The AAAI-17 Workshop on
What's Next for AI in Games?
WS-17-15

Cognitively-Grounded Procedural Content Generation

Rogelio E. Cardona-Rivera
Department of Computer Science
North Carolina State University
Raleigh, NC 27695
recardon@ncsu.edu

Abstract

Procedural content generators overly focused on numeric variations of content suffer from what we term the *Kaleidoscope Effect*: because we readily grasp the potential of the generative space, it is not interesting. In this position paper, we argue that the future of procedural content generation will be limited by this effect. We therefore propose a shift toward cognitively-grounded procedural content generators as a promising next step for artificial intelligence in games.

The algorithmic creation of content, known as *procedural content generation* (Togelius et al. 2011; Smith 2015), is a tool that can help reduce the needed expertise and budget inherent in creating video games (Blow 2004; Murphy-Hill, Zimmermann, and Nagappan 2014). However, it is not a panacea for creating interesting content. For instance, while one of the main selling points of the game *No Man's Sky* (Hello Games 2016) was the ability to explore its procedurally generated universe (with 1.8×10^{19} planets), players expressed discontent with the generated content, which they felt was repetitive and monotonous (Machkovech 2016; Heaven 2016).

This problem stems from a mismatch between what the generator considers unique and what the player considers unique. Consider the sequence of algorithmically created content in Figure 1. All images in that sequence of kaleidoscope frames are definitionally unique (i.e. there exists only one of each kind), yet even from this small sample of the generative space, one is able to quickly comprehend and summarize the generative capacity. Figure 1 figure illustrates the broader issue: in the context of procedural content generation, players care about what is perceptually unique (Compton 2016). Generators that do not account for this suffer from what I term the *Kaleidoscope Effect*: because a player can rapidly comprehend the *expressive range* (Smith and Whitehead 2010) of the content generator, the artifacts are not able to maintain the player's interest, regardless of the system's (numerical) generative capacity. The effect is so-named because kaleidoscopes produce unique artifactual instances, but with an underlying sameness that precludes surprise.

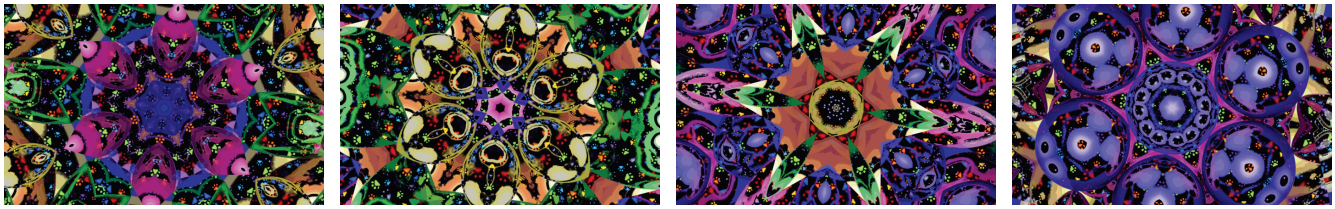
What are needed are *cognitively-grounded* procedural content generators: intelligent systems that reify the aspects of human cognition relevant to the content being algorithmically generated.

Through cognition, we can begin to address the Kaleidoscope Effect by identifying what players consider to be *meaningful content*; content that is both discernible and integrated into the larger game context (Salen and Zimmerman 2003). Research from psychophysics on *just noticeable difference* (e.g. Booth and Freeman 1993) provides a more precise vocabulary and experimental paradigm to identify perceptual determinants of meaningful difference. Research from *event cognition* (e.g. Radvansky and Zacks 2014) provides a framework to understand what features constitute meaningful discrete units of action and how we relate to them.

I am not proposing to simply combine procedural content generation with *player modeling* (Yannakakis et al. 2013), as others have proposed (Yannakakis and Togelius 2011; Shaker, Yannakakis, and Togelius 2012); i.e. the issue is not the creation of content tailored to an individual player's preferences. The issue is the lack of systematic exploration of the factors that contribute to what players understand as meaningful, in terms of structural properties of the content being created. As Calleja (2011) correctly points out, when looking at games through the lens of other disciplines, the lens itself must be examined; games carry with them dialogic conventions (Cardona-Rivera and Young 2014) that may challenge assumptions held by theories in cognitive science, which themselves must be verified.

I am proposing to increasingly focus on identifying how a player's internal makeup is affected by the generated content that is experienced, in order to understand the degree to which a content generator's notion of meaning reconciles with a player's. This is in service of what Simon (1996) might call a *science of* (game) *design*: a systematic characterization of invariant relationships between an inner environment (a player's cognitive states), interface (game discourse), and outer environment (virtual worlds).

While there exists work to unpack meaningful variations of game content (e.g. Cardona-Rivera et al. 2014, Lopes, Liapis, and Yannakakis 2016), more work is needed. This work will require an iterative process grounded in the experimental framework discussed by Hanks, Pollack, and Cohen (1993); i.e. it will require computationally



(a) Frame 8 (b) Frame 16 (c) Frame 24 (d) Frame 32

Figure 1: Each sub-figure is a frame from an animation that depicts a kaleidoscope in operation. Despite each frame being definitionally unique, we can grasp the expressive range of the artifact in a way that precludes surprise for subsequent content. This phenomenon affects content generators that opt for mathematical (as opposed to perceptual) uniqueness. Original artwork from http://fav.me/d469htr. Used under a Creative Commons BY-NC-ND 3.0 License.

precise understandings of related theories, the construction of content generators that embody those theories, and experimental evaluations of whether the output content is perceived in a manner consistent with the generator's intent.

Acknowledgements

I thank Kate Compton for her original writings on procedural content generation that inspired this paper, and for her subsequent commentary on it.

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