Introduction to advanced data structures and algorithms

CSEN 1038

German University in Cairo

Outline

1. Motivation
2. Problem Solving Methodology
3. Administrivia
4. Lab Zero

Why study advanced data structures and algorithms?

- Tasks
  - set-set intersection
  - sorting and retrieval
- Problems
  - deleting database records with dependency constraints
  - Conflict resolution among versions (e.g. version control, distributed database eventual consistency)

Why study advanced data structures and algorithms?

- Tasks
  - set-set intersection
  - sorting and retrieval
- Problems
  - deleting database records with dependency constraints
  - Conflict resolution among versions (e.g. version control, distributed database eventual consistency)

Why study advanced data structures and algorithms?

A competitive programming based course

Problem Solving Methodology

Strategies

Tactics

Tools

Adopted from *The Art and Craft of Problem Solving*

Strategies

- Read the problem carefully
- Visualize
- Draw observations, Make Conclusions
- Get your hands dirty
- Build and trust your intuition
- Argue for your solution
- Stuck? Explore other ways

Strategies

- Read the problem carefully
- Visualize
- Draw observations, Make Conclusions
- Get your hands dirty
- Build and trust your intuition
- Argue for your solution
- Stuck? Explore other ways

Strategies

- Read the problem carefully
- Visualize
- Draw observations, Make Conclusions
- Get your hands dirty
- Build and trust your intuition
- Argue for your solution
- Stuck? Explore other ways

Strategies

- Read the problem carefully
- Visualize
- Draw observations, Make Conclusions
- Get your hands dirty
- Build and trust your intuition
- Argue for your solution
- Stuck? Explore other ways

Strategies

- Read the problem carefully
- Visualize
- Draw observations, Make Conclusions
- Get your hands dirty
- Build and trust your intuition
- Argue for your solution
- Stuck? Explore other ways

Strategies

- Read the problem carefully
- Visualize
- Draw observations, Make Conclusions
- Get your hands dirty
- Build and trust your intuition
- Argue for your solution
- Stuck? Explore other ways

Strategies

- Read the problem carefully
- Visualize
- Draw observations, Make Conclusions
- Get your hands dirty
- Build and trust your intuition
- Argue for your solution
- Stuck? Explore other ways

Tactics

Methods applicable to different settings

- Cyclic dependencies or recursive relationships
  - Graph modeling
- Range queries
  - Precomputation or dedicated data structures
- Optimization problems
  - Invariants or monotonicity

Tactics

Methods applicable to different settings

- Cyclic dependencies or recursive relationships
  - Graph modeling
- Range queries
  - Precomputation or dedicated data structures
- Optimization problems
  - Invariants or monotonicity

Tactics

Methods applicable to different settings

- Cyclic dependencies or recursive relationships
  - Graph modeling
- Range queries
  - Precomputation or dedicated data structures
- Optimization problems
  - Invariants or monotonicity

Tactics

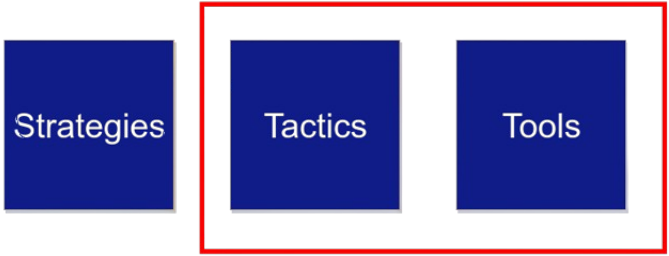
Methods applicable to different settings

- Cyclic dependencies or recursive relationships
  - Graph modeling
- Range queries
  - Precomputation or dedicated data structures
- Optimization problems
  - Invariants or monotonicity

Tools

Focused techniques and tricks for specific situations.

What is this course about?



What is this course about?

- What it is
  - practical
  - implementation oriented
- What it is not
  - theoretically formal
  - heavily rigorous

What is this course about?

