Topic 1: Introduction

COS 320

Compiling Techniques

Princeton University
Spring 2018

Prof. David August

The Usual Suspects

Me: Prof. David August, 221 CS Building
august@
Office Hours: Tu/Th after class and by appointment

TA: Sotiris Apostolakis, 226 CS Building
sapostolakis@
Office Hours: M/W 1-2PM and by appointment

What is a Compiler?

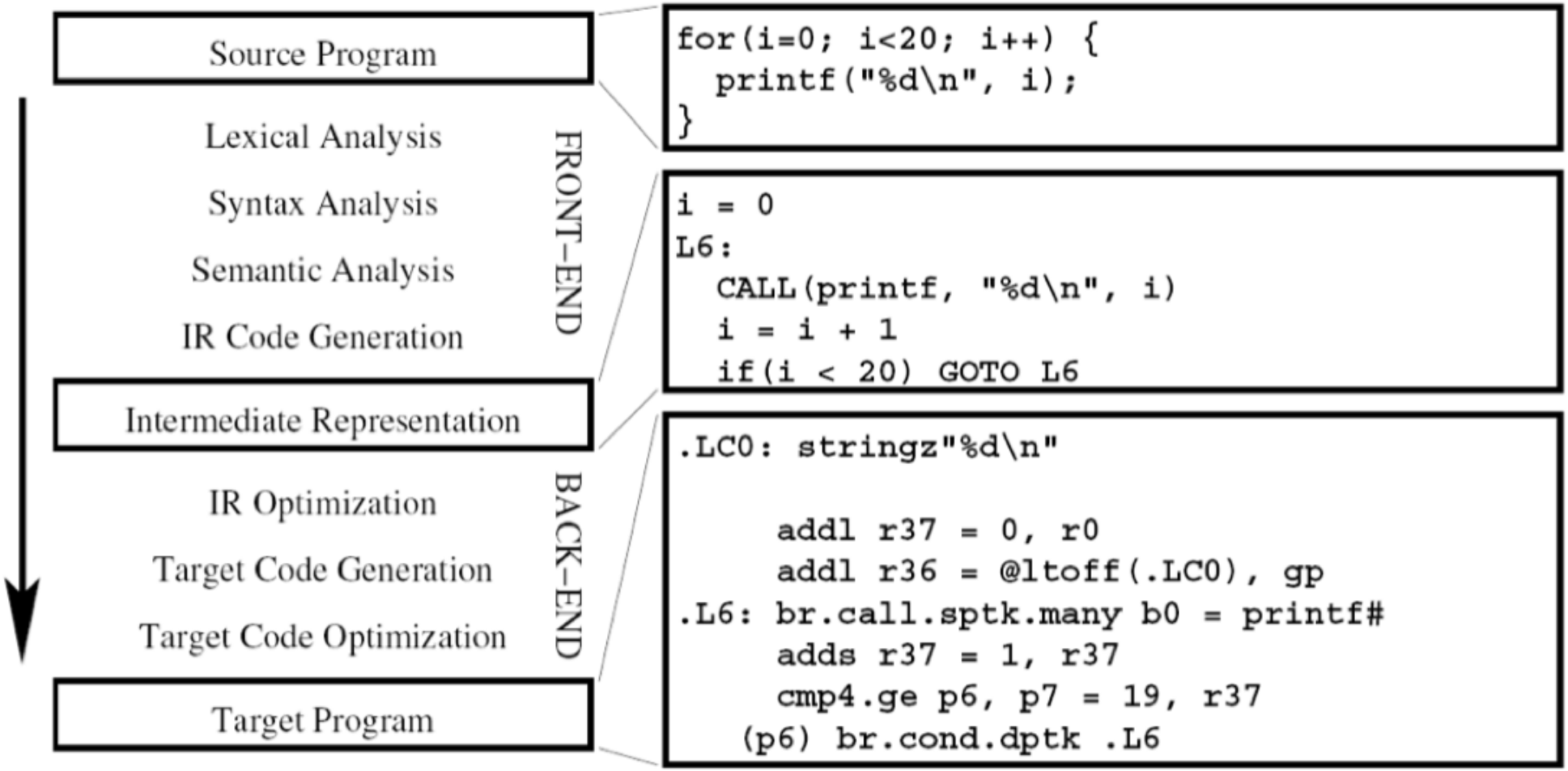
- A *compiler* is a program that takes a program written in a *source language* and translates it into a functionally equivalent program in a *target language*.

- Source Languages: C, C++, Swift, FORTRAN,...

- Target Languages: x86 Assembly, Arm, Assembly, C,…

- Compiler can also:
  - Report errors in source
  - Warn of potential problems in source
  - Optimize program

What is a Compiler?



Why Learn About Compilers?

Compiler technology everywhere.

