Generating Programs with Grammars and ASTGen

598DM Guest Lecture
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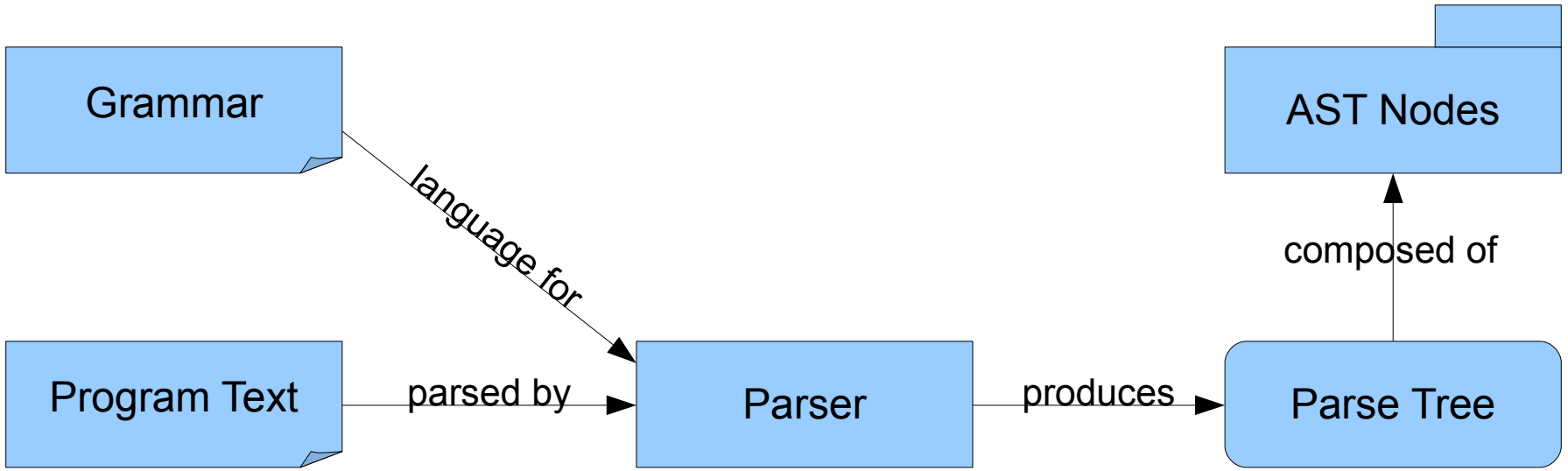
Tuesday, March 11, 2008

