CMSC330

Summer 2009
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Introduction

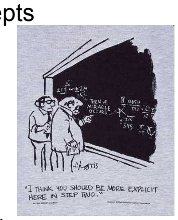
Course Goal

Learn how programming languages "work"

- Broaden your language horizons
  - Different programming languages
  - Different language features and tradeoffs
- Study how languages are implemented
  - What really happens when I write `x.foo(…)`?
- Study how languages are described / specified
  - Mathematical formalisms

Course subgoals

- Learn some fundamental CS concepts
  - Regular expressions
  - Context free grammars
  - Automata theory
  - Compilers & parsing
  - Parallelism & synchronization
- Improve programming skills
  - Learn how to learn new programming languages
  - Learn how to program in a new programming style



Course Overview

- Tests
  - Quizzes, 2 midterms, final exam
- Projects
  - Project 1 – Text processing in Ruby
  - Project 2 – Implement finite automata in Ruby
  - Project 3 – Problem solving in OCaml
  - Project 4 – Implement regular expressions in OCaml
  - Project 5 – Multithreading
- Programming languages
  - Ruby
  - OCaml
  - Java

Rules and Reminders

- Use lecture notes as your text
  - To be supplemented by readings, internet
- Keep ahead of your work
  - Get help as soon as you need it
    - Office hours, CS forum, email
- Start projects early
  - Condensed summer schedule
  - Look at schedule online

Academic Integrity

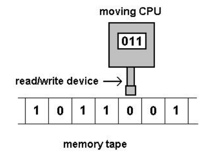
- All written work (including projects) must be done on your own
  - Do not copy code from other students
  - Do not copy code from the web
- Work together on high-level project questions
  - Do not look at/describe another student's code
  - If unsure, ask instructor!
- Can work together on practice questions for the exams

Syllabus

- Scripting languages (Ruby)
- Regular expressions and finite automata
- Context-free grammars
- Functional programming (OCaml)
- Concurrency
- Object-oriented programming (Java)
- Environments, scoping, and binding
- Advanced topics

All languages are equivalent

- A language is Turing complete if it can compute any function computable by a Turing Machine



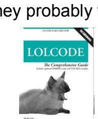
- Essentially all general-purpose programming languages are Turing complete
  - I.e., any program can be written in any programming language
- Therefore this course is useless?!

Why Study Programming Languages?

- To allow you to choose between languages
  - Using the right programming language for a problem may make programming
    - Easier, faster, less error-prone
  - Programming is a human activity
    - Features of a language make it easier or harder to program for a specific application

Why Study Programming Languages?

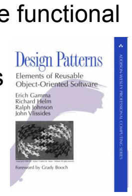
- To make you better at learning new languages
  - You may need to add code to a legacy system
    - E.g., FORTRAN (1954), COBOL (1959), …
  - You may need to write code in a new language
    - Your boss says, "From now on, all software will be written in {C++/Java/C#/Python…}"
  - You may think Java is the ultimate language
    - But if you are still programming or managing programmers in 20 years, they probably won't be programming in Java!




```
HAI
CAN HAS STDIO?
I HAS A VAR
IM IN YR LOOP
      UP VAR!!1
      VISIBLE VAR
      IZ VAR BIGGER THAN 10? KTHXBYE
IM OUTTA YR LOOP
KTHXBYE
```

Why Study Programming Languages?

- To make you better at using languages you think you already know
  - Many "design patterns" in Java are functional programming techniques
  - Understanding what a language is good for will help you know when it is appropriate to use



Changing Language Goals

- 1950s-60s – Compile programs to execute efficiently
  - Language features based on hardware concepts
    - Integers, reals, goto statements
  - Programmers cheap; machines expensive
    - Keep the machine busy

Changing Language Goals

- Today
  - Language features based on design concepts
    - Encapsulation, records, inheritance, functionality, assertions
  - Processing power and memory very cheap; programmers expensive
    - Ease the programming process

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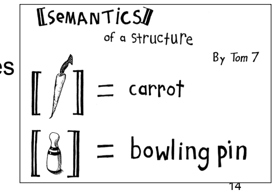
Language Attributes to Consider

- Syntax
  - What a program looks like
- Semantics
  - What a program means
- Implementation
  - How a program executes



