CSE 401 – Compilers

MiniJava Parser and AST

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Abstract Syntax Trees

- The parser's output is an abstract syntax tree (AST) representing the grammatical structure of the parsed input
- ASTs represent only semantically meaningful aspects of input program, unlike concrete syntax trees which record the complete textual form of the input
  - There's no need to record keywords or punctuation like (), ;, else
  - The rest of compiler only cares about the abstract structure

MiniJava AST Node Classes

Each node in an AST is an instance of an AST class
- `IfStmt`, `AssignStmt`, `AddExpr`, `VarDecl`, etc.

Each AST class declares its own instance variables holding its AST subtrees
- `IfStmt` has `testExpr`, `thenStmt`, and `elseStmt`
- `AssignStmt` has `lhsVar` and `rhsExpr`
- `AddExpr` has `arg1Expr` and `arg2Expr`
- `VarDecl` has `typeExpr` and `varName`

AST Class Hierarchy

- AST classes are organized into an inheritance hierarchy based on commonalities of meaning and structure
- Each "abstract non-terminal" that has multiple alternative concrete forms will have an abstract class that's the superclass of the various alternative forms
  - `Stmt` is abstract superclass of `IfStmt`, `AssignStmt`, etc.
  - `Expr` is abstract superclass of `AddExpr`, `VarExpr`, etc.
  - `Type` is abstract superclass of `IntType`, `ClassType`, etc.

AST Extensions For Project

- New variable declarations:
  - StaticVarDecl
- New types:
  - DoubleType
  - ArrayType
- New/changed statements:
  - IfStmt can omit else branch
  - ForStmt
  - BreakStmt
  - ArrayAssignStmt
- New expressions:
  - DoubleLiteralExpr
  - OrExpr
  - ArrayLookupExpr
  - ArrayLengthExpr
  - ArrayNewExpr

Automatic Parser Generation in MiniJava

- We use the CUP tool to automatically create a parser from a specification file, Parser/minijava.cup
- The MiniJava Makefile automatically rebuilds the parser whenever its specification file changes
- A CUP file has several sections:
  - introductory declarations included with the generated parser
  - declarations of the terminals and nonterminals with their types
  - The AST node or other value returned when finished parsing that nonterminal or terminal
  - precedence declarations
  - productions + actions

Terminal Declarations

- Terminal declarations we saw before:

```
/* reserved words: */
terminal CLASS, PUBLIC, STATIC,
            EXTENDS;
...
/* tokens with values: */
terminal String IDENTIFIER;
terminal Integer INT_LITERAL;
```


Nonterminal Declarations

- Nonterminals are similar:

```
nonterminal Program Program;
nonterminal MainClassDecl MainClassDecl;
nonterminal List/*<...>*/ ClassDecls;
nonterminal RegularClassDecl ClassDecl;
...
nonterminal List/*<Stmt>*/ Stmts;
nonterminal Stmt Stmt;
nonterminal List/*<Expr>*/ Exprs;
nonterminal List/*<Expr>*/ MoreExprs;
nonterminal Expr Expr;
nonterminal String Identifier;
```


Java Generics and MiniJava

- CUP did not support Java generics when the MiniJava starter code was written, so there are some hacks
- An example: we'd like to write

```
nonterminal List<Expr> Exprs;
```

  but instead the code has

```
nonterminal List/*<Expr>*/ Exprs;
```

- There are other hacks. Deal with them as gracefully as you can
  - Don't make pointless changes to the code – save your energy for more interesting things

Precedence Declarations

- Can specify precedence and associativity of operators
  - equal precedence in a single declaration
  - lowest precedence textually first
  - specify left, right, or nonassoc with each declaration
- Examples:

```
precedence left AND_AND;
precedence nonassoc EQUALS_EQUALS, EXCLAIM_EQUALS;
precedence left LESSTHAN, LESSEQUAL,
               GREATEREQUAL, GREATERTHAN;
precedence left PLUS, MINUS;
precedence left STAR, SLASH;
precedence left EXCLAIM;
precedence left PERIOD;
```


Productions

- All of the form:

```
LHS ::=  RHS1 {: Java code 1 :}
       | RHS2 {: Java code 2 :}
       | ...
       | RHSn {: Java code n :};
```

- Can label symbols in RHS with `:var` suffix to refer to its result value in Java code
  - `varleft` is set to line in input where `var` symbol was

Productions (cont.)

- Example

```
Expr ::= Expr:arg1 PLUS Expr:arg2
   {: RESULT = new AddExpr(arg1, arg2,
                           arg1left);:}
| INT_LITERAL:value{: RESULT = new
  IntLiteralExpr(
      value.intValue(),valueleft);:}
| Expr:rcvr PERIOD Identifier:message
  OPEN_PAREN Exprs:args CLOSE_PAREN
{: RESULT = new MethodCallExpr(
      rcvr,message,args,rcvrleft);:}
| ... ;
```

Error Handling

- How to handle syntax error?
- Option 1: quit compilation
  - \+ easy
  - \- inconvenient for programmer
- Option 2: error recovery
  - \+ try to catch as many errors as possible on one compile
  - \- difficult to avoid streams of spurious errors
- Option 3: error correction
  - \+ fix syntax errors as part of compilation
  - \- hard!!

Panic Mode Error Recovery

- When finding a syntax error, skip tokens until reaching a "landmark"
  - landmarks in MiniJava: ;,), }
    - FOLLOW sets can be a useful source of "landmarks"
  - once a landmark is found, hope to have gotten back on track
- In top-down parser, maintain set of landmark tokens as recursive descent proceeds
  - landmarks selected from terminals later in production
  - as parsing proceeds, set of landmarks will change, depending on the parsing context

Panic Mode Error Recovery

- In bottom-up parser, can add special error nonterminals, followed by landmarks
  - if syntax error, then will skip tokens till seeing landmark, then reduce and continue normally
- E.g.

```
Stmt ::= ... | error ; | { error }
Expr ::= ... | ( error )
```


EBNF Syntax of initial MiniJava

```
Program       ::= MainClassDecl { ClassDecl }
MainClassDecl ::= class ID {
                      public static void main
                      ( String [ ] ID ) { { Stmt } }
ClassDecl     ::= class ID [ extends ID ] {
                      { ClassVarDecl } { MethodDecl } }
ClassVarDecl  ::= Type ID ;
MethodDecl    ::= public Type ID
                      ( [ Formal { , Formal } ] )
                      { { Stmt } return Expr ; }
Formal        ::= Type ID
Type          ::= int |boolean | ID
```


Initial miniJava [continued]

```
Stmt ::= Type ID ;
       | { {Stmt} }
       | if ( Expr ) Stmt else Stmt
       | while ( Expr ) Stmt
       | System.out.println ( Expr ) ;
       | ID = Expr ;
Expr ::= Expr Op Expr
       | ! Expr
       | Expr . ID( [ Expr { , Expr } ] )
       | ID | this
       | Integer | true | false
       | ( Expr )
Op   ::= + | - | * | /
       | < | <= | >= | > | == | != | &&
```