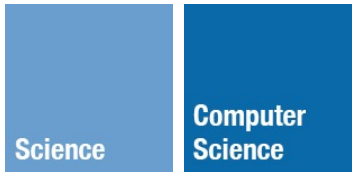
Exploring Academics: Computer Science



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ILLINOIS INSTITUTE OF TECHNOLOGY

Welcome to IIT, and thanks for coming!

Michael (Sae) Lee

Instructor — i.e., dedicated *teaching* faculty

- CS101: intro to the profession
- CS331: data structures
- CS351: systems programming
- CS450: operating systems
- CS442: mobile app development (iOS)

… and a few research interests:

- machine learning
- programming language design
- concurrent programming paradigms

Just Two Questions

- What *is* Computer Science? (What is it *not*?)
- What would you learn as a CS undergrad?

A Misnomer

"Computer Science" is:

a) not really about computers

b) not really a science

Not about computers?

- Sure: we use computers as *tools*
- But so do folks in nearly every other data/computation intensive fields!
  - Physics, Chemistry, Economics, Music Production, etc.

We don't call physicists "collider experts" or chemists "microscope specialists"

N.B., it *does help* to understand the internal workings of a computer (e.g., for "low-level" interactions and optimizations)

Across the street …

- Computer & Electrical Engineers actually design and build computers and their components
  - You may want to take some of those classes too!

Science?

science |ˈsīəns|
noun
the intellectual and practical activity encompassing the **systematic study** of the structure and behavior **of the physical and natural world** through **observation and experiment**

New Oxford American Dictionary

Science?

- i.e., the scientific method
  - observe, hypothesize, experiment, analyze → refute/validate hypothesis

Yeah. We don't really do that.

"Computer Scientists" *solve problems*.

Systematically.

Then *generalize*, *analyze*, and *modularize* our solutions to these problems.

e.g., Sudoku

"a human denial-of-service attack"

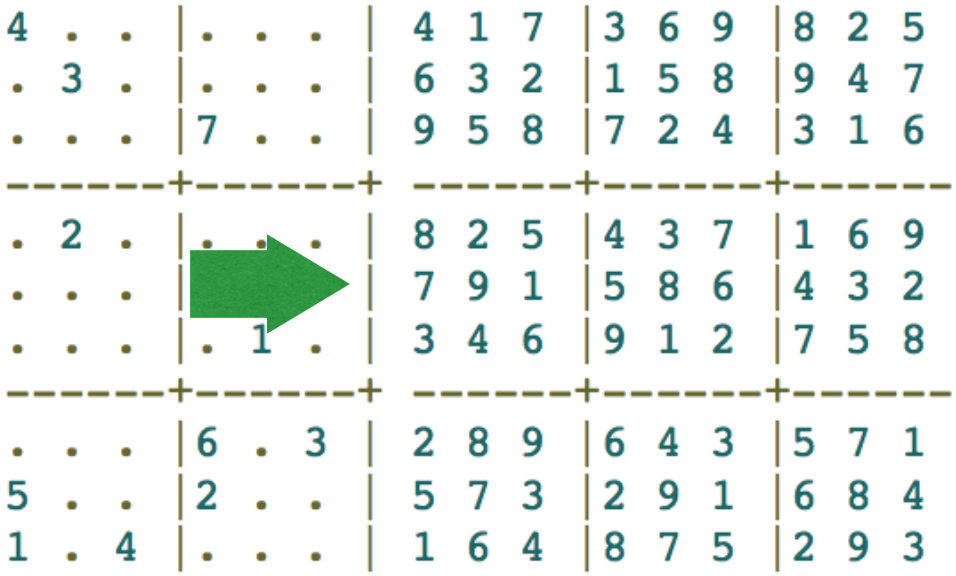
see http://norvig.com/sudoku.html

NYTimes Easy Puzzle, July 19, 2016

		8		3	1	7		4
	4	3		6	2			9
5	1		4					8
4		7	3	8		9		2
	2		6				8	
		1	2	9		3	4	
	7				6	8	2	
1	3		7	4				
6			9		3			

