

The Enhancement of Video Games by AI

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Abstract: In recent years, with the vigorous development of the global digital economy, artificial intelligence(AI)technology has been rapidly rising and profoundly transforming various industries, with the video game industry being no exception. The breakthroughs in AI technology have brought unprecedented opportunities to the gaming sector, expanding and deepening its applications from game development to player experience and operational management. This paper aims to explore how AI technology is gradually becoming a core technology in the gaming industry, focusing on analyzing the core areas where AI empowers video games, discussing the potential drawbacks and solutions, and looking forward to future development trends. The research finds that AI has shown significant potential in enhancing game development, player experience, operational management, and business model innovation. However, it also faces challenges such as technological costs, privacy protection, and algorithmic bias. Through rational application of technology and policy guidance, AI is expected to propel the video game industry into a new era of intelligence and personalization.

Keywords: Image Segmentation; Transformer; Mamba; Lightweight.

1. Research Background

(1) The Rise of AI Technology

The development of Artificial Intelligence (AI) can be traced back to the mid-20th century, and its evolution has gone through several important stages, each technological breakthrough laying the foundation for the application of AI in the gaming industry.

In the early stages of development, rule engines and expert systems were the main focus. These systems simulated human decision-making processes through preset rules and logic. In the gaming field, this was mainly reflected in the design of simple enemy behavior. For example, in the classic game Pac-Man, AI used preset rules to chase the player-controlled character. Although these early AIs had limited functionality, they provided the initial ideas and framework for subsequent AI technological development.

From the 1980s to the 1990s, AI technology gradually shifted from rule-based systems to data-driven systems. Neural networks learned from large data samples, automatically extracting features and making classifications or predictions. Machine learning techniques were used in game development to optimize complex tasks such as path planning and resource allocation within games.

Entering the 21st century, deep learning and reinforcement learning have become the core technologies in the field of AI. Deep learning, by constructing multi-layer neural networks, is capable of processing complex image, voice, and text data. Reinforcement learning, on the other hand, uses reward mechanisms to allow AI systems to autonomously learn optimal behavioral strategies in an environment.

In recent years, the emergence of generative AI has attracted widespread attention. Based on large-scale pre-trained models, generative AI is capable of creating high-quality text, images, and audio content. Its powerful content generation capabilities have provided new ideas and tools for game development. With generative AI, developers can quickly generate game plots, dialogue content, and even entire game worlds. This not only improves development

efficiency but also offers endless possibilities for game content innovation.

(2) The Needs and Challenges of the Gaming Industry

Game development is a complex and costly process, especially for high-quality AAA games. From character design, modeling, and animation production to storyline writing, each step requires a significant investment of time and labor. The development cycle of an AAA game can span several years, with costs reaching hundreds of millions of dollars. AI technology can significantly reduce development costs and shorten the development cycle by using Procedural Content Generation(PCG)to quickly create game scenes, characters, and storylines.

As competition in the gaming market intensifies, players' demands for game experiences are also increasing. However, many games suffer from homogenized experiences, failing to meet players' desires for personalization and diversity. AI technology can provide personalized experiences based on players' behaviors and preferences. It can dynamically adjust the game difficulty according to the player's gaming style or generate unique storyline branches based on the player's choices. This kind of personalized experience not only enhances player satisfaction but also increases player loyalty.

(3) Policy and Market Environment

In recent years, governments around the world have introduced policies to support the development of AI technology. For example, the US government has released the National Artificial Intelligence Strategy, emphasizing the importance of AI technology in the economy, national defense, and society. The Chinese government has also issued the New Generation Artificial Intelligence Development Plan, proposing to make China a global center for AI innovation by 2030. These policies have created a favorable policy environment for the application of AI technology in the gaming industry, encouraging companies to increase R&D investment and promote technological innovation.

With the rapid development of the digital economy, the demand for high-quality and personalized gaming experiences is continuously increasing. According to reports

from market research institutions, the global gaming market size exceeded 200 billion US dollars in 2023 and is expected to reach 300 billion US dollars by 2028. This growth in market demand provides a vast market space for the application of AI technology in the gaming industry. By introducing AI technology, game companies can not only enhance the quality of their games but also improve user retention and payment rates through personalized services and precise marketing.

