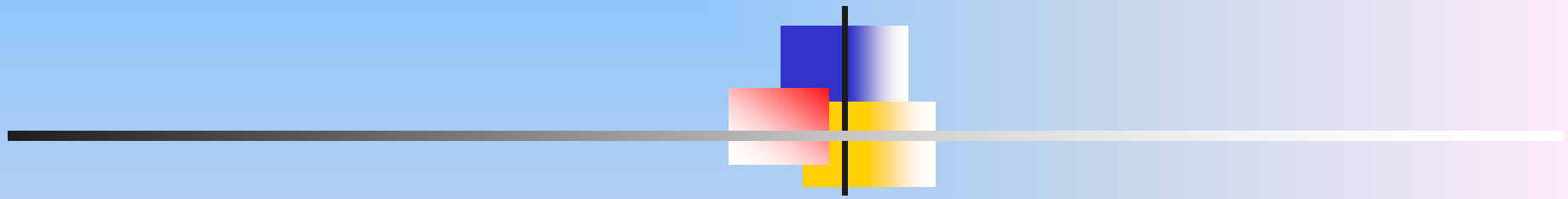
CSE302: Compiler Design



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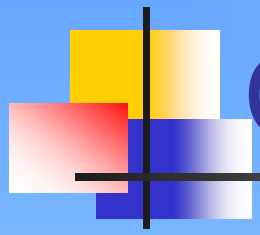
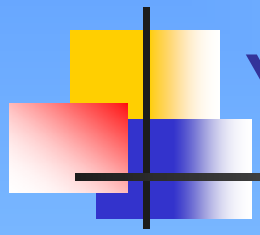


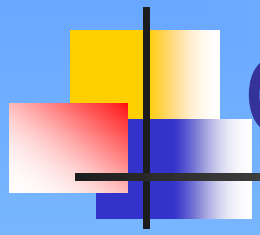
Outline

- Recap
  - Introduction (Section 2.1)
  - Syntax definition (Section 2.2)
  - Syntax directed translation (Section 2.3)
  - Parsing (Section 2.4)
  - A translator for simple expressions (Section 2.5)
  - Lexical analysis (Section 2.6)
- A simple syntax-directed translator (Chapter 2)
  - The rest of Chapter 2
- Summary and homework



You should now be able to ...

- Define language syntax using BNF grammar
- Parse sentences and detect syntax errors
- Use syntax-directed definition to perform language translation
- Understand lexical analysis

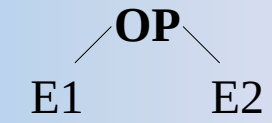


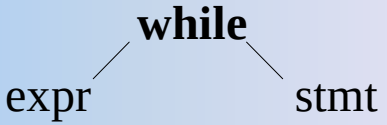
Outline

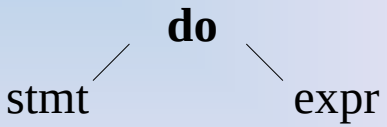
- Recap
- A simple syntax-directed translator (Chapter 2)
  - Intermediate code generation (Section 2.8)
  - Symbol tables (Section 2.7)
- Summary and homework

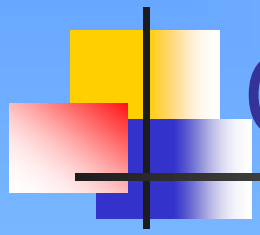
Two Kinds of Intermediate Representation

- Syntax tree representation
  - Expressions
    - E1 **op** E2
  - Statements
    - **while** (expr) stmt
    - **do** stmt **while** expr
  - Use a translation scheme
    - Semantic rules or semantic actions
- Three-address-code representation









A Translation Scheme for Constructing Syntax Tree

- Syntax tree for statements
- Syntax tree for expressions

Generating Syntax Tree: Syntax Tree for Statements

- **In Parser.java**
- Stmt stmts() throws IOException {
  if (look.tag == '}') return **Stmt.Null**;
  else return **new Seq(stmt(), stmts())**;
  }

$$
\begin{array}{lll}
stmts & \rightarrow & stmts_1 \ stmt \quad \{ \ stmts.n = \textbf{new } Seq(stmts_1.n, stmt.n); \ \} \\
 & | & \epsilon \quad \{ \ stmts.n = \textbf{null}; \ \}
\end{array}
$$

$$
\begin{array}{lll}
stmt & \rightarrow & expr \ ; \quad \{ \ stmt.n = \textbf{new } Eval(expr.n); \ \} \\
 & | & \textbf{if} \ (\ expr \ ) \ stmt_1 \\
 & & \quad \{ \ stmt.n = \textbf{new } If(expr.n, stmt_1.n); \ \}
\end{array}
$$

