BAPC 2022

Solutions presentation

October 22, 2022

DAPC 2022

Solutions presentation

September 30, 2022

BAPC 2021 Preliminaries

Solutions presentation

October 9, 2021

A: Adjusted Average

Problem Author: Ludo Pulles

- **Problem:** Given $n \leq 1500$ integers a_i, remove at most $k \leq 4$ of them to get an average as close as possible to the target $\overline{x}$.

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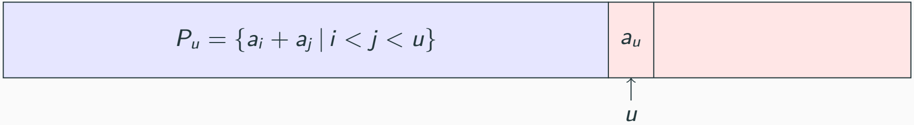

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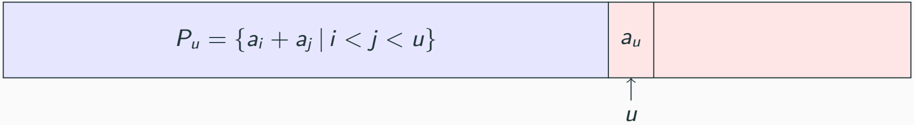

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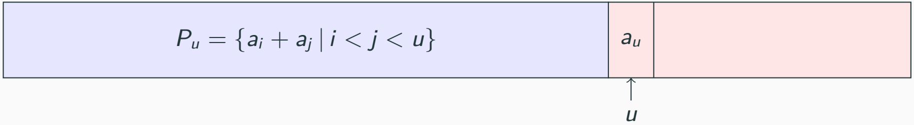

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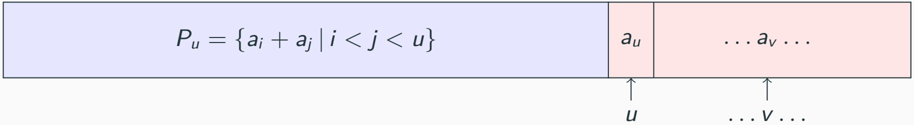

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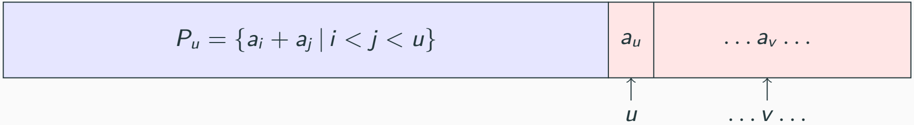

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Statistics: 25 submissions, 3 accepted, 13 unknown

B: Bellevue

Problem Author: Ragnar Groot Koerkamp

- **Problem:** Given the profile of an island, find the point with the largest viewing angle of the sea.

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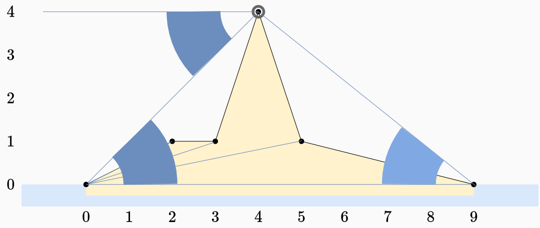
- **Solution:** take the maximum angle around the start/end.



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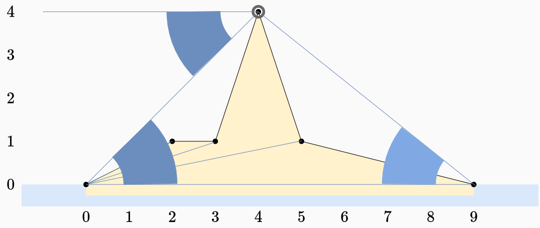

- **Alternative solution:** compute the convex hull and iterate over it.