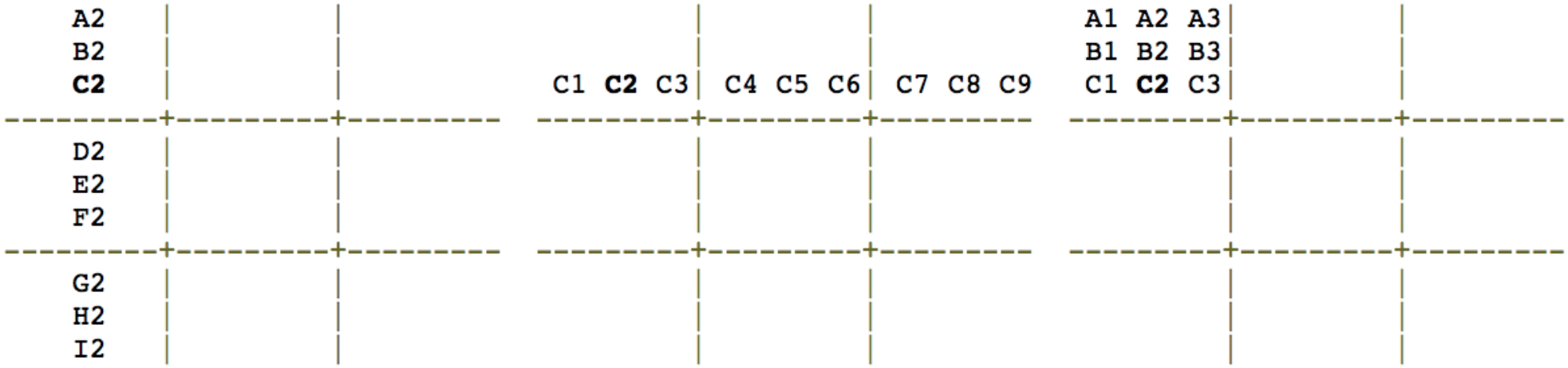
HOW TO PLAY

Fill the grid with your keyboard so that every row, column and 3×3 box contains the digits 1 to 9, without repeating.


4 . . | . . . | 4 1 7 | 3 6 9 | 8 2 5
. 3 . | . . . | 6 3 2 | 1 5 8 | 9 4 7
. . . | 7 . . | 9 5 8 | 7 2 4 | 3 1 6
. 2 . | . . . | 8 2 5 | 4 3 7 | 1 6 9
. . . | . . . | 7 9 1 | 5 8 6 | 4 3 2
. . . | . 1 . | 3 4 6 | 9 1 2 | 7 5 8
. . . | 6 . 3 | 2 8 9 | 6 4 3 | 5 7 1
5 . . | 2 . . | 5 7 3 | 2 9 1 | 6 8 4
1 . 4 | . . . | 1 6 4 | 8 7 5 | 2 9 3

```
A1 A2 A3| A4 A5 A6| A7 A8 A9
B1 B2 B3| B4 B5 B6| B7 B8 B9
C1 C2 C3| C4 C5 C6| C7 C8 C9
---------+---------+---------
D1 D2 D3| D4 D5 D6| D7 D8 D9
E1 E2 E3| E4 E5 E6| E7 E8 E9
F1 F2 F3| F4 F5 F6| F7 F8 F9
---------+---------+---------
G1 G2 G3| G4 G5 G6| G7 G8 G9
H1 H2 H3| H4 H5 H6| H7 H8 H9
I1 I2 I3| I4 I5 I6| I7 I8 I9
```

1. name our squares



column unit *row unit* *box unit*

2. identify a square's (e.g., `C2`'s) "peers"

```
123456789  123456789  123456789 | 123456789  123456789  123456789 | 123456789  123456789  123456789
123456789  123456789  123456789 | 123456789  123456789  123456789 | 123456789  123456789  123456789
123456789  123456789  123456789 | 123456789  123456789  123456789 | 123456789  123456789  123456789
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123456789  123456789  123456789 | 123456789  123456789  123456789 | 123456789  123456789  123456789
123456789  123456789  123456789 | 123456789  123456789  123456789 | 123456789  123456789  123456789
123456789  123456789  123456789 | 123456789  123456789  123456789 | 123456789  123456789  123456789
---------------------------------+---------------------------------+---------------------------------
123456789  123456789  123456789 | 123456789  123456789  123456789 | 123456789  123456789  123456789
123456789  123456789  123456789 | 123456789  123456789  123456789 | 123456789  123456789  123456789
123456789  123456789  123456789 | 123456789  123456789  123456789 | 123456789  123456789  123456789
```
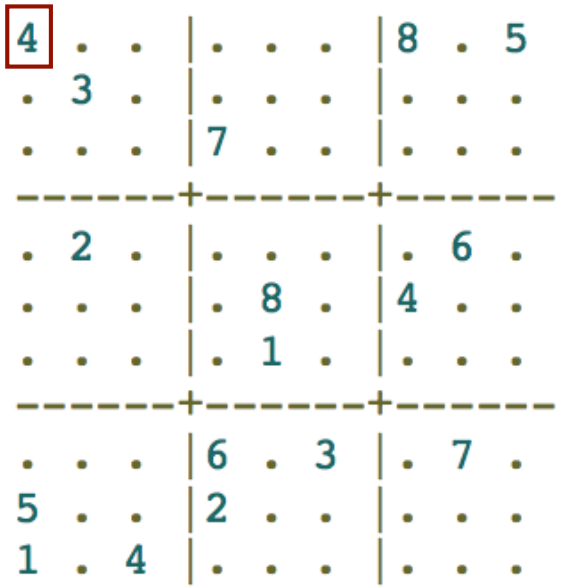

