

# Machine Learning in Gaming

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## ABSTRACT

Machine learning (ML) is a subset of artificial intelligence that uses historical data to build predictive and analytical models. From agriculture to cancer diagnosis in healthcare, machine learning is changing nearly every industry. ML is a powerful tool that is already in use across game development. It is used in gaming for a variety of purposes, including creating more dynamic AI for non-player characters, personalizing the player experience, and streamlining game development. It allows developers to create better-looking, higher-quality games with less time and effort. In this paper, we will explore the various applications of machine learning in gaming.

**KEYWORDS:** machine learning, artificial intelligence, deep learning, gaming, gaming industry, video games.

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## INTRODUCTION

Machine learning (ML) is the field of computer science that trains computers to learn and act and predict things like humans do, and improve their learning over time in autonomous fashion. It is a way for computers to learn things without being told what to do step-by-step. It is like teaching a computer to figure things out by showing examples of things you want it to recognize or do. It works by giving a computer many examples to learn from. Machine learning is revolutionizing almost every industry, from crop planning in agriculture to cancer diagnosis in healthcare. There are lots of examples of machine learning in use today. These include speech recognition, self-driving cars, and personalized recommendations [1].

Machine learning is transforming the gaming industry in various ways, supporting everything from asset creation to automated testing. It is applied to improve gameplay through adaptive difficulty and realistic animations, generate game content like landscapes and quests, and even aid in quality assurance through automated playtesting. Machine learning technology has transformed the gaming world, making games

more engaging, adaptable, and life-like for players. ML also helps analyze player behavior to inform game design and marketing strategies.

## WHAT IS MACHINE LEARNING?

Machine learning is a subfield of artificial intelligence that uses algorithms trained on data sets to create models capable of performing tasks that would otherwise only be possible for humans, such as categorizing images, analyzing data, or predicting price fluctuations. It uses algorithms (essentially lists of rules) trained on data sets to create self-learning models capable of predicting outcomes and classifying information without human intervention. It focuses on algorithms that can “learn” the patterns of training data and, subsequently, make accurate inferences about new data. This pattern recognition ability enables machine learning models to make decisions or predictions without explicit, hard-coded instructions. To ensure such algorithms work effectively, however, they must typically be refined many times until they accumulate a comprehensive list of instructions that allow them to function

correctly [2]. A symbol of machine learning is shown in Figure 1 [3].

Generally speaking, a learning problem considers a set of samples of data and then tries to predict properties of unknown data. ML builds heavily on statistics because when we train a machine to learn, we have to give it a statistically significant random sample as training data. Intelligent machines are increasing doing incredible things: Facebook recognizes faces in photos, Siri understands voices, and Google translates websites [4].

Machine learning techniques are transforming many fields including computer science, engineering, mathematics, physics, neuroscience, and cognitive science. We are surrounded by ML-based technologies: search engines learn how to bring us the best results, digital cameras learn to detect faces, credit card transactions are secured by a software that detects frauds, and cars are equipped with accident prevention systems that are built using ML algorithms [5]. In ML, data plays an indispensable role, and the learning algorithm is used to learn from the data. ML algorithms are now easy to use. One can download packages in Python. Programming languages used in ML include C++, Java, Python.

As its name indicates, machine learning works by creating computer-based statistical models that are refined for a given purpose by evaluating training data, rather than by the classical approach where programmers develop a static algorithm that attempts to solve a problem. Because the algorithm adjusts as it evaluates training data, the process of exposure and calculation around new data trains the algorithm to become better at what it does. Algorithms are the computational part of a machine learning project. Once trained, algorithms produce models with a statistical probability of answering a question or achieving a goal. Unlike in expert systems, the logic by which a machine learning model operates is not explicitly programmed; it is learned through experience. Machine learning has come to dominate the field of AI: it provides the backbone of most modern AI systems, from forecasting models to autonomous vehicles to large language models (LLMs) and other generative AI tools. Machine learning has become a household term in recent years as the concept moved from science fiction to a key driver of how businesses and organizations process information [6].

