



# Applications and Future Trends of AI-based NPC Logic: an Analysis of GTA-HD Series Games

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**Abstract.** Non-Player Character (NPC) logic, is crucial for game realism and playfulness as it determines the behavior and interactions of all non-player entities within a game. Intelligent NPC logic allows characters to respond to player actions and in-game events in a believable manner, creating a more immersive and engaging experience. It also contributes to the narrative depth by enabling NPCs to have unique personalities, goals, and reactions that can influence the game's storyline and the player's emotional connection to the game world. This work conducts an analysis of the advancement of NPC logic mainly in the Grand Theft Auto (GTA)-HD series of games developed by Rockstar Studios. It also provides a glimpse into how Rockstar used Artificial Intelligence (AI) and machine learning to create these NPCs based on existing information and actual gameplay feedback. By analyzing the development of NPC logic in open-world games, its pioneering and innovative designs are revealed. As technology continues to advance, it could be expected that NPC logic will become more sophisticated and adaptive, offering players an unprecedented level of immersion and interactivity.

**Keywords:** Artificial Intelligence, Non-Player Character Logic, Grand Theft Auto.

## 1 Introduction

Recently, Rockstar published the first trailer of Grand Theft Auto 6 (GTA) [1]. This inspired the author to investigate the use of Artificial Intelligence (AI) and machine learning in open world games further, as many people on the internet started discussing the revolutionary Non-Player Character (NPC) technology Rockstar used, which inspired the author's interest in learning more about the NPC technology and how it has developed throughout the years of the series released and the trend in the whole gaming-industry.

In the modern game industry, as the gameplay got more advanced, more new technology was used in the production of new games with more resources and money invested into the game. The emergence of a lot of these well-developed and enjoyable open-world games leads to a positive cycle in the market where the game's good reputation encourages companies to develop better games using better technology and invest more. This positive cycle is currently what drives the open-world game

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industry forward, producing games not just the GTA series but also masterpieces such as Baldur's Gate and Legend of Zelda that all represent new and better technological innovation in the industry. The release of GTA-6 represents the whole trend of innovation in the open-world gaming industry and gives us a clue about what video games will be like in the future.

The two main components of gameplay are realism and the playfulness of the game. These two aspects are what attract players in an open-world game, and NPC contributes a great part to both of them. The NPCs in the GTA games include a lot of innovative and special abilities powered by machine learning and simple use of AI, such as In-game navigation and reacting to in-game danger. More NPC functions in GTA-HD series are demonstrated, which will be expanded and explained.

NPC Logic is a very important part of how NPC works in Open World Games, NPCs are usually all programmed to perform special jobs and assignments such as police and medics. NPC logic not only serves to give the game's NPC more daily routine and jobs, but it also can help NPC to navigate the in-game environment where the codes would help the NPC avoid obstacles in game and would also help NPC to follow in game rules like not disobeying traffic lights, crossing the street weirdly and hitting into each other. This would help make the game better, as it would make it more immersive and realistic for the players with the NPC behaving like real-life individuals more due to NPC logic being more advanced and intelligent, and the improvements in GTA-6 especially will bring on a revolution in this area by reshaping how programmers code the NPC for the open world games and how the NPCs in it functions and responds to environmental changes.

In the following chapters, several theories will be mentioned in this article, including road navigation and pathfinding, machine learning to train NPCs, AI-controlled NPCs with self-consciousness, and NPCs that can independently avoid danger.

## **2 The Development of GTA-HD Series and Other Open World Games**

The GTA-HD Series game is developed by Rockstar Gaming after the success of the GTA-3D universe, which was one of the most popular game in early 2000s. So, Rockstar pushed out the new GTA-HD series in 2008 along with the release of GTA-4. Rockstar applies the use of the new RAGE (Rockstar Advanced Game Engine) engine to replace the renderware engine from the 3D era, which could provide the game with better graphics, more diverse NPCs, larger map and better modelling of structures and characters [2]. Later, in 2013, GTA5 was released, which received even better feedback from players, reaching a record 140 million copies sold since its initial release, widely regarded by many (IGN) as the best video game ever made. This generation introduced an even larger map and more diversified NPCs which further improves the gameplay experience. The next game in-line for the series is the GTA-6, rumours has been going around on the internet for a while now, and Rockstar just announced it to be released in 2025, confirming the rumours. This

