NCPC 2017
Presentation of solutions

The Jury

2017-10-07

NCPC 2017 Jury

- Per Austrin (KTH Royal Institute of Technology)
- Pål Grønås Drange (Statoil ASA)
- Markus Fanebust Dregi (Statoil ASA/Webstep)
- Antti Laaksonen (CSES)
- Ulf Lundström (Excillum)
- Jimmy Mårdell (Spotify)
- Lukáš Poláček (Google)
- Johan Sannemo (Google)
- Pehr Söderman (Kattis)

J — Judging Moose

Problem

Classify moose based on their horns.

Some solution (guess the language)

```
solve(0, 0) :-
    !, write('Not a moose').
solve(L, R) :-
    type(L, R, Type),
    Val is 2*max(L, R),
    write(Type), write(' '), write(Val).
type(L, L, "Even") :- !.
type(_, _, "Odd").
```

Statistics: 347 submissions, 252 accepted, first after 00:03

B — Best Relay Team

Problem

Pick best relay team, given runners' standing and flying start times.

Solution

1. Pre-sort runners by their flying start time

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Statistics: 491 submissions, 189 accepted, first after 00:08

G — Galactic Collegiate Programming Contest

Problem

There are n teams who solve m problems in an ICPC style programming contest. After each successful submission, print the rank of your team.

Solution

1. Maintain a set S: the teams whose score is better than your team's score. Your rank is $|S| + 1$.

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Statistics: 578 submissions, 79 accepted, first after 00:29

I — Import Spaghetti

Problem

The dependencies form a directed graph, and the task is to find a shortest cycle in a directed graph.

Solution

1. Use the Floyd–Warshall all pairs shortest path algorithm with diagonals initialized to ∞

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Complexity is $O(n^3)$ or $O(n(n+m))$.

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Statistics: 290 submissions, 52 accepted, first after 00:30

E — Emptying the Baltic

Problem

How much water can we drain from a point at the bottom of the sea?

Solution

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    3. In each iteration, pick the square s with the lowest tentative depth and mark it *final*. Update tentative depth of all neighbours of s.

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Time complexity is $O(n \log n)$, where $n = w \cdot h$ is the size of the grid.

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Statistics: 296 submissions, 55 accepted, first after 00:47

D — Distinctive Character

Problem

Given n bit vectors of length k, find a bit vector whose minimum Hamming distance is maximum.

Solution

1. There are a total of 2^k possible bit vectors.

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1. There are a total of 2^k possible bit vectors.
2. Create a graph where each node is a bit vector and there is an edge between two nodes if they differ in a single bit.
   (aka the k-dimensional hypercube graph)

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Time complexity is$O(n + k \cdot 2^k)$

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Statistics: 461 submissions, 40 accepted, first after 00:17

C — Compass Card Sales

Problem

Dynamically keep track of "uniqueness values" of cards while cards are being sold off.

Solution

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Dynamically keep track of "uniqueness values" of cards while cards are being sold off.

Solution

1. When card is sold, at most 6 other cards (the 2 "adjacent" cards of each color) can change their uniqueness values.

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Dynamically keep track of "uniqueness values" of cards while cards are being sold off.

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1. When card is sold, at most 6 other cards (the 2 "adjacent" cards of each color) can change their uniqueness values.
2. For $c \in \{R, G, B\}$, keep set S_c of cards ordered by angle in color c.

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1. When card is sold, at most 6 other cards (the 2 "adjacent" cards of each color) can change their uniqueness values.
2. For $c \in \{R, G, B\}$, keep set S_c of cards ordered by angle in color c.
3. When selling card, find the ≤ 6 affected cards and recompute their uniqueness values, using fast lookup in the sets S_c.

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4. Keep all cards in another ordered set ordered by uniqueness value for fast extraction of next card to sell.

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Complexity is $O(n \log n)$ with balanced search trees or similar.

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Statistics: 105 submissions, 14 accepted, first after 01:10

K — Kayaking

Problem

Assign pool of weak/normal/strong people to 2-person kayaks (of different speed factors) to maximize speed of slowest kayak.

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1. Binary search over the answer.

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Solution

1. Binary search over the answer.
2. Check feasibility by greedily assigning people to kayaks
   - kayaks requiring strong+strong or strong+normal get that
   - kayaks that can handle weak+weak or weak+normal get that
   - pair up remaining weaks with strongs and normals with normals and check if this can make all kayaks fast enough

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Time complexity is $O(n \log n)$ for n people.

Statistics: 82 submissions, 23 accepted, first after 00:46

A — Airport Coffee

Problem

Find fastest way of walking distance L. At certain points x_i we can choose to get a future temporary speedup (by buying a coffee), at the cost of cancelling any current speedup.