As shown in Figure 2 [3], there are different types of machine learning. The four major types of machine learning are supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning, each suited to different kinds of data and

outcomes. Different types of machine learning include the following [7]:

- *Supervised Learning*: The program is “trained” on a pre-defined set of “training examples” from a “teacher,” which then facilitate its ability to reach an accurate conclusion when given new data. In this case, the data comes with additional attributes that we want to predict. A common case of supervised learning is to use historical data to predict statistically likely future events. Under supervised ML, we have regression ML and classification ML.
- *Unsupervised Learning*: As their name suggests, unsupervised learning algorithms can be broadly understood as somewhat “optimizing themselves.” Unsupervised algorithms do not need to be trained with desired outcome data. The program is given a bunch of data and must find patterns and relationships therein. A typical goal of unsupervised learning may be as straightforward as discovering hidden patterns within a dataset. Without being told a “correct” answer, unsupervised learning methods can look at complex data and organize it in potentially meaningful ways.
- *Reinforcement Learning*: Reinforcement learning models are trained holistically through trial and error. Reinforcement learning is a method with reward values attached to the different steps that the algorithm must go through. So, the model’s goal is to accumulate as many reward points as possible and eventually reach an end goal. Reinforcement learning is an area of machine learning concerned with how software agents ought to take actions in an environment so as to maximize some notion of cumulative reward.
- *Deep Learning*: Deep learning (DL) is a specialized form of machine learning that uses artificial neural networks to mimic the human brain. It is a type of machine learning technique that is modeled on the human brain. It is an advanced technique for handling complex tasks like image and speech recognition. The way in which neural networks are trained can be described as deep learning. It is called deep because the network of neurons is arranged in several hierarchical levels. Deep learning laid the foundation for advances in generative artificial intelligence.

## MACHINE LEARNING IN GAMING

Recent developments in machine learning have conquered the gaming industry. Games of late have changed radically mostly due to machine learning

(ML) innovations. Today, machine learning in games can be observed in all stages of game development. Machine learning agents have shown great success in a variety of different games. There has been a significant application of machine learning on games such as Atari/ALE, Doom, Minecraft, StarCraft, and car racing. There have been attempts to make machine learning agents that are able to play more than one game. The reason that machine learning has exploded in the last 5 years is due to major improvements in GPU processing speed and the monumental amount of data that is available for machine learning and deep learning algorithms to feed on.

Games are becoming more lifelike and fun due to natural language processing (NLP) and conversational AI. Applying AI in games permits the construction of competitive opponents to challenge players. ML enables games to create intelligent non-player characters (NPCs) that act and respond like real beings. Deep learning takes things a step further by learning from players and environments. These technologies let players chat with characters in a very human-like way. NLP also powers in-game features. Players can use voice commands to interact with the game. For example, Google's Dialogflow is a platform for natural language processing that enables users to create conversational interfaces and chatbots [8].

## APPLICATIONS OF MACHINE LEARNING IN GAMING

Regardless of learning style or function, all combinations of ML algorithm consists of representation, evaluation, and optimization. Most games incorporate machine learning models to some degree. This helps developers save time while creating more engaging video game attributes. One of the applications of machine learning in game development that has taken the most precedence is the realization of new functionality in the form of non-player characters (NPCs) that possess superior intelligence. Common areas of application of machine learning in gaming include the following [9-11]:

- *Gaming:* There are currently two key areas machine learning assists in game development: helping game developers build the games and act as a gaming companion against or alongside players. The most publicly known application of machine learning in games is likely the use of deep learning agents that compete with professional human players in complex strategy games. Chess is a turn-based strategy game that is considered a difficult AI problem due to the computational complexity of its board space. Go

is another turn-based strategy game which is considered an even more difficult AI problem than chess. Machine learning can allow the graphics of the game to change based on a player's actions. AI, ML, and gaming are all complex concepts, but they do not have to be confusing for kids. Figure 3 shows how to explain AI/ML gaming to kids [1], while Figure 4 shows a kid playing a game [12].

- *Video Games:* The video game market has become an established and ever-growing global industry. AI and ML are key driving factors in the video game industry. They could be the key for video game developers to generate the level of content needed to remain competitive and keep players engaged. Implementing machine learning in video games can help developers create higher quality, more entertaining, and dynamic game experiences that adapt to the player's in-game choices and actions. Video game developers can use machine learning in both gameplay and the game development process. Cloud gaming and virtual and mixed reality games are two of the trends driving AI/ML in video games. Figure 5 is a representation of ML in video-game industry [13], while Figure 6 shows an example of playing games [14].

