Implementing Java-like languages in Xtext with Xsemantics

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XTEXT Eclipse framework

- XTEXT provides a higher-level framework that generates most of the typical and recurrent artifacts necessary for a fully-fledged IDE on top of Eclipse.
  - Really quick and easy to have a working implementation
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  - Implement while designing and formalizing
- Type system and reduction rules still implemented in Java
- Gap between the formalization and implementation

FEATHERWEIGHT JAVA

- a lightweight functional version of Java:
  - mutually recursive class definitions,
  - class inheritance,
  - object creation,
  - method invocation,
  - method recursion through `this`,
  - subtyping and
  - field access.

A. Igarashi, B. Pierce, and P. Wadler. **Featherweight Java: a minimal core calculus for Java and GJ**. *ACM Transactions on Programming Languages and Systems*, 23(3):396–450, 2001.

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```
Selection: receiver=Expression '.' message=[Member]
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interface Selection extends Expression {
    Expression getReceiver();
    Member getMessage();
    EList<Expression> getArgs();
}
```

Featherweight Java grammar in Xtext

```
Program: (classes += Class)* (main = Expression)?;
Class: 'class' name=ID ('extends' superclass=[Class])? '{'
       (members += Member)* '}';
Member: Field | Method;
Field: type=[Class] name=ID ';' ;
Method: type=[Class] name=ID
    '(' (params+=Parameter (',' params+=Parameter)*)? ')'
    '{' body=MethodBody '}';
Parameter: type=[Class] name=ID;
TypedElement: Member | Parameter;
MethodBody: 'return' expression=Expression ';' ;
```

XTEXT FJ grammar (part II)

```
Expression: Selection | TerminalExpression ;
Selection: receiver=Expression '.' message=[Member]
      ('(' (args+=Expression (',' args+=Expression)*)? ')')? ;
TerminalExpression: This | ParamRef | New | Cast | Paren ;
This: variable='this';
ParamRef: parameter=[Parameter];
New: 'new' type=ClassType
   '(' (args+=Expression (',' args+=Expression)*)? ')';
Cast: '(' type=[Class] ')' expression=TerminalExpression;
Paren: '(' Expression ')';
```

FJ IDE

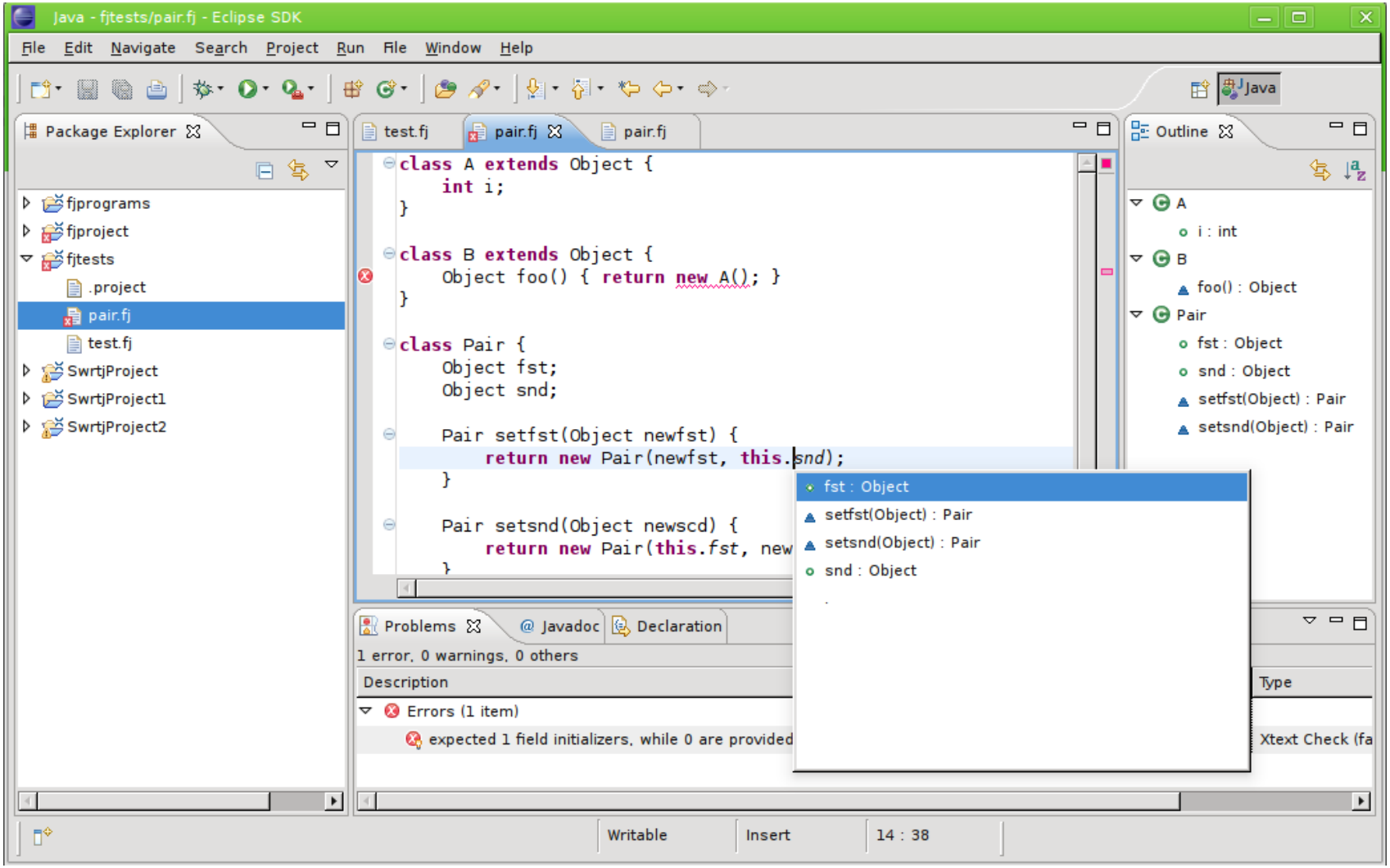

Figure: A screenshot of the FJ IDE.

Checking that a program is semantically correct in the XTEXT:

- *scoping*: cross references can be resolved, e.g., the binding of a variable to its definition in the program

