Lecture 1: Introduction

CS105: Great Insights in Computer Science
Michael L. Littman, Fall 2006

Welcome!

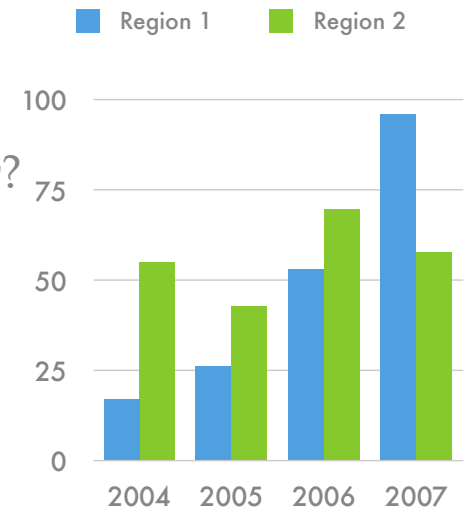
- CS105, taught last semester as "Topics in Computer Science", but is now officially "Great Insights in Computer Science".
- Several innovations this semester:
  - Using Rutgers' online course support
  - iClickers for in-class interaction
  - Programs for out-of-class interaction

Survey

- Do you have a clicker?

  A. no

  B. yes



About Me

- 1996: PhD, "Algorithms for Sequential Decision Making" (AI).
- 1996-1999: Professor at Duke.
- 2000-2002: (Back) to NJ, AT&T Labs Research.
- 2002–: Rutgers: heading "Rutgers Laboratory for Real-Life Reinforcement Learning" (RL^3).

Michael Littman and his "dog" are working together to unlock secrets of intelligence. Littman, whose research may have defense applications, uses the dog to figure out how machines can make decisions toward a goal. Photo by Nick Romanenko, Rutgers University.

My Course Goals

- Cool facts, cool ideas. Ideas are "how to" facts. Shoot for one or two per lecture.
- People (my parents, say), don't understand how I have a PhD in CS and can't help them when their Windows box crashes.
- If it's not about XP, what else ***is*** there?

  - That's what I want to tell you...

Introduction to CS101s

- Target audience: Undergrads, as a first (possibly only) computer-science course.

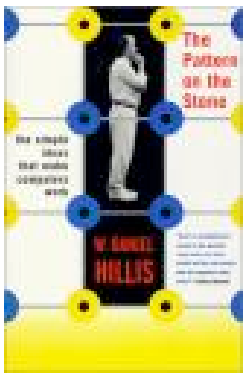
- *Seminar in Computers and Society*: What impact have computers had on the world?
- *Introduction to Computer Science*: How do I learn to create my own software?
- *Introduction to Computers and Their Application*: What do I need to know about computing technology?

Course Goals: Questions

- What is Computer Science?
- Why is it fun/interesting?
- How is it different from software engineering?
- What are the insights that make computer science its own academic discipline?

Textbook

- Not too daunting or detailed.
- Inspiring and informative.
- *Pattern on the Stone, the simple ideas that make computers work*, Danny Hillis, Basic Books, 1998.
- Enjoyable to read; not really a textbook at all.
- I will add meat to the wonderful skeleton he creates.



Clickers

- Available at several bookstores.
- Can keep them (most popular clicker at Rutgers) or sell them back.
- We'll use them for attendence, reading comprehension quizzes, straw polls.
- Hope to eventually add interactive demos, but software not yet ready.

i>clicker

http://www.iclicker.com/

Syllabus: Top-level View

Organizing the material into three major sections:

I. How does a computer work?

II. What do we know about computation?

III. What cool things are computers doing?

I. How Computers Work

- Sequence of easy-to-understand layers.
- Top: high-level programming languages express ideas in a computer-friendly form.
- Bottom: bits and logic gates, computer's work done by physical components.
- We'll go bottom up, conceptually creating a working computer in the process.

II. Computation

- Computers compute. But, what is computation, and how powerful is it?
- How do computer scientists see the world in terms of computational problems?
- What's an algorithm, why might one be preferred to another if they solve the same problem?
- What problems can be solved and how fast?

III. Useful Applications

We'll survey how computing power is being harnessed.

- machine learning, pattern recognition
- computer graphics
- AI search
- language games
- robotics
- genetic algorithms
- data compression

They Are Everywhere!

1977: "There is no reason for any individual to have a computer in his home."

- Today: Cell phone? PDA? Computers at home? Laptop? Video games? Digital camera?

Survey

- How many computers are with you right now? Laptop, handheld game, cell phone, GPS device, PDA, mp3 player, ...

