

A SHORT ANALYSIS OF THE APPLICATION(S) OF INTELLIGENT AGENTS IN COMPUTER GAMES

Nevila Baci, Denisa Millo, Pamela Kuka

University of Tirana, Faculty of Economy, 1001 Tirana, Albania

Abstract

The study of artificial intelligence techniques quickly moved to computer games, a sector in which they are of enormous practical utility. Artificial intelligence has advanced significantly in the last five decades. The concept of intelligent agents provides a crucial theoretical framework to compare numerous diverse methods to the smart, logical conduct of computer-controlled characters in games. Computer games represent one of the best environments for artificial intelligence research as they are typically designed to be played multiple times by many players and can thus be studied. Furthermore, advances in computer hardware have allowed game developers to create increasingly complex and engaging games that have forced computer scientists to produce even more creative solutions to complex problems.

Artificial intelligence techniques are often used to make computer games more exciting and entertaining by providing the designers with the tools they need to create interactive characters capable of responding to the player's actions. We can achieve behavior that resembles that of a human player, which is also preferred in games, by combining rationality with some restrictions on our agents' skills. In addition, we can simulate behaviors observed in humans during social interaction between individuals or groups. In this paper we interpret, analyze, and bring a simple case study for using intelligent agents for computer games. From an interpretative literature review and a case study approach, we concluded that intelligent agents could improve the gameplay experience, gain insight into Artificial Intelligence behavior, and increase game difficulty.

Keywords: *artificial intelligence, intelligent agent, computer games*

1. INTRODUCTION

“When looking for intelligence in a computer-controlled entity, i.e., an agent, we are far more concerned with behavior - something visible - rather than thinking (a decision-making entity). Ethology, or the science of behavior in living entities, is based on observation of behavior (an entity's reaction to a situation/an external influence) and is unconcerned with the inner workings of the mind that may cause the behavior. Although planning, which requires knowledge, understanding, and reasoning, would result in behavior, it is an internal process that cannot be observed”, as described in (Anderson 2005). Another way to view Artificial Intelligence is that of the ability “to find solutions that would require intelligence if solved by humans” or a system's ability to adapt to its environment through learning. Regardless of definition, the purpose of Artificial Intelligence (AI) remains the same: to comprehend and create intelligent entities. Several philosophers like Searle, Dreyfus, or Chalmers, question whether AI will ever achieve a level of intelligence comparable to that of humans. However, only some consider human-level intelligence to be the goal of AI development. Each “artificial intelligence” interpretation corresponds to a different approach to achieving AI. An example is the psychological approach, which tends to identify the different changes in definitions, varying from the way AI is perceived as mentioned in (Chassang et al, 2020). From the point of view of Boming Xia et al, (2020), the perspectives of the games are analyzed taking into consideration the general game AI and hybrid intelligence. Each approach is appropriate for various areas of AI research.

This study analyzes reasoning and learning techniques within the context of innovative computer games. Non-AI experts can use these techniques to define behaviors for characters, which can then be adjusted to various situations and individual players, minimizing the development effort required to handle all contingencies in a complex game. We are particularly interested in adaptive games that can improvise

for unexpected situations. Adaptive games can: improve the player experience because an adaptive game can adapt to each player's playing style and goals; and reduce development effort because if a game can adapt itself, developers must spend less time trying to anticipate all scenarios. Back in 1999, intelligent agents were an important topic to be analyzed. The work of Lent et al, (1999), there is mentioned the increasing demand for intelligent agents used since consumer demands and complexity become more sophisticated.

Because technology has advanced rapidly over the years, an ever-increasing number of operations can be performed per second. Game development, particularly in shooter games, has focused on graphics rendering and realistic visual representations of game worlds. In such games, artificial intelligence rarely feels alive, and computer-controlled units always run to their deaths in stupidity. This has resulted in Artificial Intelligence that does not challenge human players because it can be easily exploited once the player understands the AI's design (Wodecki 2022). In the work of Fairclough et.al, 2002) it is written explicitly that "The computer games industry has surpassed the film industry in size. Until recently, technology in games was motivated by a desire to achieve real-time photo-realistic graphics. To a substantial extent, this has now been achieved." The behavior of non-player-characters (NPCs) frequently results in a superficial and unsatisfying gaming experience, even though graphics technology makes it possible to create games set in environments that look incredibly realistic. A roadmap to AI for Games is presented by Yannakakis (2012), where there are stressed: "the game AI flagship research areas include the computational modeling of player experience, the procedural generation of content, the mining of player data on massive-scale and the alternative AI research foci for enhancing NPC capabilities." Although, applying sophisticated AI techniques to control NPCs could rectify this situation and result in more immersive games as (Eastwood 2017) explains.

