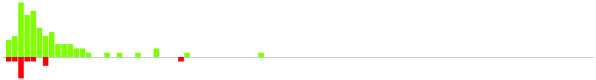
BAPC 2021

Solutions presentation

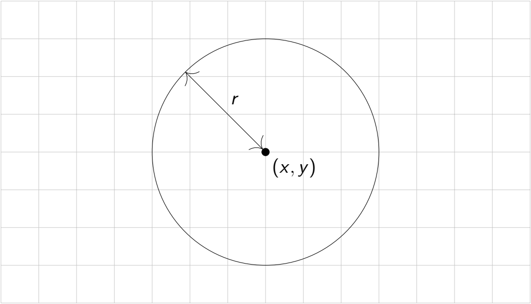
November 1, 2021

A: Arm Coordination

Problem Author: Reinier Schmiermann



- **Problem:** Given a circle, find the smallest square which encloses this circle.



Statistics: 94 submissions, 82 accepted, 0 unknown

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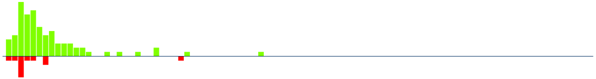
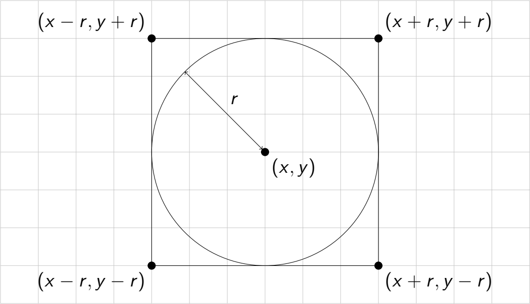


- **Problem:** Given a circle, find the smallest square which encloses this circle.
- **Solution:** simple arithmetic



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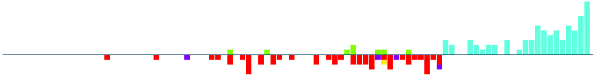
B: BnPC

Problem Author: Harry Smit



- **Problem:** increase attribute scores so that you maximize a certain score function.

Statistics: 139 submissions, 8 accepted, 78 unknown

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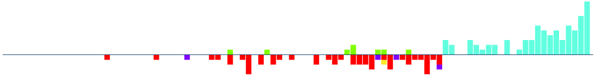

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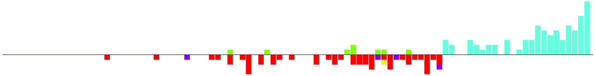

- **Problem:** increase attribute scores so that you maximize a certain score function.
- First set all attributes to the lowest value they need to be to pass all the challenges (if this is impossible, the maximum score is 0).
- Improve your score by increasing an attribute by one. There are two cases:
  - If the attribute score equals *a* of the challenge requirements, you get points equal to *a* times the new attribute score, plus the number of events that require a lower score for that attribute.
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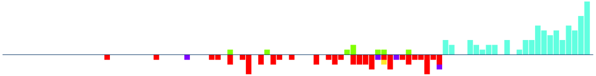

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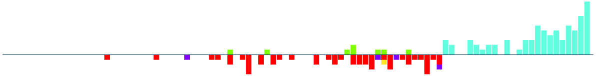

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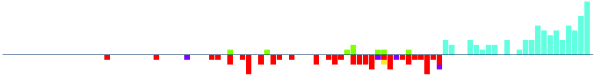

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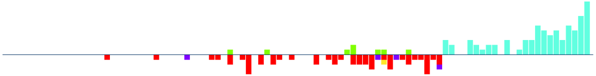

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- You can only spend one point on the first case (per attribute).
- Be greedy: sort these options and spend points until none are left.
- If you ever run into the second case, spend all of your points there.
- Runtime: $\mathcal{O}(n \log n + l)$.

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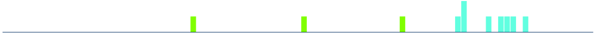
C: Cangaroo

Problem Author: Abe Wits



- **Problem:** Given a $n \times m$ grid with marked locations, what is the minimum amount of 2×2 cans needed to cover all marked locations?

