Punch Out Model Synthesis

A Stochastic Algorithm for Constraint Based Tiling Generation

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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

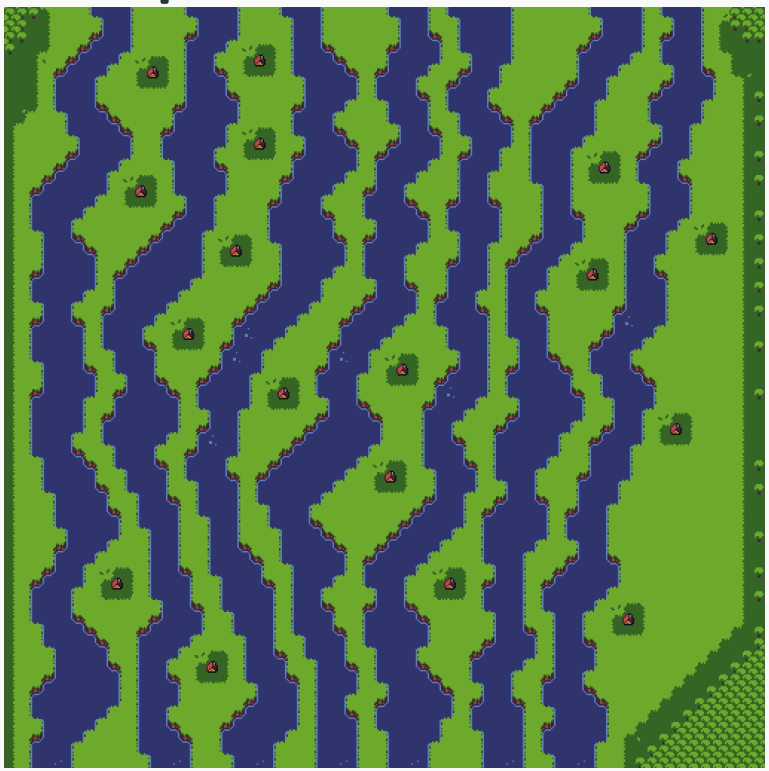
Constraint Based Tiling Generation (*CBTG*) Problem

Find a valid grid realization

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

(*Cells* hold array of *tiles*)

