Exploring GenAI-Driven Innovation in Game Development

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***Abstract*—The game industry, now generating over $200 billion annually, has become a major force in entertainment, yet game development remains underexplored in software engineering research. Generative AI (GenAI) has introduced new opportunities for content automation in game development, offering benefits in testing, design, and player engagement. However, integrating GenAI across game development phases presents unique technical, creative, and collaborative challenges. This study aims to develop an adaptable framework that addresses these challenges by providing practical insights and strategies to enhance collaboration, creativity, and efficiency. Using a mixed-methods approach, including open-source analysis and developer surveys and interviews, we will construct a grounded theory on GenAI adoption. The insights will inform a framework refined with industry feedback, contributing datasets, guidelines, and tools to support sustainable GenAI integration in game development.**

***Index Terms*—Generative AI; Game Development; Mining Software Repositories; Empirical Studies; Artificial Intelligence; Open Source; Software Engineering**

I. Motivation And Background

Globally, the game industry has surpassed the combined revenues of film, television, and music, generating over $200 billion and positioning itself as a dominant force in the entertainment industry [10]. Although video games are a successful part of software systems, they have only recently started drawing significant attention from software engineering researchers [23]. Game development is a distinctive domain within software engineering, blending technical and creative demands and requiring developers with specialized skills [2], [26]–[28] and differing substantially from other software development fields [4], [14], [21]. Unlike traditional software, video games function as sophisticated systems that simultaneously embody complex forms of creativity and art [8]. Yet, despite these unique characteristics, game development has historically received limited attention in software engineering research [1].

Artificial intelligence (AI) has long played a significant role in game development practices. Early efforts to categorize AI in games identified three primary roles: AI that plays the game, AI that assists in designing the game, and AI that models the behaviour of human players [31]. One of the most active fields within game AI is Procedural Content Generation (PCG) [12] that assists game developers in creating project-specific elements, such as maps and levels [25]. Building on traditional AI approaches, recent advancements in generative artificial intelligence (GenAI) have further expanded these applications, opening new possibilities for automatic content generation across diverse game content formats. Studies have demonstrated GenAI's effectiveness in various aspects of game development, including game testing [29], multimedia generation [18], game design [15], [16], [30], player engagement [19], game commentary [24], and even as AI players in collaborative design tasks within distributed games [20], and beyond.

While studies reveal GenAI's potential to automate specific tasks, they often focus on proprietary environments and lack a holistic view of its impact across the game development pipeline. Unlike traditional software engineering, game development involves diverse multimedia assets (e.g., animations, music) and iterative design processes to balance technical feasibility with creative vision [14], creating unique challenges for GenAI integration [7]. Traditionally, GenAI in game development has focused on isolated tasks, but a comprehensive approach across phases could better address emerging challenges, especially with the advent of foundation models (FMs) like Large Language Models (LLMs) [11]. FMs represent a paradigm shift, and FM-based software (FMware), including GenAI-driven games, faces unique issues such as consistency, prompt engineering, and quality control under non-deterministic outputs. This study aims to provide game developers with a structured framework to tackle these challenges, supporting cohesive, adaptable workflows from concept to player engagement.

II. Problem Statement

This study aims to provide practical solutions and insights to support GenAI integration across diverse phases, roles, and game types in game development. By addressing the unique challenges and opportunities GenAI brings to each stage of the workflow, we hypothesize that our framework can enhance collaboration, creativity, and efficiency within development teams while ensuring consistency in content and adaptability to iterative design changes. To achieve this, we seek to answer the following research questions:

RQ1 How is GenAI currently being utilized across various stages of game development workflows?

RQ2 What are the main benefits and challenges game developers face when integrating GenAI across different phases of game development?

RQ3 How does GenAI impact collaboration, creativity, and productivity within game development teams?

RQ4 What adaptations and best practices can facilitate sustainable and scalable GenAI integration across diverse game types and development roles?

III. Research Methodology

To address the outlined research questions, we have divided the research tasks into five distinct phases.

A. Collection and Analysis of Data from Repositories and Communities

To gain an initial understanding of current GenAI practices in game development, we will analyze open-source repositories (e.g., GitHub, Hugging Face), focusing on projects tagged related to "game development" and "GenAI". By examining codebases, commits, pull requests, issues, and discussions, we aim to identify commonly used GenAI tools, techniques, and collaboration patterns. In addition, we will analyze discussions from game development communities (e.g., Reddit) using natural language processing (NLP) and topic modelling to categorize recurring themes, challenges, and best practices. The insights from this phase will provide a foundational view of GenAI integration, answering RQ1, and facilitating further qualitative analysis in the subsequent research phases.

