WaveFunctionCollapse (WFC)

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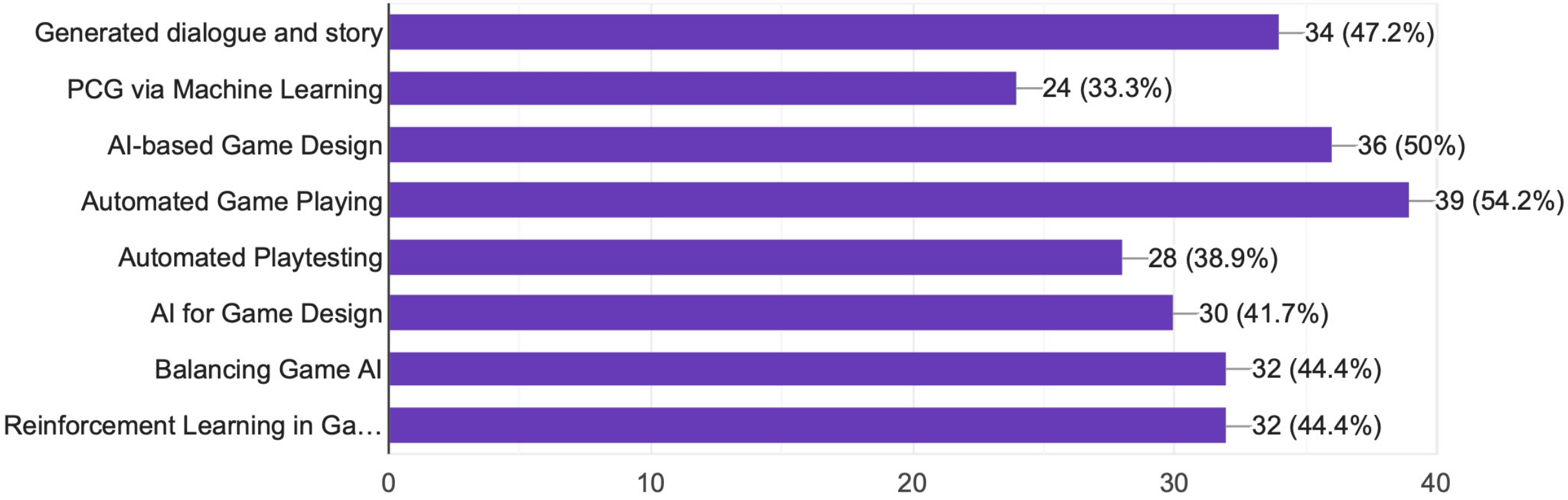
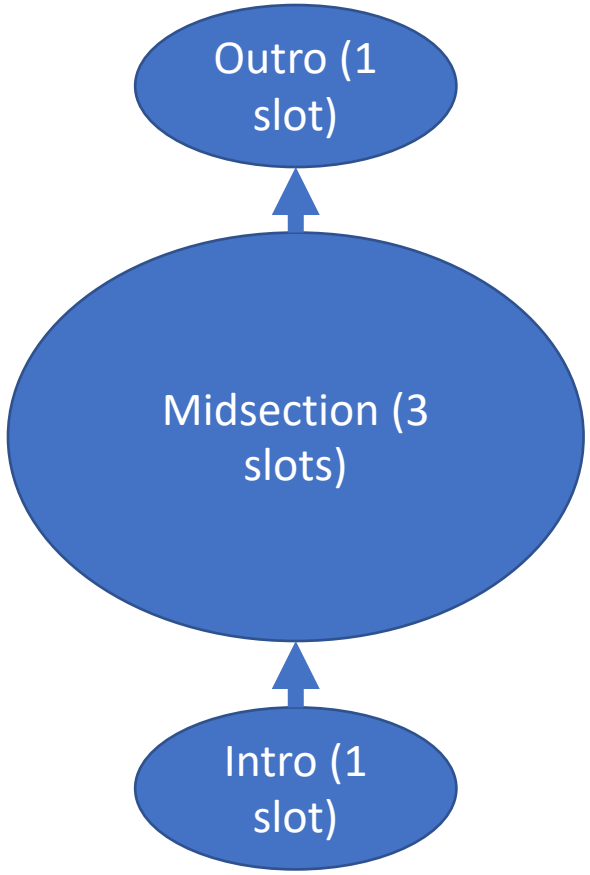
Announcements

- Final PCG topic coverage today
- Monday: wrap-up of PCG topics (maybe touch on some other PCGML topics)
- Future of Game AI topic voting closing soon!*
- Practice Quiz Today
- Quiz 5 on PCG next week

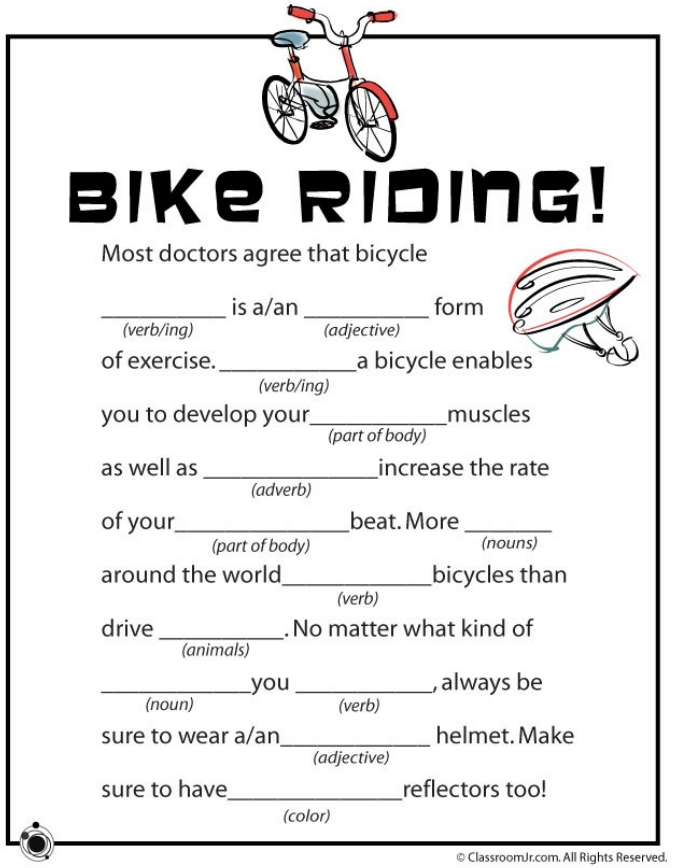
Topic Voting (72/86)



Last Time Review



Perlin Noise



BIKE RIDING!

Most doctors agree that bicycle

_____ (verb/ing) is a/an _____ (adjective) form of exercise. _____ (verb/ing) a bicycle enables you to develop your _____ (part of body) muscles as well as _____ (adverb) increase the rate of your _____ (part of body) beat. More _____ (nouns) around the world _____ (verb) bicycles than drive _____ (animals). No matter what kind of _____ (noun) you _____ (verb), always be sure to wear a/an _____ (adjective) helmet. Make sure to have _____ (color) reflectors too!

Procedural Content Generation Thus Far

We either need to…

- (1) iteratively develop a set of tokens and rules by generating and testing

OR

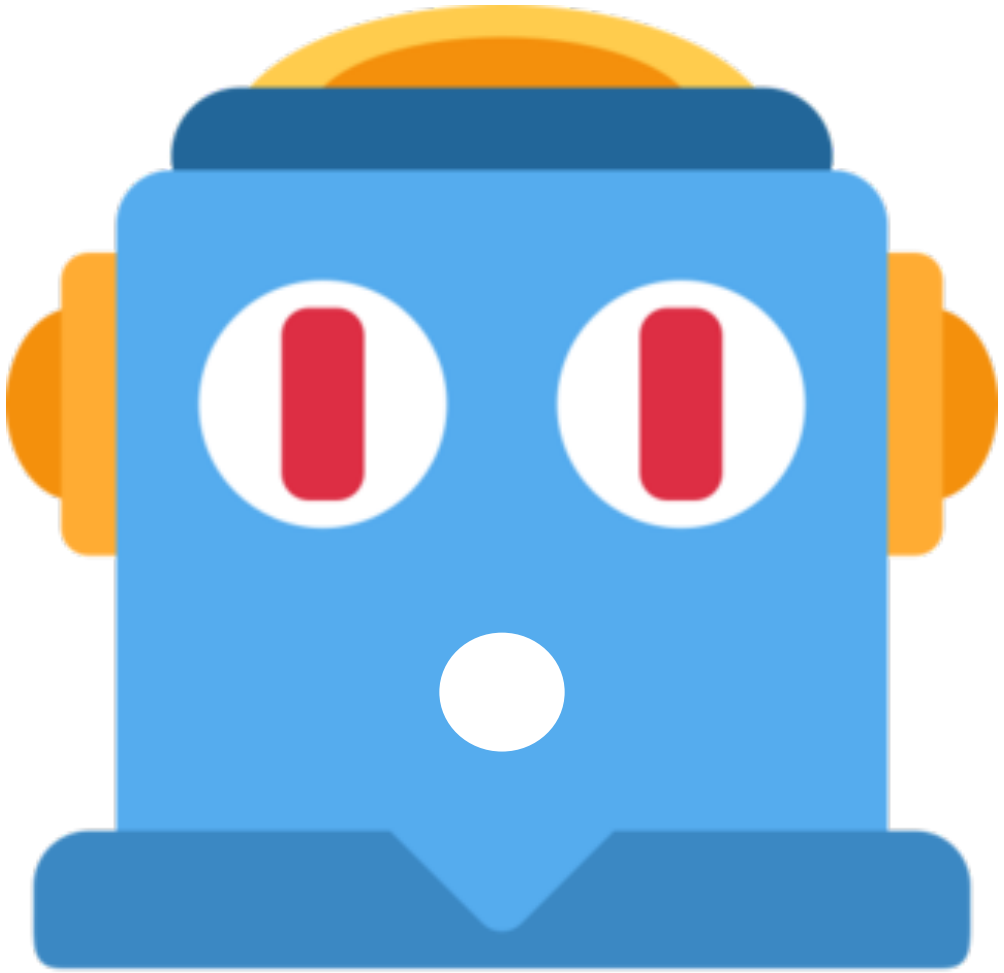
- (2) iteratively develop a way to produce initial random levels, a neighbor function, and a fitness function by generating and testing

This sounds like a lot of work!

