iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** III **Month of publication:** March 2025

DOI: https://doi.org/10.22214/ijraset.2025.67470

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

The Survey of Machine Learning Techniques in PUBG: Strategies for AI and Player's Gameplay

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Abstract: ***This research paper delves into the integration of machine learning (ML) techniques within PlayerUnknown's Battlegrounds (PUBG), focusing on strategies that enhance artificial intelligence (AI) performance and player interaction. By analyzing large-scale gameplay datasets, the study evaluates the effectiveness of generative AI frameworks and reinforcement learning algorithms. Key findings highlight improvements in AI adaptability, strategic decision-making, and player satisfaction. The research identifies gaps in real-time AI adaptability, trust-building in high-stakes environments, and fairness in gameplay, aiming to advance AI capabilities in multiplayer gaming scenarios.***

Keywords: Machine Learning (ML), PlayerUnknown's Battlegrounds (PUBG), Artificial Intelligence (AI), Reinforcement Learning, Player-AI Interaction

I. INTRODUCTION

The importance of AI in PUBG has multiple aspects. First, AI contributes to game balance by simulating human-like behaviors that challenge players while maintaining fairness (Szwoch & Szwoch, 2015). Second, AI enhances the gaming experience by adapting to players' strategies, providing dynamic and engaging gameplay (Wu et al., 2023). Third, AI facilitates the development of training tools that help players improve their skills through realistic simulations (Spronck et al., 2006). This research explores the application of ML techniques in PUBG, focusing on improving AI teammates' performance. The study addresses the challenges of predictable AI behaviors, lack of adaptability, and issues related to player trust and fairness (Eun et al., 2022).

By leveraging neural networks, reinforcement learning, and natural language processing, the research aims to develop AI companions capable of strategic thinking and effective communication (Sen et al., 2022). Furthermore, the integration of AI in PUBG not only improves gameplay dynamics but also provides insights into broader applications of AI in competitive environments (Cunha & Chaimowicz, 2010). The ability of AI to adapt to real-time scenarios, understand player behavior, and make strategic decisions is pivotal for the evolution of gaming experiences (Heryanto et al., 2024).

Moreover, AI-driven game environments encourage immersive experiences by simulating realistic adversaries and dynamic scenarios that challenge even the most skilled players (Kim et al., 2024). This adaptability is achieved through reinforcement learning, where AI agents learn optimal strategies through trial-and-error interactions with the game environment (Reinhardt, 2023). Additionally, generative AI models enable the creation of new content, such as maps, characters, and missions, enhancing replay ability and player engagement (Barros e Sá & Madeira, 2025).

The implementation of AI in multiplayer games like PUBG also raises ethical and practical considerations. Issues such as data privacy, algorithmic bias, and the transparency of AI decision-making processes are critical for maintaining player trust and ensuring fair gameplay (Karimi & Rahimi, 2021). Addressing these challenges requires continuous research and development, focusing on creating AI systems that are not only intelligent but also ethical and transparent (Bakkes et al., 2009).

Furthermore, the potential of AI extends beyond gameplay mechanics to include player behavior analysis, cheat detection, and personalized game recommendations (Xia et al., 2020). By analyzing player data, AI can identify patterns and predict behaviors, allowing developers to create more engaging and customized experiences (El Rhalibi et al., 2009). This capability also supports the development of anti-cheat mechanisms that detect irregular behavior signifying unfair play (Sun et al., 2024).

In addition to these applications, AI's role in enhancing game accessibility has become increasingly important. For players with disabilities, AI can provide adaptive interfaces, personalized controls, and assistive technologies that improve the overall gaming experience (Ki et al., 2006). These advancements ensure that games like PUBG are inclusive, catering to a broader audience and fostering a more diverse gaming community (Smerdov et al., 2023).

