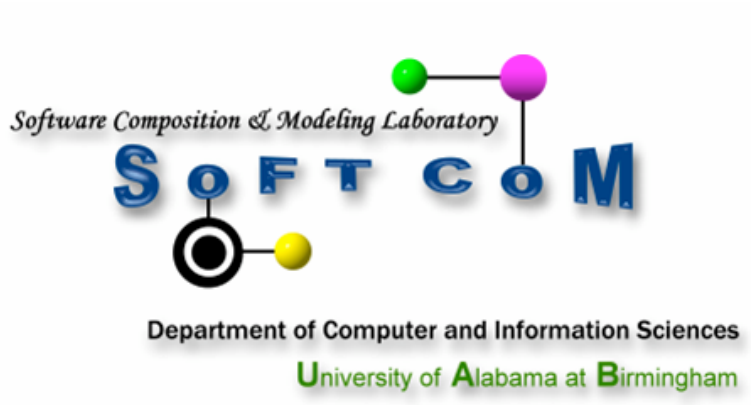
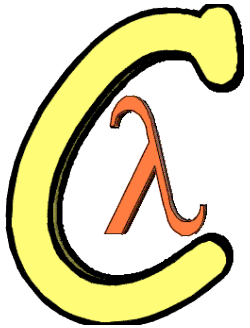
Separation of Concerns in Compiler Development Using Aspect-Orientation

