Revolutionizing Game Development: An AI Strategy for Enhanced Cost-Efficiency and Time-Saving using Procedural Content Generation and Machine Learning

1st Aaron Goldstein
College of Computing, Engineering and Construction
University of North Florida
Jacksonville, United States
n01421643@unf.edu

***Abstract*—Game development is a complex and resource-intensive process, necessitating significant human capital and computational resources. Considering the recent advancements in gaming technology, these development costs and extended production timelines will only continue to increase if improvements are not made in streamlining the creation process. Moreover, there is a growing gap between small development studios and triple AAA companies as aspiring developers struggle to complete and produce games promptly that can meet modern customer expectations. Consequently, there will be less competition for large game studios, providing less incentive to innovate in new titles, leading to worse customer experiences. This study aims to explore how, utilizing artificial intelligence (AI) methodologies such as machine learning (ML), procedural content generation (PCG), and automated testing, game developers can optimize game development processes to make them more time and cost-efficient.**

***Index Terms*—Artificial Intelligence, Game Development, Cost Efficiency, Time Efficiency, Procedural Content Generation, Machine Learning, Video Games**

I. Introduction

The problem this research addresses is the substantial work and resources required to create modern games, which can inhibit innovation and limit market competition. Through the employment of AI technologies, we can streamline the game development process, reduce reliance on manual labor, and empower more individuals to pursue their creative endeavors within the game development industry, fostering innovation and creativity. Coupled with the power to enhance brainstorming processes and game design aspects, all these advantages can significantly reduce time and monetary investments.

The motivation for this study lies in the potential of reducing the large gap between small game studios and large triple AAA companies by making the development process more efficient. In this paper, we will survey the current research on the field, compare similar games that utilize PCG and those that don't, as well as the sizes of those respective studios, the amount of innovation these games show according to the gaming public, and as researchers and developers what lessons we can learn and apply in new projects. In addition, due to the reduced cost of development when utilizing AI, we hope studios will be driven to focus more on creative endeavors, be apt to take risks and innovate to create a superior overall gaming experience for the public.

Existing research and papers on this topic were sourced from Google Scholar and Phind, an artificial intelligence tool specialized in technical tasks. Papers were selected based on their relevance to key terms such as Artificial Intelligence, Procedural Content Generation, Video Games, and Video Game Development, and the reputation of the publishing journal. Essential definitions pertinent to this article are listed below, followed by a literature review.

A. Definitions

1) **Procedural Content Generation (PCG):** Procedural Content Generation (PCG) is a method used in game development where game content, such as levels, landscapes, characters, or objects, is generated algorithmically rather than being manually created by designers. PCG automatically creates a vast and varied amount of content, enabling more diverse and dynamic game environments and experiences.
2) **Triple AAA Companies (AAA):** Triple AAA companies, or simply "AAA," refer to the largest video game developers and publishers that have higher development and marketing budgets. AAA games, produced by these companies, are high-quality, big-budget games that offer profound, immersive gaming experiences, often featuring cutting-edge graphics and technology.
3) **Streamlining:** In the context of game development, streamlining refers to the process of making game design, production, or mechanics more efficient and user-friendly. It involves simplifying or optimizing various aspects of game development or the gameplay itself, such as interfaces, controls, or processes, to improve the overall player experience or development workflow.
4) **Artificial Intelligence (AI) in Game Development:** AI in game development refers to the simulation of

human intelligence processes by machines to enhance gaming experiences. This can include controlling non-player character (NPC) behavior, optimizing game mechanics, and adapting in-game elements based on player behavior.