3. start with a “catch-all” solution

4. *Recursively* apply a general AI approach known as "constraint propagation"

constraints:

- If a square has only one possible value, then *eliminate* that value from its peers
- If a unit has only one possible square for a value, then *assign* the value there




```
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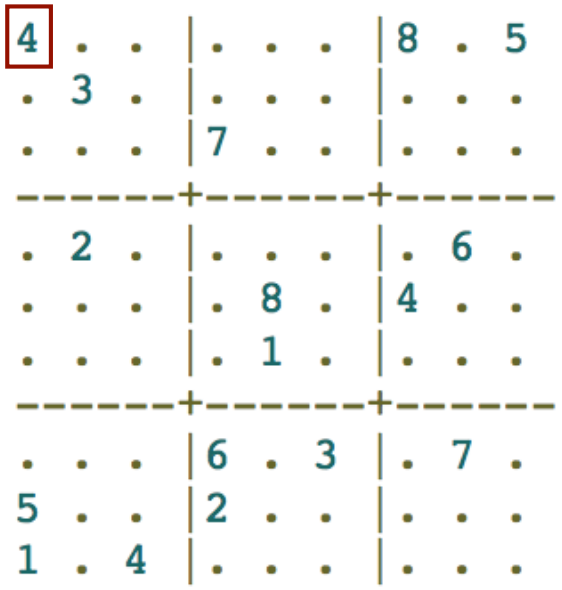


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123 56789 123 56789 123 56789 |123456789 123456789 123456789 |123456789 123456789 123456789
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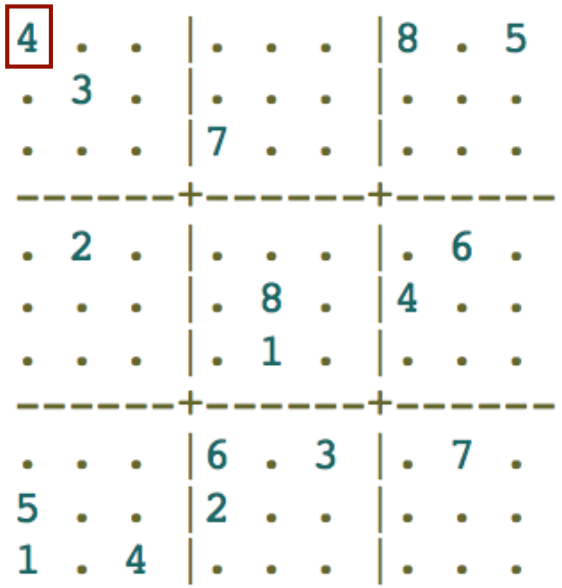


```
   4       123 56789 123 56789 |123 56789 123 56789 123 56789 |123 56789 123 56789 123 56789
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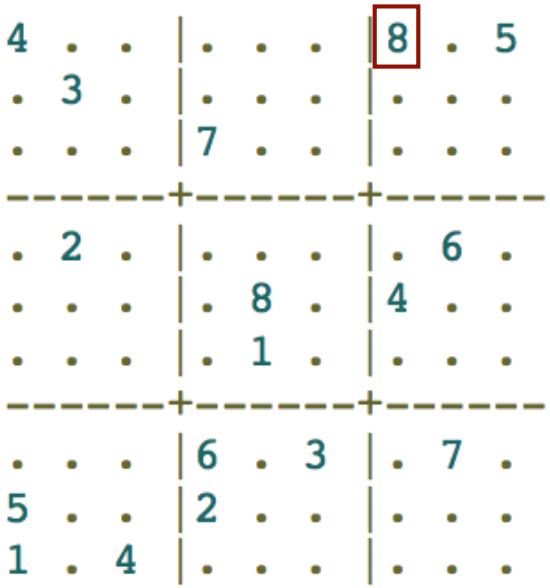

