NWERC 2023

Solutions presentation

The NWERC 2023 jury

November 26, 2023

The NWERC 2023 Jury

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Big thanks to our proofreaders and test solvers

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A: Arranging Adapters

Problem Author: Michael Zündorf

Problem

Given $1 \leq n \leq 2 \cdot 10^5$ chargers, each $3 \leq w \leq 10^9\,\mathrm{cm}$ wide, how many fit into a powerstrip comprising a row of $1 \leq s \leq 10^5$ sockets, each of width $3\,\mathrm{cm}$?

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- If the answer is k, we can use the k smallest chargers.

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Solution

- First, greedily put the two largest chargers on the outside.
- If the answer is k, we can use the k smallest chargers.
- To test if the smallest k chargers fit:
  - Start with those of length $0 \mod 3$.
  - Then pair up $1 \mod 3$ and $2 \mod 3$ chargers, filling the gaps.
  - Then pair up remaining $1 \mod 3$, leaving a gap of 1 in between.
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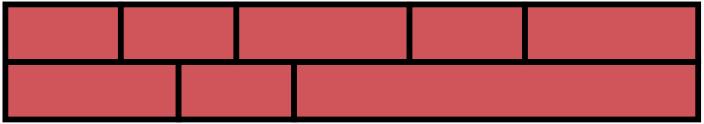
Statistics: ... submissions, ... accepted, ... unknown

B: Brickwork

Problem Author: Michael Zündorf

Problem

Given n types of bricks $b_1, \ldots, b_n$, can you build a wall of width w where no two gaps appear above each other?



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Subtask

Can at least one row be built?

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Can at least one row be built?

Solution

This is known as the *coin change problem* and can be solved like this:

- $\mathcal{O}(\frac{w^2}{64})$ with dp + bitsets
- $\mathcal{O}(w \log(w)^2)$ with fft (faster is possible)

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- $\mathcal{O}(\frac{w^2}{64})$ with dp + bitsets
- $\mathcal{O}(w \log(w)^2)$ with fft (faster is possible)
- Bitsets are much faster

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- $w \in \{b_1, \ldots, b_n\}$

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Case 2

- There is a row that uses two bricks b_x, b_y

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- $w \in \{b_1, \dots, b_n\}$

Case 2

- There is a row that uses two bricks b_x,b_y
- WLOG:
  - Let b_x be the shortest
  - Let b_y be the second shortest
  - there are as few b_x as possible
    (still at least one)

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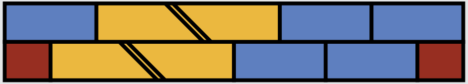

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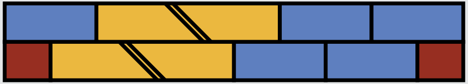
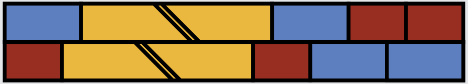


Case 2.2

- Else



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Case 4

- Impossible

Conclusion

The solution exists in two cases:

- Trivial: $w \in \{b_1, \dots, b_n\}$
- There exist two bricks that both can be part of a solution

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The solution exists in two cases:

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C: Chair Dance

Problem Author: Michael Zündorf

Problem

Given are $n \leq 10^5$ players playing a deterministic version of *musical chairs*. Player i starts on chair i. Apply up to 10^5 commands:

- Rotate by $+r$: the person on chair i moves clockwise to chair $i + r$.
- Multiply by $*m$, the person on chair i moves to $i \cdot m$, where the person walking the least gets it.
- On $?q$, print who sits on chair q.

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Naive solution

Store who sits on each chair, and apply each command. $\mathcal{O}(n^2)$

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Be *lazy*! Initialize $p[i] = i$, the person on chair i.

- Instead of rotating by $+r$, increment the *total rotation* R. $p[i]$ is now at $i + R$, so query $p[q - R]$.

