

10 Years of the PCG workshop: Past and Future Trends



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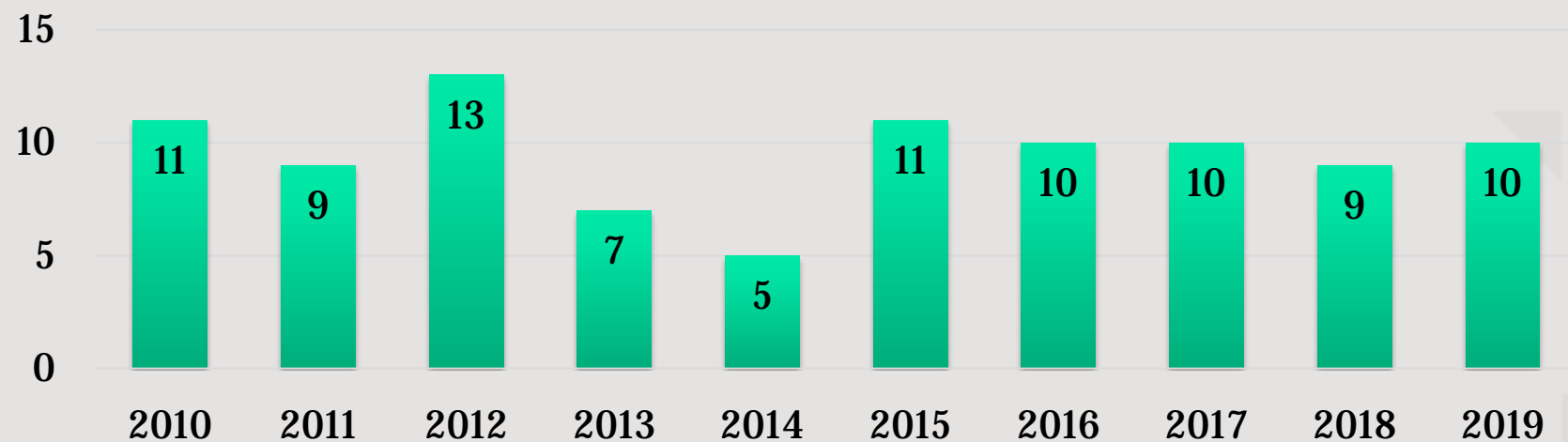
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Motivation

- | This is the 11th PCG workshop!
- | Survey the paper corpus of the first 10 workshops, identifying algorithms, game genres and other trends
- | 95 papers surveyed over 10 years

Published Papers



A Short History

- | **FDG 2010: 1st workshop**
 - | organized by R. Bidarra, I. Bogost, I. Parberry, K. O. Stanley, J. Togelius, J. Whitehead, R. M. Young
- | **6 instances in USA, 4 instances in Europe**



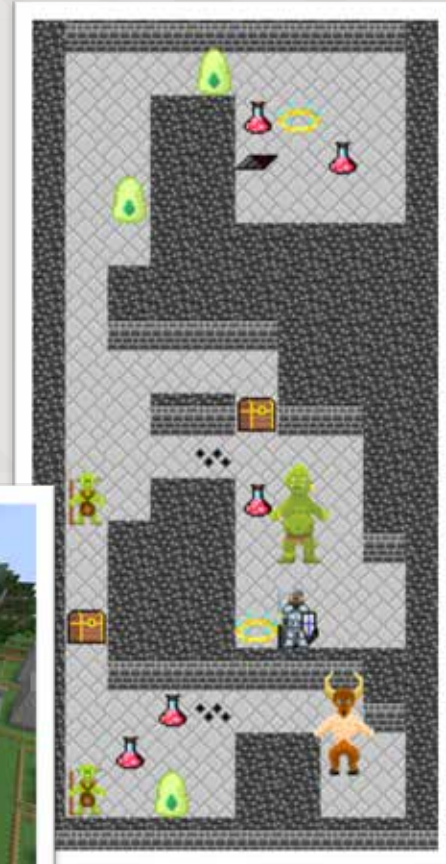
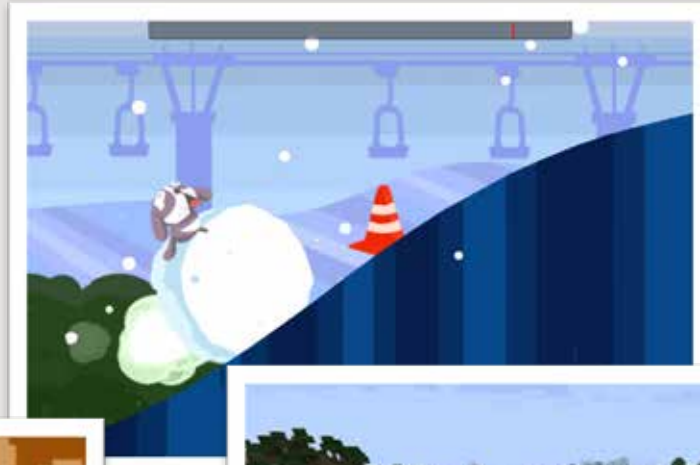


Survey #1: Types of Content Generated



Types of Content Generated

Levels/worlds (49 papers)



Vectorization of Gridded Urban Land Use Data by C. Sexton and B. Watson (2010)

Mobile adaptive procedural content generation by R. Lopes, K. Hilf, L. Jayapalan and Rafael Bidarra (2013)

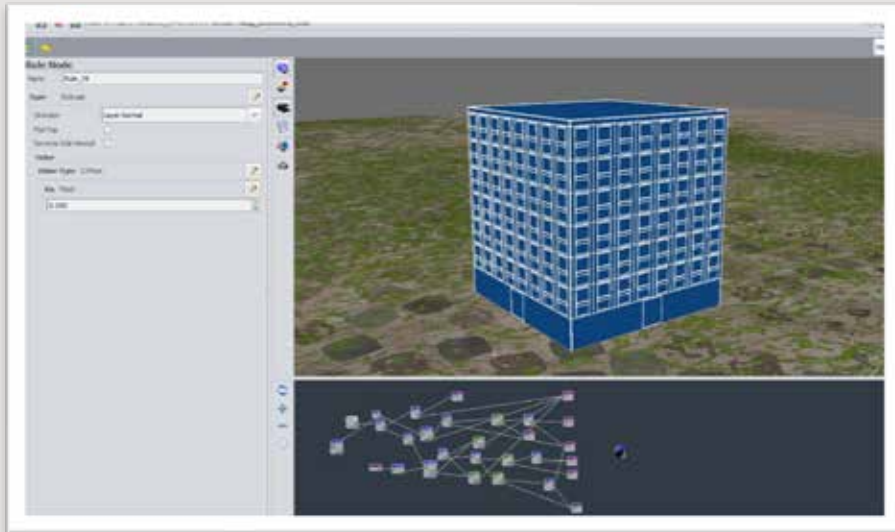
Danesh: Helping Bridge The Gap Between Procedural Generators And Their Output by M. Cook, J. Gow and S. Colton (2016)

Generative Design in Minecraft (GDMC): Settlement Generation Competition by C. Salge, M. Cerny Green, R. Canaan, J. Togelius (2018)

Two-step Constructive Approaches for Dungeon Generation by M. Cerny Green, A. Khalifa, A. Alsoughayer, D. Surana, A. Liapis and J. Togelius (2019)

Types of Content Generated

- | Levels/worlds (49 papers)
- | Architecture (6 papers)



Lessons in User Interface Design in the Procedural City Generation for Games Tool Urban PAD by L. Barret , C. Vance and G. Michael Youngblood (2011)

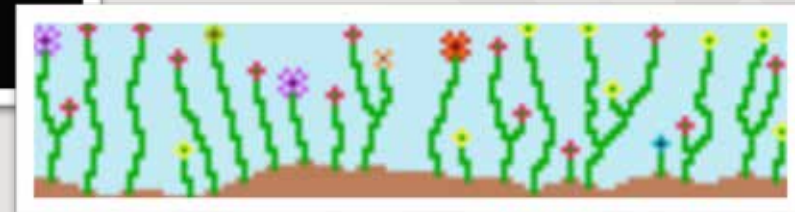
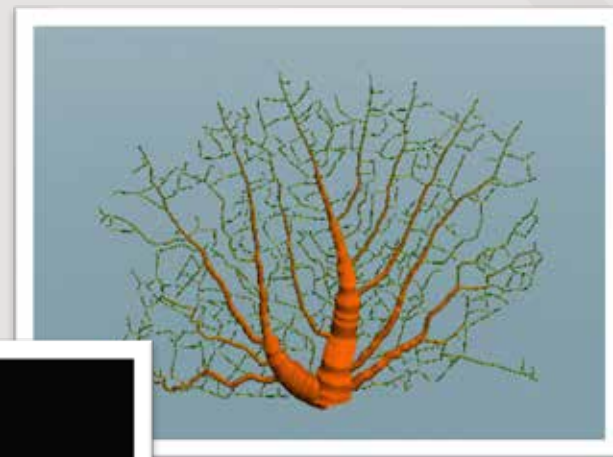
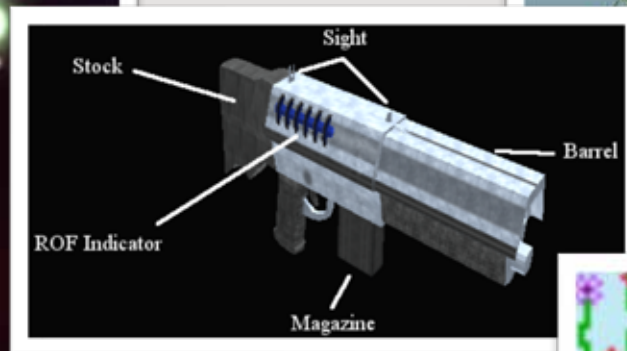
Procedural filters for customization of virtual worlds by T. Tuteneel, R. van der Linden, M. Kraus, B. Bollen and R. Bidarra (2011)

