Data Structures and Algorithms

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spring 2020

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Mohamed Ayman

Experience

- Valeo [2019-Present]
  - Deep Learning Researcher
  - Algorithm Software Engineer
- The American University in Cairo (AUC) [2019-Present]
  - Research Assistant
  - Teaching Assistant
- ICPC - International Collegiate Programming Contest [2016-Present]
  - Coach at ACPC Africa and Arab Collegiate Programming Contest
  - Mentor at ACPC Africa and Arab Collegiate Programming Contest

Education

- MSc in Deep Learning, Cairo University [2018-2021]
- BSc in Computer Science, Cairo University [2013-2017]

Data Structures and Algorithms Training

Lecture Agenda

We will discuss in this lecture the following topics

1- Data Structures and Algorithms Features

2- Data Structures and Algorithms Content

3- Practice on Online Judges

4- Programming Competitions

5- Tutorials and References

6- Online Courses

Let's STARTUP

Lecture Agenda

Section 1: Data Structures and Algorithms Features

Section 2: Data Structures and Algorithms Content

Section 3: Practice on Online Judges

Section 4: Programming Competitions

Section 5: Tutorials and References

Section 6: Online Courses

Data Structures and Algorithms Features

- Data structure is a way to store and organize data in order to support efficient insertions, queries, searches, updates, and deletions. Although a data structure in itself does not solve the given programming problem, the algorithm operating on it does, using the most efficient data structure for the given problem may be a difference between passing or exceeding the problem’s time limit. There are many ways to organize the same data and sometimes one way is better than the other on different context.
- Algorithms is the current term of choice for a problem-solving procedure, algorithm, is commonly used nowadays for the set of rules a machine (and especially a computer) follows to achieve a particular goal. It does not always apply to computer-mediated activity, however. Algorithm is often paired with words specifying the activity for which a set of rules have been designed.
- Characteristics of Data Structures and Algorithms:

1 - Correctness: Data structures and Algorithms implementation should implement its interface correctly.

2 - Time Complexity: Running time or the execution time of operations must be as small as possible.

3 - Space Complexity: Memory usage of a data structure operation should be as little as possible.

Data Structures and Algorithms Features

- Why we need data structures and algorithms? there are several advantages of using them, few of them are as follows:

1. Data Organization: We need a proper way of organizing the data so that it can accessed efficiently when we need that particular data. DS provides different ways of data organization so we have options to store the data in different data structures based on the requirement.

2. Efficiency: The main reason we organize the data is to improve the efficiency. We can store the data in arrays then why do we need linked lists and other data structures? because when we need to perform several operation such as add, delete update and search on arrays , it takes more time in arrays than some of the other data structures. So the fact that we are interested in other data structures is because of the efficiency.

- Time Complexity: It is a way to represent the amount of time required by the program to run till its completion. It's generally a good practice to try to keep the time required minimum, so that our algorithm completes it's execution in the minimum time possible. We will study about Time Complexity in details in later sections.

- Space Complexity: Its the amount of memory space required by the algorithm, during the course of its execution. Space complexity must be taken seriously for multi-user systems and in situations where limited memory is available.

Data Structures and Algorithms Features

Data Structures and Algorithms Features

Lecture Agenda

- ✓ Section 1: Data Structures and Algorithms Features
- Section 2: Data Structures and Algorithms Content
- Section 3: Practice on Online Judges
- Section 4: Programming Competitions
- Section 5: Tutorials and References
- Section 6: Online Courses

Data Structures Content

Part 1: Linear Data Structures

Lecture 1: Complexity Analysis & Recursion

Lecture 2: Array

Lecture 3: Linked List

Lecture 4: Stack

Lecture 5: Queue

Lecture 6: Deque

Lecture 7: Built-in Linear Data Structures

Part 2: Non-Linear Data Structures

Lecture 8: Binary Tree

Lecture 9: Binary Search Tree

Lecture 10: Self Balancing BST (AVL Tree)

Lecture 11: Self Balancing BST (Red Black Tree)

Lecture 12: Binary Heap Tree

Lecture 13: Hash Table

Lecture 14: Built-in Non Linear Data Structures

Data Structures Content

Part 3: Advanced Data Structures

Lecture 15: Disjoint Set

Lecture 16: Skip List

Lecture 17: Trie

Lecture 18: Segment Tree

Lecture 19: Binary Indexed Tree (Fenwick Tree)

Lecture 20: Treap (Randomized Binary Search Tree)

Lecture 21: Splay Tree

Part 4: Advanced Data Structures

Lecture 22: AA Tree

Lecture 23: K-Dimensional Tree

Lecture 24: B/B+ Tree

Lecture 25: Sparse Table

Lecture 26: Suffix Array

Lecture 27: Suffix Tree

Lecture 28: Advanced Trees

Hands-on Projects & Assignments & Practices

Data Structures Projects (4 Projects)

Project 1: Mathematical Equations Calculator (linear data structures application)

Project 2: Mobile Contacts Indexing (linear & non-linear data structures application)

Project 3: Big Families (non-linear data structures application)

Project 4: University Friends (non-linear data structures application)

Data Structures Assignments (10 Assignment)

- After each lecture we have an assignment (Implementing & Testing the Data Structures on each Lecture)

Data Structures Practices (30+ Practice Problems) on each Lecture.

Algorithms Content

Part 1: Basic Algorithms

Lecture 1: Analysis of Algorithms

- Analysis Methods in Time & Space Complexity
- Master theorem - Substitution method
- Recursion tree method

Lecture 2, 3: Sorting Algorithms

- Selection Sort
- Bubble Sort
- Merge Sort
- Heap Sort
- Bitonic Sort
- Bucket Sort
- Tim Sort
- Insertion Sort
- Shell Sort
- Quick Sort
- Count Sort
- Radix Sort
- Pigeonhole Sort
- Cartesian Tree Sort

Lecture 4, 5: Searching Algorithms

- Linear Search
- Ternary Search
- Exponential Search
- Fibonacci Search
- Binary Search
- Jump Search
- Sublist Search
- Interpolation Search

Lecture 6: Divide and Conquer Algorithms

- Binary Search
- Fast Power
- Count Inversions
- Merge & Quick Sort
- Closest Pair of Points
- Multiply Two Polynomials
- Strassen’s Matrix Multiplication
- Karatsuba Algorithm for Fast Multiplication

Algorithms Content

Part 2: Graph Algorithms

Lecture 7, 8, 9, 10: Graph Algorithms

- Graph Traversal
- Topological Sort
- Connectivity
- Lowest Common Ancestor
- Matching
- Cycles
- Backtracking
- Maximum Flow

- Single source shortest paths

- All pairs shortest paths
- Dijkstra
- Spanning trees
- Minimum Spanning Tree
- Floyd Warshall
- Bellman Ford
- Kirchhoff Theorem
- Prim & Kruskal

Lecture 11, 12: Greedy Algorithms

- Standard Greedy Algorithms
- Greedy Algorithms in Graph
- Greedy Algorithms in Arrays
- Greedy Algorithms in Operating Systems

Algorithms Content

Part 3: Mathematical Algorithms

Lecture 13, 14: Mathematical Algorithms

- Greatest Common Divisor (GCD)
- Latest Common Multiple (LCM)
- Prime Factorization and Divisors
- Chinese Remainder Theorem
- Sieve Algorithm - Modular Arithmetic
- Euler Totient Function - Number Theory
- nCr Computations - Series

Lecture 15, 16: Geometric Algorithms

- Lines - Polygon - Circle - Quickhull
- Triangle - Rectangle - Square - Convex Hull
- Quadrilateral - 3D Objects - Plane Sweep
- Voronoi diagrams - Delaunay triangulations

Lecture 17, 18, 19, 20: Computer Graphics Algorithms

- Line Generation Algorithm
- Circle Generation Algorithm
- Polygon Filling Algorithm
- Viewing & Clipping Algorithm
- 2D Transformation
- 3D Transformation
- Projection from 3D to 2D
- Computer Graphics Curves
- Computer Graphics Surfaces
- Visible Surface Detection
- Computer Graphics Fractals

Algorithms Content

Part 4: Dynamic Programming

Lecture 21: Bitwise Algorithms

- Bit Manipulation
- Bitmasks Algorithm
- Bit Stuffing in Computer Networks
- Error Detection in Computer Networks

Lecture 22, 23, 24: Dynamic Programming

- Overlapping Sub-problems Property
- Optimal Sub-structure Property
- Tabulation vs Memoization
- Bitmasking & Dynamic Programming

Lecture 25, 26: Randomized Algorithms

- Randomized Quick Sort
- Monte Carlo Algorithms
- Las Vegas Algorithms
- Atlantic City Algorithms
- Computational Complexity

Algorithms Content

Part 5: String Algorithms

Lecture 27: String Algorithms

- Anagram
- Palindrome
- Binary String
- Subsequence
- Pattern Searching

Lecture 30, 31, 32: Pattern Searching Algorithms

- Naïve Pattern Searching
- KMP Algorithm
- Rabin-Karp Algorithm
- Finite Automata
- Boyer Moore Algorithm
- Z Algorithm
- Aho-Corasick Algorithm
- Kasai’s Algorithm
- Anagram Substring Search
- Pattern Searching using a Trie of all Suffixes

Lecture 28, 29: String Compression Algorithms

- Lempel-Ziv Compression (LZ77 & LZ78)
- Lempel-Ziv-Markov Chain Algorithm (LZMA)
- Lempel-Ziv-Oberhumer (LZO)
- Lempel-Ziv-Storer-Szymanski (LZSS)
- Lempel-Ziv-Welch (LZW)
- Lempel-Ziv Finite State Entropy (LZFSE)
- Standard Huffman Coding Algorithm
- Modified Huffman Coding Algorithm
- Adaptive Huffman Coding Algorithm
- Arithmetic Coding (Float & Binary)

Hands-on Projects & Assignments & Practices

Algorithms Projects (6 Projects)

Project 1: Dictionary Sorting Simulator	(sorting application)
Project 2: Dictionary Searching Simulator	(searching application)
Project 3: Advanced Mathematical Calculator	(mathematical application)
Project 4: Advanced Geometric Simulator	(geometric application)
Project 5: Advanced Computer Graphics Generator	(computer graphics application)
Project 6: Advanced Computer Graphics Simulator	(computer graphics application)

Algorithms Assignments (8 Assignment)

- After each lecture we have an assignment (Implementing & Testing the Algorithms on each Lecture)

Algorithms Practices (30+ Practice Problems) on each Lecture.

Lecture Agenda

- ✓ Section 1: Data Structures and Algorithms Features
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Practice on Online Judges

codeforces.com

hackerearth.com

hackerrank.com

topcoder.com

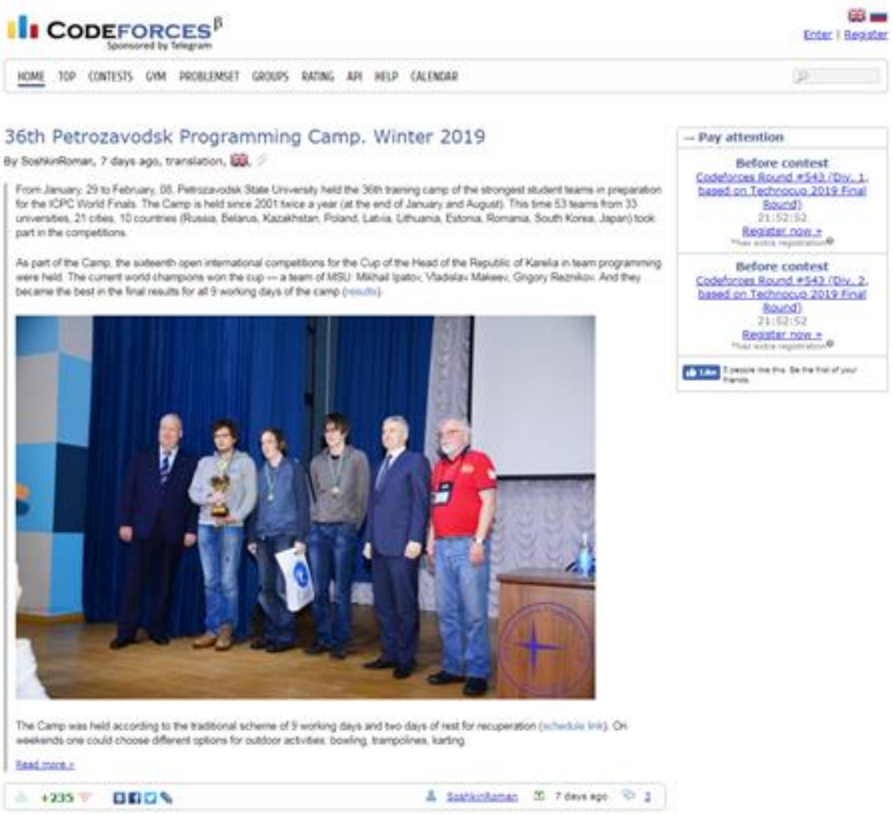
atcoder.jp

onlinejudge.org

Codeforces Online Judge

Codeforces is a website that hosts competitive programming contests.

It is maintained by a group of competitive programmers from ITMO University led by Mikhail Mirzayanov.



36th Petrozavodsk Programming Camp. Winter 2019

By SoshkinRoman, 7 days ago, translation,

From January, 29 to February, 08, Petrozavodsk State University held the 36th training camp of the strongest student teams in preparation for the ICPC World Finals. The Camp is held since 2001 twice a year (at the end of January and August). This time 53 teams from 33 universities, 21 cities, 10 countries (Russia, Belarus, Kazakhstan, Poland, Latvia, Lithuania, Estonia, Romania, South Korea, Japan) took part in the competitions.

As part of the Camp, the sixteenth open international competitions for the Cup of the Head of the Republic of Karelia in team programming were held. The current world champions won the cup — a team of MSU: Mikhail Ipatov, Vladislav Makeev, Grigory Reznikov. And they became the best in the final results for all 9 working days of the camp (results).

The Camp was held according to the traditional scheme of 9 working days and two days of rest for recuperation (schedule link). On weekends one could choose different options for outdoor activities: bowling, trampolines, karting.

