Last Lecture

CS 106B

Programming Abstractions
Fall 2016
Stanford University
Computer Science Department
Today’s Goal

1. Know where you came from
2. Show you where you could go
Final review, today at 3:30p in Bishop Aud

Final is on Monday at 8:30a

Last name A-G: Cubberley Auditorium

Last name H-Z: Dinklespiel
Final Exam

- Short answer question
- Class Implementation
- Linear Structures + Hashing
- Recursion
- Trees
- Graphs

* We care about writing a fair final

Only material covered in lecture.
Heavy emphasis on assignments
Leave a review on Axess
CS 106B Montage
CS106B Instructors

Chris Piech

Chris Gregg
Who are you?

- Applied Physics
- Aeronautics & Astro.
- Bioengineering
- Biology
- Business Administration
- Chemical Engineering
- Chemistry
- Classics
- Civil and Environmental Engineering
- Computational and Mathematical Engineering
- Computer Science
- Creative Writing
- East Asian Studies
- Economics
- Education
- Electrical Engineering
- Energy Resource Engineering
- English
- Financial Mathematics
- Film and Media Studies
- French
- International Relations
- Japanese
- Law
- Materials Science and Engineering
- Mathematical and Computational Sciences
- Mathematics
- Mechanical Engineering
- Medicine
- Management Science and Engineering
- Modern Language
- Music
- Neuroscience
- Physics
- Political Science
- Psychology
- Science, Technology, and Society
- Statistics
- Symbolic Systems
- Undeclared!
Assignment 0: Year

What is your class year at Stanford (426 responses)

- Frosh: 27.5%
- Sophomore: 27.7%
- Junior: 25.8%
- Senior: 6.5%
- Graduate, non-professional school: Other
Assignment 0: Major

What is your (intended) major  (426 responses)

- Computer Science
- CS-related (but not CS) major (Symbolic Systems, Math & C...)
- Other Engineering (not CS, n...)
- Humanities (e.g., Philosophy,...)
- Social Science (e.g., Econo...)
- Physical sciences (e.g., Biolo...)
- Undeclared (don't know yet)
- Professional school (Law, Me...)
- Other
Assignment 0: Why?

Why are you taking CS106B? (426 responses)

- 36.2%: Required for my (intended) major
- 25.4%: Required for my (intended) minor
- 26.3%: Exploring Computer Science as a potential major
- 9.2%: To satisfy a General Education or Ways of Thinking/Ways of
  thinking
- 7.1%: For fun and enlightenment
- 17.2%: Other
Any sufficiently advanced technology is indistinguishable from magic
- Arthur Clark
Welcome to the CS106B game show! You stand in front of three doors and behind each door is a special prize. Will you be:

```
void doorOne(string & prize) {
    int dollars = 1 / 5 * 100;
    prize = "$" + integerToString(dollars);
}

void doorTwo(string prize) {
    prize = "a Maasai rungu";
}

void doorThree(string & prize) {
    prize = "a pineapple";
}
```
Velociraptor Safety
Welcome to Fauxtoshop!
Enter name of image file to open (or blank to quit): stanford-oval.jpg
Opening image file, may take a minute...
Which image filter would you like to apply?
   1 - Scatter
   2 - Edge detection
   3 - "Green screen" with another image
   4 - Compare image with another image
Your choice: 3
Now choose another file to add to your background image.
Enter name of image file to open: godzilla-green.jpg
Opening image file, may take a minute...
Now choose a tolerance threshold: 70
Enter location to place image as "(row,col)" (or blank to use mouse): (100, 100)
Enter filename to save image (or blank to skip saving):
Write a program to find all anagrams of a word the user types.

Type a word [Enter to quit]: scared

Anagrams of scared:
cadres
cedars
sacred
scared

What is the appropriate collection to solve this problem?

Hint: Use a compound collection.
Best Map Application?

Bright Simons
Recursion
Fractals
Boggle
Pointers

What is a pointer???

A memory address!
Big O and Sorting
Implementing Collections

push(6);
Beacons of Gondor

// add a new tower
Tower * temp = new Tower;
temp->name = towerName;
temp->link = head;
head = temp;
Recursion and Pointers?!