2. The Core Areas of AI Empowerment in Video Games

(1) Game Development

Procedural Content Generation (PCG) is an important application of AI in game development. Through algorithms, developers can dynamically generate game levels, materials, and entire game environments, thereby providing players with unique and diverse gaming experiences. First, in level design, existing level data is input into the AI model, which learns the layout, difficulty curve, enemy distribution, and other characteristics of the levels before generating new ones. These new levels are not only structurally similar to the original levels but can also be adjusted according to different

difficulty settings and player progress, greatly enriching the game content.

The application of AI in the generation of art assets is also very extensive. Developers can use Generative Adversarial Networks (GANs) to generate realistic character appearances and textures, or use neural networks to generate animation sequences. This not only significantly shortens the development cycle but also reduces the cost of creating art assets.

AI-driven Non-Player Characters (NPCs) are an important direction in modern game development. Unlike traditional script-driven NPCs, AI-driven NPCs can respond more reasonably to player actions and exhibit behavior patterns that are more consistent with their character settings. Through machine learning algorithms, NPCs can learn player behavior patterns and react accordingly.

AI can also be used to generate game storylines and dialogue content. In the game *Whiteout Survival*, the story content and NPC interactions generated by AI greatly enrich the game ecosystem. AI can dynamically generate storyline branches based on player choices and actions, making each player's gaming experience unique.



Figure 3.1 Whiteout Survival

Game testing is an important part of the game development process, but traditional testing methods are often time-consuming and costly. AI technology can simulate the behavior patterns of real players to automatically conduct game tests, quickly identify and fix potential bugs and vulnerabilities, thereby improving game quality.

AI testing tools can simulate various player behaviors, including movement, attacks, and interactions. These tools can generate a large number of test cases to cover various scenarios and functions in the game, ensuring the game's stability and compatibility. AI testing tools can also provide repair suggestions through data analysis when problems are found in the game. By analyzing game logs and player feedback, they can quickly locate the root causes of problems and offer possible solutions.

(2) The experience of players

In the modern gaming market, the demand for personalized gaming experiences is growing increasingly among players,

and the emergence of AI technology provides powerful support to meet this demand. AI can analyze players' behaviors and preferences in real-time, thereby dynamically adjusting the game's difficulty, storyline, and reward mechanisms to offer a customized experience for each player.

Firstly, AI can automatically adjust the game's difficulty. This dynamic difficulty adjustment not only ensures that players always maintain a sense of challenge and enjoyment but also effectively prevents players from losing interest due to the game being too easy or too difficult. AI can also generate different story branches based on players' choices, making each player's gaming story unique and enhancing the sense of immersion. Additionally, AI can optimize the reward mechanism based on players' behaviors and preferences. If a player prefers exploring the game world, AI can increase the proportion of exploration-related rewards; if a player focuses more on combat, AI can provide more combat-related rewards.

Voice interaction is an important application of AI

technology in games. Players can interact with NPCs through voice commands, and the AI system can recognize and understand these commands in real-time and respond accordingly. In some adventure games, players can converse with NPCs via voice commands to obtain information or

request assistance. This type of voice interaction is not only more natural and convenient but also enhances the player's sense of immersion. For example, in *Cyberpunk 2077*, voice recognition technology enables natural dialogue between players and NPCs.



Figure 3.2 Cyberpunk2077

AI systems are also capable of identifying players' emotional states and responding accordingly. If the AI detects that a player is feeling frustrated or anxious, it can adjust the game's difficulty level or offer more support. Conversely, if the player is excited or happy, the AI can increase the game's challenge or provide additional rewards.

(3) Operational Management

Optimizing the game economy is crucial for the long-term success of a game. AI technology, by analyzing player behavior in real time, can dynamically adjust in-app pricing strategies to help developers maximize revenue across different user segments. At the same time, AI-driven ad placement ensures that ads appear at the optimal moments, minimizing disruption to the gaming experience while increasing user engagement and conversion rates. For high-value players, AI can appropriately increase the prices of certain rare items; for casual players, AI can offer more discounts and promotional activities. This dynamic pricing strategy not only maximizes revenue but also enhances player satisfaction.

