

# Punch Out Model Synthesis

A Stochastic Algorithm for Constraint Based Tiling Generation

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November 19th, 2024

## Punch Out Model Synthesis

A Constraint Based Tiling  
Generation algorithm

- Contradiction resilience
- Works on large grids
- Minimal setup requirements

*Pill Mortal* Tile Set  
64x64 cells, 190 tile count

# Introduction

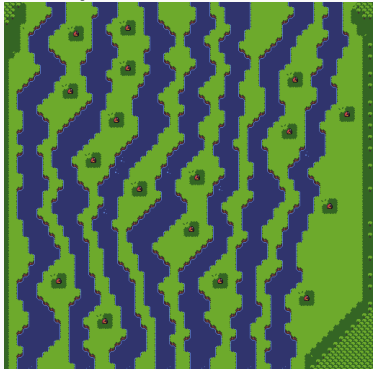
## Constraint Based Tiling Generation (CBTG) Problem

### Find a valid grid realization

A *realization* is a single *tile* placement at each *cell* respecting *constraints*.

(*Cells* hold array of *tiles*)

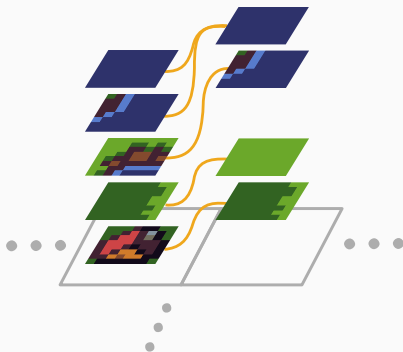
### Example



64x64 cells, 159 tile count

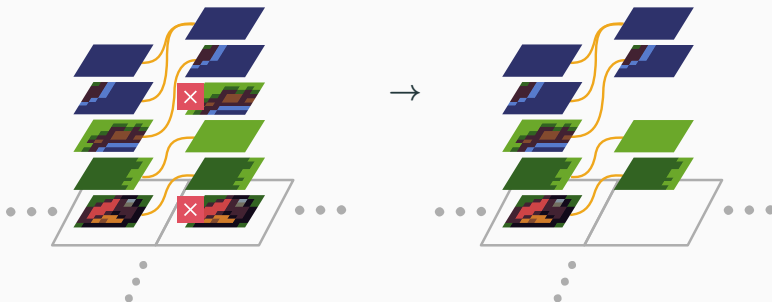
# Introduction

*Arc Consistency*: all *tiles* in every *cell* have at least one valid neighbor in each direction



# Introduction

Basis for *Constraint Propagation* algorithm by repeatedly removing tiles without valid neighbors after tile choice



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

*Grid Level Solver*: only keep minimal information for the entire grid but work on *block* sub-regions

## Related Work

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

*WFC : Wave Function Collapse (Gumin)*

*BMS : Breakout Model Synthesis (Hoetzlein)*

*MMS : Modify in Blocks Model Synthesis (Merrell)*

*POMS : Punch Out Model Synthesis*

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

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

Finite correlation  $\rightarrow$  independent regions



## Related Work

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

#### TACCL

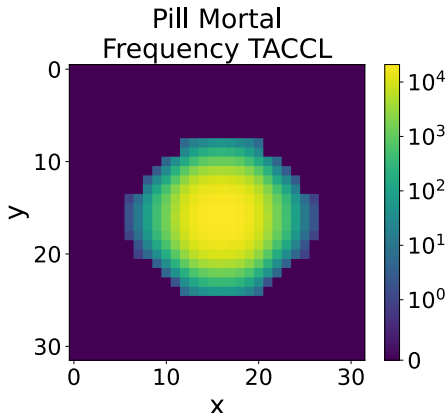
Isolated block, for all tiles:

- Fix tile at the center
- Take bounding box of constraint propagation

Heuristic for correlation length

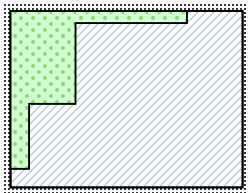
POMS block  $\geq$  TACCL

#### Example



## Algorithm

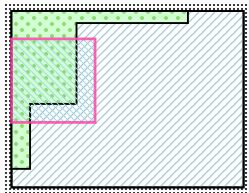
Grid partially realized



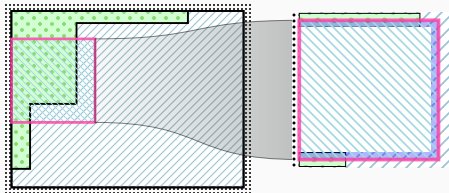
cells fully realized or  
marked indeterminate

