

COS 226, SPRING 2014

**ALGORITHMS
AND
DATA STRUCTURES**

KEVIN WAYNE



**PRINCETON
UNIVERSITY**

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

COS 226 course overview

What is COS 226?

- Intermediate-level survey course.
- Programming and problem solving, with applications.
- **Algorithm:** method for solving a problem.
- **Data structure:** method to store information.

topic	data structures and algorithms
data types	stack, queue, bag, 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	B-tree, k-d tree, suffix array, maxflow

Why study algorithms?

Their impact is broad and far-reaching.

Internet. Web search, packet routing, distributed file sharing, ...

Biology. Human genome project, protein folding, ...

Computers. Circuit layout, file system, compilers, ...

Computer graphics. Movies, video games, virtual reality, ...

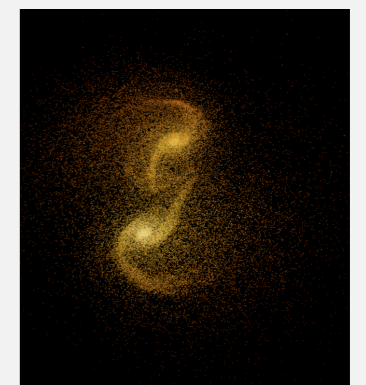
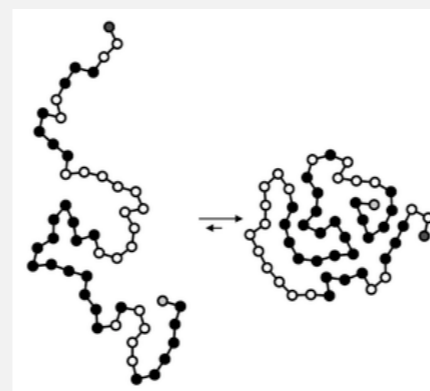
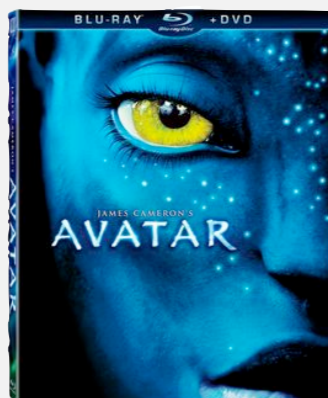
Security. Cell phones, e-commerce, voting machines, ...

Multimedia. MP3, JPG, DivX, HDTV, face recognition, ...

Social networks. Recommendations, news feeds, advertisements, ...

Physics. N-body simulation, particle collision simulation, ...

⋮



Why study algorithms?

Their impact is broad and far-reaching.

Mysterious algorithm was 4% of trading activity last week

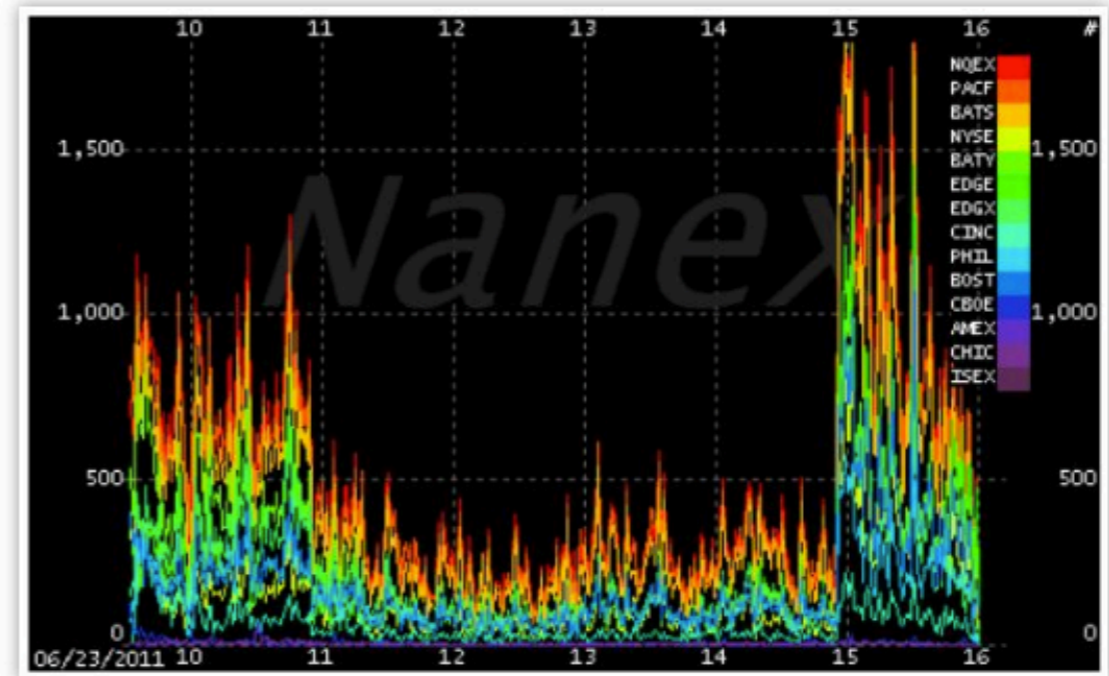
October 11, 2012

A single mysterious computer program that placed orders — and then subsequently canceled them — made up 4 percent of all quote traffic in the U.S. stock market last week, according to the top tracker of [high-frequency trading activity](#).

The motive of the algorithm is still unclear, [CNBC](#) reports.

The program placed orders in 25-millisecond bursts involving about 500 stocks, according to Nanex, a market data firm. The algorithm never executed a single trade, and it abruptly ended at about 10:30 a.m. ET Friday.