Modeling Urban Environments from Geospatial Data: A Pipeline for Procedural Modeling by D. Jesus, A. Coelho, C. Rebelo and A. Cardoso (2012)

A Generalized Semantic Representation for Procedural Generation of Rooms by J. T. Balint and R. Bidarra (2019)

Types of Content Generated

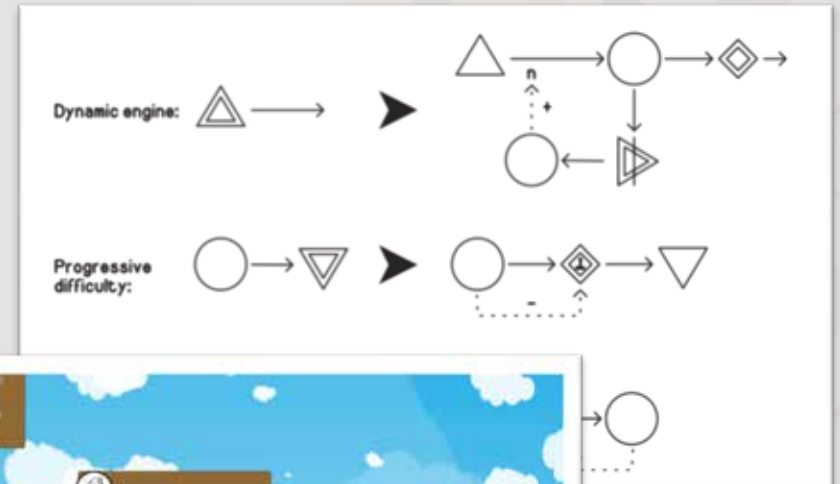
- | Levels/worlds (49 papers)
- | Architecture (6 papers)
- | 2D/3D Graphics (8 papers)



Interactive Genetic Engineering of Evolved Video Game Content by E. J. Hastings and K. O. Stanley (2010)
Team Blockhead Wars: Generating FPS Weapons in a Multiplayer Environment by E. McDuffee and A. Pantaleev (2013)
A Constructive Approach for the Generation of Underwater Environments by R. Abela, A. Liapis and G. N. Yannakakis (2015)
Addressing the Fundamental Tension of PCGML with Discriminative Learning by Isaac Karth and Adam M. Smith (2019)

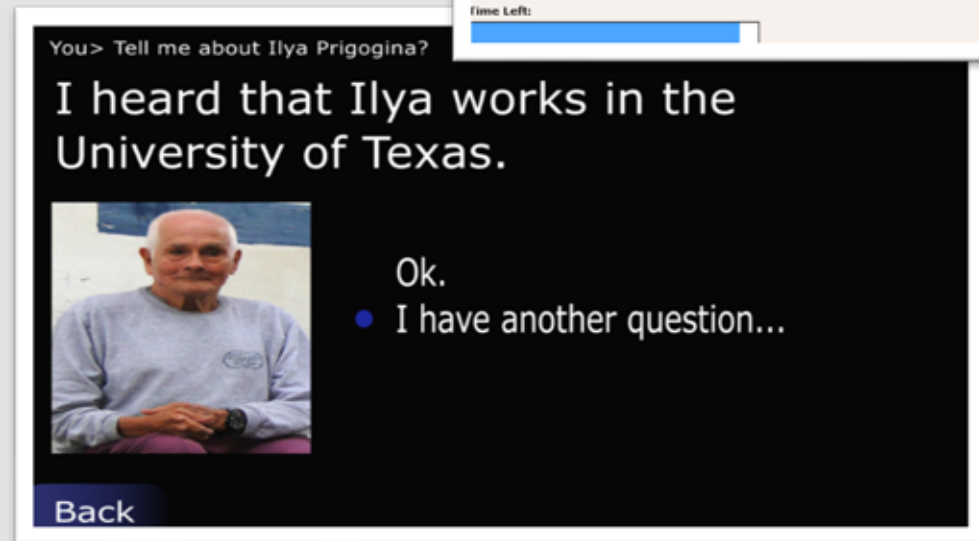
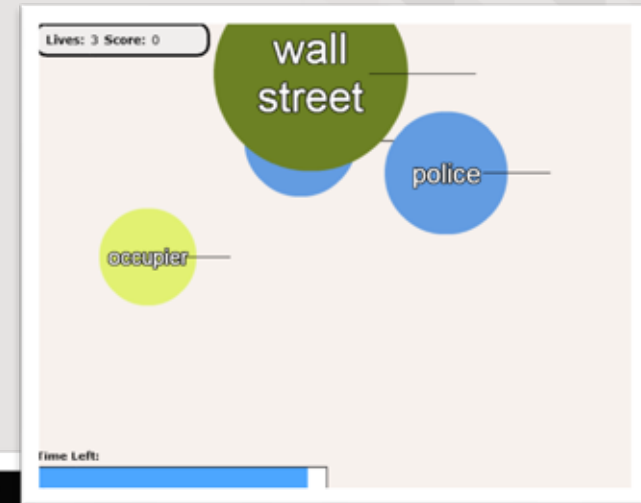
Types of Content Generated

- | Levels/worlds (49 papers)
- | Architecture (6 papers)
- | 2D/3D Graphics (8 papers)
- | Mechanics (8 papers)



Types of Content Generated

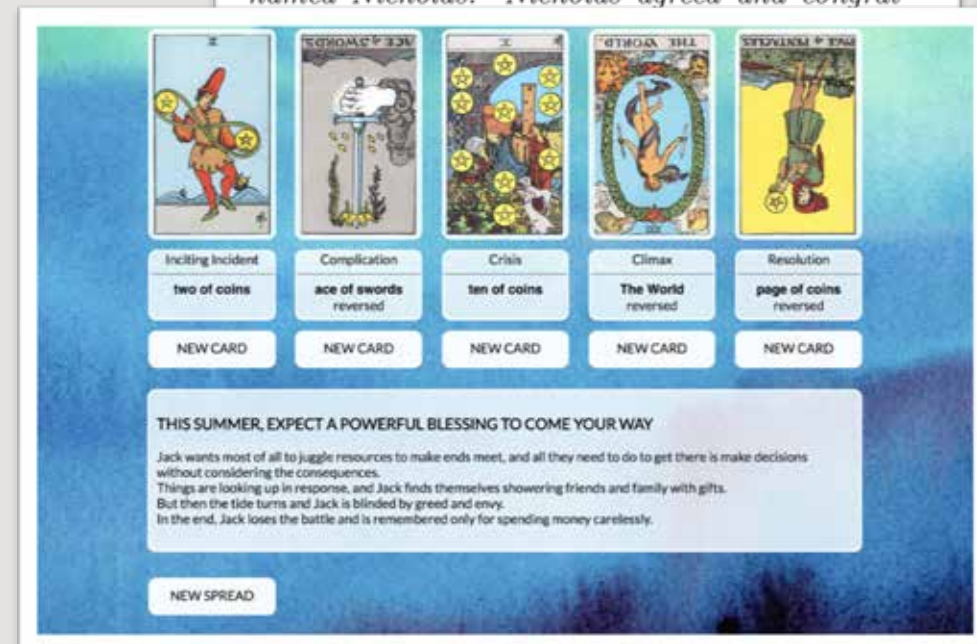
- | Levels/worlds (49 papers)
- | Architecture (6 papers)
- | 2D/3D Graphics (8 papers)
- | Mechanics (8 papers)
- | Games (3 papers)