- *Game Development:* Today, it is a must that each game developer applies ML in his or her game helping to make the game more attractive and easier. Game developers rely on assessing the behavior and habits of each gamer. Their goal is to enable them to be fully involved, improve the chance of buying content, and provide them with the best possible gaming experience. AI and ML can touch every part of the game development lifecycle, from automating tedious or cyclical tasks to generating code and content. Game developers can use machine learning to make the game development lifecycle as a whole more efficient, especially with the ability to automate testing for bugs. Machine learning and AI could be the key for video game developers to generate the level of content needed to remain competitive and keep players engaged. Figure 7 shows what ML in game development entails [14].

- *Music Generation:* Advancements in machine learning have enhanced the algorithms capable of supporting creativity - the creation of not just games but music, art, and more. Music is often seen in video games and can be a crucial element for influencing the mood of different situations and story points. Machine learning has seen use in the experimental field of music generation; it is



uniquely suited to processing raw unstructured data and forming high level representations that could be applied to the diverse field of music.

- *Racing Games:* Deep learning has found its way into racing games, where AI learns to drive vehicles autonomously. This application is closely related to real-world AI technologies used in self-driving cars. In racing games, AI agents are trained in simulated environments, where they learn to navigate tracks, avoid obstacles, and compete against human players. Over time, racing game becomes so good that it can react to unpredictable player moves, making races more competitive and exciting.

## BENEFITS

Machine learning can save game engineers time and energy while at the same time offering a unique user experience to players. By using machine learning both in the game design itself and in the game development lifecycle, game developers can bring their products to market faster and for a lower cost. Machine learning can also give you insight into the best method of optimizing your pricing model for games. Other benefits of machine learning in gaming include the following [14]:

- *Automation:* Repetitive tasks take up a lot significant part of a game's development time. Machine learning can automate tedious tasks like game testing and feedback analysis and allow your team to focus on tasks that add higher value to your software, such as creating a vision for the product, developing concepts, and prioritizing features. This can shorten the time span in getting games to market and provide clients with a higher quality product. ML can automate aspects of quality assurance (QA) by having algorithms playtest games to identify bugs and issues, reducing the burden on QA teams.
- *Personalization:* Game designers can use AI/ML to better understand player behavior and to create personalized and more engaging experiences. By analyzing player data, machine learning can tailor the experience to individual players, such as adjusting difficulty levels or recommending content.
- *Game Testing:* Machine learning algorithms are incredibly useful for game testing because they can process and analyze large amounts of data very quickly. They can test the game on many different hardware configurations and platforms to ensure compatibility across various systems. By using machine learning for testing, game developers can catch and fix problems more

efficiently before releasing their games to players. For example, Amazon Web Services (AWS) ML consists of services and tools that are very widely used for multiple applications like game testing and quality assurance.

- *Predictive Analytics:* Understanding player behavior is a key element in the gaming industry's quest to enhance player engagement. Machine learning algorithms analyze player data to predict preferences, playstyles, and potential points of disengagement. Developers can use ML to predict player actions and behavior, which helps in creating more engaging scenarios and predicting which players are most valuable. Deep learning algorithms are more accurate at making predictions about player behavior and analyzing behavior to gain insights.
- *Build Bigger Games:* The competitive nature of the gaming industry means that game makers have to go further to stand out. One trend in gaming is to make increasingly larger and larger games, offering players more content, like additional storylines or characters.
- *Fraud Detection:* In the realm of online gaming, fraud and cheating pose significant challenges. Machine learning algorithms play a crucial role in detecting and preventing fraudulent activities. Fraud detection is one of the most necessary applications of machine learning. The number of transactions has increased due to a plethora of payment channels – credit/debit cards, smartphones, numerous wallets, and much more. At the same time, the amount of criminals have become adept at finding loopholes. Figure 8 shows a typical fraud detection [15].
- *Immersive Experience:* Video game developers are constantly trying to get games to be more immersive and realistic. Advanced machine learning techniques, such as deep learning, help game developers create the immersive and personalized worlds players expect in modern games. Figure 9 shows some users of immersive technology [16].
- *Enhanced Player Experience:* Machine learning in gaming definitely promises to bring profound effect on both the games and the player. The main driver of success in a video game is whether or not the players have fun playing it. Machine learning in game development helps developers identify what players like and dislike by aiding in the analysis of how players interact with each other and the game world. These tools can help identify and prevent cheating, making online

