Vérification de systèmes et réécriture de plus en plus efficace

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JIRC 08, Orléans

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Context

Java Bytecode analysis

- Rewriting semantics for the Java Bytecode
- Static analysis from reachability analysis in rewriting
  - Tree automata technique [RTA98]
  - Timbuk tool (`http://www.irisa.fr/lande/genet/timbuk`)

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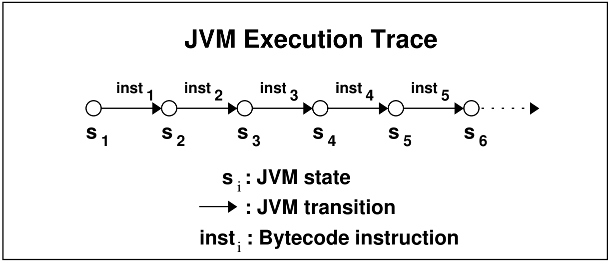
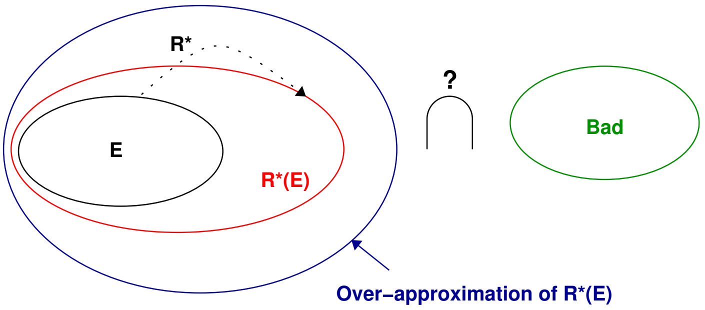
Rewriting Semantics for the Java Bytecode



For a given program `P`

- JVM states as Terms
- Rewrite rules for
  - the Bytecode instructions interpretation (generic rules)
  - the program

Reachability Analysis in Rewriting

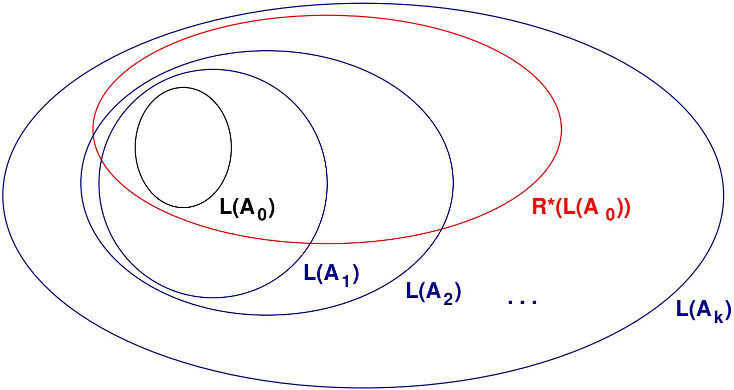


E : initial terms ⟶ JVM initial state

R : term rewriting system ⟶ JVM Transition relation for the given program

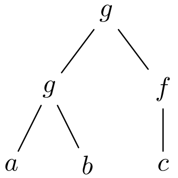
Bad : forbidden terms ⟶ Forbidden JVM states

Tree automata completion



- A set of terms is represented by a tree automaton language
- $\mathcal{A}_{i+1} = \mathcal{A}_i +$ new transitions and states
- Completion stops when a fix point automaton is found

Computing substitutions for a completion step



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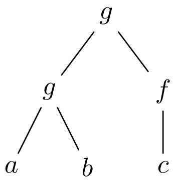

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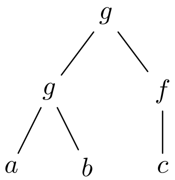

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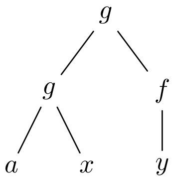

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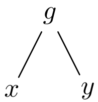

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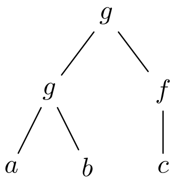

