The Power and Peril of PCG

Gillian Smith
Northeastern University

Julian Togelius
New York University

Who Are We?

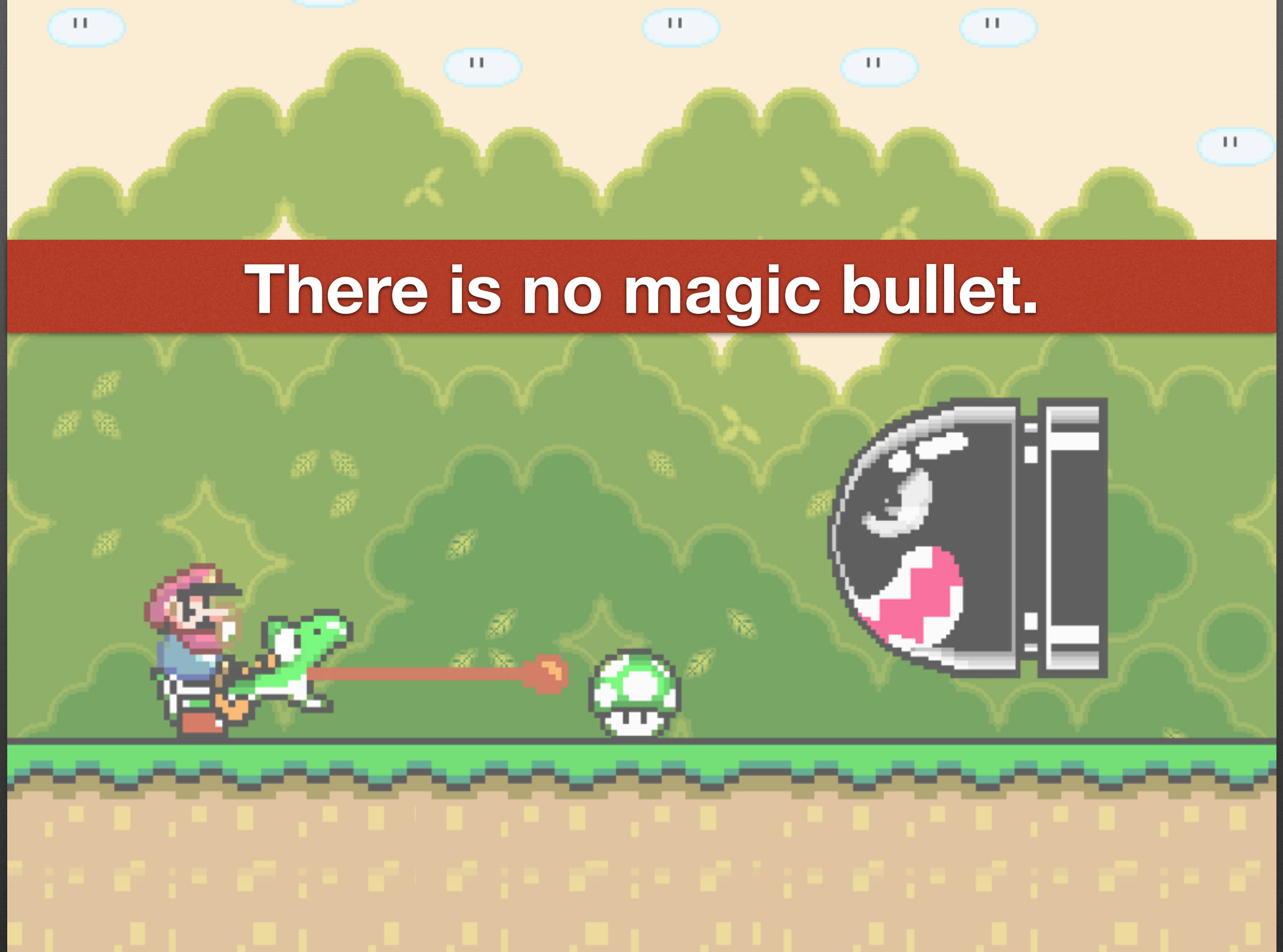
- Gillian Smith
- Assistant Professor, Northeastern University
- PCG-based game design, mixed-initiative design tools, history of PCG, constraints, grammars
- Super Mario World, western roleplaying games, puzzle games

Who Are We?

- Julian Togelius
- Associate Professor,
  New York University
- Search-based PCG, cellular automata, PCG for game adaptation, game generation
- StarCraft, Super Mario Bros, Cut the Rope, racing games

What Are We Talking About?

- **Technical approaches to gameplay-oriented PCG**
  - What is available?
  - What are strengths and weaknesses?
  - Examples
- **Practical PCG advice**
  - Choosing an approach
  - Why is PCG in the game?
- **Using PCG to help designers**
- **Debugging and visualization strategies**


There is no magic bullet.

flickr: oter

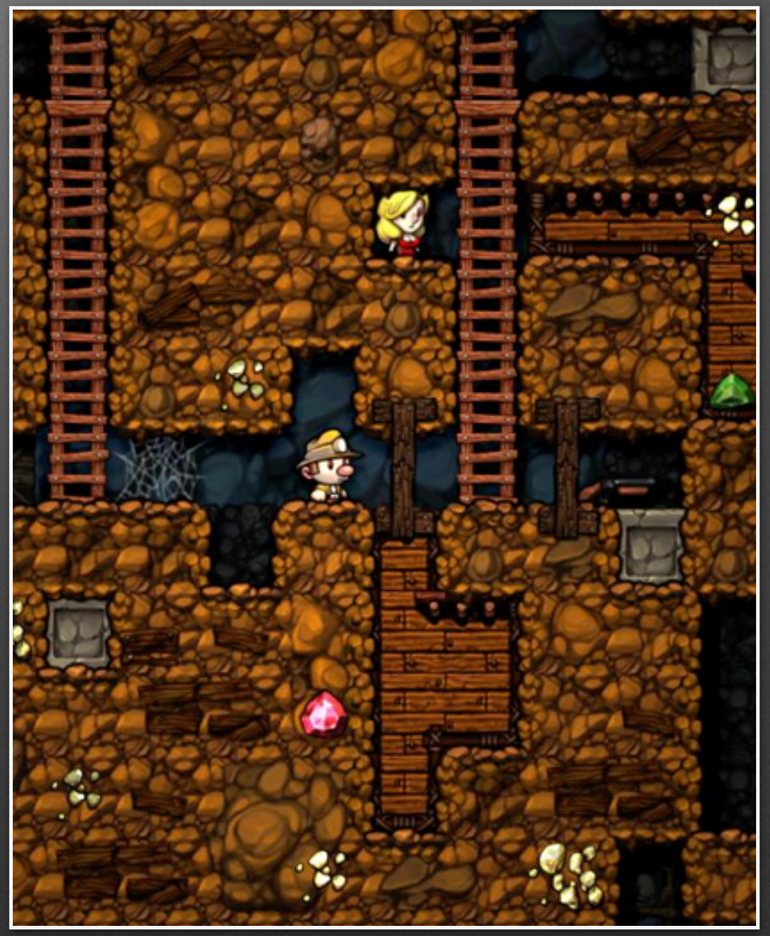
PCG Methods and Approaches

their power and peril

Constructive Methods

Description

- Piece together random building blocks
- Direct randomness via:
  - Knowledge representation
  - Altering distribution
  - Indirection, lookup tables
- “Let’s just hack this thing together.”



Spelunky

Constructive Methods

Power and Peril

- Light-weight algorithmically
- Customized to design
  - This is good and bad…
- Fighting against human pattern recognition skills
- Authoring burden on artists, designers to make highly modular content

Diablo 3

Constructive Methods

Extreme Example

- 4 pages of lookup tables
- Build entire dungeon at runtime
- Highly customized
- Hard to debug
- PCG as part of play!

TABLE I.: PERIODIC CHECK (d20)

Die	Result
1-2	Continue straight — check again in 60′ (this table)
3-5	Door (see TABLE II.)
6-10	Side Passage (see TABLE III.) — check again in 30′ (this table)
11-13	Passage Turns (see TABLE IV., check width on TABLE III.) — check again in 30′ (this table)
14-16	Chamber (see TABLE V.) — check 30′ after leaving (this table)
17	Stairs (see TABLE VI.)
18	Dead End (walls left, right, and ahead can be checked for Secret Doors, see TABLE V.D., footnote)
19	Trick/Trap (see TABLE VII.), passage continues — check again in 30′ (this table)
20	Wandering Monster, check again immediately to see what lies ahead so direction of monster's approach can be determined.

