Scenario Week 4:
Art Gallery Competition

Organisers' Report

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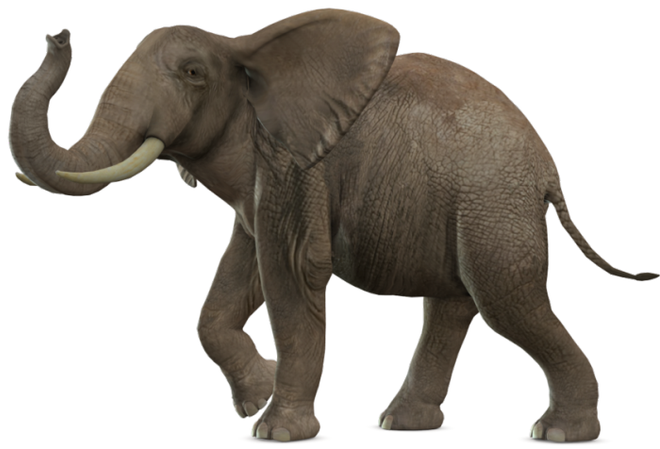
26 February 2016

The Week

- **94** participants
- **24** teams
- **1892** submissions for **Part 1**
- **468** submissions for **Part 2**



- **One** subtle server bug discovered (non-lethal)
  - floating-point arithmetic is a nasty thing…

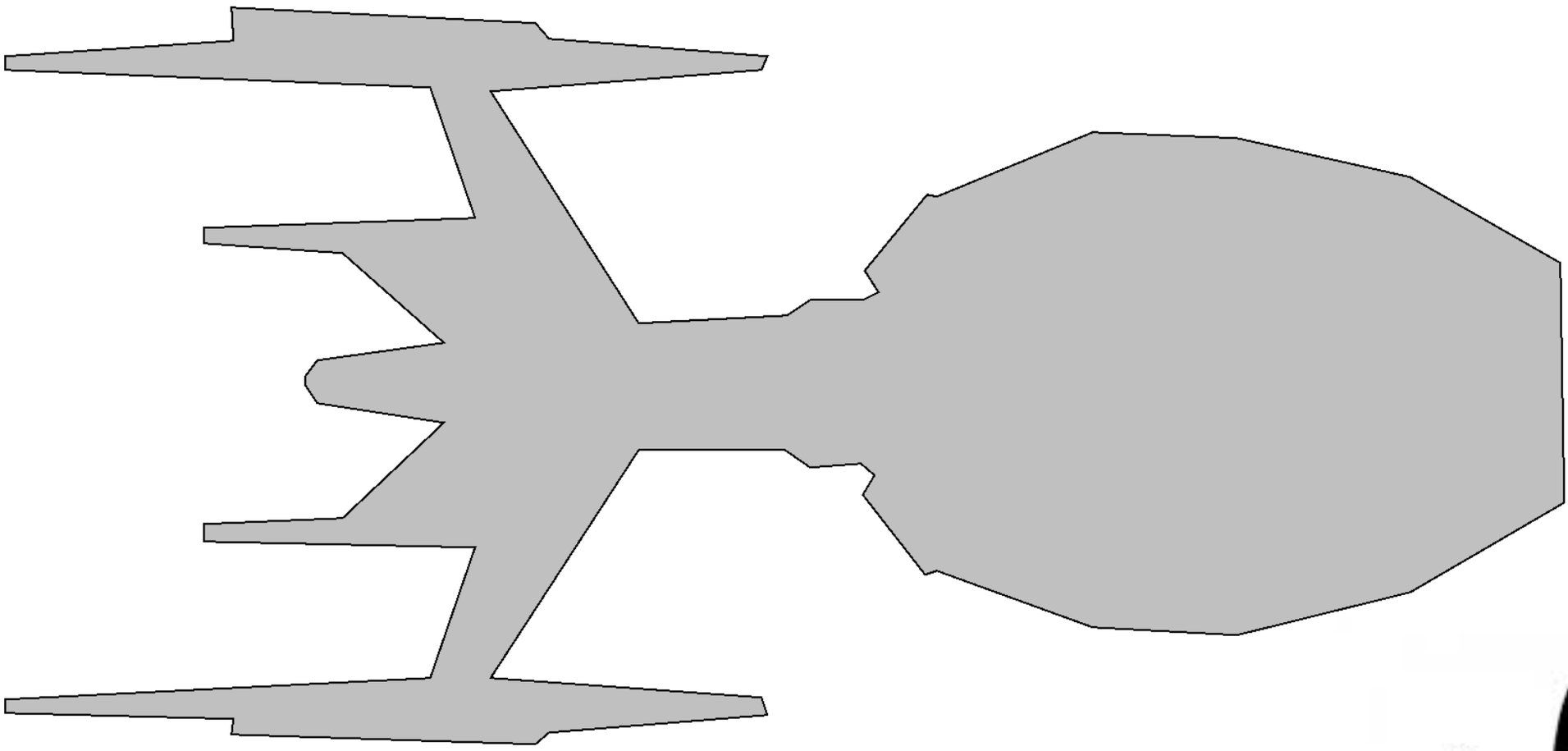
The Problem and its solutions

- Original formulation is due to Chvátal (1975)
- Textbook algorithm by Fisk (1978)
  - Triangulation and 3-colouring, delivers a decent $\lfloor n/3 \rfloor$ solution
- Better solutions exist for specific polygons
  - L-partitioning for rectilinear polygons: $\lfloor n/4 \rfloor$ solution
  - Detecting convex suqpolygons — just one guard required;
  - Even better: detecting "star" sub-polygons;
- A good survey: *"Art Gallery Theorems and Algorithms"* by O'Rourke

Initial setup

- **Part 1**: *30* polygons for finding the best guards sets
  - **1–5** are trivial — to test intuition (small size);
  - **8–13** are rectilinear (74–334 vertices);
  - **15–17** composed from triangles (42-360 vertices);
  - **18–26** are "quasi-convex" with large convex regions;
  - **27–30** composed from various random shapes.
- **Part 2**: *20* polygons/guards to find refutations
  - About **2/3** problems had one node non-covered (easy to find);
  - **6** or **7** problems required a proper algorithms (or *a lot* of patience).

