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# *Advanced Algorithms*

## *– Course Presentation –*

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Joaquim Madeira

Version 0.7 – September 2024

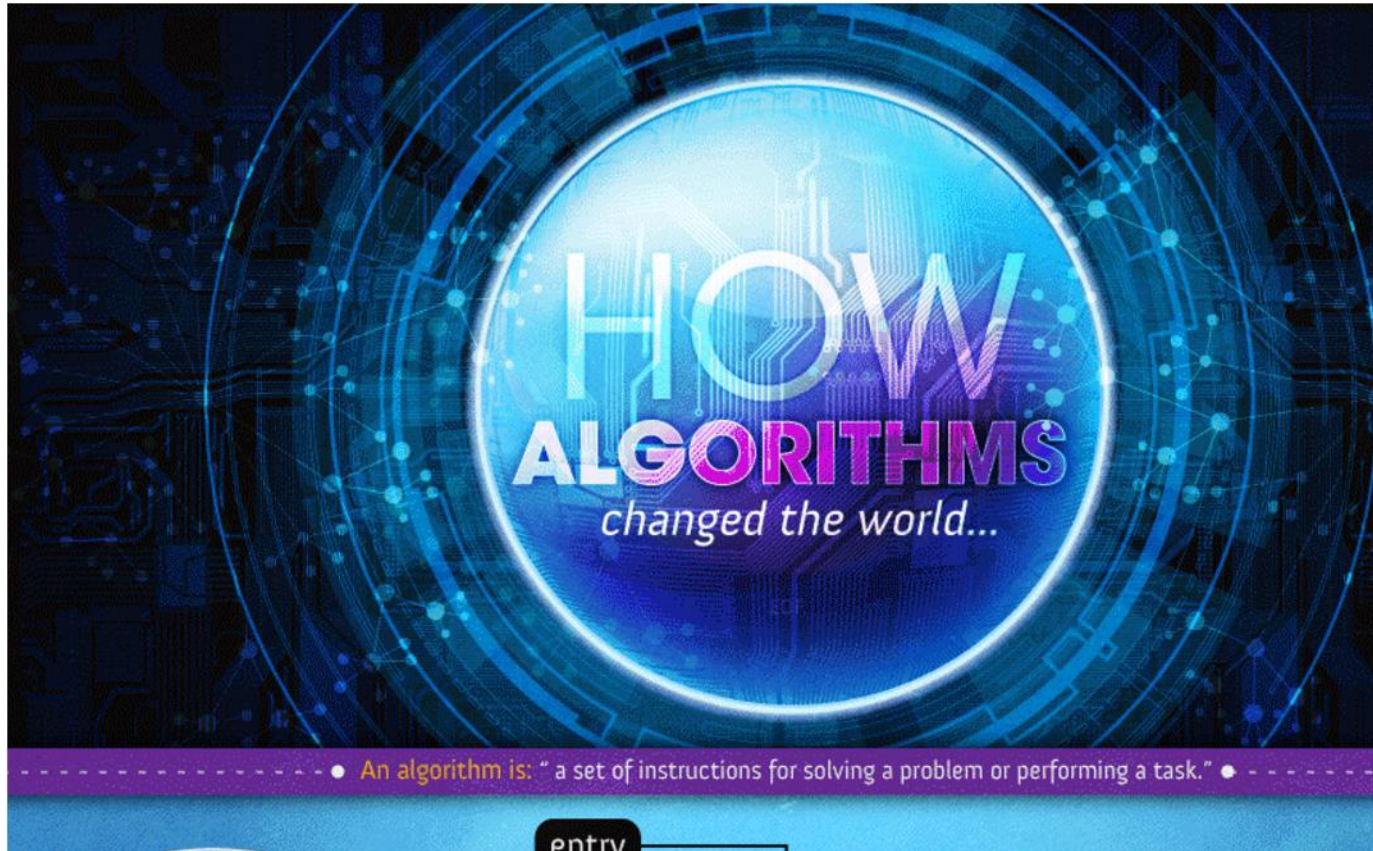
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# Overview

- Motivation
- Goals
- Tentative syllabus
- Evaluation
- Class organization
- Some useful books

