The Role of Artificial Intelligence in Video Game Development

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Abstract

In this paper, we study the vital role of artificial intelligence (AI) in the development of video games, with a focus on various aspects of AI application in this industry. In the introduction, we discuss both the development of video games and the role of AI systems in the user experience, defining the progression of AI's role in video games. In the following section, we investigate how in-game entities and AI collaborate. Here, we analyze basic concepts such as Non-Playable Characters (NPCs) and how AI enhances their intelligence and reactivity in the game. The mechanisms of AI in video games are a crucial point of consideration in the next part of the paper. We explain how various AI techniques are used for decision-making, player tracking, and adapting the game to their actions. Furthermore, we explore the use of AI in video games beyond NPC control, examining examples such as procedurally generated worlds and player experience modeling. This application of AI contributes to a deeper and more dynamic player experience. In the modern application of AI in video games, we delve into advanced uses of machine learning and deep neural networks in game development. Here, we consider how AI is used for game personalization, user data analysis, and enhancing graphics and sound. Finally, we discuss the future of video games and the role of neural networks in their development. We predict the growth of AI in various aspects of games and how it will shape the future player experience. In conclusion, we assert that artificial intelligence has become an indispensable part of video game development, and its impact will inevitably expand in the future, enabling increasingly rich, dynamic, and personalized games for players worldwide.

Key words: video game entities, video game mechanics, AI mechanisms in video games, NPCs, neural networks

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The Role of Artificial Intelligence in Video Game Development

Introduction

Raison d'être of every video game resides deep within the competitive sphere of human mental constitution, particularly in its innate impulses (Russell, 2009). A video game is always a competition with someone or something: either an opponent, a rival, or an adversary. This competitiveness is sometimes perceived as an "inherent animal spirit" of humans, which ultimately leads to an "immaterial civil war" (see more: Lukić, 2010). Given that the real protagonist of a video game is necessarily homo ludens, that is, a human, either directly or through their avatar (although the first video games did not have avatars per se, and interaction between the player and the software occurred directly, as in the game Tetris), their opponent is always the software that powers the device on which the game is played, and whose software must adapt and oppose its activities in the game to compete with and often challenge or enhance the player's experience (especially in certain genres where the goal is not for the player to win but to stay in the game as long as possible, as seen in earlier games like Space Invaders) (see more: Filipović, 2022). Thus, even in rudimentary video games, we have the use of artificial intelligence in shaping gameplay. Individuals who have experienced video games have unquestionably engaged with artificial intelligence (AI). Irrespective of the video game genre, AI has consistently governed various aspects. Typically, this governance is linked to the conduct of non-player characters, be they neutral or antagonistic figures.

Software or primary artificial intelligence in video games is defined as a set of software techniques used in a game engine to simulate intelligence in the actions of computer-controlled characters reflecting one of the essential characteristics of intelligence, which is "perceiving relevant relationships in a specific situation" (Bajac & Bjelajac, 2022). The game engine that controls AI in video games, in addition to traditional AI methods, also includes algorithms from control theory, robotics, computer graphics, and computer science in general.

The implementation of AI significantly impacts the game, system requirements, and the game's budget. Game developers aim to create interesting and undemanding AI at the lowest cost possible. Artificial intelligence in video games widely employs various simplifications, emulations, and even slight deceptions, so the approach and ethics of using AI in game development differ significantly from the approach to cognitive artificial intelligence (see more: Bjelajac, Filipović & Stošić, 2022). In a broader sense, artificial intelligence, which we are witnessing a massive proliferation of applications for, brings forth challenges, risks, and threats on the internet, especially for children and young individuals. Consequently, special attention must be paid to the protection of these vulnerable population groups (see more: Bjelajac & Filipović, 2020; Bjelajac & Filipović, 2021a). This preventive approach is most effective when the principles of internet safety culture are applied (see more: Bjelajac & Jovanović, 2013), alongside the establishment of appropriate local and international regulations (see more: Bjelajac, Matijašević & Dimitrijević, 2012). It poses an additional threat for even deeper human alienation (see more: Bjelajac, 2014). On the other hand, what we refer to as artificial intelligence in the context of video game creation is significantly narrower in scope and inherently contained, thus not posing the same type of risk as narrow artificial intelligence (ANI).