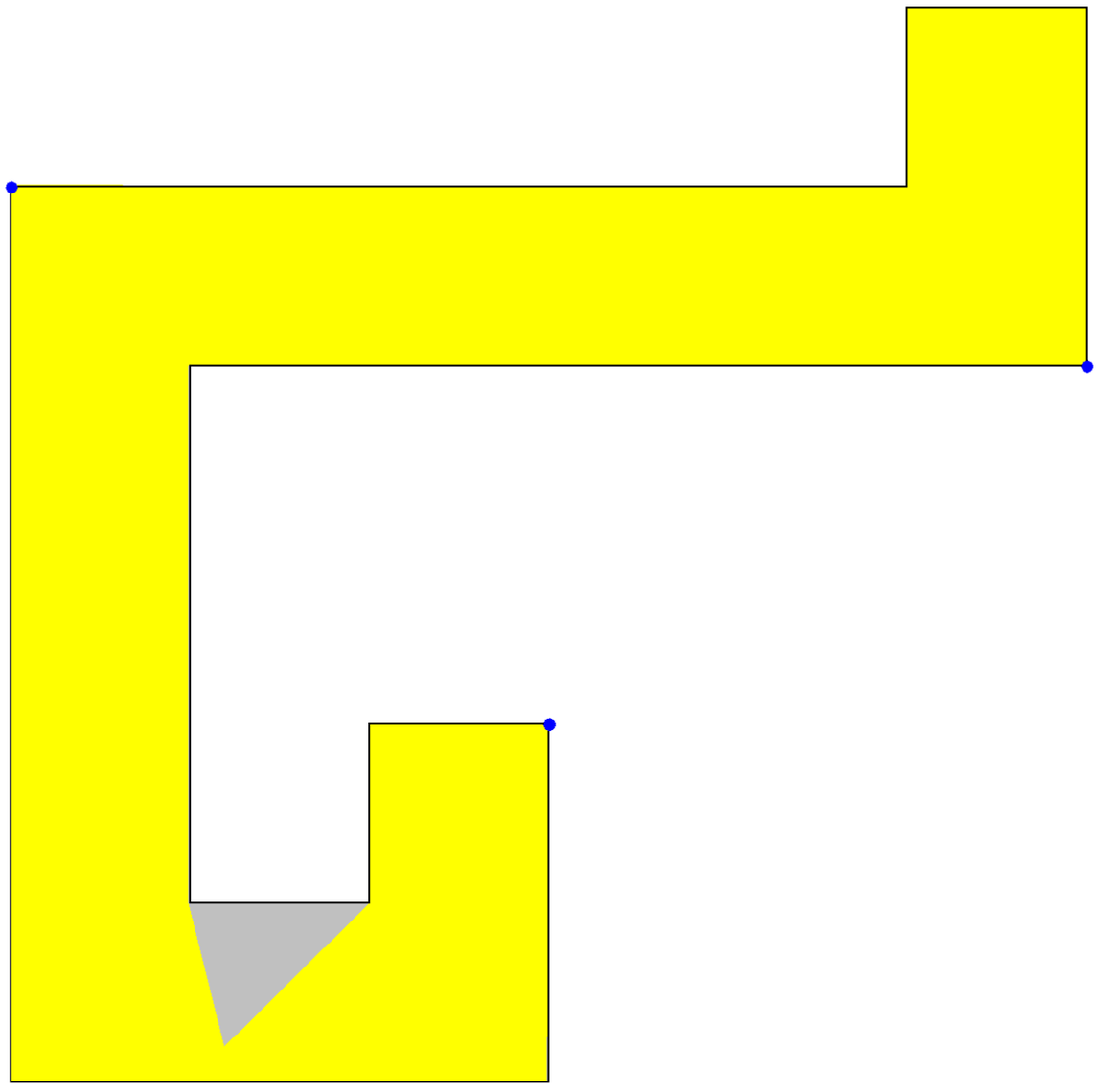
Part 1, polygon 14



Checking your solutions

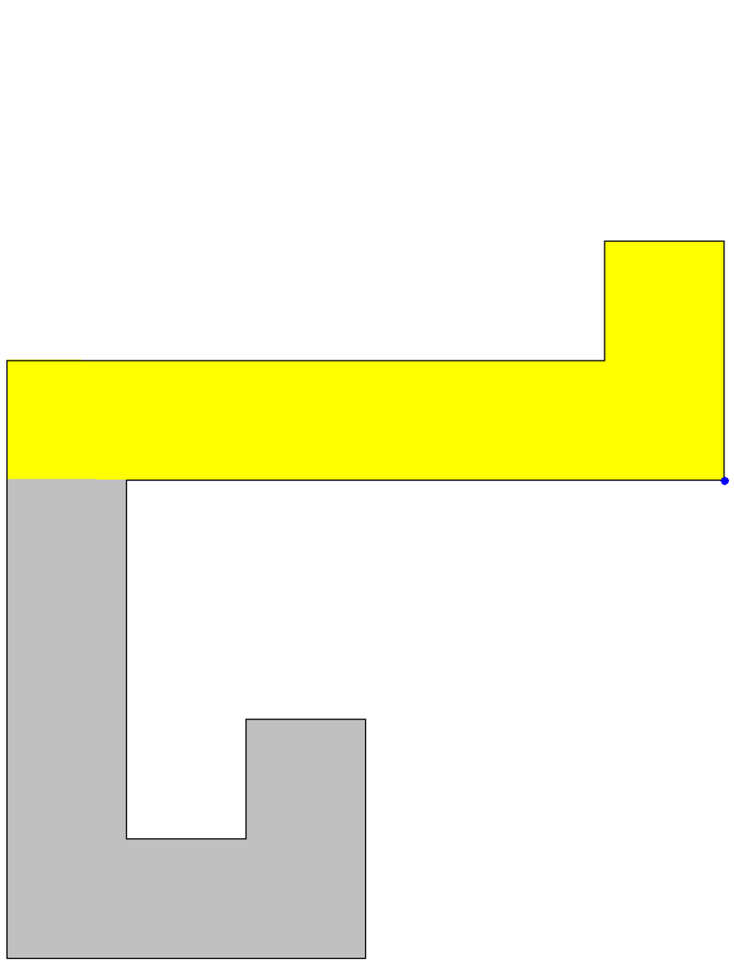
- Server is written in ***Scala*** via ***Spray*** framework on servlets (**1500 LOC)**;
  - Run during the week on a single Linux machine with 4 GB RAM;
  - Each team's submissions are processed by a separate ***actor*** (non-blocking);
- All geometric processing is implemented in ***Scala*** from scratch, no third-party libraries (**1800 LOC**, including tests);
- ~150 unit tests + several randomised testing procedures (*bazillions* of randomly-generated polygons);
  - still missed one floating-point bug :(
- Guards checking procedure is a slightly modified version of *Joe-Simpson algorithm* for visibility polygons (1985).

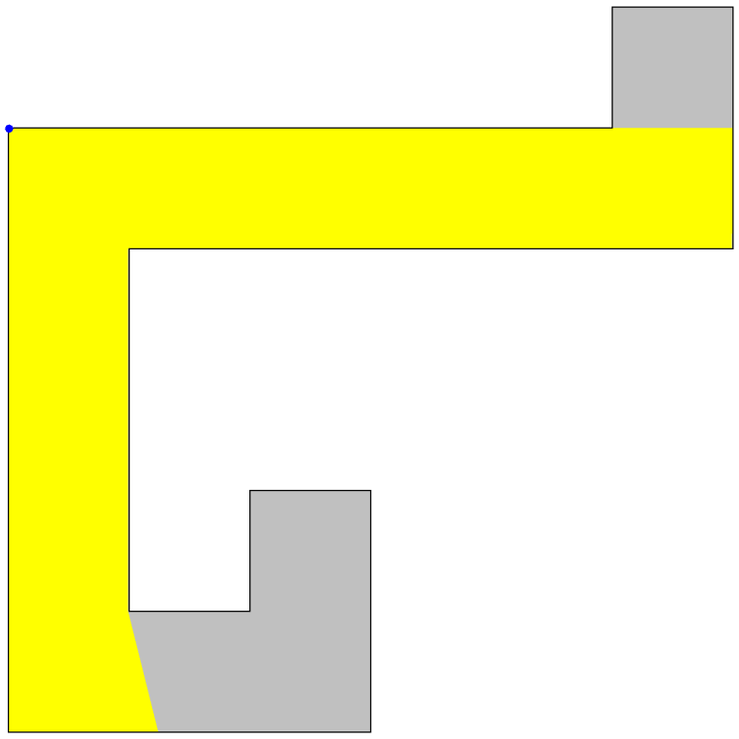
Checking your solutions

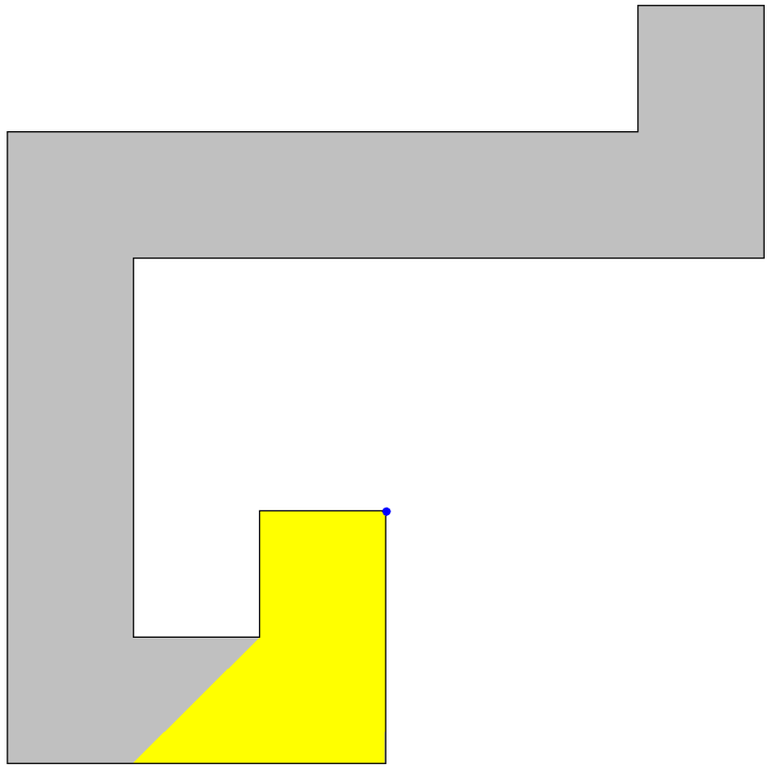


Detecting grey areas *precisely*

Step 1: compute *all* individual visibility areas
via Joe-Simpson algorithm.