B. Survey and Interviews with Game Developers

Based on findings from Phase 1, we will design targeted survey and interview questions to gather insights on GenAI integration from game developers. The survey and semi-structured interviews will follow established guidelines to ensure clarity and relevance [5], [32], distributed across multiple developer communities to capture diverse perspectives on experiences, challenges, and needs. Both survey and interview questions will explore specific GenAI applications and adaptation challenges. Survey data will undergo quantitative analysis to identify common themes, while interview data will be analyzed through thematic analysis [3], coding responses to reveal in-depth insights into the practical benefits and challenges of GenAI adoption. Together, these analyses will address RQ2, clarifying obstacles and factors influencing GenAI integration in real-world game development.

C. Grounded Theory Development

Based on the data collected from previous phases, we will develop a grounded theory to identify and explain the key patterns influencing GenAI integration in game development. Following established methodologies [9], [17], our analysis will begin with open coding to categorize insights on GenAI-related challenges and practices, followed by axial coding to uncover relationships among these categories. Finally, selective coding will integrate themes into a cohesive model, representing GenAI adoption within diverse game development contexts [6]. The insights gained from this grounded theory will answer RQ3 and serve as a foundation for designing a practical framework to support sustainable and scalable GenAI integration across different phases and team roles in game development.

D. Framework Development and Evaluation

Finally, we will synthesize our findings into a practical framework aimed at supporting game developers in effectively integrating GenAI across various phases of game development. This framework will include best practices, recommended tools, and adaptation strategies tailored to address the technical, creative, and collaborative challenges identified in earlier phases. Drawing on principles from established design science research [13], the framework will provide a scalable and sustainable approach to GenAI-driven game development, incorporating iterative testing and refinement.

To ensure the framework's real-world applicability and effectiveness, we will collaborate with industry developers for testing and feedback, following an iterative refinement process. This user-centered approach [22] will allow us to incorporate practical insights from game developers, ensuring the framework meets diverse project needs and remains adaptable across different development contexts. The final framework will serve as a comprehensive guide to help developers optimize GenAI integration, addressing scalability, workflow adaptation, and collaborative practices.

IV. Expected Contributions

Our research will follow open science principles. We intend to make all collected repositories and community data, survey and interview guidelines, and both raw and processed data publicly accessible. Specifically, we aim to provide the following contributions throughout our research efforts:

C1 A comprehensive dataset encompassing online repository and community data, including codebases, commits, issues, pull requests, and discussions, offering a rich resource for understanding GenAI practices in game development.

C2 A structured list of survey and interview questions designed to capture the benefits and challenges of GenAI integration across various phases of game development, which can serve as a foundation for future research.

C3 A grounded theory that systematically explains the patterns, challenges, and factors influencing GenAI integration across game development workflows, providing theoretical insights for both academia and industry.

C4 A practical framework that serves as a structured guide for game developers and studios, presenting best practices, tools, and strategies to address integration challenges and support sustainable, scalable GenAI adoption.

C5 A set of evaluation metrics to assess the effectiveness of the framework in helping game developers integrate GenAI across various phases of development, ensuring its applicability and value in real-world settings.

References

[1] Apostolos Ampatzoglou and Ioannis Stamelos. Software engineering research for computer games: A systematic review. *Information and Software Technology*, 52(9):888–901, 2010.

[2] Yasunori Baba and F Ted Tschang. Product development in japanese tv game software: The case of an innovative game. *International Journal of Innovation Management*, 5(04):487–515, 2001.

[3] Virginia Braun and Victoria Clarke. Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2):77–101, 2006.

[4] Jorge Chueca, Javier Verón, Jaime Font, Francisca Pérez, and Carlos Cetina. The consolidation of game software engineering: A systematic literature review of software engineering for industry-scale computer games. *Information and Software Technology*, 165:107330, 2024.

[5] Don A Dillman, Jolene D Smyth, and Leah Melani Christian. *Internet, phone, mail, and mixed-mode surveys: The tailored design method*. John Wiley & Sons, 2014.

[6] Kathleen M Eisenhardt. Building theories from case study research. *Academy of management review*, 14(4):532–550, 1989.

[7] Henrik Engström. Game development research, 2020.

[8] Henrik Engström, Björn Berg Marklund, Per Backlund, and Marcus Toftedahl. Game development from a software and creative product perspective: A quantitative literature review approach. *Entertainment Computing*, 27:10–22, 2018.