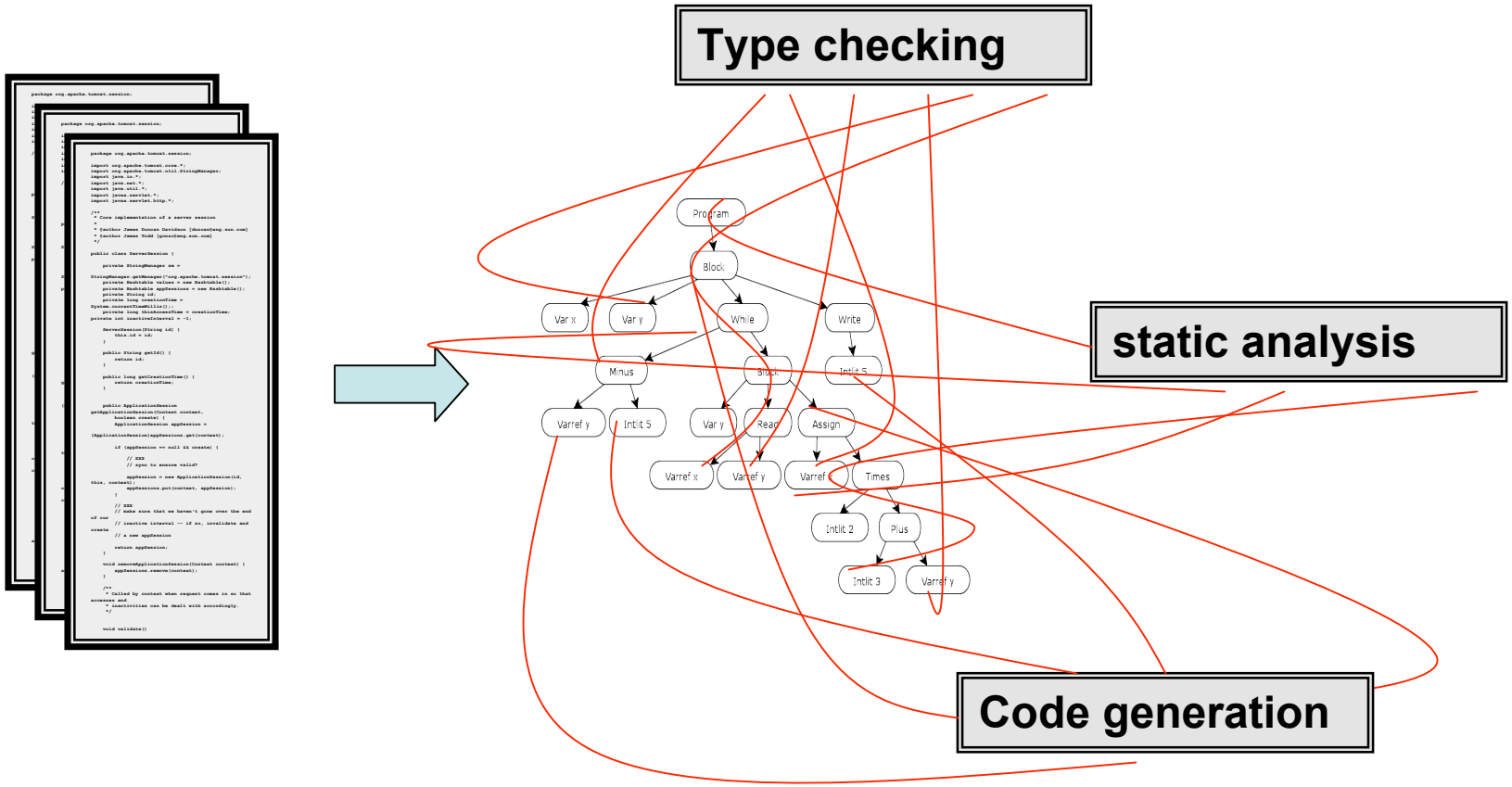




Carl (Xiaoqing) Wu, Barrett R. Bryant, Jeff Gray and Suman Roychoudhury
University of Alabama at Birmingham

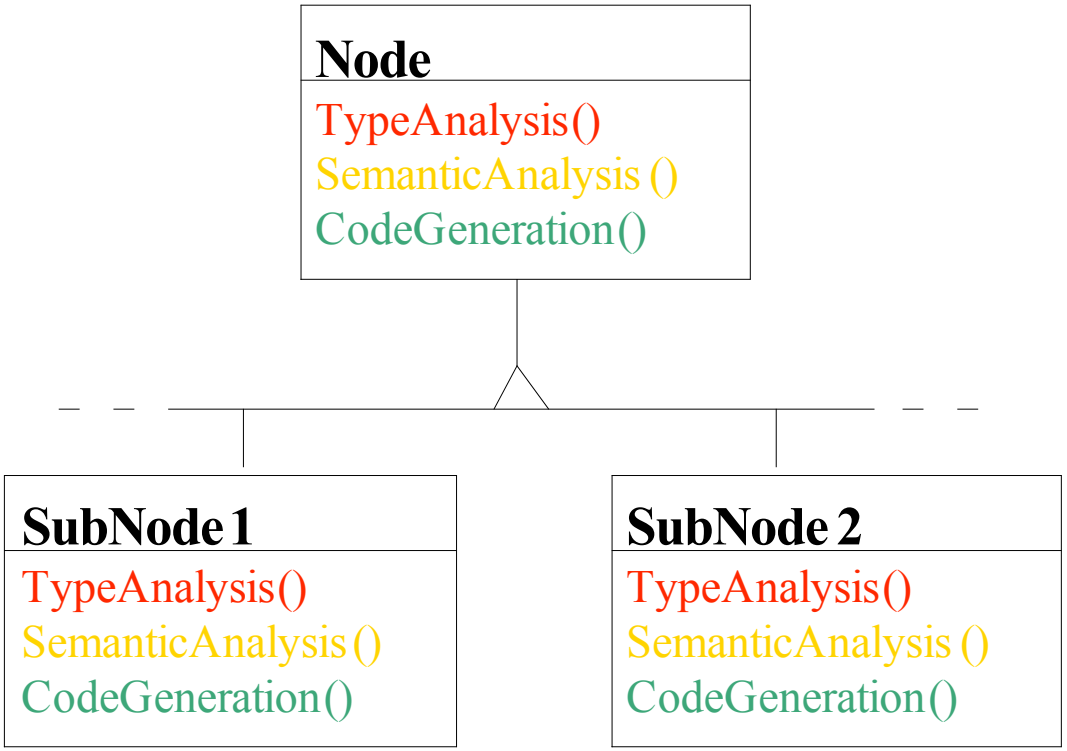
Marjan Mernik
University of Maribor

The Problem: Modularization of Compiler Phases



Compiler implementation is often an intricate task due to the complexity and interconnected nature of various stages within the compiler.