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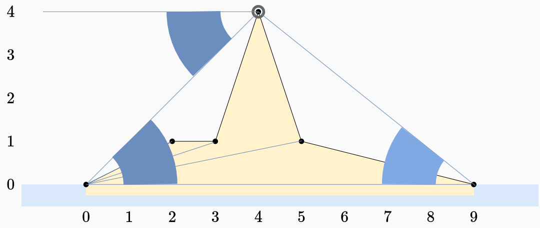

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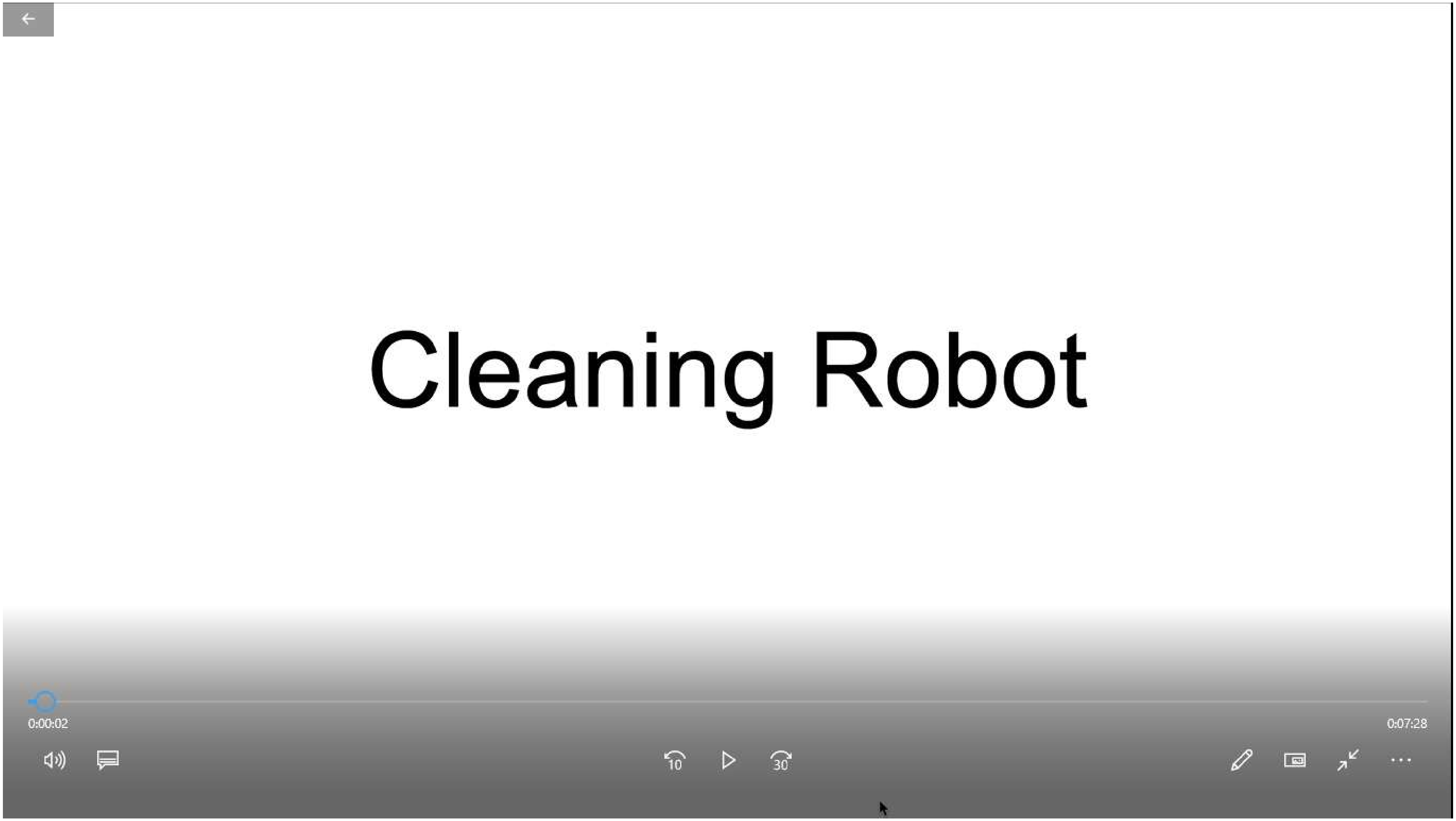
Cleaning Robot
0:00:02
0:07:28
10
30

Cleaning Robot

Two steps:

- Preprocess the room so we can answer: what's the largest square that fits, starting here?
- Binary search on robot size, testing connectivity and coverage.

