COMP 520 - Compilers

Lecture 12 – Mar 10, 2022

Contextual Analysis

- PA3 – Contextual Analysis assignment online
  - Due Thursday Mar 31

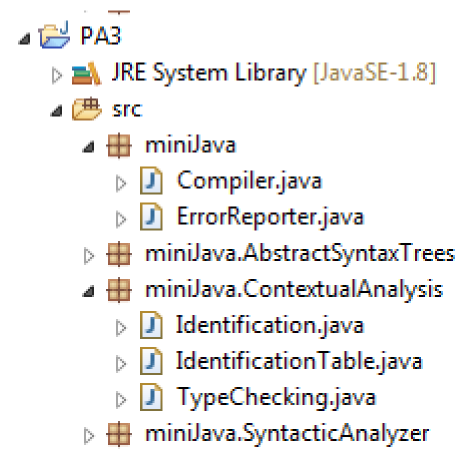
PA3 Contextual Analysis

- Implement contextual analysis in a subpackage
  - `miniJava.ContextualAnalysis`

- Contextual Analysis consists of
  1. Identification
  2. Type checking

- Also add `null` to miniJava!

- Sample PA3 project structure
  (within miniJava.ContextualAnalyzer
  choose classes and class names as you wish)



- Due Thu March 31
  - 21 days but 9 are spring break
  - Today’s lecture includes details on implementation

PA3 Implementation: Identification

- What needs to be done in Identification
  - Declarations need to be entered
    - ClassDecl, MemberDecl, LocalDecl
  - Identifiers need to be linked to their declaration
    - add field to Identifier class: `public Declaration decl`
    - work out a correct order to visit different parts of the AST to ensure all applicable declarations will have been seen before visiting an Identifier
    - link each identifier in the AST to its declaration using the appropriate idTable(s)
  - What constructs need identification?
    - Basically all
      - Declarations
      - Statements, Expressions, References, TypeDenoters
        - » anything that could contain an Identifier

Identification

string	Decl	level
class names	ClassDecl	1
member names	MemberDecl	2
parameter names	ParameterDecl	3
local var names	LocalDecl	4+

- IdTables
  - enter(String s, Decl d)
    - associate s with Decl d
  - Decl retrieve(String s)
    - yields decl or null
- Specific id tables
  - is *s* a class name?
  - is *s* a member of class X?
- *Scoped* id table
  - enter or exit a scope
  - what declaration is associated with *s* in the current scope?
  - is *s* already declared in the current scope?
  - is *s* already declared in a scope with level ≥ 3 ?
  - enter a new <name,Decl> at the current scope level

Identification in miniJava

- Parameters to the identification process
  - Class declarations
    - to identify uses of class names e.g.

```
Foo x  =  …
new Foo()
```

  - Member declarations in current class
    - to identify uses of fields or methods
  - Local declarations in current method
    - to identify uses of parameters or local variables
  - Member declarations in other classes
    - to identify qualified references, e.g.

```
Foo.field
x.y.z
```

scoped identification table

EXAMPLE

miniJava package

```
class Foo {
    int x;

    int p(int y) {
        if (p(x)) {
            int x = 10;
            x = y;
        }
        return x;
    }
}
```

AST $\xrightarrow{2}$ $\downarrow_1$

Scoped id table

Foo
x p
y
x

```
Package
  ClassDeclList [1]
    ClassDecl
  .   "Foo" classname
  .   FieldDeclList [1]
  .   . (public) FieldDecl
  .   .     INT BaseType
  .   .     "x" fieldname
  .   MethodDeclList [1]
  .   . (public) MethodDecl
  .   .     INT BaseType
  .   .     "p" methodname
  .   .     ParameterDeclList [1]
  .   .   . ParameterDecl
  .   .   .     INT BaseType
  .   .   .     "y"parametername
```

```
.   .     StmtList [2]
.   .   . IfStmt
.   .   .   CallExpr
.   .   .     IdRef
.   .   .       "p" Identifier
.   .   .     ExprList + [1]
.   .   .     . RefExpr
.   .   .     .   IdRef
.   .   .     .     "x" Identifier
.   .   .   BlockStmt
.   .   .     StatementList [2]
.   .   .     . VarDeclStmt
.   .   .     .   VarDecl
.   .   .     .     INT BaseType
.   .   .     .     "x" varname
.   .   .     .   LiteralExpr
.   .   .     .     "10" IntLiteral
.   .   .     . AssignStmt
.   .   .     .   IdRef
.   .   .     .     "x" Identifier
.   .   .     .   RefExpr
.   .   .     .     IdRef
.   .   .     .       "y" Identifier
.   .   . ReturnStmt
.   .   .   RefExpr
.   .   .     IdRef
.   .   .       "x" Identifier
```