5) **Machine Learning (ML) in Game Development:** ML in game development involves enabling computers to learn and improve from experience, adjusting in-game elements without being explicitly programmed. ML can be used for various applications, such as personalizing player experiences and improving NPC behaviors.
6) **Automated Testing in Game Development:** Automated testing in game development involves using tools and scripts to automatically execute test cases and evaluate the results, ensuring that the game runs as expected and identifying bugs or areas for improvement.
7) **Innovation in Game Development:** Innovation refers to introducing new ideas, devices, or methods. In game development, this can involve creating unique game mechanics, narratives, technologies, or design approaches to enhance player experience and engagement.
8) **Small Development Studios:** Small development studios typically operate with limited resources and smaller teams, focusing on niche markets or innovative game ideas. They might lack the extensive budgets of AAA studios but often offer unique and creative game titles.
9) **Cost Efficiency and Time Efficiency in Game Development:** These terms refer to optimizing game development processes to reduce expenses and shorten production timelines, making the industry more sustainable and allowing for the production of games that meet player expectations within reasonable budgets and schedules.
10) **Video Game Development:** Video game development encompasses the entire process of creating a video game, from initial concept and design to programming, testing, and release. It involves various disciplines like design, art, programming, and project management.

B. Literature Review

The first paper the author reviewed was a ”Rule-Based Procedural Content Generation System” by Oliveira et al. [1]. This paper proposed a PCG system for utilizing biome seeds to create multiple biomes and densely populate them with specific assets. As a result of this paper's work, the time and resources taken to create massive open worlds may be drastically reduced while also being flexible enough to meet the requirements of a level designer.

The second paper reviewed by the author was ”Procedural Content Generation for Games: A Survey” by Hendrikx et al. [2]. In this paper, the authors thoroughly review the different classes of game content that can be generated procedurally: game bits (textures, sounds), game space (indoor, outdoor maps), game systems (ecosystems, road networks, entity behavior), game scenarios (puzzles, stories), game design (game rules, setting, story, and theme), and derived content (news broadcasts of user actions in games, or leaderboards). Additionally, they provide an overview of games currently using PCG, such as Elite, a space exploration and trading game, and directions for future research in PCG, such as more detailed generators to improve realism and semi-automatic evaluation of generated content to ensure it meets game requirements or developer standards.

The third paper reviewed by the author was Experience-Driven Procedural Content Generation by Yannakakis et al. [3]. This paper focuses on utilizing affective and cognitive modeling alongside real-time adjustment of game content to personalize the user experience. They additionally provide a taxonomy of PCG algorithms and a framework for PCG, which computational models of user experience drive; they call their approach Experience-Driven Procedural Content Generation (EDPCG). In this paper, the authors discuss some of the challenges around this approach, such as the quantification of the user experience and the assessment of content quality, a point also made by Hendrikx et al. The authors also discuss how the usage of this technology also expands beyond that of games, referring to its potential applications in web applications, interface design, and art.

The fourth article the author reviewed is ”Deep Learning for procedural content generation” by Liu et al. [4]. This article focuses on how deep learning can be applied to content generation and the range of inventions it has powered in content production. The article talks about how deep learning has been used for game levels, think of (2D Super Mario Bros maps), generating game text (AI Dungeon 2), character models, and even music and sound with quite a few games now involving procedural soundtracks. It also details the various neural architectures used for game development, such as GANS, and the different methods used: supervised learning, standard unsupervised learning, reinforcement learning, adversarial learning, and evolutionary computation. The article suggests a learning method for training generators, to train them on content from other similar games; they provide an example of the FPS genre, mentioning how it should be possible to train on levels from Quake, Halo, and Call of Duty to learn how to generate new levels for a Half-Life Game, as all these human-designed content generally share the same functionality constraints (i.e, it's complete, usually free of major of game-breaking bugs that destroy immersion, floating buses, cars, or buildings, etc). They apply the same logic to generating character models to train generators on characters from other games, as they will also meet the same functionality constraints.

