THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE GAME DEVELOPMENT PROCESS

WPŁYW SZTUCZNEJ INTELIGENCJI NA PROCES TWORZENIA GIER

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Abstract: The development of artificial intelligence (AI) opens up new possibilities for the video game industry in terms of automation, personalization, and the quality of experiences offered to players. Thanks to advanced machine learning and deep learning algorithms, game developers can implement systems for dynamic content generation, more realistic non-player character (NPC) behaviours, and tailor gameplay based on the player's style. The paper will present both the specific applications of AI and the potential challenges related to integrating this technology into the production process. The first part of the article focuses on discussing the current state and predictions for artificial intelligence actors in games, including opponents, allies, and other non-player characters. Next, the development of artificial intelligence influencing the quality of gameplay is addressed. The following section presents artificial intelligence used for game content creation, along with a discussion of various models and their potential use in the production process. The conclusion highlights the ethical and technical challenges associated with the implementation of AI, including concerns about excessive computational resource consumption, user data privacy, and potential limitations arising from algorithmic imperfections. As a result, the article demonstrates how the responsible and thoughtful use of AI can revolutionise game production while supporting the development of the industry.

Streszczenie: Rozwój sztucznej inteligencji (AI) otwiera przed branżą gier wideo nowe możliwości w zakresie automatyzacji, personalizacji oraz podnoszenia jakości doświadczeń oferowanych graczom. Dzięki zaawansowanym algorytmom uczenia maszynowego i głębokiego uczenia deweloperzy mogą wdrażać systemy dynamicznego generowania zawartości, bardziej realistycznego zachowania postaci niezależnych (NPC) oraz dostosowywać rozgrywkę do stylu gracza. W niniejszym artykule zostaną zaprezentowane zarówno konkretne zastosowania AI, jak i potencjalne wyzwania wynikające z wykorzystania tej technologii w procesie produkcji gier. Pierwsza część tekstu koncentruje się na omówieniu aktualnej sytuacji oraz prognoz dotyczących funkcjonowania aktorów sztucznej inteligencji w grach, w tym przeciwników, sojuszników oraz pozostałych postaci niezależnych. Następnie zostanie poruszony temat rozwoju AI wpływającego na jakość rozgrywki. Kolejna część przedstawia sposób wykorzystania sztucznej inteligencji w tworzeniu zawartości gier, a także omawia różne modele i ich potencjalne zastosowanie w procesie produkcji. W podsumowaniu zostają opisane wyzwania etyczne i techniczne związane z wdrażaniem AI, obejmujące między innymi obawy o nadmierne zużycie zasobów obliczeniowych, kwestie prywatności danych użytkowników oraz potencjalne ograniczenia wynikające z niedoskonałości algorytmów. W efekcie artykuł wskazuje, w jaki sposób odpowiedzialne i przemyślane posługiwanie się sztuczną inteligencją może zrewolucjonizować produkcję gier, wspierając jednocześnie rozwój całej branży.

Keywords: *video games, artificial intelligence, game production*

Słowa kluczowe: *gry video, sztuczna inteligencja, produkcja gier*

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1. Introduction

Artificial intelligence has been associated with video games almost since their inception. For years, the benchmark for AI capabilities was competitions against grandmasters in chess[2]. In recent years, there has been a dynamic development of artificial intelligence – the most popular models have become available to all users, and AI is now implemented in virtually every electronic device – ranging from smartphones to cars, and even vacuum cleaners. The number of scientific papers and research focused on AI has also increased[3]. These changes have also impacted the video game industry – not only has the production process changed, but so have methods of data collection and processing, as well as the customisation of games to meet user needs. The artificial intelligence used in games is typically divided into the following elements[4]:

- NPCs (Non-Player Characters): These are characters in the game that are not directly controlled by the player. AI is used to manage their behaviour, making them authentic and responsive to player interactions.
- Enemies and adversaries: AI can control opponents or hostile entities in the game, determining their tactics, skills, and responses to the player.
- Allies: AI can control the players' allies, providing support and assistance during gameplay. This includes combat strategies, navigation, and other forms of help.
- System elements: AI can manage various system elements in the game, such as dynamic weather conditions, the economy, and others, to create a realistic environment.
- Procedurally generated elements: In some games, AI can randomly or procedurally generate units as part of the game, such as enemies, levels, or worlds.
- Game mechanics: Artificial intelligence can also be used to control different gameplay mechanics, such as physics, animations, and interactions with objects in the game.
- Customising player experiences: AI can analyse the player's behaviour and adjust the game to create personalised experiences, including adjusting the difficulty levels or game dynamics.
- Player behaviour analysis: AI can track and analyse the player's behaviour to develop statistics, recommendations, or challenges within the game.
- Player assistants: AI units can serve as guides or assistants for players, providing them with information, advice, or instructions during gameplay.
- Interactive dialogue: AI can control dialogue between players and NPCs, allowing diverse and dynamic conversations in the game.

Despite listing content-creating models, such as interactive dialogues, procedurally generated elements, and system elements, these are presented as an integral part of the game. The emergence of widely accessible models such as Midjourney, Luna AI, and Suno AI has led to the establishment of a new type of artificial intelligence, used exclusively in the game production process, but not forming an integral part of the final production. Therefore, AI in the game production industry can be divided into three categories: artificial intelligence of actors and games (NPCs, allies, opponents), artificial intelligence improving gameplay quality (analysing player behaviour), and artificial intelligence used to generate game content (whether as an integral

2 C. E. Shannon, *Programming a Computer for Playing Chess*, [in:] *Computer Chess Compendium*, D. Levy (ed.), New York 1988, pp. 2–13.