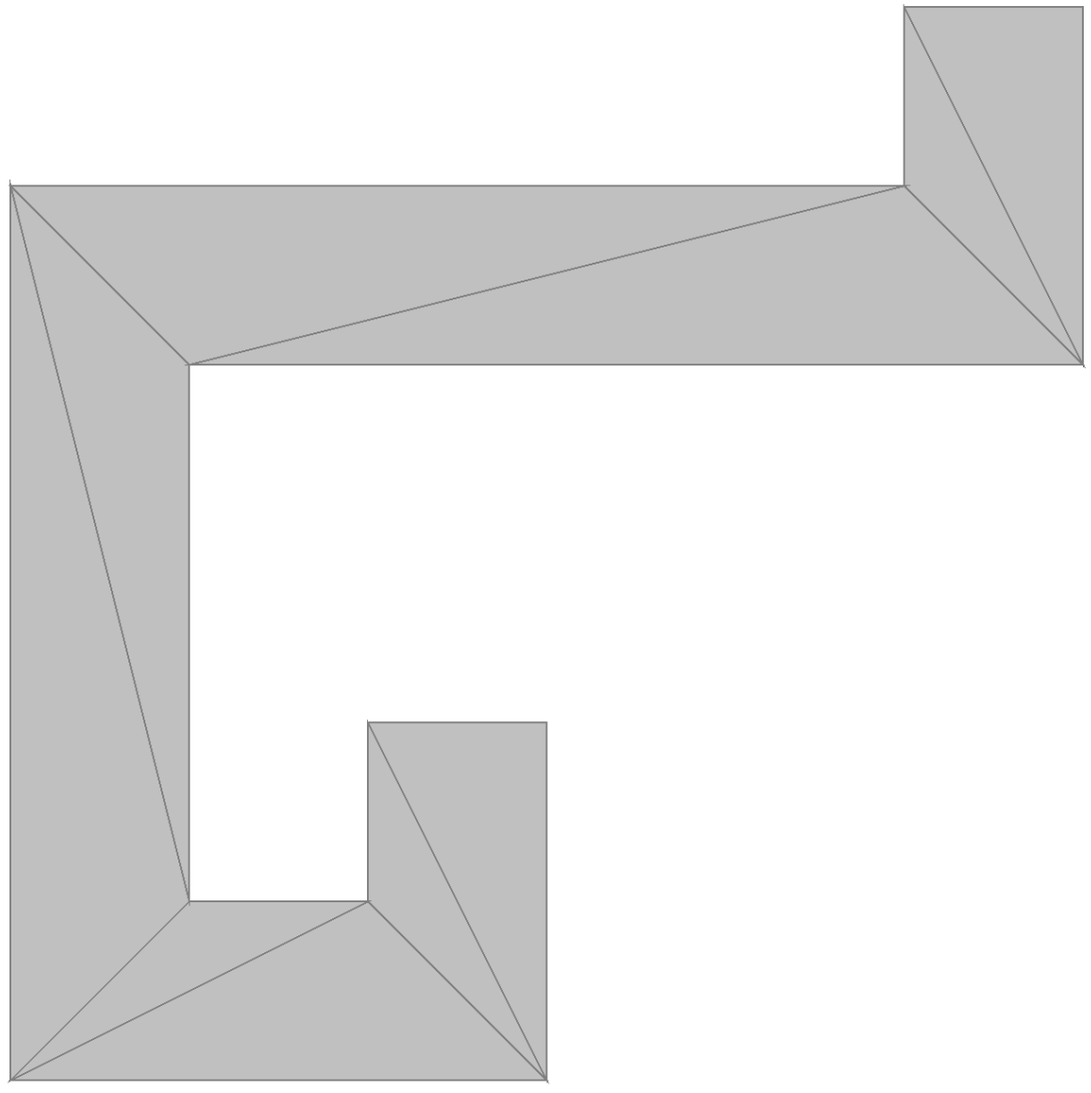






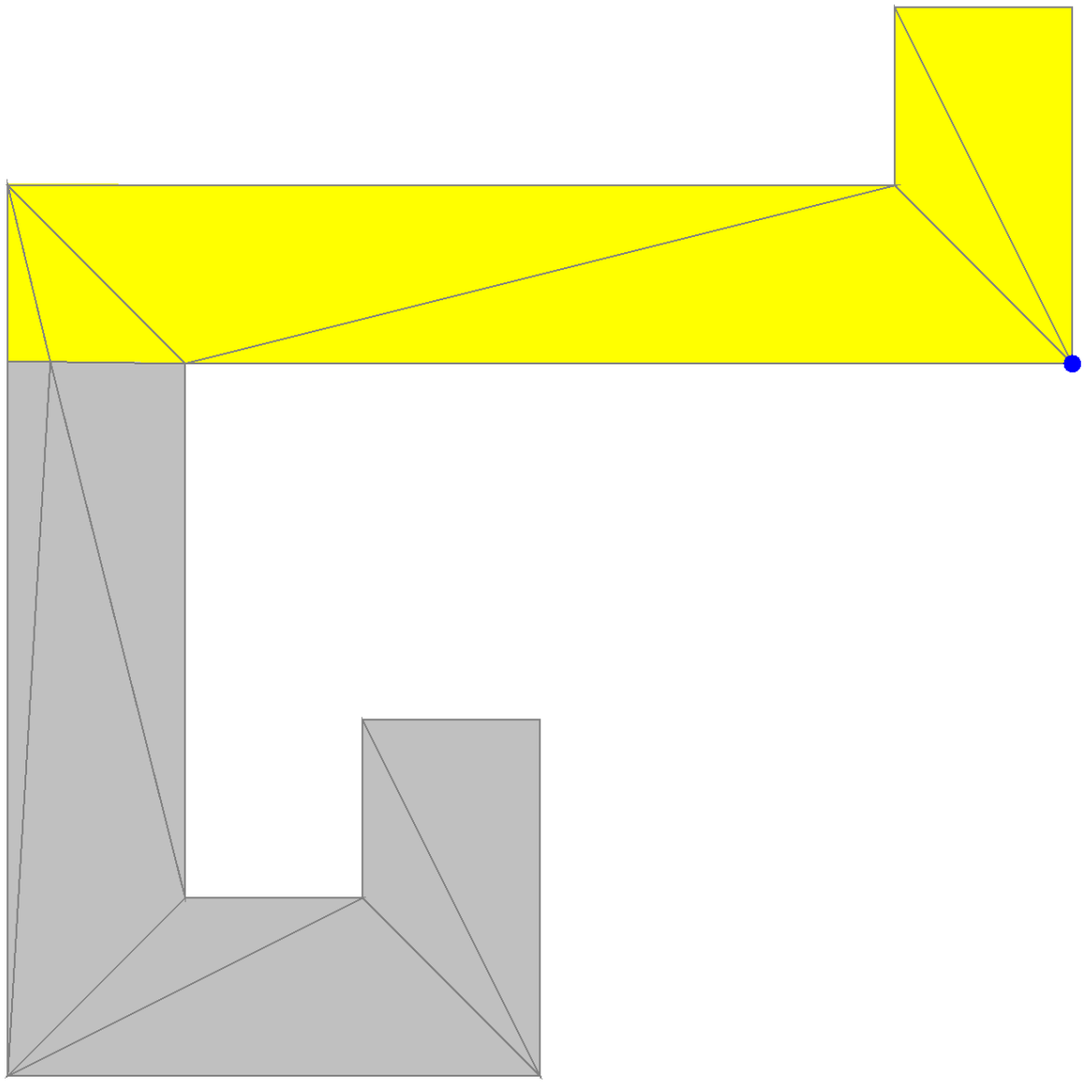
Detecting grey areas *precisely*

Step 2: *triangulate the* initial polygon



Detecting grey areas *precisely*

Step 3*: add visibility areas one by one, compute intersections with present triangles and Δ-partition again



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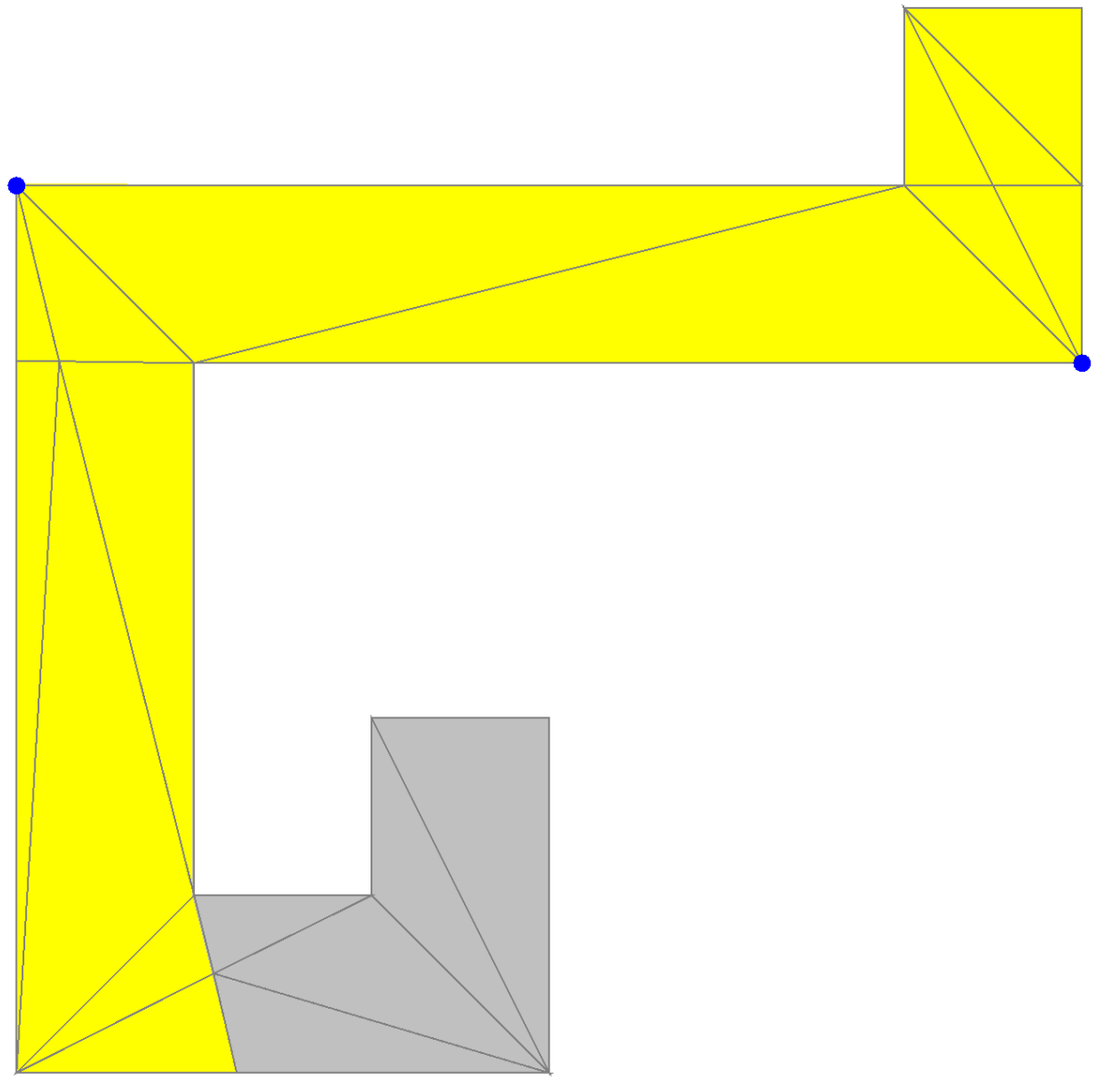

