An Experiment on Content Generation of Game Software Engineering

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ABSTRACT

Background Video games are complex projects that involve a seamless integration of art and software during the development process to compound the final product. In the creation of a video game, software is fundamental as it governs the behavior and attributes that shape the player's experience within the game. When assessing the quality of a video game, one needs to consider specific quality aspects, namely 'design', 'difficulty', 'fun', and 'immersibility', which are not considered for traditional software. On the other hand, there are not well- established best practice for the empirical assessment of video game as instead there are for the empirical evaluation of more traditional software. **Aims** Our goal is to carry out a rigorous empirical evaluation of the latest proposals to automatically generate content for videogames following best practise established for traditional software. Specifically, we compare Procedural Content Generation (PCG) and Reuse-based Content Generation (RCG). Our study also considers the perception of players and professional developers on the content generation. **Method** We conducted a controlled experiment where human-subjects had to play with and evaluate content automatically generated for a commercial video-game by the two techniques (PCG and RCG) based on specific quality aspects of video games. 44 subjects including professional developers and players participated in our experiment. **Results** The results suggest that RCG generates content of higher quality than PCG which is more aligned with the pre-existent content. **Conclusions** The results can turn the tides for content generation. RCG has been underexplored so far because the reuse factor of RCG is perceived as repetition by the developers, who ultimately want to avoid repetition in their video games as much as possible. However, our study revealed that using RCG unlocks latent content that is actually favoured by players and developers.

KEYWORDS

Empirical Study, Automated Software Transplantation, Procedural Content Generation

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1 INTRODUCTION

Video games industry is in continuous growth every year [38]. To adapt to this trend video game software engineering needs to be in constant change. Interestingly, despite being one of the fastest growing industries, video game software engineering has been identified as an area of knowledge that needs more fundamental research [2].

One of the areas where video game software engineering needs more research are ~~game engineering~~ empirical research methods [2]. While theoretical frameworks provide foundational understanding, empirical studies offer the necessary validation and refinement crucial for effective implementation. As in other disciplines dealing with human behaviour (e.g., social sciences or psychology), empirical research allows building a reliable knowledge base in software engineering [43, 49]. By empirically investigating the user experience of video game techniques, researchers can illuminate both the strengths and limitations of existing approaches, paving the way for advancements that align more closely with the diverse needs and preferences of players. Through rigorous experimentation and analysis, empirical studies serve as the cornerstone for fostering innovation and pushing the boundaries of what is achievable within video game techniques.

There are studies that establish the particularities of the study of the quality of video games compared to other software developments [39]. Video games have characteristics that are difficult to measure and define, such as 'fun' or 'entertainment'. Thus, it makes automating tests challenging due to the multitude of options available to players. Moreover, it is considered that the users under study must have specific characteristics and that not ranodm profiles can be useful in the testing of this type of artefacts.

In this work, we aim to evaluate empirically two different video game content generation techniques along with two different users profiles (players and developers). We study the feasibility of Reuse-based Content Generation (RCG), and Procedural Content Generation (PCG), and whether they have an impact on the quality of the generated content. We do so by analyzing Kromaia, a commercial video game released on PlayStation 4 and Steam.

We present an experiment in which we compare content generated by RCG and PCG, in terms of video game specific measures 'design', 'difficulty', 'fun', and 'immersibility'. A total of 44 subjects performed the tasks of the experiment, assessing the generated content in two scenarios of Kromaia. We conduct three distinct sessions, one for players and the other two for developers, in order to investigate whether the profile of the participants assessing video games influences their perception.

Our results suggest that RCG generate content of higher quality than PCG which is more aligned with the pre-existent content. TODO *add more conclusions from the results.*

The structure of this paper is as follows. Section 2 reviews the related works in the area. Section 3 presents the approaches under study and the context of the experiment, Kromaia. Section **??** outlines the experimental design. Section **??** presents the experiment results, followed by a discussion in Section 4. Section **??** summarizes the threats to the validity. Finally, Section **??** concludes the paper.

2 RELATED WORK

Experimentation in software engineering is a practice that has been studied for decades [6]. Throughout time, researches have adopted established guidelines to be rigorous [49], such as the use of hypothesis, validity, statistical analysis or replication packages.

Content generation is a large field [50]. The types of content generated are diverse, such as vegetation [29], sound [34], terrain [19], Non-Playable Characters [47], dungeons [46], puzzles [15], and even the rules of a game [9]. However, it is difficult to find experiments with human-subjects that compare approaches [3].