Purists even argue that using the term "artificial intelligence" in the context of "artificial intelligence in video games" is scientifically unfounded (Uofa, 2023) since AI in video games does not conform to the scientific definition of AI and only uses a few branches of academic "artificial intelligence" science. While "true" AI refers to branches of self-learning systems and decision-making based on arbitrary data input, even to the ultimate goal of "cognitive" artificial intelligence capable of reasoning, AI in video games often consists of a few basic heuristic rules that are sufficient to provide the player with a good game, a satisfying experience, and an enjoyable game (Uofa, 2023).

Video game entities and AI

Since the earliest games, players have interacted with autonomous entities in video games, commonly referred to as non-playable characters (NPCs). The term NPC was first used for characters

in role-playing games but is now widely used for characters in almost all genres. NPCs populate the game world to provide an immersive gaming experience, and as such, they should be as realistic as possible in their appearance, movements, dialogues, and decisions. One of the most overlooked challenges in artificial intelligence (AI) for computer games is creating in-game characters (NPCs) with human-like behavior (Uludagli et al., 2023). Contemporary NPCs determine their actions in different situations using specific decision-making methods, allowing them to change the current state of the game world.

Entities in video games controlled and managed by software artificial intelligence (AI) can be diverse and include:

NPC (Non-Playable Characters): These are characters within the game that are not under direct player control. AI is used to manage their behavior to make them authentic and responsive to player interactions.

Opponents and Enemies: AI can control opponents or enemy entities in the game, determining their tactics, abilities, and reactions to the player.

Allies: AI can control player allies, providing support and assistance during the game. This includes combat strategies, navigation, and other forms of support.

Systemic Elements: AI can manage various systemic elements in the game, such as dynamic weather conditions, economies, and more, to create a realistic environment.

Procedurally Generated Entities: In some games, AI can generate randomly or procedurally created entities as part of the game, such as enemies, levels, or worlds.

Game Mechanics: Artificial intelligence can also be used to control various gameplay mechanics, such as physics, animations, and interactions with objects in the game.

Player Experience Customization: AI can analyze player behavior and adjust the game to create a personalized experience, including adjusting difficulty levels or game dynamics.

Player Behavior Analysis: AI can track and analyze player behavior to develop statistics, recommendations, or in-game challenges.

Player Assistants: AI entities can serve as guides or assistants to players, providing them with information, advice, or instructions during the game.

Interactive Dialogue: AI can control the dialogue between players and NPCs, allowing for diverse and dynamic conversations in the game.

Depending on the type of game and its objectives, AI can have different roles and functions in managing these various entities within the video game.

The mechanisms of operation of AI in video games

People tend to perceive every interaction with AI as a threat because they view AI as something superior, surpassing human capabilities in every field. Such a stance is generally correct (see more: Bjelajac & Filipović, 2021b). However, in video games, it's different. Instead of learning how to defeat human players, artificial intelligence in video games is designed to enhance the gaming experience of human players (Lou, 2017). Timur Bukharayev (2009) captures the role of software AI in video games nicely, stating that the "main task of AI in a video game is not to defeat the player but to provide a good experience."

