Design & Implementation Overview

COS 301

Fall 2017

Outline

Influences on language design

Ontological commitments

Imperative languages

- Architecture:
    - Memory cells ⇝ variables
    - Data movement (memory→memory, CPU→memory) ⇝ assignment
    - Sequential machine instruction execution ⇝ sequential statements
    - Conditional execution ⇝ `if-then-else` constructs, `goto`
    - Iteration via conditionals + jump ⇝ loops

Ontological commitments

Functional languages

- Variables “standing for” value ⇝ binding, not pointers/addresses
- Function application → produce new values ⇝
  - No notion of “executing” sequential statements
  - No statements, only functions (with values)
  - Function composition as major characteristic
  - Recursion as primary way of repeating function application

Ontological commitments

Object-oriented languages

- World consists of objects $\leadsto$ classes, instances, inheritance, instantiation
- No notion of address: variables hold value or references
- $\exists$ classes of objects $\leadsto$ inheritance, instantiation
- Instance variables as properties or relations to other objects
- Objects affordances (things they can do) $\leadsto$ methods

Factors affecting design: early (< mid-1960s)

- Computer time extremely valuable
  - $\gg$ programmers' time
  - $\rightsquigarrow$ languages tailored toward machine, not humans
- Computers relatively slow
  - Thousands–millions of instructions/s (kIPS – MIPS)
  - E.g.: IBM 360 mainframe, mid-60s, ~ 34 kIPS – ~ 17 MIPS
  - $\rightsquigarrow$ extreme concern for efficiency
    - $\rightsquigarrow$ compilation rather than interpretation
    - $\rightsquigarrow$ simple languages
- Relatively simple applications $\rightsquigarrow$ small programs

Factors affecting design: late 60s–mid-70s

- Cheaper processors $\rightsquigarrow$ cost of programmer time $\gg$ computer time
- Demand for capable/sophisticated software applications $\rightsquigarrow$
  - More programming time
  - Larger programs $\rightsquigarrow$ harder to design, debug, maintain
- Result:
  - Focus on
    - Human-friendly languages
    - Languages supporting design, debugging, maintenance
  - Structured programming:
    - Top-down design
    - Stepwise refinement
    - More sophisticated control structures
  - Prominence of ALGOL-like languages (PL/I, C, Pascal, etc.)

Factors affecting design: more recently

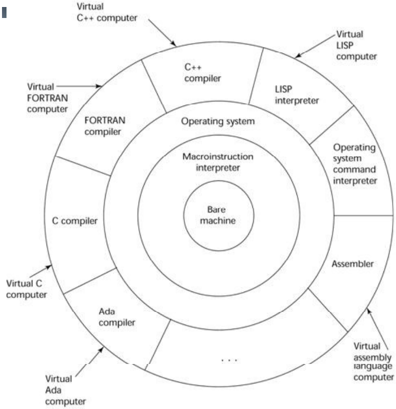
- Data abstraction (Modula-2, Ada, etc.)
- Object-orientation
  - Revived early work on CLU, Smalltalk, etc.
  - C++, Objective-C, Java. . .
- More powerful computers $\rightsquigarrow$
  - More sophisticated compilers possible $\rightsquigarrow$ more sophisticated/complex languages
  - Practical interpreters $\rightsquigarrow$ rapid prototyping/incremental (iterative) development
- Widespread availability of multi-core systems, clusters $\rightsquigarrow$ new languages (C*, StarLisp, Parallel Euclid,. . .)

Language as VM

Virtual machine

- Programming language ⇒ virtual machine
- VM can be implemented as a compiler, interpreter or a hybrid

