Class 1: Introduction

CS150 Spring 2009
University of Virginia
Computer Science

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http://www.cs.virginia.edu/cs150

What is *Computer Science*?
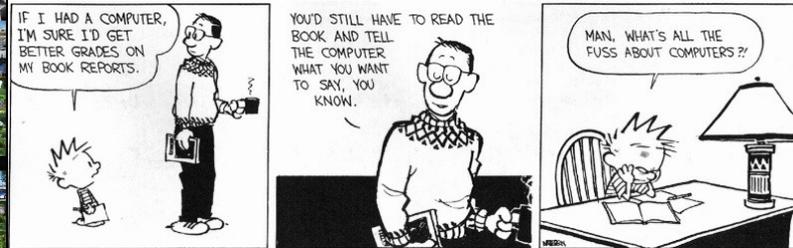
Let *AB* and *CD* be the two given numbers not relatively prime. It is required to find the greatest common measure of *AB* and *CD*.

If now *CD* measures *AB*, since it also measures itself, then *CD* is a common measure of *CD* and *AB*. And it is manifest that it is also the greatest, for no greater number than *CD* measures *CD*.

Euclid's Elements, Book VII, Proposition 2 (300BC)

The note on the *inflected* line is only difficult to you, *because it is so easy*. There is in fact nothing in it, but you think there must be some grand mystery hidden under that word *inflected*!

Whenever from any point *without* a given line, you draw along to any point *in* the given line, you have *inflected* a line *upon a given line*.

Ada Byron (age 19), letter to Annabella Acheson (explaining Euclid), 1834

By the word operation, we mean any process which alters the mutual relation of two or more things, be this relation of what kind it may. This is the most general definition, and would include all subjects in the universe... Supposing, for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expression and adaptations, the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent.
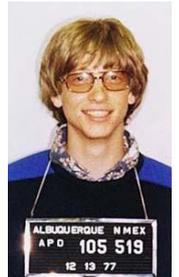
Ada Byron, 1843

I ask you: What's the difference between Euclid and Ada?

I have no idea what you're talking about when you say the word "ask".

Bill Gates (deposition at Microsoft's anti-trust trial)

Today's Class

- Ada and Euclid
- Engineering and Science
- Moore's Law and Computing Power
- The Liberal Arts
- Course Expectations
- Recursive Definitions and Languages
- Nuclear Weapons
- Formal Languages and Systems

Geometry vs. Computer Science

- Geometry (mathematics) is about *declarative* knowledge: "what is"

  If now *CD* measures *AB*, since it also measures itself, then *CD* **is** a common measure of *CD* and *AB*

- ~~Computer Science~~ is about *imperative* knowledge: "how to"

  > Computer Science has little to do with beige (or spiffy black) boxes called "computers" and is not a real science.

Computer Science

"How to" knowledge:

- Ways of describing information processes (computations)

  Language

- Ways of predicting properties of information processes

  Logic

Science, Engineering or Other?

Science?

- **Science** involves understanding nature through observation
  - About *real* things like bowling balls, black holes, antimatter, electrons, comets, etc.
- Math and Computer Science are about *fake* things like numbers, graphs, functions, lists, etc.
  - Computer Science is a useful tool for *doing* real science, but is not a real science

Engineering?

"**Engineering** is **design under constraint**… Engineering is synthetic - it strives to create what can be, but it is constrained by nature, by cost, by concerns of safety, reliability, environmental impact, manufacturability, maintainability and many other such 'ilities.' ..."

William Wulf and George Fisher, 2002

Liberal Arts Trivia: Music

- Q. What is the name of a musical scale with twelve pitches, each a semitone or half step apart? Such a scale is nondiatonic, consisting entirely of half-step intervals and having no tonic due to the symmetry or equal spacing of its tone.

Liberal Arts Trivia: Psychology

Say the *color* each word is printed in:

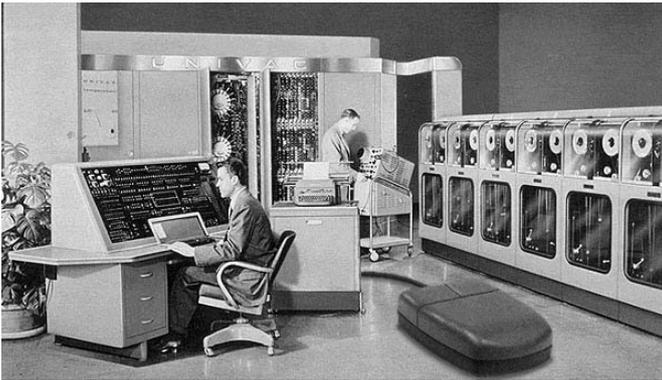Green Red Blue

Purple Blue Purple

Blue Purple Red

Green Purple Green

Q. Name the effect that refers to the fact that naming the color of the first group of words is easier and quicker than the second.