started a whole round of speculation on the internet about how the game will improve compare to previous generation of the HD series and games from other companies. One of the main points of speculation is the NPC Logic, insightful gamers have found out that in 2020, Rockstar’s parent company Take Two has applied a patent that is related to NPC navigation. So, this article explores the development of NPC technology in the GTA-HD Series and how it impacted the gaming industry as a whole. This work mainly focused on how the new NPC Navigation Technology works in GTA6 what effect will it have on future games in the industry and the insight it gave us to the unbelievable improvements in NPC technology in the game world throughout the years.

### 3 NPC Logic in Each GTA-HD Series Game

#### 3.1 GTA4

In GTA4, Rockstar introduced new NPC logic in the game, including pedestrians, police, and medics. These can all be engaged with by the player. The game included many competitions where players could fight NPCs, and Rockstar designed these special NPCs to fight and interact with players. The NPCs can help advance the plot as players interact with them, providing special bonuses for players once they reach a certain level of friendship, as shown in Fig. 1. This is an evolution compared to the previous editions of GTA 3D versions, the game includes far more dynamic and realistic NPC behavior which is going to be explained blow.

	Roman Bellic	Little Jacob	Bruce Kibbutz	Dwayne Forge	Patrick McReary
					
Unlocked by	Bleed Out	Shadow	No. 1	The Holland Play	Three Leaf Clover
Available time	Anytime	1:00pm - 4:00am	7:00am - 1:00am	12:00pm - 1:00am	4:00pm - 6:00am
Activities	Eating Drinking Bowling Pool Darts Strip Club Shows Calls for lift	Eating Drinking Pool Darts Strip Club Shows Calls for lift	Eating Drinking Bowling Strip Club Shows Calls for lift Heli Ride Boating	Eating Drinking Bowling Strip Club Calls for lift	Drinking Bowling Pool Darts Strip Club Shows Calls for lift
Favorite eating place	Burger Shot	Cluckin' Bell	Superstar Café	Cluckin' Bell	N/A
Favorite Radio	The Vibe 98.8	Tuff Gong Radio Massive B 96.9	The Beat 102.7 The Classics 104.1 Liberty Rock Radio	The Beat 102.7 The Classics 104.1 The Vibe 98.8	Liberty Rock Radio

**Fig. 1.** Demonstration of Friendship System in GTA4 [3].

**Friendship System.** In GTA4, Rockstar introduced several special and new features in the game that differs it from previous games in the GTA series [3]. One of the most notable features is the new Friendship System, this is a system that allows the player in the game to be required to constantly engage with certain NPCs that have higher “intelligence” and can perform more activities compared to other NPCs. In GTA-4, Rockstar gave the players options to engage with special NPCs around town that can respond to their calls and have a more intelligent response to player’s actions. The player’s actions also determine these NPC’s actions and how they would respond to players, if the player treats them well, they will give the player benefits that help their gameplay experience. This is a revolution in the GTA Series and the whole Open World Game Play, as shown in the graph below, the Friends will each have their own life cycle and their own interest and favourite. This made them more like real life individuals instead of in-game characters, which increases the realism and immersivity of the game.



**Fig. 2.** Example of a voice reaction to player of environmental simulation in GTA5 [4].

**NPC Navigation.** In GTA-4, with the new renderware engine, Rockstar can now develop new NPC Navigation logic with far more improvements compared to before. In the previous GTA-3D series, the NPCs’ have simple navigation techniques that only allows them to identify obstacles in their path of movement and move away from it [5]. But in a more complex environment with multiple obstacles and other NPCs obstructing their path, they would be stuck in the middle of traffic. In example if being blocked by two cars from the side-walk, the NPCs can’t get around the sidewalks and will not follow its original path and travel backwards. This common glitch in early GTA games has been solved in the new GTA-4 where the flow is much more natural and the car now knows to avoid hitting pedestrians or the main character

crossing the street. When faced with an obstacle, Rockstar uses the new renderware engine to help develop new collision volume that make sure the NPCs will avoid the obstacle and go another route to reach their destination, unlike before when they would bump into the car and then turn around. An example of voice reaction is demonstrated in Fig. 2.