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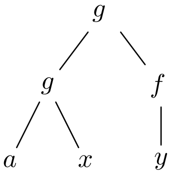

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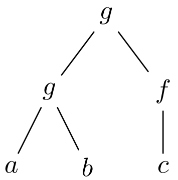

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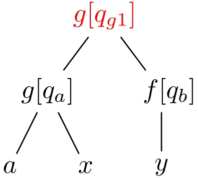

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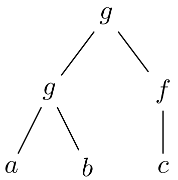

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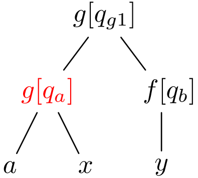

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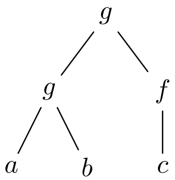

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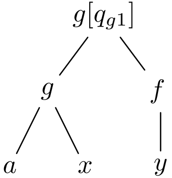

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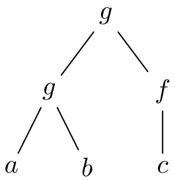

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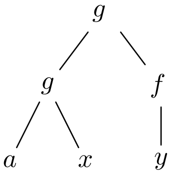

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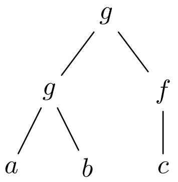

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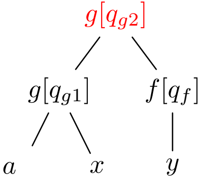

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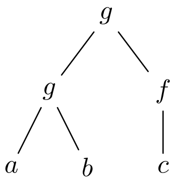

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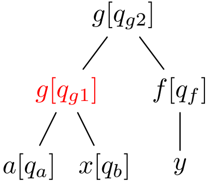

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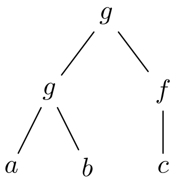

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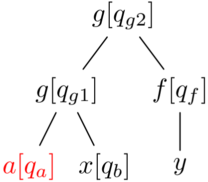

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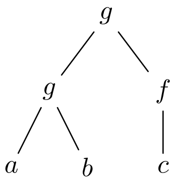

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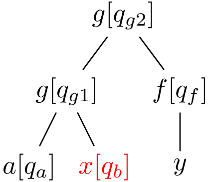

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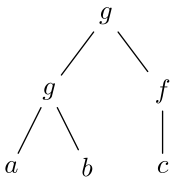

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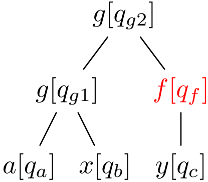

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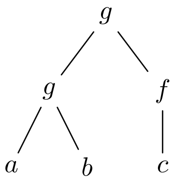

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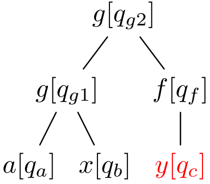

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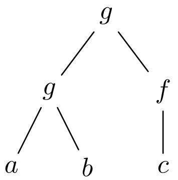

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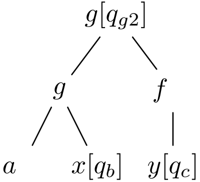

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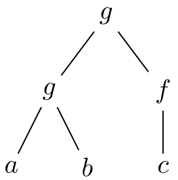

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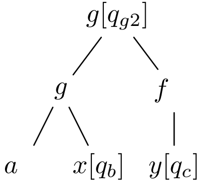

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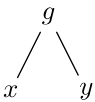

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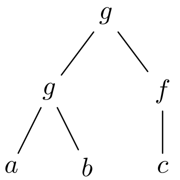

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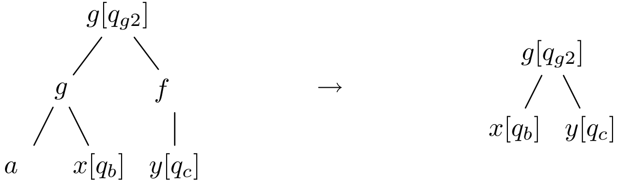

