

# **Punch Out Model Synthesis**

A Stochastic Algorithm for Constraint Based Tiling Generation

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November 19th, 2024

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# Introduction

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# Introduction

## Punch Out Model Synthesis (*POMS*)

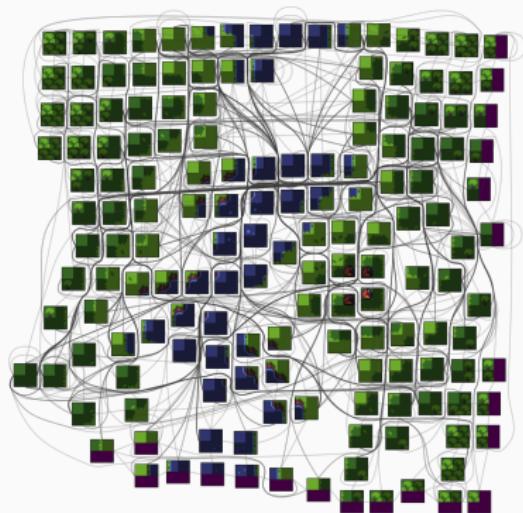
A Constraint Based Tiling Generation (*CBTG*) algorithm:

- Can work on large grids
- Minimal initial setup requirements
- Contradiction resilience via stochastic backtracking

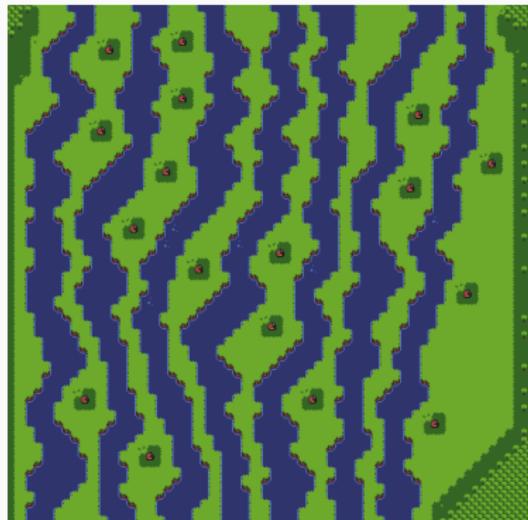
# Introduction

Constraint Based Tiling Generation (*CBTG*)

**Given Constraints**



**Find a Realization**



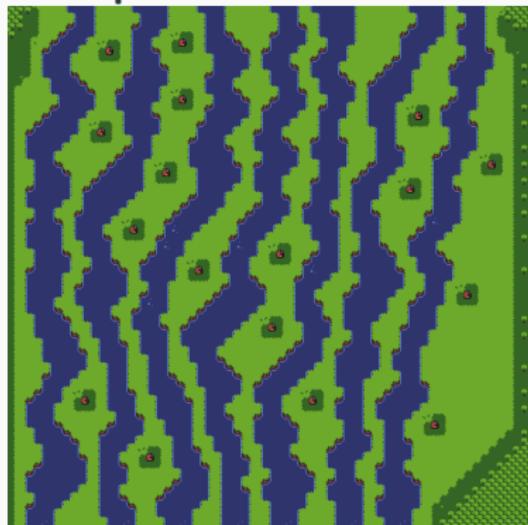
# Introduction

## Constraint Based Tiling Generation (*CBTG*)

### Definitions

- *Grid* composed of *cells*

### Example



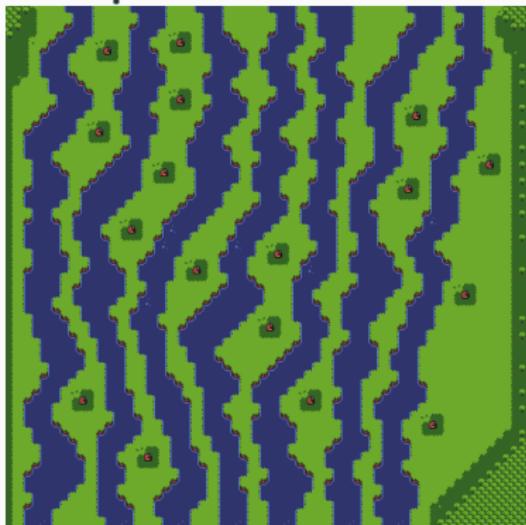
# Introduction

## Constraint Based Tiling Generation (*CBTG*)

### Definitions

- *Grid* composed of *cells*
- Each *cell* can hold  $D$  *tiles*

### Example



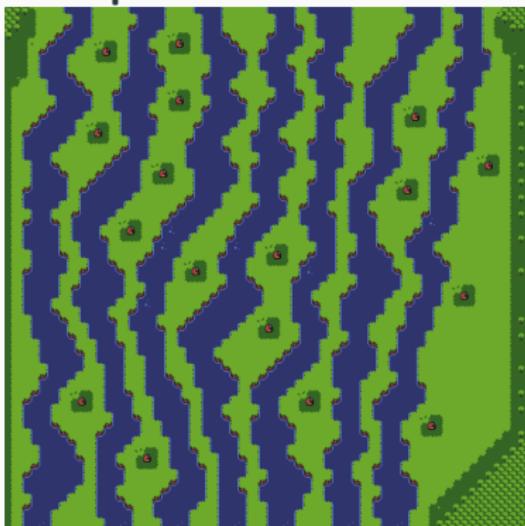
# Introduction

## Constraint Based Tiling Generation (CBTG)

### Definitions

- *Grid* composed of *cells*
- Each *cell* can hold  $D$  *tiles*
- Pairwise tile *constraints* in each dimension  
 $(\pm X, \pm Y, \pm Z)$

### Example



# Introduction

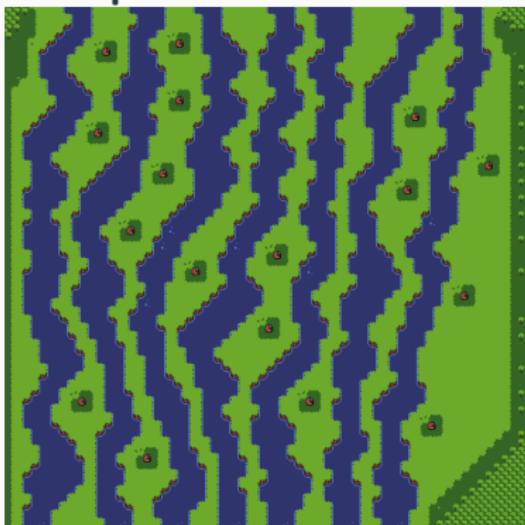
## Constraint Based Tiling Generation (CBTG)

### Definitions

A *realization* is a *grid* that has a single *tile* at each *cell* respecting the *constraints*.