Table 1 shows content generation work with human-subjects. In content generation, it is common that experiments with human subjects explore the quality of the generated content [8, 44] or different variants of the proposed approach [1, 33]. On other hand, work such us Pereira *et al.* [32] or Prasetya *et al.* [37] compared the generated content by their approach to a baseline. In this work, we compare two techniques for generating content that the community uses without any previous experiments to compare them.

In terms of measurements, studies have been conducted to examine the distinctive characteristics of video games [39]. Studies have investigated subjects, more precisely players, preferences and perceptions regarding various aspects of video games, including design [24, 31], difficulty [27, 32], or fun [34, 37]. Another aspect of video games is the user engagement and immersion, which plays crucial roles in shaping the overall gaming experience [23]. Our work considers all these measurements simultaneously.

Table 1 shows that none of the previous work is compliant with the practices adopted in experiments by traditional software. In fact, 65% have neither hypothesis and validity, statistical analysis nor replication package. Our work aims to compare with empirical rigour the content generated. To do so, we adopted traditional software guidelines for experimentation.

Thus far, previous work has only used players to evaluate content. In other words, they have not considered the perception of the developers themselves. We study not only the players assessment, but also the point of view of professional video game developers, and their differences when assessing the quality of the generated content.

Table 1: Measurements: Design (De), Difficulty (Diff), Fun (F), Human Made (HM), Immersibility (I). Evaluation of the content generated by the proposed algorithm (A), variants of the proposed algorithm (VA), or the proposed algorithm compared to a baseline (C).

Work Year	Evaluation	Measurements	Hypothesis & Validity	Statistical Analysis	Replication Package	Sample size
Cardamone *et al.* [10] 2011	VA	De	✗	✗	✗	5 players
Plans *et al.* [34] 2012	A	F	✗	✓	✗	31 players
Adrian *et al.* [1] 2013	VA	De, Diff, F	✗	✗	✗	22 players
Dahlskog *et al.* [14] 2013	VA	De, Diff, F	✗	✗	✗	24 players
Togelius *et al.* [44] 2013	A	De, Diff, F	✓	✓	✗	147 players
Gravina *et al.* [21] 2015	A	F	✗	✗	✗	35 players
Kaidan *et al.* [24] 2015	VA	De	✗	✗	✗	12 players
Olsted *et al.* [31] 2015	VA	De	✗	✗	✗	13 players
Prasetya *et al.* [37] 2016	C	F	✗	✗	✗	33 players
Ferreira *et al.* [17] 2017	VA	De, Diff, F, I	✗	✓	✗	139 players
Charity *et al.* [11] 2020	A	De, Diff	✗	✗	✗	2 players
Lopez-Rodriguez *et al.* [27] 2020	VA	Diff	✗	✗	✗	30 players
Kraner *et al.* [25] 2021	A	De	✗	✗	✗	5 players
Pereira *et al.* [32] 2021	VA	Diff, F, HM	✗	✓	✗	70 players
Pereira *et al.* [33] 2021	C	Diff, F	✗	✓	✗	16 players
Brown *et al.* [8] 2022	A	De	✗	✗	✗	35 players
De Lima *et al.* [16] 2022	A	HM	✗	✓	✗	38 players
Our work	PCG vs RCG	De, Diff, F, I	✓	✓	✓	32 players + 12 developers

3 BACKGROUND

In this section, we present the importance of software in video game development, the generation of content for video games, and the real-world context that we make use of on our experiment to perform the corresponding tasks.

3.1 Software in video games

The development process of video games requires a harmonious combination of artistic elements and software integration, resulting in intricate and multifaceted creations. Software plays a crucial role in every aspect of a video game's creation as it dictates the behavior and features that can be seen or experienced within the game. For instance, software is responsible for controlling the logic behind the behaviors of non-playable characters (NPCs) in a game. As video games evolve and become more sophisticated, the software powering them also becomes increasingly intricate.

Nowadays, most video games are developed by means of game engines. One can argue that game engines are software frameworks [36]. Game engines integrate a graphics engine and a physics engine as well as tools for both to accelerate development. The most popular ones are Unity and Unreal Engine, but it is also possible for a studio to make its own specific engine (e.g., CryEngine [13]).