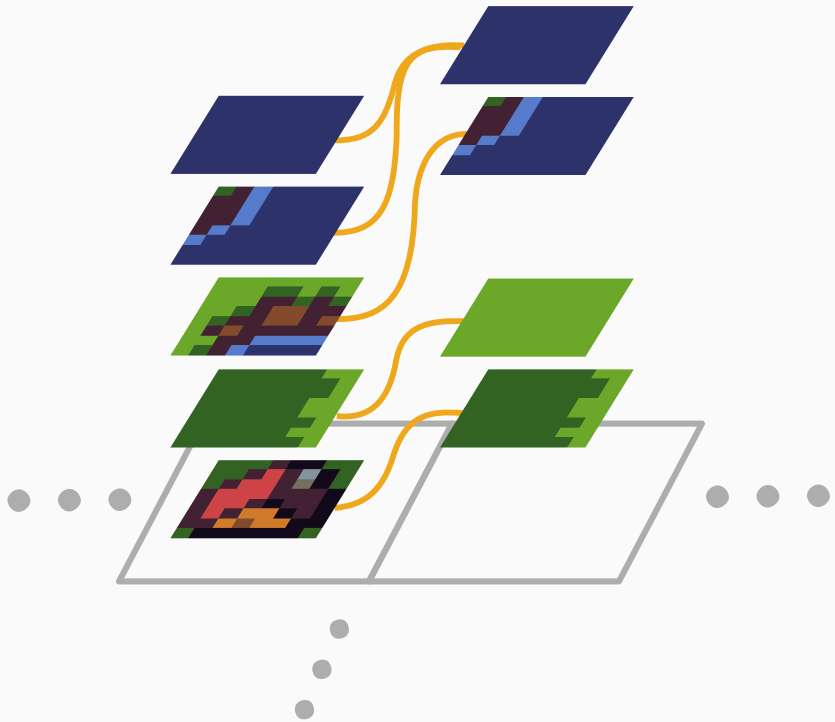
Example



64x64 cells, 159 tile count

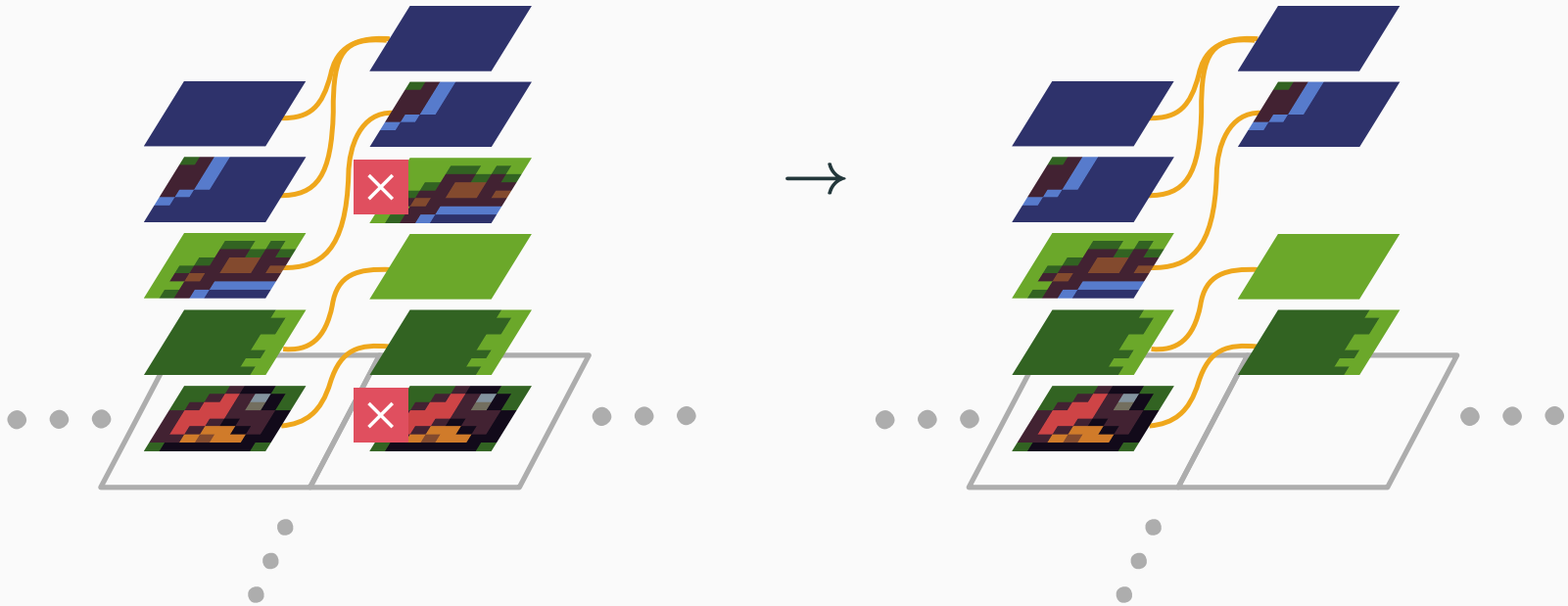
Introduction

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



Introduction

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

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

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

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

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

POMS : *Punch Out Model Synthesis*

Related Work

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

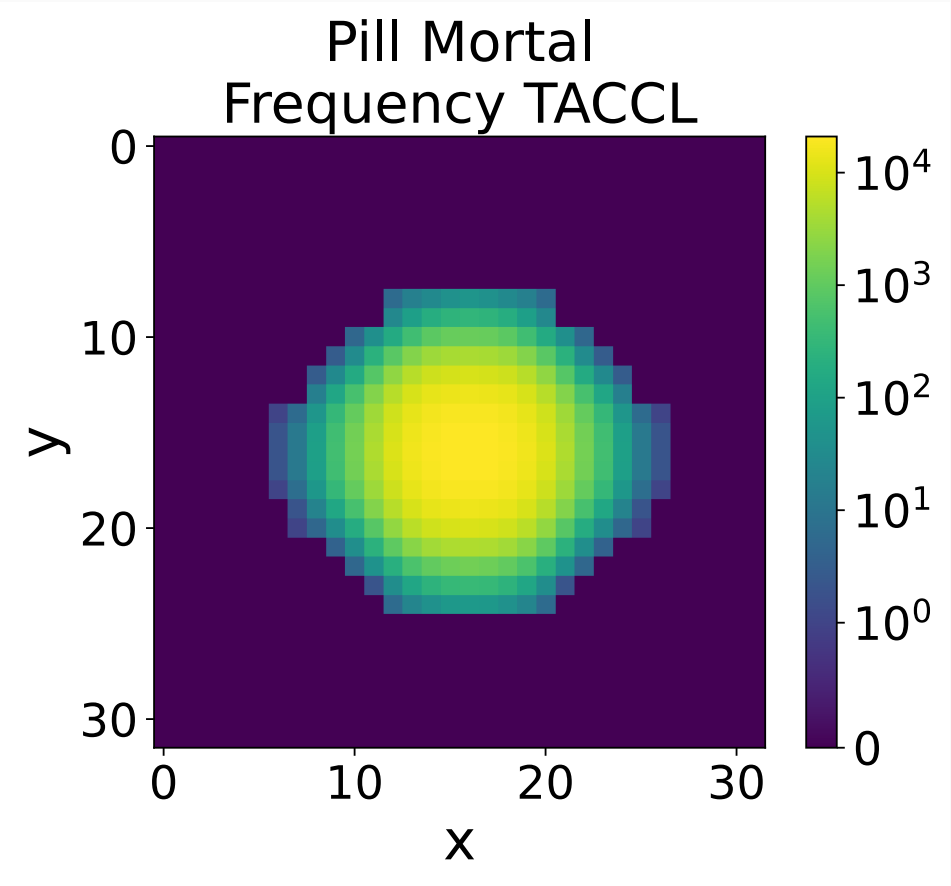
Isolated block, for all tiles:

