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Amsterdam University of Applied Sciences

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Measuring Quality of Grammars for Procedural Level Generation

Procedural Content Generation Workshop
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Riemer van Rozen[1,2,3] Quinten Heijn[3]

1. Amsterdam University of Applied Sciences – Play & Civic Media
2. Centrum Wiskunde & Informatica – Software Analysis & Transformation
3. University of Amsterdam – Master of Software Engineering

Live Game Design

- **Premise: Live Game Design project**
  - case study with Ludomotion
  - quality assurance of procedurally generated game levels
  - Ludoscope

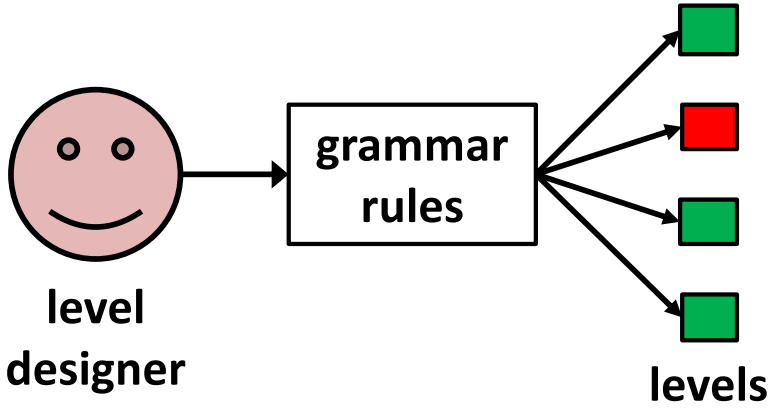
- **Problem.** grammar-based procedural level generation raises productivity of level designers at the cost of quality assurance

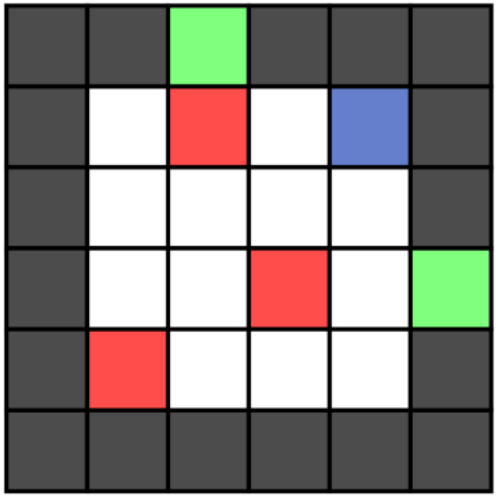
Unexplored: a roguelike dungeon crawl game that embeds a grammar-based dungeon generator

Ludomotion
Advancing Games

Problem Statement

- **Problem.** authoring, improving, maintaining grammars is difficult
  - lack of direct manipulation
  - hard to predict how each grammar rule impacts the overall level quality
- **Challenge.** lack of tools and techniques for debugging and testing
- **Question:** How can the quality of grammars that work on tile maps for procedural level generation be improved?
- **Objectives.** Better tools & techniques

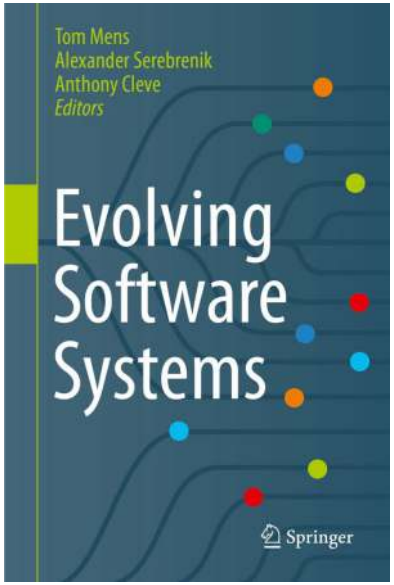




problematic level

Software Evolution

- **Software Evolution**
  - software conforms less and less to the changing expectations of its users
  - it becomes harder to adjust the software and maintain its quality
  - games = changing requirements
- **Two branches of research**
  1. **What evolves.** improve knowledge, plan and predict, e.g., by analyzing source code over time
  2. **How to evolve.** improve techniques for adjusting software to new requirements, e.g., with model transformations



Software Evolution. Editors: Tom Mens and Serge Demeyer. Springer, 2008

Evolving Software Systems. Editors: Tom Mens, Alexander Serebrenik, Anthony Cleve. Springer 2014

Approach and Contributions

- **Level Designer questions**
  1. **Efficiency.** No dead content?
  2. **Effectiveness.** Are the intended parts in the level?
  3. **Root-cause analysis.** Given a level with a problem, by which rules were the affected tiles generated?
  4. **Bug-fixing.** Does changing a rule improve levels, or does it also introduce new problems?
  5. **Bug-free.** How to test?