TABLE II.: DOORS* (d20)

Location of Door:		Space Beyond Door Is:	
Die	Result	Die	Result
1-6	Left	1-4	Parallel passage**, or 10′ × 10′ room if door is straight ahead
7-12	Right	5-8	Passage straight ahead
13-20	Ahead	9	Passage 45 degrees ahead/behind***
		10	Passage 45 degrees behind/ahead***
		11-18	Room (go to TABLE V.)
		19-20	Chamber (go to TABLE V.)
			Always check width of passage (TABLE III. A.)

* Check again immediately on TABLE I. unless door is straight ahead; if another door is not indicated, then ignore the result and check again 30′ past the door. If a room or chamber is beyond a door, go to TABLE V.

** Extends 30′ in both directions.

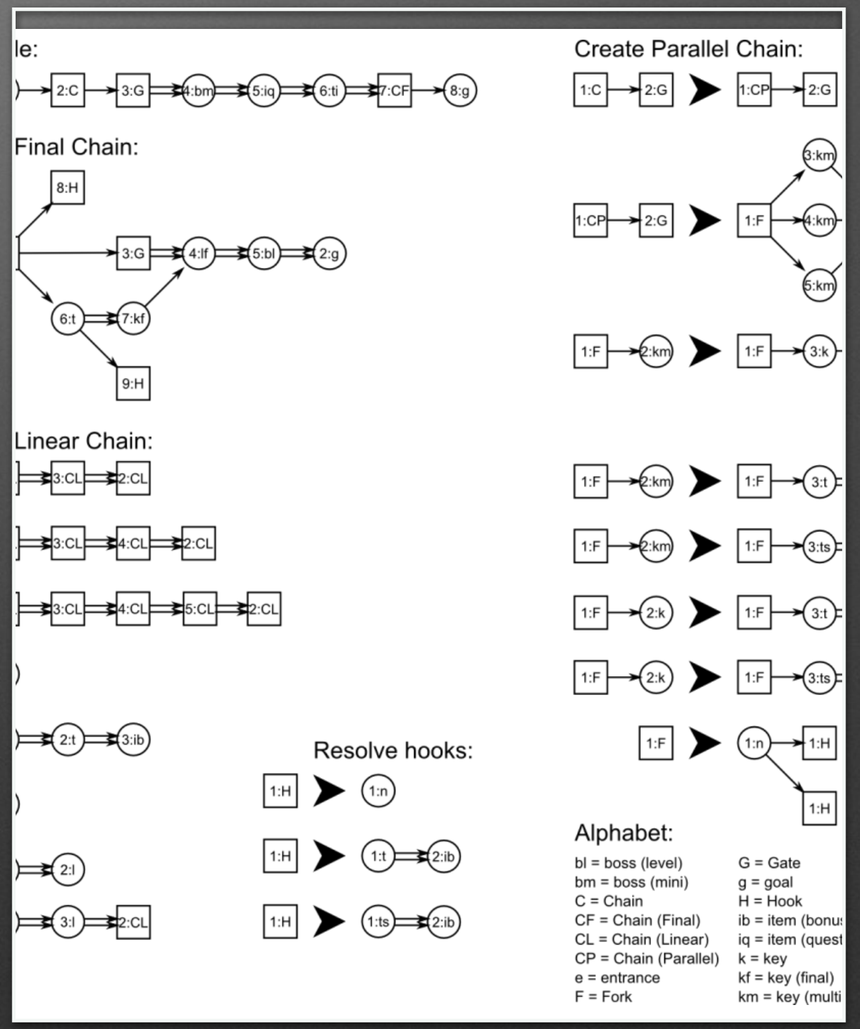
*** The direction will be appropriate to existing circumstances, but use the direction before the slash in preference to the other.

AD&D Dungeon Generation

Grammars

Description

- Specify an ontology, an axiom and a set of production rules
- The rules determine how symbols are expanded
- Well-known example: L-systems
- Much broader applicability, e.g. quests, dungeons, caves…

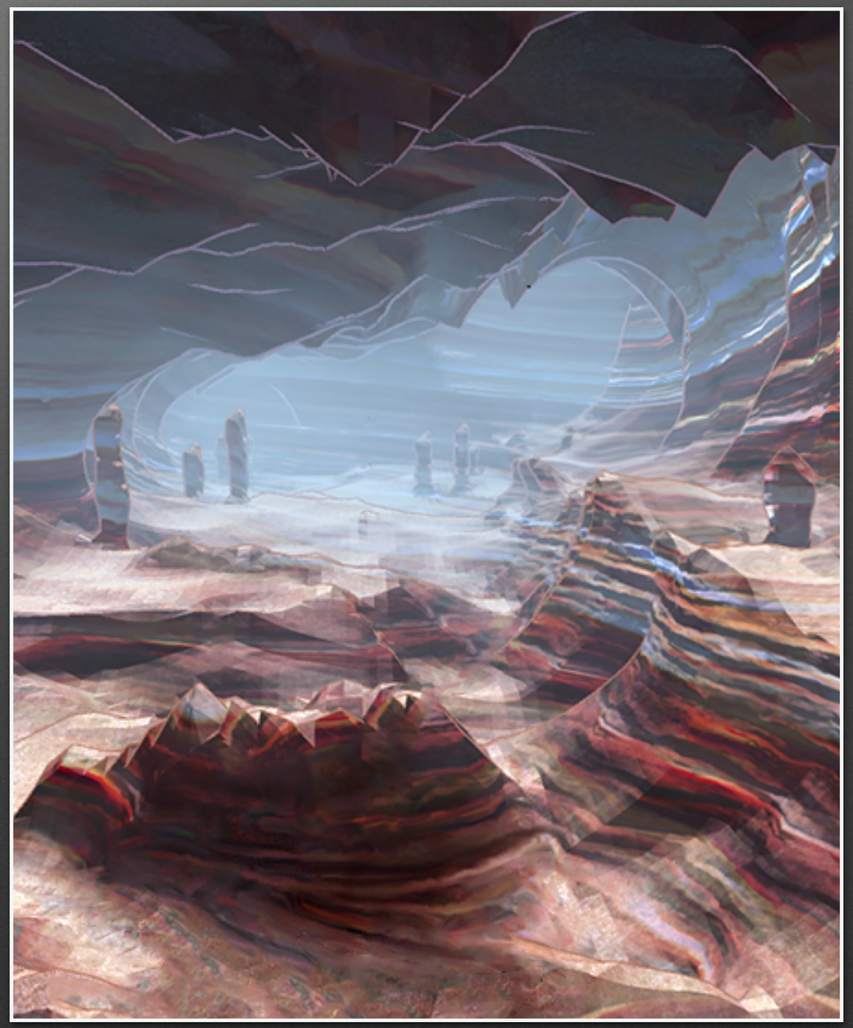


Joris Dormans' Missions and Spaces

Grammars

Power and Peril

- Power: easy to author chunks of content, surprisingly complex structures generated
- Perils: over- and under-generating, repetitiveness
- Generate-and-test



Benjamin Mark et al. 3D Caves for Games on the GPU

Constraint-Based Systems

Description

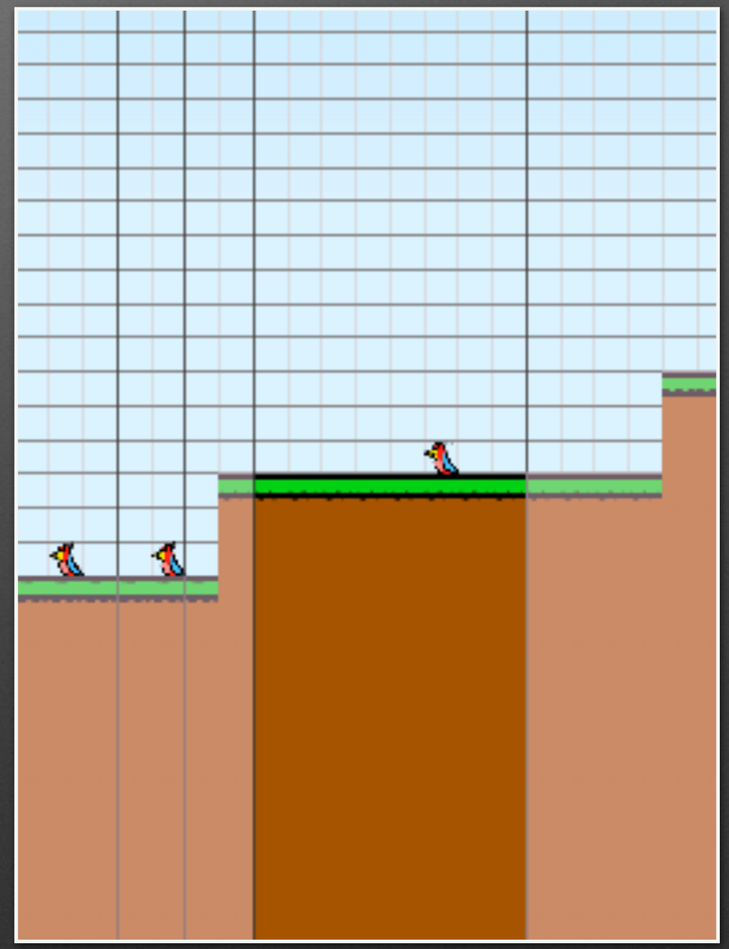
- Define domain in terms of variables and numerical and/or logical constraints
- Off-the-shelf solver
- “I need to meet hard design constraints and I love logic programming.”

