On the Introduction of Guarded Lists in Bach: Expressiveness, Correctness, and Efficiency Issues

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Coordination as a powerful paradigm

- a concurrent framework based on shared information
- clear separation between interactional and computational aspects
  - many models and languages
  - many theoretical pieces of work
  - many implementations

Coordination as a powerful paradigm … but in practice

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  - how to describe (real-life) problems?
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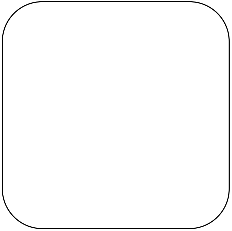
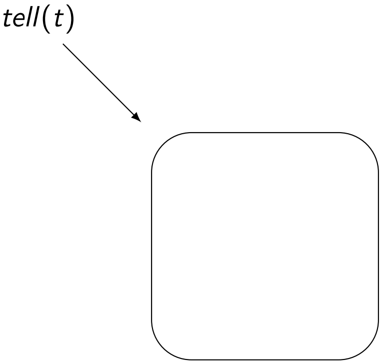
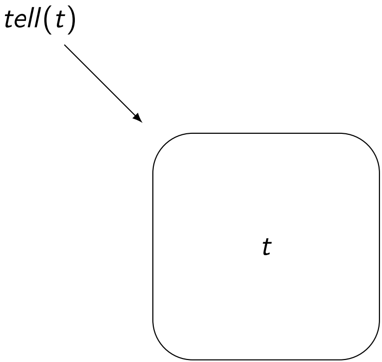
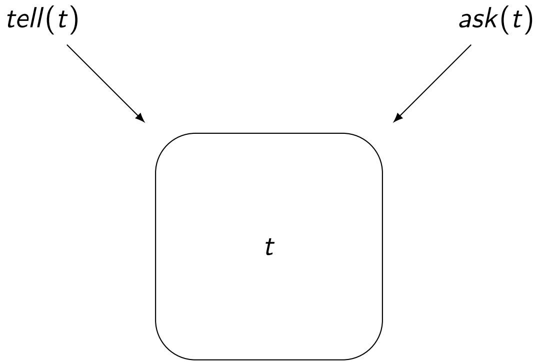


The Bach Coordination Language




tell(t)
t


tell(t)
ask(t)
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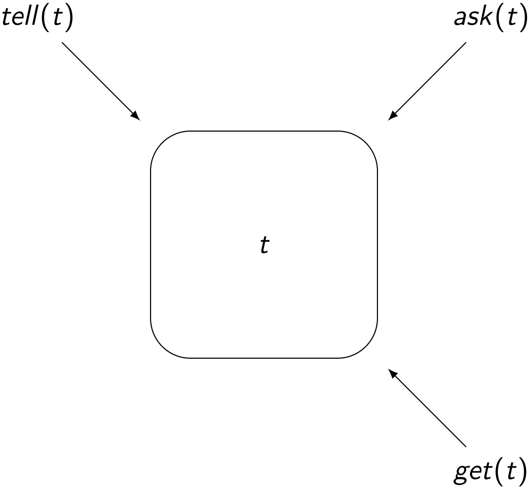

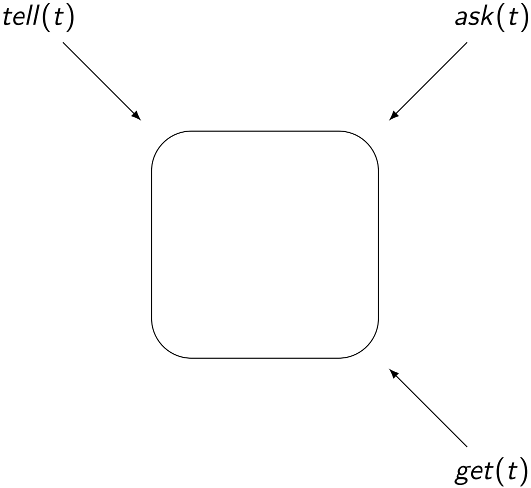
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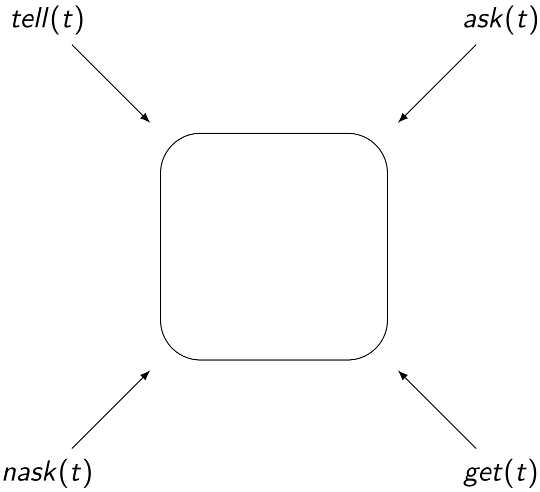