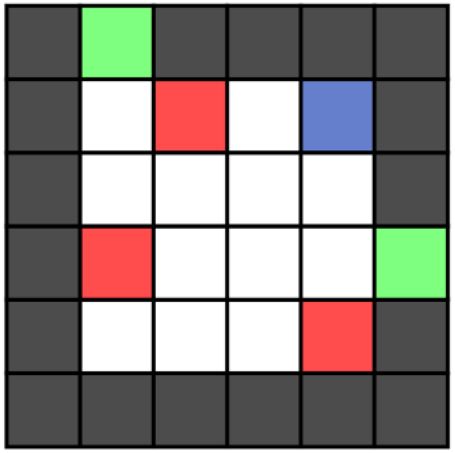
- **Approach**: use SE techniques to answer level designer questions

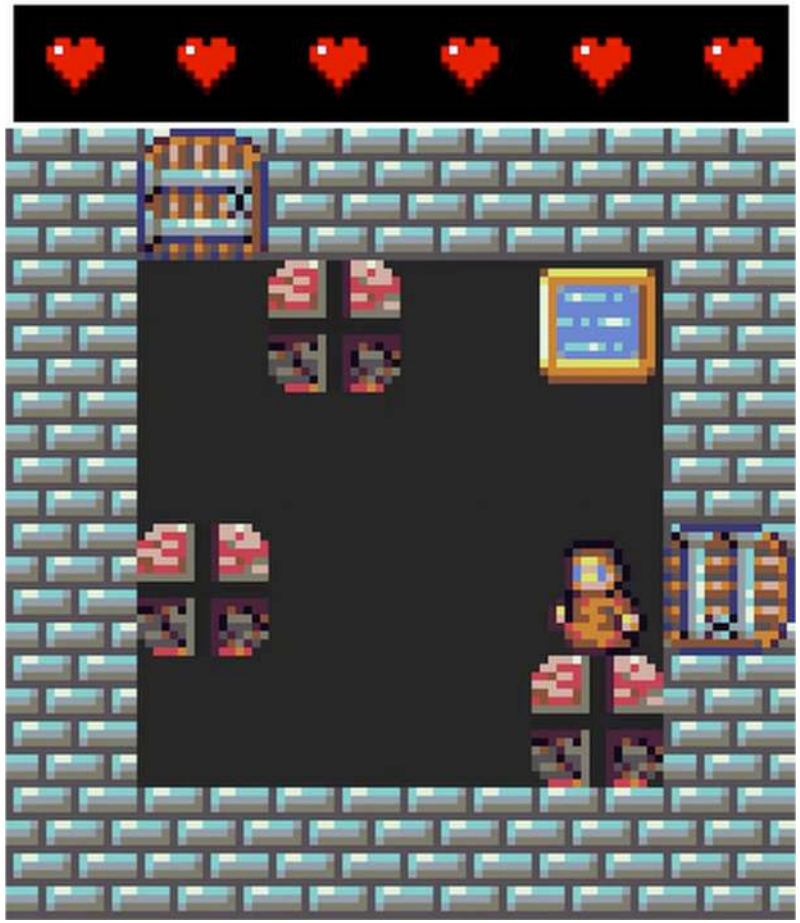
1. **Metric of Added Detail (MAD)**
   - Lines of Code (LOC): used to measure volume (or size)
   - Cyclomatic Complexity (CC): calculates branch points in control flow
   - addresses question 1

2. **Specification Analysis Reporting (SAnR)**
   - grammar rules perform model transformations
   - apply origin tracking, record transformations, analyze history
   - specify level properties
   - addresses questions 2, 3, 4, 5

Dungeon Room Generator

- **Dungeon room generator**
  - toy example
  - simple, representative
- **Goals**
  - Traverse the room
  - Evade fire pillar traps
  - Extinguish the flames
- **Level shown**