If a cell has no tiles left, no realization is possible and is considered a *contradiction*.

### Example



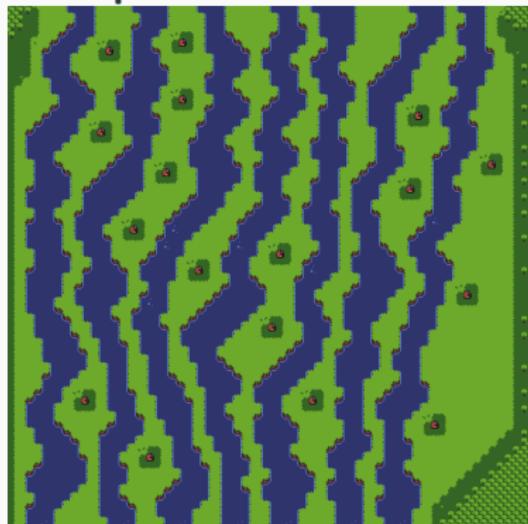
# Introduction

## Constraint Based Tiling Generation (*CBTG*)

### **CBTG Problem**

Find a valid grid realization

### **Example**



# Introduction

## Definitions

- A tile has *support* if there's a valid neighbor in each grid dimension direction
- A region is *Arc Consistent* if all *tiles* within the region are *supported*

## Example



# Introduction

## Definitions

The basis for a *Constraint Propagation* algorithm can be made by removing *unsupported tiles* from a *cell's domain*

## Example

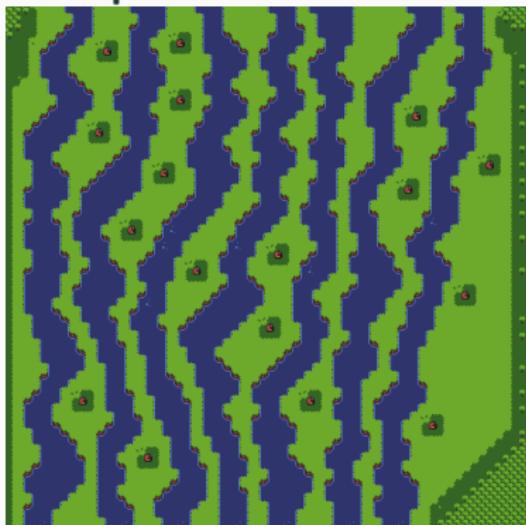


# Introduction

## Definitions

- *Block Level Solver:*  
completely maintains *Arc Consistency*

## Example

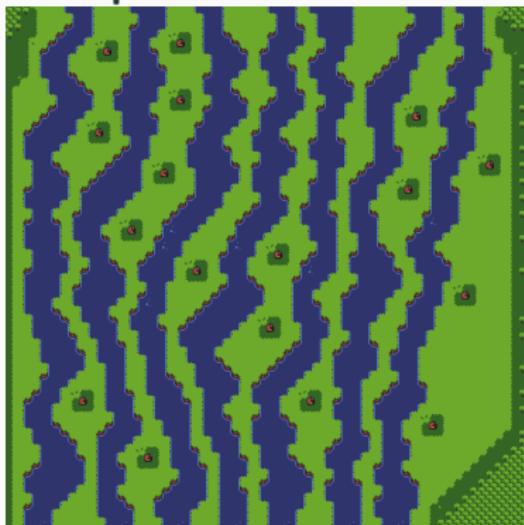


# Introduction

## Definitions

- *Block Level Solver:*  
completely maintains *Arc Consistency*
- *Grid Level Solver:*  
only keep summary  
information for the entire  
grid but work on *block*  
sub-regions

## Example



## Related Work

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## Related Work

WFC, BMS, MMS

- Gumin's *Wave Function Collapse* (*WFC*)
- *Breakout Model Synthesis* (*BMS*)  
(Hoetzlein's *just\_math* project)
- Merrell's *Modify in Blocks Model Synthesis* (*MMS*)

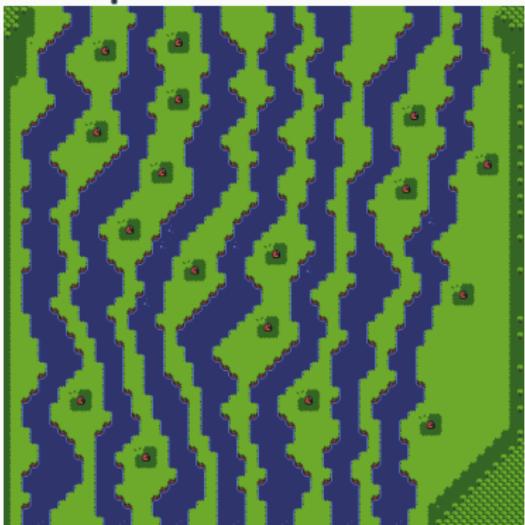
# Related Work

## *Wave Function Collapse (WFC)*

### WFC

- Resolve tile at cell (min. entropy heuristic)
- Constraint Propagate
- Loop until solution or contradiction

### Example



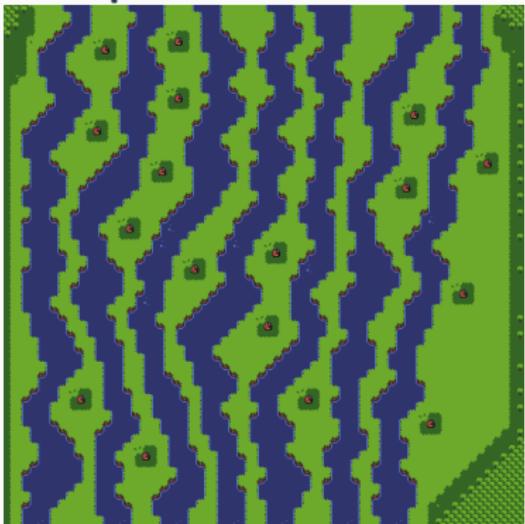
# Related Work

## *Wave Function Collapse (WFC)*

### WFC

- *Block Level*
- One-shot
- Indeterminate initial condition
- Ergodic

### Example



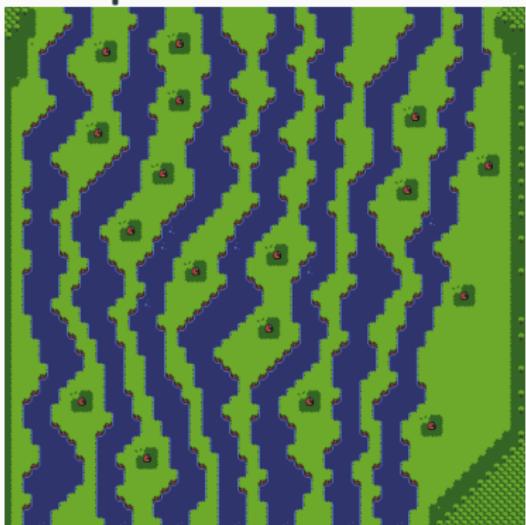
# Related Work

## *Breakout Model Synthesis (BMS)*

### BMS

- Resolve tile at cell
- Constraint Propagate
- If contradiction
  - Revert small region
- Loop until solution or timeout