Overview


Grammar
language for
AST Nodes
composed of
Program Text
parsed by
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produces
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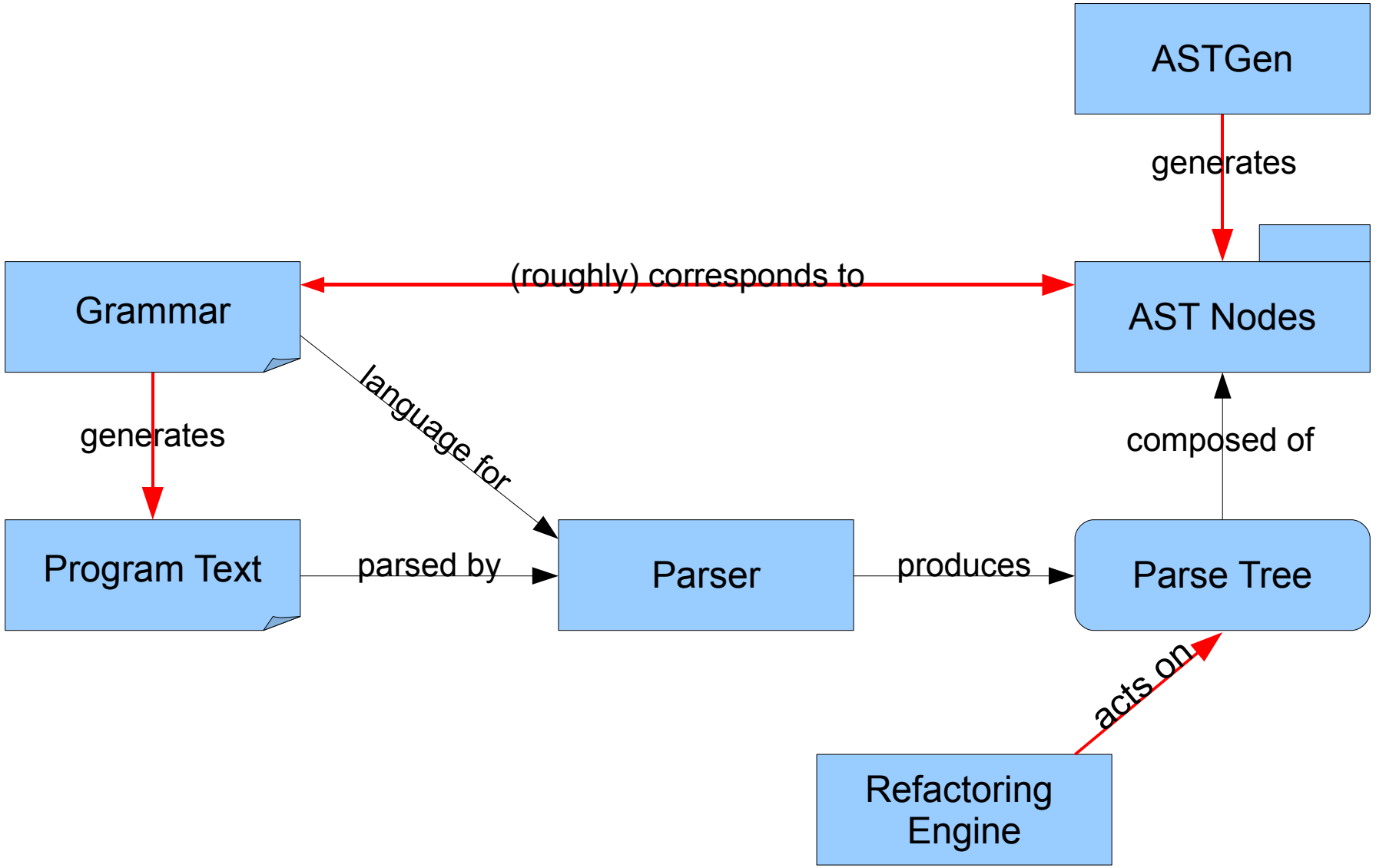
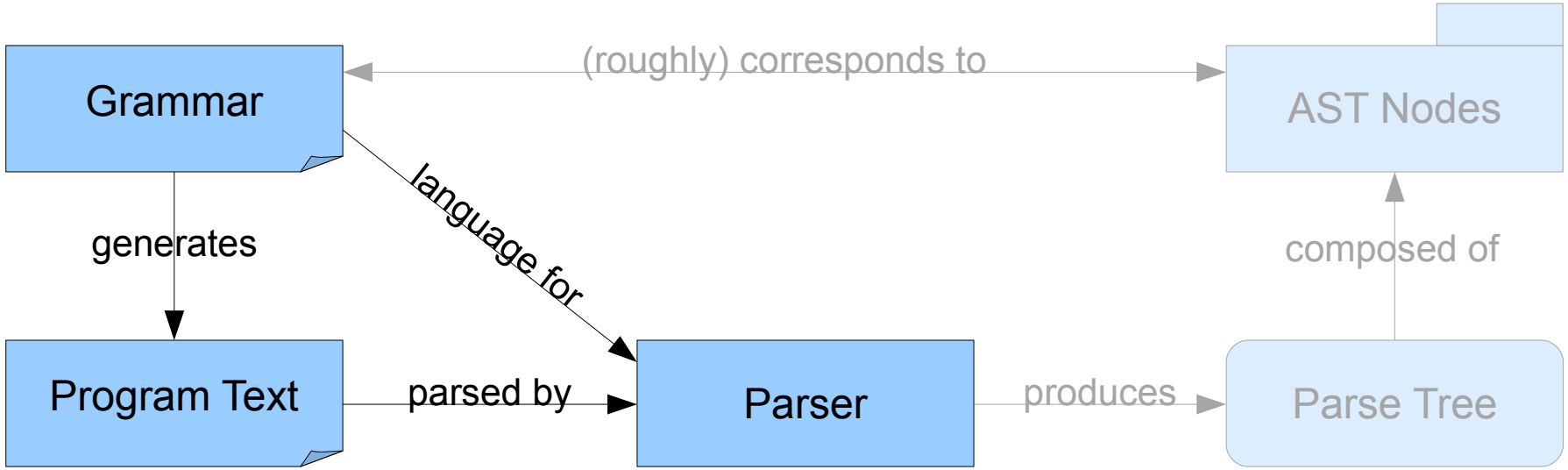
Overview

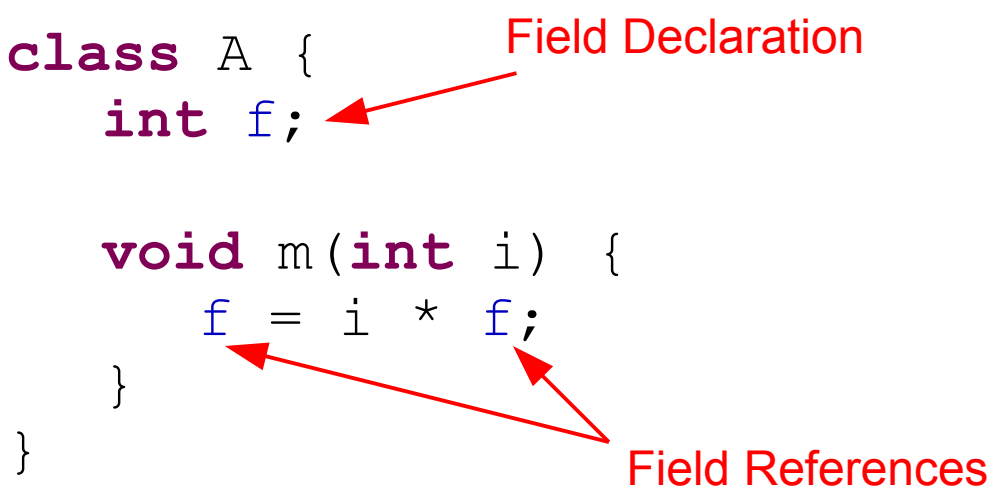

ASTGen
generates
Grammar
(roughly) corresponds to
AST Nodes
generates
language for
composed of
Program Text
parsed by
Parser
produces
Parse Tree
acts on
Refactoring Engine

Grammar-Based Testing

- Produce many programs from grammar
- Used to test parser/compiler



Example: Fields



Field Declaration Grammar

```
FieldDeclaration ::= Modifier Type Identifier “;”

Modifer ::= “public”
          | “protected”
          | “private”
          | ε

Type ::= BasicType
       | Identifier

BasicType ::= “int”
            | “boolean”

Identifier ::= [a-zA-Z_]+
```