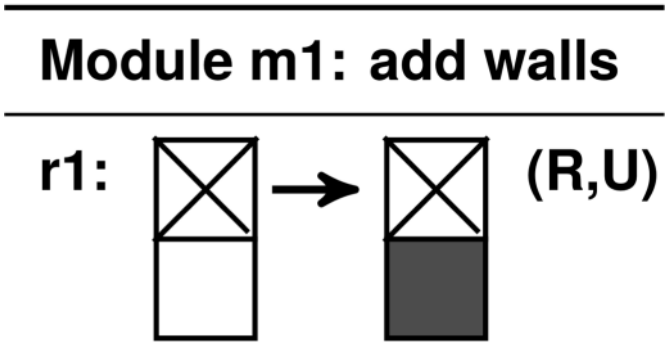




Dungeon room pipeline – stage 1

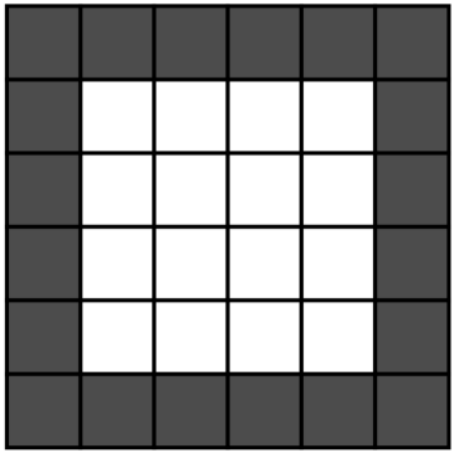
- First, we add walls

☒ =off map ☐ =empty ■ =wall



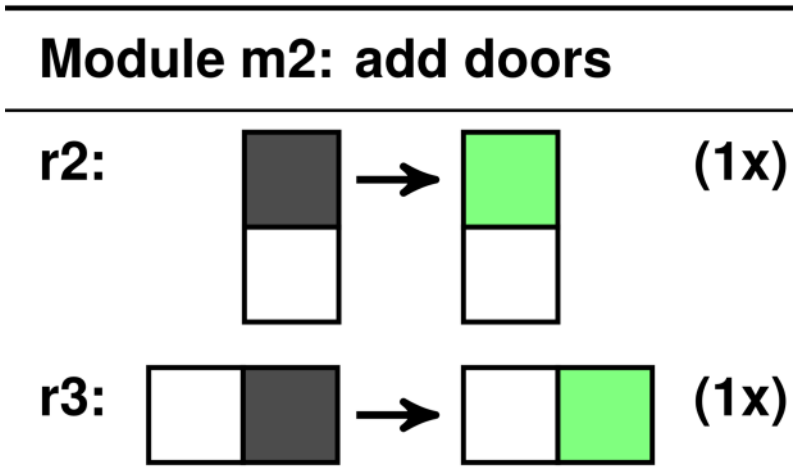
- Rule r1 replaces empty cells on the room borders by walls
  - (R) includes rule rotations
  - (U) repeats until the rule can no longer be applied

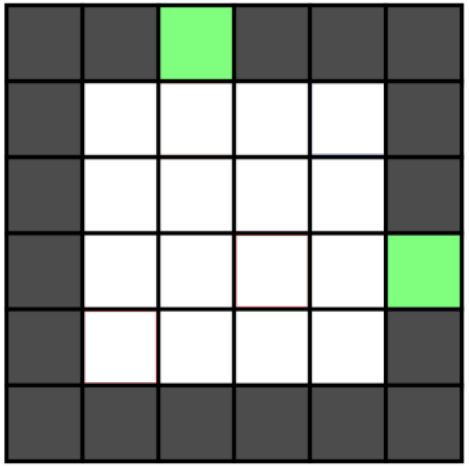
- Running the module results in an empty room with walls



Dungeon room pipeline – stage 2

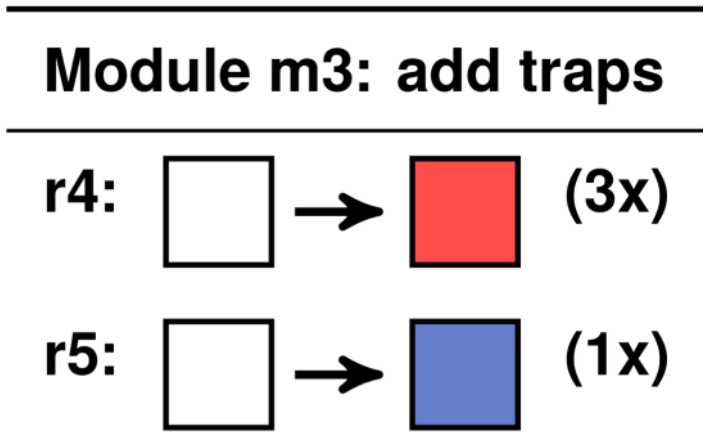
- Next, we add doors
  =door
- North door. Rule r2 replaces a north wall (neighboring an empty cell) by a door
- East door. Rule r3 replaces an east wall (neighboring an empty cell) by a door
- Running module m2 results in two doors in the walls