The fifth and final paper analyzed for this review was ”Recent Research on AI in Games” from Xia et al. [5], who performed a systematic survey of recent research on AI in games with a particular focus on believable agents in non-playable characters, game level generation with procedural content generation, and player profiling in player modeling. For more intelligent game NPCs, they discussed existing research involving reinforcement learning through a framework to evolve believable agents. With this framework, NPC agents can explore huge state space and exhibit behavior diversity

while still being able to react to different users, according to the framework creators. For PCG, the survey authors discuss the commonly seen games used for PCG research; again, Super Mario Bros is discussed. The authors also discuss a level generator for Angry Birds that can produce stable levels by selecting pre-defined segments. In discussing player experience modeling, they point out how a big challenge is to gain access to the game engine or log information to retrieve player game data. They also mention a potential solution provided by a researcher: convolutional neural networks and transfer learning to derive game logs from a game video. The researcher who proposed this solution explored three different deep CNNs to evaluate player interest in a game through videos. They evaluated their methods through an annotated gameplay video dataset and determined an overall accuracy rate of 75%. Xia et al. also discuss current research utilizing a player's heart rate data to evaluate a player's state while playing HeartStone or Dota 2. The survey notes how the current field of game AI is limited to a few types of games and much expansion is needed to realize the generalization of game AI. Given the aforementioned information, this paper's study will focus on analyzing how to use these techniques to improve the efficiency of the game development process with a focus on reducing costs and allowing each developer to maximize their development potential. The author hypothesizes through the effective usage of AI, developers can see substantial improvements in game design, potential world scale, and cost savings in time, money, and human resources.

II. Methodology

The study will use similar methods to those papers discussed in the review. The author will research existing games that have utilized cutting-edge PCG and AI techniques in their game development process and analyze how those techniques have impacted their success, the quality of their game, and resource usage, and discuss how such similar methods can be generally applied throughout the game development industry to streamline the development process irrespective of game type or genre. In short, a detailed investigation will be conducted through case studies, interviews with game developers (if possible), and analysis of various game development projects employing AI.

1) **Literature Review:**
   - Conduct a comprehensive exploration of existing academic and industry resources.
   - Focus on established AI technologies and their applications in game development.
2) **Case Studies:**
   - Choose specific game development projects that have incorporated AI technologies.
   - Analyze the application, challenges, and outcomes of using AI in these cases.
3) **Surveys and Interviews:**
   - Distribute questionnaires and conduct interviews with professionals in the field.
   - Focus on collecting personal insights, experiences, and practical challenges developers face.
4) **Data Analysis:**
   - Collect and analyze quantitative data such as development time, cost, and game performance.
   - Compare and contrast these metrics against traditional game development methodologies.

III. Evaluation

The study will use an analytical approach to the problem solution. The author will analyze various games using AI development strategies, their similar counterparts that did not use AI in development, and how the two compared in development times, their design, the quality of their programming (the stability of the game on various systems and how well the game plays), and the level of innovation demonstrated by the developers according to the general gaming public. Opinions from the general public will be obtained using public online forums, reviews, datasets, and APIs located on the Awesome Game Data Sets repository [6]. The capability of any specific AI method to reduce cost and improve efficiency will be evaluated based on how well studios and games utilizing it reduced the cost and time invested in various phases of game development, such as design, programming, testing, and debugging.

- **Efficiency:**
  - Compare development timelines with and without the implementation of AI technologies.
  - Focus on identifying any significant reductions in development time and resources.
- **Cost-Effectiveness:**
  - Analyze financial aspects such as budget allocations and actual expenditures.
  - Identify potential cost-saving aspects brought about by the implementation of AI.
- **Quality and Performance:**
  - Evaluate the developed games' overall quality, stability, and performance.
  - Focus on user experiences, bug frequency, and other relevant performance indicators.
- **Innovation:**
  - Assess the novelty and technological advancement the AI integration brings.
  - Evaluate how AI has contributed to the creativity and uniqueness of the games.

IV. Results

In this study, various metrics and visualization methods will be employed to comprehensively evaluate and present the findings concerning the impact of AI and ML technologies on streamlining game development processes in both AAA and small gaming studios.