“Design Knowledge”

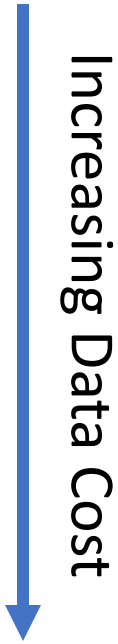
We can think of either of these options as examples of **Design Knowledge**, information about how to design whatever it is we want to generate.

Intuition: What if instead of trying to author the design knowledge for PCG, we had an AI learn it.



PCGML Level Generation Overview

1. Wave Function Collapse
2. Markov Methods
3. Bayesian Networks
4. Long Short-Term Memory Recurrent Neural Networks (LSTMs) and Autoencoders
5. Generative Adversarial Neural Networks (GANs)



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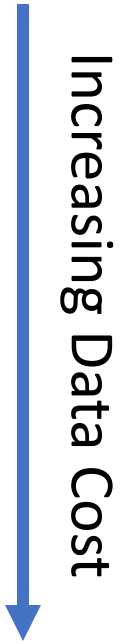
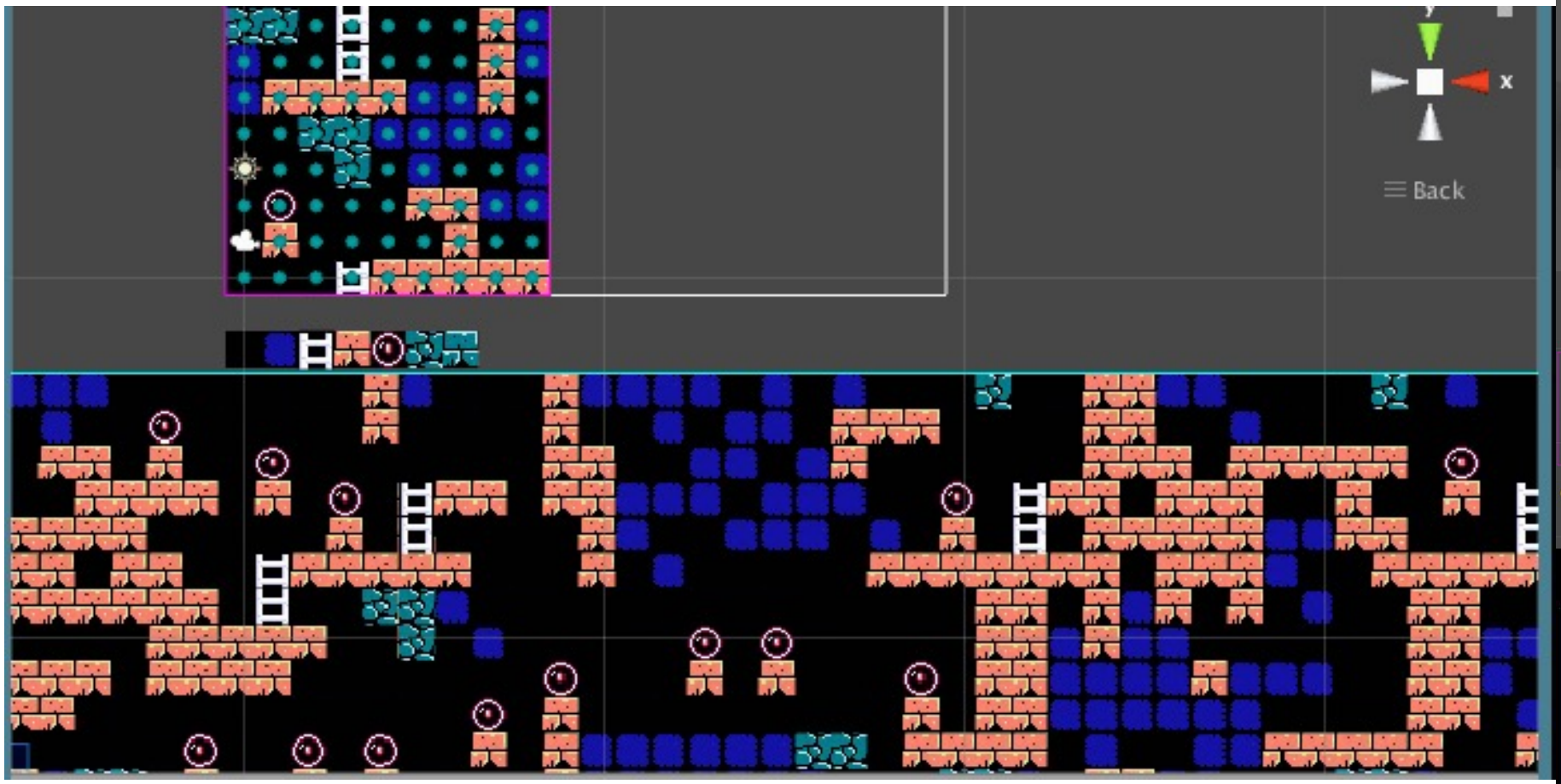
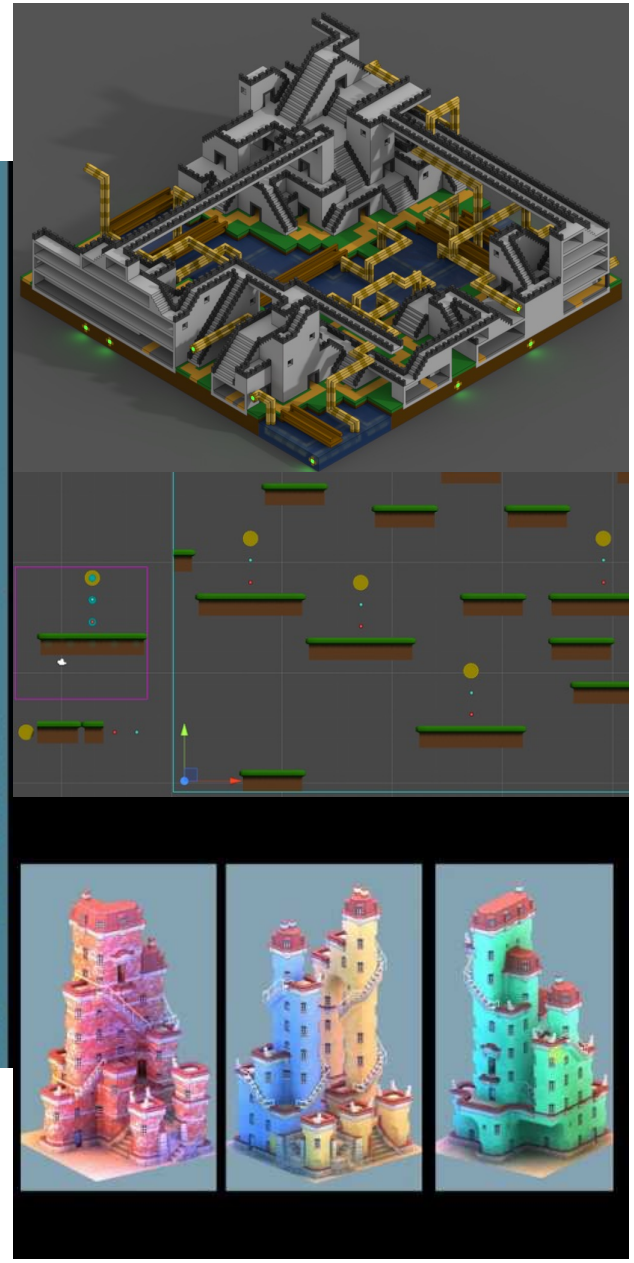


Wave Function Collapse (WFC)





Example: https://www.youtube.com/watch?v=7ffT_8wViBA&feature=emb_title
WFC Tutorial: http://www.procjam.com/tutorials/wfc/

Bad North, 2018

Townscaper, 2020

Caves of Qud, 2015

WFC: How it Works?