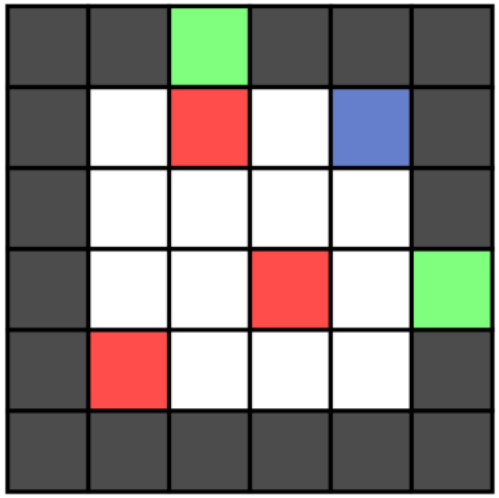




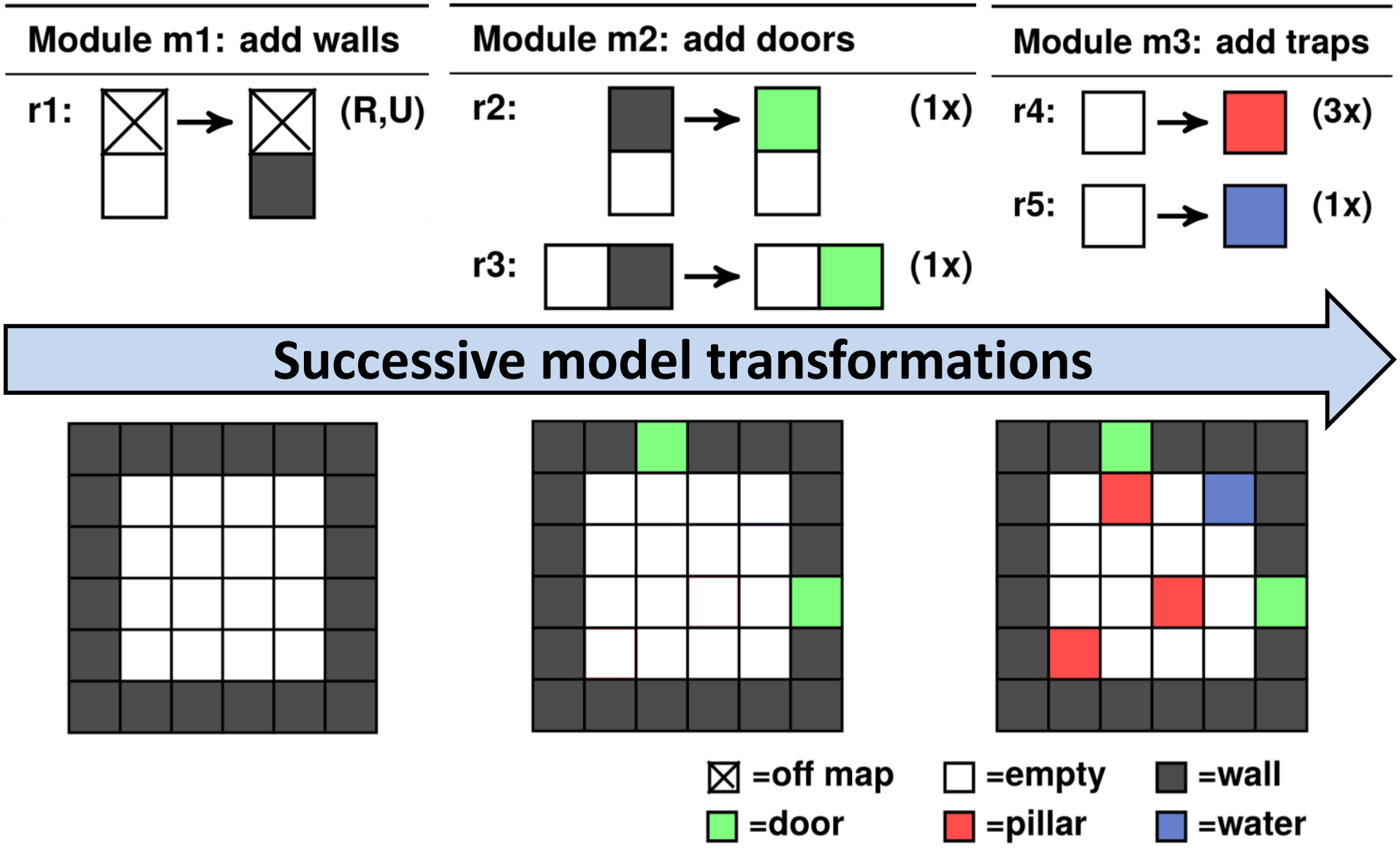
Dungeon room pipeline – stage 3

- Finally, we add a challenge
  =pillar =water
- Fire pillars set players on fire when they remain close for too long
- Water from a pond enables players to extinguish the flames
- Running module m3 results in a room populated with three fire pillars and a pond