Types of Content Generated

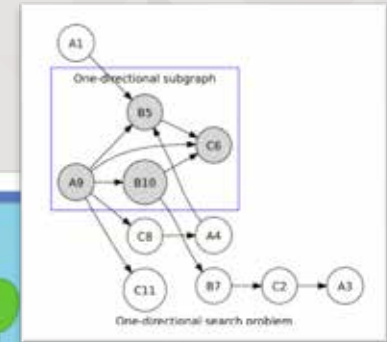
- | Levels/worlds (49 papers)
- | Architecture (6 papers)
- | 2D/3D Graphics (8 papers)
- | Mechanics (8 papers)
- | Games (3 papers)
- | Stories (6 papers)

A sexy student named Oswald expressed concern and wooed a second student named Cassandra. Cassandra allowed Oswald. Cassandra smiled and wooed Oswald. Oswald discouraged Cassandra and blamed her. Oswald smiled and wooed Cassandra. Cassandra allowed Oswald and blushed. Cassandra expressed concern and asked Oswald to date Cassandra. Oswald didn't agree. Cassandra attempted to plan to meet a third student named Nicholas. Nicholas agreed and congrat-



Types of Content Generated

- | Levels/worlds (49 papers)
- | Architecture (6 papers)
- | 2D/3D Graphics (8 papers)
- | Mechanics (8 papers)
- | Games (3 papers)
- | Stories (6 papers)
- | Other (12 papers)



Fast exact graph matching using adjacency matrices by Marlon Etheredge (2012)

Automatic Generation of Game-based CAPTCHAs by H. Yu and M. O. Riedl (2015)

Design Motifs: A Grammar Based Approach by J. Mazeika and J. Whitehead (2015)

Procedural Generation of Linguistics, Dialects, Naming Conventions and Spoken Sentences by M. R. Johnson (2016)

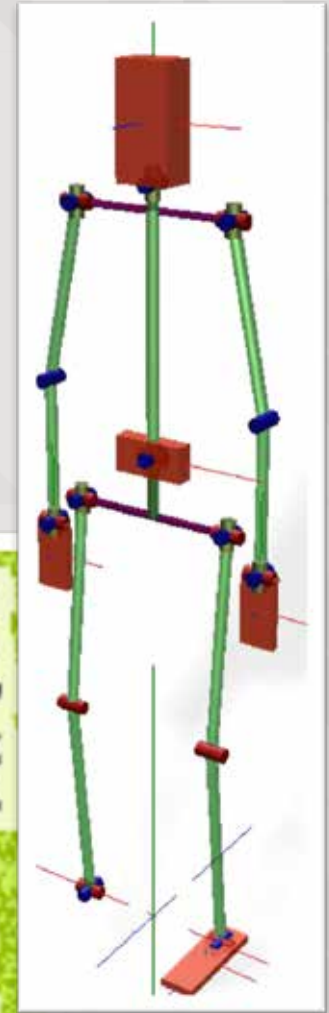
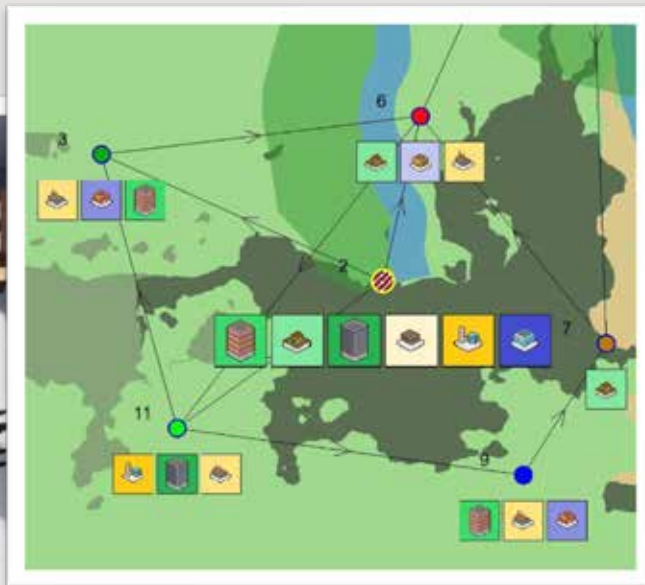


Survey #2: Target Game Genres



Target Games

- Platformers (14 papers)
- Real-world simulation (13 papers)



Generating Responsive Life-Like Biped Characters by B. Kenwright (2012)

Procedural generation of populations for storytelling by B. in het Veld, B. Kybartas, R. Bidarra and J-J Ch. Meyer (2015)

A Generalized Semantic Representation for Procedural Generation of Rooms by J. T. Balint and R. Bidarra (2019)

TownSim: Agent-based city evolution for naturalistic road network generation by A. Song and J. Whitehead (2019)

Target Games

- Platformers (14 papers)
- Real-world simulation (13 papers)
- RPGs (12 papers)



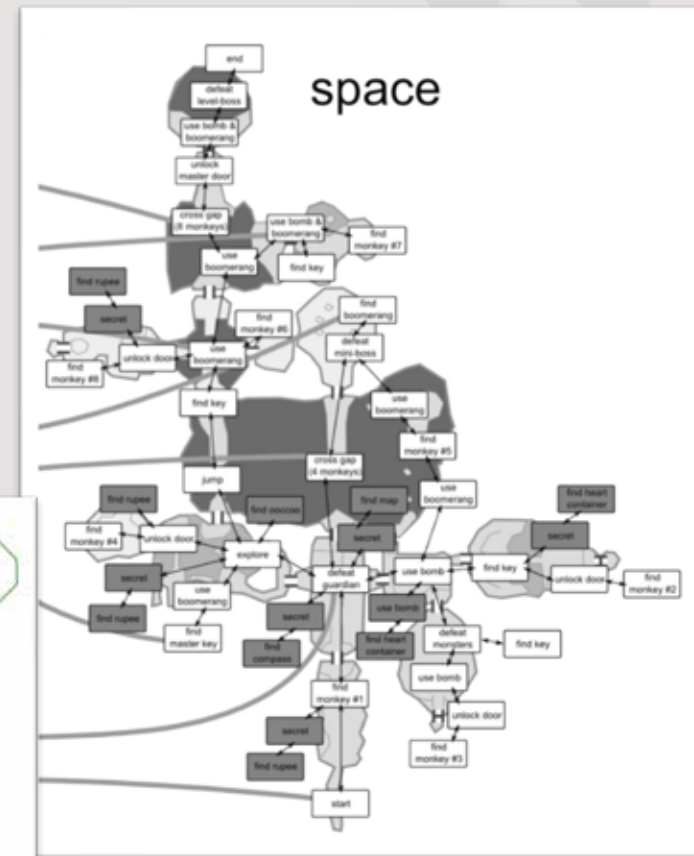
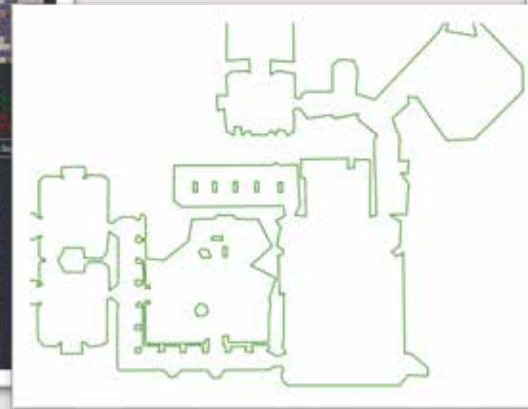
	Action	Pre-condition
1.	ε	None.
2.	capture	Somebody is there.
	damage	Somebody or something is there.
	defend	Somebody or something is there
	escort	Somebody is there
	exchange	Somebody is there, they and you have s
	experiment	Something is there.
	explore	None.
	gather	Something is there.
	give	Somebody is there, you have something.
	goto	You know where to go and how to get there.
	kill	Somebody is there.
	listen	Somebody is there.
	read	Something is there.
	repair	Something is there.
	report	Somebody is there.
	spy	Somebody or something is there.
	stealth	Somebody is there.
	take	Somebody is there, they have something.
	use	There is something there.



You have it.
 They have it, and you don't.
 You are there.
 They're dead.
 You have some of their information.
 You have information from it.
 It is less damaged.
 They have information that you have.
 You have information about it.
 Sneak up on them.
 You have it and they don't.
 It has affected characters or environment.

