Implementing Rho-Calculus in TOM

with the help of slides from C. Kirchner, P.-E. Moreau, A. Reilles, E. Balland

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The title is not: A full presentation of TOM

Once upon a time [...]

and the end of the story was:

Nice: how can I use it?

elan provides a robust and efficient implementation of these concepts [...]

But...

I have 2 000 000 lines of C code, should I rewrite everything in ELAN ?

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It is fundamentally useful

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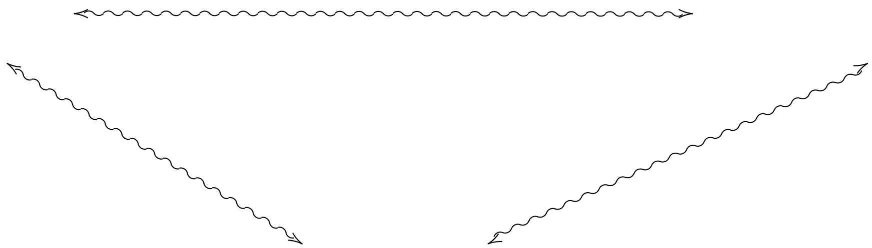
- Usable at code design or maintenance time.
- Allows one to use proof techniques to validate properties of the formal part of the code.
- An intensive use induces absolutely no dependence since the formal part is compiled into the target language.
- The generated code is safer.

The TOM-project

Syntax



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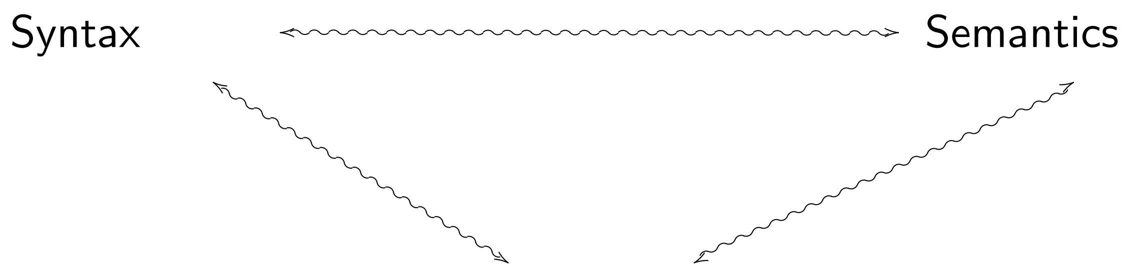

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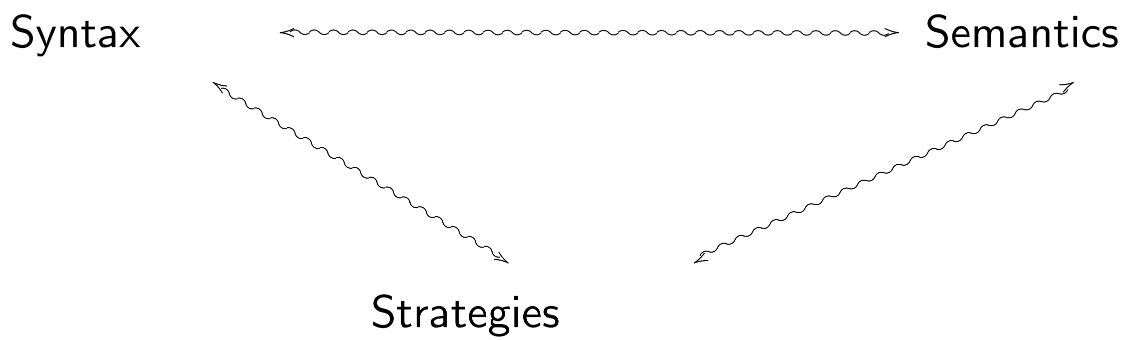

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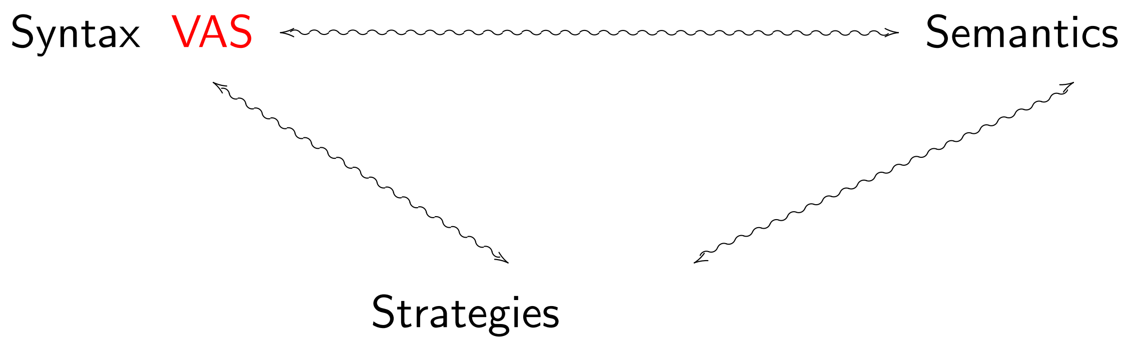

