# COS 226

# ALGORITHMS
and
# DATA
# STRUCTURES

ARVIND NARAYANAN · MAIA GINSBURG · IBRAHIM ALBLUWI

# INTRO TO COS 226

‣ *motivation*

‣ *course details and policies*

Algorithms

ROBERT SEDGEWICK | KEVIN WAYNE

https://algs4.cs.princeton.edu

# COS 226 course overview

What is COS 226?

- Intermediate-level survey course.
- Programming and problem solving, with applications.
- Algorithm:  sequence of instructions for solving a problem.
- Data structure:  method to organize data in a computer.

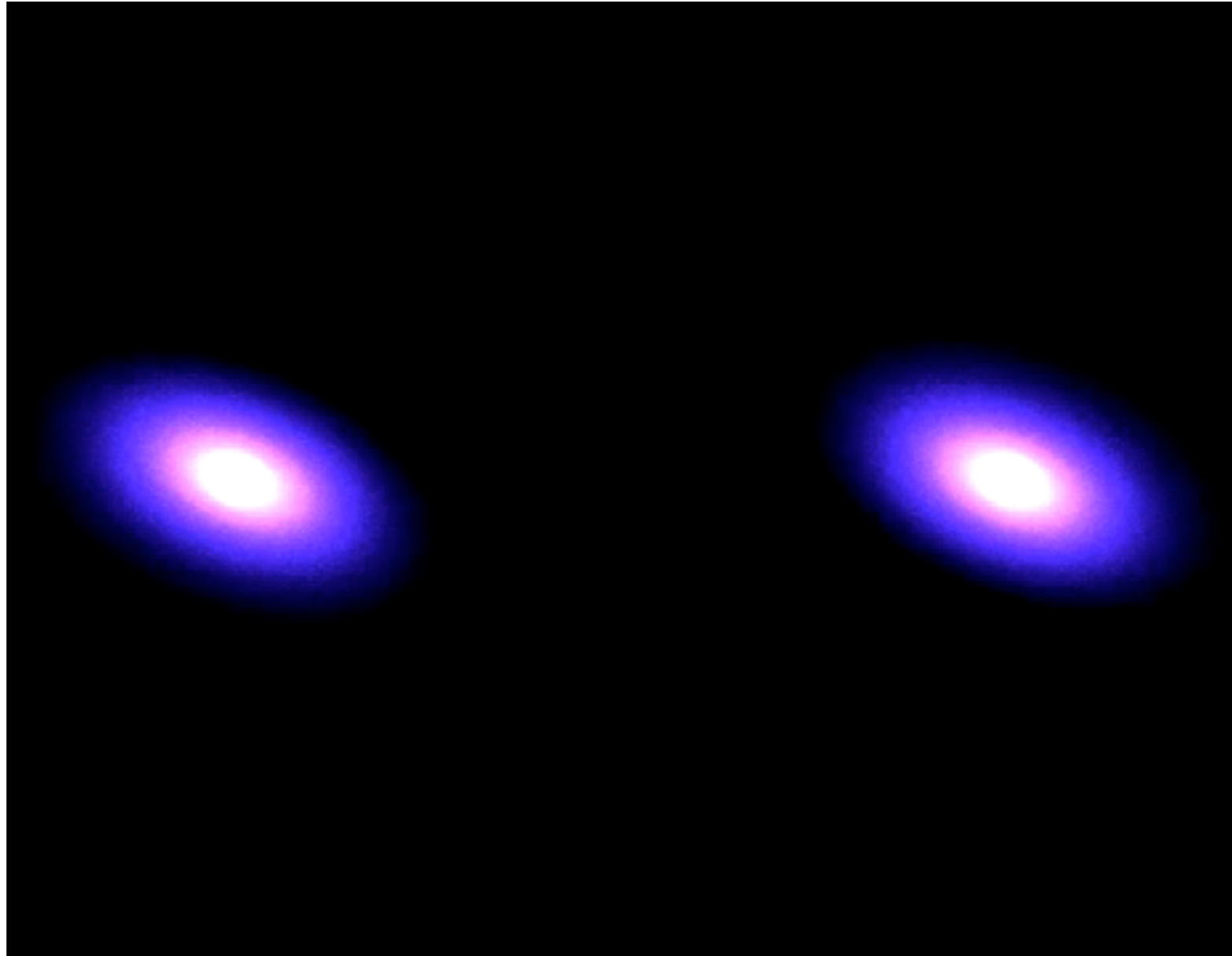| topic | data structures and algorithms |
|---|---|
| data types | stack, queue, union-find, priority queue |
| sorting | quicksort, mergesort, heapsort, radix sorts |
| searching | BST, red-black BST, hash table |
| graphs | BFS, DFS, Prim, Kruskal, Dijkstra |
| strings | KMP, regular expressions, tries, data compression |
| advanced | k-d tree, suffix array, maxflow |