Target Games

- Platformers (14 papers)
- Real-world simulation (13 papers)
- RPGs (12 papers)
- Roguelikes (12 papers)



Target Games

- | Platformers (14 papers)
- | Real-world simulation (13 papers)
- | RPGs (12 papers)
- | Roguelikes (12 papers)
- | Serious games (6 papers)



Towards Procedural Level Generation for Rehabilitation by D. Dimovska, P. Jarnfelt, S. Selvig and G. N. Yannakakis (2010)

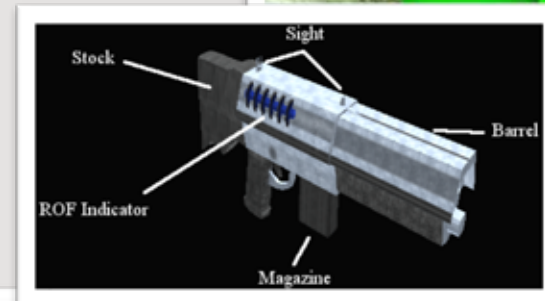
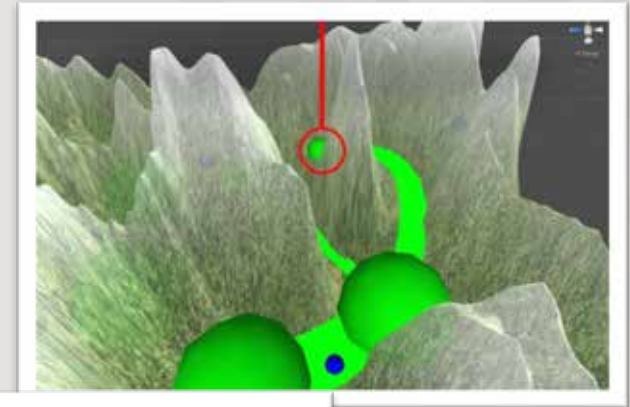
Automatic Generation of Game-based CAPTCHAs by H. Yu and M. O. Riedl (2015)

Teaching Japanese through Game Mechanics: An exploratory study by C. Olson, D. Kauffman, A. Fowler and F. Khosmood (2015)

Generating Game Mechanics in a Model Economy: a MoneyMaker Deluxe Case Study by S. Leijnen, P. Brinkkemper and A. Bouwer (2015)

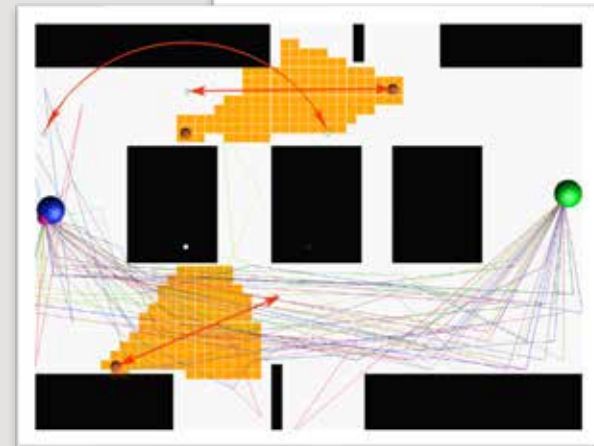
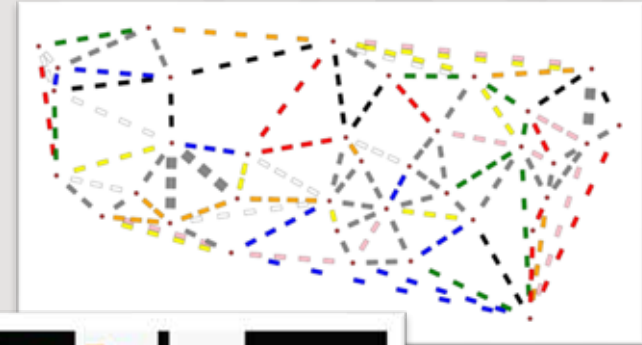
Target Games

- | Platformers (14 papers)
- | Real-world simulation (13 papers)
- | RPGs (12 papers)
- | Roguelikes (12 papers)
- | Serious games (6 papers)
- | Shooters (6 papers)



Target Games

- | Platformers (14 papers)
- | Real-world simulation (13 papers)
- | RPGs (12 papers)
- | Roguelikes (12 papers)
- | Serious games (6 papers)
- | Shooters (6 papers)
- | Other: boardgames, strategy, mazes, stealth...



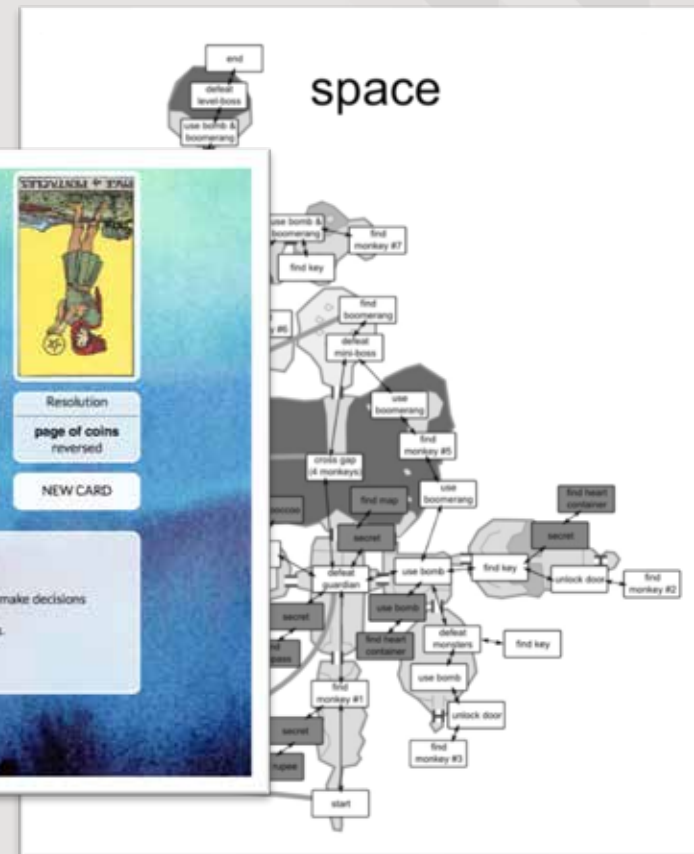
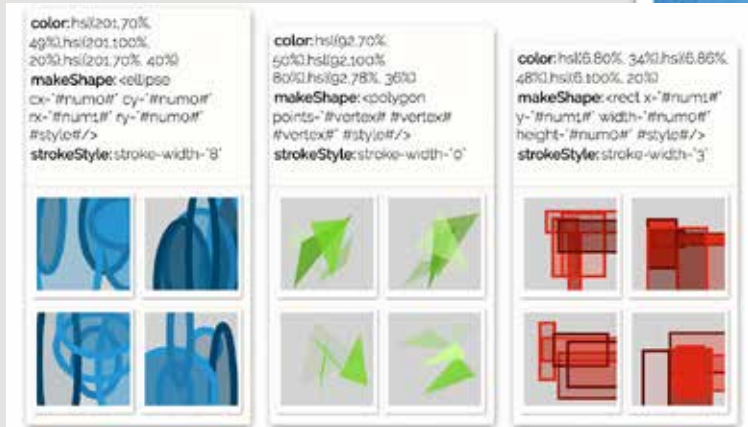
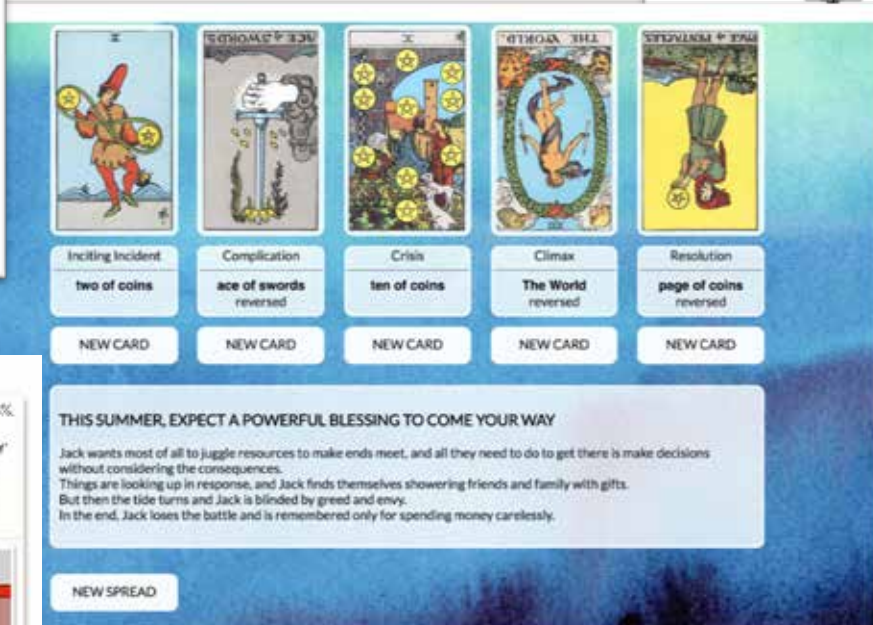


Survey #3: Algorithmic Approaches



Algorithmic Approaches

Grammars (15 papers)