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

Heuristic for correlation length

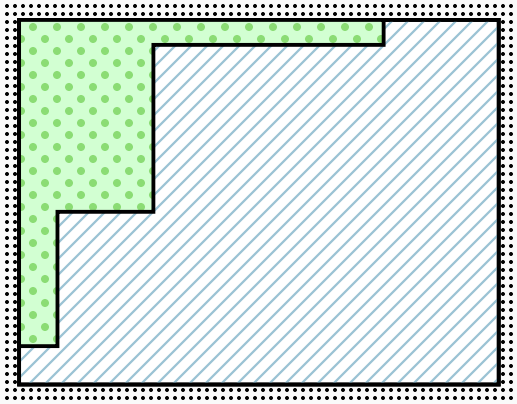
POMS block $\geq$ TACCL

Example



Algorithm

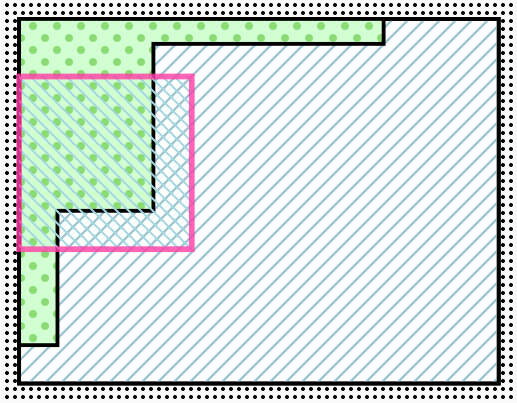
Grid partially realized



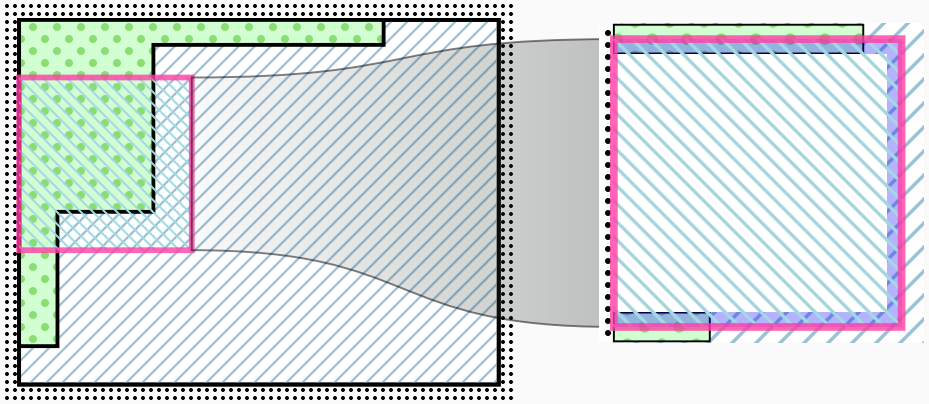
cells fully realized or
marked indeterminate

Algorithm

Choose block



Algorithm

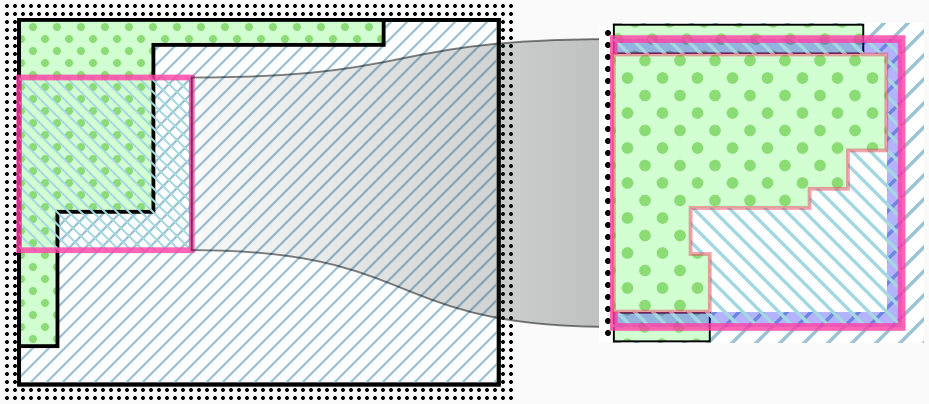


Initialize block

- Pin boundaries
- Revert interior

(Apply any restrictions)