Dr. Harbing Lou (2017) writes that designers often use tricks to make NPCs appear intelligent. One of the most commonly used tricks, known as the Finite-State Machine (FSM) algorithm, was introduced into video game design in the early 1990s (Lou, 2017). In FSM, the designer generalizes all possible situations the artificial intelligence could encounter and then programs a specific reaction for each situation. Essentially, FSM AI would immediately respond to the player's action with its pre-programmed behavior. In shooter games, artificial intelligence may attack the player but withdraw when the avatar's health is dangerously low, leading to a potential "game over." In an FSM-based game, a specific character has the capability to execute four fundamental actions in reaction to potential scenarios: seeking help, evading, wandering, and taking action. Many well-known games, such as Battlefield, Call of Duty, and Tomb Raider, include

successful examples of FSM AI design. Even the turtles in Super Mario have rudimentary FSM designs (Lou, 2017).

A more advanced method that developers use to enhance the individualized gaming experience is the Monte Carlo Algorithm (MCTS or Monte Carlo Tree Search). The MCTS algorithm was created to avoid the repetition aspect present in the FSM algorithm. The MCTS algorithm first evaluates all possible moves available to the NPC at a given moment. Then, for each of these possible moves, it analyzes all the actions the player could respond with. Afterward, it returns to assess the NPC's estimation based on the player's actions (Cowling et al., 2012). This artificial intelligence algorithm was used by IBM to create Deep Blue, the first chess supercomputer, which made history on May 11, 1997, by defeating world chess champion Garry Kasparov in a six-game match.

A similar algorithm is used in many strategy games. However, since there are far more possible moves than in chess, it's impossible to consider them all. In such games, the MCTS algorithm will randomly select some of the possible moves. As a result, NPC actions become much less predictable for players. This is crucial in games like Civilization, which have a vast number of options available to the computer opponent. Building a tree for every possible choice and scenario would take a very long time. Therefore, to avoid such extensive calculations, the MCTS algorithm randomly selects a few possible options. Consequently, the game consumes fewer system resources while still surprising players with its AI (Lou, 2017).

The use of AI in video games other than NPC control

The use of AI in game development is not necessarily limited to NPC control. Georgios N. Yannakakis (2012) highlighted, in addition to NPC control, four potential areas of AI application in video games:

Player Experience Modeling: Recognizing the abilities and emotional state of the player to adapt the game appropriately. This can include dynamically balancing the game's difficulty, adjusting the game's difficulty in real-time based on the player's abilities. AI in games can also help infer player intentions (such as motion recognition).

Procedural Content Generation: Creating game environment elements such as environmental conditions, levels, and even music automatically. Artificial intelligence methods can generate new content or interactive stories.

User Behavior Data Mining: This allows game designers to explore how people use the game, which parts they play the most, and what causes them to stop playing, enabling developers to fine-tune the game or improve monetization.

Alternative Approaches to NPC Characters: These involve changing game settings to enhance the believability of NPCs and exploring social, rather than individual NPC behavior.

Instead of procedural generation, some researchers (Goodfellow et al., 2014) have used Generative Adversarial Networks (GANs) to create new content. Researchers at the University of Cornwall implemented GANs in 2018 to generate a thousand levels that developers had written for the video game DOOM (1993). After training, the neural network prototype could design new levels for the game autonomously. Similarly, researchers at the University of California created a GAN prototype for generating levels for Super Mario, and in 2020, Nvidia demonstrated a GAN clone of the cult game Pac-Man. GANs learned how to recreate the game by observing 50,000 game levels, mostly generated by bots.

Contemporary application of AI in video games

Heuristic artificial intelligence algorithms in games are used across a wide spectrum in many industries within the video game industry (Korotkov, 2017). The most obvious use of AI in games is in controlling NPCs, although scripting is also a common form of control. Pathfinding is another widespread use of artificial intelligence in video games, especially in real-time strategy games. Pathfinding is a method for determining how an NPC should move from one point on the map to another, considering the terrain, obstacles, and possible fog of war. AI in video games is also associated with dynamic game balancing. The concept of AI unpredictability has been explored in games such as Creatures, Black & White, Nintendogs, and toys like Tamagotchi (Korotkov, 2017). The "pets" in these games have the ability to "learn"

from the player's actions, and their behavior changes accordingly. While these solutions are drawn from a limited set of possible solutions, they often provide the desired illusion of intelligence on the other side of the screen.