We will look at the current state-of-the-art in-game AI. This will include a look at both commercial game techniques and those being pursued by academic research projects. We will review the advantages of game AI as a research topic and some of its unique challenges. Finally, we will give an example of an application by using a platform for the creation of a game using AI tools and AI agents. Going step by step to the above topics, let us follow the materials and methods used to reach our goals.

2. MATERIALS AND METHODS

As mentioned in the previous paragraphs, there is a need to search for earlier and recent research into the topic we are concerned about. To do this we follow a mixed methodology. The paper's methodology is combined by using many literature papers, review articles, web pages, and reports that have been selected using a topic modeling approach and combining it with a case study approach. The first methodology involves reviewing the literature to present the current research on using AI agents in computer games and identifying best practices and techniques. The second methodology, that of the case study, focuses on creating a simple game application with the findings and analyzing the various aspects of the game. After collecting the necessary data, a game concept will then be developed based on the results. This will include identifying the ideal game genre and the target audience.

We will go through game designing as a critical tool mentioned in the literature that can make the world feel alive and engaged by developing characters capable of interacting with players meaningfully. Personalization involves creating a customized experience for each player based on their play style, skills, and preferences. With the help of AI, developers can analyze data and adjust the game's rewards, challenges, and content based on their players' behavior and preferences.

The principles of game design play an essential role in creating captivating and immersive experiences. With the help of AI and its ability to analyze and adapt gameplay, game designers can enhance these principles and create more engaging and personalized experiences, as explained in Morazan (2022).

2.1 AI algorithms and techniques used in Game Designing

Therefore, the development of games relies on AI methodologies and algorithms, which are crucial tools that can help create intelligent agents that can enhance players' experience. During the time of development, there have been numerous AI techniques proposed to be used in Game Designing. Many

of them can be mentioned referring to Barzanji (2019) and Yunlong and Wenxin (2022) where the role of AI in Game Development is given by using techniques and paradigms to better user-performance. The articles of Barzanji (2019) and (Graham, McCabe & Sheridan 2003) describe the following algorithms as Path Finding that follows then the Natural Paths and the Bezier Curve to gain a more natural performance. Other algorithms mentioned in Barzanji (2019), include the Finite State Machines and Decision Trees. The Path Finding Algorithm e.g., uses several steps for an agent to reach a certain goal "Avoiding Obstacles along the Way, Moving in Random Directions. Going Around the Obstacle. Plan before Move. Breadth-First Search, Bidirectional Breadth-First Search, Dijkstra's Algorithm, Depth-First Search, Iterative Deepening Depth-First Search, and Best First Search."

In the work of Yunlong and Wenxin (2022), chapter three, there are listed also several AI techniques for game designing and development, which also evolve in time, by differentiating some of them and focusing on some other ones. The three groups of games are Games with Perfect Information (Genetic Algorithms, Coevolution, Minimax, etc.) Games with Imperfect Information (Regret Matching, Double Oracle, Fictitious Play, etc.), and multi-agent games (involving a mixture of the above types of games techniques and other new evolved ones), with each of them using different techniques. The authors Yunlong and Wenxin (2022) mention explicitly that "A typical AI to play a specific game usually involves some 'prior' knowledge, either explicitly incorporated by human experts or learned through pre-training phases. Such knowledge is then used in the gameplay, combined with real-time planning and reasoning." The authors of the article Yunlong and Wenxin (2022) based on the mechanics and the features in modern games, conclude that deep reinforcement learning is the most general and scalable paradigm to train strong AIs in games with higher complexity. Even though other studies might have shown different results. The study of Hoekstra (2006) shows that "there are two particularly good techniques that provide an ability to adapt. These are dynamic scripting and genetic algorithms. Where one falls short, the other picks up. Another technique incorporates two types of AI techniques, neural networks, and Particle Swarm Optimization. The neural network needs a solution to change its output, and the particle swarm provides these solutions. In all this adapting and evolving, the entire goal is to provide the player with a more enjoyable experience." This constrains the AI to perform as the character it is playing should perform. Besides this, nothing is keeping AI from adapting and evolving to best the human player in the competition. While adapting, some players also have the role of fighting. The latter ability is a crucial point in the evolution of AI in Gaming referring to Lie and Istiono (2022). But below we will refer to other studies to analyze how AI can change Game Difficulty, an important metric of the Game.