Read more »

+235 SoshkinRoman 7 days ago 2

→ Pay attention

Before contest
Codeforces Round #543 (Div. 1, based on Technocup 2019 Final Round)
21:52:52
Register now »
*has extra registration

Before contest
Codeforces Round #543 (Div. 2, based on Technocup 2019 Final Round)
21:52:52
Register now »
*has extra registration

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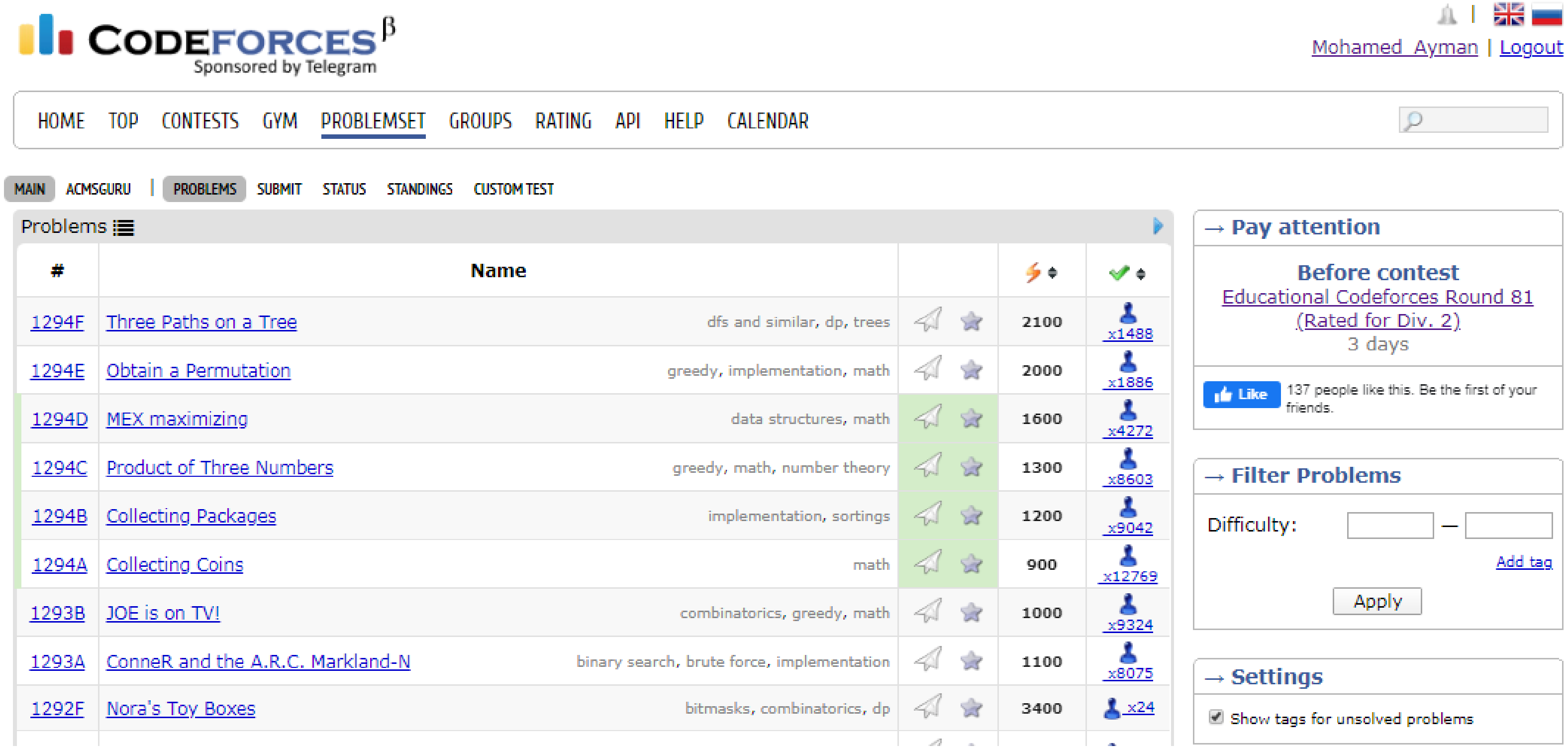
Codeforces Online Judge



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MAIN ACMSGURU | PROBLEMS SUBMIT STATUS STANDINGS CUSTOM TEST

Problems

#	Name			⚡	✓
1294F	Three Paths on a Tree	dfs and similar, dp, trees		2100	x1488
1294E	Obtain a Permutation	greedy, implementation, math		2000	x1886
1294D	MEX maximizing	data structures, math		1600	x4272
1294C	Product of Three Numbers	greedy, math, number theory		1300	x8603
1294B	Collecting Packages	implementation, sortings		1200	x9042
1294A	Collecting Coins	math		900	x12769
1293B	JOE is on TV!	combinatorics, greedy, math		1000	x9324
1293A	ConneR and the A.R.C. Markland-N	binary search, brute force, implementation		1100	x8075
1292F	Nora's Toy Boxes	bitmasks, combinatorics, dp		3400	x24

→ Pay attention

Before contest
Educational Codeforces Round 81 (Rated for Div. 2)
3 days

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→ Filter Problems

Difficulty: ___ — ___

Add tag

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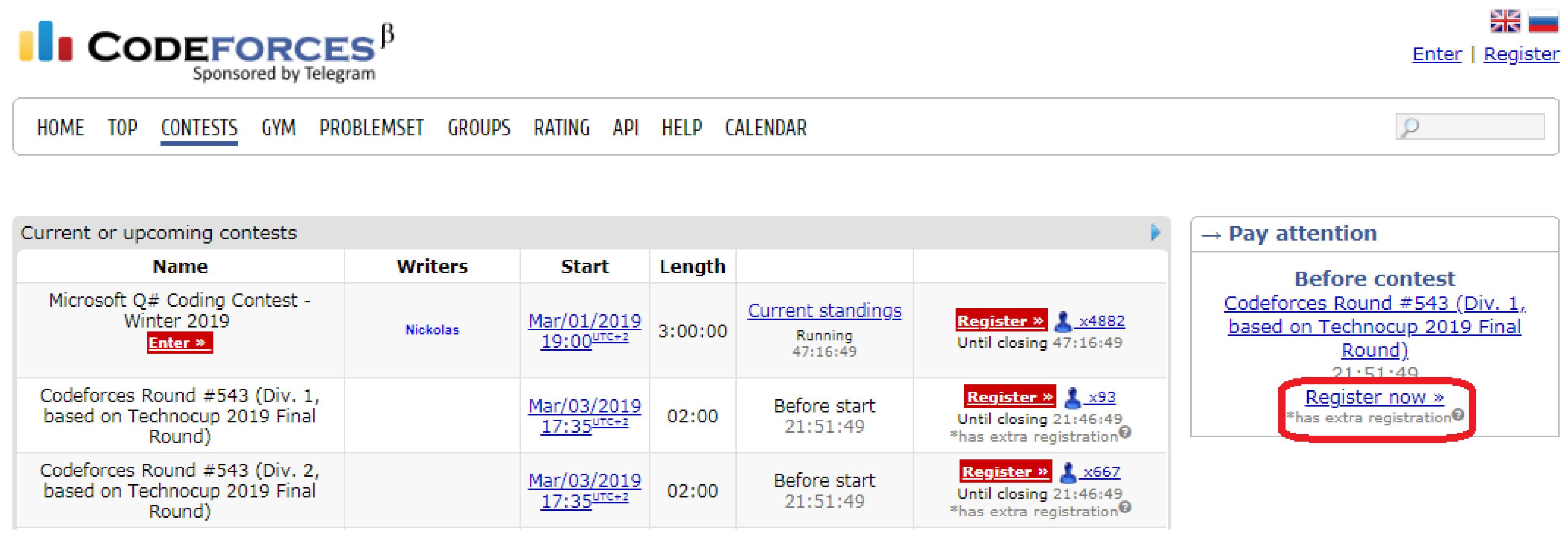
☑ Show tags for unsolved problems

Register in New Contest

Register The Contest from Register now ›› link



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Current or upcoming contests

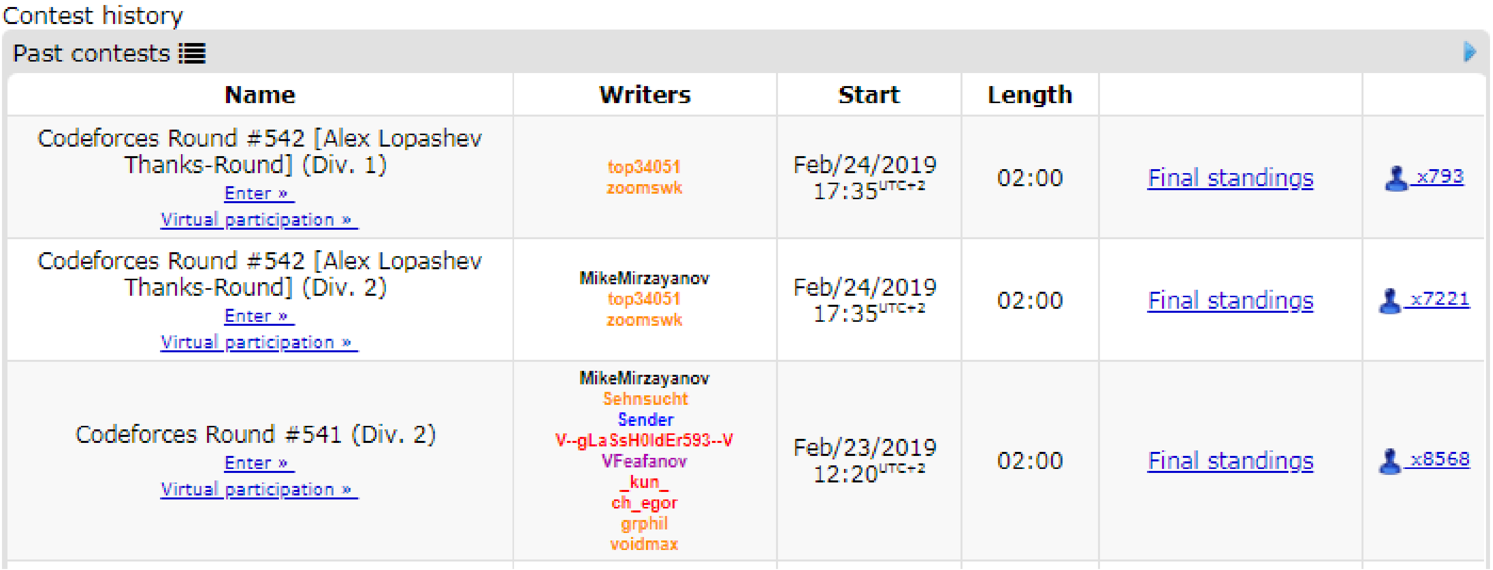
Name	Writers	Start	Length		
Microsoft Q# Coding Contest - Winter 2019 Enter »	Nickolas	Mar/01/2019 19:00UTC+2	3:00:00	Current standings Running 47:16:49	Register » x4882 Until closing 47:16:49
Codeforces Round #543 (Div. 1, based on Technocup 2019 Final Round)		Mar/03/2019 17:35UTC+2	02:00	Before start 21:51:49	Register » x93 Until closing 21:46:49 *has extra registration
Codeforces Round #543 (Div. 2, based on Technocup 2019 Final Round)		Mar/03/2019 17:35UTC+2	02:00	Before start 21:51:49	Register » x667 Until closing 21:46:49 *has extra registration

→ Pay attention

Before contest
Codeforces Round #543 (Div. 1, based on Technocup 2019 Final Round)
21:51:49
Register now »
*has extra registration

Register in Previous Contest

You Can Compete in Previous Contests

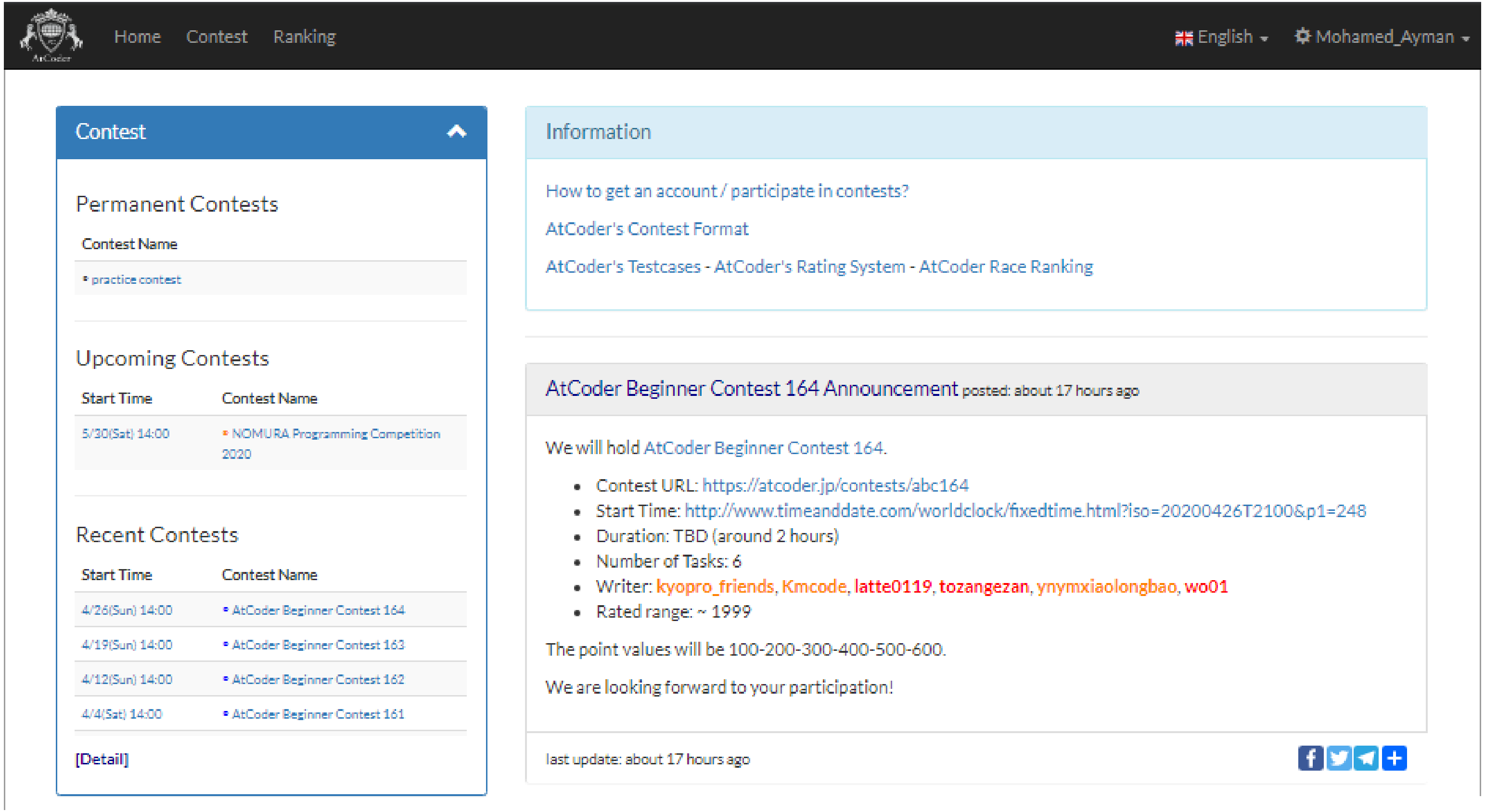


Contest history

Past contests

Name	Writers	Start	Length		
Codeforces Round #542 [Alex Lopashev Thanks-Round] (Div. 1) Enter » Virtual participation »	top34051 zoomswk	Feb/24/2019 17:35^{UTC+2}	02:00	Final standings	👤 x793
Codeforces Round #542 [Alex Lopashev Thanks-Round] (Div. 2) Enter » Virtual participation »	MikeMirzayanov top34051 zoomswk	Feb/24/2019 17:35^{UTC+2}	02:00	Final standings	👤 x7221
Codeforces Round #541 (Div. 2) Enter » Virtual participation »	MikeMirzayanov Sehnsucht Sender V--gLaSsH0ldEr593--V VFeafanov _kun_ ch_egor grphil voidmax	Feb/23/2019 12:20^{UTC+2}	02:00	Final standings	👤 x8568

AtCoder - Online Judge



Contest

Permanent Contests

Contest Name
practice contest

Upcoming Contests

Start Time	Contest Name
5/30(Sat) 14:00	NOMURA Programming Competition 2020

Recent Contests

Start Time	Contest Name
4/26(Sun) 14:00	AtCoder Beginner Contest 164
4/19(Sun) 14:00	AtCoder Beginner Contest 163
4/12(Sun) 14:00	AtCoder Beginner Contest 162
4/4(Sat) 14:00	AtCoder Beginner Contest 161

[Detail]

Information

How to get an account / participate in contests?