3 J. P. Sousa, R. Tavares, J. P. Gomes, V. Mendonça, *Review and analysis of research on Video Games and Artificial Intelligence: a look back and a step forward*, "Procedia Computer Science" 2022 (204), pp. 315–323.

4 A. Filipović, *The Role of Artificial Intelligence in Video Game Development*, "Kultura polisa" 2023 (3), pp. 54–55.

part of production or as external tools allowing the creation of content elements). The proposed division is presented below:

Tab. 1. Division of artificial intelligence according to its use in video games

AI of actors and the game	AI affecting gameplay quality	AI generating game content
NPC Opponents and enemies Allies Player assistants System elements Game mechanics	Customising player experiences Analysis of player behaviour	Procedurally generated elements Interactive dialogue Game elements generated by external tools

This article discusses the changes, development directions, and potential applications of each of the indicated types of AI.

2. Artificial Intelligence of actors and the game

Now we have increasingly advanced AI models. Creating new artificial intelligences is certainly easier than it was a decade ago. Basic machine learning methods are an integral part of many academic curricula[5]. Computers have more processing power and are able to analyse an increasing number of parameters; opponents can learn from mistakes and adapt to the player's strategies, forcing them to employ diverse approaches. AI is capable of anticipating the player's moves in advance, as seen in chess where millions of combinations can be examined. Stockfish is able to predict 15–20 moves for both sides, while grandmasters can predict 4–6 moves[6]. According to the latest research, however, it is a less effective algorithm, often defeated by neural networks[7].

It must be remembered that in video games, AI has to share computational resources with graphics, physics, player input, and other processes. Therefore, it is unrealistic to expect the opponent to foresee many moves ahead. However, we can create artificial intelligence capable of always defeating the player. As Sid Meier, the creator of the Civilisation series, pointed out years ago, game developers had already reached such a level of AI development that the player had no chance of winning against artificial intelligence. Meier's experience demonstrated that players prefer to have an advantage. They prefer that, even in situations with low probability, the game ends with their success. On the contrary, they expect artificial intelligence to occasionally lose, even when it has greater chances of winning[8].

Therefore, it can be assumed that despite the fact that modern technologies allow the creation of highly advanced AI actors in games, no one actually does it. This is neither the goal of the

5 Cf. *Machine Learning – nowy kierunek na studiach II stopnia*, https://www.mimuw.edu.pl/pl/studia/machine-learning-nowy-kierunek-na-studiach-ii-stopnia/ (on-line: 05.03.2025).

6 A. Manzo, P. Cianciarini, *Enhancing Stockfish: A Chess Engine Tailored for Training Human Players*, [in:] *Entertainment Computing – ICEC*, P. Cianciarini, A. Di Iorio, H. Hlavacs, F. Poggi (eds.), Berlin 2023, pp. 275–289.

7 E. Modi, K. Acuna, *The Effects of Computer and AI Engines on Competitive Chess*, "Journal of Student Research" 2023 (3), pp. 1– 9.

8 S. Meier, *Sid Meier przedstawia. Wspomnienia*, Kraków 2021, pp. 297–300.

developers nor the expectation of the audience. Despite the growing possibilities in this field, game developers do not opt for a significant expansion of this AI segment, and it can be assumed that there will be no substantial changes in the future.

3. AI influencing gameplay quality

In the segment of artificial intelligence influencing gameplay quality, a significant increase in interest in the use of such solutions can be observed. Developers are increasingly opting to support artificial intelligence in order to better understand players, as well as optimise gameplay mechanics and improve user interaction, aiming to influence an even deeper immersion in the game world[9].

Game developers, with the help of artificial intelligence, can analyse not only basic game data, such as the frequency of using specific mechanics, the moment when the player abandons the game, and the complexity of individual levels, but they are also capable of collecting and processing physiological or environmental data. It is possible to study the player's perception of the game by measuring and analysing heart rate, skin resistance, muscle activity, chair acceleration and rotation, eye movement, and mouse movement[10].

It is worth noting Unity's report (one of the largest game engine providers), which highlights that more than 71% of studios used AI in 2023. According to the study, the primary reason for adopting AI is to accelerate the production process. As the market demands larger and more complex games, the average development time has increased by 86 days in a year. In response, developers are expanding their R&D departments and integrating artificial intelligence, which is most commonly used for[11]:

- Improving character animations – 46%
- Writing code/speeding up code writing – 37%
- Generating artwork and game levels – 36%
- Writing and narrative design – 36%
- Automated play testing – 36%
- Adaptive difficulty – 35%
- In-game text and voice chat moderation – 33%
- In world building itself, AI is most often used for[12]:
- Non-playable characters (NPCs) – 64%
- Creating one-of-a-kind experiences – 54%
- Speech recognition and natural language processing – 52%
- Body/object detection or classification – 43%
- Image, video, or 3D model classification – 39%
- User-generated content – 34%

9 K. Ravichandran, S. K. Ilango, *Influence of AI Powered Gaming Developers and Analyzing Player Behavior and Enhancing User Experience*, "First International Conference on Advances in Electrical, Electronics and Computational Intelligence (ICAEECI), Tiruchengode, India" 2023.

10 A. Smerdov, A. Somov, E. Burnaev, *AI-enabled prediction of video game player performance using the data from heterogeneous sensors*, "Multimedia Tools and Applications" 2022 (82), pp. 11021–11046.

11 *2025 Unity Gaming Report*, https://unity.com/resources/gaming-report (on-line: 05.03.2025).

12 *Ibidem*.