- Adventures in Level Design: Generating Missions and Spaces for Action Adventure Games by J. Dormans (2010)
- Do You Like This Art I Made You: Introducing Techne, A Creative Artbot Commune by J. Pagnutti, K. Compton and J. Whitehead (2016)
- Design Motifs: A Grammar Based Approach by J. Mazeika and J. Whitehead (2015)
- Tarot-Based Narrative Generation by A. Sullivan, M. Palosaari Eladhari and M. Cook (2018)

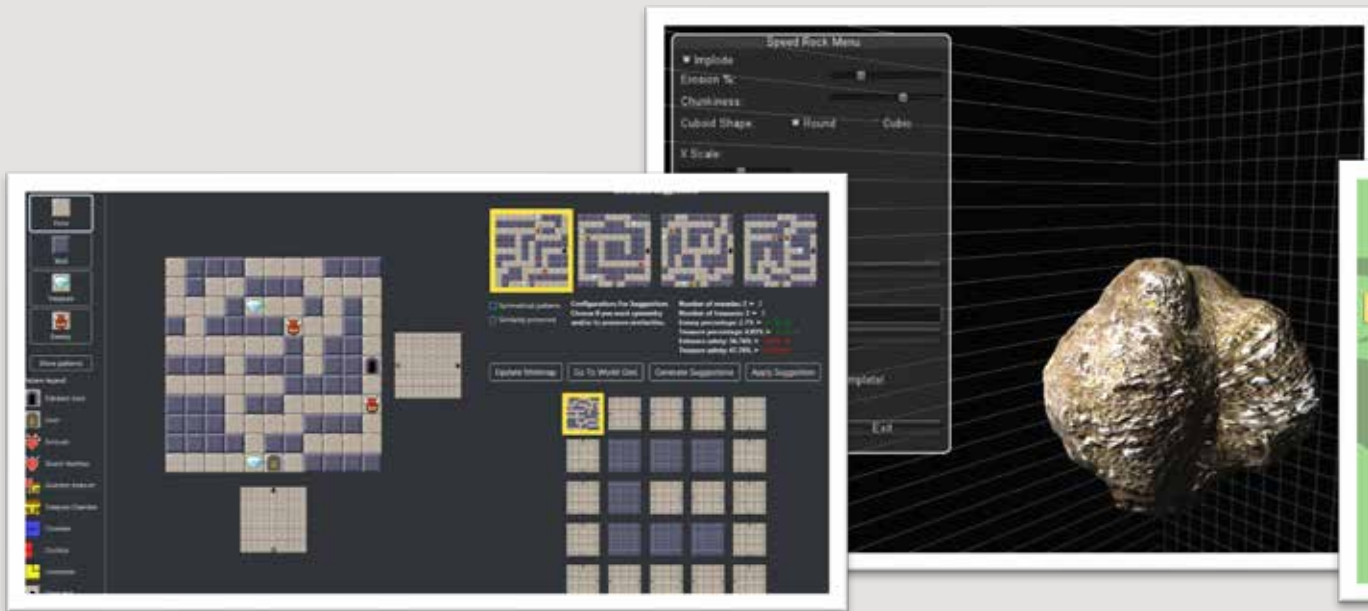
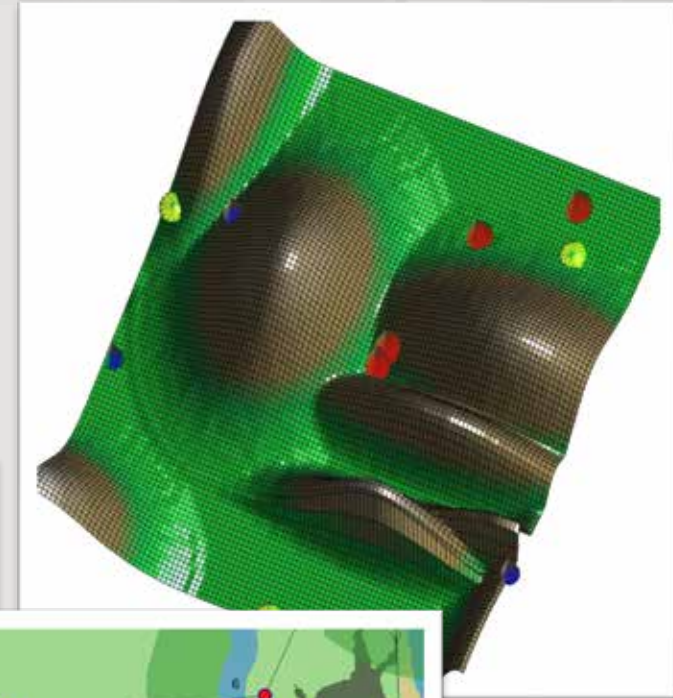


Algorithmic Approaches

- | Grammars (15 papers)
- | Constructive methods (14 papers)

Algorithmic Approaches

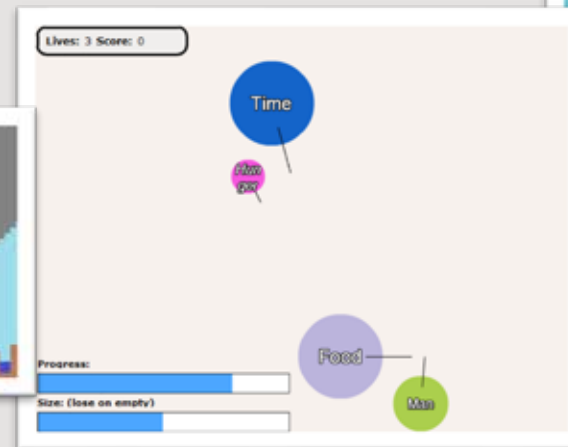
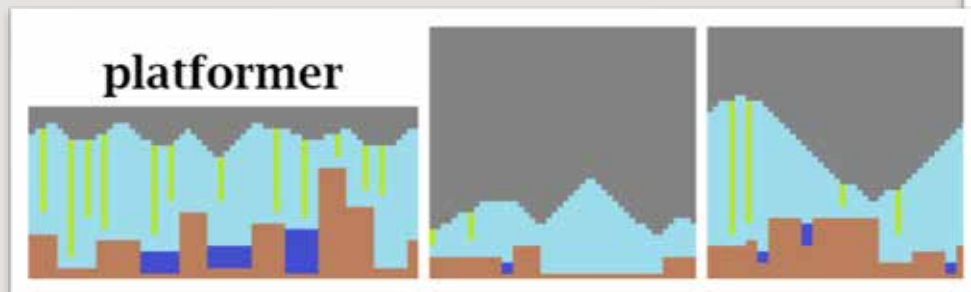
- | Grammars (15 papers)
- | Constructive methods (14 papers)
- | Artificial evolution (14 papers)



Towards multiobjective procedural map generation by J. Togelius, M. Preuss and G. N. Yannakakis (2010)
SpeedRock: procedural rocks through grammars and evolution by I. M. Dart, G. De Rossi and J. Togelius (2011)
Procedural generation of populations for storytelling by B. in het Veld, B. Kybartas, R. Bidarra and J-J Ch. Meyer (2015)
Fostering Creativity in the Mixed-Initiative Evolutionary Dungeon Designer by A. Alvarez, S. Dahlskog, J. Font, J. Holmberg, C. Nolasco and A. Österman (2018)

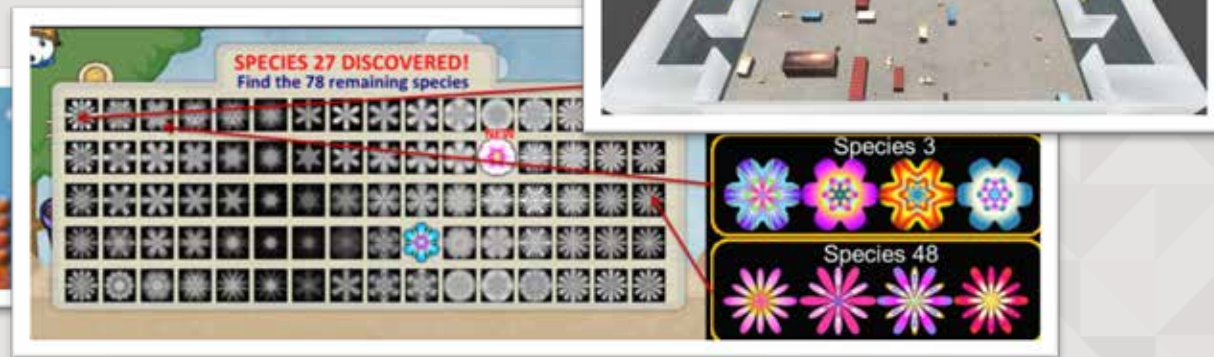
Algorithmic Approaches

- | Grammars (15 papers)
- | Constructive methods (14 papers)
- | Artificial evolution (14 papers)
- | Declarative programming (13 papers)