A. 0

B. 1

C. 2

D. 3

E. 4 or more

Previously Unthinkable

Google™

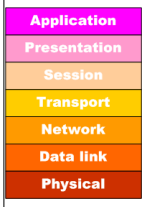
Life After Death?

One-Word Summary

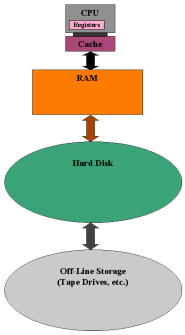
- If I had to summarize the intellectual contribution of computer science in one word, it would be "**reduction**".
- Computer scientists solve problems by reducing them to simpler problems.
- We'll see this same idea played out over and over again in different settings...

Levels of Complexity

- **Networking** (OSI Layers): application, presentation, session, transport, network, data link, physical.



- **Computing**: application, high-level language, machine language, logic blocks, logic gates, physical.
- **Vision** (Marr): computational, algorithmic, implementation.
- **Storage hierarchy**: offline-storage, hard disk, RAM, cache, registers.



Today's Idea

- I will start with the textbook next time, introducing bits and some simple gates.
- Please read the Preface and Chapter 1, Section 1.
- But, I want to give you something to chew on to get those gears turning...

Your Choice

- Babbage's Difference Engine
  - Simple computation for sequences
- How do UPC barcodes work?
  - Hierarchy of codes

A. Difference Engine

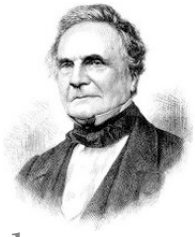
B. UPC barcodes

Charles Babbage: Facts

- Charles Babbage lived in England in the 1800s. A polymath, he solved problems from Astronomy to Zoology.

- **Invented**: cowcatcher, flat-rate postage, Operations Research, standard RR gauge.
- Held Newton's chair at Cambridge, but spent his last years railing against organ grinders.
- His design for the *analytical engine* presaged much of the design of modern digital computers.

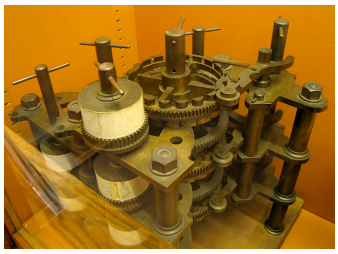
The Difference Engine



- Originally a "computer" was a job description of a person who created numerical tables. Useful, if tedious.
- Babbage had a scheme to automate table creation using "finite differences".
- 25,000 parts, 15 tons, 8 feet high, never built!
- His redesigned Difference Engine No. 2 was built in 1990 and actually worked!

Difference Engine: Ideas

Let's play a game:



- 0,1,2,3,4,__?
- 3,5,7,9,11,__?
- 1,4,9,16,25,__?
- 1,3,6,10,15,__?

Generating the Evens

2→4→6→8→10→12

2 2 2 2 2

Instructions:
1. Start with **2**.
2. To get the next one, add **2** to the previous one.

Generating Squares

1→4→9→16→25→36

3→5→7→9→11

2 2 2 2

Instructions:
1. Start with **1**.
2. Start the increment with **3**.
3. To get the next one, add the increment.
4. To get the next increment, add **2** to the previous one.

Naming The Sequences

2→4→6→8→10→12

2 2 2 2 2

The Evens

Sequence: 1,4, 9, 16, 25, 36, …

1→4→9→16→25→36

Program: 1,3,2

3→5→7→9→11

2 2 2 2 2

The Squares

Programming the "DE"

- So, to produce the Evens, we enter "2 2" into the Difference Engine and turn the crank.
- The Squares are "1 3 2".
- The Triangle numbers are "1 2 1".
- Try:
  - Odds?
  - Count by 5s?
  - Cubes?
- What do these do:
  - "4"?
  - "10 -1"?
  - "100 -19 2"?
  - "0 1 2 1"?

CS in a Microcosm?

- Get a feel for programming: need to figure out how to say what you want to say in a way the machine understands.
- Simple operation (repeated addition) used to build up more complex objects.

More Advanced Stuff

- Each difference sequence corresponds to a polynomial and vice versa. Why? What is the relationship between the length of the difference sequence and the degree of the polynomial?
- Can match any finite-length sequence. How long might the difference sequence need to be?
- You can start a sequence at any point by starting with the corresponding column. How can a sequence be moved backward automatically?
- Download "Python" and play with it yourself!
  http://www.cs.rutgers.edu/~mlittman/courses/cs442-06/python/differences.py

Bar Codes

- See http://en.wikipedia.org/wiki/Barcode .
- Many different styles of barcodes.
- Most common is UPC-A, in use in most North American retail stores.
- I will describe the UPC encoding.
- Many of the same ideas apply to other codes: checks, photostamps, IR remotes

Universal Product Codes

- First scanned product, Wrigley's gun (1974).
- Method of identifying products at point of sale by 11-digit numbers.
- Method of encoding digit sequences so they can be read quickly and easily by machine.