Statistics: 11 submissions, 3 accepted, 8 unknown

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- **Solution:** Do DP and calculate what the minimal number of cans is needed if you fill up the last r rows for a given can placement of the top row.
  For calculating the next row, iterate over all rows that support a can placement and take the best.

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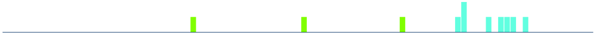

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$$\mathtt{DP}[\mathrm{row}][\mathcal{C}] = \begin{cases} |\mathcal{C}| + \min\limits_{\mathcal{D} \text{ supports } \mathcal{C}} \mathtt{DP}[\mathrm{row}-1][\mathcal{D}] & \text{if } \mathcal{C} \text{ covers locations,} \\ \infty & \text{else.} \end{cases}$$

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- Number of can placements is F_{m+1}, the $(m+1)$th Fibonacci number.
  Time complexity: $\mathcal{O}\left(n \cdot F_{m+1}^2\right) = \mathcal{O}\left(n \cdot 3.3^m\right)$ when using bitmasks.

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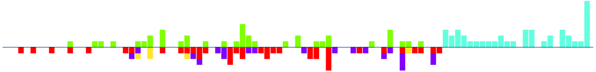
D: Decelerating Jump

Problem Author: Onno Berrevoets



- **Problem:** Given a sequence of n integers $p_1, \ldots, p_n$, find a subsequence $1 = p_{i_1} < p_{i_2} < \cdots < p_{i_k} = n$ such that the distance between consecutive elements does not increase.

Statistics: 146 submissions, 38 accepted, 43 unknown

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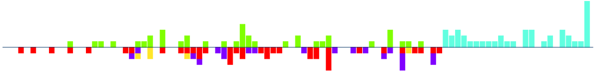

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- **Cubic solution:** Keep a DP table `dp[position][speed]`, which is computed as

$$\mathrm{dp}[i][s] = p_i + \max_{k \geq s} \mathrm{dp}[i-k][k]$$

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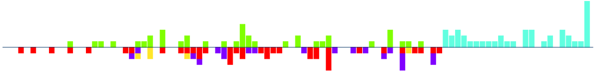

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- **Quadratic solution:** Loop over speed s from $n-1$ to 1, keeping track of the maximum score if you end in each cell with speed at least s. Then update all positions i from 1 to n:

$$\mathrm{dp}[i] = \max(\mathrm{dp}[i], p_i + \mathrm{dp}[i-s])$$

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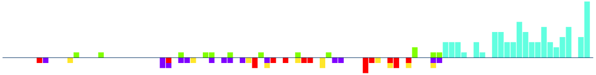
E: Evolutionary Excerpt

Problem Author: Ragnar Groot Koerkamp



- **Problem:** Given two independent uniform random sequences over "`ACTG`" of length $n = 10^6$, find a common subsequence of length at least 500 000.

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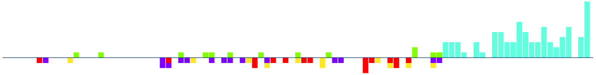

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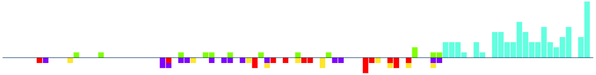

- **Problem:** Given two independent uniform random sequences over "`ACTG`" of length $n = 10^6$, find a common subsequence of length at least 500 000.
- Naive solution: run the Longest Common Subsequence algorithm. $\mathcal{O}(n^2)$ is too slow!
- Greedy: if the front two characters are the same, take it. Otherwise, remove the first character from the longer sequence. $\rightarrow$ length 400 000.

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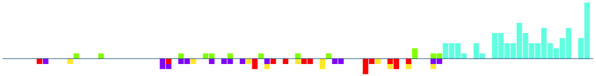

- Greedy, second attempt: Instead of only comparing the front characters, we can compare the front character of each sequence with the first three or four characters of the other sequence, and use the first match we find. $\rightarrow$ length 531 000.