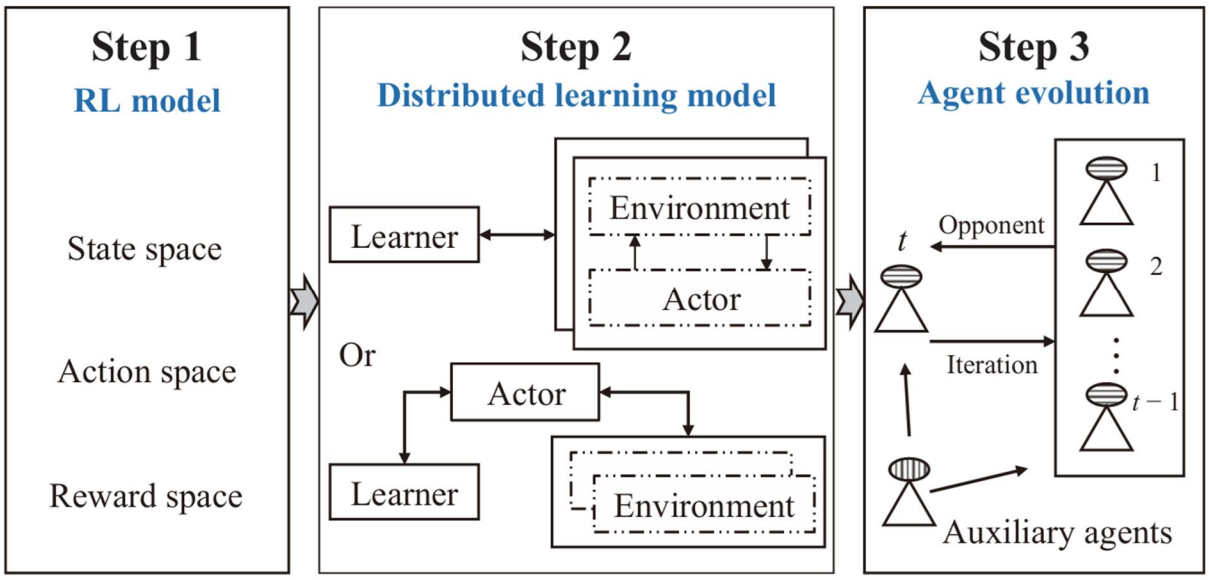

Fig. 1 Steps for a general technology to train AIs (Yin et al., 2023)

Another critical area of AI in gaming is procedural content generation (PCG), where AI algorithms autonomously (to act independently) create game content, such as terrains, quests, and levels (Uludağlı & Oğuz, 2023). In PUBG, PCG can be utilized to design varied and unpredictable battlegrounds, ensuring that each match offers a unique challenge. This dynamic content generation keeps the game fresh and engaging for long-term players (Duan et al., 2019).

AI also plays a vital role in enhancing in-game economies and virtual marketplaces. By analyzing player behavior and market trends, AI can optimize pricing strategies, recommend in-game purchases, and detect fraudulent activities (Francos & Bruckstein, 2023). This not only boosts revenue for game developers but also creates a more balanced and fairer in-game economy for players (Mortazavi et al., 2024).

Another dimension where AI exhibits transformative potential is in real-time strategy adaptation. Through continuous learning algorithms, AI systems can dynamically adjust their strategies based on evolving in-game situations and player actions (Zheng et al., 2024). This enables AI to react to unexpected scenarios with high efficiency, thereby increasing the unpredictability and excitement of matches (Yin et al., 2023). Adaptability is essential for creating AI opponents that are both challenging and engaging, mirroring the complexity of human behavior (Fang & Ting, 2009).

Furthermore, the integration of AI into matchmaking systems has significantly improved the fairness and competitiveness of multiplayer games like PUBG (Hernandez et al., 2020). By analyzing player statistics, behavioral patterns, and performance metrics, AI-driven matchmaking algorithms can create balanced teams, ensuring fair play and enhancing the overall gaming experience (Barros et al., 2021). This not only increases player retention but also encourages a more competitive and rewarding gaming environment (Zhu et al., 2021).

Another crucial aspect of AI development in PUBG is ensuring continuity in gameplay. If a player disconnects due to network issues or leaves a match, AI-driven bots with similar capabilities should seamlessly replace them, maintaining team balance and competitiveness. These AI replacements should exhibit decision-making abilities comparable to human players, effectively engaging opponents and supporting teammates to sustain an uninterrupted gaming experience.

AI's influence also extends to game narrative development, where natural language processing (NLP) and machine learning techniques are employed to create dynamic storytelling experiences (Mohebbi Moghaddam et al., 2023). In PUBG, such technologies can be utilized to generate personalized narratives that evolve based on player decisions and gameplay outcomes, adding a new layer of depth and immersion to the game (Waltham & Moodley, 2016).

Additionally, AI's integration with virtual and numerous reality technologies offers new dimensions for immersive gameplay. AI can adapt virtual environments in real-time based on player interactions, creating highly personalized and engaging experiences (Törhönen et al., 2024). This level of immersion deepens player involvement and encourages a more interactive gaming landscape (Szwoch & Szwoch, 2015).