Bellagio, Las Vegas

- C++ → Assembly
- Assembly → Machine Code
- Microcode → microcode binary
- Interpreters: Perl, Python, Java, …
- JITs: Android Dalvik VM, Java VM, …
- Publishing: Latex → PDF → Print on Paper
- Hardware Design: HW Description → Circuit/FPGA
- SPAM → /dev/null
- Automation: Water Fountain DL → Water Display
- Next Revolution in Processors

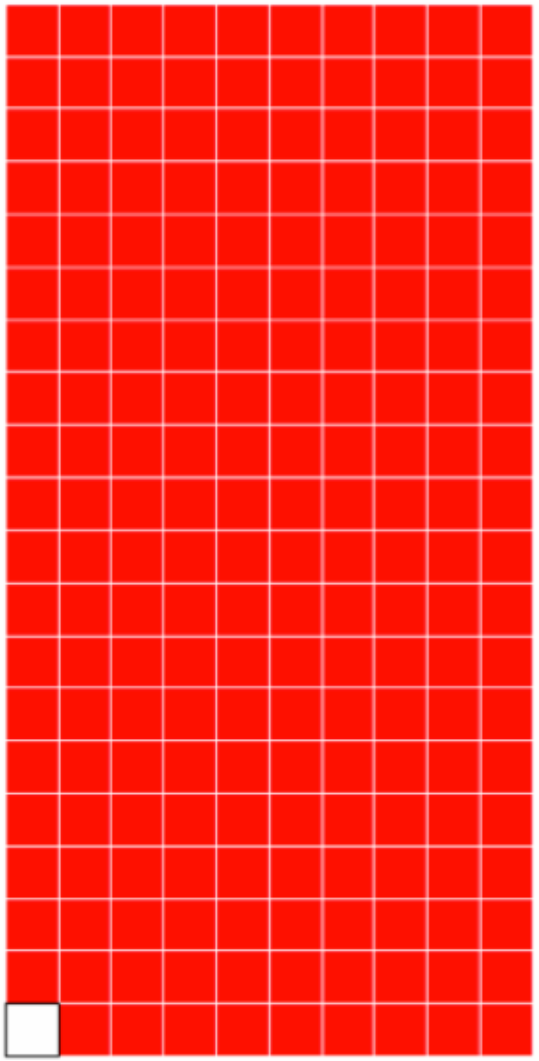
Why Learn About Compilers?

Almost all code goes through a compiler.

Linux

- C = 2,558,100 lines
- x86 assembly = 12,164 lines

99.5% of Linux source goes through a compiler!



Compilers teach us about:

- Programming Languages
- Computer Architectures

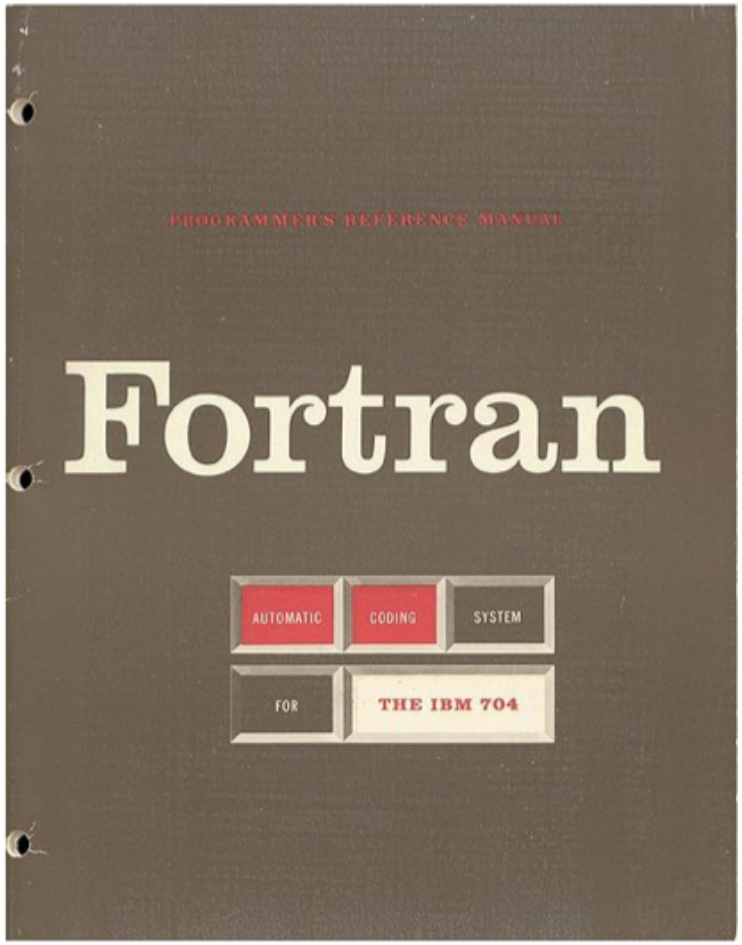
Why Learn About Compilers?

```
sum = 0;
for(i = 0; i < 1000000; i++)
  {
    sum = sum + big_array[i];
  }
```

```
sum = 0;
for(i = 0; i < 250000; i+=4)
  {
    sum = sum + big_array[i];
    sum = sum + big_array[i+1];
    sum = sum + big_array[i+2];
    sum = sum + big_array[i+3];
  }
```