Linked list

value

value

value
New Diabetes Insulin Device

Whatever you major in, you have the potential to influence the world for good. Of course, we do have to "learn to walk before we run," and there is a lot to learn in CS before you are developing "advanced algorithms."
Priority Queue

It's a Christmas tree with a heap of presents underneath!

...we're not inviting you home next year.
Implemented Wikipedia

Wikipedia:

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

"John Coltrane" ➔ Hash Fn ➔ 8

49,999
... and Hashzam
Binary Search Trees

Searching for the value 31 from the root
Huffman Encoding
Who do you love?

Your significant other 376
Search

Path hops: 9
Trailblazer
End Montage
Insert Chris Gregg
Learn how to model and solve complex problems with computers.

To that end:

- Explore common abstractions for representing problems.
- Harness recursion and understand how to think about problems recursively.
- Learn and analyze different approaches for solving problems.
Why Data Structures are Important

One reason we care about data structures is, quite simply, time. Let’s say we have a program that does the following (and times the results):

- Creates four “list-like” containers for data.
- Adds 100,000 elements to each container – specifically, the even integers between 0 and 198,998 (sound familiar?).
- Searches for 100,000 elements (all integers 0-100,000)
- Attempts to delete 100,000 elements (integers from 0-100,000)

What are the results?
The Importance of Data Structures

Results:

<table>
<thead>
<tr>
<th>Structure</th>
<th>Overall(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsorted Vector</td>
<td>15.057</td>
</tr>
<tr>
<td>Linked List</td>
<td>92.202</td>
</tr>
<tr>
<td>Hash Table</td>
<td>0.145</td>
</tr>
<tr>
<td>Binary Tree</td>
<td>0.164</td>
</tr>
<tr>
<td>Sorted Vector</td>
<td>1.563</td>
</tr>
</tbody>
</table>

Processor: 2.8GHz Intel Core i7 (Macbook Pro)
Compiler: clang++

A factor of 103x
A factor of 636x!

Note: In general, for this test, we used optimized library data structures (from the "standard template library") where appropriate. The Stanford libraries are not optimized.

Overall, the Hash Table "won" — but (as we shall see!) while this is generally a great data structure, there are trade-offs to using it.
<table>
<thead>
<tr>
<th>Structure</th>
<th>Overall(s)</th>
<th>Insert(s)</th>
<th>Search(s)</th>
<th>Delete(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsorted Vector</td>
<td>15.057</td>
<td>0.007</td>
<td>10.307</td>
<td>4.740</td>
</tr>
<tr>
<td>Linked List</td>
<td>92.202</td>
<td>0.025</td>
<td>46.436</td>
<td>45.729</td>
</tr>
<tr>
<td>Hash Table</td>
<td>0.145</td>
<td>0.135</td>
<td>0.002</td>
<td>0.008</td>
</tr>
<tr>
<td>Binary Tree</td>
<td>0.164</td>
<td>0.133</td>
<td>0.010</td>
<td>0.0208</td>
</tr>
<tr>
<td>Sorted Vector</td>
<td>1.563</td>
<td>0.024</td>
<td>0.006</td>
<td>1.534</td>
</tr>
</tbody>
</table>

Why are there such discrepancies??

Bottom line:
- Some structures carry more *information* simply because of their design.
- Manipulating structures takes time
Where to from here?
CS Core

- CS 106B: Programming Abstractions
- CS 107: Computer Organization and Systems
- CS 110: Principles of Computer Systems
- CS 103: Mathematical Foundations of Computing
- CS 109: Introduction to Probability for Computer Scientists
- CS 161: Design and Analysis of Algorithms
CS 106B
Programming Abstractions

CS 107
Computer Organization and Systems

CS 109
Introduction to Probability for Computer Scientists

CS 103
Mathematical Foundations of Computing

CS 110
Principles of Computer Systems

CS 161
Design and Analysis of Algorithms

CS Core
Can computers solve all problems?

**Spoiler alert: no!**

Why are some problems harder than others?

We can do find in an unsorted array in $O(N)$, and we can sort an unsorted array in $O(N \log N)$. Is sorting just inherently a harder problem, or are there better $O(N)$ sorting algorithm yet to be discovered?