Artificial intelligence (AI) has been a part of computer games for decades, but recent advances in machine learning and deep learning have ushered in a new era of "Generative Artificial Intelligence (GenAI)." This technology is poised to revolutionize the gaming industry by offering highly impressive, personalized, and realistic gaming experiences (Gartner, n.d.). One innovative application of artificial intelligence in games is the creation of hyper-realistic worlds and non-player characters (NPCs). Game creators can use generative artificial intelligence to train voice actors and generate dialogue in a fraction of the time it would take to write scripts by hand. This not only saves time but also allows for the creation of endless worlds populated by realistic characters. These worlds can be customized and transformed based on player actions, opening up endless possibilities for replayability. Another area where AI shines is dynamic storytelling. Traditionally, game narratives have been devised by developers, but generative AI enables unplanned narrative digressions and personalized stories. By analyzing player behavior and choices, artificial intelligence in video games can adapt and offer highly personalized stories while maintaining the overall game structure (Gartner, n.d).

GenAI also opens up new possibilities for creating levels, missions, and side tasks. Game developers can use generative artificial intelligence to create unique missions or levels based on player skills, progress, or characteristics. This not only adds diversity to the game but also retains player interest. Music generation is another area where AI has an impact. AI-based tools can compose original music for video games based on user input. With further advances in AI, in the future, it will be able to create music that matches the style and mood created by game developers.

One of the most significant applications of AI in games is real-time image enhancement (Crider, 2023). Technologies like Nvidia Deep Learning Super Sampling (DLSS), AMD Fidelity Super Resolution (FSR), and Intel Xe Super Sampling (XeSS) have already improved graphical fidelity in video games by increasing frame rates while maintaining

graphics quality. As AI continues to advance, real-time image enhancement will continue to evolve, offering players stunning visual experiences (Archer, 2022).

AI has an essential role in the development and testing of video games. It can automate tedious tasks such as bug detection and gameplay testing, saving time and developer resources. AI enhances game testing, a critical aspect of game development. Traditional game testing, involving human testers or scripted bots, has its limitations. AI-based testing addresses these limitations by automating many aspects of game testing, reducing the need for human testers and speeding up the process (Hawk, 2023).

Predictive analysis using artificial intelligence algorithms can help identify potential issues before they become serious, providing players with a smoother gaming experience. AI can be used to improve storytelling in video games by helping to generate narrative content or enhance the overall storytelling experience. Natural language processing (NLP) techniques can be used to analyze player feedback and adapt the narrative in response, generate new content including unique character backgrounds, create new dialogue options, or even generate new stories (Hawk, 2023). AI is ready to revolutionize the gaming industry with hyper-realistic worlds, dynamic storytelling, personalized experiences, and improved game development processes. As this technology continues to evolve, players can expect even more impressive and enjoyable gaming experiences in the future.

Gartner (n.d) sees "Generative Artificial Intelligence becoming a general-purpose technology with an impact akin to that of the steam engine, electricity, and the internet. The hype will settle as the reality of implementation takes hold, but the impact of generative artificial intelligence will continue to grow as people and enterprises discover more innovative applications for the technology in everyday work and life."

Neural networks and the future of gaming

Neural networks, specifically artificial neural networks (ANN) or simulated neural networks (SNN), constitute a subset of machine learning and serve as the backbone of deep learning algorithms. They

are called "neural" because they mimic the way neurons in the human brain communicate with each other (IBM Data and AI Team, 2023). Possessing the capacity to acquire knowledge from data and formulate forecasts, they are exceptionally well-suited for tasks like image and speech recognition, processing natural language, and autonomously making decisions.

The utilization of neural networks in video games holds the promise of transforming the way games are crafted, produced, and experienced. Neural networks can be employed to create smarter and more advanced artificial intelligence systems for non-player characters (NPCs) in games. NPCs powered by neural networks will be able to react to players' actions in a more sophisticated and realistic way, making gameplay more impressive and enjoyable (Kagan et al., 2022).