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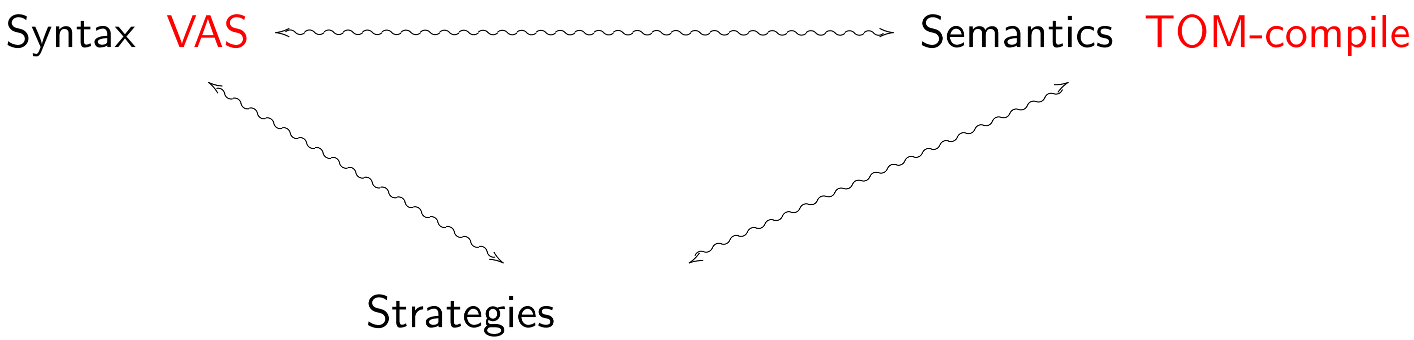

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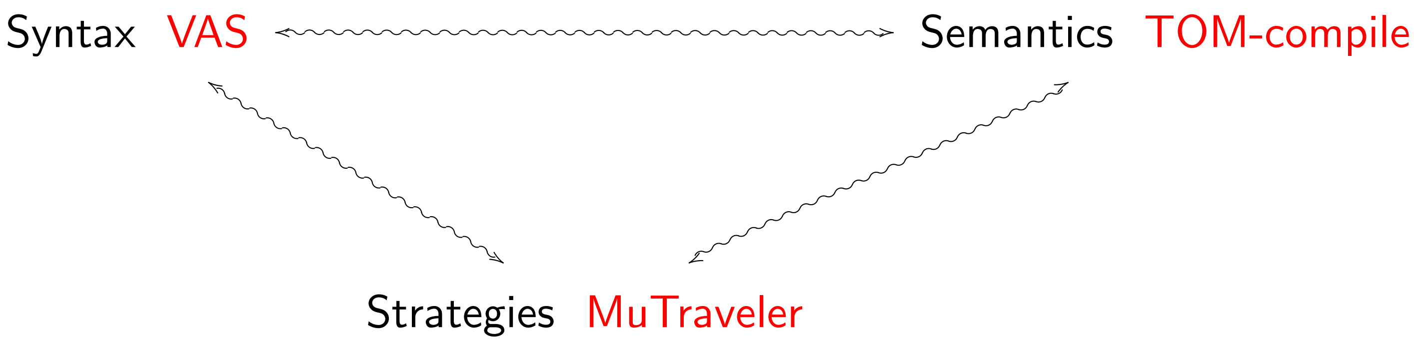

Syntax of the $\rho_{\mathtt{x}}^{\circ}$

Terms	M, N, P	$::=$	X	(Variables)
		$\mid$	c	(Constants)
		$\mid$	$P \twoheadrightarrow M$	(Abstraction)
		$\mid$	$M \bullet N$	(Functional application)
		$\mid$	$M \wr N$	(Structure)
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where $\wedge$ is associative and id_s and id_m are neutral elements

From rewrite rules to constraints

(ρ)	$(P \rightarrow M)^{\bullet} N$	$\longrightarrow$	$[P \ll N]M$
(δ)	$(M_1 \wr M_2)^{\bullet} N$	$\longrightarrow$	$M_1{}^{\bullet} N \wr M_2{}^{\bullet} N$

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From constraints to substitutions