AtCoder's Contest Format

AtCoder's Testcases - AtCoder's Rating System - AtCoder Race Ranking

AtCoder Beginner Contest 164 Announcement posted: about 17 hours ago

We will hold AtCoder Beginner Contest 164.

- Contest URL: https://atcoder.jp/contests/abc164
- Start Time: http://www.timeanddate.com/worldclock/fixedtime.html?iso=20200426T2100&p1=248
- Duration: TBD (around 2 hours)
- Number of Tasks: 6
- Writer: kyopro_friends, Kmcode, latte0119, tozangezan, ynymxiaolongbao, wo01
- Rated range: ~ 1999

The point values will be 100-200-300-400-500-600.

We are looking forward to your participation!

last update: about 17 hours ago

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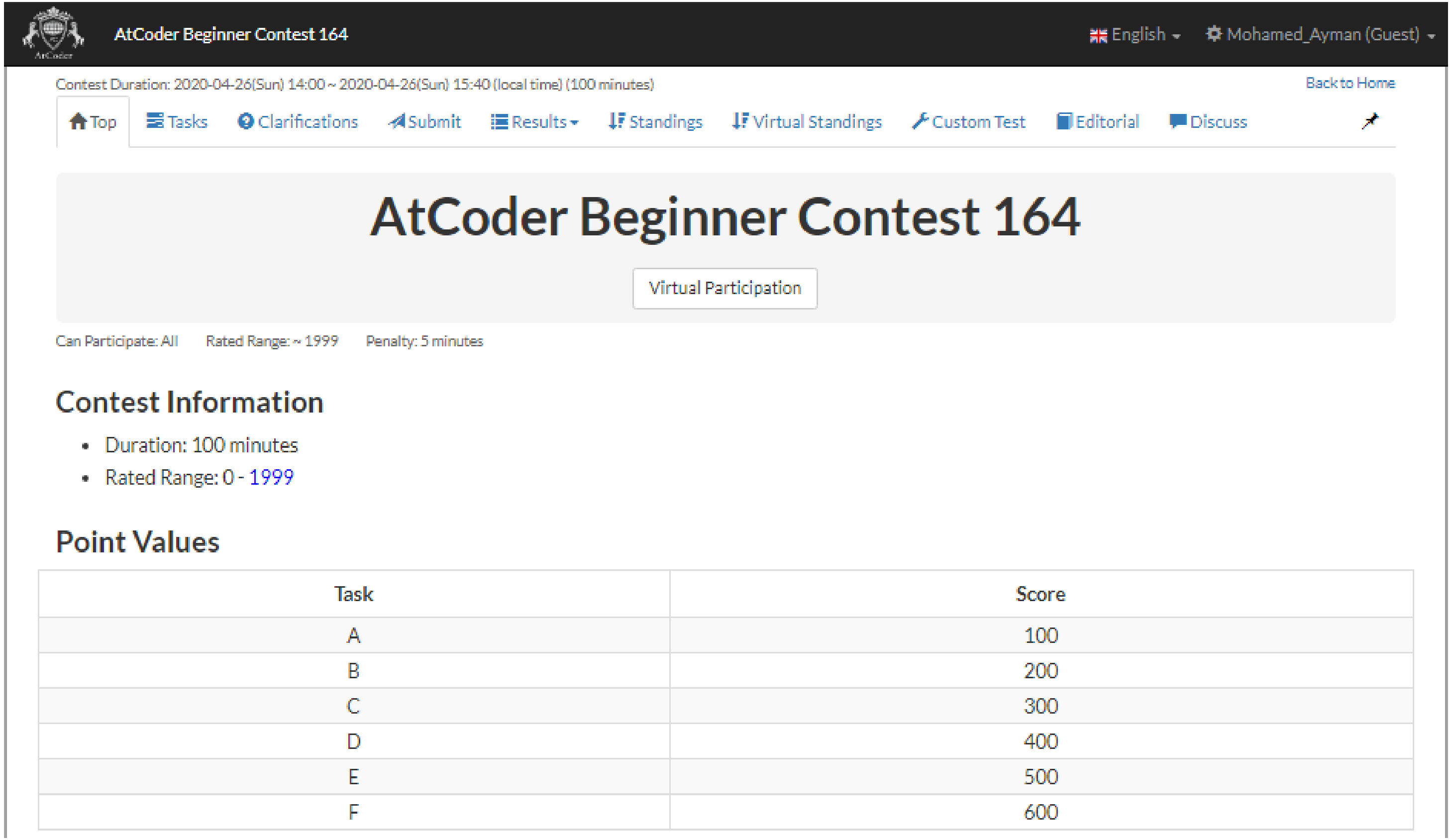
AtCoder - Online Judge



Contest Duration: 2020-04-26(Sun) 14:00 ~ 2020-04-26(Sun) 15:40 (local time) (100 minutes)

AtCoder Beginner Contest 164

Can Participate: All Rated Range: ~ 1999 Penalty: 5 minutes

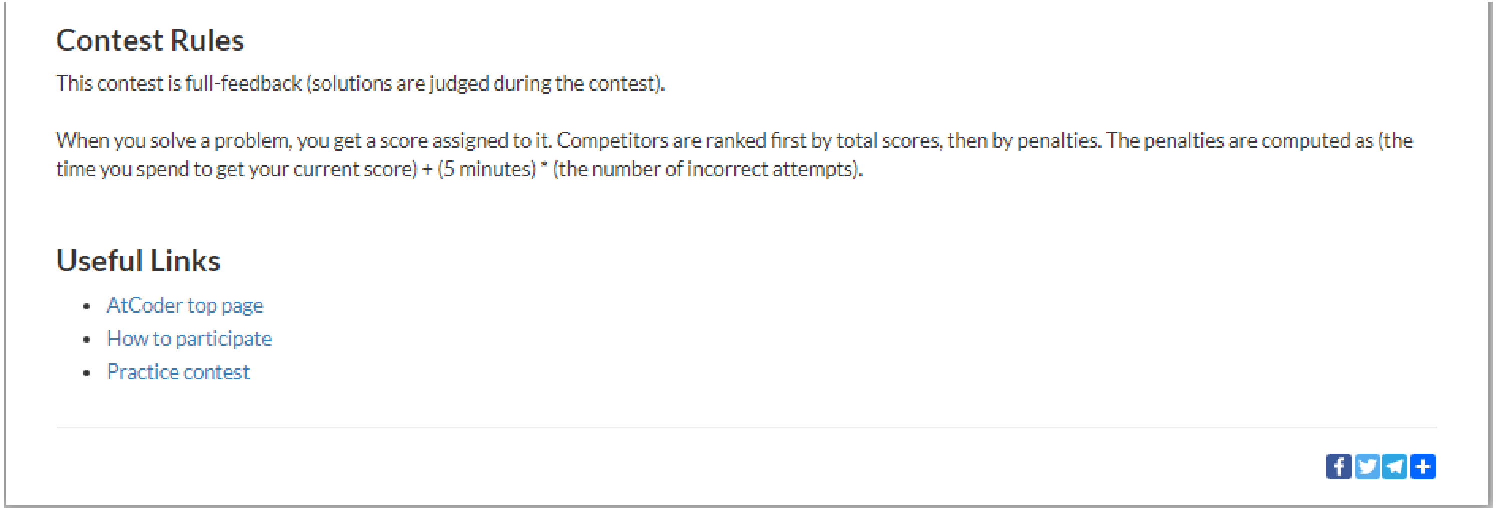
Contest Information

- Duration: 100 minutes
- Rated Range: 0 - 1999

Point Values

Task	Score
A	100
B	200
C	300
D	400
E	500
F	600

AtCoder - Online Judge



Contest Rules

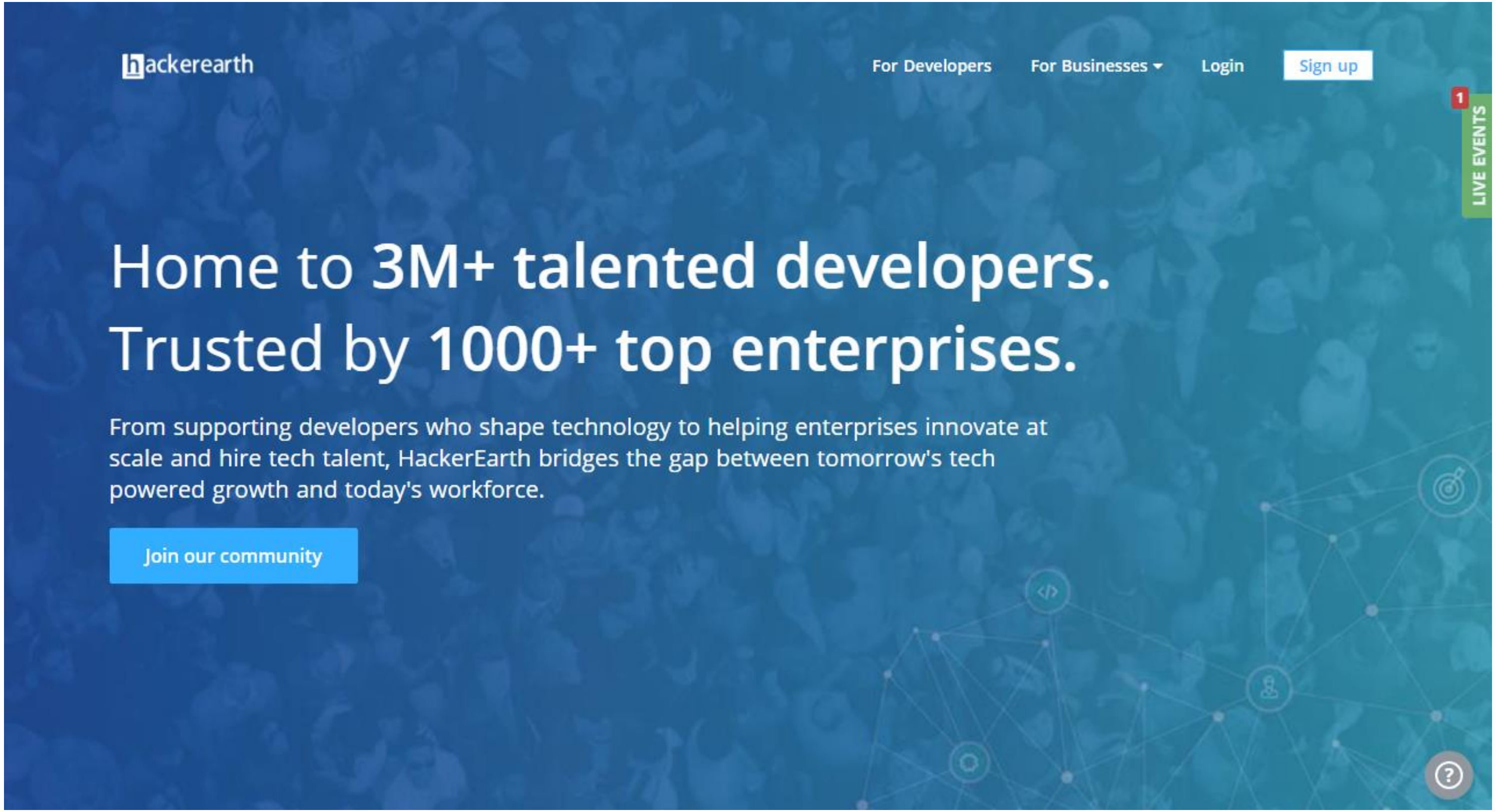
This contest is full-feedback (solutions are judged during the contest).

When you solve a problem, you get a score assigned to it. Competitors are ranked first by total scores, then by penalties. The penalties are computed as (the time you spend to get your current score) + (5 minutes) * (the number of incorrect attempts).

Useful Links

- AtCoder top page
- How to participate
- Practice contest

HackerEarth - Online Judge



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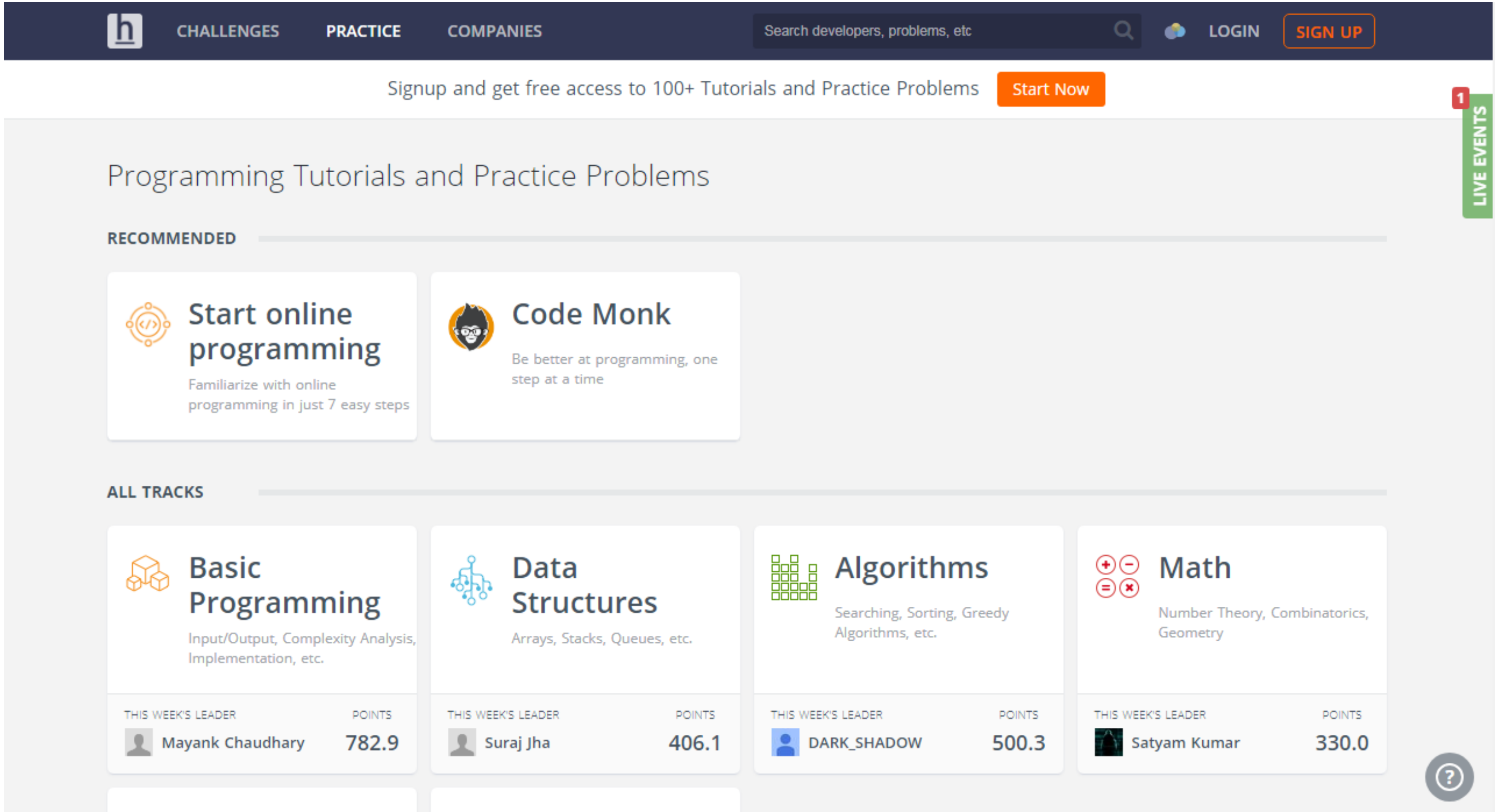

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Be better at programming, one step at a time

ALL TRACKS

Basic Programming
Input/Output, Complexity Analysis, Implementation, etc.