Refraction

Constraint-Based Systems

Power and Peril

- Can make promises about design issues
  - Solvability / validity
  - Player experience
- Flexible, general-purpose language
- Must define domain very tightly, including common sense
- Scalability depends on domain representation
- Debugging is difficult

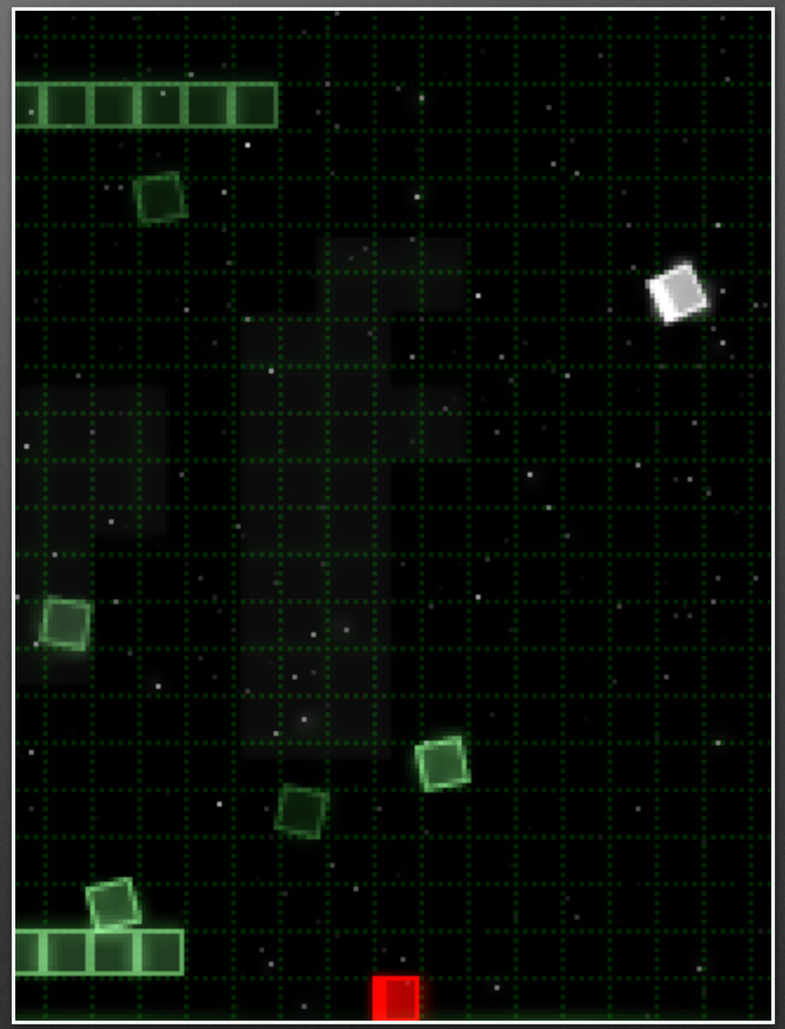


Tanagra

Constraint-Based Systems

Extreme Example

- Game generation with modular, logically expressed rulesets
- Constraints on how rulesets can be combined
- Generated result constitutes explanation of rules for player



Variations Forever

Optimization

Description

- Also known as search-based PCG
- Use an evolutionary algorithm to evolve the content
- Fitness function: “goodness” of content
- Representation: creates a search space where good content can be found

City Conquest

Optimization

Power and Peril

- Power: extremely general, requires little domain knowledge,
  finds unexpected solutions
- Peril: takes time,
  hard to find fitness function, finds unexpected solutions
- Different levels of ambitions possible - from tuning the game to creating new rules

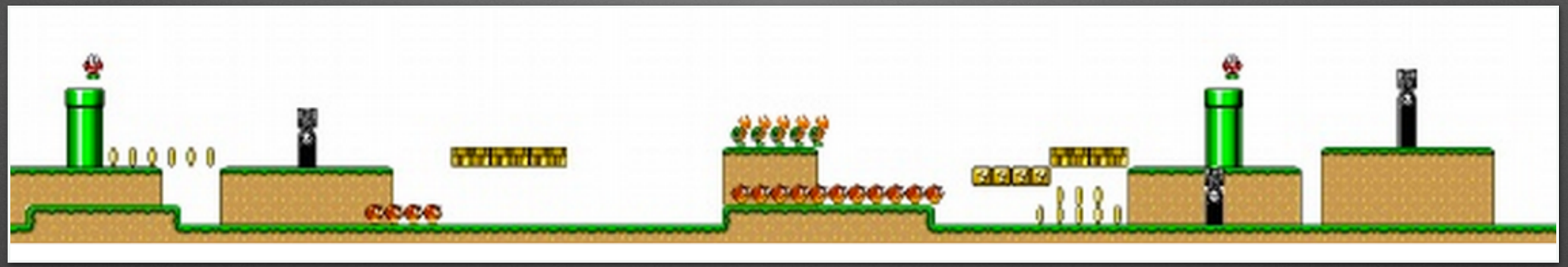
Optimization

Extreme Example

- Angelina: generates complete games
- Evolves levels, selects art
- Also in previous version: evolves mechanics

ANGELINA

Mix-and-Match



- Optimization + grammars
- Constraints + grammars
- Optimization + constraints
- Multi-layer constructive

Summary

METHOD	POWER	PERIL
CONSTRUCTIVE	simple to author customization	repetitiveness in content ad hoc
CONSTRAINT-BASED	design guarantees declarative	translating to constraints debugging
OPTIMIZATION-BASED	generality emergence	fitness function speed
GRAMMARS	emergence easy to author	prone to over- and under-generation

flickr: justinbaeder

Practical Advice

okay but now what?

What Do You Care About?