3.1. Industry leaders

Artificial intelligence aimed at enhancing gaming quality is being developed by major corporations and made available to game creators. One of the most widely adopted solutions today is Deep Learning Super Sampling (DLSS) by Nvidia. This technology improves graphical performance while maintaining high image quality by leveraging deep neural networks. These networks analyse visuals and perform adaptive upscaling in real-time: games are rendered at a lower resolution, and AI upscales them to the native resolution of the monitor. As a result, the number of frames per second (FPS) increases without compromising graphical fidelity, even with ray tracing enabled. Recent data indicates that DLSS is implemented in more than 540 games and applications, including 15 of the top 20 most-played PC games of 2024[13].

Another example of AI-driven game development is the Muse system of Microsoft and Xbox Game Studios' Ninja Theory. Designed to support the recreation of classic games on modern hardware, Muse also streamlines the prototyping phase for game developers[14].

Muse is built upon another Microsoft innovation, World and Human Action Models (WHAM). Utilising a transformer-based architecture, WHAM is an advanced sequential model capable of generating dynamic and diverse gameplay scenarios. This AI model not only predicts game developments based on initial input data, but also allows developers to implement and test new mechanics without manual intervention. Consequently, AI can analyse fundamental human behaviour patterns while capturing contextual and nuanced dependencies, significantly improving realism and flexibility in game simulations[15].

Electronic Arts (EA) is also advancing AI applications in gaming. In particular, during the GENEA Challenge 2023, teams were tasked with developing a model capable of generating gestures based on speech. The study evaluated the likelihood of human movement, the appropriateness of gestures in relation to spoken content, and their alignment with conversational partner behaviours[16].

Additionally, EA is working on AI-driven animation generation without relying on motion capture (MoCap). By using a robust character model trained via reinforcement learning, followed by progressively weaker versions, AI can simulate realistic animations, such as a character recovering from a fall using a ragdoll physics approach. This method could also enable animations for injured characters or those with plaster casts on specific limbs[17].

Furthermore, AI is being used to optimise game testing processes. EA researchers propose shifting from reinforcement learning-based approaches to adversarial imitation learning, incorporating discriminators as reward models. This method, referred to as Multimodal Generative

13 *C. Guyton, Nvidia releases stats that prove DLSS and Frame Generation are here to stay – sorry, angry gamers,* https://www.techradar.com/computing/gpu/nvidia-releases-stats-that-prove-dlss-and-frame-generation-are-here-to-stay-sorry-angry-gamers (on-line: 05.03.2025).

14 *Introducing Muse: Our first generative AI model designed for gameplay ideation,* https://www.youtube.com/watch?v=c15vxDHJ2lU&t (on-line: 03.03.2025).

15 A. Kanervisto, D. Bignell, L. Wen *et al.*, *World and Human Action Models towards gameplay ideation*, "Nature" 2025 (638, 656–663), pp. 1–23.

16 T. Kucherenko, R. Nagy, Y. Yoon *et al.*, *The GENEA challenge 2023: a large-scale evaluation of gesture generation models in monadic and dyadic settings* [in:] *Proceedings of the 25th International Conference on Multimodal Interaction*, E. André, M. Chetouani, D. Vaufreydaz *et al.* (eds.), New York 2023, pp. 792–801.

17 T. Tao, M. Wilson, R. Gou, M. van de Panne, *Learning to Get Up* [in:] *ACM SIGGRAPH 2022 conference proceedings*, M. Nandigjav, N. J. Mitra, A. Hertzmann, New York 2022, pp. 1–10.

Adversarial Imitation Learning (MultiGAIL), could significantly enhance AI-driven testing efficiency[18].

Another example of leading gaming companies actively exploring AI applications to enhance game development processes is CD Projekt Red. It has established a dedicated team to investigate broader AI integration to improve production workflows[19].

The company has been developing proprietary AI-driven technologies for years, including City Creation – an advanced system designed to construct expansive, real-time playable urban environments. This technology relies on AI principles and automation, incorporating innovative tools to support the creation of large-scale, open-world games. The technology enabling the generation of urbanised environments in video games will be characterised by vast, fully interactive areas with a high degree of infrastructural complexity. This system facilitates the design of multi-level playable spaces (both terrestrial and aerial) that collectively form virtual cities. By leveraging advanced algorithms, the system autonomously generates and distributes content, dynamically shaping the game world without the need for manual creation of all elements. Developers emphasise that this approach will enhance immersion and exploration dynamics, which makes it particularly valuable for games with nonlinear gameplay. Additionally, the system incorporates audiovisual modules that accurately replicate the atmosphere and structural complexity of real-world cities. The creators anticipate that this technology will significantly expand the freedom of exploration in video games[20].

Square Enix also adopts a similar approach to artificial intelligence, with its president stating that the studio intends "to be aggressive in applying AI and other cutting-edge technologies to both our content development and our publishing functions"[21].

3.2. Medium companies

Medium-sized enterprises are also striving to develop their own AI technologies that improve game quality or optimise the production process. For instance, Kinetix created the AI-UGC Fund, aimed at engaging creators in utilising their Generative AI technology – the AI Emote Creator. In games that use this artificial intelligence, players can create their own custom 3D animations using in-game video. This type of gameplay modification enables players to become creators of the game themselves, enriching the game. This initiative also has a marketing aspect, as the best animations are shared by users on social media and have the potential to go viral[22].