Pure Object-Oriented Design



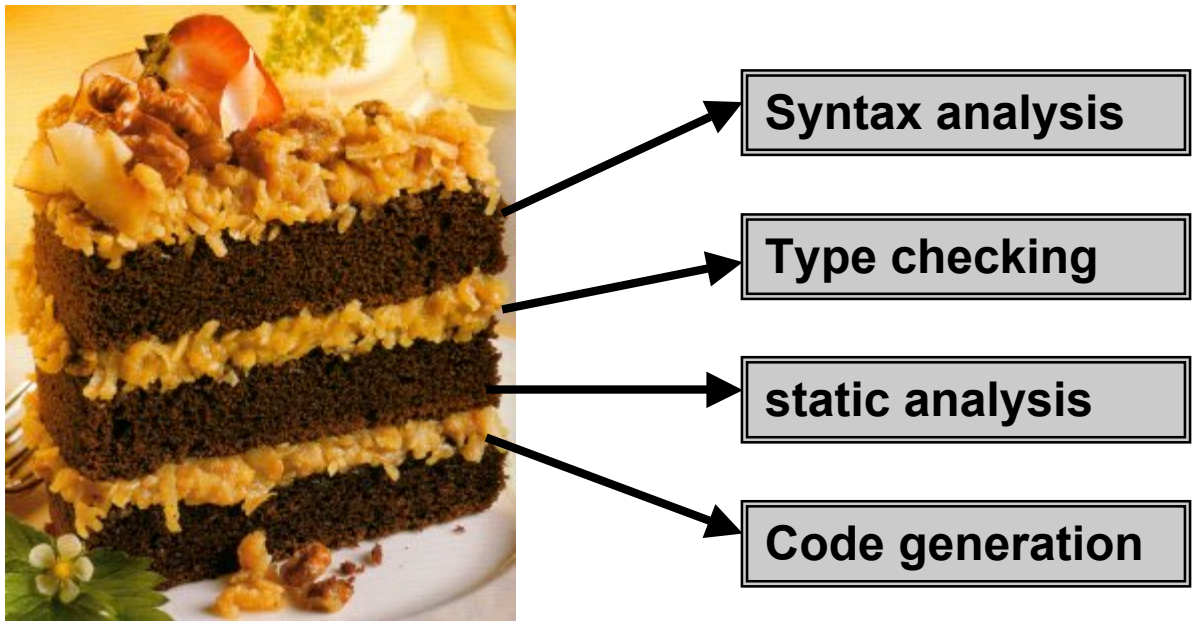
Problems

1. Code scatters all over the classes.

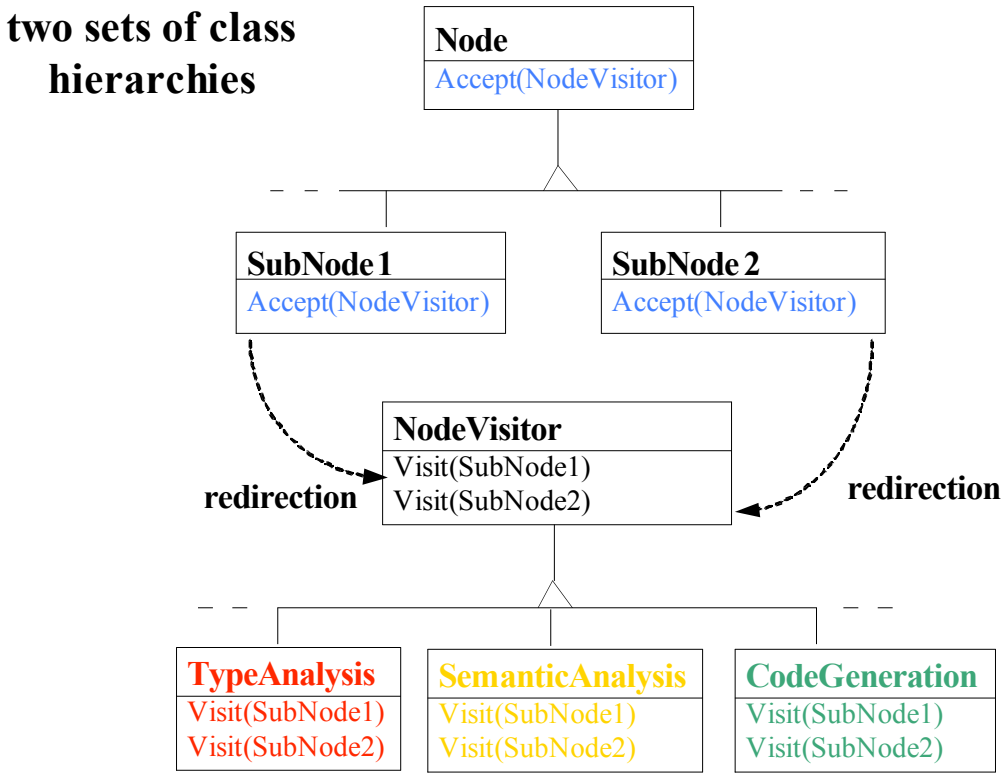
2. Hard to maintain and evolve.

