Programming Languages and Translators

COMS W4115

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Columbia University

Department of Computer Science

Instructor

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Office Hours: 4–5 PM Monday, Wednesday

Schedule

Mondays and Wednesdays 2:40 to 3:55 PM

Room 207, Mathematics

January 23 to May 6

Midterm 1: March 13

Spring Break: March 18 and 20

Midterm 2: May 1

Objectives

Theory of language design

- Finer points of languages
- Different languages and paradigms

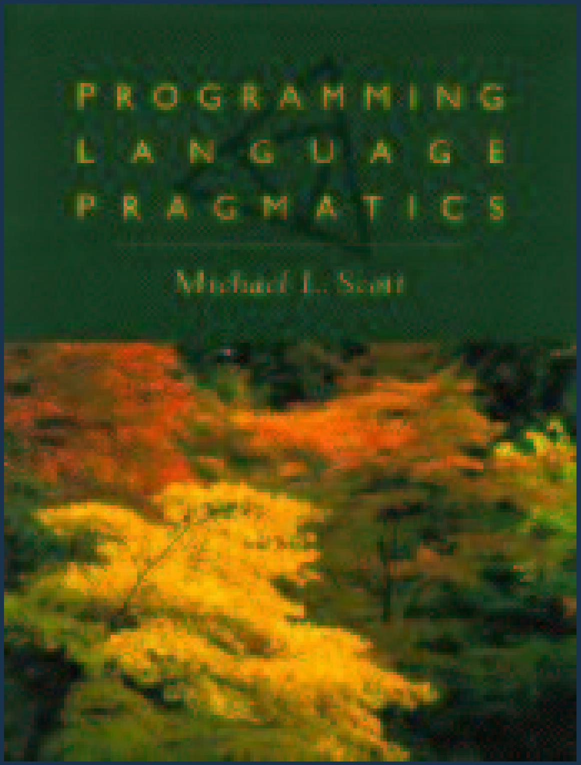
Practice of Compiler Construction

- Overall structure of a compiler
- Automated tools and their use
- Lexical analysis to assembly generation

Required Text

Michael L. Scott.
Programming Language Pragmatics.
Morgan Kaufmann, 2000.

Available from Papyrus, 114th and Broadway.



Other Text

Andrew W. Appel.
Modern Compiler Implementation in Java.
Cambridge University Press, 1998.

Describes the Tiger language, which we are compiling.
Focuses more on compilers, less on languages.

Assignments and Grading

40% Programming Project

25% Midterm 1 (near middle of term)

25% Midterm 2 (at end of term)

10% Individual homework

Prerequisite: COMS W3156 Software Engineering

Teams will build a large software system.

Makefiles and possibly version control

Testing will be as important as development.

Prerequisite:
COMS W3261 Computability

You need to understand grammars.

We will be working with regular and context-free languages.

Prerequisite: COMS W3824 Computer Organization

You need to be able to program in MIPS assembly language.

Your compiler will generate MIPS assembly code.

Class Website

Off my home page,
http://www.cs.columbia.edu/˜sedwards/

Contains syllabus, lecture notes, and assignments.

Schedule will be continually updated during the semester.

Programming Project

Implement a compiler for the Tiger language.

Tiger is described in Appel, but we will deviate from the assignments there.

Compiler implemented in Java.

Some code generated by ANTLR.

Generates MIPS assembly code.

Programming assignments

1. Lexer, parser, and AST generator
2. Perform type checking (semantic analysis)
3. Translate into three-address code
4. Generate MIPS assembly

Two weeks each.

Teams

Immediately, start thinking about forming 4- or 5-person teams to do the programming project.

Each team will build its own compiler.

Think carefully about how you will divide the work.

Testing is as important as coding.

Late Policy

Very simple:

If you turn anything in late without the instructor’s permission, you get no credit.

Collaboration

Collaborate with your team on the programming assignment.

Teams may share ideas, but not code. If I find two teams submitting similar files, both teams will receive zero credit, may flunk the class, and I may involve the dean.

Homework is to be done by yourself.

Tests: Will be closed book.

Topics

Syntax, Parsing, and ASTs

Names, Types, and Scopes

Control-flow and subroutines

Code generation

Functional and logic programming

Concurrency

Scripting languages

Types of Programming Langauges

The world does not revolve around Java.

Imperative langauges

Object-oriented languages

Functional languages

Logic languages

Dataflow langauges

Imperative (von Neumann) Languages

What you are familiar with. e.g., C

```
int gcd(int a, int b)
{
  while (a != b) {
    if (a > b) a -= b;
    else b -= a;
  }
  return a;
}
```

Imperative (von Neumann) Languages

Computation is the sequential modification of variables.

Programs are sequences of steps that evolve state.

Everything interesting has a side effect.

```
Again: if (a == b) goto Done
       if (a < b) goto ALess
       a = a - b;
       goto Again
ALess: b = b - a;
       goto Again
Done:
```

Imperative (von Neumann) Languages

Virtually every assembly language

FORTRAN

C

Pascal

Modula-2

Algol

BASIC

Object-Oriented Langauges

Refinement of the imperative approach.

Memory partitioned into objects (small regions).

Objects have methods: imperative procedures to query or modify object state.

More disciplined than simple imperative languages.

Naturally enforce information hiding.

Currently taking over the world.

Object-Oriented Language: Smalltalk

```
class name Polygon
superclass Object
instance variable names OurPen
                        numSides
new     "Create an instance"
  ˆ super new getPen

getPen  "Get a pen for drawing polygons"
  OurPen <- Pen new defaultNib: 2

draw    "Draw a polygon"
  numSides timesRepeat: [OurPen go: sideLength;
                         turn: 360 // numSides]
```

Object-Oriented Languages

Simula 67

C++

Java

Modula-3

Functional Languages

Computation based on recursive definition of *functions*.

Function: produce a consistent result based exclusively on their arguments.

No side-effects. Mathematically very clean.

Declarative: program defines what the function *is*, not how to evaluate it.

Allows certain optimizations (e.g., laziness).

Do people think this way?

Functional Language: ML

A list of the form $(m, m+1, \ldots, n)$:

```
fun op through (m,n) =
  if m > n
  then nil
  else m :: (m+1 through n)
```

Calculating area:

```
let
  pi = 3.14159;
in
  pi * radius * radius
end;
```

Functional Languages

LISP

ML

Haskell

Erlang

Logic Languages

Computation based on propositional logic.

You declare things; program execution is an attempt to satisfy what you declare.

Goal-directed search.

Interesting for AI-type applications.

Logic Languages: Prolog

```
rainy(seattle).                 % clause
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X) , cold(X). % implication

?- snowy(C).                    % query
C = rochester                   % response
```

Dataflow Languages

Computation based on exchange of data tokens among concurrently-running processes.

Nice match for engineering diagrams.

Fundamentally concurrent.

Awkward for decisions, modes, etc.

Dataflow Language: Lustre

Module counts edges: 0 → 1 transitions on the c input.

System is a collection of expressions evaluated in lockstep. Order from data dependencies.

```
node EDGECOUNT(c : bool)
returns (count : int)
let
  edge = false -> (c and not pre(c));
  edgecount = 0 ->
     if edge then pre(edgecount) + 1
             else pre(edgecount);
tel
```

Next Time

Structure of a Compiler

Lexical Analysis

Parsing

Syntax