Compilers

Lecture 1

Introduction

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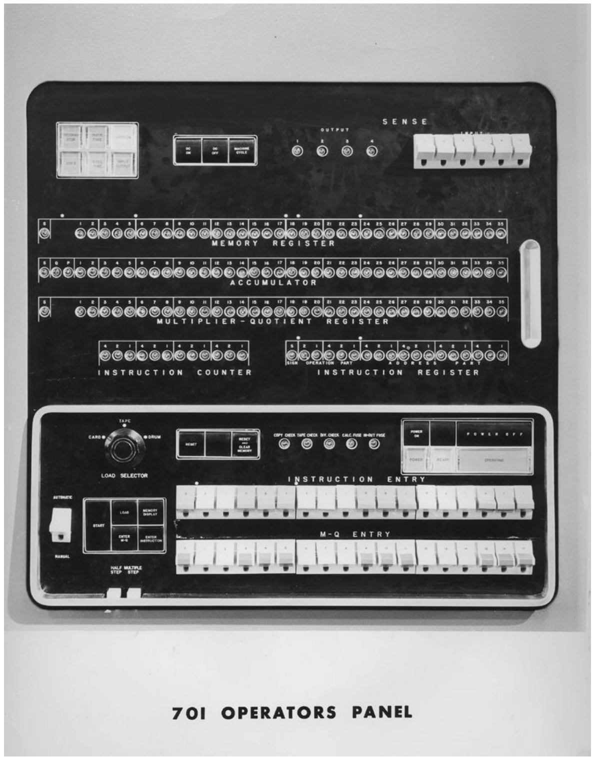
(original slides by Sam Guyer@Tufts)

Discussion

- What does a compiler do?
- Why do you need that?
- Name some compilers you have used

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



Programming

- **What's the problem?**
  - Assembly programming very slow and error-prone
  - Software costs exceeded hardware costs!
- John Backus: "*Speedcoding*"
  - Simulate a more convenient machine
  - But, ran 10-20 times slower than hand-written assembly
- Backus
  - **<u>Idea</u>**: 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
  - Huge impact on computer science
  - Produced code almost as good as hand-written

- 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

Language implementations

- Two major strategies:
  - Interpretation
  - Compilation

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

- What are the main differences?
  - ***"Online"***: read program, execute immediately
  - ***"Offline"***: convert high-level program into assembly code

- Compilation is a language translation problem
  - What are the languages?