Algorithmic Approaches

- | Grammars (15 papers)
- | Constructive methods (14 papers)
- | Artificial evolution (14 papers)
- | Declarative programming (13 papers)
- | Machine learning (7 papers)



Towards Challenge Balancing for Personalised Game Spaces by S. Bakkes and S. Whiteson (2014)

Automatically Categorizing Procedurally Generated Content for Collecting Games by S. Risi, J. Lehman, D. B. D'Ambrosio and K. O. Stanley (2014)

Learning the Patterns of Balance in a Multi-Player Shooter Game by D. Karavolos, A. Liapis and Georgios Yannakakis (2017)

Addressing the Fundamental Tension of PCGML with Discriminative Learning by I. Karth and A. M. Smith (2019)

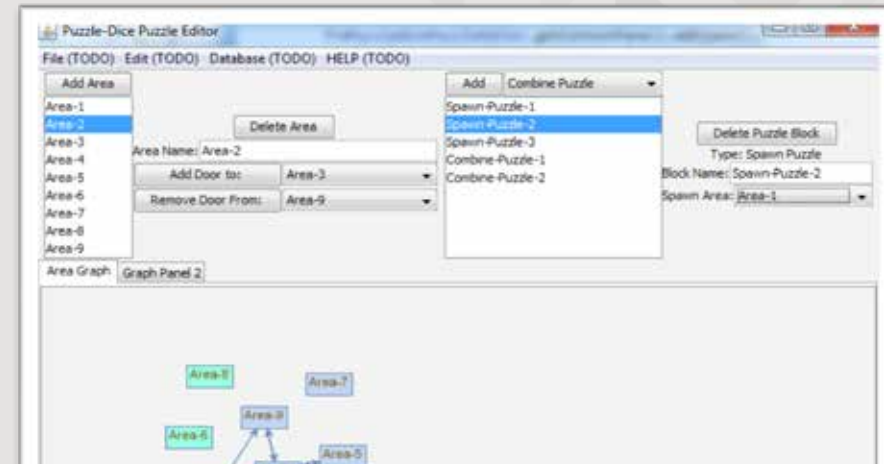
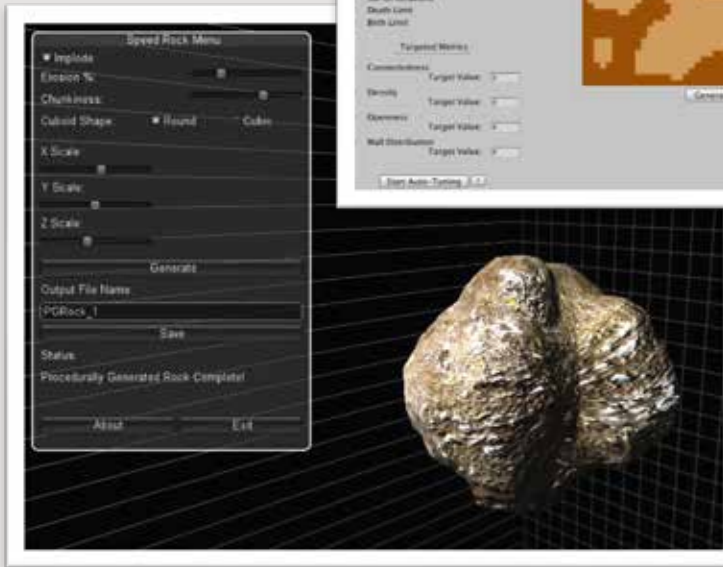
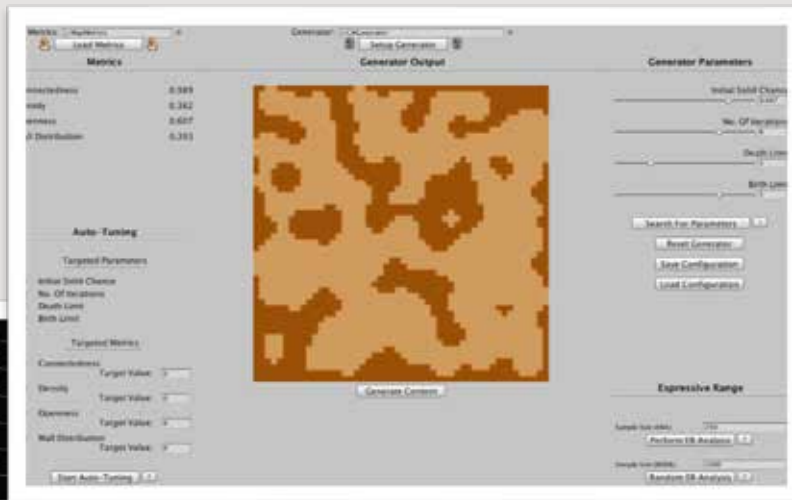


Survey #4: Other Facets



Other Facets

Design tools (19 papers)



SpeedRock: procedural rocks through grammars and evolution by I. M. Dart, G. De Rossi and J. Togelius (2011)

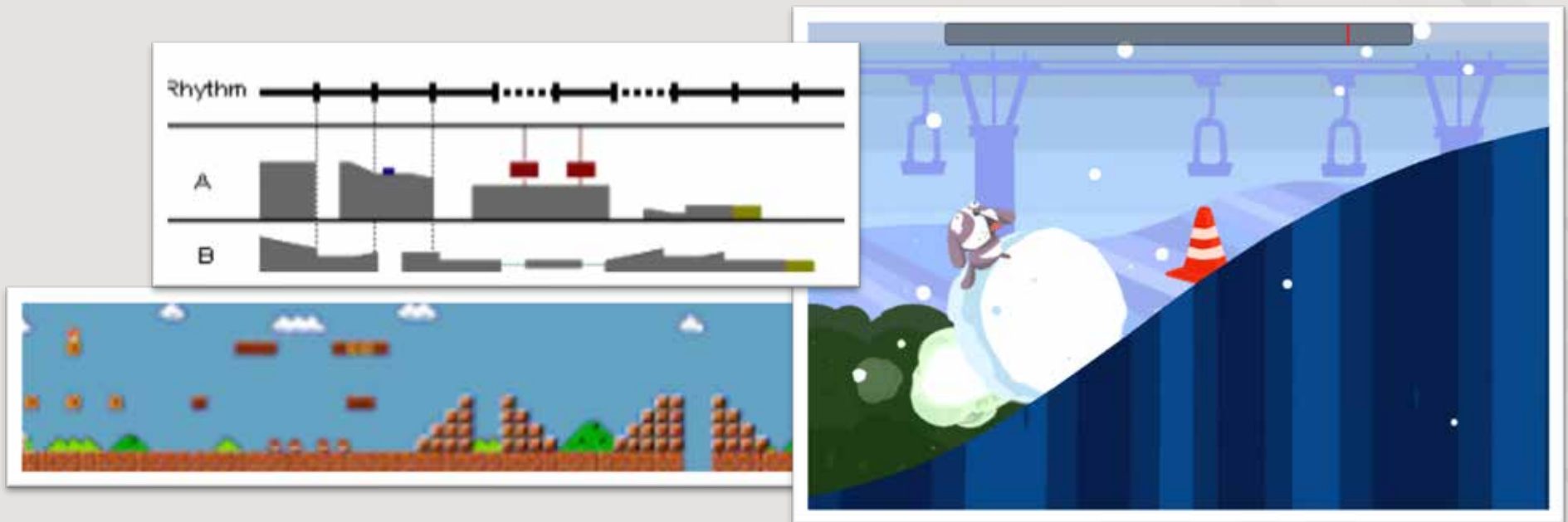
Procedural Generation of Narrative Puzzles in Adventure Games: The Puzzle-Dice System by C. Fernández-Vara and A. Thomson (2012)

Shopping for Game Mechanics by T. Machado, I. Bravi, Z. Wang, A. Nealen and J. Togelius (2016)

Danesh: Helping Bridge The Gap Between Procedural Generators And Their Output by M. Cook, J. Gow and S. Colton (2016)

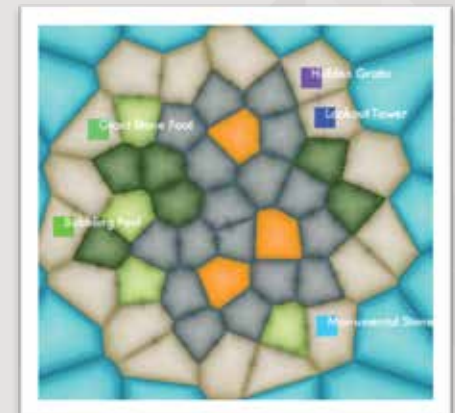
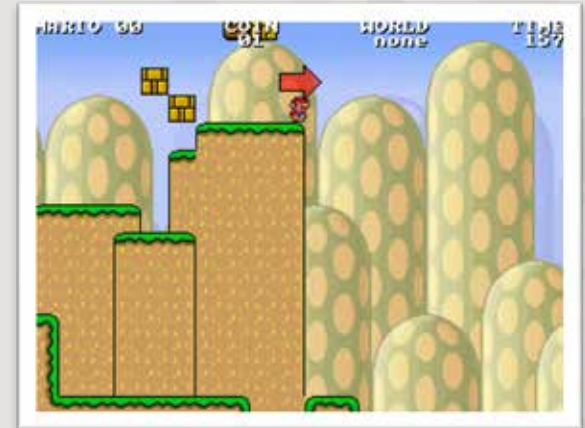
Other Facets