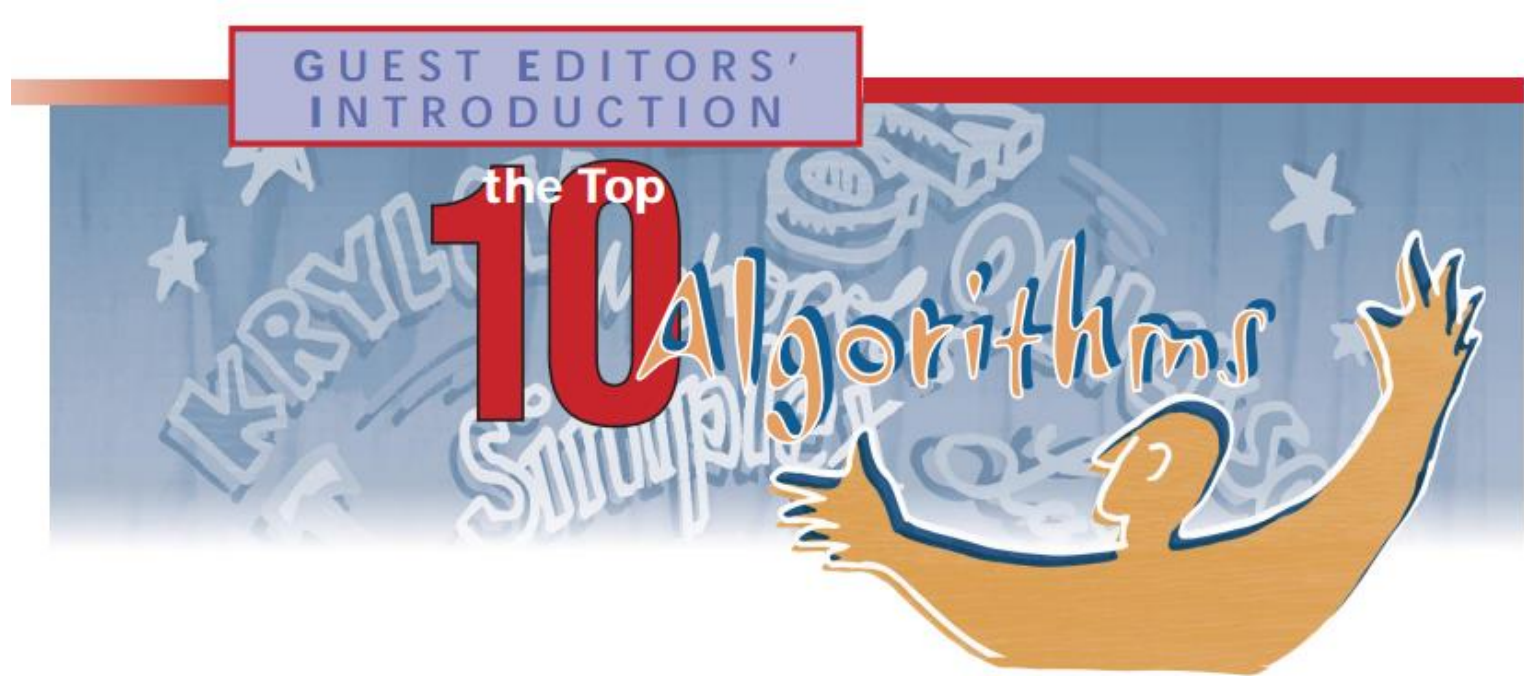


# Algorithms have changed the world !



Check the [infographic on the Web](#)

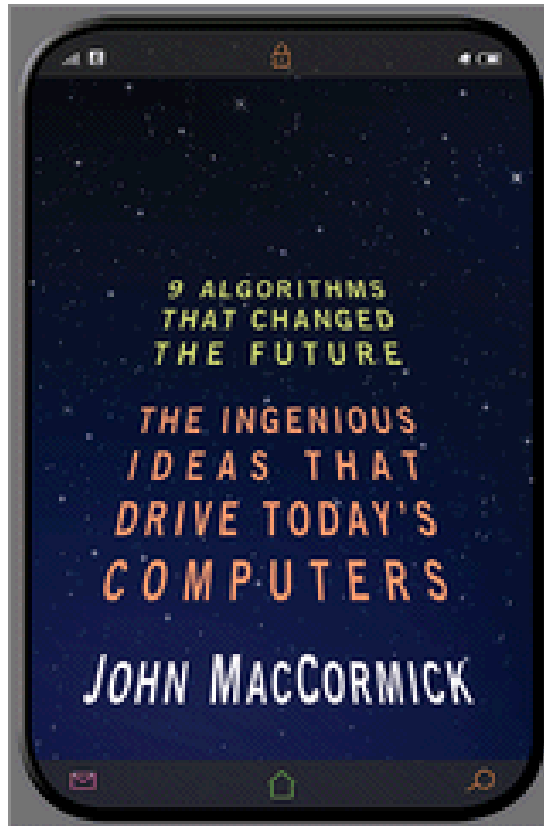
# Top 10 algorithms of the 20th century



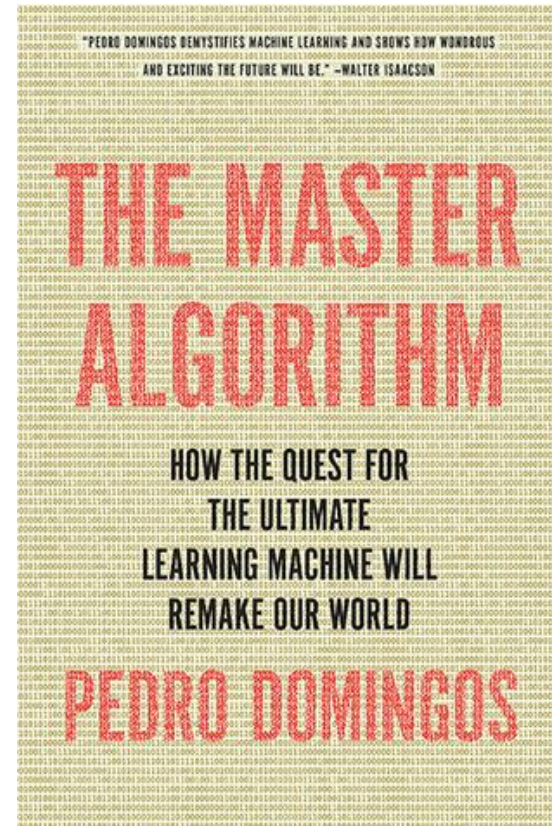
Special issue of IEEE CISE, Jan/Feb 2000