Terminal Symbol Coverage

- The set of test inputs contains each terminal symbol

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Production Coverage

- The set of test inputs contains each production

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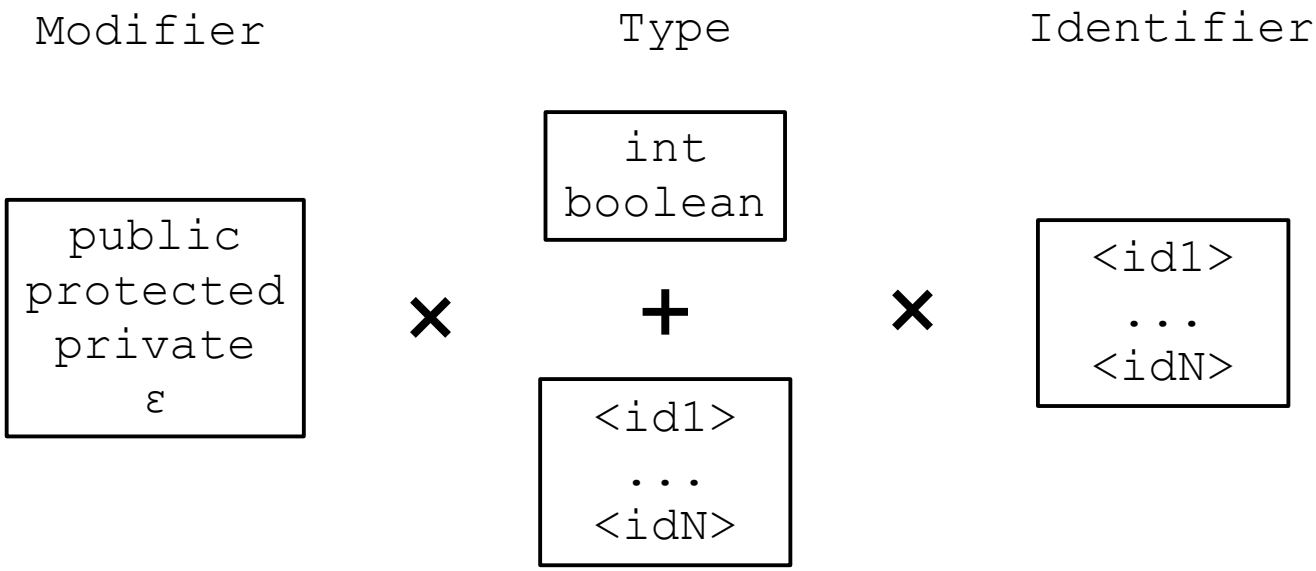
```

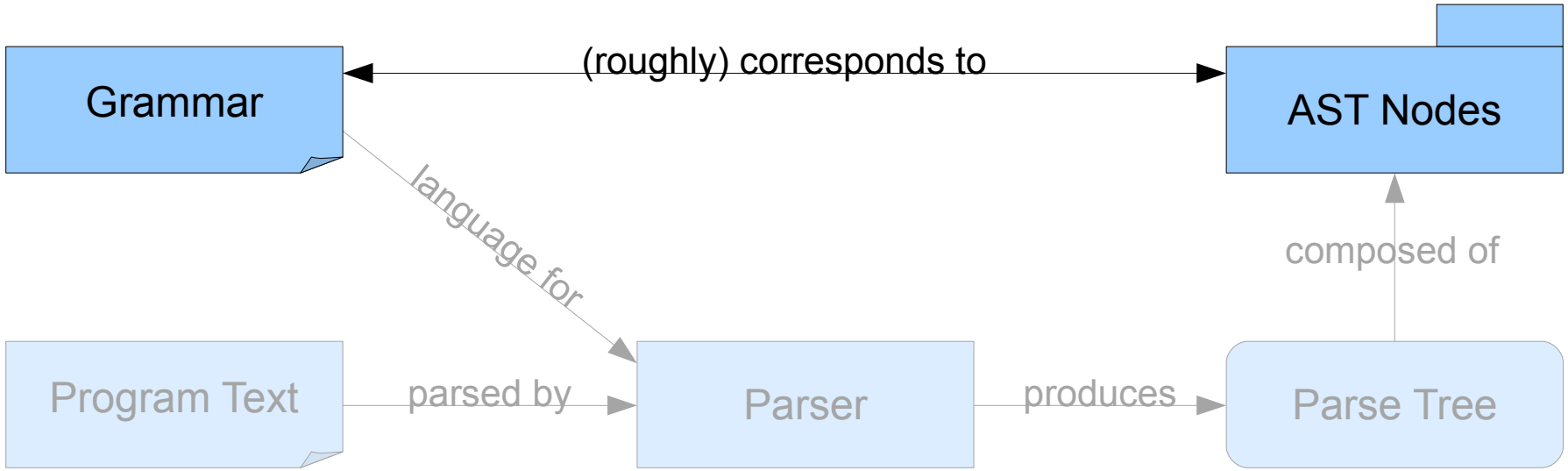
Derivation Coverage

- The set of test inputs contains every possible string

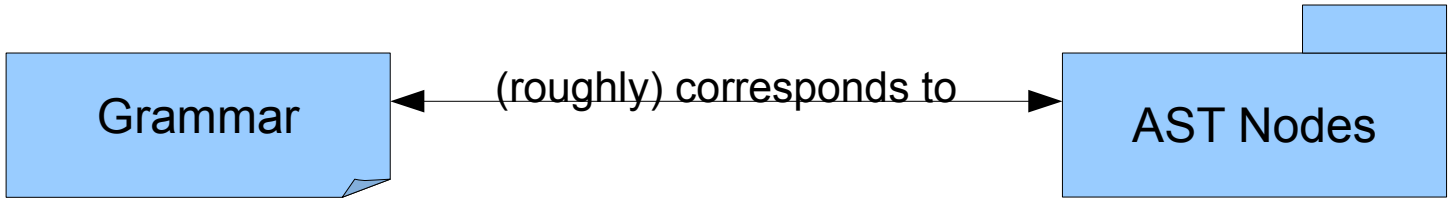