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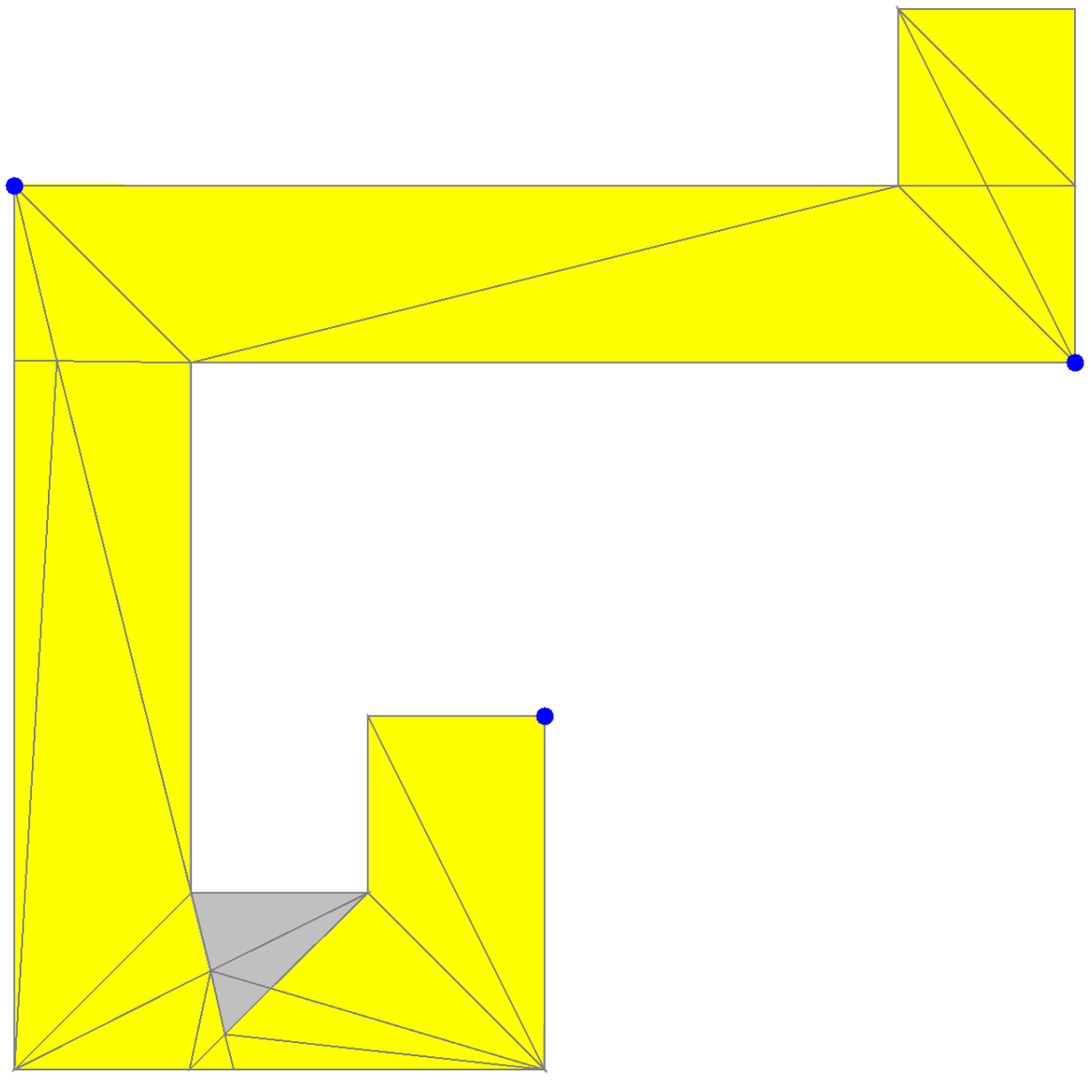
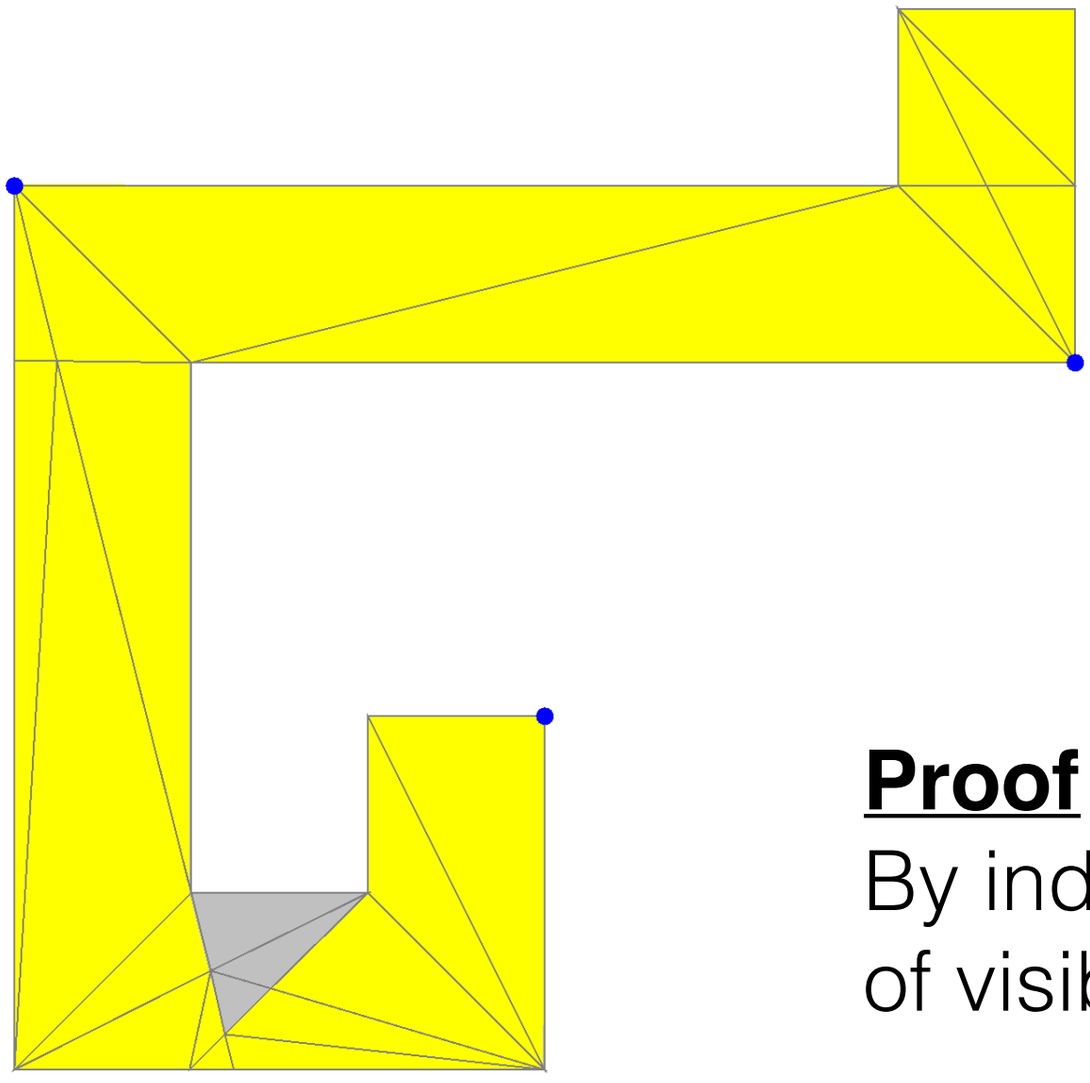


Detecting grey areas *precisely*

Loop Invariant: at the end of each iteration,
each triangle is either *fully visible* or is *fully grey* (invisible).

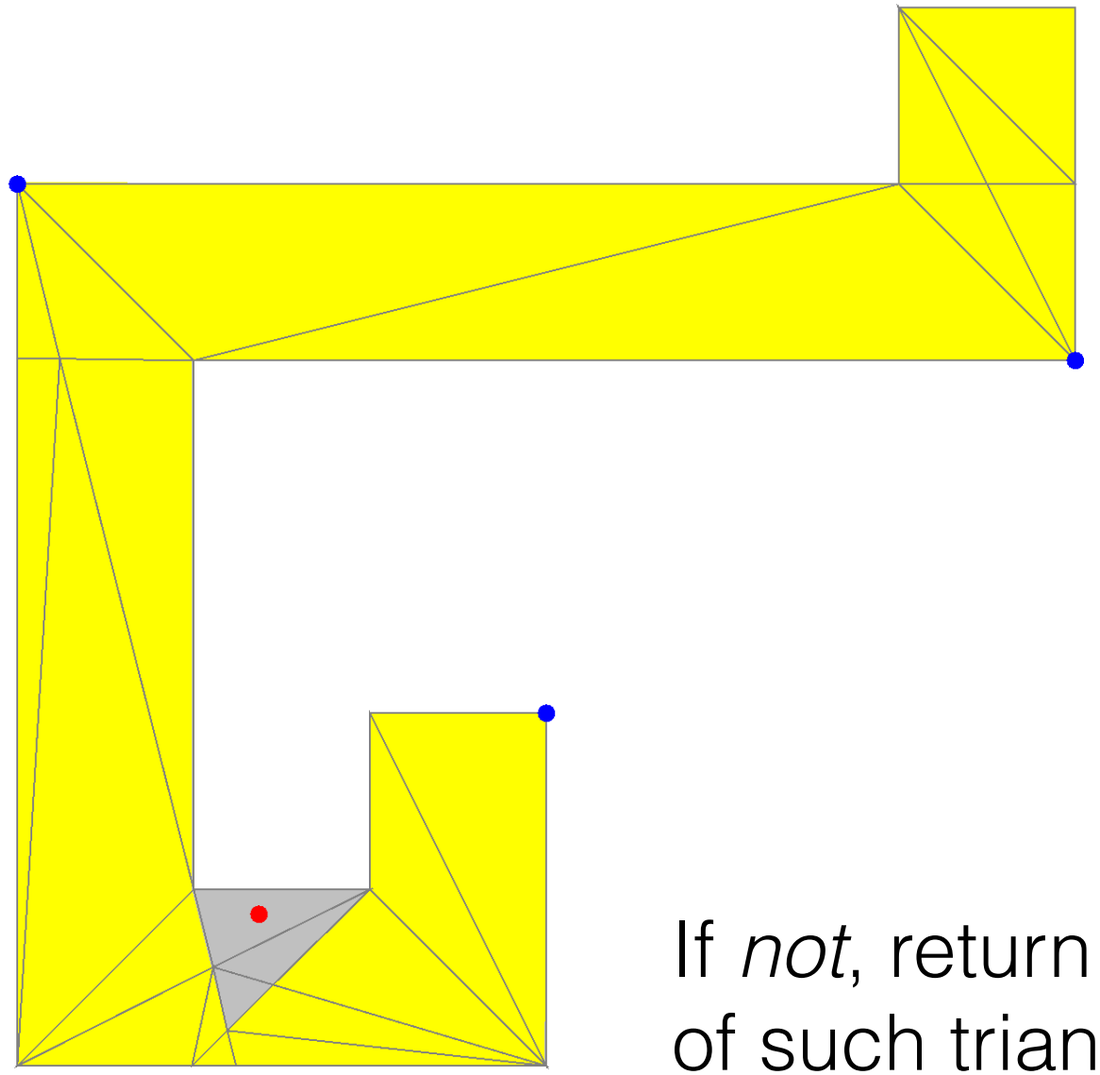


Proof

By induction on edges of visibility areas.

Detecting grey areas *precisely*

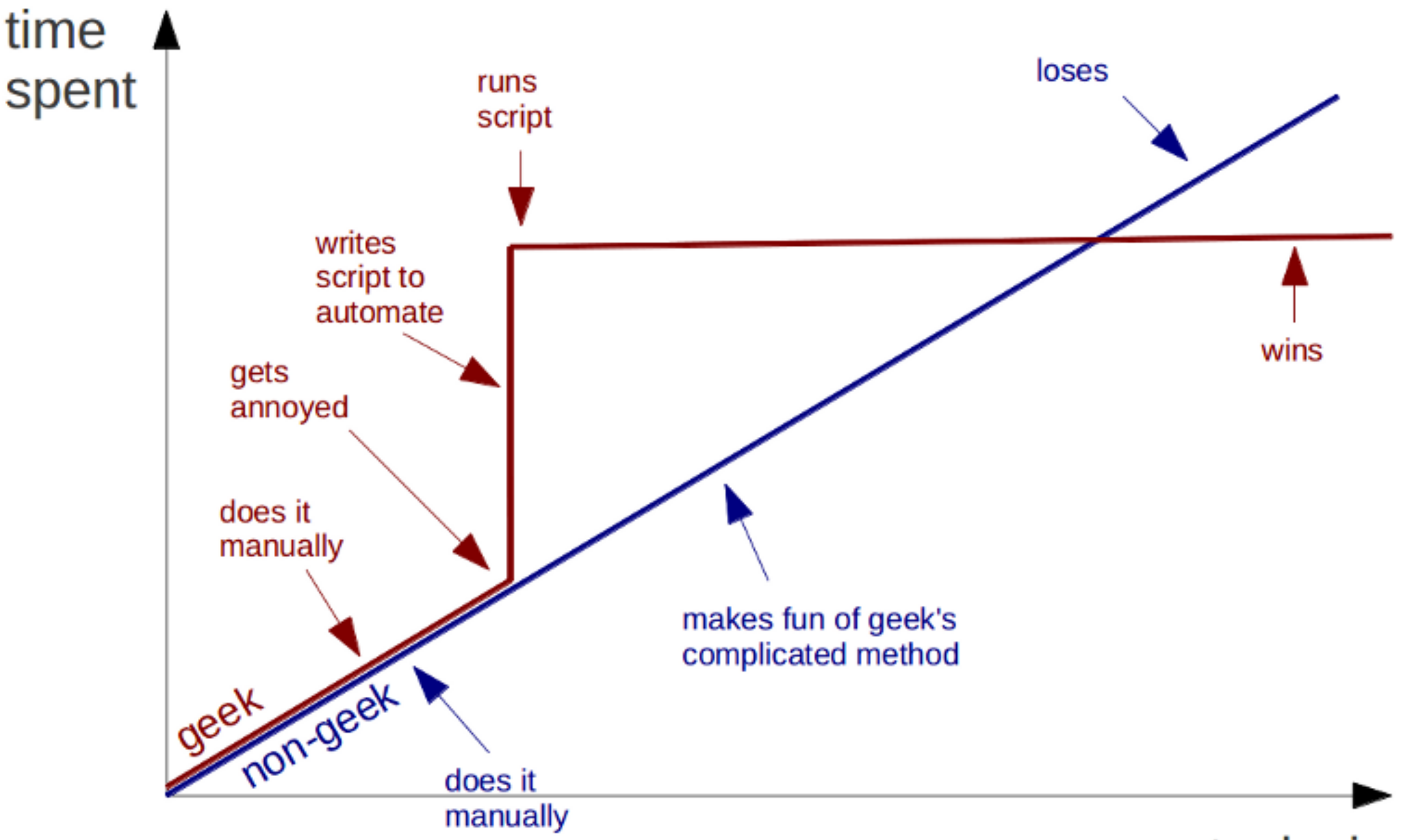
Step 4: iterate through *all* the triangles of the partition and check if a centre of each *belongs* to *some* visibility area.



