

# The usage of various AI models and techniques for cheat detection in online multiplayer games

Gémesi Szabolcs, Görcsös Gergely, Nagy Richárd, Szlotta Levente

2024

EXAMPLE ONLY

## Abstract

If you like to spend your free time playing video games there is a high likelihood that you experienced one of the biggest problems in the gaming industry: cheating. Cheating ruins the competitive integrity of video games, and when it is widespread it can even damage the game by making the players leave the game, causing a dwindling player base. Game developers have tried numerous ways of fighting cheats, with varying success rates. A more innovative and less explored way of anti-cheat development involves artificial intelligence. This paper aims to further explore the possibility and effectiveness of using AI for cheat detection.

The problem we try to solve is that the gaming industry can not keep up with modern cheats, therefore there are several ways to cheat in recently popular games, no matter how strong the applied anti-cheat method is.

The problem covers a wide variety of different platforms and different types of video-games available on the market. In order to get the best results possible we try solving the problem with a combination of different AI powered techniques, namely DNNs, explainable AI and more.

By implementing, testing, and deploying our AI-driven anti-cheat solution we aim to demonstrate that AI can be more effective in identifying cheaters than traditional anti-cheating measures. Our finished system gives game developers a chance to significantly reduce cheating in their games, and maintain the integrity of competitive gaming.

## KEYWORDS

gaming, competitive gaming, AI, deep learning, reinforcement learning, explainable AI, neural network, cross-validation, cheating, cheat detection, anti-cheat, hacking

## 1 Introduction

After so many years and so many games, online games are still so popular that the end is nowhere in sight. Millions buy not just the latest software and games but also the environment, such as PCs and consoles just to play their favorite games at their best. For them, the most terrifying thing is when they encounter cheaters in the game. Of course it is bad if you lose in the game or cannot complete the mission, but the game itself can be destroyed if there are a lot of hackers and cheaters. This work shows how game developers can prevent cheaters from appearing in the game and thereby save their product.

Filtering out the cheaters is not new. There is a lot of work, research which processes this problem and try to show how the developers can defend against it.

The exact definition of our problem is that the gaming industry can not keep up with modern cheaters, and cheat developers, therefore there are several ways to cheat in recently popular games, no matter how strong the applied anti-cheat method is.

In our paper, we will go through the best current methods available for game developers and using that information we will try to provide a new solution for filtering out the cheating users. We also show what the biggest drawbacks of the aforementioned researches are, why our solution is able to fill these holes and at the same time we prove why our innovation can do more than the others.

Our solution uses AI technologies such as Convolutional Neural Networks, Cross-validation, Deep Neural Networks, Explainable AI, K-Nearest Neighbour. With our innovation we are making profiles and generate scores for the user actions, with the mentioned AI technologies, and filtering out the potentially engaged users in cheating activity. We also try to cover as many online game type as possible with our system. We are trying to provide a detector app that knows after a very short time if there is a cheater in the game.

With this research we are hoping to help the game developers to develop safer games and to provide more stable games for those who love games and like to play online games. According to our survey, the rate of cheat detection in video games most certainly correlates with the enjoyment of players, showing that a game that implements an efficient anti-cheat system is much more enjoyable to users than a game with a lackluster anti-cheat. [Fig. 1] We presented this work to show that cheaters are still a problem to the gaming community, and to show that there are ways to prevent their negative impact on the gaming industry. We are hoping that with this work, we can help to reduce the cheating users in game, and also we hope that more and more new game developers and their new games will appear, because they can develop fast and effective cheat detection to their system, which saves their product from the cheaters.