The first studio to benefit from the fund was SmokeSpot Games, the creators of the game Dropcult. Their game offers character customisation and supports mods, making it an ideal environment to test the new AI. SmokeSpot could receive up to $75,000 to cover the costs of

18 W. Ahlberg, A. Sestini, K. Tollmar, L. Gisslén, *Generating Personas for Games with Multimodal Adversarial Imitation Learning*, https://arxiv.org/abs/2308.07598 (on-line: 05.03.2025).

19 A. Ebert, *CD Projekt aims to start production phase of 'Polaris' in 2024*, https://www.reuters.com/technology/cd-projekt-aims-start-production-phase-polaris-2024-2024-01-22/ (on-line: 05.03.2025).

20 *City Creation – kompleksowa technologia służąca do kreacji "żywego", grywalnego w czasie rzeczywistym, miasta o wielkiej skali, która bazuje na zasadach, sztucznej inteligencji i automatyzacji oraz uwzględnia opracowanie innowacyjnych procesów i narzędzi wspierających tworzenie najwyższej jakości gier z otwartym światem*, https://mapadotacji.gov.pl/projekty/743661/?lang=en (on-line: 05.03.2025)

21 T. Kiryu, *A New Year's Letter from the President*, https://www.hd.square-enix.com/eng/news/2024/html/a_new_years_letter_from_the_president_4.html (on-line: 05.03.2025).

22 *Kinetix launches $1M fund to accelerate AI-UGC in gaming*, https://www.gamedeveloper.com/press-release/kinetix-launches-1m-fund-to-accelerate-ai-ugc-in-gaming (on-line: 05.03.2025).

implementing this technology. The fund's founders expect this to accelerate the introduction of user-generated content features[23].

Another example might be QEDgames, developing the Grail system – an artificial intelligence framework designed for seamless transfer between different projects. This solution enables game studios to reduce costs by eliminating the need to develop AI systems from scratch for each new production. Grail incorporates a multi-agent system, allows for AI preference modeling using mathematical curves, supports long-term sequence planning, and facilitates AI behavior simulation within a simplified game model[24].

Another noteworthy example is Jabali, a company that develops artificial intelligence capable of generating entire games. Currently, the company claims its AI can create games across more than ten different genres[25].

Among such AI solutions, it is worth highlighting Polish companies that are attempting to develop their own technologies. An example is the platform for automating the generation, gameplay, and difficulty level determination of blast levels, based on AI and Machine Learning, developed by Vivid Games[26] or the project aimed at creating an innovative system for optimizing user and revenue parameters in games through artificial intelligence—the Automatic Parameterization and Optimization System developed by T-BULL[27]. Artifex Mundi, on the other hand, has been working on a system that enables the automatic generation of new levels for "match-3" type games, while simultaneously enhancing the quality of these levels through self-learning capabilities and player behavior prediction[28]. CI GAMES developed an innovative technology based on advanced artificial intelligence algorithms, dedicated to generating the player's environment, including crowds and animal herds[29].

An alternative approach is being pursued by ECC Games with their GearShift project. The studio developed a behaviour engine for wheeled motor vehicles and map generation based on artificial intelligence algorithms using the Unreal Engine platform. This is the first technology to integrate a vehicle physics engine with a dynamic map generation module. The engine allows for the customization of vehicle physics according to the environmental conditions on the generated map, taking into account game mechanics elements such as suspension physics, tire behaviour physics, engine models that consider power, torque, friction, and engine type characteristics (e.g., inline engines, V engines, electric motors), braking systems that account for brake temperature, differential systems with adjustable parameters, and driving assistance systems such as ABS, ESP, and TRC[30].

23 *Ibidem*.

24 *Grail whitepaper June 2021*, https://grail.com.pl/media/Grail_Whitepaper_June_2021.pdf (on-line: 05.03.2025).

25 *Introducing Jabali, the AI Engine for Aspiring Game Developers*, https://www.gamedeveloper.com/press-release/introducing-jabali-the-ai-engine-for-aspiring-game-developers (on-line: 05.03.2025).

26 *Vivid Games otrzyma 3,8 mln zł dofinansowania NCBiR*, https://www.biznesradar.pl/a/115290,vivid-games-otrzyma-3-8-mln-zl-dofinansowania-ncbir (on-line: 05.03.2025).

27 K. Pieczonka, *75 mln dofinansowania na gry, NCBiR wspiera innowacje cyfrowe*, https://antyweb.pl/ncbir-przyznalo-75-mln-dofinansowania-na-gry (on-line: 05.03.2025).

28 *NCBR wybrało 27 projektów do dofinansowania w ramach programu GAMEINN*, https://www.money.pl/gielda/ncbr-wybralo-27-projektow-do-dofinansowania-w-ramach-programu-gameinn-6429062445454977a.html (on-line: 05.03.2025).

29 *Lista ocenionych projektów złożonych w ramach Programu Operacyjnego Inteligentny Rozwój 2014–2020 działanie 1.2,* https://archiwum.ncbr.gov.pl/fileadmin/gfx/ncbir/userfiles/_public/fundusze_europejskie/inteligentny_rozwoj/gameinn/lista_rankingowa_3_1.2_2016_poir__gameinn.pdf (on-line: 05.03.2025).

30 *Silnik fizyki*, https://eccgames.com/ecc-uslugi/silnik-fizyki/ (on-line: 05.03.2025).

3.3. Indie studios

Developing proprietary AI models involves significant costs. It is necessary to establish an R&D department and conduct a series of research and tests to develop a new solution. This means spending resources for several years before the benefits of the new models can be realised. In the case of small indie game studios, their own funds are typically insufficient to develop proprietary solutions. In Poland within the development of AI, significant opportunities for the gaming industry are provided by competitions organised by the Polish Agency for Enterprise Development (Polska Agencja Rozwoju Przedsiębiorczości) and the National Centre for Research and Development (Narodowe Centrum Badań i Rozwoju), which mediate the financing of R&D projects from European Funds.