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4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
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. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
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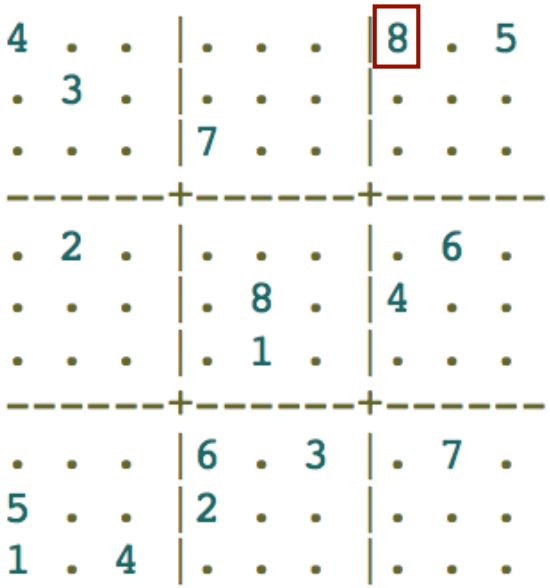


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   4       123 567 9 123 567 9 |123 567 9 123 567 9 123 567 9 |123 56789 123 567 9 123 567 9
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123 56789  123456789 123456789 |123456789 123456789 123456789 |1234567 9 123456789 123456789
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123 56789  123456789 123456789 |123456789 123456789 123456789 |1234567 9 123456789 123456789
123 56789  123456789 123456789 |123456789 123456789 123456789 |1234567 9 123456789 123456789
123 56789  123456789 123456789 |123456789 123456789 123456789 |1234567 9 123456789 123456789
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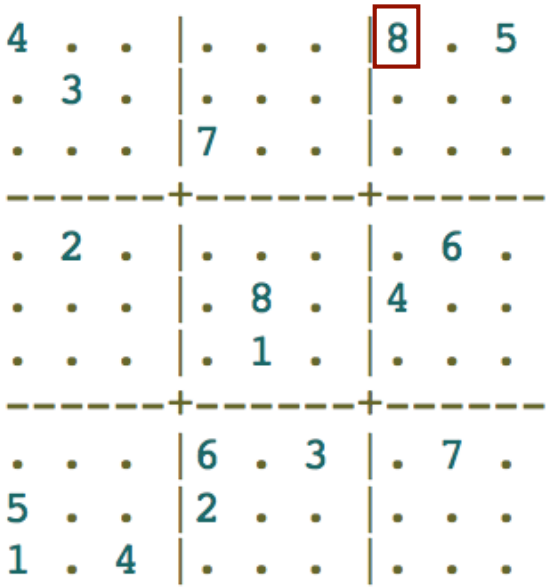


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   4       123 567 9 123 567 9 |123 567 9 123 567 9 123 567 9 |       8  123 567 9 123 567 9
123 56789 123 56789 123 56789 |123456789 123456789 123456789 |1234567 9 1234567 9 1234567 9
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123 56789 123456789 123456789 |123456789 123456789 123456789 |1234567 9 123456789 123456789
123 56789 123456789 123456789 |123456789 123456789 123456789 |1234567 9 123456789 123456789
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4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
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. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4      1679   12679  |  139    2369   269    |  8     1239   5
26789     3    1256789 | 14589  24569  245689  | 12679  1249  124679
 2689   15689  125689  |   7    234569 245689  | 12369  12349 123469
-----------------------+-----------------------+-----------------------
 3789     2     15789  |  3459  34579   4579   | 13579   6    13789
 3679   15679   15679  |  359     8    25679  |   4    12359 12379
36789     4     56789  |  359     1    25679  | 23579  23589 23789
-----------------------+-----------------------+-----------------------
 289     89      289   |   6    459     3     |  1259   7    12489
  5     6789     3     |   2    479     1     |  69    489    4689
  1     6789     4     |  589   579    5789   | 23569  23589 23689
```

(some squares are solved)

5. Choose the square with the minimum number of possible values > 1, and "guess" a value to *assign* to the square
   - If constraint propagation fails (e.g., square ends up blank), *backtrack*
     - (computers have perfect memory!)

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4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
------+-------+------
. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4      1679   12679  |  139    2369   269    |  8     1239   5
26789    3    1256789  | 14589  24569  245689  | 12679  1249  124679
 2689   15689  125689  |   7    234569 245689  | 12369  12349 123469
----------------------+-----------------------+----------------------
 3789    2     15789   |  3459  34579   4579   | 13579   6    13789
 3679   15679  15679   |  359     8     25679  |   4    12359 12379
36789    4     56789   |  359     1     25679  | 23579  23589 23789
----------------------+-----------------------+----------------------
 289    [89]   289     |   6    459     3     |  1259   7    12489
  5     6789    3      |   2    479     1     |  69     489   4689
  1     6789    4      |  589   579     5789  | 23569  23589 23689
```