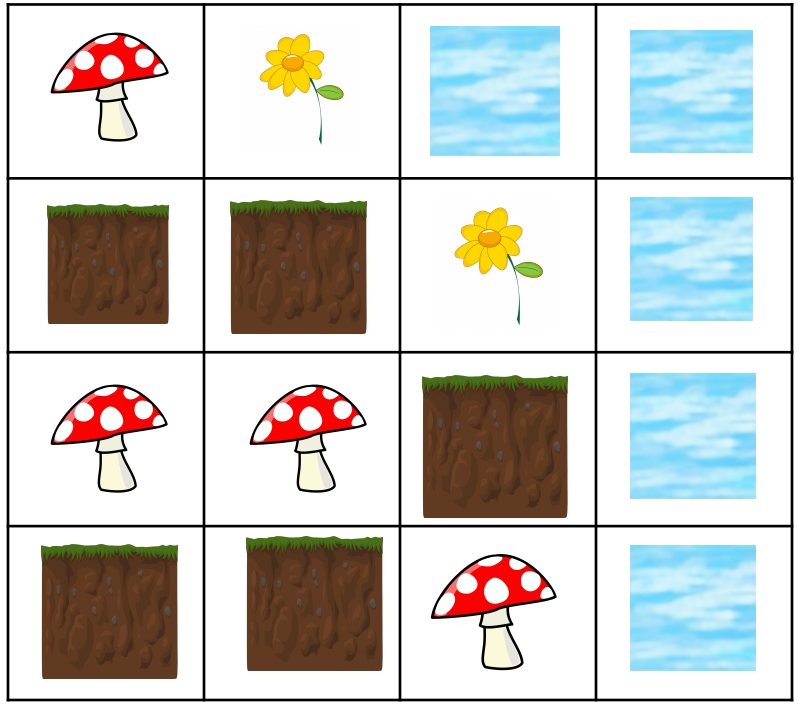
1. Extract constraints from example as X*Y windows.
2. Generate content according to these constraints in a standard CSP.

“Wave Function Collapse is Constraint Satisfaction” (https://adamsmith.as/papers/wfc_is_constraint_solving_in_the_wild.pdf)

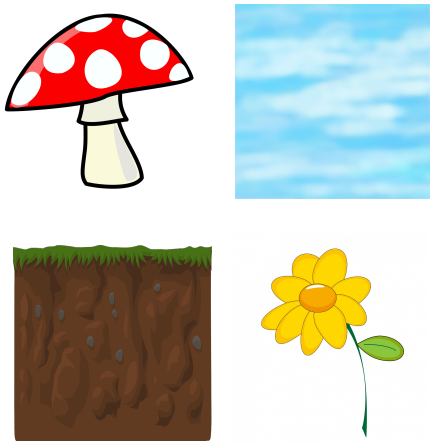
Blog version: https://robertheaton.com/2018/12/17/wavefunction-collapse-algorithm/

CSP Example Step N

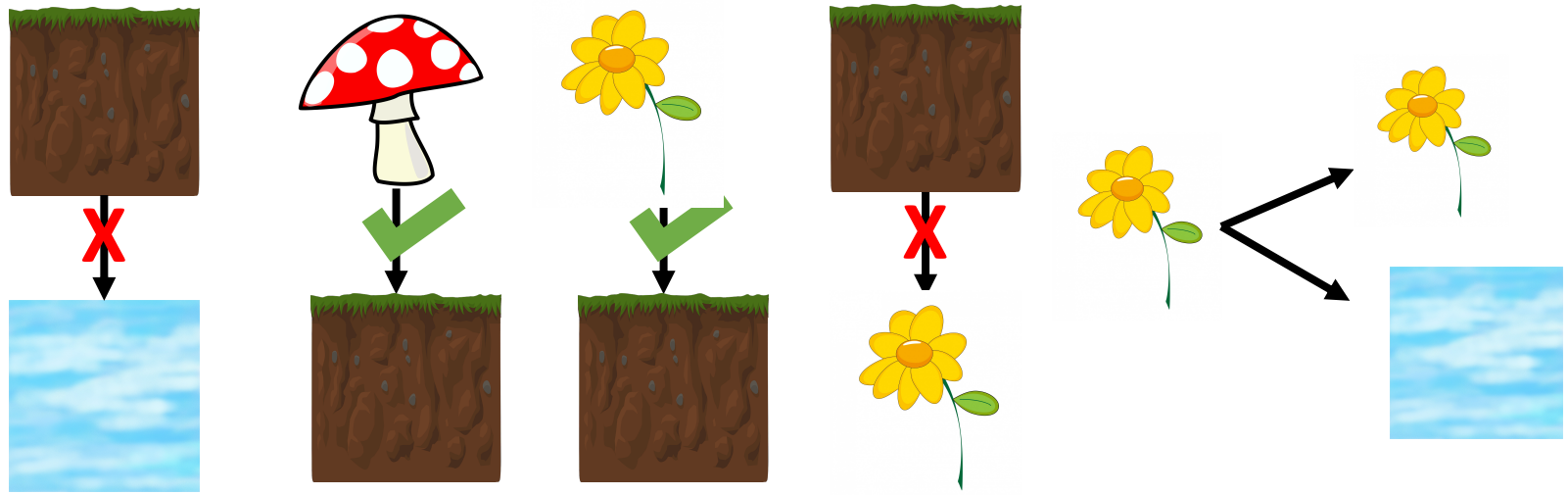
Option 2 (From the Intro)