Let's Start With Classic Computers

Apollo Guidance Computer, 1969

1 Cubic Foot   Why did they need to fit the guidance computer in the rocket?

Measuring Computers

- 1 **bit** = smallest unit of information
  - True or False
  - 0 or 1
  - If we start with 2 possible choices, and get 1 bit, we can eliminate one of the choices

How much power?

- Apollo Computer: 61440 bits of changeable memory
- Lab machines have 1 GB (RAM)
  - 1 Gigabyte = 1024 Megabytes,
    1 Megabyte = 1024 Kilobytes,
    1 Kilobyte = 1024 Bytes,
    1 Byte = 8 bits

> You will understand this notation soon…but don't worry if you don't now

> (* 1024 1024 1024 8)

8589934592   ~ 8.6 Billion bits
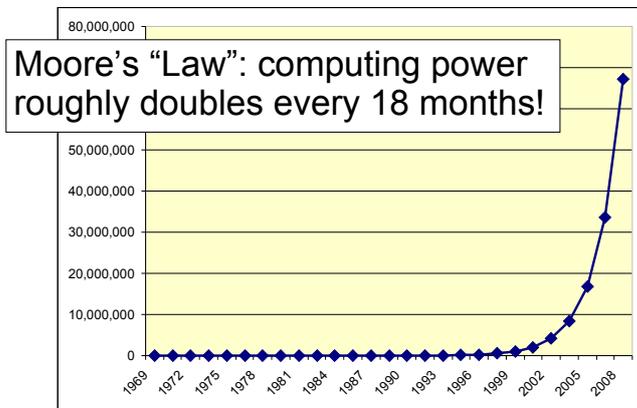
> (round (/ (* 1024 1024 1024 8) 61440))

139810   You have 139 810 times more power than AGC

If Apollo Guidance Computer power is 1 inch, you have 2.2 miles!

Computing Power 1969-present (in Apollo Control Computer Units)

Moore's "Law": computing power roughly doubles every 18 months!

Constraints Computer Scientists Face

- Not like those for engineers:
  - Cost, weight, physics, etc.
  - If today's ~20 Million times what people had in 1969 isn't enough for you, wait until 2011 and you will have ~80 Million times…
- More like those for Musicians and Poets:
  - Imagination and Creativity
  - Complexity of what we can understand

So, what is computer science?

- ~~Science~~
  - No: it's about fake things like numbers, not about observing and understanding nature
- ~~Engineering~~
  - No: we don't have to deal with engineering-type constraints
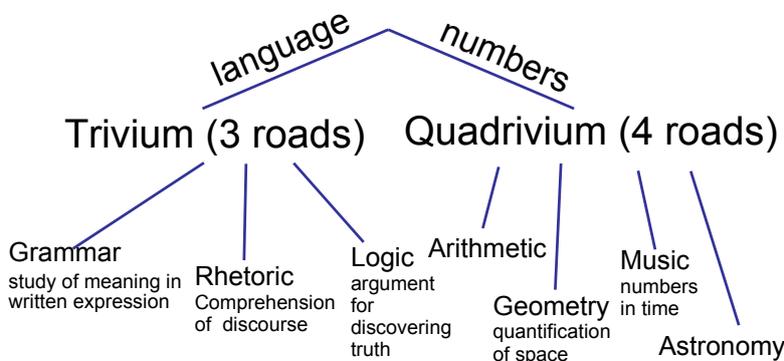- Liberal Art

Liberal Arts: ~1100 AD

- **Illiberal Arts**
  - arts for the non-free: pursued for economic reasons
- **Liberal Arts**
  - arts for the *free*: pursued for intrinsic reasons

The Liberal Arts

language   numbers

Trivium (3 roads)   Quadrivium (4 roads)

Grammar
study of meaning in
written expression

Rhetoric
Comprehension
of discourse

Logic
argument
for
discovering
truth

Arithmetic

Geometry
quantification
of space

Music
numbers
in time

Astronomy

We will see all of these in this class!