# There are even best-sellers !!

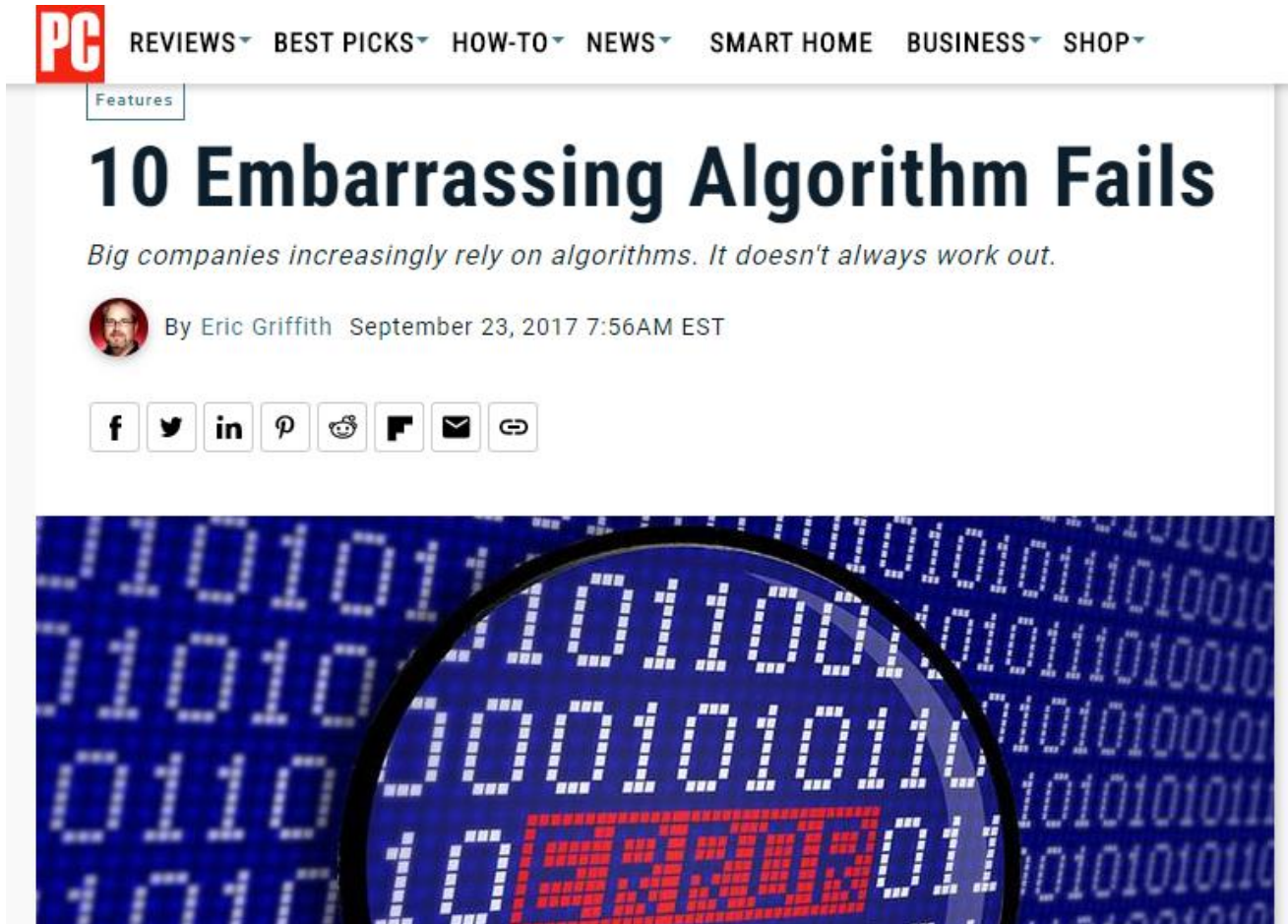


[2012]



[2015]

# Algorithm failures !!



<https://www.pcmag.com/feature/356387/10-embarrassing-algorithm-fails>

# Algorithm failures !!

11 May 2018 | 17:40 GMT

## 450,000 Women Missed Breast Cancer Screenings Due to “Algorithm Failure”

A disclosure in the United Kingdom has sparked a heated debate about the health impacts of an errant algorithm

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By **Robert N. Charette** (/author/charette-robert-n)



Nearly half a million elderly women in the United Kingdom missed mammography exams because of a scheduling error caused by one incorrect computer algorithm, and several hundred of those women may have died early as a result.

[\[https://spectrum.ieee.org/riskfactor/computing/it/450000-woman-missed-breast-cancer-screening-exams-in-uk-due-to-algorithm-failure\]](https://spectrum.ieee.org/riskfactor/computing/it/450000-woman-missed-breast-cancer-screening-exams-in-uk-due-to-algorithm-failure)



# Algorithm failures !!

## Franken-algorithms: the deadly consequences of unpredictable code

The death of a woman hit by a self-driving car highlights an unfolding technological crisis, as code piled on code creates 'a universe no one fully understands'

by [Andrew Smith](#)

**T**he 18th of March 2018, was the day tech insiders had been dreading. That night, a new moon added almost no light to a poorly lit four-lane road in Tempe, Arizona, as a specially adapted Uber Volvo XC90 detected an object ahead. Part of the modern gold rush to develop self-driving vehicles, the SUV had

<https://www.theguardian.com/technology/2018/aug/29/coding-algorithms-frankenalgos-program-danger>

# IT failures !!

27 Dec 2018 | 15:49 GMT

## The Biggest IT Failures of 2018

Technical mishaps occurred in trains, planes, automobiles, and many more places

By **Robert N. Charette**



<https://spectrum.ieee.org/riskfactor/computing/it/it-failures-2018-all-the-old-familiar-faces>

# Biased algorithms

**The Home Office is using algorithms to sort visa applicants, but they have a history of 'discriminatory' failures**

Biased algorithms could be affecting the livelihoods of vulnerable people



<https://inews.co.uk/news/politics/home-office-visa-application-algorithms-history-failures/>

# 2020 UK's exam grade fiasco

**The Observer**

## **From viral conspiracies to exam fiascos, algorithms come with serious side effects**



**John Naughton**

Sun 6 Sep 2020 09.00 BST

**W**ill Thursday 13 August 2020 be remembered as a pivotal moment in democracy's relationship with digital technology? Because of the coronavirus outbreak, A-level and GCSE examinations had to be cancelled, leaving education authorities with a choice: give the kids the grades that had been predicted by their teachers, or use an algorithm. They went with the latter.