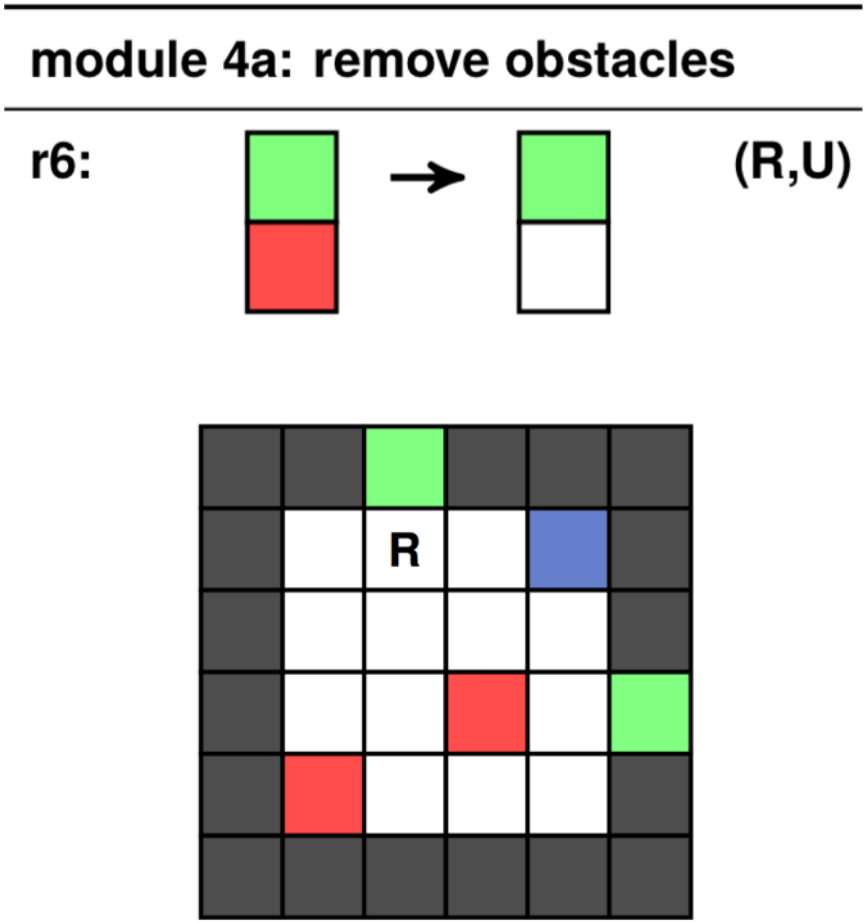


Dungeon room pipeline – complete



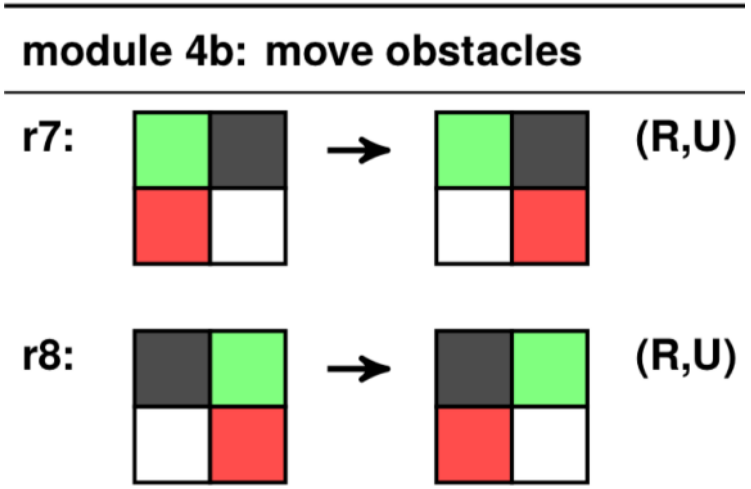
Dungeon room pipeline – problems

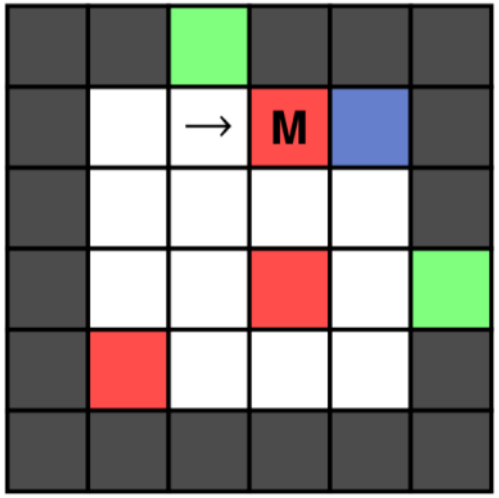
- **Problem:** fire pillars can block access to doors
- **Patch 1**: remove obstacles
  - Rule r6 removes fire pillars blocking doors
- **Result:** fewer traps than intended may reduce the difficulty



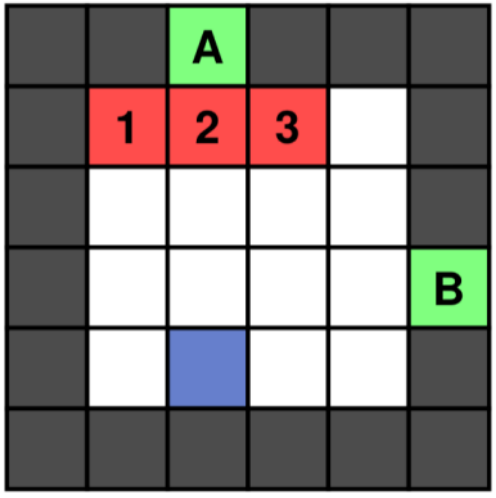
Dungeon room pipeline – problems

- **Patch 2:** move obstacles
  - Rule r7 move a fire pillar blocking a door to the left
  - Rule r8 moves a fire pillar blocking a door to the right