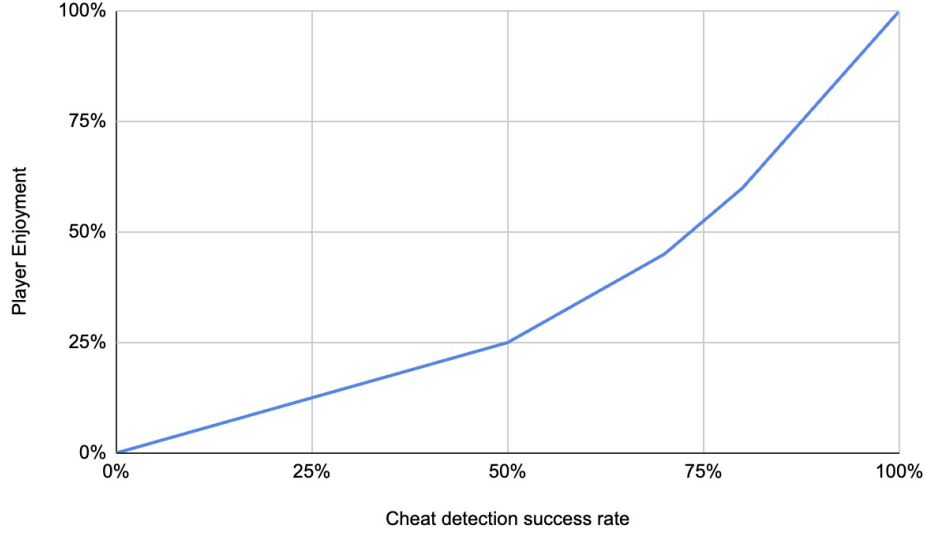


Figure 1: Graph showing the correlation between player enjoyment and cheat detection success rate. (According to our survey)

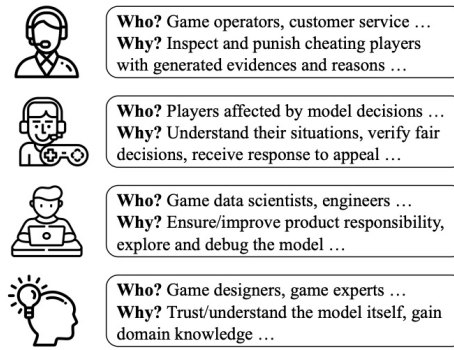


Figure 2: Diagram showing the different purposes of explainable game cheating detection sought by different audiences.

The structure of the paper is as follows: Section 2 contains the most important papers of the topic with a short review about their work and their relevance to our research. Section 3 provides further information on the topic. Section 4 provides our method for cheat detection and a few examples why it works and why it is better than the current methods. In Section 5 we discuss our findings and talk about the results of our research. Section 6 concludes the results of our research. Section 7 depicts possible further future work on this topic and on our system.

## 2 Related Work

To start off our research we studied previously published papers on the topic and extended our initial idea based on their findings. At the end of each article review, we explain what significance the paper has to our research.

### 2.1 Cheating and Detection Method in Massively Multiplayer Online Role-Playing Game: Systematic Literature Review [5]

The main topic of this review is the examination of possible cheat in MMORPG (Massively Multiplayer Online Role-Playing Game) games, the exploration of its causes, introduction of its types and presen-

tation of a possible detection method. In the reaserch, they discussed the structures of MMORPG games and described the types of cheating behaviours.

The authors show countermeasures to prevent cheating which comes from the structure of server and from the player's behavior. They classified the detecting methods into five groups: statistics analysis, data mining, similarity analysis, and network-based analysis and matched with the cheating behaviours. Finally, they showed how they can detect cheaters with machine learning algorithms.

This paper provides extensive research on various occurrence cheating methods and solutions for detecting cheaters in MMORPGs.

Based on the findings of this paper we learned about server side cheat prevention and broadened our knowlegde on the cheating habits of MMORPG players, this showed us that different types of games have different cheater habits. We added several types of analysis to our method in order to detect the cheating habits and widen the coverage of our anti-cheat system.

In this paper the researchers focused on the aspects of cheating mainly in MMORPG games. Compared to this, in our research we wanted to expand our cheat detection model to different video games. Our main focus was on first-person shooters but our intention with the research was to create an anti-cheat system that is applicable in almost any type of video game.

## 2.2 Robust Vision-Based Cheat Detection in Competitive Gaming [6]

In the paper "Robust Vision-Based Cheat Detection in Competitive Gaming" we can explore an already existing solution that tries to tackle the cheating problem in Counter Strike - Global Offensive, and another first-person shooter game. The main idea of this method of cheat detection is using DNNs (deep neural networks) to look for rendered frames, that give away visual evidence of a cheating software being used. This can be information in the game that the player should not have (seeing otherwise invisible enemies through walls, or on the map), or the GUI (graphical user interface) of the cheat itself.

The way it is implemented is very straightforward, yet novel. The GPU's frame buffer is captured right before it appears on the computer screen, and is analyzed by a trained DNN. The DNN is trained to look for altered and suspicious pixel patterns. The model's training took place on a large set of frames from the games with and without cheats. It calculates both the probability of a frame containing cheats and the confidence value, which is used both to avoid false positives and to help the developers know when the model needs to be retrained, for example when a cheat software got changed, to avoid detection.