“My guess is that the algo was testing the market, as high-frequency frequently does,” says Jon Najarian, co-founder of TradeMonster.com. “As soon as they add bandwidth, the HFT crowd sees how quickly they can top out to create latency.” ([Read More: Unclear What Caused Kraft Spike: Nanex Founder.](#))

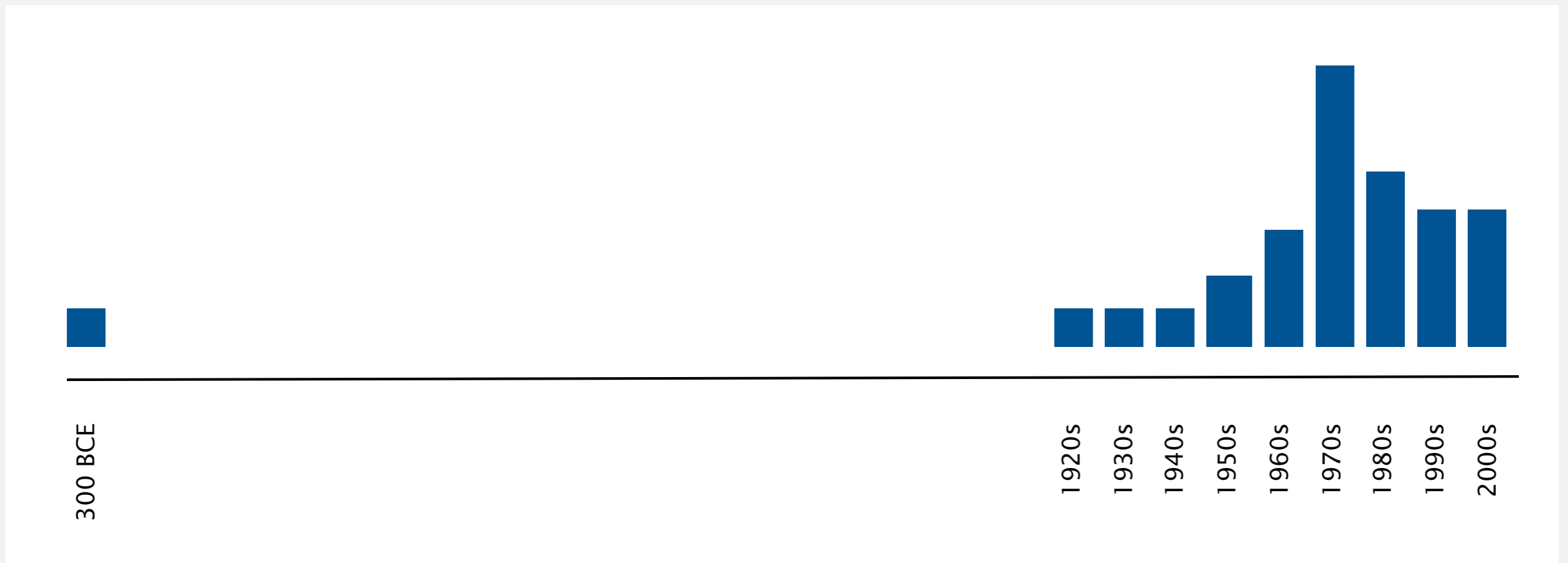


Generic high frequency trading chart (credit: Nanex)

Why study algorithms?

Old roots, new opportunities.

- Study of algorithms dates at least to Euclid.
- Formalized by Church and Turing in 1930s.
- Some important algorithms were discovered by undergraduates in a course like this!

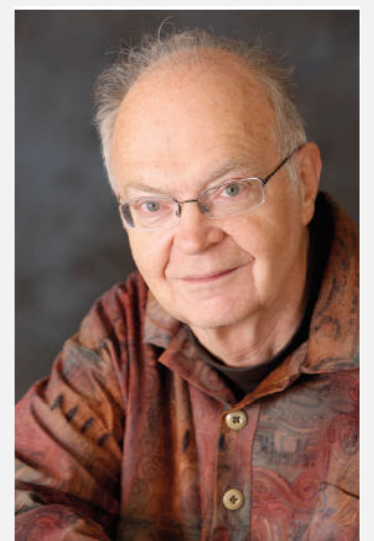
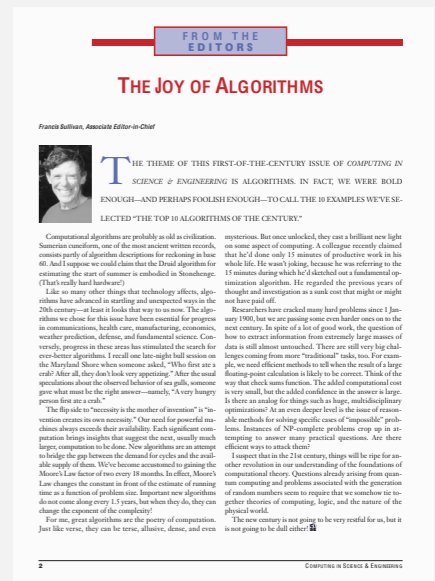


Why study algorithms?

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

“ An algorithm must be seen to be believed. ” — Donald Knuth



Why study algorithms?

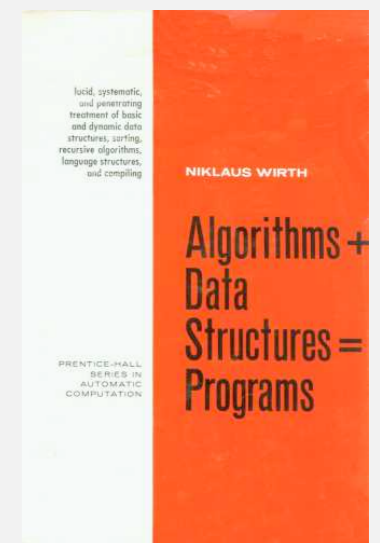
To become a proficient programmer.

“ 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 (creator of Linux)



“ Algorithms + Data Structures = Programs. ” — Niklaus Wirth



Why study algorithms?

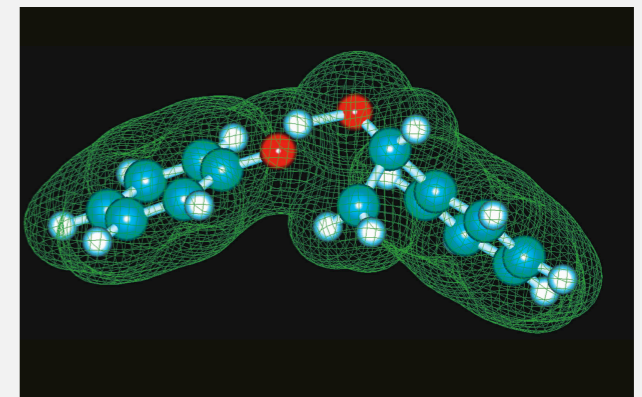
They may unlock the secrets of life and of the universe.