EXAMPLE

miniJava package

```
class Foo {
    int x;

    int p(int y) {
        if (p(x)) {
            int x = 10;
            x = y;
        }
        return x;
    }
}
```

AST $\xrightarrow{2}$ (AST $\downarrow 1$)

```
.    .    StmtList [2]
.    .    . IfStmt
.    .    .   CallExpr
.    .    .     IdRef
.    .    .       "p" Identifier
.    .    .     ExprList + [1]
.    .    .     . RefExpr
.    .    .     .   IdRef
.    .    .     .     "x" Identifier
.    .    .   BlockStmt
.    .    .     StatementList [2]
.    .    .     . VarDeclStmt
.    .    .     .   VarDecl
.    .    .     .     INT BaseType
.    .    .     .     "x" varname
.    .    .     .   LiteralExpr
.    .    .     .     "10" IntLiteral
.    .    .     . AssignStmt
.    .    .     .   IdRef
.    .    .     .     "x" Identifier
.    .    .     .   RefExpr
.    .    .     .     IdRef
.    .    .     .       "y" Identifier
.    .    . ReturnStmt
.    .    .   RefExpr
.    .    .     IdRef
.    .    .       "x" Identifier
```

Scoped id table

Foo
x p
y

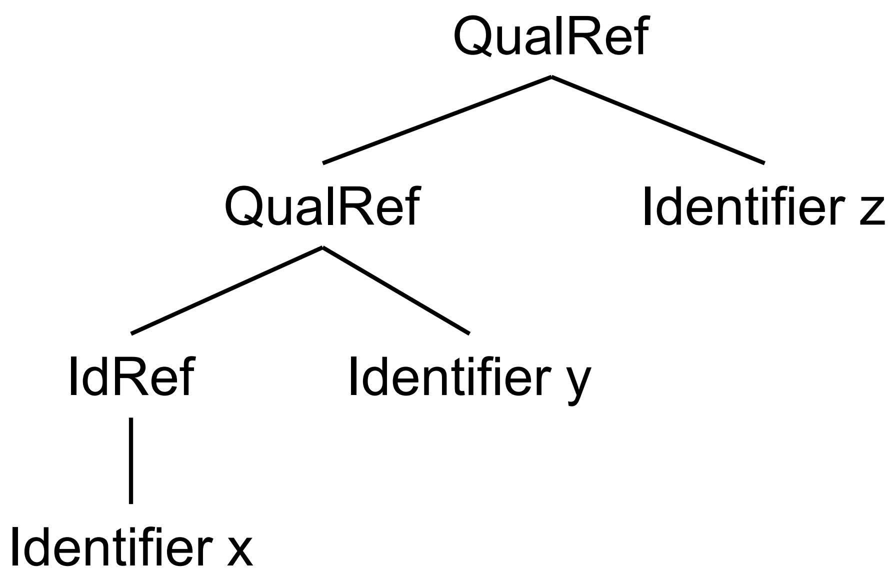
```
Package
  ClassDeclList [1]
  ClassDecl
  .   "Foo" classname
  .   FieldDeclList [1]
  .   . (public) FieldDecl
  .   .   INT BaseType
  .   .   "x" fieldname
  .   MethodDeclList [1]
  .   . (public) MethodDecl
  .   .   INT BaseType
  .   .   "p" methodname
  .   .   ParameterDeclList [1]
  .   .   . ParameterDecl
  .   .   .   INT BaseType
  .   .   .   "y"parametername
```

Identification

- challenges
  - Access and Visibility restrictions of MemberDecls
    - Non-static members are not always accessible
    - private members are not always accessible
    - need a “context” for a reference to make a judgment

  - Qualified references
    - example
      - x.y.z

    - what needs to be checked at each node of the Reference ast?