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- Collisions occur when $\gcd(m, k) > 1$ ($k = \#$leftover people).
  Simulate these fully, set $k \leftarrow k / \gcd(m, k)$, and reset R and M.

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Given your availability for every hour in a week, pick at least $1 \leq d \leq 7$ days in the first poll and at least $1 \leq h \leq 24$ hours in the second poll to get the highest probability that you will be available.

Fun fact: based on a true story, while the jury was planning their first meeting!

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Brute-force solution

For every combination of (a subset of d days) and (a subset of h hours), calculate the number of free timeslots, take the maximum, and divide by $d \cdot h$.

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Greedy Solution

To avoid having to check all combinations, only check all combinations of d days.

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Greedy Solution

To avoid having to check all combinations, only check all combinations of d days.

For every combination of d days:

- For every hour, count the number of cells with '.'.
- Sort this list and select the h hours with the most open timeslots.
- Calculate the number of free timeslots, take the maximum, and divide by $d \cdot h$.

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E: Exponentiation

Problem Author: Reinier Schmiermann

Problem

There are n variables $x_1, x_2, \ldots, x_n$, initially set to 2023. You are given m queries that either assigns x_i to $x_i^{x_j}$, or asks you to compare x_i and x_j.

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- To make the numbers slightly less huge, take the logarithm twice. Let $y_i = \log\log(x_i)$.

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- $x_i = x_i^{x_j} \equiv y_i = y_i + 2023^{y_j}$.
- Consider these numbers in base 2023. Each operation, one of the digits will increase by one. But no carry will ever happen since there are fewer than 2023 operations.

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Solution

- Represent every variable as a list containing the positions of its non-zero digits. Two such numbers can be compared by lexicographically comparing their lists.

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- When a variable gets updated, it is much easier to create a new variable $y' = y_i + 2023^{y_j}$.

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- When a variable gets updated, it is much easier to create a new variable $y' = y_i + 2023^{y_j}$.
- Order the variables by size at all times. When a new variable y' is created, copy the list of y_i and add y_j to it. Sort the list of y' and insert it into the order.

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- **Challenge**: can you solve the problem faster than quadratic time?

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- **Challenge**: can you solve the problem faster than quadratic time?

Statistics: ... submissions, ... accepted, ... unknown

F: Fixing Fractions

Problem Author: Michael Zündorf

Problem

Given a fraction $\frac{a}{b}$, try to make it equal to $\frac{c}{d}$ by cancelling some digits in a and b

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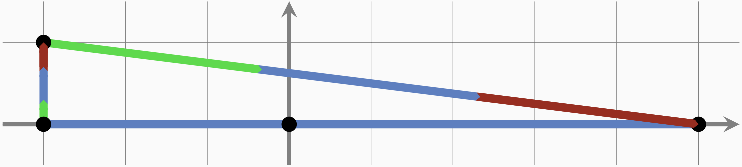
G: Galaxy Quest

Problem Author: Mike de Vries

Problem

You are given a graph consisting of line segments in 3D space. You travel on a ship with constant acceleration and constant fuel consumption for the time spent accelerating. You need to come to a standstill at each vertex. Given a target location and a time limit, find the minimum amount of fuel needed to get there. You need to answer multiple queries, all from the same starting location.



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- Consider a path consisting of multiple line segments.
- Suppose the i-th segment is d_i metres long and we accelerate/decelerate for x_i seconds along it.
- Then it takes $x_i + \frac{d_i}{x_i}$ seconds to traverse the i-th segment.
- New problem: minimize $\sum 2x_i$ subject to $\sum x_i + \frac{d_i}{x_i} \leq t$.
- **Key insight**: optimum is reached when $x_i = c \cdot \sqrt{d_i}$ for some constant c.
- We can compute c by solving $c + \frac{1}{c} = t / \sum \sqrt{d_i}$. When the RHS is < 2, no solution exists.