If *not*, return the centre of such triangle as a refutation.

Behind the Scenes

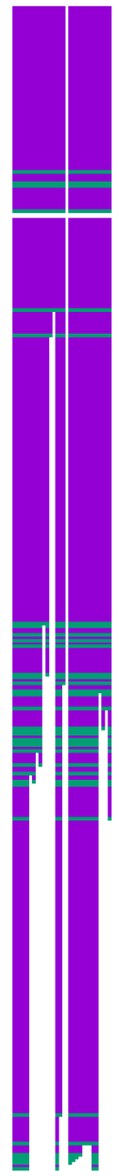
Geeks and repetitive tasks



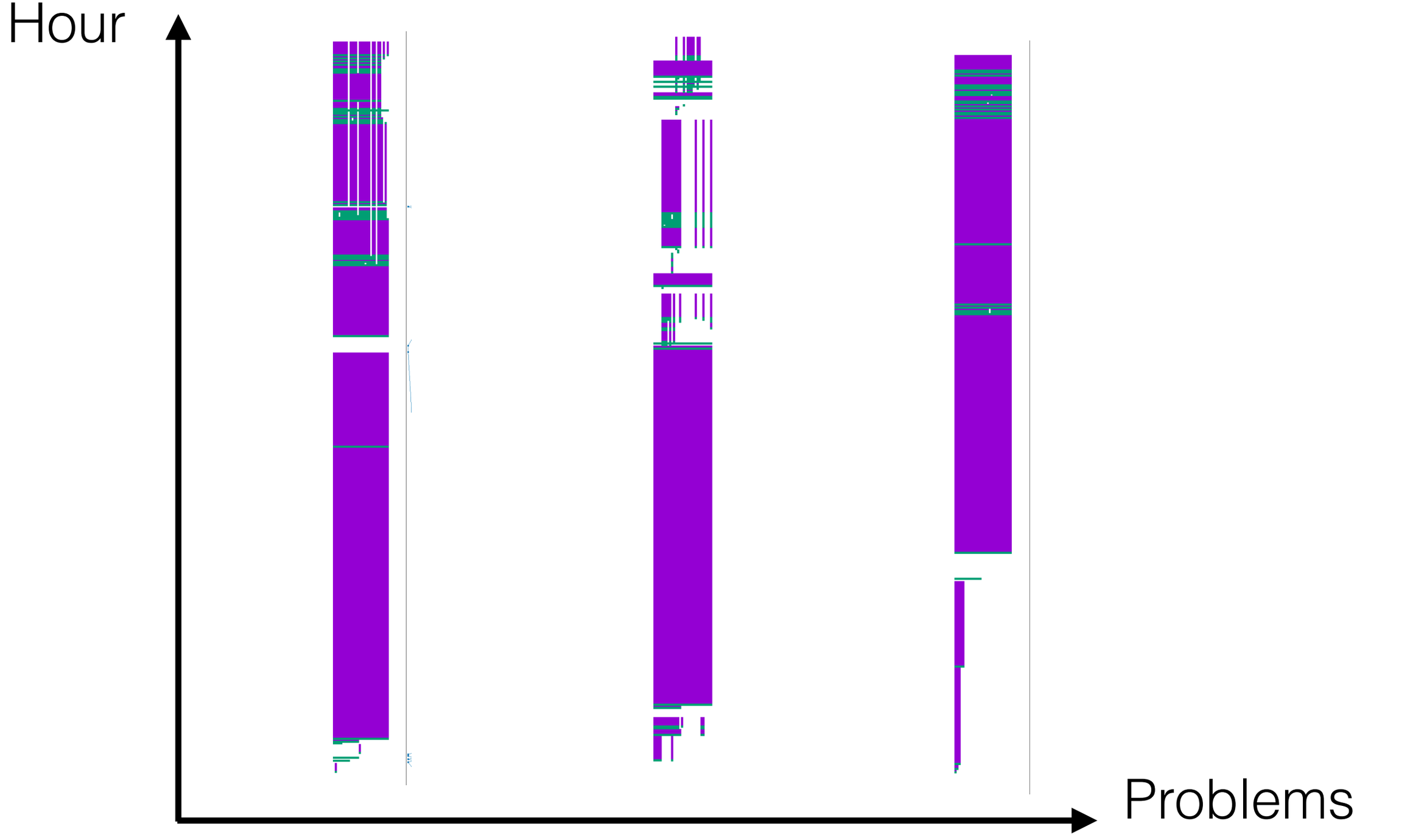
Kareem's Demo

Analysing submission patterns

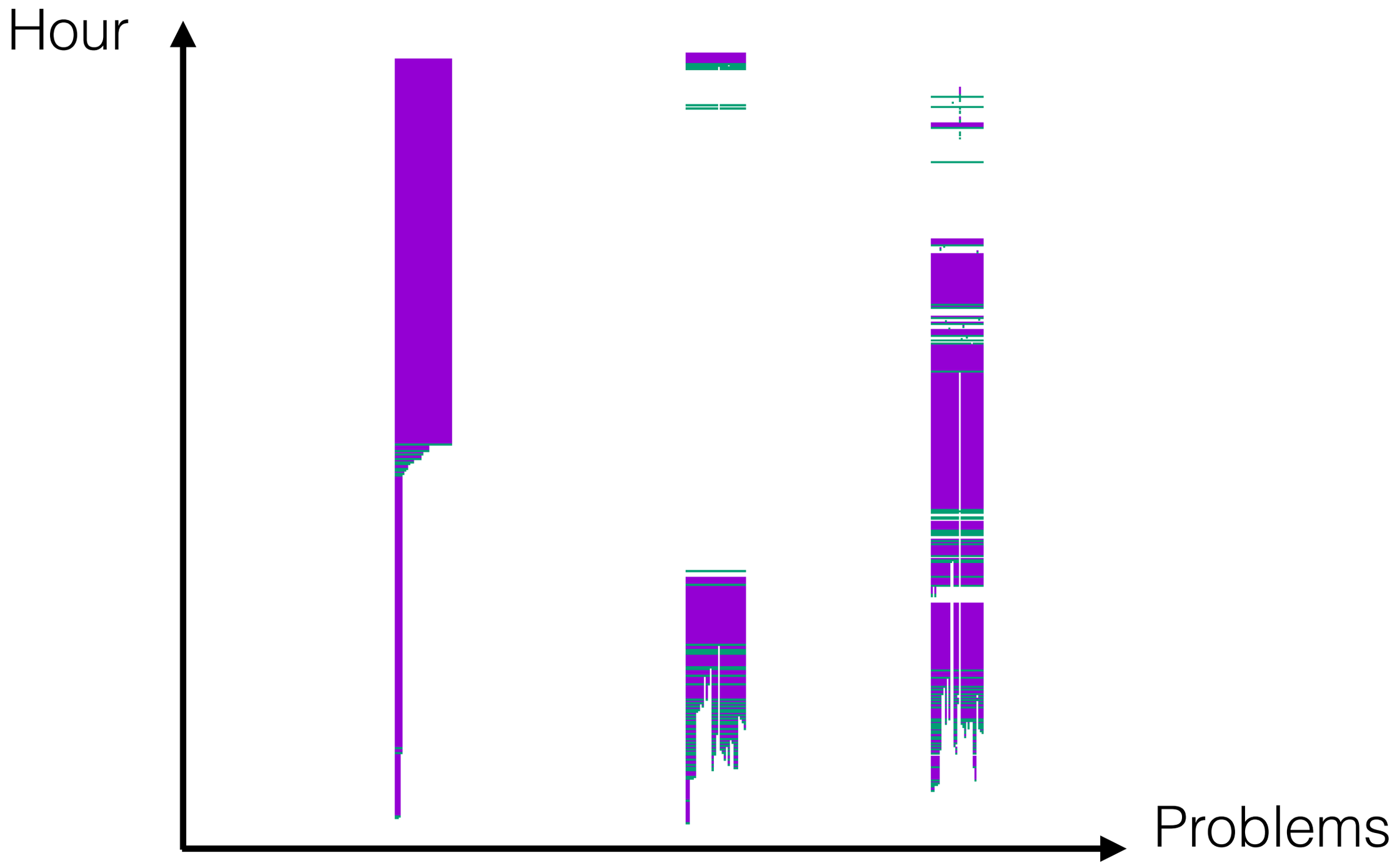
- Taking data about **Part I** submissions
- Recording time of successful submissions (green)
- Propagated submissions (purple)
- No submission (blank)