2.1.1 Using AI to change the Game difficulty

Artificial Intelligence (AI), besides game development, also impacts the difficulty and challenge of computer games. Developers can utilize AI techniques and algorithms, as below, to dynamically alter the game's difficulty and challenge level to create an engaging and balanced experience for players. Dynamic Difficulty Adjustment is a topic studied by Chapman (2004), which introduces "Hamlet" as a Dynamic Difficulty Adjustment (DDA) system built using Valve's Half-Life game engine. Using techniques drawn from Inventory Theory and Operations Research, Hamlet analyzes and adjusts the supply and demand of game inventory to control overall game difficulty. The Hamlet system involves functions such as: Monitoring game statistics according to predefined metrics, defining adjustment actions and policies, executing those actions and policies, displaying data and system control settings, and generating play session traces. Another study by Zohaib (2018) presents a broad review of the DDA application's techniques and gives hints on how to use them in gaining an intensive game experience. But for the Game to be fully adopted, testing systems should be used so to maintain an elevated level of user-friendly experience in gaming. While the study of (Silva, Silva, & Chaimowicz 2017 shows that a player's expertise has a greater influence on the perception of the difficulty level and dynamic adaptation (DDA).

2.2 Testing Systems for Artificial Agents in Games

Artificial agents' behavior, performance, and functionality are evaluated using validated methodologies and testing systems. With the development of *General General Game AI* (Yannanakis & Togelius 2016), the testing process goes into a mixture of problem-solving, art, and engineering. The need for testing

systems ensures the agents fulfill the intended functions and provide a smooth and enjoyable gaming experience. The testing can be done using different algorithms, or even by creating other testing agents, as presented by Prasetya et al (2022). For more related areas to the effect of AI and Computer Intelligence in Games, the work of (Yannakakis & Togelius 2015) could be a point of exploration.

While this paragraph tends to explore the various testing, procedures utilized in the Game area as follows from (Freeman 2020).

Unit Testing: artificial agents are designed to be isolated and analyzed in a way that allows for a thorough evaluation of their various components. This approach helps identify and address issues at a granular level.

Integration Testing: the goal of integration testing is to ensure that an artificial agent's various systems and components work seamlessly together. This process also helps identify potential issues that could arise due to the integration of these components.

Performance Testing: performance testing evaluates the efficiency and effectiveness of artificial agents under different workloads, stress conditions, or resource constraints. This testing approach measures processing speed, memory usage, response times, and scalability. Performance testing ensures the agent can perform optimally and reliably within the game environment, even under demanding scenarios.

Functional Testing: Functional Testing ensures that an agent follows the specified requirements and performs well in assigned tasks. This process involves testing an agent's responsiveness, actions, and overall behavior.

User Acceptance Testing: acceptance testing is a process that involves getting feedback from game testers and real users about an artificial agent's effectiveness and performance. Testers play the game and interact with the agent to provide feedback on its responsiveness, behavior, and effectiveness. This type of Testing helps to validate the agent's engagement and usability.

Simulation Testing: through simulation testing, an agent's behavior and performance can be evaluated in real-world settings. This method simulates the various game scenarios and challenges encountered in each situation. It allows for the iterative refinement of an agent's abilities.

Comparative Testing: a comparative test is conducted to compare the performance of an artificial agent against that of other agents or human gamers. It allows the evaluation of an agent's weaknesses and strengths and provides insight into its competitiveness.

To ensure that the quality and performance of artificial agents are maintained in their games, developers can utilize various testing methods. These include comparative analysis, user acceptance, and simulation-based Testing. These methods can help evaluate the integration of individual components, performance under varying conditions, and adherence to the game's functional requirements (Freeman 2020).