gaming fairer and more enjoyable for all. However, it takes a lot of people, time, money, and other resources to create a truly all-encompassing lifelike experience for players. By surprising players, you will entertain them, making your game memorable and interesting.

## CHALLENGES

There is great potential for advanced learning in games, but it must be used carefully to avoid common problems such as mimicking stupidity, set behavior, and more. Research has shown that challenge that is too far above a player's skill level will ruin lower player enjoyment. By studying how players behave, games can adjust their difficulty and challenges to keep things exciting. Developing AI and ML technologies can be incredibly challenging for software developers. One of the biggest obstacles faced by developers is finding the right data to train their algorithms effectively. Other challenges of machine learning in gaming include the following [17-19]:

- *Ethical Considerations:* While the integration of machine learning in gaming brings forth a myriad of benefits, it also raises ethical considerations. The collection and analysis of player data for personalization and improvement must be conducted with utmost respect for player privacy. Striking a balance between enhancing gameplay and safeguarding player information is crucial to maintaining trust in the evolving landscape of machine learning-powered gaming.
- *Human Employment:* Concerns has been raised about the potential impact to human employment as is often the case with any example of a machine taking over a task that had historically been done by people. Researchers in this case responded that AI would “aid in development” and will help novice game developers reach levels of development that would have been out of their reach without AI assisting.
- *Limitations:* One challenge of applying machine learning to game development is the significant difference between the two disciplines. It is rare for a machine learning practitioner to understand the ins and outs of game development, or for a game developer to understand the complexities of machine learning. Although this situation has begun to change more recently, we still have a long way to go.
- *Training:* Training time is a costly, scarce resource across domains such as commercial aviation, healthcare, gaming, and military operations. Students becoming disengaged in

learning exercises is a chronic problem that greatly hampers the ability of educators to give students the tools they need to succeed. Researchers in artificial intelligence and machine learning have sought to develop methods for predicting student and player retention, which is a strong first step in correcting the problem of trainee dropout.

- *Complex Systems:* There is a lot of complexity involved in designing AI systems that can learn from data with minimal human intervention. It is no wonder that many developers in this field feel overwhelmed. A machine learning algorithm's strength is its ability to model complex systems. Complex systems are developed with codes and specialized tools to build a gaming world that is more real and practical. Game app developers pay close attention to detail and work on presenting minute information so that images stand out dynamically. The player is able to interact with its environment and the opponents. Figure 10 depicts balancing the video game complexity [15].

## FUTURE OF MACHINE LEARNING IN GAMING

The global game industry has been on the rise ever since the introduction of smartphones and video game consoles like the Xbox and the Playstation. As illustrated in Figure 11 [14], the game industry is already bigger than the film, television, and music industries combined. Video games are one of the most profitable forms of entertainment. There are many ways to include machine learning in video games. More and more games rely on machine learning in gaming, and the game players are thrilled to see this technology in action. The more a game is played, the more machine learning actions will happen behind the curtain. Many game players can see the importance of machine learning which is visible in many games [20]. However, machine learning is well greeted with a certain amount of caution by game developers.

Machine learning has various use cases in almost every industry in this generation, and almost most of the things will be replaced by machines and robots by the end of this era.

Highly effective deep learning agents are likely only a desired choice in games that have a large competitive scene. As current technology continues to develop, the more advanced machine learning in the gaming industry will open the doors for something truly wonderful such as combining the virtual world with the real one. In the future, it could even enable game teams to create things that are currently impossible due to time, cost, and effort constraints.

