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Adaptive AI Behaviour in Stealth NPCs: A Narrative Review of Current Approaches and Research Directions

Perilaku AI Adaptif dalam NPC Siluman: Ulasan Naratif terhadap Pendekatan Semasa dan Arah Penyelidikan Masa Hadapan

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ABSTRACT

The problem statement of the current paper is the necessity of creating a dynamic artificial intelligence for the design of stealth non-player characters so that they may create a more dynamic and interesting gaming experience. Today's players expect realistic and flexible game design together with an interesting challenge ratio from the AI techniques applied in the video game, which cannot be done by employing traditional methods based on finite state machines or programming code. In spite of the fact that there has been much progress in reinforcement learning, the development of behavior trees and the combination of the two mentioned techniques which extended the possibilities of AI designs, the synthesis concerning their implementation in stealth NPCs has not yet been done. Thus, the aim of this study is to provide a narrative review of the problem of adaptive AI in stealth NPCs with a focus on the technical and design aspect of development. Literature databases like Scopus, IEEE and ACM digital libraries for the period of 2010-2025 are analyzed.The assessment concludes on the issues and opportunities in the future and it implies that stealth AI research needs to be player-driven assessment systems and cross-genre flexibility. The article introduces a systematic perspective to enlighten researchers and designers in the creation of adaptive NPC behavior in the direction of meaningful and sustainable design of any game.

Keywords: Adaptive Artificial Intelligence (AI), Game AI Design, Narrative Review, Player Engagement and Scalability, Stealth Non-Player Characters (NPCs).

ABSTRAK

Kecerdasan buatan (AI) adaptif telah menjadi ciri penting dalam reka bentuk watak bukan pemain (NPC) jenis siluman, yang membolehkan pengalaman permainan yang lebih dinamik dan sukar dijangka. Teknik AI tradisional, yang lazimnya berasaskan finite state machines atau rutin skrip, sering gagal memberikan tahap realisme, kebolehsuaian, dan keseimbangan cabaran yang diharapkan oleh pemain moden. Walaupun kemajuan terkini seperti reinforcement learning, behavior trees, dan model hibrid telah memperluas kemungkinan reka bentuk, sintesis yang komprehensif masih terhad dalam konteks aplikasi kepada NPC siluman secara khusus. Objektif kajian ini adalah untuk menyediakan ulasan naratif terhadap pendekatan AI adaptif dalam NPC siluman, dengan memberi tumpuan kepada aspek pembangunan teknikal serta implikasi reka bentuk. Literatur dari tahun 2010 hingga 2025 yang diperoleh daripada pangkalan data Scopus, IEEE, dan ACM Digital Library telah dianalisis bagi mengenal pasti strategi umum, corak metodologi, dan jurang penyelidikan utama. Dapatan menunjukkan bahawa kaedah adaptif mampu meningkatkan tindak balas taktikal, kebolehulangan permainan, dan tahap penghayatan pemain, namun kebanyakan kajian masih kekurangan penilaian empirikal berdasarkan data pemain, serta mengabaikan isu kebolehskalaan, kecekapan pengiraan, dan pertimbangan etika. Kajian ini menyoroti beberapa cabaran dan arah penyelidikan masa hadapan, termasuk keperluan terhadap kerangka penilaian berpusatkan pemain serta kebolehsuaian rentas genre dalam penyelidikan AI siluman. Kajian ini menyumbang satu perspektif berstruktur yang dapat membimbing penyelidik dan pereka bentuk permainan dalam memajukan perilaku NPC adaptif ke arah reka bentuk permainan yang lebih bermakna dan mampan.

Kata kunci: Kecerdasan Buatan Adaptif, Reka Bentuk AI Permainan, Ulasan Naratif, Penglibatan Pemain dan Kebolehskalaan, Watak Bukan Pemain (NPC) Siluman.

INTRODUCTION

The AI has become an integral part of digital games, and it gives the opportunity to make the experience more customized, reactive, and more real. Adaptive systems have been shown to increase engagement, motivation and realism in entertainment and educational contexts, by changing mechanics and stories in response to player behavior (Yu 2024; Kandur 2025). Nevertheless, as advancements in affective gaming, adaptive robotics, and dynamic decision-making systems have shown to be more broadly applicable, the incorporation of adaptive AI in game environments still raises issues related to scalability, transparency, and sustainable design (Zheng 2025). These dilemmas suggest that a better organized insight into the ways adaptive AI can be implemented successfully and ethically in interactive game systems is necessary.