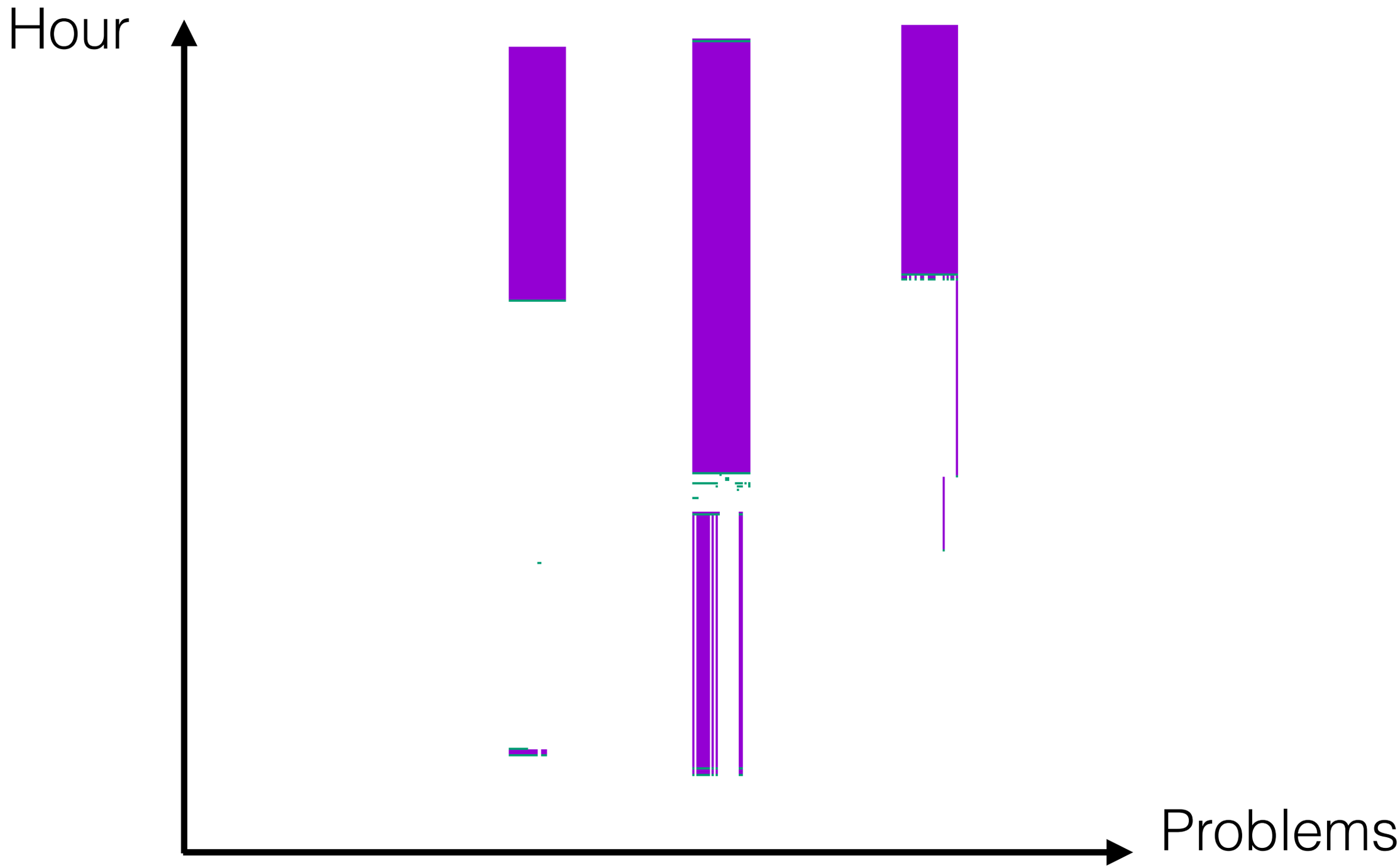
“Experimentators”



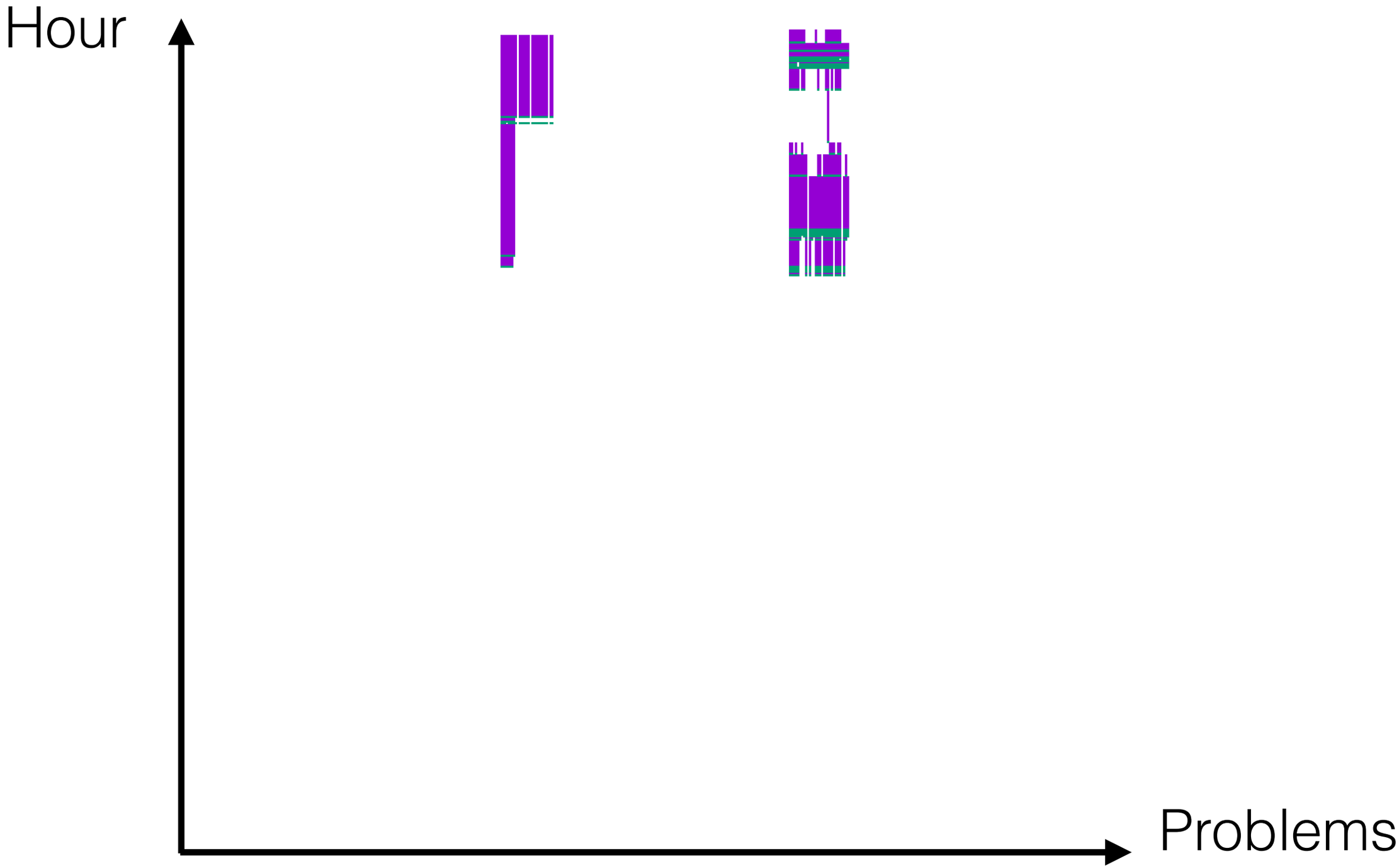
“Hard workers”



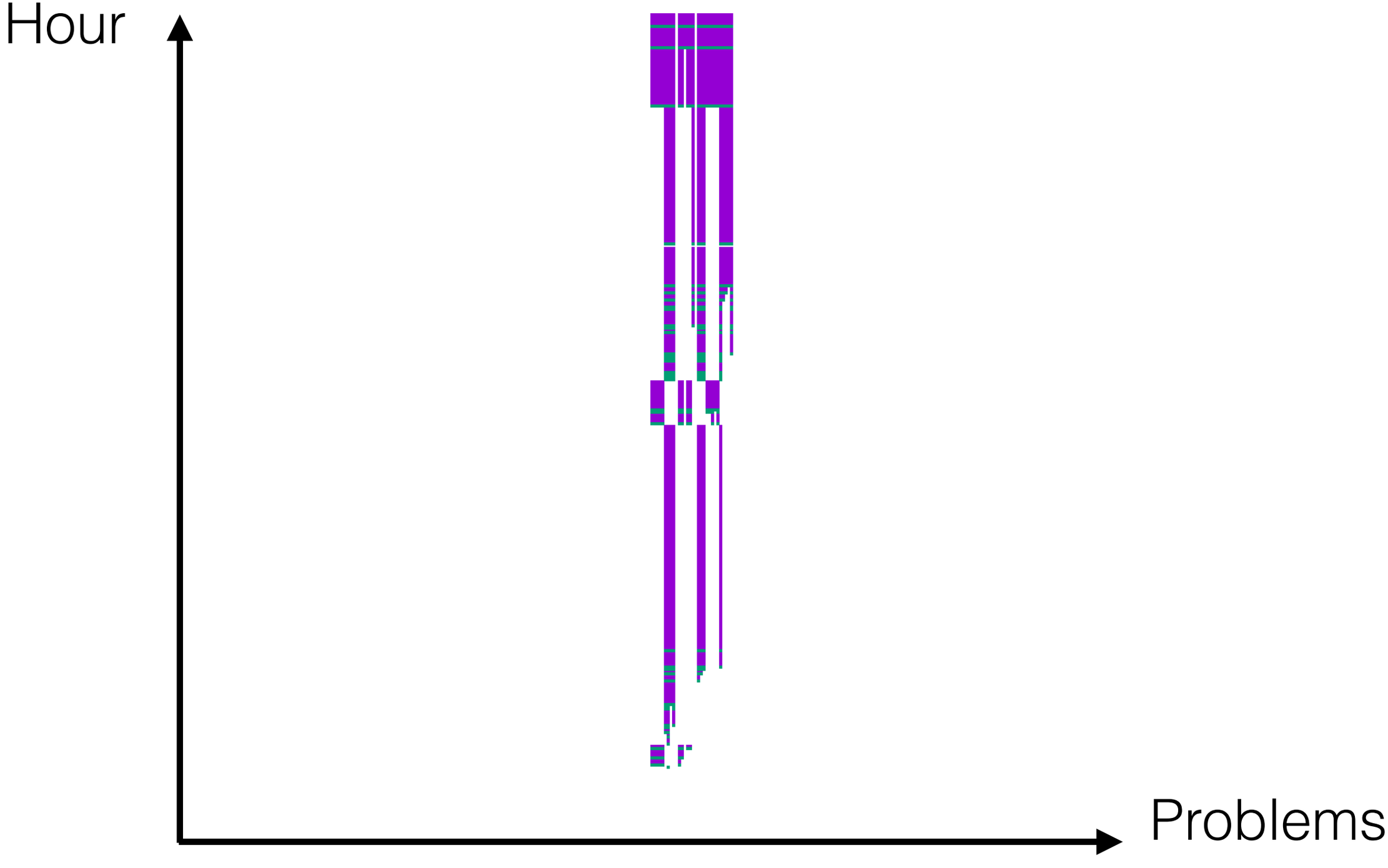
“Real geeks”