Tokens

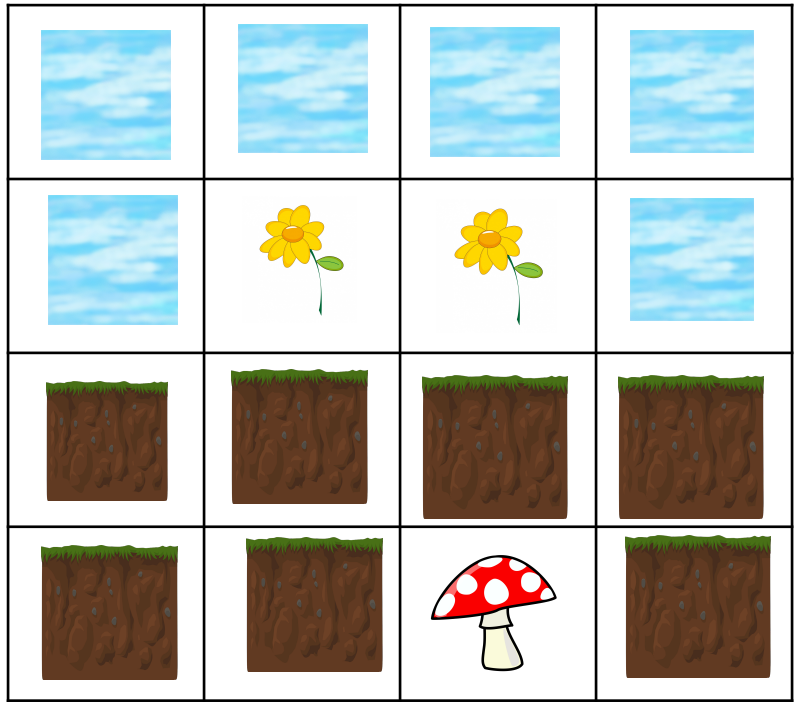


Rules

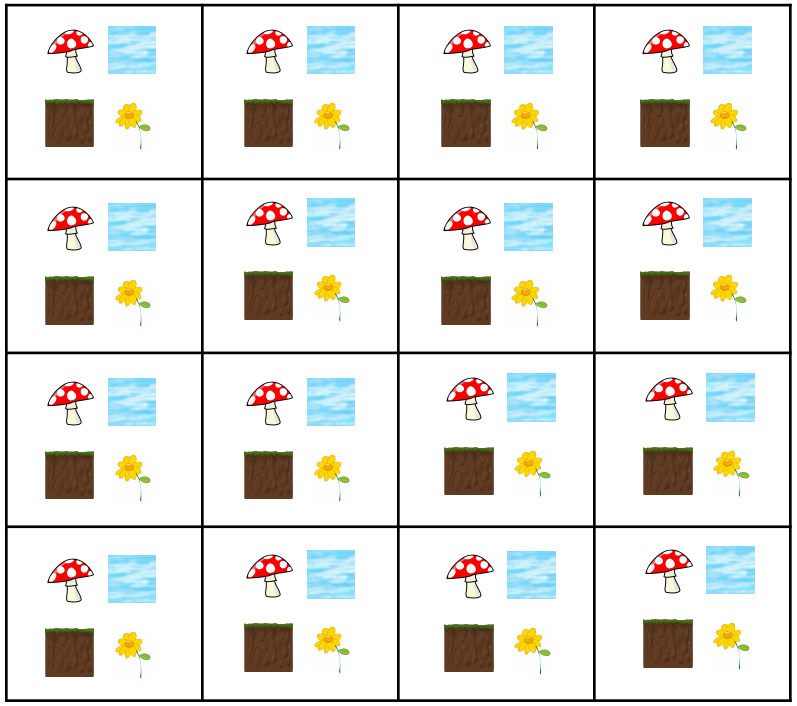


WFC Example
Step 0

Input



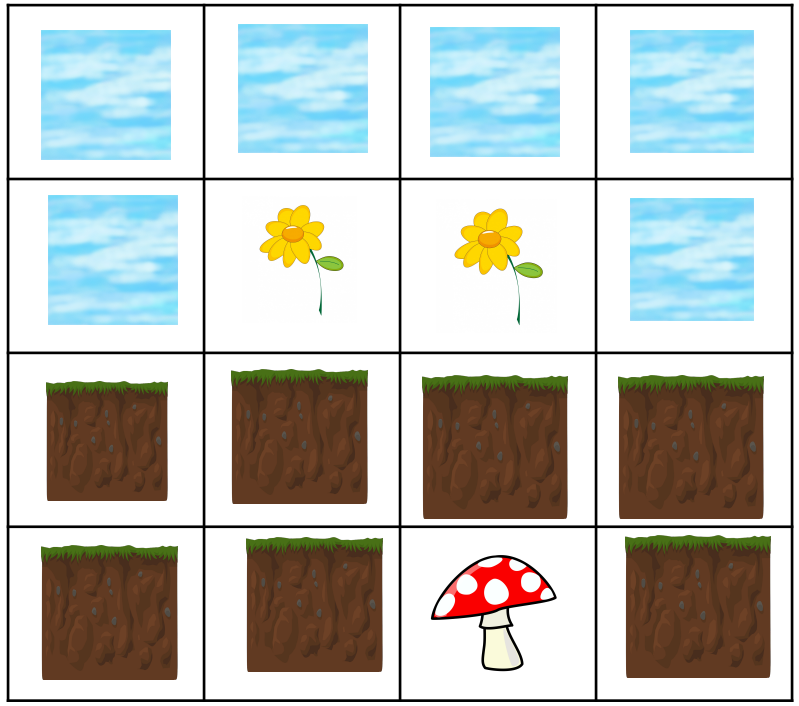
Output



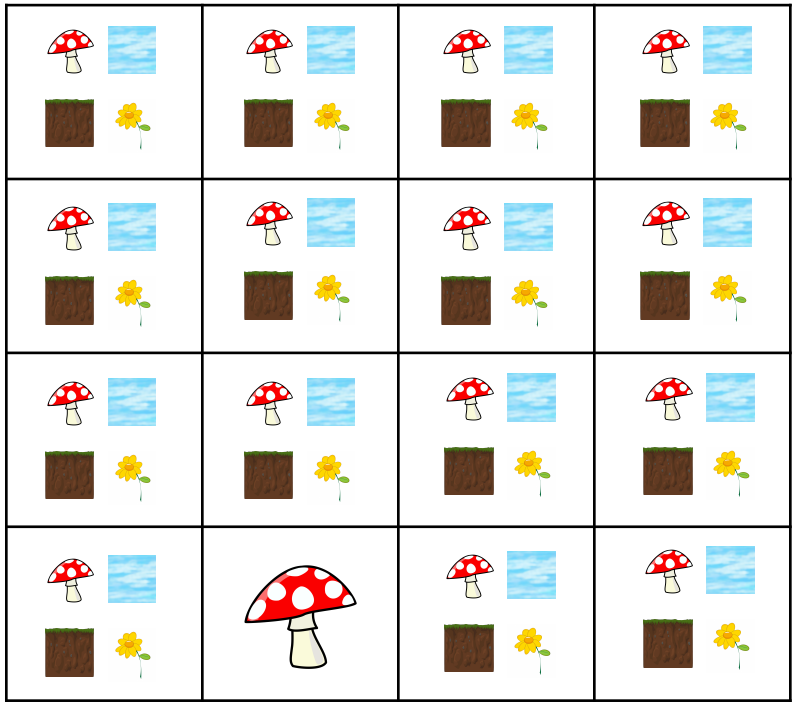
Window size 2 by 2

WFC Example
Step 1: Decision

Input



Output



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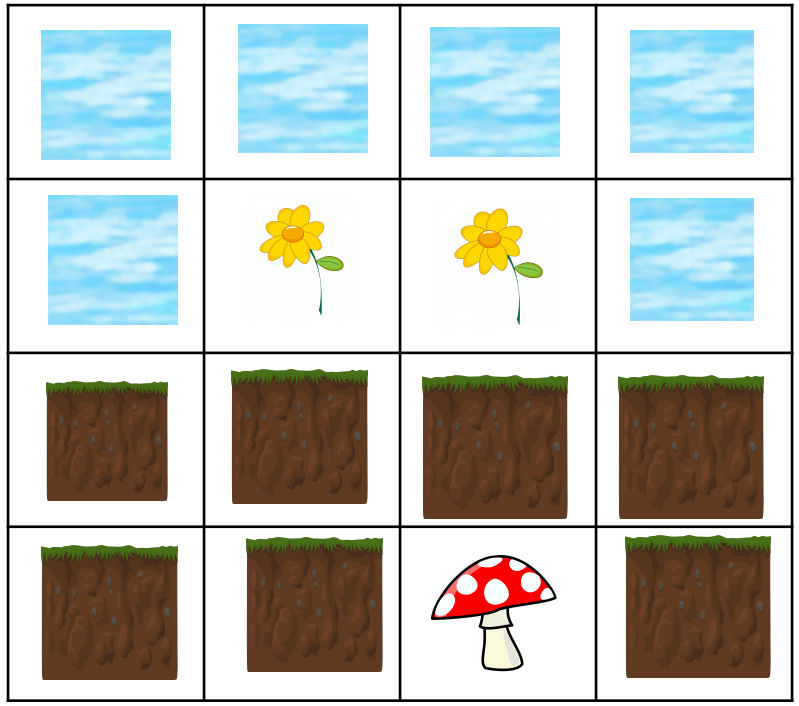
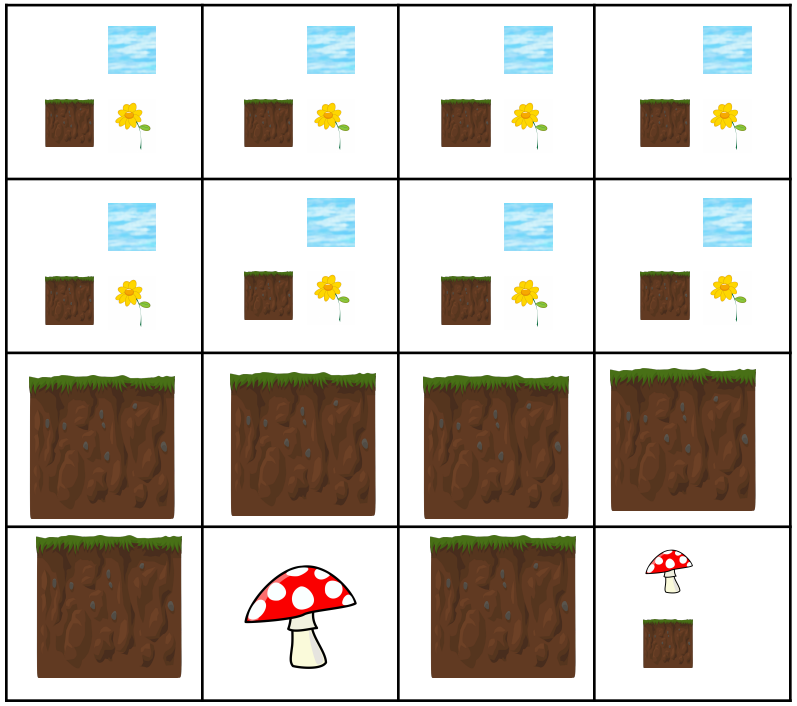
WFC Example
Step 1: Implication

Input



Output



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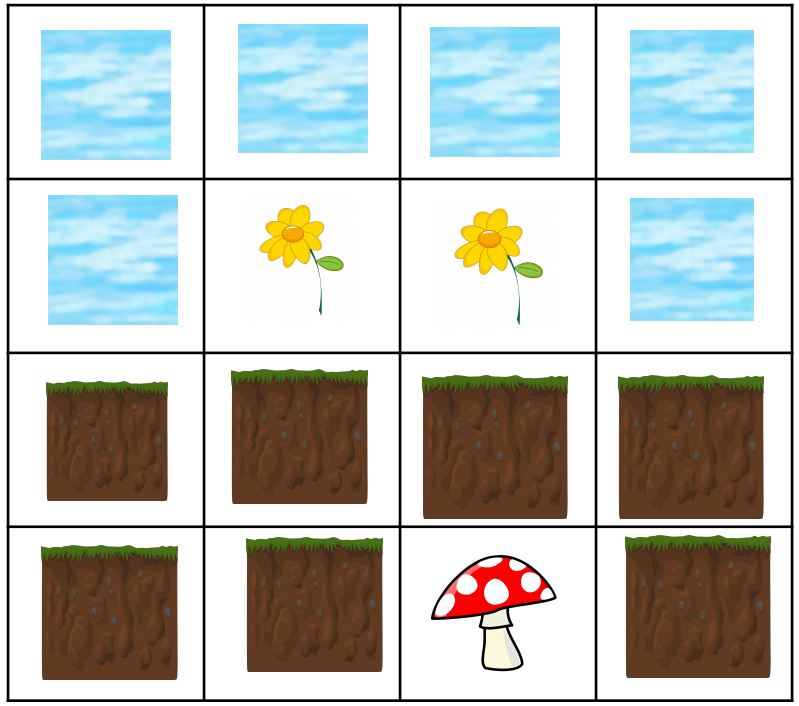
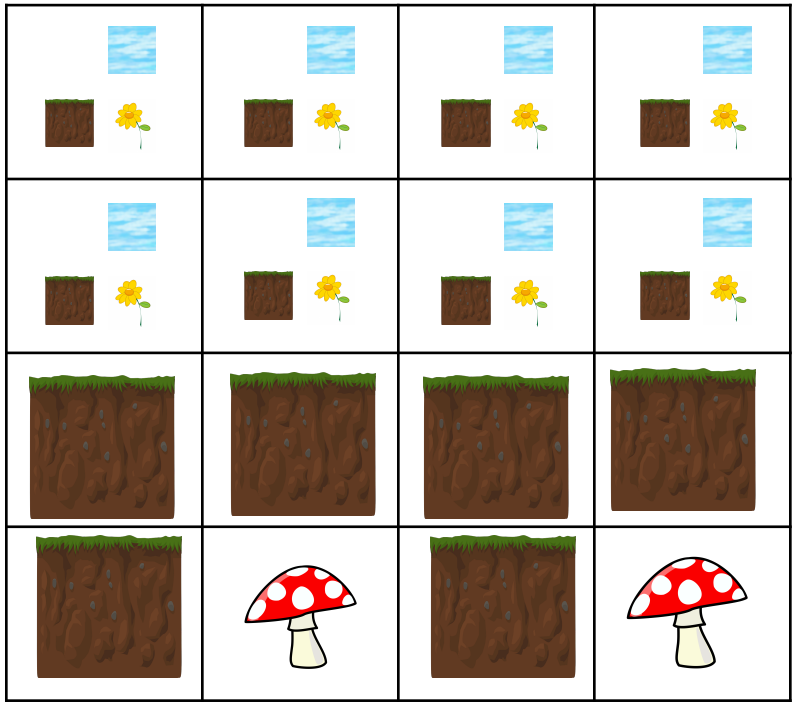
WFC Example
Step 2: Decision