- Stmt stmt() throws IOException {
  Expr x; Stmt s, s1, s2;
  switch(look.tag) {
  case Tag.IF:
  match(Tag.IF); match('('); x = bool(); match(')'); s1 = stmt();
  if(look.tag != Tag.ELSE) return **new If(x, s1)**;
  match(Tag.ELSE); s2 = stmt();
  return **new Else(x, s1, s2)**;
  ...

Generating Syntax Tree: Syntax Tree for Statements, Expressions

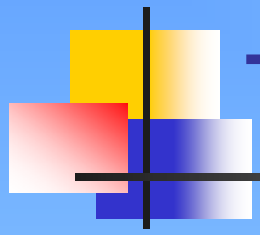
- **In Parser.java**

$$
\begin{array}{lll}
stmt \rightarrow & expr\ ; & \{\ stmt.n = \textbf{new}\ Eval(expr.n);\ \} \\
| & \textbf{if}\ (\ expr\ )\ stmt_1 & \{\ stmt.n = \textbf{new}\ If(expr.n, stmt_1.n);\ \} \\
| & \textbf{while}\ (\ expr\ )\ stmt_1 & \{\ stmt.n = \textbf{new}\ While(expr.n, stmt_1.n);\ \}
\end{array}
$$

```
Stmt stmt() throws IOException{
    Expr x;  Stmt s, s1, s2;
    switch( look.tag ) {
      case Tag.WHILE:
        While whilenode = new While();
        match(Tag.WHILE); match('('); x = bool(); match(')'); s1 = stmt();
        whilenode.init(x, s1); return whilenode;
    ...

Expr expr() throws IOException {
    Expr x = term();
    while( look.tag == '+' || look.tag == '-') {
      Token tok = look;
      move();
      x = new Arith(tok, x, term());
    }
    return x;
}
```

$$
\begin{array}{lll}
add \rightarrow & add_1\ +\ term & \{\ add.n = \textbf{new}\ Op('+', add_1.n, term.n);\ \} \\
| & term & \{\ add.n = term.n;\ \}
\end{array}
$$

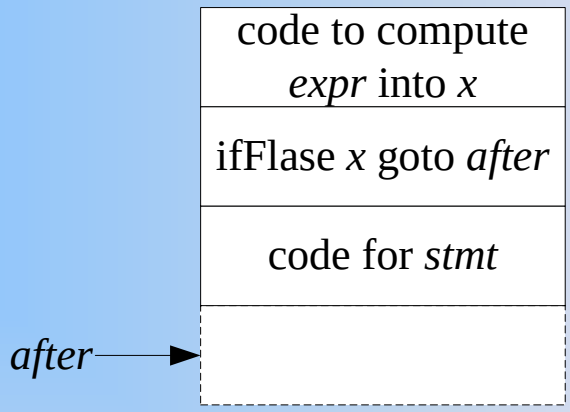


Translation to 3-Address Code

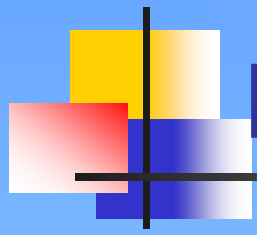
- Each node in the syntax tree may encapsulate various actions
  - Translation actions
  - Type checking actions
- Three-address code
  - x = y **op** z where x, y, and z are names (ids), constants, or compiler-generated temps
    - x = y, x[y] = z, or x = y[z]
  - Sequential execution except conditional or unconditional jumps
    - ifFlase x goto L, ifTure x goto L, or goto L

