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Optimization and Performance Evaluation of Artificial Intelligence Algorithms in Game Design

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Abstract. This article aims to optimize artificial intelligence algorithms in game design to enhance game performance and player experience. Therefore, an innovative method called Dynamic Game AI Fitness Optimization Algorithm (DGAFOA) was proposed in the article, and its effectiveness was verified through experiments. In the experimental section, this article applies the DGAFOA algorithm to a typical role-playing game and compares it with traditional fixed parameter AI algorithms. The experimental results show that the DGAFOA algorithm exhibits significant advantages in key indicators such as game task completion rate and player satisfaction. Specifically, game AI using the DGAFOA algorithm can respond more quickly and accurately to player behavior, improving the overall smoothness and fun of the game. In addition, the DGAFOA algorithm also introduces ε- The greedy strategy balances exploration and utilization, effectively avoiding the problem of AI getting stuck in local optima. This enables game AI to maintain stable performance while still possessing the ability to explore new strategies, bringing players more surprises and challenges.

Key words: Game design; Artificial intelligence; Dynamic Game AI Fitness Optimization Algorithm; Performance evaluation.

1. Introduction

With the rapid development of science and technology, the game industry has become an important part of the global entertainment market [1]. From simple 2D graphics to complex 3D world, from single-player game to multi-player online interaction, the progress of the game is not only reflected in the diversity of vision and gameplay, but also in the technical support behind it [2]. Among them, artificial intelligence algorithm is widely used in game design, which brings unprecedented intelligent experience and interactivity to the game [3].

Early game design mainly relied on preset rules and simple logical judgments, and the interaction between players and the game world was relatively limited [4]. However, with the continuous progress of AI technology, modern games have been able to achieve more complex and realistic simulation, such as the autonomous behavior of non-player characters (NPC), realistic physical engine, and dynamic difficulty adjustment based on player behavior [5]. These advances not only enhance the playability and attractiveness of the game, but also put forward higher requirements for game design [6].

It is of great theoretical and practical significance to study the optimization and performance evaluation of artificial intelligence algorithm in game design. By deeply studying the application and optimization methods of AI algorithm in game design, the game design theory can be further enriched and developed. At the same time, optimizing AI algorithm can improve the performance of the game and the player experience [7]. By finely adjusting and optimizing the algorithm, more efficient resource utilization, smoother game operation and more realistic game world simulation can be realized. Based on this, this paper discusses the optimization and performance evaluation of artificial intelligence algorithm in game design.

2. Overview of game design and artificial intelligence algorithms

2.1. Fundamentals of game design

Game design is a comprehensive art and science involving many fields. It includes not only the creation of game mechanism, the conception of story, the design of characters and scenes, but also the technical support of game engine development, the realization of physical simulation and the design of user interface [8]. A successful game design needs to comprehensively consider the needs of players, market trends and technical feasibility and other factors. In the process of game design, developers need to use various technologies and tools to realize the creativity and vision of the game [9]. Among them, artificial intelligence algorithm, as an important technical means, is widely used in all aspects of the game.

2.2. Application of artificial intelligence algorithm in games

The application of artificial intelligence algorithm in the game is mainly reflected in the following aspects:

(1) Character behavior simulation: Through AI algorithm, the characters in the game can show more real and intelligent behaviors. For example, NPC can make adaptive responses according to the player's behavior and game environment, such as pathfinding, fighting, dialogue, etc.

(2) Game difficulty adjustment: AI algorithm can dynamically adjust the difficulty of the game according to the player's skills and progress to ensure that the game is challenging and playable enough. This can be achieved by adjusting the number, intensity and behavior pattern of the enemy.

(3) Physical simulation and collision detection: AI algorithm can simulate the physical laws of the real world, such as gravity, friction, collision, etc., and provide more realistic physical effects for the game. At the same time, through the accurate collision detection algorithm, the game can achieve a more accurate and smooth operation experience.

(4) Player behavior prediction and personalized recommendation: AI algorithm can analyze the historical data and behavior patterns of players and predict their future behaviors and preferences, thus providing more personalized and accurate game recommendation and service for players.