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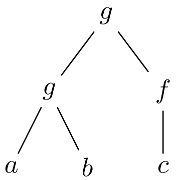

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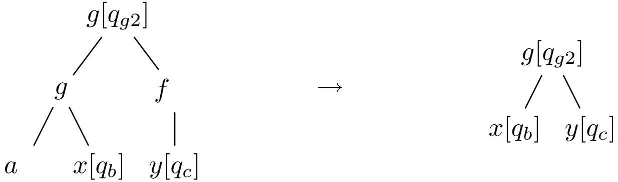

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But for the verification of Java programs. . .

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Goal: Propose practical techniques to solve scalability issues

Reachability Preserving TRS Transformation

Fact: Collecting all possible ground instances of a deep pattern may be expensive

Idea: Transform TRS into simpler TRS

- A simple form for the left hand-side of rules (depth max=2)
  - Flat: $f(x_1, \ldots, x_n)$ or c
  - $f(t_1, \ldots, t_n)$ where each t_i is flat
- Reachability preserving (Terms computed with the original TRS must be also computed by the resulting TRS)

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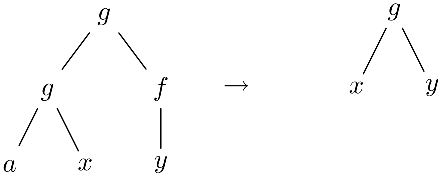
Transformation of the example rule

$\mathcal{R}$



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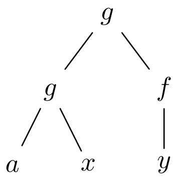

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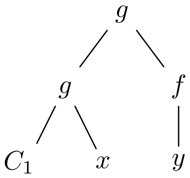

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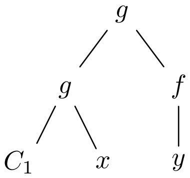
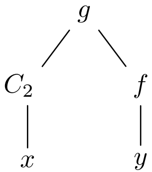


$$\begin{aligned} a &\quad\rightarrow\quad C_1 \\ g(C_1, x) &\quad\rightarrow\quad C_2(x) \end{aligned}$$

Transformation of the example rule



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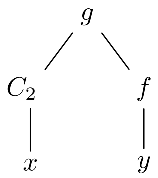

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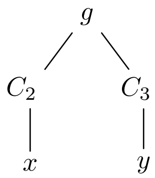

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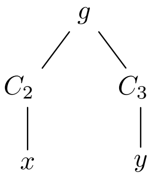

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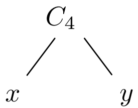

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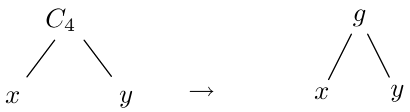

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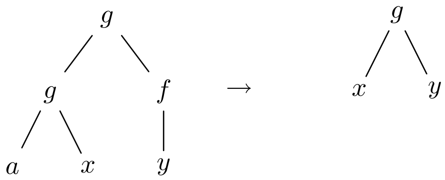
Transformation of the example rule

$\mathcal{R}$



$$\phi(\mathcal{R}) \quad \begin{array}{lcl} a & \to & C_1 \\ g(C_1, x) & \to & C_2(x) \\ f(y) & \to & C_3(y) \\ g(C_2(x), C_3(y)) & \to & C_4(x, y) \\ C_4(x, y) & \to & g(x, y) \end{array}$$

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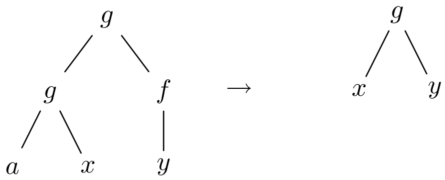