Building Blocks
Authored Chunks
Templates
Components
Subcomponents

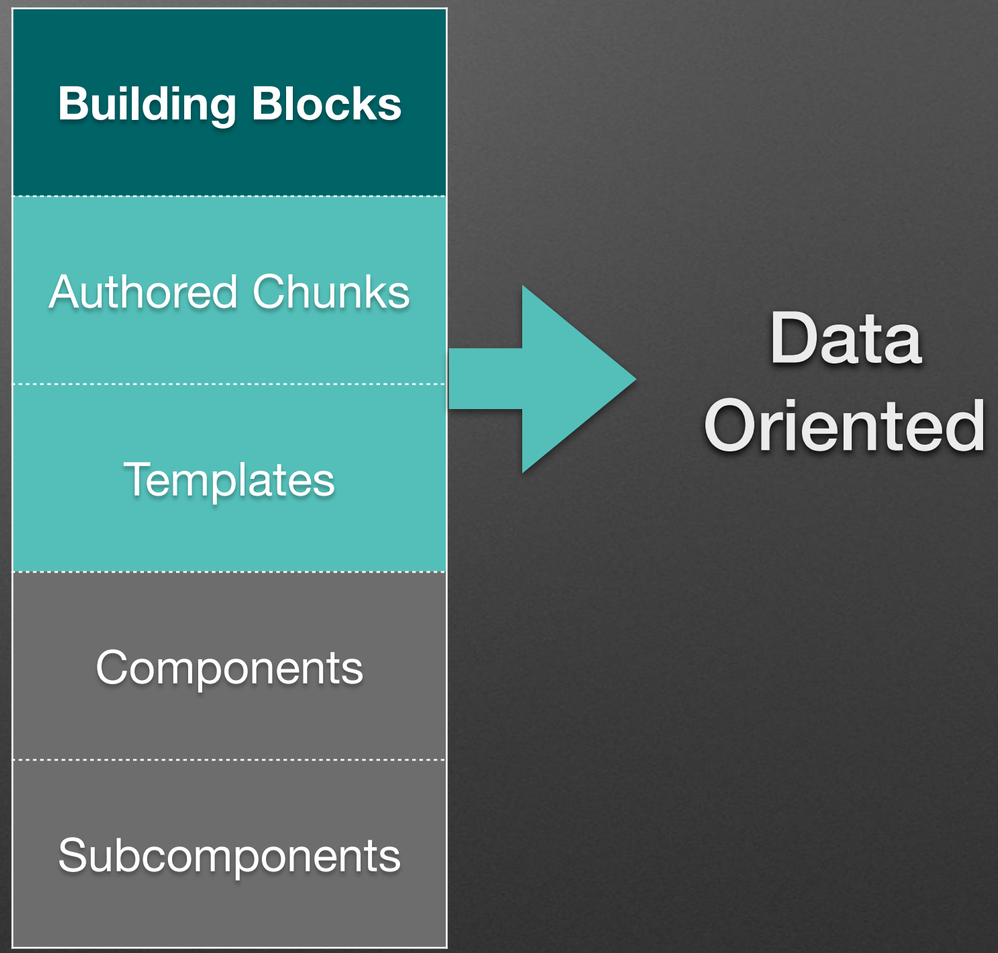
Game Stage
Online
Offline

Player Interaction
None
Parameterized
Indirect
Direct

Design Control
Indirect
Compositional
Experiential

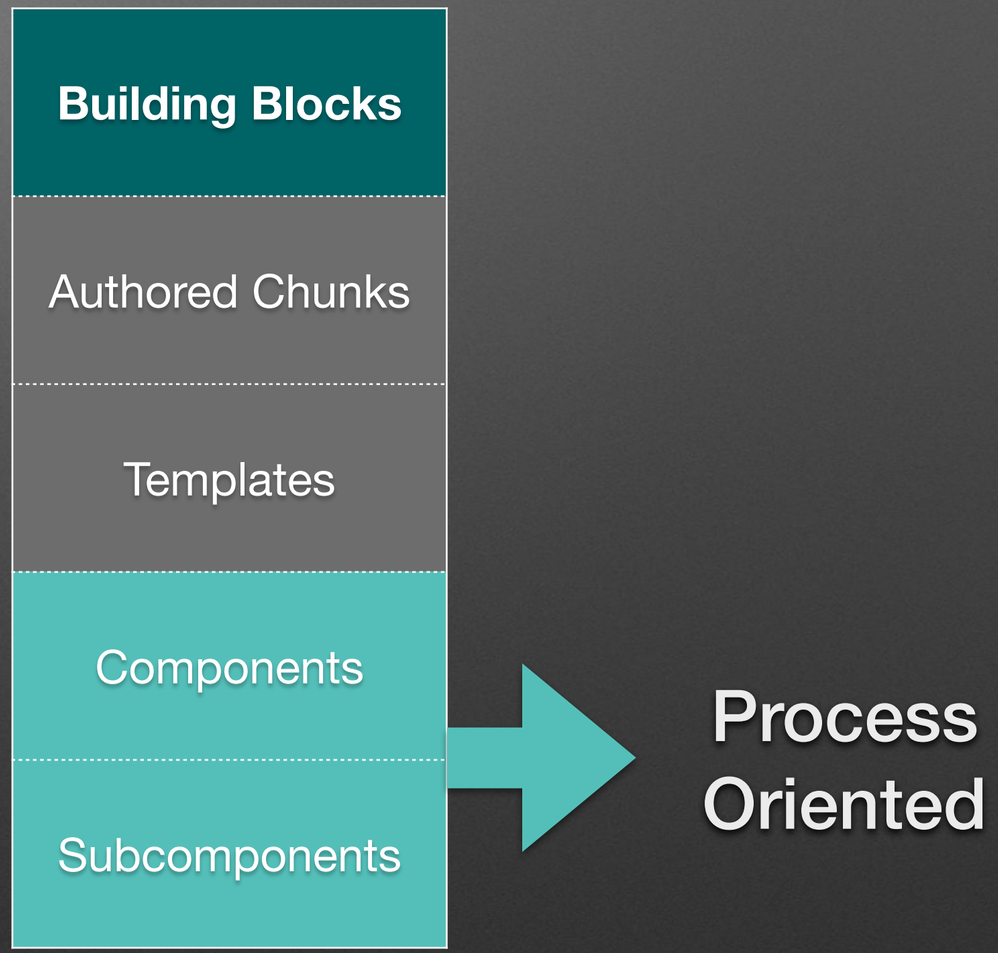
Data vs. Process

- Where do you place authorial control?



Data vs. Process

- Where do you place authorial control?



Algorithm Speed

- Online
  - Speed is paramount
  - Human-in-the-loop?
- Offline
  - Flexible in algorithm choice
  - Automated curation

Game Stage
Online
Offline

What about the players?

- Type of control dictates algorithm choice
  - Weighting of grammar rules
  - Fitness Function
  - Changing constraints

Player Interaction	Design Control
None	Indirect
Parameterized	Compositional
Indirect	Experiential
Direct	

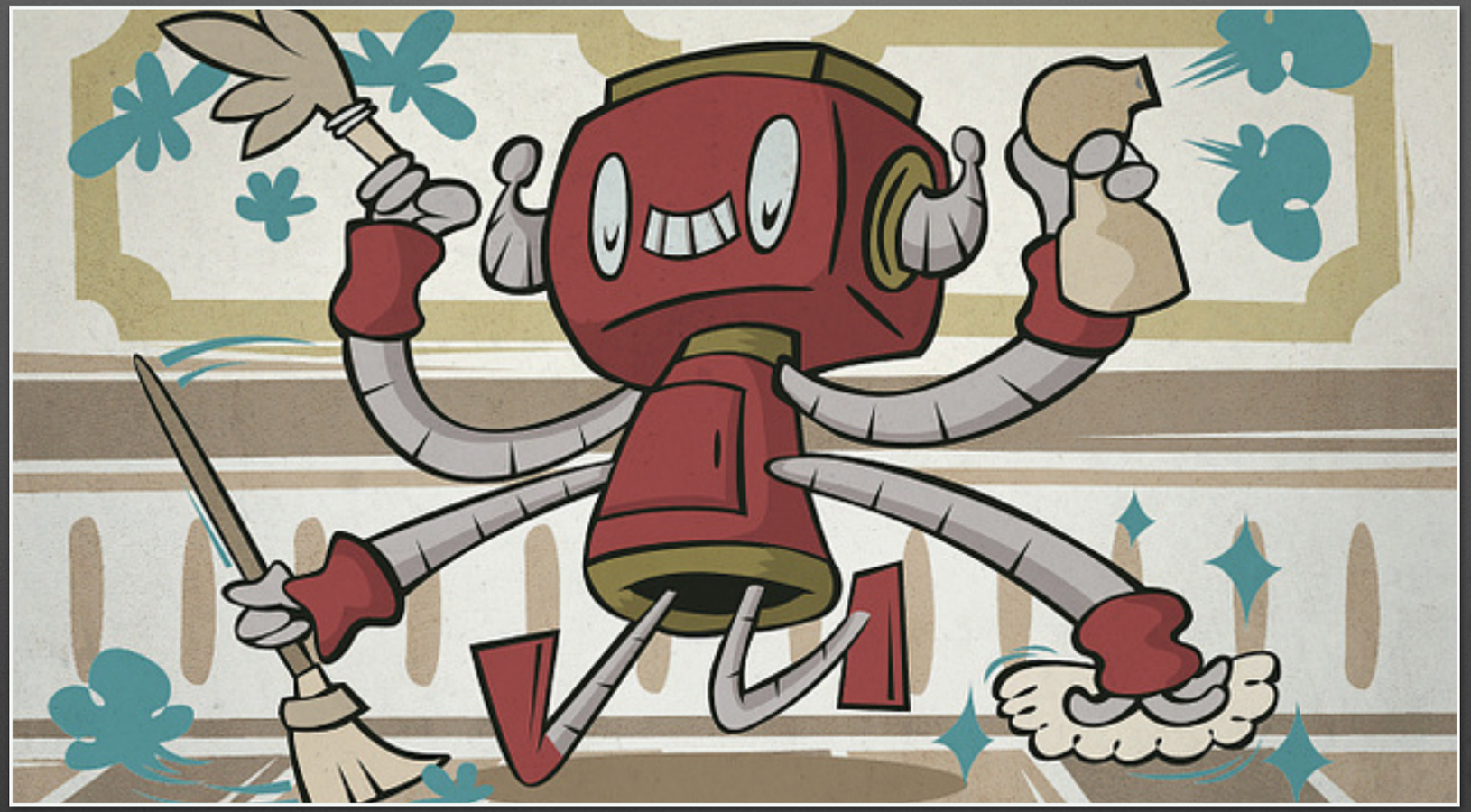
What about the players?