THIS WEEK'S LEADER	POINTS
Mayank Chaudhary	782.9

Data Structures
Arrays, Stacks, Queues, etc.

THIS WEEK'S LEADER	POINTS
Suraj Jha	406.1

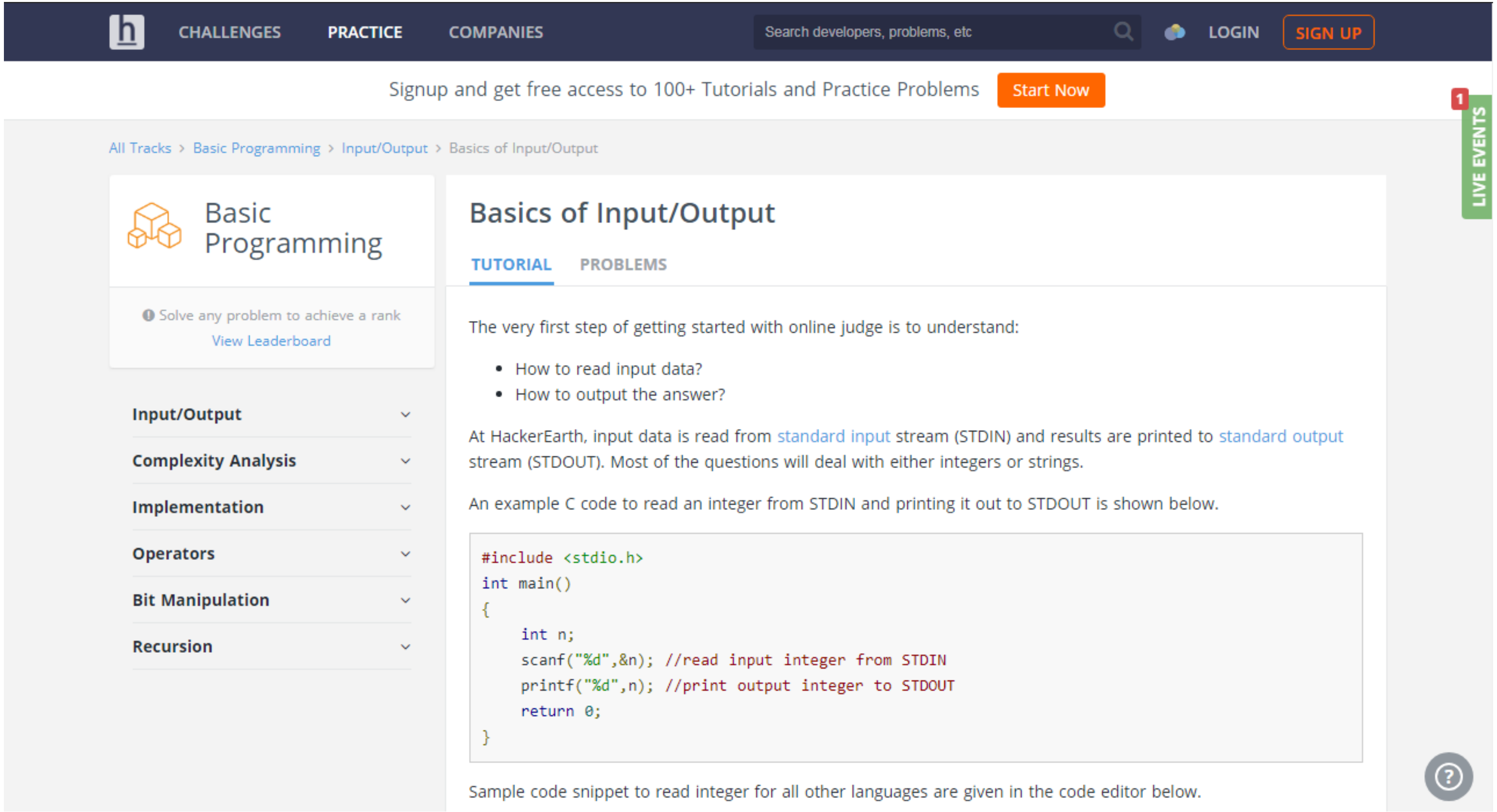
Algorithms
Searching, Sorting, Greedy Algorithms, etc.

THIS WEEK'S LEADER	POINTS
DARK_SHADOW	500.3

Math
Number Theory, Combinatorics, Geometry

THIS WEEK'S LEADER	POINTS
Satyam Kumar	330.0

HackerEarth - Online Judge



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All Tracks > Basic Programming > Input/Output > Basics of Input/Output

Basic Programming

Solve any problem to achieve a rank

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- Input/Output
- Complexity Analysis
- Implementation
- Operators
- Bit Manipulation
- Recursion

Basics of Input/Output

TUTORIAL PROBLEMS

The very first step of getting started with online judge is to understand:

- How to read input data?
- How to output the answer?

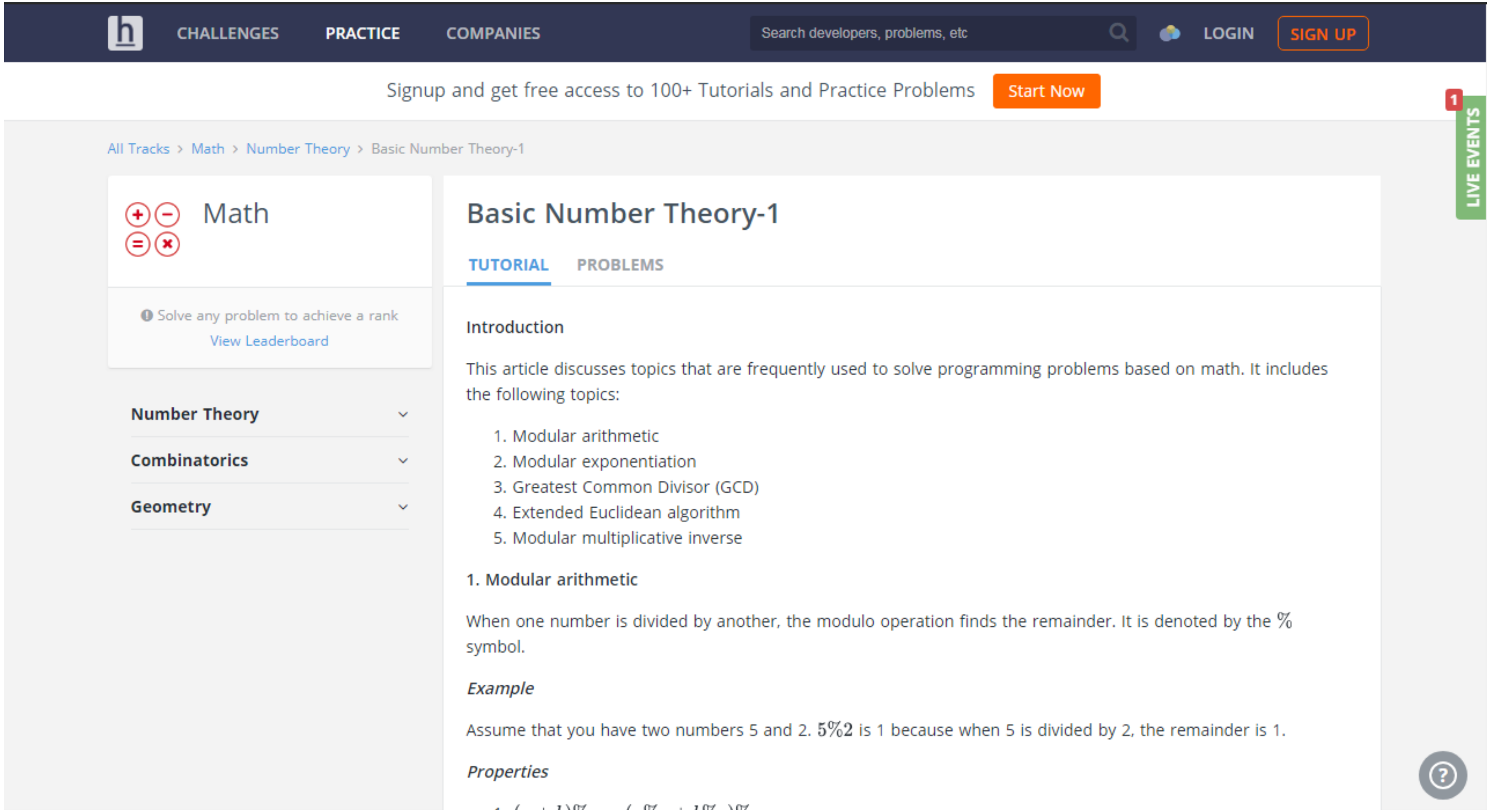
At HackerEarth, input data is read from standard input stream (STDIN) and results are printed to standard output stream (STDOUT). Most of the questions will deal with either integers or strings.

An example C code to read an integer from STDIN and printing it out to STDOUT is shown below.

```
#include <stdio.h>
int main()
{
    int n;
    scanf("%d",&n); //read input integer from STDIN
    printf("%d",n); //print output integer to STDOUT
    return 0;
}
```

Sample code snippet to read integer for all other languages are given in the code editor below.

HackerEarth - Online Judge



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All Tracks > Math > Number Theory > Basic Number Theory-1

Math

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Number Theory
Combinatorics
Geometry

Basic Number Theory-1

TUTORIAL PROBLEMS

Introduction

This article discusses topics that are frequently used to solve programming problems based on math. It includes the following topics:

1. Modular arithmetic
2. Modular exponentiation
3. Greatest Common Divisor (GCD)
4. Extended Euclidean algorithm
5. Modular multiplicative inverse

1. Modular arithmetic

When one number is divided by another, the modulo operation finds the remainder. It is denoted by the $\%$ symbol.

Example

Assume that you have two numbers 5 and 2. $5\%2$ is 1 because when 5 is divided by 2, the remainder is 1.

Properties

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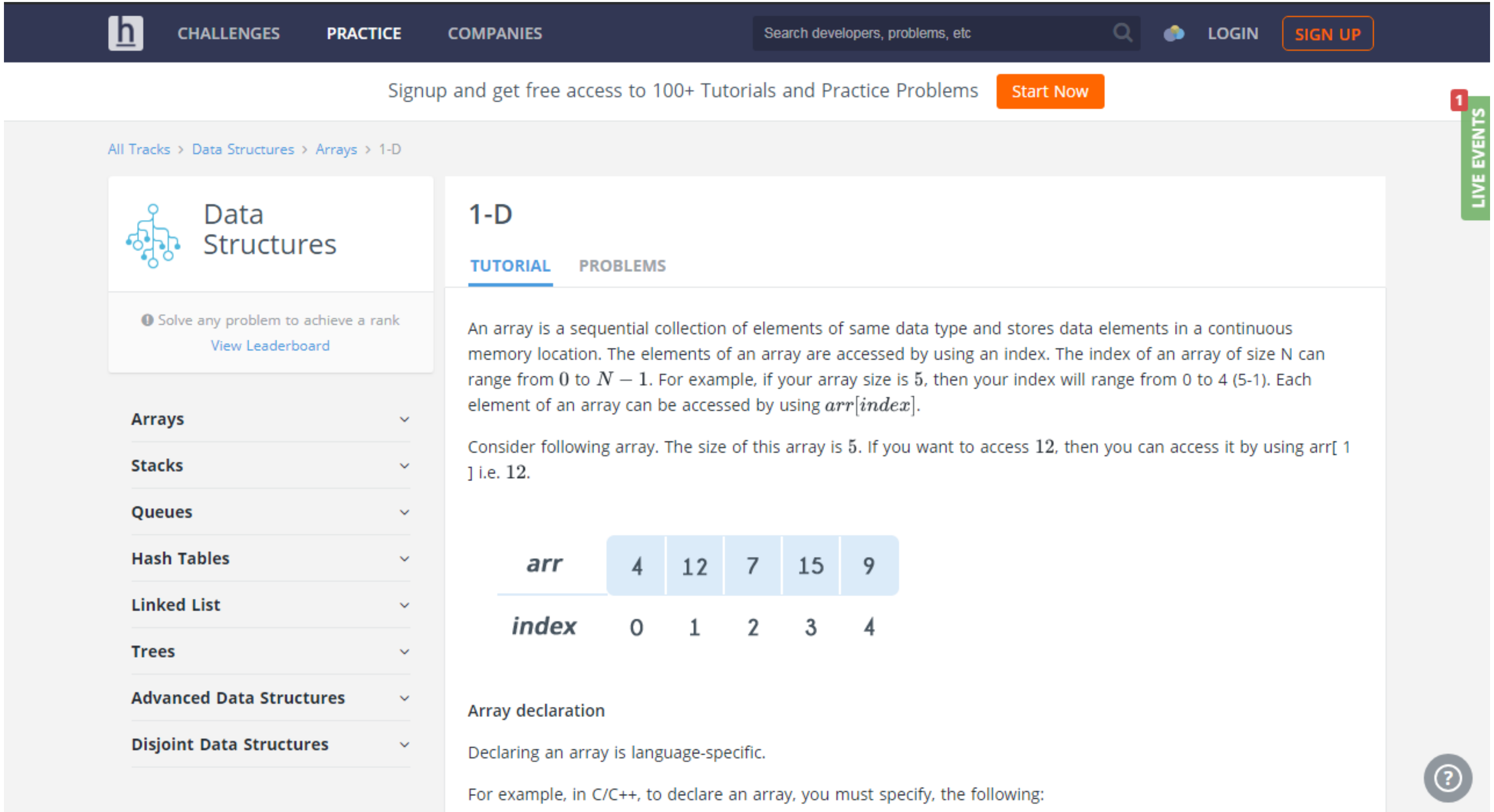

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Solve any problem to achieve a rank

1-D

An array is a sequential collection of elements of same data type and stores data elements in a continuous memory location. The elements of an array are accessed by using an index. The index of an array of size N can range from 0 to $N-1$. For example, if your array size is 5, then your index will range from 0 to 4 (5-1). Each element of an array can be accessed by using $arr[index]$.

Consider following array. The size of this array is 5. If you want to access 12, then you can access it by using arr[1] i.e. 12.

arr	4	12	7	15	9
index	0	1	2	3	4

Array declaration

Declaring an array is language-specific.