- | Design tools (19 papers)
- | Design patterns (7 papers)
- | Player modeling (5 papers)



Other Facets

- | Design tools (19 papers)
- | Design patterns (7 papers)
- | Player modeling (5 papers)
- | Real-time change during gameplay (7 papers)
- | PCG as game mechanic (5 papers)



Other Facets

┆ Vision papers (8 papers)

**Art and Science of Engineered Design:
What Kind of Discipline is PCG?**

Little Procedural People

Playing politics with generators

Characteristics of Generatable Games



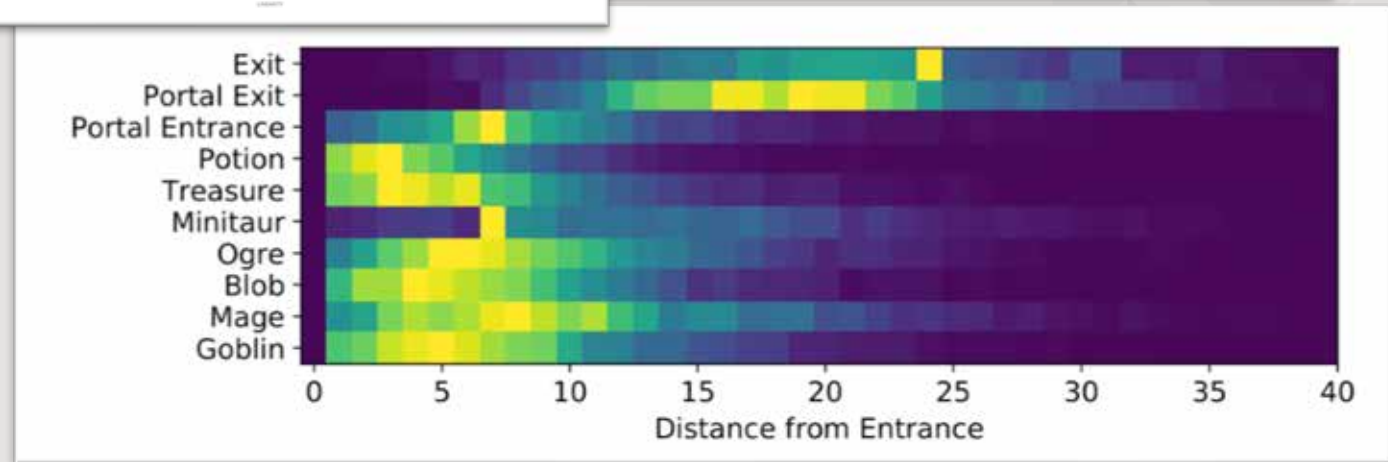
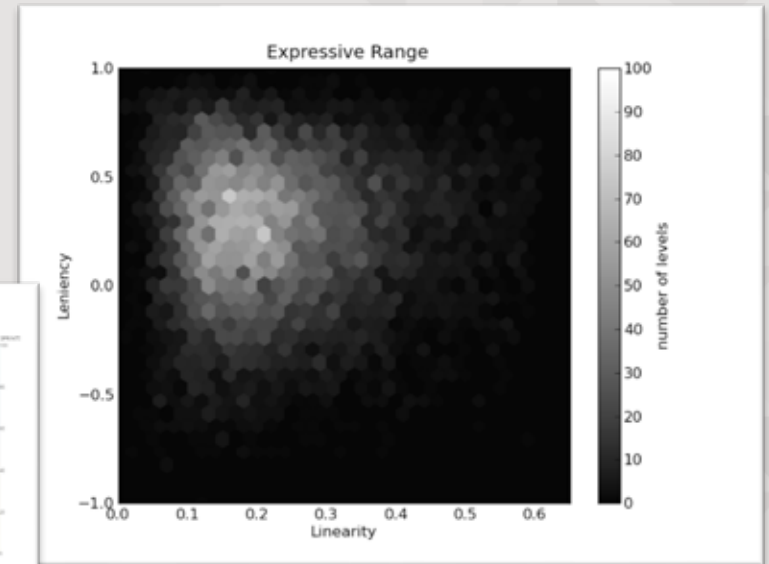
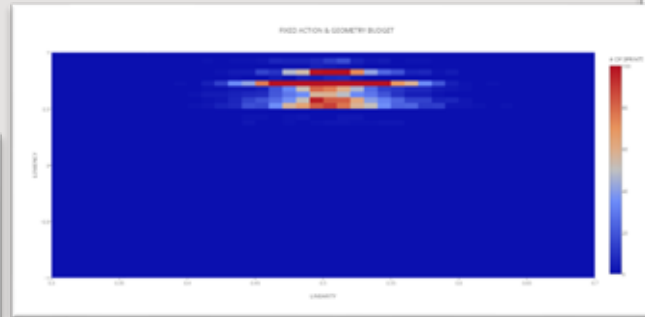
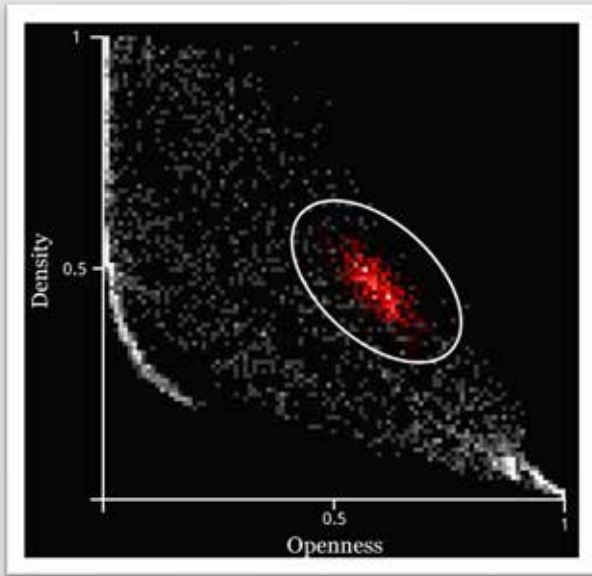
MEXICO	
Annual freshwater withdrawals (billion cubic meters)	79.80
Ease of doing business index (1=most business-friendly regulations)	48
Short-term depth (% of total external debt)	19.50
Total enrollment, primary, female (% net)	99.83



- Toward Procedural Decorative Ornamentation in Games by J. Whitehead (2010)
Data Games by M. Gustafsson Friberger, J. Togelius, A. Borg Cardona, M. Ermacora, A. Mousten, M. Møller Jensen, V-A. Tanase and U. Brøndsted (2013)
Characteristics of Generatable Games by J. Togelius, M.J. Nelson and A. Liapis (2014)
Little Procedural People: Playing politics with generators by K. Compton (2017)
Art and Science of Engineered Design: What Kind of Discipline is PCG? by J. Whitehead (2017)
Generative Design in Minecraft (GDMC): Settlement Generation Competition by C. Salge, M. Cerny Green, R. Canaan and J. Togelius (2018)

Other Facets

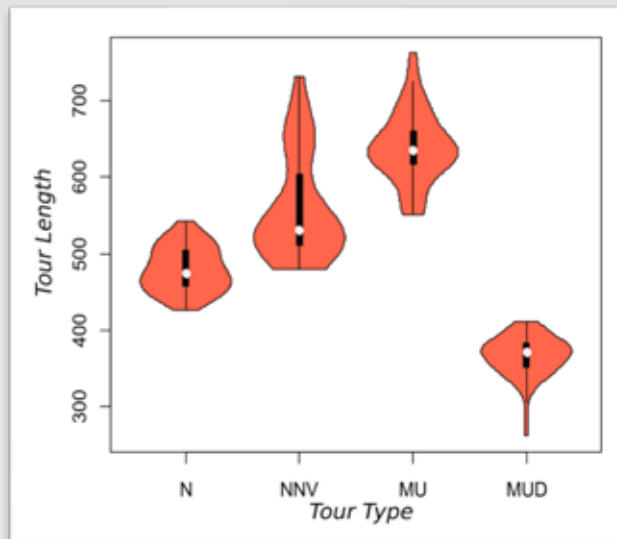
- ▮ Vision papers (8 papers)
- ▮ Expressive range (7 papers)