# Why study algorithms and data structures?

Their impact is broad and far-reaching.



MANAGEMENT

**Algorithm That Tells the Boss Who Might Quit**

Wal-Mart, Credit Suisse Crunch Data to See Which Workers Are Likely to Leave or Stay

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**Algorithms Will Drive Future Health Gains, Dean of Stanford Med**

"We are... level,"

POPULAR ON WSJ

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**Prisons turn to computer algorithms for deciding who to parole**

By Jacob Kastrenakes on October 14, 2013 10:06 am ✉ Email ✚ @jake_k

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**ALGORITHMS TAKE CONTROL OF WALL STREET**

**Can maths find you love? eHarmony's love algorithm**

PERSONALITY TESTS

**This Algorithm Knows You Better Than Your Facebook Friends Do**

**New Google algorithm elevates facts; critics worry 'dissidents' will be quashed**

29 comments

maths find you love? The dating armony, who claim to have esponsible for a n marriages, u se.

**The Algorithm Economy Heads To Amazon**

Posted Nov 30, 2014 by Danny Crichton (@DannyCrichton)

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THE SATURDAY ESSAY

**Bitcoin and the Digital-Currency Revolution**

For all bitcoin's growing pains, it represents money and global finance.

THE WALL STREET JOURNAL. ☰ | TECH

f 1832

TECHNOLOGY

**At UPS, the Algorithm Is the Driver**

Turn right, turn left, turn right: inside Orion, the 10-year effort to squeeze every penny

959

By STEVEN ROSENBUSH and LAURA STEVENS

Feb. 16, 2015 8:28 p.m. ET

4

# Why study algorithms and data structures?

To solve problems that could not otherwise be addressed.



**http://www.youtube.com/watch?v=ua7YlN4eL_w**

# Why study algorithms and data structures?

They may unlock the secrets of life and of the universe.

" *Computer models mirroring real life have become crucial for most*

*advances made in chemistry today…. Today the computer is just as*

*important a tool for chemists as the test tube.* "

— *Royal Swedish Academy of Sciences*

(*Nobel Prize in Chemistry 2013*)

# Why study algorithms and data structures?

Old roots, new opportunities.

