CS321 Languages and Compiler Design I

Winter 2012

Lecture 1

COURSE GOALS

- Improve understanding of **languages** and **machines**.
- Learn practicalities of **translation**.
- Learn **“anatomy”** of programming languages.
- Apply computer science **theory** to practical problems (using **tools**).
- Do large programming **project**.

COMPILERS

A **compiler** is a **translator** from “high-level” language to assembly code/object language.

Language L $\longrightarrow$ $\boxed{\textbf{TRANSLATOR}}$ $\longrightarrow$ Language L’

Examples of translators:

Pascal,C, etc.	$\longrightarrow$	**Compiler**	$\longrightarrow$	Machine Code
Java	$\longrightarrow$	**Compiler**	$\longrightarrow$	Byte Code
Ratfor	$\longrightarrow$	**Preprocessor**	$\longrightarrow$	Fortran
Tex	$\longrightarrow$	**Text Formatter**	$\longrightarrow$	Postscript
SQL	$\longrightarrow$	**DB Optimizer**	$\longrightarrow$	Query plan

We study common features of translators, by building one.

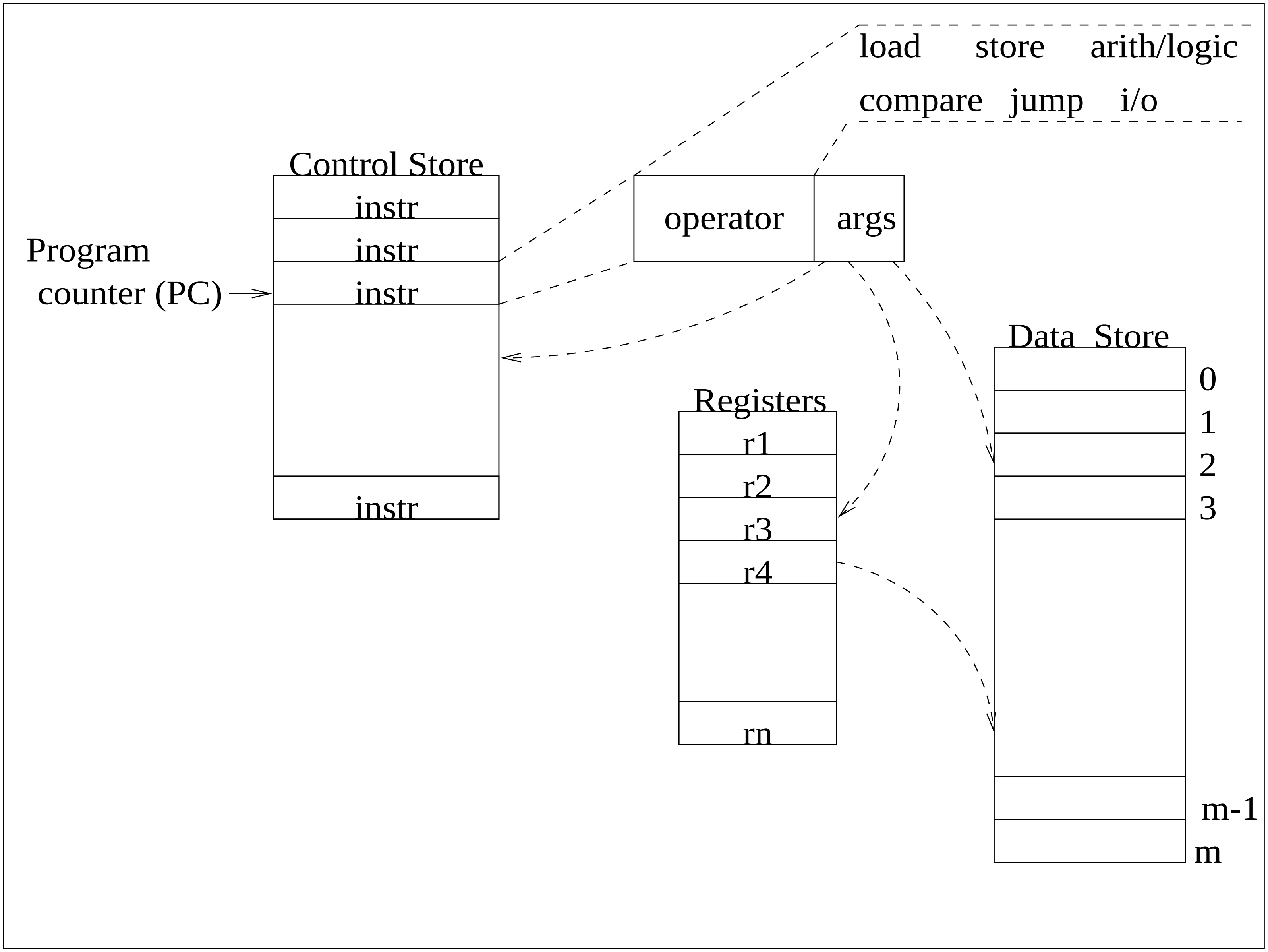
Language Design

We study languages mainly from an **implementor's** viewpoint.

- How do **compilation feasibility** and **runtime efficiency** affect language design?

(There are more "theoretical" approaches to studying programming languages, and there are interesting and useful languages that don't compile easily...)

"Von Neumann" Machine



FEATURES OF LOW-LEVEL CODE

- Sequential control flow + labels + jumps
- Small set of built-in data types and operators (e.g., byte, integer, floating point)
- Flat linear address space.
- Memory hierarchy (registers faster than memory faster than disk).

"High-Level" Languages

E.g., Fortran, Pascal, C, Cobol, Java, JavaScript, Python...

Example

```
func rev (a: @real, n:int) {
  var i := 0;
  var j := n - 1;
  while i < j do {
     var x := a[i];
     a[i] := a[j];
     a[j] := x;
     i := i + 1;
     j := j - 1
  }
}
```

FEATURES OF HIGH-LEVEL CODE

- Expressions (arithmetic, logical)
- Control structures (loops, conditionals, etc.)
- Type declarations and type checking
- Composite types (arrays, records, etc.)
- Procedures/Functions, with private scope
- **Abstraction** facilities!

MEETING IN THE MIDDLE

How can we make high-level language run on a Von Neumann machine?

Answer:

- Translate HLL into lower-level code

(in traditional compiler, to machine code.)