Algorithm

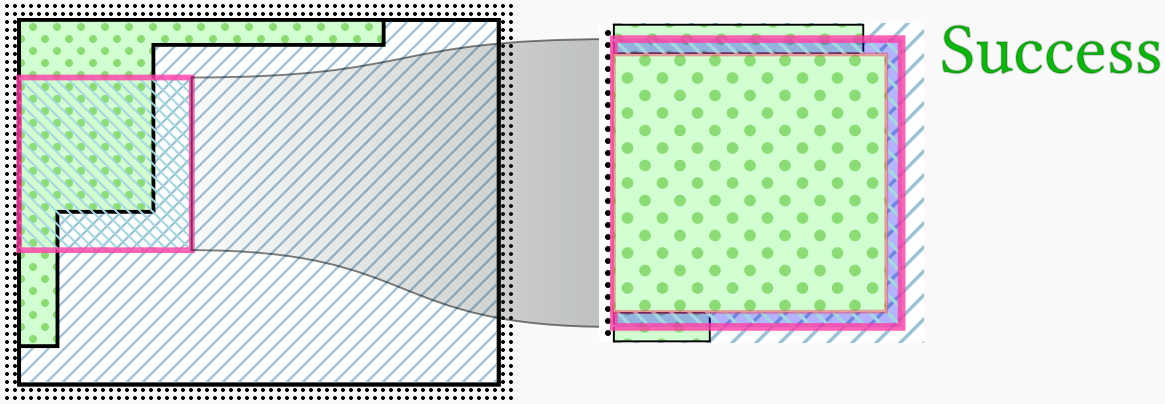


Attempt to solve

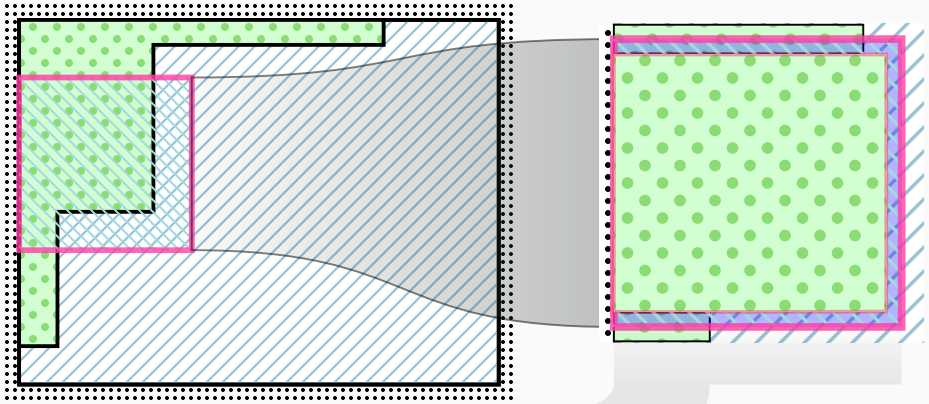
block level solver

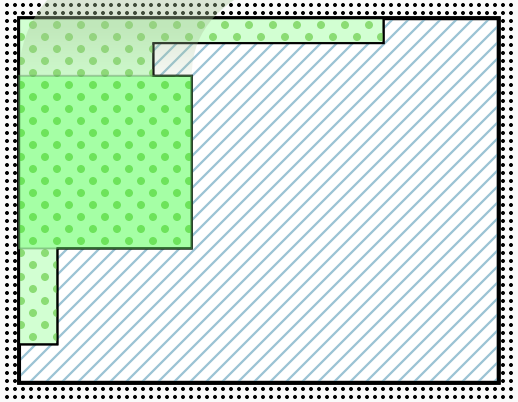
maintain full AC

Algorithm



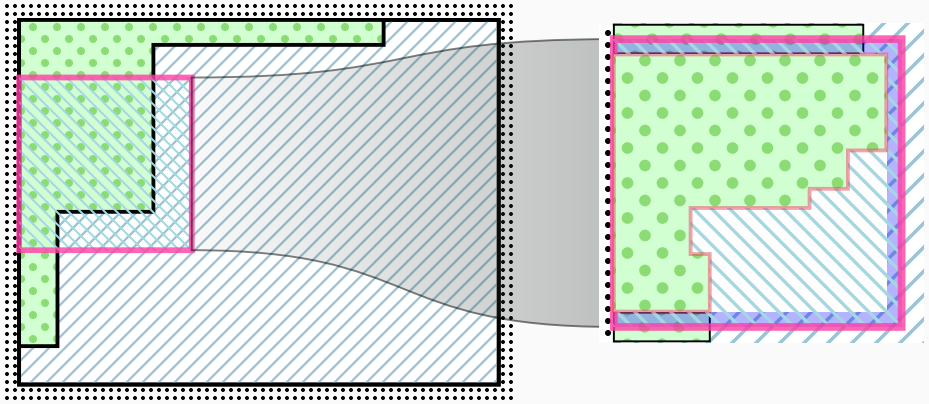
Algorithm





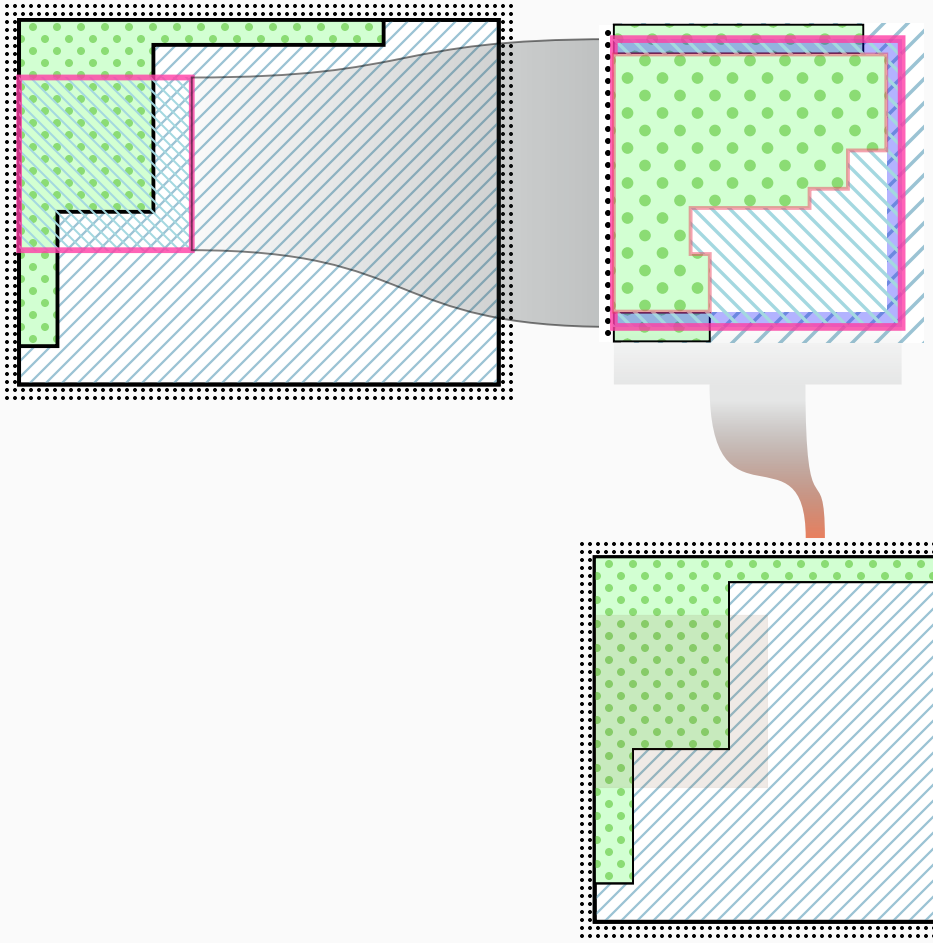
Incorporate resolved block into grid

Algorithm



Resolution failure

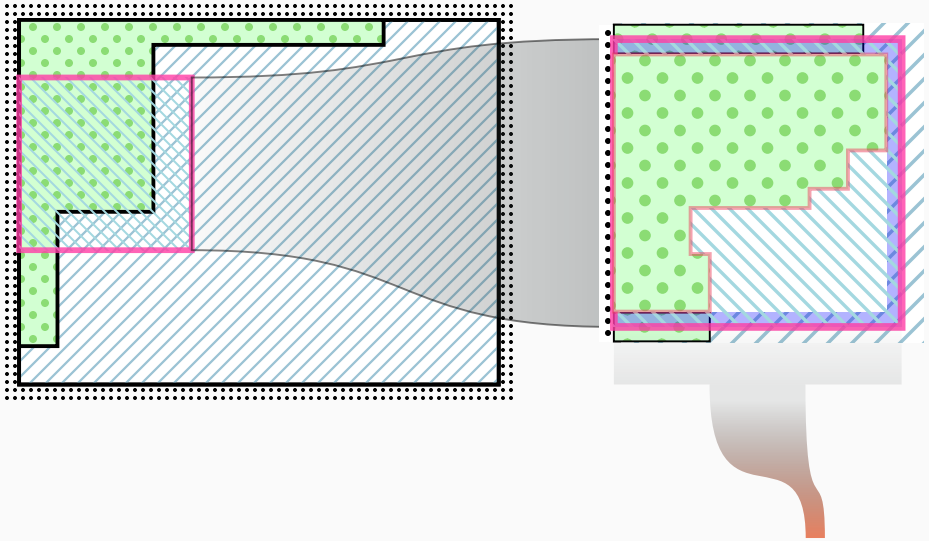
Algorithm