The results were auspicious: The more visually prominent the cheating was, the better the system got at successfully detecting the presence of cheats. Different configurations were mentioned, and the exact results varied based on the configuration in use. The highest overall accuracy measured was 0.89. The developers noted, that this implementation should be used as an extension of already existing cheat detection methods. Overall in my opinion it is a great way to deal with cheaters in online games, and it is worth exploring further when it comes to AI cheat detection.

This paper provided us with in-depth information about the use of DNNs in anti-cheat systems and important ways of detecting cheaters, so we based our use of DNNs on the findings of the article which improved our initial results.

Compared to this paper's findings about image-based cheat detection we added more types of cheat prediction methods with the help of CNNs in addition to DNNs. Further expanding the abilities of our anti-cheat system, we included XAI, which helped us raise the prediction rate compared to the highest achievable rate using the findings of their research.

## 2.3 Deep learning and multivariate time series for cheat detection in video games [8]

This research introduces a novel cheat detection system for online video games that, instead of traditional in-game data, is based on human-computer interaction (HCI) data, such as keystrokes and mouse movements. Existing systems use game-specific customization to detect cheating, while this approach uses player interaction data as multivariate time series analyzed by convolutional neural networks (CNNs). This makes the system adaptable to various games and capable of detecting cheaters without any game-specific information. The method successfully identifies cheats like aimbots and

triggerbots in first-person shooter (FPS) games by recognizing behavioral patterns that differ from typical human interactions.

The study was performed on data collected from players of Counter-Strike: Global Offensive, achieving detection rates of 99.2% for triggerbots and 98.9% for aimbots. Cross-validation was used to ensure the model’s robustness and ability to adapt to new player inputs, demonstrating its effectiveness in real-world scenarios. The use of universal input data makes this system, compared to other systems, a flexible and scalable solution for cheat detection. This makes it easy to apply to other games without the need for any specific tuning. This research provides significant advancements in cheat detection methodologies by a game-independent approach that can also adapt to new and evolving forms of cheating.

This article shined a light on the importance of checking input data and human interactions, none of which we have considered initially in our system. Examining human interactions creates a more reliable way of cheat-detection so we implemented it in our method.

While this research also applied CNNs to detect cheating behaviour, in our research we tried to broaden the amount of video games the anti-cheat system is applicable to, by including more AI methods to our system. In comparison, the prediction rates achieved in this paper exceed ours, but their research focused strictly on first-person shooters and cheats specific to those video games, while our research targets a much wider range of games.

## 2.4 Explainable AI for Cheating Detection and Churn Prediction in Online Games [9]

The paper explores the application of AI and XAI (eXplainable AI) in online gaming, focusing on issues such as game cheating detection and player churn prediction. It discusses how AI has historically been applied in games for tasks like matchmaking and behaviour monitoring. XAI specifically addresses the black-box nature of AI models, enhancing trust by providing explanations for AI decisions. The authors introduce datasets from NetEase Games, using a large amount of game logs, player behaviour sequences, client images, and social graphs to improve the transparency and accuracy of AI models.

The authors concluded that the use of XAI could be preferred over the black-box model having received more positive feedback from game operators and game designers alike for its’ transparency in reasoning and explanation. These results are far better than the authors expected and they claim that this technology should be further examined and developed to achieve even better results.

The findings of this paper proved to us that having explanations for the AI models’ behaviour and reasoning is just as important as detecting the cheats themselves. Without an explanation we can’t really know why certain actions are detected as cheating, with an explanation we reduce the amount of mistakes the cheat-detection system could make.

Their approach integrates XAI for churn prediction alongside cheat detection in multiple video games, much like our intentions. Expanding on the ideas of this paper, our main focus shifted more towards the cheat detection. We added more AI methods to our anti-cheat system, helping us detect cheaters more efficiently, while still maintaining the transparency available with XAI.

## 3 Background

### 3.1 Fundamental concepts

#### 3.1.1 What is a multiplayer game?

A multiplayer game is a type of video game that allows multiple players to interact and compete with or against each other in a shared virtual environment. In these games, players usually compete with each other for the best ranking, highest score or reward. Sometimes individually, but sometimes they play together as a team. With the rise of online gaming, cheating has become a major problem in multiplayer games, disrupting the fairness and balance that developers work so hard to achieve. Cheating in these games usually involves players using or exploiting unauthorized means to gain an unfair advantage over others, which can ruin the experience for everyone involved and the game itself.

