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EMBEDDING ARTIFICIAL INTELLIGENCE IN GAMES NPC AND EFFECTS ON EMOTIONAL HEALTH

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Abstract

Artificial Intelligence (AI) has transformed the role of Non-Playable Characters (NPCs) in video games, enhancing their realism, interaction, and narrative depth. In this study we have discussed the most used Artificial Intelligence techniques in games NPCs like pathfinding algorithms, decision and behavior trees, emotional modelling and adaptive difficulties and concluded the best applicable techniques. The main advantage is to determine and separate the most effective techniques based on time and space complexity from non-effective techniques and to tell how they one is better than the other and in what way. This is achieved by performing comparisons and identifying differences between difference techniques along with the explanations and examples. To validate the accuracy of the proposed method, we compared Dijkstra's algorithm and A algorithm with the same problem statement and conducted 2 tests between them. Both time A* algorithm outperformed Dijkstra's algorithm in time complexity and 1 time in space complexity. It was found that the proposed method was accurate and determined the best techniques among others. This method is useful in making an open world realistic game where NPCs are roaming around the game world or driving vehicles in the game as it makes the game more realistic with realistic NPCs, which can be achieved by using the techniques proposed in this study.*

INTRODUCTION

Non-Playable Characters (NPCs) are the important aspects of modern video games, serving as the backbone of storytelling, gameplay mechanics, and player immersion. They make the game look more realistic. These characters, controlled by artificial intelligence (AI) rather than human players. They are important for creating dynamic, immersive, and realistic game worlds. From guiding players through missions to providing emotional depth and challenge, NPCs have evolved significantly [1]. However, despite their critical role and the development of NPCs faces several challenges including limitations in AI capabilities, behavior prediction and the inability to adapt dynamically to the player actions in the game [2]. This paper explores the evolution of the NPCs that identifies the gap in the current research and proposes solutions to enhance their functionality and the realism that ultimately aims to improve the player engagement and immersion in the game.

The primary issue with the NPCs in the video games is their lack of true dynamism and adaptability to the games [3]. Advancements in the AI have enabled NPCs to perform complex tasks such as pathfinding, decision-making and emotional modeling that they often remain constrained by the predefined scripts and behavioral trees [4],[5]. This limitation causes predictable and repetitive interactions, which can make player's experience bad. For instance, in the *Resident Evil 5*, the NPC partner Sheva often makes irrational decisions that frustrates the players and breaking immersion [6]. Similarly, while the games like *Detroit: Become Human* and *Horizon Forbidden West* have made the strides in the emotional modeling and adaptive difficulty that these systems are still limited in the scope and fail to fully replicate human-like behavior in their games[7].

The concept of NPCs in early years in role-playing games like *Dungeons & Dragons* (1974), where non-player characters were used to enhance the storytelling and gameplay. Early video games, such as *Pong* (1972) and *Adventure* (1979), introduced primitive NPCs that interacted with players in basic ways [8]. Over time, games like *The Legend of Zelda* (1986) and *Ultima* (1981) expanded NPC roles, offering missions, trading, and narrative depth. Recent research, such as Haodong Du's work, highlights how AI advancements have made NPCs smarter and more active, enhancing gameplay and storytelling. However, studies also explained the limitations of current NPC systems, particularly in achieving natural and intelligent interactions [9].

Even with good advancements, there is still a gap in making NPCs that can adjust to how players act and show human-like reactions. Current methods depend a lot on pre-written like behavior and decision trees, which restrict their ability to react to unexpected player choices [10]. While emotional modeling and systems for changing difficulty have made NPC interactions better, they often miss the depth needed for a truly engaging experience. For instance, the emotions in NPCs are generally based on simple psychological ideas, like the OCC model which is although useful but does not cover all human feelings [11]. Moreover, the systems that adjust difficulty, while maintaining creativeness, can sometimes break the immersion by changing too quickly based on how well a player is doing in the game.

This study aims to address these gaps by exploring the advanced AI techniques, such as the deep reinforcement learning and generative adversarial networks (GANs) that are helpful in the creation of more dynamic and the responsive NPCs. The objectives are threefold: firstly, develop NPCs capable of learning from player interactions and adapting their behavior in the real-time, secondly enhance emotional modeling by incorporating more nuanced emotional states and social dynamics and thirdly refine the adaptive difficulty systems to ensure the seamless and immersive gameplay for players. By leveraging these technologies, our aim is to create NPCs that not only respond to the player actions but also anticipate and adapt to their preferences and playstyles and give them more real the world scenario experience [12].