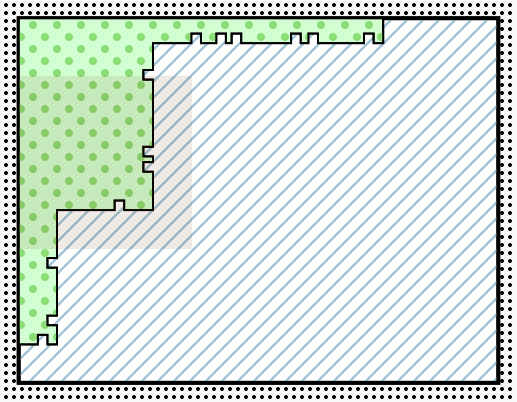
Resolution failure

Restore block

Algorithm

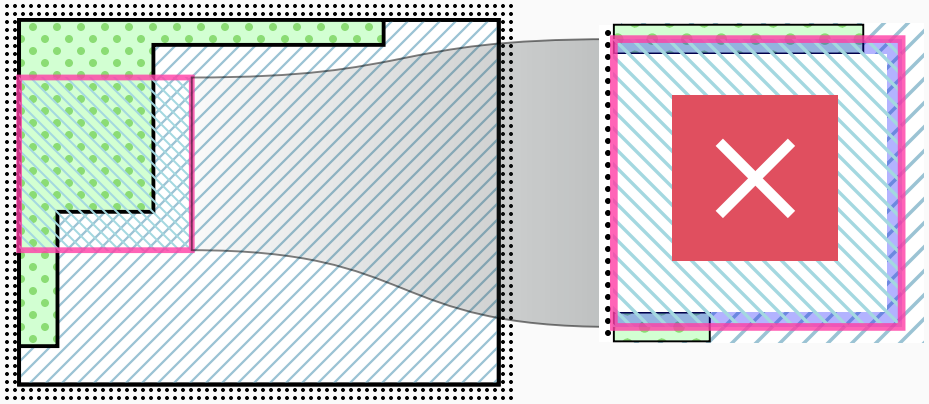


Resolution failure



Restore block
Erode boundary

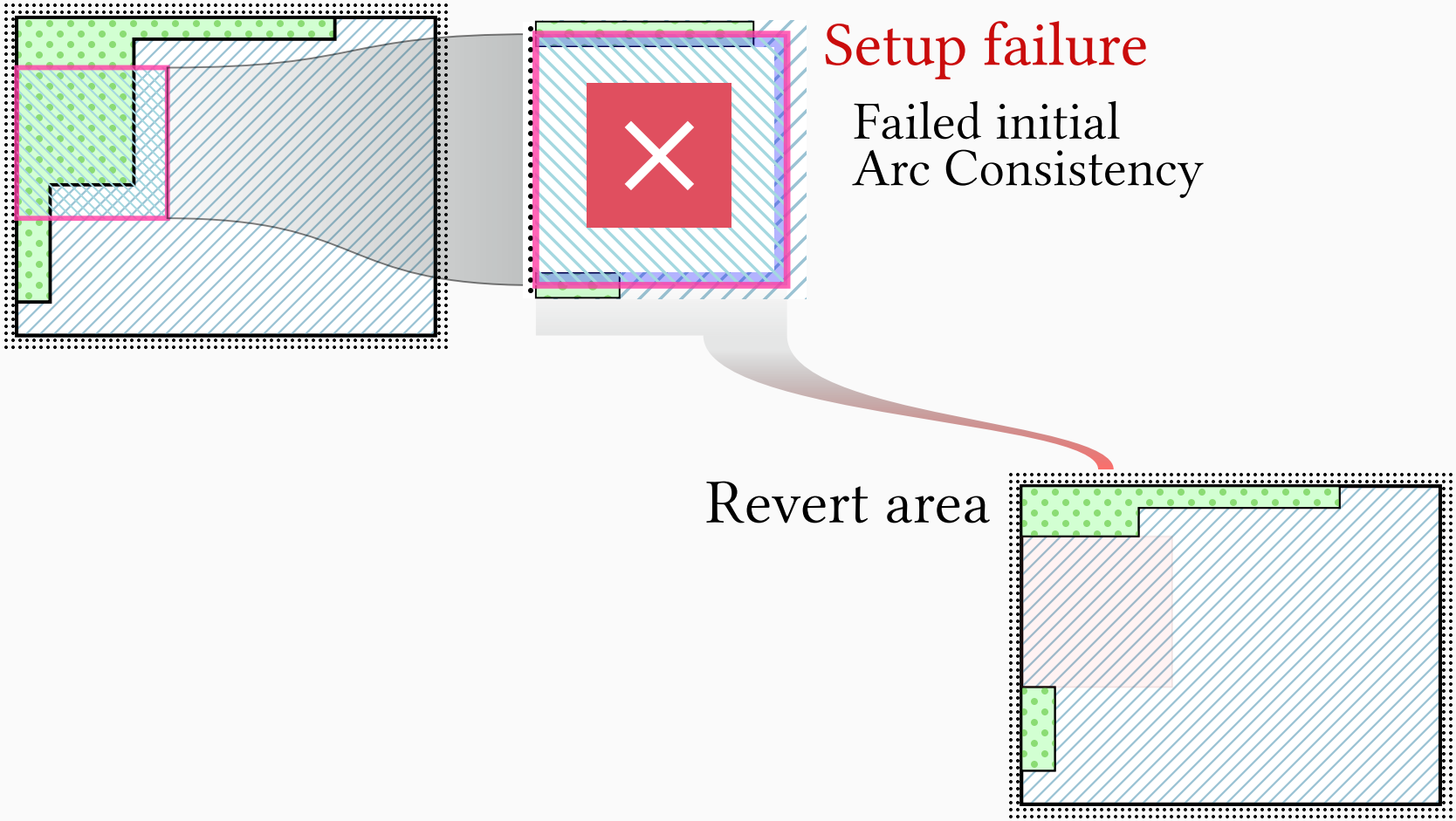
Algorithm



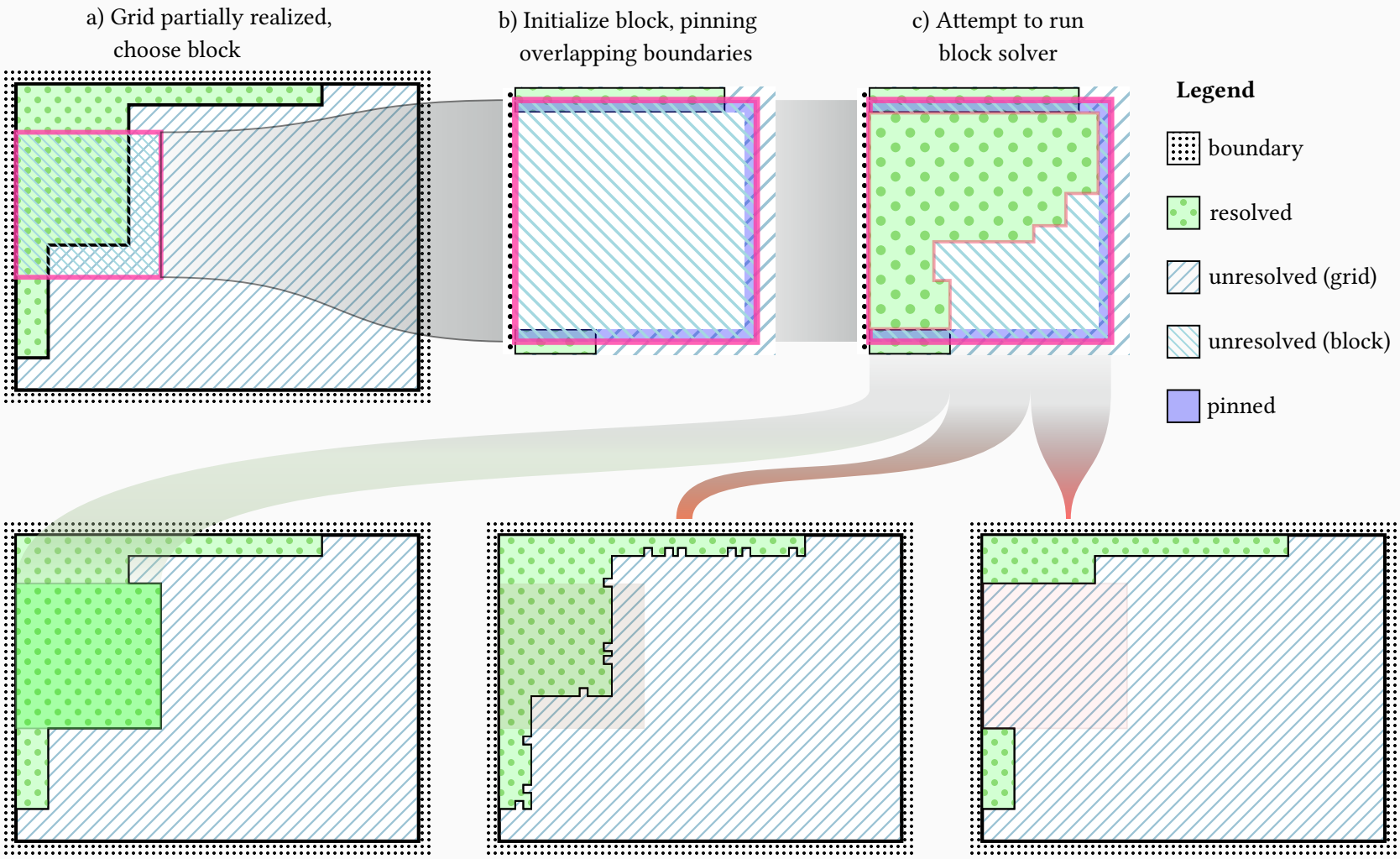
Setup failure

Failed initial
Arc Consistency

Algorithm



Algorithm

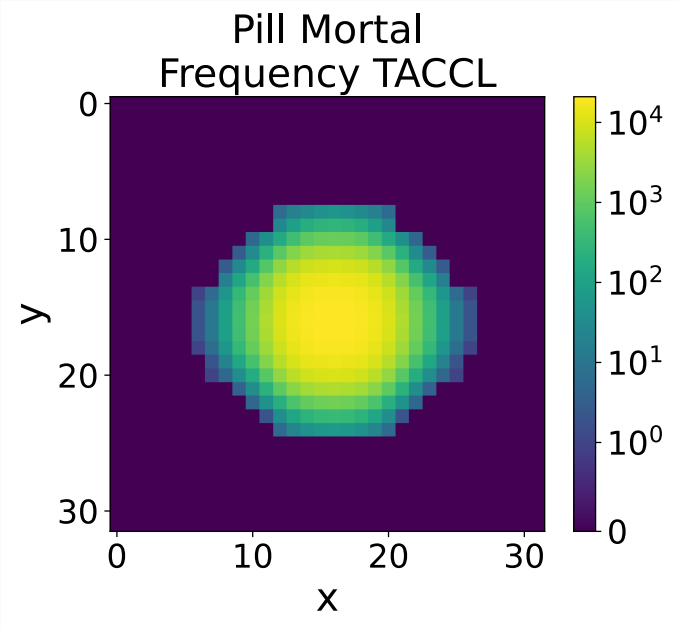


d) Success
incorporate resolved block into grid

