Combining temporal relations and signal processing into Interactive Scores

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October 4, 2018

1 Introduction

Process calculi has been applied to the modeling of interactive music systems [18, 17, 23, 28, 16, 27, 1, 24, 19, 4, 14, 11, 13, 15, 2, 22, 12, 20, 21, 10] and ecological systems [25, 6, 26, 7]. In addition, research on algorithms [5, 3, 9] and software engineering [8] also contributes to this field.

1.0.1 table for faust

1.1 Block diagram algebra

1.2 Example 1

1.2.1 Block-diagram algebra for Figure 3.

Acquisition := Difussion := _

Process := ((Acquisition : @ Δ_1 : Treatment : Difussion) , Mp3) :> _

1.2.2 Ntcc model

$$LowFreq_{I,S,Pr,\mathcal{R}} =^{def} Points_{I,S,Pr} \parallel Intervals_{\mathcal{R}} \parallel User_I \\ \parallel Clock(0) \parallel \prod_{i \in S \cup I} !tell(0 \leq p_i < n_{\infty})$$

$$HighFreq_{input,output} =^{def} Acquisition(input,x) \parallel @\Delta_1(x,y) \parallel Treatment(z,w) \\ \parallel Difussion(w,u,v) \parallel Mp3(!,q) \parallel !tell(output = u + v + q)$$

$$System_{I,S,Pr,\mathcal{R}} =^{def} HighFreq_{I,S,Pr,\mathcal{R}} \parallel LowFreq_{input,output}$$

1.3 Example 2

1.3.1 Block-diagram algebra for Figure 8.

Acquisition := _

Process := ((Acquisition : Arpeggio) , Mp3) :> _

Figure 1: Example of Interactive Score

Figure 2: Example of the Event Structure semantics of the Interactive Score in Figure 1. We suppose that $\Delta_1 = 0$.

Figure 3: Example of the block diagram semantics of the Interactive Score in Figure 1. Δ_1 must be a unary set.

Figure 4: Example of Interactive Score

Figure 5: Example of the Event Structure semantics of the Interactive Score in Figure ?. We suppose that $\Delta_1 = 0$.

Figure 6: Example of the block diagram semantics of the Interactive Score in Figure 1. Δ_1 must be a unary set.

Signals	Meaning
Constant signals	Always same value
Integer signals	Always same integer
Tuples of signals	n-tuples of signals
Signal Processors (S.P)	Meaning
Identity box	Identity function
Cut box	one input, no output
S.P. composition	Symbol
Sequential	:
Parallel	;
Split	<:
Merge	:>
Recursive	~
Faust primitives	Examples
Arithmetic	+, -, ×, /
Comparison	<, ≤, >, ≥, =
Bitwise	<<, >>, &,
Constants	1, 2, 3, 4
Read Tables	read only buffer
Read and write table	read&write buffer
Selectors	conditional branching
Graphical interface	buttons, checkboxes

Table 1: Semantics of Faust.

2 Faust

A signal is a function $s : \mathbb{N} \longrightarrow \mathbb{R}$, $s(t)$ means signal at discrete time $t \in \mathbb{N}$. Set $\mathbb{S}$ is the set of all signals. A signal processor is a function from tuples of signals to tuple of signals $p : \mathbb{S}^n \longrightarrow \mathbb{S}^m$.

3 Complete framework

4 Encoding

4.1 Encoding a signal

$$\llbracket s \rrbracket_n = \prod_{i \in [0, n]} \text{next}^i \text{ tell } (s = s(i))$$

Figure 7: Strategies to represent macroscopic and microscopic delays

Figure 8: ?

4.2 Encoding primitive signal processors

We assume the existence of the constraints for arithmetic and bitwise operators $*$ $\in \{+, -, \times, /, \%\} \cup \{<, >, \&, |, \wedge\}$ and for comparison operators $\bowtie \in \{<, >, \leq, \geq, ! =, ==\}$ in the constraint system.