Translation of Statements

- Code layout for
  - **if** (*expr*) *stmt*

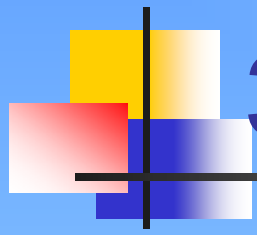



```
class If extends Stmt {
        Expr E; Stmt S;
        public If(Expr x, Stmt y) { E = x; S = y; after = newlabel(); }
        public void gen() {
                Expr n = E.rvalue();
                emit( "ifFalse " + n.toString() + " goto " + after);
                S.gen();
                emit(after + ":");
        }
}
```



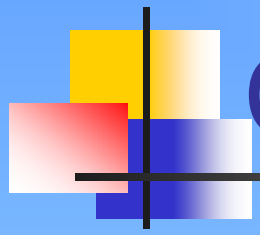
Expression Translation Guidelines

- No code is generated for ids and constants
  - They appear as addresses in instructions
- If a node *x* of class Expr has an operator **op**, e.g. *i*-*j*, then an instruction is emitted
  - The value computed at node *x* is stored at a temp: $t = i - j$
- Array accesses and assignments need to distinguish *l*-values and *r*-values
  - 2*a[i] needs the r-value of a[i]
  - a[i]=2 needs the l-value of a[i]



3-Address Code Generation

- Perform tree traversal to generate three-address code
  - The function *gen* is called at the root of the syntax tree
  - All statement classes contain a function *gen*



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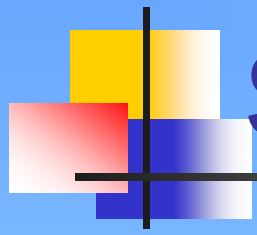
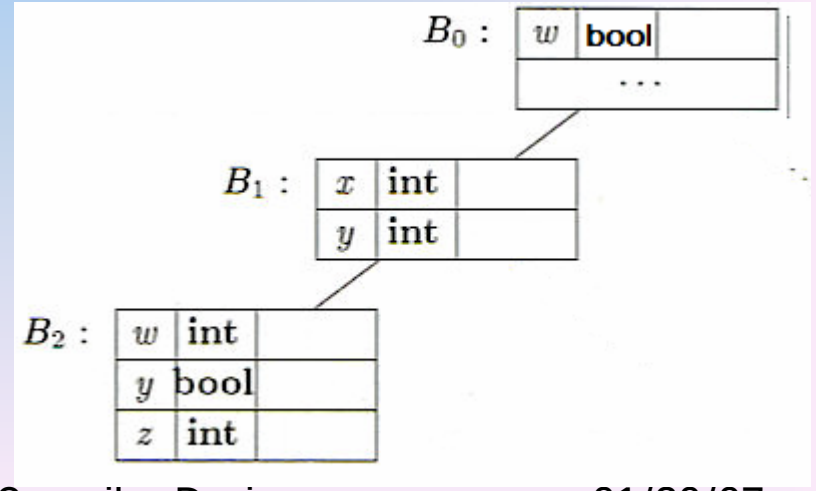


Symbol Tables

- Hold info of source program constructs
  - Collected during analysis
  - Used for synthesis
- Support multiple declarations of the same identifier within a program
  - A separate symbol table for each scope
    - A program block
    - A class

Chained Symbol Tables for Nested Blocks

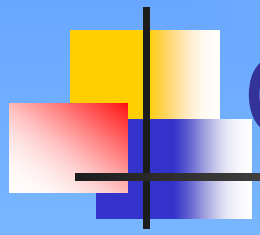
```
{ bool w;
    { int x; int y;
        { int w; bool y; int z;
            ... w ...; ... x ...; ... y ...; ... z ...;
        }
        ... w ...; ... x ...; ... y ...;
    }
    ... w ...
}
```



Data Structure for Chained Symbol Tables

```
public class Env {
    private Hashtable tab;
    protected Env prev;
    public Env(Env p) {table=new Hashtable(); prev=p;}
    public void put(String s, Symbol sm) {tab.put(s,sm);}
    public Symbol get(String s) {
        for (Env e=this; e!=null; e=e.prev) {
            Symbol found=e.table.get(s);
            if(found!=null) return found;
        }
        return null;
    }
}
```

- Syntax-directed translation using this data structure



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