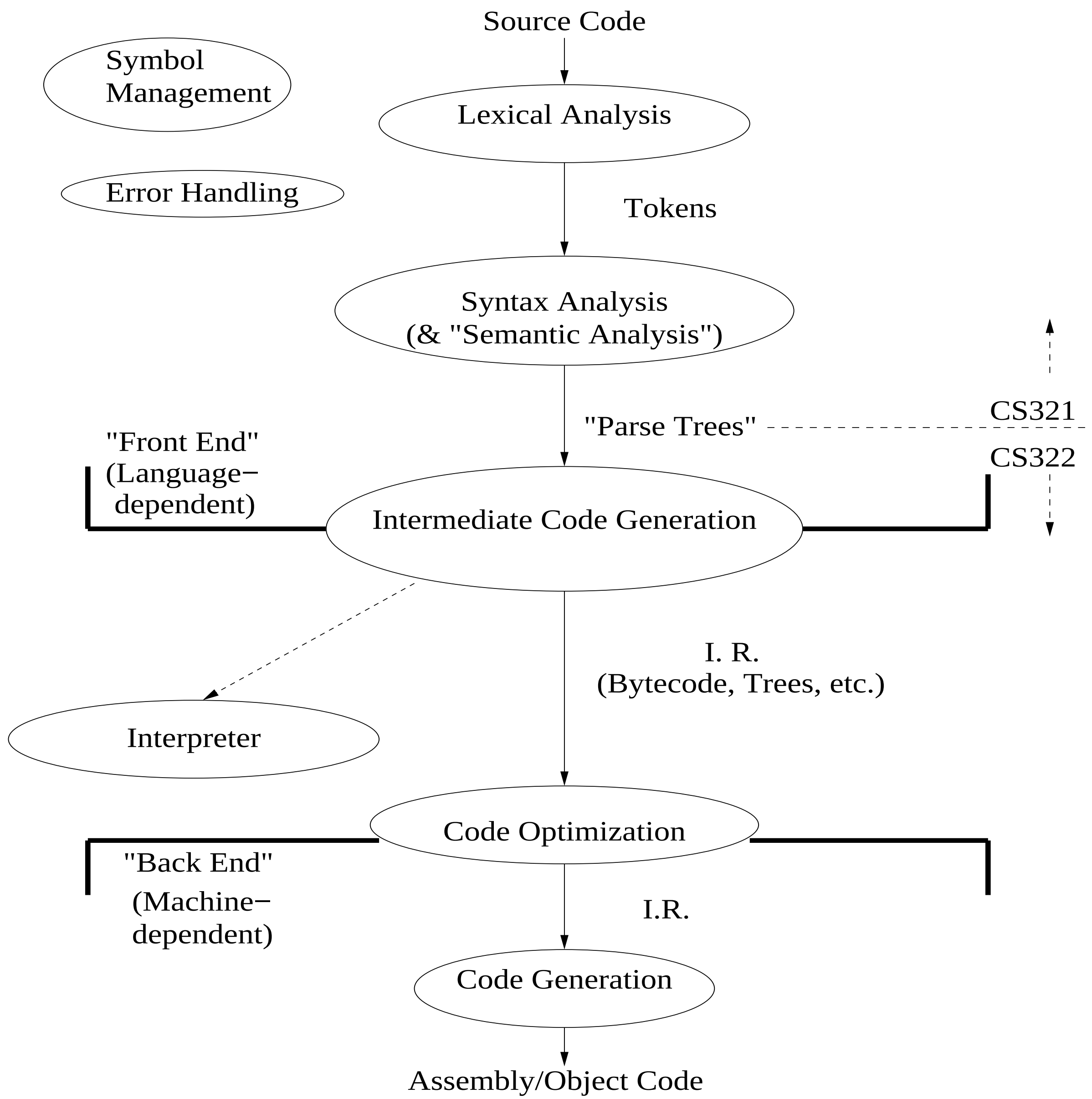
and/or

- Build a “higher level” virtual machine

(in traditional interpreter, perhaps a stack machine.)

In practice, we do some of both, even in a compiler, since generated machine code makes use of a runtime library and operating system.

COMPILER STRUCTURE: WANT SIMPLICITY AND FLEXIBILITY



FRONT-END EXAMPLE

Source characters: `if (a <= b[i]) a := 4.5 ;`

Lexical Analysis — Theory: regular languages, FAs

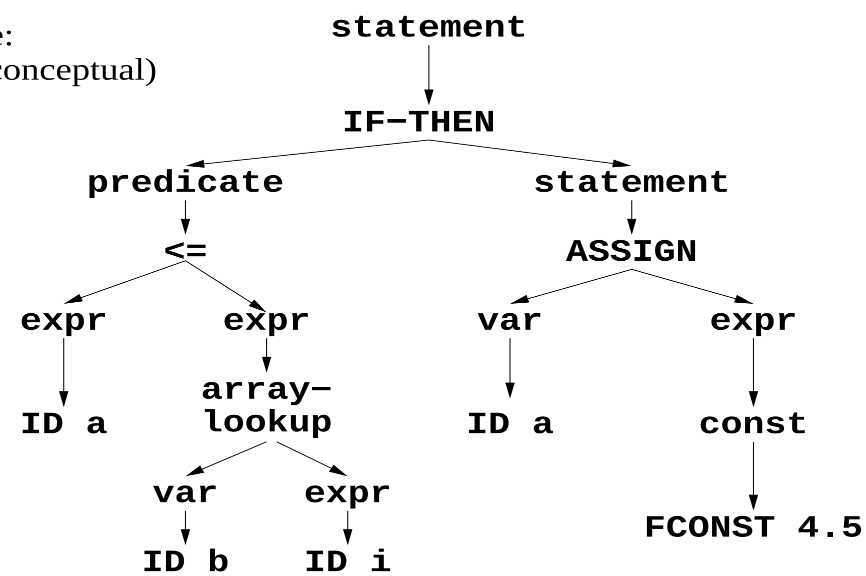
"linear" — Tools: lex,Jflex, etc.

Token stream: `IF '(' (ID a) LE (ID b) '[' (ID i) ']' ')' (ID a) ASSGN (FCONST 4.5) ';'`

Syntax Analysis — Theory: context−free languages, PDA's

"hierarchical" — Tools: yacc, javaCup, jacc, etc.

Parse tree:
(real or conceptual)



LANGUAGE DEFINITION

Syntax is easy.

- Well-understood.
- Good theory: regular and context-free languages and automata.
- Good tools, even for complex cases.

Semantics are hard.

- Inherently complex.
- Variety of choices:

Informal	—	Reference Manual
Operational	—	Definitional interpreter
		(↑ we will focus here)
Axiomatic	—	Logic
Denotational	—	Mathematical functions
		etc.

- Few tools.