Cleaning Robot

Calculate suffix lengths on rows, right to left:

		4	3	2	1
	5	4	3	2	1
6	5	4	3	2	1
6	5	4	3	2	1
5	4	3	2	1	
4	3	2	1		

Cleaning Robot

Calculate suffix lengths on columns, bottom to top:

		6	6	5	4
	5	5	5	4	3
4	4	4	4	3	2
3	3	3	3	2	1
2	2	2	2	1	
1	1	1	1		

Cleaning Robot

Calculate biggest square, reverse raster order.

Minimum of:

- Row suffix sum,
- Column suffix sum,
- 1+square to southeast

We call this the unit square's *label.*

		4	3	2	1
	4	3	3	2	1
4	3	3	2	2	1
3	3	2	2	1	1
2	2	2	1	1	
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Cleaning Robot

Binary search on possible size of robot.

Monotonic function, so binary search will work:

- If a bot of size s works, so do all smaller bots;
- If a bot larger than s fails to work, so do all larger bots.

Cleaning Robot

To test if size s works, we need to check:

- Connectedness: are all unit squares labeled s or larger connected?
- Coverage: do all unobstructed squares have a unit square labeled s or more within s units up and to the left?

Cleaning Robot

Connectedness test at size s is just breadth-first search on unit squares labeled s or greater.

4? No.

3? Yes.

		4	3	2	1
	4	3	3	2	1
4	3	3	2	2	1
3	3	2	2	1	1
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Cleaning Robot

Coverage test. Initialize a row vector v with zeros.

For each row, do the following:

- Extend from squares labeled s or bigger, else row-1.
- Check each unit square for coverage

		4	3	2	1
	4	3	3	2	1
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Cleaning Robot

Extension of row k at size s:

```
j = 0
for i in [0,w):
  if label(k, i) >= s:
    while j<i+s:
      v[j++] = s
  else:
    if j==i:
      v[j++]--
```

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Cleaning Robot

Start with [0 0 0 0 0 0]; s=3:

Row 1: [-1 -1 3 3 3 3]

Row 2: [-2 3 3 3 3 3]

Row 3: [3 3 3 3 3 2]

Row 4: [3 3 3 3 2 1]

Row 5: [2 2 2 2 1 0]

Row 6: [1 1 1 1 0 -1]

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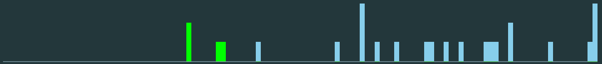
Cleaning Robot

Asymptotic complexity for board of size n x m is

$O(n\ m \log(\min(n,m)))$

D: Dimensional Debugging

Problem Author: Ragnar Groot Koerkamp



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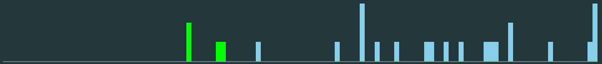

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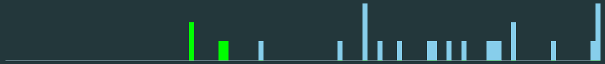

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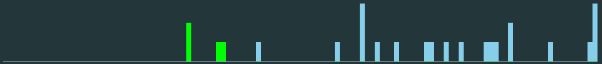

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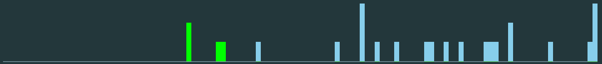

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Problem Author: Abe Wits

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- Verification:

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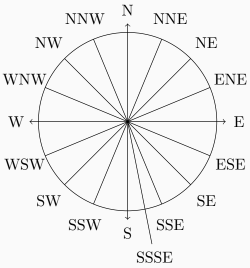
F: Failing Flagship

Problem Author: Ruben Brokkelkamp

- **Problem:** Compute the minimum angle in degrees between two wind directions.