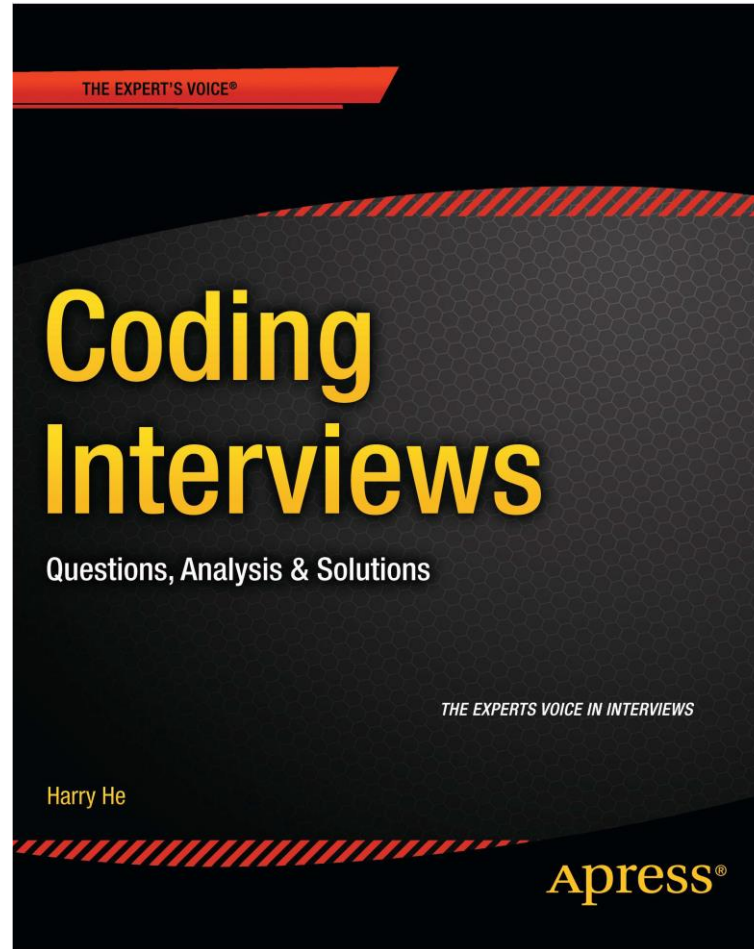
<https://www.theguardian.com/technology/2020/sep/06/from-viral-conspiracies-to-exam-fiascos-algorithms-come-with-serious-side-effects>



# Technical Job Interviews – Skills

- Basic programming knowledge, including understanding of **programming languages**, **data structures**, and **algorithms**
- Abilities to write **clean**, **complete**, and **robust code**
- Capabilities to analyze and solve **complex problems**
- Abilities to improve **time and space efficiencies**
- Skills involving communication, learning, divergent thinking, etc.

# Harry He's book



# ALGORITHM REPOSITORIES

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# rosettacode.org



ROSETTACODE.ORG

Community ▾

Explore ▾

*Main page* [Discussion](#) [View source](#) [History](#)

## Rosetta Code

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Rosetta Code is a [programming chrestomathy](#) site. The idea is to present solutions to the same task in as many different languages as possible. Languages are similar and different, and to aid a person with a grounding in one approach to a problem in learning another. Rosetta C



# Stony Brook Algorithm Repository

Steven Skiena

Dept. of Computer Science

Stony Brook University

Books

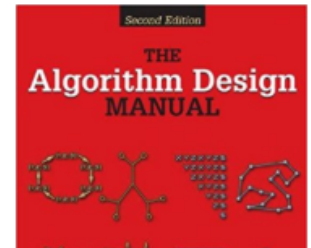
By Language ▾

By Problem ▾

## The Stony Brook Algorithm Repository

Steven Skiena

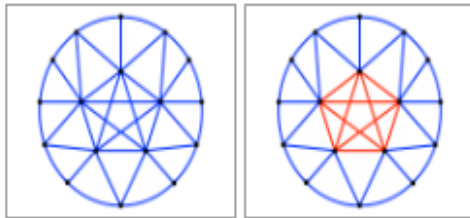
This page provides a comprehensive collection of algorithm implementations for seventy-five of the most fundamental problems in combinatorial algorithms. The problem taxonomy, implementations, and supporting material are all drawn from my book *The Algorithm Design Manual*. Since the practical person is more often looking for a program than an algorithm, we provide pointers to solid implementations of useful algorithms when they are available.