Course Expectations

Course Roadmap

Computer Science
from Euclid and Ada
} 1 Class

to
} PS 1-6

Quantum Computing
} Lecture

and

the World Wide Web
} PS 7-9

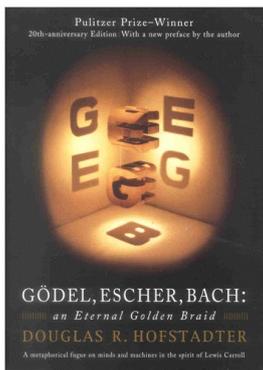Liberal Arts (Intellectual) Illiberal Arts ($$$$)

Like Drinking from a Firehose

Don't be overwhelmed!
You will do fine.

It may hurt a little bit, and a lot of water will go by you, but you won't go away thirsty!

Books

GÖDEL, ESCHER, BACH:
an Eternal Golden Braid
DOUGLAS R. HOFSTADTER

"GEB"

Computational Thinking
A Whirlwind Introduction
to the Third Millennial Liberal Art
from Ada and Euclid
to Quantum Computing
and the World Wide Web

A new book written for this course by
Professor David Evans (UVA)

Bonuses for helping us improve it:
- Less pretentious title (?)
- More exciting cover
- Notice any mistakes
- Improve the writing or presentation

"Course Book"

Help Available

- Me: Westley Weimer (call me "Wes")
  - Office Hours will be posted (after your surveys)
  - Always available via email and **forum**, if I don't reply in 24 hours, send again and complain
- Teaching Assistants: Zak Fry, Paul DiOrio, ???
  - **Structured lab hours** in OLS 001. W 7-8, W 8-9
  - Staffed lab hours in Small Hall
  - Officse hours TBA (after your surveys)
- Web site: **http://www.cs.virginia.edu/cs150**
  - *Everything* goes on the web, you should visit it often
- **Your classmates** (read the course pledge carefully!)

What I Expect of You

1. Everything on the Course Pledge
   - You should actually **read it** not just sign it (you will lose points on the problem sets if your submission reveals that you didn't read it!)

2. You are a "Jeffersonian Student"

   1. Believe knowledge is powerful
   2. Interested in lots of things, ahead of your time
   3. Want to use what you learn to do good things
   4. Care more about what you learn than grades and degree requirements
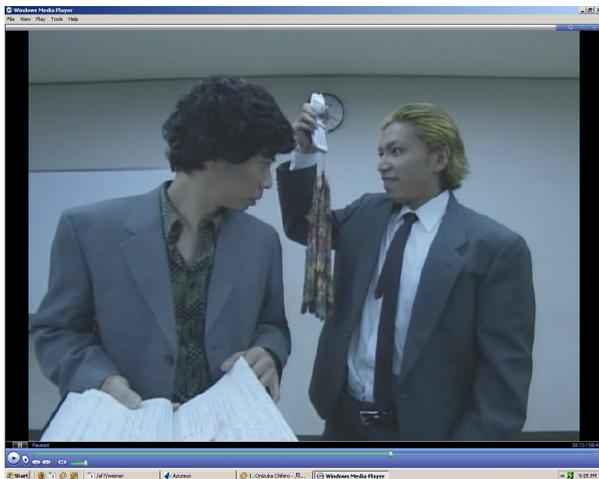

Background Expected

- Language:
  - Reasonable reading and writing in English
  - Understanding of subject, verb and object
- Math:
  - Numbers, add, subtract, multiply, divide
  - Exponentiation, logarithms (we will review)
- Logic: *and, or, not*
- Computer Literacy: read email, browse web
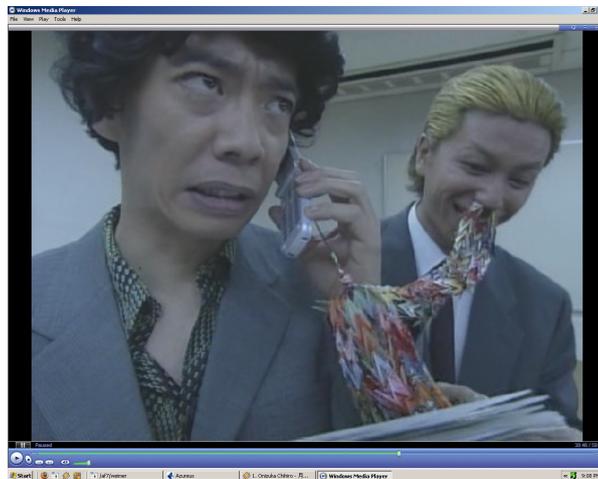
If I ever appear to expect anything else, stop me!