A good example of AI development in an indie studio using this type of subsidy could be Jujubee. The first research project from this company was an AI that manages the computational power consumption of the computer and decides how to allocate resources to various AI actors. This was carried out within the project titled "Development of a framework for building artificial intelligence behavior systems in multi-actor real-time 'Grand Strategy' games – GS-AIM (Grand Strategy Artificial Intelligence Mechanism)"[31]. One of the outcomes of the project was the creation of a completely new category of games – 'Real Time Grand Strategy' mobile games, using the developed GS-AIM system. The project solved a research problem related to ensuring proper game performance when developing real-time strategy games with multiple actors from a technical perspective. Until then, this involved excessive usage of computational power and memory, leading to prolonged interval calculations and a decrease in frame rate per second. The problem was associated, on the one hand, with the variety of available behavioural options that each AI actor could use and, on the other hand, with the management of the units by each actor.

The second Jujubee's project from this area focused on enhancing the capabilities of artificial intelligence and integrating it with a new environment, additionally supporting the work of developers. This project was titled "Development of the Grand Strategy Engine tool for designing multi-actor real-time or turn-based Grand Strategy games and integrating it with the Grand Strategy Artificial Intelligence Mechanism"[32]. The goal of the project was to create an independent Grand Strategy Engine (GSE) tool for designing real-time Grand Strategy games. The development of GSE reduced the involvement of developers in game creation, accelerated game production, and decreased the frequency of issues related to faulty code functioning. Optimisation in this regard allowed games to be created for less powerful devices. GSE enables game production for computers and mobile devices, contributing to the development of the type of games known as Real-Time Grand Strategy mobile games, initiated by the company.

31 The project was part of Action 1.2: "Sectoral R&D Programs" – GameINN, within the Operational Program Intelligent Development 2014–2020, co-financed by the European Regional Development Fund. The value of the project was 1,946,295 PLN, of which the contribution from the European Funds covered 1,341,171 PLN.

32 The project was part of Action 1.1: R&D Projects for Enterprises, part of the Operational Program Intelligent Development 2014–2020, co-financed by the European Regional Development Fund. The value of the project was 3,535,000 PLN, of which the contribution from the European Funds covered 2,585,500 PLN. Project co-financed by the European Union from the European Regional Development Fund under the Smart Growth Operational Programme. Project implemented as part of the National Centre for Research and Development competition: Fast Track.

Another example of companies of this size developing their own AI technologies with the support form EU Founds might be[33]:

- Esports Lab with their Better Games project – development and validation of an AI-based tool for psychological profiling and player segmentation
- Symbiote Sp. z o.o. with their INVICTUS – a modular solution utilising artificial intelligence for the expansion of games.
- 4Gate with their *Chowaniec* – a tool for creating and managing AI-based animal companions in video games.
- Games Operators with their project of development of advanced algorithms for generating game world AI based on map data using reinforcement learning methods for innovative modules in the game tentatively titled *Urban Warfare*.
- All Investments with their FinAISym project – a playable financial market simulator based on multi-agent AI/RL algorithms with a high degree of real-world replication in a digital twin model, enabling the study of market behaviours and participants under various market and economic parameters.
- Baad Games Studio with their project of development of algorithms and models in the field of artificial intelligence using behavioural tree methods for implementation in Real-Time Strategy games.
- Silver Bullet Solutions with their project of development of an external modular tool for the implementation and optimisation of advanced artificial intelligence with broad applications in video games.

In conclusion, within the segment of AI that improves gameplay quality, a significant technology development of the technology is visible. However, it requires substantial financial investment, which makes it primarily the domain of larger enterprises. For smaller companies, European Funds present an opportunity to acquire the necessary resources for technology development.

4. Artificial Intelligence for the creation of game content

The creation of game content is typically managed by generative AI, represented by a class of models that generate new data based on the patterns and structures of the data analysed by them[34]. Thanks to the rapid development of natural language processing and deep learning techniques in neural networks, models have been created that allow the generation of text, images, music, sound, 3D models, and other elements[35].

4.1. Content generation models

Content generation models are responsible for creating content and data that are difficult to distinguish from those generated by humans. The idea of such artificial intelligence dates back to the 1970s when methods like ELIZA and MYCIN were developed, allowing pattern matching with scripted responses. Currently, advanced language models are used, which have been trained

33 K. Pieczonka, *op. cit. Lista ocenionych projektów złożonych w ramach Programu Operacyjnego Inteligentny Rozwój 2014–2020 działanie 1.2*, *op. cit.*

34 R. W. McGee, *A. Chan. Three Short Stories Written with Chat GPT*, 2023, pre-print, (on-line: 05.03.2025).

35 E. N. Naumova, *A mistake-find exercise: a teacher's tool to engage with information innovations, ChatGPT, and their analogs*, "Journal of Public Health Policy" 2023 (44), pp. 173–178.

on massive datasets, enabling significant development of this segment and potential applications of artificial intelligence in fields such as medicine, education or arts[36].

An example of a content generation model is ChatGPT. This model operates based on the Generative Pre-trained Transformer (GPT) architecture[37]. The idea behind creating this model was to support a variety of tasks, including not only text generation but also text translation and data analysis[38].

In game production, the model can be used for text correction. It can analyse a submitted text for spelling and punctuation accuracy, and even for readability, appropriately shortening sentences.