Grammars and ASTs

- Grammar roughly corresponds to AST class structure



Grammars and ASTs

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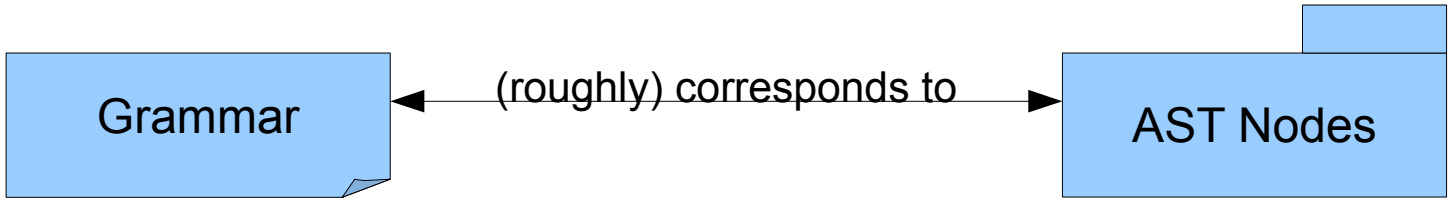
?

Grammars and ASTs

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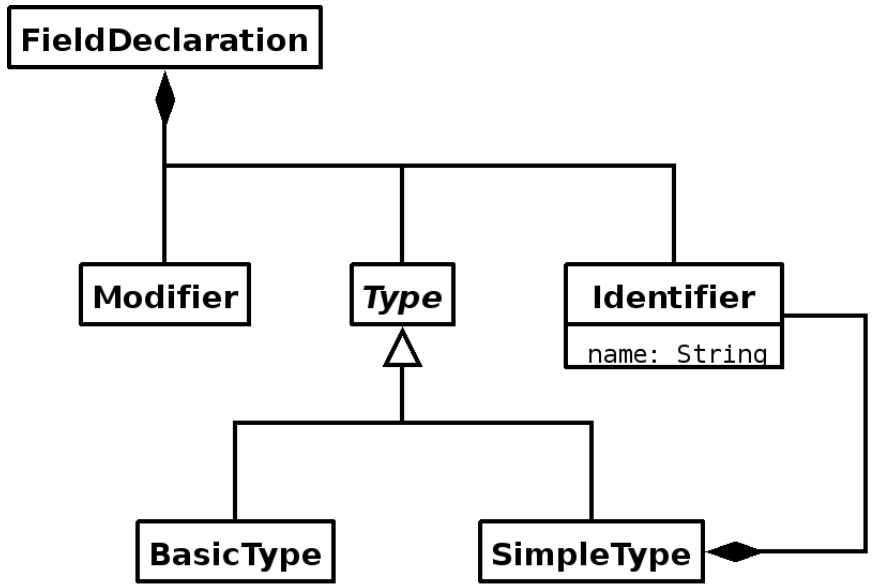


Abstract Grammars

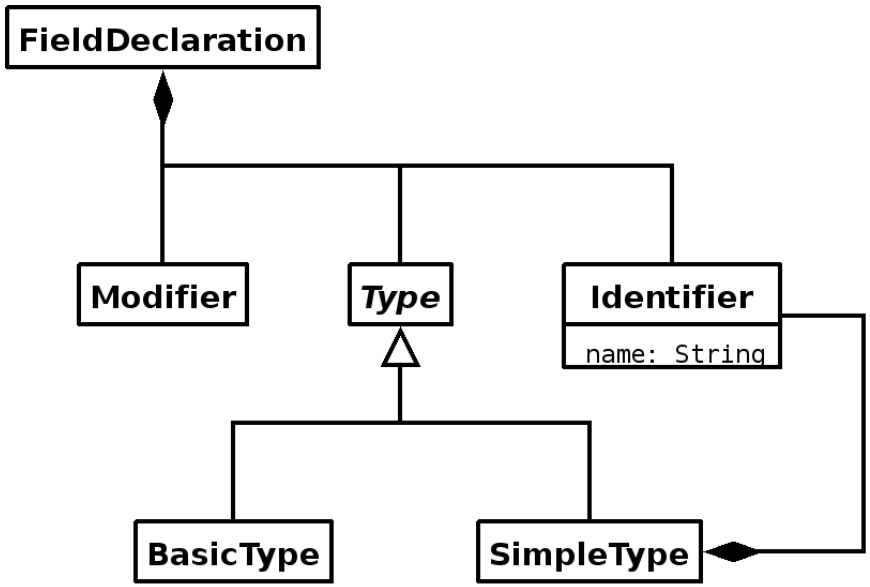
- Grammar used to generate AST class and composition structure