In this context, NPCs are crucial to the experience of the players, especially in stealth-based games where tension, unpredictability, and immersion largely rely on the behaviour of NPCs. Conventional NPCs, created with Finite State Machines (FSMs) or behaviour trees, are not always flexible enough to behave in a realistic way, which results in predictable and repeated behaviour (Machalewski, Marek, and Ochmann 2022). More recent studies have examined the more advanced techniques of promoting adaptive NPC behaviours through Reinforcement Learning (RL), hybrid models and procedural generation (Lin et al. 2024; Levkivskyi and Marchuk 2024; Román 2018). Nevertheless, applications are still in pieces and rarely tested in

stealth-specific settings, which makes the knowledge about the impact of these adaptive techniques on the gameplay realism and the engagement of the players limited.

The purpose of this review is to summarize existing studies on adaptive AI in stealth NPCs to elucidate existing methods, issues, and gaps in the research. It aims to answer the question: How have adaptive AI methods been used to improve NPC behaviour in stealth games, and what should future research take? The main aim is to explore the advantages and disadvantages of adaptive strategies like RL and hybrid AI systems in facilitating responsive, unpredictable, but computationally viable NPC behaviour. This narrative review offers a starting point to future research by integrating discoveries in related areas to create more intelligent and ethically sound NPCs that would be able to maintain immersion and realism in stealth gameplay (Kumbharkar 2025).

METHODOLOGY

This study uses a narrative synthesis method to analyse the current literature about adaptive AI behaviour in stealth NPCs. Scopus, IEEE Xplore, ACM Digital Library and Google Scholar were searched with combinations of the keywords adaptive AI, stealth NPC, game AI, reinforcement learning, and behaviour trees. The methodological framework adheres to the past reviews in the fields of AI and game studies that focus more on narrative integration than quantitative meta-analysis (Jagoda 2023; Shin and Jung 2024). Preliminary sample of 120 studies was found. The inclusion criteria were (a) the study should be published in 2008-2025, (b) should directly focus on adaptive AI implementation in stealth NPCs or other similar game environments, and (c) should be full-text available. The exclusion criteria filtered out articles that (a) investigated general AI applications without adaptive mechanism, (b) did not focus on stealth or behavioural adaptation, or (c) were not peer-reviewed articles, e.g. blog posts or editorials (Zhao 2024). Following the screening process, 45 articles were kept in the full-text analysis process. Coding of studies was done descriptively followed by synthesis of the studies in themes in order to capture methodological heterogeneity, technical frameworks, and contextual uses of AI in stealth NPC behaviour. The narrative synthesis methodology allows systematically comparing RL, behaviour-tree, and hybrid adaptive models to game types and considers the qualitative variation in design and implementation (Gutiérrez-Sánchez et al. 2021; Lin et al. 2024). In order to present a better understanding of the review process, Figure 1 shows how the study selection and analysis flow. It starts with the identification of databases, screening and evaluation of eligibility according to the established inclusion and exclusion criteria. A narrative synthesis approach was then used to analyse the final set of the selected studies.

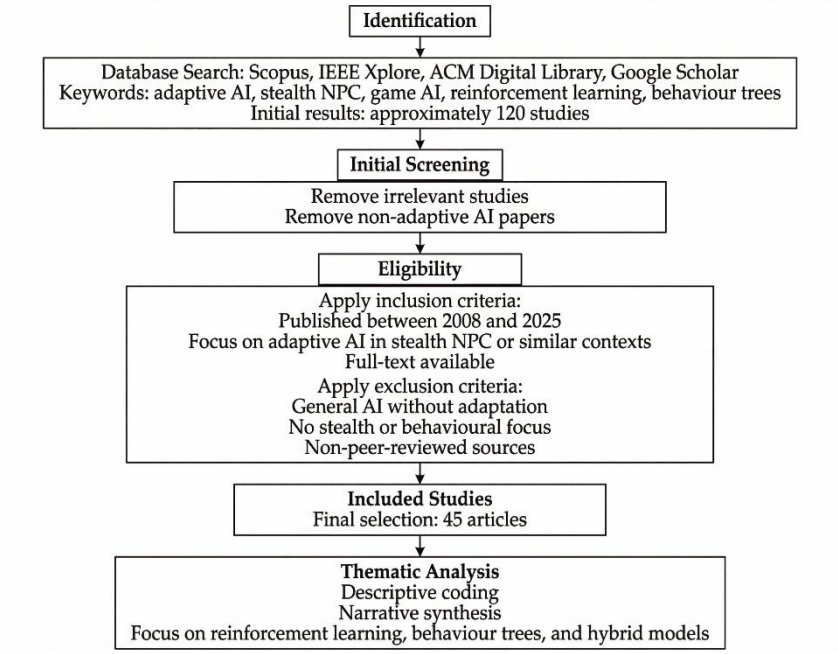

FIGURE 1. The Flow of Study Selection and Analysis.