The Goal: Separation of Concerns

The key challenge is to provide exceptional modularity that assists in properly separating several crosscutting concerns, which not only helps the developer to divide-and-conquer the complexity, but also improves the readability, reusability and extensibility of the compiler implementation.



Popular Solution: the Visitor Pattern

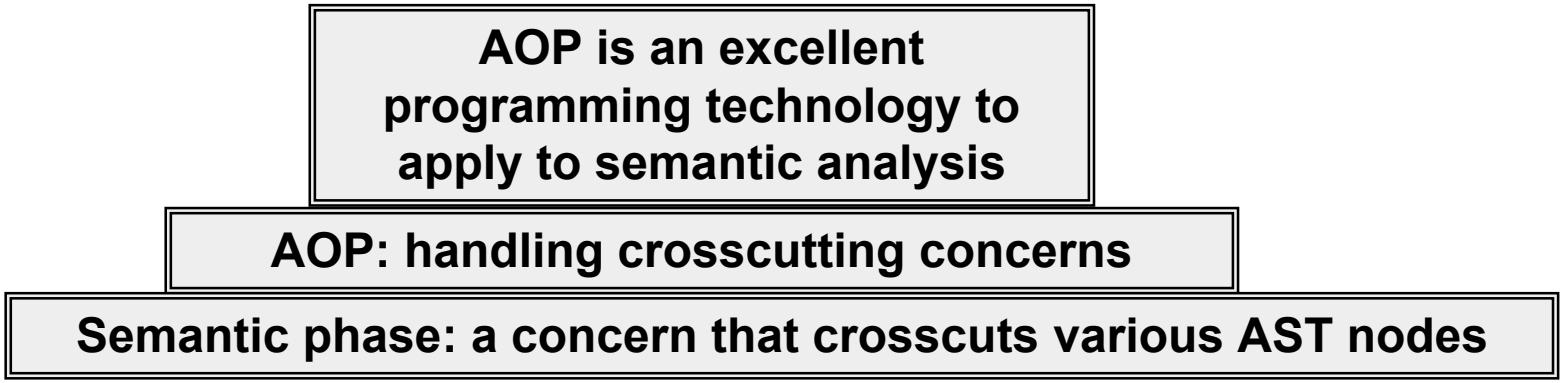


Problems

1. Introduce a lot of extra code.
2. Forces all concrete visitors share the same interface.
3. New semantics are always introduced by traversal of the whole tree.
4. Cannot access non-public members of a node class.

