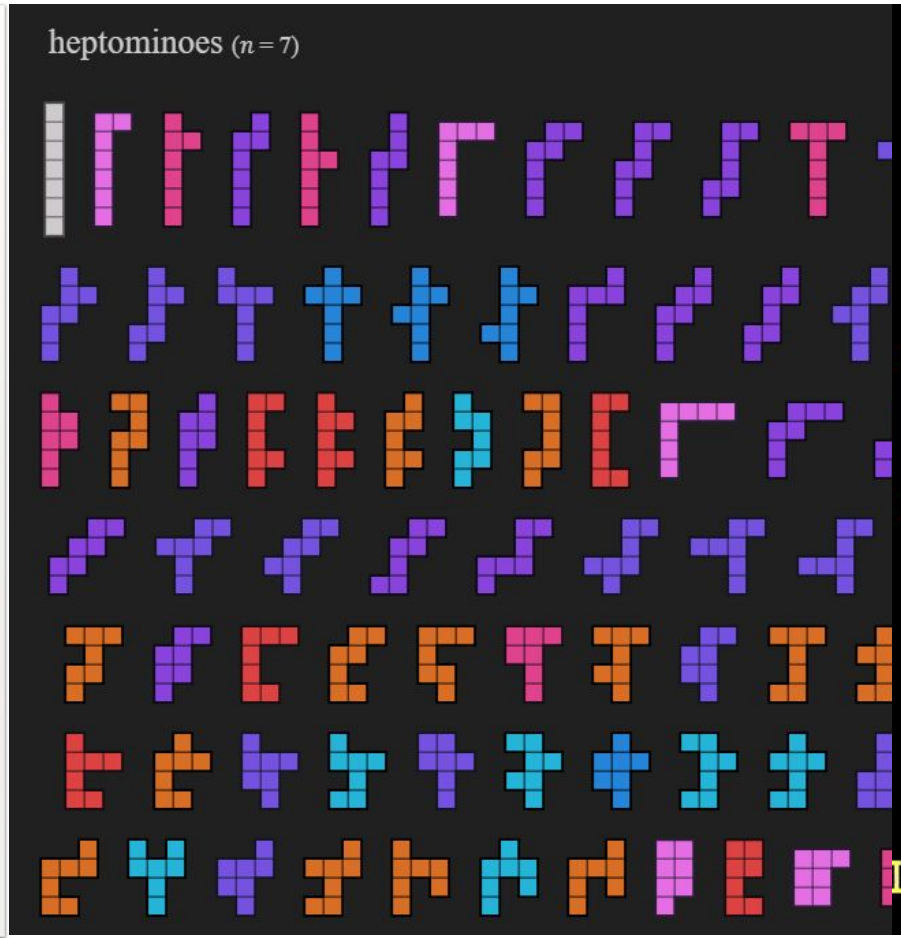
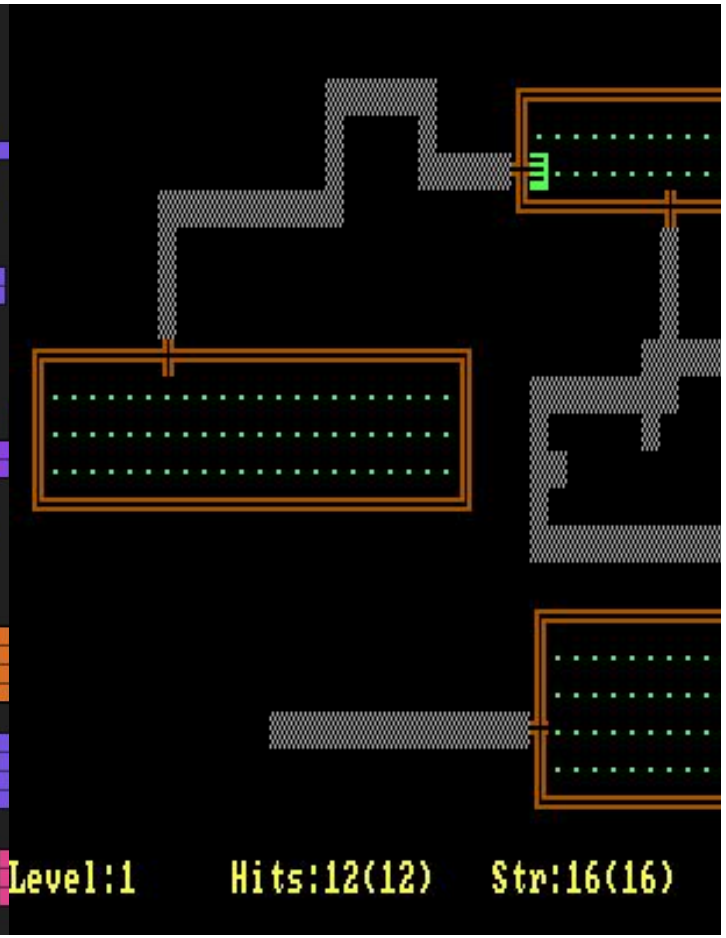




Sol LeWitt, Combinatorial Enumeration, and Rogue

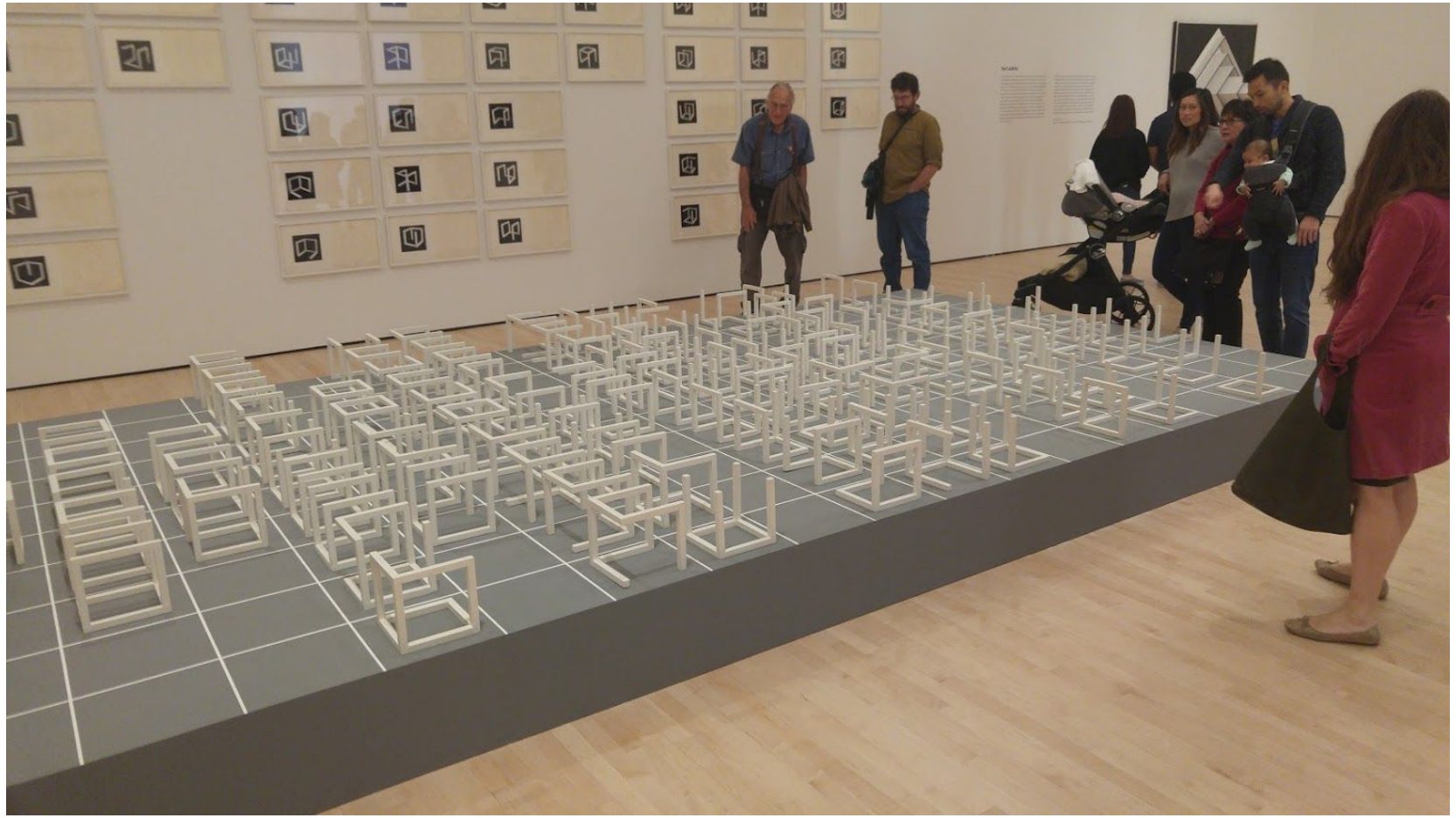
Mark Gritter (novice Artificer)
Roguelike Celebration
October, 2025

Sol LeWitt, "'All One, Two, & Three-Part Combinations of Three Transparent Colors', 1985

Labyrinth of Polyominoes, heptominoes

Rogue (PC port)

Sol LeWitt



20th Century Conceptual Artist, 1928-2007

- wall drawings
- minimalism
- lots of cubes!

← “Incomplete Open Cubes”, 1974

Photo by the speaker, at San Francisco Museum of Modern Art, 2018

Wall drawings

Sol LeWitt, “Wall Drawing 289”, 1976

A 6-inch (15 cm) grid covering each of the four black walls. White lines to points on the grids. Fourth wall: twenty-four lines from the center, twelve lines from the midpoint of each of the sides, twelve lines from each corner.