### 3.2 GTA5

In 2013, the series introduced its 5-th edition, GTA5, which included a new 3-character system that allows players to choose from three different protagonists and switch any time during the game. This requires Rockstar to develop a routine for the two characters that the player is not playing. This caused Rockstar to develop much more complex NPC behavior for the two playable characters when we are not controlling them, such as moving around, answering phone calls and interacting with normal NPCs with similar behavior and design from GTA4. The new game also adds off-roading ability for the NPCs and allows them to climb mountains and explore the wilderness (such as Blaine County), not only walking on roads.

The elimination of the friend system (actively requiring players to interact with them) made gameplay easier for players, as they had less to worry about when they were doing missions.

**Character Switching System.** In GTA-5, Rockstar introduced a multi-character switching system where the player can choose to play any of the three of the main characters in the game at any time, this meant that Rockstar developed special kind of code to control the other two characters when we are not controlling them. These characters are specially designed with their own voice system and copied some of the Friend System from GTA-4, where the characters can be phoned and have their special voice response to outside stimulation, and they could be asked outside by the players and engage in some similar activities to the GTA-4 Friend System requirements. Rockstar here listened to the player's concern from last gen on how the Friend System has been too demanding for the players to constantly interact with. So, the new character switching system enables the players to only call for help from the other two characters while they are in NPC mode and they will only respond to your action without demanding anything. This makes the player experience much easier and allows for more concentrated and simpler gameplay.

**NPC Off-Roading Abilities.** In GTA-5, Rockstar further improves NPC's navigation capabilities; the company added a new wild feature to the map compared to before, where large parts of the map are wilderness, and Rockstar specially designed NPC to navigate in the wild, too. This represents a big upgrade from previous NPC Navigation technology as the easily changing wilderness that's unregular and full of obstacles requires far more sophisticated technology and this has been a big improvement as it gave players the opportunity to find NPC climbers in the wilderness while they are exploring the map and this meant it engages them more

with the map as Rockstar also set a lot of unique challenges in the wilderness only for that area. This also enriches the content of the map and makes the player experience more diversified compared to the previous generation, which is only limited to city scope. The wilderness became a great part of the player experience as many players are surprised when they found out about the NPCs in the wilderness, which has been a new thing in the GTA games.

### 3.3 GTA6

In GTA6, Rockstar applies new NPC navigation technology using machine learning and a bit of AI in game development. On October 29th, 2020, Rockstar's parent company, Take-Two, filed for a patent [6]. It is believed by many that it will forever change the NPC in the GTA6 world compared to before and give them a more advanced response to changes in the environment and better road navigation compared to previous games. This improved NPC logic is based on the patent [6]

This technology could help provide more realistic movement for NPCs compared to the previous generations and doesn't require better computers to achieve this function. This system also gave the NPCs more options to navigate the map, unlike the previous games that only gave the NPC one route to go to one point on the map, the new node system gave NPCs multiple options and routes to go to one point and came up with different action of response for the NPC themselves to choose from when facing change in the gaming environment. The new navigation system allows more NPC action diversity as their movement can change in acceleration, speed times/distances, breaking times/distances, top speed, cornering speeds and more such as physical data like vehicle size, width and type.

This is a really big improvement compared to previous GTA games and other open world games. As the diversification of NPC logic and movement is a very important part to increase the engagement of players with the world in a game. This technology allows NPCs to make independent choices and diversified actions based on different scenarios they are in, instead of the old way in earlier Open World games where NPC will react to obstacles in the same way and always drive in the same speed, this new technology will make the game more immersive and realistic with diversified NPC actions, which has always been the selling point of open world games.

### 3.4 NPC Logic in Other Games

**Baldur's Gate.** Companions and dating systems are used in Baldur's Gate's NPC system [7]. The companion system functions similarly to GTA5's character-switching system, and the dating system with other NPCs is like GTA4's friend system.