- What granularity of control?
  - “Fun” and other fitness functions
  - Specific content or experiential (eg. pacing) requirements

Player Interaction	Design Control
None	Indirect
Parameterized	Compositional
Indirect	Experiential
Direct	

PCG Dynamics

- How coupled is it to other mechanics?
- Memorization vs. reaction
- Player builds strategies to influence generator
- Player seeks new content in large world
- Player practices mechanics in new settings
- Communities of players interacting



flickr: omnitarian

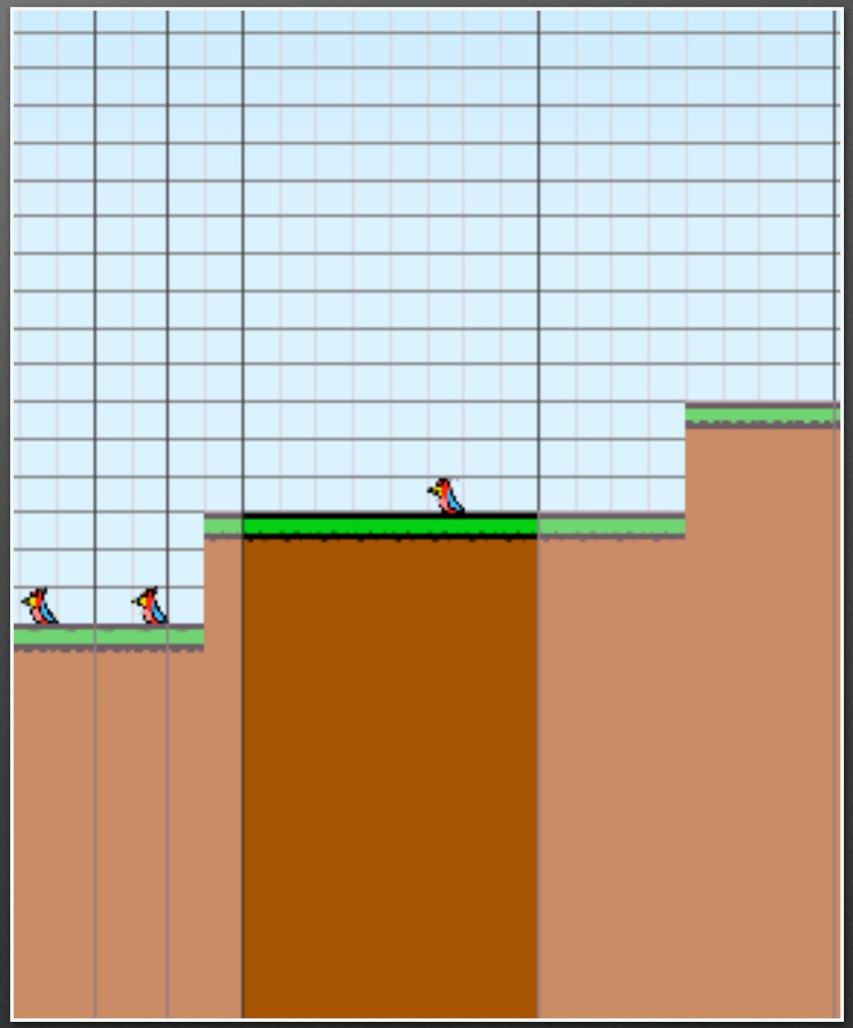
Mixed-Initiative Tools

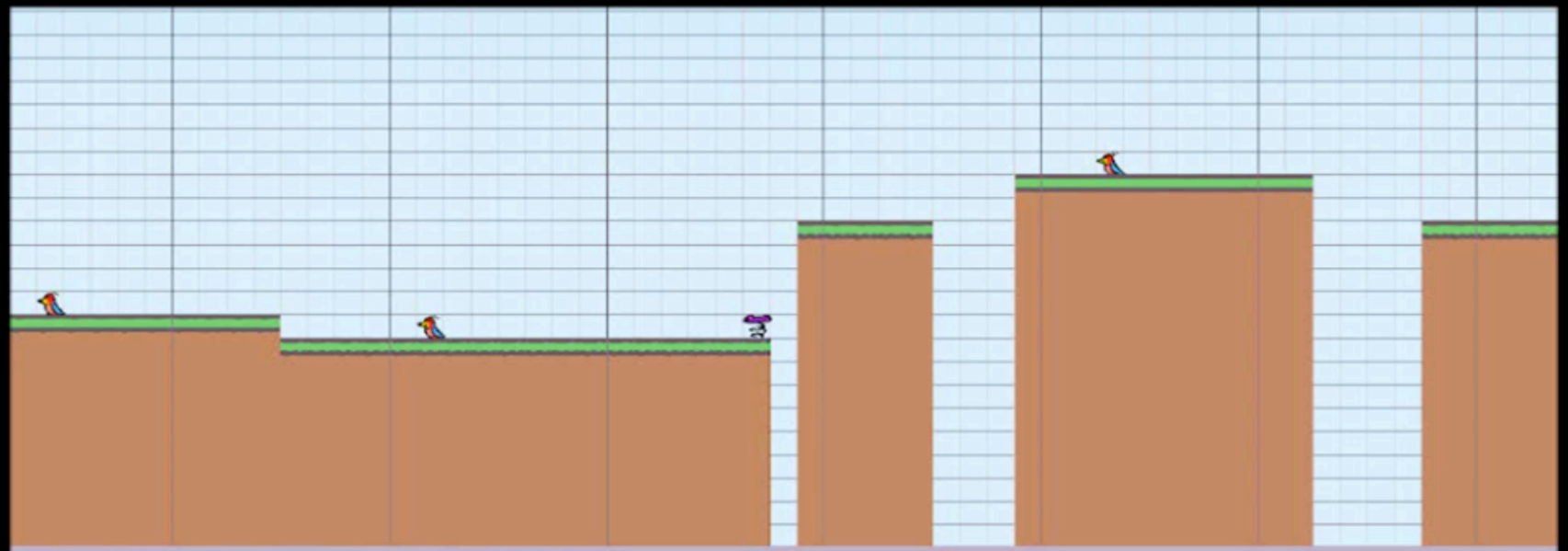
pcg to help designers

Tanagra

Constraints and Reactive Planning for Platformer Levels

- Human-machine realtime (-ish) design collaboration
- Human continually edits constraints on level, machine brainstorms
- Experiential control: manipulate pacing independent of geometry





GAMES AND PLAYABLE MEDIA

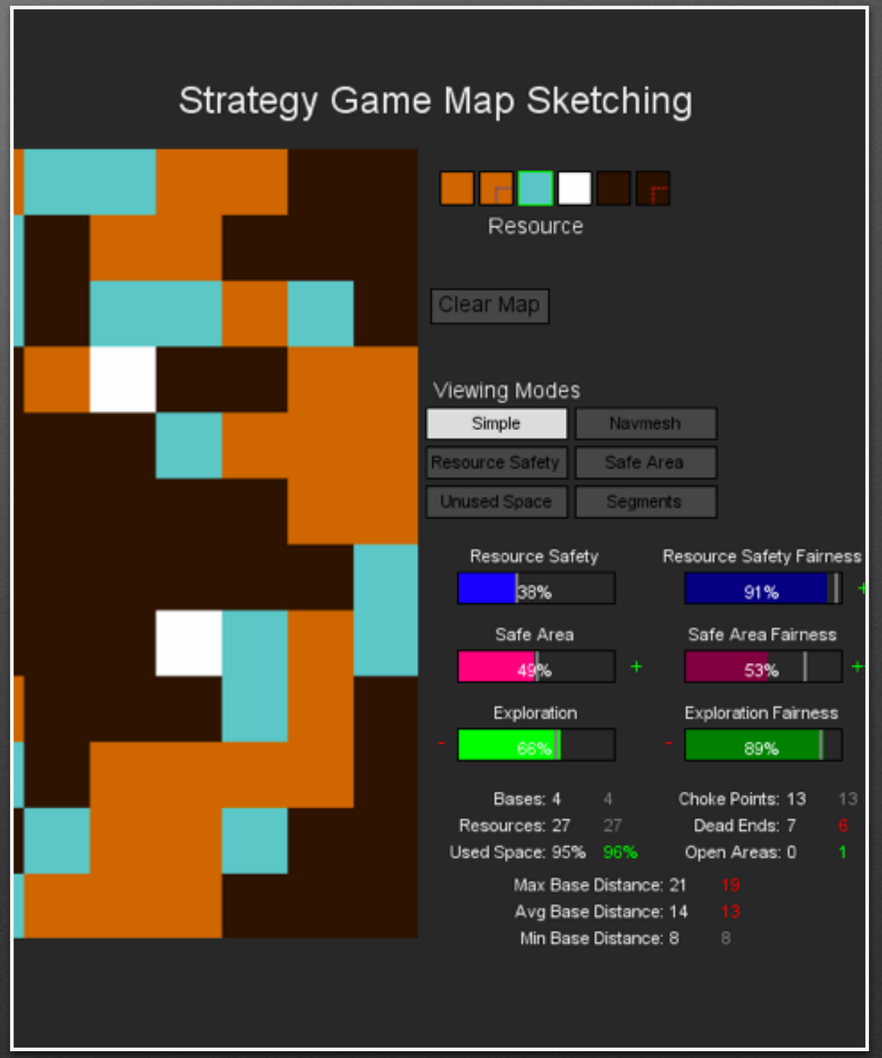
Tanagra: An AI-Supported Level Design Tool