AI-driven tools can analyze match data to provide insights into team strategies, player performance, and game dynamics, benefiting both professional players and coaches (Eun et al., 2022). This analytical approach enhances competitive gaming, making it more strategic and data driven (Wu et al., 2023).

Moreover, AI holds significant potential in optimizing game development processes. By leveraging automated testing and quality assurance systems, developers can identify bugs and performance issues more efficiently, reducing development time and costs (Iarovoi et al., 2024). This leads to faster updates and more polished game releases, ultimately enhancing player satisfaction (Fu et al., 2015).

AI's role in psychological modeling is another emerging area of interest. By analyzing in-game behaviors, AI can infer players' emotional states and adapt gameplay accordingly to maintain engagement and reduce frustration (Spronck et al., 2006). This personalized approach fosters a deeper emotional connection between the player and the game, enhancing the overall gaming experience (Muller et al., 2020).

II. GAPS AND CHALLENGES

Despite notable progress, several gaps and challenges persist in the development of AI systems for PUBG:

A. Scalability in Large-Scale Matches

While AI systems perform well in controlled scenarios or small teams, they struggle to scale effectively in large multiplayer matches. The complexity of managing numerous human and AI players in real-time is a major limitation.

B. Real-Time Adaptability

AI systems often struggle to adapt quickly to dynamic and unpredictable game events, such as sudden shifts in player behavior or environmental changes. Achieving rapid decision-making without sacrificing quality remains a significant challenge.

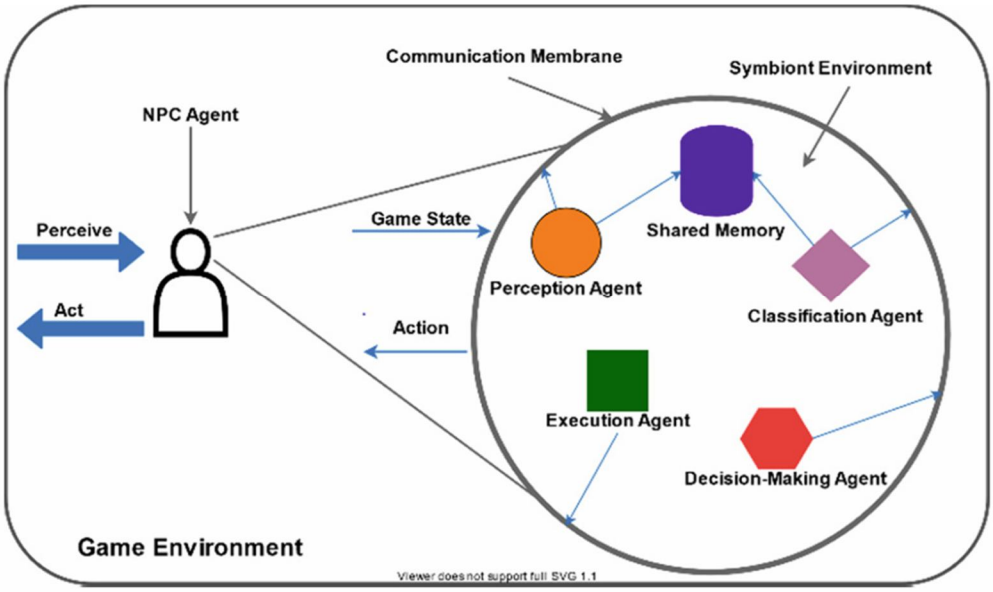

Fig. 2 The AdaptiveSGA model for achieving DDB through AGAI. (Sithungu & Ehlers, 2020)

C. Player-AI Trust and Interaction

Effective communication and trust between AI agents and human players are critical for smooth collaboration. While NLP has been implemented to allow for better communication, emotional understanding and the ability to build trust between AI and players remain underdeveloped.

D. Fairness and Ethical Issues

AI opponents can sometimes dominate human players, creating unfair advantages. Balancing AI difficulty, preventing overpowered bots, and ensuring AI transparency are ongoing concerns.

E. Generalization of AI Behavior

AI often fails to generalize well to new scenarios or highly complex behaviors not covered in training data. This is particularly problematic in combat and tactical decision-making, where AI must be able to anticipate and react to unforeseen actions.