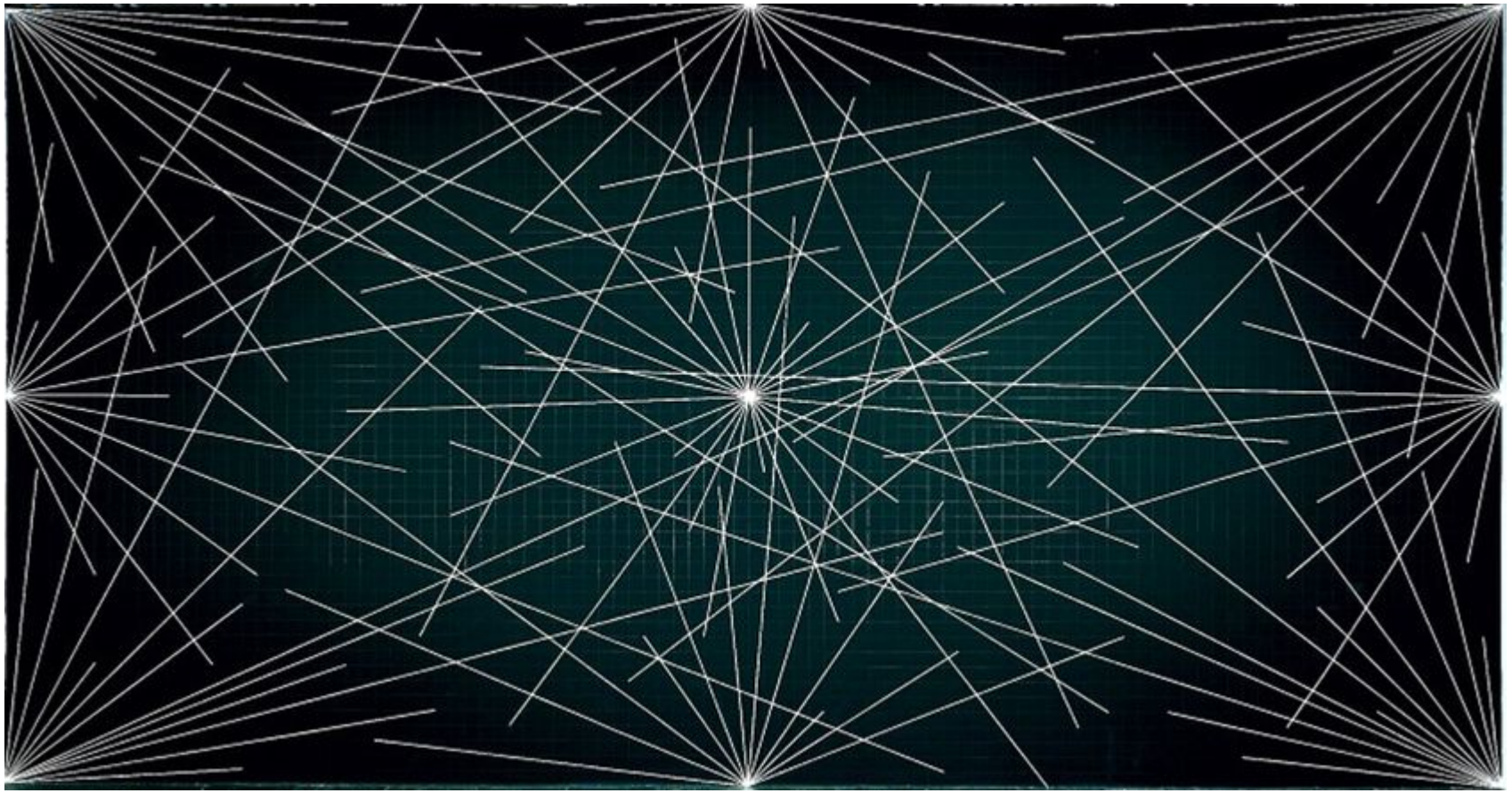


Image from https://whitney.org/collection/works/25530

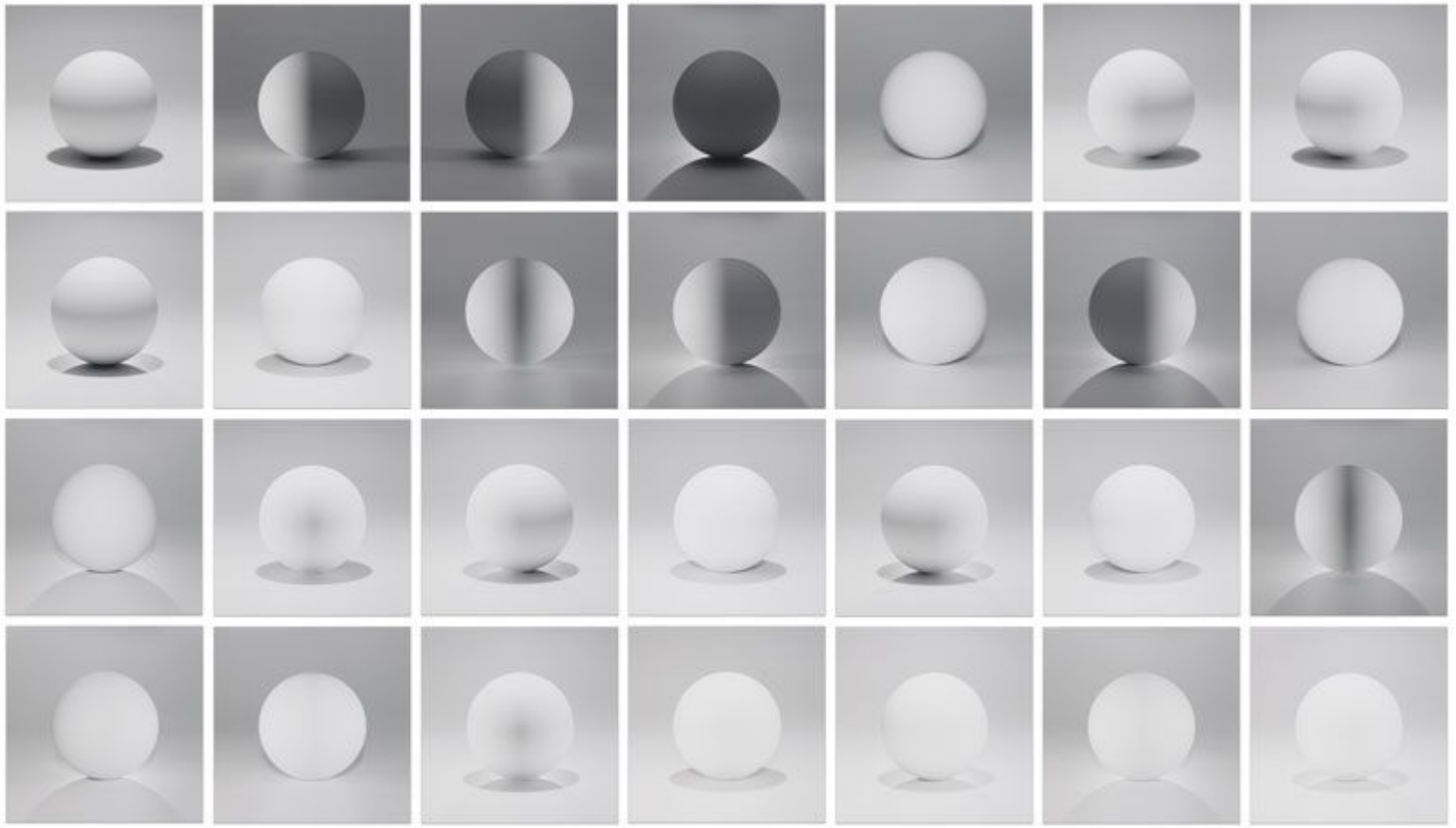
Wall drawings (2)

Wall drawings are generative art! They are given as **instructions** rather than as an image. (*)

"The only permanent, concrete form of Wall Drawing #289 is a set of typewritten guidelines and a certificate of authenticity signed by the artist… The exact angle and length of the lines are determined by those who draw them, and the work's precise configuration and scale may be adapted to fit a variety of architectural contexts. Consequently, the wall drawing can differ significantly with each realization." – Whitney Museum of American Art, https://whitney.org/collection/works/25530

(*) this separation is ruined a bit by having to hire a draftsperson from the LeWitt Studio to execute an "official" drawing.

Serial Art



Sol LeWitt, “A sphere lit from the top, four sides, and all their combinations”, 2004

Image from sollewittprints.org

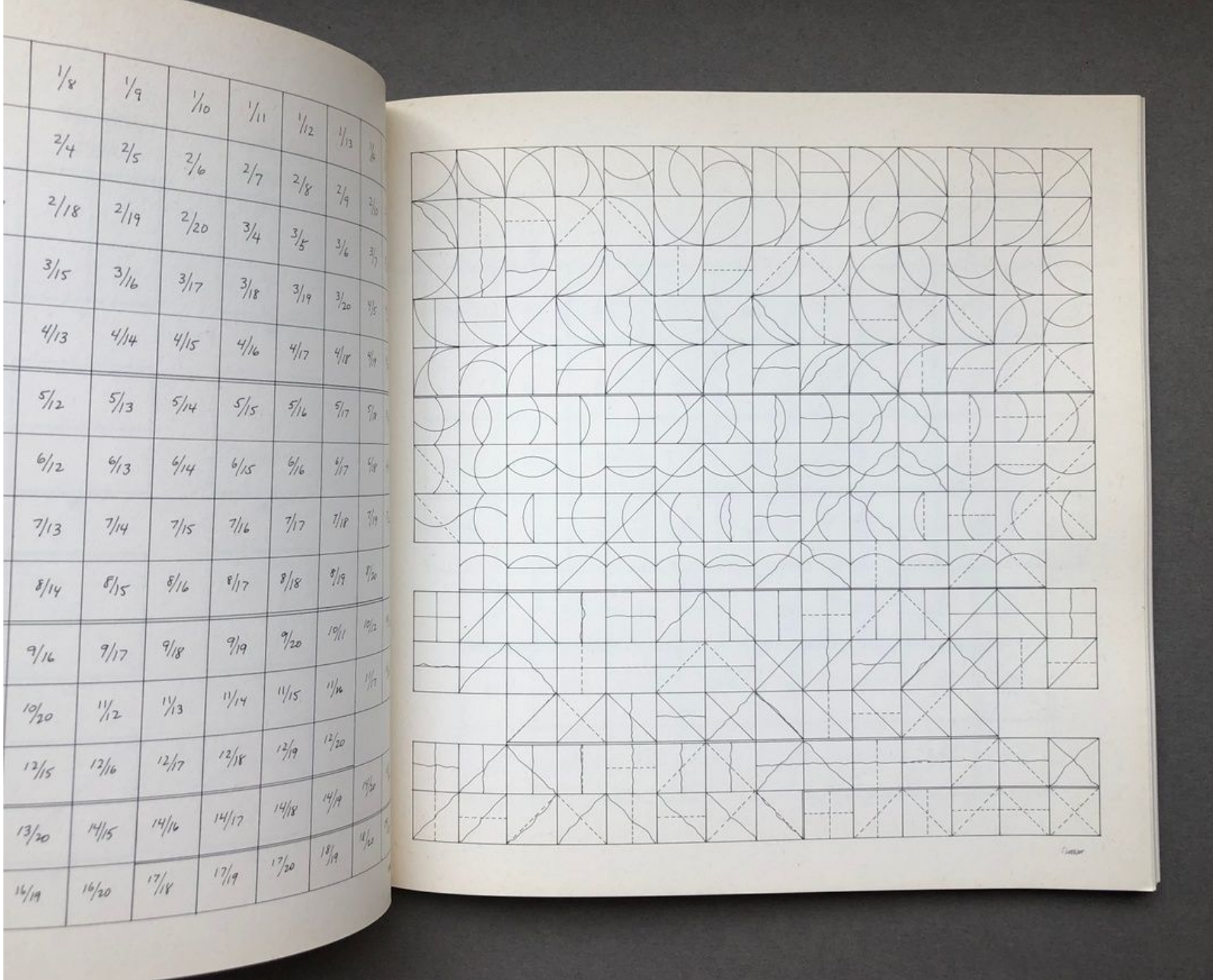
(P.S. there should be 32, or 31, not 28?)

“Arcs and Lines”, Sol LeWitt, 1974

“All combinations of arcs from four corners, arcs from four sides, straight lines, not-straight lines, and broken lines”

Image from https://www.printedmatter.org/catalog/14771/

(A used copy will set you back about $200-$350 so I don’t, alas, own this.)



Serial Art (2)

This takes a further step backwards into abstraction. The artwork is a description of a condition or axiom or law, which is then carried out to produce a tangible result. The artwork typically juxtaposes all of these results together as a finished work.

"*The serial artist does not attempt to produce a beautiful or mysterious object but functions merely as a clerk cataloguing the results of his premise.*" – Sol LeWitt

(I disagree, I think these *are* beautiful and mysterious. – Mark)

Serial Art (3)

"Three basic operating assumptions separate serially ordered works from multiple variants:

1. The derivation of the terms or interior divisions of the work is by means of a numerical or otherwise systematically predetermined process (permutation, progression, rotation, reversal).

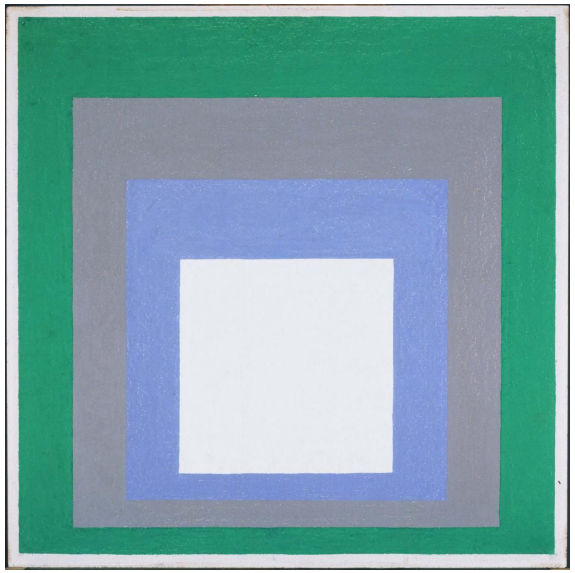
2. The order takes precedence over the execution.

3. The completed work is fundamentally parsimonious and systematically self exhausting."

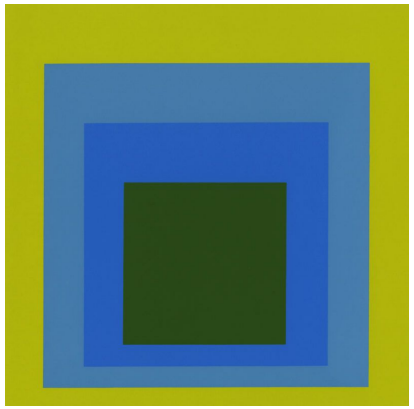
– Mel Bochner, "The Serial Attitude", Artforum, December 1967

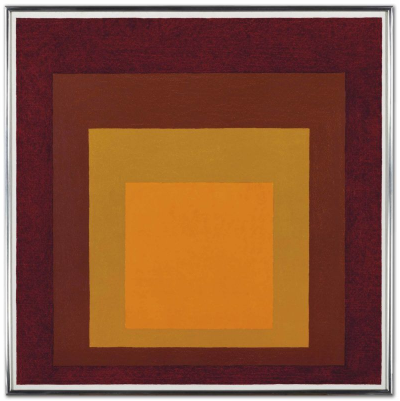
(Of course, not everybody agrees with this either – Mark)

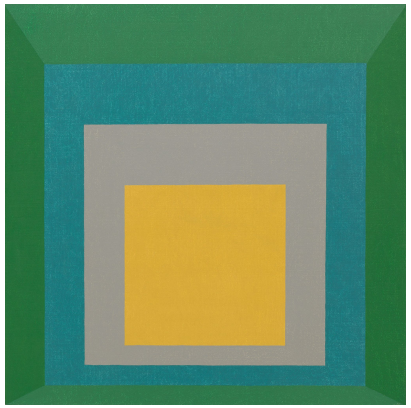
Josef Albers, “Homage to the Square”. Photo by Selena N. B. H. (cc-by-2.0) at the Tate Modern.