- Study of algorithms dates at least to Euclid.
- Named after Muḥammad ibn Mūsā al-Khwārizmī.
- Formalized by Church and Turing in 1930s.
- Some important algorithms were discovered by undergrads in a course like this!
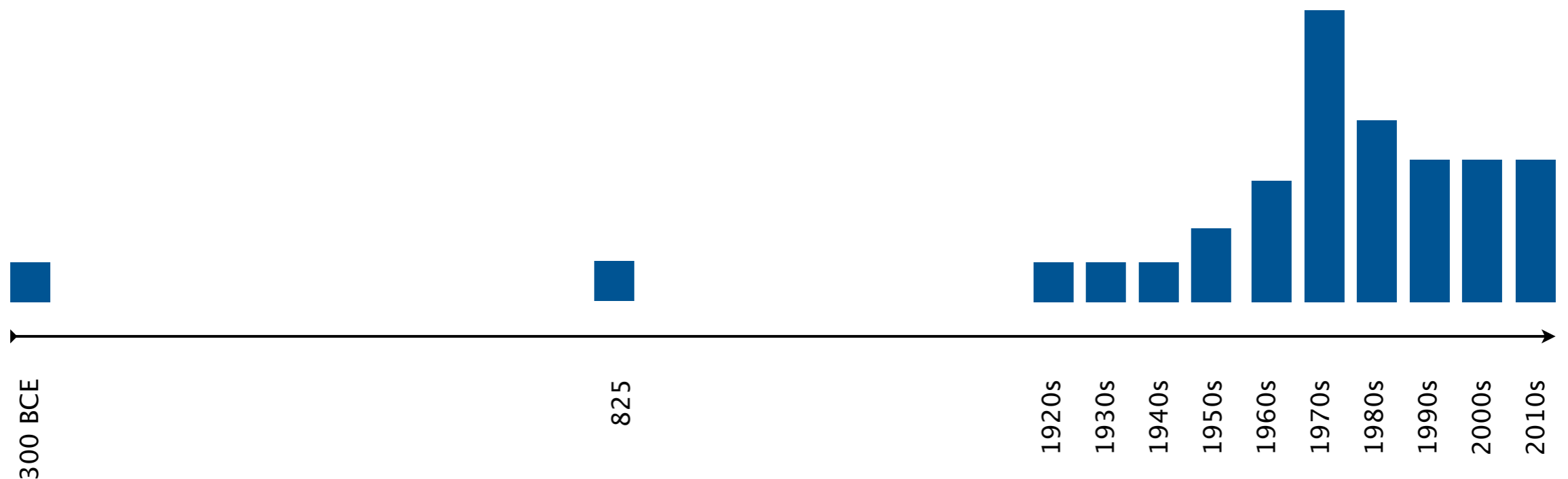
# Why study algorithms and data structures?

To become a proficient programmer.

" *I will, in fact, claim that the difference between a bad programmer*

*and a good one is whether he considers his code or his data structures*

*more important. Bad programmers worry about the code. Good*

*programmers worry about data structures and their relationships.* "

     — *Linus Torvalds (architect of Linux and git)*

# Why study algorithms and data structures?

For intellectual stimulation.

" *For me, great algorithms are the poetry of computation. Just*

*like verse, they can be terse, allusive, dense, and even mysterious.*

*But once unlocked, they cast a brilliant new light on some*

*aspect of computing.* " — *Francis Sullivan*

# Why study algorithms and data structures?

For fun and profit.

# Algorithms can be misused



**MANAGEMENT**

## Algorithm That Tells the Boss Who Might Quit

Wal-Mart, Credit Suisse Crunch Data to See Which Workers Are Likely to Leave or Stay

**POPULAR ON WSJ**

1. Fossil Fuels Will Save the World

ILLUSTRATION: OTTO STEININGER

## ALGORITHMS TAKE CONTROL OF WALL STREET

18

thousands of little algorithms, and they've created a new
le, and impossible for humans to comprehend. Photo: Mauricio

## Prisons turn to computer algorithms for deciding who to parole

By Jacob Kastrenakes on October 14, 2013 10:06 am     Email     @jake_k

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## New Google algorithm elevates facts; critics worry 'dissidents' will be quashed

**29 comments**

Google is developing an algorithm that would elevate "trustworthiness" in its search results. *(The Associated Press)*

## The Algorithm Economy Heads To Amazon

Posted Nov 30, 2014 by *Danny Crichton (@DannyCrichton)*

**1,796 SHARES**

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# Why study algorithms and data structures?