Neural networks can also enhance the player's experience in other ways. They can be used to create procedurally generated content, such as levels, enemies, and unique weapons tailored to each player. This means that each player will have a unique gaming experience, and no two playthroughs will be exactly the same.

Another application of neural networks in games is reinforcement learning (Jones, 2017), a subfield of machine learning that focuses on training systems to make decisions based on rewards and penalties. Reinforcement learning is applied to instruct neural networks to excel in games like chess and Go, surpassing human capabilities, and it holds the potential to achieve similar results in diverse game genres, including first-person shooter games and real-time strategy games.

In most modern video games, NPC behavior is scripted; no matter how many times a player exploits an NPC's weakness, that weakness is never improved. However, if NPCs in a game could learn through interaction with the player, their behavior could improve over the course of gameplay, keeping the game interesting. The NeuroEvolution of Augmenting Topologies (rtNEAT) method is used to develop increasingly complex artificial neural networks in real-time while the game is being played (Stanley et al., 2005). The rtNEAT technique permits agents to adapt and enhance their performance as the game progresses. In essence, rtNEAT has the potential to usher in a novel category of video games where players instruct a group of

agents through a sequence of tailored training drills. To illustrate this concept, in the NeuroEvolvingRoboticOperatives (NERO) game, players train a squad of robots for combat. Looking ahead, rtNEAT could open up possibilities for fresh educational and training applications that adjust in real-time as users acquire new skills.

Finally, neural networks can be used to create adaptive games (Redepenning et al., 2022) that change and evolve based on player behavior to enable individuals with disabilities to actively participate in gaming communities. Current adaptive gaming technology not only allows individuals to engage in games but also to compete on a level playing field with those who do not use adaptive gaming equipment. Games based on neural networks can generate unique challenges for each player based on their motor skills and gameplay style and can adjust the game's difficulty level in real-time based on the player's progress. This level of adaptability can lead to a more personalized and enjoyable gaming experience for an underserved population of players. Studies (Redepenning et al., 2022) show clear evidence of improved quality of life and social benefits from participating in adaptive gaming, strongly supporting the need to increase the availability of adaptive gaming services as part of the rehabilitation of individuals with disabilities.

Current applications of neural networks for improving the gaming experience suggest that rtNEAT technology brings immediate commercial value to modern games. Any game in which NPC behavior endlessly repeats and becomes boring can be improved by allowing rtNEAT to partially modify tactics in real-time. This is particularly useful in persistent video games like Massive Multiplayer Online Games (MMOGs) that last for months or years. In these games, rtNEAT's potential is constantly adapted and optimized for NPC behavior, potentially permanently altering the gaming experience for millions of players worldwide (Stanley et al., 2005).

Incorporating neural networks into video games can inaugurate a fresh era of gaming, offering players more immersive and tailored experiences.. As technology continues to evolve and improve, it is exciting to think about what the future of gaming may look like and what role neural networks will play in shaping it.

Conclusions

It's incredible how much artificial intelligence has achieved in so many industries in such a relatively short time. However, the question arises: what do we do next? Will artificial intelligence have the capability to completely replace humans within a few decades? Or are there things that humans are capable of doing that AI will never learn? In any case, many good things can come out of this. Although we can't know exactly what will happen, we are excited to see what the future of artificial intelligence will bring.

Artificial intelligence is an swiftly progressing technology, and its possible uses in game design are striking. Game design with artificial intelligence could potentially transform the gaming industry by facilitating the development of hyper-realistic virtual environments and customizable difficulty levels. However, there are still many challenges to overcome before these potentials can be realized. Nevertheless, as artificial intelligence technology continues to improve, it is likely that AI game design will become an integral part of future games.