For example, in C/C++, to declare an array, you must specify, the following:

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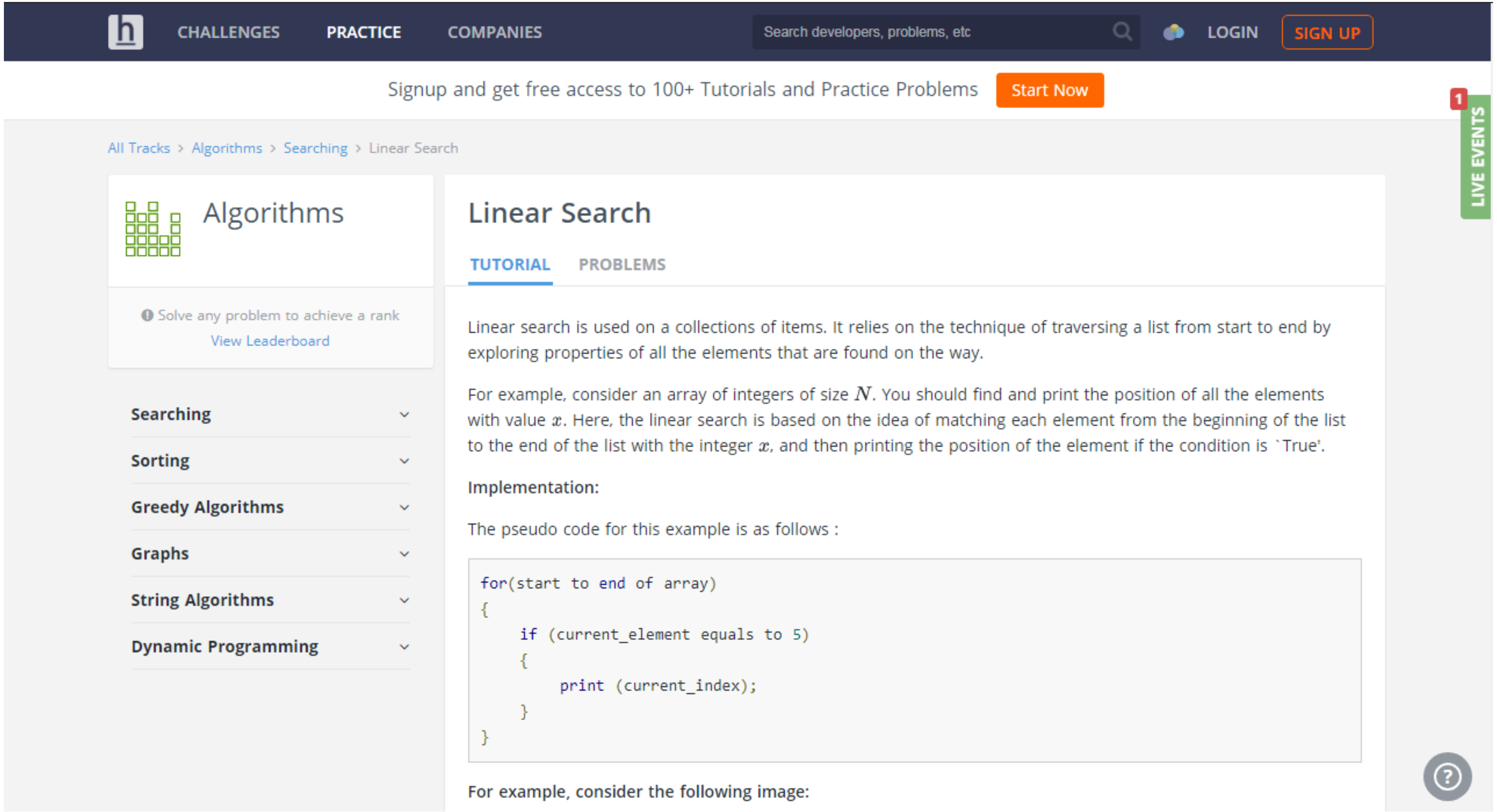

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Graphs
String Algorithms
Dynamic Programming
TUTORIAL
PROBLEMS

Linear Search

Linear search is used on a collections of items. It relies on the technique of traversing a list from start to end by exploring properties of all the elements that are found on the way.

For example, consider an array of integers of size N. You should find and print the position of all the elements with value x. Here, the linear search is based on the idea of matching each element from the beginning of the list to the end of the list with the integer x, and then printing the position of the element if the condition is `True'.

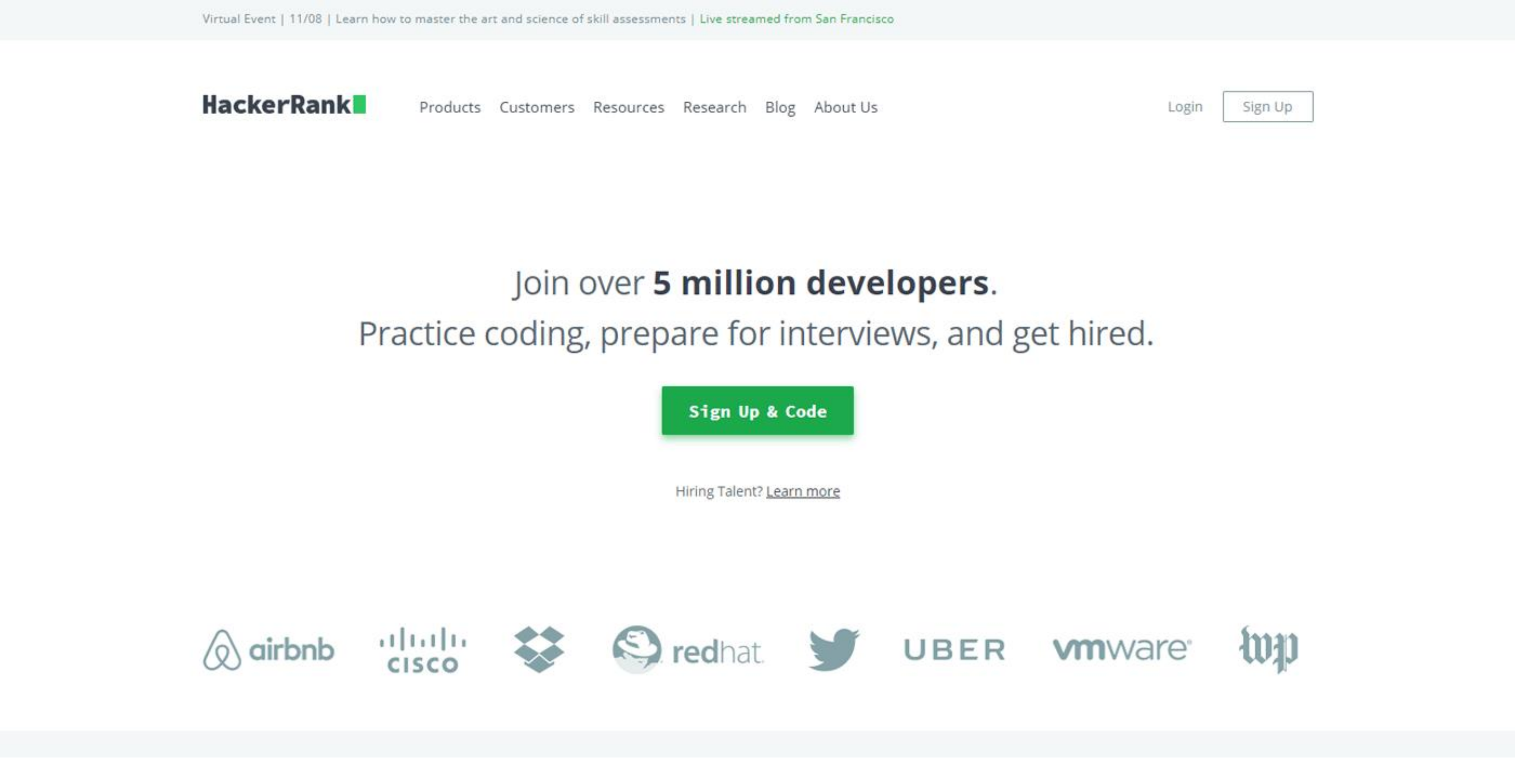
Implementation:

The pseudo code for this example is as follows :

```
for(start to end of array)
{
    if (current_element equals to 5)
    {
        print (current_index);
    }
}
```

For example, consider the following image:

HackerRank - Online Judge



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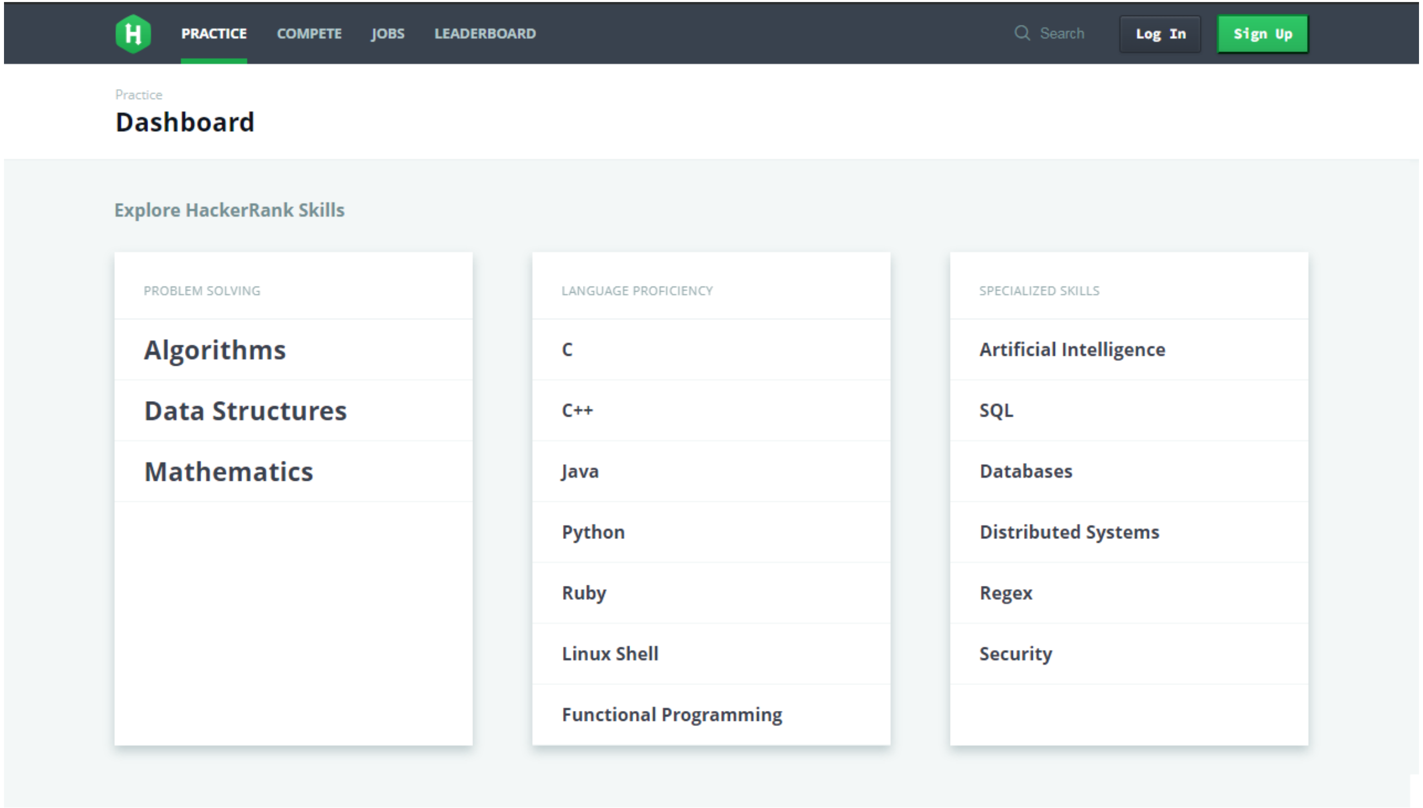
HackerRank - Online Judge



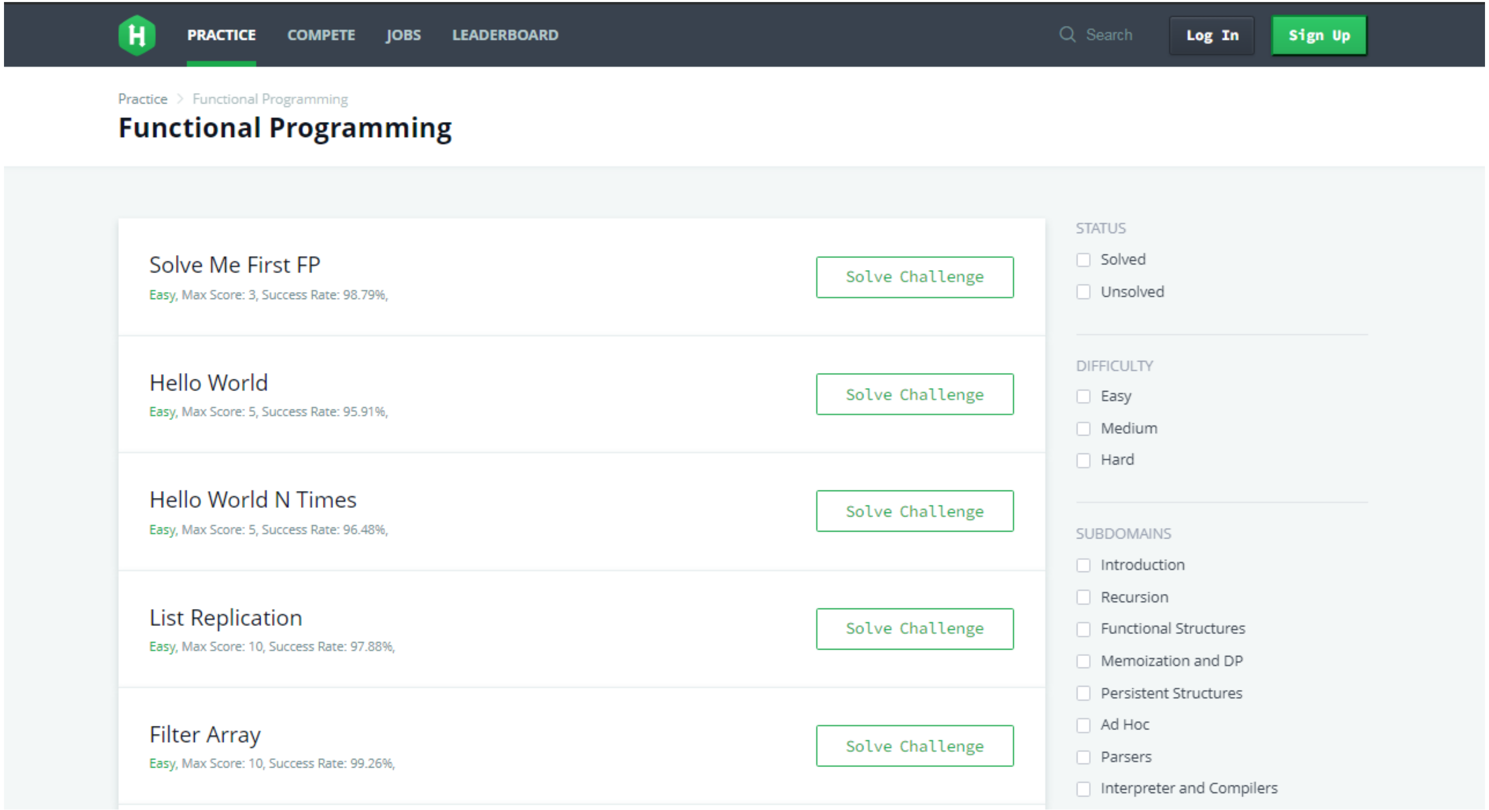
Practice

Dashboard

Explore HackerRank Skills

PROBLEM SOLVING	LANGUAGE PROFICIENCY	SPECIALIZED SKILLS
Algorithms	C	Artificial Intelligence
Data Structures	C++	SQL
Mathematics	Java	Databases
	Python	Distributed Systems
	Ruby	Regex
	Linux Shell	Security
	Functional Programming	