An interesting example is used by (Trankov et al 2020) where the experiment showed that “the use of an autonomous software agent can simulate a player and facilitate the software testing of a multiplayer network game. The implementation performed is suitable for testing any type of navigation games - car racing, arcade games with airplanes, bikes, and other vehicles.”

Developers can enhance and refine artificial agents through rigorous testing to ensure they deliver immersive and seamless experiences for players. To have a closer look at the results of our game created by using AI agents, a short analysis of our artificial agent performance explains in detail the platform used for game generation and we go next to the Results paragraph.

3. RESULTS

The evaluation and testing of AI-based agents in computer games involves assessing their capabilities, efficiency, and suitability. This ensures the agents fulfill their assigned tasks and behave appropriately to improve the gaming experience.

Developers and researchers can analyze and evaluate the impact of artificial agents in games by using performance metrics. This data can provide valuable insight into how these agents perform in various areas, such as their adaptability, decision-making capacity, player engagement, and realism. Game studios can create more effective and immersive environments by improving and assessing these metrics.

The ability to adapt and robustness metrics are used to measure the stability and resilience of an AI agent. They analyze an agent's ability to handle unexpected events, adjust strategies, or recover from mistakes. Evaluating an agent's adaptability and robustness helps determine its level of reliability and how it can handle various gaming situations.

The believability and realism metrics are tools that measure the ability of an agent to exhibit emotions and behaviors in a video game. They analyze several factors, such as an agent's facial expressions and natural language interactions. They help determine the impact of an agent on the creation of immersive experiences and storytelling.

Performance metrics are used in games to measure an agent's effectiveness, efficiency, and competitiveness. They can range from factors such as an agent's score and win rates to predefined benchmarks. They can help players identify areas of their game where they can improve and determine the impact of their actions on the outcome.

The goal of player engagement metrics is to measure the impact of an artificial agent on various aspects of an individual's experience, such as enjoyment, immersion, and satisfaction. They analyze factors like the frequency of interactions, emotional reactions, and feedback with the agent to evaluate their capability to enhance the gameplay experience.

The quality of AI agents' decision-making is evaluated through various metrics that assess their ability to make educated decisions based on the applicable rules, objectives, and context. These tools can help determine if an agent can contribute to challenging and engaging gameplay experiences, a reference to the book (Yannakakis & Togelius 2018).

The goal of task completion metrics is to measure the efficiency of an artificial intelligence agent in performing specific tasks or objectives in a game. They can be used to evaluate the agent's accuracy and efficiency and their ability to complete predefined goals. They can also help determine the agent's contribution to the gameplay progression.

Artificial intelligence agents are measured and evaluated through performance metrics in computer games. These tools help researchers and developers understand these agents' various strengths and weaknesses and their impact on gameplay a reference to the book (Yannakakis & Togelius 2018).

3.1. Analysis of Artificial Agent Performance

The performance of artificial agents in video games is evaluated by assessing their efficiency and effectiveness, such as *Accuracy and Precision*, *Responsiveness and Reaction Time*, *Adaptability and Learning*, *Efficiency and Resource Utilization*, and *Player Experience Enhancement*.

The performance of artificial agents in video games is evaluated by assessing their efficiency and effectiveness. This subtopic examines the different metrics used to measure the agents' effectiveness.

Accuracy and Precision: An artificial agent's precision and accuracy are evaluated by looking at its accuracy when performing tasks and making correct decisions. Various metrics, such as error and success rates, can measure an agent's accuracy in specific scenarios.

Responsiveness and Reaction Time: When assessing the capabilities of artificial intelligence to make real-time decisions, it is essential to consider the agents' reaction time and responsiveness. Various metrics, such as response time and latency, can be used to evaluate how quickly the agents can respond to specific events, referred to (Rumburg 2020).

Adaptability and Learning: Learning from experience can help artificial agents improve their adaptability and learning efficiency. Performance metrics, such as learning curves and convergence rates, can analyze an agent's learning effectiveness and adaptability, referred to (Rumburg 2020).