In line with the aforementioned idea, it is also useful for text translation. In the video game industry, localisation can consume a significant portion of the budget, especially in independent productions. The use of content-generating AI allows for considerable cost reductions, and in some cases, even facilitates the release of the game in new languages. This is particularly important for small studios or games created by a single individual, often semi-amateur productions. Utilising content-generating models opens new markets for them. It is worth noting that introducing additional languages also increases the accessibility of games, especially for those who do not speak English – many interesting, yet niche productions miss out on this player type due to lack of translation.

However, content-generating models can substitute more advanced services provided by localisation companies – cultural context analysis and the detection of sensitive content. For example, analysing reviews of the game *Realpolitiks II* on the Steam platform shows considerable dissatisfaction with certain geographical names – some countries do not recognise universally accepted terms and use names valid only within specific regions. Using, for instance, ChatGPT for translation analysis in terms of cultural adaptation would help avoid such issues. Content-generating models can also be used to check the accuracy of translations, particularly with regard to tailoring them for specific markets.

The core functions of content-generating models, namely text creation, can also be employed in game production as a source of inspiration. Models have not only analysed large quantities of game reviews, design guides, and other cultural works, but can also help find ideas for quests, mechanics, events, and characters in a game. They can directly generate in-game text, both on a creative level, where the model can realistically simulate dialogue between two NPCs based on the characters' traits and the topic of conversation, and on a generative level, creating secondary texts, such as numerous item descriptions or location overviews. Models can also be useful in creating various forms of documentation, from shortening or extending texts for funding applications, to generating reports, creating checklists, documenting best practices, generating presentation content, and producing test scripts.

Artificial intelligence, such as ChatGPT, can also aid in the analysis of documentation. Newer models allow for the creation of custom bots based on supplied data. In game production, one can upload the Game Design Document (GDD), game script, mechanics descriptions, marketing documents, or company strategies, and use the bot created in this way to analyse game information. This is an efficient way to find inconsistencies between documents or current actions. It is also very useful for searching for specific information, by simply asking a question about

36 P. Gupta, B. Ding, C. Guan, D. Ding, *Generative AI: A systematic review using topic modelling techniques*, "Data and Information Management" 2024 (8), pp. 1–66.

37 F. Y. Wang, Q. Miao, X. Li, X. Wang, Y. Lin, *What does ChatGPT say: the DAO from algorithmic intelligence to linguistic intelligence*, "IEEE/CAA Journal of Automatica Sinica" 2023 (10), pp. 575–579.

38 P. Ray, *ChatGPT: A comprehensive review on background, applications, key challenges, bias, ethics, limitations and future scope*, "Internet of Things and Cyber-Physical Systems" 2023 (3), pp. 121–154.

a particular mechanic, character, or item, one can obtain all the necessary data without having to search through hundreds of pages of documentation across multiple documents. Such actions not only accelerate conceptual work, but also prevent errors that would only become apparent after the implementation of mechanics – significantly shortening the number of iterations in the project and reducing the number of mistakes.

Another function of content-generating models is to assist in programming. Artificial Intelligence manages secondary changes in code or simple solutions. In more complex problems, the code may not work, but it may serve as a good inspiration for finding a solution.

4.2. 2D graphics generation models

Artificial intelligence dedicated to 2D graphics is responsible for creating graphic data, both abstract and spatial. Thanks to this technology, it is possible to generate diverse content, such as sequential data (ordered texts, codes, music, videos, time series), tabular data (structured rows and columns, as seen in spreadsheets and databases), or graphs (modelled network structures – social networks, molecular structures, or recommendation systems). In video games the most significant aspect is the creation of 2D images, which involves representing spatial data (including pixels, voxels, or points with 2D coordinates) within Euclidean spaces. This allows, through the use of such processes as Data enhancement, Visual mapping generation, Stylisation and Interaction, to create, among others, visualisation images, sketches and natural images. The same methods are also responsible for creating QR codes, volumetric data or density maps. The AI that generates 2D graphics uses methods such as image synthesis, style transfer, and digital visual art creation[39].

An example of such a model is Midjourney – artificial intelligence based on Dall-E technology, built on a version of GPT-3 containing 12 billion parameters and trained to generate images using a text-image dataset[40].

2D graphics generation models can be used in the process of creating conceptual artwork. These are simple drawings, often sketches, aimed at finding the right graphic direction or presenting an initial design of a character or a game element.

The traditional process involves the design team specifying the requirements for a given game element and describing it. Then, a 2D artist prepares several versions of the drawing for that element. Typically, this process takes 2 to 3 days. With the use of 2D graphics generation models, it is possible to obtain dozens of proposals in 15–20 minutes. It is worth noting that the graphics can reflect typical concept art in the form of drawings or sketches, or they may already be more advanced graphics, including colours. Conceptual graphics are created exclusively for internal use by the studio, so the presence of typical artifacts, such as excessive fingers or distorted proportions, is not problematic. On the other hand, AI cannot yet make specific corrections to graphics – for example, if we want to replace a sword with an axe, a beard with a moustache, or even red hair with grey hair, an artist is still needed to finish the image. However, it should be emphasised that with the use of artificial intelligence, studios can now produce 1–2, sometimes even 3 graphics per day, resulting in productivity increases of 100% to 900%.

A much simpler task for this type of AI model would be the creation of moodboards – fundamental tools in the design industry that encompass a wide range of boards with reference

39 Y. Ye, J. Hao, Y. Hou *et al*., *Generative AI for visualization: State of the art and future directions*, "Visual Informatics" 2024 (8), pp. 43–66.