This research is important because it could change the gaming industry by making experiences for players better and more engaging. NPCs that can change based on what players do and show emotions similar to humans will improve stories, game mechanics, and how players feel involved. Additionally, these advancements may be useful in areas outside of entertainment, such as education, training, and virtual reality. By solving the current issues with NPC systems, this research helps improve AI in gaming and prepares for new developments in interactive storytelling and virtual settings. In summary, NPCs play a key role in video game success, and their growth is vital for keeping players engaged and involved. By identifying the gaps in current research and proposing innovative solutions, this paper seeks to push the boundaries of what NPCs can achieve, ultimately creating more dynamic, responsive, and lifelike game worlds [13].

1. LITERATURE REVIEW

We have summarized various Artificial Intelligence (AI) techniques in this paper which includes pathfinding techniques, decision and behavior trees, emotional modelling and adaptive difficulties in games non-player characters (NPCs). We have summarized what are pathfinding algorithms, how are they used in games for NPCs and what are some best algorithms amongst all. We have also provided a detailed comparison between Dykstra's and A* algorithms. We have also explained how A* algorithms are better from Dijkstra's and under what conditions it most suitable. We also explained in detail about decision trees and behavior trees, what are their major components, how they work and explained the types of control flow nodes used in them. Drawbacks of behavior trees are also discussed in the paper [14].

We explored how emotional reasoning in NPCs and adaptive difficulty enhance player engagement and immersion. Through emotional modelling, NPCs develop dynamic emotional states that influence their responses and decision-making [15]. As depicted in Figure 4, Detroit: Become Human demonstrates this concept through Connor, who prioritizes empathy over logic to resolve a hostage situation, showcasing the role of AI-driven emotional intelligence in shaping narratives. Similarly, adaptive difficulty systems refine gameplay by adjusting challenges in real time [16]. As shown in Figure 5, Horizon Forbidden West exemplifies this by modifying enemy behavior creatures like the Thunder jaw adapt their attack strategies to match the player's skill level. By leveraging rule-based logic and probabilistic models, these systems ensure smooth difficulty transitions without disrupting immersion. The combination of emotional modelling and adaptive difficulty creates more realistic NPC interactions and a personalized gaming experience, keeping players engaged [17].

2. METHODOLOGY

The approach used for intelligent NPC designing in games combines three essential modules: pathfinding, behavior decision-making, and emotional modeling, all designed to mimic dynamic and realistic non-player character behaviors. The game environment is first set up with a 2D map that includes static and dynamic obstacles. NPCs are initialized and instilled with mobility through classical pathfinding algorithms like Dijkstra, A*, and BFS, tested for effectiveness in navigation, obstacle circumvention, and rule compliance such as crossing roads or walking along footpaths [18]. A* is found to be most effective because it uses heuristic-based optimization, providing speedier computation time while retaining shortest-path reliability. Behavioral logic is controlled by Behavior Trees, which include root, control flow, and leaf nodes, with control nodes like Sequence, Selector, and Parallel handling decision flows [19][20][21]. These trees permit NPCs to behave contextually based on game events and user interaction, while decision trees dictate response timing. Dialogue and action modules permit NPCs to chat and respond in real time to player input. In order to further increase realism, emotional modeling is incorporated through the use of the OCC model, enabling NPCs to create emotional responses such as fear, pride, or happiness, which drive their behavior and decisions. Emotional states are discretely quantified, adapting dynamically with in-game events. Emotions also modify decision logic and movement, for instance, fear causing avoidance [22][23]. Emotions fade with time or grow stronger with repeated triggers, creating more human-like variability [20]. The emotional engine works together with behavior trees to adjust actions and speech patterns [24]. All the modules of the pathfinding, their behavior trees, and also emotional modeling are tied into outputting final NPC actions. This integrated system creates intelligent, adaptive, and emotionally responsive NPCs, greatly improving immersion and realism in the game [25][26].