- Their impact is broad and far-reaching.
- To solve problems that could not otherwise be addressed.
- They may unlock the secrets of life and of the universe.
- Old roots, new opportunities.
- To become a proficient programmer.
- For intellectual stimulation.
- For fun and profit.
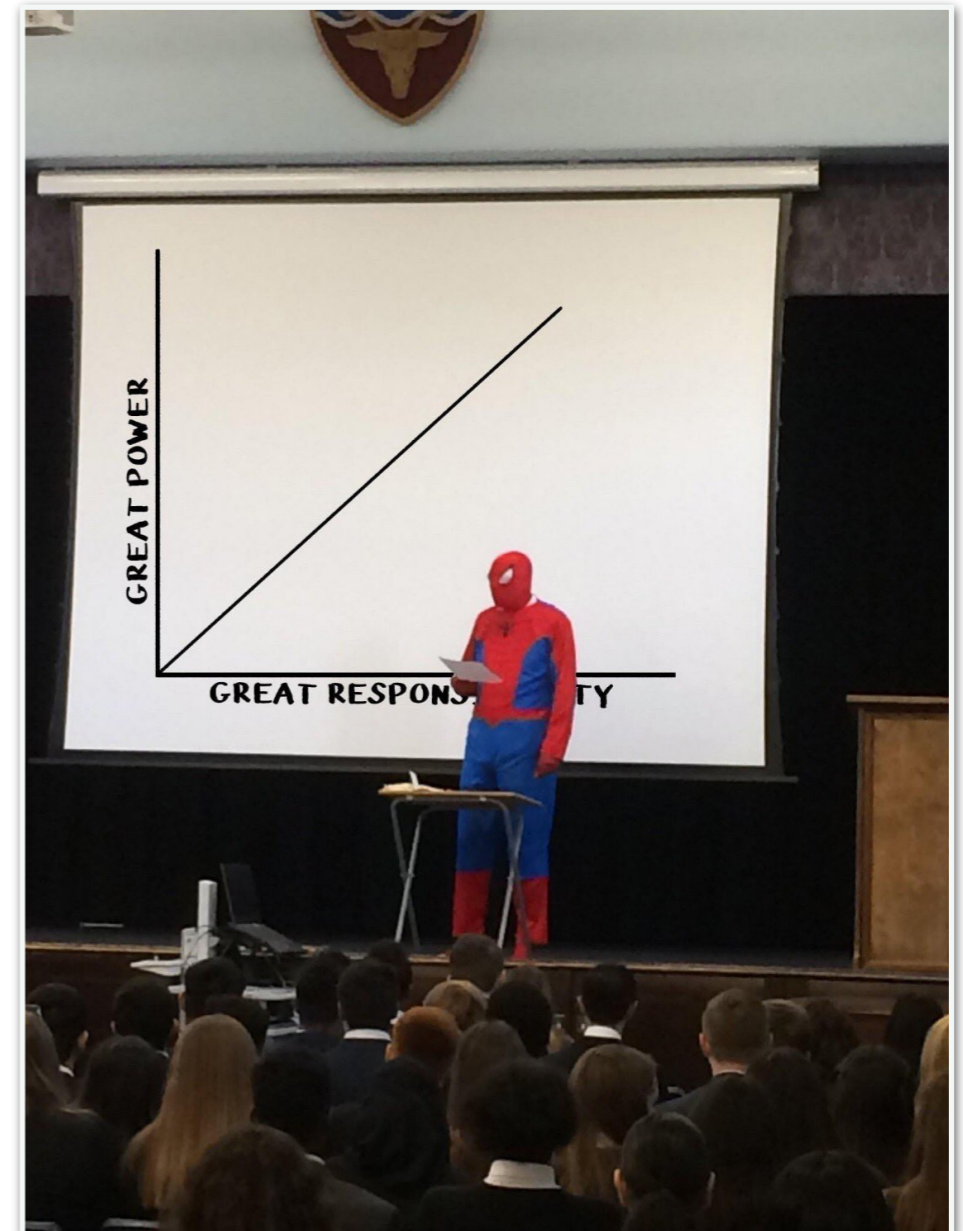
# Intro to COS 226

‣ *motivation*

‣ *course details and policies*

Algorithms

ROBERT SEDGEWICK | KEVIN WAYNE

https://algs4.cs.princeton.edu

Peter Arkle

# Laptop use — even for note taking — negatively impacts learning

Lots of peer-reviewed research on this topic

The laptop and the lecture: The effects of multitasking in learning environments by Helene Hembrooke and Geri Gay, *Journal of Computing in Higher Education*, 2003