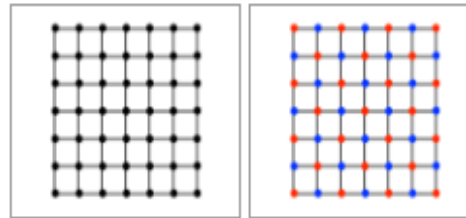
<http://algorist.com/algorist.html>

# Stony Brook Algorithm Repository

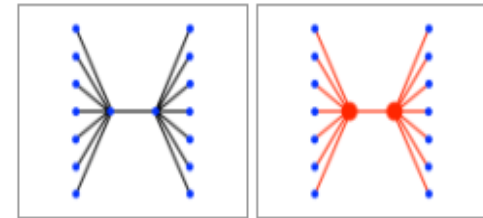
## Graph: Hard Problems



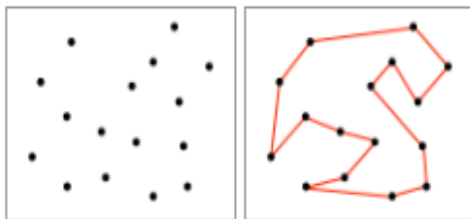
Clique



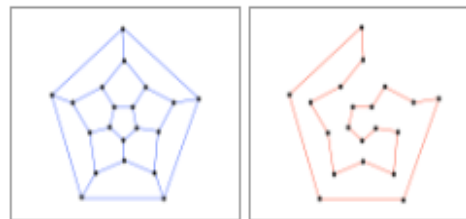
Independent Set



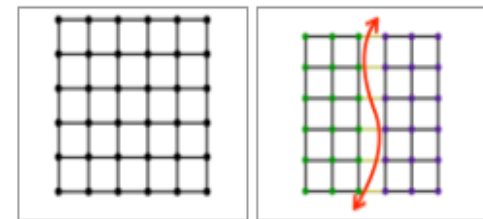
Vertex Cover



Traveling Salesman Problem



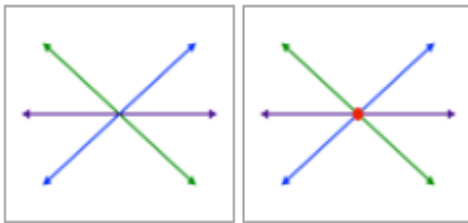
Hamiltonian Cycle



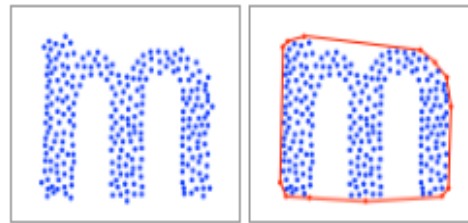
Graph Partition

# Stony Brook Algorithm Repository

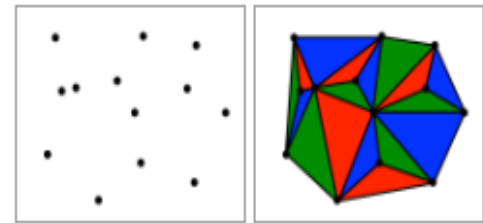
## Computational Geometry



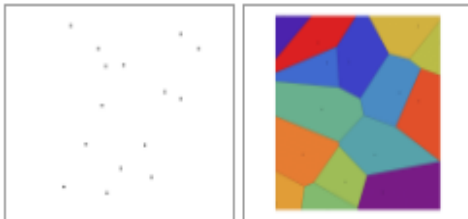
Robust Geometric Primitives



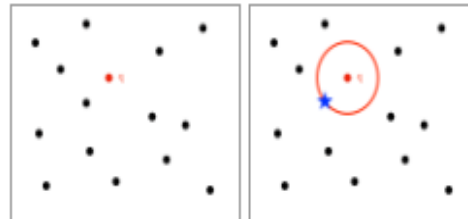
Convex Hull



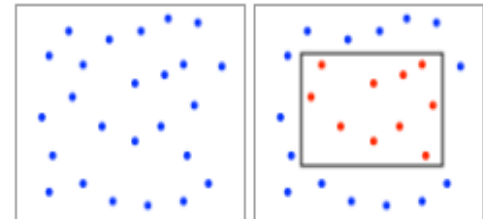
Triangulation



Voronoi Diagrams



Nearest Neighbor Search



Range Search

# github.com/TheAlgorithms



## The Algorithms

Open Source resource for learning Data Structures & Algorithms and their implementation in any Programming Language

📍 India 🔗 <https://gitter.im/TheAlgorithms> ✉ [1anuppanwar@gmail.com](mailto:1anuppanwar@gmail.com) [dynamitechetan@gmail.com](mailto:dynamitechetan@gmail.com)

📁 Repositories 18

📦 Packages

👤 People 29

📁 Projects

### Pinned repositories

#### 📁 Python

All Algorithms implemented in Python

🟠 Jupyter Notebook ★ 55.1k 🍴 16.4k

#### 📁 Java

All Algorithms implemented in Java

🟡 Java ★ 16.8k 🍴 6.2k

#### 📁 C-Plus-Plus

All Algorithms implemented in C++

🟡 C++ ★ 2.8k 🍴 955

#### 📁 C

All Algorithms implemented in C

#### 📁 Go

Algorithms Implemented in GoLang

#### 📁 Javascript

A repository for All algorithms imple  
[https://github.com/TheAlgorithms/javascript](#)





[adp.com]

# GOALS

# Goals

- Review main **algorithm design strategies**
- Introduce **probabilistic / randomized algs.**
- Apply probabilistic methods to large-scale (**big-data**) problems
- Explore problems from different **application areas**

# Goals

- BUT, course **contents** and **depth** can be somewhat adapted to your background and interests...
- Today's lecture and the first weeks should show us how we can proceed...

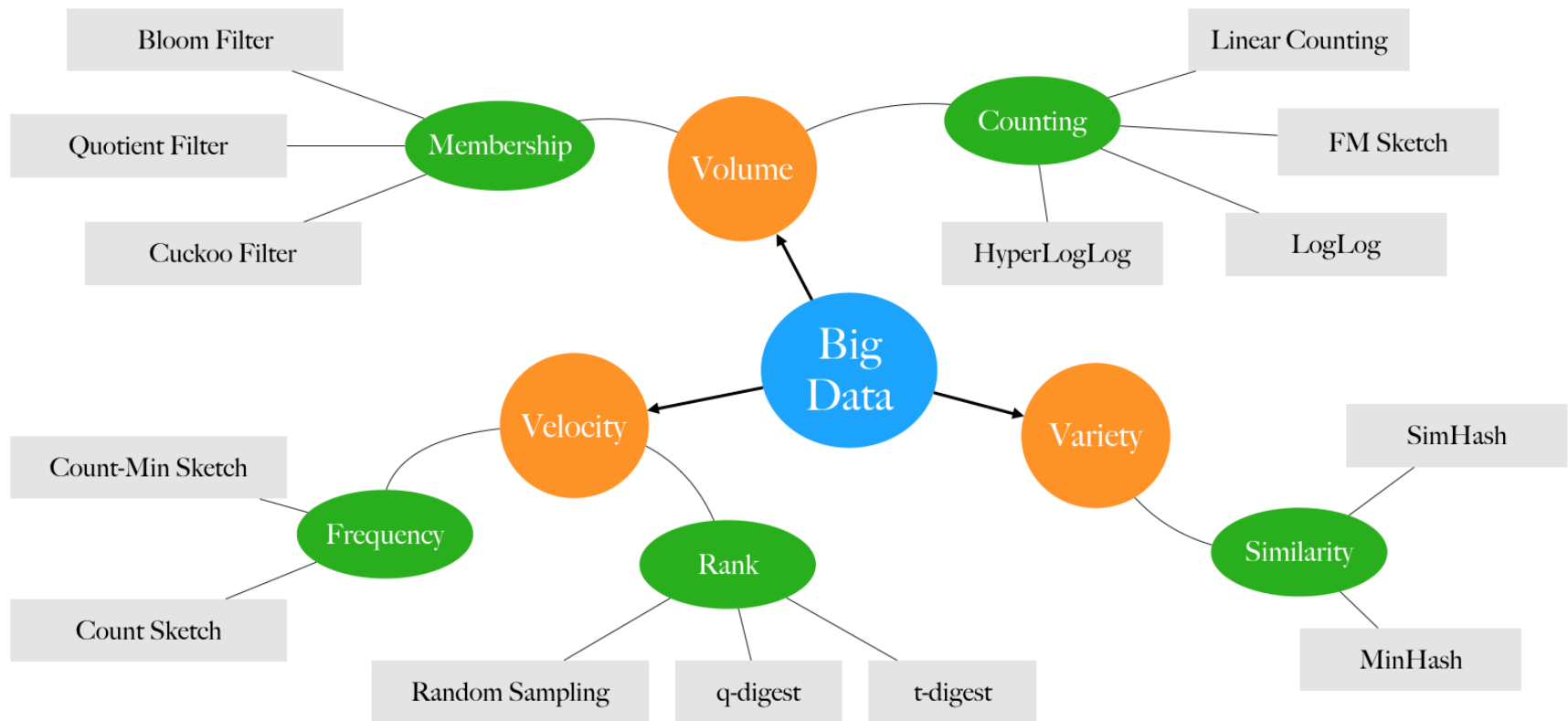
# Why Big-Data ?