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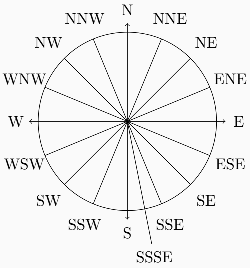

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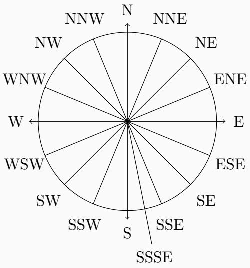

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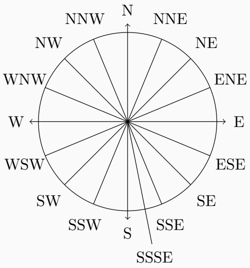

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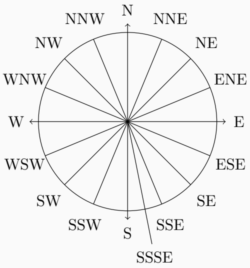
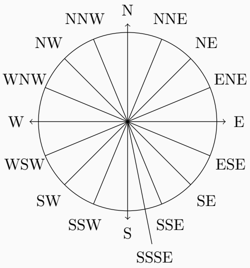
  - Return $\min(d_2 - d_1, 360 + d_1 - d_2)$.



F: Failing Flagship

Problem Author: Ruben Brokkelkamp

- **Problem:** Compute the minimum angle in degrees between two wind directions.
- **Solution:**
  - Convert both wind directions into degrees $d_1 \geq d_2$.
  - **Observation:** For every extra letter the degrees it represents halves: $45, 22.5, 11.25, 6.125, \ldots$.
  - Return $\min(d_2 - d_1, 360 + d_1 - d_2)$.
- **Remark:** Only 29 characters are needed for the required precision.



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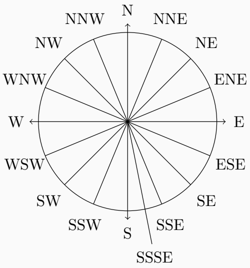

Statistics: 144 submissions, 39 accepted, 21 unknown

G: Grinding Gravel

Problem Author: Daan van Gent, Onno Berrevoets

- **Problem:** Given $n \leq 100$ integers, split them into groups of size $k \leq 8$ making as few cuts as possible.

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- Instead of 4-deep nested loops, we can use a dictionary of tuples.

Statistics: 5 submissions, 1 accepted, 1 unknown

H: Heavy Hauling

Problem Author: Ragnar Groot Koerkamp

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- **Observation:** The boxes will remain in their original order (they will never overtake each other).
- **Observation:** Groups of consecutive boxes map to an interval.
- The cost of moving a box from position p to a position x, can be modelled with a quadratic function $C_p(x) = (x - p)^2$.
  - Example: For one box with original position 3 moved to position x, $C_3(x) = (x - 3)^2 = x^2 - 6x + 9$.

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  - Example: For one box with original position 3 moved to position x, $C_3(x) = (x-3)^2 = x^2 - 6x + 9$.
- When adding the costs of two groups of boxes that overlap together, *translate* the cost function of the right group of boxes by the size of the left group.
  - Example: For two boxes with original position 3, moved such that the left-most box is at position x, the summed cost is $C_{3,3}(x) = C_3(x) + C_3(x+1) = (x-3)^2 + (x-2)^2 = 2x^2 - 10x + 13$.

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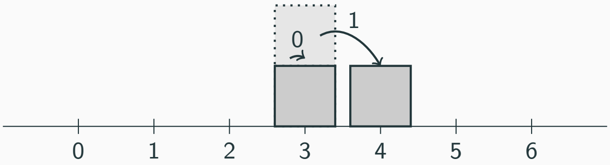
  What is the minimal cost to make all box positions distinct?
- The cost of a box at a position x, starting at position p, can be modelled with a quadratic function $C_p(x) = (x - p)^2$.
  - For two boxes that start at position 3, the summed cost is
    $C_{3,3}(x) = C_3(x) + C_3(x+1) = (x-3)^2 + (x-2)^2 = 2x^2 - 10x + 13$.