```
class A {
        String s;
        String toString() {
                return this.s;
        }
}
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```

- *validation*, the AST model is correct, e.g., checking that the return value of a method body is consistent with the method signature

```
class A {
        String s;
        String toString() {
                return 10;
        }
}
```

Our aim

- Scoping and Validation usually rely on types;
- the programmer needs to implement a type system in Java.
- Instead, we would like to implement the type system functionalities with a DSL.
- This would allow us to have the typing rules in a compact form,
- and then have the corresponding Java code

Our proposal

We present XSEMANTICS, a DSL for writing rules for languages implemented in Xtext

- the static semantics (type system),
- the dynamic semantics (operational semantics) and
- relation rules (subtyping).

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  - and a set of *rules* which have a conclusion and a set of premises (and a rule environment)

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  - a set of *judgments*
  - and a set of *rules* which have a conclusion and a set of premises (and a rule environment)

Starting from the definitions of judgments and rules, XSEMANTICS generates Java code that can be used for scoping and validation.

XSEMANTICS and Xbase

- an extensible and reusable statically typed expression language
- a Java with "less noise"
  - type inference
  - closures
- integrates completely with Java and Eclipse JDT
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Example

```
val personList = newArrayList(
        new Person("James", "Smith", 50),
        new Person("John", "Smith", 40),
        new Person("James", "Anderson", 40),
        new Person("John", "Anderson", 30),
        new Person("Paul", "Anderson", 30))
personList.filter[firstname.startsWith("J")].
    sortBy[age].take(3).map[surname + ", " + firstname].
        join("; ")
```

FJ judgments in XSEMANTICS

```
judgments {
    type |- Expression expression : output Class
        error "cannot type " + expression
    subtype |- Class left <: Class right
        error left + " is not a subtype of " + right
    subtypesequence |-
        List<Expression> expressions << List<? extends TypedElement> elements
    reduce |- Expression exp ~> output Expression
}
```

XSEMANTICS rules

```
rule MyRule
    G |- Selection exp : Class type
from {
    // premises
    type = ... // assignment to output parameter
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XSEMANTICS axioms

```
axiom TThis
    G |- This _this : env(G, 'this', Class)
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Examples

Rule for subtyping

```
rule Subclassing
    G |- Class left <: Class right
from {
    left == right or
    right.name == "Object" or
    G |- left.superclass <: right
}
```