AI can determine the best timing for displaying ads based on players' progress and emotional states. For instance, showing ads when a player completes a mission or receives a reward can increase the ad's click-through rate without interrupting the player's experience at critical moments. Additionally, AI can tailor ad content to players' preferences and behaviors, further enhancing the effectiveness of the ads.

3. Potential Drawbacks

(1) Technical Costs and Resource Requirements

The training and deployment of generative AI models require high-performance computing devices. Deep learning models typically need to use GPUs (Graphics Processing Units) or TPUs (Tensor Processing Units) for large-scale parallel computing. These hardware devices are expensive and need to be updated regularly to meet the growing computational demands. For small and medium-sized game development studios, purchasing and maintaining such

hardware devices is a significant burden.

In addition to hardware requirements, the integration of AI technology also requires a specialized technical team. Developers need to have professional knowledge in the fields of machine learning, deep learning, natural language processing, etc., in order to effectively develop and optimize AI models. The scarcity of these specialized talents leads to high labor costs.

AI-driven real-time interactive features, such as intelligent NPCs, dynamic storyline generation, and voice interaction, require servers to process large amounts of data in a short period of time. This high-concurrency computing demand places extremely high requirements on the server's processing capabilities, potentially leading to server overload and, consequently, affecting the smoothness of the game.

To meet the resource demands of AI technology, game companies may need to purchase more server equipment or use cloud services to expand computing power. Both hardware procurement and cloud service leasing will significantly increase operating costs. In addition, the maintenance and optimization of AI systems also require continuous investment, further increasing the burden on game companies.

(2) Data Collection and Privacy Protection

To provide personalized gaming experiences, AI systems need to collect various behavioral data from players, including gaming habits, preference settings, and social interactions. These data can help AI algorithms better understand players' needs, thereby dynamically adjusting game content and difficulty to enhance player engagement and satisfaction. However, this data collection also poses privacy risks. Sensitive information may be obtained by unauthorized third parties, leading to privacy breaches. If these data are misused, they could interfere with players' personal lives and even cause security issues.

Hack attacks are one of the biggest threats to game data security. Hackers can use various means, such as SQL injection, DDoS attacks, and malware, to infiltrate game servers and steal user data. Once data is leaked, players'

personal information, payment details, and game accounts may be exposed, resulting in financial losses or identity theft for players.

In addition to external attacks, poor internal management can also lead to data leaks. Employees within game companies, if lacking sufficient data security awareness, may inadvertently disclose user data. For example, employees accessing or downloading user data without authorization, or storing data on insecure devices, can lead to data leaks. Moreover, malicious actions by insiders, such as data trafficking or intentional leaks, are also significant data security risks.

(3) Technological Bias and Cultural Differences

Bias may stem from multiple sources. First, the selection and labeling of training data can introduce bias. If the training data is imbalanced or inaccurately labeled, AI models may learn incorrect patterns. Second, the design and optimization process of algorithms can also introduce bias. Some algorithms may favor certain types of input during optimization, leading to unfair treatment of other types of input. In multiplayer online games, if the AI-driven matching system is biased, it may unfairly match high-skill players with low-skill players, affecting the fairness of the game. Moreover, if the AI-driven reward mechanism favors certain player groups, it may cause some players to feel neglected or unfairly treated, thereby affecting player retention and satisfaction.

Cultural sensitivity is crucial in game development. Players from different regions and cultural backgrounds have significantly different acceptance levels and preferences for game content. Certain cultures may have specific views on certain religious symbols or historical events. If AI-generated content ignores these cultural contexts, it may cause player dissatisfaction or even resistance. Therefore, game developers need to ensure that AI-generated content respects and adapts to the needs of different cultures.