Languages involved

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

Source

```
     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
```

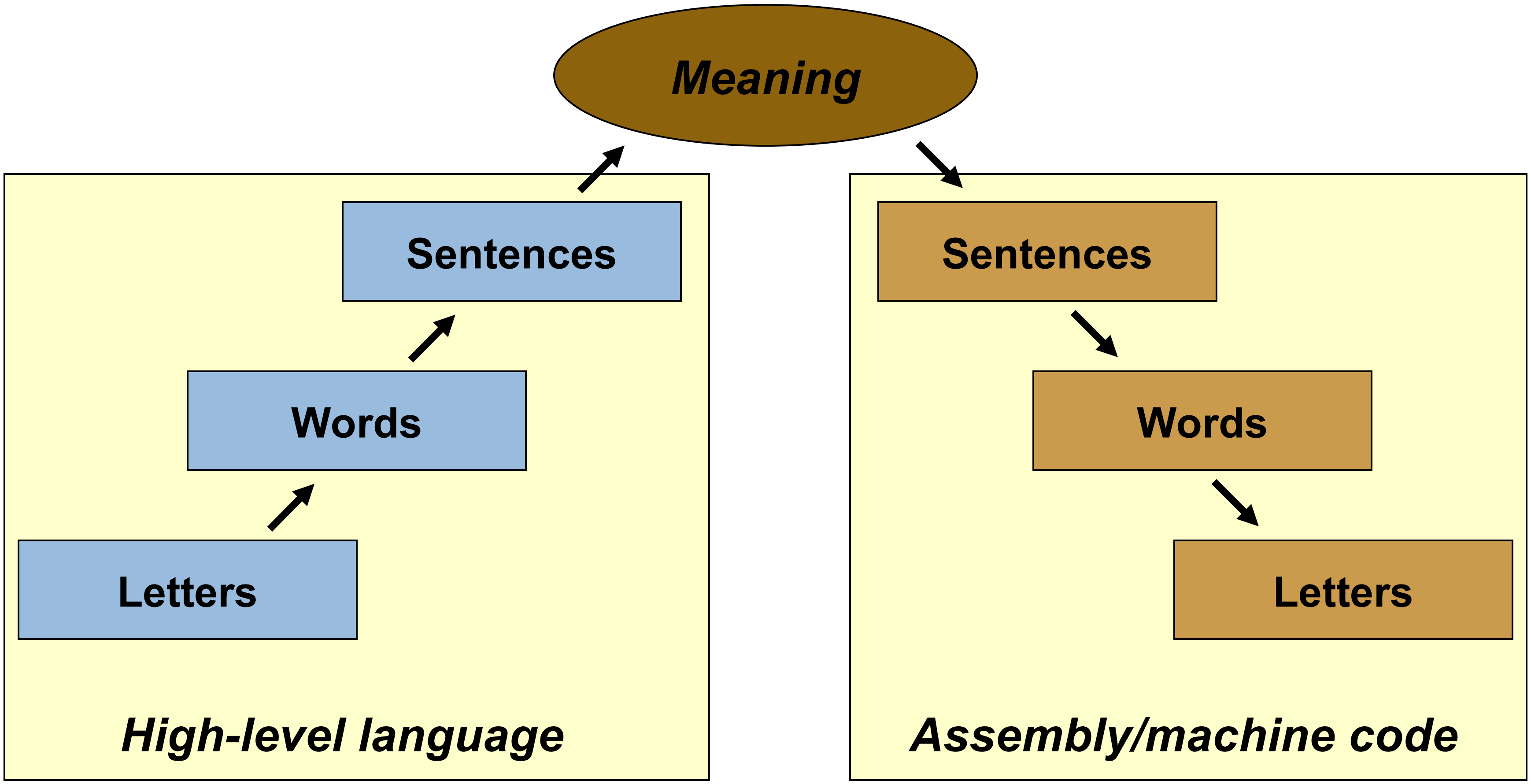
Target

The compilation problem

- Assembly language
  - Converts trivially into machine code
  - No abstraction: load, store, add, jump, etc.
  - Extremely painful to program
  - What are other problems with assembly programming?

- High-level language
  - Easy to understand and maintain
  - Abstractions: control (loops, branches); data (variables, records, arrays); procedures
  - **Problem**: how do we get from one to the other?
    (*systematically*)

Translation process



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

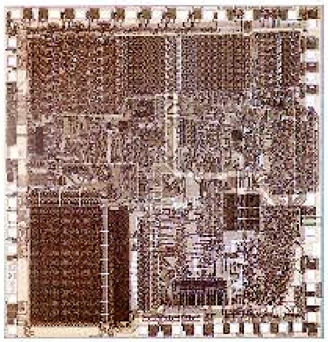
- What does that mean for compilers?

  *Good performance – **optimization***

  - Reduce the amount of work ("be concise")
  - Utilize the hardware effectively ("choose your words carefully")

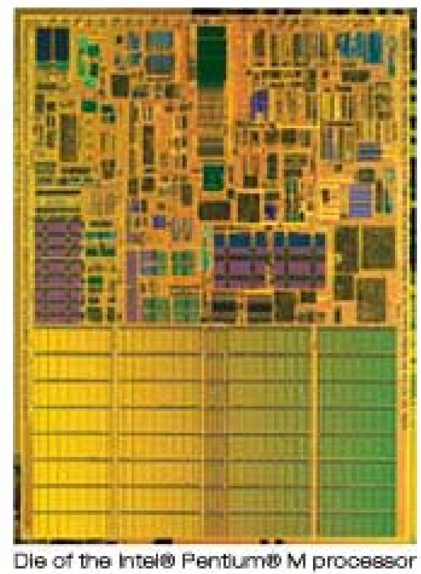
- How hard could that be?