F. Complex Combat and Tactical Decision-Making

Combat in PUBG is unpredictable, requiring AI to make complex decisions about positioning, resource management, and tactical maneuvers. Despite progress in AI decision-making algorithms, such as deep learning and decision trees, the AI still struggles with high-level combat strategies, particularly in fast-paced, chaotic scenarios.

G. Diversity in Player Behavior

Human players are inherently diverse in their playstyles and behaviors, ranging from aggressive, tactical decision-makers to more cautious and exploratory players. AI systems often fail to adapt sufficiently to this diversity, relying on predefined behaviors or strategies that do not account for the full spectrum of player tactics.

H. Transparency and Explainability

As AI systems become more integral to gameplay, there is a growing demand for transparency and explainability in AI decision-making. Players may become frustrated or disengaged if they cannot understand why their AI teammates make certain decisions or why they behave in specific ways. This lack of clarity can diminish trust and create a barrier between players and AI agents.

III. METHODOLOGY

This paper analyzes the integration of various machine learning and AI techniques used in PUBG, drawing from studies that utilize reinforcement learning, behavioral modeling, game theory, and natural language processing.

A. Reinforcement Learning (RL)

Reinforcement learning has been widely applied in AI development for real-time decision-making and strategy adaptation. AI agents can improve their performance by receiving feedback from interactions within the game environment. In PUBG, this method is used to train AI teammates to react to player actions and adapt their strategies accordingly.

B. Natural Language Processing (NLP)

NLP allows AI to communicate more effectively with players. By processing and responding to human language, AI can offer strategic suggestions, coordinate with players, and simulate realistic in-game dialogue. NLP models have been tested in PUBG to enhance team communication and create a more immersive player experience.

C. Game Theory

Game theory is particularly useful in modeling team strategies and long-term decision-making. By using game-theoretic models, AI can better align its actions with the collective goals of the team, improving overall coordination in PUBG's team-based gameplay .

D. Behavioral Modeling and Imitation Learning

AI can learn from human behavior, adapting its strategies based on the patterns and preferences of players. By incorporating imitation learning, AI can develop more realistic and responsive strategies, improving its ability to work as a teammate in cooperative missions .

E. Adversarial Training

Adversarial environments are used to improve AI's ability to perform under pressure. By simulating hostile or competitive conditions, AI agents can be trained to respond effectively to stress and uncertainty, essential for surviving in PUBG's unpredictable combat situations .

F. Multi-Agent Systems and Collaborative Learning

AI systems in PUBG can also benefit from multi-agent systems, where agents must work together, coordinate, and optimize collective behavior. Cooperative Multi-Agent AI in PUBG introduces the use of genetic algorithms to evolve cooperative behaviors,

enabling AI agents to improve their teamwork in a multiplayer environment. This approach leads to better coordination between AI teammates and enhances the overall performance in team-based objectives.

Furthermore, AI and Cooperative Learning in PUBG focuses on cooperative learning, where AI agents improve based on shared experiences, collaborating with each other to solve complex in-game tasks. This methodology enhances AI cooperation, making the system more effective in multiplayer matches.

IV. CONCLUSION

The integration of AI into multiplayer games like PUBG presents both exciting opportunities and significant challenges. As we've explored throughout this paper, machine learning techniques have greatly enhanced the capabilities of AI in gameplay, allowing AI agents to mimic human-like decision-making, improve communication, and adapt to dynamic environments. Despite these advancements, there are several unresolved issues that need to be addressed to fully realize the potential of AI in multiplayer games.

One of the key challenges lies in scalability—AI systems must be capable of operating effectively in large-scale matches with hundreds of players. As the game grows in complexity, AI must handle real-time decisions in dynamic environments without compromising performance. This is particularly important for ensuring that AI maintains a level of competency in both cooperative and competitive gameplay, where the stakes are high and the behavior of human players can be unpredictable.

Another significant hurdle is real-time adaptability. While AI has made significant strides in decision-making, the ability to respond quickly and intelligently to sudden changes in the game environment, such as shifts in player strategies or unexpected events, remains a challenge. AI systems need to evolve beyond pre-programmed responses and become more agile, able to adapt to new circumstances on-the-fly without sacrificing strategic integrity.

Player-AI communication and trust continue to be pivotal in enhancing the collaborative experience between human players and AI agents. While natural language processing (NLP) has improved communication, there is still a long way to go in enabling AI to understand and respond emotionally to player inputs. Trust, especially in high-stakes gameplay, plays a critical role in the success of AI teammates, and without a deeper understanding of how to foster this trust, AI will struggle to achieve meaningful collaboration with players.