```
FieldDeclaration ::=
  Modifier Type Identifier;

Modifer;

abstract Type;
BasicType : Type;
SimpleType : Type ::= Identifier;

Identifier ::= <Name:String>;
```



What About Field References?

- Difficult to define grammar for all types of field references

```
class A {
    int f;

    void m(int i) {
        f = i * f;
    }
}
```

```
class A {
  boolean f;
}

class B {
  void m() {
    new A().f = true;
  }
}
```

```
class A {
  int f;
}

class B extends A {
  void m() {
    super.f = 0;
  }
}
```

```
class A {
  int f;

  class B {
    void m() {
      int i = f;
    }
  }
}
```

What About Field References?

- Difficult to define grammar for all types of field references
  - Want both read and write references
  - Expressions depend on field name
  - Productions spread across language grammar
  - Multiple classes, inheritance relationships, containment, etc.
- Alternative: “Extended Grammars”

Generating ASTs

- ASTGen generators produce many AST Nodes
- Combining generators produces many parse trees

Generators

- Normal Java Classes

```
ModifierGenerator modGen =
  new ModifierGenerator(
    Modifier.PUBLIC,
    Modifier.PRIVATE);
```

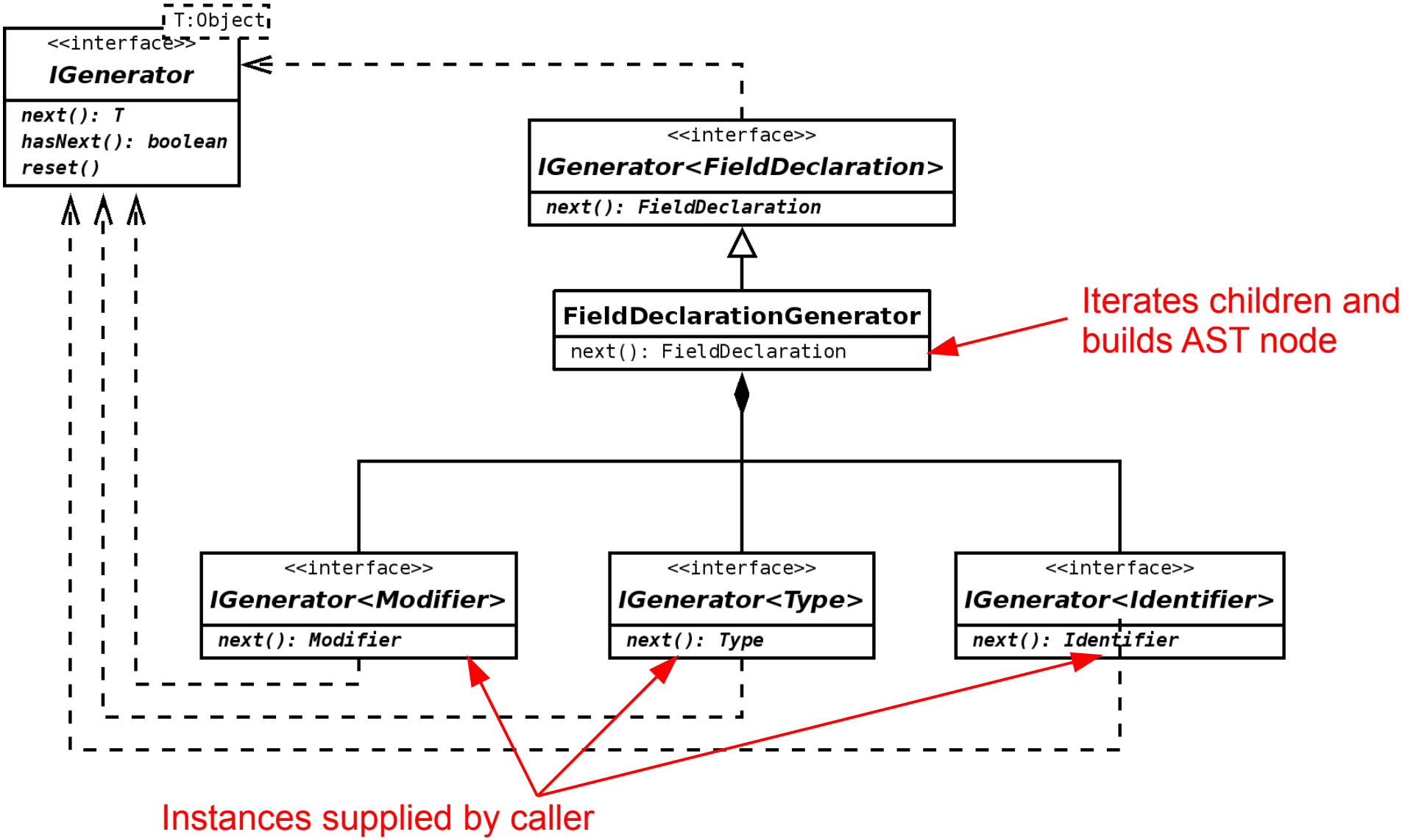
- Produce values when prompted

```
Modifier = modGen.next();
```

Generator Characteristics

- Iterative
  - Act like collection of AST fragments
  - Internally, produce fragments lazily
- Composable
  - Tester creates complex generators by reusing simpler parts
  - Generators contain code to combine AST fragments
- Bounded-Exhaustive
  - Achieves derivation coverage within bounds

Field Declaration Generator



Field Declaration Generator