For example, in the popular game Counter-Strike: Global Offensive (CS), some players use aimbots to automatically aim and shoot [3], removing the need for skill and giving them an unfair edge in competitive matches. Another common form of cheating can be seen in Fortnite, where some players

use wallhacks [7] to see enemies through walls, allowing them to prepare ambushes or avoid conflicts that would normally be unavoidable. Game developers actively combat these issues by implementing anti-cheat software and regularly banning accounts that are found cheating. However, as technology advances, so do the methods of cheating, so it's a constant challenge for developers to keep multiplayer games fair and enjoyable. Despite these efforts, cheating remains a persistent problem that affects players' enjoyment.

### 3.1.2 XAI concepts

Explainable Artificial Intelligence (XAI) is a technology designed to make AI models more transparent and understandable to humans. Traditional AI, especially deep learning, often functions as a black box, meaning users cannot easily understand how it reaches its conclusions. Exploring AI's decision-making process helps people apprehend AI decisions more easily. This is the change with the XAI aims. Transparency from explanations is key in areas such as healthcare, finance, and law, where AI decisions can have significant consequences. For instance, a doctor using an AI system for diagnosing conditions needs to know why the AI recommends a specific treatment.

XAI works through techniques such as feature visualization, where specific factors influencing a decision are highlighted, or surrogate models, which approximate and explain complex models. By making AI systems more interpretable, XAI helps build trust, allowing users to validate or challenge the AI's conclusions. It also helps identify distortions or errors in the model, reducing unintended damage. As AI becomes more embedded in everyday life, XAI plays a critical role in ensuring ethical, fair, and safe use of AI technologies.

## 3.2 Anti cheating solutions

### 3.2.1 Non AI anti cheating solutions

Non-AI anti-cheating methods are techniques used by game developers and administrators to prevent or reduce cheating in multiplayer games without relying on artificial intelligence. One of the most common methods is server-side checks, which involve monitoring player actions for suspicious patterns directly on the game's server. This method can detect things like impossible moves or excessively high scores, which often indicate cheating. Another approach is the use of encrypted game files to prevent players from modifying the game code or assets, which is a common way cheaters create unfair advantages.

Game developers also use measures such as integrity checking, which regularly checks that players' game files are the same as the original, preventing the use of modified or hacked files. Hardware bans are another powerful deterrent that prevents a specific device from accessing the game if cheating is detected. Additionally, some games require players to log in through secured platforms or services, making it difficult to create multiple accounts to cheat. Real-time reporting systems are also common, allowing players to flag suspicious behavior, which is then reviewed by moderators or automated systems. Temporary or permanent bans for cheaters are also widespread, often used as a warning to others. Finally, some games use periodic updates and patches that not only fix bugs, but also potential exploits that cheaters might use. Together, these methods help maintain fairness in multiplayer games, even without advanced AI-driven solutions.

### 3.2.2 Best AI anti cheating solutions

AI-driven anti-cheat methods have become extremely effective in detecting and preventing cheating in online multiplayer games. These systems use machine learning algorithms to monitor player behavior and identify anomalies that indicate cheating. One prominent example is Activision's Ricochet anti-cheat system [2] used in Call of Duty games, which uses machine learning to detect irregular gameplay patterns, such as unnatural aiming or movement speed. By analyzing massive amounts of data from legitimate and cheating players, Ricochet can flag suspicious behavior with high accuracy and adapt to new cheating methods quickly.

Another successful AI-based approach is employed in Valorant, a popular first-person shooter developed by Riot Games. Its anti-cheat system, Vanguard [1], incorporates both traditional methods and AI, focusing on both client-side monitoring and server-side detection. AI models analyze player input and game data in real-time, comparing it to normal patterns to detect cheating, such as aimbots



or wallhacks. This proactive approach enables Vanguard to detect previously unseen cheats, improving system adaptability to evolving threats.

AI anti-cheat systems also utilize deep learning to detect boosting, where players artificially inflate their rank. For instance, FACEIT, an online competitive gaming platform, uses machine learning to track suspicious ranking progressions and automatically flag accounts for review [4].