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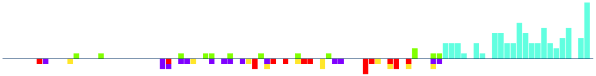

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- LCS DP, but smarter: instead of computing the full n^2 DP table, we can only keep entries close to the diagonal. Keeping a diagonal of width $k = 10 \rightarrow$ length 624 000, $\mathcal{O}(nk)$.

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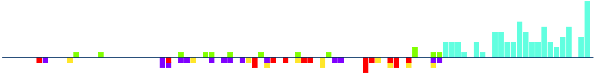

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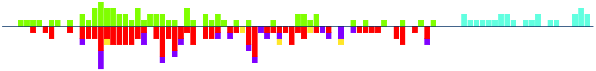
- LCS DP, but smarter: instead of computing the full n^2 DP table, we can only keep entries close to the diagonal. Keeping a diagonal of width $k = 10 \rightarrow$ length 624 000, $\mathcal{O}(nk)$.
- Split the input in chunks of size $k \geq 7$, and run LCS for each chunk. $\rightarrow \mathcal{O}(nk)$, length 502 000 for $k = 7$, length 530 000 for $k = 10$.
  Probability of failure is less than 10^{-16} for $k = 7$, and less than 10^{-1000} from $k = 9$ onward.

F: Fair Play

Problem Author: Robin Lee



- **Problem:** decide if it is possible to pair up vectors so that the sum of each pair is the same.

Statistics: 208 submissions, 66 accepted, 25 unknown

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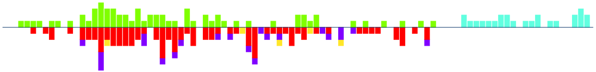

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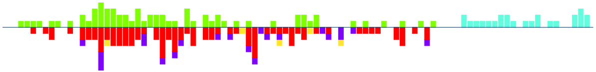

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- If this is possible, then the sum is equal to two times the average. Calculate this average, and check if it is integer.
- If it is, say it is (a, b), pair up the vectors one by one: for every vector (x, y) there needs to be a vector $(2a - x, 2b - y)$.

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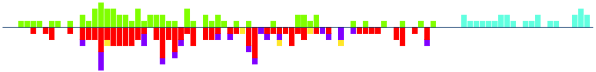

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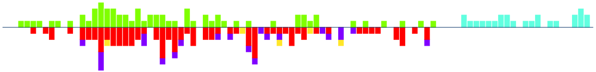

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- Make sure to check that (x, y) and $(2a - x, 2b - y)$ occur equally often!
- Runtime: $\mathcal{O}(n)$.

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G: Gyrating Glyphs

Problem Author: Reinier Schmiermann

- **Problem:** Reverse engineer the ≤ 20000 operators using ≤ 1400 queries:

$$f_n(a_0, \ldots, a_n) := (\ldots(((a_0 \operatorname{op}_1 a_1) \operatorname{op}_2 a_2) \operatorname{op}_3 a_3) \ldots \operatorname{op}_n a_n) \bmod 10^9 + 7$$

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- First solve the problem for 15 operators with a single query $0, q_1, \dots, q_{15}$.
- Use this to find all operators in $20000/15 < 1400$ queries.
- Example with 30 operators:

Recover last 15 operators:

???...??	???...???	Ops
$\underbrace{000\dots000}_{16}$	$q_1 q_2 \dots q_{15}$	Query 1

$+0$ and $\times 1$ do not change the query outcome.

Continue with the next 15 operators.

???...??	$\cancel{+\times+\dots+\times}$	Ops
$0q_1 \dots q_{15}$	$\cancel{010\dots01}$	Query 2

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- Let $0, q_1, \ldots, q_{15}$ where q_i is random in $\{1, \ldots, 10^9 + 6\}$.
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- If all outcomes are distinct $\pmod{10^9 + 7}$ we have a lookup table.

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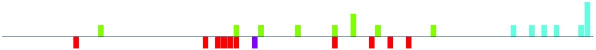
- If not, repeat with a new random query.