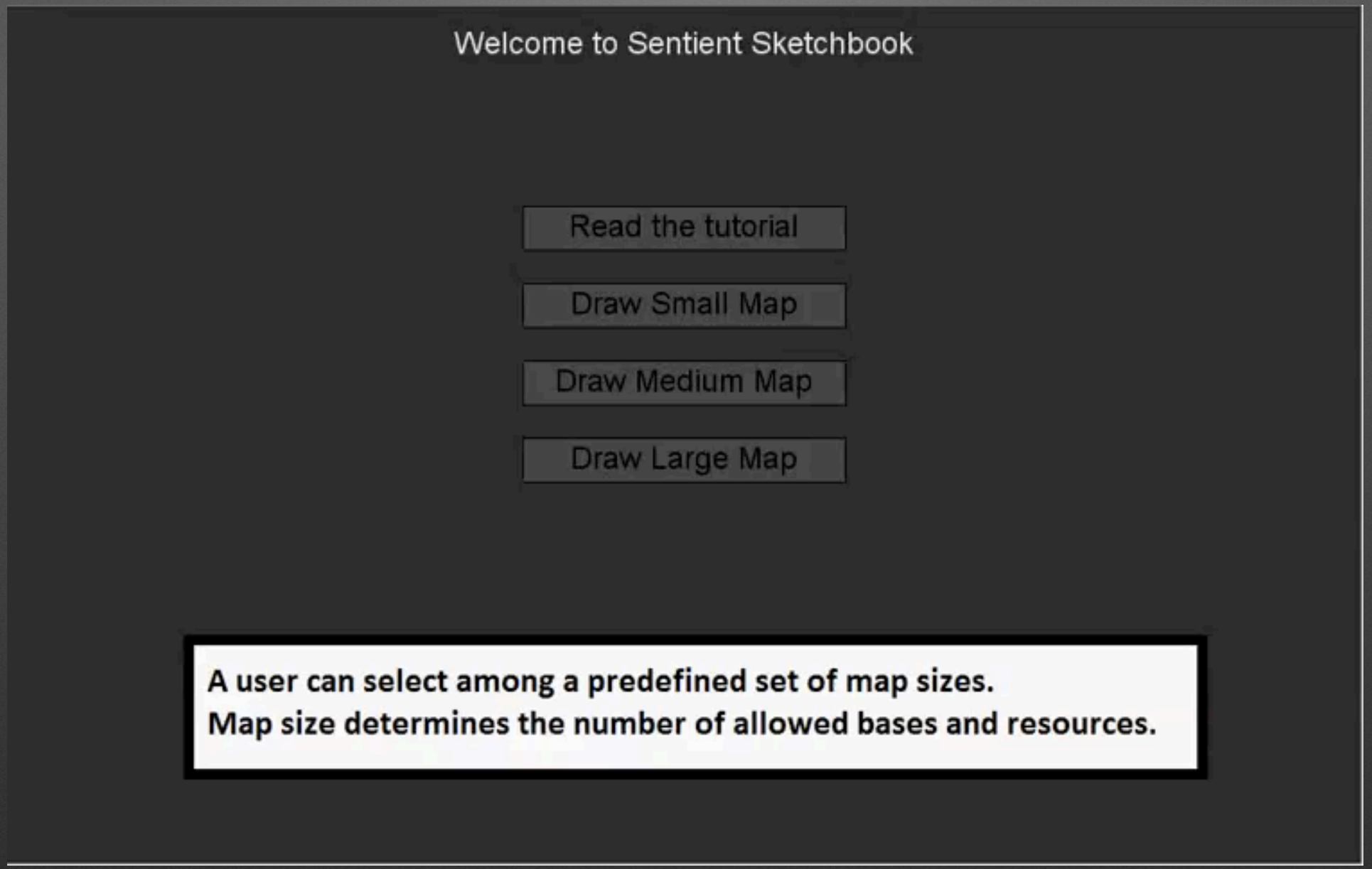
Gillian Smith, Jim Whitehead, Michael Mateas

Sentient Sketchbook

Optimization for strategy map levels

- Maps represented as sketches
- Suggestions continuously generated in reaction to user actions
- Human aesthetic preferences recorded from editing operations



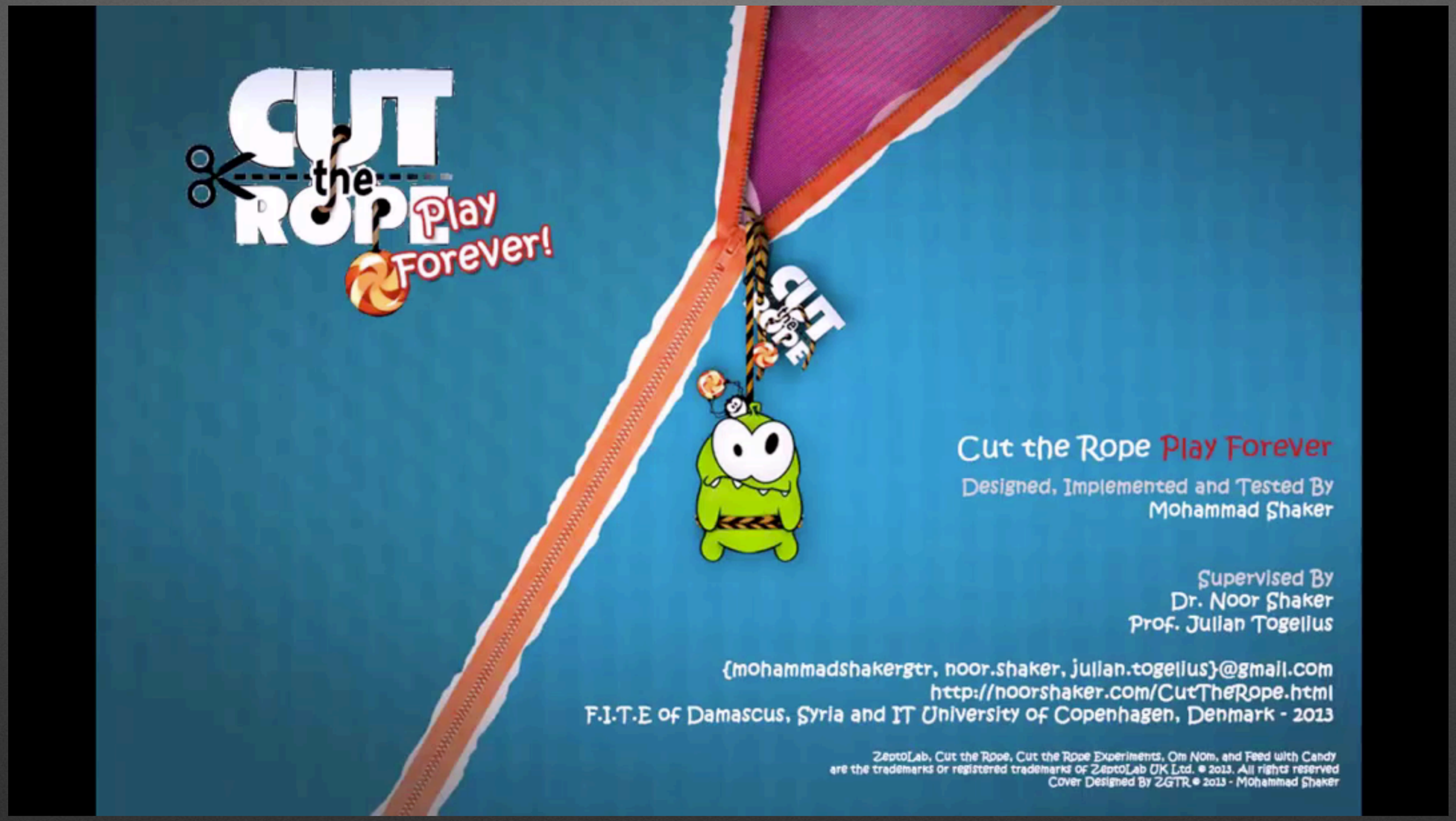


A user can select among a predefined set of map sizes.
Map size determines the number of allowed bases and resources.