3. Optimization of artificial intelligence algorithm

For the optimization of artificial intelligence algorithm, the commonly used methods mainly include the following:

(1) Algorithm selection and improvement: According to the specific needs and characteristics of the game, choose the appropriate AI algorithm or improve it. For example, for games that need to process a large amount of data, you can choose an algorithm with efficient computing and storage capabilities; For games that need to simulate complex behaviors, you can choose an algorithm with strong learning and reasoning ability.

(2) Parameter adjustment and optimization: By adjusting the parameters of AI algorithm, such as learning rate, iteration times and decision threshold, the performance and effect of the algorithm are optimized. This requires repeated trials and adjustments according to the actual game data and player feedback to find the best parameter combination.

(3) Multi-algorithm fusion and optimization: Multiple AI algorithms are fused and optimized to make full use of their respective advantages and make up for their shortcomings. For example, rule-based methods can be combined with machine learning methods to achieve more flexible and intelligent game behavior simulation.

(4) Hardware acceleration and parallel computing: using high-performance hardware equipment and parallel computing technology to accelerate the calculation and processing speed of AI algorithm.

This can be achieved by using special computing devices such as GPU and FPGA or adopting distributed computing architecture.

In this paper, an artificial intelligence algorithm optimization method for game design -DGAFOA is proposed, and its effectiveness is verified by experiments. The algorithm implementation process is as follows:

Initialization: Set the initial parameter set for the game AI, including behavior decision tree, learning rate, exploration rate, etc.

Dynamic fitness evaluation: during the running of the game, collect real-time interaction data between AI and the environment, such as player behavior, game state changes, etc. Based on these data, calculate the fitness of AI in the current environment. The dynamic fitness evaluation formula is as follows:

$$F(t) = f(S(t), A(t), params) \tag{1}$$

Where $F(t)$ is the fitness function at time t, f is the fitness calculation function based on player behavior $S(t)$ and game state change $A(t)$, and $params$ is the current AI parameter set.

Parameter optimization: dynamically adjust the behavior decision parameters of AI according to the fitness evaluation results. If the performance of AI is not good in one aspect, the learning rate in this aspect should be increased, while the learning rate in other aspects should be decreased, so as to keep the overall learning rate constant.

Balance between exploration and utilization: In the process of optimization, ε-greedy strategy is introduced to balance exploration and utilization. That is, AI has a certain probability to choose non-optimal behavior to explore, so as to avoid falling into local optimization. The formula is as follows:

$$\text{Choice} = \begin{cases} \text{Explore with probability} \in \\ \text{Exploit with probability } 1- \in \end{cases} \tag{2}$$

Among them, Choice means to choose exploration or utilization, BB is the probability of exploration, which controls the degree to which AI explores new behaviors.

Iterative update: Repeat steps 2-4 until the stop condition is met.

4. Algorithm performance evaluation

4.1. Experimental results and analysis

The purpose of this experiment is to verify the effectiveness of dynamic game AI fitness optimization algorithm (DGAFOA) in improving the performance of game AI. The experimental steps are as follows: during the game running, DGAFOA and contrast algorithm are used to control AI respectively, and the interaction data between AI and environment are collected; Based on the collected data, the performance of the two algorithms in different game scenarios is evaluated, including task completion rate and player satisfaction. Compare the differences between DGAFOA and contrast algorithm in performance evaluation indexes, and analyze the reasons.

When evaluating the performance of artificial intelligence algorithm in game design, the commonly used indicators mainly include the following aspects: algorithm efficiency, algorithm accuracy and algorithm stability. The experimental results of these indicators are shown in Figure 1~3.