[9] Barney Glaser and Anselm Strauss. *Discovery of grounded theory: Strategies for qualitative research*. Routledge, 2017.

[10] Todd Harris. Georgia's got game: Why the gaming industry is larger than film, television and music combined, 2024. [Accessed: 2024-11-10].

[11] Ahmed E Hassan, Dayi Lin, Gopi Krishnan Rajbahadur, Keheliya Gallaba, Filipe Roseiro Cogo, Boyuan Chen, Haoxiang Zhang, Kishanthan Thangarajah, Gustavo Oliva, Jiahuei Lin, et al. Rethinking software engineering in the era of foundation models: A curated catalogue of challenges in the development of trustworthy fmware. In *Companion Proceedings of the 32nd ACM International Conference on the Foundations of Software Engineering*, pages 294–305, 2024.

[12] Mark Hendrikx, Sebastiaan Meijer, Joeri Van Der Velden, and Alexandru Iosup. Procedural content generation for games: A survey. *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM)*, 9(1):1–22, 2013.

[13] Alan R Hevner, Salvatore T March, Jinsoo Park, and Sudha Ram. Design science in information systems research. *MIS quarterly*, pages 75–105, 2004.

[14] Christopher M Kanode and Hisham M Haddad. Software engineering challenges in game development. In *2009 Sixth International Conference on Information Technology: New Generations*, pages 260–265. IEEE, 2009.

[15] J Lee, So-Youn Eom, and JunHee Lee. Empowering game designers with generative ai. *IADIS International Journal on Computer Science & Information Systems*, 18(2):213–230, 2023.

[16] Jiaqi Li and Qinchuan Liu. Application of generative artificial intelligence aigc technology under neural network algorithm in game character art design. *Journal of the Knowledge Economy*, pages 1–32, 2024.

[17] Yvonna S Lincoln. *Naturalistic inquiry*, volume 75. sage, 1985.

[18] Tomi Linkinen. Generative artificial intelligences: Challenges and benefits for game development. 2024.

[19] Yize Liu. Research on game development and revenue based on generative artificial intelligence: A case study of netease. *Journal of Education, Humanities and Social Sciences*, 35:434–440, 2024.

[20] Jenna Matthews, Ha Nguyen, and Hillary Swanson. Shall we play a game? distributed games with a generative ai player. In *Proceedings of the 17th International Conference on Computer-Supported Collaborative Learning-CSCL 2024, pp. 139-146*. International Society of the Learning Sciences, 2024.

[21] Emerson Murphy-Hill, Thomas Zimmermann, and Nachiappan Nagappan. Cowboys, ankle sprains, and keepers of quality: How is video game development different from software development? In *Proceedings of the 36th international conference on software engineering*, pages 1–11, 2014.

[22] Donald A Norman and Stephen W Draper. *User centered system design; new perspectives on human-computer interaction*. L. Erlbaum Associates Inc., 1986.

[23] Luca Pascarella, Fabio Palomba, Massimiliano Di Penta, and Alberto Bacchelli. How is video game development different from software development in open source? In *Proceedings of the 15th International Conference on Mining Software Repositories*, pages 392–402, 2018.

[24] Noah Ranella and Markus Eger. Towards automated video game commentary using generative ai. In *EXAG@ AIIDE*, 2023.

[25] Mark Owen Riedl and Alexander Zook. Ai for game production. In *2013 IEEE conference on computational inteligence in games (CIG)*, pages 1–8. IEEE, 2013.

[26] William Swartout and Michael van Lent. Making a game of system design. *Communications of the ACM*, 46(7):32–39, 2003.

[27] F Ted Tschang. Balancing the tensions between rationalization and creativity in the video games industry. *Organization science*, 18(6):989–1005, 2007.

[28] F Ted Tschang and Janusz Szczypula. Idea creation, constructivism and evolution as key characteristics in the videogame artifact design process. *European management journal*, 24(4):270–287, 2006.

[29] Qingyang Wang. *Generative AI in Game Pedagogy*. PhD thesis, WORCESTER POLYTECHNIC INSTITUTE, 2024.

[30] Stefan Werning. Generative ai and the technological imaginary of game design. In *Creative Tools and the Softwarization of Cultural Production*, pages 67–90. Springer, 2024.

[31] Georgios N Yannakakis and Julian Togelius. *Artificial intelligence and games*, volume 2. Springer, 2018.

[32] Robert K Yin. *Case study research: Design and methods*, volume 5. sage, 2009.