The *end* of CS?!

- Final homework (*projects*) due Monday, 6/26
- Hours tonight, Sunday evening, & Mon. evening!

Also...!

**CS 60?**  
2-3 languages

**CS 35?**  
1 language...
2-3 languages

Racket

(\(define\) \(\text{whoami} n\))
\[
(\text{if} \ (= n 0) \ 1 \ (*\ n (\text{whoami} (- n 1))))
\]

Java

\[
\text{public static int whoami(int n)}\n\{\n\quad \text{if} \ (n<2) \ \text{return} \ 1;\n\quad \text{else return} \ n * \ \text{whoami}(n-1);\n\}\n\]

Prolog

\[
\text{whoami}(0,1). \quad \text{whoami}(\text{N},\text{F}) : - \ \text{N1 is N-1,} \quad \text{whoami(N1,F1), F is N*F1.}
\]
CS 35?    Same as CS5    2 x the work    Much harder

8-10 libraries

Jinja

Welcome
Jinja is a full featured template engine for Python. It has full unicode support, an optional integrated sandbox execution environment, widely used and BSD licensed.
Jinja is Beautiful

matplotlib

Introduction
matplotlib is a python 2D plotting library which produces publication quality figures in a variety of hardcopy formats and interactive environments across platforms. matplotlib can be used in python scripts, the python and python shell (aka MATLAB® or Mathematica®), web application servers, and as graphical user interface toolkits.

scikit-learn

Machine Learning in Python

- Simple and efficient tools for data mining and data analysis
- Accessible to everybody, and reusable in various contexts
- Built on NumPy, SciPy, and matplotlib
- Open source, commercially usable - BSD license

Natural Language Toolkit

NLTK is a leading platform for building Python programs to work with human language data.

VPython

3D Programming for Ordinary Mortals
The CS view of the world...

Input → Algorithm → Output

CS's challenge
Final project state machine

- It's broken
  - Stop adding features + start adding print statements
  - Still broken
- It works
  - Comment out print statements + start adding more features
  - Still works
- Store a copy somewhere else!
State-machine *limits*?

Let's build a FSM that accepts strings with *any* # of 0s followed by the *same* # of 1s.

You don't need three eyes to see some problems here!

Let's build a FSM that accepts strings with *any* # of 0s followed by the *same* # of 1s.

**FSMs "can't count"**

at least, not arbitrarily high

rejected
011
001
11100
00110

accepted
000111
0011
01
λ
FSMs can't count...

So, let's build a better machine!

Turing Machine
a Turing Machine rule:

0; 1, R

READ  WRITE  MOTION

try it in JFLAP...
a Turing Machine rule:

```
0 ; 1 , R
```

READ WRITE MOTION

try it in JFLAP...

if a transition is missing, the input FAILS!

Accepted Input!
a Turing Machine rule:

\[ 0 \; ; \; 1 \; , \; R \]

READ  WRITE  MOTION

an accepting state _always halts_ -- then basks in its success!

if a transition is missing, the input FAILS!

try it in JFLAP...
a Turing Machine rule:

```
0 ; 1 , R
```

READ  WRITE  MOTION

if it gets here, it succeeds.

if a transition is missing, the input FAILS!

What happens here?

try it in JFLAP...
a Turing Machine rule:

0 ; 1 , R

READ  WRITE  MOTION

an accepting state **always halts** -- then basks in its success!

if a transition is missing, the input FAILS!

"blanks" are everywhere else

try it in JFLAP...
CS 5 spokesperson of the day!

I want a 1950's network!
Can TMs compute everything?

Alan Turing says yes...

Turing called them Logical Computing Machines

Turing’s Intelligent Machines, 1948

http://www.alanturing.net/turing_archive/archive/l/l32/L32-005.html
So far, all known computational devices can compute only what Turing Machines can...
Alan Turing
1912-1954

Enigma machine ~ The axis’s encryption engine

WWII
1946

Bletchley Park
2007

AI!
Alan Turing
1912-1954

Father of Computer Science
Mathematician, Logician
Wartime Codebreaker
Victim of Prejudice

"Mathematics, rightly viewed, possesses not only truth, but supreme beauty, a beauty cold and austere, like that of sculpture." — Bertrand Russell
2012: Turing Celebration

http://aturingmachine.com/examplesSub.php

https://www.youtube.com/watch?v=aBToqFJLrl4
What inputs are accepted in general?