## CONCLUSION

Machine learning is the ability for a system to learn and improve from experience, without being explicitly programmed. It may be regarded as an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Integrating AI and machine learning in gaming has revolutionized how we play and learn. Machine learning algorithms also enable games to adapt to the player's level and playing style, making the experience more enjoyable and engaging. Unfortunately for the gaming industry, machine learning in game development is still in its infancy and has not been hitting the headlines.

As computers and software continually advance, the gaming community can look forward to even more advanced applications of machine learning in game development. AI and ML are increasingly important in today's job market, and students who are proficient in these technologies will be well-positioned for future success. More information on machine learning in gaming is available in the books in [5,21-24].

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Figure 1 A symbol of machine learning [3].

### Types of Machine Learning

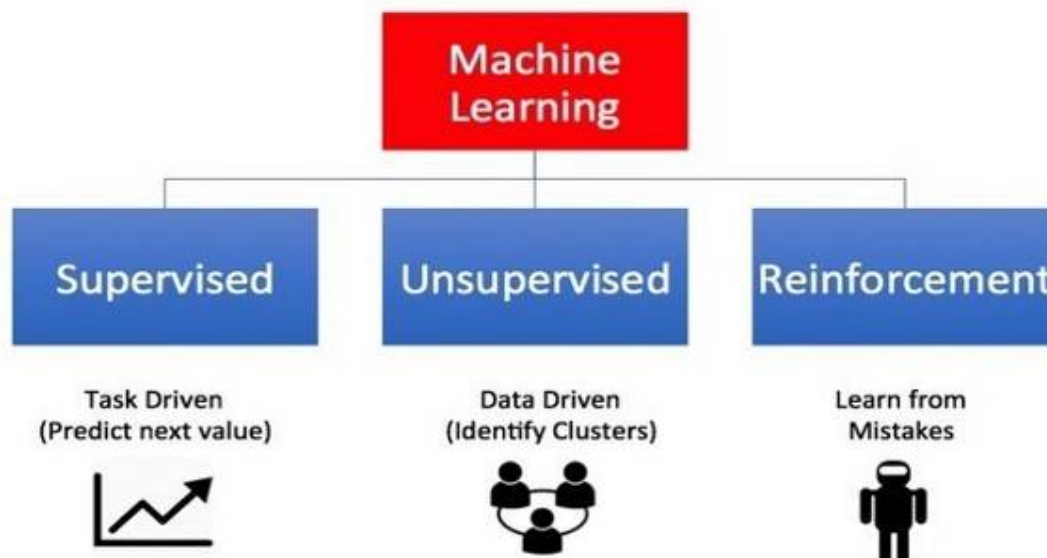
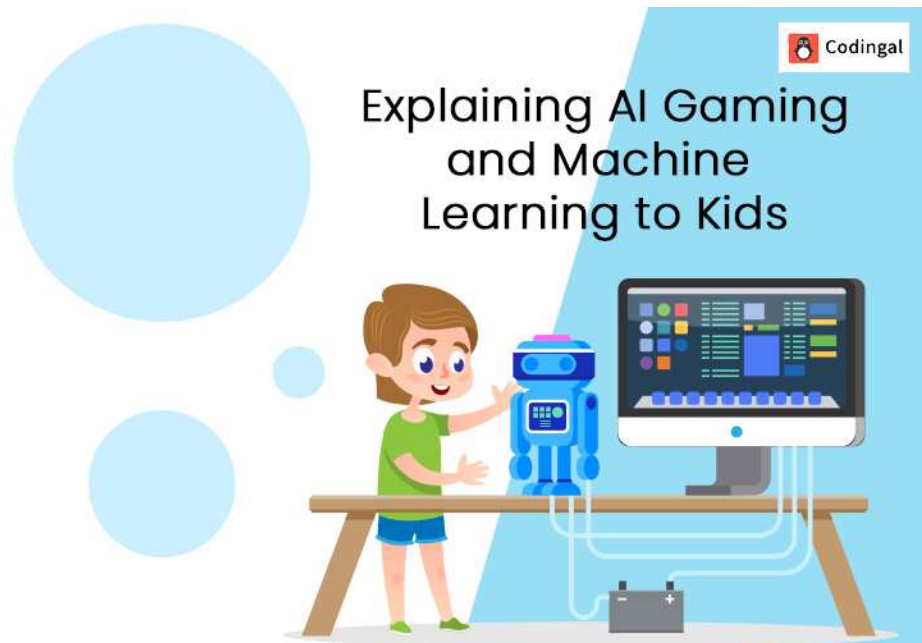


Figure 2 Different types of machine learning [3].