# Algorithm

Choose block

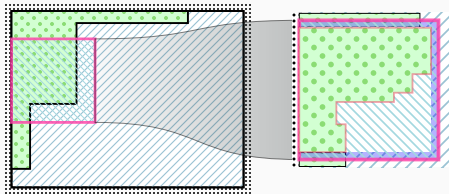


# Algorithm



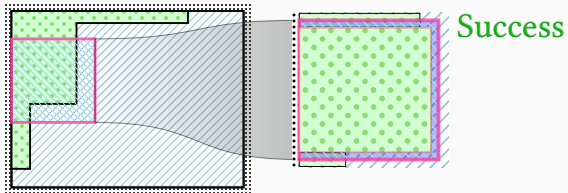
Initialize block  
Pin boundaries  
Revert interior  
(Apply any restrictions)

# Algorithm

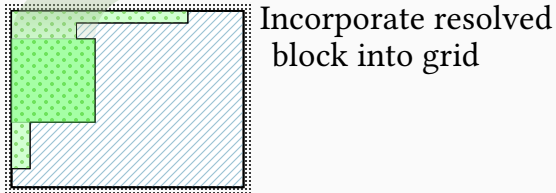
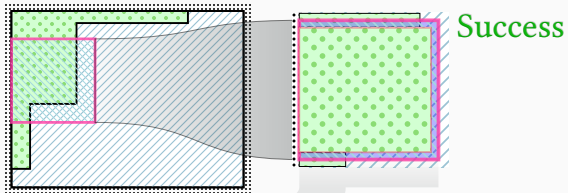


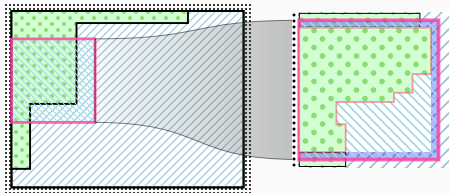
Attempt to solve  
block level solver  
maintain full AC

# Algorithm



# Algorithm



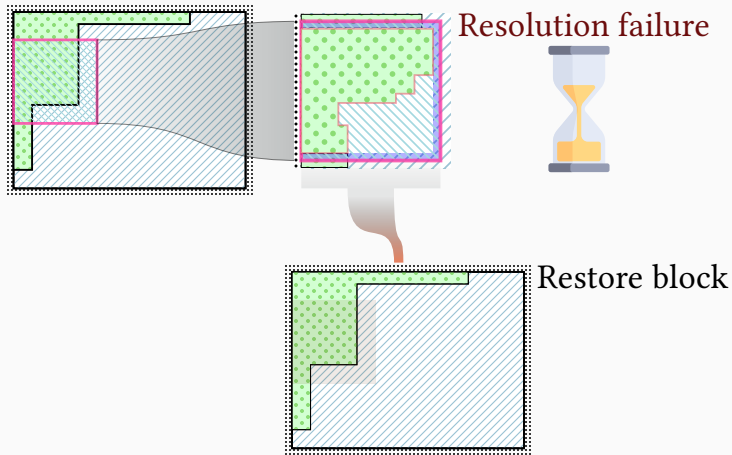


Resolution failure

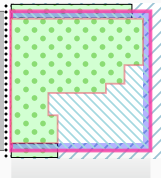
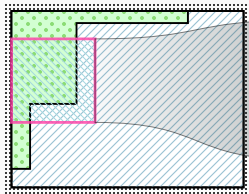




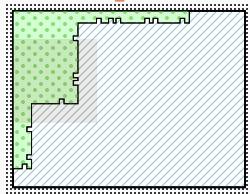
# Algorithm



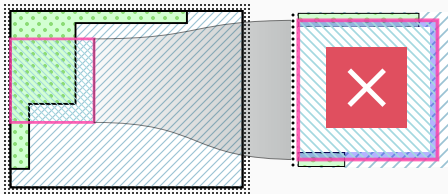
# Algorithm



Resolution failure



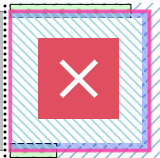
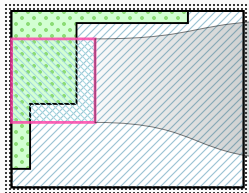
Restore block  
Erode boundary