To reduce problems caused by cultural differences, game developers can adopt various strategies. First, diverse datasets can be introduced during AI training to ensure that models learn content from different cultural backgrounds. Second, a cultural review mechanism can be established to audit AI-generated content and ensure it complies with cultural norms in different regions. In addition, developers can collaborate with local cultural experts to optimize AI-generated content, making it more culturally adaptable.

4. Measures for Resolution

(1) Technical Optimization and Cost Control

Open-source deep learning frameworks, such as TensorFlow and PyTorch, have become standard tools in the field of AI development. These frameworks provide a rich set of APIs and pre-trained models, enabling developers to quickly get started and implement complex AI functionalities. The vast developer communities surrounding these frameworks offer a wealth of tutorials, code examples, and troubleshooting solutions, which help developers swiftly overcome technical challenges. Utilizing open-source frameworks can significantly reduce development costs. Unlike commercial software, open-source frameworks are freely available, eliminating the need for developers to pay high licensing fees. Moreover, the flexibility and scalability of open-source frameworks allow developers to customize them according to their specific needs, further optimizing the development process and costs.

Cloud computing offers the capability of elastic computing and powerful resource scheduling functions, enabling game companies to dynamically adjust and optimize server resource allocation based on the number of players and game demands. During peak gaming hours, companies can rapidly increase server resources to handle high-concurrency access demands; during off-peak hours, they can reduce resources to save costs. This elastic computing not only improves resource utilization but also reduces operational costs. Through automatic scaling of instances, cloud computing platforms can ensure that games receive optimal resource support at different times. Additionally, cloud computing platforms provide a variety of resource management tools to help developers monitor and optimize resource usage.

(2) Privacy Protection and Data Security

Advanced encryption technologies can effectively prevent data from being stolen or tampered with during transmission and storage. Anonymizing data can remove or replace information that identifies individuals, such as names and account numbers. For example, a player's IP address can be replaced with a randomly generated identifier, or player behavior data can be aggregated so that it cannot be traced back to an individual. This anonymization not only protects players' privacy but also makes the data safer for analysis and use.

Game companies need to clearly inform players about the scope of data collection, the purpose of its use, and the measures for data protection. During the game installation or registration process, they should provide a clear and easily understandable privacy policy text and ensure that players fully understand its content before giving their consent. The privacy policy should detail the methods of data collection, the duration of data storage, the purposes of data use, and the circumstances of data sharing with third parties.

Game companies should ensure that players consent to the privacy policy voluntarily and provide convenient means for players to withdraw their consent at any time. For example, they can offer privacy options in the game settings, allowing players to choose how their data is used.

(3) Algorithm Optimization and Fairness Protection

Through visualization tools, developers can gain an intuitive understanding of the decision-making process of AI models. For example, tools like TensorBoard can help developers visualize the training process of models, analyze their performance and behavior. With these tools, developers can identify potential issues in the models, such as overfitting or underfitting, and adjust the model structure in a timely manner.

Developers need to regularly assess the fairness of AI algorithms to ensure that they are fair to all player groups. Fairness metrics (such as equal opportunity, equal error rate, etc.) can be used to evaluate the fairness of algorithms, and adjustments can be made based on the assessment results. Through these measures, developers can reduce algorithmic bias and enhance the fairness and user experience of the game.

A cultural review mechanism can be established to review the content generated by AI. Local cultural experts can be invited to assess the generated content to ensure that it complies with local cultural customs and values. Through this mechanism, companies can promptly identify and correct content that may cause controversy. Moreover, player data from different regions can be collected to ensure that the model can learn behavioral patterns from diverse cultural backgrounds. With a diverse dataset, the content generated by

AI will be more inclusive.

5. Future Outlook

(1) Technological Innovation and Application Expansion

In the future, AI will be capable of achieving more complex interaction logic and emotion recognition, making the game world more realistic and vivid. AI-driven NPCs will not only be able to respond reasonably to players' actions but also make autonomous decisions in complex scenarios. This complex interaction logic will make the game world more authentic and enhance players' sense of immersion.

AI technology will be widely applied across various gaming platforms, including PCs, consoles, mobile devices, and cloud gaming. This cross-platform application will provide players with a more seamless gaming experience.