Ropossum

Optimization and solving for Cut the Rope

- Tree search for finding solvable levels
- Grammatical evolution for placing level items
- Any part of the level can be locked for human edits


CUT the ROPE Play Forever!
Cut the Rope Play Forever
Designed, Implemented and Tested By
Mohammad Shaker
Supervised By
Dr. Noor Shaker
Prof. Julian Togelius
{mohammadshakergtr, noor.shaker, julian.togelius}@gmail.com
http://noorshaker.com/CutTheRope.html
F.I.T.E of Damascus, Syria and IT University of Copenhagen, Denmark - 2013
ZeptoLab, Cut the Rope, Cut the Rope Experiments, Om Nom, and Feed with Candy
are the trademarks or registered trademarks of ZeptoLab UK Ltd. © 2013. All rights reserved
Cover Designed By ZGTR © 2013 - Mohammad Shaker

flickr: Robert Körner

Visualizing and Debugging

making sense of your generator

Generative Space

- PCG moves us from designing content to designing *spaces* of content
- Minor algorithm choices can lead to large changes in space of output

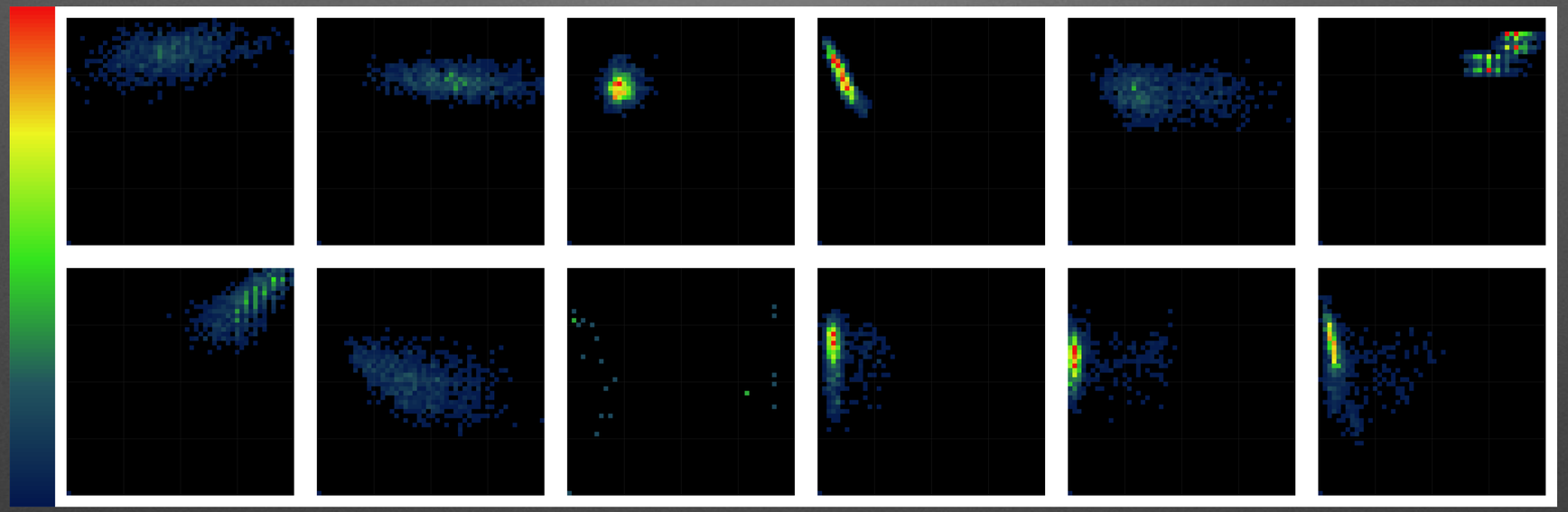
flickr: Diana Robinson

Sampling from the Space

- Tempting to look at a few examples of content and judge entire space
- Sampling problems: how do you know you have a representative sample?

flickr: William Warby

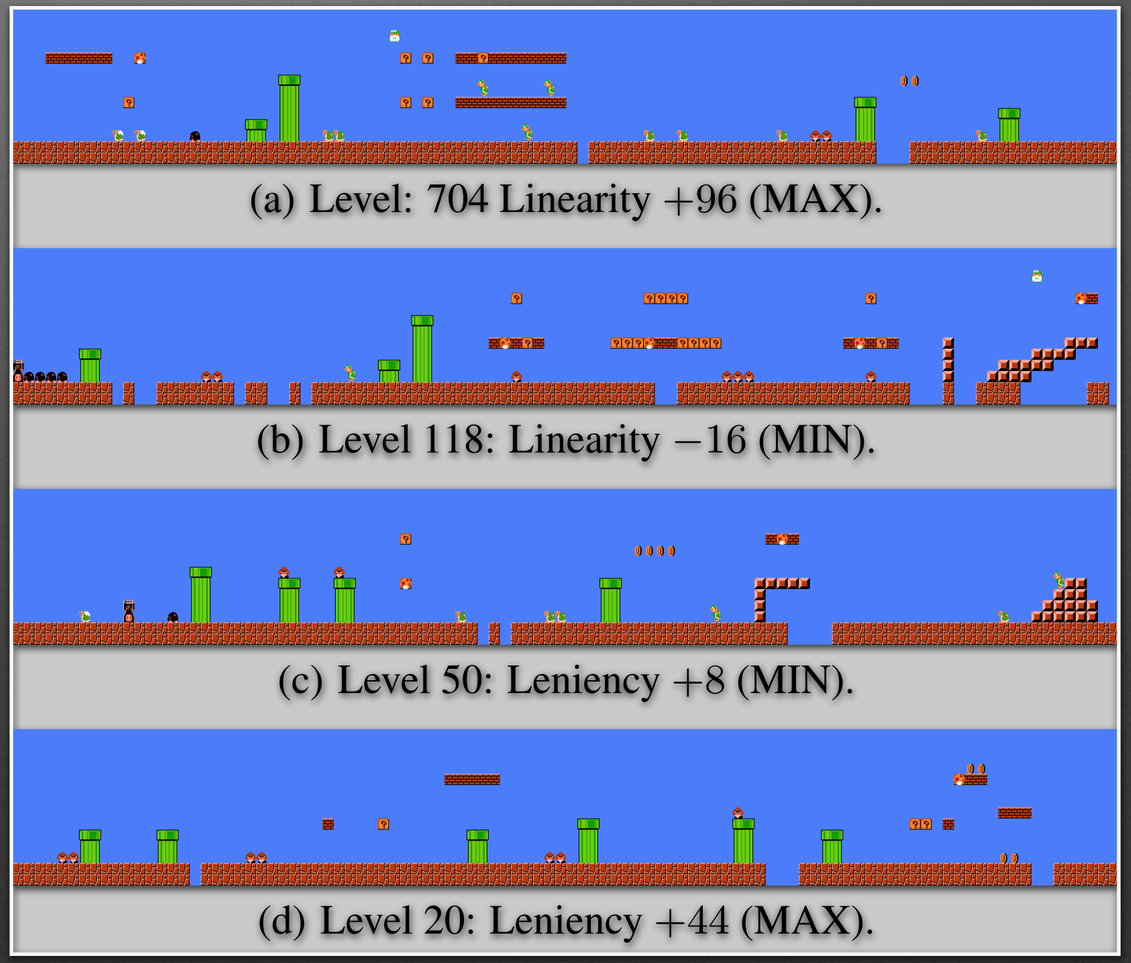
Expressive Range



- Define several metrics for “evaluating” produced content
- Plot sample output of generators against axes defined by metrics
- Produce 2D histograms visualizing generative space