Setup failure

Failed initial  
Arc Consistency

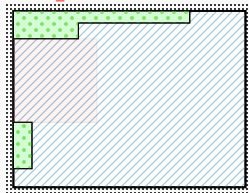
# Algorithm



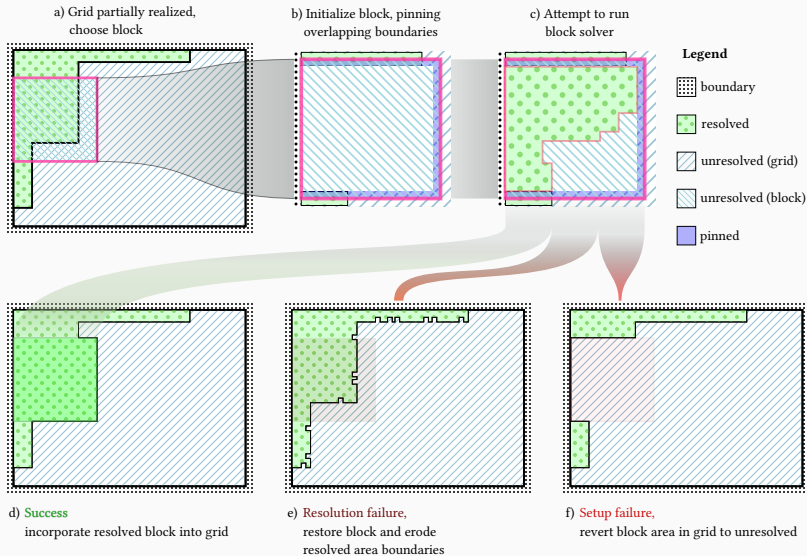
Setup failure

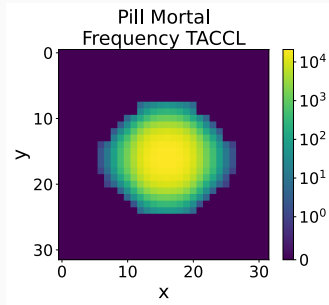
Failed initial  
Arc Consistency

Revert area

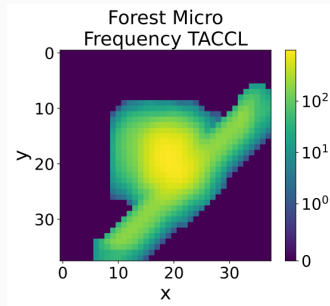


# Algorithm



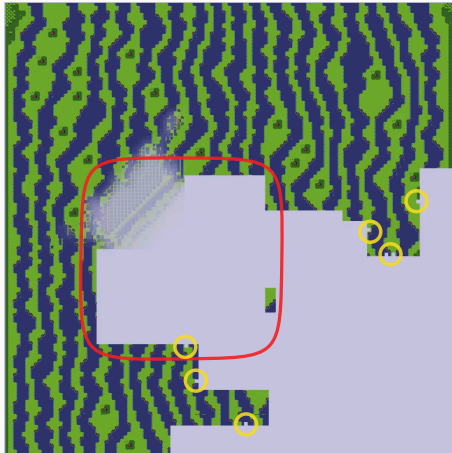


*Pill Mortal*  
64x64 cells, 190 tiles  
30x30 block



*Forest Micro* (ThKaspar)  
128x128 cells, 159 tiles  
48x48 block

## Reversion and Erosion





Punch Out Model Synthesis is an alternative CBTG algorithm when:

- Grid is large
- Resources are limited
- Minimal setup requirements are needed/desired

<https://zzyzek.github.io>

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

<https://zzyzek.github.io/PunchOutModelSynthesisWebDemo/>

Thanks!

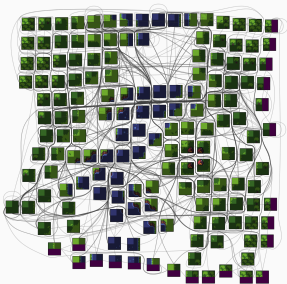
# Auxiliary Slides

Automatic Tile Generation

<https://zzyzek.github.io/TileRuleHighlighter/>

**Rule Graph (Forest Micro)**

**Rule Highlighter**



## Highlighted Runs

LUNARSIGNAL's *Overhead Action*  
*RPG Overworld* Tile Set (x10)

## Highlighted Runs

0x72's *Two Bit Micro Metroidvania* Tile Set (x10)

## Highlighted Runs

Kingel's *Minirogue* Tile Set (x10)

### *Wave Function Collapse (WFC) (Gumin)*

- Block level solver (maintain AC for the block)
- One-shot solver, give up first contradiction
- Min. entropy heuristic to fix tiles

### *Breakout Model Synthesis (BMS) (Hoetzlein)*

- Block level solver (maintain AC for the block)
- Stochastic backtracking, revert small region around contradiction point to indeterminate



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

- Grid level solver (maintain summary info for grid, AC only for block)
- Needs fully resolved initial state
- Try to resolve block sub-regions, re-incorporating if resolution successful
- Never fails (block step consistency)
- Misses solution space if features larger than block and not already in grid (non-ergodic)

## Auxiliary Slides

- Bitter lesson includes learning *and* search
- Trade off between resources used to learn vs. resources used for run time search
- “Parables of the Power of Planning in AI” by Noam Brown (<https://www.youtube.com/watch?v=eaAonE58sLU>)

### Other Problems

- Salad
- Oatmeal
- Global Cohesion/(weak) Global Constraints

CBTG algorithms are good at maintaining local consistency but are bad at resolving global constraints

Weak global constraints (path connections, etc.) can confound POMS and other CBTG algorithms

Sometimes global constraints are weak enough to be overcome by solving local constraints

### Potential Future Work

- Spectral Graph Decomposition methods for automatic biome detection
- AC4 speedups via templates
- Weak global constraints