HackerRank - Online Judge



Practice > Functional Programming

Functional Programming

Solve Me First FP
Easy, Max Score: 3, Success Rate: 98.79%,
Solve Challenge

Hello World
Easy, Max Score: 5, Success Rate: 95.91%,
Solve Challenge

Hello World N Times
Easy, Max Score: 5, Success Rate: 96.48%,
Solve Challenge

List Replication
Easy, Max Score: 10, Success Rate: 97.88%,
Solve Challenge

Filter Array
Easy, Max Score: 10, Success Rate: 99.26%,
Solve Challenge

STATUS

- □ Solved
- □ Unsolved

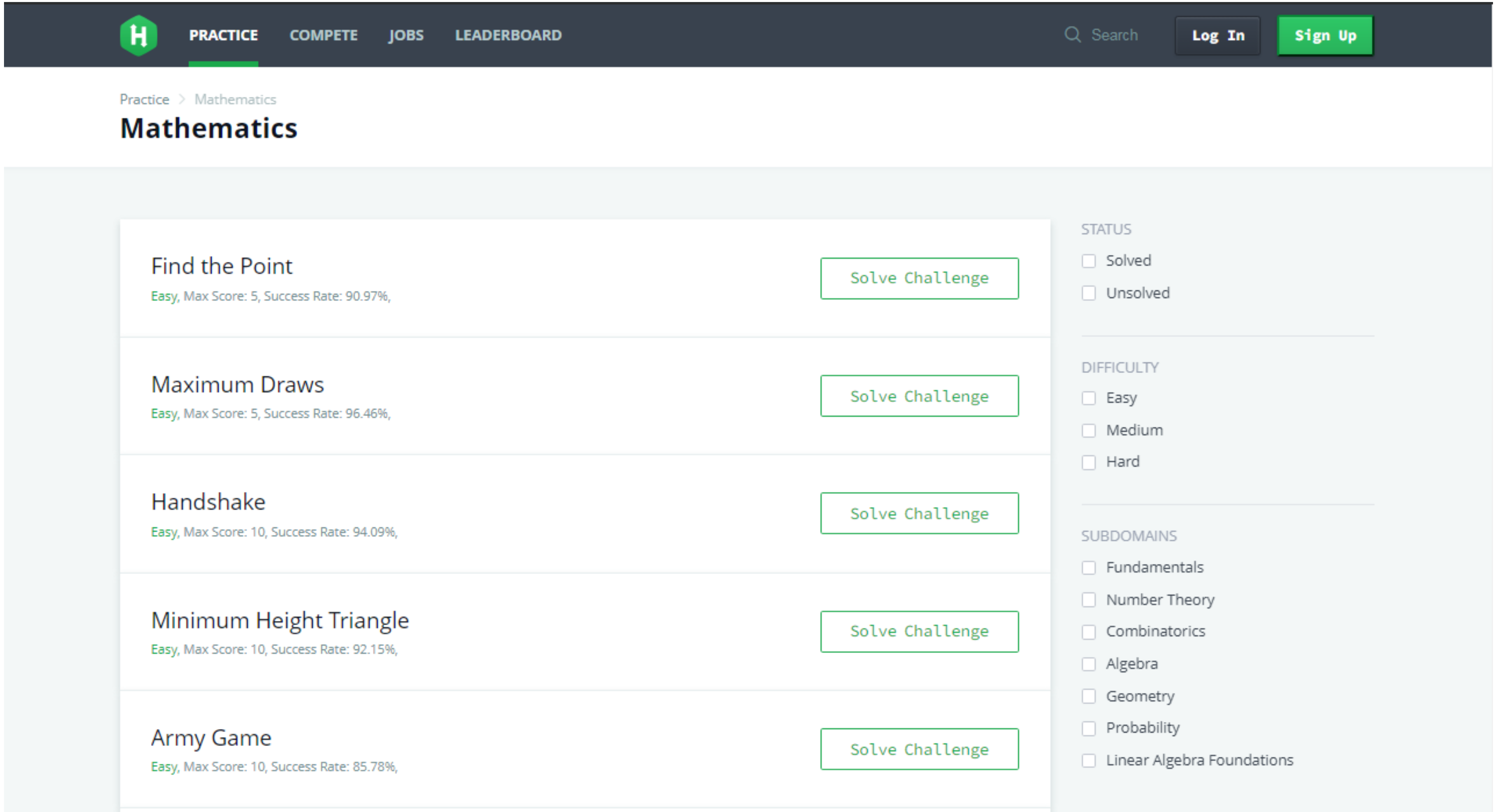
DIFFICULTY

- □ Easy
- □ Medium
- □ Hard

SUBDOMAINS

- □ Introduction
- □ Recursion
- □ Functional Structures
- □ Memoization and DP
- □ Persistent Structures
- □ Ad Hoc
- □ Parsers
- □ Interpreter and Compilers

HackerRank - Online Judge



Practice > Mathematics

Mathematics

Find the Point
Easy, Max Score: 5, Success Rate: 90.97%,
Solve Challenge

Maximum Draws
Easy, Max Score: 5, Success Rate: 96.46%,
Solve Challenge

Handshake
Easy, Max Score: 10, Success Rate: 94.09%,
Solve Challenge

Minimum Height Triangle
Easy, Max Score: 10, Success Rate: 92.15%,
Solve Challenge

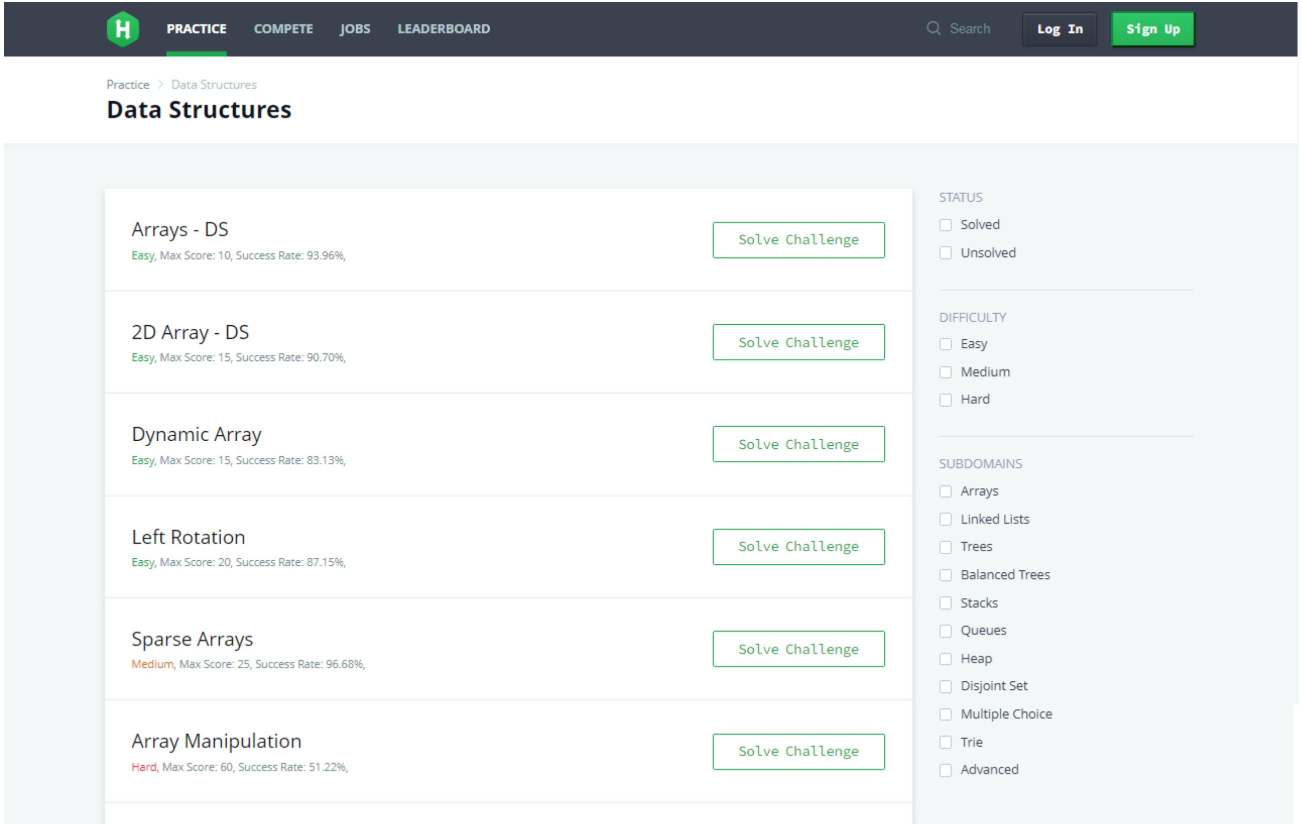
Army Game
Easy, Max Score: 10, Success Rate: 85.78%,
Solve Challenge

STATUS
- □ Solved
- □ Unsolved

DIFFICULTY
- □ Easy
- □ Medium
- □ Hard

SUBDOMAINS
- □ Fundamentals
- □ Number Theory
- □ Combinatorics
- □ Algebra
- □ Geometry
- □ Probability
- □ Linear Algebra Foundations

HackerRank - Online Judge



Practice > Data Structures

Data Structures

Arrays - DS
Easy, Max Score: 10, Success Rate: 93.96%,
Solve Challenge

2D Array - DS
Easy, Max Score: 15, Success Rate: 90.70%,
Solve Challenge

Dynamic Array
Easy, Max Score: 15, Success Rate: 83.13%,
Solve Challenge

Left Rotation
Easy, Max Score: 20, Success Rate: 87.15%,
Solve Challenge

Sparse Arrays
Medium, Max Score: 25, Success Rate: 96.68%,
Solve Challenge

Array Manipulation
Hard, Max Score: 60, Success Rate: 51.22%,
Solve Challenge

STATUS
- □ Solved
- □ Unsolved

DIFFICULTY
- □ Easy
- □ Medium
- □ Hard

SUBDOMAINS
- □ Arrays
- □ Linked Lists
- □ Trees
- □ Balanced Trees
- □ Stacks
- □ Queues
- □ Heap
- □ Disjoint Set
- □ Multiple Choice
- □ Trie
- □ Advanced

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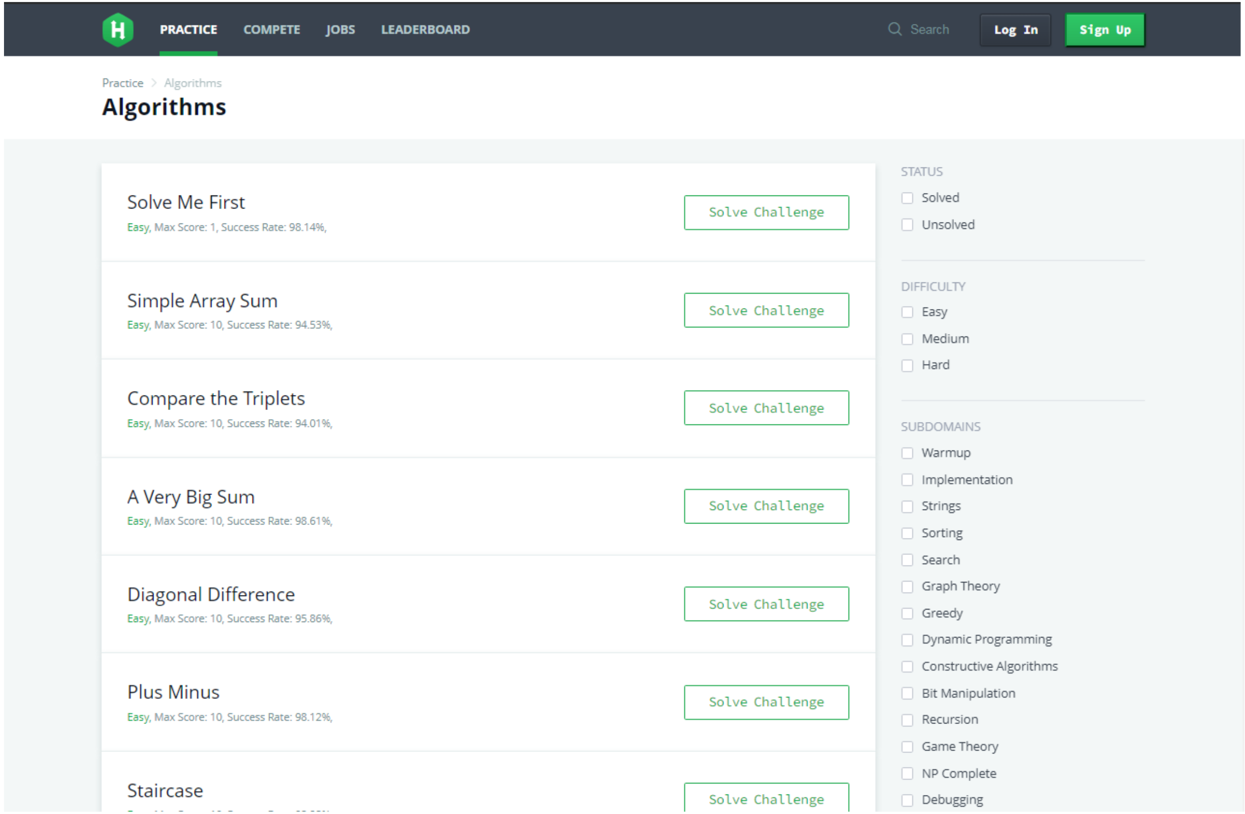
HackerRank - Online Judge



Practice > Algorithms

Algorithms

Solve Me First
Easy, Max Score: 1, Success Rate: 98.14%,
Solve Challenge

Simple Array Sum
Easy, Max Score: 10, Success Rate: 94.53%,
Solve Challenge

Compare the Triplets
Easy, Max Score: 10, Success Rate: 94.01%,
Solve Challenge

A Very Big Sum
Easy, Max Score: 10, Success Rate: 98.61%,
Solve Challenge

Diagonal Difference
Easy, Max Score: 10, Success Rate: 95.86%,
Solve Challenge

Plus Minus
Easy, Max Score: 10, Success Rate: 98.12%,
Solve Challenge

Staircase
Solve Challenge

STATUS
- □ Solved
- □ Unsolved

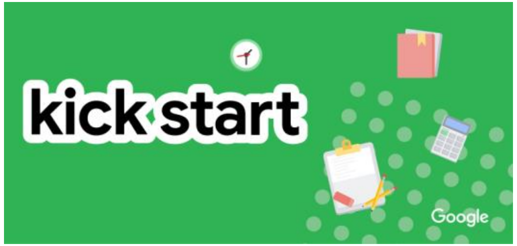
DIFFICULTY
- □ Easy
- □ Medium
- □ Hard

SUBDOMAINS
- □ Warmup
- □ Implementation
- □ Strings
- □ Sorting
- □ Search
- □ Graph Theory
- □ Greedy
- □ Dynamic Programming
- □ Constructive Algorithms
- □ Bit Manipulation
- □ Recursion
- □ Game Theory
- □ NP Complete
- □ Debugging

Lecture Agenda

- ✓ Section 1: Data Structures and Algorithms Features
- ✓ Section 2: Data Structures and Algorithms Content
- ✓ Section 3: Practice on Online Judges
- **Section 4: Programming Competitions**
- Section 5: Tutorials and References
- Section 6: Online Courses

Programming Competitions



Google Competitions

code jam

hash code

kick start

Google Competitions - Code Jam

Google Competitions - Code Jam

Code Jam - Practice Session	March
Code Jam - Qualification Round	March
Code Jam - Round 1A	April
Code Jam - Round 1B	April
Code Jam - Round 1C	May
Code Jam - Round 2	May
Code Jam - Round 3	June
Code Jam - World Finals	August