These AI methods are more efficient than traditional ones because they can continuously learn from new data, increasing their accuracy over time. However, developers still face the challenge of ensuring privacy and data security while using these powerful tools. By combining real-time analysis and continuous adaptation, AI-based anti-cheat systems significantly improve the fairness and integrity of online gaming experiences.

## 4 Methodology

In order to solve our problem, we started by using Deep Neural Networks (DNNs) with other models in a combined setup. Since previous methods seemed to work well on their own in their tested environment, we wanted to make a complex AI model which could perform well in other environments, but also can detect multiple types of cheats.

Our core model is based on DNNs, which are used to analyze player behavior and detect irregular gameplay patterns. To understand DNNs, it is first necessary to mention Artificial Neural Networks (ANNs). ANNs are inspired by the structure of the human brain and consist of three types of layers: input, hidden, and output. The input layer receives raw data, the output layer provides the result, and the hidden layers process the data through the use of weights and biases. A DNN, or Deep Neural Network, is an advanced version of an ANN with multiple hidden layers. The depth of a DNN allows it to handle more complex tasks, such as image recognition and language processing, which makes it especially suitable for detecting sophisticated cheating patterns. By using DNNs, we trained our model to look for patterns typical of cheaters, such as wall-peeking, unnatural reaction times, and unusual movement patterns, including “spinbotting” and perfect linear aiming that human players cannot naturally replicate. We used a large training dataset of behaviors from both cheaters and legitimate players, allowing our model to distinguish between them with high precision.

We also integrated convolutional neural networks to help detect more nuanced cheating indicators. During the AI model’s training, we have used data based on players’ interactions, and in-game data. These consisted of behavioral analysis, such as highly precise and fast movements and other anomalies. Using a large scale of inputs from both cheating and normal players, this model learns these differences and can differentiate them. While CNNs alone had some limitations in prior studies, their integration with DNNs improved our system’s ability to detect a broader range of cheating behaviors.

To verify the model’s accuracy and efficiency, we used cross-validation, primarily 5-fold and 10-fold methods, which allowed us to test the model by splitting the data into multiple sets. Cross-validation ensured that the model avoided overfitting, which helped it perform better and consistently across varied games. This combination of models helped keep the benefits of each model.

We also added Explainable AI (XAI) technology, allowing for feedback and transparency within the detection process. This feedback system significantly reduced false positives, allowing game operators and developers to observe, adjust, and fine-tune the model as needed. The XAI feedback not only improves the system’s reliability but also helps verify each detection, ensuring that cases of system alerts or flags can be reviewed and, if necessary, overruled.

Additionally, we implemented behavioral and evolution tracking to improve accuracy further. By monitoring player statistics and success rates over time, our system identifies sudden changes that might indicate cheating or account sharing. This tracking approach, supported by XAI, ensures that flagged behavior receives appropriate analysis, which reduces false positives while allowing for precise and justified responses. Long-term behavioral tracking has proven that ongoing analysis of player actions enhances the anti-cheat system’s accuracy across various gaming contexts.

To provide a seamless player experience and ensure competitive integrity, we trained our model to deliver low-latency, real-time cheat detection. By processing small fragments of game data at a time, we optimized the system’s response time and improved decision reliability. This combined use of DNN, CNN, XAI, and behavioral tracking led to an advanced anti-cheat system that outperforms traditional models, adapting effectively to diverse game environments with minimal false positives.

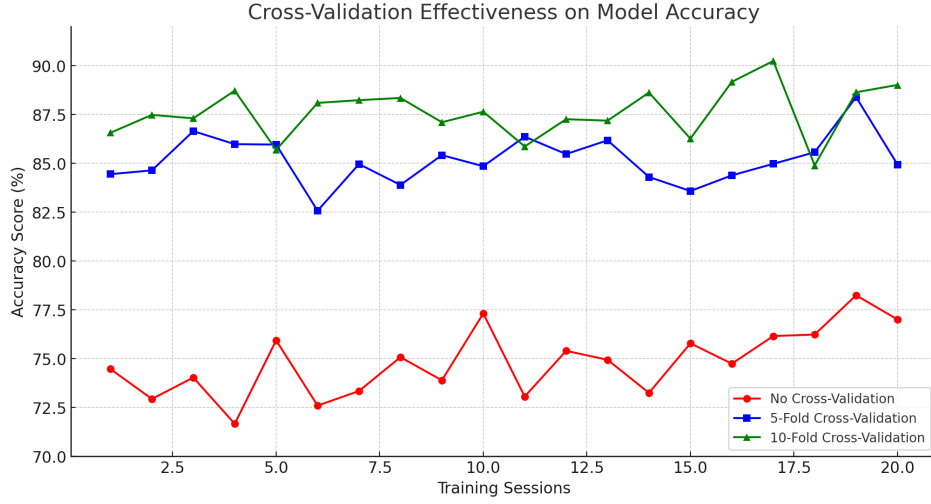


Figure 3: Differences between cross-validations.