A. Metrics

1) **Efficiency Improvement:** Measurement of the time saved in the game development process due to the implementation of AI and ML technologies.
2) **Cost Reduction:** Analyzing the cost-effectiveness by comparing the investment in AI and ML technologies against the overall cost savings in the development process.
3) **Quality Enhancement:** Evaluation based on the improvement in game quality, considering factors such as bug reduction, gameplay improvement, and user experience.
4) **Innovation:** Assessment of the novelty and uniqueness brought into the game development process and the final product due to AI and ML incorporation.
5) **Player Satisfaction:** Collecting and analyzing user reviews and ratings to gauge the impact of AI and ML technologies on user satisfaction and gaming experience.
6) **Development Flexibility:** Measuring how AI and ML technologies enhance the adaptability and flexibility of the development process to incorporate changes and improvements.

B. Visualization

1) **Bar Charts:** Used to represent the comparative analysis of time and cost factors between different projects or various stages of a single project.
2) **Pie Charts:** Utilized to showcase the distribution of resources, such as time spent on different development stages or cost allocation in various development aspects.
3) **Line Graphs:** Employed to show trends over time, such as improvement trends in efficiency or quality over different project phases or multiple projects.
4) **Heat Maps:** Useful in representing areas of intense activity or focus in the development process, enabling the identification of hotspots of innovation or issues.
5) **Scatter Plots:** Deployed to present correlations, such as the relationship between the level of AI and ML integration and various metrics like quality or user satisfaction.
6) **Histograms:** To display the frequency of specific outcomes, such as the number of bugs found in different stages of development, aiding in identifying patterns or common issues.

Each metric and visualization tool will be chosen and customized based on its relevance and effectiveness in clearly conveying the required analysis and insights of the study.

By the end of the study, the paper will:

- Present the findings from the case studies, detailing how AI was utilized and its effectiveness.
- Highlight insights from surveys and interviews, emphasizing common trends, benefits, and challenges.
- Summarize the data analysis, emphasizing key metrics that showcase the impact of AI on game development.
- Provide suggestions for further usage of AI technologies in video games and directions for future research.

V. Results

In this study, various metrics and visualization methods will be employed to comprehensively evaluate and present the findings concerning the impact of AI and ML technologies on streamlining game development processes in both AAA and small gaming studios.

Table of studied games and the dataset on which the analysis was performed.

A. Metrics

The following figures illustrate the key findings from our analysis:

VI. Results

A. Visualizations

The following figures illustrate the key findings from our analysis:

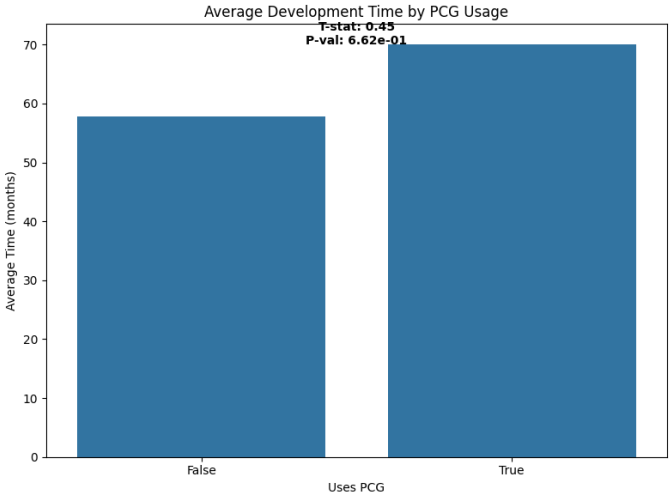

Fig. 1. Average Development Time Comparison

VII. Description of List of Required Resources

The list of required resources for this study is shown below. It contains research papers, case studies, datasets, and APIs useful for working with AI for video game applications.