Decomposition

$(Decompose_{\wr})$	$M_1 \wr M_2 \ll N_1 \wr N_2$	$\longrightarrow$	$M_1 \ll N_1 \wedge M_2 \ll N_2$
$(Decompose_{\mathcal{F}})$	$f(M_1, \ldots, M_n) \ll f(N_1, \ldots, N_n)$	$\longrightarrow$	$\bigwedge_{i=1}^{n} (M_i \ll N_i)$

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$(Idem)$	$\mathcal{C} \wedge (X \ll M) \wedge \mathcal{D} \wedge (X \ll M) \wedge \mathcal{E}$	$\to$	$\mathcal{C} \wedge (X \ll M) \wedge \mathcal{D} \wedge \mathcal{E}$
$(ToSubst)$	$[\mathcal{C} \wedge (X \ll M) \wedge \mathcal{D}]\, N$	$\to$	$[\mathcal{C} \wedge \mathcal{D}]\, ([X = M]\, N)$ if $X \notin \mathcal{D}om(\mathcal{C} \wedge \mathcal{D})$

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Substitution applications

$(Identity)$	$[\mathtt{id}]\, M$	$\rightarrow$	M	
$(Replace)$	$[\phi \wedge X = M \wedge \psi]\, X$	$\rightarrow$	M	
(Var)	$[\phi]\, Y$	$\rightarrow$	Y	$Y \notin \mathcal{D}om(\phi)$
$(Const)$	$[\phi]\, c$	$\rightarrow$	c	
(Abs)	$[\phi]\, (P \rightarrow M)$	$\rightarrow$	$P \rightarrow [\phi]\, M$	
(App)	$[\phi]\, (M^{\bullet} N)$	$\rightarrow$	$[\phi]\, M^{\bullet}\, [\phi]\, N$	
$(Struct)$	$[\phi]\, (M \wr N)$	$\rightarrow$	$[\phi]\, M \wr [\phi]\, N$	
$(Constraint)$	$[\phi]\, ([P_i \ll N_i]_{i=1}^{n}(M))$	$\rightarrow$	$[P_i \ll [\phi]\, N_i]_{i=1}^{n}([\phi]\, M)$	$n > 0$
$(Compose)$	$[\phi]\, ([X_i = M_i]_{i=1}^{n}(N))$	$\rightarrow$	$[\phi \wedge X_i = [\phi]\, M_i]_{i=1}^{n}(N)$	$n > 0$

Examples

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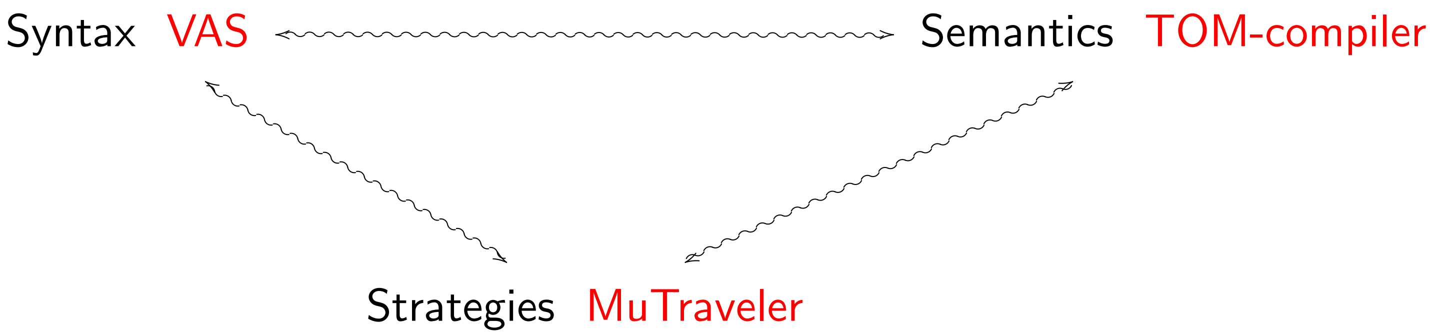

Syntax VAS

- Terms could be user defined.
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 & | & c \\
 & | & M \bullet N \\
 & | & \ldots
\end{array}
$$

```
%vas{    [...]
   var(na:String)                  -> RTerm
   const(na:String)                -> RTerm
   app(lhs:RTerm, rhs:RTerm)       -> RTerm
   [...]
}
```

Back to The TOM-project

Syntax VAS

- List Matching (and thus Associative and Unitary matching [Reilles05])

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   appC(co:ListConst , term:RTerm)          -> RTerm
   [...]