Solution

1. Let $S(i)$ be best time if we start from i'th cart.

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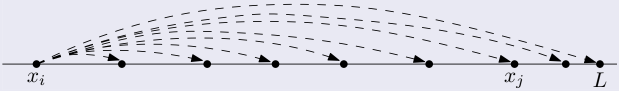
Solution



1. Let $S(i)$ be best time if we start from i'th cart.
2. Easy dynamic programming: for each $j > i$, try buying next coffee at cart j

$$S(i) = \min_{j>i} S(j) + \text{Time to go from } x_i \text{ to } x_j$$

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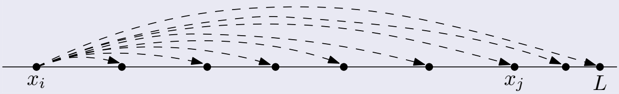

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3. Alas, leads to $\Omega(n^2)$ time – too slow!.

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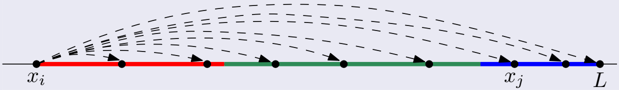

1. From each x_i, three categories of choice for best next cart x_j: During cooldown, during drinking, and after finishing the coffee

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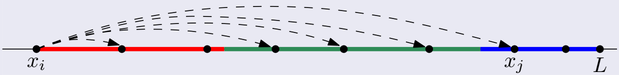

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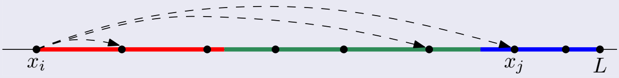

1. From each x_i, three categories of choice for best next cart x_j: During cooldown, during drinking, and after finishing the coffee
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3. During drinking: best to pick **largest** such j (keep drinking coffee as long as possible)

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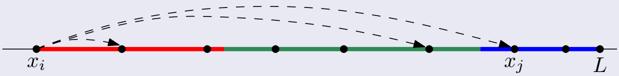

1. Only need to consider three values of j when computing $S(i)$.

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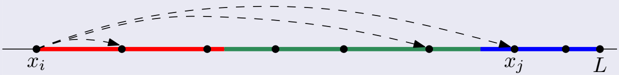

1. Only need to consider three values of j when computing $S(i)$.
2. Can use binary search over cart positions to find them in $O(\log n)$ time.

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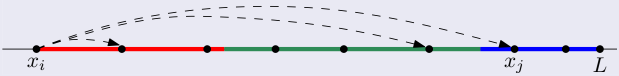

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(Exercise: can be improved to $O(n)$ time.)

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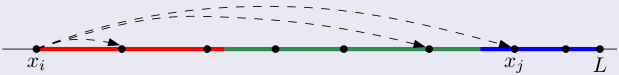

1. Only need to consider three values of j when computing $S(i)$.
2. Can use binary search over cart positions to find them in $O(\log n)$ time.

Overall complexity $O(n \log n)$.
(Exercise: can be improved to $O(n)$ time.)

Statistics: 65 submissions, 7 accepted, first after 02:50

H — Hubtown

Problem

Given a set of rays from in 2D $(0, 0)$, and some points, assign max #points to a ray of minimum angular distance from the point, subject to ray capacities.

Phase 1

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Phase 1

1. Sort all rays and points by angle.

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Given a set of rays from in 2D $(0,0)$, and some points, assign max #points to a ray of minimum angular distance from the point, subject to ray capacities.

Phase 1

1. Sort all rays and points by angle.
2. For each point, compare distances to its two neighboring rays (Use sweep approach or binary search to find the two rays quickly)

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4. Can also check this using only integer computations. (But, despite small coordinates, need 64 bits.)
5. Points with a unique neighboring ray can be immediately assigned to that ray (if it has capacity left).

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1. For remaining points (having two closest rays) we get a bipartite matching problem between points and rays.

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2. Graph is very simple (either a cycle, or a collection of paths)

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   1. Time complexity with Ford-Fulkerson is $O(p^2)$ where p is the number of train lines adjacent to some remaining person.

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    1. Time complexity with Ford-Fulkerson is $O(p^2)$ where p is the number of train lines adjacent to some remaining person.
    2. However p is hard to analyze. Turns out that $p \approx \text{max coordinate} = 1000$, so this approach is fast enough.

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3. Approach 2: greedyish solution

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1. For remaining points (having two closest rays) we get a bipartite matching problem between points and rays.
2. Graph is very simple (either a cycle, or a collection of paths)
3. Approach 2: greedyish solution
    1. First cut the cycle anywhere to get a path, solve path with simple greedy

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Statistics: 17 submissions, 0 accepted

F — Fractal Tree

Problem

Given a huge tree with potentially $100000^{2^{30}}$ vertices, find distances between pairs of vertices.