“ 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)*

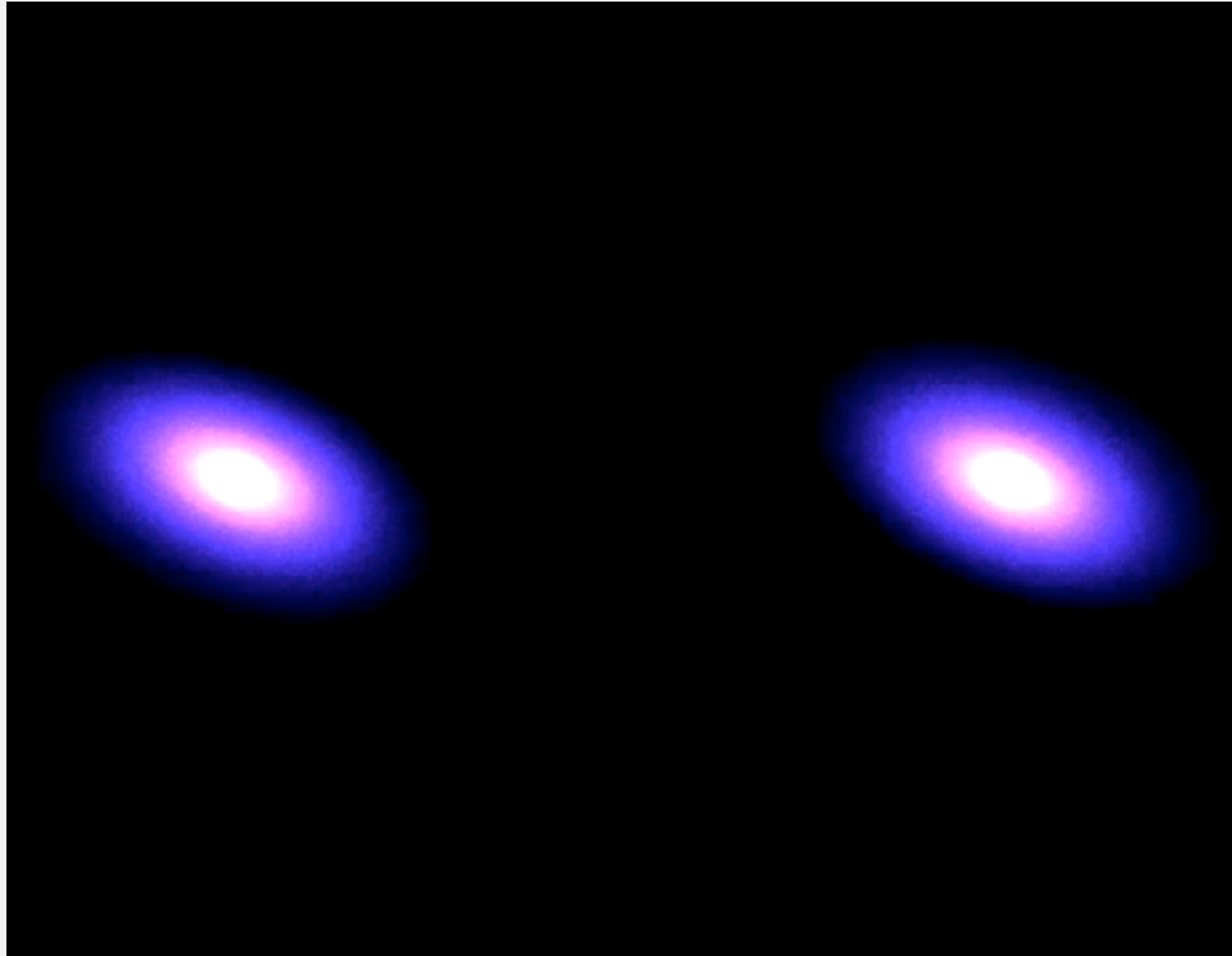


Martin Karplus, Michael Levitt, and Arieh Warshel



Why study algorithms?

To solve problems that could not otherwise be addressed.



http://www.youtube.com/watch?v=ua7YIN4eL_w

Why study algorithms?

Everybody else is doing it.

```
% sort -rn PU2013-14.txt
774 COS 126 General Computer Science
615 ECO 100 Introduction to Microeconomics
471 ECO 101 Introduction to Macroeconomics
444 ENG 385 Children's Literature
440 MAT 202 Linear Algebra with Applications
414 COS 226 Algorithms and Data Structures
405 MAT 201 Multivariable Calculus
384 CHV 310 Practical Ethics
344 REL 261 Christian Ethics and Modern Society
320 PSY 101 Introduction to Psychology
300 COS 217 Introduction to Programming Systems
...
```

Why study algorithms?

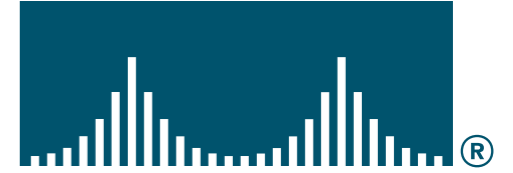
For fun and profit.



Apple Computer

facebook

CISCO SYSTEMS



IBM

Nintendo



Morgan Stanley

NETFLIX



DE Shaw & Co

ORACLE



YAHOO!

amazon.com

Microsoft



Why study algorithms?

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

Why study anything else?



Lectures

Traditional lectures. Introduce new material.

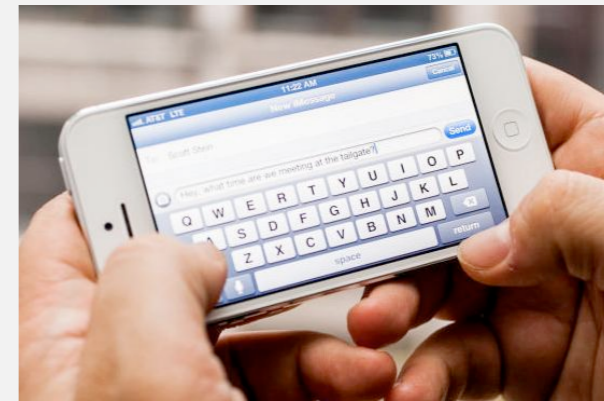
Electronic devices. Permitted, but only to enhance lecture.



no



no



no

What	When	Where	Who	Office Hours
L01	MW 11-12:20	McCosh 10	Kevin Wayne	see web

Lectures

Traditional lectures. Introduce new material.