Input



Output



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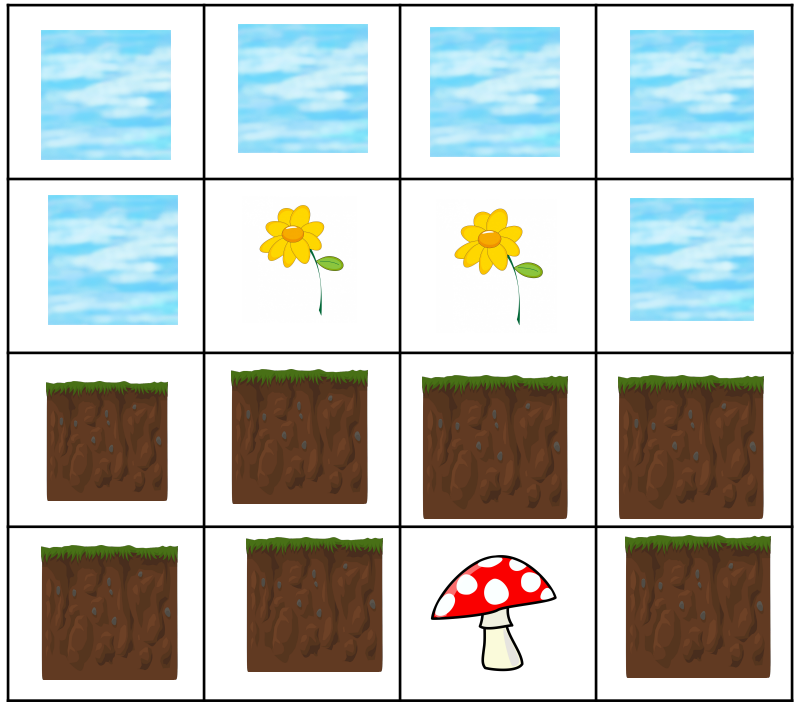
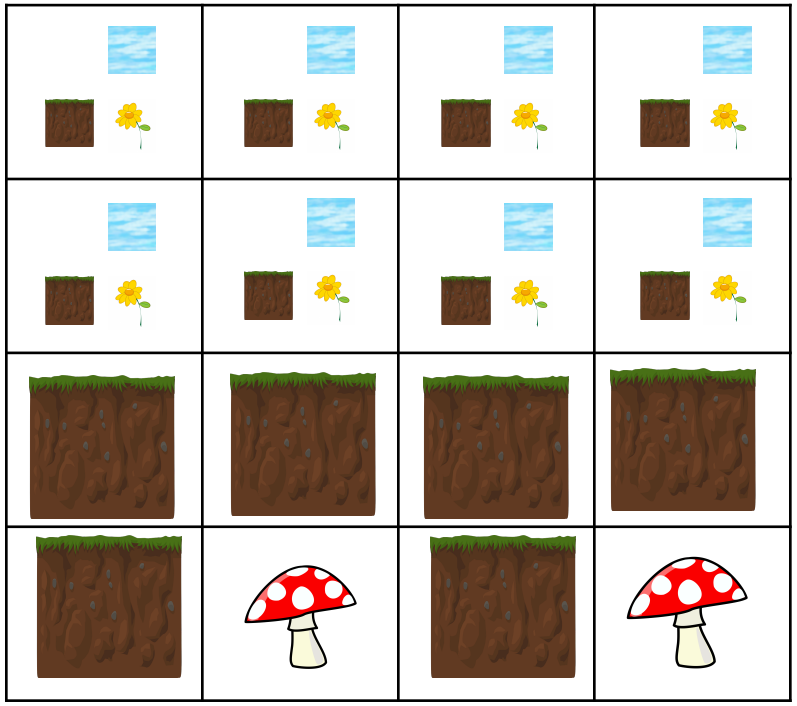
Input



Output



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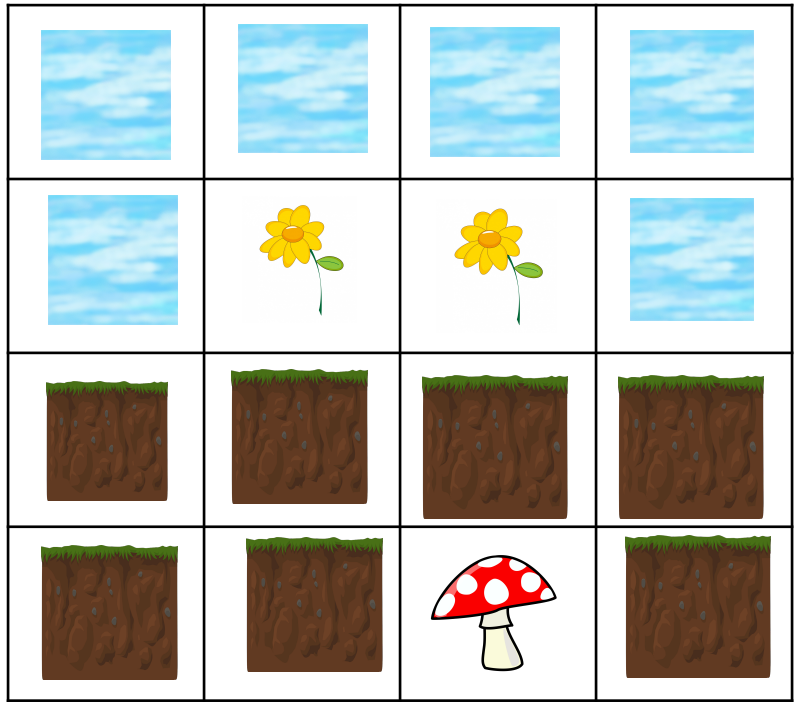
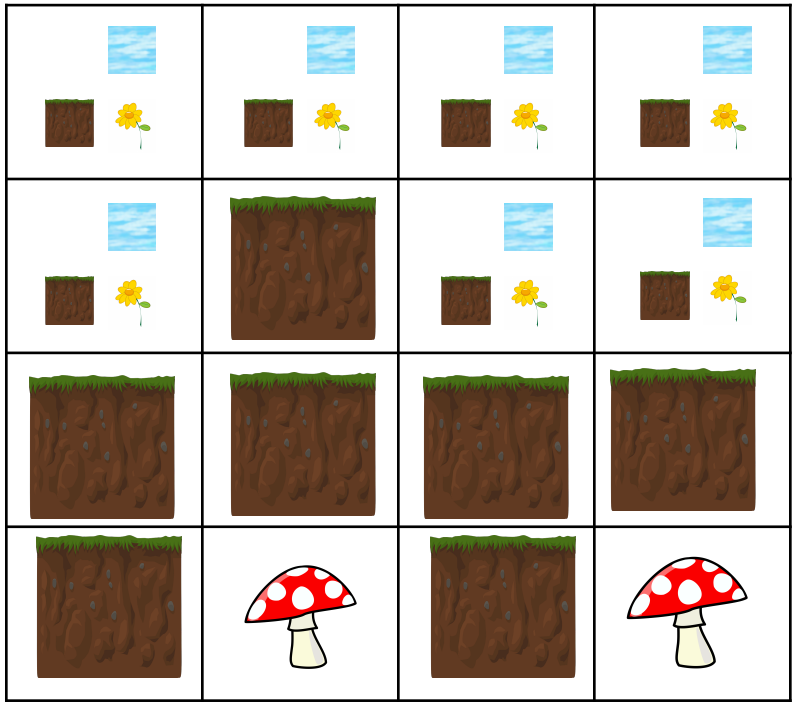
WFC Example
Step 3: Decision