- What it is
  - practical
  - implementation oriented
- What it is not
  - theoretically formal
  - heavily rigorous

What is this course about?

- What it is
  - practical
  - implementation oriented
- What it is not
  - theoretically formal
  - heavily rigorous

What is this course about?

- What it is
  - practical
  - implementation oriented
- What it is not
  - theoretically formal
  - heavily rigorous

What is this course about?

- What it is
  - practical
  - implementation oriented
- What it is not
  - theoretically formal
  - heavily rigorous

What is this course about?

- What it is
  - practical
  - implementation oriented
- What it is not
  - theoretically formal
  - heavily rigorous

Course Material

All course material will be uploaded here
`https://github.com/AhmadHoseiny/ADSA-2025`

Course Resources

- `https://cp-algorithms.com/`
- **Introduction to Algorithms, 3rd Edition (CLRS)** by Cormen, Leiserson, Rivest, and Stein.

Course Assessment

- All assessments will be in the form of Codeforces contests and problems
- Lab and Home assignments are weekly based
- Attendance of lectures is highly recommended

Lab Assignments	20%
Home Assignments	50%
Project	30%

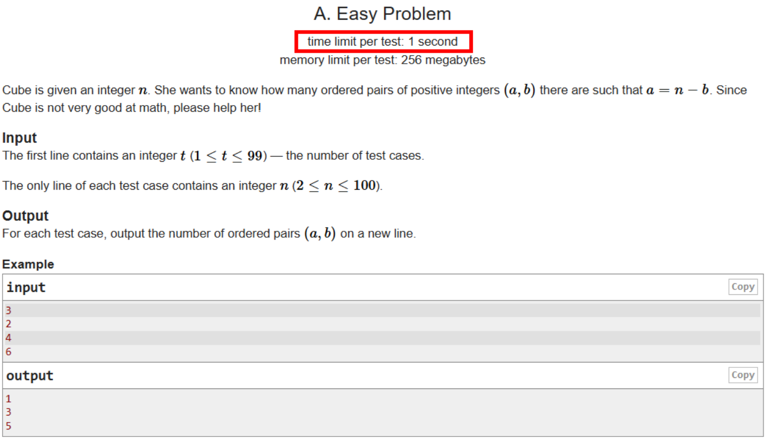
Course outline

Week	Topic
1	Introduction
2	Persistent Data Structures and Disjoint Sets Union
3	Matrix Exponentiation
4	Segment Trees with Lazy Propagation
5	Binary Search and Meet in the Middle
6	Advanced Dynamic Programming
7	Fast Fourier Transform
8	Cycle Detection and Strongly Connected Components
9	Tree Diameter and Lowest Common Ancestor
10	String Processing Algorithms
11	Max Flow Algorithms
12	Joker

Lab Zero

Lab Zero

Codeforces



A. Easy Problem

time limit per test: 1 second

memory limit per test: 256 megabytes

Cube is given an integer n. She wants to know how many ordered pairs of positive integers (a, b) there are such that $a = n - b$. Since Cube is not very good at math, please help her!

Input

The first line contains an integer t $(1 \leq t \leq 99)$ — the number of test cases.

The only line of each test case contains an integer n $(2 \leq n \leq 100)$.

Output

For each test case, output the number of ordered pairs (a, b) on a new line.