Examples

Grammar for FJ

Cast: '(' type=[Class] ')' expression=Expression;

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Rule for cast

```
rule TCast
    G |- Cast cast : cast.type
from {
    G |- cast.expression : var Class expType

    { G |- cast.type <: expType }
    or
    { G |- expType <: cast.type }
}
```

Examples

```
rule SubtypeSequence
G |- List<Expression> expressions << List<TypedElement> elems
from {
    expressions.size == elems.size
    var i = 0
    for (exp : expressions) {
        G |- exp : var Class expType
        G |- expType <: elems.get(i++)
    }
}
```

Examples

```
rule SubtypeSequence
G |- List<Expression> expressions << List<TypedElement> elems
from {
    expressions.size == elems.size
    var i = 0
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        G |- expType <: elems.get(i++)
    }
}
```

Rule for "new"

```
rule TNew
    G |- New newExp : newExp.type
from {
    var f = fields(newExp.type)
    G |- newExp.args << f
}
```

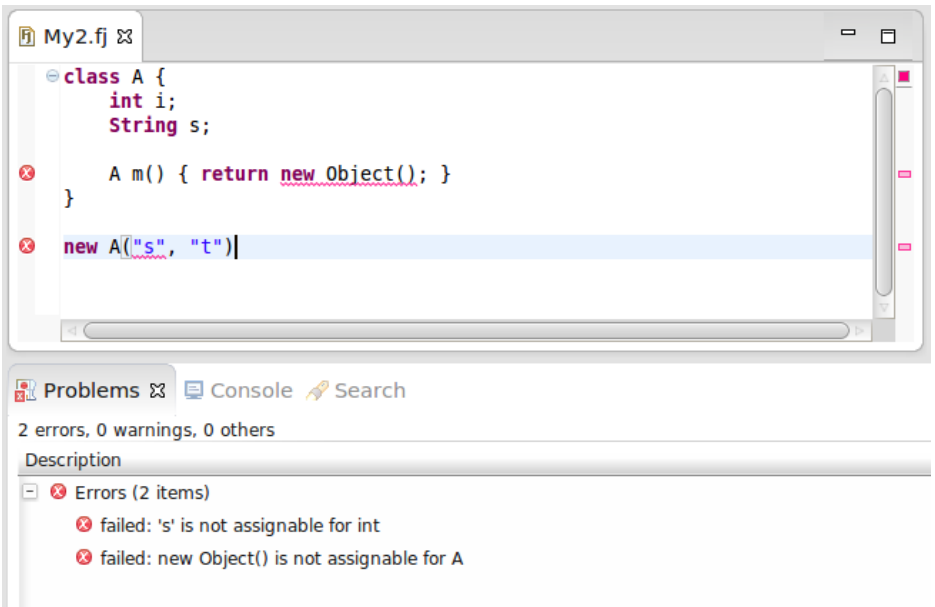
Checkrules

For generating the Validator

```
checkrule CheckMethodBody for
    Method method
from {
    val C = method.getContainerOfType(typeof(Class))
    'this' <- C |- method.body.expression : var Class bodyType
    empty |- bodyType <: method.type
}
```

Errors and Traces

- in case one of the premises fails the whole judgment fails
- the error trace will be used to automatically generate all the error markers
- in general the trace of the rules applied is available to the programmer for testing and debugging



Using traces: Example

Expressing *Subject Reduction*

```
judgments {
    subjred |= Expression e ~> output Expression : output Class <: output Class
}

rule SubjRed
    G |= Expression e ~> Expression e1 : Class C1 <: Class C
from {
    G |- e : C
    G |- e ~> e1
    G |- e1 : C1
    G |- C1 <: C
}
```

Using traces: Example

```
class A {
    Object m() { return this.n(new B()); }
    A n(A o) { return new A(); }
}
class B extends A {}
new A().m()
```