Input



Output



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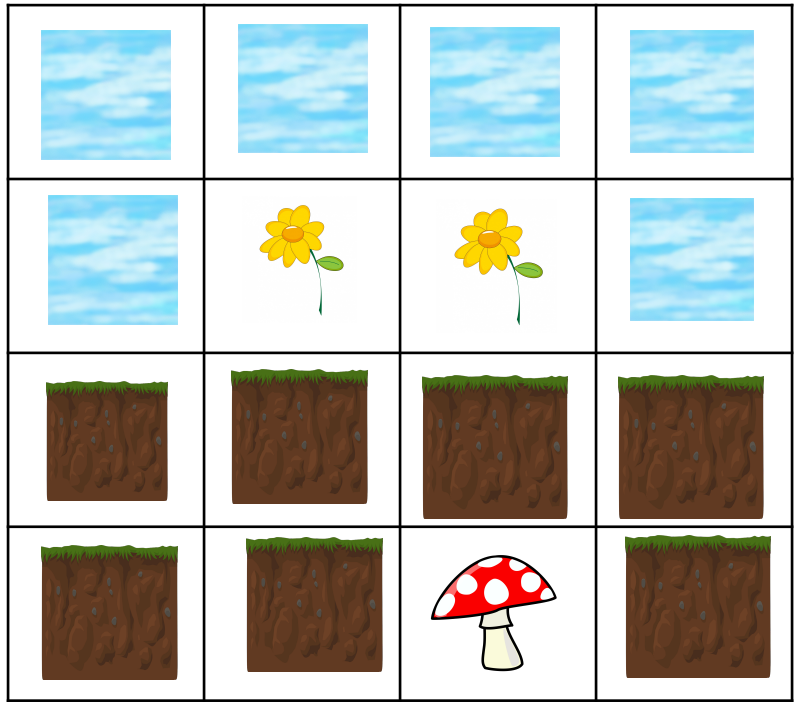
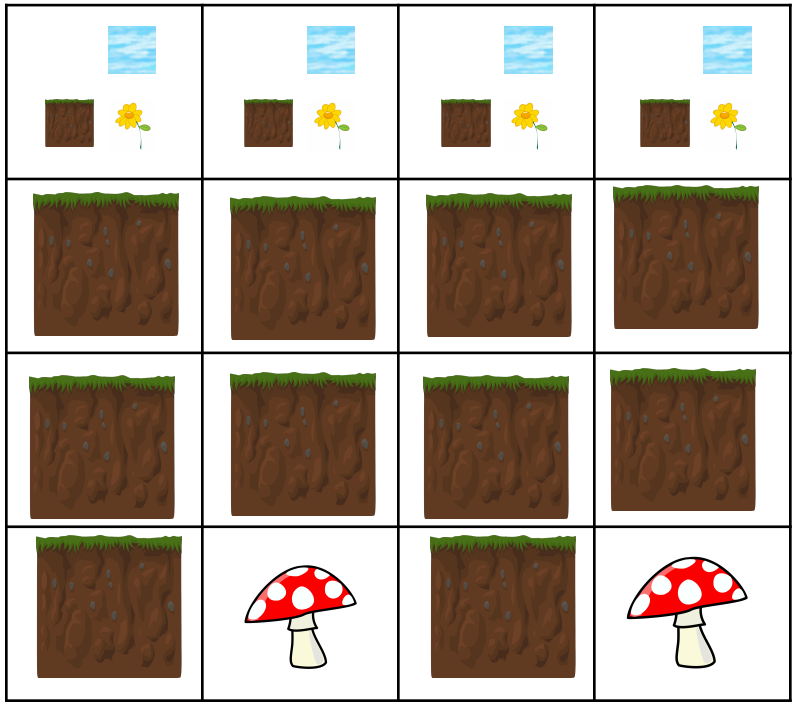
WFC Example
Step 3: Implication

Input



Output



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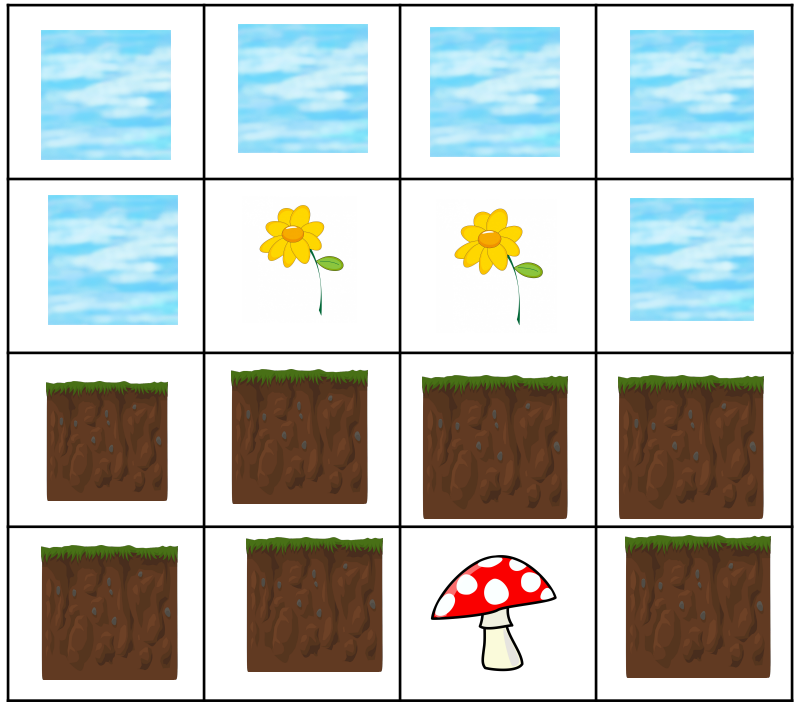
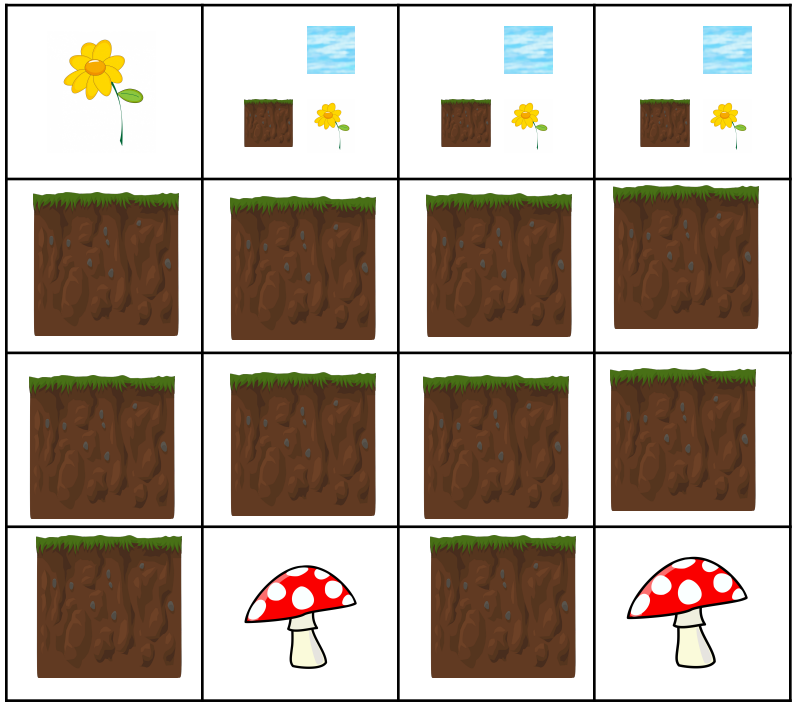
WFC Example
Step 4: Decision

Input



Output



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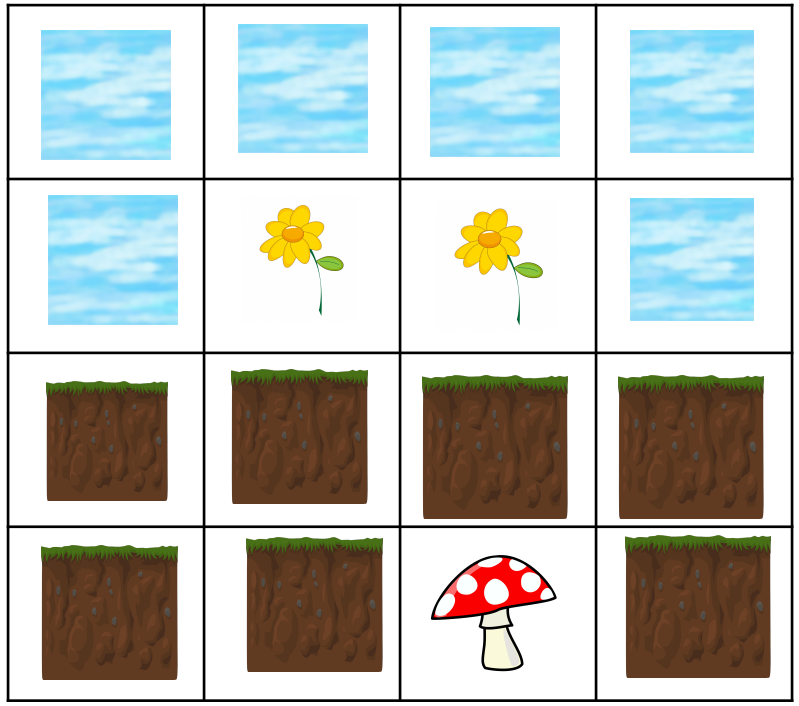
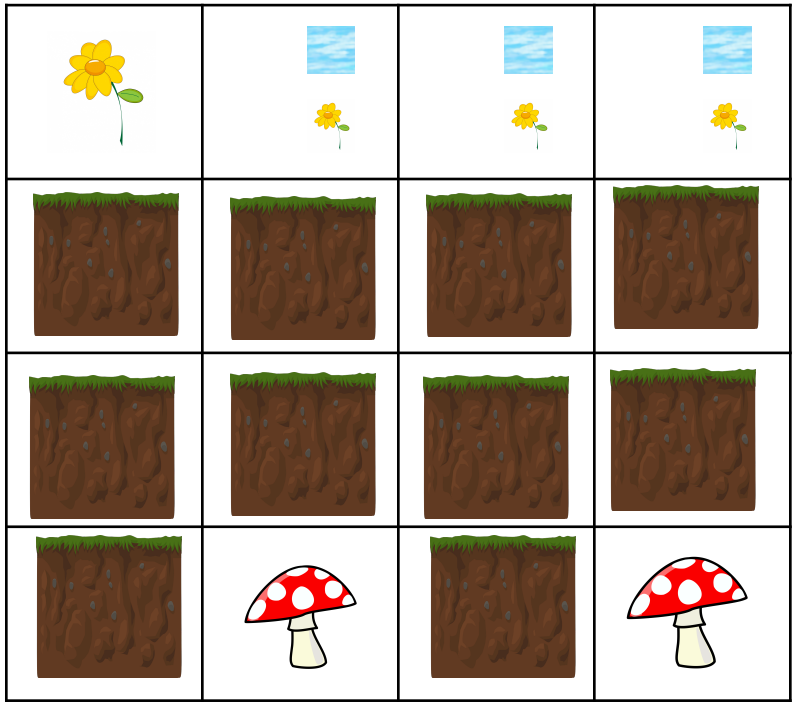
WFC Example
Step 4: Implication