Many of you have fancy phones

No ringing: you will look foolish

A Course for Everyone!

- CLAS, SEAS, Commerce, Arch, etc.
- 1st, 2nd, 3rd, 4th, 5th Years, Community Scholars, Faculty
- No background expected … but challenging even for students with lots of previous CS courses
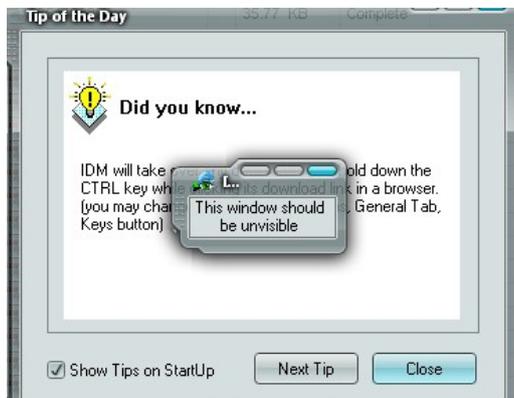- Computer Science (future-) majors … but worthwhile even if you don't take another CS course

First Assignment

- Read Course Book Chapters 1-3 **by tomorrow**
- Problem Set 0 ("Managing Mars with Automatic Adjudication") is due **Midnight this Thursday**
  - It is very short
- Due before CLAS drop deadline
  - If the class is too crowded for you, or if you *can't make the structured office hours* (W 7-8 or 8-9), or if PS0 is too confusing, drop CS150 now and take it later
  - If you are in the class now and you drop it now but plan to take it later, I will write you a note to skip you past the waitlist later

First Main Theme:
Recursive Definitions

Tip of the Day

Did you know…

IDM will ... old down the
CTRL key whi ... its download link in a browser.
(you may cha ... , General Tab,
Keys button)

This window should
be unvisible

☑ Show Tips on StartUp   Next Tip   Close

What is the longest word in the English language?

Can you think of one longer than "**boustrophedon**" ?
From Greek βουστροφηδόν ("ox-turning"—that is, turning like oxen in ploughing), it is an ancient way of writing manuscripts and other inscriptions.
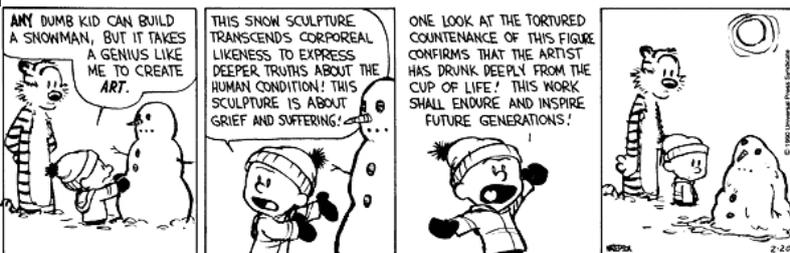
Ancient Greek boustrophedon inscription, Gortyn code, Crete, 5th c. B.C

According to Guinness

floccipoccinihilipilification

the act of rendering useless

Making Longer Words

antifloccipoccinihilipilification
the act of rendering not useless

antiantifloccipoccinihilipilification
the act of rendering   useless

Language is *Recursive*

No matter what word you think is the longest word, I can always make up a longer one!

word ::= **anti-*word***

If you have a word, you can always make up a new word by adding **anti** in front. Since the result is a word, you can make a longer new word by adding **anti-** in front again.

Recursive Definitions

- We can define things in terms of *(smaller versions of)* themselves
- **Recursive definitions** are different from circular definitions: they eventually end with something real

word ::= **anti-*word***

word ::= **floccipoccinihilipilification**

Recursive Definitions

Allow us to express infinitely many things starting with a few.

This is powerful!
We will see **lots** of examples in this course.

Liberal Arts Trivia: Astronomy

- Q. What is the name given to highly magnetized rotating neutron stars that emit a beam of electromagnetic radiation? The radiation can only be observed when the beam of emission is pointing towards the Earth, yielding a "lighthouse effect".

Liberal Arts Trivia: Literature

- Q. This French author's works touched on topics such as solidarity, the absurd, and totalitarianism. His works include L'Étranger, L'Homme révolté, and Caligula. In 1957 he became the second-youngest recipient of the Nobel Prize for Literature and the first African-born writer to win it.