RESULT AND DISCUSSION

FOUNDATIONS OF STEALTH NPC DESIGN IN GAMES

Stealth game design has long been based on artificial intelligence, to determine how non-player characters sense, chase, and react to the player. Initial applications were predominated by scripted behaviours and FSMs. Although these systems provided the developers with accurate control, they tended to produce inflexible and predictable interactions. The stealth games of the classic type had guards that moved in pre-determined routes and responded to the actions within a narrow range, which made them susceptible to the actions of the players as they understood the behavioural patterns. This predictability brought about transparency but compromised replayability and immersion as players got to know more about the mechanics (He et al. 2008; Merrick and Maher 2009). This historical dependence on rule-based designs is both a sign of the advantages of design simplicity and the ongoing difficulty of sustaining plausibility in changing stealth scenarios.

The flaws of the rule-based systems became obvious with the increased sophistication of the game environments. The programmed artificial intelligence was not capable of handling unexpected player strategies, which would most probably result in the reenactment or artificial play. These weaknesses have been noted in robotics and simulations where the FSM-based models limited flexibility despite the technical performance being enhanced (Atqiya, Sholahuddin, and Suharsih 2024; Adetiya et al. 2023). Subsequent inventions encompassed mechanisms like behaviour trees (BTs), grammatical evolution, which allowed FSMs to be more adaptable, allowing hierarchical and modular design, and resulting in a broader range of NPC behaviours (Yao, Huang, and Wang 2015). These advances demonstrated that FSM-based models could be made to be more flexible, even though a state-only model was still unable to represent the uncertainty of dynamic stealth situations (Deokar et al. 2023).

The shift towards adaptive models and away from rule-based models brought about new design tensions. The developers aim at balancing the issues of fairness and consistency on one hand and on the other hand, realism and unpredictability. Excessive adaptability is a risk to players that become overwhelmed and excessive adaptability is a weakness since it reduces interaction. Studies indicate that believability and immersion require NPCs to have purposeful and meaningful behavior as opposed to being algorithmically complex (Al Enezi and Verbrugge 2023; Zhai 2024). Narrative-based research also shows that adaptive interactions do improve emotional bonding and trust between players and NPCs but also lead to ethical and transparency issues (Zou 2024). Taken together, this literature highlights a critical balancing act: adaptive AI can enhance stealth experiences by giving them greater realism and emotional richness, but it is the balance between the level of computational sophistication and player-centred design principles that will make adaptive AI succeed. Although there are some improvements, empirical evidence of adaptive frameworks in stealth-specific situations is still scarce, which highlights the necessity of additional experimentation (Lin et al. 2024; Kumbharkar 2025).

STEALTH BEHAVIOUR ADAPTIVE AI APPROACHES

Investigations into adaptive AI to stealth NPCs have grown exponentially, with models aiming to balance responsiveness, realism and computational efficiency. One of the most powerful paradigms has become RL. With RL, NPCs optimize strategies by interacting with the environment repeatedly, and it generates emergent behaviours, which improve as the interaction proceeds. In stealth scenarios, NPCs may eventually be able to learn how to anticipate or mitigate hiding behaviours and strategy of players. Research indicates that NPCs controlled by RL enhance tactical complexity and unpredictability, minimizing scripted behaviour and increasing immersion (Sukmana et al. 2024; Ponce and Padilla 2014). Nonetheless, deep RL systems require significant processing power and require a long training time, which restricts their use in real-time applications (Zheng 2025). In spite of these limitations, RL offers a fundamental process of simulating perception, pursuit, and planning in a highly realistic manner (Gutiérrez-Sánchez et al. 2021).

In addition to RL, evolutionary algorithms and dynamic scripting have also been embraced to produce adaptive tactics by optimisation. Dynamic scripting allows NPCs to change decision rules using weighted probabilities which change with gameplay, and evolutionary learning automatically creates and optimizes these rule bases. Empirical findings indicate that hybrid approaches like evolutionary dynamic scripting produce greater and more effective opponent behaviours (Spronck et al. 2006; Kop et al. 2015). These methods strike a balance between algorithmic autonomy and developer control, but can be unsatisfactory in more complex stealth cases (Oliveira et al. 2018). In this way, the issue of the trade off between control and emergence is fundamental to adaptive design.