### Example



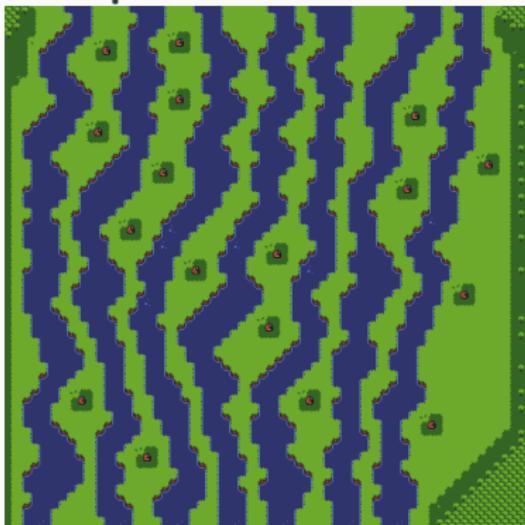
# Related Work

## *Breakout Model Synthesis (BMS)*

### BMS

- *Block Level*
- Stochastic backtracking
- Indeterminate initial condition
- Ergodic

### Example



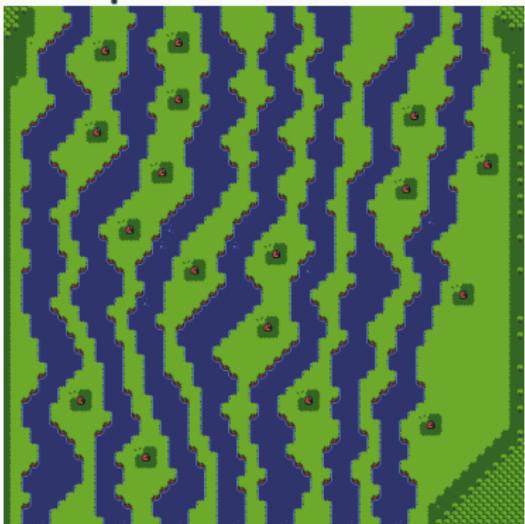
# Related Work

## *Modify in Blocks Model Synthesis (MMS)*

### MMS

- Start from resolved grid
- Choose block
- Try to resolve block
- If block resolved
  - incorporate block
- Else restore block
- Loop to taste

### Example



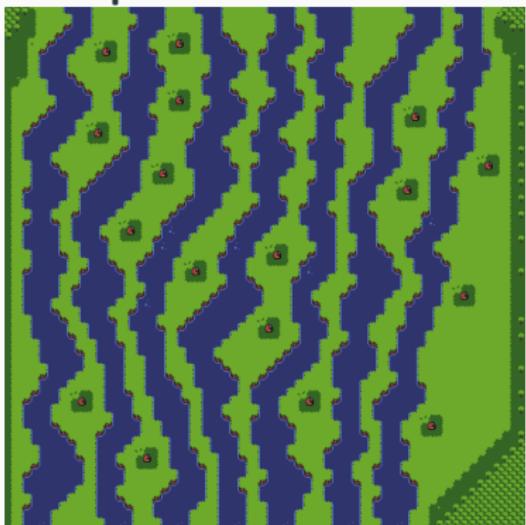
## Related Work

### *Modify in Blocks Model Synthesis (MMS)*

#### MMS

- *Grid Level*
- Contradiction resilience via Block step consistency
- Requires bootstrap initial realization
- Non-ergodic

#### Example



## Related Work

	<i>WFC</i>	<i>BMS</i>	<i>MMS</i>	<i>POMS</i>
Solver Type	Block	Block	Grid	<b>Grid</b>
Contradiction	No	Yes	Yes	<b>Yes</b>
Resilience				
Block Step	n/a	n/a	Yes	<b>No</b>
Consistent				
Indeterminate	Yes	Yes	No	<b>Yes</b>
Initial State				
Ergodic	Yes	Yes	No	<b>Yes</b>

# Related Work

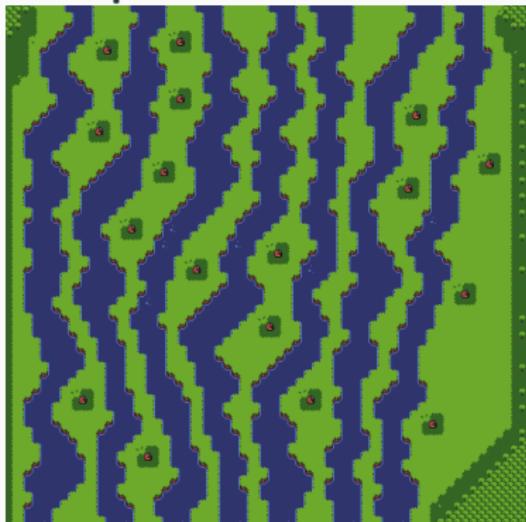
## Intuition

How much influence does a tile choice have over long distances?

