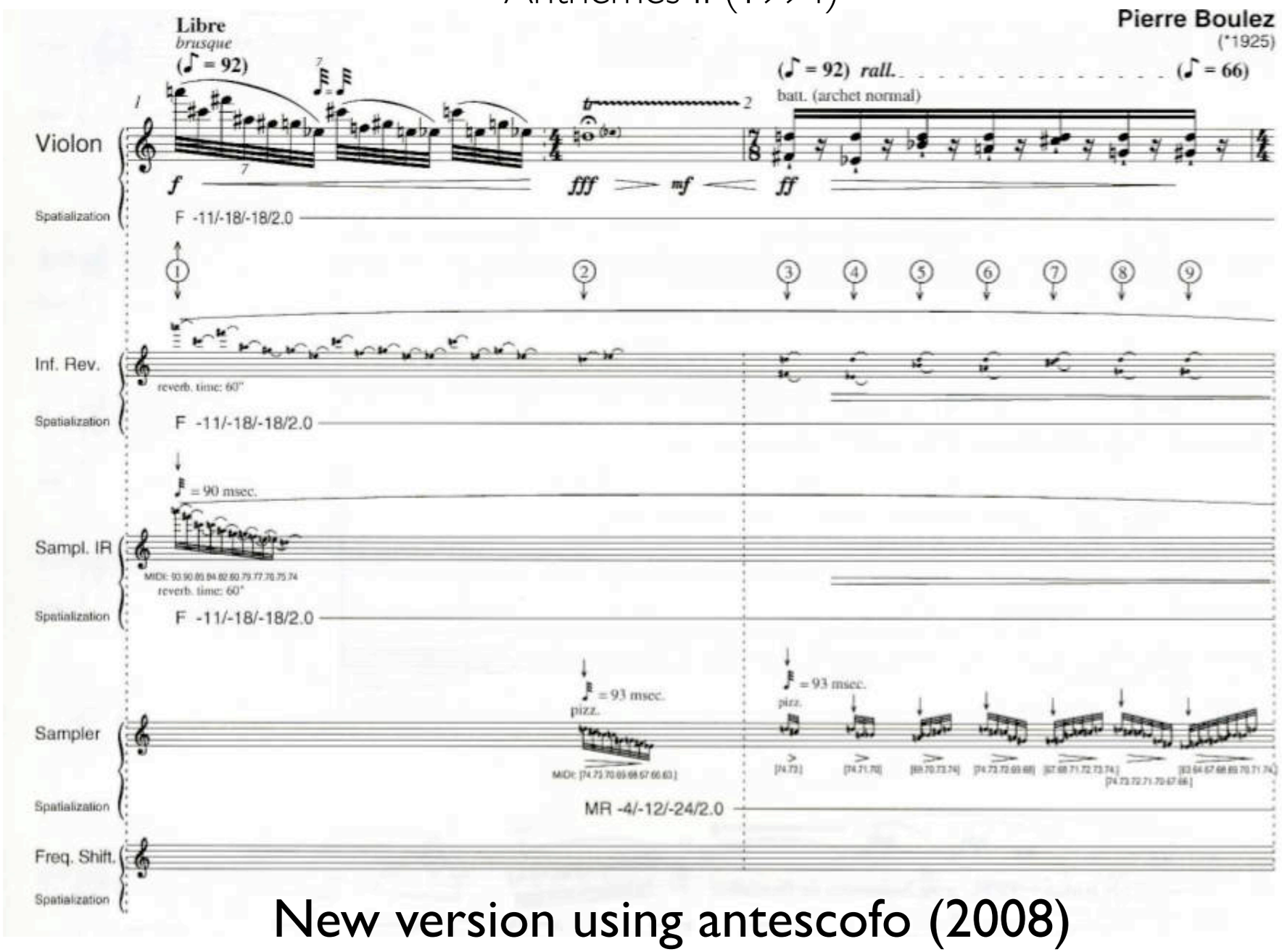


The score is a specification of a musical reactive system

The Antescofo Language

Goal: Jointly specify electronic and instrumental parts

Anthèmes II (1994)

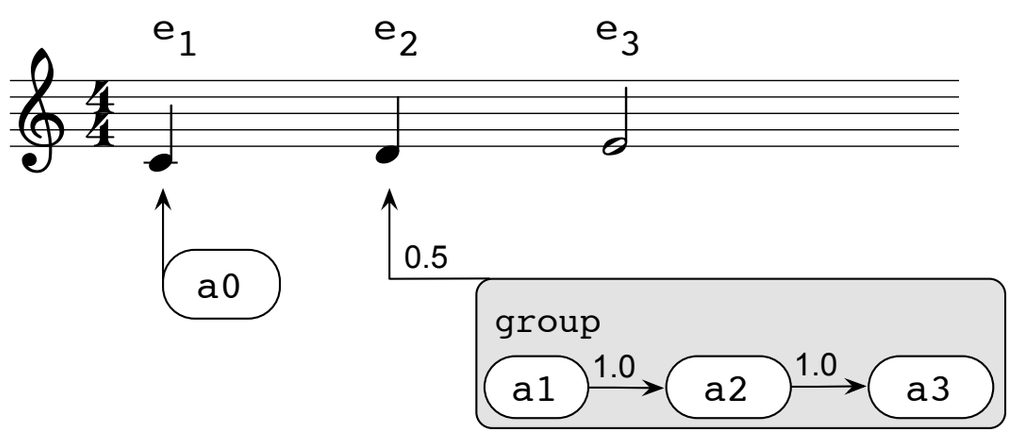


New version using antescofo (2008)

The Antescofo Language

Goal: Jointly specify electronic and instrumental parts

[Echeveste et al. 2012]




```
NOTE  60  1.0
0.0  'a_0'

NOTE  62  1.0
0.5  GROUP  loose  causal
     { 0.0  'a_1'
       1.0  'a_2'
       1.0  'a_3' }

NOTE  64  2.0
```

- Time is relative to the tempo
- Electronic actions are characterized by a delay
- Hierarchical structure: *groups and nested groups*
- Synchronization with the musician : *tight, loose*
- Error handling strategies : *partial, causal*

The Antescofo Language

Goal: Jointly specify electronic and instrumental parts

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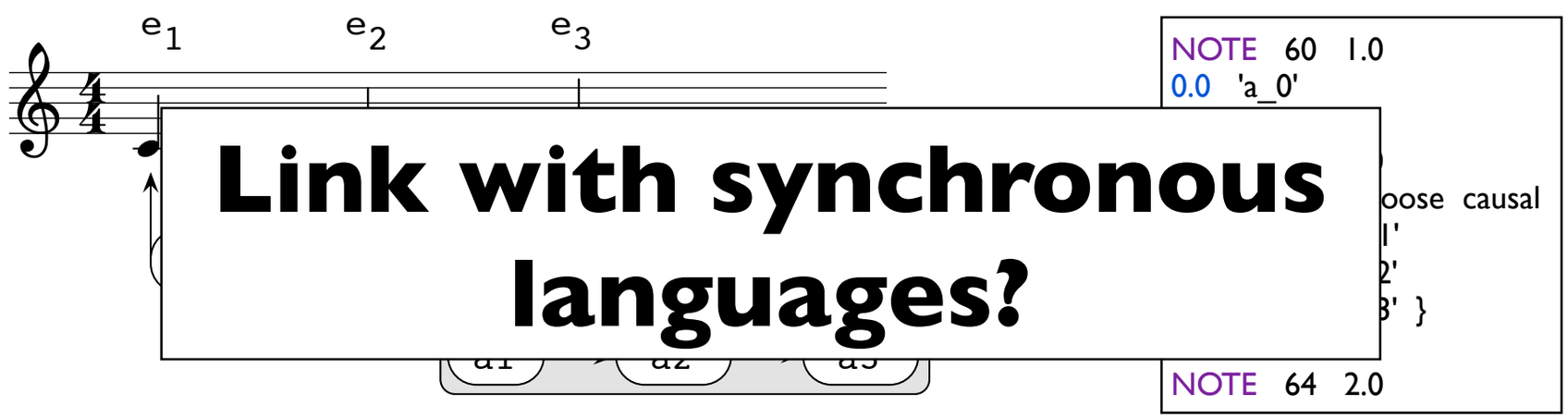


Link with synchronous languages?