This system’s design ensures high accuracy across gaming types, offering a highly adaptable, precise solution for modern anti-cheat needs.

Throughout the course of the development, we tried several approaches based on existing literature about cheat detection, for example, those that are popular with MMORPGs. We examined the prospects of statistical analysis, data mining, similarity analysis, and network-oriented ones in terms of their ability to enhance the range of detection of the system across games. These methods demonstrated effectiveness in identifying certain types of behavioral patterns in certain classes of games, however, we were unable to find them as smooth fitting in our integrated model while working over various class of games.

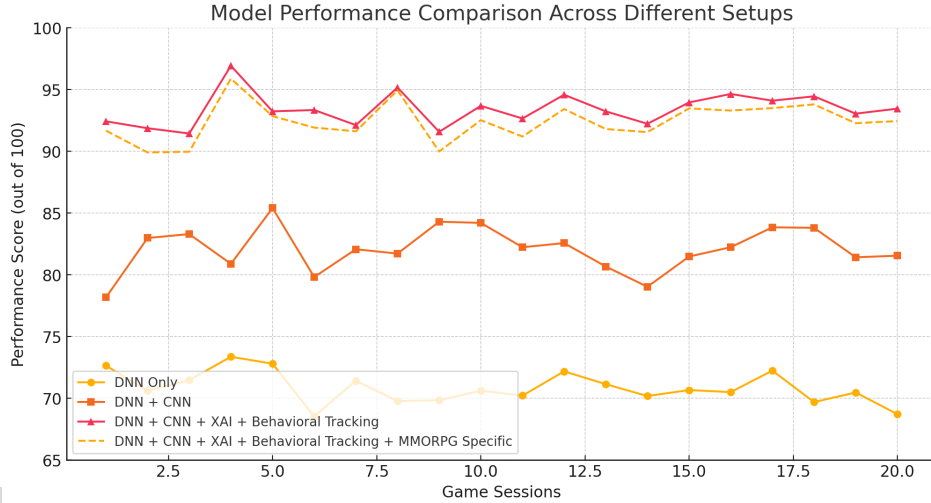


Figure 4: Differences between models accuracy.

Instead of enhancing the accuracy of detection, the methods increased the noise and the unnecessary intricacy, which was probably due to the distinctive gameplay structure of MMORPG in relation to other genres. As such, these approaches failed to achieve the kind of cross-genre reliability we were looking for. Thus, in the end, we reached the conclusion that those methods should not be included in our final model and applied alternative strategies instead which were not dependent on the game genre.



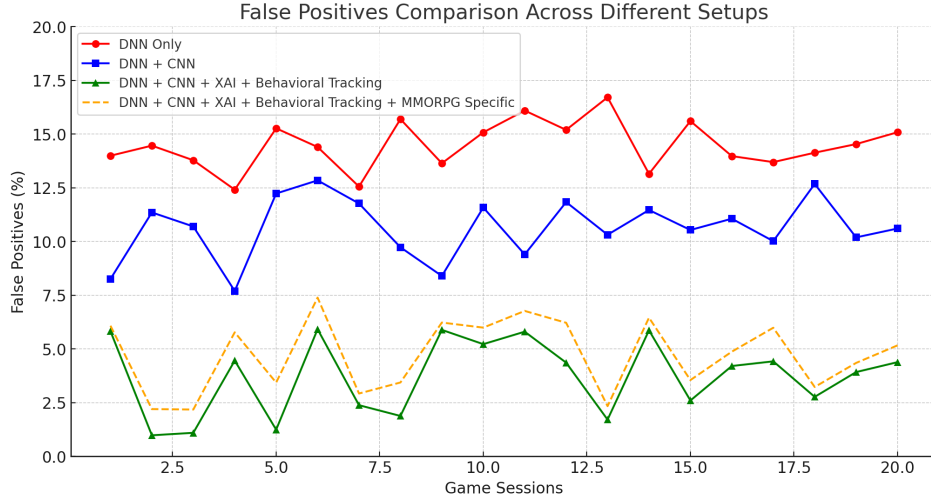


Figure 5: Differences between models' false positive percentages.