Difficult to define and/or calculate

As a heuristic,  
*Tile Arc Consistent Correlation Length (TACCL)* from  
Hoetzlein's *just\_math* project

## Example



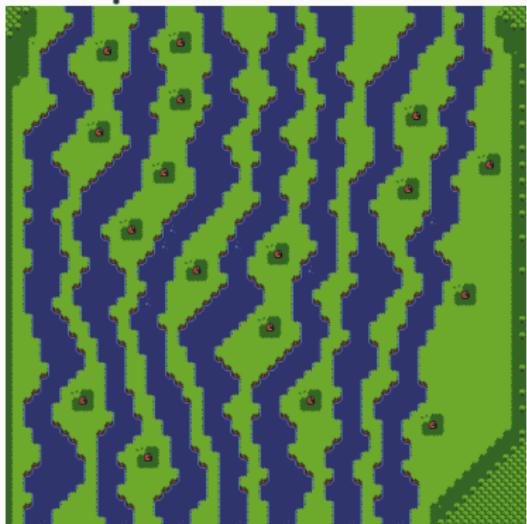
## Related Work

### *Tile Arc Consistent Correlation Length (TACCL)*

#### TACCL

- Take block in isolation

#### Example



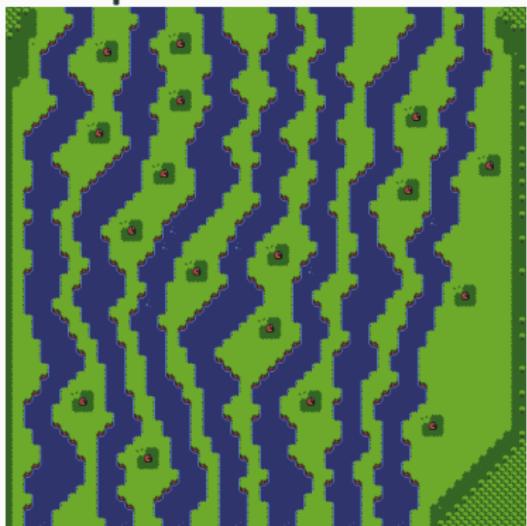
## Related Work

### *Tile Arc Consistent Correlation Length (TACCL)*

#### TACCL

- Take block in isolation
- Set block to indeterminate state

#### Example



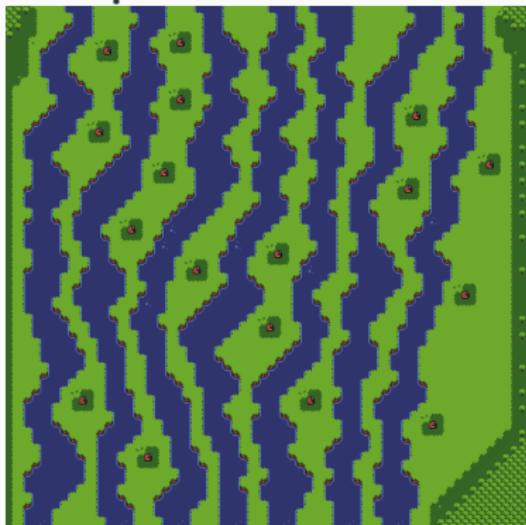
## Related Work

### *Tile Arc Consistent Correlation Length (TACCL)*

#### TACCL

- Take block in isolation
- Set block to indeterminate state
- Fix a tile at the center

#### Example



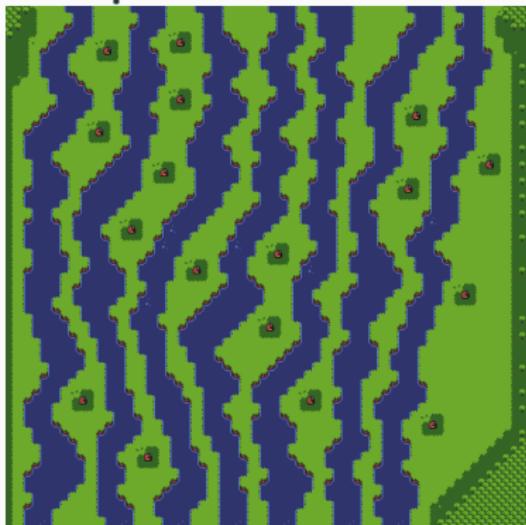
## Related Work

### *Tile Arc Consistent Correlation Length (TACCL)*

#### TACCL

- Take block in isolation
- Set block to indeterminate state
- Fix a tile at the center
- Propagate constraints

#### Example



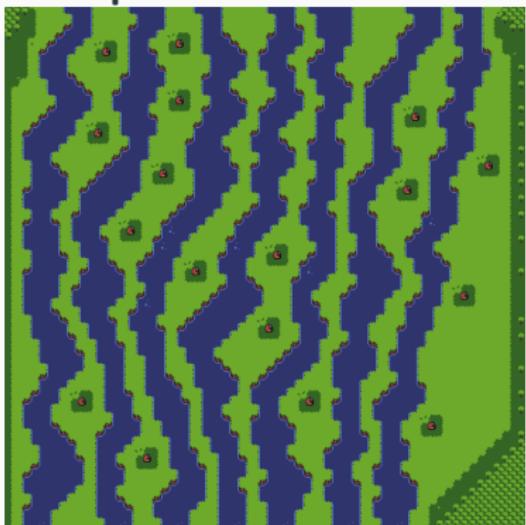
## Related Work

### *Tile Arc Consistent Correlation Length (TACCL)*

#### TACCL

- Take block in isolation
- Set block to indeterminate state
- Fix a tile at the center
- Propagate constraints
- Take minimum bounding box of altered cells

#### Example



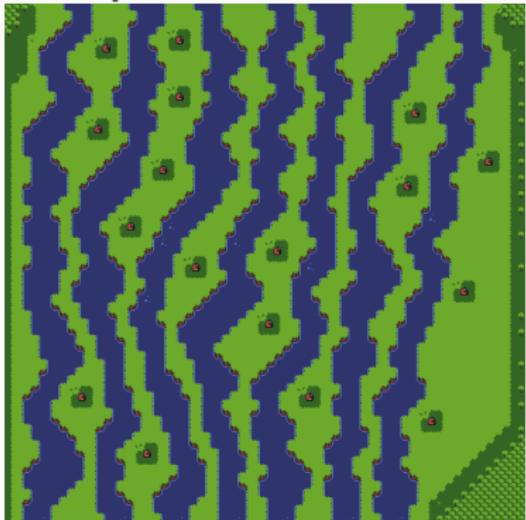
## Related Work

### *Tile Arc Consistent Correlation Length (TACCL)*

#### TACCL

- Take block in isolation
- Set block to indeterminate state
- Fix a tile at the center
- Propagate constraints
- Take minimum bounding box of altered cells
- Repeat for all tiles