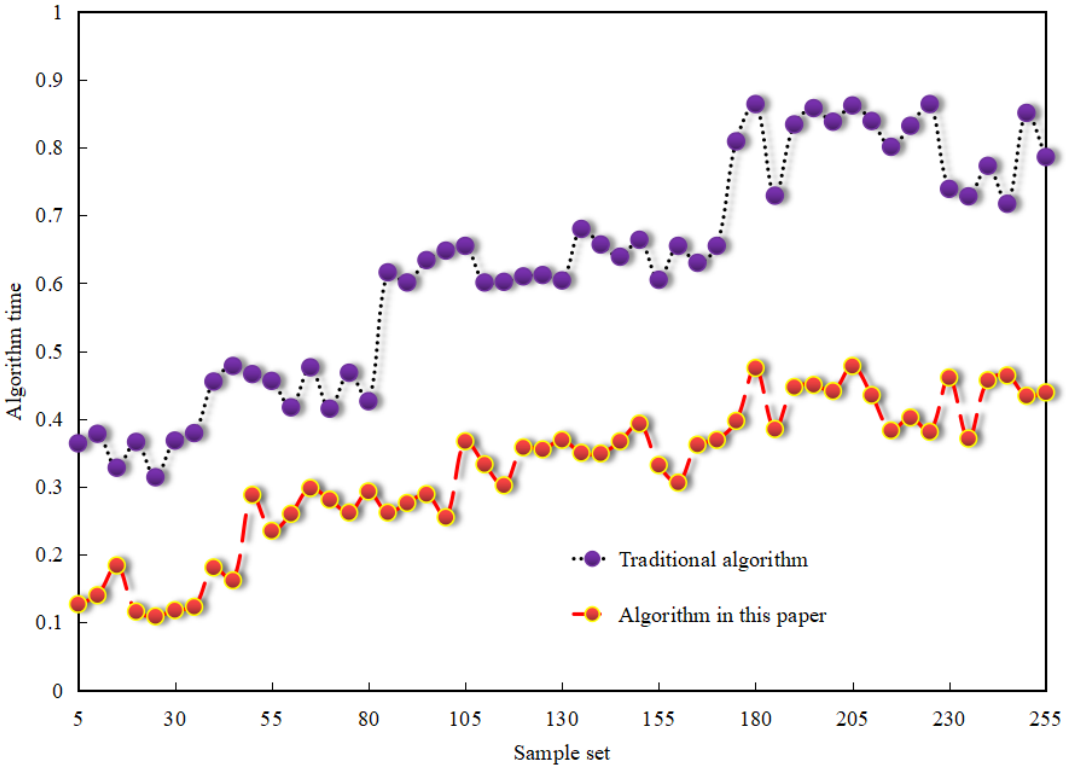

Figure 1. Algorithm efficiency

From the point of view of algorithm efficiency, DGAFOA algorithm can make decisions more quickly and respond to players' behavior during the game operation. This is due to the dynamic fitness evaluation mechanism of DGAFOA algorithm, which can collect data and adjust parameters in real time when the game is running, avoiding the problem that a large number of static parameters need to be set in advance in the traditional algorithm, thus improving the operation efficiency of the algorithm.