In-class laptop use and its effects on student learning by Carrie B. Fried, *Computers & Education*, 2007

Daydreaming and its correlates in an educational environment by Sophie Lindquist and John McLean, *Learning and Individual Differences*, 2011

Examining the impact of off-task multi-tasking with technology on real-time classroom learning by Eileen Wood, Lucia Zivcakova, Petrice Gentile, Karin Archer, Domenica De Pasquale, Amanda Nosko, *Computers & Education*, 2011

The impact of laptop-free zones on student performance and attitudes in large lectures by Nancy Aguilar-Roca, Adrienne Williams, and Diane O'Dowd, *Computers & Education*, 2012

Laptop multitasking hinders classroom learning for both users and nearby peers by Faria Sana, Tina Weston, Nicholas J. Cepeda, *Computers & Education*, 2013

The pen is mightier than the keyboard: Advantages of longhand over laptop note taking by Pam A. Mueller and Daniel M. Oppenheimer, *Psychological Science*, 2014

The impact of computer usage on academic performance: Evidence from a randomized trial at the United States Military Academy by Susan Payne Carter, Kyle Greenberg, Michael S. Walker, *Economics of Education Review*, 2017

Logged in and zoned out: How laptop internet use relates to classroom learning by Susan Ravizza, Mitchell Uitvlugt, Kimberly Fenn, *Psychological Science*, 2017

# Laptop use harms <u>other</u> students



Computers & Education

Volume 62, March 2013, Pages 24-31

## Laptop multitasking hinders classroom learning for both users and nearby peers

Faria Sana [a] ✉, Tina Weston [b, c] ✉, Nicholas J. Cepeda [b, c] ✉

⊞ Show more

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open access

Policy: no laptops/phones/tablets in class

Student response system (required).

- Any hardware version of iClicker.
  (use iClicker Reef at your own risk, WiFi issues?)
- Register your iClicker in Blackboard. **Bb**
- Available at Labyrinth Books ($30). ← save serial number
  to maintain resale value

**We'll start using them on Thursday.**

# Course staff

**Arvind Narayanan** ✉
Faculty
Instructor

**Maia Ginsburg** ✉
Faculty
Lead Preceptor
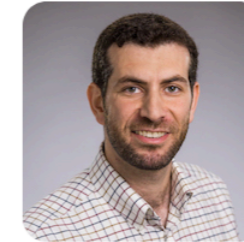
**Ibrahim Albluwi** ✉
Faculty
Lead Preceptor