Extra: How could you change this TM to accept palindromes?

(thought experiment and ex. cr.)
What inputs are accepted in general?

Extra: How could you change this TM to accept palindromes?

(Thought experiment and ex. cr.)

What does one "loop" of (q0-q1-q2-q3-q0) do?

Is this input accepted or rejected by this TM?

What inputs are accepted in general?
Turing-Machine *machines*!
Uncomputable functions

Sometimes an algorithm simply does *not* exist...

*more precisely:* every possible algorithm contains bugs!
Halting problem

From Wikipedia, the free encyclopedia

In computability theory, the halting problem can be stated as follows: Given a description of a computer program, decide whether the program finishes running or continues to run forever. This is equivalent to the problem of deciding, given a program and an input, whether the program will eventually halt when run with that input, or will run forever.

Alan Turing proved in 1936 that a general algorithm to solve the halting problem for all possible program-input pairs cannot exist. A key part of the proof was a mathematical definition of a computer and program, what became known as a Turing machine; the
original iPhone icon for Maps
the iPhone's icon for Google Maps …

CS tourism!
the iPhone's icon for Google Maps …

CS tourism!
CS tourism!
CS tourism!
CS tourism!
CS tourism!
More CS tourism...

(Google)
Meaningful functions?

Input \rightarrow \text{Algorithm} \rightarrow \text{Output}

but nearly all \textit{meaningful} functions \textit{are} computable...
CS 5's examples...

Input → Algorithm → Output

- Connect 4 Board
- Input text
- current gener. of “life” cells
- intelligent move
- Markov model + new text
- next gener. of “life” cells
CS 5's examples...

Input → Algorithm → Output

Connect 4 Board

Input

next gener. of “life” cells

intelligent move

Markov model

+ new text

balance of utility & creativity & aesthetics?
Mandelbrot Vistas!
"Science without religion is lame, religion without science is blind."
"Two things are infinite: the universe and human stupidity; and I'm not sure about the universe."
"Duct tape is like the force, it has a light side, a dark side, and it holds the world together"
"If you die in an elevator, be sure to push the Up button."
"All generalizations are false, including this one."
"Clearly you've never been to Singapore!"
"Luke, I am your father."
"To be, or not to be."
"You shall not pass!"
(... all with authors ...)
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"To be, or not to be."
"You shall not pass!"
(... all with authors ...)

"I have a dream! Duct tape is written on. Luke, I am your thoughts and what lies within us."
    ---- Audrey Rooney

"Your work is lame, religion is lame, religion is nearly the Up button."
    ---- Abraham Marx

"Two things are false, including this one."
    ---- Captain_Jack Truman
Fortunately, nearly all meaningful functions are computable... but this doesn't mean we know how to compute them (yet)!
the computer vision problem
computer vision: what's the input and output?
Input → Algorithm → Output

2d array of ints

That's the Mona Lisa

(low difficulty)

That's a woman in the 16th c., maybe smiling

(high difficulty)
Input → Algorithm → Output

btw, are these really the same data?

an image ... of what?
a woman, smiling?
Actual input: pixels

Actual image →

Happily, this problem is being solved...

but why is it so challenging?

Actual output: contents
What's red?

**Goal:** a coke-can collecting robot...
What's red?

not good enough...
Idea: Use hue

Increasing hue

- hue = 25°
- hue = -25°
What's red?

hue's too much!
Idea: Use **hue** and **saturation**
What's red?

The door is still matched, too... why?
What's red?

Aargh!

Remarkably, this problem is, in a sense, our own vision systems' fault...!

Door is still matched, too... why?
Try it! Illusions? What **computations** is your brain doing to cause them? Why?

two tones

two towers

two tables

two segments
2 layers
2 layers
2 layers
Are these four lines parallel?
Try it! Illusions? What **computations** is your brain doing to cause them? **Why?**

Vision is more challenging than it might seem on first "**glance**"!
we don't always give our own vision system credit for *all the work* it's doing...
we don't always give our own vision system credit for *all the work* it's doing...
we don't always give our own vision system credit for all the work it's doing...