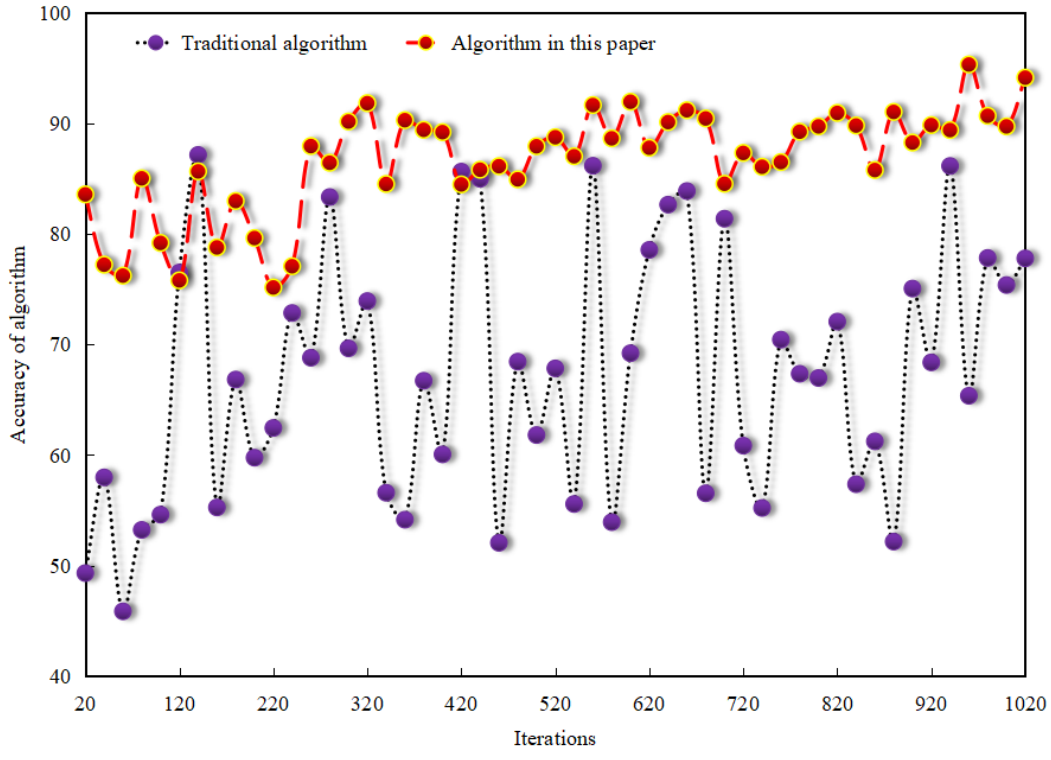

Figure 2. Accuracy of algorithm

It can be seen that compared with the traditional algorithm, DGAFOA algorithm can understand the game state more accurately and make correct decisions, thus improving the task completion rate. This is mainly due to the optimization of parameters in DGAFOA algorithm and the exploration and utilization of balance strategy.