**Ross Teixeira** ✉
Graduate Student
Preceptor

**Qasim Nadeem** ✉
Graduate Student
Preceptor

**Lisa Jian** ✉
Graduate Student
Preceptor

**Matthew Weaver** ✉
Graduate Student
Preceptor

**Mohamed El-Dirany** ✉
Graduate Student
Preceptor

**Alberto Mizrahi Benmaman** ✉
Graduate Student
Preceptor

# Precepts:
Discussion, problem solving, assignment prep

# A note about division of responsibility

For assignment help, go to precepts, preceptor office hours, labs

# Programming assignments

Implement an efficient algorithm or data structure.
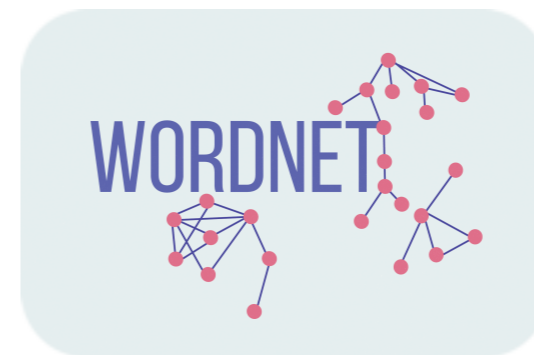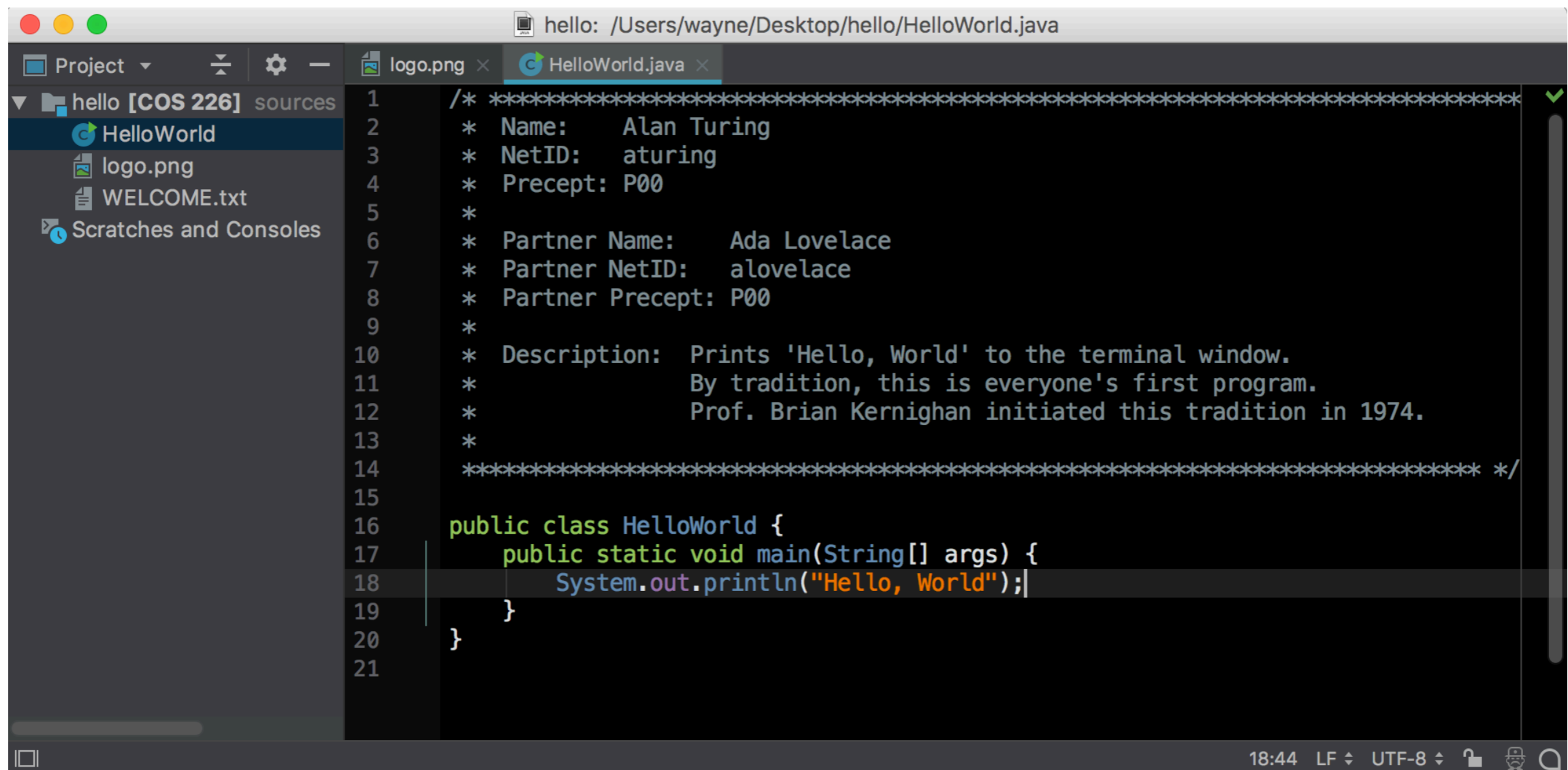