40 D. Hanna, *The Use of Artificial Intelligence Art Generator "Midjourney" in Artistic and Advertising Creativity*, "Journal of Design Sciences and Applied Arts" 2023 (4), pp. 42–58.

graphics[41]. Therefore, this is an element that does not require any corrections, as it serves solely to convey references, mood, and the atmosphere of the production.

Another use of this kind of artificial intelligence in the game production process may occur during the prototyping phase or internal demo creation. In the traditional process, when developing an early version of a game for investors, publishers, or management, placeholder elements are used, typically with text that indicates what should appear in a given place. Thanks to the new AI models, studios can now provide graphics close to the final effect, helping to better understand the game, especially for those not directly involved in the production process. It is worth noting that artificial intelligence is ineffective when it comes to generating UI elements or icons. There are also certain elements that it often struggles with – for example, bows.

The use of 2D graphics generation models for the full version of a game delivered to the customer raises ethical concerns, especially regarding proper labeling of such productions. The quality of the generated graphics is often high enough that it could potentially be used in the full game version as the main elements, after reducing artifacts – such as poorly generated hands, incorrectly placed eyes, or distorted proportions. However, it must be remembered that for independent creators or very small teams, often working on semi-amateur productions, even raw AI-generated graphics can be the deciding factor in completing the project – hence, it should not be surprising that such raw graphics can be found in games.

The last example of using these models is in marketing materials – preparing newsletters, distributor website materials, devblogs, social media posts, forum contributions, servers, and other places where developers communicate with players may require significant processing power, which could otherwise be needed for other areas of production. Depending on the strategy adopted by the studio and the reach of the campaign, the materials may require more or fewer corrections by artists – but in any case, this approach speeds up the work. This type of artificial intelligence is used, among others, by Activision in *Call of Duty: Black Ops 6*. However, it is important to note that the use of generative AI in games is often met with negative reactions from players, which is why studios tend to conceal this fact[42].

4.3. Sound generation models

Among the numerous technologies for sound generation, not all can be fully classified as artificial intelligence. An example is the Markov chain, which models event sequences based on the probabilities of subsequent states that depend only on the previous state, indicating what is possible or impossible in the ensuing sequence – chord by chord, beat by beat. However, the chain can be integrated with a neural network, thus becoming AI. We can also mention evolutionary algorithms that modify musical fragments according to harmonic rules and adjust the output through an adaptation function. Among neural networks, architectures such as Feedforward Networks, Recurrent Neural Networks, Generative Adversarial Networks, Variational Autoencoders, and Transformers are commonly cited[43]. Among these models, one can distinguish models that generate music, ambient sounds, or speech.

41 T. Cassidy, *The Mood Board Process Modeled and Understood as a Qualitative Design Research Tool*, "Fashion Practice" 2011 (3), pp. 225–252.

42 C. Kerr, *Players lambast Activision after publisher confirms generative AI was used in Black Ops 6*, https://www.gamedeveloper.com/production/players-lambast-activision-after-publisher-confirms-generative-ai-was-used-in-black-ops-6 (on-line: 05.03.2025).

43 M. Civit, J. Civit-Masot, F. Cuadrado, M. J. Escalona, *A systematic review of artificial intelligence-based music generation: Scope, applications, and future trends*, "Expert Systems with Applications" 2022 (209), pp. 1–16.

An example of a music-generating model is SunoAI. This model also has a text-generation function, focused on generating song lyrics. The user can input their own text and specify the type of music, such as: "Hip hop R&B, Electronic synths, 80s retro, fast paced" or more specifically: "Cyberpunk, Soviet Pop, dubstep, voodoo, death metal, [tempo: 150–259 BPM], acid glitch, mechanical, melancholy, dirty, duet, female singer, female backup vocals". The second option is simply providing a description of the song – the artificial intelligence will then generate both the lyrics and the music. For example, one could enter the phrase: "A song about rain in the park; piano; nostalgic" and within minutes receive two versions of a four-verse, nearly four-minute piece on the specified theme. The AI can sing in many languages, but with Polish it often produces incorrect pronunciation. A downside is the frequently audible autotune effect. Sometimes the song is unable to fully generate and abruptly cuts off or turns into an entirely different piece. Nevertheless, of 10 attempts, or 20 generated songs, 6 are generally of good quality.

The model also has an "instrumental" option, which generates only the music, without lyrics. Due to this, music-generating models can be used to create background music for games, trailers, and other marketing materials. The tracks can serve as a basis or reference for musical artists creating game soundtracks or even as a complete soundtrack for smaller productions.

An example of a model that generates dialogue could be Play HT. Improving models allow for the use of various voices or even mimic real voices based on a sound sample. The user has the ability to adjust emotions and speak in different languages. This technology can primarily be used for voice-overs, which have often represented a very significant cost. It is also important to note the accessibility aspect. The model can read text in most languages. In addition, it can be implemented as a support for people with disabilities, particularly those with reading difficulties. For example, in Jujubee, a system is being developed where an AI voiceover reads every clicked text – menu elements, UI, or dialogues – to assist individuals who have difficulty with large amounts of text in the game. An example of the use of this type of AI can be seen in the dubbing of the character Viktor Vektor in the *Phantom Liberty* expansion for *Cyberpunk 2077* after the death of the actor who originally voiced the character[44]. Another example of AI usage for voice-overs is demonstrated by Paradox in the game *Stellaris*. In *The Machine Age* expansion, which introduces a new faction consisting of artificial intelligence, the developers utilized AI to generate the voices of the characters from this group[45].