- Time is relative to the tempo
- Electronic actions are characterized by a delay
- Hierarchical structure: *groups and nested groups*
- Synchronization with the musician : *tight, loose*
- Error handling strategies : *partial, causal*

ReactiveML

The temporal expressiveness of synchronous languages with the power of functional programming

ReactiveML

[Mandel-Pouzet 2005]

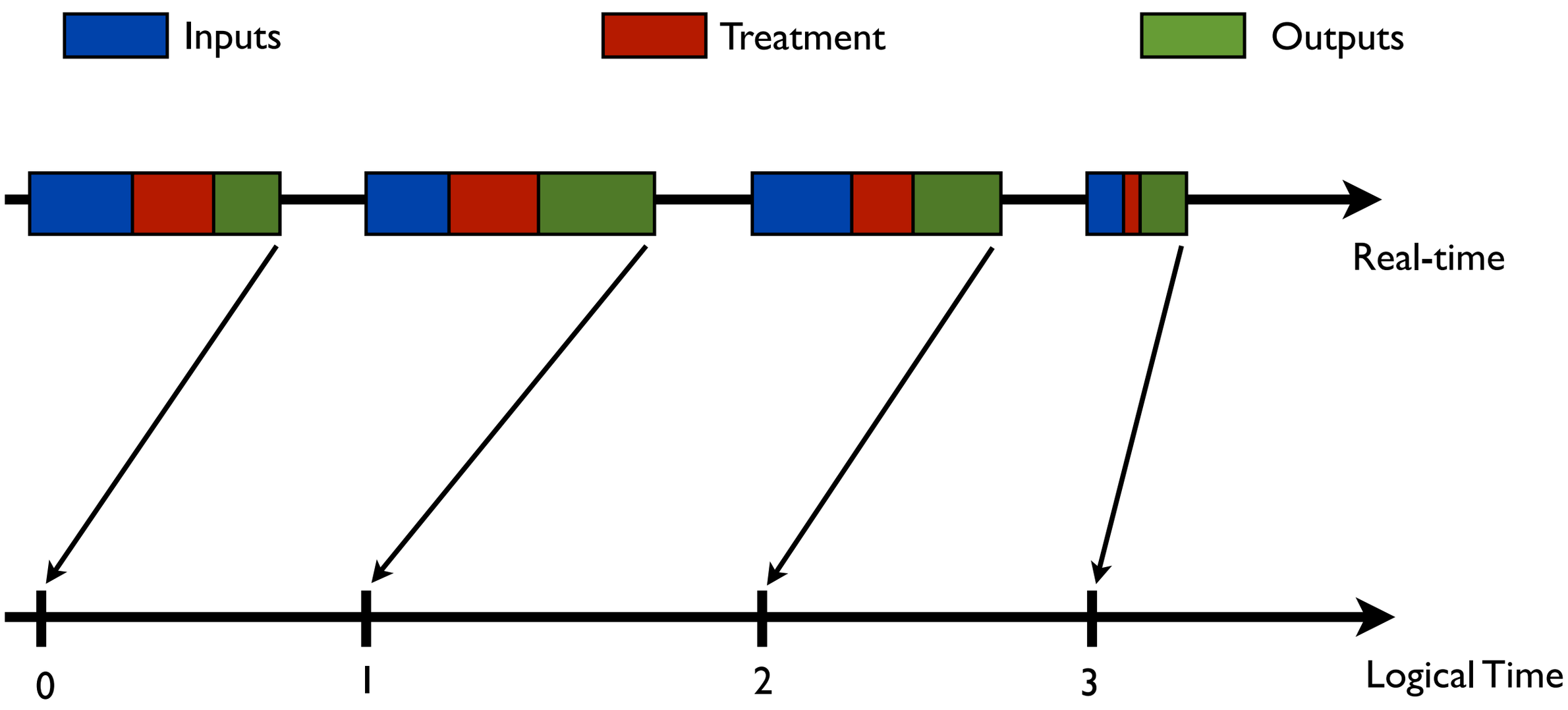
OCaml

- Data structures
- Control structures

Synchronous model of concurrency

- A global logical time
- Parallel composition
- Communication between processes

The Synchronous Hypothesis



The Language

Process

`let process <id> {<pattern>} = <expr>`

State machines, executed through several instants.
Simple OCaml functions are considered to be instantaneous.

Basics

Synchronization: `pause`
Execution: `run <expr>`

Composition

Sequence: `<expr> ; <expr>`
Parallelism: `<expr> || <expr>`

Signals

Definition: `signal <id>`
Emission: `emit <id>`
Waiting: `await <id>`

Broadcast communication between processes

First Example

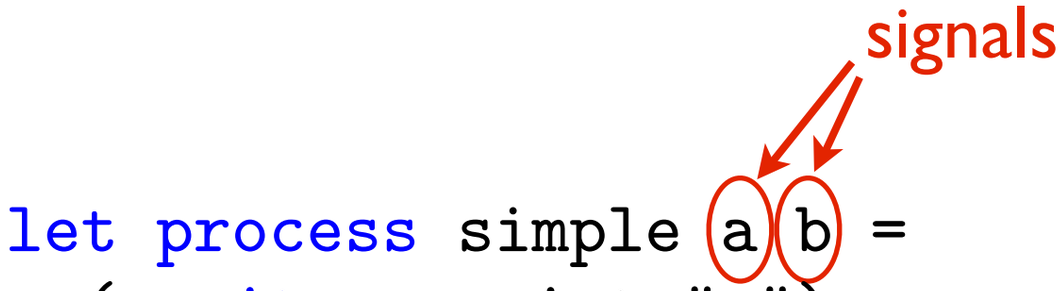
Wait in parallel for the emission of two signals

```
let process simple a b =
  (await a; print "a")
  ||
  (await b; print "b")
val simple:
  (unit, unit) event -> (unit, unit) event ->
    unit process
```

||

First Example

Wait in parallel for the emission of two signals

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```

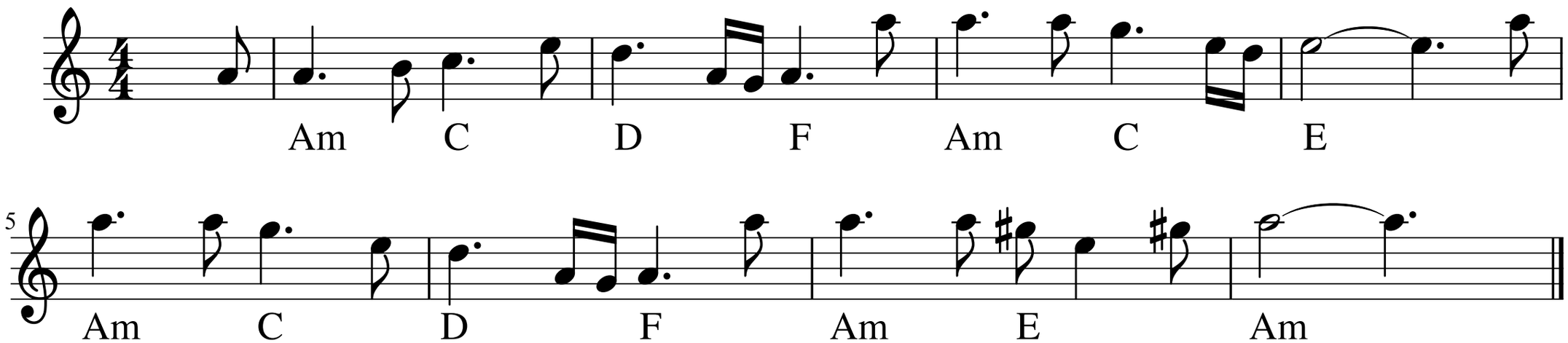
Parallel composition

Live Coding

Modify, correct and interact with the score
during the performance

Automatic Accompaniment

The house of the rising sun



- **Functional programming**
  modular definition of the accompaniment
- **Reactive programming**
  interaction with the score during the performance

Definitions

1. Define the bass line

```
let bass = [0.0, (A, Min); 2.0, (C, Maj); ...]
val bass: (delay * chord) list
```

2. Define the accompaniment style

```
let arpeggio chord =
  ...
  group Loose Local
    [0.0, action_note (fond);
     1.0, action_note (third);
     2.0, action_note (fifth);}]
val arpeggio: chord -> asco_event
```

3. Link with the performance

```
let process basic_accomp =
  run (link asco 2 roots)
val basic_accomp: unit process
```

Interactions

- **Kill a process when a signal is emitted**
  allow to modify the accompaniment
- **Suspend a the execution of a process**
  pause and resume a process with a signal
- **Dynamically change the behavior of a process**
  switch between different kinds of accompaniment

Kill a Process

Example of a higher-order process

```
let process killable k p =
  do
    run p
  until k done
val killable:
  (unit, unit) event -> unit process ->
    unit process
```

Kill a Process

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process

Kill a Process

Example of a higher-order process

control signal

```
let process killable k p =
  do
    run p
  until k done
val killable:
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```

process

Dynamic Changes

Example of a recursive higher-order process

```
let process rec replaceable replace p =
  do
    run p
  until replace (q) ->
    run (replaceable replace q)
  done
val replaceable:
  (unit process, unit process) event ->
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Dynamic Changes