Solve an interesting application using a "textbook" algorithm.
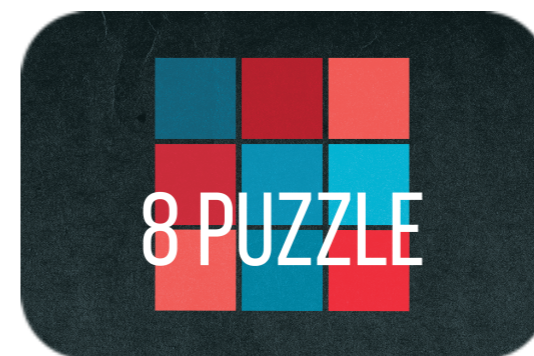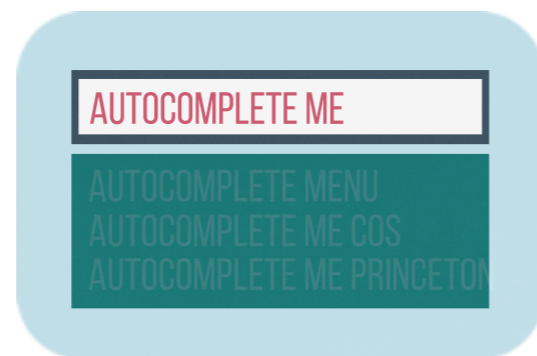
# Programming assignments

IntelliJ–based programming environment (highly recommended).

- Continuous inspection; integrated Checkstyle and Findbugs.

- Autoformat, autoimport, and autocomplete.

- Embedded bash terminal.

# Quizzes

- 2-3 short questions per lecture.
- 3 attempts per question.
- Use pencil and paper.

# Midterm and final

- Questions drawn from quizzes and lectures.
- Emphasizes non-programming material.

| COS 226 | Algorithms and Data Structures | Fall 2017 |
|---|---|---|
| | **Midterm** | |

This exam has 10 questions (including question 0) worth a total of 55 points. You have 80 minutes. This exam is preprocessed by a computer, so please **write darkly** and **write your answers inside the designated spaces.**

**Policies.** The exam is closed book, except that you are allowed to use a one page cheatsheet (8.5-by-11 paper, one side, in your own handwriting). No electronic devices are permitted.

# Grading

Programming assignments.  45%
- Due at 6pm on Mondays via TigerFile.
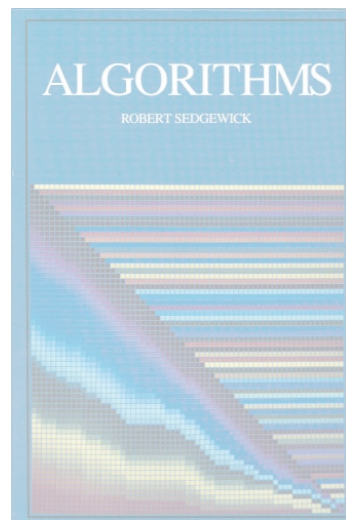- Collaboration/lateness policies: see web.

Quizzes.  10%
- Due at 6pm on Fridays via Quizzera.
- Collaboration/lateness policies: see web.
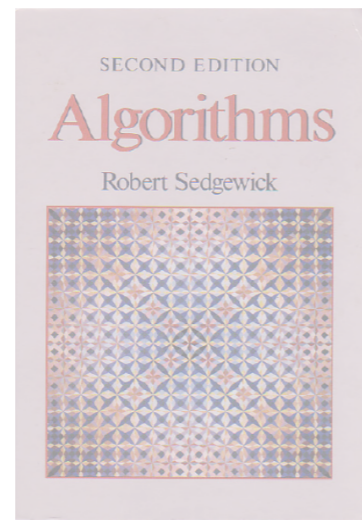
Exams.  15% + 30%
- Midterm (in class on Thursday, March 14).
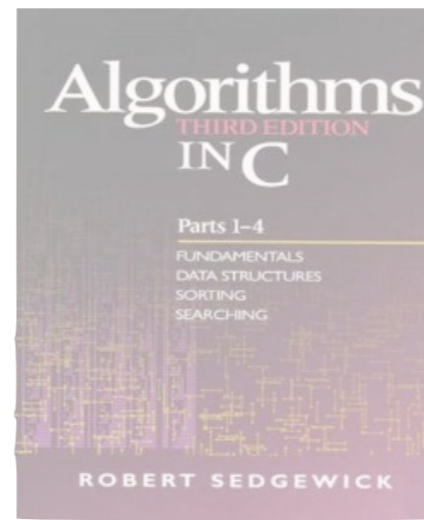- Final (to be scheduled by Registrar).