Flipped lectures.

- Watch videos online **before** lecture.
- Complete pre-lecture activities.
- Attend only one "flipped" lecture per week (interactive, collaborative, experimental).
- Apply via web ASAP: results by 5pm today.



What	When	Where	Who	Office Hours
L01	MW 11-12:20	McCosh 10	Kevin Wayne	see web
L02	W 11-12:20	Frist 307	Josh Hug Andy Guna	see web

Precepts

Discussion, problem-solving, background for assignments.

What	When	Where	Who	Office Hours
P01	Th 11-11:50	CS 102	Andy Guna †	see web
P02	Th 12:30-1:20	Bobst 105	Andy Guna †	see web
P03	Th 1:30-2:20	Bobst 105	Nevin Li	see web
P04	F 10-10:50	Bobst 105	Jennifer Guo	see web
P05	F 11-11:50	Bobst 105	Madhu Jayakumar	see web
P05A	F 11-11:50	Sherrerd 001	Ruth Dannenfelser	see web
P06	F 2:30-3:20	Friend 108	Chris Eubank	see web
P06A	F 2:30-3:20	Friend 111	TBA	see web
P06B	F 2:30-3:20	Friend 109	Josh Hug †	see web
P07	F 3:30-4:20	Friend 108	Josh Hug †	see web

↑
likely to change

† lead preceptor

Coursework and grading

Programming assignments. 45%

- Due on Tuesdays at 11 pm via electronic submission.
- Collaboration/lateness policies: see web.

Exercises. 10%

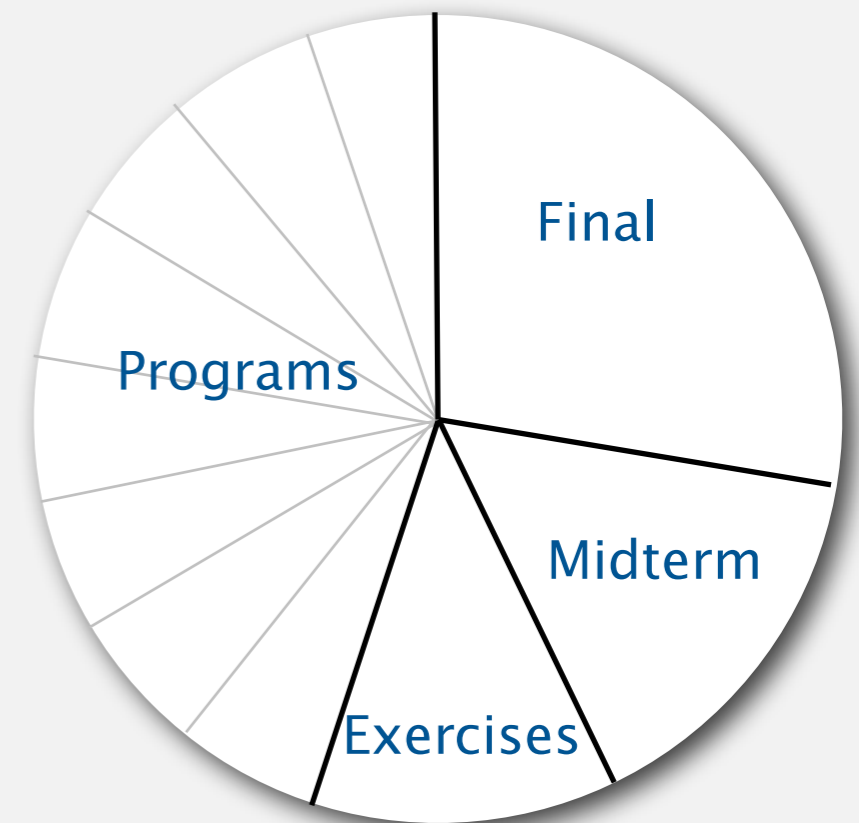
- Due on Sundays at 11 pm in Blackboard.
- Collaboration/lateness policies: see web.

Exams. 15% + 30%

- Midterm (in class on Wednesday, March 12).
- Final (to be scheduled by Registrar).

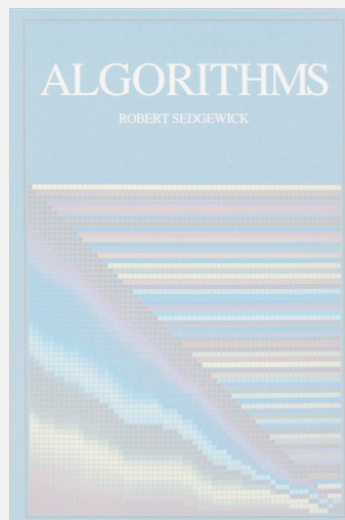
Staff discretion. [adjust borderline cases]

- Report errata.
- Contribute to Piazza discussion forum.
- Attend and participate in precept/lecture.

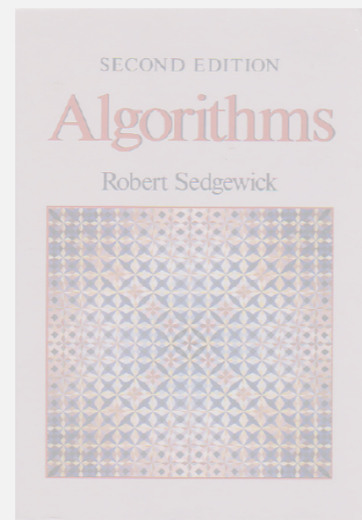


Resources (textbook)

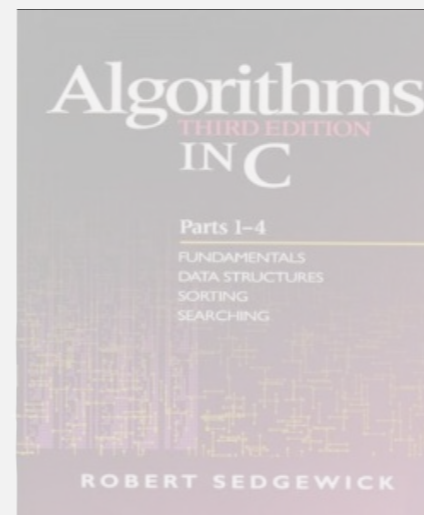
Required reading. Algorithms 4th edition by R. Sedgwick and K. Wayne, Addison-Wesley Professional, 2011, ISBN 0-321-57351-X.



