CSE 5343: Introduction

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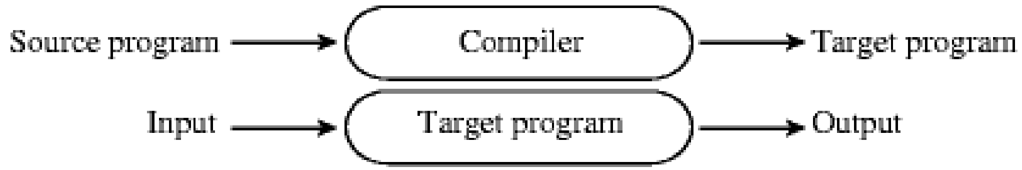
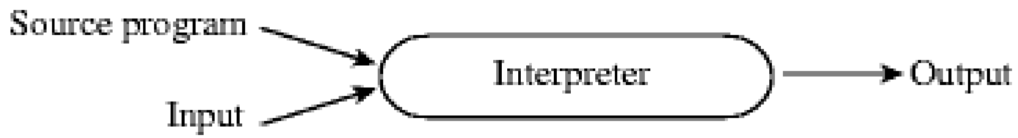
Chapter 1, Sections 1.1, 1.2, 1.5

Implementation Methods

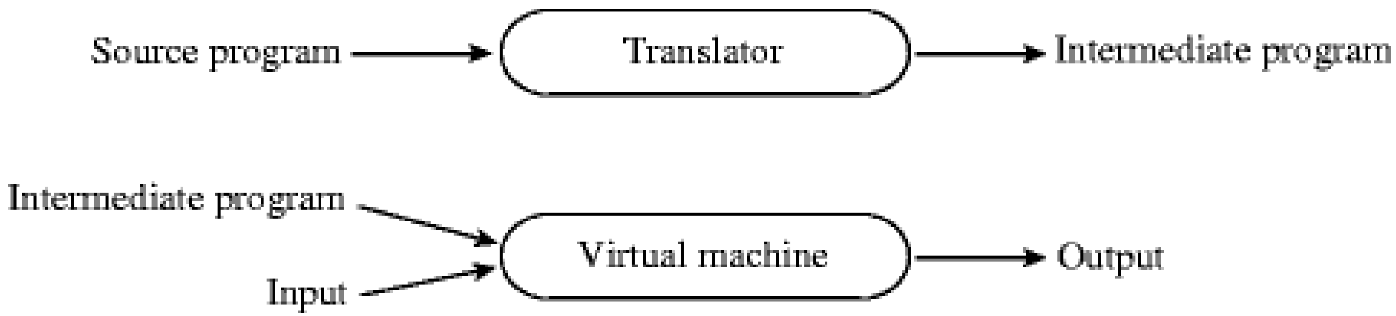
- Compilation (C, C++, ML)



- Interpretation (Lisp)



- Hybrid systems (Java)



The Entire Toolchain (1/2)

- Preprocessor: source to source translation
  - E.g. GNU C/C++ macro preprocessor **cpp**
    - Inlines **#include**, evaluates **#ifdef**, expands **#define**
    - Produces valid C or C++ source code
- Compiler: source to assembly code
  - E.g. GNU C/C++/… compiler **gcc**
  - Produces assembly language for the target processor
  - Assembly is easier to generate/debug than object code
- Assembler: assembly to relocatable object code
  - E.g. GNU assembler **as**
  - Translates mnemonics (e.g. ADD) to opcodes; resolves symbolic names for memory locations

The Entire Toolchain (2/2)

- Linker: relocatable object code from several modules (including libraries) to single executable program
  - E.g. GNU linker **ld**
  - Resolves inter-module symbol references; relocates the code (recomputes addresses)
- Example: **gcc** from Unix command line is a driver program that invokes the entire toolchain
  - **gcc -E test.c**: preprocessor (output: C code)
  - **gcc -S test.c**: preprocessor+compiler (output: assembly)
  - **gcc -c test.c**: preprocessor+compiler+assembler (output: object code for this compilation unit)

Inside the Compiler: **Front End**

- Lexical analyzer (aka scanner)
  - Converts ASCII or Unicode to a stream of tokens
- Syntax analyzer (aka parser)
  - Creates a parse tree from the token stream
- Semantic analyzer
  - Type checking and conversions; other semantic checks
- Generator of intermediate code
  - A parse tree is too high-level for code generation & optimization
  - Create lower-level **intermediate representation** (IR): e.g., three-address code

Inside the Compiler: **Middle Part**

- Analysis of intermediate code
  - Additional IRs: control-flow graph (CFG), static single-assignment form (SSA), def-use graph, etc.
  - Control-flow analysis, dataflow analysis, pointer analysis, side-effect analysis, polyhedral analysis, …
- Machine-independent optimization of intermediate code: better three-address code
  - Copy propagation, dead code elimination, code motion, constant propagation, redundancy elimination, parallelization, data locality optimizations, …
- Currently, this is where most of compiler research is focused

Inside the Compiler: **Back End**

- Code generator: from intermediate code to assembly code
  - Instruction selection, instruction ordering, register allocation, storage allocation, …
- Machine-dependent code optimizations
  - Elimination of redundant loads and stores, elimination of unreachable code, use of machine idioms (e.g., specialized instructions)
- A symbol table maintains information about names, types, and scopes
  - Used by all phases of the compiler

The Bigger Picture: Compiler Technology

- Very strong connections with language design and with computer architecture
  - Compiler technology had direct impact on the success of C, C++, Java, and C#
  - Intel has its own compiler
  - How to take advantage of multi-core/GPU/TPU?
- Strong connection with software engineering tools
  - IDEs have many code analyses and transformations
  - Static verification tools – heavy use of compiler analyses (real-world impact)
  - Automated debugging tools
  - Test coverage tools & test generation tools