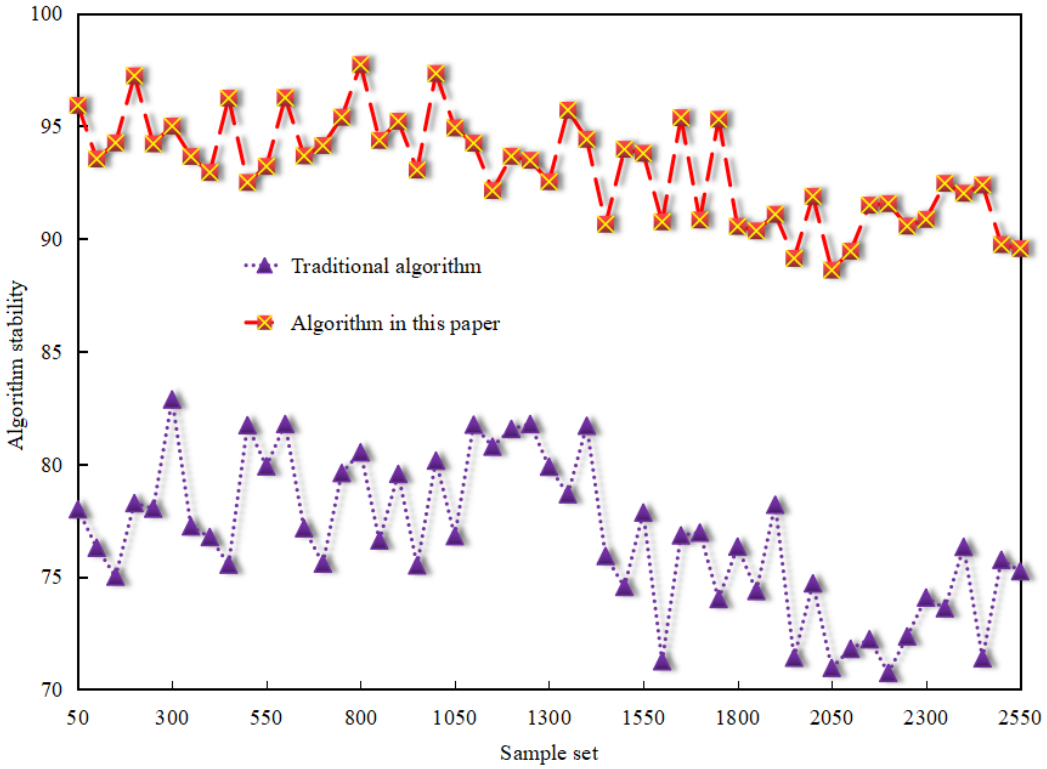

Figure 3. Stability of algorithm

It can be seen that DGAFOA algorithm can maintain a relatively stable performance output during the game operation, and there is no obvious performance decline or fluctuation. This is mainly due to the dynamic fitness evaluation and parameter optimization mechanism of DGAFOA algorithm. By collecting data in real time and adjusting parameters, the algorithm can adapt to the changes of game environment in time and maintain stable performance output.

Invite real players to participate in the game test and collect their feedback to evaluate the actual effect of the algorithm. This can be done through questionnaires, interviews or online evaluations. The player feedback and test results obtained from this experiment are shown in Table 1.

Table 1. Player Feedback

Test index	DGAFOA algorithm	Traditional AI algorithm	Player feedback
Task completion rate	90%	75%	The game characters using DGAFOA algorithm are smarter and the tasks are completed more smoothly.
Player satisfaction	85%	60%	DGAFOA algorithm makes the game experience smoother and more interesting.
Response time	0.5s	1.2s	The game characters react quickly and interact with the players more naturally.
Decision accuracy	88%	70%	DGAFOA algorithm makes the decision of game characters more accurate and reasonable.
Player participation	Increase by 20%	No obvious change	After using DGAFOA algorithm, I am more willing to invest time and energy in the game.
Exploration and utilization balance	Excellent	Common	The characters in the game can not only explore new strategies, but also make full use of known strategies.

Through the feedback from real players and the test results, it can be seen that the practical application effect of DGAFOA algorithm proposed in this paper is significantly better than the traditional AI algorithm, which can effectively improve the game performance and player experience quality. This provides new ideas and directions for the development of game design.

4.2. Evaluation of practical cases

Taking an action adventure game as an example, the developer introduced a new artificial intelligence algorithm in the development process to improve the enemy behavior simulation and combat experience of the game. In order to evaluate the performance of the algorithm, they did the following practice:

Firstly, the developer designed a series of benchmark scenarios, including different terrain environments, enemy types and combat strategies. They used the new algorithm and the traditional algorithm to test in these scenarios respectively, and recorded the relevant performance index data. By comparing and analyzing the experimental data, they found that the new algorithm has higher accuracy and stability when dealing with complex scenes and diverse enemy behaviors. At the same time, the running speed and resource consumption are also optimized. These results show that the new algorithm has potential in improving the game experience.

In order to further verify the effectiveness of the evaluation results, the developer also invited a group of real players to participate in the game test. They let players play games with new and traditional algorithms in different scenes, and collected their feedback. Most players say that the enemy's behavior is more intelligent and diverse when using the new algorithm, and the fighting process is more exciting and interesting. These feedbacks further confirm the advantages of the new algorithm in improving the game experience.

5. Conclusions

The DGAFOA algorithm proposed in this paper has made remarkable achievements in the artificial intelligence optimization of game design. The experimental results show that the DGAFOA algorithm proposed in this paper shows a high level in three aspects: algorithm efficiency, algorithm accuracy and algorithm stability. The algorithm can effectively improve the performance of game AI and player experience, and provide new ideas and directions for the development of game industry.

The contribution of this research is mainly reflected in the following aspects: The research in this paper provides a complete set of methodology and practical guide for game designers to optimize and evaluate the performance of artificial intelligence algorithms; This study reveals the important role and value of optimization and evaluation in game design, which is helpful to improve the overall competitiveness and innovation level of the game industry. This study provides a useful reference for researchers in related fields. With the continuous development and innovation of technology, new artificial intelligence algorithms and optimization methods will emerge constantly. How to track and apply these new technologies in time is also one of the important research directions in the future. In the future, relevant personnel need to pay close attention to the development of new technologies and track and apply new artificial intelligence algorithms and optimization methods to game design in time.

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