One key artefact of game engines are software models. These are software models such as those proposed by the Model Driven Development paradigm [41] which should not be confused with either 3D Meshes or AI Models. Unreal proposes Unreal Blueprints [7], Unity proposes Unity Visual Scripting [40], and a recent survey in Model-Driven Game Development [51] reveals that UML and Domain Specific Language (DSL) models are also being adopted by development teams. Developers can use the software models to create video game content instead of using the traditional coding approach (C++ on Unreal or C# on Unity). While code allows for more control over the content, software models raise the abstraction level, thus promoting the use of domain concepts and minimizing implementation and technological details.

3.2 Content Generation for Video Games

The process of content generation for video games is typically slow, tedious, expensive, and susceptible to errors. Thus, leading to problems that the industry have such us: (1) excessive delays in content creation (with notorious examples in Cyberpunk 2077 [48] or GTA VI [28]) or (2) the ever-increasing demand for game content derived from post-launch updates, Downloadable Content (DLCs), games as a service, or platform-exclusive content.

To address these challenges, researchers have been exploring procedural content generation techniques as a potential solution to (semi)automate the generation of new content within video games [22].

Procedural content generation can be grouped in three main categories according to the survey by Barriga *et al.* [5]: Traditional techniques that generate content under a procedure without evaluation; Machine Learning techniques [26, 42] that train models to generate new content; and Search-Based techniques [45] that generate content through a search on a predefined space guided by a meta-heuristic using one or more objective functions.

Content can also be created through reuse. In fact, since the term software engineering was coined at the NATO Conference held in Garmisch in 1968 [30], its evolution has been tied to the concept of reuse. Either applying an opportunistic approach such as clone-and-own [18], or applying systematic approaches as software product lines (assembling predefined features) [35] or as software transplantation (a feature is transplanted from a donor to a host) [4]. A recent SLR on game software engineering [12] identifies the relevance of both Reuse-based Content Generation (RCG) and Procedural Content Generation (PCG).

3.3 Kromaia Video Game for the Experiment

Kromaia is a commercial video game released on Playstation and Steam, translated into eight languages. On Kromaia, each level consists of a three-dimensional space where a player-controlled spaceship has to fly from a starting point to a target destination, reaching the goal before being destroyed. The gameplay experience involves exploring floating structures, avoiding asteroids, and finding items along the route, while basic enemies try to damage the spaceship by firing projectiles. If the player manages to reach the destination, the ultimate antagonist corresponding to that level (which is referred to as *boss*) appears and must be defeated in order to complete the level.

In the context of Kromaia, developers generate content through PCG by means of the work of Gallota *et al.* (which combines an L-system with an evolutionary Algorithm) [20] because it is specific for spaceships that can play the role of bosses, and it achieves the best state-of-the-art results for this type of content. Developers also generate content through RCG by means of reusing features between Kromaia´s content. Specifically, the developers select a feature (a fragment of content) from a donor, and a host (another content) that will receive the feature. Despite the research efforts in both PCG and RCG and the importance of content generation for video game development, there is no study that directly compares them.

4 DISCUSSION

In the context of video games, reuse is not perceived as a completely positive practice. Developers fear that reusing might be perceived as repetitive by players. On the other hand, the randomness of PCG is perceived positively as an extension in the range of the creativity space for new content. Our experiment shows that this negative view of reuse is not aligned with the results. On the contrary, it reinforces the RCG pathway which boosts the latent content and leads to better results than PCG. During the focus group, subjects agree on that RCG was a natural evolution of the original content. In contrast, PCG was negatively classified as content that did not appear to have been developed by professional developers.

Previous studies considered only players as the subjects of the experiments. In our experiment, we go one step ahead and analyse the differences between players and developers. For researchers it can be difficult to find developers to run experiments. However, that could not be the case for development studios. For instance, a large studio can enroll developers from different projects from the studio. This is relevant for studios because they put a lot of effort into enrolling players (not developers) for their games. It may seem paradoxical that it is hard to find players, but the experience of testing parts of a game in development is not the same as testing a full game as the developers in the focus group pointed out. Our experiment reveals that there are no relevant differences in terms of statistical values between players and developers, suggesting that studios can leverage their developers. Furthermore, when it comes to feedback developers provided more beneficial feedback as the focus group acknowledge.

This experiment combines the specific quality aspects of video games ('design', 'difficulty', 'fun', and 'immersibility') and the rigorousness of more traditional software work. This includes the replication package that we have not found in previous work. One may think that the complexity of video games makes it difficult to design packages for replication. Nevertheless, we expect that our work along with the replication package available will provide a basis and inspiration for future researchers of the game software engineering community.

Availability Replication package is at:

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