Not real life?
What's the most famous of patterns like these?
the now-familiar striped dress... !

blue + black
vs.
white + gold
**IS THE DRESS IN SHADOW?**
If you think the dress is in shadow, your brain may remove the blue cast and perceive the dress as being white and gold.

**THE DRESS IN THE PHOTO**
If the photograph showed more of the room, or if skin tones were visible, there might have been more clues about the ambient light.

**IS THE DRESS IN BRIGHT LIGHT?**
If you think the dress is being washed out by bright light, your brain may perceive the dress as a darker blue and black.
Let it go!

Door == coke can?  *We'll work around it!*
The coke-can collector: *seeking*...
The coke-can collector: *seeking*...
The coke-can collector: success!
so many pixels!

Actual output: *contents*  people, walking...
How good is CV?

*with human help*, pretty good!
CS 5: the past...

Functions & variables
Recursion
Representations (binary, ascii)
Circuit design & Hmmm
Loops, 2d arrays
Dictionaries
Objects and Classes
Computability

Caesar cipher
4-bit multiplier
Mandelbrot, Life
Markov Text Gen.
Date, C4, Project
Finite state machines
Uncomputable functions
CS 5: the past...

Functions & variables
Recursion
Representations (binary, ascii)
Circuit design & Hmmm
Objects and Classes
Loops, 2d arrays
Dictionaries
Computability

Future CS?

looks like broccoli to me!

looks like broccoli to me!

multiplier
Mandelbrot, Life
Markov Text Gen.
Date, C4, Project
Finite state machines
Uncomputable functions
Interfaces

User Interfaces, Graphics, Animation
CS 124, 155, 157

AI

AI, Neural Networks, Computer Vision, Robotics
CS 151, 152, 153, 154

Systems

Compilers, Programming Languages, Networking, Operating Systems, Computer Architecture
Eng 85, 155, 158 & CS 125, 131, 132, 133, 134

Theory

Theory of Computation, AI
Math 167, 168 & CS 141, 142

Other CS courses?

SW Engineering & Data structures
CS 70, 121

Logic & Computability
CS 81

Principles of CS
CS 60
Beyond classes?

Systems

Compilers, Programming Languages, Networking, Operating Systems, Computer Architecture

Eng 85, 155, 158 & CS 125, 131, 132, 134, 136

Other CS courses?

Theory

Theory of Computation, Advanced Algorithms

Math 167, 168 & CS 141, 142

SW Engineering & Data structures

CS 70, 121

Logic & Computability

CS 81

Principles of CS

CS 60
Beyond classes?

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**Nathan Falk** <nathan.falk@gmail.com>  
Mar 13

to Zachary

Professor Dodds,

I hope you’re having a great semester so far and have a fun spring break planned!

I never thought I’d say this, but thank you so much for forcing us to learn all of the different data structures in your CS5 class last year. A lot of my day today was spent deciding whether list of lists or dictionaries were more appropriate structures for a dataset I’m building (and I’m not even a programmer, so tell your students that saying they want to go into consulting isn’t an excuse anymore)!

Regardless, it reminded me of the three-eyed alien.

I hope all is well,  
Nathan
However you're CSing, enjoy!

but what if I'm nostalgic for CS 5 itself?
However you're CSing, enjoy!

consider *grutoring* for CS5 next term or beyond...

but what if I'm nostalgic for CS 5 itself?
# BWAHAHAHAHAHAHAHAHAHAHAHAHAHAHAHAHAHAHA 
# I AM THE WINNER AND IT ALL WORKS!!!
# GWAHAHAHAHAHAHAHAHAHAH!!
# I started at noon, I'm done at 11:11
# minus a brief break to watch
# shawshank redemption and eat dinner,
# I've been working solid
#
# I AM TOTALLY THE WINNER!
# final project

one of many favorite grading - encountered comments
may you find equal success (and equal movie-watching time!)
No matter what path you choose, it's likely to be in binary...
Thank you for joining CS5!

Final Projects: due *Monday* evening...

**Hours:**
Optional office and tutoring hours
Sunday and Monday 7-10pm...
here in Beckman B126