```
// define child generators
ModifierGenerator modGen =
  new ModifierGenerator(Modifier.PUBLIC, Modifier.PRIVATE);

IGenerator<Type> typeGen =
  new Chain<Type>(BasicType.INT, new SimpleType("Object"));

IdentifierGenerator idGen =
  new IdentifierGenerator("f", "g");

// compose generator
FieldDeclarationGenerator fieldDeclGen =
  new FieldDeclarationGenerator();
fieldDeclGen.setModifierGenerator(modGen);
fieldDeclGen.setTypeGenerator(typeGen);
fieldDeclGen.setIdentifierGenerator(idGen);

// loop over values
for(FieldDeclaration fieldDecl : fieldDeclGen) {
  System.out.println(fieldDecl);
}
```

Complex Generator

- Double-class field reference generator

"Produces pairs of classes related by containment and inheritance. One class declares a field, and the other references the field in some way."

```
class A {
  int f;
}

class B extends A {
  void m() {
    super.f = 0;
  }
}
```

```
class A {
  boolean f;
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…

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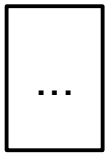

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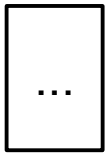

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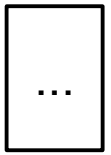

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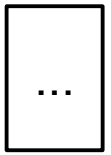
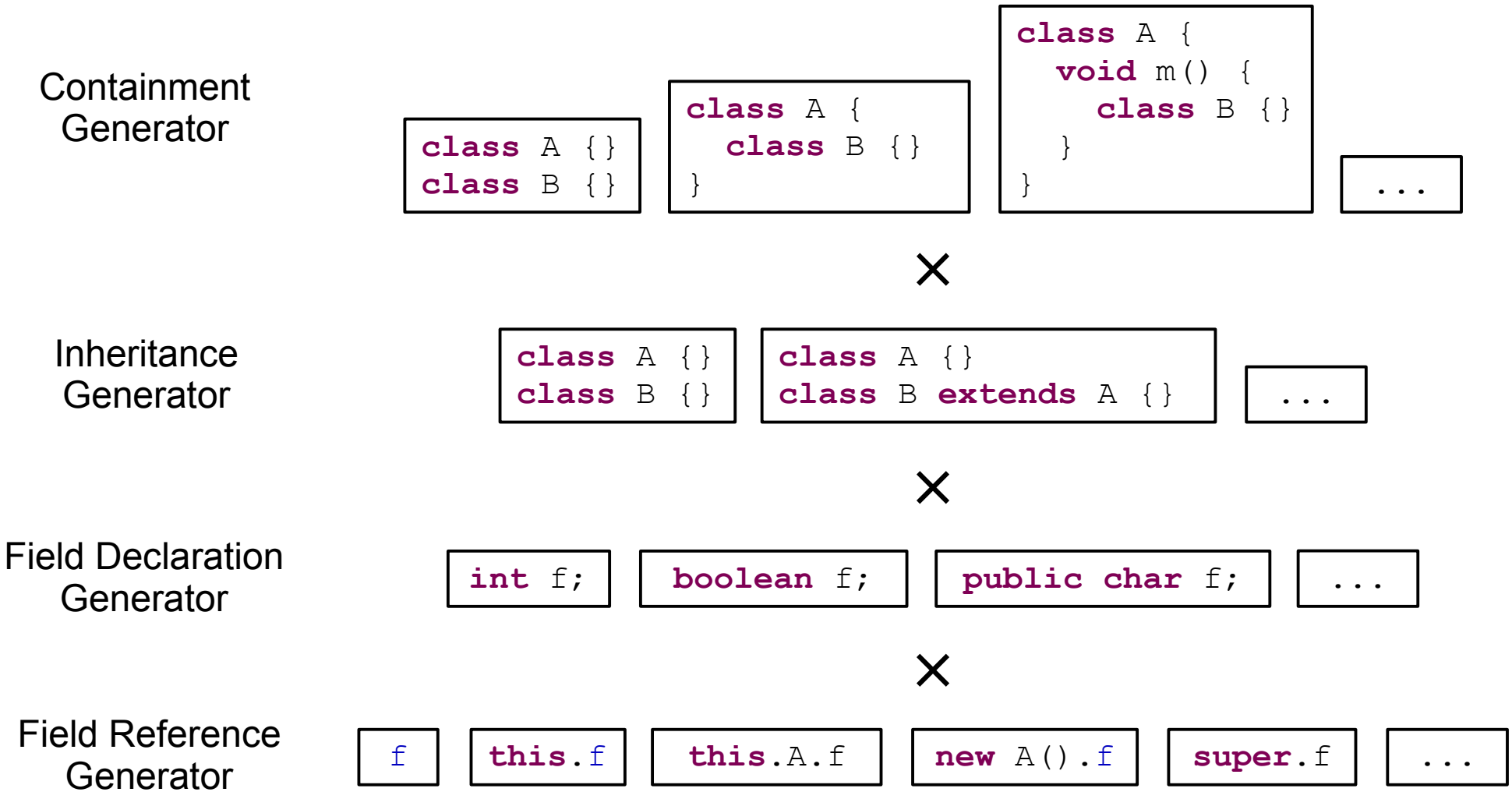
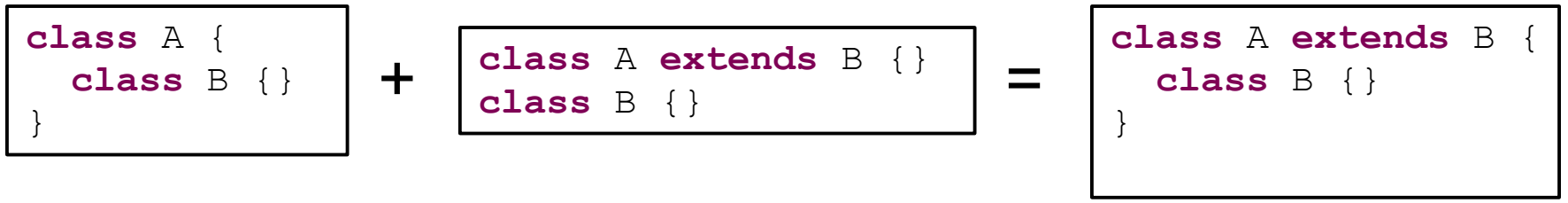