Proof by example:



$$C_{3,3}(3) = 2 \cdot 3^2 - 10 \cdot 3 + 13 = 1$$

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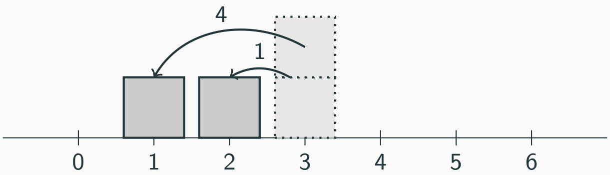

$$C_{3,3}(1) = 2 \cdot 1^2 - 10 \cdot 1 + 13 = 5$$

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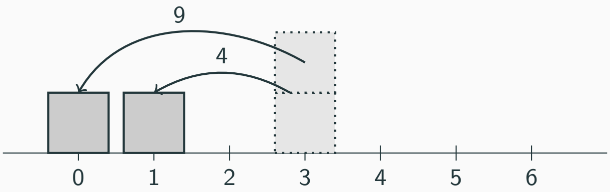

$$C_{3,3}(0) = 2 \cdot 0^2 - 10 \cdot 0 + 13 = 13$$

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- **Problem:** Given n boxes at given positions. Moving a box d positions costs d^2.
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- **Solution:** Add every box from left to right, maintaining the optimal placement by maintaining the cost function for every group of boxes.

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- For every group with cost $C(x) = ax^2 + bx + c$, the minimal cost is:

$$C\left(\left\lfloor \frac{-b}{2a} + \frac{1}{2} \right\rfloor\right)$$

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Statistics: 10 submissions, 0 accepted, 9 unknown

I: Ice Growth

Problem Author: Jorke de Vlas

- Given a weather report for n days and k people that have a required minimal ice thickness, how many days can each person skate?

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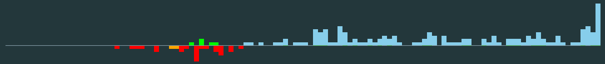
- Sort the days by ice thickness [$\mathcal{O}(n \log(n))$].
- For each person binary search how many days have the required thickness [$\mathcal{O}(k \log(n))$].
- Alternative: store the number of days for each ice-thickness $\leq 10^6$, and accumulate once [$\mathcal{O}(k + n)$].

J: Jabbing Jets

Problem Author: Abe Wits



- **Problem:** Given n concentric circles, find the maximal number of points on these circles such that the distance between any two points is at least e.

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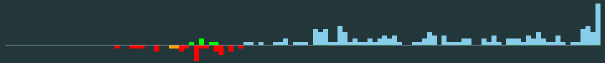

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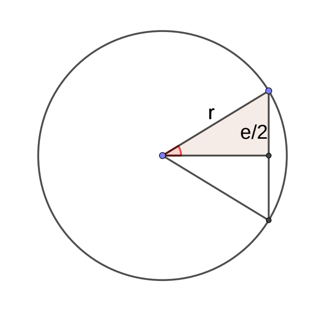

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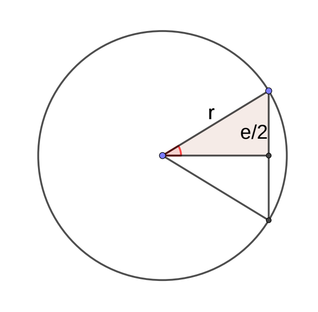

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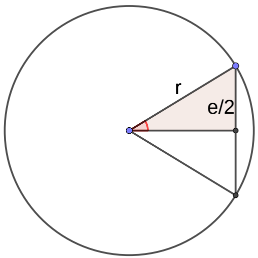

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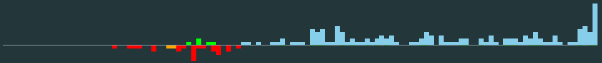