Example of a recursive higher-order process

process

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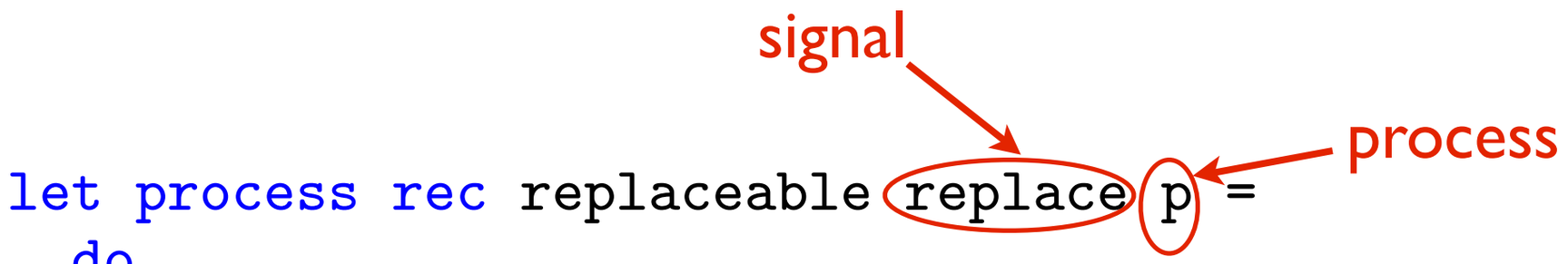


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```

signal

process

new behavior

signal can carry processes

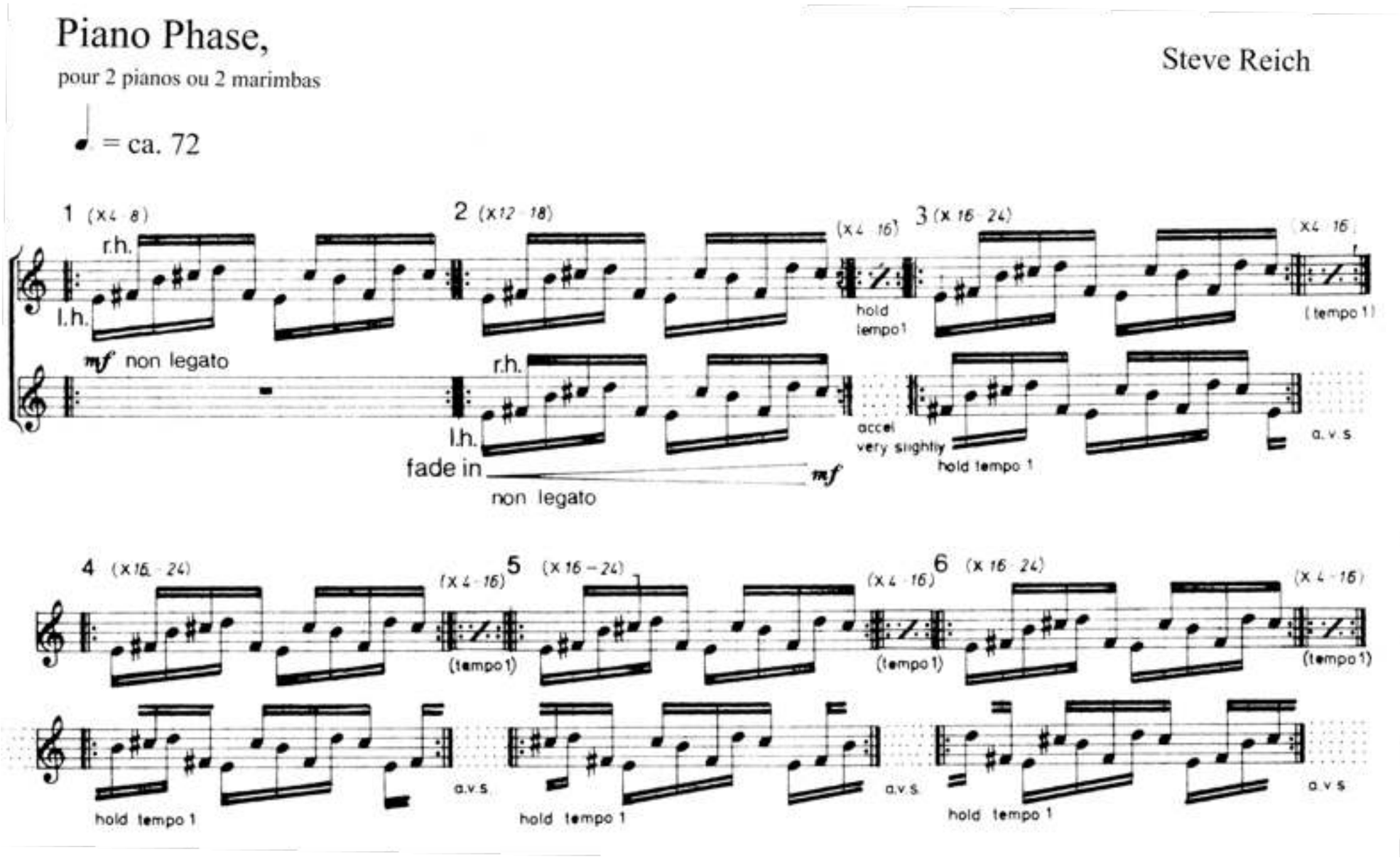
New Reactive Behaviors

Example: Steve Reich's Piano Phase

Piano Phase ...

Bob

Alice



Piano Phase ...

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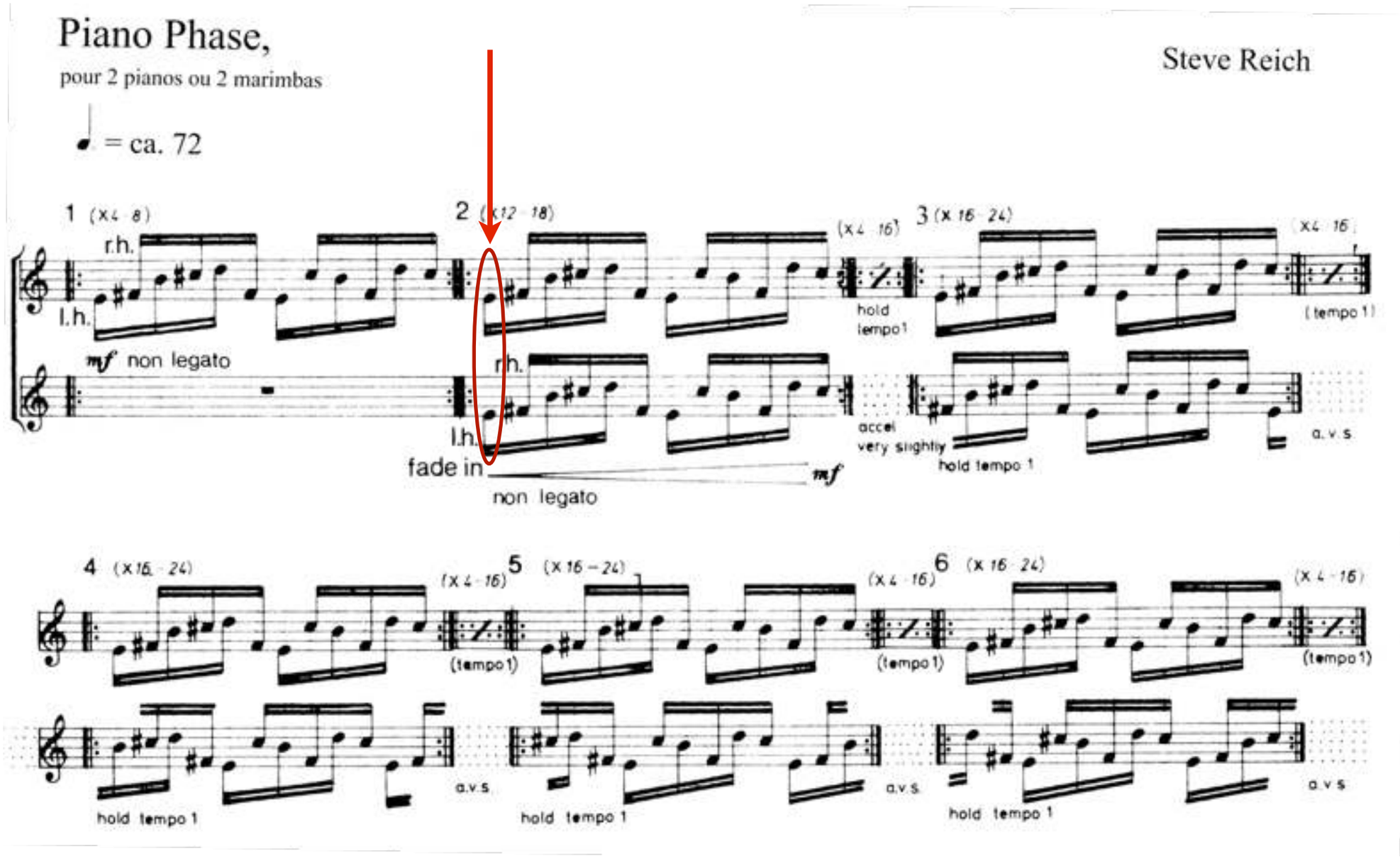

Synchronization

Piano Phase ...