   match(lhs:RTerm, rhs:RTerm)              -> Const
   andC( Const* )                           -> ListConst
```

Back to The TOM-project

TOM-compiler

$$(P \multimap M)^{\bullet} N \qquad \mapsto \quad [P \ll N]\, M$$

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%match(RTerm arg)

 app(abs(P,M),N) ->
    {return `appC(andC(match(P,N)),M);}
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 appC(andC(C*,match(X@var[],M),D*),N) ->
    {return `appC(andC(C*,D*),appS(andS(eq(X,M)),N));}
```

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Strategies

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- Visitor combination and traversal control. [Visser OOPSLA'01]
  Strategies à la Stratego in an object point of view (Visitor Design Pattern): JJTraveler

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try(s) & = & choice(s, id) \\
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oncebu(s) & = & \mu x.choice(One(x), s) \\
innermost(s) & = & repeat(oncebu(s)) \\
fast-innermost(s) & = & \mu x.All(x); try(s; x)
\end{array}
$$

Exercise: try to define the weak normalization strategy

- In ELAN you need to define congruence rules for each symbol of the signature.

Exercise: try to define the weak normalization strategy

- In ELAN you need to define congruence rules for each symbol of the signature.
- Using MuTraveler library:

$$
\begin{array}{lcl}
oneStepWeakNormalisation & = & \mu x.Choice(rules, One_a bs(x)) \\
myStrategy & = & repeat(oneStepWeakNormalisation)
\end{array}
$$

Exercise: try to define the weak normalization strategy

And print each intermediate step

```
VisitableVisitor myStrategy =
        `Repeat(Seq(oneStepWeakNormalisation,print));
```

OVERALL OF THE IMPLEMENTATION

Weak normalisation strategy for linear patterns

No α-conversion

```
class Rho {
    %vas{
        module rhoterm
            var(na:String) -> RTerm
            const(na:String) -> RTerm
            app(lhs:RTerm,rhs:RTerm) -> RTerm
            appC(co:ListConstraint,term:RTerm) -> RTerm
            [...]
            }

    %op VisitableVisitor One_abs(strat:VisitableVisitor) {
        make(v) {`Sequence(Not_abs(),One(v)) }
    }
    VisitableVisitor rules = new ReductionRules();
    VisitableVisitor print = new Print();
    VisitableVisitor oneStepWeakNormalisation = `mu(MuVar("x"),Choice(rules,One_abs(MuVar("x"))));
    VisitableVisitor myStrategy = `Repeat(oneStepWeakNormalisation);

    RTerm subject = factory.RTermFromString(s);
    System.out.println(myStrategy.visit(subject));
```

```
class Print extends rhotermVisitableFwd {
        Print() {
                super(`Fail());
        }
        RTerm visit_RTerm(RTerm arg) throws  VisitFailure {
                System.out.println("|-->>" + arg);
                return arg;
        }
}
```

```
class Not_abs extends rhotermVisitableFwd {
        Not_abs() {
                super(`Identity());
        }

        RTerm visit_RTerm_Abs(Abs arg) throws jjtraveler.VisitFailure {
                throw new VisitFailure();
        }

}
```

```
class ReductionRules extends rhotermVisitableFwd {
        ReductionRules() {
              super(`Fail());
        }
        RTerm visit_RTerm(RTerm arg) throws  VisitFailure {
              %match(RTerm arg){
                     /*Compose */
                     appS(phi@andS(l*),appS(andS(L*),N)) -> {
                            ListSubst result = `mapS(((ListSubst)(L.reverse())),phi,andS());
                            return `appS(andS(l*,result*),N);}
                     appS(phi,struct(M,N)) -> {return `struct(appS(phi,M),appS(phi,N));}
                     /*Rho*/
                     app(abs(P,M),N) -> {return `appC(andC(match(P,N)),M);}
                     /*Delta*/
                     app(struct(M1,M2),N) -> {return `struct(app(M1,N),app(M2,N));}
               }
               throw new VisitFailure();
        }
        ListConstraint visit_ListConstraint(ListConstraint l) throws VisitFailure {
              %match(ListConstraint l){
                     /*Decompose et Decompose_ng min(n,m) > 0 */
                     l:(X*,m@match(app[],app[]),Y*) -> {
                            ListConstraint head_is_constant = `headIsConstant(m);
                            %match(ListConstraint head_is_constant) {
                                   (match[]) -> { break l; }
                                   (matchKO()) -> { return `andC(X*,matchKO(),Y*); }
                            }
                            ListConstraint result = `computeMatch(andC(m));
                            return `andC(X*,result*,Y*);
                     }
              }
              throw new VisitFailure();}}
```

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Conclusion

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- use TOM to make easy, trustable and modular implementation of calculi.
- The three components of the TOM-project make a bridge between the rewriting community and real-life programmers.
- How to provide a nice way to trace intermediate computation?