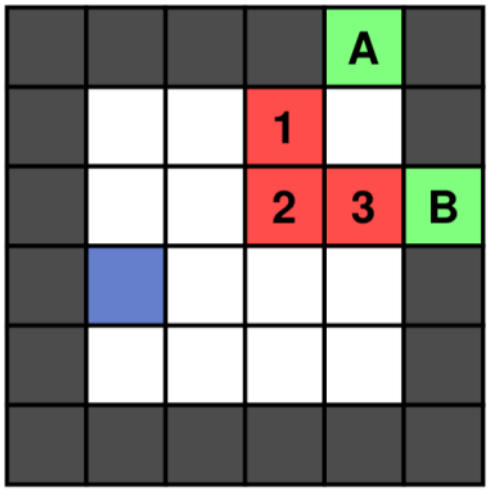




Rule r7 moved pillar M



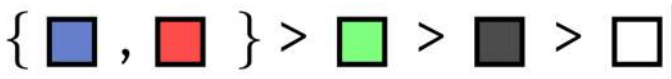
Cannot move pillar 2



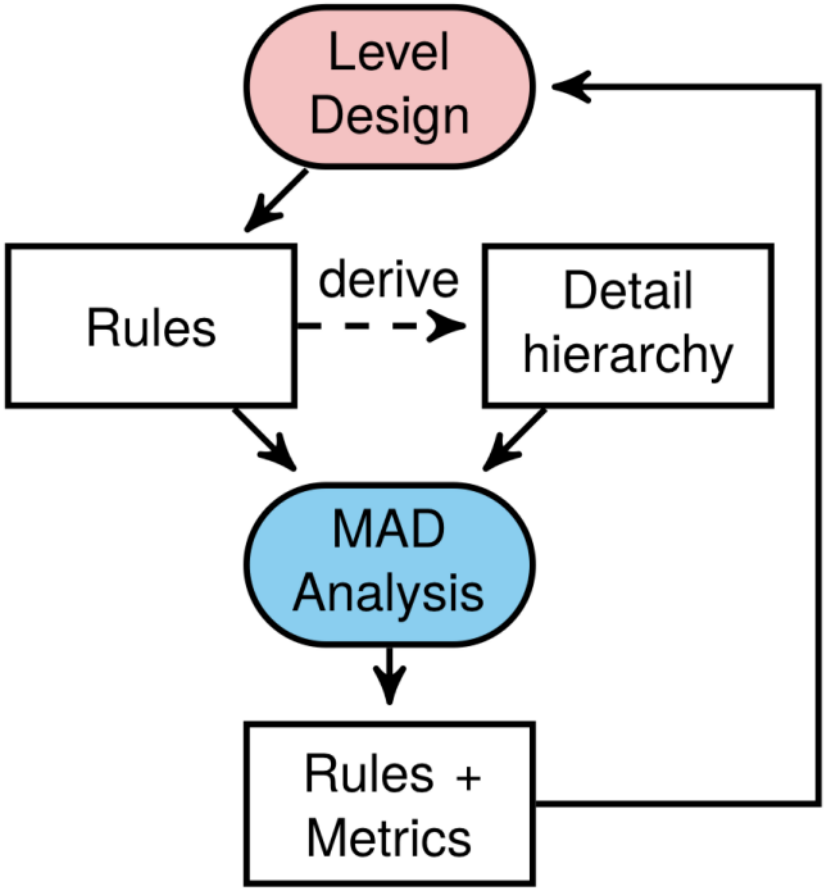
Problems moving pillar 3

MAD Level Design

- Analyzing rule effect with the Metric of Added Detail (MAD)
  - Design a rule and calculate the MAD score with respect to a symbol hierarchy

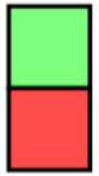
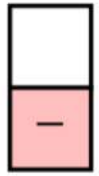


- Calculating the metric
  - Neutral effect (0): cell remains the same
  - Add detail (+1): cell is rewritten to a new symbol
  - Remove detail (-1): cell is rewritten to an old symbol

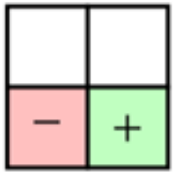
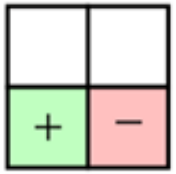


MAD Level Design

Symbol hierarchy { , } > > >

module m4a: remove obstacles				MAD score	heat map
r6:		→		(R,U)	-1 (+0-1) 

Rule r6 has a negative MAD score, since it removes detail.

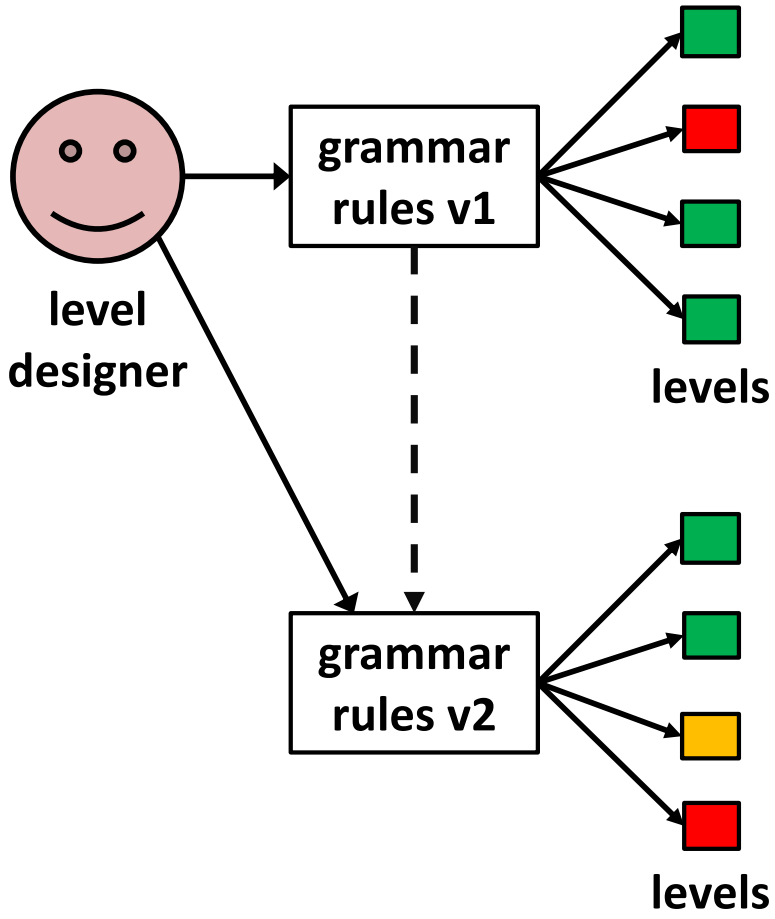
module m4b: move obstacles				MAD score	heat map
r7:		→		(R,U)	0 (+1-1) 
r8:		→		(R,U)	0 (+1-1) 

Rules r7 and r8 have a neutral MAD score, since they preserve detail.