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- I.e.: the dual graph must be bipartite.
- That's true iff in each intersection point an even number of lines meet.
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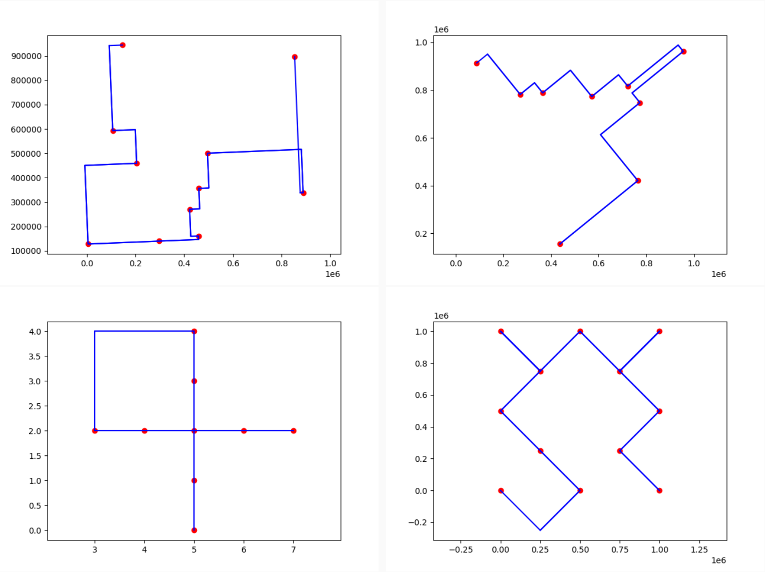

K: Klompendans

Problem Author: Maarten Sijm

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- Create two copies of the grid, one for "the last move was of type (a, b)" and one for "the last move was of type (c, d).
- Starting from the two top left corners, run BFS or DFS to find the reachable states. After each move, transfer over to the other grid.
- Count all cells that are reachable in at least one of the grids.
- Total time: $\mathcal{O}(n^2)$.

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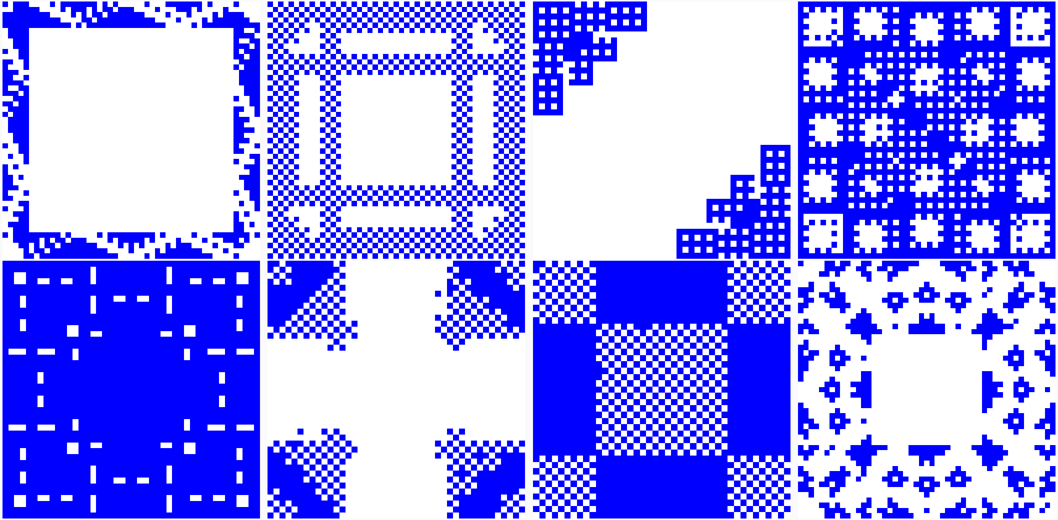