A. Papers

(Descriptions of papers may be found in the Literature Review)

- A rule-based procedural content generation system [1]
- Procedural content generation for games: A survey [2]
- Experience-driven procedural content generation [3]
- Deep learning for procedural content generation [4]
- Recent research on ai in games [5]

TABLE I
GAMES ANALYZED IN THE STUDY

Game Name	PCG	Dev Time (months)	Cost (USD)	Performance	Innovation	User Satisfaction
No Man's Sky	True	32	20,000,000	85	90	61
Elite Dangerous	True	34	25,000,000	88	85	80
Starfield	True	84	30,000,000	90	92	86
Minecraft	True	35	5,000,000	95	95	93
Stardew Valley	True	48	1,000,000	90	88	88
Terraria	True	5	2,000,000	88	85	83
Valheim	True	71	1,500,000	92	90	90
Dwarf Fortress	True	251	200,000	85	80	93
The Legend of Zelda: Breath of the Wild	False	60	70,000,000	95	95	97
The Witcher 3: Wild Hunt	False	42	81,000,000	95	90	93
Red Dead Redemption	False	60	80,000,000	90	88	95
Grand Theft Auto V	False	60	265,000,000	95	90	97
God of War (2018)	False	60	50,000,000	95	92	94
Horizon Zero Dawn	False	72	47,000,000	90	88	90
Spider-Man (PS4)	False	48	50,000,000	92	90	87
Ghost of Tsushima	False	60	60,000,000	90	88	83

TABLE II
SUMMARY OF STATISTICAL ANALYSIS FOR GAME DEVELOPMENT METRICS

Category	Average for PCG	Average for non-PCG	T-stat	P-value
Development Time	70.00	57.75	0.45	0.662
Development Cost	10,587,500.00	87,875,000.00	-2.96	0.0103
Game Performance	89.12	92.75	-2.43	0.029
Innovation Score	88.12	90.12	-1.07	0.303
User Satisfaction	84.25	92.00	-1.89	0.0791