New solution: Aspect-Oriented Programming

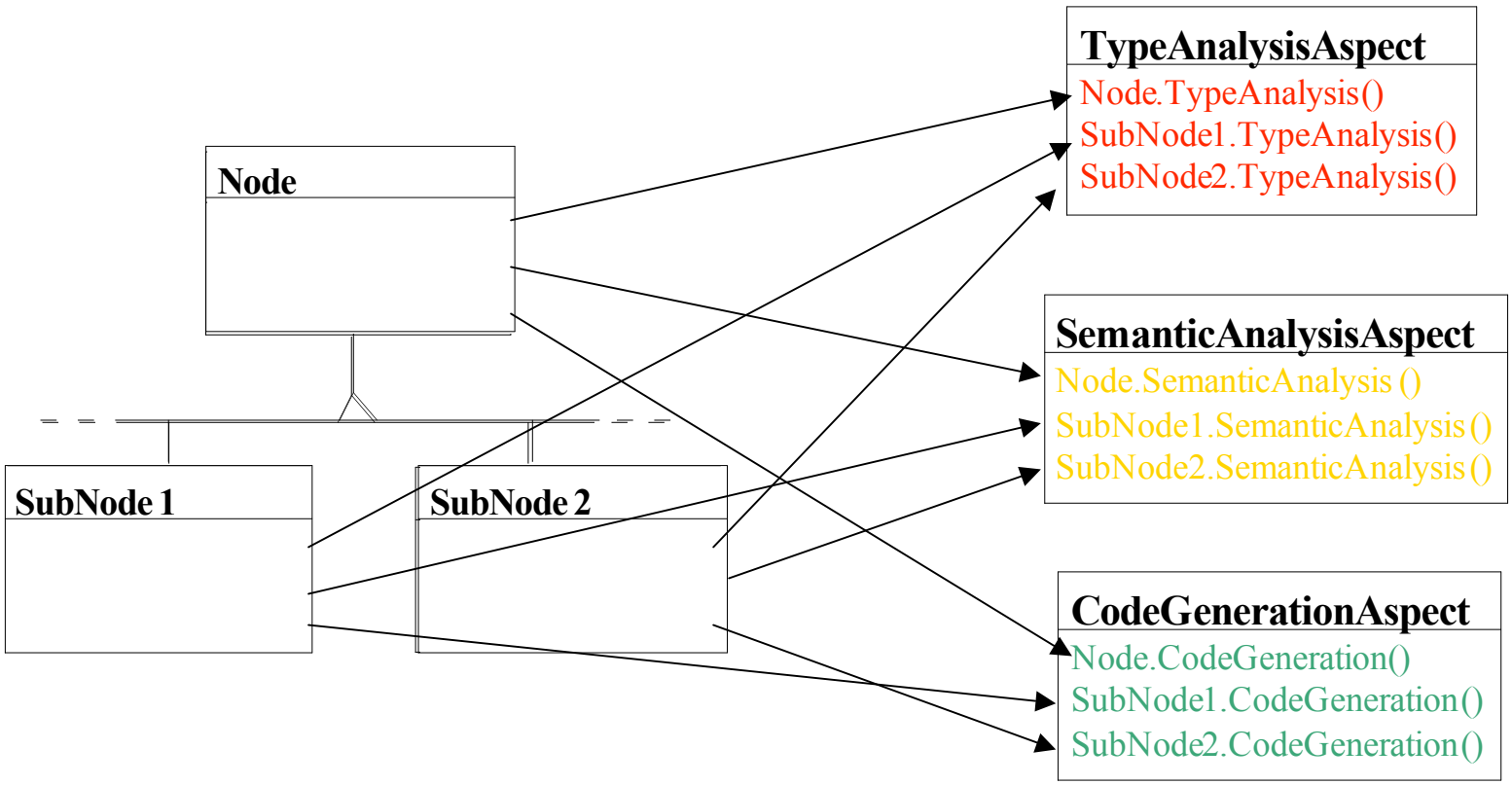
- Aspect-Oriented Programming provides special language constructs called aspects to modularize crosscutting concerns in conventional program structures.
  - Introduction (inter-type declarations)
  - Interception (join-points)