$$\begin{aligned}
\llbracket * \rrbracket_n(in_1, in_2, out_1) &= \text{!tell}(out_1 = op_1 * op_2) \parallel \llbracket in_1 \rrbracket(op_1) \parallel \llbracket in_2 \rrbracket(op_2) \\
\llbracket \bowtie \rrbracket_n(in_1, in_2, out_1) &= \text{!}(\text{when } op_1 \bowtie op_2 \text{ do tell}(out_1 = 1) \\
&\quad \parallel \text{when not}(op_1 \bowtie op_2) \text{ do tell}(out_1 = 0)) \\
&\quad \parallel \llbracket in_1 \rrbracket(op_1) \parallel \llbracket in_2 \rrbracket(op_2) \\
\llbracket k \rrbracket_n(out_1) &= \text{!tell}(out_1 = k) \\
\llbracket select2 \rrbracket_n(in_1, in_2, out_1) &= \text{!}(\text{when } op_1 = 1 \text{ do tell}(out_1 = op_{2,1}) \\
&\quad \parallel \text{when } op_1 = 0 \text{ do tell}(out_1 = op_{2,2})) \\
&\quad \parallel \llbracket in_1 \rrbracket(op_1) \parallel \llbracket in_{2,1} \rrbracket(op_{2,1}) \parallel \llbracket in_{2,2} \rrbracket(op_{2,2}) \\
\llbracket select3... \rrbracket_n(in_1, out_1) &= \text{!} \sum_{i \in [0, n]} \text{when } i = in_1 \text{ do next tell}(out_1 = i) \parallel \llbracket in_1 \rrbracket(op_1) \\
\text{Read-only table} &= ? \\
\text{Read-write table} &= ? \\
\llbracket @ \rrbracket_n &= ? \\
\llbracket ffunction(p, i, l) \rrbracket_n(out_1) &= \text{!tell}(ffunction(p, i, l, out_1))
\end{aligned}$$

4.2.1 GUI

We suppose that the ambient sends signals *label* and $\neg label$.

$$\begin{aligned}
\llbracket button("label") \rrbracket(out_1) &= \text{when } label \text{ do tell}(out_1 = 1) \\
&\parallel \text{when } \neg label \text{ do tell}(out_1 = 0) \\
\llbracket checkbox \rrbracket & \\
\llbracket hslider \rrbracket &= vslider \dots
\end{aligned}$$

4.3 Encoding composed signal processors

4.3.1 Sequential composition

Example where $o_A < i_B$.

$$\begin{aligned}
\llbracket A : B \rrbracket(in_1, in_2, in_3, out_1) &= \text{local } zin \text{ in } \llbracket A \rrbracket(in_1, in_2, zin) \parallel \llbracket B \rrbracket(in_3, zin, out_1) \\
A(in_1, \dots, in_n, out_1 \dots out_m) &: B(in_1, \dots, in_p, out_1 \dots out_q)
\end{aligned}$$

Case $n < p$:

$$\llbracket A : B \rrbracket(in_1 \dots in_{n+p-m}, out_1 \dots out_q) = \text{local } zin_1, \dots, zin_m \text{ in } \llbracket A \rrbracket(in_1 \dots in_n, zin_1 \dots zin_m) \parallel \llbracket B \rrbracket(zin_1, \dots, zin_m, in_{n+1} \dots in_{n+p-m})$$

Case $n = p$

$$\llbracket A : B \rrbracket(in_1 \dots in_n, out_1 \dots out_q) = \text{local } zin_1, \dots, zin_m \text{ in } \llbracket A \rrbracket(in_1 \dots in_n, zin_1 \dots zin_m) \parallel \llbracket B \rrbracket(zin_1, \dots, zin_m, out_1 \dots out_q)$$

Case $n > p$

$$\llbracket A : B \rrbracket(in_1 \dots in_n, out_1 \dots out_{q+m-p}) = \text{local } zin_1, \dots, zin_m \text{ in } \llbracket A \rrbracket(in_1 \dots in_n, zin_1 \dots zin_m) \parallel \llbracket B \rrbracket(zin_1, \dots, zin_m, in_{m+1} \dots in_q)$$

4.3.2 Parallel composition

$$A(in_1, \dots, in_n, out_1 \dots out_m), B(in_1, \dots, in_p, out_1 \dots out_q) \\ [A, B](in_1 \dots in_{n+p}, out_1 \dots out_{m+q}) = [A](in_1 \dots in_n, out_1 \dots out_m) \parallel [B](in_{n+1} \dots in_{n+p}, out_{m+1} \dots out_{m+q})$$

4.3.3 Split composition

$$A(in_1, \dots, in_n, out_1 \dots out_m) <: B(in_1, \dots, in_{m.k}, out_1 \dots out_q) \\ [A <: B](in_1 \dots in_n, out_1 \dots out_q) = \mathbf{local} \ zin_1 \dots zin_m \ \mathbf{in} \ [A](in_1 \dots in_n, zin_1 \dots zin_m) \parallel [B](\overbrace{zin_1 \dots zin_m}^1 \dots \overbrace{zin_1 \dots zin_m}^k)$$