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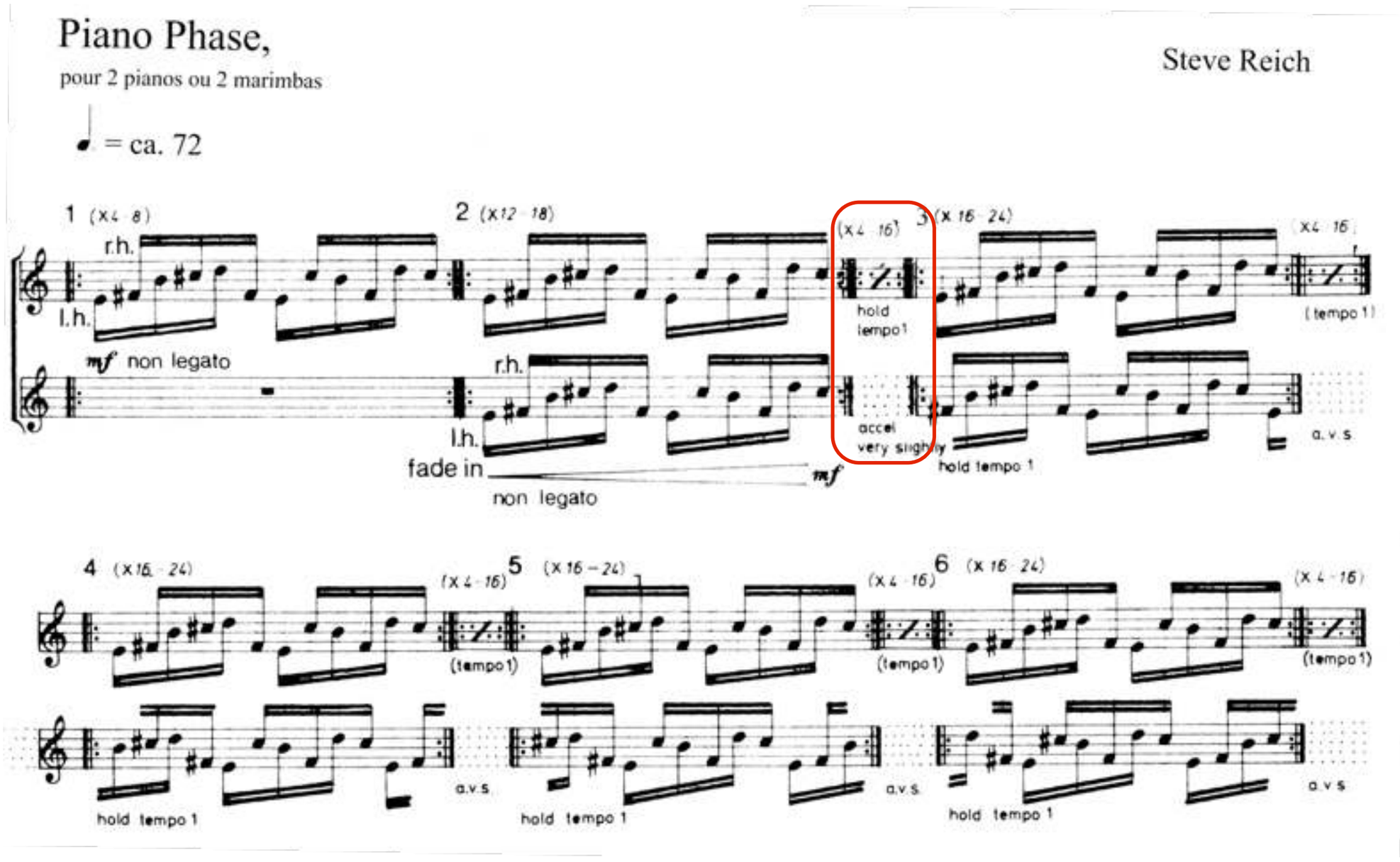

Desynchronization

Piano Phase ...

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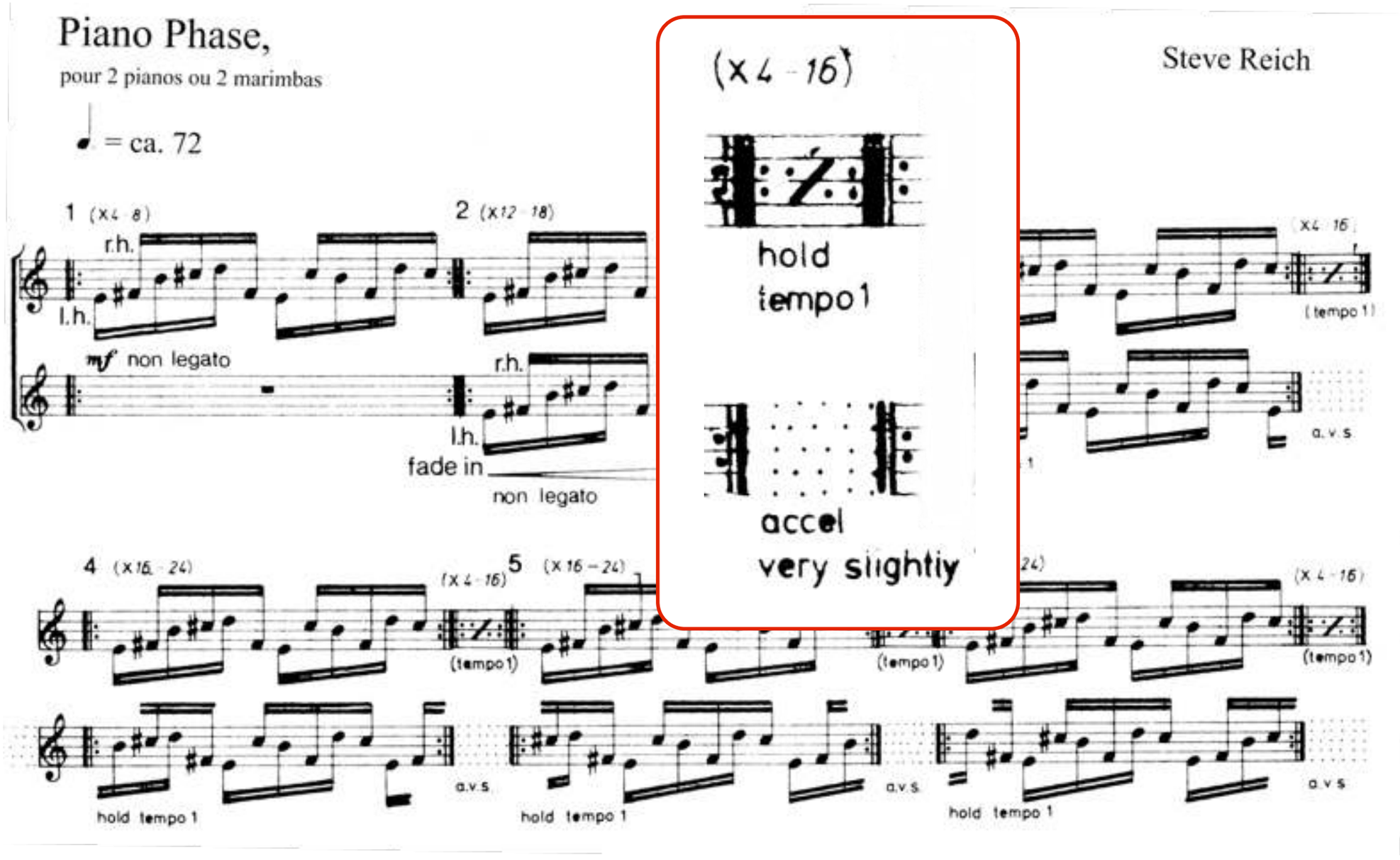