1st edition (1982)

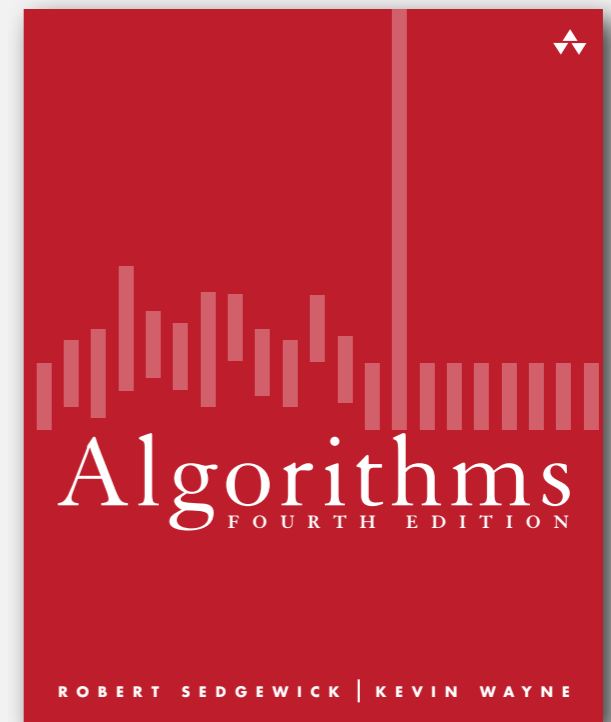


2nd edition (1988)



3rd edition (1997)

3rd book scanned
by Google books



4th edition (2011)

Available in hardcover and Kindle.

- Online: Amazon (\$60/\$35 to buy), Chegg (\$25 to rent), ...
- Brick-and-mortar: Labyrinth Books (122 Nassau St).
- On reserve: Engineering library.


Resources (web)

Course content.

- Course info.
- Lecture slides.
- Flipped lectures.
- Programming assignments.
- Exercises.
- Exam archive.

Booksite.

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




COMPUTER SCIENCE 226
ALGORITHMS AND DATA STRUCTURES
SPRING 2014

[Course Information](#) | [Lectures](#) | [Flipped](#) | [Precepts](#) | [Assignments](#) | [Exercises](#) | [Exams](#)

COURSE INFORMATION

Description. This course surveys the most important algorithms and data structures in use on computers today. Particular emphasis is given to algorithms for sorting, searching, and string processing. Fundamental algorithms in a number of other areas are covered as well, including geometric and graph algorithms. The course will concentrate on developing implementations, understanding their performance characteristics, and estimating their potential effectiveness in applications.

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



ALGORITHMS, 4TH EDITION

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

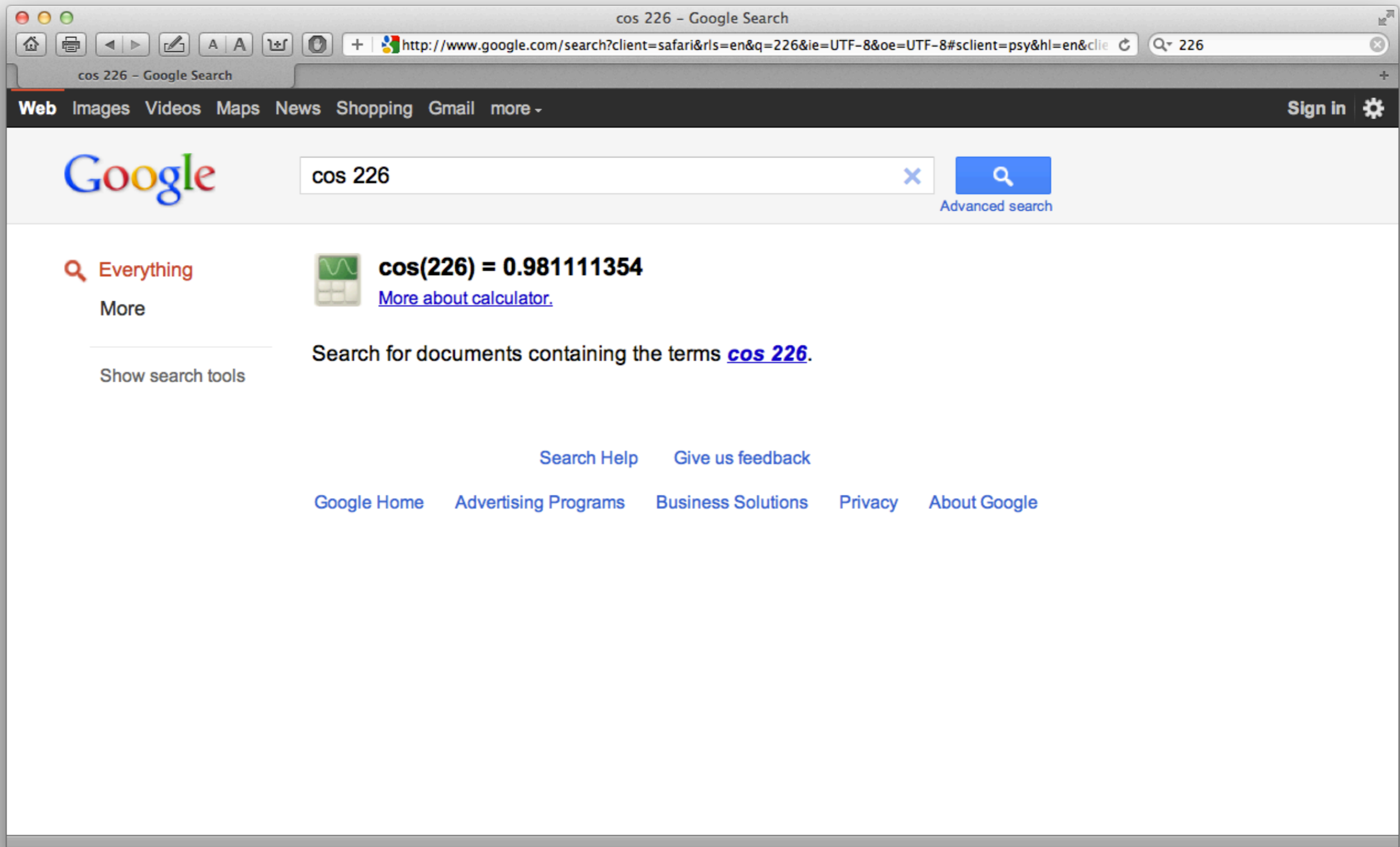
Textbook. The textbook *Algorithms, 4th Edition* by Robert Sedgewick and Kevin Wayne [[Amazon](#) · [Addison-Wesley](#)] surveys the most important algorithms and data structures in use today. The textbook is organized into six chapters:

- **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.