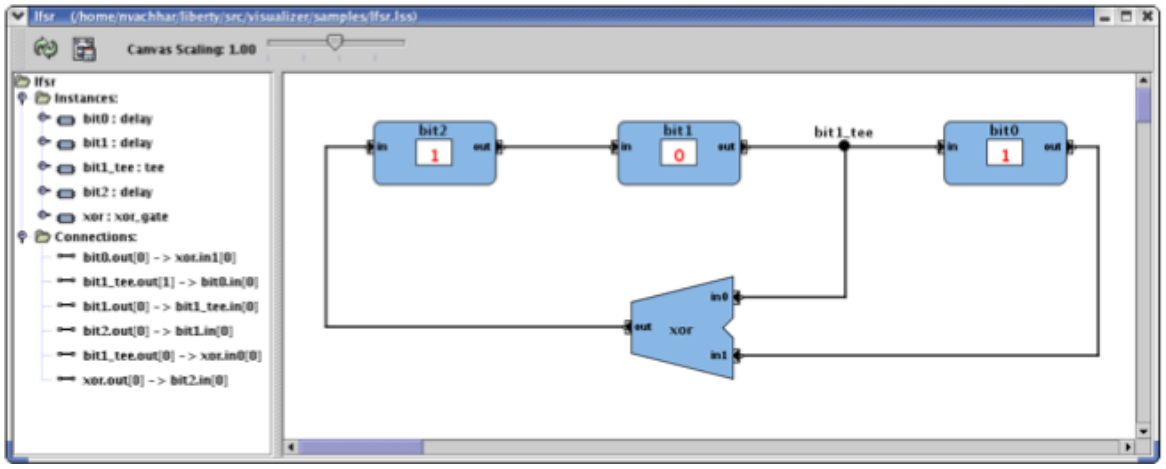
Why Learn About Compilers?

- IBM developed the first FORTRAN compiler in 1957
- Took 18 person-years of effort
- You will be able to do it in less than a week!



Why Learn About Compilers?

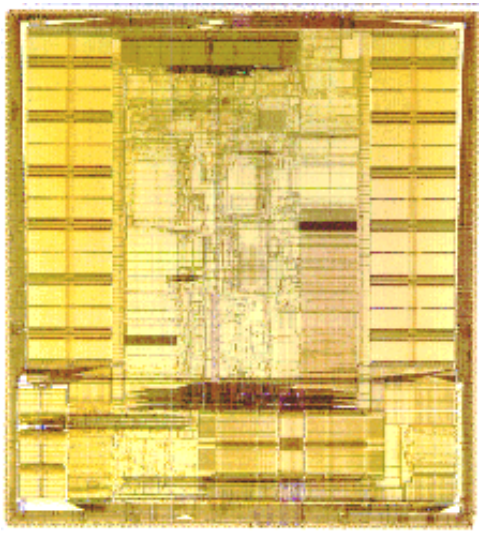
Hardware Design



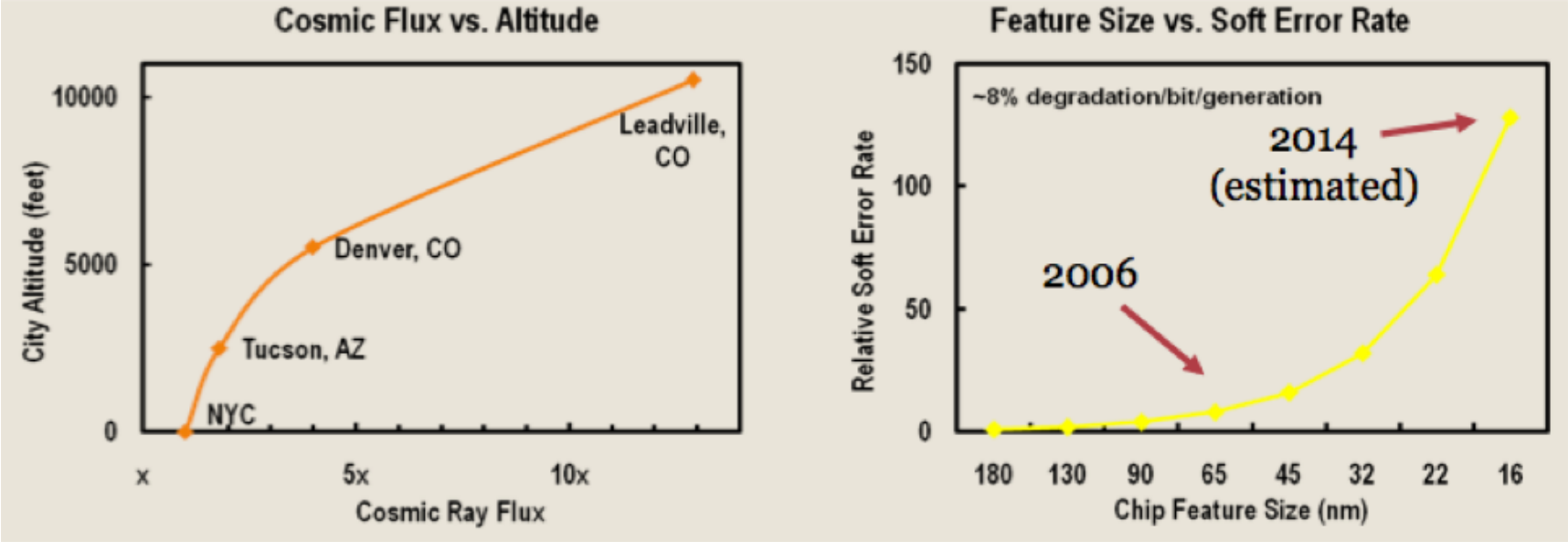

```
module toplevel(clock,reset);
  input clock;
  input reset;

  reg flop1;
  reg flop2;

  always @ (posedge reset or posedge clock)
    if (reset)
      begin
        flop1 <= 0;
        flop2 <= 1;
      end
    else
      begin
        flop1 <= flop2;
        flop2 <= flop1;
      end
endmodule
```