Aspect-Oriented Semantics Implementation

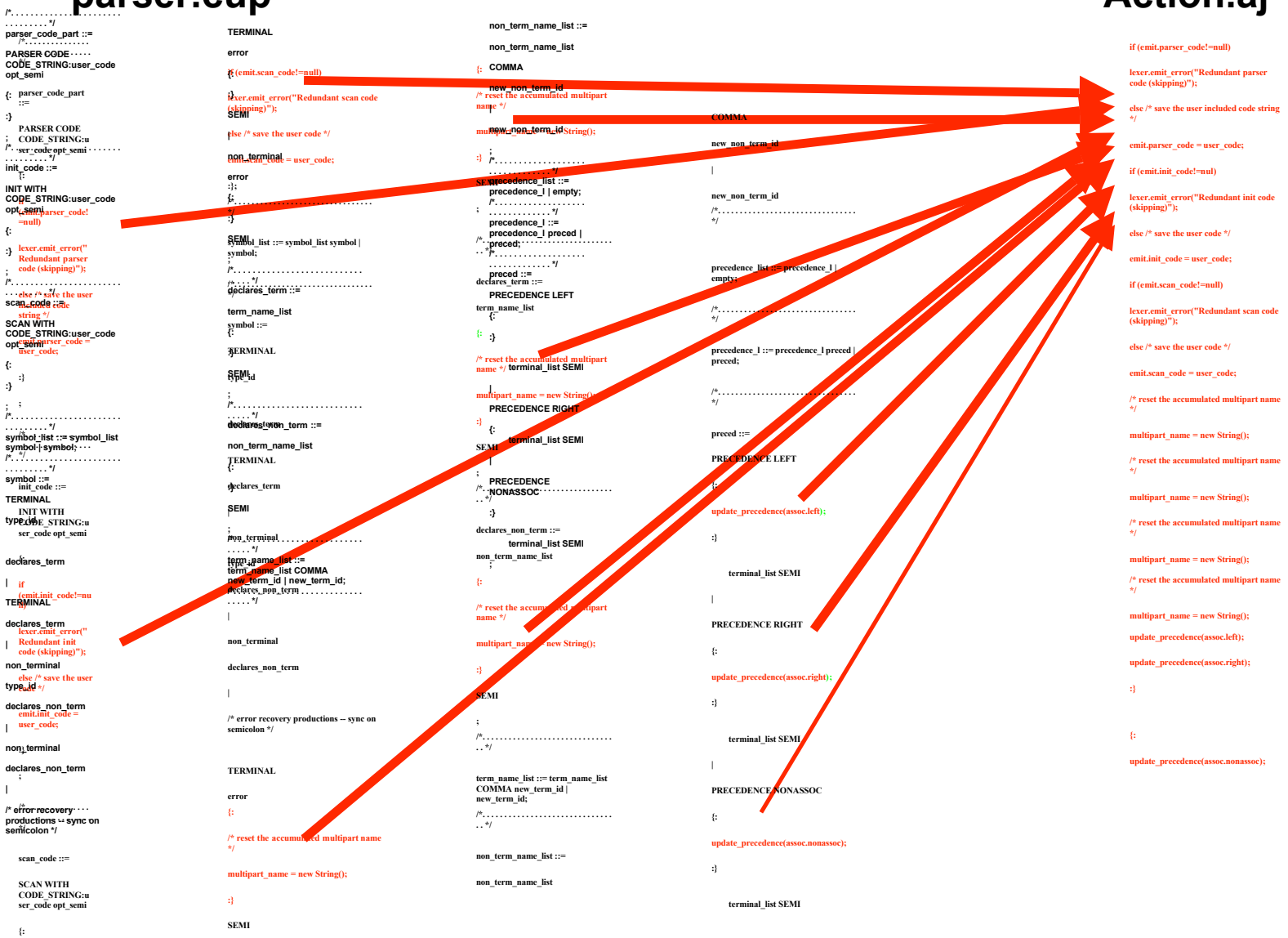
- Each concern is modularized as an aspect
  - An independent semantic pass
  - A group of action codes
- Semantic pass (i.e., a visitor)
  - Implemented as introductions of the AST classes
- Crosscutting actions applied to a group of nodes
  - Weaved into AST classes as interceptions.

Introduction



Interception

parser.cup



Action.aj

```
if (emit.parser_code!=null)

lexer.emit_error("Redundant parser
code (skipping)");

else /* save the user included code string
*/

emit.parser_code = user_code;

if (emit.init_code!=nul)

lexer.emit_error("Redundant init code
(skipping)");

else /* save the user code */

emit.init_code = user_code;

if (emit.scan_code!=null)

lexer.emit_error("Redundant scan code
(skipping)");

else /* save the user code */

emit.scan_code = user_code;

/* reset the accumulated multipart name
*/

multipart_name = new String();

/* reset the accumulated multipart name
*/

multipart_name = new String();

/* reset the accumulated multipart name
*/

multipart_name = new String();

/* reset the accumulated multipart name
*/

multipart_name = new String();

update_precedence(assoc.left);

update_precedence(assoc.right);

:}


{:

update_precedence(assoc.nonassoc);
```

Benefits (I)

- Aspect-orientation can isolate crosscutting semantic behavior in an explicit way.
  - Each semantic aspect can be freely attached to (generated) AST nodes without “polluting” the parser or AST node structure.
  - Different aspects can be selectively plugged in for different purposes at compile time.
  - Since each aspect is separated with other aspects, developers can always come back to the previous phase while developing a later phase.