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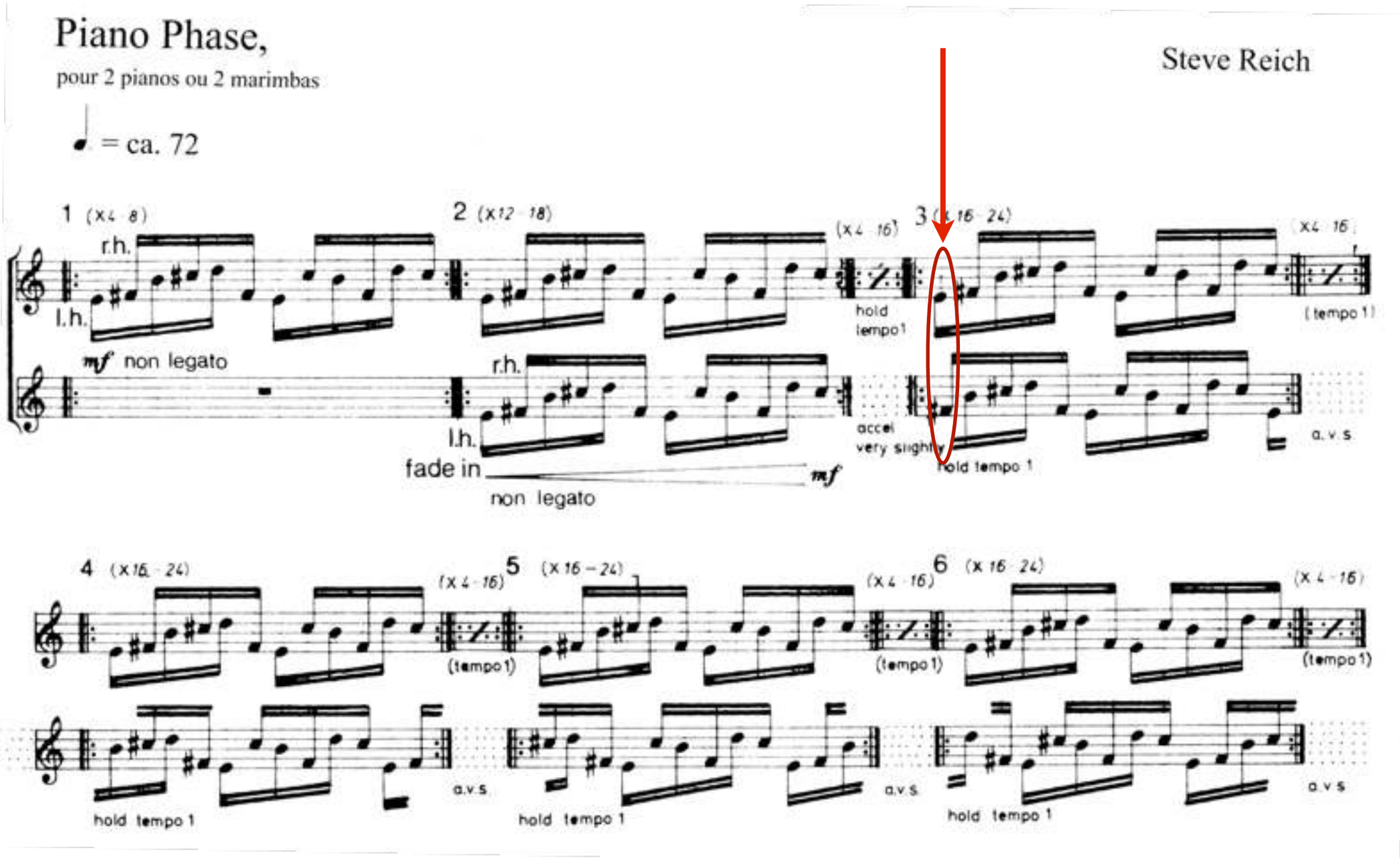

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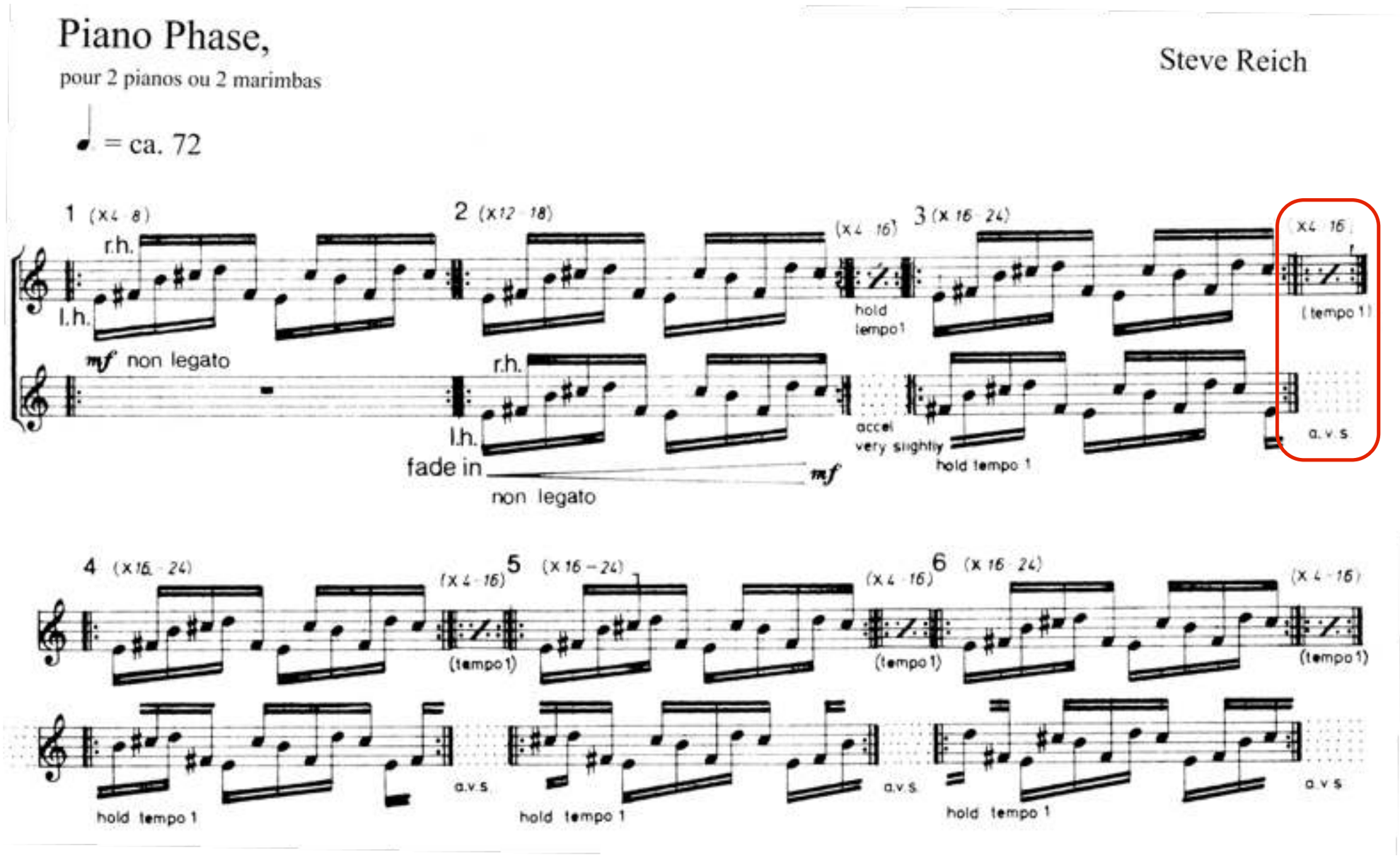