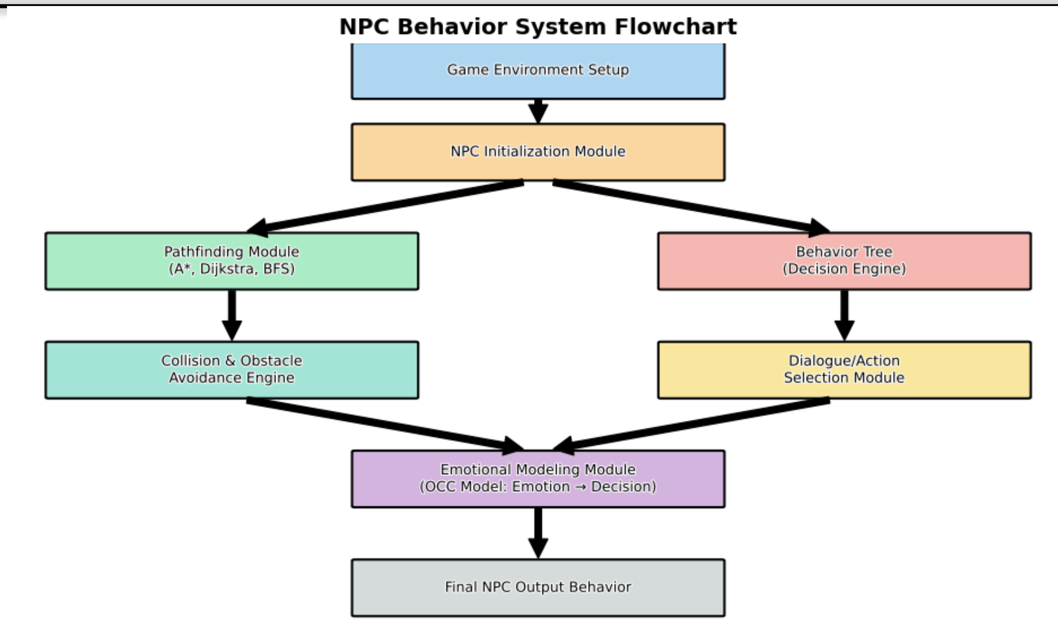

Figure 1: NPC Behavior

3. RESULTS AND DISCUSSION

The research emphasizes the efficacy of the combining algorithms for pathfinding, their behavior trees and emotional modeling in producing the intelligent and life-like NPCs. The study contrasted between algorithm performance, decision-making efficacy and emotional reactivity. Evaluation was based on the execution time, behavior correctness and the responsiveness in dynamic environments. The results provide insights into how each of the component separately works toward life-like NPC behavior.

4.1 . PATHFINDING TECHNIQUES IN NPCs

Pathfinding algorithms are vital for designing NPCs in games that enables them to navigate through complex environments efficiently and realistically. These algorithms help NPCs to deal with the scenarios like walking on the footpath, avoiding collisions, crossing the road, even recognizing and following traffic rules [1]. There are algorithms like Dijkstra's, BFS and A* that are used to explore entire map, searching all possible paths and selecting the shortest one while avoiding the collisions of NPCs. Factors like performance optimization, collision avoidance and static and dynamic constraints are kept in mind while using these algorithms to best optimize the game using AI. [2].

Dijkstra's Algorithm was published in 1959 that is a conventional method for finding the shortest path between a start node and an end node in a graph as long as the edges between the points are not negative [2]. To find the shortest path from the starting node to the ending node, we have to visit all the paths from starting node to all the points. This problem is known as single source shortest path as it moves toward the closest unvisited points rather than moving towards the ending node. Due to the single source shortest path problem, this is not an ideal choice for pathfinding for the NPCs [3].

Konrad Zuse invented Breadth-First Search (BFS) algorithm in 1945. In 1959 Edward F. Moore reinvented BFS for finding the shortest path in a maze game [4]. BFS is a widely used search algorithm that works by traversing nodes in a broad and level-by-level order. It starts from the starting node and systematically explores its neighboring nodes to find desired node. This procedure is continued until the targeted node is found [5]. It uses the First – In – First – Out (FIFO) queue. BFS visits one node at a time. It has large space complexity (O (V) where V is the number of vertices) but guarantees the shortest path to find nodes. [6].

The A* algorithm is a highly efficient and widely used pathfinding algorithm that identifies the shortest path while avoiding the obstacles, from a starting node to an ending node [1][7]. This algorithm combines feature of uniform-cost search, Dijkstra and heuristic search [1][8]. Its stability and speed have been refined over the years, with potential for further improvements [9]. A pathfinding study was done between A* and Dijkstra's algorithm to prove that A* algorithm is the most suitable. In the Fig. 1 we can see the time taken by A* algorithm is almost half than Dijkstra's. Same experiment was performed again as shown in Fig. 2. The lengths of the paths didn't vary in both cases, but the time varies. It is because the Dijkstra's algorithm scans more part of the map than A*. A* uses Best First Search while Dijkstra's algorithm uses Greedy Best First Search [10].