e) Resolution failure,
restore block and erode resolved area boundaries

f) Setup failure,
revert block area in grid to unresolved

Algorithm

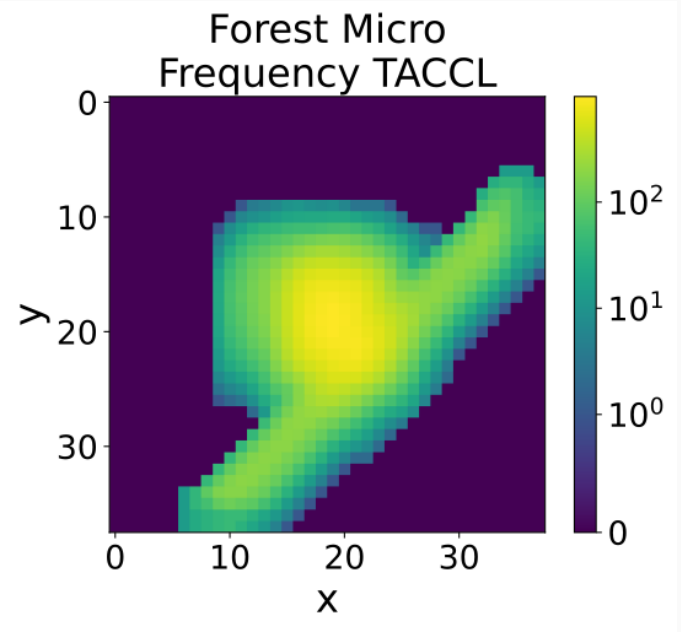


Pill Mortal

64x64 cells, 190 tiles

30x30 block

Algorithm



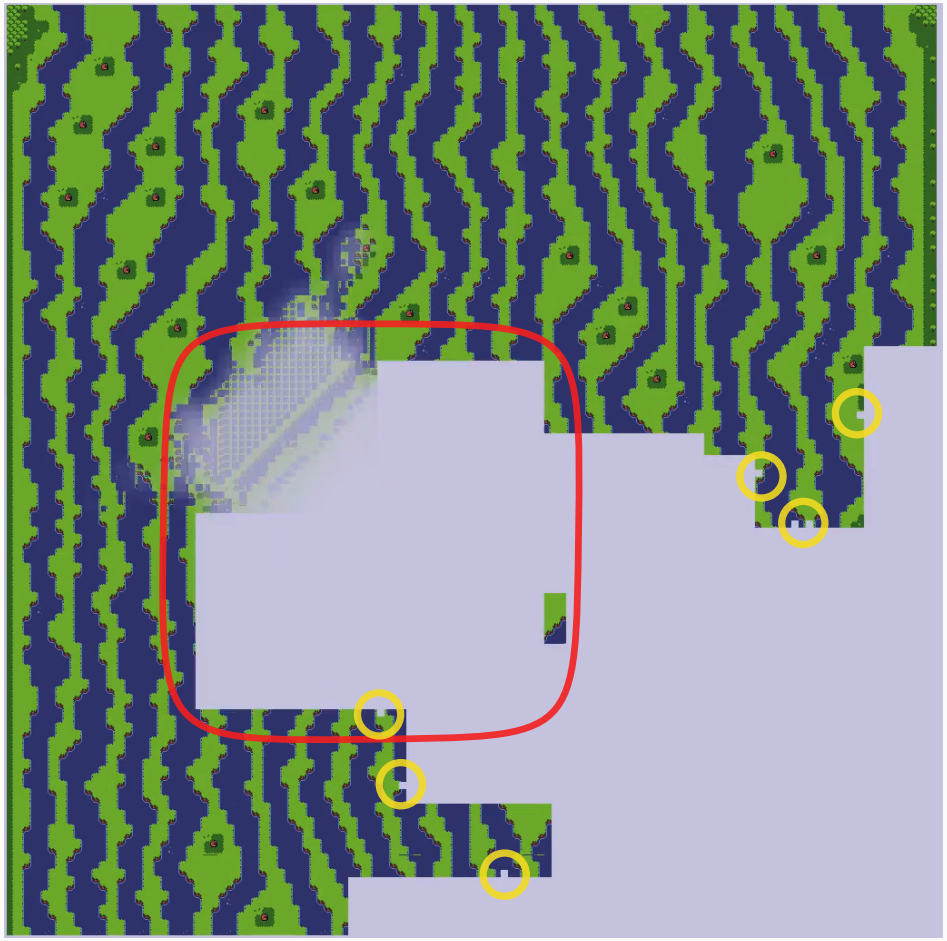
Forest Micro (ThKaspar)

128x128 cells, 159 tiles

48x48 block

Algorithm

Reversion and Erosion



Conclusion