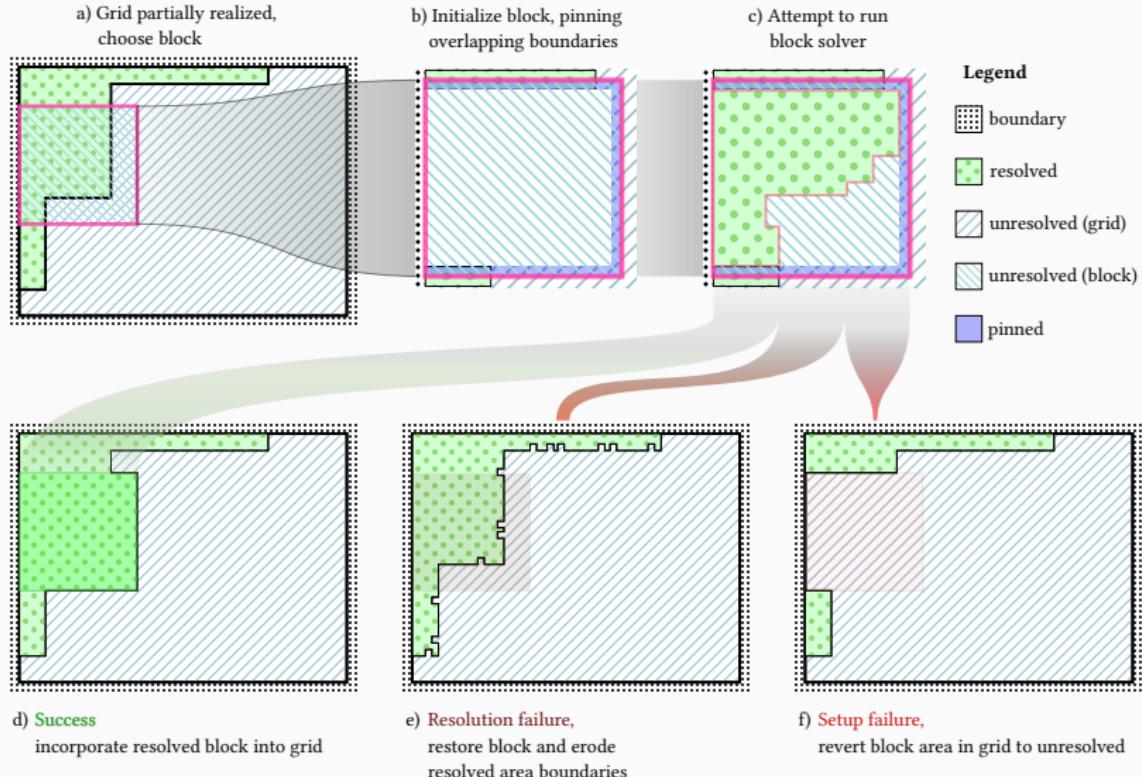
#### Example



# Algorithm

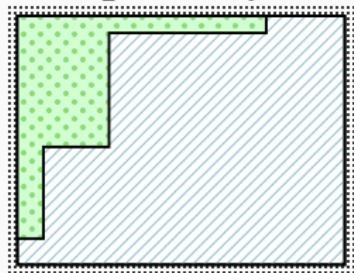
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# Algorithm: Overview



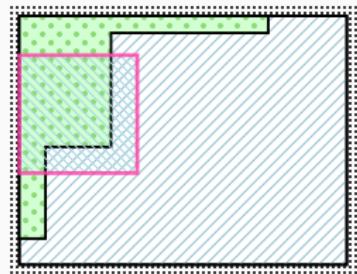
# Algorithm

Grid partially realized

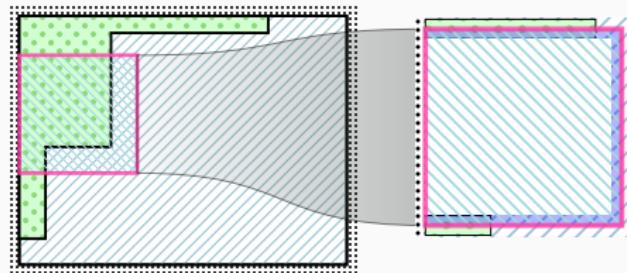


# Algorithm

Choose block

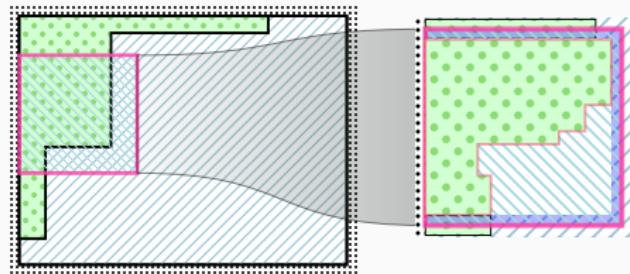


# Algorithm

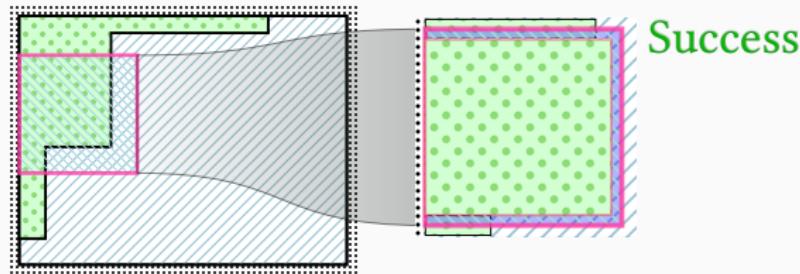


Initialize block  
Pin boundaries  
Revert interior  
(Apply any restrictions)

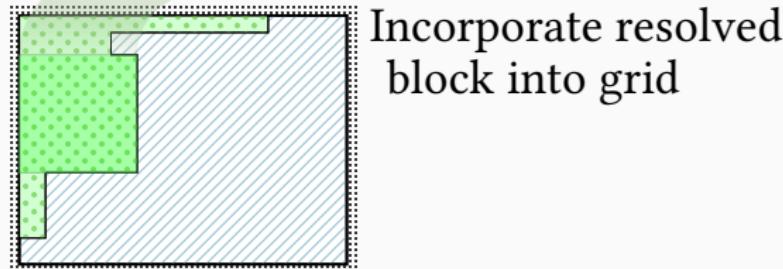
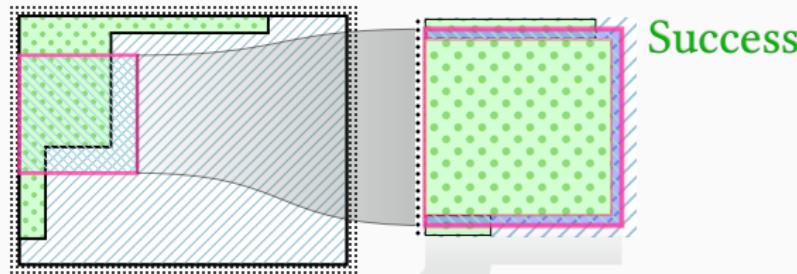
# Algorithm