Why Learn About Compilers?
Computer Architecture



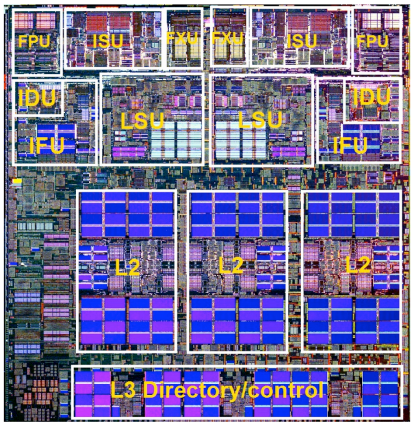
Princeton Research on Fault Tolerance wins CGO Test of Time Award

February 2, 2015

Every year, the International Symposium on Code Generation and Optimization (CGO) recognizes the paper appearing 10 years earlier that is judged to have had the most impact on the field over the intervening decade. This year at CGO 2015, the paper entitled "SWIFT: Software Implemented Fault Tolerance" by George A. Reis, Jonathan Chang, Neil Vachharajani, Ram Rangan, and David I. August won the award. The paper originally appeared at CGO 2005 and also won the best paper award that year at the conference. Congratulations to Princeton's Liberty Research Group for winning this prestigious award!

Why Learn About Compilers?

Your chosen field of computer architecture effectively dead?



SPEC CINT Performance (log scale)