Solution

1. A copy of F_{30} will have at least 2^{30} vertices (assuming F_0 has at least 2 leaves)

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3. Reduces the problem to $k \leq 30$.

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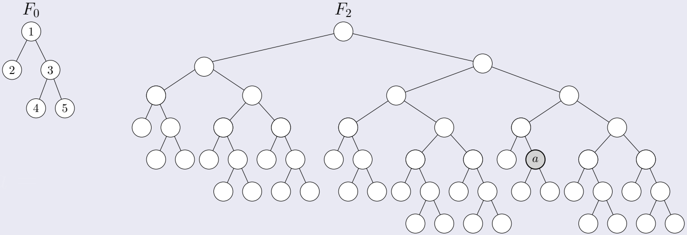

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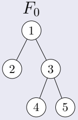

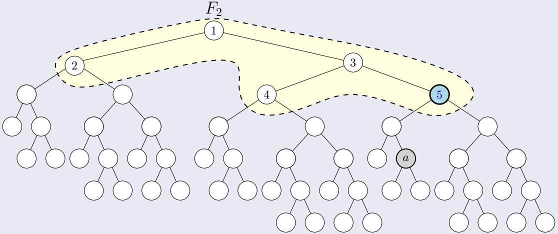

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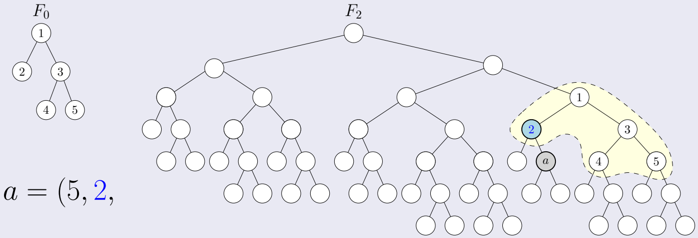

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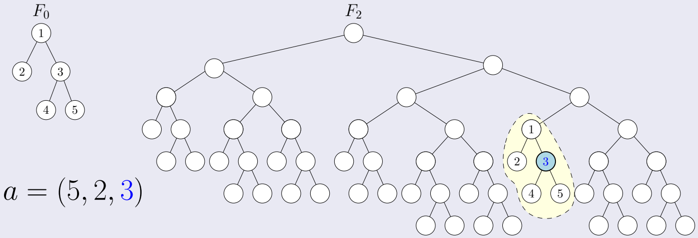

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    2. Finally add which node a corresponds to in last copy of F_0.

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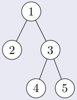
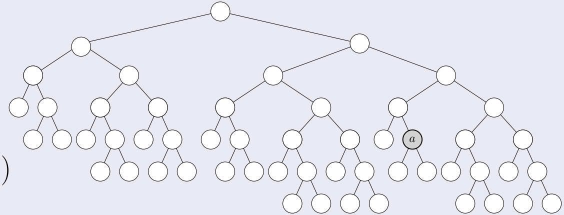
Solution

F_0



F_2



$$a = (5, 2, 3)$$

1. Representation of vertex *a* in the big tree.
2. Can find this representation in $O(k \log n)$ time using binary search and precomputation of subtree sizes.

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1. What is distance between $(a_1, \ldots, a_p)$ and $(b_1, \ldots, b_q)$?

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3. Then, when $a_1 \neq b_1$, distance is
$$d(a_1, b_1) + \sum_{i=2}^{p} h(a_i) + \sum_{i=2}^{q} h(b_i)$$
4. $d(a_1, b_1) =$ distance between a_1 and b_1 in F_0
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Statistics: 5 submissions, 0 accepted

Random numbers

253 teams

611 contestants

2819 total number of submissions

10 programming languages used by teams

Ordered by #submissions: C++ (1016), Java (865), Python (763), C (67), C# (65), Haskell (16), Prolog (9), Scala (8), Go (6), Ruby (4)

438 number of lines of code used in total by the shortest **jury** solutions to solve the entire problem set. (Significantly smaller than previous years – no killer problem in terms of implementation this year.)

Random facts

- All but two of the problems have **near-linear solutions**

  Exceptions:

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- The jury wrote Python solutions for all problems except C (**Compass Card Sales**). But mostly in Python 2, which is faster than Python 3 on Kattis due to using pypy instead of CPython. The Python solutions are always the shortest (often by a wide margin).

What now?

- Northwestern Europe Regional Contest (NWERC):
  November 26 in Bath (UK).
  Teams from Nordic, Benelux, Germany, UK, Ireland.

- Each university sends up to two teams to NWERC to fight for spot in World Finals (April 2018, in Beijing, China)