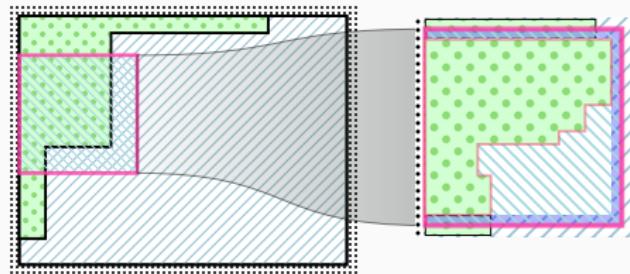
# Algorithm



# Algorithm



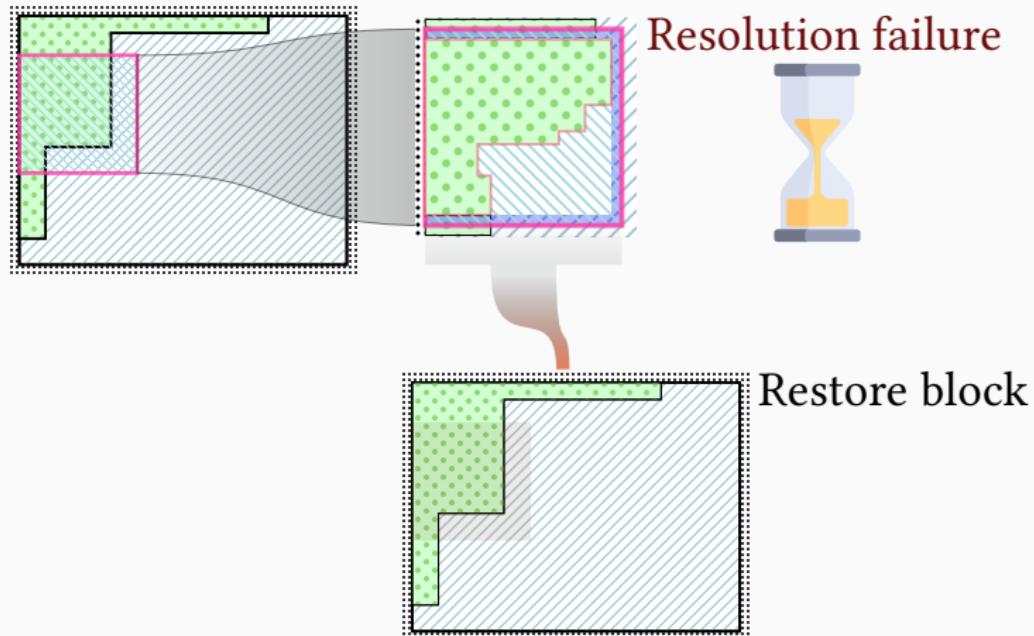
# Algorithm



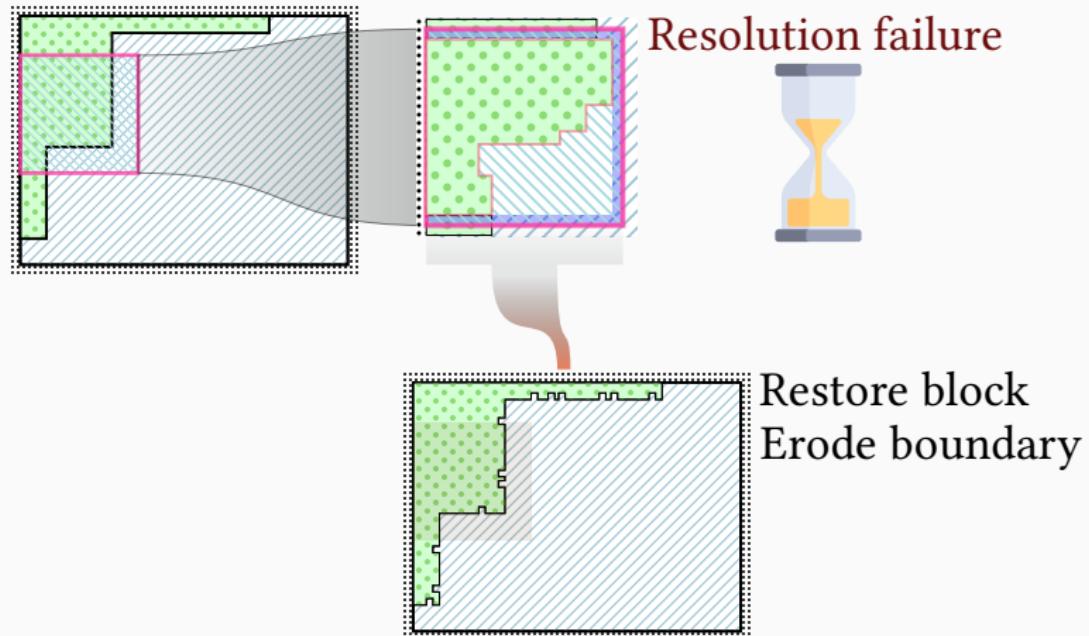
Resolution failure



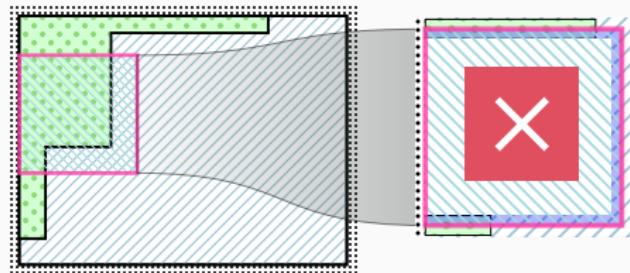
# Algorithm



# Algorithm



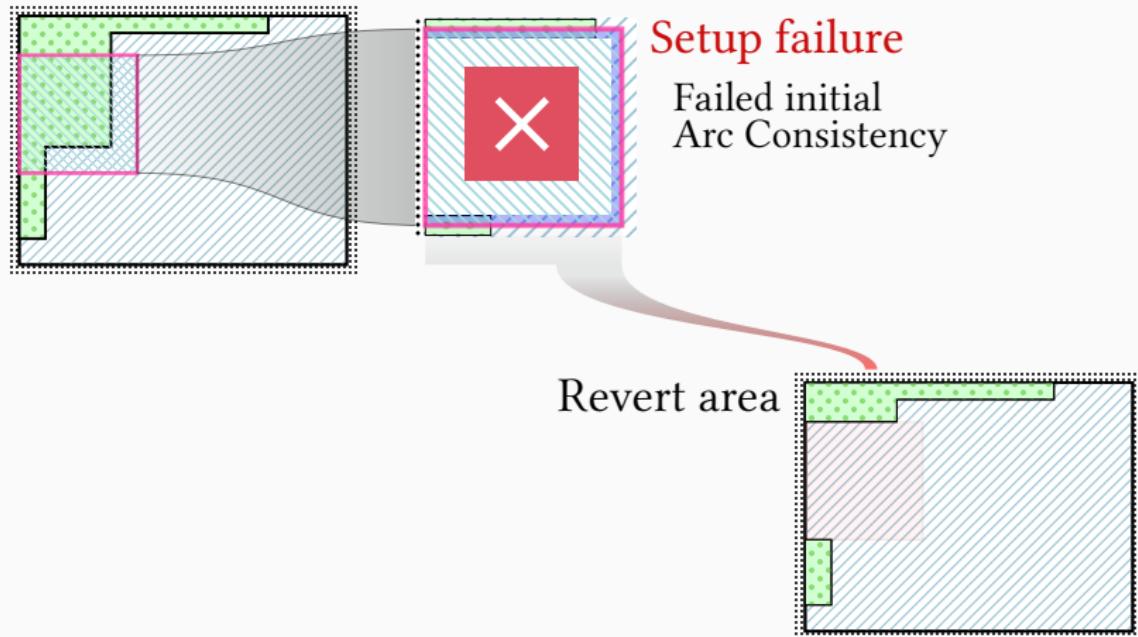
# Algorithm



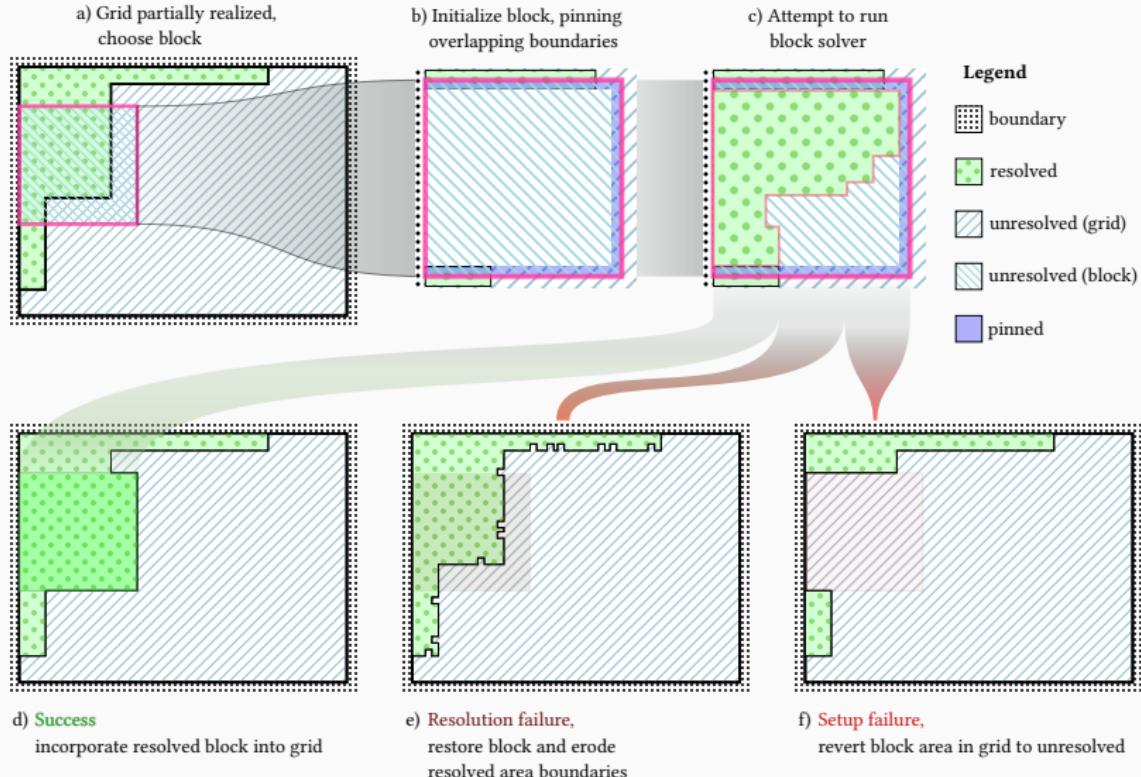
Setup failure

Failed initial  
Arc Consistency