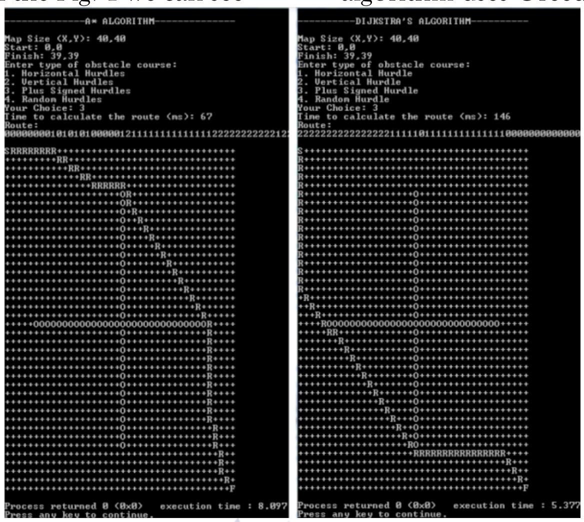

Figure 2: A Uses Best First Search while Dijkstra's algorithm uses Greedy Best First Search*

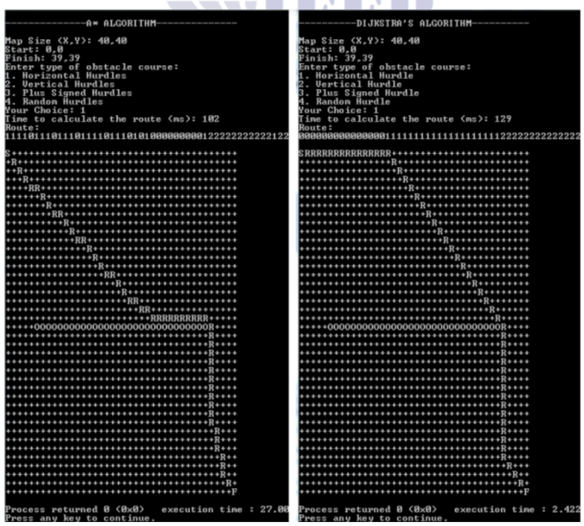

Figure 3: A Uses Best First Search while Dijkstra's algorithm uses Greedy Best First Search with Time Varies*

Another study was conducted in a Maze Runner game which focused on evaluating the efficiency of pathfinding algorithms as the NPC navigates from a starting point to a destination while overcoming obstacles. A* and Dijkstra's algorithms were used in the study. As a result, A* algorithm was proved to be more suitable due to its less computational requirements and faster search times [11].

