An algorithm must be seen to be believed.

(Donald Knuth)

izquotes.com

Introduction to Algorithms

COMP 3270

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Assistant Professor
Computer Science and Software Engineering
Auburn University

Welcome to the world

of

Algorithms

This course is really about

Computational Problem Solving (CPS)

Algorithms just happen to be key parts of computational solutions to problems!

Computational Problem Solving is the art of coming up with a correct AND efficient computational solution (i.e., one or more algorithms) to a given problem.

Problems and Problem Instances

- An <u>instance of a problem</u> consists of <u>one set of valid inputs</u> from which a solution to the problem can be computed.
- "How to sort a set of numbers in the ascending order" is a problem.
- "Sorting the set of numbers 4,5,7,1,2,0 in the ascending order" is a problem instance.

Steps of Computational Problem Solving

- Problem specification
- Designing solution **strategies**
- Developing corresponding **algorithms**
  - Understand existing algorithms and modify/reuse, or
  - Design new algorithms
- Understanding the algorithms by simulating their operation on inputs
- Ensuring/proving correctness of the algorithms
- Analyzing and comparing the performance/efficiency of algorithms
  - Theoretically: Using a variety of mathematical tools
  - Empirically: Code, run and collect performance data
- Choosing the best algorithm to code

This course is intended to teach you how to...

Understand

Analyze

Design

Algorithms

that solve computational problems

Why should you care about algorithms?

A random sampling of news about algorithms...

https://www.scpr.org/news/2017/08/19/74843/did-a-bail-reform-algorithm-contribute-to-this-san/

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Crime & Justice

Did a bail reform algorithm contribute to this San Francisco man's murder?

Eric Westervelt | NPR | August 19 2017

Edward French, 71, was killed in San Francisco on July 11. One of the murder suspects was arrested two weeks before his death for gun possession and parole violations. The suspect was released based on a "public-safety assessment score" — a computer generated score that helps calculate whether a suspect is a flight risk or likely to return to court. /COURTESY OF BRIAN HIGGINBOTHAM

SHARE

In the dawn hours of July 16, Edward French, a professional film and TV scout and avid photographer, stood atop Twin Peaks, the famed San Francisco hillside with its panoramic views of his hometown.

French, 71, had his camera with him, as he always did.

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www.businessinsider.com/wikileaks-algorithm-dnc-julian-assange-podesta-emails-new-yorker-2017-8

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Creating a beautiful website is simple with drag & drop tools and customizable templates.

Julian Assange explains how WikiLeaks used an algorithm to catch the Clinton camp off-guard with email dumps

Eliza Relman
Aug. 14, 2017, 8:58 PM 7,790

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www.dailycal.org/2017/08/20/uc-berkeley-graduate-student-fights-human-trafficking-algorithms/

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THE DAILY CALIFORNIAN
Monday, August 21, 2017

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CAMPUS | SUNDAY, AUGUST 20, 2017

UC Berkeley graduate student fights human trafficking through algorithms

BY MALINI RAMAIYER | STAFF | LAST UPDATED 1 MIN AGO

Rebecca Portnoff, a doctoral candidate in the UC Berkeley School of Engineering, developed two algorithms aimed to scan through online sex advertisements and find human trafficking circles.

Portnoff presented her dissertation findings Wednesday at KDD 2017, a data science conference in Canada. The algorithms look through sex advertisements on Backpage, an online classified advertisements site, to find human traffickers, according to Portnoff. There is a difference, she added, between sex advertisements that are consensual and those that are related to human trafficking.

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The Daily Californian
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www.npr.org/sections/thetwo-way/2015/08/05/429720274/obstructions-vanish-from-images-treated-with-new-software-from-mit-google

AMERICA

Obstructions Vanish From Images Treated With New Software From MIT, Google

August 5, 2015 · 2:18 PM ET

LUCY PERKINS

Researchers from MIT and Google used a video to explain how their new algorithm separates background and foreground.

