COMP 181
Compilers

Lecture 1

Introduction

Tuesday, Sept. 5, 2005

Welcome

- You are in comp181 – Compilers
- Lectures: *Tuesday, Thursday 1:30 to 2:45*
  - If you're here, you probably know this
  - Will be on the web page … but, I urge you to attend class
- Class web page
  `www.cs.tufts.edu/~sguyer/classes/comp181`
- Mailing list
  `www.eecs.tufts.edu/mailman/listinfo/comp181`
- Book
  - None right now, but stay tuned…

Introduction

- What is this artifact?
  The Rosetta Stone
- Significance?
  Same document in Greek and Egyptian hieroglyphics
- Why are you telling us this?
  Compilers are language translators

A Brief History of High-Level Languages

- 1953 IBM develops the 701
  - Memory: 4096 words of 36 bits
  - Speed: 60 msec for addition
  - All programming done in assembly code
- **Problem**: Software costs exceeded hardware costs!
- John Backus: "*Speedcoding*"
  - Simulate a more convenient machine
  - But, ran 10-20 times slower than hand-written assembly

FORTRAN I

- 1954 IBM develops the 704
- John Backus
  - **Idea**: translate high-level code to assembly
  - Many thought this impossible
    Had already failed in other projects
- 1954-7 FORTRAN I project
  - By 1958, >50% of all code is in FORTRAN
  - Cut development time dramatically
    From weeks to hours

FORTRAN I

- The first compiler
  - Produced code almost as good as hand-written
  - Huge impact on computer science
- Led to an enormous body of work
  - Theoretical work on languages, compilers
  - Program semantics
  - Thousands of new languages
- Modern compilers preserve the outlines of FORTRAN I

Languages involved

Variables vs registers

```
int i = 10;
while (i > 0) {
    x = x * 2;
    i = i - 1;
}
```

Source

Control vs jumps

```
    movl    %esp, %ebp
    subl    $4, %esp
    movl    $10, -4(%ebp)
.L2:
    cmpl    $0, -4(%ebp)
    jle     .L3
    movl    8(%ebp), %eax
    sall    %eax
    movl    %eax, 8(%ebp)
    leal    -4(%ebp), %eax
    decl    (%eax)
    jmp     .L2
.L3:
    movl    8(%ebp), %eax
```

Target

The compilation problem

What's another problem with coding in assembly?

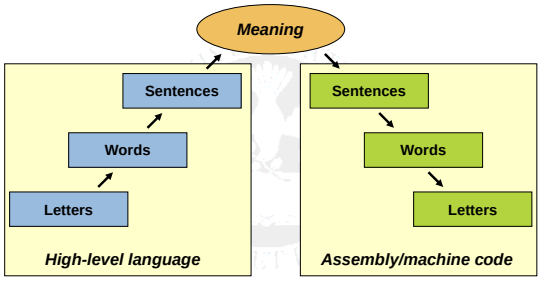
- Assembly language
  - Converts trivially into machine code
  - No abstraction: load, store, add, jump, etc.
  - Extremely painful to program
- High-level language
  - Easy to understand and maintain
  - Abstractions: control (loops, branches); data (variables, records, arrays); procedures
  - **Problem**: how to ***implement*** the language?

Language implementations

- Two major strategies:
  - Interpretation
  - Compilation
- Interpreter
  - ***"Online"***: read program, execute immediately
  - Examples?
- Compiler
  - ***"Offline"***: convert high-level program into assembly code
  - Examples?
- Compilation is a **language translation** problem

Can you think of another strategy – a "hybrid"?

How does translation work?



Sounds easy!

- Translation can be tricky…

  Infallible source: the Internet

I saw the Pope ("el Papa")	*I saw the potato ("la papa")*
It won't leak in your pocket and embarrass you ("no los embarass")	*It won't leak in your pocket and make you pregnant ("no embarazado")*
It takes a tough man to make a tender chicken	*It takes a hard man to make a chicken affectionate*

Job #1

- What is our primary concern?

  *Words or code: translate it **correctly***
- How do we know the translation is correct?