Transition system

(T) $$\langle\, \mathrm{tell}(t) \mid \sigma \,\rangle \longrightarrow \langle\, E \mid \sigma \cup \{t\} \,\rangle$$

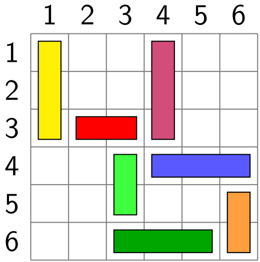
(A) $$\langle\, \mathrm{ask}(t) \mid \sigma \cup \{t\} \,\rangle \longrightarrow \langle\, E \mid \sigma \cup \{t\} \,\rangle$$

(G) $$\langle\, \mathrm{get}(t) \mid \sigma \cup \{t\} \,\rangle \longrightarrow \langle\, E \mid \sigma \,\rangle$$

(N) $$\frac{t \notin \sigma}{\langle\, \mathrm{nask}(t) \mid \sigma \,\rangle \longrightarrow \langle\, E \mid \sigma \,\rangle}$$

Rush hour as a running example

Modeling rush-hour



- trucks and cars as concurrent agents
- competing through free places on the shared space

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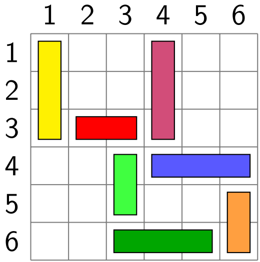

- trucks and cars as concurrent agents
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- finite sets

```
eset RCInt = { 1, 2, 3, 4, 5, 6}.
```

- maps and equations as rewriting rules

```
map down_truck : RCInt -> RCInt.
eqn down_truck(1) = 4. down_truck(2) = 5.
    down_truck(3) = 6.
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- structured pieces of information
  - flat tokens: a, b, . . . , t, u, . . .
  - composed terms: $f(a_1, \ldots, a_n)$

    free places as `free(i,j)`

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Agents

$$
\begin{aligned}
A \quad ::= \quad & Prim \mid Proc \mid \\
& A \,;\, A \mid A \parallel A \mid A + A \mid \\
& C \rightarrow A \diamond A \mid \sum_{e \in S} A_e
\end{aligned}
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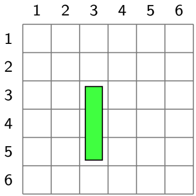
where *Prim* represents a primitive, *Proc* a procedure call, C a condition, e a variable and S a set.




```
eset RCInt = { 1, 2, 3, 4, 5, 6}.
     Colors = { yellow, green, blue, purple, red, orange}.

proc VerticalTruck(r: RCInt, c: RCInt, p: Colors) =
       ( (r>1 & r<5) -> ( get(free(pred(r),c));
                          moveTruck(pred(r),c,p);
                          tell(free(succ(succ(r)),c));
                          VerticalTruck(pred(r),c,p) ))
       +
       ( (r<4) -> ( get(free(down_truck(r),c));
                    moveTruck(succ(r),c,p);
                    tell(free(r,c));
                    VerticalTruck(succ(r),c,p) )).
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Model checking

- Key information on the store: $\#free(1,1)$
- Basic formulae: equalities or inequalities involving integers and key information
  - $\#free(1,1) = 3$
- Propositional state formulae: combination of basic formulae by usual Boolean operators
- Linear temporal logic fragment:

$$TF \ ::= \ PF \mid Next\ TF \mid PF\ Until\ TF$$

- Reach formulae:

$$Reach\,(\#out = 1) \ \equiv \ true\ Until\,(\#out = 1)$$

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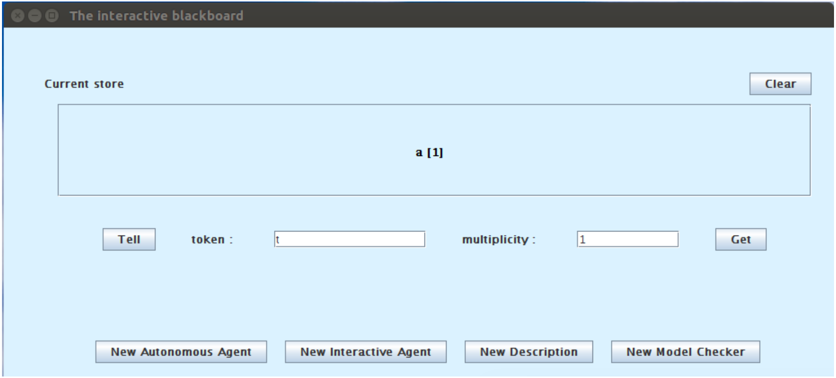