Historic Performance Growth Rate

Advent of Multicore

7 Years Behind

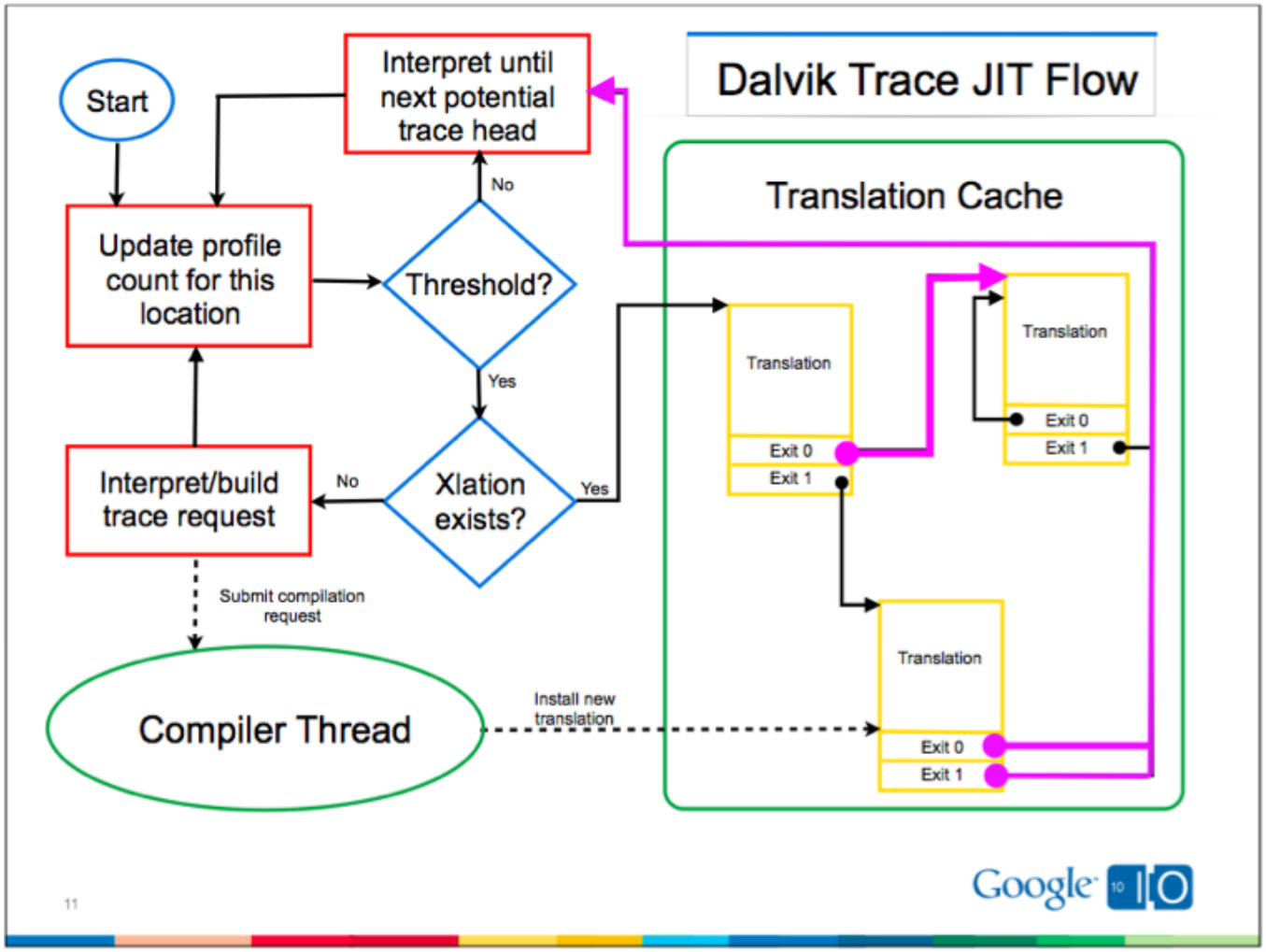
12x

CPU92
CPU95
CPU2000
CPU2006
CPU2017

1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

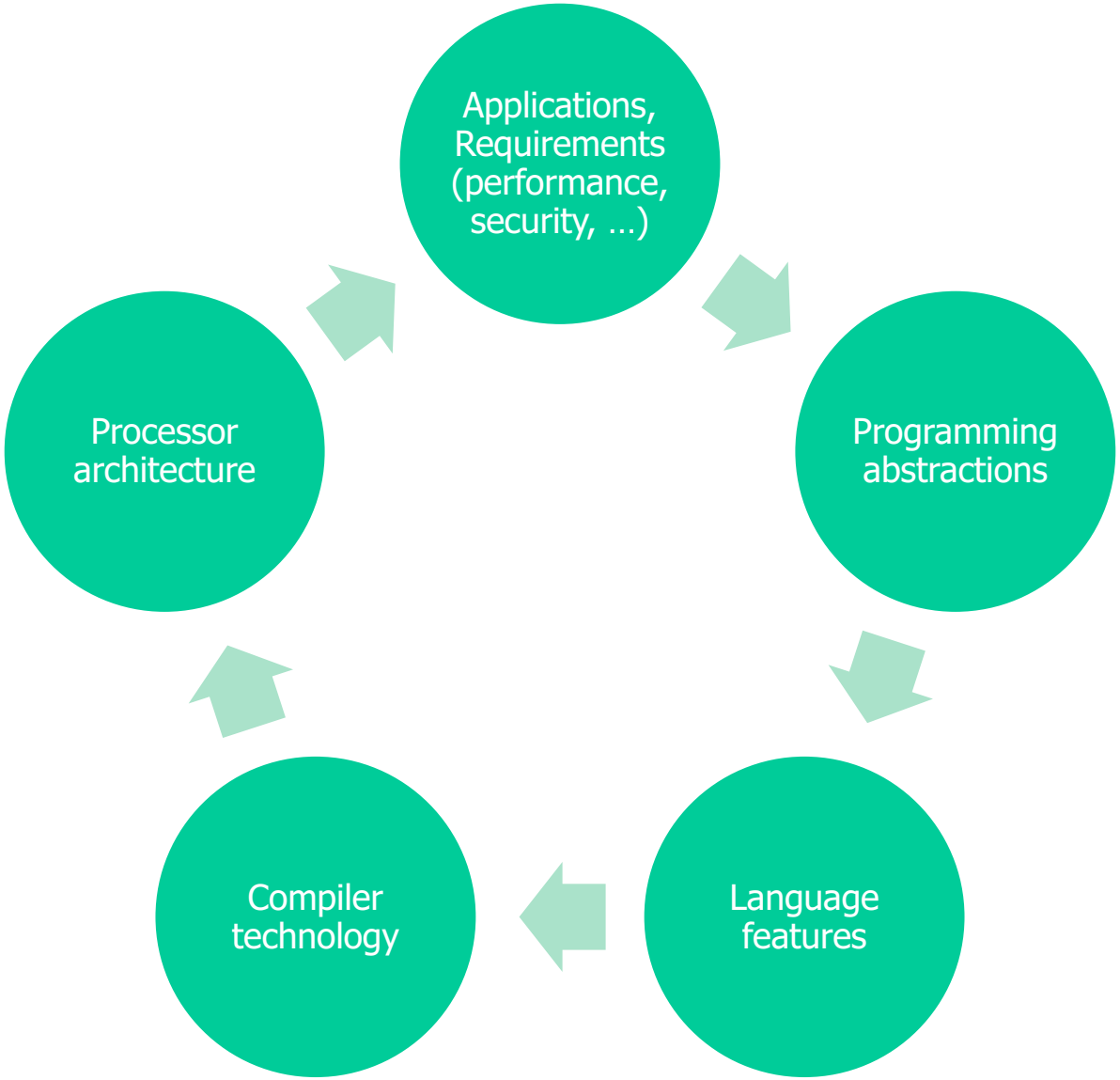
Year

Why Learn About Compilers?



Why Learn About Compilers?

Your chosen field of computer architecture effectively dead?



Why Take 320 Seriously?

Ge Wa

ChucK : Strongly-timed, Concurrent, and On-the-fly Audio Programming Language

PROFIT!!!

Why Take 320 Seriously?

Dear Professor August,

Having had almost a year to digest COS 320, I wanted to add to my course review:

Last summer, a significant portion of my internship was based around compilers. We had a "language" that we provided to non-CS people, and when they inserted it into their work, it turned into complicated diagrams and pictures. We could also reuse nodes, building what was essentially ASTs. I actually really enjoyed that component of my work, and I thought it was a very efficient way of structuring our code.