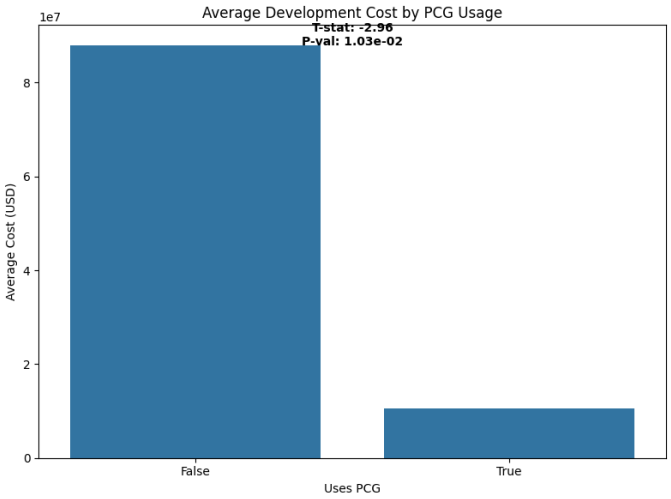

Fig. 2. Average Development Cost Comparison

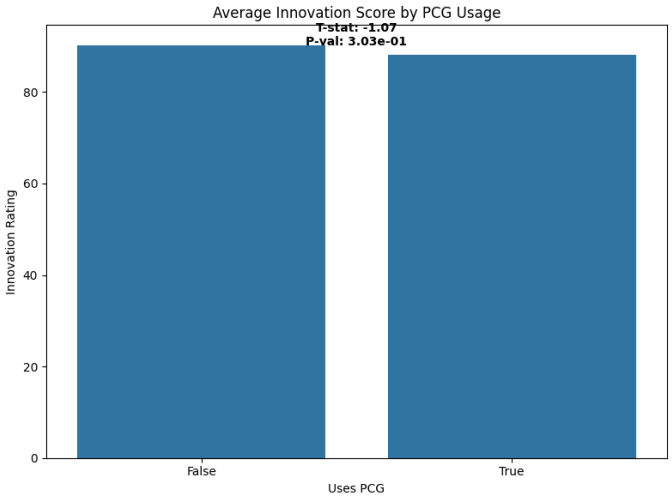

Fig. 4. Average Innovation Score Comparison

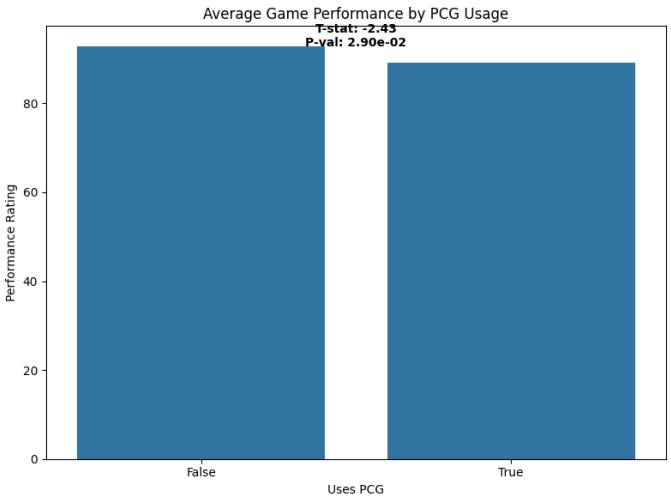

Fig. 3. Average Game Performance Comparison

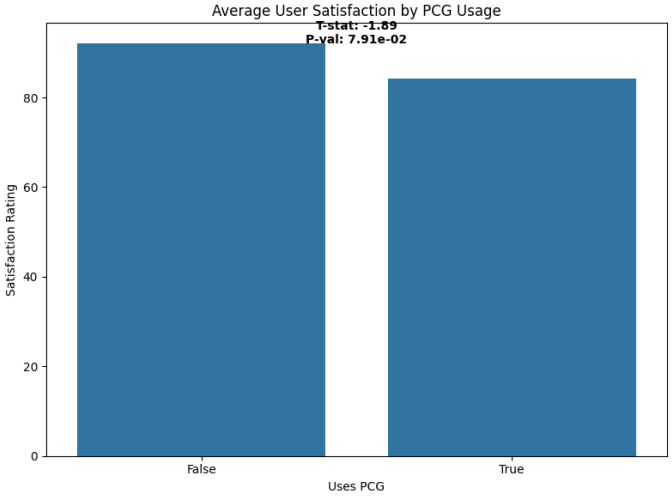

Fig. 5. Average User Satisfaction Comparison

B. Datasets and APIs

- Awesome Game Datasets [6]: A repository of APIs and datasets for working with Artificial Intelligence in Digital Games
- OpenAI's GPT API: This can be used for data generation, testing, brainstorming for game design, and player support.

VIII. Completion Timeline

- Week 7-8: Conducting literature review and defining the research gap.
- Week 9-10: Collecting data, case studies, and expert opinions.
- Week 11-12: Analyzing the data and identifying patterns and impacts of AI in game development.
- Week 13-14: Drafting the results and discussions.
- Week 15-16: Review, revision, and submission of the final research project.

References

[1] G. Oliveira, L. Almeida, J. P. Sousa, B. Barroso, and I. Barbedo, "A rule based procedural content generation system," in *International Conference on Optimization, Learning Algorithms and Applications*. Springer, 2022, pp. 107–113.

[2] M. Hendrikx, S. Meijer, J. Van Der Velden, and A. Iosup, "Procedural content generation for games: A survey," *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM)*, vol. 9, no. 1, pp. 1–22, 2013.

[3] G. N. Yannakakis and J. Togelius, "Experience-driven procedural content generation," *IEEE Transactions on Affective Computing*, vol. 2, no. 3, pp. 147–161, 2011.

[4] J. Liu, S. Snodgrass, A. Khalifa, S. Risi, G. N. Yannakakis, and J. Togelius, "Deep learning for procedural content generation," *Neural Computing and Applications*, vol. 33, no. 1, pp. 19–37, 2021.

[5] B. Xia, X. Ye, and A. O. Abuassba, "Recent research on ai in games," *2020 International Wireless Communications and Mobile Computing (IWCMC)*, pp. 505–510, 2020.

[6] L. Mauro, “Game datasets,” GitHub repository, 2022, [Online]. Available: https://github.com/leomaurodesenv/game-datasets.