Level Property Language

- **Problems with patching**
  - difficult to get right
  - side-effects
  - do not express level properties

- **Solution: Level Property Language**
  domain-specific language for expressing level properties
  - declarative instead of transformative
  - uses names of tiles and grammar rules
  - add new properties when needed
  - Iterative testing



Level Property Language

- **Amounts.** counts locations of specific tile types and verifies expected amount
  - **1x** water. size {w} == 1: true
  - **3x** pillar. size {a,b,c} == 3: true
- **Adjacency.** filters tile locations
  - **no** pillar **adjacent to** doors
    size {a} == 0: false
- **Topographical inclusion.** filters level generation history using rule names to obtain tile locations
  - **2x** doors **in** walls. collects tiles affected by the walls rule. size {x, y} == 2: true

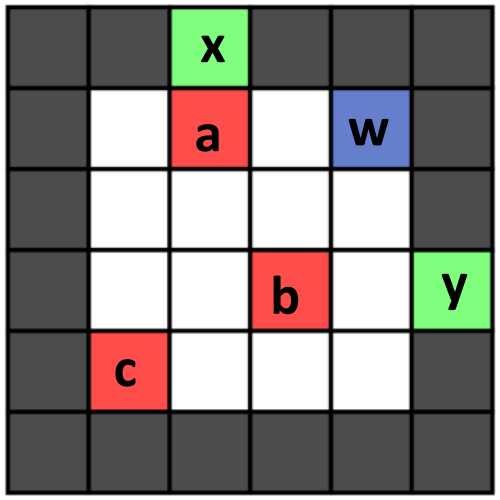
1x water

3x pillar

no pillar **adjacent to** door

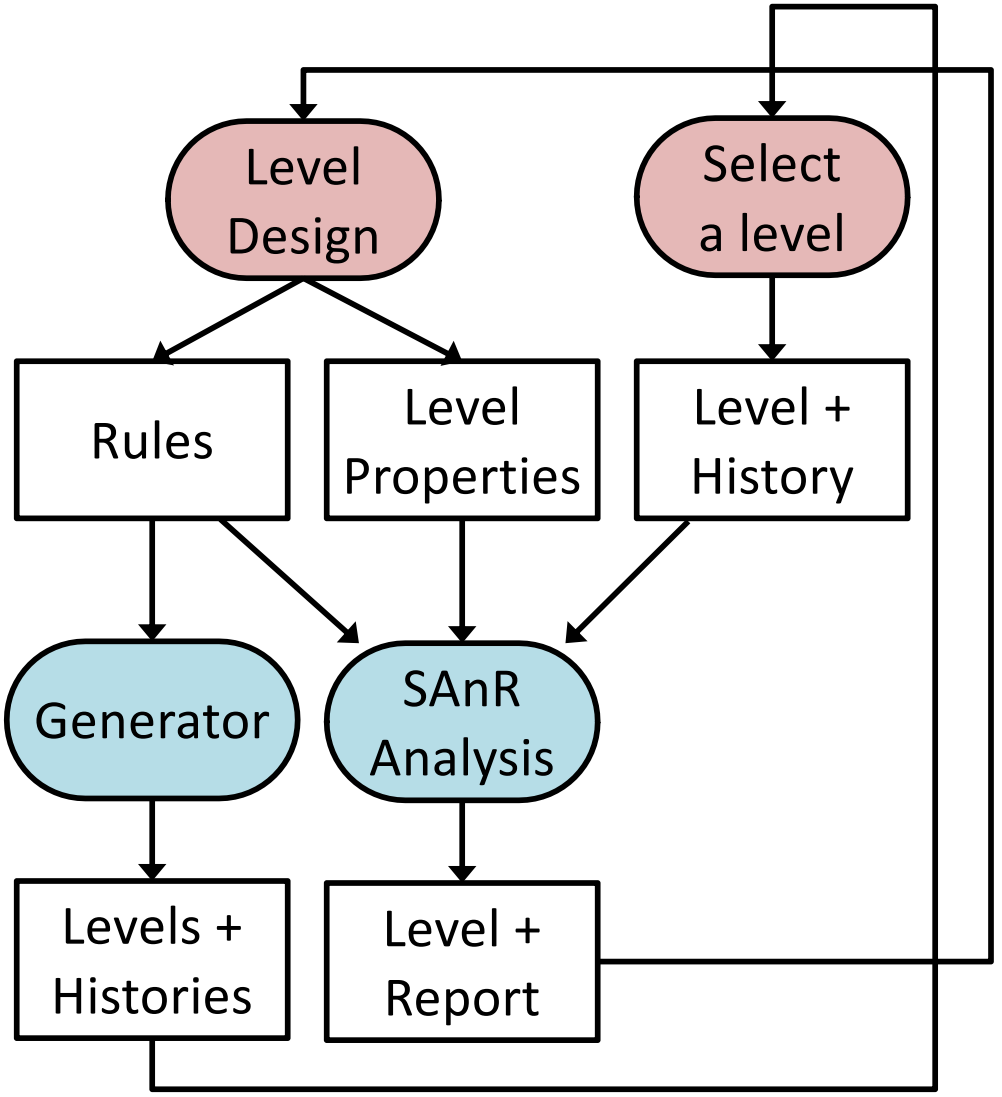
no water **adjacent to** pillar

2x door **in** walls



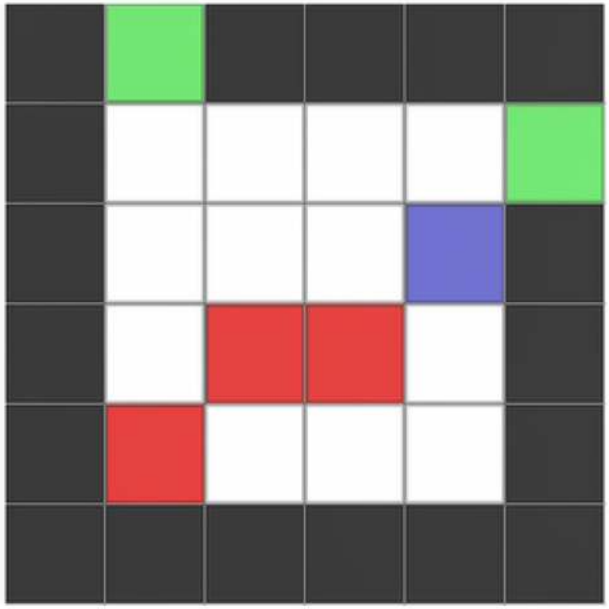
SAnR Level Design

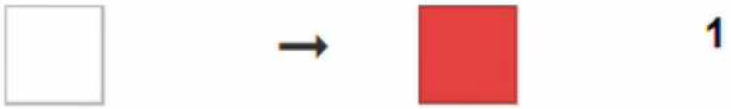
- Mixed-initiative level design using Specification Analysis Reporting (SAnR)
  1. Design grammar rules and level properties
  2. Generate levels
  3. Select a level to debug
  4. Analyze how properties evolved in its level generation history



Ludoscope Lite Project File Execute

#	Module	Rule
0	m1	addWalls
1	m2	addNorthDoo
2	m2	addEastDoor
3	m3	addWater
4	m3	addPillar
5	m3	addPillar
6	m3	addPillar





Properties

- 2x door in addWalls
- 1x water
- 3x pillar