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4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
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. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4      1679   12679  |  139    2369   269    |  8     1239   5
26789    3    1256789  | 14589  24569  245689  | 12679  1249  124679
 2689   1569   125689  |   7    234569 245689  | 12369 12349  123469
----------------------+-----------------------+----------------------
 3789    2     15789   |  3459  34579   4579   | 13579   6    13789
 3679  15679   15679   |  359     8    25679  |   4    12359 12379
36789    4     56789   |  359     1    25679  | 23579  23589 23789
----------------------+-----------------------+----------------------
 29      8      29     |   6    459     3     |  1259   7    1249
  5     679     3      |   2    479     1     |   69   489   4689
  1     679     4      |  589   579    5789   | 23569  23589 23689
```

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4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
------+-------+------
. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4      1679   12679  |  139    2369   269    |  8     1239   5
26789    3    1256789  | 14589  24569  245689  | 12679  1249  124679
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----------------------+-----------------------+----------------------
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----------------------+-----------------------+----------------------
  29     8      29     |   6    459     3     |  1259   7     1249
   5    679     3      |   2    479     1     |   69   489    4689
   1    679     4      |  589   579    5789   | 23569  23589  23689
```

```
4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
------+-------+------
. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4      1679   1267  |  139    2369   269   |  8     1239   5
 6789    3      125678| 14589   24569  245689| 12679  1249   124679
 689     1569   12568 |  7      234569 245689| 12369  12349  123469
---------------------+----------------------+---------------------
 3789    2      1578  |  3459   34579  4579  | 13579  6      13789
 3679    15679  1567  |  359    8      25679 |  4     12359  12379
36789    4      5678  |  359    1      25679 | 23579  23589  23789
---------------------+----------------------+---------------------
 2       8      9     |  6      45     3     |  15    7      14
 5       67     3     |  2      479    1     |  69    489    4689
 1       67     4     |  589    579    5789  | 23569  23589  23689
```

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4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
------+-------+------
. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4      1679   1267  |  139    2369   269   |  8     1239   5
 6789    3      125678| 14589   24569  245689| 12679  1249   124679
 689     1569   12568 |  7      234569 245689| 12369  12349  123469
---------------------+----------------------+---------------------
 3789    2      1578  |  3459   34579  4579  | 13579  6      13789
 3679    15679  1567  |  359    8      25679 |  4     12359  12379
36789    4      5678  |  359    1      25679 | 23579  23589  23789
---------------------+----------------------+---------------------
 2       8      9     |  6      45     3     |  15    7      14
 5       67     3     |  2      479    1     |  69    489    4689
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```

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4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
------+-------+------
. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4      1679   1267  |  139    2369   269   |  8     1239   5
 6789    3      125678| 14589   2569   245689| 12679  1249   24679
 689     1569   12568 |  7     23569   245689| 12369  12349  23469
---------------------+----------------------+---------------------
 3789    2      1578  |  3459   3579   4579  |  1379  6      3789
 3679   15679   1567  |  359    8      25679 |  4     12359  2379
36789   4      5678  |  359    1      25679 |  2379  23589  23789
---------------------+----------------------+---------------------
 2      8      9     |  6      4      3     |  5     7      1
 5      67     3     |  2      79     1     |  69    489    4689
 1      67     4     |  589    579    5789  |  2369  2389   23689
```

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4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
------+-------+------
. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4      1679   1267  |  139    2369   269   |  8     1239   5
 6789    3      125678| 14589   2569   245689| 12679  1249   24679
 689     1569   12568 |  7     23569   245689| 12369  12349  23469
---------------------+----------------------+---------------------
 3789    2      1578  | 3459   3579    4579  | 1379   6      3789
 3679   15679   1567  | 359     8      25679 | 4      12359  2379
36789   4      5678  | 359     1      25679 | 2379   23589  23789
---------------------+----------------------+---------------------
 2      8      9     |  6      4      3     |  5     7      1
 5      67     3     |  2      79     1     |  69    489    4689
 1      67     4     | 589    579    5789   | 2369   2389   23689
```