Google Competitions - Kick Start

Google Competitions - Kick Start

Kick Start - Round A	March
Kick Start - Round B	April
Kick Start - Round C	May
Kick Start - Round D	July
Kick Start - Round E	August
Kick Start - Round F	September
Kick Start - Round G	October
Kick Start - Round H	November

Google Competitions - Hash Code

Google Competitions - Hash Code

Hash Code - Hub registration opens	November
Hash Code - Individual registration opens	January
Hash Code - Registration closes	February
Hash Code - Online qualification round	February
Hash Code - Results announced	March
Hash Code - Final round	April

Facebook Hacker Cup Competition

Facebook Hacker Cup - Qualification round	June
Facebook Hacker Cup - Round 1	June
Facebook Hacker Cup - Round 2	July
Facebook Hacker Cup - Round 3	August
Facebook Hacker Cup - Onsite Final	September

ICPC - International College Programming Contest

Qualification Round in Universities	September
ECPC Egyptian College Programming Contest	October
ACPC Arab College Programming Contest	January
ICPC International College Programming Contest	May

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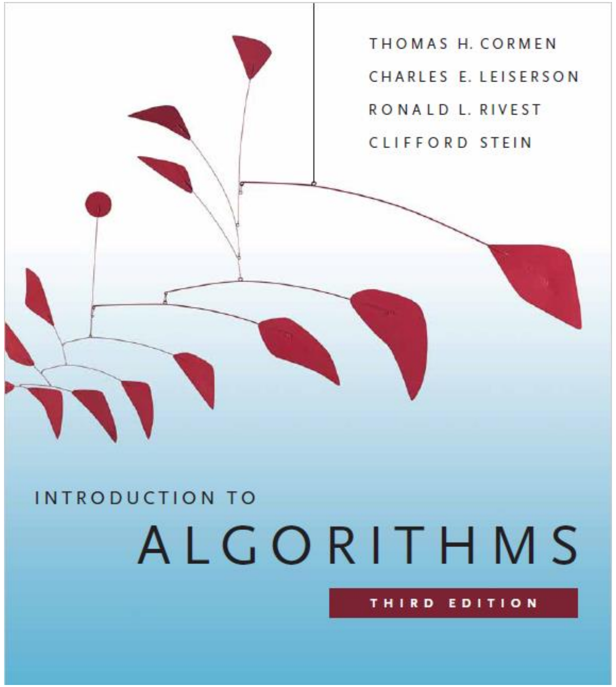
Introduction to Algorithms Thomas H. Cormen

Foundations	[005 - 145]
Sorting and Order Statistics	[145 - 220]
Data Structures	[230 - 350]
Advanced Design and Analysis Techniques	[355 - 460]
Advanced Data Structures	[480 - 575]
Graph Algorithms	[585 - 750]
Selected Topics	[770 - 1130]



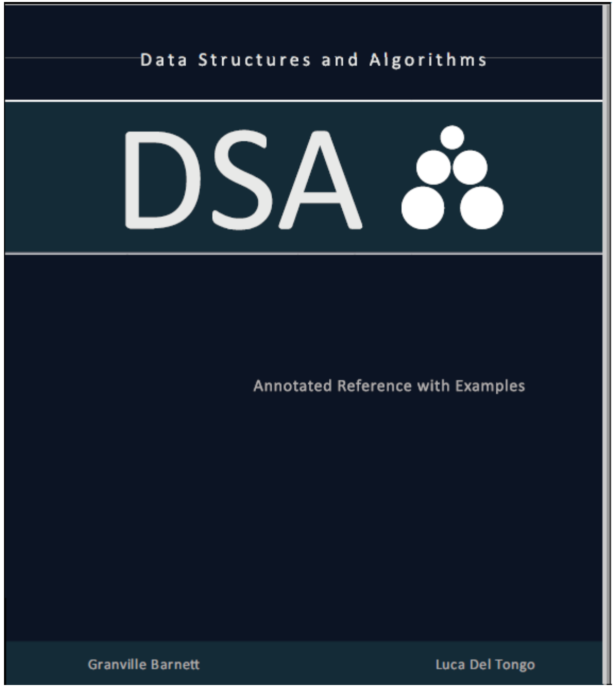
THOMAS H. CORMEN
CHARLES E. LEISERSON
RONALD L. RIVEST
CLIFFORD STEIN

INTRODUCTION TO
ALGORITHMS
THIRD EDITION

Introduction to Algorithms Thomas H. Cormen

Data Structures and Algorithms Annotated Reference

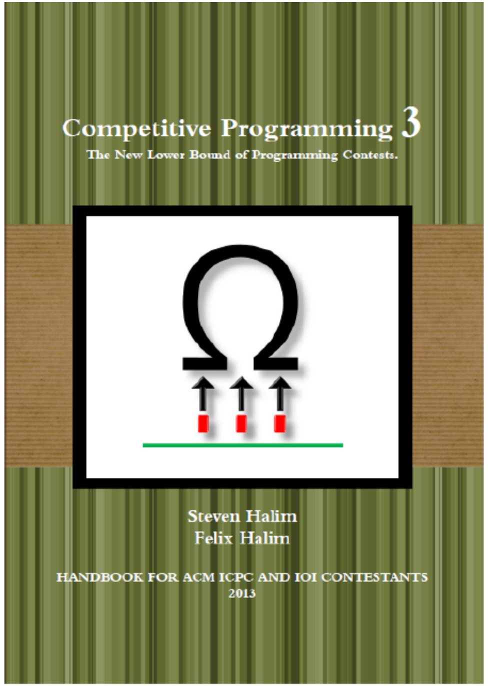
Introduction	[01 - 10]
Linked Lists	[10 - 20]
Binary Search Tree	[20 - 30]
Heap	[30 - 40]
Sets	[40 - 50]
Queues	[50 - 55]
AVL Tree	[55 - 60]
Sorting	[60 - 70]
Numeric	[70 - 75]
Searching	[75 - 80]
Strings	[80 - 85]


Data Structures and Algorithms
DSA
Annotated Reference with Examples
Granville Barnett
Luca Del Tongo

Data Structures and Algorithms Annotated Reference

Competitive Programming 3 Steven Halim

Introduction	[001 - 030]
Data Structures and Libraries	[030 - 070]
Problem Solving Paradigms	[070 - 120]
Graph	[120 - 190]
Mathematics	[190 - 230]
String Processing	[230 - 270]
(Computational) Geometry	[270 - 300]
More Advanced Topics	[300 - 330]
Rare Topics	[330 - 390]



Competitive Programming 3

The New Lower Bound of Programming Contests.

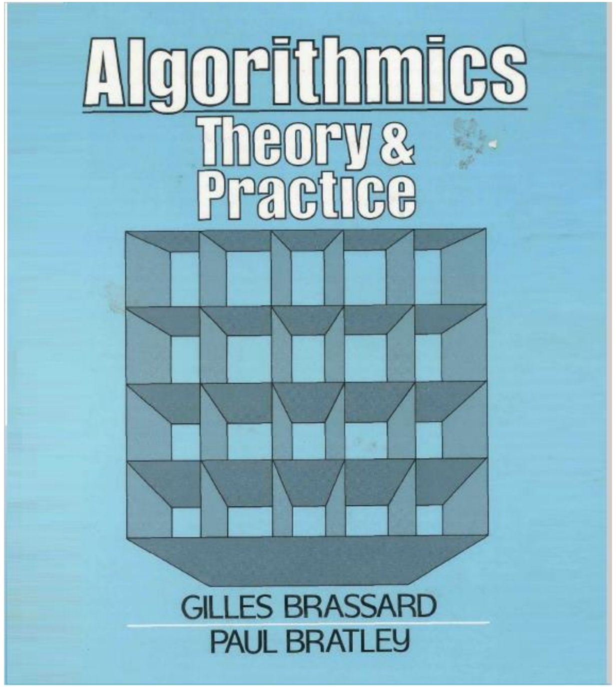
Steven Halim
Felix Halim

HANDBOOK FOR ACM ICPC AND IOI CONTESTANTS
2013

Competitive Programming 3 Steven Halim

Fundamental of Algorithmics Gilles Brassard

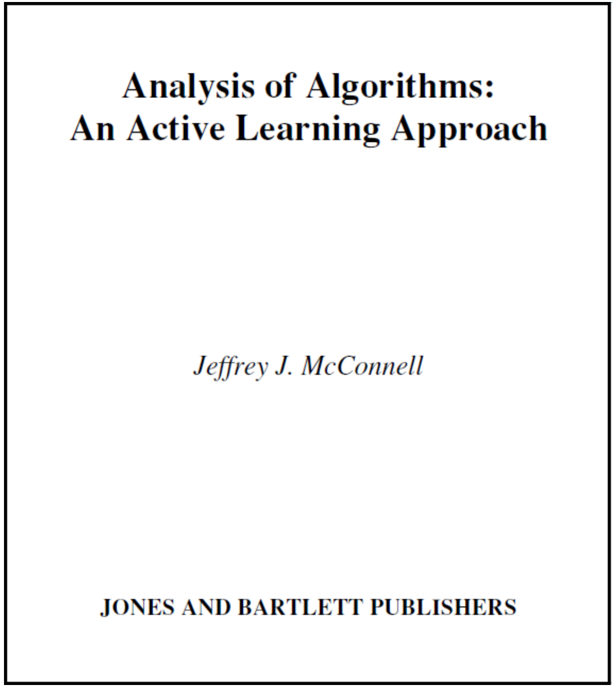
Preliminaries	[001 - 035]
Analyzing the Efficiency of Algorithms	[035 - 080]
Greedy Algorithms	[080 - 105]
Divide and Conquer	[105 - 140]
Dynamic Programming	[140 - 170]
Exploring Graphs	[170 - 205]
Preconditioning and Pre-computation	[205 - 225]
Probabilistic Algorithms	[225 - 275]
Transformations of the Domain	[275 - 290]
Introduction to Complexity	[290 - 335]



Fundamental of Algorithmics Gilles Brassard and Paul Bartley

Analysis of Algorithms An Active Learning Approach

Analysis Basics	[001 - 040]
Searching and Selection Algorithms	[040 - 055]
Sorting Algorithms	[060 - 100]
Numeric Algorithms	[105 - 120]
Matching Algorithms	[120 - 140]
Graph Algorithms	[145 - 175]
Parallel Algorithms	[175 - 210]
Nondeterministic Algorithms	[210 - 230]
Other Algorithmic Techniques	[230 - 260]



Analysis of Algorithms:
An Active Learning Approach

Jeffrey J. McConnell

JONES AND BARTLETT PUBLISHERS

Analysis of Algorithms An Active Learning Approach

Competitive Programmer’s Handbook

- Basic techniques [001 - 105]

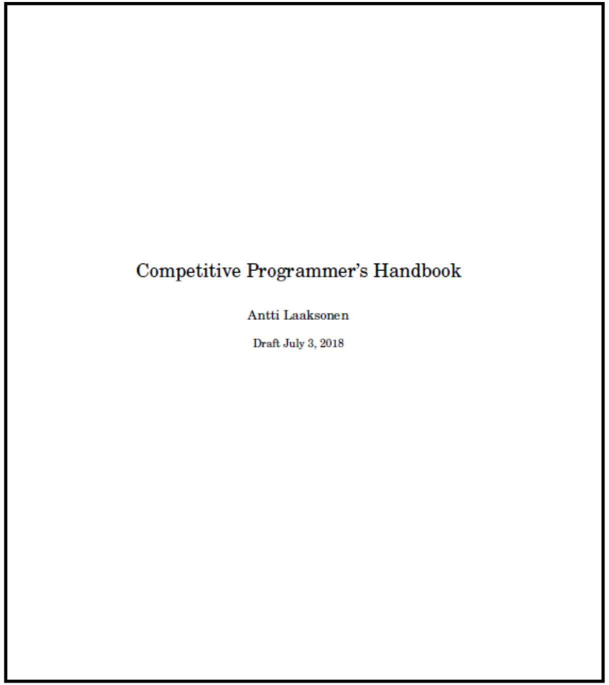
Time complexity
Complete search
Dynamic programming
Range queries
Sorting
Greedy algorithms
Amortized analysis
Bit manipulation

- Graph algorithms [105 - 195]

Graph traversal
Spanning trees
Tree queries
Shortest paths
Directed graphs
Paths and circuits
Tree algorithms
Strong connectivity
Flows and cuts

- Advanced topics [195 - 275]

Number theory
Game theory
Segment trees revisited
Combinatorics
String algorithms
Geometry
Matrices
Square root algorithms
Sweep line algorithms



Competitive Programmer’s Handbook

Antti Laaksonen

Draft July 3, 2018

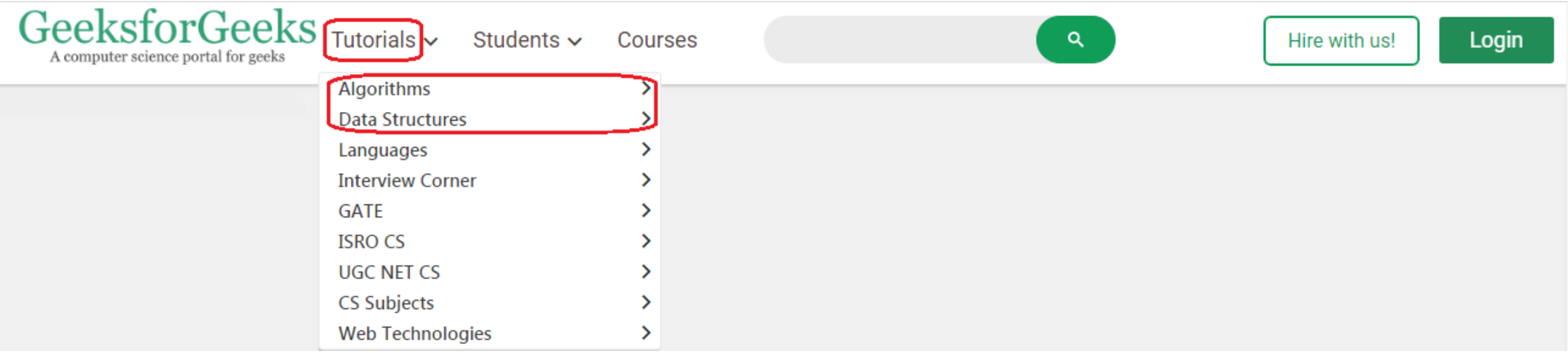
Competitive Programmer’s Handbook

GeeksforGeeks Articles

GeeksforGeeks

A computer science portal for geeks

geeksforgeeks.org



Lecture Agenda

- ✓ Section 1: Data Structures and Algorithms Features
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Section 6: Online Courses

Data Structures & Algorithms Specializations

- Accelerated Computer Science Fundamentals Specialization (3 Courses)

by University of Illinois at Urbana-Champaign coursera.org/specializations/cs-fundamentals

Course : Object-Oriented Data Structures in C++

Week 1: Orientation; Writing a C++ Program
Week 2: Understanding the C++ Memory Model
Week 3: Developing C++ Classes
Week 4: Engineering C++ Software Solutions

Course : Ordered Data Structures

Week 1: Orientation; Linear Structures
Week 2: Introduction to Tree Structures
Week 3: Advanced Tree Structures
Week 4: Heap Structures

Course : Unordered Data Structures

Week 1: Orientation; Hashing
Week 2: Disjoint Sets
Week 3: Graph Data Structures
Week 4: Graph Algorithms

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Data Structures & Algorithms Specializations

- Algorithms Specialization (4 Courses) by Stanford University coursera.org/specializations/algorithms