Using traces: Example

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class A {
    Object m() { return this.n(new B()); }
    A n(A o) { return new A(); }
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```

```
SubjRed: [] |= new A().m() ~> new A().n(new B()) : A <: Object
 TSelection: [] |- new A().m() : Object
  TNew: [] |- new A() : A
   SubtypeSequence: [] |- [] << []
  SubtypeSequence: [] |- [] << []
 RSelection: [] |- new A().m() ~> new A().n(new B())
 TSelection: [] |- new A().n(new B()) : A
  TNew: [] |- new A() : A
   SubtypeSequence: [] |- [] << []
  SubtypeSequence: [] |- [new B()] << [A o]
   TNew: [] |- new B() : B
    SubtypeSequence: [] |- [] << []
   Subclassing: [] |- B <: A
 Subclassing: [] |- A <: Object
```

Case study: type inference for λ-calculus

- we also developed a prototype implementation of λ-calculus in XTEXT;
- we used XSEMANTICS to write a type system for inferring types with type variables (generic types);
- we implemented *unification* in order to infer the most general type.

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```
lambda x .  x                                  a -> a
lambda x .  10                                 a -> int
lambda x .  -x                                 int -> int
(lambda x .  lambda y .  y) 10                 a -> a
lambda x .  lambda y.  x y                     (a -> b) -> a -> b
lambda x .  lambda y.  y x                     a -> (a -> b) -> b
lambda f .  (lambda x.  (f (f x)))
                                               (a -> a) -> a -> a
lambda f .  lambda g.  lambda x.  (f (g x))
                                               (a -> b) -> (c -> a) -> c -> b