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Types of Languages

- Imperative
- Functional
- Logical
- OO
- Scripting

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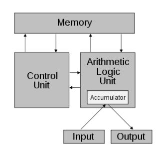
Imperative Languages

- Also called procedural or von Neumann
- Building blocks are functions and statements
  - Programs that write to memory are the norm
    - `int x = 0;`
    - `while (x < y) x := x + 1;`
  - FORTRAN (1954)
  - Pascal (1970)
  - C (1971)



Functional Languages

- Also called applicative languages
- No or few writes to memory
  - Functions are higher-order

```
let rec map f = function [] -> []
    | x::l -> (f x)::(map f l)
```

  - LISP (1958)
  - ML (1973)
  - Scheme (1975)
  - Haskell (1987)
  - OCaml (1987)

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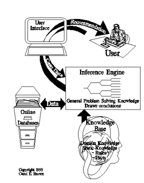
Logical Languages

- Also called rule-based or constraint-based
- Program consists of a set of rules
  - "`A :- B`" – If `B` holds, then `A` holds



  - PROLOG (1970)
  - Various expert systems

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Object Oriented Languages

- Programs are built from objects
  – Objects combine functions and data
  – Often have classes and inheritance
  – "Base" may be either imperative or functional
    - `class C { int x; int getX() {return x;} … }`
    - `class D extends C { … }`
  – Smalltalk (1969)
  – C++ (1986)
  – OCaml (1987)
  – Java (1995)

Scripting Languages

- Rapid prototyping languages for "little" tasks
  – Typically with rich text processing abilities
  – Generally very easy to use

```
#!/usr/bin/perl
for ($j = 0; $j < 2*$lc; $j++) {
$a = int(rand($lc));
…
```

  – sh (1971)
  – perl (1987)
  – Python (1991)
  – Ruby (1993)

Other languages

- There are lots of other languages w/ various features
  – COBOL (1959) – Business applications
    - Imperative, rich file structure
  – BASIC (1964) – MS Visual Basic widely used
    - Originally an extremely simple language
    - Now a single word oxymoron
  – Logo (1968) – Introduction to programming
  – Forth (1969) – Mac Open Firmware
    - Extremely simple stack-based language for PDP-8
  – Ada (1979) – The DoD language
    - Real-time
  – Postscript (1982) – Printers- Based on Forth

Ruby

- An imperative, object-oriented scripting language
  – Created in 1993 by Yukihiro Matsumoto
  – Similar in flavor to many other scripting languages
    - (e.g., perl, python)
  – Much cleaner than perl
  – Full object-orientation (even primitives are objects!)

Small Ruby Example

- Let's start with a simple Ruby program

`intro.rb:`

```
def greet(s)
  print("Hello, ")
  print(s)
  print("!\n")
end
```

```
% irb # you'll usually use "ruby" instead
irb(main):001:0> require "intro.rb"
=> true
irb(main):002:0> greet("world")
Hello, world!
=> nil
```


Ocaml

- A mostly-functional language
  – Has objects, but won't discuss (much)
  – Developed in 1987 at INRIA in France
  – Dialect of ML (1973)
    - Natural support for pattern matching
  – Makes writing certain programs very elegant
    - Has a really nice module system
  – Much richer than interfaces in Java or headers in C
    - Includes type inference
  – Types checked at compile time, but no annotations

Small Ocaml Example

- Let's start with a simple Ruby program
  `intro.ml:`

```
let greet s =
begin
  print_string "Hello, ";
  print_string s;
  print_string "!\n"
end
```

```
$ ocaml
Objective Caml version 3.08.3
# #use "intro.ml";;
val greet : string -> unit = <fun>
# greet "world";;
Hello, world!
- : unit = ()
```


Attributes of a good language

- 1.Clarity, simplicity, and unity
  - Provides both a framework for thinking about algorithms and a means of expressing those algorithms
- 2. Orthogonality
  - Every combination of features is meaningful
  - Features work independently
    - What if, instead of working independently, adjusting the volume on your radio also changed the station?
    - You would have to carefully change both simultaneously and it would become difficult to find the right station and keep it at the right volume.