# Resources (textbook)

Readings (required).  Algorithms 4th edition by R. Sedgewick and K. Wayne, Addison–Wesley Professional, 2011, ISBN 0-321-57351-X.



1st edition (1982)     2nd edition (1988)     3rd edition (1997)     **4th edition (2011)**

Available in various formats.
- Online:  Amazon ($85 hardcover, $60 Kindle, $40 rent), …
- Brick–and–mortar:  Labyrinth Books ($60 hardcover).
- On reserve:  Engineering library.

# The creator gods of COS 226



Robert Sedgewick



Kevin Wayne

# Resources (videos)

Lecture videos (optional).

- Missed lecture.
- Review for exams.

cos 226

About 35,000,000 results (0.30 seconds)

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## 0.98111135433

| Rad | | x! | ( | ) | % | AC |
|---|---|---|---|---|---|---|
| Inv | sin | ln | 7 | 8 | 9 | ÷ |
| π | cos | log | 4 | 5 | 6 | × |
| e | tan | √ | 1 | 2 | 3 | − |
| Ans | EXP | x$^y$ | 0 | . | = | + |

More info

### COS 226 Syllabus (Spring 2019)
www.princeton.edu/~cos226/ ▾

Syllabus. Description. This course surveys the most important algorithms and data structures in use on computers today. Particular emphasis is given to ...

Google
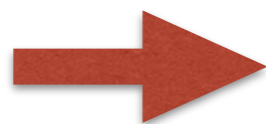
226 cos

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COS 226 Syllabus (Spring 2019)
www.princeton.edu/~cos226/ ▼
Syllabus. Description. This course surveys the most important algorithms and data structures in use on
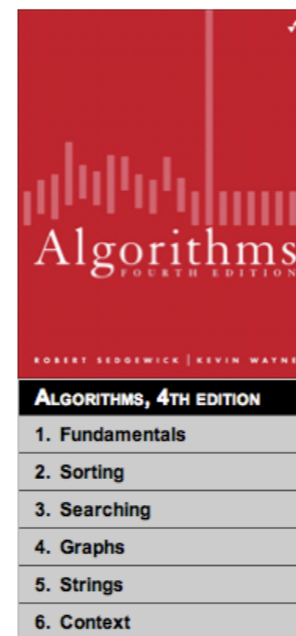computers today. Particular emphasis is given to ...

# Resources (web)

Course content.

- Course info.
- Lecture slides.
- Programming assignments.
- Quizzes.
- Exam archive.

Booksite.

- Brief summary of content.
- Download code from book.
- APIs and Javadoc.



**ALGORITHMS, 4TH EDITION**

*essential information that
every serious programmer
needs to know about
algorithms and data structures*

**Textbook.** The textbook *Algorithms, 4th Edition* by Robert Sedgewick and Kevin Wayne [ Amazon · Addison-Wesley ] surveys the most important algorithms and data structures in use today. The textbook is organized into six chapters:

- *Chapter 1: Fundamentals* introduces a scientific and engineering basis for comparing algorithms and making predictions. It also includes our programming model.
- *Chapter 2: Sorting* considers several classic sorting algorithms, including insertion sort, mergesort, and quicksort. It also includes a binary heap implementation of a priority queue.
- *Chapter 3: Searching* describes several classic symbol table implementations, including binary search trees, red-black trees, and hash tables.

**https://algs4.cs.princeton.edu**

# Resources (people)

## Piazza discussion forum.

- Low latency, low bandwidth.
- See Piazza for guidelines.



http://piazza.com/princeton/fall2018/cos226

## Office hours.

- High bandwidth, high latency.
- See web for schedule.
- For assignment questions,
  go to preceptor office hours



http://www.princeton.edu/~cos226

## Computing laboratory.

- Undergrad lab TAs.
- For help with debugging.
- See web for schedule.



http://labta.cs.princeton.edu