Efficiency and Resource Utilization: The utilization of resources and computational requirements of artificial agents are two of the most critical factors analyzed when assessing their efficiency. Various performance metrics can be used to evaluate an agent's efficiency, such as memory, energy, and CPU utilization, referred to (Rumburg 2020).

Player Experience Enhancement: An analysis of the performance of artificial agents involves considering how they affect the engagement and experience of players. This can be accomplished through various methods like playtesting sessions and surveys, referred to (Rumburg 2020).

Performance metrics related to responsiveness, accuracy, adaptability, efficiency, and the gamer experience can be used by developers to understand how well AI agents perform in certain gaming environments. This process can help them identify areas for improvement and implement fixes in the design and evolution of their artificial agents, referred to by Barzanji (2019) and to (Rumburg 2020).

3.2. Platform and computer game creation using AI

GDevelop 5 is an open-source, cross-platform game engine designed for everyone, <https://editor.gdevelop.io/>. With GDevelop, one can do simple projects for fun, build educational content, publish promotional games for your brand, and create ambitious and successful games. GDevelop is focused on making video games that are easy to create and require no programming knowledge. This can be achieved through various methods.

Event-based logic: The main goal of GDevelop is to make games that are simple to create without requiring knowledge about programming languages or coding. This can be accomplished through an Event system, which creates logic with the help of monitoring conditions. Most of the events are presented in a normalized language, making developers more comfortable with coding concepts commonly found in other programming languages.

Behaviors: Developers can create various behaviors that can be used in combination with pre-built events and functions to add logic, such as pathfinding, physics-based movement, and platforming. These can be added to an object's list of behaviors and used to interact with the user. The Event system can also be used to extend these behaviors.

Easy content pipeline: The game's content, such as text, backgrounds, and character art, can be added to the editor through a simple point-and-click interface. Some examples of content types include Sprites, Tiled Sprites, Text Objects, and Shape Painters. Importing music and sounds into events can also be done.

3.3. My platformer AI

The mini-game is created by simple objects, as shown in Figure 1 and Figure 2, which include an AI agent as 3(three) different attackers for the player:

- left and right AI; moving only in these directions,
- jumping AI; moving left and right but also jumping-climbing AI;
- moving left and right, jumping but capable of climbing into objects.

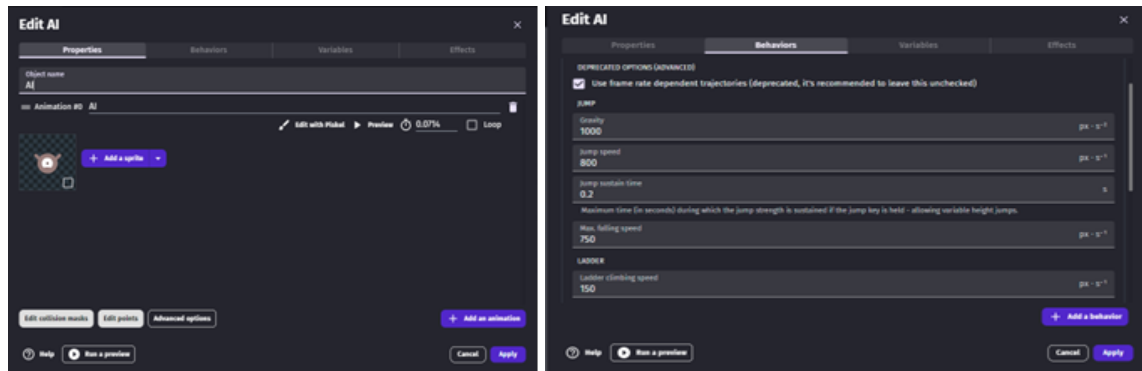


Fig. 1. and Fig. 2. AI Properties and Behavior Conditions

The other objects are static and do not move; they help create the base of the territory and can be added to the game without a problem when they do not have an interactive role with the player.

Usually, these objects do not have any behavior or effect; they can serve as critical points to indicate to the AI where a specific action starts or ends.