“a rigorously formulaic project comprising more than one hundred paintings and prints and developed over twenty-five years.” – MOMA.org





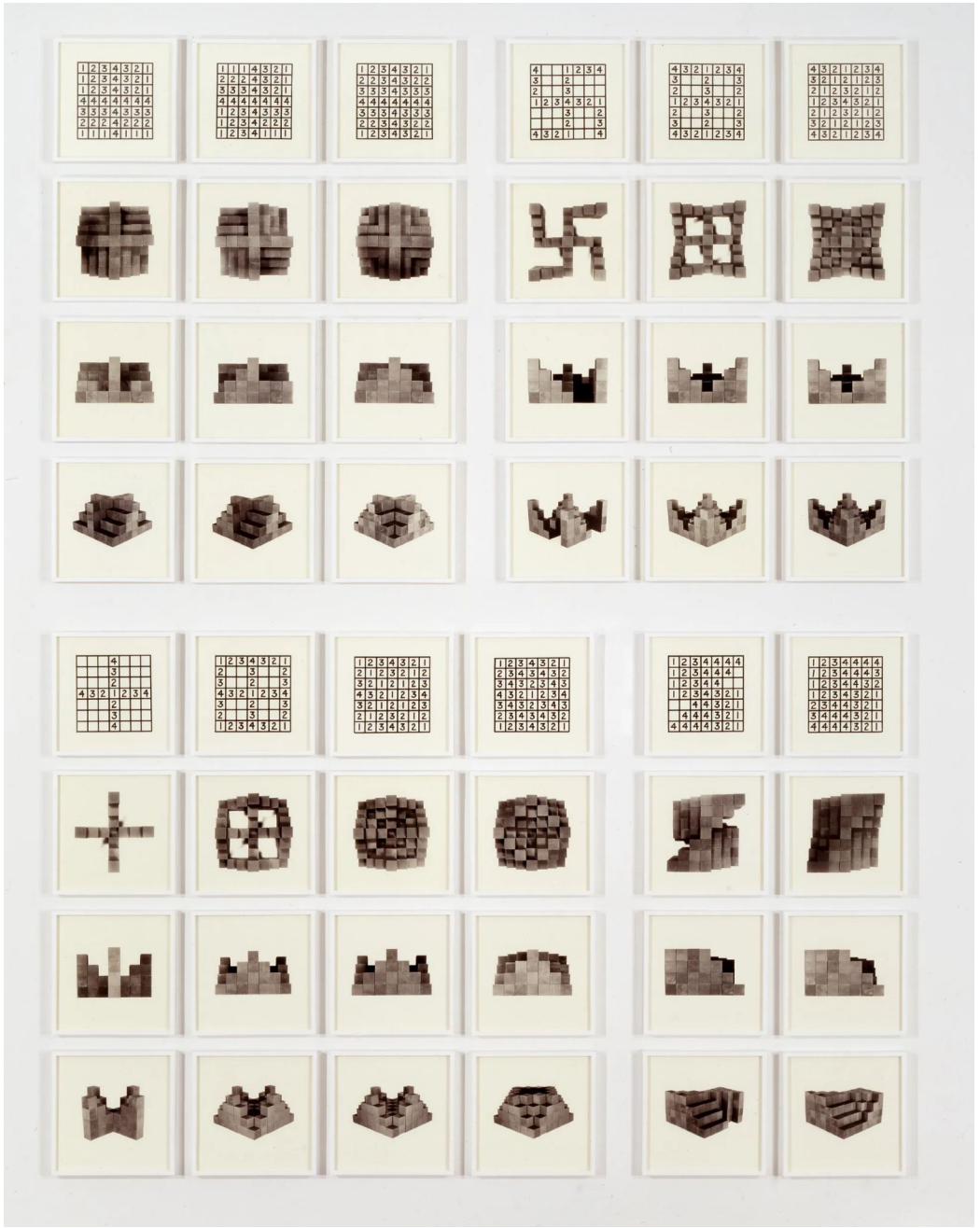


Yayoi Kusama, “Infinity Mirrored Room - Aftermath of Obliteration of Eternity”, 2009

from https://hirshhorn.si.edu/kusama/infinity-rooms/#aftermath

Hanne Darboven, (Süd-) Koreanischer Kalender, 1991

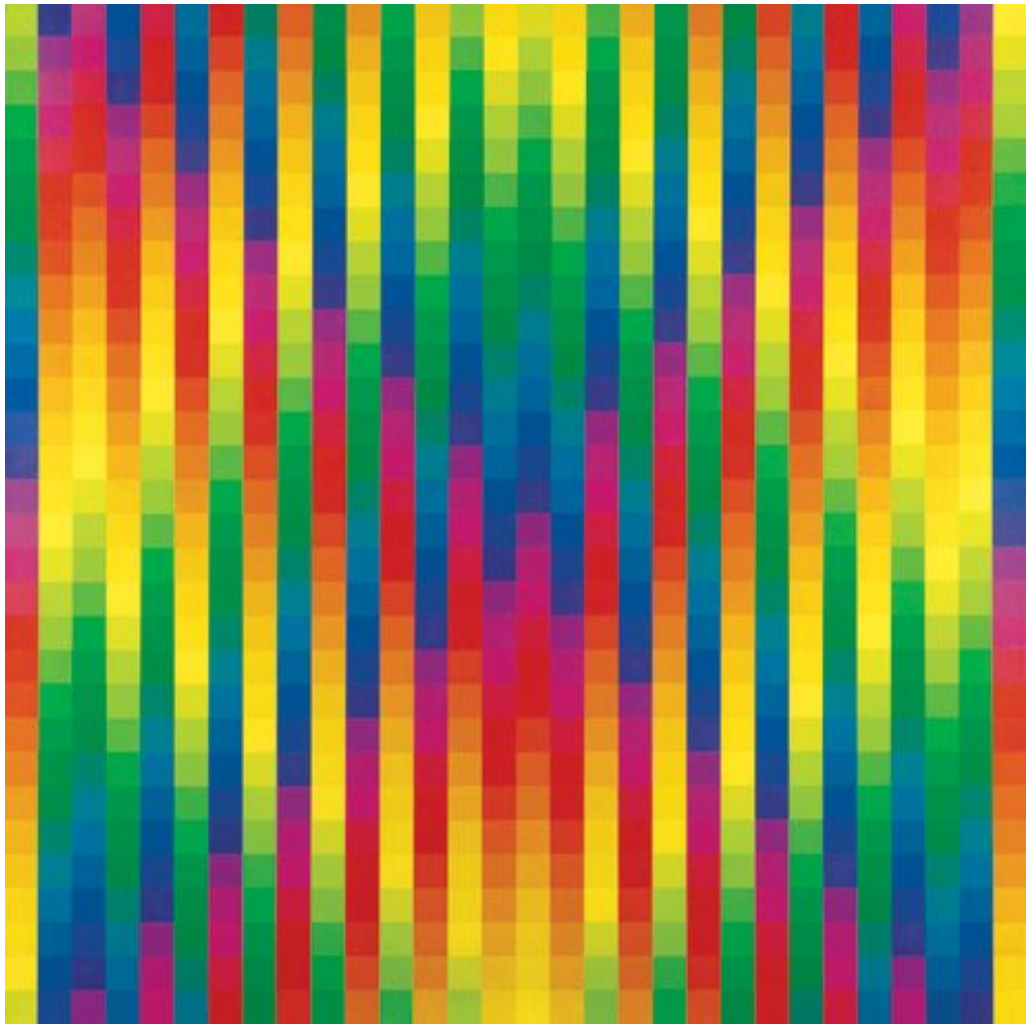
https://spruethmagers.com/artists/hanne-darboven/



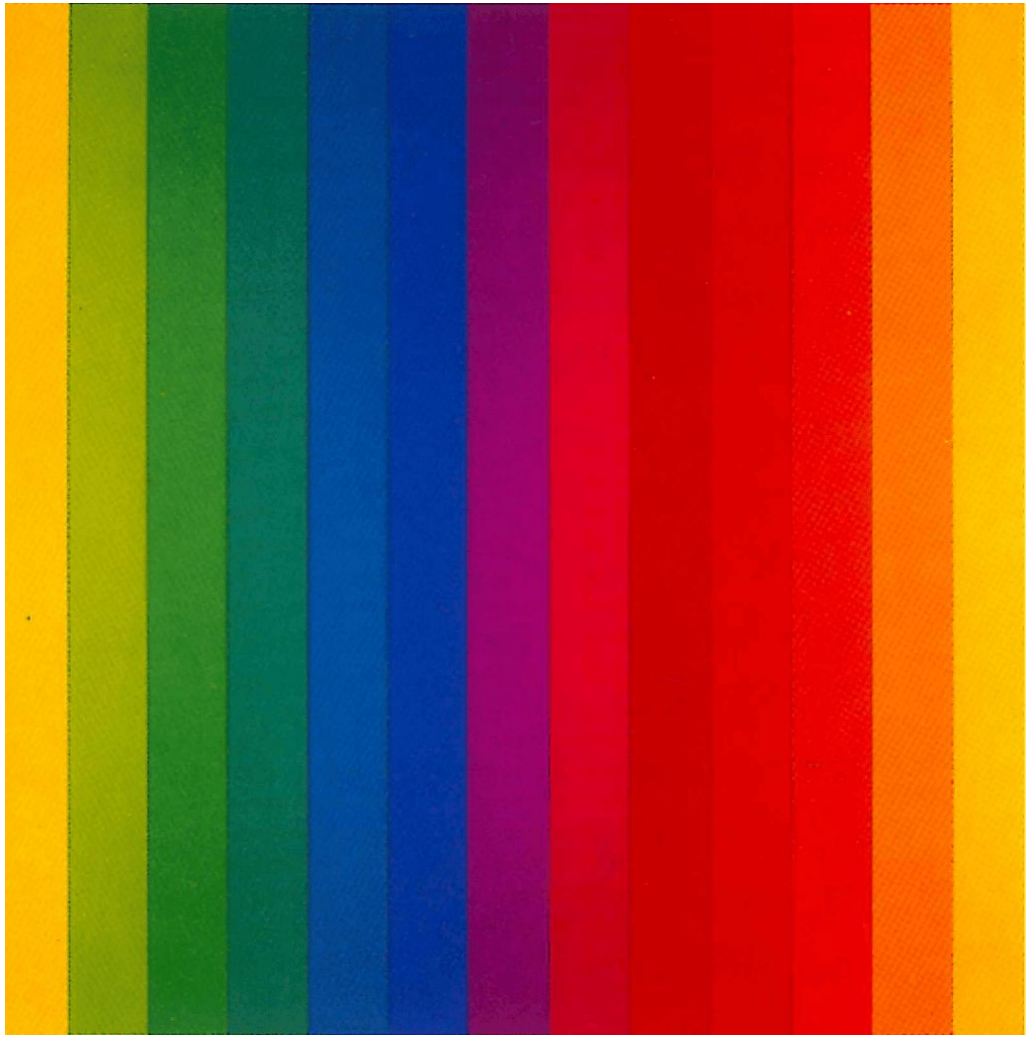
Mel Bochner, “36 Photographs and 12 Diagrams”, 1966, https://www.glenstone.org/artworks/36-photographs-and-12-diagrams

Mel Bochner, “Counting (Double Over)”, 1995, https://www.melbochnerprints.org/krakow-1994-01/#198

Richard Paul Lohse, “Dreissig vertikale systematische Farbreihen in gelber Rautenform”, 1943/1970
from https://www.lohse.ch/works_paintings3_e.html



Ellsworth Kelly, “Spectrum IV”, 1967
https://www.miandn.com/exhibitions/ellsworth-kelly/installation-views?view=thumbnails