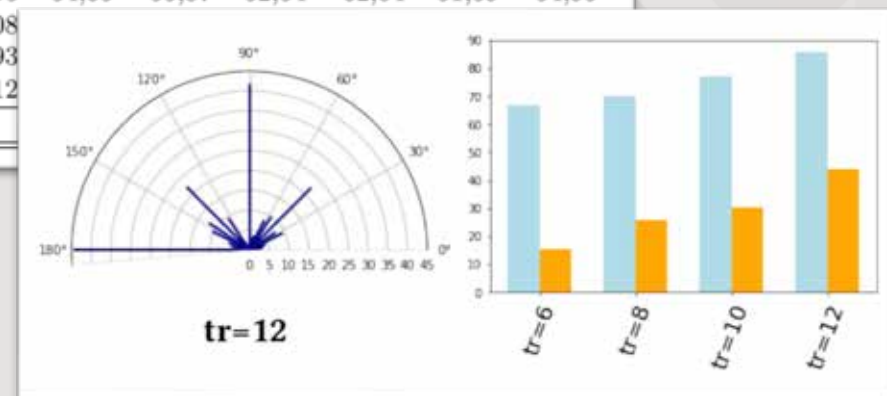
Analyzing the Expressive Range of a Level Generator by G.n Smith and J. Whitehead (2010)
Scalable Level Generation for 2D Platforming Games by N. Dewsbury, A. Nunn, M. Syrett, J. Tatum and T. Thompson (2016)
Danesh: Helping Bridge The Gap Between Procedural Generators And Their Output by M. Cook, J. Gow and S. Colton (2016)
Two-step Constructive Approaches for Dungeon Generation by M. Cerny Green, A. Khalifa, A. Alsoughayer, D. Surana, A. Liapis and J. Togelius (2019)

Other Facets

- ▮ Vision papers (8 papers)
- ▮ Expressive range (7 papers)
- ▮ Evaluation (32 papers), even if 92% papers technical



	Control		Subject A				Subject B			
	Game 1		Game 1		Game 2		Game 1		Game 2	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
$\max\{F\}$ (Kg)	64,34	53,31	52,50	58,95	54,65	55,87	52,54	62,04	51,59	54,95
$\min\{F\}$ (Kg)	38,89	42,45	34,38	40,08						
$\sigma\{F\}$ (Kg)	3,33	3,29	3,74	3,93						
	9,73	2,67	35,57	103,12						
	-0,19		-0,07							



*Quantitative analysis of multiple runs of the generator (with or without human testers) which reports aggregated statistics and/or performs significance tests

Towards Procedural Level Generation for Rehabilitation by D. Dimovska, P. Jarnfelt, S. Selvig and G. N. Yannakakis (2010)

Exhaustive Exploration Strategies for NPCs by M. Chowdhury and C. Verbrugge (2016)

TownSim: Agent-based city evolution for naturalistic road network generation by A. Song and J. Whitehead (2019)

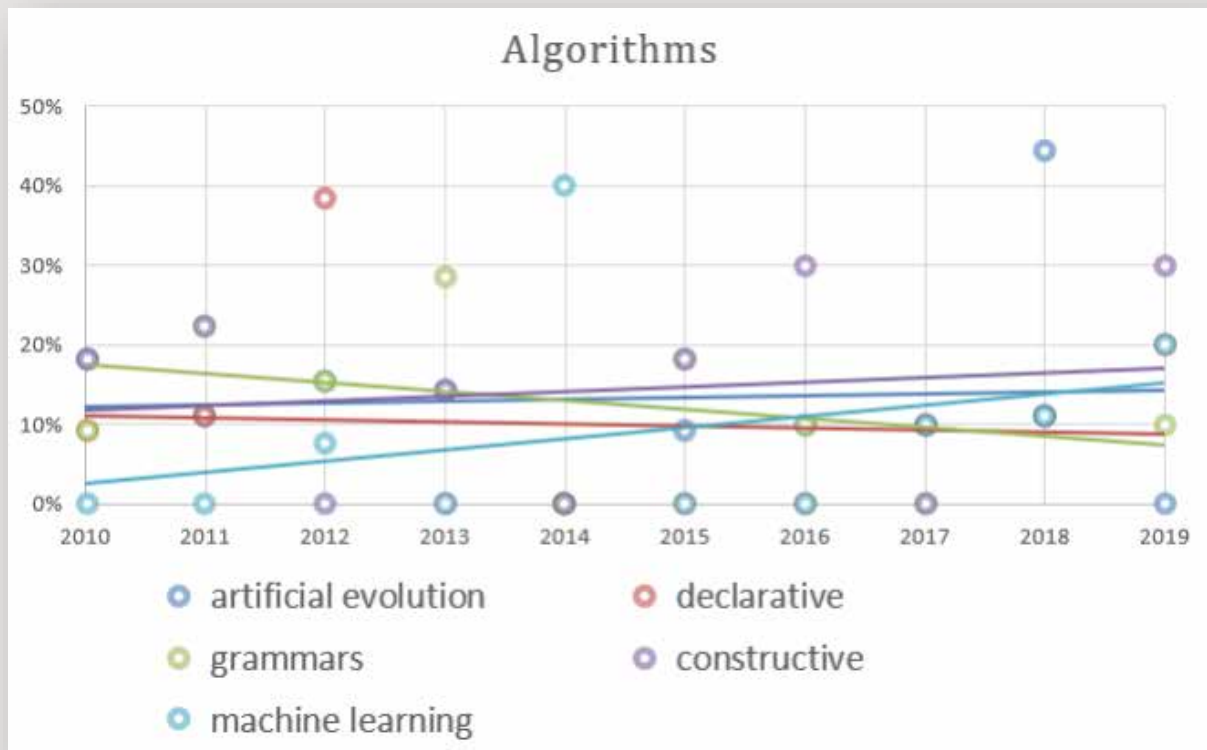


Parting Words



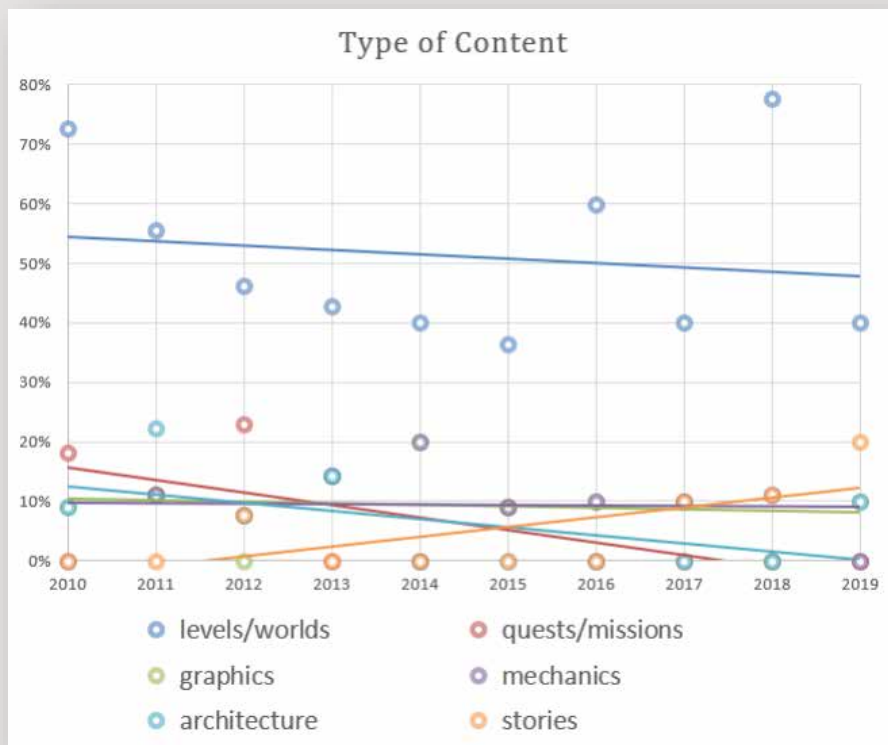
Takeaways

- Deep learning becoming commonplace and bringing new life to other methods



Takeaways

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- Level generation will never go away, pushed by industry, competitions, libraries





Takeaways

- | Deep learning becoming commonplace and bringing new life to other methods
- | Level generation will never go away, pushed by industry, competitions, libraries
- | Level gen and constructive methods easy
- | We need an industry success and/or build communities & libraries for other content
- | Minecraft is well-poised to be the next PCG favorite

Caveats

- | This is a survey of the 95 PCG workshop papers
- | Workshops focus on WIP and in discussion points
- | Each year, local authors/groups submit

- | Yet the PCG workshop encompasses much of the PCG community in Game AI...
- | ...but we as a community have different interests than e.g. the CC community (e.g. DL for visuals)



Thank you!