- Many of today's data sets cannot be processed by conventional methods
  - Within a reasonable amount of time !
- Why ?
  - Volume – Huge data volumes
  - Variety – Different data modalities /types
  - Velocity – Rapid generation and/or growth  
(how fast data is coming in?)



# PDSA – Probabilistic DSs and Algs

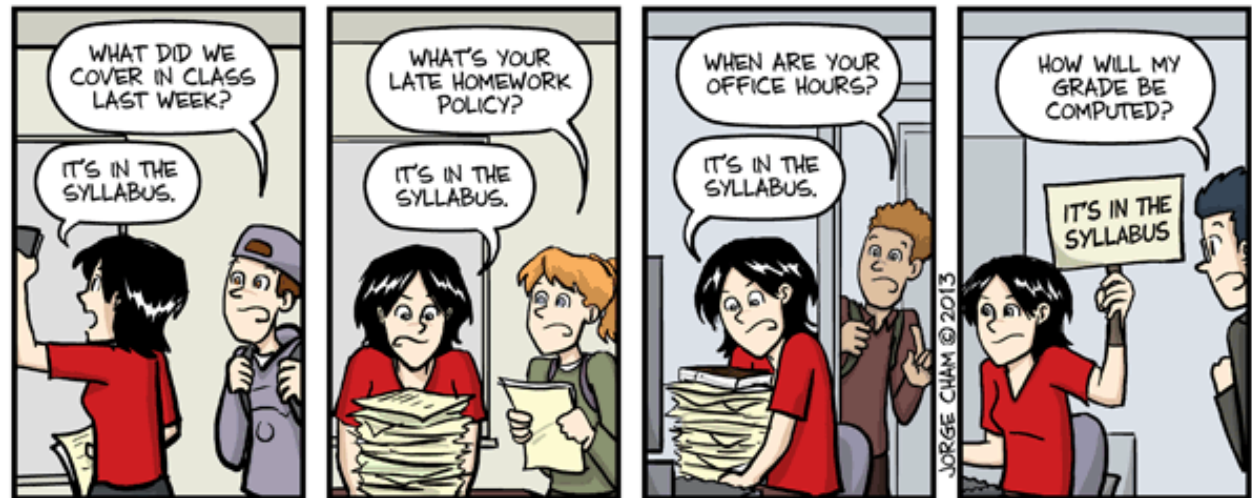
## Problems Solved by PDSA



PDSA in Big Data Ecosystem

gakhov

[ A. Gakhov – <https://www.gakhov.com/> ]



[phdcomics.com]

# SYLLABUS

# Tentative Syllabus

- Algorithm complexity analysis – Review
  - Complexity classes / Formal and empirical analysis
- Algorithm design strategies – Review
  - Brute-force / Divide-and-Conquer / ...
- Deterministic vs Probabilistic algorithms
  - Las Vegas and Monte Carlo algorithms
- Probabilistic counting
- Sets and membership
- ...



[python.org]

# PYTHON


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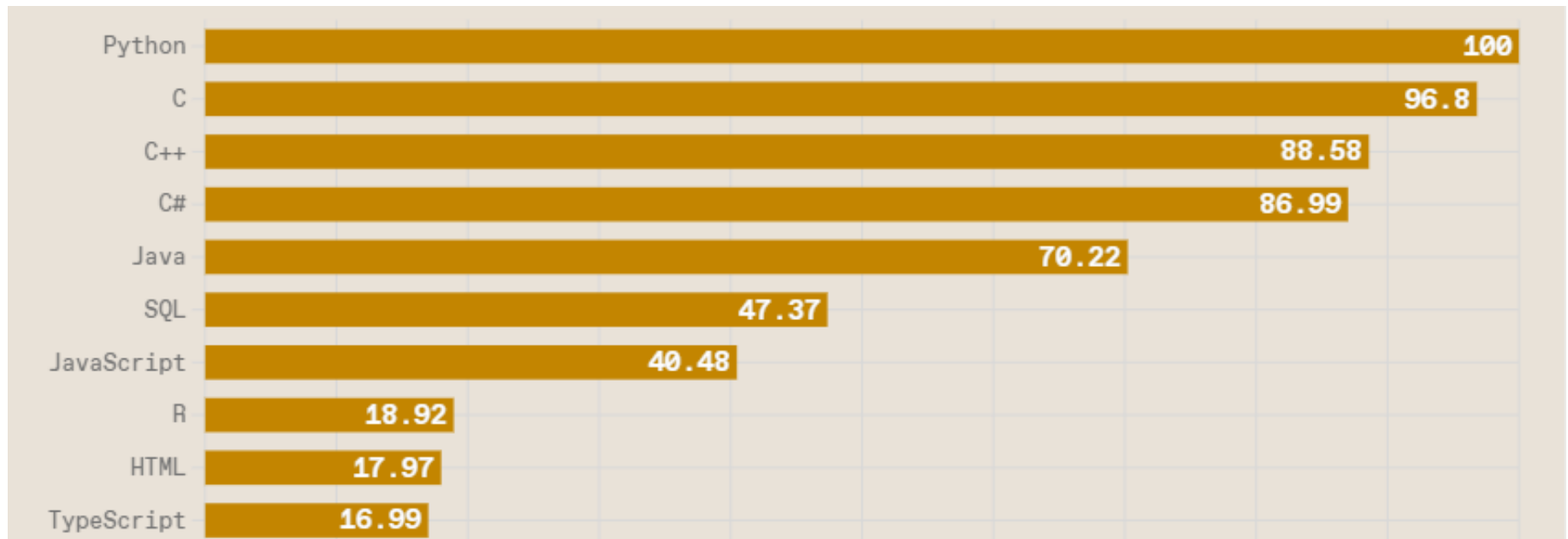
# Programming Language