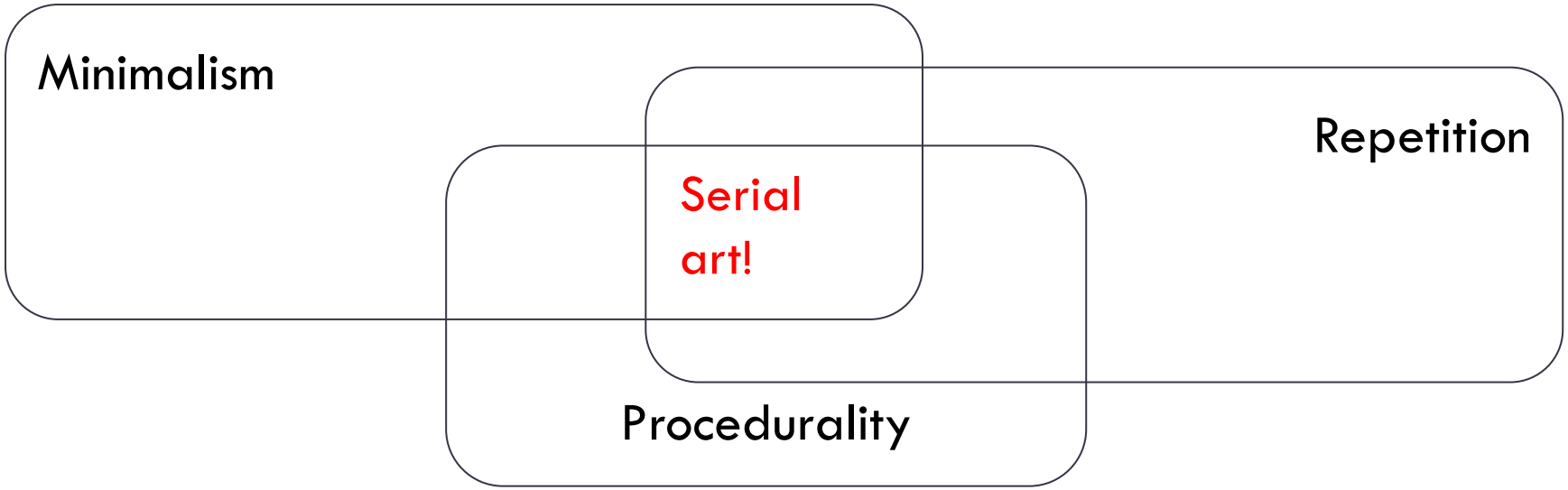


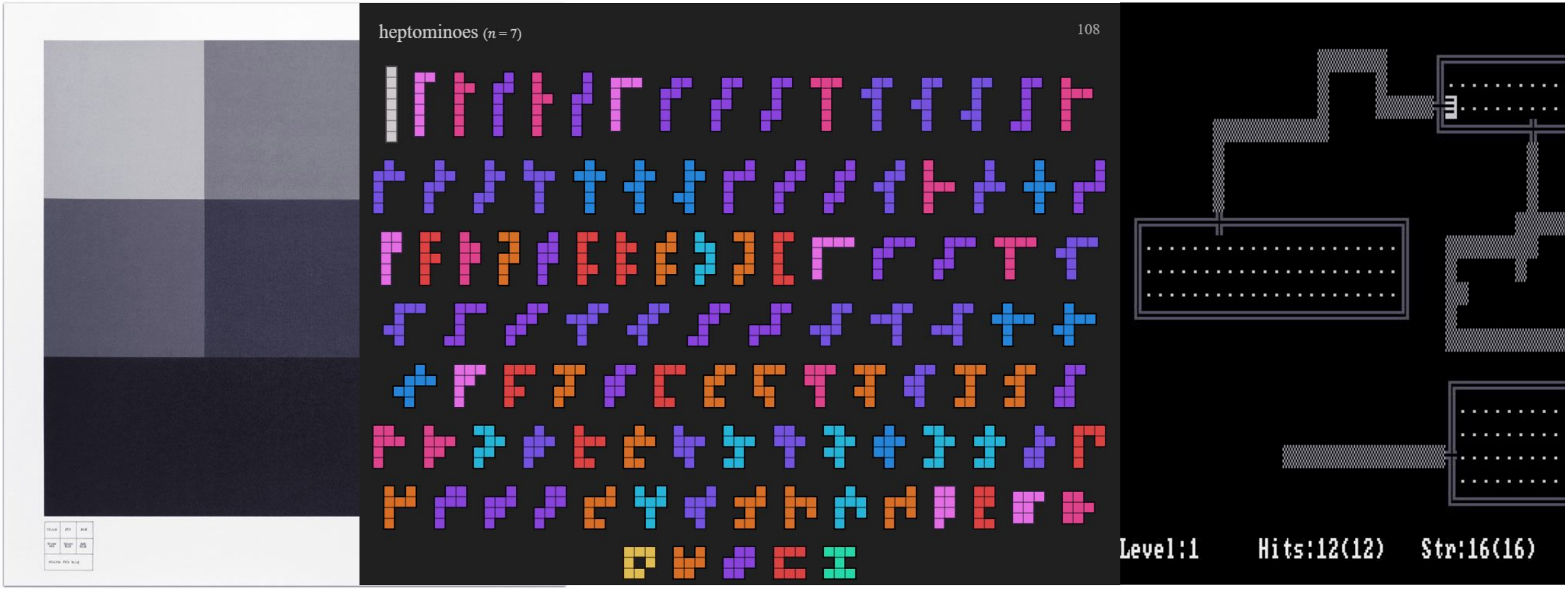
Other Serial Art

- “Change Ringing” – playing all permutations of a set of bells

The idea becomes a machine that makes the art.

– Sol LeWitt, “Paragraphs on Conceptual Art”, 1967





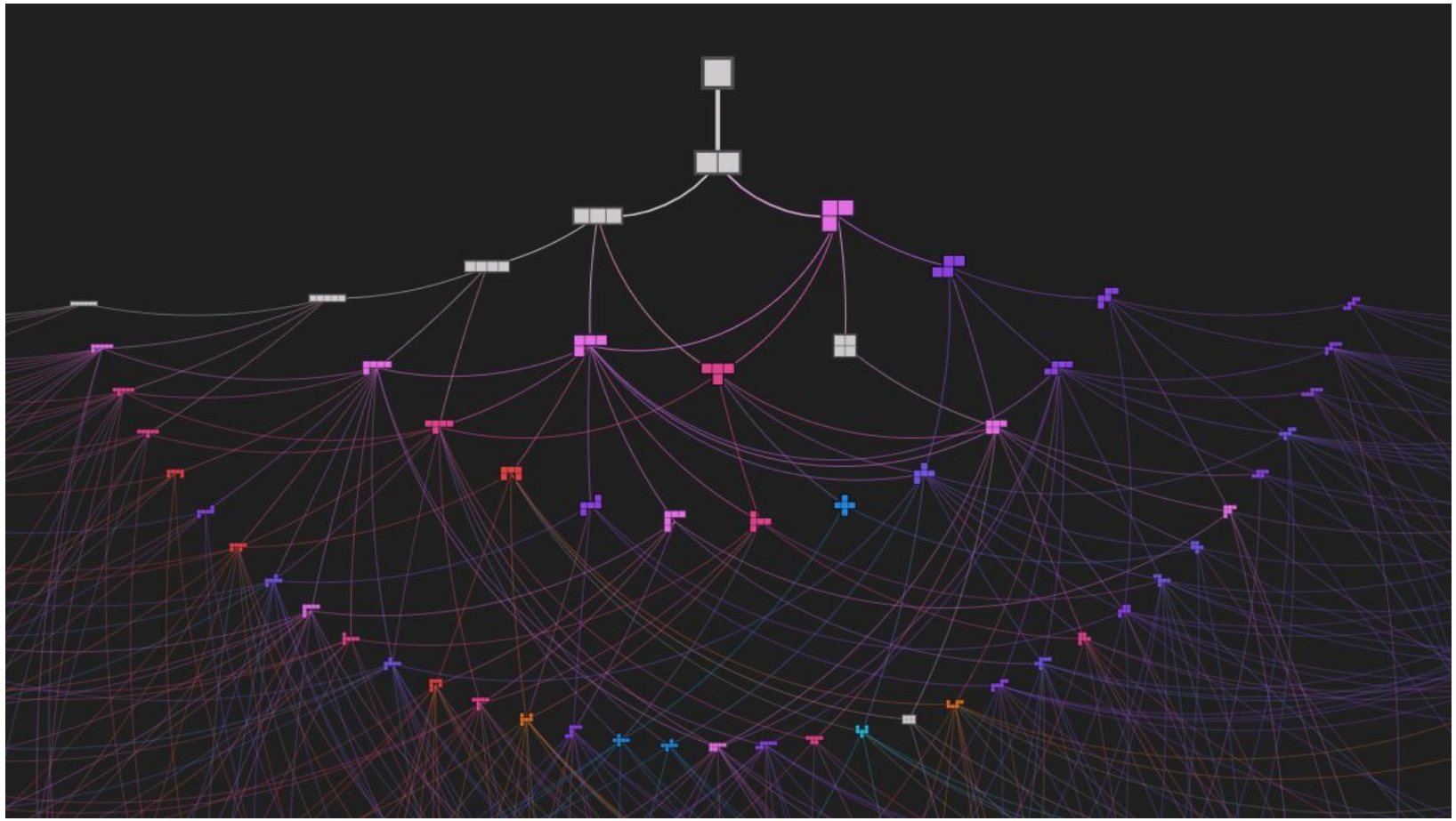
Enumerating All the Things

The Labyrinth of Polyominoes

By Roguelike Celebration 2024 speaker @tesseralis!

All polyominoes (up to n=8) here arranged by "genealogy".