Video games have come a long way from Pong and Pac-Man, and with the advent of artificial intelligence, game developers can now create virtual worlds where anything is possible. But with this new technology, what kind of future can we realistically expect in terms of game design?

The potential of AI game design is impressive, but there are still several significant challenges to overcome before it can be realized. One of the biggest obstacles is cost. Designing games with artificial intelligence requires immense computational power, which can be quite expensive. Additionally, ethical and legal considerations need to be addressed, as well as potential questions about the "soul" or "mind" of AI-driven games. The development of AI game design should also be accompanied by advancements in artificial intelligence algorithms. AI algorithms are still relatively simple, and they need to be improved to unlock the technology's full potential. As AI becomes more sophisticated, more complex interactions and responses can be implemented, making games even more enjoyable. It is clear that the use of artificial intelligence in game design has the potential to revolutionize the gaming industry. AI game design has the potential to

create an entirely new type of game where players are truly immersed in virtual worlds. This technology could also enable the creation of games that continually self-improve, increasing their capacity.

However, there are still many challenges to overcome before all these ideas become applicable. More research is needed on the development and implementation of AI game design, taking into account ethical and legal implications. It is evident that AI game design is still in its infancy, and only time will tell what kind of games will emerge in the future. In the end, "to be useful, AI must fight well but lose more often than it wins. Such a role should make the player feel smart, cunning, and powerful" (Buckland, 2004).

In the future, the development of artificial intelligence in games will likely not focus on creating more powerful NPCs that seek sophisticated ways to defeat players (Lebedev, 2023). Instead, the focus will be on how to create a unique player experience for each individual. Players today pay great attention to details, including not only the appearance and quality of graphics but also how alive and interactive the game is in every possible way. Artificial intelligence is what can elevate the gaming experience to a higher level. Perhaps one day, players won't be able to tell whether a character in the game is controlled by artificial intelligence or another player.

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Uloga veštačke inteligencije u kreiranju video igara

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Sažetak

U ovom radu istražujemo ključnu ulogu veštačke inteligencije (AI) u razvoju video igara, sa fokusom na različite aspekte primene AI u ovoj industriji. U uvodu, govorimo kako o razvoju video igara, tako i o ulozi AI sistema u korisničkom iskustvu, definišući progresiju uloge AI u video igrama. U sledećem delu, istražujemo kako entiteti video igara i AI sarađuju. Ovde analiziramo osnovne koncepte kao što su NPC (Non-Playable Characters) i kako AI unapređuje njihovu inteligenciju i reaktivnost u igri. Mehanizmi delovanja AI u video igrama su ključna tačka razmatranja u narednom delu rada. Objašnjavamo kako se različite tehnike AI koriste za donošenje odluka, praćenje igrača i prilagođavanje igre njihovim akcijama. Dalje, istražujemo upotrebu AI u video igrama izvan kontrole NPC-a, istražujući primere kao što su proceduralno generisani svetovi i modeliranje iskustva igrača. Ova primena AI doprinosi dubljem i dinamičnijem iskustvu igrača. U savremenoj aplikaciji AI u video igrama, istražujemo napredne primene mašinskog učenja i dubokih neuronskih mreža u razvoju igara. Ovde razmatramo kako se AI koristi za personalizaciju igara, analizu korisničkih podataka i unapređenje grafike i zvuka. Na kraju, raspravljamo o budućnosti video igara i ulozi neuronskih mreža u njihovom razvoju. Predviđamo rast AI-a u raznim aspektima igara i kako će to oblikovati buduće iskustvo igrača. Zaključujemo da je veštačka inteligencija postala nezaobilazan deo razvoja video igara i da će njen uticaj samo rasti u budućnosti, omogućavajući sve bogatije, dinamičnije i personalizovanije igre za igrače širom sveta.

Ključne reči: Veštačka inteligencija (AI), video igre, entiteti video igre, mehanizmi AI u video igrama, NPC, neuronske mreže.