- Python 3 !!
- If you are at ease with it, that's great !!
- Otherwise, it is easy to learn the basics and start coding quickly...
  - And it will be an important addition to your portfolio !

# IEEE Spectrum – Top prog. languages

## Top Programming Languages 2022 › Python's still No. 1, but employers love to see SQL skills

BY STEPHEN CASS | 23 AUG 2022 | 4 MIN READ | 



[\[https://spectrum.ieee.org/top-programming-languages-2022\]](https://spectrum.ieee.org/top-programming-languages-2022)



# IEEE Spectrum – Top prog. languages

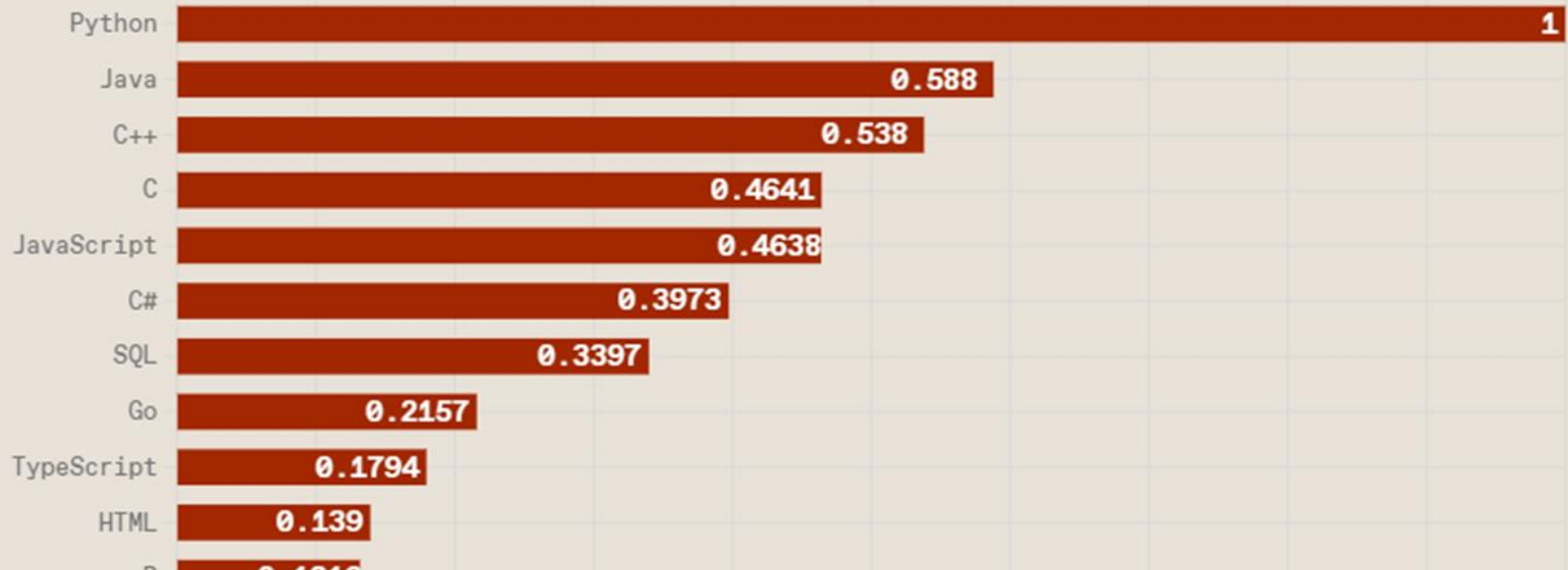
## Top Programming Languages 2023

Click a button to see a differently weighted ranking

Spectrum

Jobs

Trending



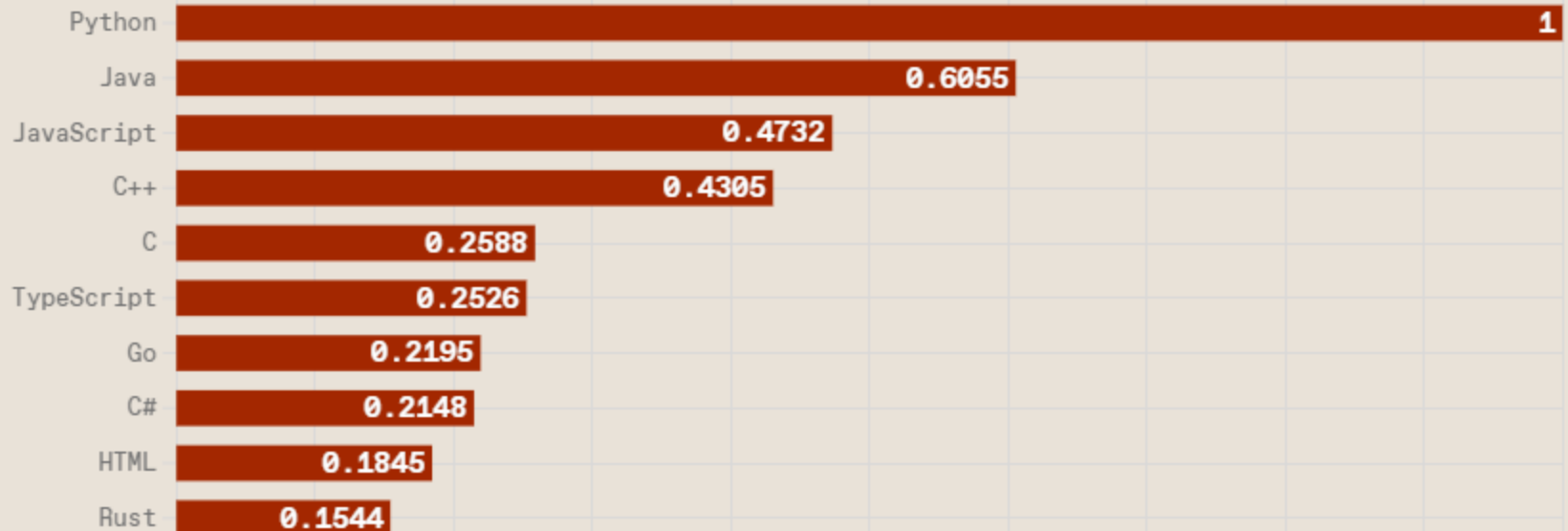
[\[https://spectrum.ieee.org/top-programming-languages-2023\]](https://spectrum.ieee.org/top-programming-languages-2023)

# IEEE Spectrum – Top prog. languages

## Top Programming Languages 2024

Click a button to see a differently weighted ranking

Spectrum **Trending** Jobs



[\[https://spectrum.ieee.org/top-programming-languages-2024\]](https://spectrum.ieee.org/top-programming-languages-2024)



[irinstitutes.org]

# EVALUATION

# Grading

## ■ Mixed grading

- 65% – Individual assignments / projects