```

Inferring λ types

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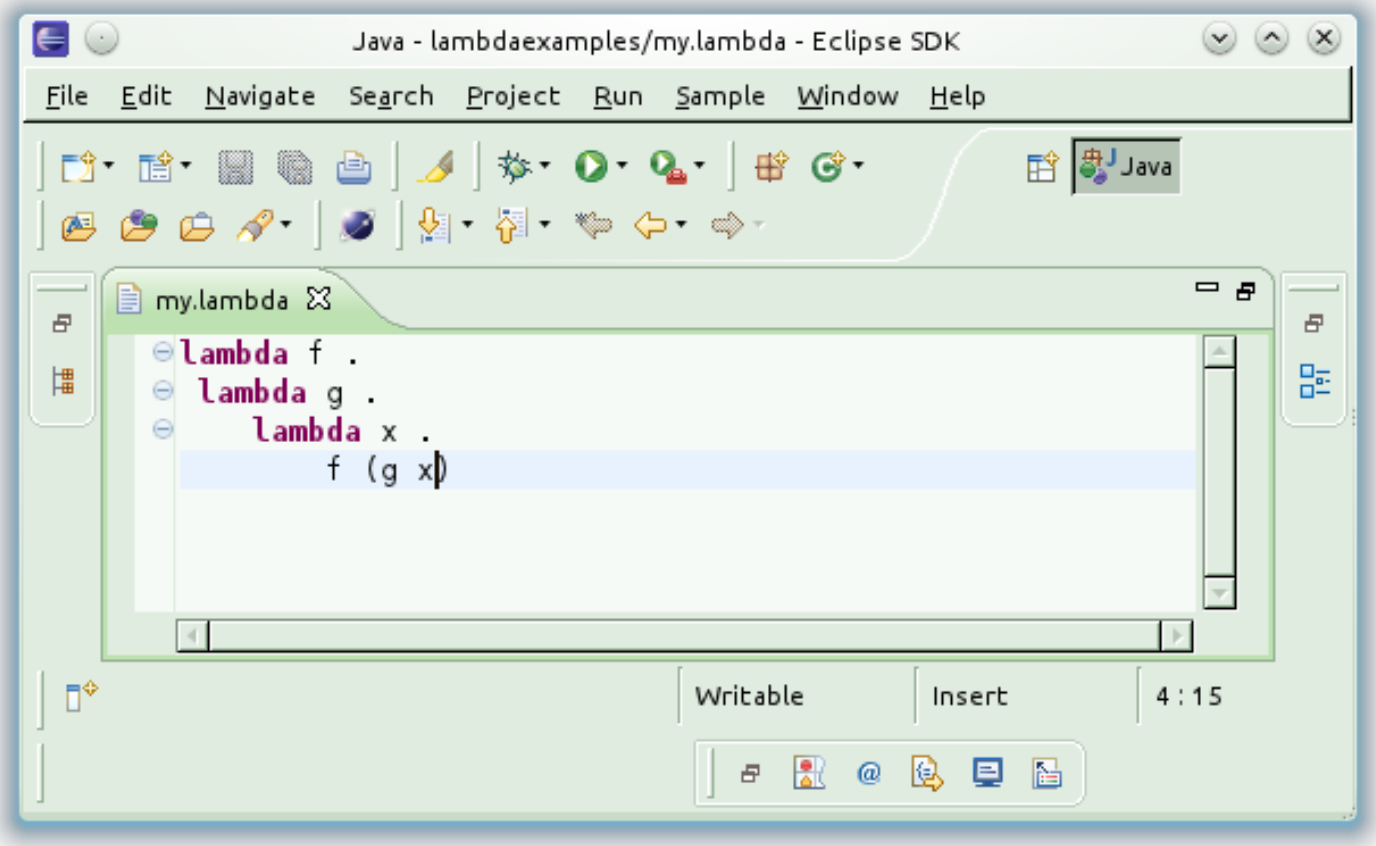
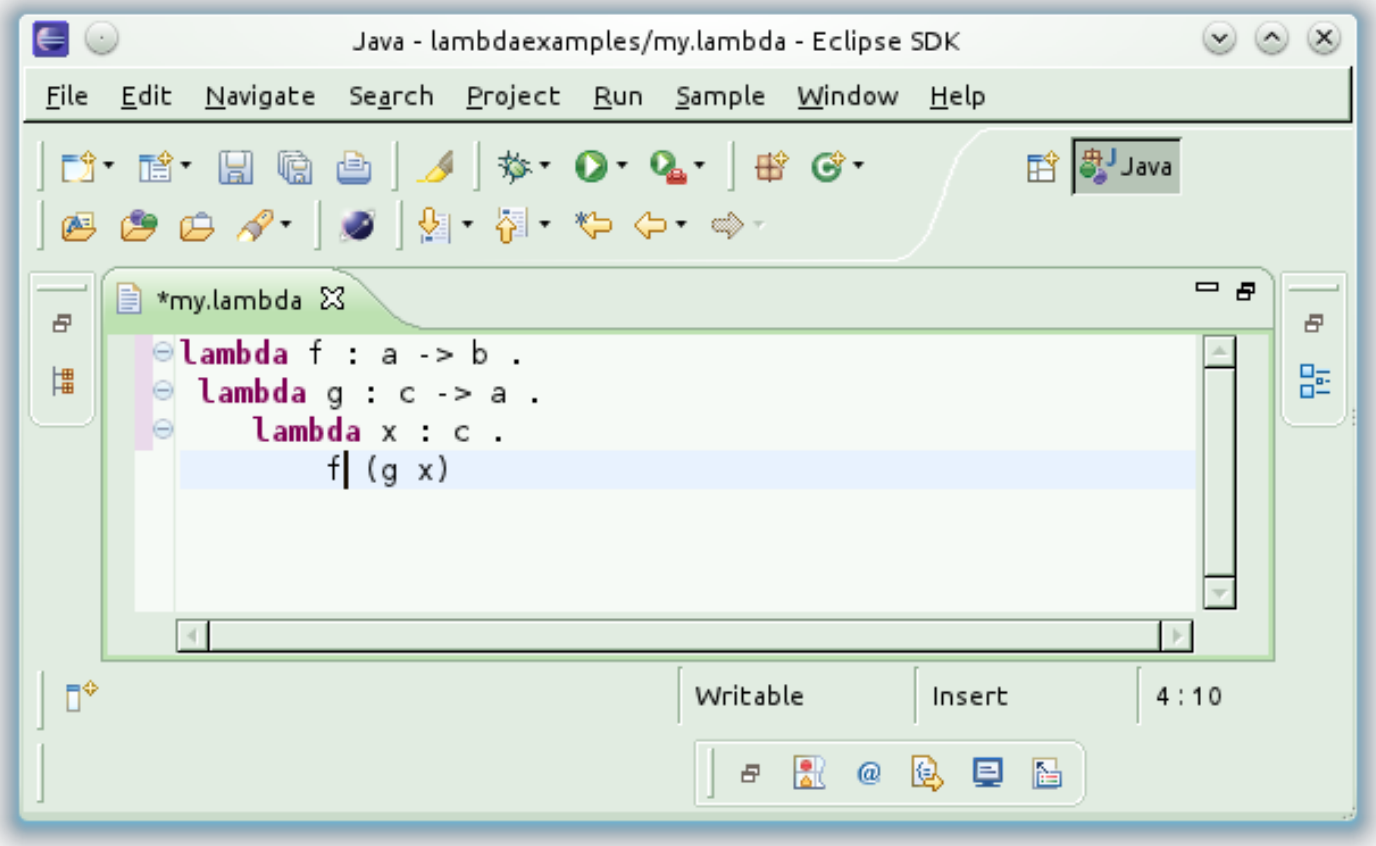
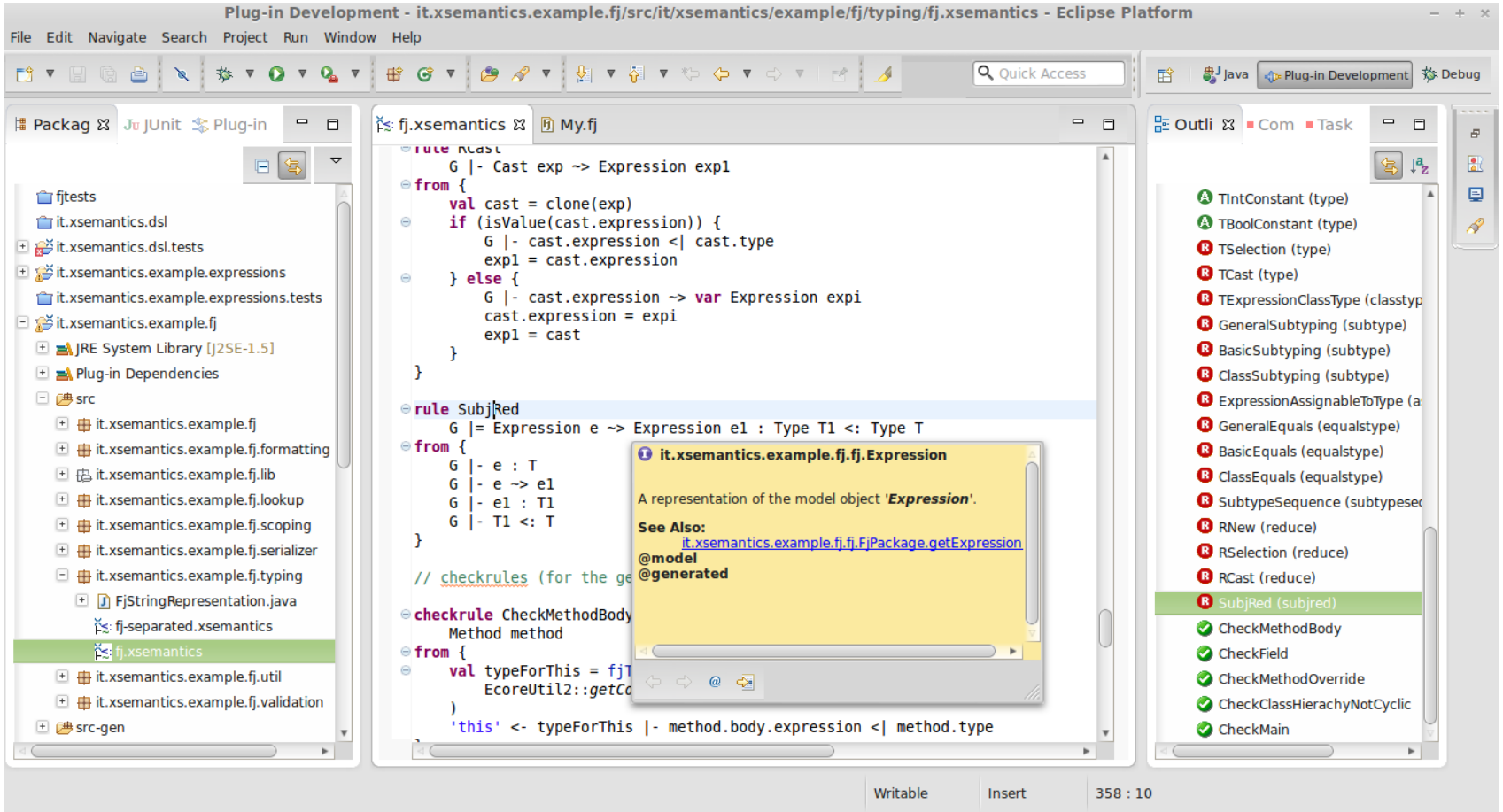


Inferring λ types

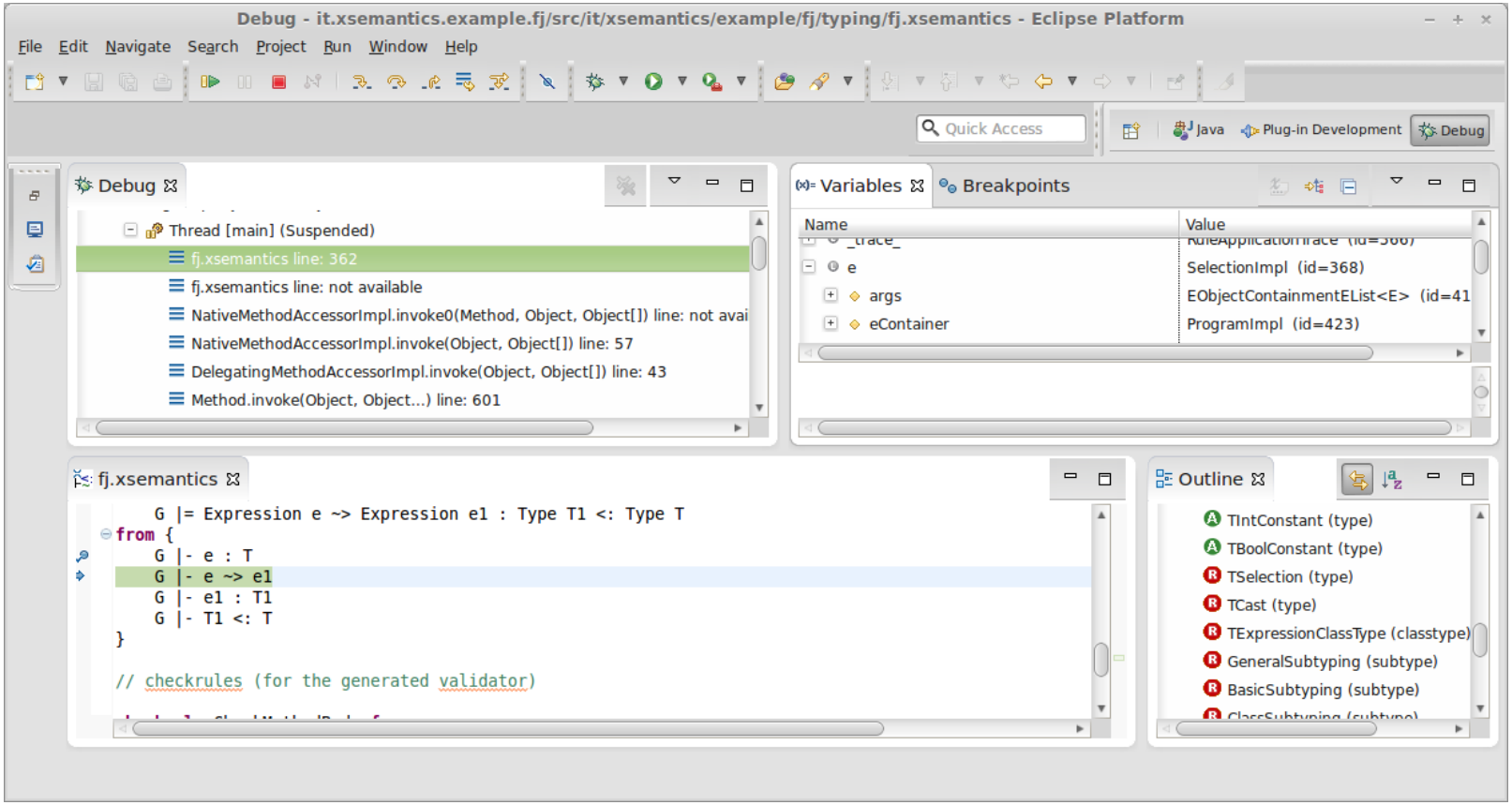
we can use the generated type system to write Eclipse editor pop-up actions for automatically inferring the types of terms:



Fully featured IDE



Debugging rules



Conclusions

http://xsemantics.sourceforge.net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