Reduction Idea

- Each level uses an **encoding** to translate to the next level.
  - Patterns of ink.
  - Sequence of 95 zeros and ones.
  - Sequence of 12 digits.
  - Sequence of 11 digits.
  - Name of a retail product.

Product Name

- Ponds Dry Skin Cream
  - 3.9 oz (110g)
  - Unilever Home and Personal Care USA
- Name Badge Labels (Size 2 3/16" x 3 3/8")
  - 100 Labels
  - Avery Dennison/Avery Division

11-Digit Number

- Digit = {0,1,2,3,4,5,6,7,8,9}
- Sequence of 11 digits
- How many different items can they encode?

A. 10,000,000,000

B. 100,000,000,000

C. 9,999,999,999

D. 19,999,999,999

Encode Name By 11 Digits

- First 6 digits: Manufacturer
  - First digit, product category:
    - 0, 1, 6, 7, 8, or 9: most products
    - 2: store's use, for variable-weight items
    - 3: drugs by National Drug Code number
- Last 5 digits: Manufacturer-assigned ID

Examples

- Labels: 0-72782-051440
  - 0=general product
  - 72782= Avery
  - 051440=Avery's code for this product
- Ponds: 3-05210-04300
  - 3=drug code
  - 05210= Unilever
  - 04300=National Drug Code for this product

12-Digit Number

- The UPC folks decided to include another digit for error checking. Example:
  - 01660000070 Roses Lime Juice (12 oz)
  - 04660000070 Eckrich Franks, Jumbo (16 oz)
  - 05660000070 Reese PB/Choc Egg (34 g)
  - 08660000070 Bumble Bee Salmon (14.75 OZ)
- Misread digit #2 and you turn sweet to sour.

Check Digit

1. Add the digits in the odd-numbered positions (first, third, fifth, etc.) together and multiply by three.
2. Add the digits in the even-numbered positions (second, fourth, sixth, etc.) to the result.
3. Subtract the result from the next-higher multiple of ten. The result is the check digit.

Code and Example

```
def checkDigit(d1,d2,d3,d4,d5,d6,d7,d8,d9,d10,d11):
    step1 = (d1+d3+d5+d7+d9+d11)*3
    step2 = step1+d2+d4+d6+d8+d10
    step3 = (-step2)%10
    return step3
```

01660000070

odd-digit sum: 0+6+0+0+0+0=6
even-digit sum: 1+6+0+0+7=14
odd*3+even = 6*3+14=32
subtract from mult of 10=40-32=8

- Lime juice: 01660000070→016600000708
- Franks: 04660000070→046600000705
- Choc Egg: 05660000070→056600000704
- Salmon: 08660000070→086600000701

all are two digits different now

Bits

- We've gone from a product name to an 11-digit number to a 12-digit number. Next: bits.
- abcdefghijkl→101abcdef01010ghijkl101

Last 6 digits have 0s and 1s reversed!

Digits encoded as 7-bit patterns, chosen to be:

- as different as possible
- start with 0, end with 1
- switch from 0 to 1 twice
- no more than 4 of the same bit in a row

0: 0001101	5: 0110001
1: 0011001	6: 0101111
2: 0010011	7: 0111011
3: 0111101	8: 0110111
4: 0100011	9: 0001011

How Many Bits?

- From our 12-digit number, how many bits (zeros and ones) long is the code now?

A. 84

B. 95

C. 100

D. 23

E. 12

Finally, Ink!

- Given the long pattern of bits, we write a 1 as a bar and a zero as a space.
- Two 1s in a row become a double wide bar.
- Two 0s in a row become a double wide space.
- Never have more than 4 in a row.
- Starts and ends with bars.

Example

- Barcode for skin cream:
- 3-05210-04300-8 (8 is the check digit)

  start: 101; 3: 0111101

  05210: 0001101-0110001-0010011-0011001-0001101

  middle: 01010

  04300: 1110010-1011100-1000010-1110010-1110010 (rev)

  8: 1001000 (rev); end: 101
- The digits underneath are for our benefit.

Close Up

Summary

- Product name turned to 11-digit code
- 11-digit code extended to 12 digits by adding a check digit
- 12 digits become a 95-bit sequence
- 95 bits are drawn in ink 1=black,0=white

Reverse the process to get the product!

Next Time

- Get iClicker
- Read Hillis: Preface and Chapter 1, up to and including “Boolean Logic”.
- We’ll have a brief iClicker quiz on the material.