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gadgets.ndtv.com/apps/news/googles-new-algorithm-can-remove-watermarks-from-photos-suggests-replacement-1739894

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Google's New Algorithm Can Remove Watermarks From Photos, Suggests Replacement

Press Trust of India, 21 August 2017

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irishtechnews.ie/deliveroos-new-algorithm-reduces-delivery-time-to-7-minutes/

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OSCAR MICHEL × AUGUST 21, 2017

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How Web Technologies are
W3C PUBLISHING SUMMIT TAKING PLACE ON NOVEMBER 9-10 IN SAN FRANCISCO
AUGUST 21, 2017

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AUGUST 21, 2017

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Deliveroo's new algorithm reduces delivery

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Facebook Can't Fix Our Political Divide With an Algorithm

ETHAN CHIEL
Aug 18 2017, 3:49pm

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Computer Algorithm Maps Brain for First Time

Economy
Sci & Tech
Monday, August 21, 2017

Computer Algorithm Maps Brain for First Time

A US research team for the first time has developed a computer algorithm that is nearly as accurate as people are at mapping brain neural networks.

When fully operational the new system will be a breakthrough that could speed up the image analysis that researchers use to understand brain circuitry, according to Neuro Science journal.

The software is similar to having a satellite image of the earth and trying to map out 100 billion homes, all of the connecting streets and everyone's destinations, said Shuiwang Ji, associate professor in the School of Electrical Engineering and Computer Science at Washington State University.

Researchers took more than a decade to fully map the circuitry of just one animal's brain — a worm

MOVEMENT DISORDERS ADVISOR

Linda Peckel
August 21, 2017

Algorithm Accurately Predicts Cognitive Decline in Parkinson's Disease

An Algorithm Can Detect Depression By Looking At Your Instagram Posts

algorithms affect almost all facets of your life

your financial transactions

IBM Research: Machine learning for financial fraud detection - Mozilla Firefox

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www.research.ibm.com/foiling-financial-fraud.shtml

IBM Research: Machine learning for financial...

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Using machine learning and stream computing to detect financial fraud

How IBM Research can help companies save billions annually

Fraud costs the financial industry approximately $80 billion annually[1]; U.S. credit and debit card issuers alone lost $2.4 billion[2]. For individual victims of fraud, the experience can be costly and even lead to identity theft, which can take years to resolve. But by using **machine learning** and **stream computing** to create virtual "data detectives," IBM researchers are working to reduce the risk.

Existing fraud detection systems operate on a set of rules, such as flagging ATM withdrawals over a certain amount or credit card purchases that take place outside a card holder's home country. While this method helps stop a large number of fraudulent cases, a team of researchers in the Machine Learning Technologies group at IBM Research - Haifa are taking

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Meet the researchers

Yaara Goldschmidt

Manager, Machine Learning

Algorithms that learn your spending patterns and detect anomalies

your privacy (actually, lack of it)

http://www.ted.com/talks/malte_spitz_your_phone_company_is_watching

your entertainment

Amazon.com: The Hunger Games: Jennifer Lawrence, Josh Hutcherson, Liam Hemsworth, Woody Harrelson: Movies & TV - Mozilla Firefox

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www.amazon.com/Hunger-Games-Jennifer-Lawrence/dp/B008602KQI/ref=sr_1_1?s=movies-tv&ie=UTF8&qid=1389290078&sr=1-1&keywords=hunger+games

Amazon.com: The Hunger Games: Jennifer L...

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The Hunger Games PG-13

(8,335 customer reviews) | IMDb 7.2/10

Also available in HD
Watch in HD on supported devices

THE FIRST FILM IN THE HUNGER GAMES FRANCHISE. Based on the best-selling book, 16-year-old Katniss (Jennifer Lawrence) volunteers to take her younger sister's place in the Hunger Games.

Starring: Jennifer Lawrence, Josh Hutcherson
Directed by: Gary Ross
Runtime: 2 hours 23 minutes
Release year: 2012
Studio: Lionsgate

Play trailer

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Anna Kendrick
(3,190)

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The Goonies
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(1,696)

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https://en.wikipedia.org/wiki/Recommender_system

your romantic life

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Quartz Media LLC (US) https://qz.com/1058013/online-dating-sucks-because-of-the-algorithms-not-the-people/

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Online dating sucks because of the algorithms not the people

Algorithms may be taking over the world...

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https://www.theguardian.com/science/2013/jul/01/how-algorithms-rule-world-nsa

Mathematics

How algorithms rule the world

The NSA revelations highlight the role sophisticated algorithms play in sifting through masses of data. But more surprising is their widespread use in our everyday lives. So should we be more wary of their power?