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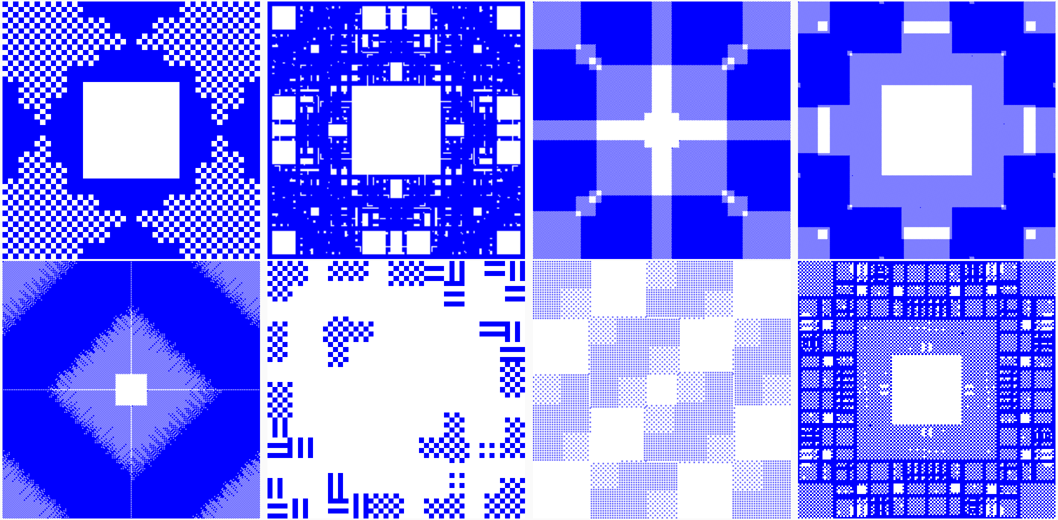

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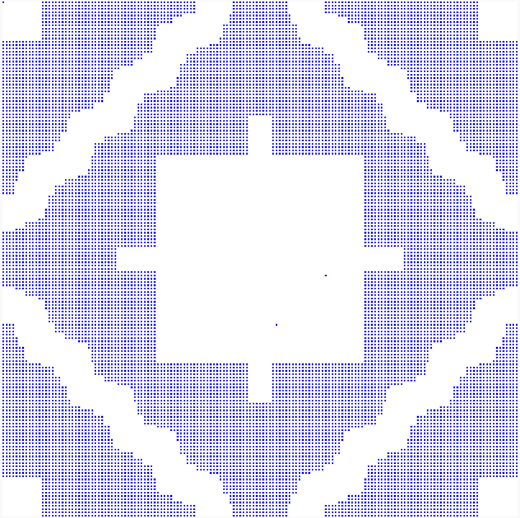

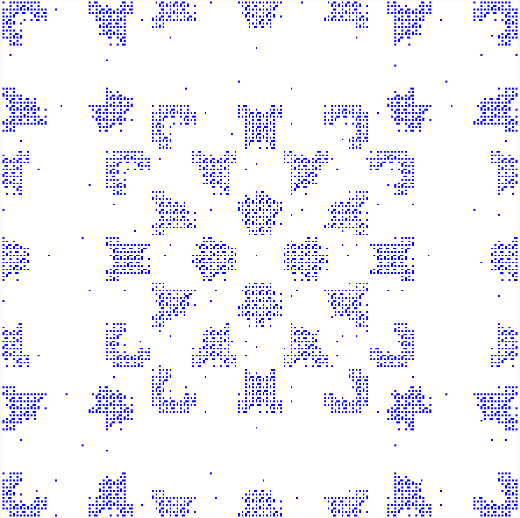

L: Lateral Damage

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- Generalizing this observation over two dimensions:
  shoot every position on every fifth diagonal line.
- For every hit, shoot the four positions left, right, above, and below to sink the full ship.

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- Only team ORTEC beat us: they have a submission of 22 lines for Justice Served!

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