H: Hamiltooonian Hike



Problem Author: Jorke de Vlas

- **Problem:** Find a hiking path that visits all cabins, walking at most three trails every day.

Statistics: 28 submissions, 9 accepted, 8 unknown

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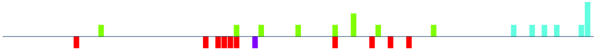

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- **Solution:** A modified DFS, starting from an arbitrary cabin s.

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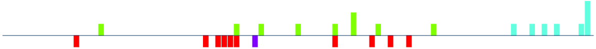
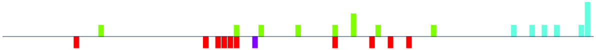


- **Problem:** Find a hiking path that visits all cabins, walking at most three trails every day.
- **Solution:** A modified DFS, starting from an arbitrary cabin s.
- **Variant 1:**
  - While *descending*, only stop at cabins that have *odd* distance to s.
  - While *ascending*, only stop at cabins that have *even* distance to s.

Statistics: 28 submissions, 9 accepted, 8 unknown

H: Hamiltooonian Hike

Problem Author: Jorke de Vlas



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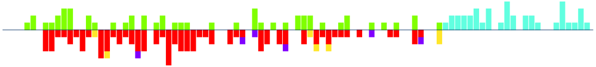
- **Variant 2:**
  While *descending*, only stop at a cabin c if either:
  - you have walked three trails since the last cabin you stopped at, or
  - you have already walked past all neighbouring cabins of c and need to *ascend* again.

Statistics: 28 submissions, 9 accepted, 8 unknown

I: Implementation Irregularities



Problem Author: Ragnar Groot Koerkamp

- **Problem:** Given a list of $n \leq 10^5$ problems, the computer time t_i needed to solve each of them, and the time s_i each was solved, find the minimal number of computers used.

Statistics: 190 submissions, 52 accepted, 39 unknown

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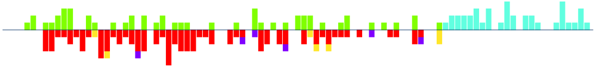

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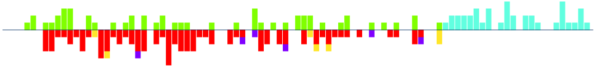

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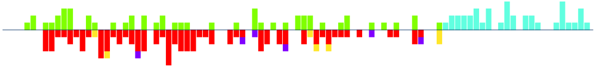

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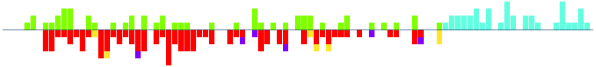

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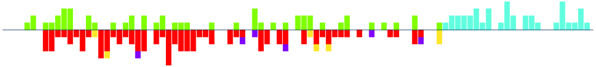

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- For each k we must have $\sum_{i=1}^{k} t_i \leq C \cdot s_k$.
- The answer C is the maximum of $\left(\sum_{i=1}^{k} t_i\right) \Big/ s_k$, rounded up.
- Alternatively, you can binary search.

Statistics: 190 submissions, 52 accepted, 39 unknown

J: Jail or Joyride

Problem Author: Reinier Schmiermann

- **Problem:** find the least distance that a police car needs to travel to catch a group of teenagers on a graph, given that the teenagers flee as far away as possible on every approach.

Statistics: 5 submissions, 0 accepted, 2 unknown

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- Observation 1: If the police can approach the teenagers via multiple edges, then the teenagers can always reach every vertex in the graph.
  - In particular: the approach direction of the police does not matter.
  - The police should always take the shortest path.

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- Observation 1: If the police can approach the teenagers via multiple edges, then the teenagers can always reach every vertex in the graph.
  - In particular: the approach direction of the police does not matter.
  - The police should always take the shortest path.
- Observation 2: If the police can approach the teenagers via only one edge, then either the teenagers are in a leaf, or they are not as far away as possible from the police.
  - Second case only happens at the start.
  - After this, the teenagers can always either reach the whole graph, or nothing at all.