4.4. Models generating 3D elements

Artificial intelligence models generating 3D elements utilise machine learning, primarily networks such as GAN and VAE, capable of creating three-dimensional structures based on available input data. These models recognize characteristics of shapes, textures, and spatial relationships, enabling them to generate new forms[46].

An example of such a model is LumaAI – Genie. In this model, it is enough to input a simple prompt, such as "slavic young warrior, t-pose" to generate a preliminarily textured, optimised model within a few minutes. However, the quality of the models is very low – there are many

44 J. Henry, *CD Projekt Red Wants to Use AI for Future Game Development – Will We See It for New Witcher, Cyberpunk Games?*, https://www.techtimes.com/articles/300902/20240123/cd-projekt-red-use-ai-future-game-developmentwill-see-new.htm (online 05.03.2025).

45 M. Jarvis, *Stellaris director insists "ethical use of AI is very important to us" after generating voices in latest DLC*, https://www.rockpapershotgun.com/stellaris-director-insists-ethical-use-of-ai-is-very-important-to-us-after-generating-voices-in-latest-dlc (online 05.03.2025).

46 Q. C. Xu, T. J. Mu, Y. L. Yang, *A survey of deep learning-based 3D shape generation*, "Computational Visual Media" 2023 (9), pp. 407–442.

artefacts, and the models often lack symmetry. The AI does not understand many terms and tends to generate rather generic, very stereotypical characters. After entering the prompt, four model proposals are provided, with few details, very simple meshes, and angular shapes. It is possible to select the Hi-Res option, which in theory should improve the quality of the textures and character mesh. In practice, however, the process textures the model in a different way, introducing variations that distort the idea of improving the resolution of the already selected model. The model contains more details, and its resolution increases, as seen by the file size – from 2.24MB in the case of the basic model to 3.02MB in the case of the file with the improved resolution. An example comparison of a generated character along with a character whose resolution has been enhanced by the model is shown in Figure 1.

Fig. 1. Comparison of a low-resolution model with a model of improved resolution

The model encounters significant issues when generating animal models, often producing highly distorted shapes. Sample glitches are presented in Figure 2. One can observe additional stands, elements unrelated to the character, generation of material instead of the entire character, errors in the limbs, model duplication, lack of proportion, or incorrect interpretation of prompts.

Fig. 2. An example of artefacts in models generated by artificial intelligence

In the case of 3D elements, it is therefore impossible to directly use AI-generated content in a game. Each model must undergo processing by a 3D artist, who will refine the mesh, remove unnecessary elements, and create new textures. An example of a model generated by artificial intelligence and modified by a 3D artist, along with its use in a game engine, is shown below.

Fig. 3. Comparison of an AI-generated model with a model modified by an artist and placed in the game engine

Models generated by artificial intelligence can thus only serve as a basis for further work, but this is sufficient to speed up the pace of character production. The scope of necessary changes depends not only on the quality of the generated model but also on the type of game and camera settings. In strategy games, where units are usually depicted from a large distance, the amount of modifications will be significantly smaller than in RPGs with an isometric camera angle and a closer view of the character. In TPS or FPS games, AI-generated models would require so many changes that they could only serve as conceptual art or model elements – at the current stage of AI development, the artist would need to make such substantial modifications that creating the model from scratch could be a faster process. Therefore, such 3D models are more suitable for prototyping stages, internal demos, or games with a considerably distant camera angle from the units.

5. Challenges

The development of artificial intelligence offers significant opportunities to streamline the game production process. However, it also requires changes in studio strategy and current workflow. Before implementing artificial intelligence, it will be necessary to address a series of challenges, among which concerns can be defined about the potential replacement by AI. There are many movements opposing the use of artificial intelligence in art.

Another challenge may be the lack of knowledge about how to teach the use of AI. Professionals need to face the task of acquiring knowledge and experience in artificial intelligence on their own. AI is evolving so rapidly that it is difficult to answer questions such as: “should we teach AI?”, “how should we teach about AI?”, “what should we teach about it?”, and “how should we combat AI-assisted plagiarism?”.

There are also issues related to AI legislation. Most countries are still developing regulations regarding artificial intelligence. Creators are uncertain about how to properly label products that use AI, what restrictions should be imposed on AI, and what the copyright situation is for elements, as well as entire games, that use AI-generated content.

The issue of legal regulation, education, and the use of AI in different countries must also be considered. There are concerns about overly restrictive approaches to using and developing artificial intelligence, especially in heavily regulated markets. Countries with a more liberal approach to the development and use of AI may significantly accelerate progress, improve product quality, and lower costs.

Ethical challenges may also arise, particularly concerning how AI is used to influence users, the proper labelling of AI-utilising projects, and the databases employed by artificial intelligence.

The resistance to AI should not be overlooked: many users, employees, and creators oppose the use of artificial intelligence in artistic productions, including video games. Negative review bombing can be observed in the case of games using AI-generated elements.

Furthermore, the issue of excessive computational power and energy consumption by artificial intelligence must be addressed. Currently, most popular models use neural networks that have high resource demands. AI developers must focus on creating more optimised network architectures, improving the transfer of complex knowledge from larger models to smaller ones, and using energy-efficient components.

6. Conclusions

The development of artificial intelligence opens new opportunities for game developers. Among the greatest benefits, one can mention the increased accessibility of technology for game creators, the acceleration of the production process, which translates into reduced production costs, or the ability to create larger games within the same budget. Artificial intelligence does not develop uniformly, and some areas remain untapped – therefore, there is a perspective for the emergence of more advanced AI models that will change the way games are produced and the operating principles within the market. However, the use of artificial intelligence in games and its development have led to new problems that must be addressed not only by developers, but also by players, businesses, educators, and governments.

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