Leo Hickman

Monday 1 July 2013 13.32 EDT

The financial sector has long used algorithms to predict market fluctuations, but they can also help police identify crime hot spots or online shops target their customers. Photograph: Danil Melekhin/Getty Images

On 4 August 2005, the police department of Memphis, Tennessee, made so many arrests over a three-hour period that it ran out of vehicles to transport the detainees to jail. Three days later, 1,200 people had been arrested across the city - a new police department record. Operation Blue Crush was hailed a huge success.

...but when they go wrong

In August 2012 a trading algorithm lost money at the rate of 10+ million dollars per minute and humans did not notice until more than half an hour had passed.

In 2015, users found the photo-sharing site Flickr's new image-recognition technology was labeling dark-skinned people as "apes" and auto-tagging photos of Nazi concentration camps as "jungle gym" and "sport."

A Boeing 787 has 6.5 million lines behind its avionics and online support systems. What is at stake if the algorithms upon which this software is based have flaws?

Why study algorithms?

You could make a living if you know how to design algorithms...
https://www.kickstarter.com/projects/fbz/knityak-custom-mathematical-knit-scarves

Or get hired by Google...

Or convince some investors to fund your startup...

Why study algorithms?

Or you could become immensely rich...

https://www.forbes.com/profile/sergey-brin/

http://pr.efactory.de/e-pagerank-algorithm.shtml

Why study algorithms?

Or you could become the richest person on earth by inventing a single algorithm...

... we will talk about *that* during the last week of classes.

What is an algorithm?
Three perspectives

https://www.youtube.com/watch?v=k0xgjUhEG3U

https://www.youtube.com/watch?v=vSi6YoTPWLw

https://www.khanacademy.org/computing/computer-science/algorithms/intro-to-algorithms/v/what-are-algorithms

watch them before the next class

What is an algorithm?

An algorithm is a well-defined computation procedure (i.e., a <u>finite</u> number of <u>computational steps</u> specified at the required <u>level of detail</u>) that generally (but not always) takes some data as input and generally (but not always) produces some data as output in order to solve a problem.

An Example: Stable Matching Problem

```
StableMatching(men's preference matrix for women, women's preference matrix for men)
  Initialize all m ∈ M and w ∈ W to free
  while ∃ free man m not yet matched with a woman w
    w=first woman on m's ordered preference list with whom a match has not yet been considered
    if w is free
      (m, w) become matched
    else some pair (m', w) already exists
      if w prefers m to m'
        m' becomes free
        (m, w) become matched
      else
        (m', w) remain matched
```

http://en.wikipedia.org/wiki/Stable_marriage_problem#Algorithm

Take Home Message

Computation is everywhere!
And, as a computer science major or minor, or software engineering, wireless engineering or computer engineering major, what you are learning about is computation.

Algorithms form the backbone of all computations.
So the technical skills you need to succeed are:
understanding
analyzing
designing
algorithms

What have we covered so far?

- Problems and Problem Instances
- The process of Computational Problem Solving
- A little pep talk about why algorithms are important
- We will begin to delve into the technical material next
- **Meanwhile, you have a reading/watching assignment**

Reading/Watching Assignment

1. Read "How algorithms rule the world"
   https://www.theguardian.com/science/2013/jul/01/how-algorithms-rule-world-nsa
2. Read "How Google's algorithm rules the web"
   https://www.wired.com/2010/02/ff_google_algorithm/
3. Watch these two videos:
   https://www.youtube.com/watch?v=TDaFwnOiKVE
   https://www.youtube.com/watch?v=H_aLU-NOdHM
4. Check out other links on this slide set

before next class and raise any issues/questions that came to mind in the next class

What exactly will we study?

- In particular, we will study:
  - How to specify problems so that one can start to think about computational solutions
  - How to come up with solution strategies
  - How to turn those strategies into algorithms
  - How to write algorithms
  - How to understand algorithms written by others
  - How to analyze algorithms
  - How to modify and reuse algorithms
  - How to design new algorithms
- We will also look at algorithms and data structures designed by others to solve fundamental computational problems

This course is divided into three parts:

- Basics of Computational Problem Solving

  Specifying problems, coming up with computational strategies to solve problems, turning those strategies into algorithms, understanding, designing and writing algorithms.