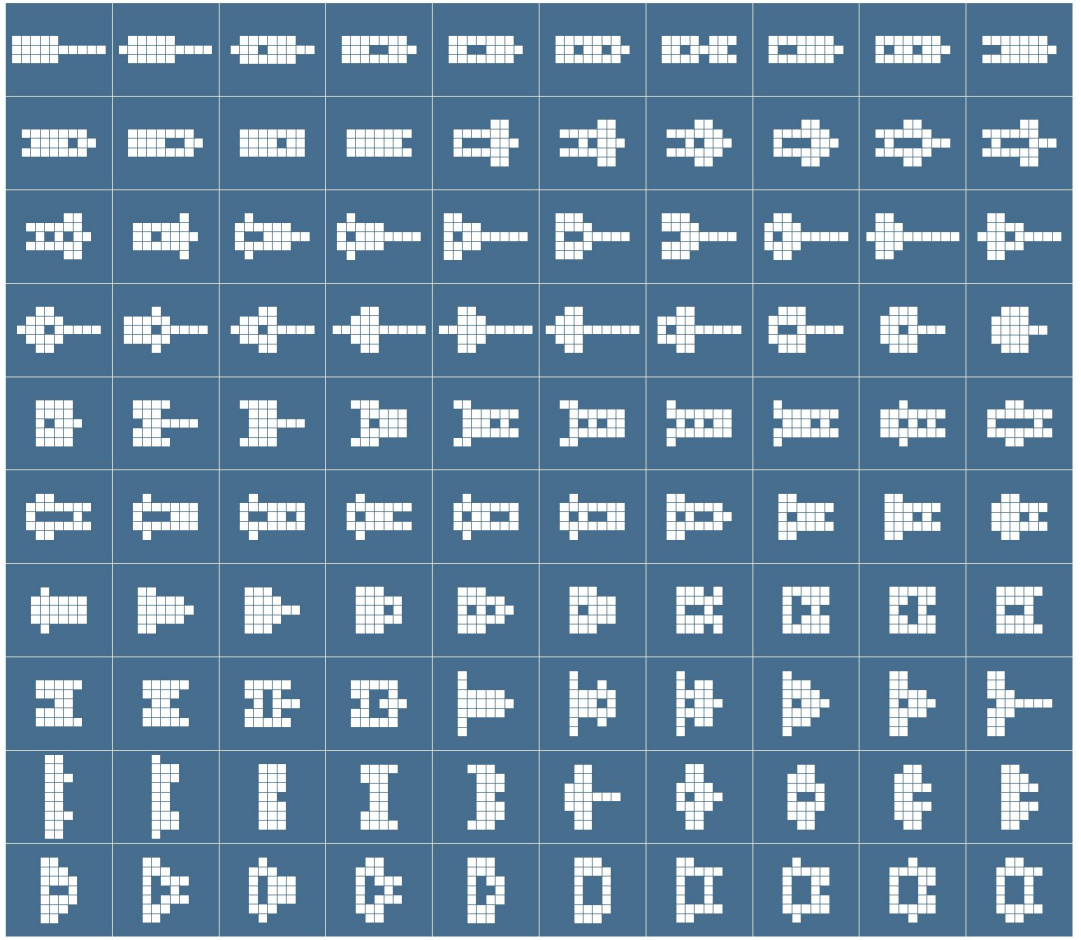
https://minos.tessera.li/



All symmetric shapes constructible from the tetrominoes

Jacob Siehler, 2025

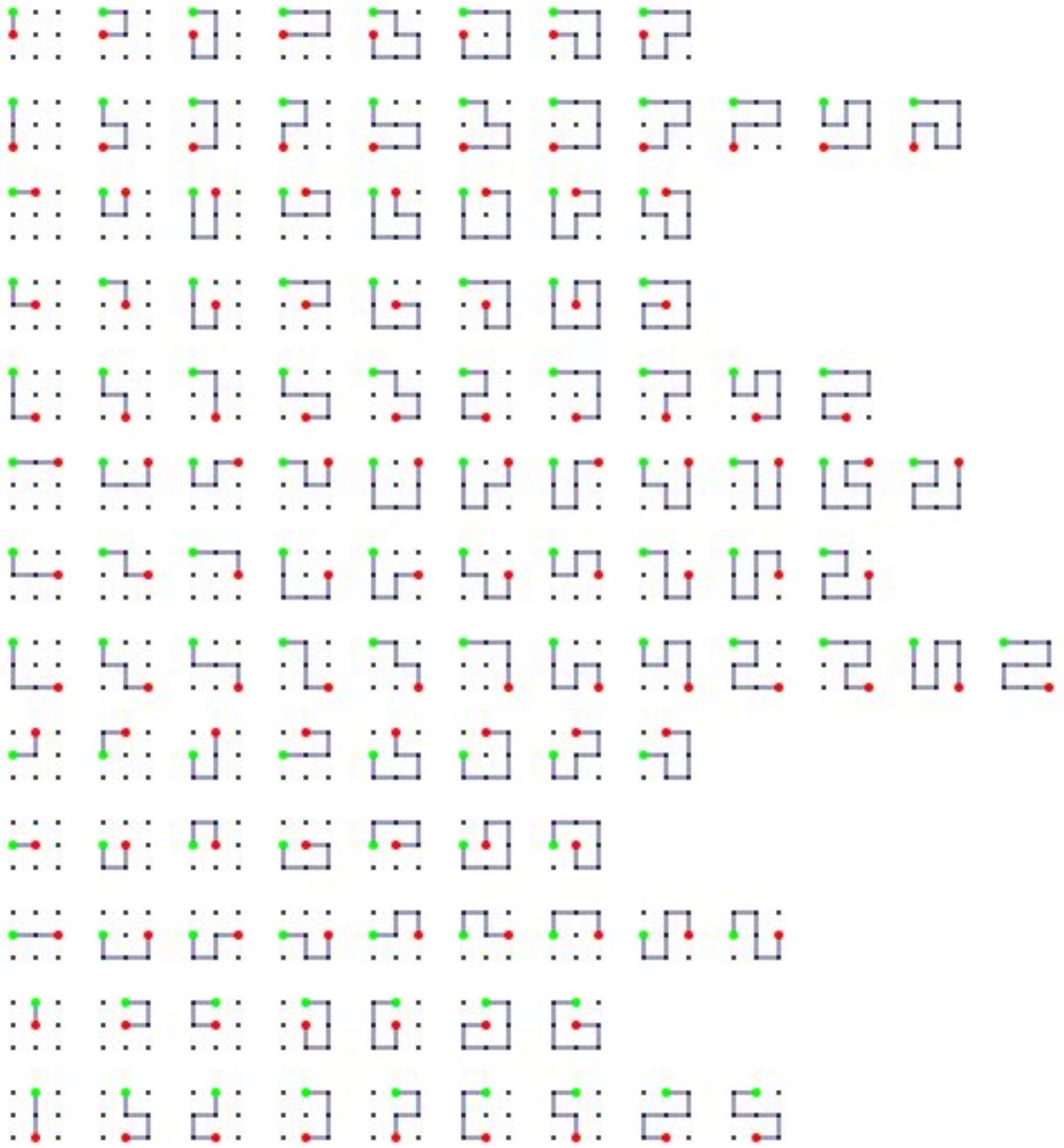
https://mathstodon.xyz/@jsiehler/114744887537037820



All simple paths on a 3x3 lattice

Visualization by the speaker

These show directed paths from the green point to the red point, up to symmetries of the rectangle (so, flips but not rotations) and interchange of start and end.

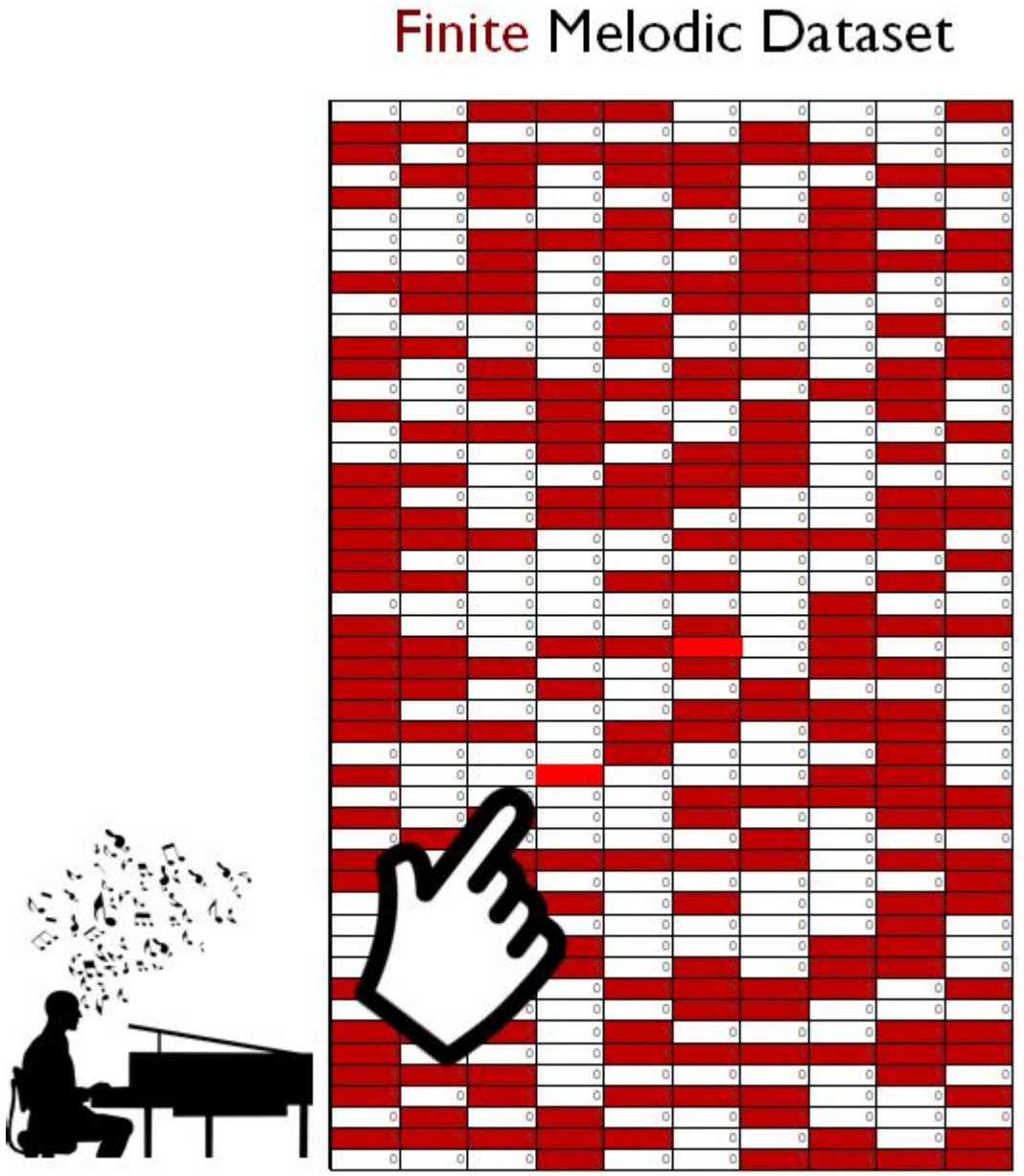


All the Music

Damien Riehl and Noah Rubin,
https://allthemusic.info/

1. Generate every possible melody, up to 10 or 12 notes long.
2. Copyright them all.
3. Stop “substantially similar” music lawsuits forever?

Argument: either Riehl has copyrighted every unused melody, and they are free to use, or melodies aren’t copyrightable.

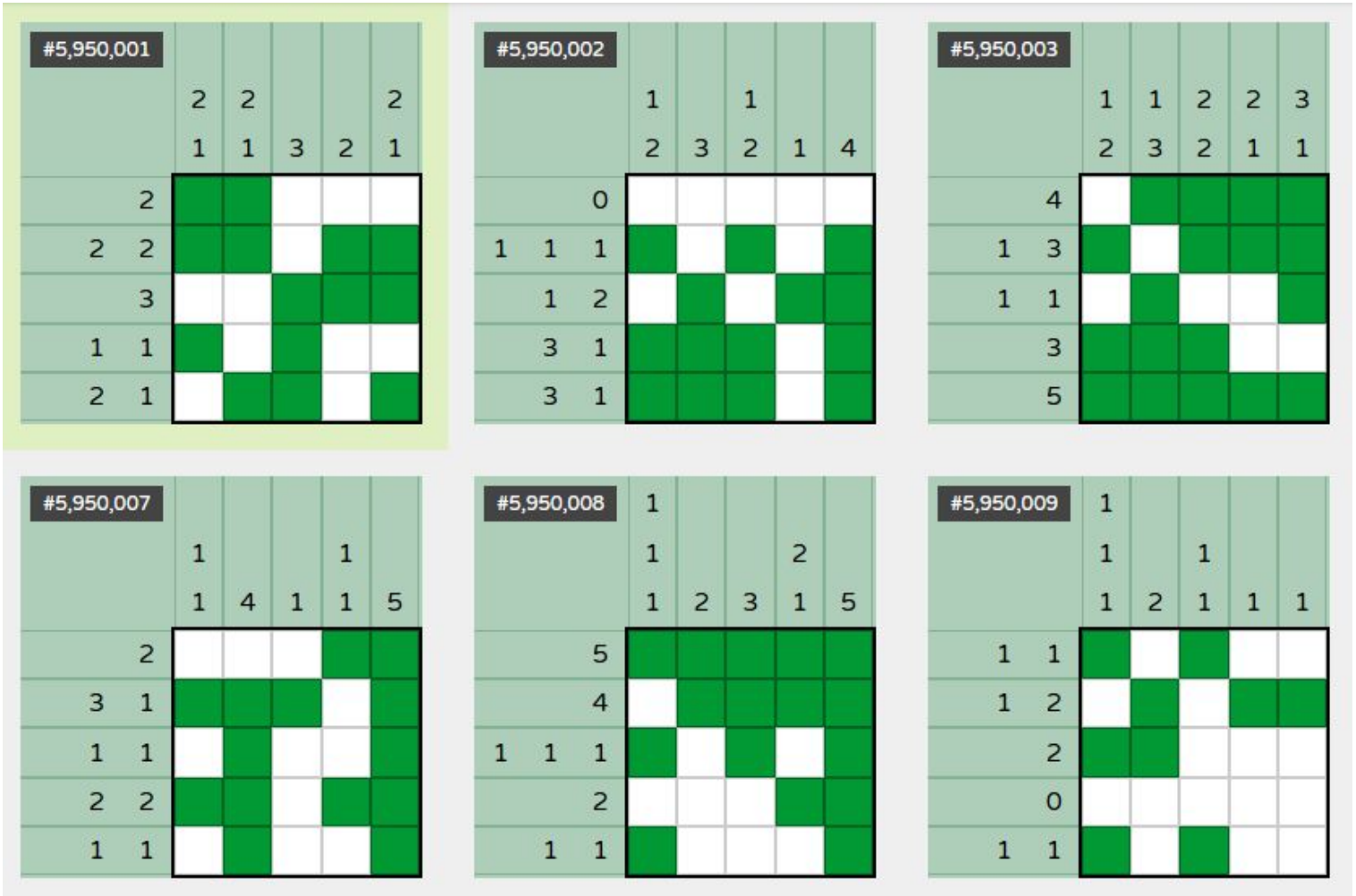


P.S. in the age of generative AI you should be able to find the unfortunate flaw in this argument.

Every 5x5 Nonogram

Okayest Studio, https://pixelogic.app/every-5x5-nonogram

24,976,511 possibilities, all solved by humans via a collaborative effort.



SmallCategories

Ben Spitz,
https://smallcats.info/
("in beta")

A "category" is a mathematical object consisting of dots with arrows in between them, obeying a couple simple rules.

164,975 categories each with properties listed, the "multiplication table" of composition, and a visualization.

Quick Reference

Web ID	6ca55ed1-f425-4004-a199-29def9560838
Morphisms	9
Objects	3
Index	59248
Name	N/A
Description	N/A

Visualization

This feature is still janky! Please excuse the mess.