Example

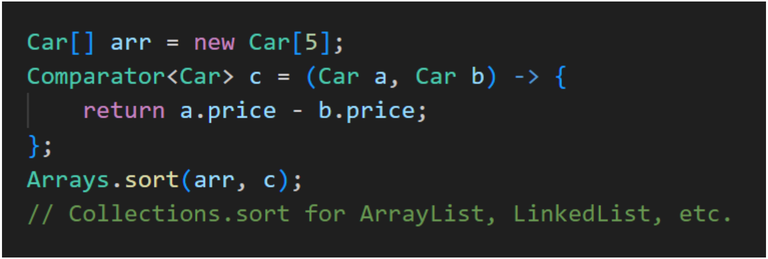
input

```
3
2
4
6
```

output

```
1
3
5
```

Java Refresher - Sorting

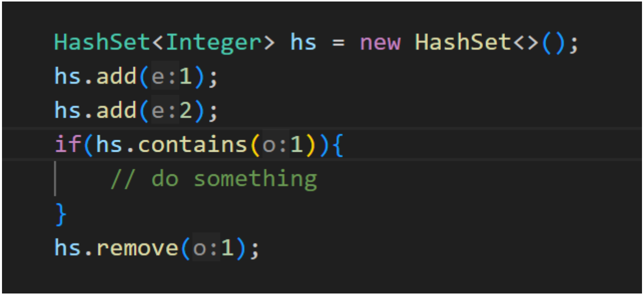


```java
Car[] arr = new Car[5];
Comparator<Car> c = (Car a, Car b) -> {
    return a.price - b.price;
};
Arrays.sort(arr, c);
// Collections.sort for ArrayList, LinkedList, etc.
```

Remark

Time complexity of the sorting is $O(n \log n)$

Java Refresher - HashSets

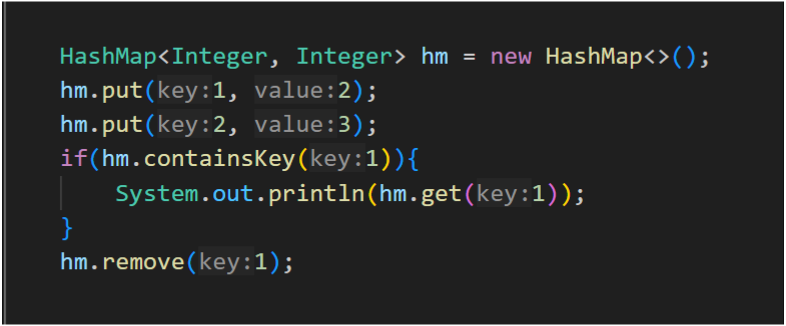


```
HashSet<Integer> hs = new HashSet<>();
hs.add(e:1);
hs.add(e:2);
if(hs.contains(o:1)){
    // do something
}
hs.remove(o:1);
```

Remark

Time complexity of these methods is roughly $O(1)$

Java Refresher - HashMaps



```java
HashMap<Integer, Integer> hm = new HashMap<>();
hm.put(key:1, value:2);
hm.put(key:2, value:3);
if(hm.containsKey(key:1)){
    System.out.println(hm.get(key:1));
}
hm.remove(key:1);
```

Remark

Time complexity of these methods is roughly $O(1)$

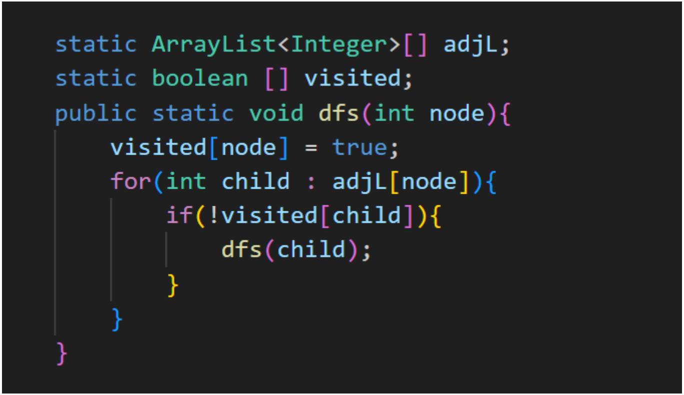
Graphs Refresher - Representation

- Adjacency Matrix
- Adjacency List

Graphs Refresher - Representation

- Adjacency Matrix
- Adjacency List

Graphs Refresher - DFS



```
static ArrayList<Integer>[] adjL;
static boolean [] visited;
public static void dfs(int node){
    visited[node] = true;
    for(int child : adjL[node]){
        if(!visited[child]){
            dfs(child);
        }
    }
}
```

Remark

Time complexity of DFS $O(n + m)$

Codeforces

Let’s ace some problems !