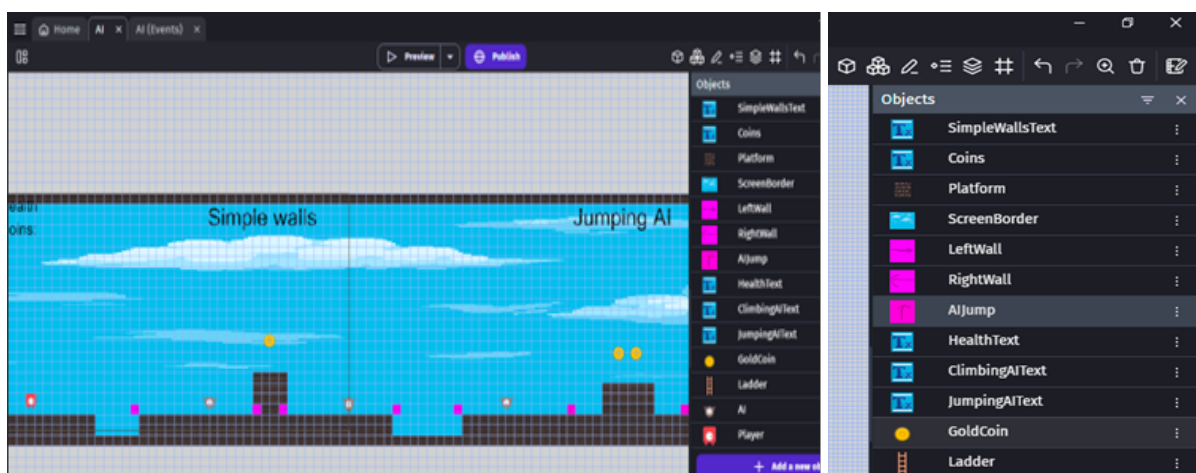


Fig. 3. and Fig. 4. Mini-Games Objects'

In this mini-game, these objects are represented by "Leftwall", "Rightwall," and "AI Jump", as shown in Figure 3 and Figure 4, and have been inserted into the platform where the AI moves along. When AI collides with these objects, it will act as per instructions.

The instructions for the game to be functional will be given as written code, but mostly with simplified events that the platform already has created. Some of the events can be:

- Object flashing,
- Acceleration,
- Gravity,
- Collision,
- Delete,
- Value/text of an object variable
- Pick the nearest object, etc.

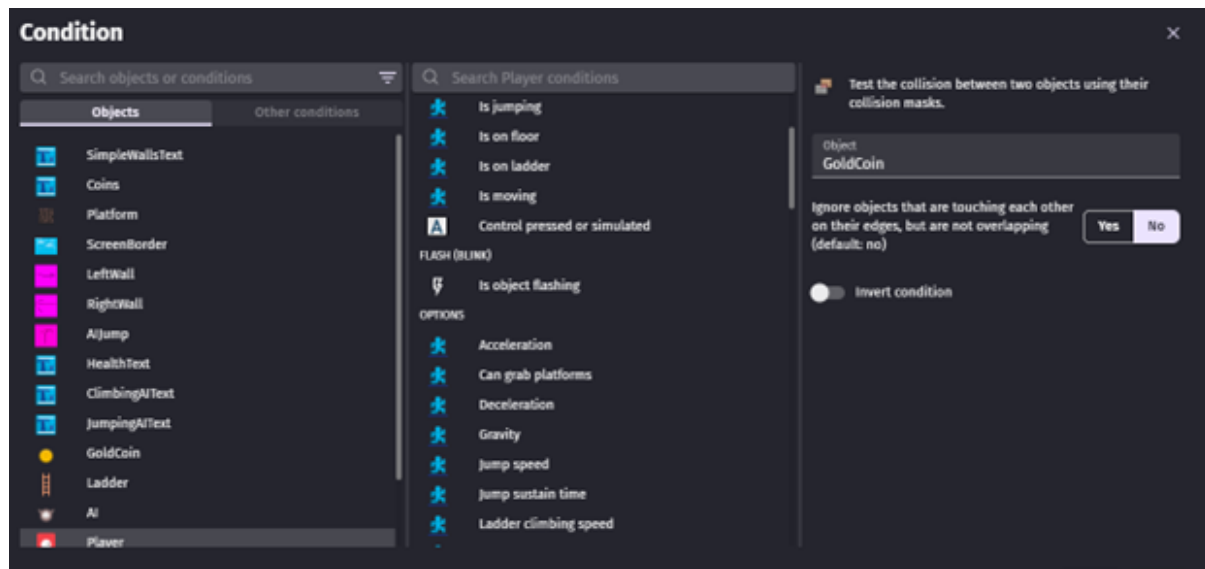


Fig. 5. Game Events and Conditions for Creating Instructions

All these conditions, as shown in Figure 5 and Figure 6, are reflected on the platform, and applied in the game depending on how the creator uses them if they are repeated or happen only in a particular moment.