Punch Out Model Synthesis is an alternative CBTG algorithm when:

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

fin

https://zzyzek.github.io

https://github.com/zzyzek/PunchOutModelSynthesis

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

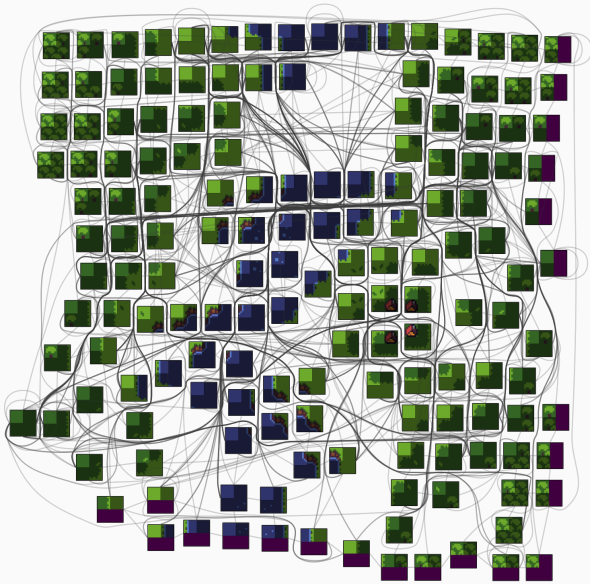
Thanks!

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)

Auxiliary Slides

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

Auxiliary Slides

Breakout Model Synthesis (BMS) (Hoetzlein)

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

Auxiliary Slides

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`)

Auxiliary Slides

Other Problems

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

Auxiliary Slides

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

Auxiliary Slides

Potential Future Work

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