Virtual machine: layers



Compilation

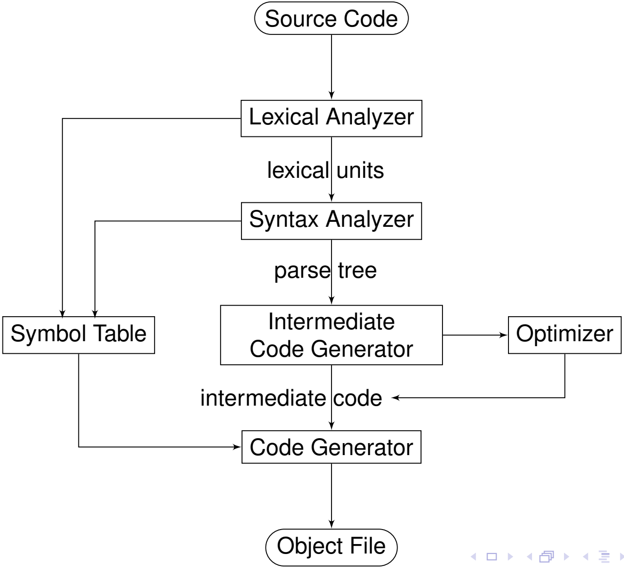
Compilation

- Compiler: program that translates HLL ⇒ object code
- Link editor:
  - Gathers multiple object modules (e.g., subprograms, libraries)
  - Patches (links) unresolved references in object modules
  - ⇒ executable
- Loader:
  - Part of OS
  - Allocates (virtual) memory
  - Loads (copies) executable file into (virtual) memory
  - May treat parts of executable differently
  - May create memory not present in executable (heap, uninitialized data)

Overview

- Source (HLL) program → lexical analyzer
  - ⇒ lexical units
  - Updates symbol table
- Lexical units → syntax analyzer
  - Checks syntax for errors
  - Updates symbol table
  - ⇒ parse tree
- Parse tree → intermediate code generator
  - Semantic analyzer
  - ⇒ intermediate code
  - Interacts with optimizer
- Intermediate code → code generator
  - ⇒ object code file
  - Machine language program
  - May have unresolved references

Process


Source Code
Lexical Analyzer
lexical units
Syntax Analyzer
parse tree
Symbol Table
Intermediate Code Generator
Optimizer
intermediate code
Code Generator
Object File

Properties

- Fast execution
    - Running at native machine speed
    - Optimizer ⇒ often faster than hand-coded assembly
- Compiler has access to entire program at once
    - Can do global optimizations
    - Can have complex languages, easy forward references, etc.
- Possibly lengthy compilation time
    - Amortized over execution times, ameliorated by faster machines
    - But during debugging/rapid prototyping
        - compile–test cycle cumbersome
        - source level debugging somewhat difficult
        - hard to change part without recompiling whole

Interpretation

Interpretation

- Interpreter: Program that reads source code and carries out actions
- One of the very first: Lisp
- No translation of HLL to machine code
- Supports rapid prototyping
- Need significant runtime environment (i.e., the interpreter)
- Slower execution (10–100 times as slow as executable)
- Historically rare for traditional HLLs (though Lisp, Scheme)
- Now: Python, JavaScipt, PHP,. . .

Hybrid implementation

Hybrid implementations

- Compromise between compilation and interpretation
- One way: HLL translated to intermediate language that is easy to interpret
  - Faster than pure interpretation
  - E.g., Perl, Java, Smalltalk, Microsoft Common Language Runtime
- Another way:
  - Allow both compiled and interpreted code
  - E.g., most Common Lisp systems, some of Perl

Just-in-Time (JIT) compilers

- Compile to byte code first (e.g., Java byte code)
- When subprograms called, byte code compiled to machine code
- Machine code kept for subsequent calls
- JIT used for Java, .NET languages
- Makes Java competitive with fully-compiled languages

Preprocessors

Preprocessors

- Preprocessor instructions:
    - handled immediately prior to compilation…
    - …or prior to loading code in interpreter
- Types:
    - include other code (e.g., C’s `#include`)
    - macro commands (e.g., C’s `#define`)
    - templates (e.g., C++, for generic classes)
    - more complex macros: e.g., Lisp’s `defmacro`

Programming environments

Programming environments

- Collection of tools used for software development
- Compilers, editors, debuggers, profilers, linkers, etc.
- E.g., Unix
    - Command line tools (e.g., make, grep, awk, sed, gcc)
    - Editors (e.g., Emacs, vi) and IDEs

IDEs

- Integrated development environemnts (IDEs)
- Includes a compiler, linker, debugger, editor, and build automator
- May also include source control system, class browser, object inspector, profiler, etc.
- Some support multiple languages, others single language
- Examples:
    - PyCharm
    - Eclipse, Emacs
    - Netbeans
    - Xcode
    - MonoDevelop
    - Lisp machine, modern Lisp and Scheme IDEs (e.g., Allegro, PLT Scheme/Racket)

Microsoft .NET

- Collection of languages, technologies, development environment
- Most common: C++, C#, VB... – dozens available
- Large, complex visual environment (though command line available)
- .NET SDK available as free download
- Output language: machine-independent byte code for the Common Language Runtime

NetBeans

- Java answer to .NET
- Used for Java, but also supports C, PHP, Ruby, C++, others
- Written in Java
- Extensible via modules