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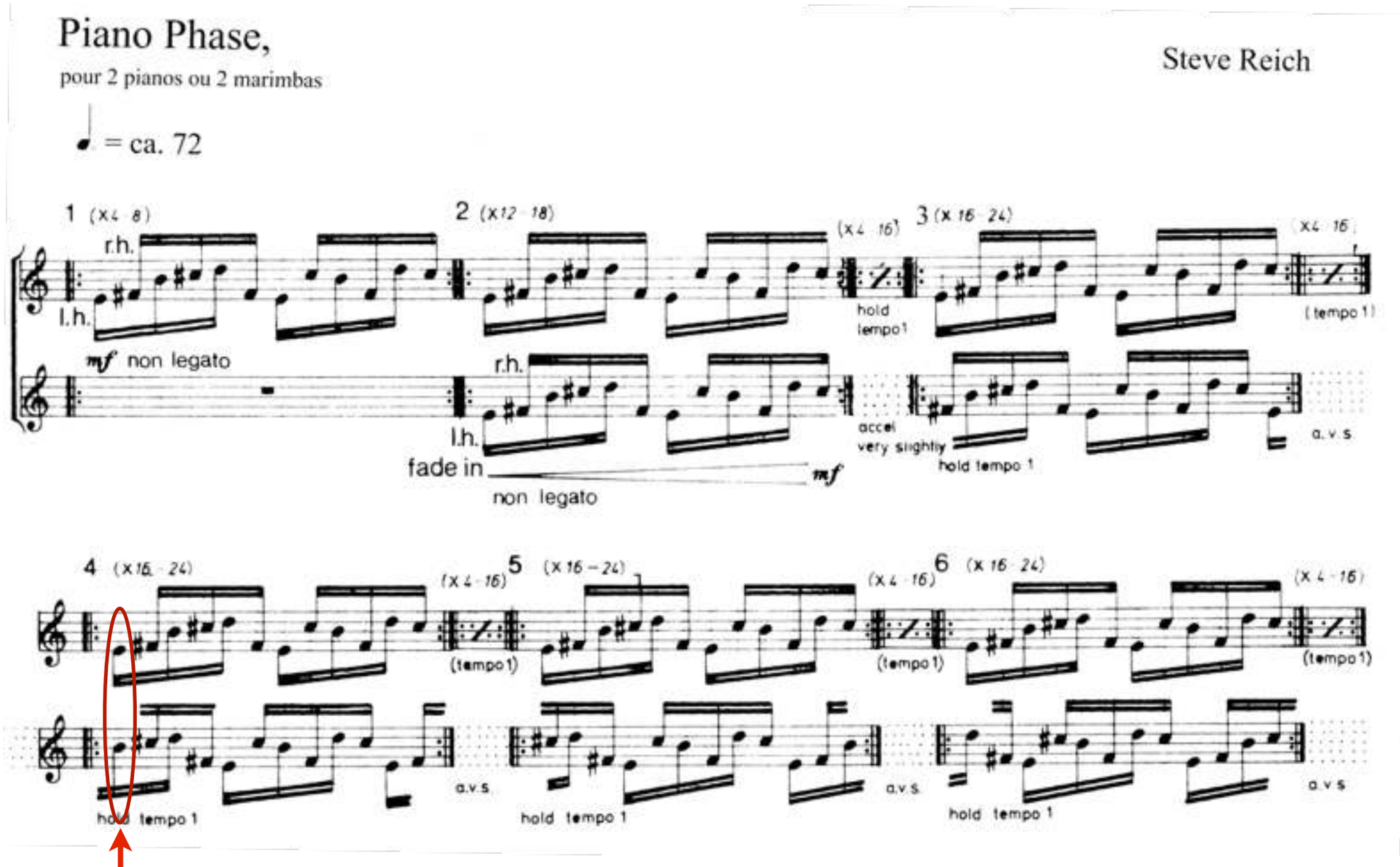

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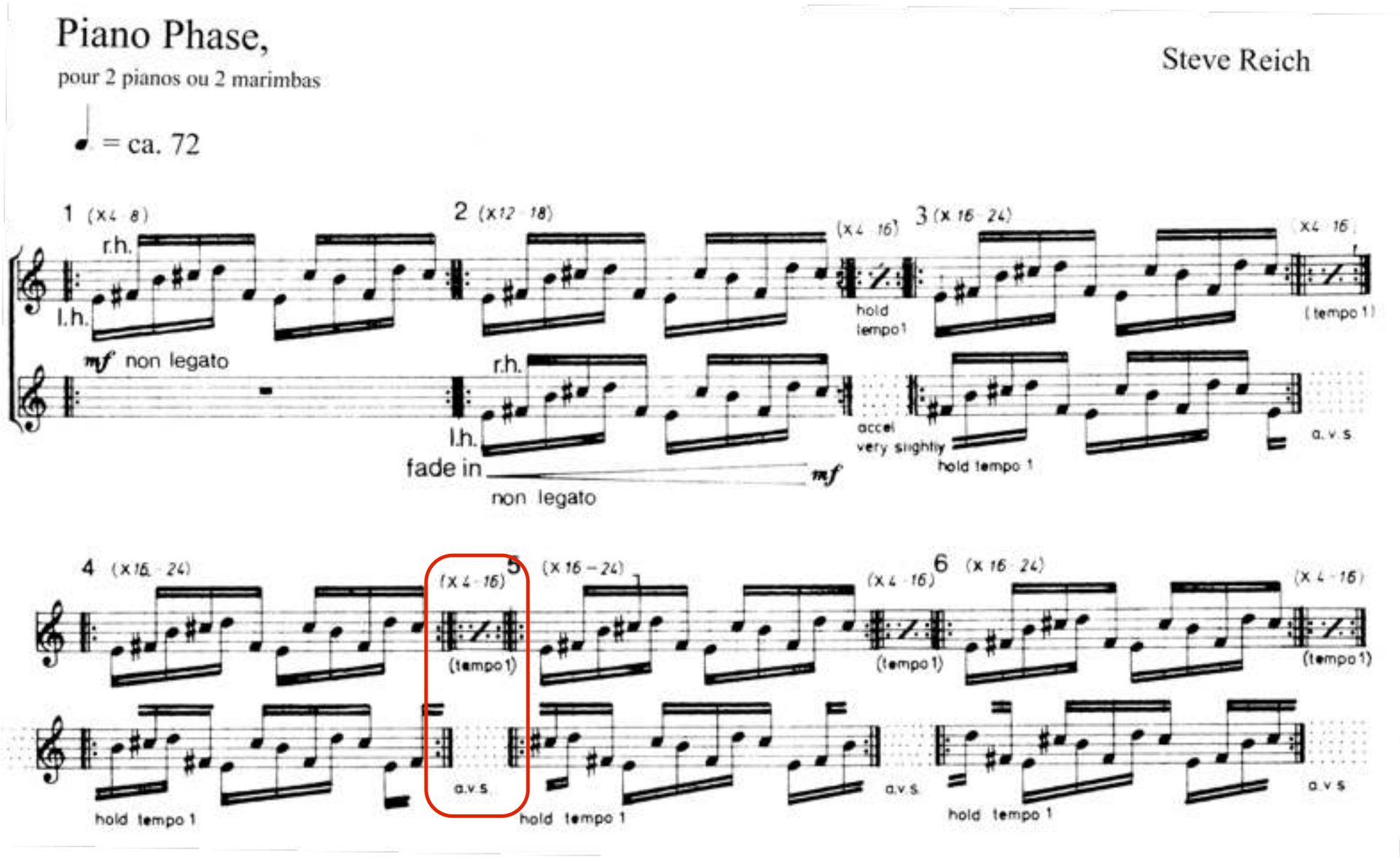

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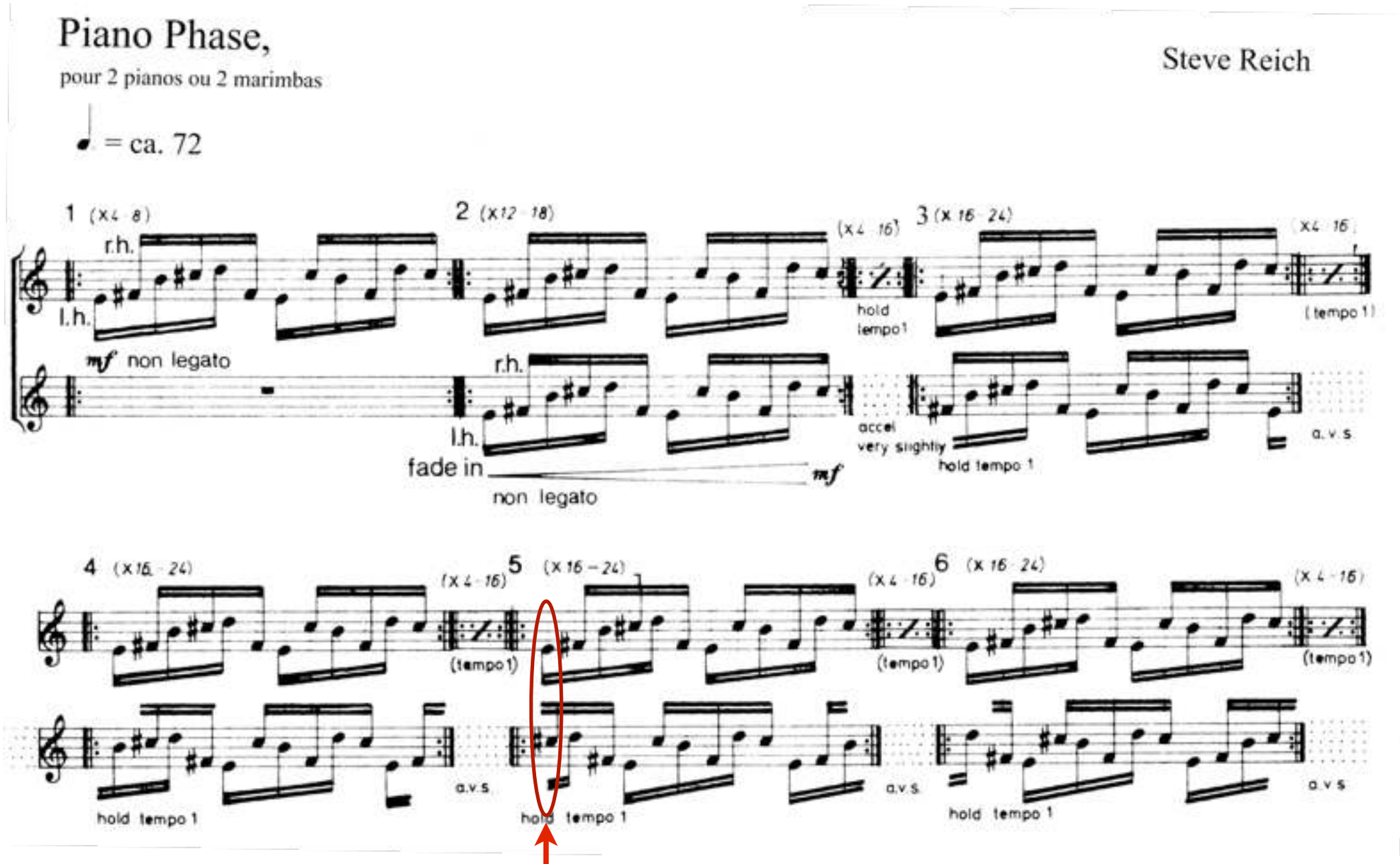