  - Code + Report + Presentation / Analysis
- 35% – Final written examination
  - Multiple-choice + True / False questions

# Grading

## ■ Final grading

- 65% – 1 final, aggregate project
  - Code + Report + Presentation / Analysis
- 35% – Final written examination
  - Multiple-choice + True / False questions

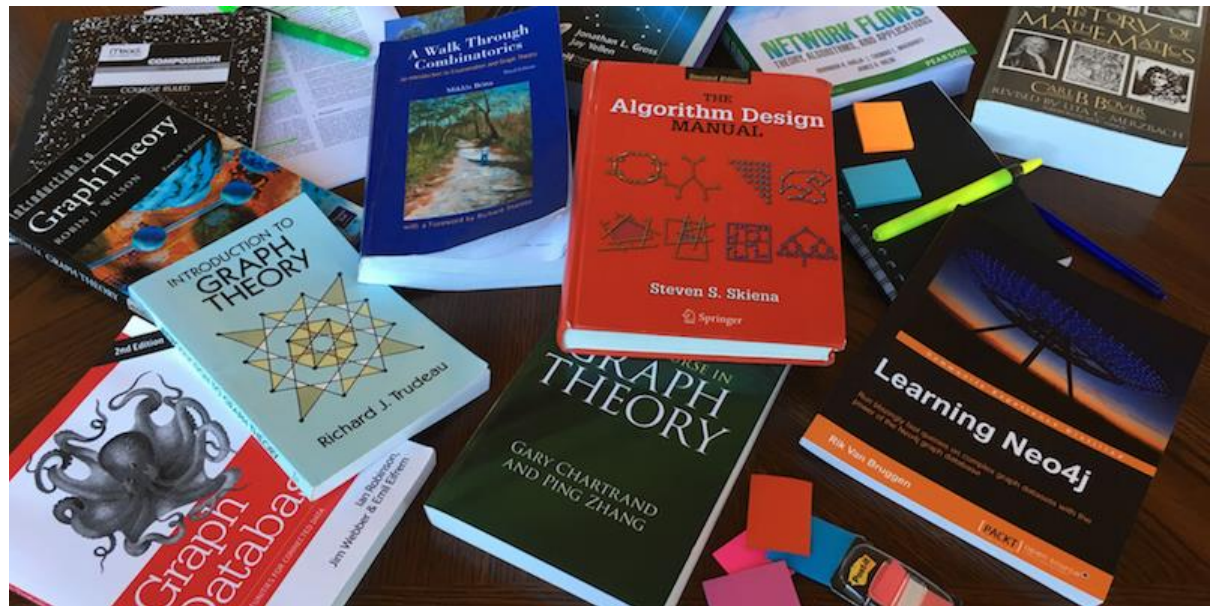
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# ORGANIZATION



# Class Organization

- 1<sup>st</sup> part (approx. 1 hour) : Lecture / presentation
- (Very) Short break 😊
- 2<sup>nd</sup> part : Design / programming / testing
- Bring your own computer !
- Individual work during classes !



[hackernoon.com]

# USEFUL BOOKS

# Bibliography – The basics

- T. H. Cormen et al., *Introduction to Algorithms*, 3<sup>rd</sup> Ed., MIT Press, 2009
- J. Kleinberg and E. Tardos, *Algorithm Design*, Pearson, 2006
- D. Vrajitoru and W. Knight, *Practical Analysis of Algorithms*, Springer 2014
- ...

# Bibliography

- J. Hromkovic, *Design and Analysis of Randomized Algorithms*, Springer, 2005
- J. Leskovec, A. Rajaraman and J. D. Ullman, *Mining of Massive Datasets*, 2<sup>nd</sup> Ed., C. U. Press, 2014
- ...