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J: Jail or Joyride

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- The police always takes the shortest path to the teenagers.
- After the first approach of the police, the teenagers can always either reach the whole graph, or nothing.

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- Simulate the first approach of the police separately.

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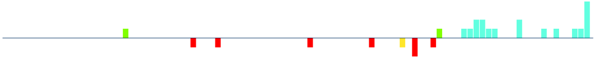
- After the first approach of the police, the teenagers can always either reach the whole graph, or nothing.
- Simulate the first approach of the police separately.
- For every vertex which is not a leaf: find all vertices which are as far away as possible (use APSP).
- Use DFS on this new directed graph to compute for every vertex v the maximal distance the police needs to travel after approaching the teenagers in v.
  - If there is a reachable cycle in this new graph, the police cannot catch the teenagers.

K: Kinking Cables

Problem Author: Boas Kluiving



- **Problem:** Connect opposite corners of a rectangle with a cable of length ℓ such that
  - Line segments do not intersect.
  - The coordinate points of the path should not be too close (< 1) to each other.

Statistics: 28 submissions, 2 accepted, 18 unknown

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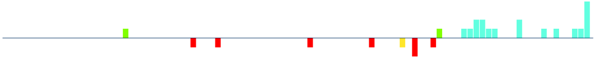

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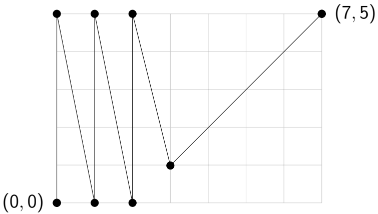

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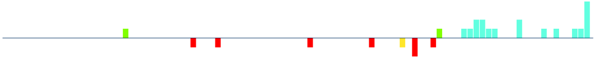

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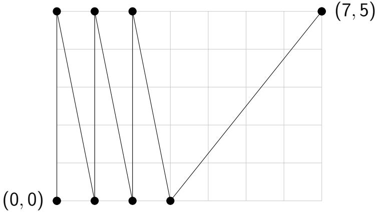

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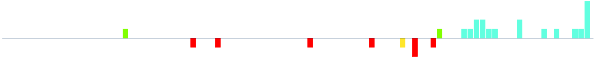

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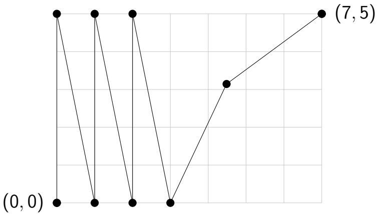

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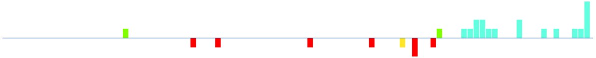

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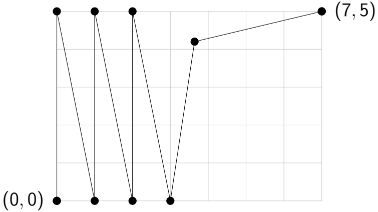

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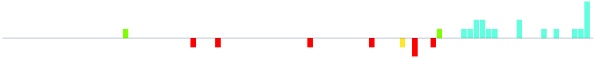

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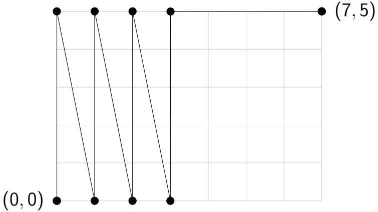

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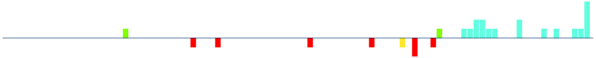

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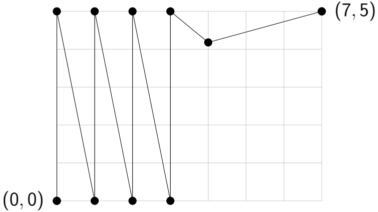