**Figure 3** How to explain AI/ML gaming to kids [1].



**Figure 4** A kid playing a game [12].



**Figure 5** A representation of ML in video-game industry [13].





**Figure 6** An example of playing games [14].

## Machine Learning in Game Development

-  **Algorithms Playing as NPCs**  
NPCs will respond to your actions in unique, unexpected ways.
-  **Modelling Complex Systems**  
The game could predict and alter downstream effects.
-  **Making Games more Beautiful**  
Textures and objects will render dynamically as you get closer
-  **More Realistic Interactions**  
NLP will create more realistic conversations and responses.
-  **Universe Creation on the Fly**  
Open world games have the potential to be unlimited in size.
-  **More Engaging Mobile Games**  
AI chips in phones will bring the power of ML to phones.

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**Figure 7** What ML in game development entails [14].



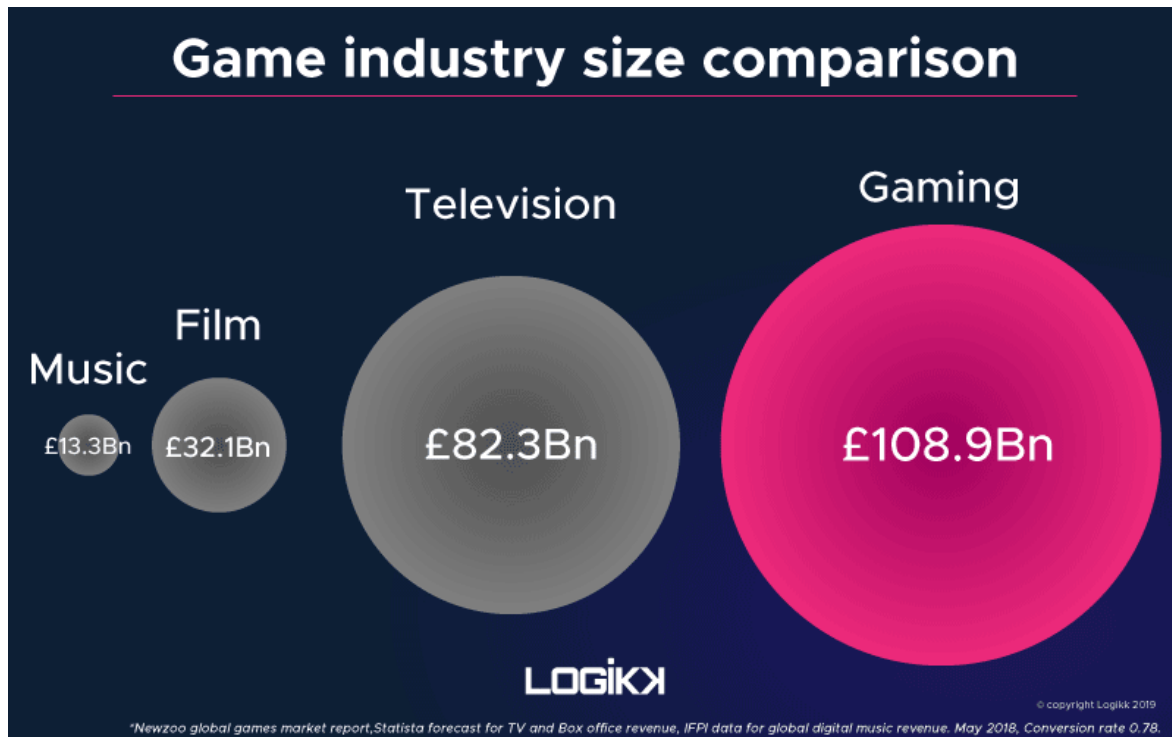
Figure 8 Fraud detection [15].



Figure 9 Some users of immersive technology [16].



Figure 10 Balancing the video game complexity [15].



**Figure 11 Game industry size comparison [14].**