**Elden's Ring.** The NPCs in Elden Ring provide information about gameplay and lore. They can also be in-game merchants that provide players with equipment. The

NPC can also interact with players by giving side quests (GTA-HD Series Side Quests) and aiding players in boss fights (Friend System in GTA5) or actively attacking a player if they appear in certain locations (GTA5 Gang System) [8].

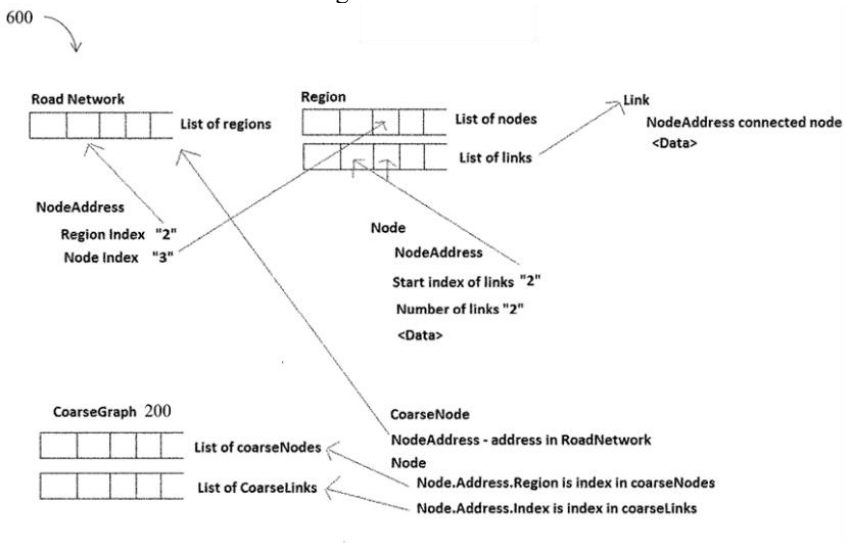
It could be observed how GTA Series have inspired/led to the use of new NPC of later games like Baldur’s Gate and Elden’s Ring, the concepts of the NPC logic used in all these also showed just how the game world has been developing through the years and how all the improvements in NPC logic through the use of AI has been used to achieve better immersivity and realism.

### 3.5 Summary

Continuously evolving technology led to the progress in NPC Logic and the GTA-HD Series embodies the transformation that the whole gaming world experiences amidst the AI age and the development of Machine Learning in enhancing gaming experiences.

## 4 New Technology in GTA6

In GTA6, the new technology used is basically a system that uses low level nodes instead of different kind of collision volume, the mapping that is going on inside the NPCs consists of a big web of low-level nodes of areas where they can go to [9]. The logic is demonstrated in Fig. 3, Fig. 4, and Fig. 5, respectively. Instead of previous games, where the mapping is done through the NPC finding where they can go and is not filled with collision volume in-game.



**Fig. 3.** The coarse graph consists of nodes and links, representing locations and road networks in-game [6]

The new system is based on the NPC only mapping through the nodes that represents certain points on the map and the nodes themselves would determine whether it is traversable or not [9], so the NPC will be given options of links of nodes to go to one certain place. This reduces the load on the computer as most of the calculation is now done online and the NPCs are trained to only compute where they can go node to node. The use of nodes and simplified “coarse graph” meant that players could see more diversified and less computing power demanding NPC navigation and action compared to before.