# Algorithm



# Algorithm



# Algorithm

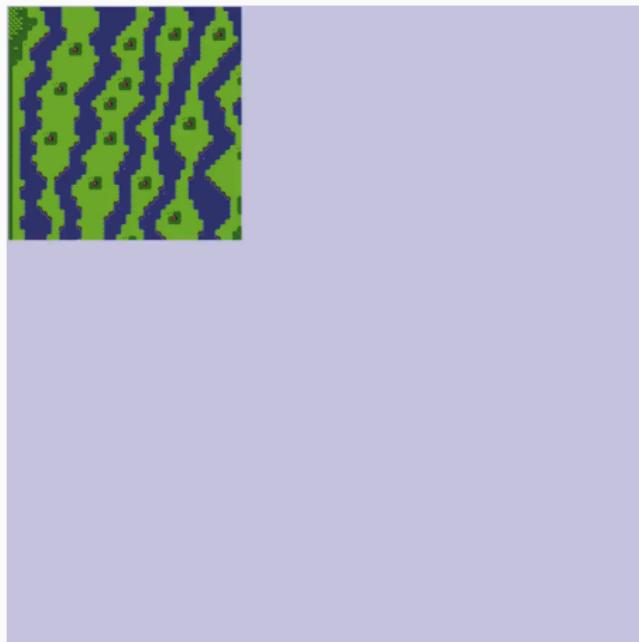
*Pill Mortal* Tile Set

# Algorithm

ThKaspar's *Forest Micro Tile Set*

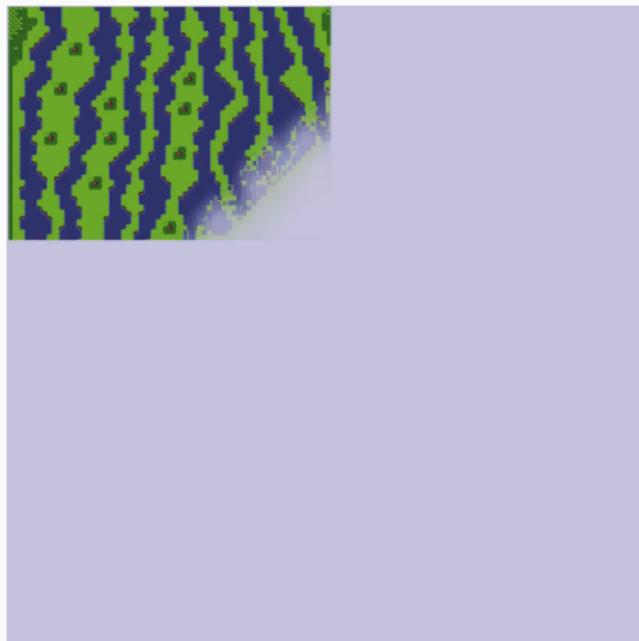
# Algorithm

Choose Block



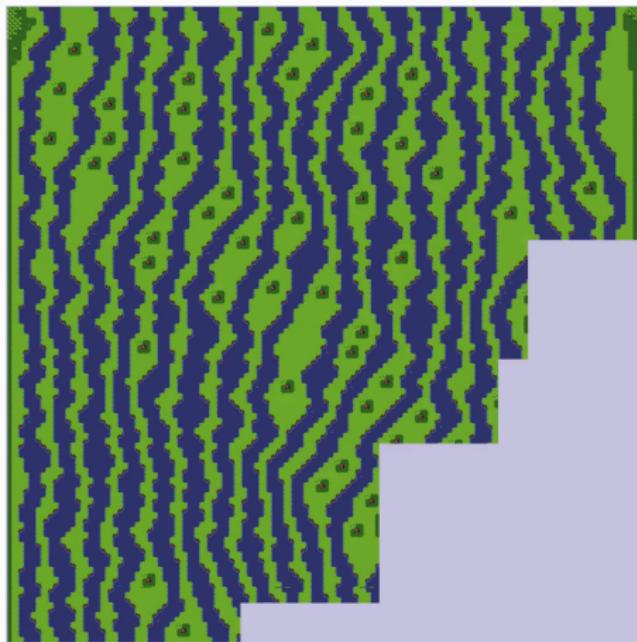
# Algorithm

Choose Block



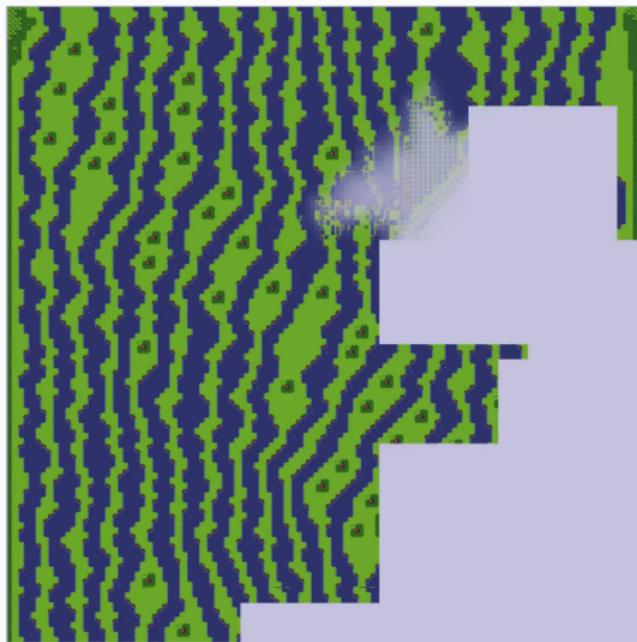
# Algorithm

Revert Block



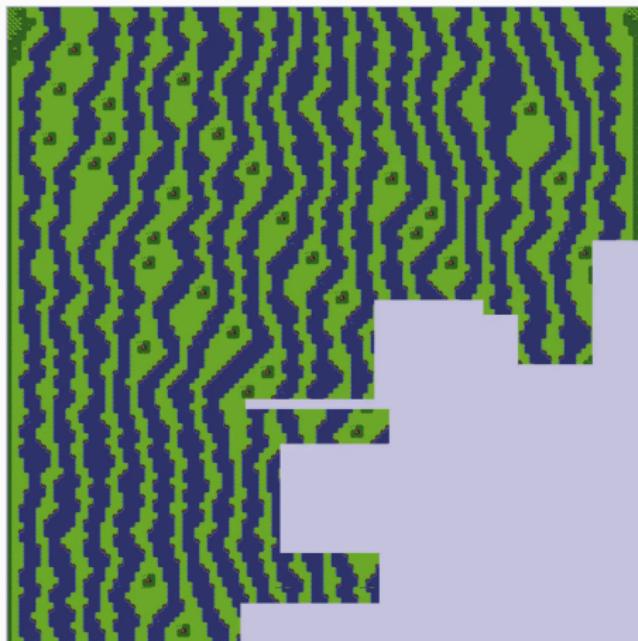