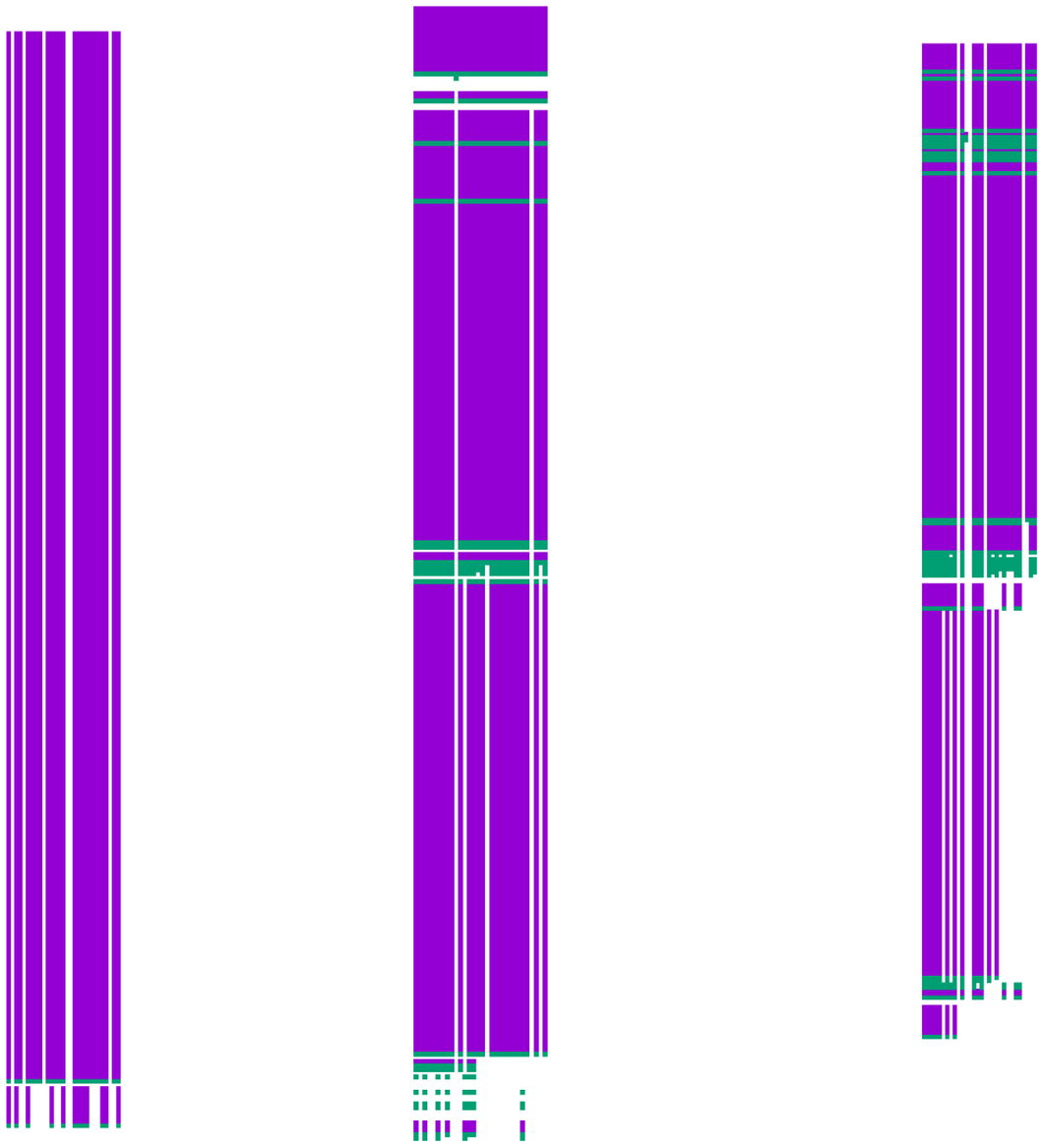
“Late bloomers”



“Parallel computers”



Part 1 problems: Toughies



- polygon 10 (338 vertices)
- polygon 12 (288 vertices)
- polygon 13 (334 vertices)
- polygon 17 (360 vertices)

Shameless Advertisement

MSc Programme by PPLV:
Logic, Semantics and Verification of Programs.

- Analysis of the correctness of *large* systems;
- *Concurrent* and *distributed* programming;
- Formal methods and theorem *proving* (yay!);
- Dark magic of *abstract algebra* and *category theory* to make better software (without actual bugs);
- Starts next year, apply in 2017!

`http://pplv.cs.ucl.ac.uk`

The Competition

Ranking solutions

- Solutions were **not** ranked based on the total sum of guards;
- Instead, (1) for *each* polygon, teams were *grouped* according to the number of guards, smaller is better (e.g., *5 groups* of solutions)
  - Teams that didn't solve a polygon were all put into the "last" group for this polygon (e.g., *group 6* for the previous example)
- (2) Next, per-polygon rankings were aggregated for each team;
- (3) *Overall* ranking is based on a *sum* of per-polygon rankings;
  - Team B that did worse than team A for some problems might still be ranked above A
- Teams that solved all 30 problems were ranked first amongst each other.

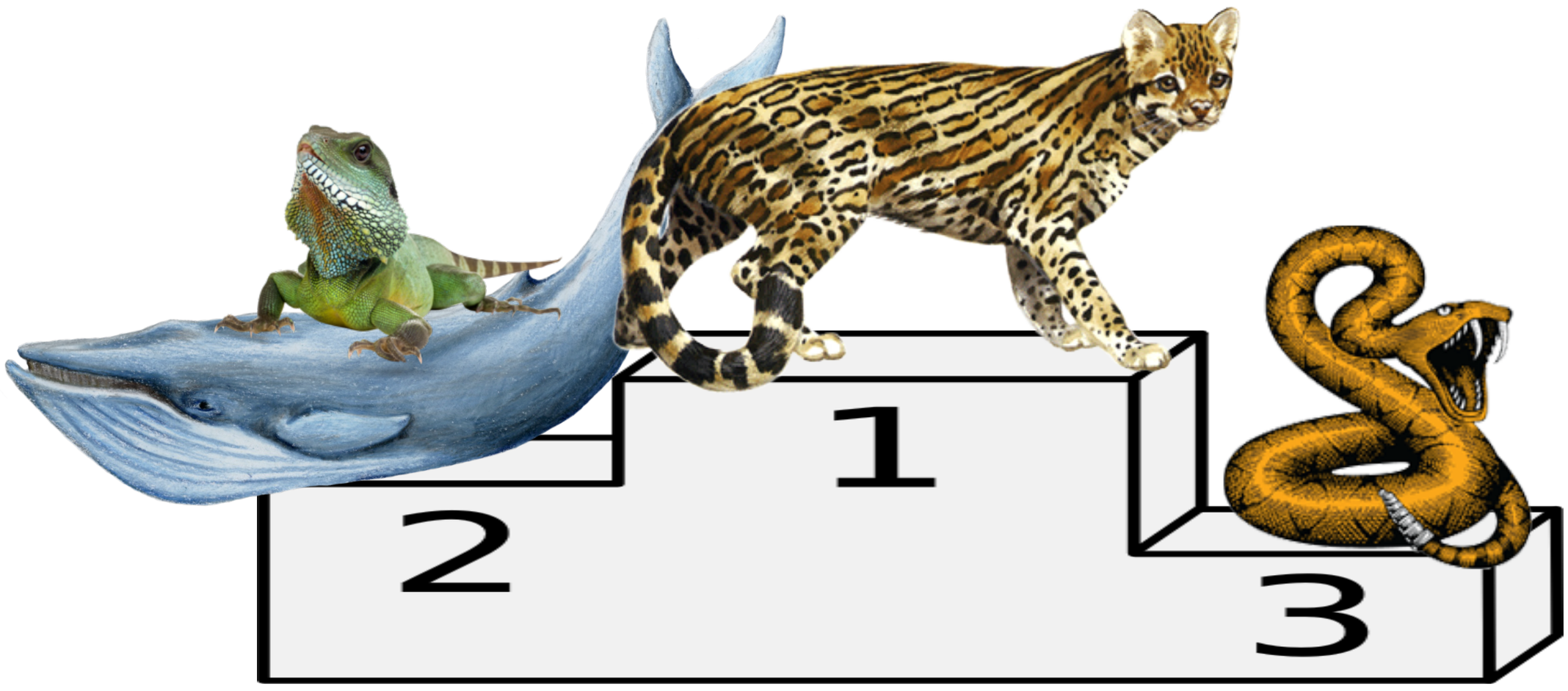
Expectations and Surprises

- For the first three days results in in **Part 1** were consistent with the triangulation-based algorithm.
- Last-minute results look *way* better than the baseline
- Several top-ranked solutions are *astonishingly* good
  - Although we suspect *some* of them to be *hand-crafted.*
- **Part 2** didn't seem to pose too much challenge after all.