I appreciated COS 320, and I'm glad I took it. Thank you for providing the opportunity.

...

Why Take 320 Seriously?

Grading

Assignments	50%
Exams	50%
Quizzes	Extra Credit
Participation	Extra Credit

Exams

- Exams cover concepts presented in the lecture material, homework assignments, and/or required readings
- One double sided 8.5x11 page of notes allowed

Midterm Exam

- Thursday before break
- In class

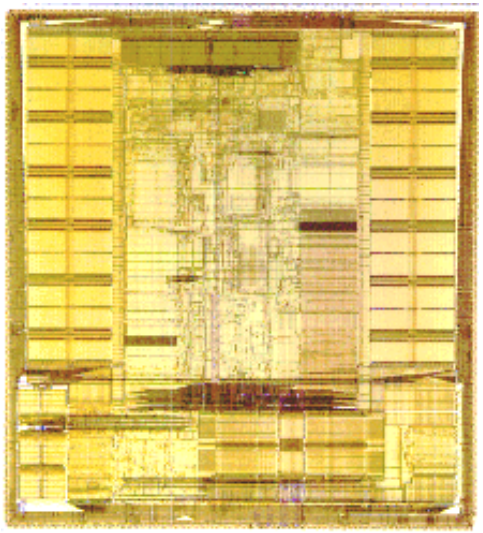
Final Exam

- ~~The final exam will be cumulative, three hours in length~~
- ~~Time/Place determined by the Registrar~~

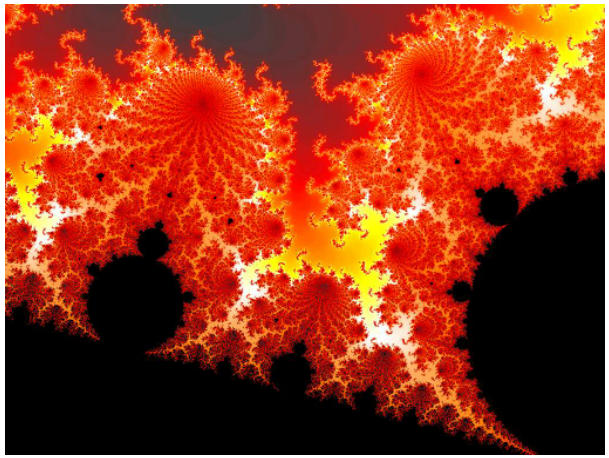
Pick a number 1,2,3

1

2



3



If the random number is the picture of a "processor", then we have a quiz.

Quizzes

- Chance quiz at the beginning of each Tuesday class
- Not intended as a scare tactic – liberally graded
- Helps assess progress of class
- Just one question usually

Participation

Negatives

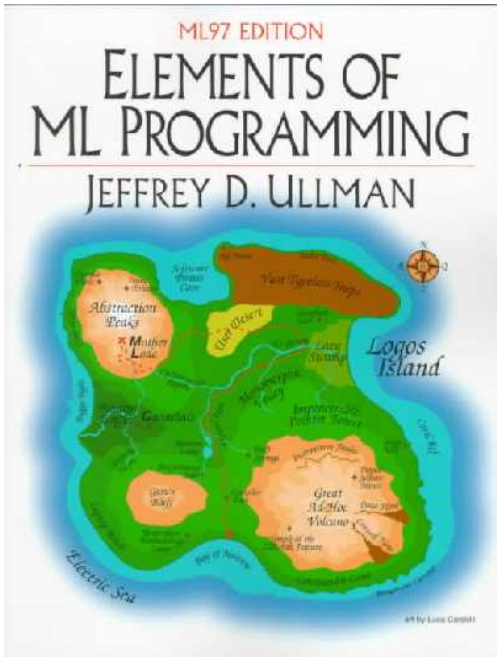
- Class disruptions (snoring, email, reading a book, etc.)
- Mistreatment of TAs