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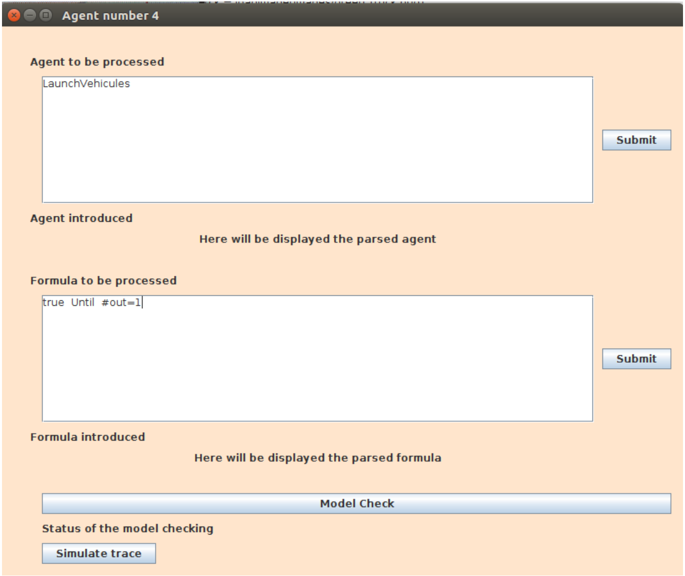
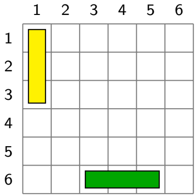


Problem

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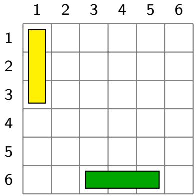


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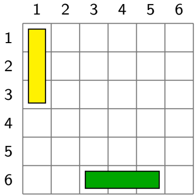


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```
get(free(r, pred(c)));
move(truck_img(c),pred(r),c);
tell(free(r, succ(succ(c))))
```