Input



Output



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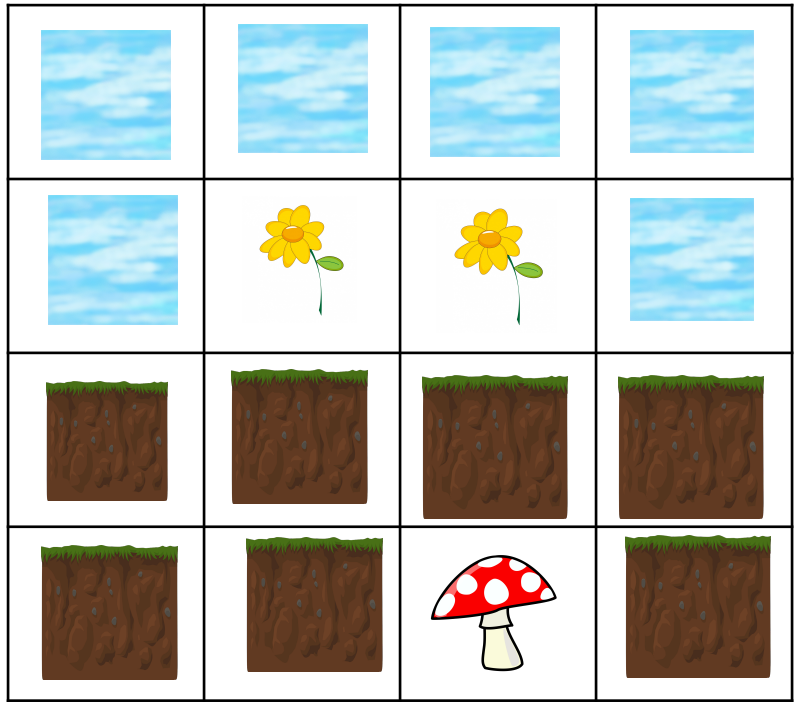
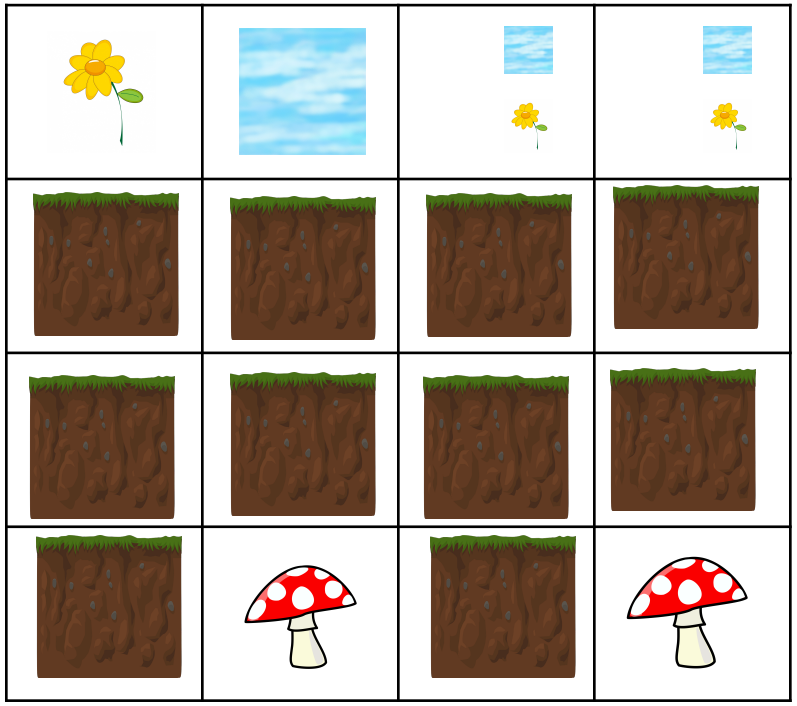
WFC Example
Step 5: Decision

Input



Output



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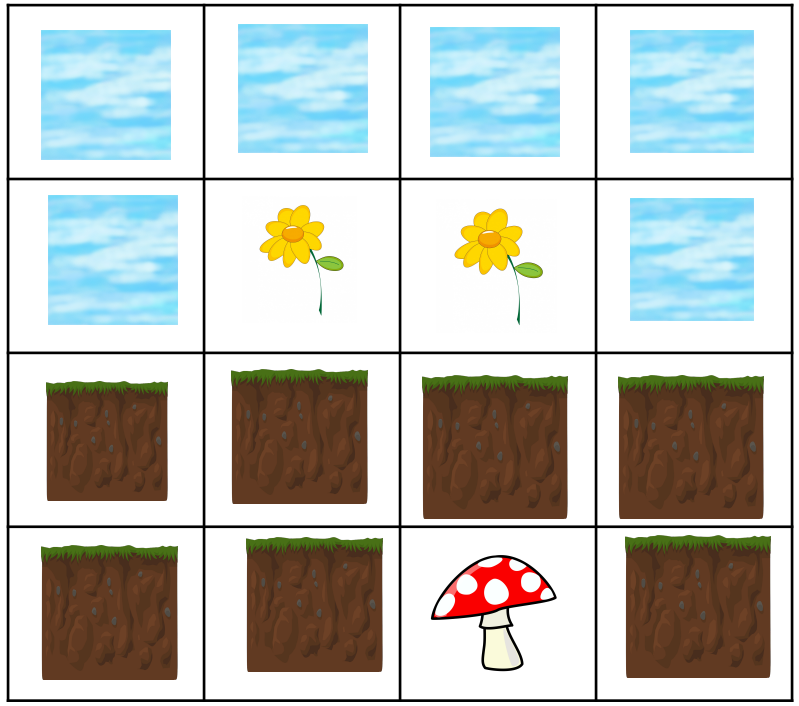
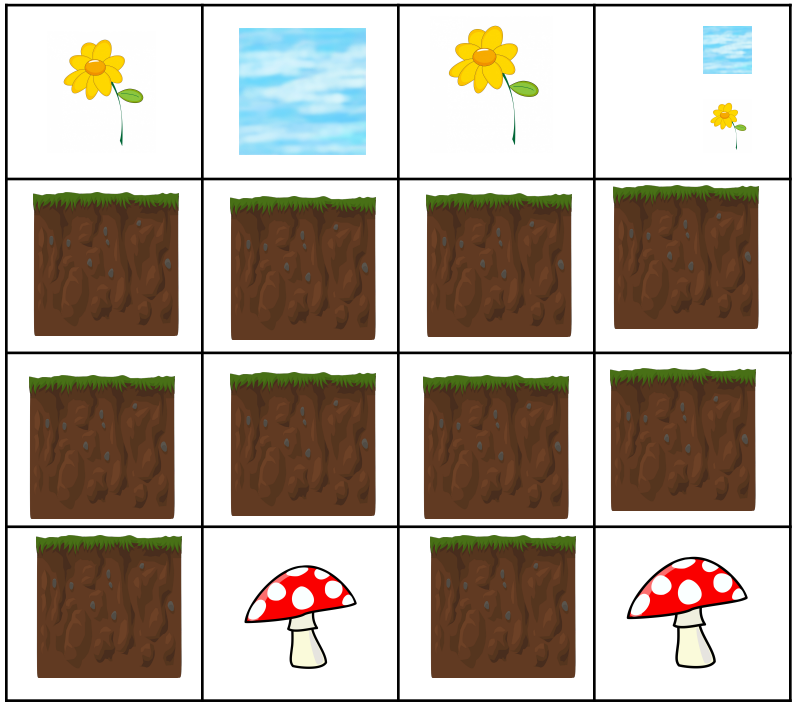
WFC Example
Step 5: Implication