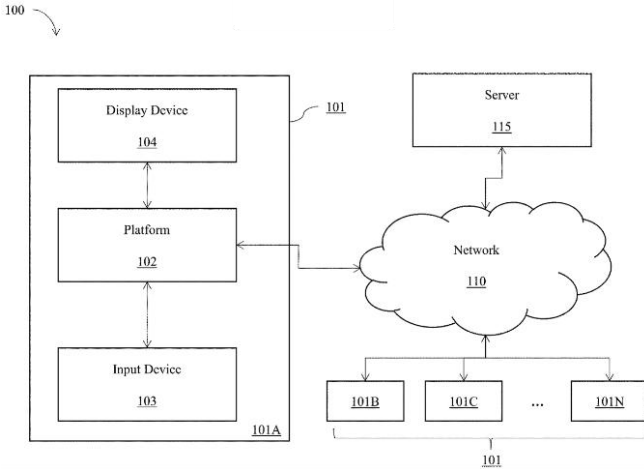
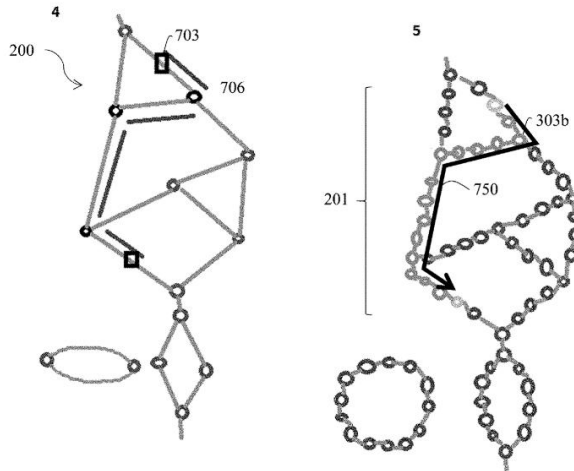


Fig. 4. Demonstration of system used for training NPC to learn how to use the node to navigate [6]

The existing technology needed for this technology to work include the use of a unified network of servers connected to Rockstar’s central operating system that can generate these low-level nodes online, and that will also be where all the NPC training takes place and machine learning will be used for the NPCs to understand how to interpret the map. The display device (computers and gaming consoles that players uses) does not carry any of that load and they only receive the NPC actions and navigations through a stable and unified server.





**Fig. 5.** An example of the coarse graph formed by the low-level nodes on a graph [6].

The effect of the New Technology includes reducing processor load and the amount of memory occupied by the game, with everything being done at Rockstar's central server and not on the player's computer. It also brings increased NPC autonomy and intelligence and improves the realism of the gameplay experience [9,10].

## 5 Discussion and Prospect

In the future, the GTA-HD series will release more games, such as the GTA6 which is due to be released in 2025. These will provide even more new NPC abilities compared to before. This would improve the playability of the game and make sure that the players can enjoy a more diversified experience in gameplay [11]. The future editions of GTA can be seen on how they have a lot of new innovations and would again revolutionize the open world game industry.

Possible new NPC functions could include them behaving autonomously, bringing versatility to the open world [11]. They do not just rely on the protagonist to move the plot forward. AI generates each NPC's self-awareness, and real-time algorithms of the NPCs generate different transition animations [12]. These all are updates from current NPC Logic and functions, but they are also based on existing functions in the existing games, this showed how the Open World Game industry is continuously improving and every new innovation is based on the revision or the improvement of something invented before. Open World Games will be even more popular in the future with possible use of medical assistance. As the realism and the playability, this work mentioned earlier in the article is going to be a really important part of it. Being that the realism will allow people under stress to view the game as a tool, and the playability made it fun, meaning it could be an escape from the real world for people with mental health problems. The NPC logic can be used to benefit society and help

gave new solutions to societal problems, showing just how big an effect the NPC Logic development can have on the world, also showing how the NPC Logic development in GTA-Series game means far more than just being a gimmick in the game.

There are already existing gaming engines that could achieve the function described above: Unreal Engine 5, where a YouTuber is able to talk to an NPC generated by Unreal Engine 5 in his own voice. The NPC has a basic self-consciousness and is able to converse with the player.

## 6 Conclusion

NPC Technology in GTA and the whole Game world in general is gradually improving and has the future possibility of using even more AI and assistive technology such as machine learning. The in-game design of NPC has been slowly improving and will introduce more and newer functions for NPCs, slowly turning them from characters controlled by line of codes into more intelligent being that are controlled by their own will. Where their self-consciousness could gradually improve and became more sophisticated and provide more realism and playability for the players. Which could benefit the whole society through being a possible solution for mental health problem, giving people a place of escape from their real-world troubles while still experiencing a very surreal experience.

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