Course : Divide and Conquer, Sorting and Searching, and Randomized Algorithms

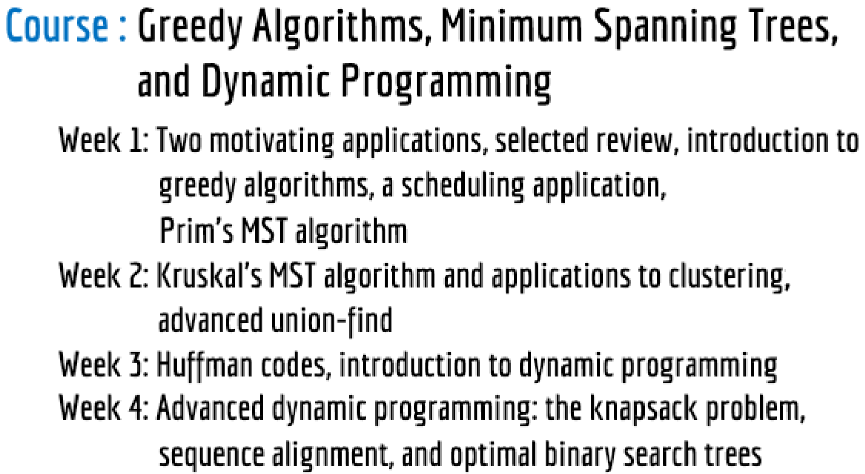
Week 1: Introduction, big-oh notation and asymptotic analysis
Week 2: Divide and conquer basics, the master method for analyzing divide and conquer algorithms
Week 3: The QuickSort algorithm and its analysis, probability review
Week 4: Linear-time selection, graphs, cuts, and the contraction algorithm

Course : Graph Search, Shortest Paths, and Data Structures

Week 1: Breadth-first and depth-first search, computing strong components, applications
Week 2: Dijkstra's shortest-path algorithm
Week 3: Heaps, balanced binary search trees
Week 4: Hashing, bloom filters

Data Structures & Algorithms Specializations

- Algorithms Specialization (4 Courses) by Stanford University coursera.org/specializations/algorithms



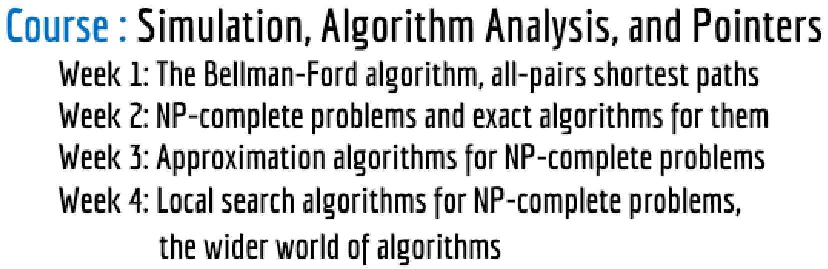
Course : Greedy Algorithms, Minimum Spanning Trees, and Dynamic Programming

Week 1: Two motivating applications, selected review, introduction to
greedy algorithms, a scheduling application,
Prim's MST algorithm

Week 2: Kruskal's MST algorithm and applications to clustering,
advanced union-find

Week 3: Huffman codes, introduction to dynamic programming

Week 4: Advanced dynamic programming: the knapsack problem,
sequence alignment, and optimal binary search trees



Course : Simulation, Algorithm Analysis, and Pointers

Week 1: The Bellman-Ford algorithm, all-pairs shortest paths

Week 2: NP-complete problems and exact algorithms for them

Week 3: Approximation algorithms for NP-complete problems

Week 4: Local search algorithms for NP-complete problems,
the wider world of algorithms

Data Structures & Algorithms Specializations

- Data Structures and Algorithms Specialization (6 Courses)

by University of California San Diego & National Research University Higher School of Economics

coursera.org/specializations/data-structures-algorithms

Course : Algorithmic Toolbox

Week 1: Programming Challenges
Week 2: Algorithmic Warm-up
Week 3: Greedy Algorithms
Week 4: Divide-and-Conquer
Week 5: Dynamic Programming 1
Week 6: Dynamic Programming 2

Course : Data Structures

Week 1: Basic Data Structures
Week 2: Dynamic Arrays and Amortized Analysis
Week 3: Priority Queues and Disjoint Sets
Week 4: Hash Tables
Week 5: Binary Search Trees
Week 6: Binary Search Trees 2

Data Structures & Algorithms Specializations

- Data Structures and Algorithms Specialization (6 Courses)

by University of California San Diego & National Research University Higher School of Economics
coursera.org/specializations/data-structures-algorithms

Course : Algorithms on Graphs

Week 1: Decomposition of Graphs 1
Week 2: Decomposition of Graphs 2
Week 3: Paths in Graphs 1
Week 4: Paths in Graphs 2
Week 5: Minimum Spanning Trees
Week 6: Advanced Shortest Paths Project

Course : Algorithms on Strings

Week 1: Suffix Trees
Week 2: Burrows-Wheeler Transform and Suffix Arrays
Week 3: Knuth–Morris–Pratt Algorithm
Week 4: Constructing Suffix Arrays and Suffix Trees

Data Structures & Algorithms Specializations

- Data Structures and Algorithms Specialization (6 Courses)

by University of California San Diego & National Research University Higher School of Economics

coursera.org/specializations/data-structures-algorithms

Course : Advanced Algorithms and Complexity

Week 1: Flows in Networks

Week 2: Linear Programming

Week 3: NP-complete Problems

Week 4: Coping with NP-completeness

Week 5: Streaming Algorithms

Course : Genome Assembly Programming Challenge

Week 1: The 2011 European E. coli Outbreak

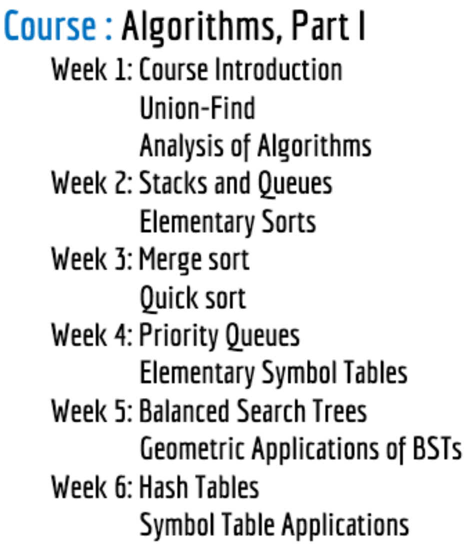
Week 2: Assembling Genomes Using de Bruijn Graphs

Week 3: Genome Assembly Faces Real Sequencing Data

Data Structures & Algorithms Specializations

- Algorithms, Part I by Princeton University

coursera.org/learn/algorithms-part1



Course : Algorithms, Part I

Week 1: Course Introduction
Union-Find
Analysis of Algorithms

Week 2: Stacks and Queues
Elementary Sorts

Week 3: Merge sort
Quick sort

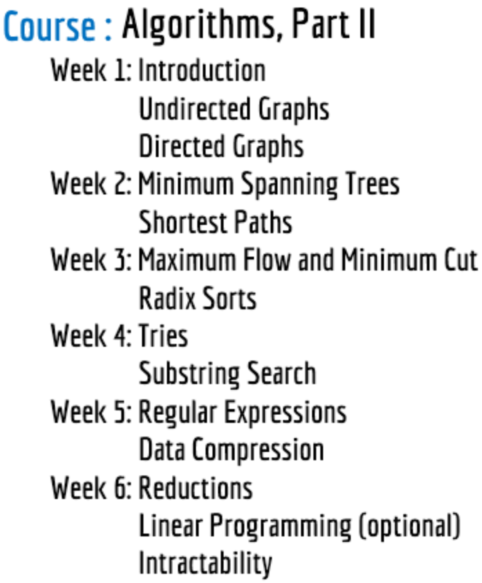
Week 4: Priority Queues
Elementary Symbol Tables

Week 5: Balanced Search Trees
Geometric Applications of BSTs

Week 6: Hash Tables
Symbol Table Applications

- Algorithms, Part II by Princeton University

coursera.org/learn/algorithms-part2



Course : Algorithms, Part II

Week 1: Introduction
Undirected Graphs
Directed Graphs

Week 2: Minimum Spanning Trees
Shortest Paths

Week 3: Maximum Flow and Minimum Cut
Radix Sorts

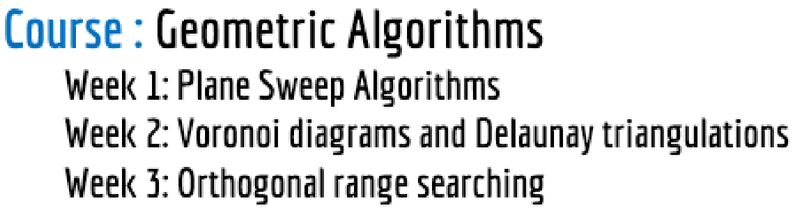
Week 4: Tries
Substring Search

Week 5: Regular Expressions
Data Compression

Week 6: Reductions
Linear Programming (optional)
Intractability

Data Structures & Algorithms Specializations

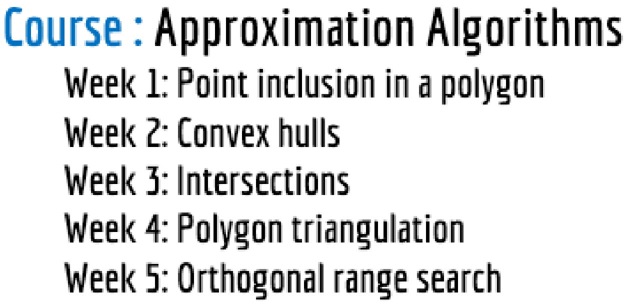
- Geometric Algorithms by EIT Digital coursera.org/learn/geometric-algorithms



Course : Geometric Algorithms

Week 1: Plane Sweep Algorithms
Week 2: Voronoi diagrams and Delaunay triangulations
Week 3: Orthogonal range searching

- Approximation Algorithms by EIT Digital coursera.org/learn/approximation-algorithms



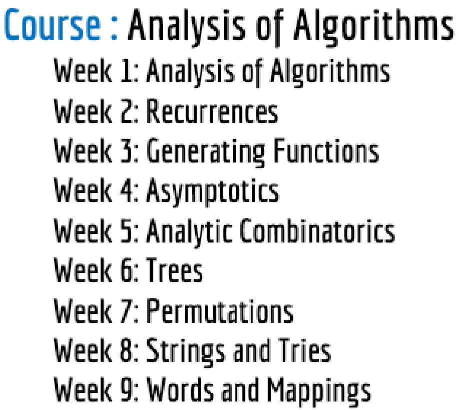
Course : Approximation Algorithms

Week 1: Point inclusion in a polygon
Week 2: Convex hulls
Week 3: Intersections
Week 4: Polygon triangulation
Week 5: Orthogonal range search

Data Structures & Algorithms Specializations

- Analysis of Algorithms by Princeton University

coursera.org/learn/analysis-of-algorithms



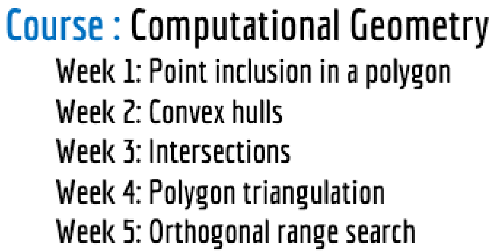
Course : Analysis of Algorithms

Week 1: Analysis of Algorithms
Week 2: Recurrences
Week 3: Generating Functions
Week 4: Asymptotics
Week 5: Analytic Combinatorics
Week 6: Trees
Week 7: Permutations
Week 8: Strings and Tries
Week 9: Words and Mappings

- Computational Geometry

by Saint Petersburg State University

coursera.org/learn/computational-geometry



Course : Computational Geometry

Week 1: Point inclusion in a polygon
Week 2: Convex hulls
Week 3: Intersections
Week 4: Polygon triangulation
Week 5: Orthogonal range search

Data Structures and Algorithms Playlists

- Playlist: Arrays | Data Structures & Algorithms [100 videos] [5 min] Channel: GeeksforGeeks
youtube.com/playlist?list=PLqM7alHXFySEQDk2MDfbwEdjd2svVJH9p
- Playlist: Linked List | Data Structures & Algorithms [60 videos] [5 min] Channel: GeeksforGeeks
youtube.com/playlist?list=PLqM7alHXFySH41ZxzrPNj2pAYPOI8ITe7
- Playlist: Stack | Data Structures & Algorithms [20 videos] [5 min] Channel: GeeksforGeeks
youtube.com/playlist?list=PLqM7alHXFySF7Lap-wi5qlaD8OEBx9RMV
- Playlist: Queue | Data Structures & Algorithms [10 videos] [5 min] Channel: GeeksforGeeks
youtube.com/playlist?list=PLqM7alHXFySG6wgjVeEat_ouTIi0IBQ6D
- Playlist: Graph | Data Structures & Algorithms [30 videos] [5 min] Channel: GeeksforGeeks
youtube.com/playlist?list=PLqM7alHXFySEaZgcg7uRYJFBnYMLti-nh
- Playlist: Trees | Data Structures & Algorithms [200 videos] [5 min] Channel: GeeksforGeeks
youtube.com/playlist?list=PLqM7alHXFySHCXD7r1J0ky9Zg_GBB1dbk
- Playlist: Matrix | Data Structures & Algorithms [10 videos] [10 min] Channel: GeeksforGeeks
youtube.com/playlist?list=PLqM7alHXFySGNyLyr8A2CBEBIbUIEC38f
- Playlist: Hashing | Data Structures & Algorithms [10 videos] [5 min] Channel: GeeksforGeeks
youtube.com/playlist?list=PLqM7alHXFySGwXaessYMemAnITqIZdZVE

Data Structures and Algorithms Playlists

- Playlist: Data Structures [90 videos] [10 min] Channel: RobEdwardsSDSU
youtube.com/playlist?list=PLpPXw4zFa0uKKhaSz87IowJnOTzh9tiBk
- Playlist: Data Structure(ETCS - 209) - IP University Syllabus [60 videos] [10 min] Channel: Easy Engineering Classes
youtube.com/playlist?list=PLV8vIYTIdSna11Vc54-abg33JtVZiiMfg
- Playlist: Data Structures and Algorithms [70 videos] [10 min] Channel: Gate Instructors
youtube.com/playlist?list=PLXVjll7-2kRkrlwlVmSTF236m3z9sRCr8
- Playlist: Data Structures [40 videos] [15 min] Channel: mycodeschool
youtube.com/playlist?list=PL2_aWCzGMAwI3W_JlcBbtYTwiQSsOTa6P
- Playlist: Algorithms and Data structures [15 videos] [30 min] Channel: Gate Lectures
youtube.com/playlist?list=PLEbnTDJUr_IeHYw_sfBOJ6gk5pie0yP-0
- Playlist: Design and Analysis of Algorithms [55 videos] [15 min] Channel: Computer Science and Engineering
youtube.com/playlist?list=PLJ5C_6qdAvBE5VcLIv1xIFMRpGu3BQneh
- Playlist: Design and Analysis of Algorithms, Spring 2015 [35 videos] [80 min] Channel: MIT OpenCourseWare
youtube.com/playlist?list=PLUl4u3cNGP6317WaSNfmCvGym2ucw3oGp
- Playlist: Introduction to Algorithms, Fall 2011 [45 videos] [50 min] Channel: MIT OpenCourseWare
youtube.com/playlist?list=PLUl4u3cNGP61Oq3tWYp6V_F-5jb5L2iHb

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DO MORE.