# CSE401 Introduction to Compiler Construction

Larry Snyder
Allen 584

## CSE401: Intro to Compiler Construction

Goals

- Learn principles and practice of language translation
  - Bring together theory and pragmatics of previous classes
  - Understand compile-time vs run-time processing
- Study interactions among
  - Language features
  - Implementation efficiency
  - Compiler complexity
  - Architectural features
- Gain more experience with oo design
- Gain more experience with working in a team
- Gain experience working with SW someone else wrote

## Administrivia

- Prerequisites: 303, 322, 326, 341, 378
- Text: *Engineering a Compiler*, Cooper and Torczon, Morgan-Kaufmann 2004
- Course Web is the place to look for materials
  - Sign up for mailing list
  - Grading:
    - Project 40%
    - Homework 15%
    - MT 15% Final 25%
    - Class Participation 5% … it's a cool topic, lock into it

## Second Day Homework

Turn In (On Paper) A Small Profile of Yourself:

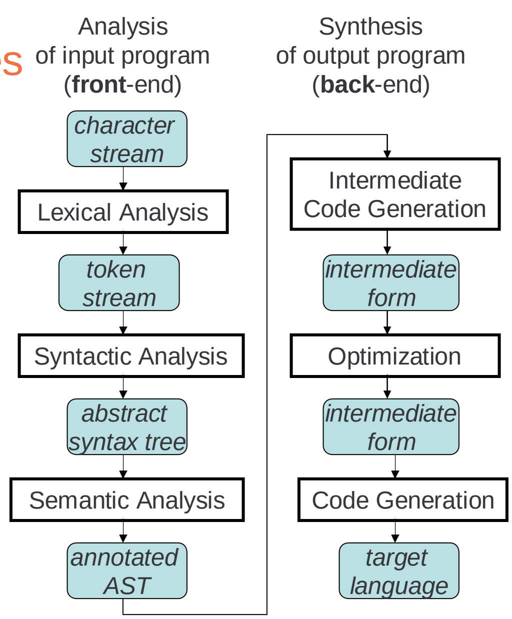
- Photo
- Email/Year/Major
- Free time activities
- An interesting fact about yourself

## Project

- Start with a MiniJava complier in Java … improve it
  - Add:
    - Comments
    - Floating-point values
    - Arrays
    - Static (class) variables
    - For loops
    - Break Statements
    - … And more
  - Completed in stages over the term
  - Strongly encouraged: Work in teams, but only if joint work, not divided work

Grading Basis
- Correctness
- Clarity of design/impl
- Quality of test cases

## Compiler Passes



## Example Compilation

Sample (extended) MiniJava program: `Factorial.java`

```
// Computes 10! and prints it out
class Factorial {
    public static void main(String[] a) {
         System.out.println(
               new Fac().ComputeFac(10));
    }
}
class Fac {
   // the recursive helper function
   public int ComputeFac(int num) {
      int numAux;
      if (num < 1)
         numAux = 1;
      else numAux = num * this.ComputeFac(num-1);
      return numAux;
   }
}
```

## First Step: Lexical Analysis

"Scanning", "tokenizing"

- Read in characters, clump into tokens
  - strip out whitespace & comments in the process

## Specifying tokens: Regular Expressions

Example:

Ident ::= Letter AlphaNum*

Integer ::= Digit+

AlphaNum ::= Letter | Digit

Letter ::= 'a' | ... | 'z' | 'A' | ... | 'Z'

Digit ::= '0' | ... | '9'

## Second Step: Syntactic Analysis

“Parsing” -- Read in tokens, turn into a tree based on syntactic structure

- report any errors in syntax

## Specifying Syntax: Context-free Grammars

EBNF is a popular notation for CFG's

Example:

```
Stmt ::= if (Expr ) Stmt [else Stmt]
    | while (Expr ) Stmt
    | ID = Expr;
    | ...
Expr ::= Expr + Expr | Expr < Expr | ...
    | ! Expr
    | Expr . ID ( [Expr {, Expr}] )
    | ID
    | Integer
    | (Expr)
    | ...
```

EBNF specifies *concrete syntax* of language; parser constructs tree of the *abstract syntax* of the language

## Third Step: Semantic Analysis

"Name resolution and type checking"

- Given AST:
  - figure out what declaration each name refers to
  - perform type checking and other static consistency checks
- Key data structure: symbol table
  - maps names to info about name derived from declaration
  - tree of symbol tables corresponding to nesting of scopes
- Semantic analysis steps:
  1. Process each scope, top down
  2. Process declarations in each scope into symbol table for scope
  3. Process body of each scope in context of symbol table

## Fourth Step: Intermediate Code Gen

- Given annotated AST & symbol tables, translate into lower-level intermediate code
- Intermediate code is a separate language
  - Source-language independent
  - Target-machine independent
- Intermediate code is simple and regular
  - Good representation for doing optimizations

Might be a reasonable target language itself, e.g. Java bytecode

## Example

```
Int Fac.ComputeFac(*? this, int num) {
  int t1, numAux, t8, t3, t7, t2, t6, t0;
  t0 := 1;
  t1 := num < t0;
  ifnonzero t1 goto L0;
  t2 := 1;
  t3 := num - t2;
  t6 := Fac.ComputeFac(this, t3);
  t7 := num * t6;
  numAux := t7;
  goto L2;
label L0;
  t8 := 1;
  numAux := t8
label L2;
  return numAux
}
```

## Fifth Step: Target Machine Code Gen

Translate intermediate code into target code

- Need to do:
  - Instruction selection: choose target instructions for (subsequences) of IR instructions
  - Register allocation: allocate IR code variables to registers, spilling to memory when necessary
  - Compute layout of each procedures stack frames and other runtime data structures
  - Emit target code