Some platform game metrics

- Leniency
- Linearity
- Density
- Pattern density
- Pattern variation

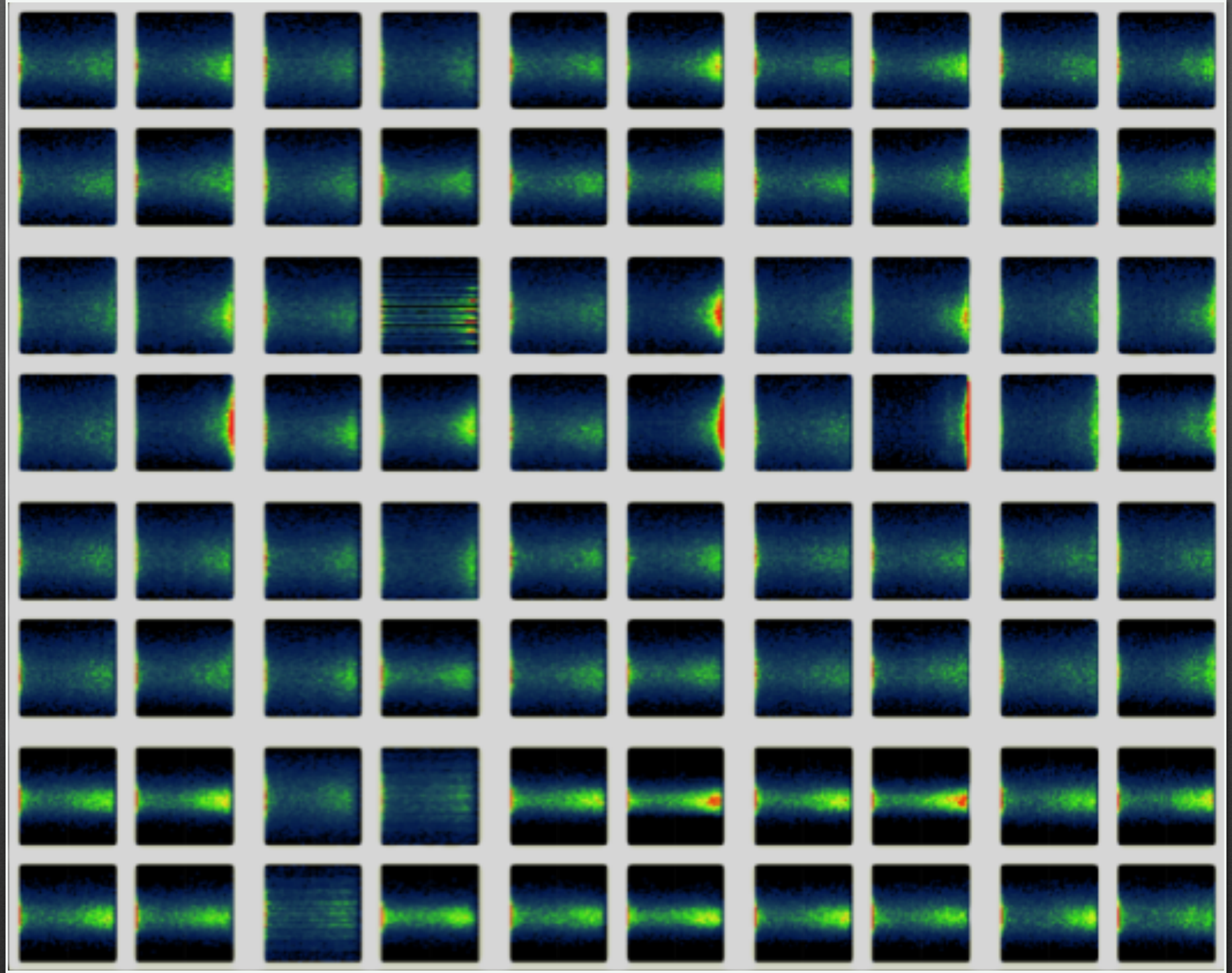


(a) Level: 704 Linearity +96 (MAX).

(b) Level 118: Linearity −16 (MIN).

(c) Level 50: Leniency +8 (MIN).

(d) Level 20: Leniency +44 (MAX).



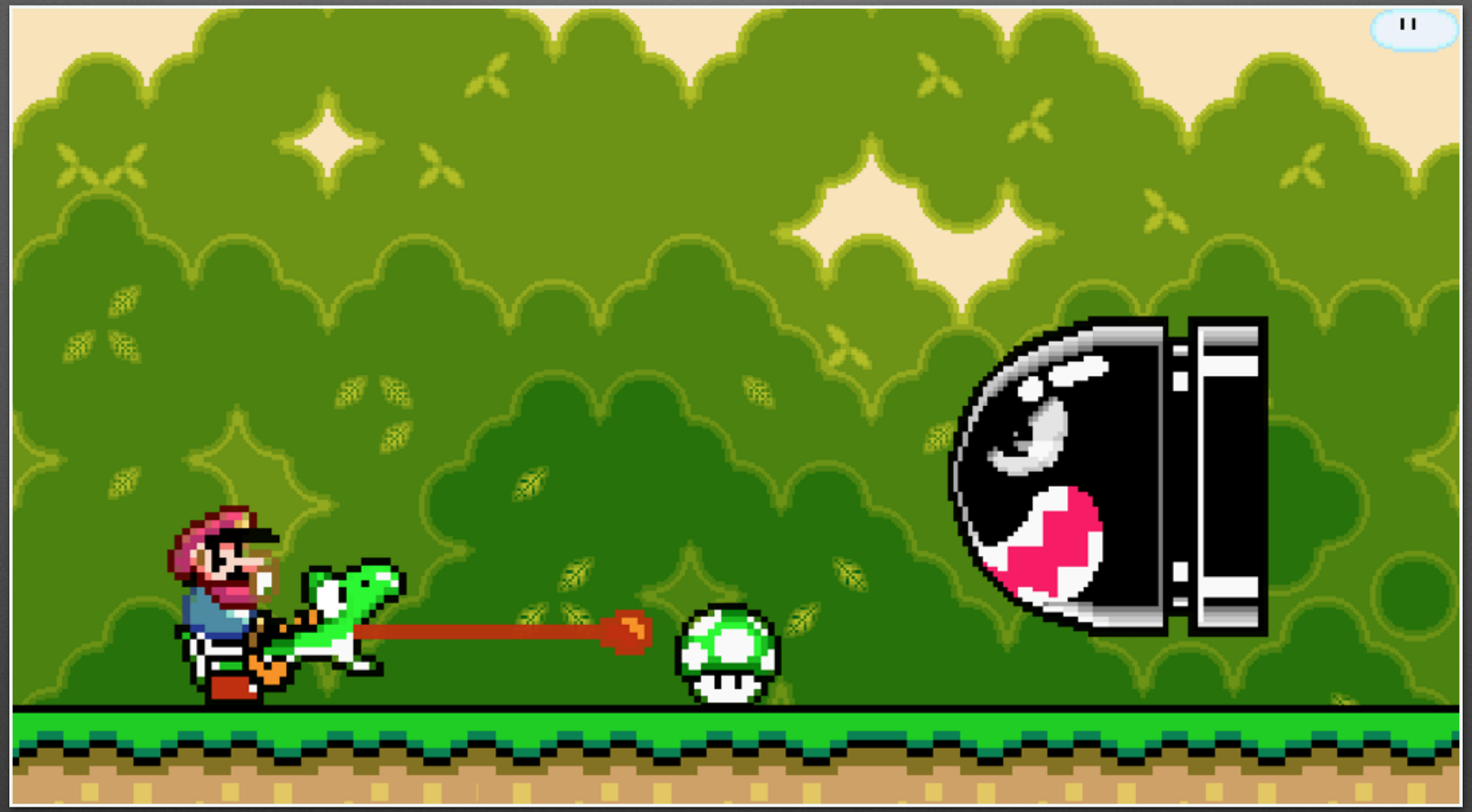
flickr: Todd Petrie

Further Resources

want to learn more?

Resources

- **proceduralcontent google group:**
  https://groups.google.com/forum/#!forum/proceduralcontent
- **#procjam** *(coming again in 2015!)*: http://procjam.com; twitter: @procjam;
  AI-jam *(March 21-29)*: http://ai-jam.com
- **procedural content generation wiki:** http://pcg.wikidot.com/
- **PCG textbook (in-progress):** http://pcgbook.com/
- **academic venues**
  foundations of digital games (mostly open access)
  artificial intelligence in interactive digital entertainment (open access)
  computational intelligence in games (mostly open access)
  transactions on AI and CI in games



Thank you!

Gillian Smith *gi.smith@neu.edu* *http://www.sokath.com*
Julian Togelius *julian@togelius.com* *http://julian.togelius.com*