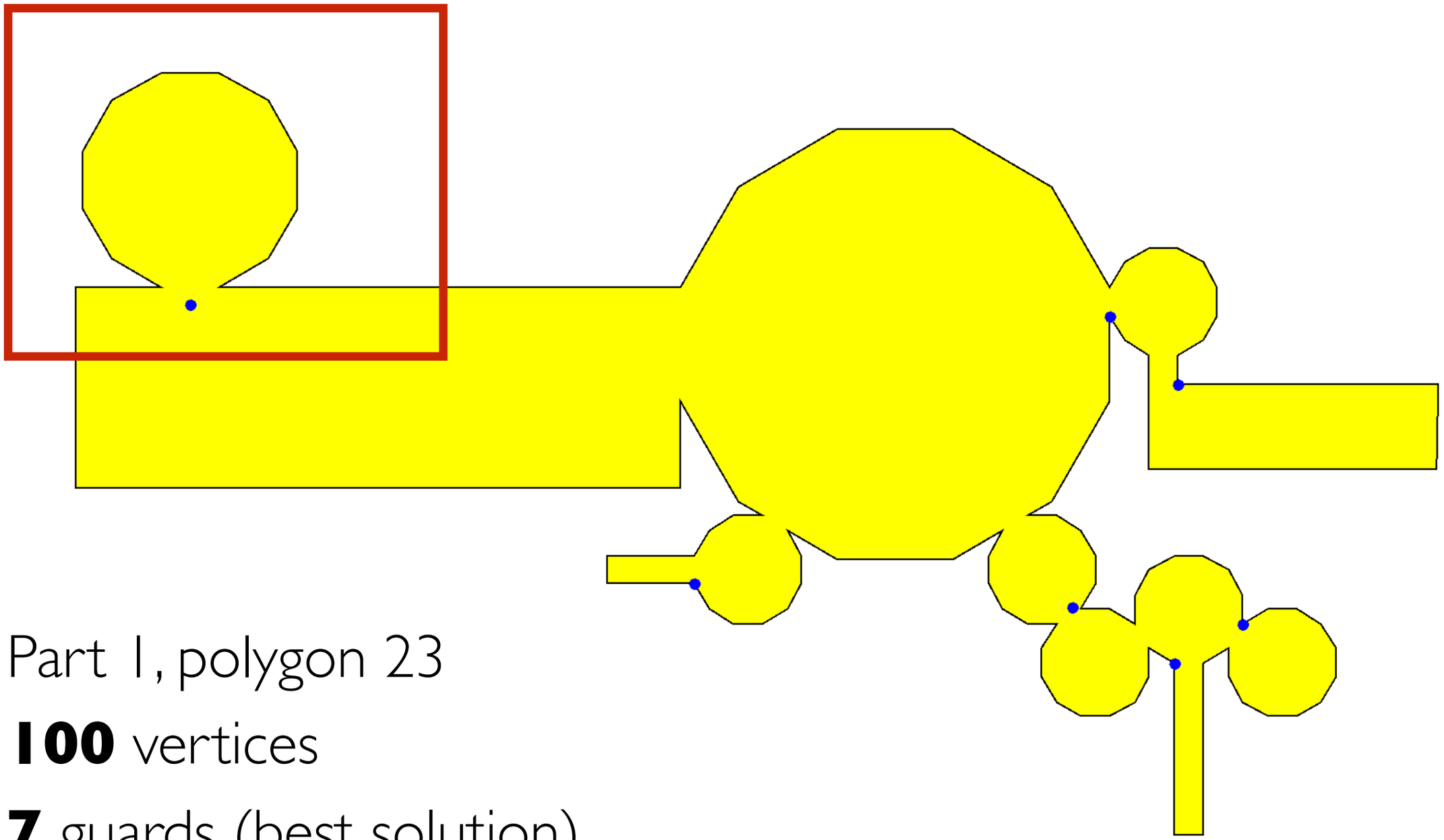
Finish line

Last submitted	Rank	Done	1 (3)	2 (4)	3 (6)	4 (8)	5 (12)	6 (180)	7 (92)	8 (244)	9 (74)	10 (338)	11 (104)	12 (288)	13 (334)	14 (58)
15:27:23, 24 Feb 2016	1	30	1	1	2	1	2	23	11	33	10	47	14	41	43	5
13:10:28, 26 Feb 2016	2	30	1	1	2	1	2	23	11	33	10	48	14	41	43	5
13:50:36, 26 Feb 2016	2	30	1	1	2	1	2	23	11	33	10	48	14	41	43	5
13:51:13, 26 Feb 2016	3	30	1	1	2	1	2	23	11	33	10	48	14	41	43	5
13:49:19, 26 Feb 2016	4	30	1	1	2	1	2	23	11	33	10	48	14	41	43	5
13:54:27, 26 Feb 2016	5	30	1	1	2	1	2	23	11	33	10	48	14	41	43	5
13:46:45, 26 Feb 2016	6	30	1	1	2	1	2	25	11	34	10	47	14	41	47	5
13:45:49, 26 Feb 2016	6	30	1	1	2	1	2	24	11	34	10	51	14	43	47	5
13:58:56, 26 Feb 2016	7	30	1	1	2	1	2	23	11	33	10	49	14	41	50	5
13:47:00, 26 Feb 2016	7	30	1	1	2	1	2	23	11	33	10	49	14	41	46	5
13:28:53, 26 Feb 2016	8	30	1	1	2	1	2	23	11	33	10	111	14	93	43	5

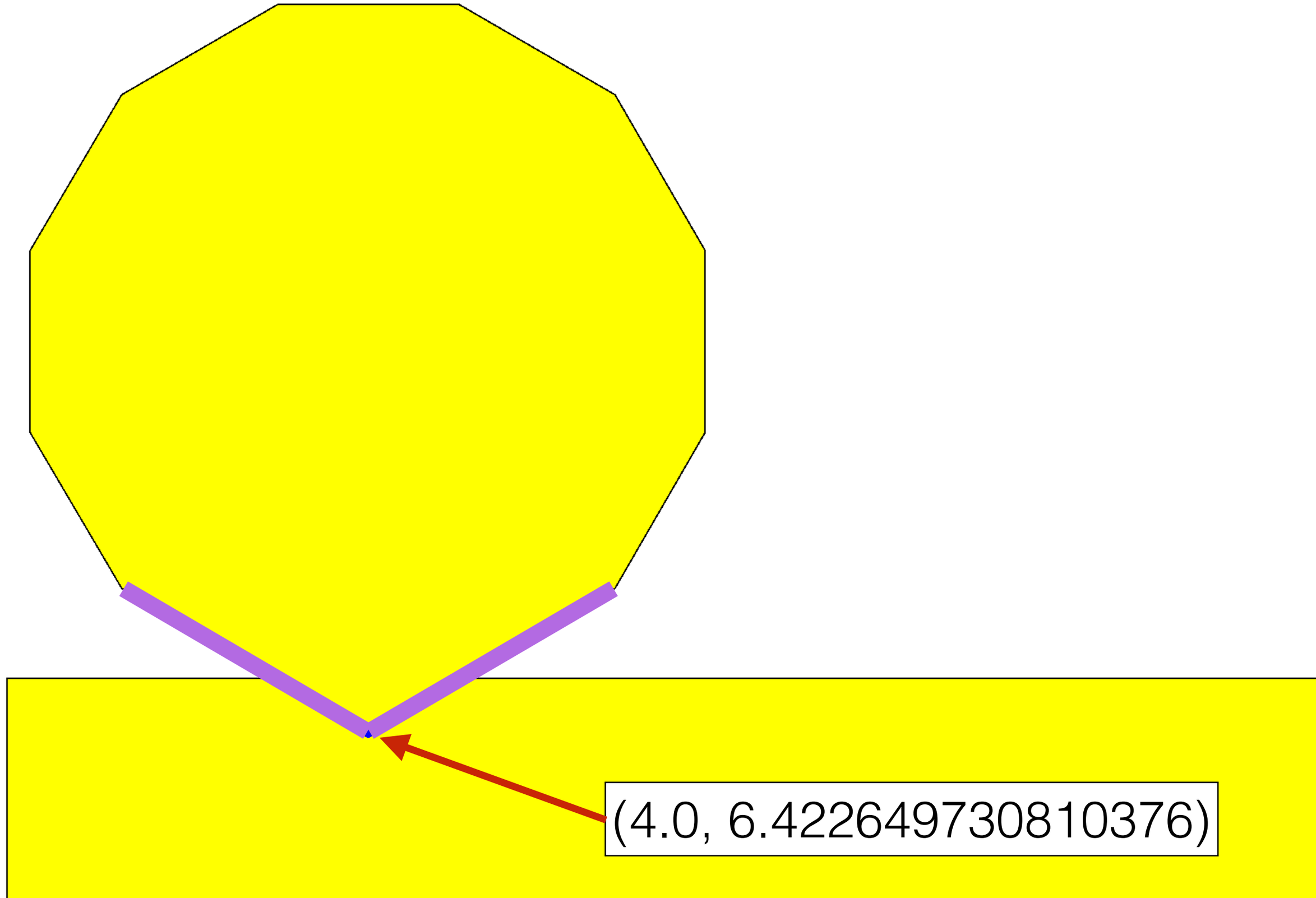
The Winners



Surprises

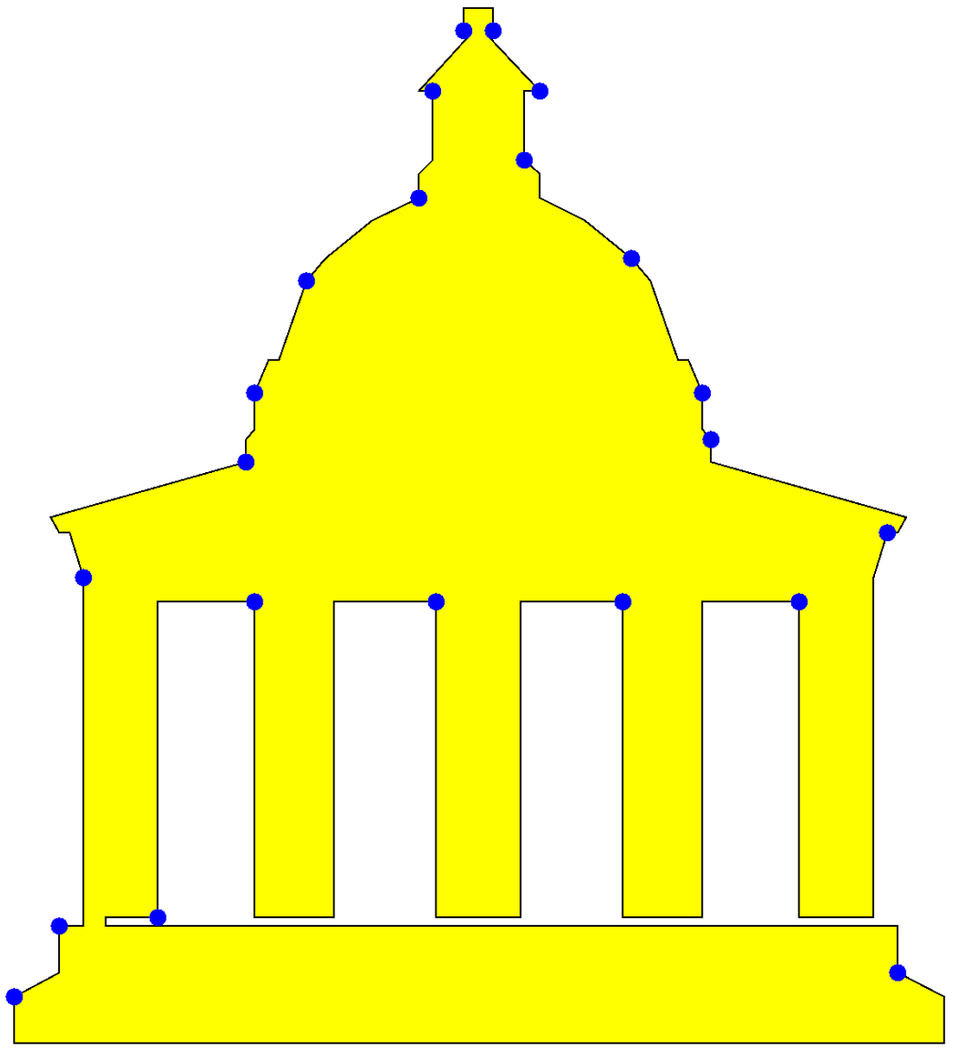


- Part 1, polygon 23
- **100** vertices
- **7** guards (best solution)


(4.0, 6.422649730810376)

In conclusion

- This week was fun to design…
- …and even more fun to observe.
- We hope, it was fun to participate in it.



Have a nice weekend…

… and take some time

to enjoy art in galleries,

which are now well-guarded.

Thanks!