***Abstract –* The purpose of this paper is to provide an overview and critical review of the various techniques for the procedural generation of game content both proposed in research and examples in commercial games. This topic has seen a large amount of academic interest over the last number of years thus a fully exhaustive review is beyond the scope of this review. Instead it will explore the strengths and weaknesses of the four main categories of content generation and analyse choice examples for each before concluding with ...**

**!// Figure out how to end this thing !!**

1. Introduction

The development of video games has become increasingly more expensive and time consuming as technology has improved with developers spending millions of dollars and taking years to produce more and more detailed games.[1] This cost is largely caused by both improvements in and the AAA[[1]](#footnote-2) market's focus on graphical technology requiring more and more assets to be created by the artists.

Similarly designing games has proved more challenging due to the wide range of play styles and expectations, even within a single game, as shown by Drachen *et al.* Study of Tomb Raider Underworld.[2] Accommodating all of these players and crafting an enjoyable experience for as many play styles as possible is a daunting task.

One approach which can be applied to both of these problems and has seen large scale adoption within the game's industry is the procedural generation of content. The most obvious benefit to generation is the ability for smaller and less costly teams to produce content rich games. It can also be used as a creative aid to augment a designer's imagination and has also be a core mechanic in Minecraft, one of the most successful games of all time. [5]

Procedural Content Generation(PCG) is the collective term for a large range of techniques to automatically create content with minimum human input. In this context, *'content'* can be defined as any non agent (Non playable Character) behaviour systems within the game i.e. textures, terrain, items, or even entire plot lines [3].

Togelius *et al.* in their taxonomy of the subject offer a further distinction of whether the content is *'necessary or optional'*[4] where necessary content is aspects of the game the player must interact with in order to progress while optional is content which can be entirely ignored by players with no great impact to their experience.

Togelius *et al.* also define several features to aid in the comparison of PCG approaches; *'Online or Offline'* refers to whether the content is generated at the runtime of the game or during development of the game. *'Random Seed or Parameter Vectors'* a detail of the algorithm itself, this property describes the number of parameters, and thus amount of control, the algorithm allows the developer or whether these parameters are 'seeded' using random numbers. Finally *'Stochastic or Deterministic'* explains the amount of randomness within the generation, i.e. a purely deterministic algorithm with generate identical content if repeatedly called with the same inputs.

Due to these sometimes conflicting properties a large array of algorithms for PCG have been developed. Despite this breadth most can be grouped into broad categories; Constructive, Generate and Test and Search Based. These will be discussed in depth in the follow sections along with a separate section for Narrative generation which comes with it's own unique challenges and approaches.

2. Content Generation Techniques

2.1 Constructive

Constructive PCG algorithms will run only once to generate content of an acceptable quality. Meaning that these algorithms must be guaranteed to produce usable content.

The earliest examples of constructive PCG were purely deterministic and used as a form of memory optimisation. As a work around of the hardware constraints of early computers content was saved in a compressed format which could then be expanded out at runtime. A prime example of this was *Elite* [6] which 8 galaxies of 256 planets which were completely generated (name, position, items etc.) from a seed number. A more modern example is *.kkrieger*[7] which compresses an entire first person shooter into a 97kb file. Advances is hardware and the large impact on load times has made the use of PCG for data compression almost entirely abandoned by the industry.

//Talk 'bout fractals here

**!// Expand the speedTree section, or cut entirely**

One of the most prolific constructive PCG tools is SpeedTree [8] which offers both online and offline tools for the generation of foliage. The tool also generates the texture atlasis for the foliage.

2.2 Generate and Test

2.3 Search Based

2.4 Narrative

3. Conclusion

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1. AAA (pronounced triple A) is a classification of games with the highest development and marketing budgets and usually form the years bestsellers. [↑](#footnote-ref-2)