(2) Social and Cultural Impact

Through AI-driven educational games, players can acquire knowledge and skills while being entertained. These educational games not only enhance the fun of learning but also provide a personalized learning experience. AI can dynamically adjust the teaching content based on players' learning progress and abilities, offering a tailored learning experience. This personalized learning approach can not only improve learning outcomes but also boost players' interest in learning.

As a cultural product, games can better preserve and innovate cultural content through AI technology. AI can generate characters, scenes, and storylines with cultural characteristics, helping players understand and experience the charm of different cultures. At the same time, AI technology can also inspire players' creativity and drive cultural innovation and development.

AI technology can be used for cultural heritage. By generating characters, scenes, and storylines with cultural characteristics, it helps players understand and experience the charm of different cultures. Games based on historical events or cultural legends can be created, allowing players to learn about and pass on cultural heritage through gameplay.

6. Summary

The rapid development of AI technology has brought unprecedented opportunities and challenges to the video game industry. From game development to player experience, and from operational management to other areas, the application scenarios of AI are constantly expanding and deepening. AI technology can not only significantly improve the efficiency and quality of game development but also provide players with a more personalized and immersive experience. However, during its application, AI technology also faces issues such as technical costs, privacy protection, and algorithmic bias. Through measures such as technological optimization, privacy protection, and algorithm optimization, these problems can be effectively addressed, promoting the

healthy development of AI technology in the gaming industry.

In the future, with the continuous innovation and application expansion of AI technology, the video game industry will usher in a broader space for development. AI will drive the globalization, diversification, and intelligent development of the gaming industry, offering players a richer and more interesting gaming experience. At the same time, AI technology will also bring new opportunities for business model innovation and social and cultural impact in the gaming industry. By making rational use of AI technology, the gaming industry is expected to occupy a more important position in the future digital entertainment market and make greater contributions to the development of society and culture.

References

- [1] World and Human Action Models towards gameplay ideation. nature.
<https://www.nature.com/articles/s41586-025-08600-3>
- [2] Aliqin·Mahemuti. (2023). Research on Innovative Applications of AI in the Gaming Industry. Wanfang Data Knowledge Service Platform
<https://d.wanfangdata.com.cn/periodical/Ch9QZXJpb2RyY2FsQ0hJTmV3UzIwMjQxMTA1MTcxMzA0Eg15c2tqMjAyNDEwMDUyGghwcGN4bm5vZA%3D%3D>
- [3] Picheng Song. (2024). AI Empowers Game Development: Evolutionary Trajectory and Application Trends. Beijing Culture Creativity, Vol.4(2024), p4-p16
https://xueshu.baidu.com/usercenter/paper/show?paperid=10600m80m2050j60e04h0gh0ew325133&site=xueshu_se
- [4] 2025 AI+Gaming Industry Research Report: Transformation and Opportunities Empowered by AI in the Gaming Industry.
<https://www.baogaobox.com/insights/250312000008574.html>
- [5] Jun Hu. Research and Application of Artificial Intelligence in Game Development. KNCI
https://kns.cnki.net/kcms2/article/abstract?v=Zb3wS6iuaOZsN1tZODyUc10wiN0wAj_fWc033uWmo21y0gRZZsHTwmS yds1x1CU594SybSuABHrOqRN98Vbc8akRRRCQOkGydEEIRn11ZEJt2g4KHbRbC-4QIOV7RCVYm4-fP6fk2cf9lkuKfnsFeqzyTGHbp4dChX6PQfOPyB8j_UZJvBlA=&uniplatform=NZKPT&language=CHS
- [6] Ziyue Zhao. Application and Problems of AI in Game Development. Applied and Computational Engineering(2024)
https://www.atalk-ai.com/talk/docs/paper/AI_in_Game_Development_Applications
- [7] Jie Cheng, Wei Tan. (2021). An Analysis of the Application of Artificial Intelligence(AI) Technology in the Gaming Domain. Wudang Martial Arts, (8), 142.
<https://doc.taixueshu.com/journal/20210249wd.html>