ALGORITHMS, 4TH EDITION
1. Fundamentals
2. Sorting
3. Searching
4. Graphs
5. Strings
6. Context

<http://algs4.cs.princeton.edu>

Resources (web)



The image shows a screenshot of a web browser displaying a Google search result. The browser's address bar shows the URL: <http://www.google.com/search?client=safari&rls=en&q=226&ie=UTF-8&oe=UTF-8#sclient=psy&hl=en&clie>. The search bar contains the text "cos 226". The search results show a calculator icon followed by the equation $\cos(226) = 0.981111354$ and a link to "More about calculator.". Below this, there is a search suggestion: "Search for documents containing the terms [cos 226](#).". At the bottom of the page, there are links for "Search Help", "Give us feedback", "Google Home", "Advertising Programs", "Business Solutions", "Privacy", and "About Google".

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

Resources (web)

The screenshot shows a Google search for the number '226'. The search bar contains '226' and the search button is labeled 'Search'. Below the search bar, it indicates 'About 236,000,000 results (0.18 seconds)'. The search results are as follows:

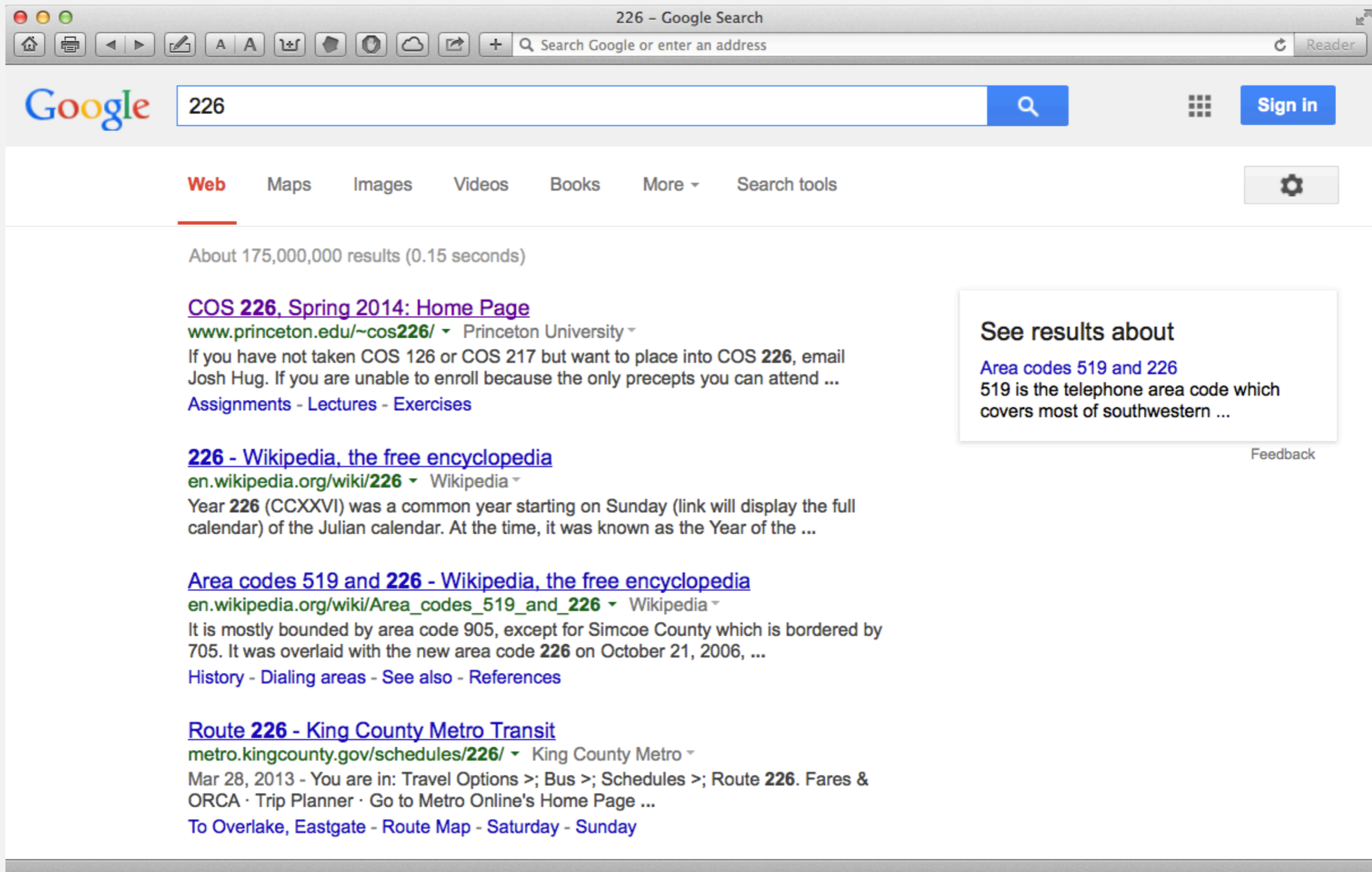
- Area codes 519 and 226 - Wikipedia, the free encyclopedia**
The **226** area code was first proposed as a result of an NPA exhaustion study conducted in the 1990s. The issue was raised with the CRTC by telecommunications ...
en.wikipedia.org/wiki/Area_codes_519_and_226 - Cached - Similar
- 226 - Wikipedia, the free encyclopedia**
226. From Wikipedia, the free encyclopedia. Jump to: navigation, search. This article is about the year **226**. For the number **226**, see **226 (number)**. ...
en.wikipedia.org/wiki/226 - Cached - Similar
- COS 226, Fall 2010: Home Page**
Princeton COS **226**: Data Structures and Algorithms. ... Computer Science **226**. Algorithms and Data Structures Fall 2010 ...
www.princeton.edu/~cos226/ - Cached - Similar

Below the text results, there is a section for 'Images for 226 - Report images' which displays a row of six image thumbnails:

- A blue and black handgun labeled 'RAP226'.
- A silver handgun.
- A black handgun.
- A black and white illustration of a dog and a child.
- A black mobile phone.
- A poster for a museum exhibit.