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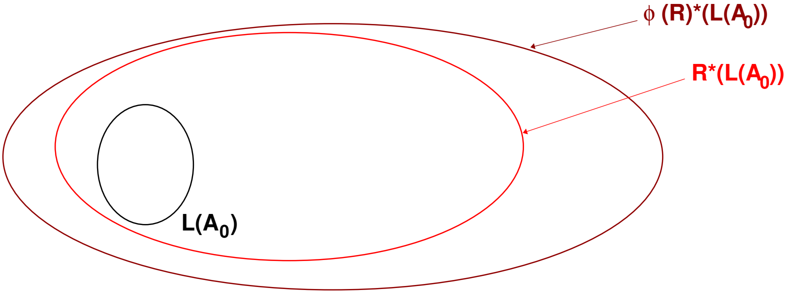
C_4(x, y) & \rightarrow & g(x, y)
\end{array}
$$

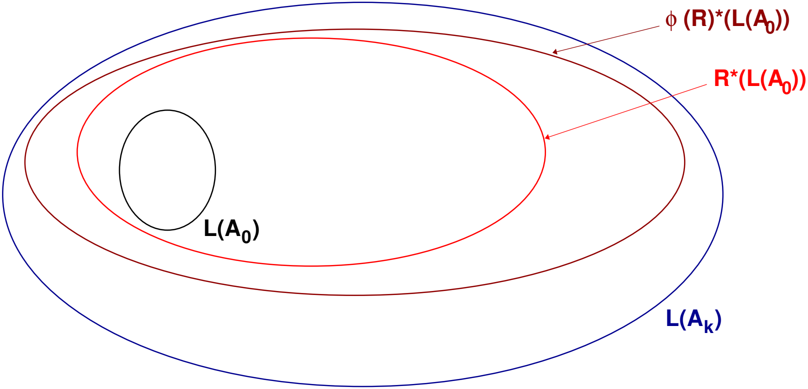
$$\forall t, t' \in \mathcal{T}(\mathcal{F}).t \rightarrow_{\mathcal{R}} t' \implies t \rightarrow^{*}_{\phi(\mathcal{R})} t'$$

Main Result



Main Result

An over-approximation computed for $\phi(\mathcal{R})$ is also an over-approximation for $\mathcal{R}$



Dedicated completion algorithm (1)

Facts

- For each $l \rightarrow r \in \phi(\mathcal{R})$, l does not exceed a depth of 2

  $g(C_2(x), C_3(y)) \rightarrow C_4(x, y)$
- Very close to a direct pattern-matching on transitions

  $g(q_{g1}, q_f) \rightarrow q_{g2}$
- For this transition, the current matching algorithm computes all possible instances from $g(q_{g1}, q_f)$

Can we reduce the substitution computation to a simple pattern-matching problem?

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Dedicated completion algorithm (2)

$$\begin{array}{lcl}
a & \rightarrow & q_a \\
b & \rightarrow & q_b \\
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g(q_a, q_b) & \rightarrow & q_{g1} \\
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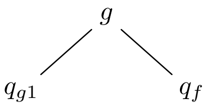

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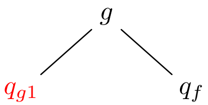

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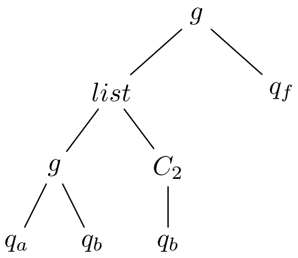

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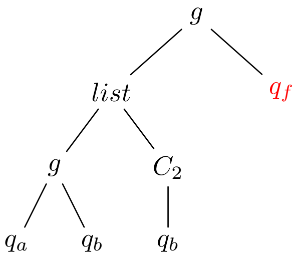

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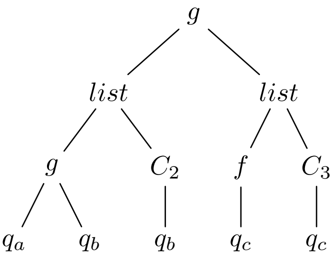
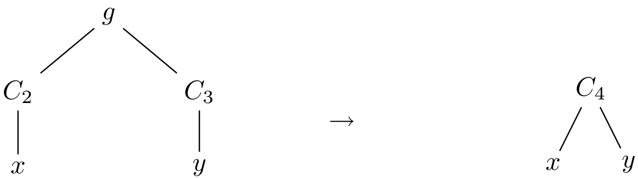


Dedicated completion algorithm (3)

We want to do a completion step with the rule
$g(C_2(x), C_3(y)) \to C_4(x, y)$.