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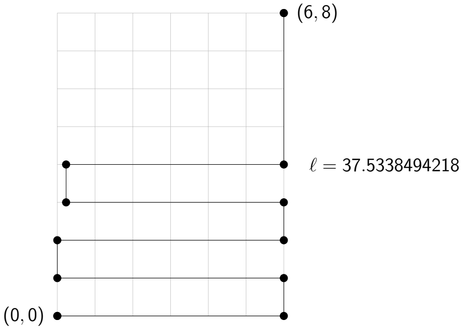
Bonus slide: Honourable mention for team "print(math.tan(float(input())))",
for creating a solution without any diagonal lines and just simple arithmetic
(which none of the jury members had thought of):



L: Lopsided Lineup

Problem Author: Jorke de Vlas

- **Problem:** Split a group of people in two equally sized teams that are as unequally matched as possible.

Statistics: 12 submissions, 7 accepted, 3 unknown

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- Although the question is about synergy, the solution is actually to take *strong players* for the winning team.

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$$c = \begin{pmatrix} \boxed{S} & \\ & \boxed{W} \end{pmatrix}$$

$$\text{score} = \frac{1}{2}(S - W)$$

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$$c = \begin{pmatrix} S & X \\ X & W \end{pmatrix}$$

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- The score of each team is the sum of its players' row sums.

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- The score of each team is the sum of its players' row sums.
- If you take any *other* strong team, you can reorder the matrix c so that your chosen team is the first $n/2$. That does not change the row sums!

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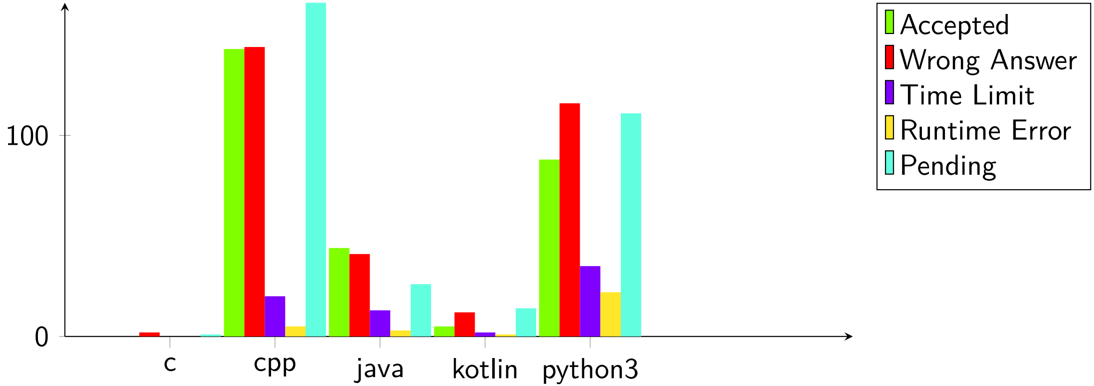
- **Solution:** for each player compute its strength (i.e. the sum of its row). Take the $n/2$ strongest players for the strong team, and the others for the weak team.
- Complexity: $\mathcal{O}(n^2)$.

Language stats



Some stats

- 917 commits, of which 507 for the main contest
- 693 secret test cases (last year: 425) ($\approx$ 58 per problem!)
- 177 jury solutions (last year: 204)
- The minimum[1] number of lines the jury needed to solve all problems is

$$2 + 15 + 15 + 6 + 5 + 5 + 14 + 12 + 5 + 26 + 8 + 2 = 115$$

On average 9.6 lines per problem, up from 7.5 in the preliminaries

[1] Most jury members do enjoy a good code golfing competition!

Thanks to the Proofreaders!

Jaap Eldering
Nicky Gerritsen
Mart Pluijmaekers
Michael Vasseur
Kevin Verbeek

The Jury

Boas Kluiving
Erik Baalhuis
Freek Henstra
Harry Smit
Joey Haas
Jorke de Vlas
Ludo Pulles
Maarten Sijm
Mees de Vries
Ragnar Groot Koerkamp
Reinier Schmiermann
Robin Lee
Ruben Brokkelkamp
Timon Knigge
Wessel van Woerden

Thanks to the Sponsors!