- Tools for analyzing algorithms

  The tools you need to understand, analyze, and guarantee the performance of algorithms. This part is mathematical, abstract and harder than other parts.

- Algorithms that solve important computational problems

  Application of the tools to understand and analyze existing algorithms that solve fundamental problems of computing.

What will I learn?

- Given a problem to solve, be able to specify it at a level that allows you to develop a computational solution
- Given a problem specification, be able to come up with computational strategies for solving it
- Be able to turn those strategies into algorithms, by either reusing existing algorithms with appropriate modifications, or designing a new algorithm
- Given an algorithm, understand how it works
- Check if it is correct
- If not, fix it
- Calculate its efficiency
- If inefficient, be able to modify it to make it more efficient
- Several fundamental computational problems and algorithms to solve them

What should you expect?

Somewhat abstract material that requires you to think about problems and how to solve them in new ways...

Mathematical…but not rocket science!

NOT a programming course

Not easy (so plan to <u>spend a lot of time</u> and <u>keep up</u> with the materials; if not, you won't be able to catch up later)

Attendance Policy

NONE!

I do not take attendance. But my experience has been that there is a <u>positive correlation</u> between attendance and your letter grade!

Required Textbook

Lecture Notes

- Lecture notes will be posted to Canvas after class
- Contains Reading Assignments (from Textbook)
- Optional Thinking Assignments

HWs, Project, Exam

5 Assignments (10% each) — Tentative schedule is in the Syllabus

1 Algorithm Design, Implementation & Analysis Project (10%) — in Java

Note: Project submission is mandatory. <u>If you do not, you will fail the course regardless of your numerical grade in other assignments and exams</u>.

Midterm 1 (10%): **Tuesday September 22 9:30 – 10:45 am**

Midterm 2 (10%): **Tuesday October 20 9:30 – 10:45 am**

Comprehensive Final Exam (20%): **Tuesday December 8 8:00 – 10:30 am**

How to Get Help: Instructor?

Bhattacharya Remote Office: https://auburn.zoom.us/j/260661484

Bhattacharya Remote Office Hours: TR 10:45 am -12:00 noon

Bhattacharya Email: bhattacharyad@auburn.edu

NO Canvas messaging, only AU email

How to Get Help: TA?

TA: Rahmatullah Roche

TA Remote Office: https://auburn.zoom.us/j/558794048

TA Remote Office Hours: MWF 9:00 am - 10:00 am

Email: rzr0057@auburn.edu

NO Canvas messaging, only AU email

Grading Algorithm

```
Grade(points: real) returns char
temp=ceiling(points)
if temp ≥ 90 then return "A"
else if temp ≥ 80 then return "B"
else if temp ≥ 65 then return "C"
else if temp ≥ 50 then return "D"
else if temp < 50return "F"
```

Re-grading

All regrading requests should be made to TA **within one week the grades are posted**.

NOT to the instructor.

If the re-grading issue is not resolved with the TA, then an appeal may be made to the instructor.

TA Remote Office: https://auburn.zoom.us/j/558794048

TA Remote Office Hours: MWF 9:00 am - 10:00 am

How do I make an A?

- Attend all classes
- Review the slides, any supplemental materials if provided, your notes and the textbook after each class and before the next class
- Complete ALL reading assignments after each class and before the next class
- Attempt as many thinking assignments as you can after each class and before the next class
- Ask questions in class
- Study with friends
- Make use of office hours – hours with instructor/TA available every day of the week
- Practice solving problems – make up and solve problems similar to those in assignments, or problems from the textbook that are listed in the slides
- **Do all assignments yourself**
- **Work regularly, not at the last minute!**

I just want a D or F; is that easy?

- Do not keep up with the course on a regular basis
- Study the night before for an exam
- Not take assignments seriously by doing a sloppy job or not doing them at all or cheating

Please do not...

send me an email like this (that actually happened):

I am in your COMP 3270 - 001 Algorithms course and just received the final grade score. I am currently a Junior and have a 4.0 GPA. This would be my first B at Auburn. I finished with an 89 in your course. Is it possible that you can round my grade up to an A?

Syllabus