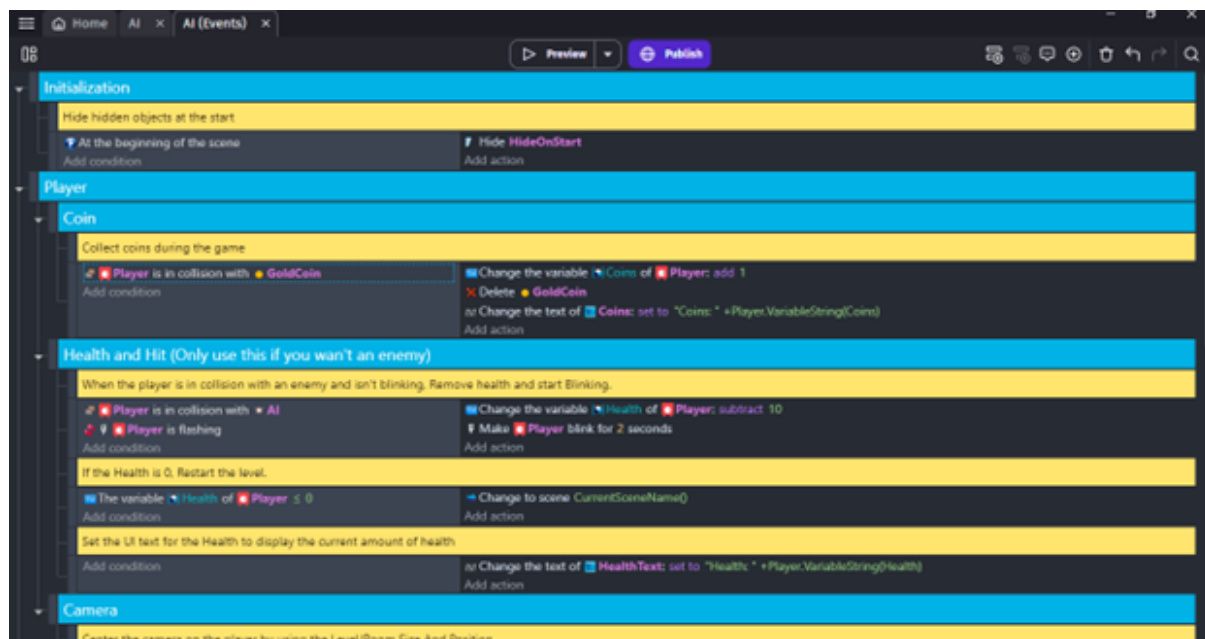


Fig. 6. Conditions of the Mini-Games

Indeed, artificial agents add a lot to a computer game; we can start by enhancing more gameplay experience, Figure 7.

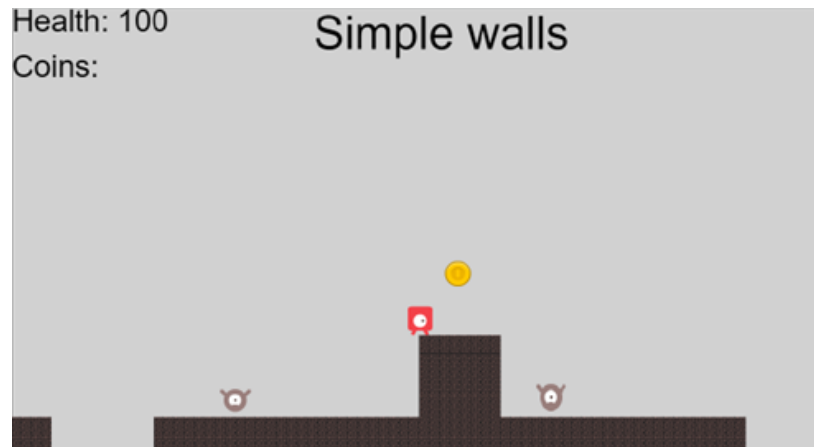


Fig. 7. Game's user interface

By incorporating AI into the game, you provide players with a more engaging and immersive experience.