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

Resources (web)



226 - Google Search

Search Google or enter an address

Google 226 Sign in

Web Maps Images Videos Books More Search tools

About 175,000,000 results (0.15 seconds)

COS 226, Spring 2014: Home Page
www.princeton.edu/~cos226/ ▾ Princeton University ▾
If you have not taken COS 126 or COS 217 but want to place into COS 226, email Josh Hug. If you are unable to enroll because the only precepts you can attend ...
[Assignments](#) - [Lectures](#) - [Exercises](#)

226 - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/226 ▾ Wikipedia ▾
Year 226 (CCXXVI) was a common year starting on Sunday (link will display the full calendar) of the Julian calendar. At the time, it was known as the Year of the ...

Area codes 519 and 226 - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Area_codes_519_and_226 ▾ Wikipedia ▾
It is mostly bounded by area code 905, except for Simcoe County which is bordered by 705. It was overlaid with the new area code 226 on October 21, 2006, ...
[History](#) - [Dialing areas](#) - [See also](#) - [References](#)

Route 226 - King County Metro Transit
metro.kingcounty.gov/schedules/226/ ▾ King County Metro ▾
Mar 28, 2013 - You are in: [Travel Options](#) >; [Bus](#) >; [Schedules](#) >; [Route 226](#). [Fares & ORCA](#) · [Trip Planner](#) · [Go to Metro Online's Home Page](#) ...
[To Overlake, Eastgate](#) - [Route Map](#) - [Saturday](#) - [Sunday](#)

See results about
[Area codes 519 and 226](#)
519 is the telephone area code which covers most of southwestern ...

Feedback

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

Resources (web)

The image shows a browser window with the title "algorithms - Google Search". The address bar contains "https://algorithms". The search bar has "algorithms" entered. The search results are displayed under the "Web" tab. The first result is "Algorithm - Wikipedia, the free encyclopedia" with a snippet: "In mathematics and computer science, an **algorithm** is a step-by-step procedure for calculations. **Algorithms** are used for calculation, data processing, and ...". The second result is "List of algorithms - Wikipedia, the free encyclopedia" with a snippet: "The following is a list of algorithms along with one-line descriptions for each.". The third result is "Algorithms, 4th Edition by Robert Sedgewick and Kevin Wayne" with a snippet: "The textbook **Algorithms**, 4th Edition by Robert Sedgewick and Kevin Wayne surveys the most important **algorithms** and data structures in use today. The broad ...". The fourth result is "HowStuffWorks 'What is a 'computer algorithm'?" with a snippet: "That's where computer **algorithms** come in. The **algorithm** is the basic technique used to get the job done. Let's follow an example to help get an understanding ...". The fifth result is "Algorithms, Part I | Coursera" with a snippet: "Algorithms, Part I is a free online class taught by Kevin Wayne and Robert Sedgewick of Princeton University."

algorithms - Google Search

algorithms

Google

algorithms

Sign in

Web Images Maps Shopping News More Search tools

About 22,700,000 results (0.13 seconds)

[Algorithm - Wikipedia, the free encyclopedia](#)
en.wikipedia.org/wiki/Algorithm
In mathematics and computer science, an **algorithm** is a step-by-step procedure for calculations. **Algorithms** are used for calculation, data processing, and ...
List of algorithms - Algorithm examples - Automated reasoning - Euclidean

[List of algorithms - Wikipedia, the free encyclopedia](#)
en.wikipedia.org/wiki/List_of_algorithms
The following is a list of algorithms along with one-line descriptions for each.

[Algorithms, 4th Edition by Robert Sedgewick and Kevin Wayne](#)
algs4.cs.princeton.edu/
The textbook **Algorithms**, 4th Edition by Robert Sedgewick and Kevin Wayne surveys the most important **algorithms** and data structures in use today. The broad ...

[HowStuffWorks "What is a "computer algorithm"?"](#)
computer.howstuffworks.com/question717.htm
That's where computer **algorithms** come in. The **algorithm** is the basic technique used to get the job done. Let's follow an example to help get an understanding ...

[Algorithms, Part I | Coursera](#)
https://www.coursera.org/course/algs4partI
Algorithms, Part I is a free online class taught by Kevin Wayne and Robert Sedgewick of Princeton University.

Where to get help?

Piazza discussion forum.

- Low latency, low bandwidth.
- Mark solution-revealing questions as private.

piazza

<http://piazza.com/princeton/spring2014/cos226>

Office hours.

- High bandwidth, high latency.
- See web for schedule.