Composing Generators



Invalid Combinations

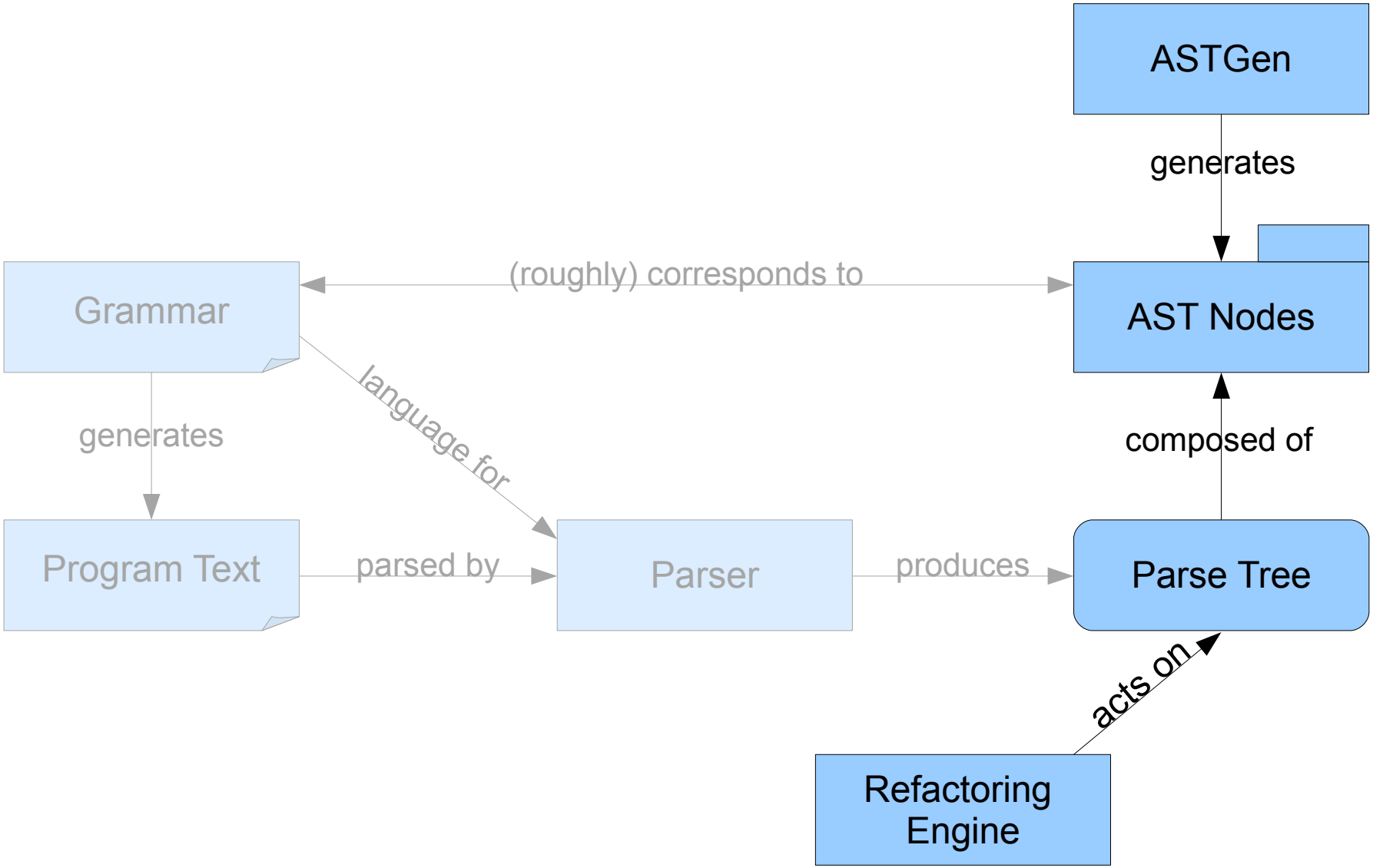
- Composition may be invalid



- Three solutions
  - Tester writes filter that verifies values
  - Dependent generators

  - Delegate to compiler

Testing Refactoring Engines

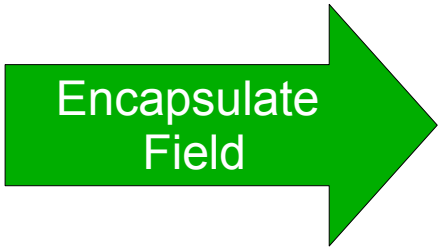


Example: Encapsulate Field

Replaces all field reads and writes with accesses through getter and setter methods

```
class A {
    int f;

    void m(int i) {
        f = i * f;
    }
}
```




```
class A {
  5 private int f;

    void m(int i) {
        setF(i * getF());
    }   4        3

  2 void setF(int f) {
        this.f = f;
    }

  1 int getF() {
        return f;
    }
}
```