Another improvement is the increase of game variability; this can result in replayability, as each playthrough may offer unique challenges and outcomes, keeping players engaged and interested. There can be several questions when developing a game using AI agents, and the following paragraph may address some of them.

4. DISCUSSION

The contributions of the agents to the field of artificial intelligence for computer games could be evaluated based on their innovations in this area. Developers can assess how their agents can address existing issues, introduce novel techniques, or expand the scope of what is possible in this field.

The novelty and innovation of artificial agents are evaluated by comparing their features with those of existing systems. Developers can then highlight how their agents can improve or surpass existing solutions' capabilities.

Case studies about using artificial agents in computer games can provide insight into the challenges and successes faced by other developers trying to implement such systems. By studying case studies, developers can better understand how existing systems perform and what design choices they can make to improve theirs.

Designing and creating effective artificial agents for games can be particularly challenging. Listed below are some of the main challenges such as Realism and Believability, Player Interaction and Responsiveness, Difficulty and Fairness, Learning and Adaptation, Development Resources and Constraints, and Ethical and Social Considerations.

Relating to the challenges, we can select the last one, as one of the most important values that a game shall bear. The design of AI agents should consider the social and ethical implications of their actions. They should not be used to promote harmful behaviors or to perpetuate stereotypes. Artificial agents should also be able to respect the boundaries of their users and maintain a positive environment.

Also, not forgetting that Testing and Iteration ensure that the AI performs well and provides a challenging and enjoyable experience for players. The developers must thoroughly test and refine the agents' behavior and performance. They should also allocate time and resources to address any issues in reference to the book (Yannakakis & Togelius 2018) and (Millington & Funge 2009).

Other issues to be taken into consideration refer to diversity and inclusion cases, which AI in Gaming shall also have an eye on. In the work of (Shams, Zowghi & Bano 2023), the “findings revealed that the integration of AI with diversity and inclusion is a less-explored area of research”.

To create artificial agents that can enhance the gameplay experience and provide engaging interactions, game designers should consider the various challenges and considerations that affect the development of such systems. They should strike the right balance between responsiveness, Fairness, realism, and ethical considerations so that such agents can captivate and contribute to players' overall gaming experience.

4.1 Limitations and Future Directions

This section aims to provide a comprehensive analysis of the various limitations and potential areas of improvement encountered in the research and development of artificial agents for computer games. It also explores the possible avenues for future progress such as Implementation Constraints, Realism and Human-like Behavior, Generalizability and Adaptability, Ethical Considerations, Player-Developer Interaction, and Advanced Learning and Adaptation.

Thus, in trying to build a simple roadmap for developing artificial agents for computer games, we must consider the various limitations that have been identified so far, as well as the opportunities that lie ahead for future research, (Cabrera et. al 2015).

5. CONCLUSION

The use of artificial agents in video games has numerous benefits and implications. Several key conclusions can be drawn from this.

In addition to providing numerous services, such as responding to calls and performing actions, using artificial agents can also enhance the gameplay experience of mini-games.

Artificial agents introduce unpredictable and variable gameplay in games. This can result in better replayability as each playthrough offers distinct outcomes and interactions, which keeps players engaged and interested.

Using artificial agents, developers can dynamically adjust their games' difficulty based on their players' skills and performance. This approach ensures that skilled and casual gamers get a fair and balanced gaming experience.

Through the development of artificial agents in games, researchers can gain a deeper understanding of how these agents perform in their decision-making and behavior. They can then apply this knowledge to improve the efficiency of their systems.

The knowledge gained from the creation of artificial agents in games can be applied to other areas of game development.

In terms of the impact of artificial agents on the gaming experience, there are various advantages to be had by integrating them into games. These include improving the gameplay experience, gaining insight into AI behavior, and increasing difficulty. On the other hand, there should be taken in consideration the ethical behavior, realism, trustworthiness, and generalizability of such systems.

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