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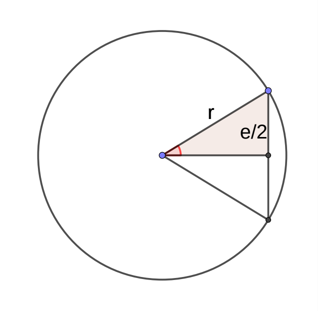

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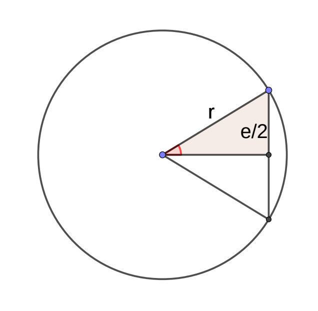

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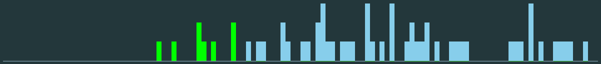
- Beware floating point issues!
  - Add $0.5 \cdot 10^{-6}$ to every radius.

Statistics: 168 submissions, 5 accepted, 137 unknown

K: Knitting Patterns

Problem Author: Maarten Sijm



- **Problem:** Given a knitting pattern and amount of wool it costs for letting the wool strand unused, using the wool in a stitch, and for starting or ending the use of wool. Compute the minimal amount of wool required for every colour of wool.

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Problem Author: Maarten Sijm

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- **Observation:** Between two times a colour of wool is used, you either leave the strand through the back unused for the entire gap, or you immediately end the use at the beginning of the gap and start using it at the end.

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- **Observation:** Between two times a colour of wool is used, you either leave the strand through the back unused for the entire gap, or you immediately end the use at the beginning of the gap and start using it at the end.
- **Solution:** For every colour, iterate through the knitting pattern and remember the index of the last time the colour occurred. If you encounter the colour again, the marginal cost is the minimum between leaving the strand unused the whole time since the last time, and the sum of the costs for ending and starting. Runs in $\mathcal{O}(|w| \cdot n)$.

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- **Remark:** Can be done in $\mathcal{O}(n)$ by doing some bookkeeping and storing for every colour the last time it occurred.

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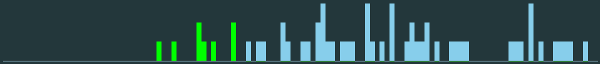

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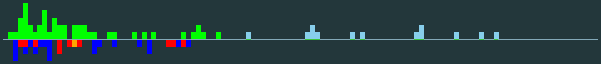
Statistics: 58 submissions, 8 accepted, 50 unknown

L: Lots of Liquid

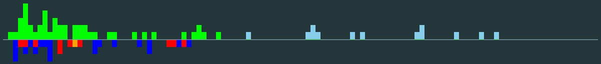
Problem Author: Maarten Sijm



- **Problem:** Find the length of the side of a cube that contains all liquid.

L: Lots of Liquid

Problem Author: Maarten Sijm

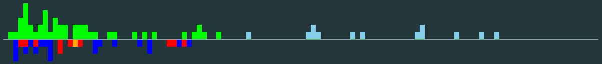


- **Problem:** Find the length of the side of a cube that contains all liquid.
- **Solution:** Calculate the value of following expression:

$$\sqrt[3]{\sum_{c} c^3}$$

L: Lots of Liquid

Problem Author: Maarten Sijm



- **Problem:** Find the length of the side of a cube that contains all liquid.
- **Solution:** Calculate the value of following expression:

$$\sqrt[3]{\sum_{c} c^3}$$

- **Pitfall:** Make sure to use `double`, not `float`

L: Lots of Liquid

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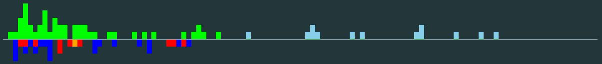

- **Problem:** Find the length of the side of a cube that contains all liquid.
- **Solution:** Calculate the value of following expression:

$$\sqrt[3]{\sum_c c^3}$$

- **Pitfall:** Make sure to use `double`, not `float`

Statistics: 97 submissions, 46 accepted, 13 unknown