Past processors



8086

29,000 transistors

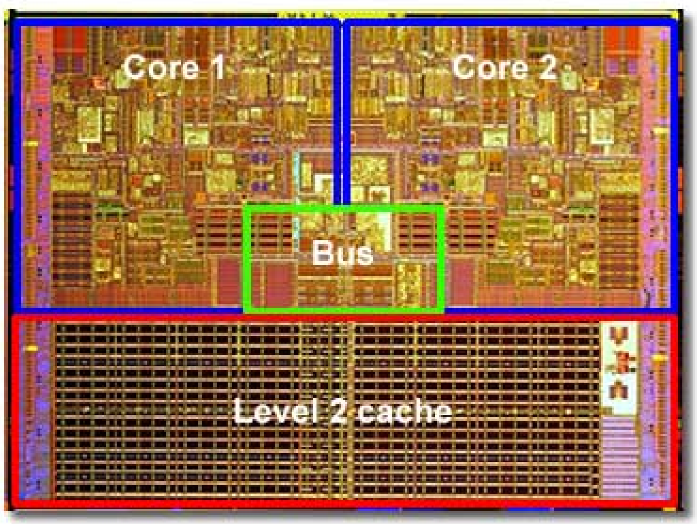


Pentium M

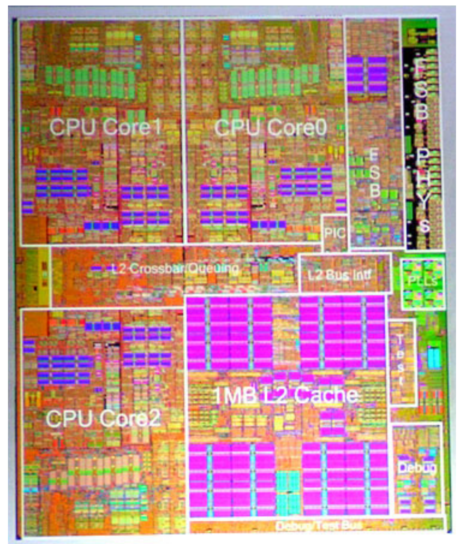
140,000,000 transistors

- More speed, more complexity
- ***But***, same machine code – why is that nice?