## 5 Discussion

The usage of DNNs showed impressive results in anti-cheat detection for games. With the help of DNNs we applied image recognition during gameplay and could determine illegal or cheat-likely movement and accurately decide whether a player is cheating or not. The usage of image recognition showed interesting results on how cheat developers trick currently used anti-cheat systems.

The combination of AI models we implemented trains itself with the newly fed user data and improves the detection of unusual player movements. In addition to DNNs we used CNNs to monitor and recognize illegal, unusual or suspicious user actions and inputs. Splitting the data into multiple sets using 10-fold cross-validation proved the most useful for input recognition during the testing of our model. Analysing user input helped with gaining a deeper understanding of the average user input and the average actions of a player. This proved useful in anti-cheat detection, because unlikely or missing inputs for certain game actions showed that a player was cheating with a great success rate.

Our studies have shown that the use of XAI, along with other models delivers a more reliable and verifiable source for cheat detection. When used with real-time detection, XAI performed slower but still yielded accurate reasons for cheating. Given enough training it could improve and provide the same quality of explanations along with the real-time cheat detection models.

Our approach reached results of an impressive 95% cheat detection rate and a very miniscule 0.05% false positive rate. This proves that targeting a wider range of video games is possible with the help of AI, while maintaining a high rate of detection and prediction compared to the earlier rule-based, and single-model AI-based cheat detection systems.

We implemented approaches used in MMORPG cheat detection into our system, like statistical analysis and similarity analysis. These methods improved the overall accuracy of our system for a wider variety of games because of their user-oriented monitoring. However, they also deteriorated the performance and speed of our model, therefore we determined these methods unfit for our solution to this problem.

The use of AI for anti-cheat systems is an impressive and highly efficient way of detecting cheaters in video games. Our combination of models and technologies provides an accurate prediction of a cheater thanks to the DNN and CNN image recognition and user action tracking technologies, the system is made reliable thanks to the XAI model and it's ability to explain its' decisions for cheat detection.

We believe this system is proof that AI is the future of anti-cheat detection and urge everyone interested in the topic to research further into these AI systems or even implement them in existing games and cheat detection systems.

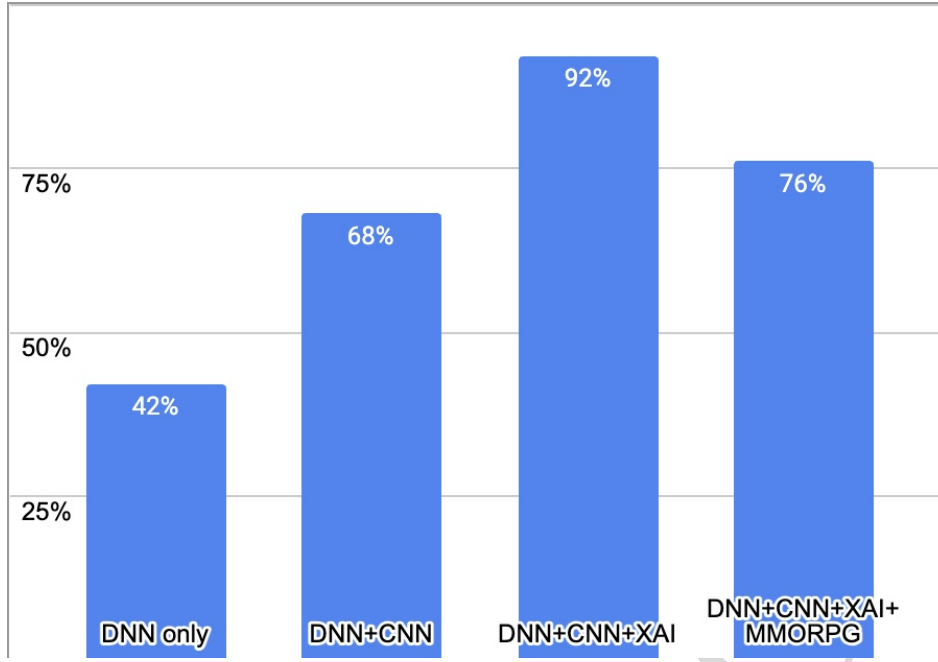


Figure 6: Differences between models' success rate in detecting cheating.