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4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
------+-------+------
. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

error!

```
 4     1     7   |  3     2     6   |  8     9     5
689    3    28   |  1   569  4589   | 267   24  2467
689    5    28   |  7  2569  4689   | 236    1  2346
-----------------+-----------------+-----------------
 8     2     5   |  4     3     7   |  1     6     9
379    9     1   |  5     8     6   |  4   235   237
 37    4     6   |  9     1     2   | 37   358   378
-----------------+-----------------+-----------------
 2     8     9   |  6     4     3   |  5     7     1
 5     6     3   |  2     7     1   |  9    48    48
 1     7     4   |  8    59    59   | 236   23   236
```

```
4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
------+-------+------
. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4      1679   1267  |  139    2369   269   |  8     1239   5
 6789    3      125678| 14589   2569   245689| 12679  1249   24679
 689     1569   12568 |  7     23569   245689| 12369  12349  23469
---------------------+----------------------+---------------------
 3789    2      1578  |  3459   3579   4579  |  1379  6      3789
 3679    15679  1567  |  359    8      25679 |  4     12359  2379
36789    4      5678  |  359    1      25679 |  2379  23589  23789
---------------------+----------------------+---------------------
 2       8      9     |  6      4      3     |  5     7      1
 5       ~~67~~ 3     |  2      79     1     |  69    489    4689
 1       67     4     |  589    579    5789  |  2369  2389   23689
```

(backtrack!)

```
4 . . | . . . | 8 . 5
. 3 . | . . . | . . .
. . . | 7 . . | . . .
------+-------+------
. 2 . | . . . | . 6 .
. . . | . 8 . | 4 . .
. . . | . 1 . | . . .
------+-------+------
. . . | 6 . 3 | . 7 .
5 . . | 2 . . | . . .
1 . 4 | . . . | . . .
```

```
  4       19      7    |  139     236     269    |  8      1239    5
 689      3     12568  | 14589    256    245689  | 1279    1249   24679
 689     159    12568  |   7      2356   245689  | 1239   12349   23469
---------------------+-----------------------+---------------------
 3789     2      158   |  3459    357     4579   | 1379    6      3789
 3679    159     156   |  359     8      25679   |  4     12359   2379
36789     4      568   |  359     1      25679   | 2379   23589   23789
---------------------+-----------------------+---------------------
  2       8      9    |   6      4       3     |  5      7       1
  5       7      3    |   2      9       1     |  6      48      48
  1       6      4    |  58      57     578    | 239    2389    2389
```

```
4 . . |. . . |8 . 5
. 3 . |. . . |. . .
. . . |7 . . |. . .
------+------+------
. 2 . |. . . |. 6 .
. . . |. 8 . |4 . .
. . . |. 1 . |. . .
------+------+------
. . . |6 . 3 |. 7 .
5 . . |2 . . |. . .
1 . 4 |. . . |. . .
```

```
4 1 7 |3 6 9 |8 2 5
6 3 2 |1 5 8 |9 4 7
9 5 8 |7 2 4 |3 1 6
------+------+------
8 2 5 |4 3 7 |1 6 9
7 9 1 |5 8 6 |4 3 2
3 4 6 |9 1 2 |7 5 8
------+------+------
2 8 9 |6 4 3 |5 7 1
5 7 3 |2 9 1 |6 8 4
1 6 4 |8 7 5 |2 9 3
```

Ultimate Problem Solvers

- After coming up with a solution — *aka an algorithm* — a monkey can apply it!
  - A monkey with perfect memory, that will follow instructions to the letter
    - I.e., a computer

Programs

- We codify solutions into *programs* which computers can execute
- And, ideally, reuse our code to build every grander programs!

Programs have *billions* of moving pieces!

The Great Wall of China has nothing on an operating system kernel's codebase.

Nor does any ingenuous *mechanical device*.

Also: *Meta*-Problems

e.g., what *classes* of problems exist?

how *hard* is a problem to solve?

can we solve a given problem?

http://xkcd.com/1425/

What will you learn?

- Programming languages
- Techniques to *design*, *analyze*, *optimize*, and *implement* algorithms
- Approaches to leveraging new technologies & software paradigms

E.g.,

- Massively multi-core architectures
- Petabyte-scale data warehouses
- “Cloud” technologies
- Ubiquitous mobile computing
- Graphics & Networking stacks

Most important takeaway: how to *analyze, break down, and solve problems*

Pattern recognition and reuse are critical skills!

Questions?