Implementation of Identification

- Use the Visitor pattern!

```
package miniJava.ContextualAnalysis;

import miniJava.AbstractSyntaxTrees.*;
import miniJava.AbstractSyntaxTrees.Package;
import miniJava.ErrorReporter;

public class Identification implements Visitor<Object, Object> {

        public IdentificationTable table;
        private ErrorReporter reporter;

        public Identification(Package ast, ErrorReporter reporter) {
                this.reporter = reporter;
                table = new IdentificationTable(reporter);
                ast.visit(this, null);
        }
```

Identification - package

```
// Package
	public Object visitPackage(Package prog, Object obj) {
		table.openScope();

		// add all the classes to the table.
		for(ClassDecl cd: prog.classDeclList) {
			table.enter(cd);
		}
		//then visit classes
		for(ClassDecl cd: prog.classDeclList) {
			cd.visit(this, null);
		}
		table.closeScope();
		return null;
	}
```

Identification – ClassDecl

```
// Declarations
        public Object visitClassDecl(ClassDecl cd, Object obj) {
                currentClass = cd;

                // add members so all fields and methods are visible
                table.openScope();
                for(FieldDecl fd: cd.fieldDeclList) {
                        table.enter(fd);
                }
                for(MethodDecl md: cd.methodDeclList) {
                        table.enter(md);
                }

                // visit all members
                  for(FieldDecl fd: cd.fieldDeclList)
                        fd.visit(this, null);
                  for(MethodDecl md: cd.methodDeclList) {
                        md.visit(this, null);
                }
                table.closeScope();
                return null;
        }
```

Identification – member declarations

```
public Object visitFieldDecl(FieldDecl fd, Object obj) {
              fd.type.visit(this, null);
              return null;
      }

public Object visitMethodDecl(MethodDecl md, Object obj) {
              md.type.visit(this, null);
              table.openScope();
              for(ParameterDecl pd: md.parameterDeclList) {
                      pd.visit(this, null);
              }
              table.openScope();
              for(Statement st: md.statementList) {
                      st.visit(this, null);
              }
              table.closeScope();
              table.closeScope();
              return null;
```

PA3 Type Checking

- Relatively simple
  - Bottom-up traversal of AST
  - Create a typeDenoter attribute in every Expression node (or possibly in every node)
    - The type rules for predefined functions are relatively simple

      `+,-,*` *etc* : Int x Int $\rightarrow$ Int

      == : α x α $\rightarrow$ Boolean

      index : Array(α) x Int $\rightarrow$ α

      assign : α x α $\rightarrow$ Stmt
    - A single upwards pass suffices for miniJava type checking
    - Study type related classes in the AST
      - TypeDenoter, TypeKind, BaseType, ArrayType, Classtype
      - create an equality function between arbitrary instances of TypeDenoter

- run only if identification has completed successfully!
  - e.g. `A x = new A();`

Type Checking

- Special types
  - *Error* type
    - Error type is *equal* to any type
    - limits propagation of errors
    - gives most useful continuation of type checking after an error

  - *Unsupported* type
    - Unsupported type is *not equal* to any type
    - therefore a value of type unsupported is not type correct in any operation
    - predefined name String can have unsupported type

Logical order of Contextual analysis

1. Identification
   – check validity of declarations
     • is this declaration allowed in the current context?
   – link references to corresponding declarations
   – AST traversal order
     • top down, declarations before references

2. Type checking
   – assign types to AST nodes
     • start from leaves using decls installed in identification to determine parent nodes
   – check type agreement
     • operators and operands
     • assignment statements
   – AST traversal order
     • bottom up (assuming no overloading)

Contextual analysis in a single traversal

- For each node
  - *inherit* some information from parent
    - e.g. Identification table
  - traverse subtree rooted at node
  - *synthesize* some information to return to parent
    - e.g. type of expression computed by node
    - e.g. updated identification table

- Traversing the subtree rooted at a node
  - for each child in turn
    - apply contextual analysis on child
    - providing inherited data
    - receiving synthesized data