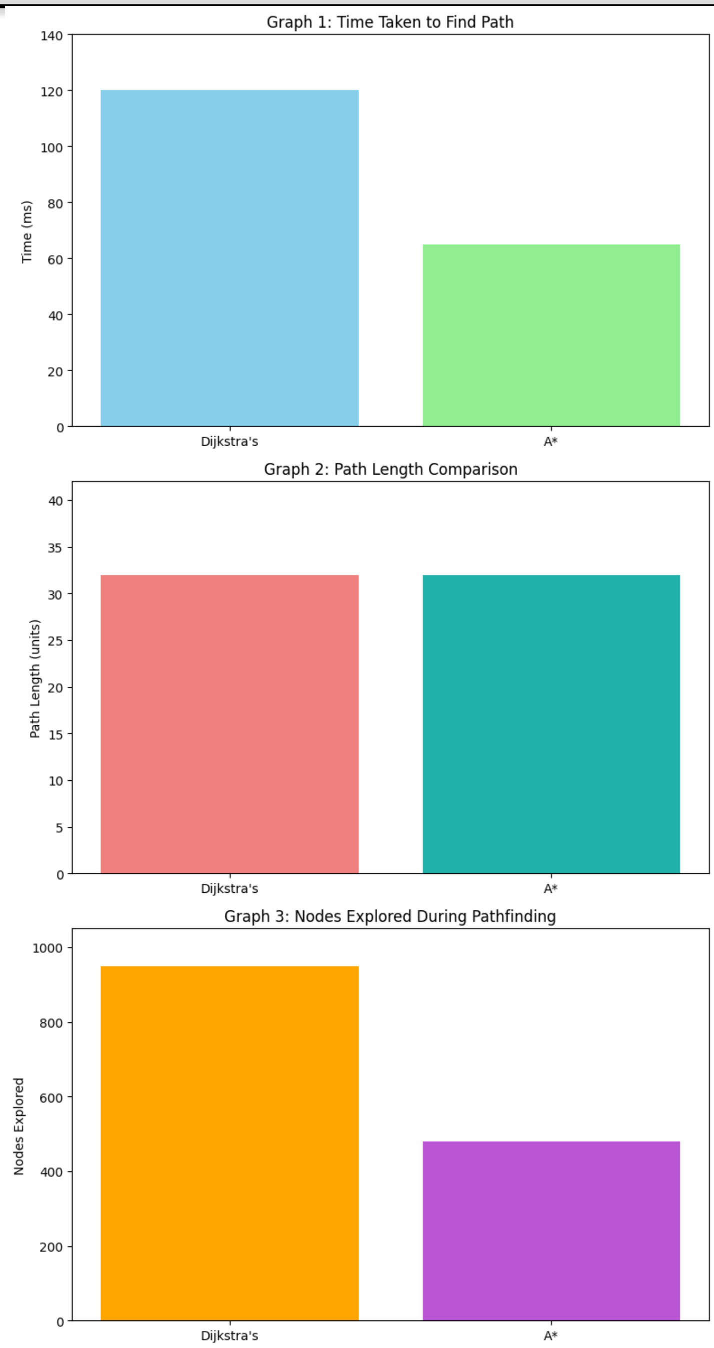

Figure 4: Results Comparison

4.2. DECISION AND BEHAVIOR TREE IN NPCs

Decision trees and behavior trees are widely used in NPC games to design and create structured and responsive AI behaviors [1]. They consisting of a root node, internal control flow nodes, and leaf nodes that perform actions. The root initiates execution by sending *ticks* at a particular frequency, spreading through the tree. Nodes only execute when receiving a tick and return one of three statuses: Running, Success, or Failure. The control flow node controls the flow of execution. There are 4 types of control flow nodes which includes Sequence (executing children in order until one fails), Selector (executing children in order until one succeeds), Parallel (executing children simultaneously), and Decorator (modifying child behavior nodes) [12]. Behavior trees and decision trees are used in dialog games, wherev the player can interact and talk with NPCs and according to the scenario NPCs respond to the player. Not only NPCs can respond via dialog, but can also perform actions in respond to player. Behavior trees can define what actions they can perform and decision trees decide when to perform which action [13].

Behavior trees come with several drawbacks. First, Depth-First Search (DFS) can be time-consuming in large trees, especially when executed every frame. Second, they lack the ability to make random decisions, limiting their effectiveness in creating truly believable character behavior. Third, describing complex behaviors requires an extensive tree structure, making it difficult to navigate and debug [14].

4.3. EMOTIONAL MODELLING IN NPCs

Emotional modelling in NPCs plays a key role in creating lifelike interactions and dynamic responses to player actions[2]. In AI systems, emotions are often represented through numerical values, with agents assigned emotional statuses that can change based on interactions[3]. For instance, in crowd modelling, agents' emotional states were adjusted to simulate collective behaviors, such as moving together when their emotional values aligned[4]. This concept of emotional modelling was extended in various projects like the Oz Project and ACASA, where multiple emotional variables were managed within a more intricate framework[5].

The emotional responses of the agents in these systems are derived from well-established psychological theories which is particularly the OCC model that defines emotions as reactions to events based on the three main factors: impact of the event on the agent’s goals, the approval of actions relative to behavioral standards and the agent’s liking of the objects in relation to their attitudes[2]. Based on these principles, the Oz Project's emotional model included basic emotions like happiness and sadness alongside more complex emotions like gratitude and pride.[5]. Although the number of emotions were limited but they were designed with the ranges of intensities that allows more nuanced emotional reactions. For example, the emotion of "Fear" could vary from comfort to panic that depends on the intensity of the emotion while "Love/Belonging" could range from loyalty to betrayal. The emotional states were connected to specific reasoning levels in the agent’s architecture, with emotions like "Pride/Shame" influencing self-awareness of agent and team dynamics and "Happiness" directly related to the goal achievement. These types of simplified emotional models allow NPCs to exhibit the emotional depth while maintaining the computational efficiency. The ability of the model to adjust the emotions based on the different type of situations helps NPCs to react in a more realistic way that enhances interactivity and reality in the game environment. Through these methods such as emotional modelling in AI can lead to more immersive and engaging experiences that showcases how NPCs can evolve and respond dynamically to the various type of scenarios.