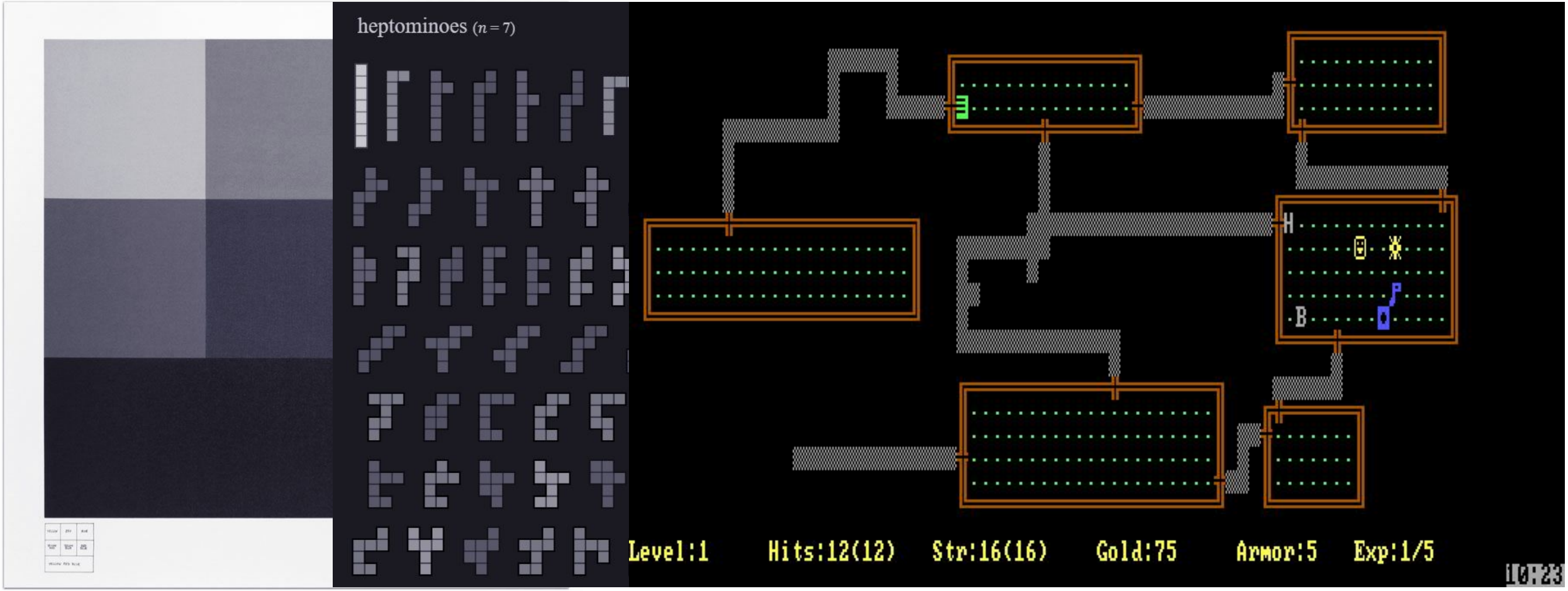
Morphisms 0 through 2 are identities, shown as objects in this visualization.

Table

row ∘ col	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0	0	/	/	3	4	5	/	/	/
1	/	1	/	/	/	/	6	7	/
2	/	/	2	/	/	/	/	/	8
3	3	/	/	3	4	5	/	/	/
4	4	/	/	3	4	5	/	/	/
5	5	/	/	3	4	5	/	/	/
6	6	/	/	6	6	6	/	/	/
7	/	7	/	/	/	/	6	7	/
8	/	/	8	/	/	/	/	/	2

Facts

- ✗ has_terminal_object
- ✗ has_binary_products
- ✗ is_discrete
- ✗ is_terminal
- ✗ has_initial_object
- ✗ has_binary_coproducts
- ✗ is_groupoid
- ✗ is_monoid
- ✗ is_connected
- ✗ has_finite_products
- ✗ is_preorder
- ✓ is_skeletal
- ✗ has_equalizers
- ✗ has_finite_coproducts
- ✗ is_complete
- ✗ is_cocomplete
- ✗ has_coequalizers
- ✗ is_initial


heptominoes (n = 7)
Level:1 Hits:12(12) Str:16(16) Gold:75 Armor:5 Exp:1/5

… and Rogue

Rogue Level Generator

9 rooms

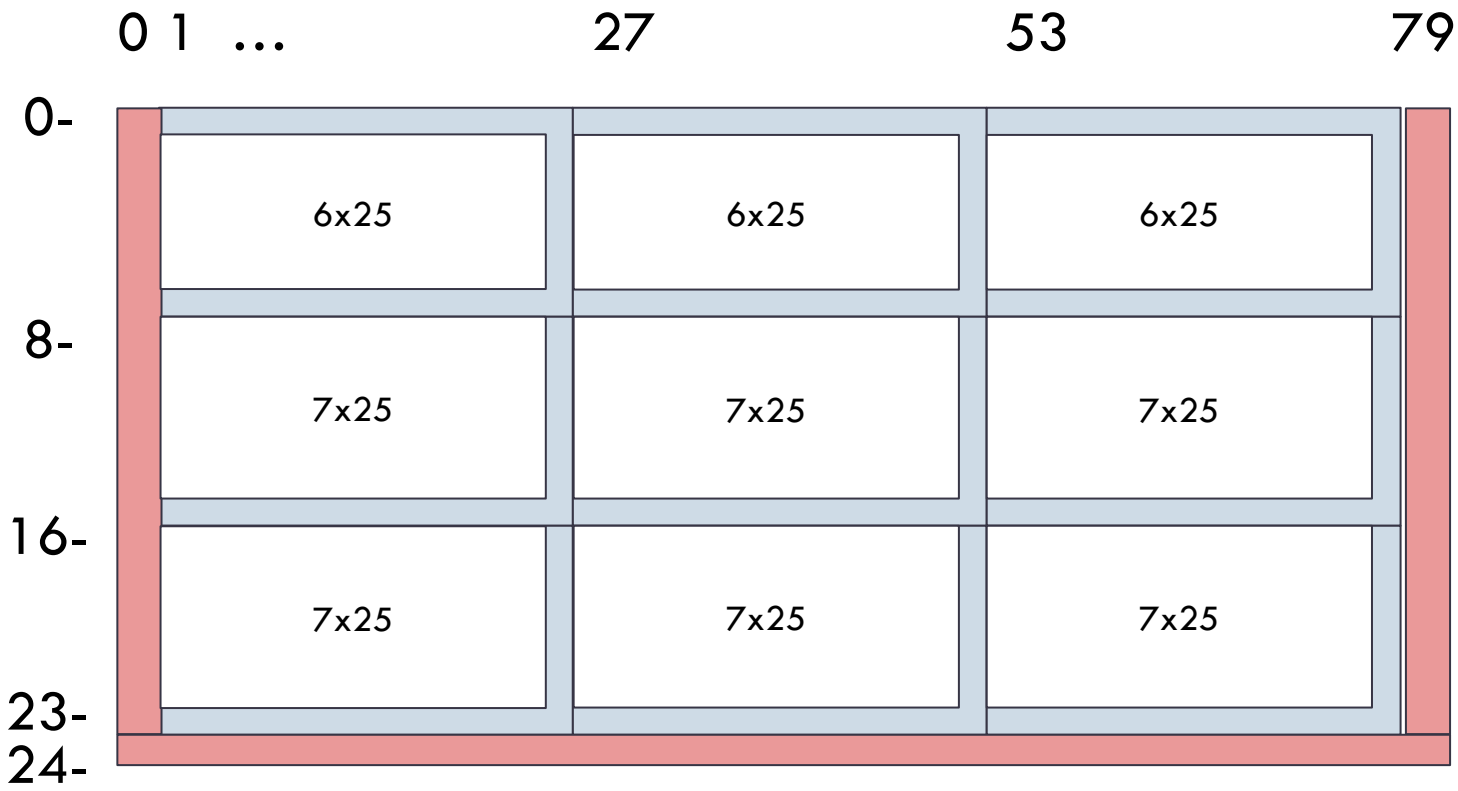
Up to 3 can be missing

For each room:

- Pick a width [4,25]
- Pick a height [4,7]

Pick a location within the "cell" that fits.

Start over if the room would be on the first row (so top rooms can only be 4-6.)



Counting the Possibilities

Width 25	Width 24	….	Width 5	Width 4	
1 horizontal position	2 horizontal positions	…	21 horizontal positions	22 horizontal positions	=253 possibilities

Same calculation for height gives 6 (top row) or 10 (other two rows) possibilities.

So, there are about (253 x 6)^3 x (253 x 10)^6 possible combinations of room sizes, if no rooms are absent. That's about 2^(99.5) possibilities.

- P.S. this number doesn't change much if we account for "gone" rooms

Rogue as Serial Art

Rogue uses a PRNG (a linear congruential generator) with a 32-bit seed value.

There are only 2^32 possible versions of a level!

We could enumerate all of them.

- As an art project?
- To better understand the generator?
- I just thought it was cool that not only are there room configurations that are impossible, they *vastly* outnumber the ones that are valid.

The Rogue RNG(s)

Original rogue:

```
(((seed = seed*11109+13849) >> 16) & 0xffff)
```

This is a standard Linear Congruential generator, but using bits 16-32 of the seed avoids some of its worst behaviors.

MS-DOS port:

```
seed *= 125;
seed -= (seed/2796203) * 2796203;
return ((ran() + ran())&0x7fffffff)
```

“This is adapted from the FORTRAN version in ‘Software Manual for the Elementary Functions’ by W.J. Cody, Jr and William Waite.”

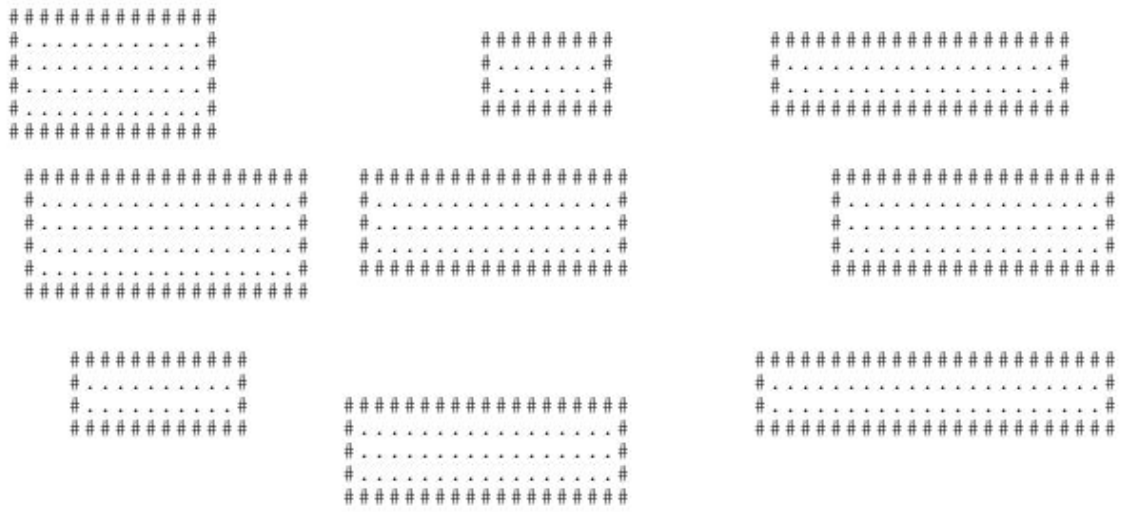
It's not even hard!

I thought that this would take some nontrivial engineering work.

- Parallelize, implement on a GPU, …?
- Implement an index for reverse lookup …?

Nope, I copied the implementation into a C++ program (*) and it only takes 11 minutes to run through every possible seed.