Benefits (II)

- Inter-type declaration (Introduction)
  - Defined within class scope, direct access to AST node class members (include private members)
  - Preserve the object-oriented inheritance relationship.
- Join-point model (Interception)
  - Provides flexibility to insert semantic behaviors into AST nodes or parser
  - Avoid code duplication
  - Trace facility
- Introduction + Interception
  - Tree traversal
  - Phase combination

Inter-Type Declaration Example

```
class UnparseVisitor extends Visitor{
  protected PrintStream out =
      System.out;
  public Object print(Node node){
    // ...
  }
  // Other utility routines
  // ...
  public Object visit(Node node){
    return print(node);
  }
  public Object visit(
                ASTCompilationUnit node){
    return print(node);
  }
  // same visit methods for another 83
      nodes.
  // ...
}
```

```
aspect Unparse{
  protected static PrintStream out =
    System.out;
  public static void print(Node node){
    // ...
  }
  // other utility routines
  // ...
  public void Node.unparse(){
    Unparse.print(this);
  }
}
```

Join-Point Model Example

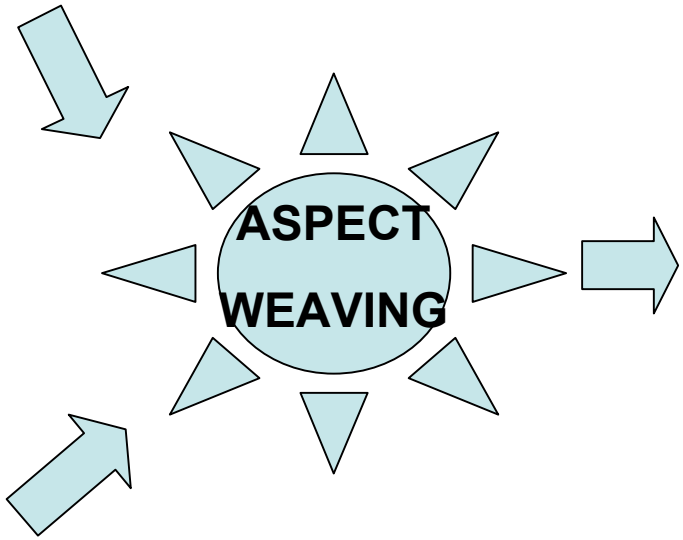
```
pointcut scopeEvaluate(): target(ScopeNode+) && call (* *.evaluate()) ;

before() : scopeEvaluate(){
    symTabs.push(currentSymTab);
    SymbolTable tmp = currentSymTab;
    currentSymTab = new SymbolTable();
    currentSymTab.parentScope = tmp;
}

after() : scopeEvaluate(){
    currentSymTab = (SymbolTable)symTabs.pop();
}
```

Executed each time entering a new scope

Occurred 46 times in a parser!

Executed each time leaving a scope

```
before() : scopeEvaluate(){
  symTabs.push(currentSymTab);
  SymbolTable tmp = currentSymTab;
  currentSymTab = new SymbolTable();
  currentSymTab.parentScope = tmp;
}
after() : scopeEvaluate(){
  currentSymTab = (SymbolTable)symTabs.pop();
}
```




```
…
// node is an instance of ScopeNode
node.evaluate();
…
```

```
…
// node is an instance of ScopeNode
symTabs.push(currentSymTab);
SymbolTable tmp = currentSymTab;
currentSymTab = new SymbolTable();
currentSymTab.parentScope = tmp;

node.evaluate();

currentSymTab =
(SymbolTable)symTabs.pop();
…
```

Summary

- The major difficulty in compiler construction is separation of concerns.
- Traditional object-oriented design and the Visitor pattern cannot address the problem adequately.
- Using aspect-orientation to describe semantics supersedes both approaches without generating side-effects. Various AOP language features fulfill the computational needs of tree traversal.
- The proposed approach improves the overall modularization of the system and provides flexibility for future evolution of the compiler.

Thank you!

http://www.cis.uab.edu/wuxi/

wuxi@cis.uab.edu