The integration of the emotional modelling within the NPC systems helps us to simulate the social behaviors that are crucial for creating life-like characters. Agents can adjust their actions based on both the internal state of their emotional system and the external events they face. For example, an agent might choose to cooperate with player after forming a bond or exhibit distrust if they feel betrayed from them. These emotional responses are influenced by the simple logic in some case can also add layers of depth and making the NPC's actions seem more genuine and unpredictable. The ability to model the complex emotional states can also affect gameplay mechanics, such as when NPCs become more cooperative or hostile depending on their emotional condition that impacts the flow of the game and the choices available to the player[5].

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Figure 5: Player Character Connor Meets the Hostage-Taker in Detroit: Become Human (2018)

In "Detroit: Become Human", the character Connor exemplifies the emotional engagement with a suspect in a critical moment where he attempts to prevent the tragic outcome. In one scene, Connor emotionally connects with a man who is threatening him to throw a girl from the building. Instead of using the forceful tactics he chooses to build an emotional rapport with the individual by appealing to his feelings and reasoning to calm him down. This emotional approach is the central to the game's narrative, because it illustrates the potential for androids to form emotional bonds and make the decisions based on the empathy not just logic. Connor's strategy highlights the growing complexity of the human-android interactions and the importance of the emotional intelligence in resolving the high-stakes situations that ultimately emphasizes the potential for deeper and the more meaningful connections in the artificial intelligence.

In "Detroit: Become Human", central concept is the emotional reasoning that shapes the interactions between the characters and influences the narrative of the game is such a way that looks like emotionally aware game. One of the main scenes in the game is when android detective Connor is tasked with negotiating with a man who is threatening to throw a girl from the edge of the building to street. Instead of using the traditional logical or aggressive methods, Connor uses the emotional reasoning to connect with the suspect with deeper and more personal level. By appealing to the emotions of man like showing empathy and acknowledging his internal struggles. Connor attempts to defuse the situation peacefully. This scene does not only highlight the power of the emotional intelligence in a high-stress situations but also reinforces the broader theme of the game of human-android relationships where the androids like Connor begin to display the emotional awareness and make the decisions based on the empathy rather than cold logic.

In these ways, the game explores the complexity of the emotional attachment where players experience a range of emotions tied to the in-game characters[5]. In this context Emotional reasoning goes beyond just mere decision-making but it becomes a tool for the character development and story progression[1], [5]. Players are encouraged to form emotional bonds with the NPCs that affects the choices they make throughout the game[4]. In the case of Connor, the growing emotional awareness of him contributes to his evolution as a character that is really a blurring the line between human and android behavior. As players interact with the characters of the games they experience a dynamic shift from the purely logical reasoning to one where emotions play a significant role in shaping the outcomes in the game[4]. This evolution highlights the overall message of the game for the potential of the artificial intelligence to develop the emotional complexity and the form meaningful connections by making the player's experience more immersive and emotionally resonant[5], [6].

4.4. ADAPTIVE DIFFICULTIES IN NPCs

The adaptive systems in education mainly within serious games are critical for delivering the personalized learning experiences.[7] These systems dynamically tailor down the content and the feedback to individual needs by enhancing engagement and higher-order cognitive skills while accommodating the diverse user traits like knowledge levels, motivation and the learning styles. The Adaptive frameworks continuously refine user models to align with evolving behaviors by leveraging real-time data by ensuring seamless alignment between educational goals and the gameplay mechanics.[8]

The design of the adaptive serious games demands the multidisciplinary collaboration to balance the pedagogy with the entertainment.[8] Unlike the traditional systems, adaptation here involves adjusting in-game parameters, such as challenge levels or narrative pathways based on the player interactions.[7] This dual focus on learning and engagement complicates design but fosters the individualized skill development and the knowledge retention.[9] The effective adaptive game design hinges on the integration of educational content organically into the interactive scenarios by creating immersive environments where experimentation and the real-time feedback drive deeper understanding.[7]

Horizon Forbidden West employs a sophisticated adaptive difficulty system designed to tailor down enemy behavior to the skill level of the player by creating a fluid and responsive game play experience. By continuously analyzing the real-time player performance metrics such as combat accuracy, frequency of failures, resource consumption (e.g., ammunition, healing items) and the reaction times. The AI of the game dynamically adjusts the intensity and the complexity of encounters.[9] For example, if a player struggles during battles against machines like Thunder jaws or Claw striders, the system may reduce enemy aggression, slow attack patterns, or weaken their Armor vulnerabilities. Conversely, consistent success could trigger enemies to adopt advanced tactics, such as coordinated group attacks, environmental exploitation (e.g., setting traps), or unleashing unique abilities like plasma bursts or shockwaves. This real-time calibration ensures that challenges remain engaging without overwhelming players, fostering a sense of progression and mastery. The AI's responsiveness extends beyond combat, subtly influencing exploration and resource availability to maintain narrative immersion.