(*) = turns out it is not possible to copy Rogue's room generation faithfully without also copying its monster and item generation, oops



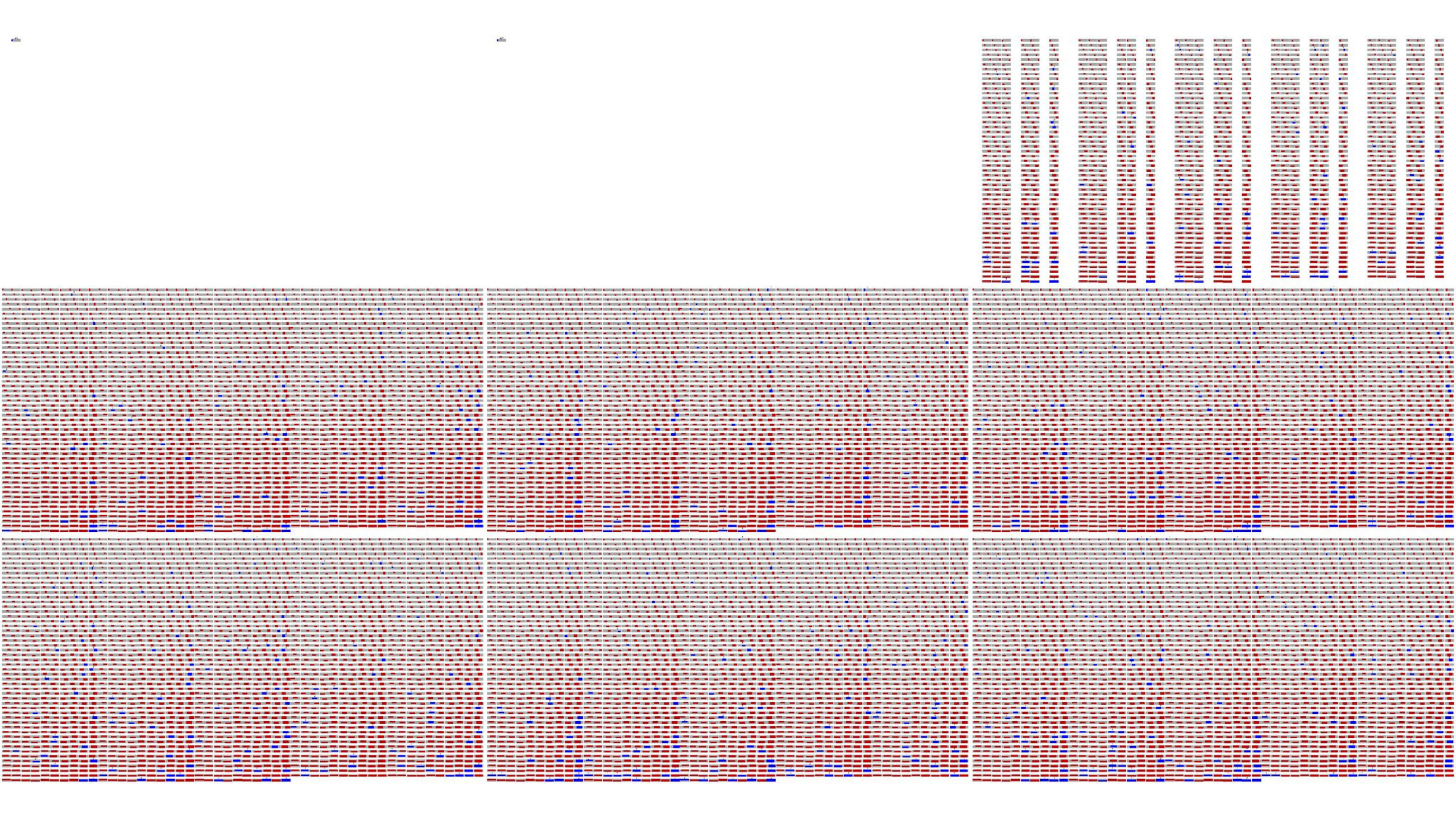
first 100 seeds

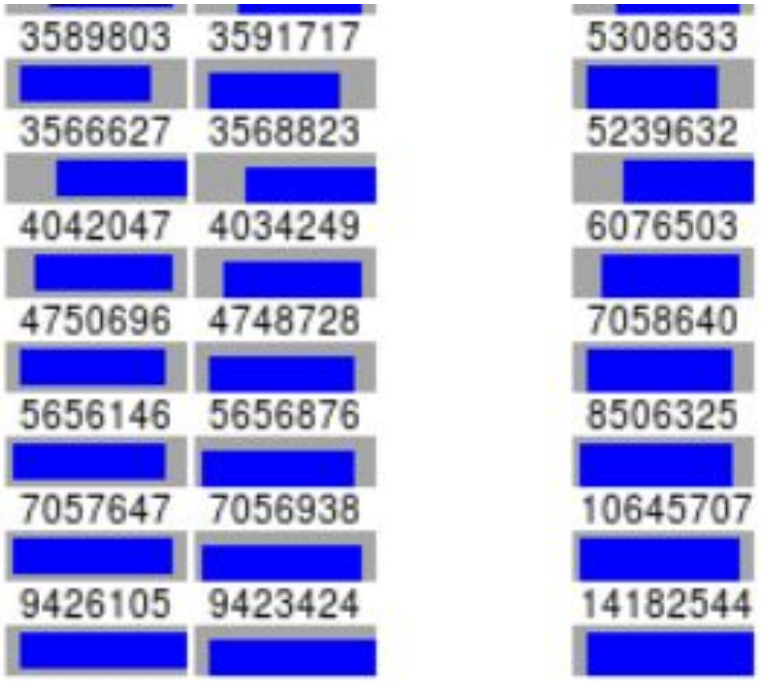
Postselection

What if the top-left room is 4x4?

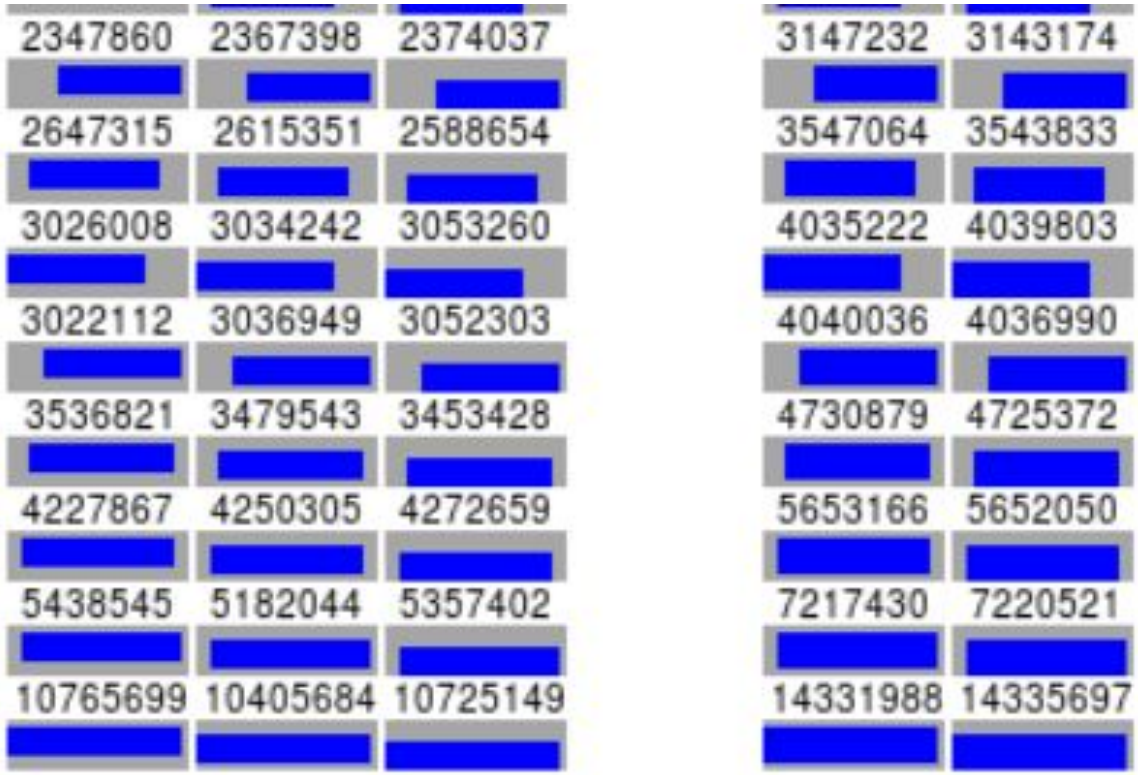
This happens 63,579,000 times. The distribution of the remaining rooms is about even.

(This plot shows how what % of time the given square is occupied.)