# Algorithm

Revert Block



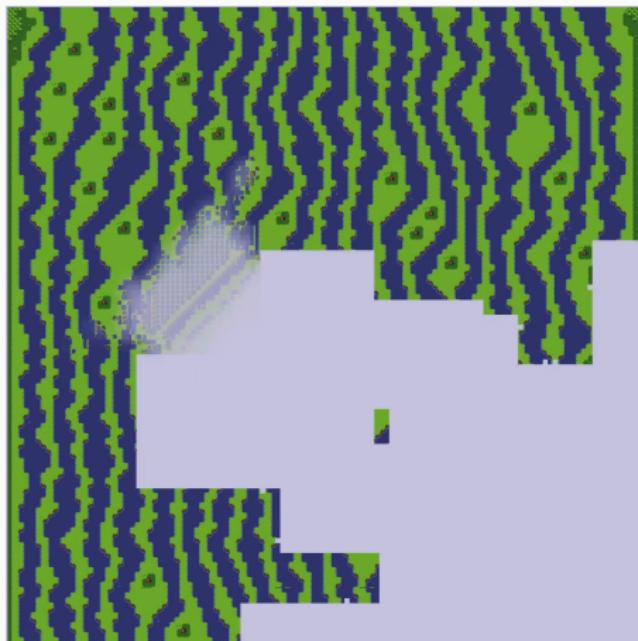
# Algorithm

Erode Boundary



# Algorithm

Erode Boundary



# Results

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# Results

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## Conclusion

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# Conclusion

<https://github.com/zzyzek/PunchOutModelSynthesis>