Figure 6: Aloy Confronts a Thunder jaw in Horizon Forbidden West (2022)

The game's adaptive framework likely integrates a hybrid of rule-based logic and machine learning techniques to balance fairness and challenge.[9] Threshold-driven rules form the foundation: predefined conditions, such as repeated deaths within a short timeframe or prolonged hesitation during combat, trigger incremental adjustments. For instance, after three failed attempts against a Shell snapper, the AI might lower the machine's health pool or delay its area-of-effect attacks. Layered atop this are probabilistic models, such as Bayesian networks or decision trees, which predict player frustration by weighting factors like session duration, playstyle (aggressive vs. stealth), and historical performance.[9] These models enable smoother transitions between difficulty tiers, avoiding abrupt changes that break immersion.[9]

CONCLUSION

In conclusion, NPCs (Non-Playable Characters) are essential to the immersive and engaging nature of video games, imparting realism, steerage, and depth to gameplay. Their evolution, pushed by using advancements in artificial intelligence (AI), has transformed them from static, scripted entities to dynamic, responsive characters able to adapting to participant movements and emotions. techniques consisting of pathfinding algorithms (e.g., A*), choice and conduct bushes, emotional modeling, and adaptive issue systems have drastically greater NPC capability, making interactions greater natural and gameplay extra personalized. video games like Detroit: come to be Human and Horizon Forbidden West exemplify how emotional intelligence and adaptive systems can create richer narratives and tailored reviews. searching in advance, AI promises to revolutionize NPCs further, with trends like procedural content technology, real-time narrative version, and greater emotional responsiveness shaping the future of gaming. But challenges which include moral issues and the balance among AI-pushed content material and human creativity stay crucial concerns. in the end, NPCs will preserve to play a pivotal function in making recreation worlds extra dynamic, immersive, and tasty for players.

REFERENCES

[1] C. Yin, "NPCs in video games: a reflective resource for sports coaches and participant engagement," *Front. Sports Act. Living*, vol. 6, Jun. 2024, doi: 10.3389/fspor.2024.1403829.

[2] "NPCs: From past to present... to future." Accessed: Feb. 17, 2025. [Online]. Available: https://inworld.ai/blog/npcs-from-past-to-present-to-future?utm

[3] "(PDF) The Progress and Trend of Intelligent NPCs in Games." Accessed: Feb. 17, 2025. [Online]. Available: https://www.researchgate.net/publication/388357388_The_Progress_and_Trend_of_Intelligent_NPCs_in_Games

[4] "The History of NPCs - The Strong National Museum of Play." Accessed: Feb. 17, 2025. [Online]. Available: https://www.museumofplay.org/blog/the-history-of-npcs/?utm

[5] "(PDF) A model of non-player character believability," *ResearchGate*, Oct. 2024, doi: 10.1386/jgvw.9.1.39_1.

[6] G. Elvery, "Undertale's Loveable Monsters: Investigating Parasocial Relationships with Non-Player Characters," *Games Cult.*, vol. 18, no. 4, pp. 475–497, Jun. 2023, doi: 10.1177/15554120221105464.

[7] C. Yin, "NPCs in video games: a reflective resource for sports coaches and participant engagement," *Front. Sports Act. Living*, vol. 6, p. 1403829, Jun. 2024, doi: 10.3389/fspor.2024.1403829.

[8] "Undertale's Loveable Monsters: Investigating Parasocial Relationships with Non-Player Characters - Gabriel Elvery, 2023." Accessed: Feb. 17, 2025. [Online]. Available: https://journals.sagepub.com/doi/full/10.1177/15554120221105464?utm_

[9] J.-P. Dyson, "The History of NPCs," The Strong National Museum of Play. Accessed: Feb. 17, 2025. [Online]. Available: https://www.museumofplay.org/blog/the-history-of-npcs/

[10] University of Kragujevac, Faculty of Technical Sciences Čačak, Serbia and V. Aleksić, "Using Artificial Intelligence Concepts to Design Non-Playable Characters in Road Traffic Safety Games," in *10th International Scientific Conference Technics, Informatic, and Education*, University of Kragujevac, Faculty of Technical Sciences, Čačak, 2024, pp. 239–248. doi: 10.46793/TIE24.239A.