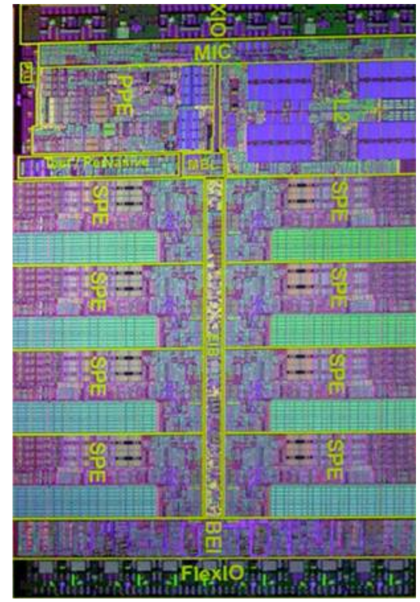
Tomorrow's processors



Intel Core Duo



Xbox 360

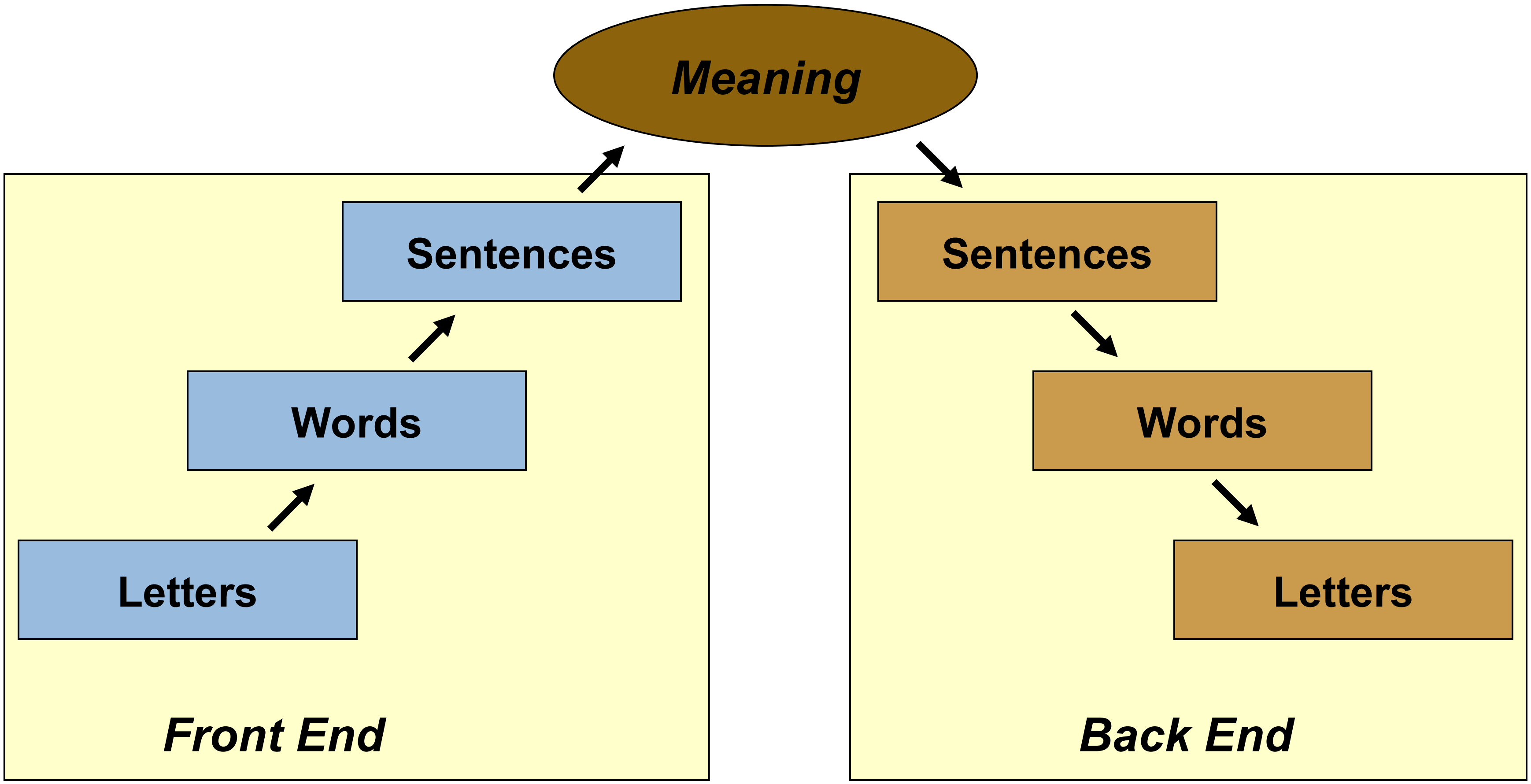


PS-3 CELL

- Parallel, heterogeneous

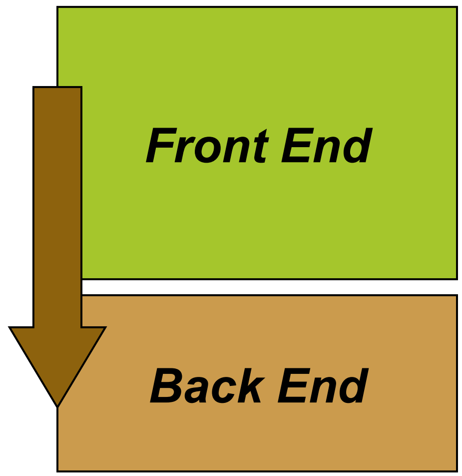
  Really hard to program!