Megabytes vs. Megatons

- A brief diversion back to Moore's Law
- Computing: 30,000,000 times increase in power since 1969
- Nuclear weapons?

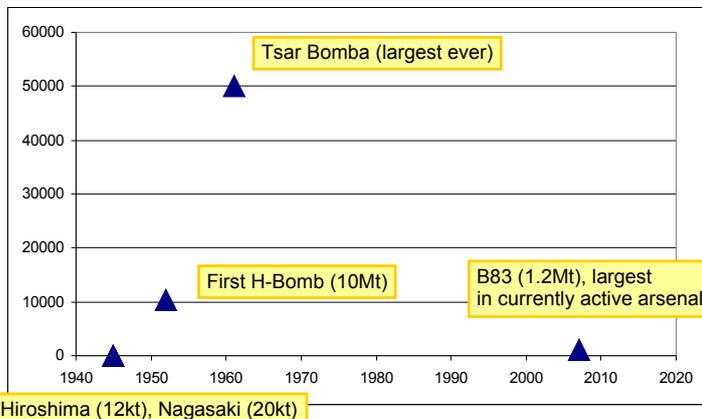Tsar Bomba 50 Megaton explosion, island in Arctic Sea, 1961

If Nuclear Weapons followed Moore's Law...

- 30M * 50 Megatons = 1.5 Teratons
- 1 Megaton TNT   = $4.184 * 10^{15}$ Joules
- 1.5 Teratons TNT   = $6.3 * 10^{21}$ Joules
- Energy from Sun to Earth

$$= 4 \times 10^{18} \text{ Joules/ Year}$$

- One bomb today would equal all the energy to reach the Earth from the Sun since 400 AD

Actual Nuclear Weapons

Tsar Bomba (largest ever)

First H-Bomb (10Mt)

B83 (1.2Mt), largest in currently active arsenal

Hiroshima (12kt), Nagasaki (20kt)

If it takes 60 seconds to compute a photomosaic for Problem Set 1 today on a typical PC, estimate how long it will take CS150 students in 2012 to compute the same photomosaic? How long will it take in 2015?

```
> (/ (* (- 2012 2009) 12) 18)
2
> (/ 60 (* 2 2))
15
> (/ (* (- 2015 2009) 12) 18)
4
> (/ 60 (* 2 2 2 2))
15/4
> (exact->inexact (/ 60 (* 2 2 2 2)))
3.75
```

Difference in years * 12 = number of months
Number of months / 18 = number of doublings
   according to Moore's Law

60 seconds today, 2 doublings by 2012
15 seconds in 2012

Reality check: Moore's "law" is just an "observation". We'll see one reason later today why it won't continue forever.

60 seconds today, 4 doublings by 2015
3.75 seconds in 2015

MU!

Formal
Systems
and
Languages

Are there any non-recursive natural languages? What would happen to a society that spoke one?

Not for humans at least.
They would run out of original things to say.

Chimps and Dolphins are able to learn non-recursive "languages" (some linguists argue they are not really "languages"), but **only humans can learn recursive languages** (as far as we know).

Running out of Ideas

"It has all been said before."

Eventually true for a non-recursive language.

Never true for a non-trivial recursive language.
There is always something original left to say!

Production Systems

• A **Post Production System** is one way of defining a language.

• Set of symbols
  – *Primitives*

• Set of rules for manipulating symbols
  – Hofstadter: Rules of Production, Rules of Inference
  – Also: Rules of Combination

The MIU System

• Symbols: M, I, U
• Rules of Production:
  – **Rule I:** If you have a string ending in I, you can add a U at the end.
  – **Rule II:** Suppose you have Mx. Then you may add Mxx to your collection.
  – **Rule III:** If III occurs in one of the strings in your collection you may make a new string with U in place of III.
  – **Rule IV:** If UU occurs inside one of your strings, you can drop it.

MIU System Example
Start with MUI, produce MIU

Rules of Production:
  Rule I: If you have a string ending in I, you can add a U at the end.
  Rule II: Suppose you have Mx. Then you may add Mxx to your collection.
  Rule III: If III occurs in one of the strings in your collection you may make a new string with U in place of III.
  Rule IV: If UU occurs inside one of your strings, you can drop it.

Any Questions?

- Read Chapters 1-3 for next class
- PS0 due Thursday at midnight!
  - Read lab guide before structured office hours tomorrow ...

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