```
[ get(free(pred(r),c)) ->
      move(truck_img(c),pred(r),c),
      tell(free(succ(succ(r)),c)) ]
```

A guarded list construct

The construct

$[p \rightarrow p_1, \cdots, p_n]$ where p, p_1, ..., p_n are primitives

$$\textbf{(Le)} \quad \langle\, [] \mid \sigma \,\rangle \longrightarrow \langle\, E \mid \sigma \,\rangle$$

$$\textbf{(Ln)} \quad \frac{\langle\, p \mid \sigma \,\rangle \longrightarrow \langle\, E \mid \tau \,\rangle,\ \langle\, L \mid \tau \,\rangle \longrightarrow^* \langle\, E \mid \phi \,\rangle}{\langle\, [p|L] \mid \sigma \,\rangle \longrightarrow \langle\, E \mid \phi \,\rangle}$$

$$\textbf{(GL)} \quad \frac{\langle\, p \mid \sigma \,\rangle \longrightarrow \langle\, E \mid \tau \,\rangle,\ \langle\, L \mid \tau \,\rangle \longrightarrow^* \langle\, E \mid \phi \,\rangle}{\langle\, [p \rightarrow L] \mid \sigma \,\rangle \longrightarrow \langle\, E \mid \phi \,\rangle}$$

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- Introduce a new construct called guarded list
- Establish an increase of expressiveness
- Propose a theory of refinement
- Show an increase of performance

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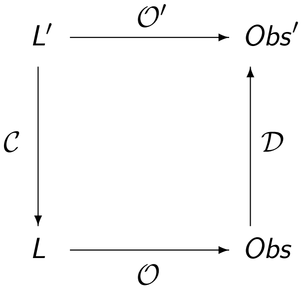
Expressiveness



L embeds L'

Expressiveness - Proof example

Propositions

- $\mathcal{L}_g(ask, tell) \not\leq \mathcal{L}_r(ask, tell)$
- Inability for $\mathcal{L}_r(ask, tell)$ to atomically test the presence of two distinct tokens a and b.

- Assume $AB = [ask(a) \rightarrow ask(b)]$ and $\mathcal{C}(AB)$ a coder (in $\mathcal{L}_r(ask, tell)$)
- $\mathcal{C}(AB)$ in general form:

$$\begin{aligned} tell(t_1) \; ; \; A_1 + \cdots + tell(t_p) \; ; \; A_p \\ + ask(u_1) \; ; \; B_1 + \cdots + ask(u_q) \; ; \; B_q \\ + gp_1 \; ; \; C_1 + \cdots + gp_r \; ; \; C_r \end{aligned}$$

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Expressiveness – Proof example

$\langle \mathcal{C}([tell(a)]) \mid \emptyset \rangle$

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$$\downarrow$$

$$\langle E \mid \{a_1, \cdots, a_m, b_1, \cdots, b_n\} \rangle$$

Expressiveness - Proof example

u_i's $\notin \{a_1, \cdots, a_m\} \cup \{b_1, \cdots, b_n\}$

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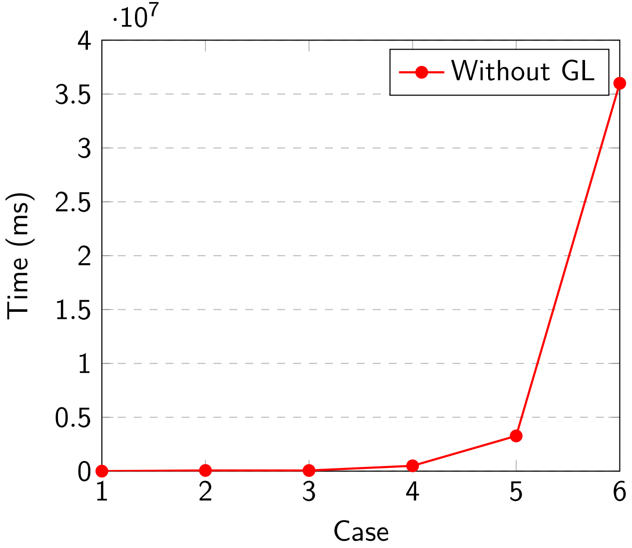
$$\langle\mathcal{C}([tell(a)] \;;\; [tell(b)] \;;\; AB) \mid \emptyset\rangle$$

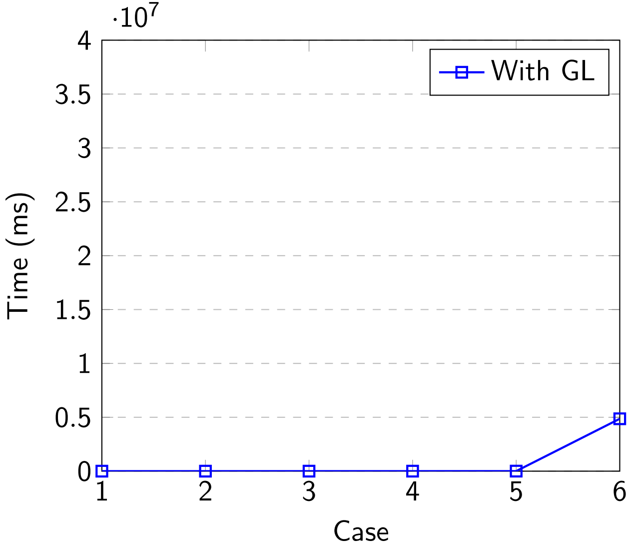
$$\longrightarrow \langle AB \mid \{a_1, \cdots, a_m, b_1, \cdots, b_n\}\rangle \not\longrightarrow$$

Performance



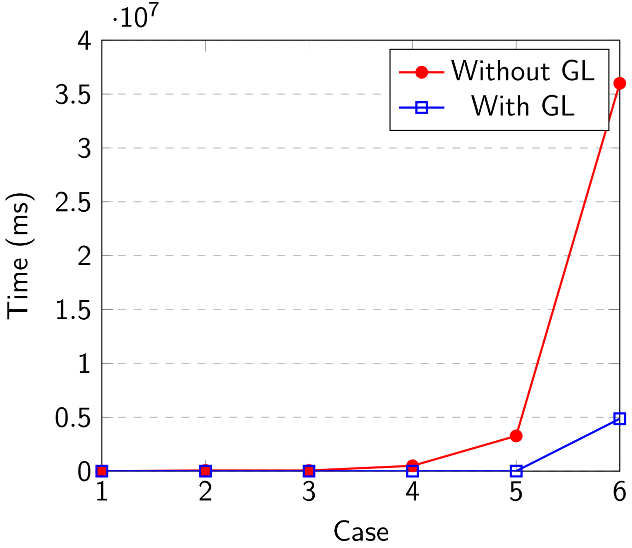
Without GL: The graph shows the time values without GL for different cases.

Performance



With GL: The graph displays the time values with GL for different cases.

Performance



Comparison: The graph compares the time values with and without GL for different cases.

Conclusion

- Introduce a new construct called guarded list
- Establish an increase in expressiveness
- Propose a theory of refinement
- Show an increase in performance

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THANK
YOU