Input



Output



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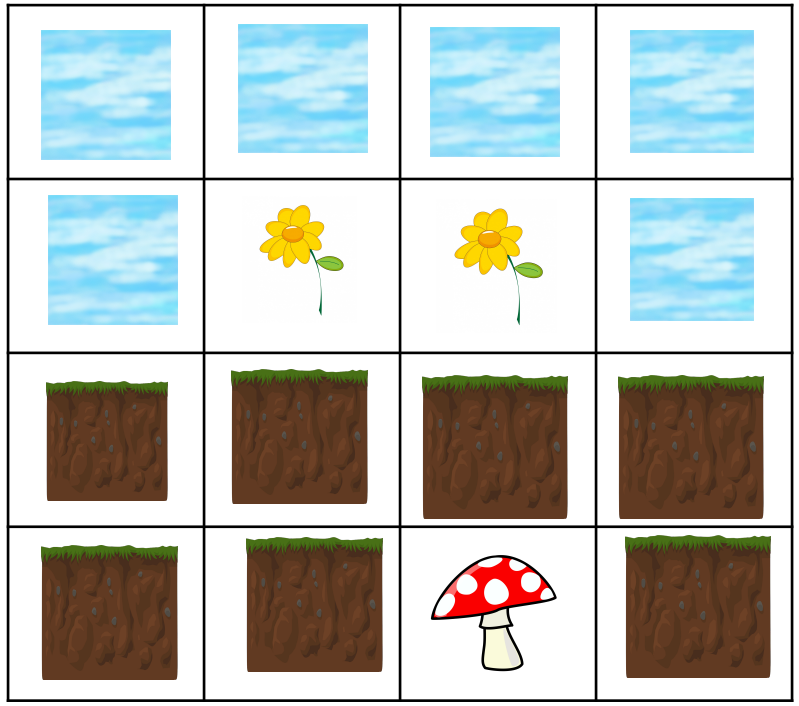
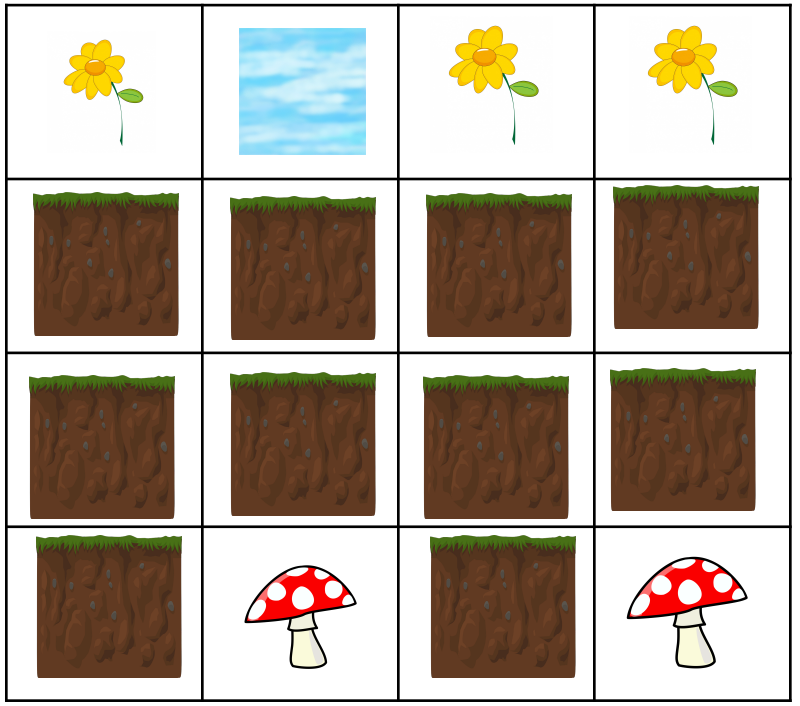
WFC Example
Step 6: Decision (FINAL)

Input



Output



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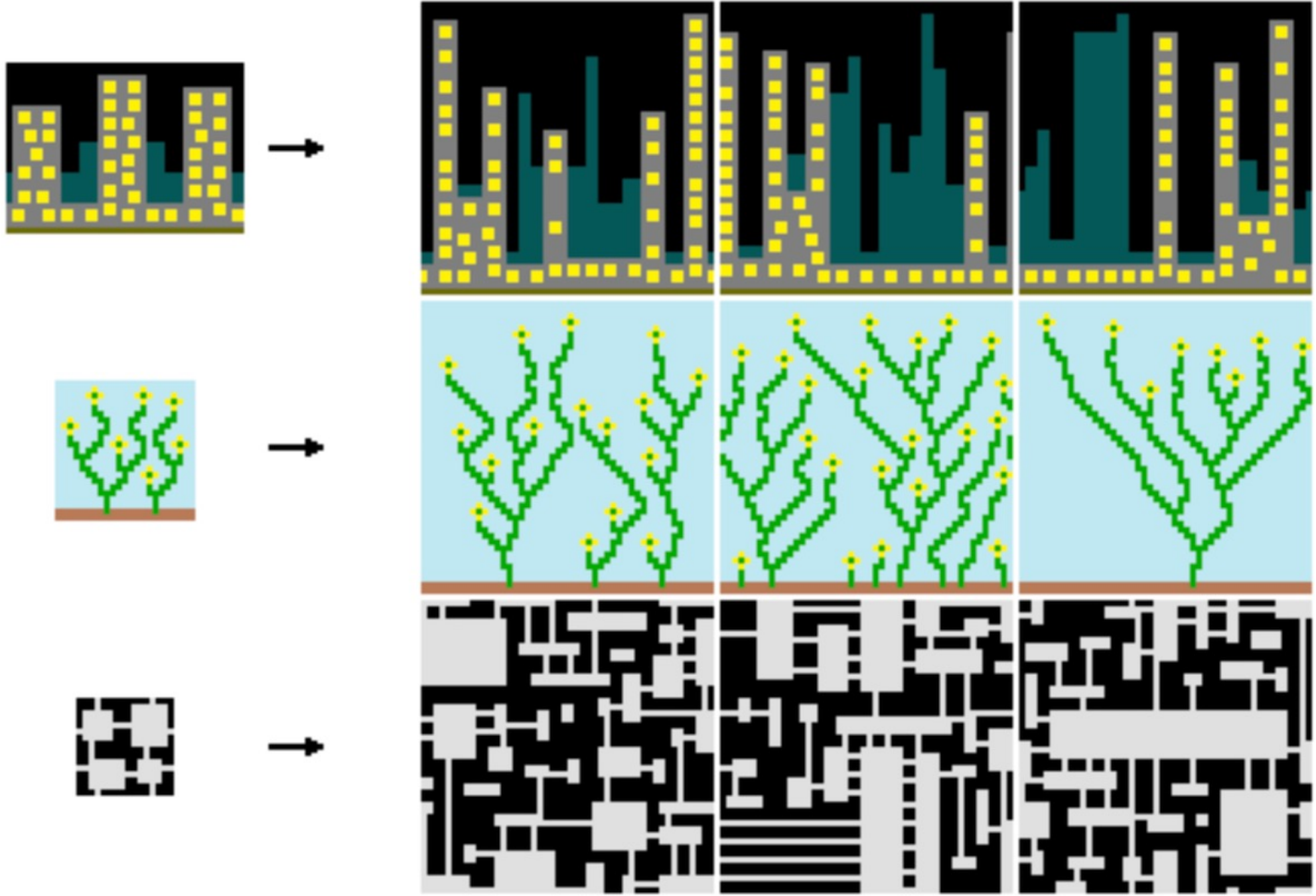

https://adamsmith.as/papers/wfc_is_constraint_solving_in_the_wild.pdf

PQ1 https://tinyurl.com/guz-pq30 https://forms.gle/auyfnfUY6UGGwZn36

Why aren't any other PCGML techniques used in any AAA or indie games?

2. Markov Methods
3. Bayesian Networks
4. Long Short-Term Memory Recurrent Neural Networks (LSTMs) and Autoencoders
5. Generative Adversarial Neural Networks (GANs)

My Answers

- Lack of training data.
- Lack of expertise/resources.
- Want high quality output that feels handmade, not the “average” of the training data.
- Training ML models like this doesn’t fit with game development cycle.

Unity Example

Code by Joseph Parker

https://selfsame.itch.io/unitywfc

Wave Function Collapse Problems

- **Controllability**: Since constraints are learned, its possible the wrong or insufficient constraints will be learned.
  - Caves of Qud designer Jason Grinblat used an additional pass to check the generated levels for correctness.
- **Complexity**: People don't tend to think about design as being based on a series of X*Y windows.

Caves of Qud, 2015

Practice Quiz

https://forms.gle/wpzs3tfirDaCMc3K8

https://tinyurl.com/guz-quiz5

1. Which of the following <u>cannot</u> be represented as a grammar?

   A. English Language
   B. Music
   C. Ikea Self-Assembly Furniture
   D. All of the above can be.

2. What PCG approach(es) would be best for a game about raising creatures, where the player needs to be able to either find a variety of generated creatures out in the wild or “combine” two creatures together to make something new? Why?
3. Let’s say you’re trying to generate an enemy, represented as HP: (0-100) and size (1,2,or 3). You randomly start with an enemy with HP=1 and size =3. Imagine you have a fitness function that returns 1 when the HP=size*33. Imagine you have a neighbour function that adds or subtracts 1 from HP or size. What would the output enemy (HP and size) be using greedy search?
4. How would you prefer to spend the majority of Monday’s lecture?

Practice Quiz Answers

1. D
2. Grammar and/or Genetic Algorithm acceptable, depending on the “Why” given.
3. HP=33, Size=1
4. You tell me!