The fairness and ethical issues surrounding AI, such as balancing the difficulty of AI opponents and ensuring that AI behavior is transparent, present ongoing challenges. There are valid concerns regarding AI's potential to dominate human players, either through sheer computational advantage or through the manipulation of game mechanics. Ethical questions also arise around transparency—players should know when they are interacting with AI rather than human players, and AI systems should act in a way that maintains fairness and respects player autonomy.

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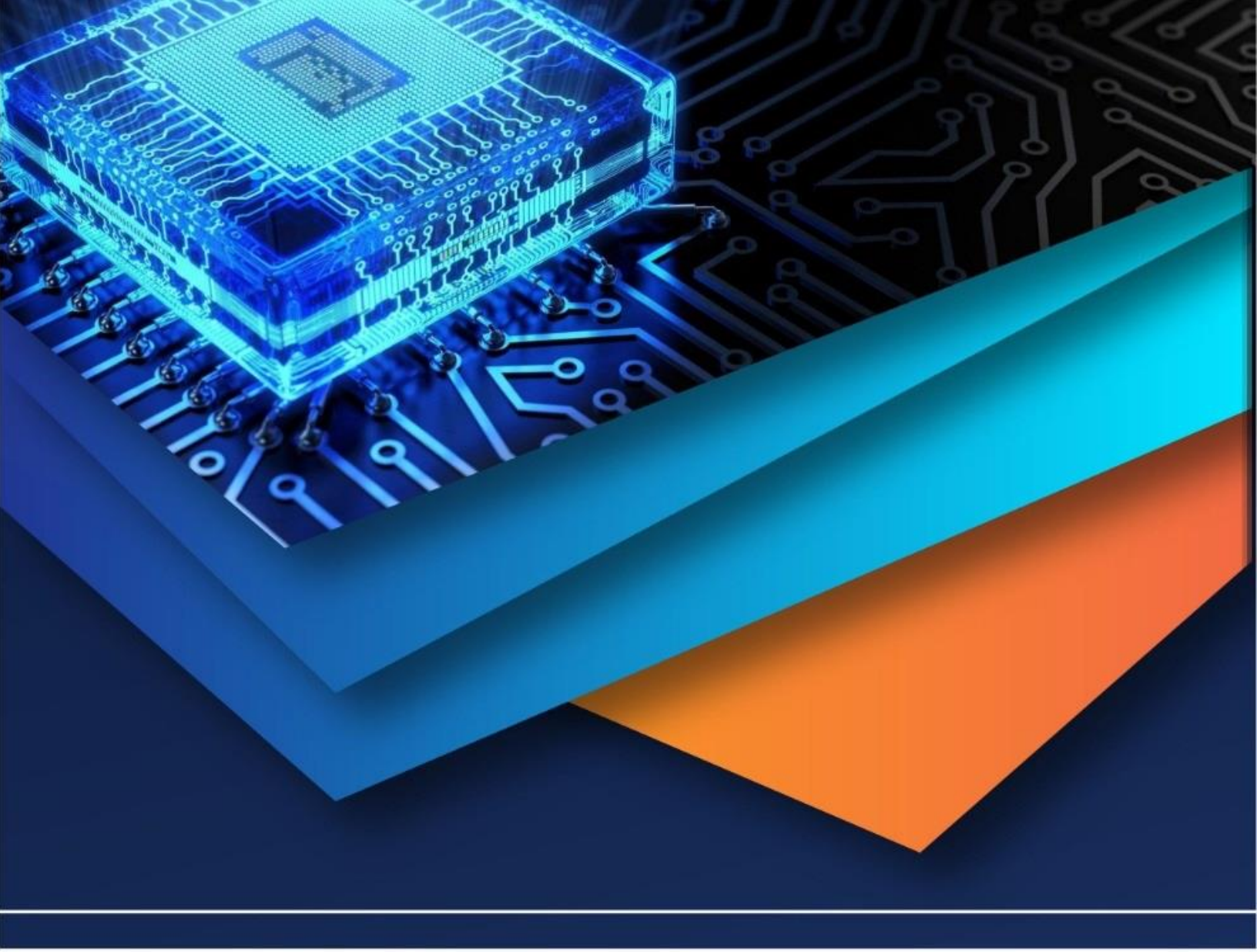

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