- 0x pillar adjacent to door
- 0x water adjacent to pillar

Ludoscope Lite Project File Execute

Number of executions: 1000

Start analysis

Executions: 1000

Unique results: 988

Broken results: 727

Property	Broken by	Occurences
0x water adjacent to pillar	addPillar	570 (57.000%)
0x pillar adjacent to door	addPillar	318 (31.8000%)

Ludoscope Lite Project File Execute

```
1 version: 0.6f
2 start: TILEMAP 1 1 0:undefined
3 rule: clearDoors(width=2, height=2,
  gt=7) = TILEMAP 2 2 0:wall 1:door
  2:floor 3:pillar > {0 = TILEMAP 2 2
  0:wall 1:door 2:pillar 3:floor}
4
```

Save changes

m4

Executed as grammar

clearDoors

Ludoscope Lite Project File Execute

Number of executions: 1000

Start analysis

Executions: 1000

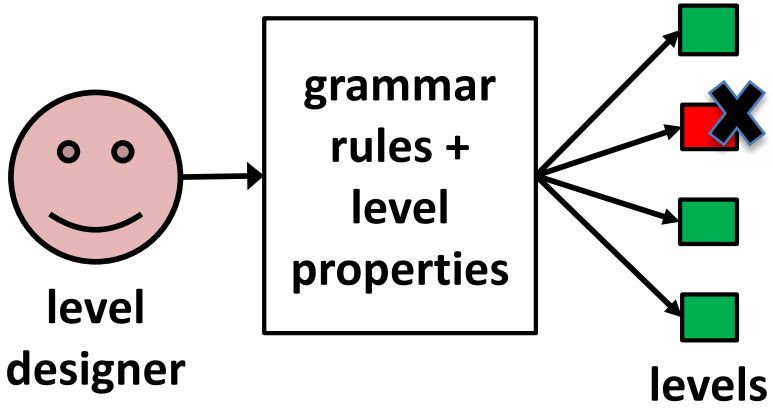
Unique results: 988

Broken results: 585

Property	Broken by	Occurences
0x water adjacent to pillar	addPillar	554 (55.4000%)
0x water adjacent to pillar	clearDoors	22 (2.2000%)
0x pillar adjacent to door	addPillar	38 (3.8000%)
↳ Execution #56		
↳ Execution #82		
↳ Execution #95		
↳ Execution #102		
↳ Execution #158		
↳ Execution #186		
↳ Execution #205		
↳ Execution #220		
↳ Execution #227		

Conclusions

- **Software Evolution perspective**
  - opportunities for tool improvements
  - Two novel techniques for grammar-based level generation, specifically for tile maps



1. **Metric of Added Detail (MAD)**
   - raises flags for rules that remove details (which may be problematic)
2. **Specification Analysis Reporting (SAnR)**
   - adds declarative level properties
   - provides insight into level generation history

- **Evaluation and validation**
  - Case study on Boulder Dash