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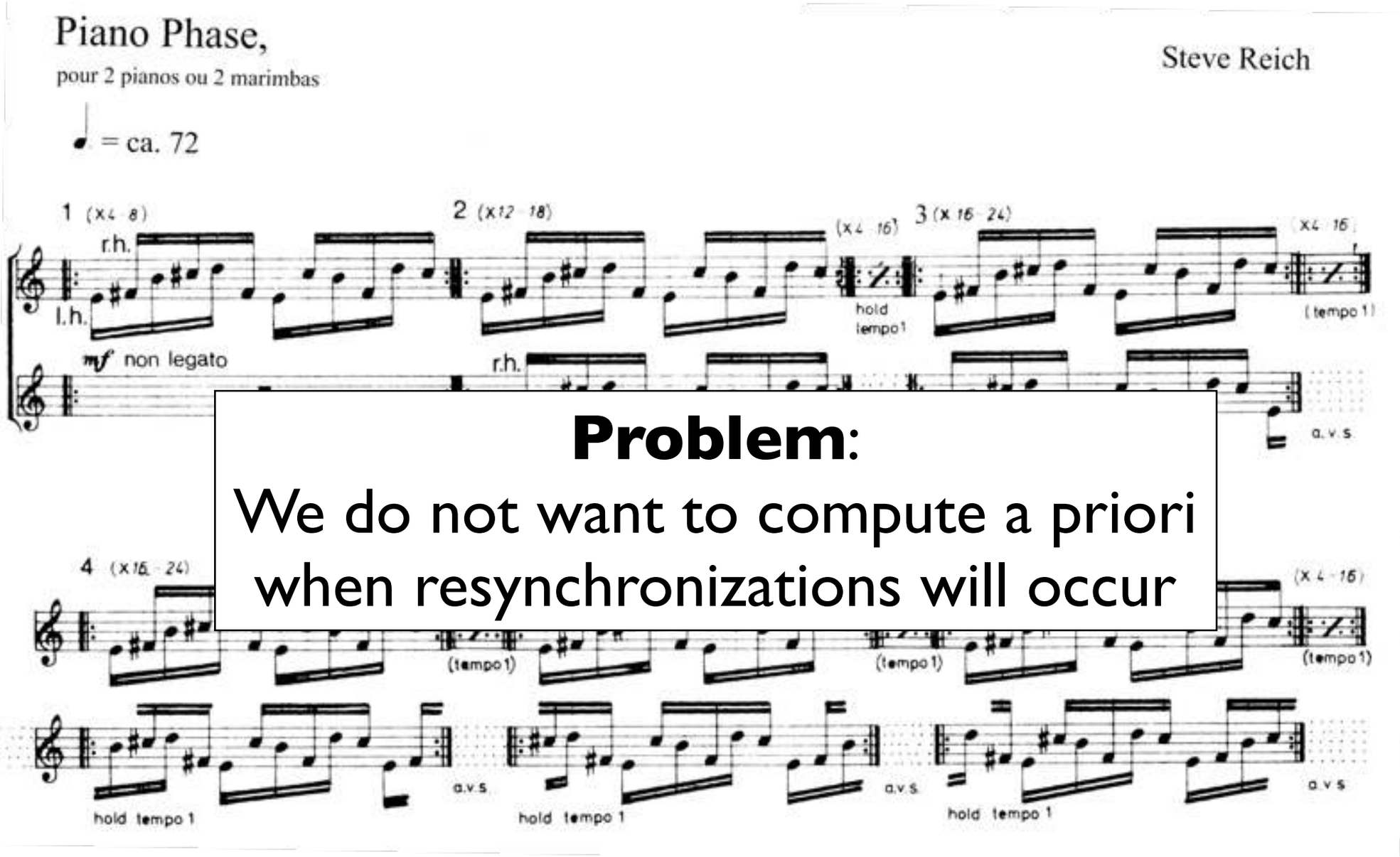


Bob

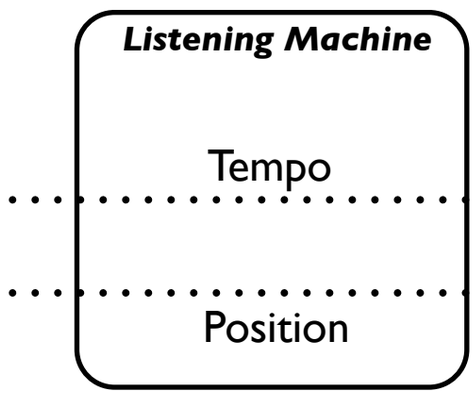
Alice

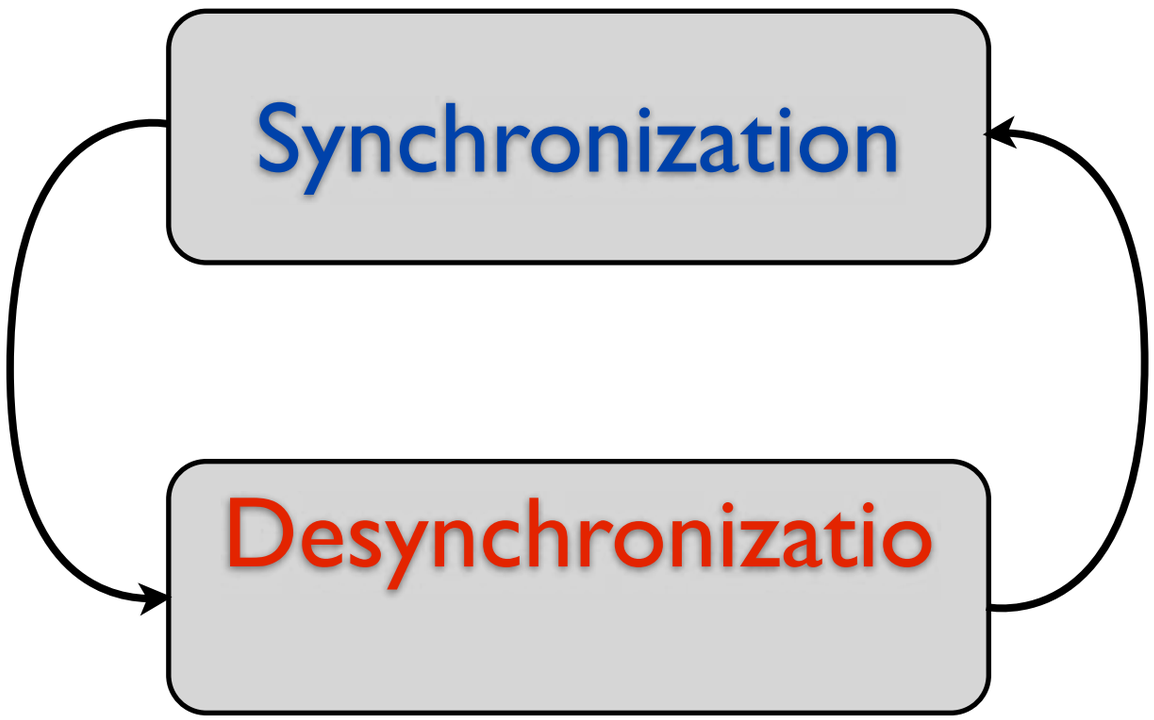
Problem:
We do not want to compute a priori when resynchronizations will occur