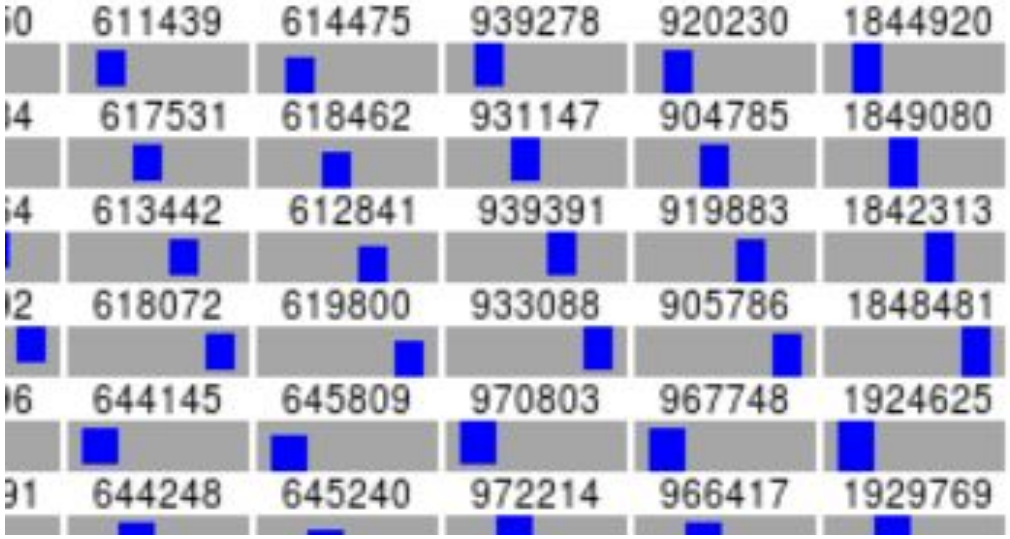


room 1

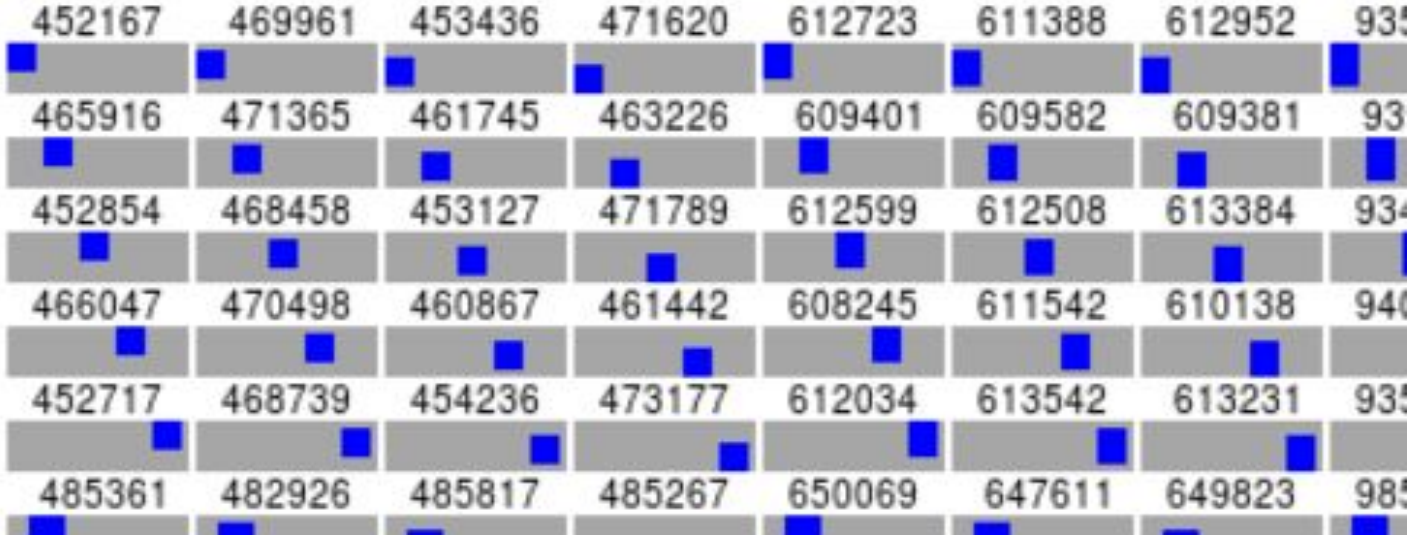


room 2

room 4



room 5

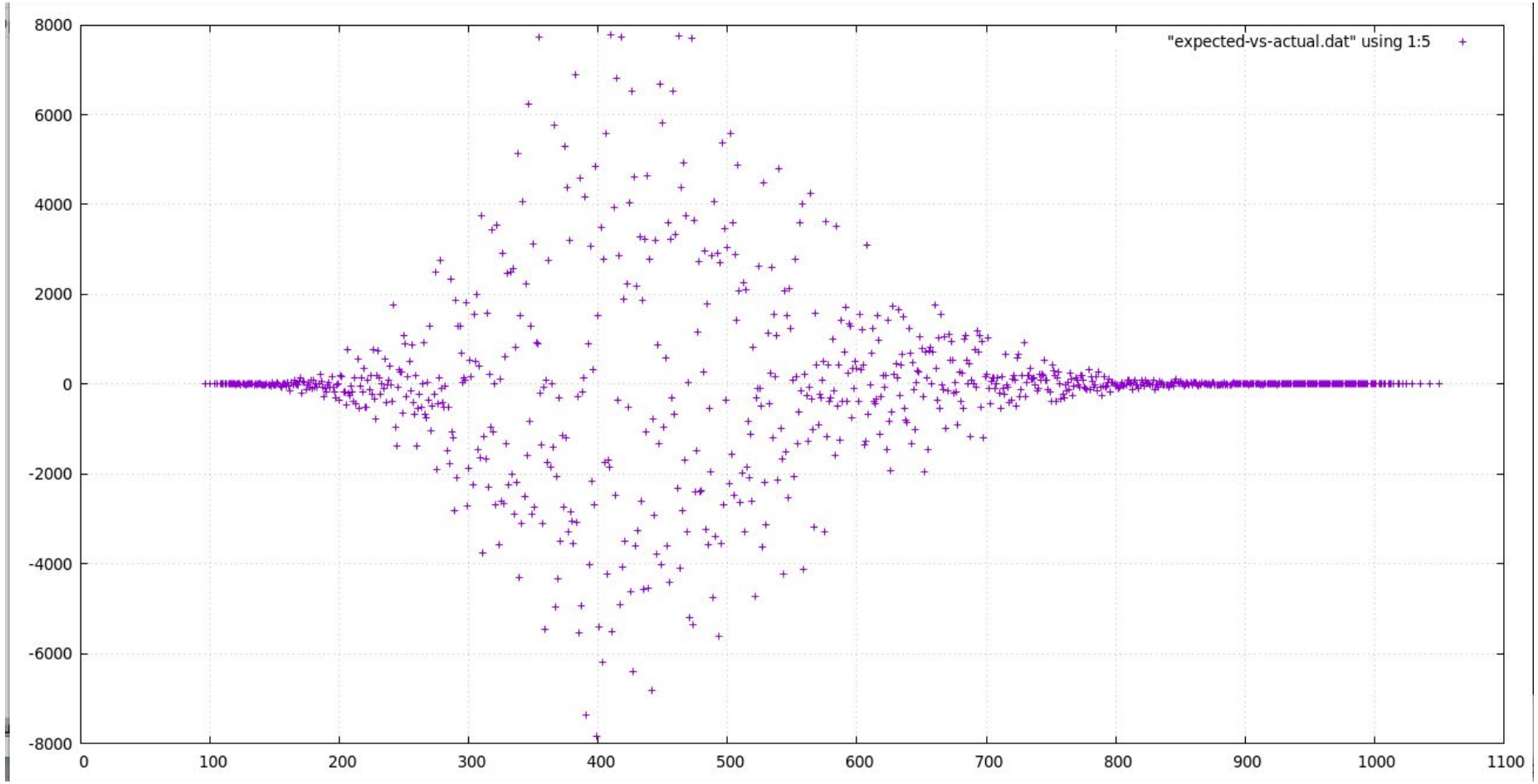


Finding extremal seeds

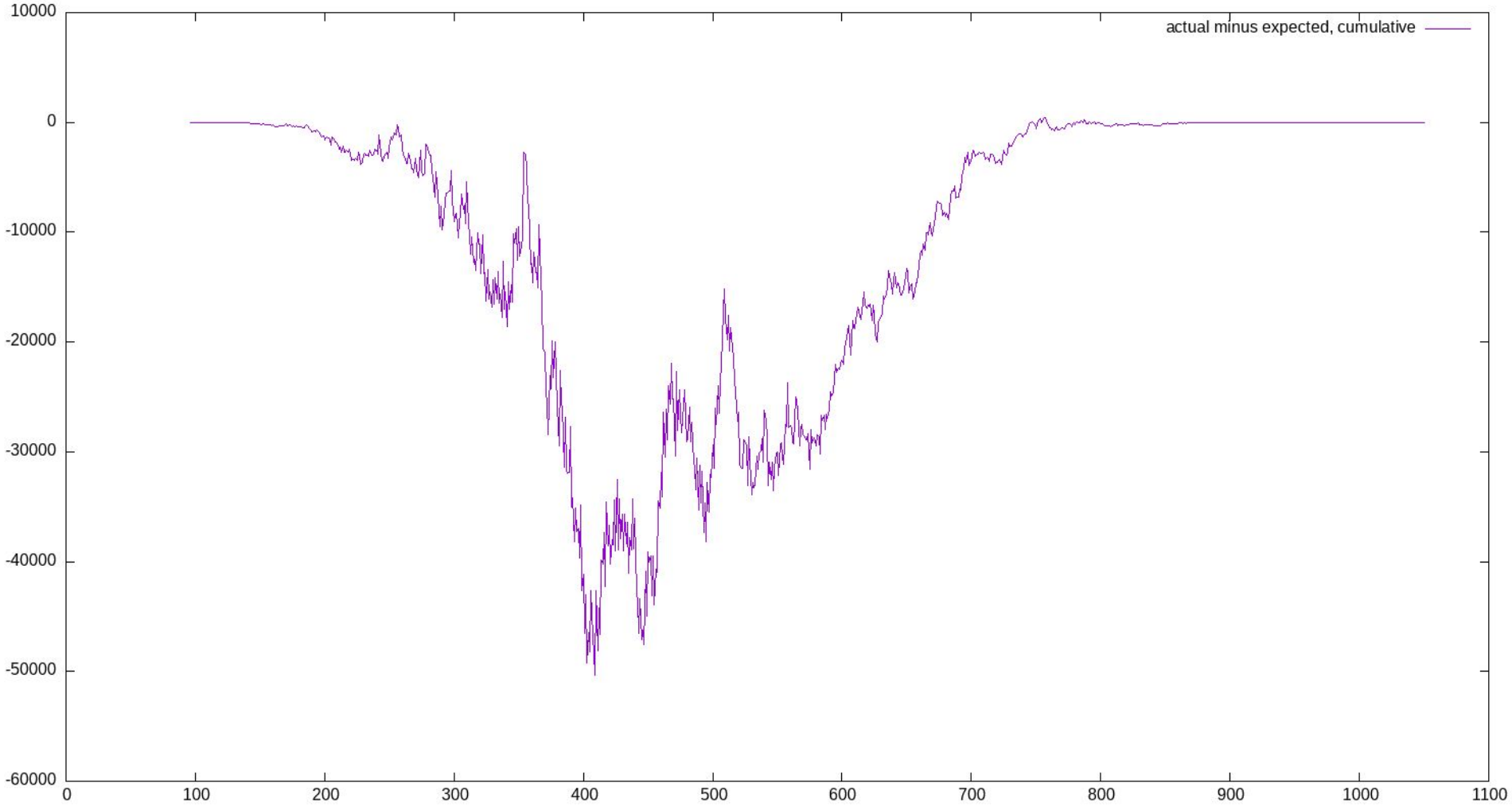
total room area	actual / cumulative	expected cumulative
96-110	0	2
112	2	7
113	4 (6)	9
116	7 (13)	21
117	6 (19)	26
118	5 (24)	30
120	18 (42)	55
121	16 (58)	69
122	11 (69)	82

There seems to be a deficit in how often the smallest areas appear, compared to their expected distribution (in the case where three rooms are gone, so 25% of the sample space.)

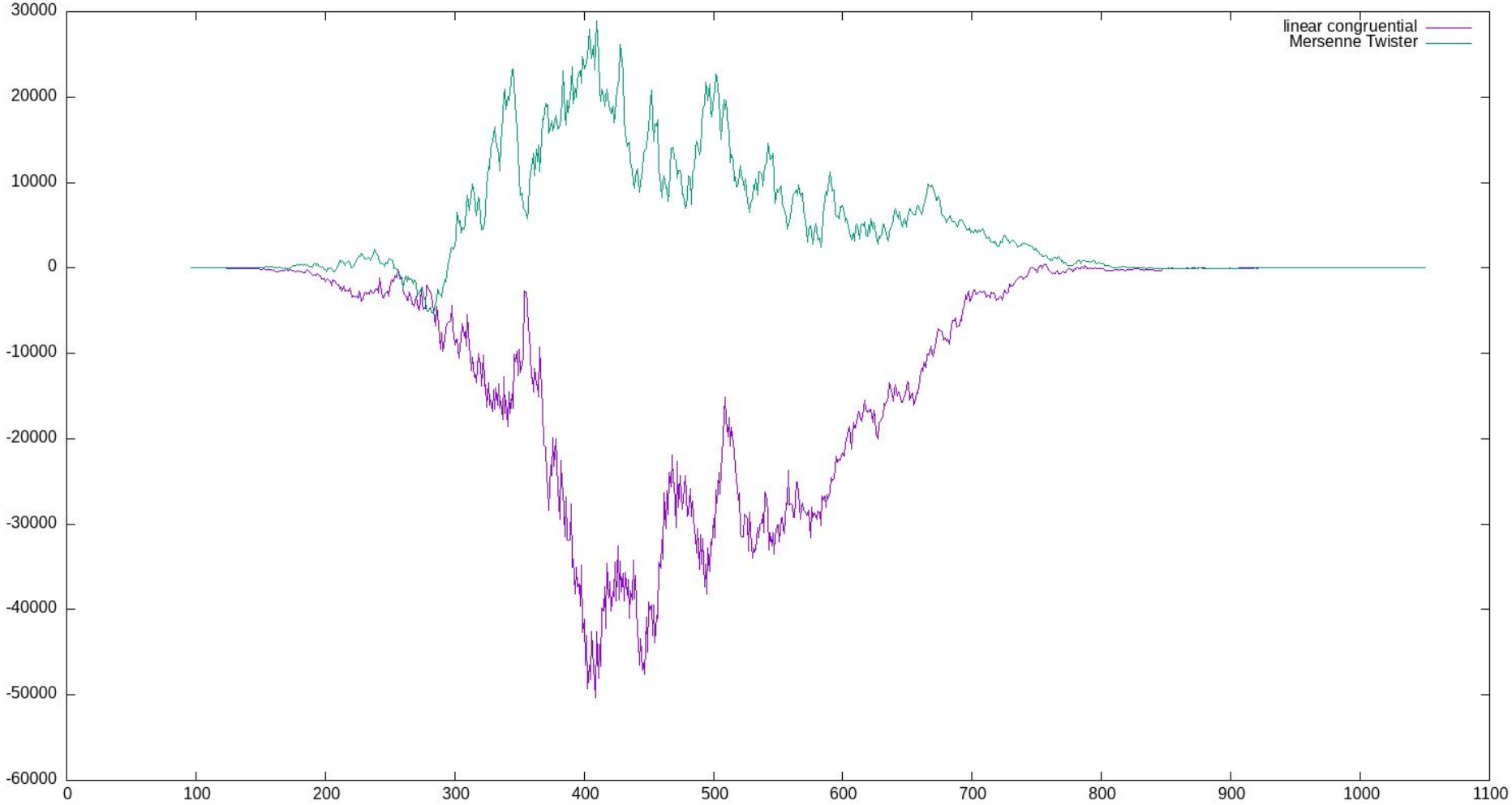
Expected vs. actual (per size)



Expected vs. actual (cumulative)



Expected vs actual (comparison)



What I'd like to find (but haven't)

- Some artifact of the room distribution that I can point to and say "this is because Rogue uses a linear congruential generator."
- Some better visualization of the 36-dimensional space of room configurations

Things to think about

Generators that use 32-bit seeds can be *fully* explored.

- As science!
- As serial art!
- As CYA? !?
- To completely solve a nontrivial roguelike game?

What are other connections between Serial Art and procedural generation?

- I'd love to hear an actual art historian or critic weigh in!

Are there natural examples of games with seeds in the hundreds or millions rather than in the billions?

THANK YOU!

2020 Roguelike Celebration speaker

On Mastodon: `@markgritter@mathstodon.xyz`
On Bluesky: `@markgritter.bsky.social`
On Github: `mgritter/rogue-room-generation`
In Real Life: Principal Engineer at thirdlaw.io

More Sol LeWitt! at NYMOMA and SFMOMA

Things to think about (2)

Building a solver for real roguelike games– could easily "reconstruct" the seed by mistake. :(

- Once we have seen as little as 3 rooms, the value of the initial random seed can be determined, which turns the game from a random one into a deterministic one.

S3 storage – about $5/month