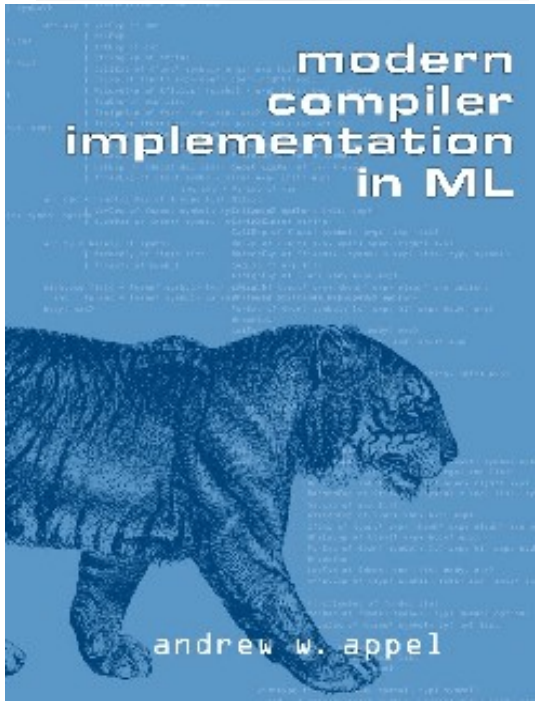
Positives

- Contribute questions and comments to class
- Participate in discussions
- Feedback
- Stop by office hours to introduce yourself

Reading

- Optional: Jeffrey D. Ullman, Elements of ML Programming, 2nd Edition, Prentice Hall.
- Required: Andrew W. Appel, Modern Compiler Implementation in ML. Cambridge University Press.
- CHECK ERRATA ON BOOK WEB SITES!
- Course Web Page – Off of CS page
  - Lecture Notes
  - Project Assignments
  - Course Announcements





Who Am I?

At Princeton (Computer Science, 1999-Present):

- Professor
- Compiler and computer architecture research
- Liberty Research Group

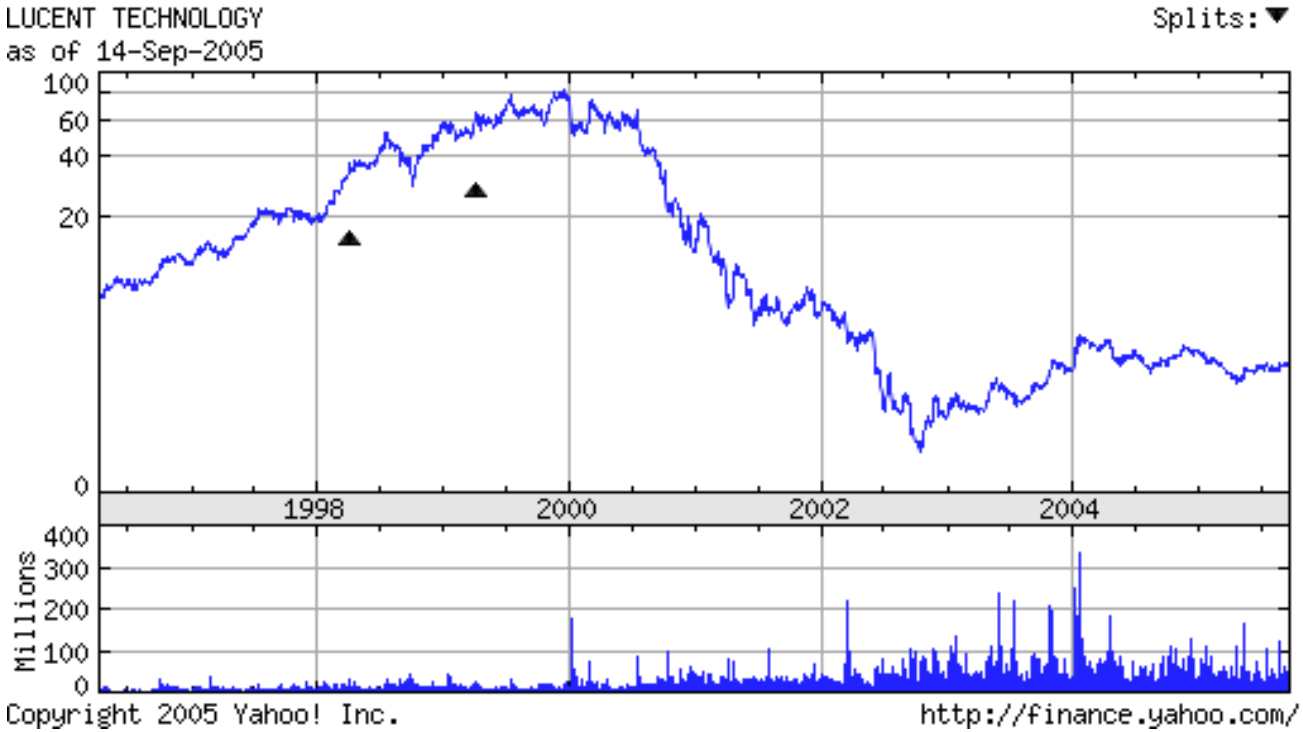
Education (Ph.D. in 2000):