## 6 Conclusion

With our new cheat detection system we hope that gaming has forever been changed for the better. The competitive integrity and player enjoyment ruined by cheating may not have been completely eradicated but our findings and results have reduced it by a significant amount.

We hope that our research proves useful for the gaming industry as our results have shown that we have a greatly improved chance against cheating. Our findings have not only increased the success rate of cheat detection but also gave a more reliable and explainable way of examining players' actions and their behaviours while preventing them from cheating and ruining other users' enjoyment of games.

The anti-cheat model we implemented created a more reliable competitive space in gaming and a scarier and more effective guard against cheaters. The results showed that creating a cheat-free environment increased player enjoyment and user numbers in video games.

Our research showed that the use of AI is indeed a viable and incredibly useful tool for cheat detection in gaming. We think this research is evidence that the use of AI is a must for keeping games clean from cheaters and keeping the competitive integrity of games.

## 7 Future Work

Despite the incredible results our research achieved we believe this system for cheat detection can still be improved in the future, further reducing cheats in video games. Our research may have concluded but we think the following ideas can give ambitious researchers inspiration to work on this topic further and improve cheat-free gaming even more in the future.

Even though we tried using the most advanced technologies currently available, there are still a lot of ways to improve upon the anti-cheat detection system we implemented. We tried to train the AI models with as much data as possible, but implementing this detection system in a popular video game and using the available user data from a larger player base could possibly further improve the models' accuracy, reaching around 97.5%.

The usage of even more or diverse AI models could enhance the effectiveness of this system. Combining more AI models can improve certain, currently not covered ways of cheat detection. While this approach may not improve the cheat detection rate itself, it could broaden the range of cheats the system can detect.

Researching more on the types of data a cheat detection system like this can use for more accurate

cheat recognition would also be a way to improve a similar system. The type of data we used proved effective but perhaps there is user or game data that gives away cheaters more simply or more obviously. Training the models with different, new types of data could possibly reduce the rate of cheating further, nearing 100% cheat detection rate.

Training the system to recognize returning cheat users and blocking them from playing or interacting with the game could also prove useful in preventing more cheating. Investigating the players who get removed from a game for cheating and returning with a different account could improve cheat prediction.

## References

- [1] Jan Bohnernth. How anti-cheat systems try to save online video games, 2021.
- [2] Arianna Boldi and Amon Rapp. “is it legit, to you?”. an exploration of players’ perceptions of cheating in a multiplayer video game: Making sense of uncertainty. *International Journal of Human-Computer Interaction*, 40(15):4021–4041, 2024.
- [3] Minyeop Choi, Gihyuk Ko, and Sang Kil Cha. BotScreen: Trust everybody, but cut the aimbots yourself. In *32nd USENIX Security Symposium (USENIX Security 23)*, pages 481–498, Anaheim, CA, August 2023. USENIX Association.
- [4] FACEIT. What is faceit anti-cheat and how does it work?, 2023. Accessed: 2024-10-27.
- [5] Mee Lan Han, Byung Il Kwak, and Huy Kang Kim. Cheating and detection method in massively multiplayer online role-playing game: Systematic literature review. *IEEE Access*, 10:49050–49063, 2022.
- [6] Aditya Jonnalagadda, Iuri Frosio, Seth Schneider, Morgan McGuire, and Joohwan Kim. Robust vision-based cheat detection in competitive gaming. *Proceedings of the ACM on Computer Graphics and Interactive Techniques*, 4(1):1–18, 2021.
- [7] Seonghyun Park, Adil Ahmad, and Byoungyoung Lee. Blackmirror: Preventing wallhacks in 3d online fps games. In *Proceedings of the 2020 ACM SIGSAC Conference on Computer and Communications Security, CCS ’20*, page 987–1000, New York, NY, USA, 2020. Association for Computing Machinery.
- [8] José Pedro Pinto, André Pimenta, and Paulo Novais. Deep learning and multivariate time series for cheat detection in video games. *Machine Learning*, 110(11):3037–3057, 2021.
- [9] Jianrong Tao, Yu Xiong, Shiwei Zhao, Runze Wu, Xudong Shen, Tangjie Lyu, Changjie Fan, Zhipeng Hu, Sha Zhao, and Gang Pan. Explainable ai for cheating detection and churn prediction in online games. *IEEE Transactions on Games*, 15(2):242–251, 2022.