4.3.4 Merge composition

$$A(in_1, \dots, in_n, out_1 \dots out_{m.k}) :> B(in_1, \dots, in_m, out_1 \dots out_q) \\ [A :> B](in_1 \dots in_n, out_1 \dots out_q) = \mathbf{local} \ zin_1 \dots zin_{m.k} \ \mathbf{in} \ [A](in_1 \dots in_n, zin_1 \dots zin_{m.k}) \parallel [B](\sum_{j=0}^k (zin_{1+j.m}) \dots \sum_{j=0}^k)$$

4.3.5 Recursive composition

$$(A(in_1, \dots, in_{n+v}, out_1 \dots out_{m+u}) \sim B(in_1^{-1} \dots in_u^{-1}, out_1 \dots out_v)) \\ [A \sim B](in_1, \dots, in_v \dots in_{n+v}, out_1 \dots out_u \dots out_{m+u}) = \mathbf{local} \ zin_1 \dots zin_u \ \mathbf{in} \ [A](zin_1 \dots zin_u \dots out_1 \dots out_n) \parallel [B](zin_1 \dots zin_v) \\ \parallel \prod_{i \in [1, u]} \mathbf{tell} \ zin_i = 0 \parallel \prod_{i \in [1, u]} \sum_{j \in [0, n]} \mathbf{when} \ out_i = j \ \mathbf{do} \ \mathbf{next} \ \mathbf{tell} \ (zin_i = j)$$

4.3.6 Identity and cut box

$$\llbracket _ \rrbracket(in_1, out_1) = \llbracket int \rrbracket(in_1, out_1) = \llbracket float \rrbracket(in_1, out_1) = \mathbf{!tell}(out_1 = in_1) \\ \llbracket ! \rrbracket(in_1) = \mathbf{skip}$$

5 Example: The Karplus-Strong algorithm

How can we make a difference in signals such as in_1 and $times$. Is the out variable a parameter of the score? What about in_1 ? The first one is a formal parameter, whereas the latter one is not.

5.1 The noise generator

$$times(in_1, timesout_1) = [\times 110351245](in_1, timesout_1) = \mathbf{local} \ z \ \mathbf{in} \ \mathbf{!tell}(timesout_1 = z \times in_1) \parallel \llbracket 110351245 \rrbracket(z) \\ plus(in_1, plusout_1) = [(\times 110351245) + 12345](in_1, plusout_1) = \mathbf{local} \ z, y \ \mathbf{in} \ \mathbf{!tell}(plusout_1 = z + y) \parallel \llbracket \times 110351245 \rrbracket(in_1, z) \parallel \llbracket 12345 \rrbracket(y) \\ random(outrandom) = \llbracket \times (110351245) + 12345 \sim _ \rrbracket(outrandom) = \mathbf{local} \ z, y \ \mathbf{in} \\ \llbracket (*110351245) + 12345 \rrbracket(y, plusout_1) \parallel \llbracket _ \rrbracket(z, y) \parallel \mathbf{!tell}(outrandom = plusout) \parallel \\ \mathbf{tell} \ z = 0 \parallel \sum_{j \in [0, n]} \mathbf{when} \ plusout = j \ \mathbf{do} \ \mathbf{next} \ \mathbf{tell} \ (z = j) \\ division(divisionout) = [1.0/2147483647.0](divisionout) = \mathbf{local} \ z, y \ \mathbf{in} \ \mathbf{!tell}(divisionout = z/y) \parallel \llbracket 1.0 \rrbracket(z) \parallel \llbracket 2147483647.0 \rrbracket(y)$$

$noise(outnoise) = \llbracket random * division \rrbracket(outnoise) = \text{local } z, y \text{ in } !\text{tell}(outnoise = z * t) \parallel random(z) \parallel division(y)$

5.2 The trigger

$minus(x, minusout) = \llbracket [x - mem(x)] \rrbracket(x, minusout) = \text{local } z \text{ in } !\text{tell}(minusout = x - z) \parallel \llbracket mem(x) \rrbracket(z)$
 $impulse(x, impulseout) = \llbracket (x - mem(x)) > 0 \rrbracket(x, impulseout) = \text{local } z \text{ in } !\text{tell}(impulseout = z > 0) \parallel \llbracket minus(x, z) \rrbracket$

6 Application to Interactive Scores

Figure 9: Example of Interactive Scores where Faust and Ntcc interact.

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