Attributes of a good language

- 3. Naturalness for the application
  - Program structure reflects the logical structure of algorithm

- 4. Support for abstraction
  - Program data reflects problem being solved
- 5. Ease of program verification
  - Verifying that program correctly performs its required function

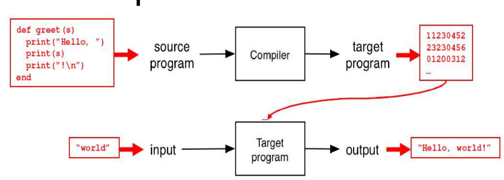
Attributes of a good language

- 6. Programming environment
  - External support for the language
- 7. Portability of programs
  - Can develop programs on one computer system and run it on a different computer system
- 8. Cost of use
  - Program execution (run time), program translation, program creation, and program maintenance
- 9. Security & safety
  - Should be very hard to write unsafe program

Executing Languages

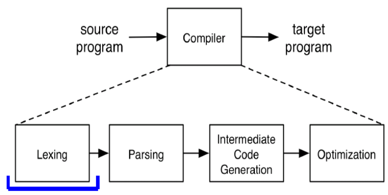
- Suppose we have a program P written in a high-level language (i.e., not machine code)
- There are two main ways to run P
  - 1. Compilation
  - 2. Interpretation

Compilation or Translation



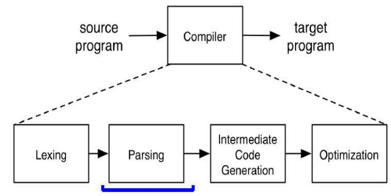
- Source program translated to another language
  - Often machine code, which can be directly executed

Steps of Compilation



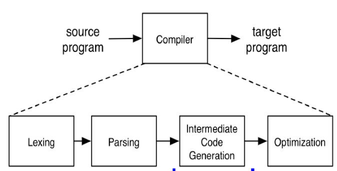
- 1. Lexical Analysis (Scanning) – Break up source code into *tokens* such as numbers, identifiers, keywords, and operators

Steps of Compilation



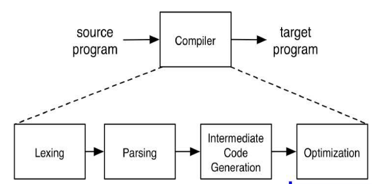
- 2. Parsing (Syntax Analysis) – Group tokens together into higher-level language constructs (conditionals, assignment statements, functions, …)

Steps of Compilation



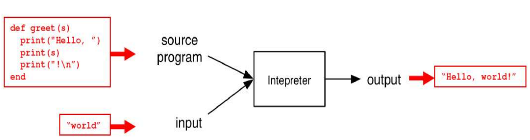
- 3. Intermediate Code Generation – Verify that the source program is valid and translate it into an internal representation
  - May have more than one intermediate rep

Steps of Compilation



- 4. Optimization (optional) – Improve the efficiency of the generated code
  - Eliminate dead code, redundant code, etc.
  - Change algorithm without changing functionality
    - (e.g., X=Y+Y+Y+Y X=4*Y X = Y shift left 2)
  - [If interested in compilation, take CMSC 430]

Interpretation



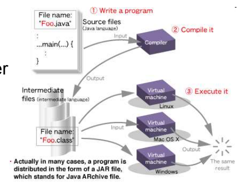
- Interpreter executes each instruction in source program one step at a time
  - No separate executable

Complied or interpreted?

- gcc
  - Compiler – C code translated to object code, executed directly on hardware
- javac
  - Compiler – Java source code translated to Java byte code
- bash
  - Interpreter – commands executed by shell program
- java
  - Interpreter – Java byte code executed by virtual machine

Decision less simple today

- Previously
  - Build program to use hardware efficiently
  - Often use of machine language for efficiency
- Today
  - No longer write directly in machine language
  - Use of layers of software
  - Concept of virtual machines
    - Each layer is a machine that provides functions for the next layer (e.g., javac/java distinction)
    - This is an example of abstraction, a basic building block in computer science



Summary

- Many types of programming languages
  - Imperative, functional, logical, OO, scripting
- Many programming language attributes
  - Clear, orthogonal, natural…
- Programming language implementation
  - Compiled, interpreted

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Reminders

- Project 1 due next Wednesday
  - Posted on website, below schedule
  - Read project description
  - Uses Ruby and Ruby regular expressions (Tuesday and Thursday lectures)

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