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

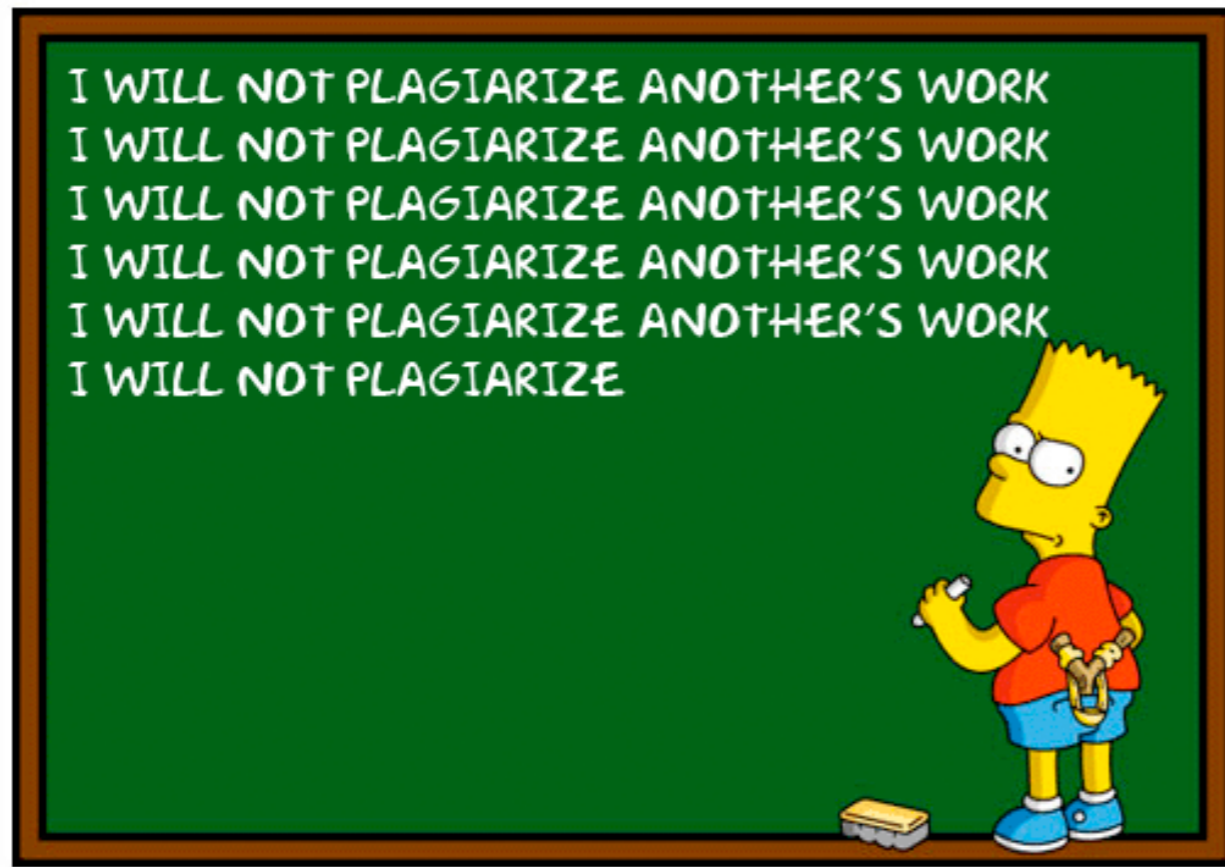
Computing laboratory.

- Undergrad lab TAs in Friend 017.
- For help with debugging.
- See web for schedule.

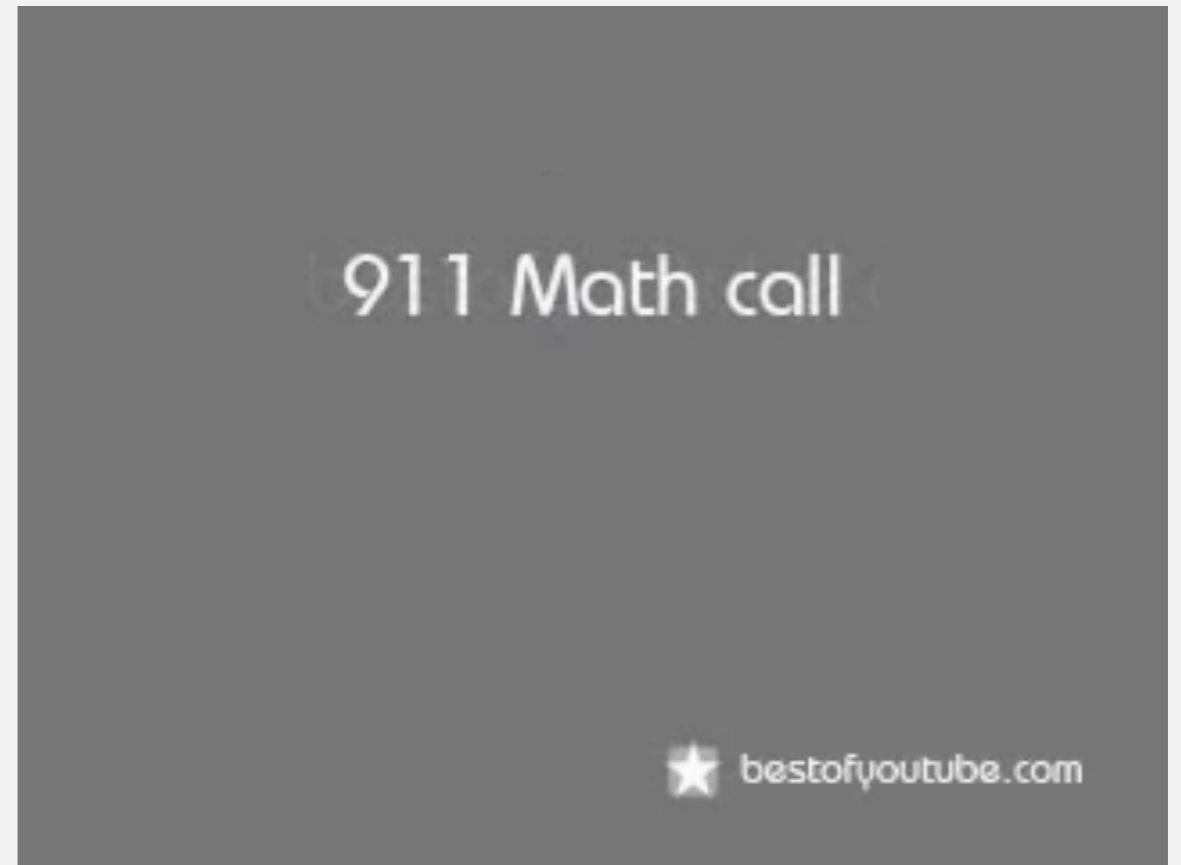


<http://www.princeton.edu/~cos226>

Where not to get help?



<http://world.edu/academic-plagiarism>



<http://www.youtube.com/watch?v=FT4NOe4vtoM>

What's ahead?

Lecture 1. [today] Union find.

Lecture 2. [Wednesday] Analysis of algorithms.

Flipped lecture 1. [Wednesday] Watch video beforehand.

Precept 1. [Thursday/Friday] Meets this week.



Exercise 1. Due via Bb submission at 11 pm on Sunday.

Assignment 1. Due via electronic submission at 11 pm on Tuesday.

← protip: start early

Right course? See me.

Placed out of COS 126? Review Sections 1.1–1.2 of Algorithms 4/e.

Not registered? Go to any precept this week.

Change precept? Use SCORE.

← see Colleen Kenny-McGinley
in CS 210 if the only precepts
you can attend are closed