Testing Encapsulate Field

```
String fieldName = "f";
IGenerator<Program> testGen =
  new DoubleClassFieldReferenceGenerator(fieldName);

for (Program in : testGen) {
  Refactoring r = new EncapsulateFieldRefactoring();
  r.setTargetField(fieldName);

  Program out = r.performRefactoring(in);
  checkOracles(out);
}
```

Oracles

- Check that the program was refactored correctly
- Challenges
  - Don't know expected output
  - Semantic equivalence is undecidable
  - Need to verify that correct structural changes were made

Oracles

Oracles

- **DoesCrash**: Engine throws exception
- **DoesNotCompile**: Refactored program does not compile
- **WarningStatus**: Engine can(not) perform refactoring
- **Inverse**: A refactoring is not undone by its inverse
- **Custom Structural**: Check for desired structural changes
- **Differential**: Perform refactoring in both Eclipse and NetBeans and compare result

Case Study

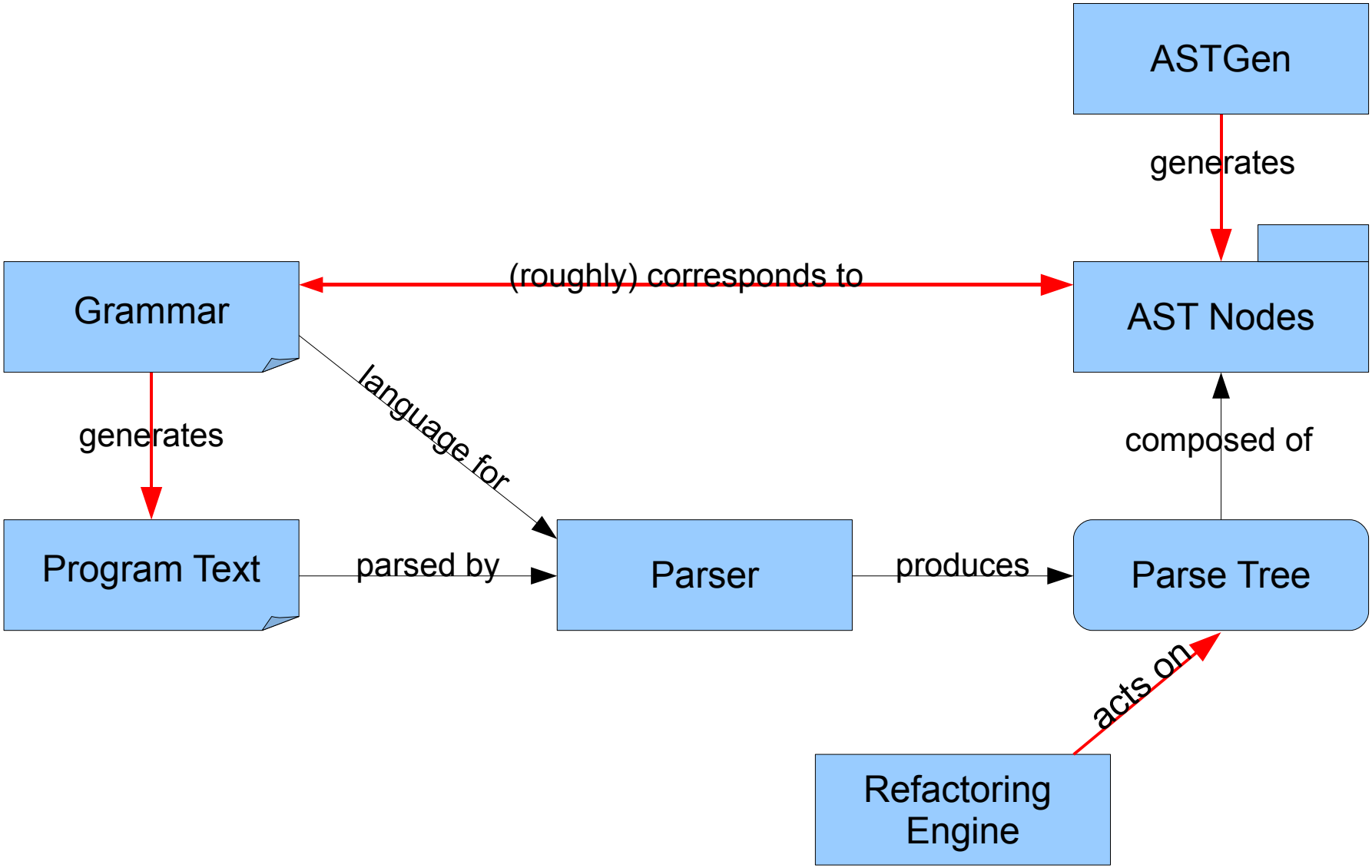
- Tested Eclipse and NetBeans
- Eight refactorings
  - Target field, method, or class
- Wrote about 50 generators
- Reported 47 new bugs
- Compared effectiveness of oracles

Results

- 47 new bugs reported
  - 21 in Eclipse: 20 confirmed by developers
  - 26 in NetBeans: 17 confirmed, 3 fixed, 5 duplicates, 1 won't fix
  - Found others, but did not report duplicate or fixed

http://mir.cs.uiuc.edu/astgen/

Recap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