- Ph.D. Electrical Engineering from University of Illinois
- Thesis Topic: Predication
- The IMPACT Compiler Research Group

Who Am I?

Professional Experience:

- Intel (Oregon) – P6 multiprocessor validation
- Hewlett-Packard (San Jose, CA) – research compiler
- Intel (Santa Clara, CA) – IA-64 design
- Startups inspired by compiler technology
- Consulting for Intel, Google, LG, Samsung, Amazon, etc.



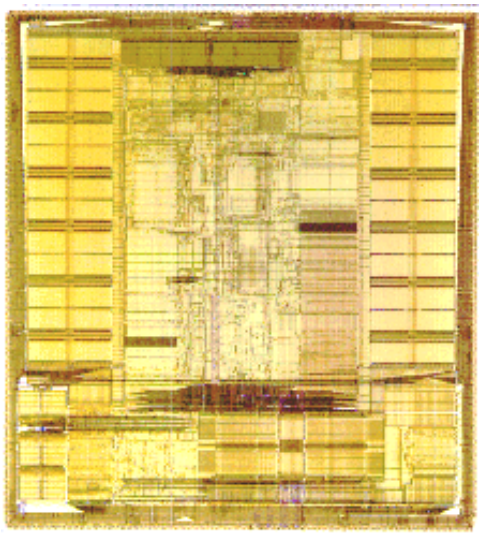
Our Pledge to You

- Quick response to questions and issues
- Reasonable late policy
  - Up to 3 days late for any single assignment without penalty
  - Up to 7 days late total across all assignments
  - Contact me prior to deadline for special circumstances
- Fast turn-around on grading

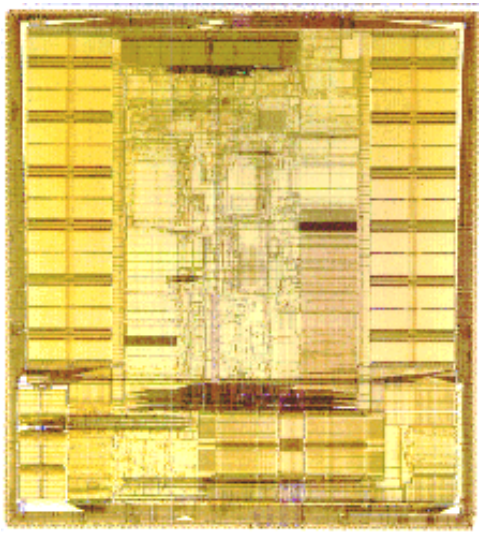
END OF ADMINISTRATIVE STUFF

It’s Tuesday: Pick a number 1,2,3

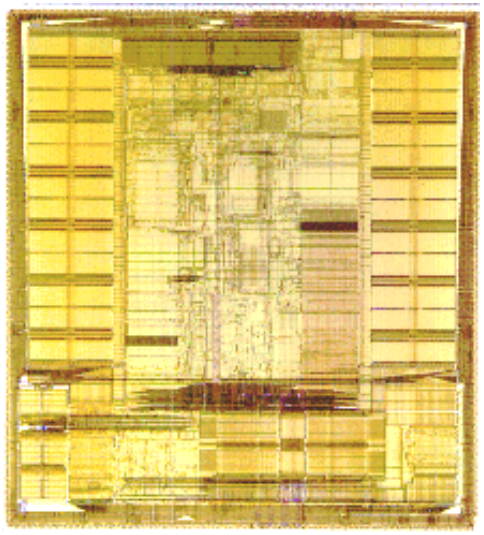
1



2



3



Quiz 0: Background (use index cards)

Front:

1. Full name and Email Address above the red line
2. Major/UG or G/Year (immediately below the red line)
3. Area (G: Research Area/UG: Interests)
4. Level of interest in "Research Project"
5. Briefly describe any ML experience.
6. Briefly describe any C/C++ experience.
7. Briefly describe any compiler experience.
8. In which programming languages are you fluent?

Back:

1. Why do processors have registers?
2. What is an instruction cache?
3. Can one always convert an NFA to a DFA? (yes, no, or what?)