**How can we be certain about this?**
How do we encode text, numbers, programs, etc. using just 0s and 1s?

Where does memory come from? How is it managed?

How do compilers, debuggers, etc. work?
In April 2014, security experts warned that users of thousands of major websites needed to change their passwords due to potential exposure caused by the "Heartbleed" vulnerability.

- Heartbleed exploited a buffer overrun bug in OpenSSL. SSL is the layer that secures web interactions, i.e., it’s what make the “s” in “http[s]://” mean something.
“heartbeat”
Are you still there? If you are, repeat this word back to me: "hello" [0x0005 bytes].
Each char is one byte, so 5 letters

Unfortunately, the software also let you send messages like this:
Are you still there? If you are, repeat this word back to me: "hello" [0xFFFF bytes].
That’s 65535 bytes—much more than the length of “hello”!
CS107 is not a litmus test for whether you can be a computer scientist.

You can be a great computer scientist without enjoying low-level systems programming.

CS107 is not indicative of what programming is “really like.”

CS107 does a lot of low-level programming. You don't have to do low-level programming to be a good computer scientist.
False Narrative

Fun

Effort

CS106A
False Narrative

Effort

Fun

CS106A

CS106B
False Narrative

Diagram:
- CS106A
- CS106B
- CS107

Axes:
- Effort
- Fun
False Narrative

Effort vs. Fun

CS106A

CS106B

CS107
False Narrative

- CS106A
- CS106B
- CS107

Axes:
- Effort
- Fun
False Narrative

- CS106A
- HCI
- Graphics
- CS106B
- Hum Bio
- AI
- CS107
- Systems

Effort

Fun
CS109

Foundations of probability

Narrative driven

Intro to Machine Learning
Other CS Courses
CS9

- 1 unit, 1 meeting per week, little to no outside work

- Prereq: 106B/X

- Practice **real** job interview questions

  - Additional topics such as resume polish, negotiating once you have multiple offers, differences between roles (Project Management vs Developer vs Test Engineer)

  - **Special guests from industry!**

  - Taught by Cynthia Lee, Keith Schwarz

  - Offered each autumn quarter
Modern ethics:

- Edward Snowden reveals that NSA knows more about you than your parents do
- GamerGate: about harassing women, or about ethics in game journalism?
- How should AirBnB be taxed?
- The password to launch the US nuclear arsenal was 00000000
- Autonomous cars. How to value human life?

*We have the power to control and create technology, but how should we use it?*
Current Efforts - Google

GFE = Google Front End Server
SSL Added and removed here!
Traffic in clear text here.
**How do you build large software systems in a team?**

Introduction to things you need to know for work in the “real world”:

- Unit-testing frameworks
- Object-oriented design
- Multithreaded applications
- Databases and web applications
- Source control
Options Besides the CS Major

- **CS Minor: only 5 more classes!**
  - 103, 107, 109, two your choice—fun!

- **CS Coterminal MS degree**
  - Earn an MS in CS while you are here earning your BS
  - Possible for CS majors and other majors
    - ex: Math major, CS co-term
CS Major

Project

Biocomputation

AI

Graphics

System

HCI

Information
Back to Chris Piech
Some may think:

Computer science is vocational
Some may think:

Computer science is vocational

Computer science is foundational
The great ideas are foundational

Just like you learn about the digestive system, photosynthesis, or electricity.
CS is the #1 source of new jobs in the US

500,000 current openings: These jobs are in every industry and every state, and they’re projected to grow at twice the rate of all other jobs.

Source: Brookings Institute via Code.org
Technology Affects Every Field
Just This Week

Haiyan Zhang

https://www.youtube.com/watch?v=R6rAlFYDfQ
Requests for Research

It's easy to get started in deep learning, with many resources to learn the latest techniques. But it's harder to know what problems are worth working on.

We have published a living collection of important and fascinating problems to help you get started.
More Just This Week

Launches Universe

Lauches DeepMind Lab

Both are platforms for people to build general A.I.
CS for Social Good
Time and Place
Everyone is Welcome

And not only is everyone welcome, we need many perspectives.
Thank You
Congrats (in advance)