[11] "A Systematic Review and Analysis of Intelligence-Based Pathfinding Algorithms in the Field of Video Games." Accessed: Feb. 17, 2025. [Online]. Available: https://www.mdpi.com/2076-3417/12/11/5499

[12] M. Hamza, Obaidullah, and A. Shahwaiz, "Optimizing Early Detection of Diabetes through Retinal Imaging: A Comparative Analysis of Deep Learning and Machine Learning Algorithms," *Journal of Computational Informatics & Business*, vol. 2, no. 1, Art. no. 1, Oct. 2024, Accessed: Jul. 08, 2025. [Online]. Available: https://jcib.org/index.php/jcib/article/view/7J.

[13] J. W. Moorin, A. L. Hubble, and A. Sharma, "Pathfinding Pac-Man: Shortest Path Optimisation Using Search Algorithms".

[14] B. V. Indriyono and Widyatmoko, "Optimization of Breadth-First Search Algorithm for Path Solutions in Mazyin Games," *Int. J. Artif. Intell. Robot. IJAIR*, vol. 3, no. 2, pp. 58–66, Nov. 2021, doi: 10.25139/ijair.v3i2.4256.

[15] "Pathfinding in Strategy Games and Maze Solving Using A* Search Algorithm." Accessed: Feb. 17, 2025. [Online]. Available: https://www.scirp.org/journal/paperinformation?paperid=70460

[16] A. Ansari, M. A. Sayyed, K. Ratlamwala, and P. Shaikh, "An Optimized Hybrid Approach for Path Finding," Apr. 09, 2015, *arXiv*: arXiv:1504.02281. doi: 10.48550/arXiv.1504.02281.

[17] A. Goyal, P. Mogha, R. Luthra, and N. Sangwan, "PATH FINDING: A* OR DIJKSTRA'S?," no. 01, 2014.

[18] H. Ali, D. Younas, K. Hamid, M. Noor, and M. Ibrar, "Human-Centered Comparable to Technology-Driven Approaches in Reducing the Bullwhip Effect: A Cross-Industry Study," vol. 3, pp. 209–248, Aug. 2025..

[19] M. Danish et al., "Security of Next-Generation Networks: A Hybrid Approach Using ML-Algorithm and Game Theory with SDWSN," vol. 3, pp. 18–36, Apr. 2025, doi: 10.63075/wdpwrr31.

[20] S. Riaz et al., "Software Development Empowered and Secured by Integrating A DevSecOps Design," Journal of Computing & Biomedical Informatics, p. 02, Mar. 2025, doi: 10.56979/802/2025.

[21] I. Nawaz et al., "Emotional Frontiers: Navigating the Interplay between Human and Machine Emotions Article Details ABSTRACT," Jul. 2025.

[22] J. Keshavelal et al., "Meta Model Investigation Empowered Mobile Apps Usability for Technology-Literate and Illiterate Users Article Details ABSTRACT," Annual Methodological Archive Research Review, vol. 3, pp. 329–344, Jul. 2025

[23] I. Nawaz et al., "AI and Digital Distraction: Impact of Smart Technologies on Time and Health Management Article Details ABSTRACT," Annual Methodological Archive Research Review, vol. 3, pp. 129–149, Jun. 2025.

[24] V. Johansson, *Player types and emotional attachments to NPCs : A methodological approach to identifying preferences regarding emotional attachments for an interactive narrative game target audience*. 2022. Accessed: Feb. 17, 2025. [Online]. Available: https://urn.kb.se/resolve?urn=urn:nbn:se:his:diva-21408

[25] U. Tehreem, M. W. Iqbal, K. Hamid, and M. Saeed, "Analysis and Development of Kids' Cell Activities Monitoring App," 2025, pp. 405–420. doi: 10.1007/978-3-031-77617-5_32.

[26] G. Çatak, "GAMEHIGHED Initial Report : Output 1: Initial Research & Analysis Report. Higher-ed Programmes for Careers in Game Design & Development (2019–2022).".