Structure of a compiler



Structure of a compiler

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



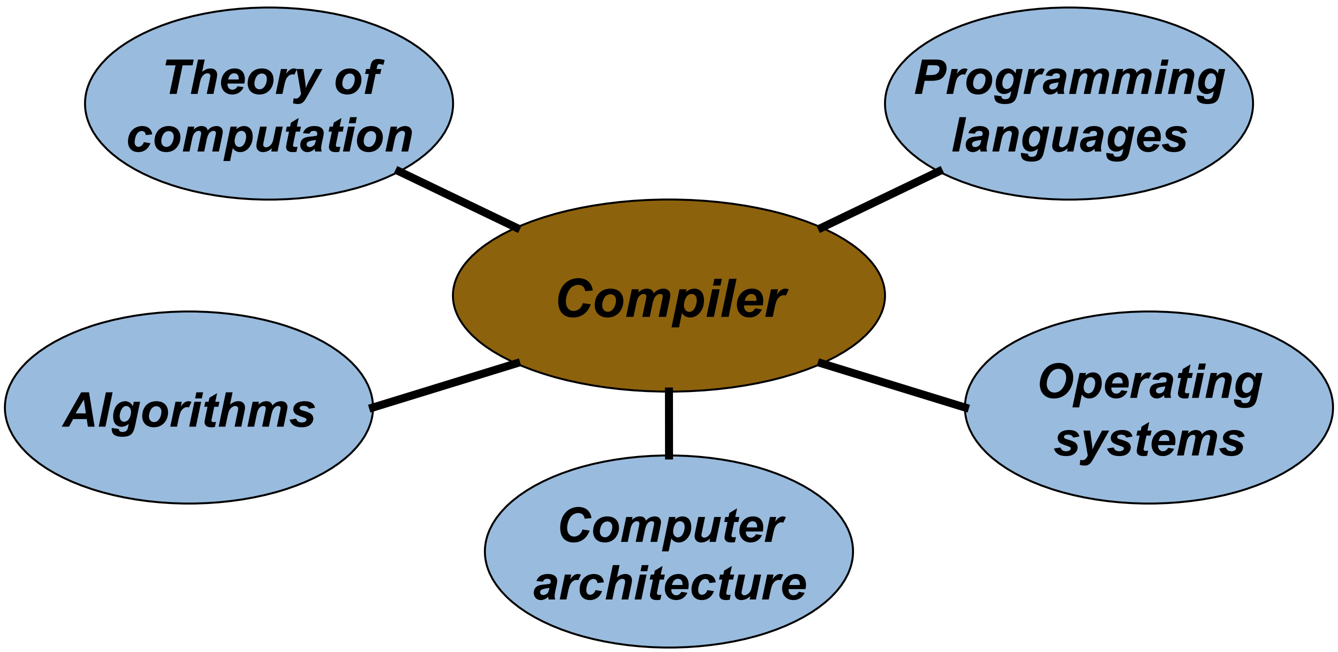
- We will follow this outline in the class

What I want you to get out of this class

- Understand how compilers work
  - Duh
- See how theory and practice work together
  - Yes, theory of computation is good for something
  - Also: graph algorithms, lattice theory, more…
- Work with a large-ish software systems
- Learn to think about tradeoffs
  - System design always involves tradeoffs
  - Impossible to maximize everything

Study of compilers

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



Course Structure

Course has theoretical and practical aspects

- Programming assignments = practice
  - Two homework projects
  - 40% of final grade

- Final exam: 65%
- Need to pass (> half points) all three (exam and each project)

Programming Assignment Logistics

- Need to "show your work", incrementally
  - at submission time, you will share a github/gitlab project with TAs
  - need to see your progress every day you work on the project
    - multiple commits per day
- You will also be interviewed for one of the projects to demonstrate ownership of the code
  - in person, not remote

Late policy:

Up to five late days per assignment, 5% penalty per day