  *Specifically, how do we know the resulting machine code **does the same thing***
- "Does the same thing"

  What does that even mean?

Correctness

- **Practical solution**: automatic tools
  - Parser generators, regular expressions, rewrite systems, dataflow analysis frameworks, code generator-generators
  - Extensive testing
- **Theoretical solution**: a bunch of math
  - Formal description of semantics
  - A proof that the translation is correct
  - ⇨ Topic of current research

Incorrectness

- What is this?

  The infamous "Blue Screen of Death"

- Internal failure in the operating system
- Buggy device driver

Good enough?

- Is there more than correctness?

> **Our wines leave you nothing to hope for.**
> *-Swiss menu*

> ***When passenger of foot heave in sight, tootle the horn. Trumpet him melodiously at first, but if he still obstacles your passage then tootle him with vigor.***
> *-Car rental brochure*

> **Drop your pants here for best results.**
> *-Tokyo dry cleaner*

Job #2

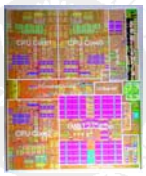
- Produce a "good" translation
- What does that mean for compilers?

  *Good performance – **optimization***
  - Find more efficient code sequences
  - Utilize the hardware effectively
- How hard could that be?

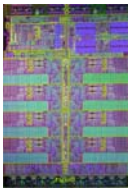
Modern processors

…are very, very complex…

Pentium 4



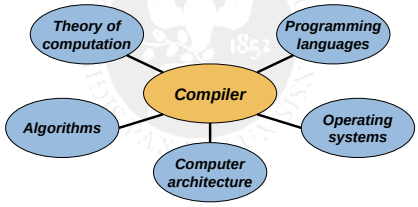
Xbox 360



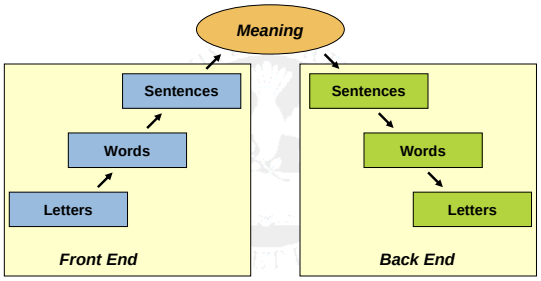
PS-3 CELL

Study of compilers

- Brings together many parts of CS
  - Practical and theoretical
  - Some solved problems, others unsolved

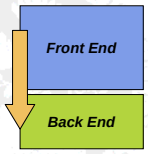


Structure of a compiler



Structure of a compiler

- Organized as a series of passes
  - Lexical Analysis
  - Parsing
  - Semantic Analysis
  - Optimization
  - Code Generation



- We will follow this outline in the class

Compilers Today

- The overall structure of almost every compiler adheres to our outline
- Emphasis has changed since FORTRAN:
  - ***Early***
    - Lexing, parsing most complex, expensive
  - ***Today***
    - Lexing and parsing are cheap
    - Good techniques for code generation
    - Optimization dominates all other phases

Related systems

- Interpreters
  - Scripting languages: Javascript, Ruby, etc.
  - XML processing
- Just-in-time compilers
  - Java JVM
  - Microsoft CLR
- Binary instrumentation
  - PIN
  - valgrind

Trends in Compilation

- Compilation for speed is less interesting. *But:*
  - Scientific computing, parallel computing
  - Advanced processors
    - Digital signal processors, multi-core
  - Implementation of modern languages (Java, C#)
    - Good performance is a challenge
- Compilation for improving code reliability:
  - Memory safety
  - Detecting concurrency errors (data races)
  - Detecting security vulnerabilities

Course Structure

Course has theoretical and practical aspects

- Programming assignments = practice
  - Five part project – more about this next time
  - 50% of final grade
- Written assignments = theory, practice
  - Class hand-in, right before lecture
  - 15% of final grade
- Midterm exam: 15%
- Final exam: 20%

Late policy:

Three free late days for assignments, use them however you want

Next time...

- Sign up on mailing list:

  `https://www.eecs.tufts.edu/mailman/listinfo/comp181`

- The view from 35,000 feet

- Information about projects