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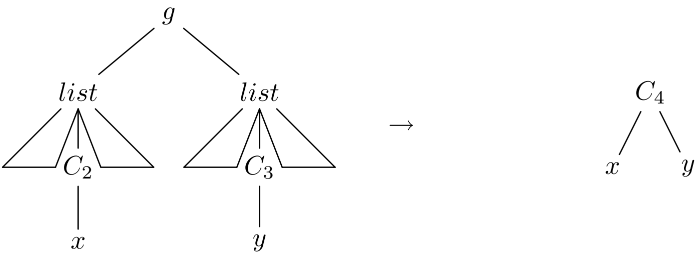

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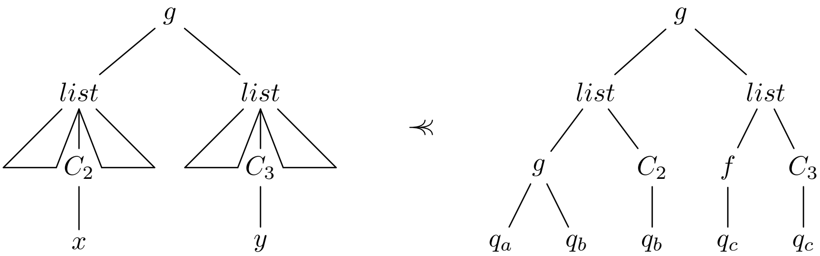

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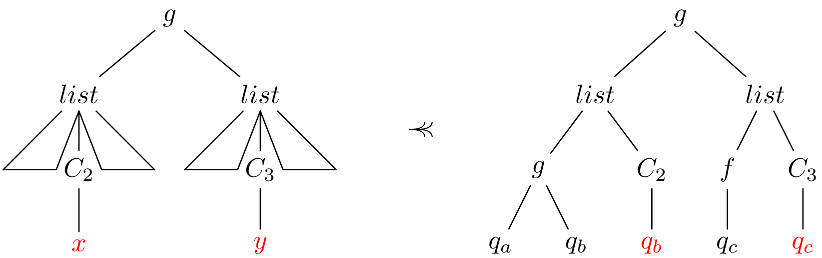

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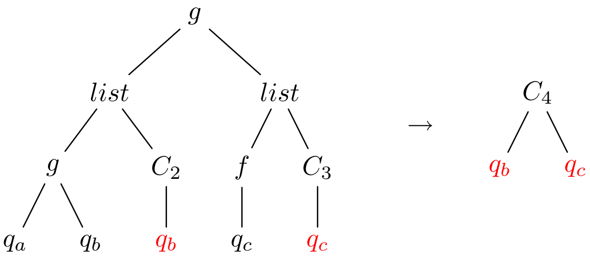

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General schema of the implementation

The Tom language [RTA'07]: Piggybacking Rewriting on top of Java

- Efficient support for algebraic terms (hash-consing),
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- Expressive strategy language (*à la* ELAN, Stratego).

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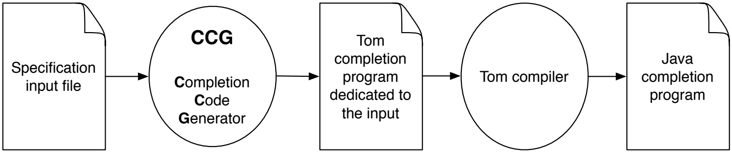
Generator of dedicated completion programs written in Tom



Experimental results

	NSPK protocol	View-Only protocol	Java program (chained lists)
TRS size (nb of rules)	13	15	303
Timbuk: Time (secs)	**19.7**	**6420**	**37387**
Tom: Time (secs)	**5.9**	**150**	**303**
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- A factor 10 in general, and up to 100 on Java examples

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- A better control of approximations
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