... in Mixed Music

Live musician
Plays the constant speed part

Electronic
Handles the desynchronization





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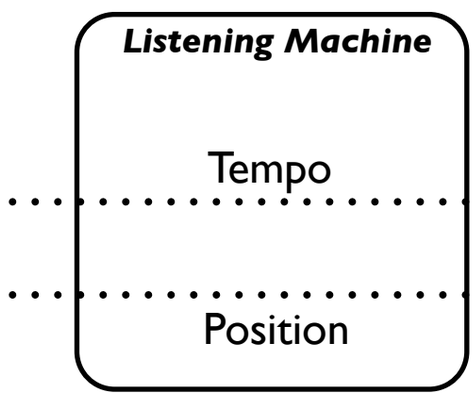

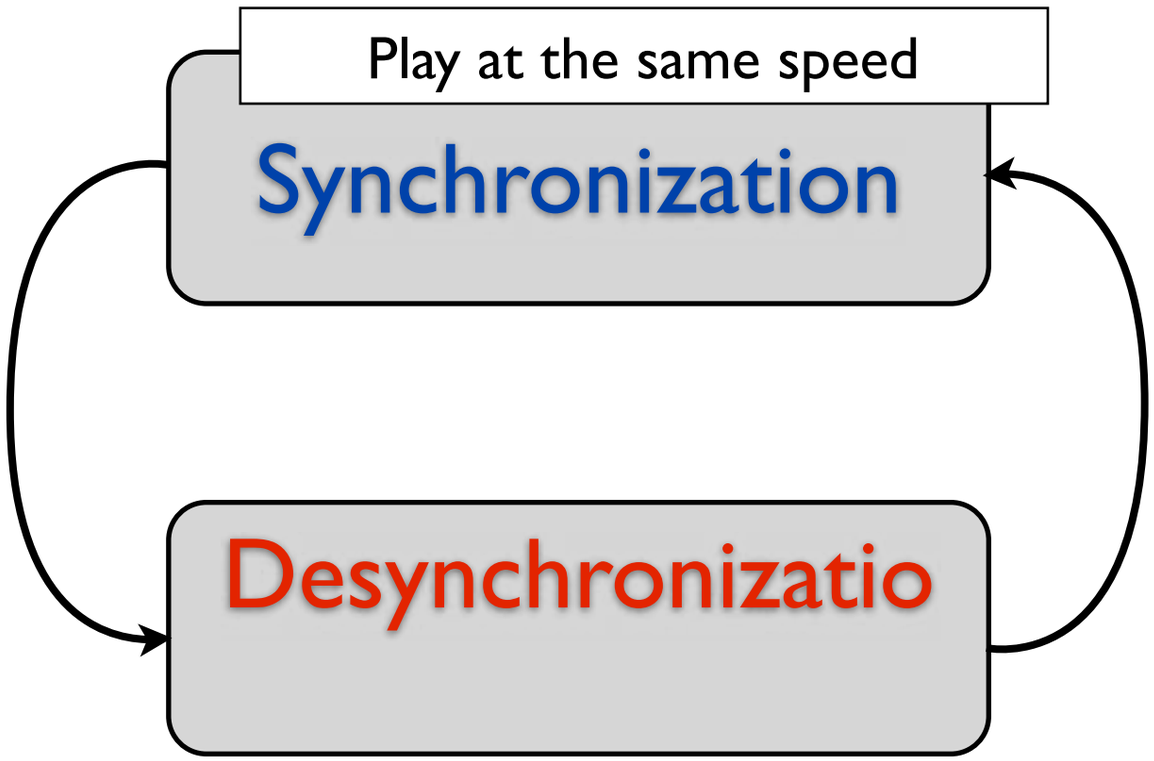

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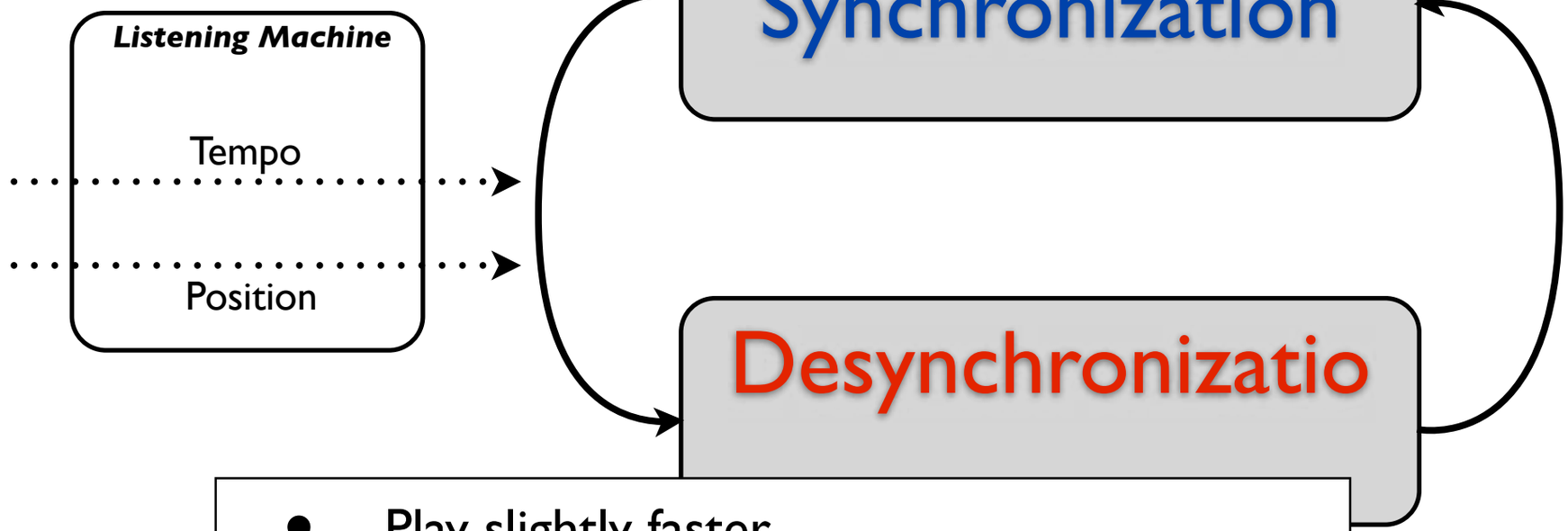

- Play slightly faster
- Track the first note of Bob
- Resynchronize when the k-th note of Alice is close enough of the first note of Bob

Implementation

Two phases:
Synchronization
Desynchronization

```
let piano_phase sync desync first_note kth_note =
  let rec process piano_phase k =
    let ev = last_event asco in
    run (melody ev 4 0.25 first_note);
    emit desync;
    do
      let ev = last_event asco in
      run (melody (ev+1) 16 0.2458 first_note) ||
      run (track asco k kth_note) ||
      run (compare asco first_note kth_note sync 0.05)
    until sync done;
    run (piano_phase ((k + 1) mod 12))
  in
  piano_phase 1
in
```

Implementation

Synchronization

Play the melody four times and follow the tempo

Emit the signal **`desync`** *after four iterations of the melody*

```
let piano_phase sync desync first_note kth_note =
  let rec process piano_phase k =
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      run (compare asco first_note kth_note sync 0.05)
    until sync done;
    run (piano_phase ((k + 1) mod 12))
  in
  piano_phase 1
in
```

Implementation

Desynchronization

Play slightly faster
and emit the signal `first_note`
whenever the first note is played

Track the k-th note of the musician

Compare the emission of signals kth_note and first_note and emit **`sync`** *when they are close enough*

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```

Why ReactiveML?

- **A synchronous language**
  expressiveness for time and events
- **Functional, typed language, on top of OCaml**
  recursion and higher order processes
- **Efficient implementation**
  no busy waiting
- **Dynamical features**
  dynamical creation of processes

In Practice

- **Embedding the Antescofo language**
  new implementation of the sequencer
  using the actual antescofo listening machine

- **Extend the Antescofo language**
  functional and reactive programming

- **A tool for prototyping new features**
  reactive behaviors, live coding, new attributes

- **Link with other media**
  graphical interface, top-level, ...

To Continue...

www.reactiveml.org/farm13

References

[Mandel-Pouzet 2005] L. Mandel and M. Pouzet. *ReactiveML: a reactive extension to ML.* In Proceedings of the International Conference on Principles and Practice of Declarative Programming, 2005.

[Mandel-Plateau 2008] L. Mandel and F. Plateau. *Interactive programming of reactive systems.* In Proceedings of Model-driven High-level Programming of Embedded Systems, 2008.

[Cont 2008] A. Cont. *Antescofo: Anticipatory synchronization and control of interactive parameters in computer music.* In International Computer Music Conference, 2008.

[Echeveste et al 2012] J. Echeveste, A. Cont, J.-L. Giavitto, and F. Jacquemard. *Operational semantics of a domain specific language for real time musician-computer interaction.* Journal of Discrete Event Dynamic Systems, 2013.