Procedural modelling and player modelling is a complementary direction. Procedural systems adjust dynamically patrol paths or detection thresholds to suit the performance of players, and player-modelling algorithms predict player behaviour or errors based on behavioural data. These methods ensure interaction with adaptive challenges and customized stealth feedback (Tan, Tan, and Tay 2011; Koch and Manoonpong 2022). Nevertheless, excessive customization threatens the ethical consideration because adaptation may become manipulative or intrusive in the case of a lack of transparency (Zou 2024). The latest case examples of hybrid architectures demonstrate that the most interesting stealth experiences are not always the result of algorithmic complexity but the harmony between adaptive systems and the perception of

players (Lin et al. 2024; Carneiro and Cunha 2012). Collectively, the developments are an indication of a slow shift to NPCs that can learn, reason, and react in contextual intelligence in dynamic stealth settings.

STEALTH AI WITH PLAYER MODELLING AND PERSONALISATION

A key aspect of adaptive AI is player modelling, in which NPCs understand, anticipate, and act in response to the actions of individual players. This is frequently done in stealth settings, where it is sought to predict future behaviour by analysing repeat strategies of the opponent, like routes of choice, hiding spots, or timing of engagement. Predictive profiles of players are increasingly created by machine learning models to create more dynamic encounters with NPCs (van der Linden et al. 2021; Zhou et al. 2020). Research indicates that these adaptive prediction systems can make the game more immersive and tense by enabling NPCs to seem attentive and smart, thus contributing to the realism of stealth gameplay (Charles and McNeill 2017; Bakkes, Tan, and Pisan 2012). Nevertheless, these systems are as accurate as the quality of behavioural data and the level of transparency allowed in the player experience (Ringer et al. 2021; Paraschos and Koulouriotis 2022).

One of the key issues in designing adaptive stealth is how to be fair and at the same time remain engaged. Adaptation can make the AI seem punitive to the players, or be overly lenient, making the gameplay less tense and less replayable. Studies on dynamic difficulty adjustment (DDA) and player modelling have shown that to be effectively adapted, unpredictability must be regulated to ensure that NPCs feel smart, but not omniscient (Tan, Tan, and Tay 2011; Fisher and Kulshreshth 2024). Psychological research also indicates that the perceived fairness and empathy play a significant role in player trust and enjoyment, which implies that adaptive AI must create a balance between competitiveness and compassion (Melhárt et al. 2023; Harefa, Soumury, and Syahputra 2024). Probabilistic learning and limited adaptation models have thus been investigated by designers, whereby NPCs evolve within set behavioural limits to maintain player agency and satisfaction (Conway and Martínez 2022; Demediuk, Raffe, and Li 2016).

In addition to mechanics, psychological and affective modelling enhance immersion by matching the behaviour of NPCs with the emotion and personality of the player. Affective computing allows the NPCs to adjust aggression or caution according to the emotional state of the player, fostering narrative cohesion and believability in stealth experiences (Martínez et al. 2021; Lin et al. 2024). But excessive personalisation also has an ethical implication when adaptive systems use cognitive biases or emotional cues to maintain attention (Zou 2024). A good design must therefore strike a balance between behavioural realism and ethical restraint, where adaptation is more likely to improve player experience, rather than to manipulate it. Taken together, these papers prove that the adaptive AI of stealth gameplay can be successful not only due to technical complexity but also its ability to replicate human perception, emotion, and decision-making, making AI a collaborator in the generation of significant player experiences.

CHALLENGES IN IMPLEMENTING ADAPTIVE STEALTH AI

Although adaptive AI is still being developed, there are significant practical and conceptual challenges to implementing it in stealth games. Computational cost of real-time adaptation is one of the most tenacious challenges. The training and resource consumption of RL and evolutionary algorithms can be extremely restrictive to run on consumer-grade hardware (Zheng 2025; Sukmana, Rahmad, and Khairy 2024). Numerous prototypes work well in small

testbeds but do not scale to large, open-world scenarios with many NPCs (Koch and Manoonpong 2022; Lin et al. 2024). Experience replay and approximate Q-learning are performance optimisation methods that have been suggested to address these limitations, but they can tend to decrease the richness or responsiveness of behaviour (Gutiérrez-Sánchez et al. 2021). The central issue is probably to find a balance between adaptivity and efficiency in such a way that the NPCs are believable without pushing the computational boundaries.

The other significant challenge is sustaining plausibility and storyline in adaptive systems. With AI becoming more reactive, it will threaten to interrupt the narrative or shatter a sense of immersion when behaviours seem to have no basis in narrative logic (Baldwin, Cook, and Whitehead 2021). Adaptive responses need to be developed in a way that they match character drives and the thematic structure of the game. Interactive storytelling research indicates that players tend to put more emphasis on coherence and predictability in the fiction rather than on algorithmic complexity (El-Nasr et al. 2020). Excessive adaptability introduces random alterations to tone and difficulty levels, causing loss of control over gameplay. Hybrid systems with rule-based narrative constraints combined with an adaptive decision-making approach are proven effective in preserving immersion (Lin et al. 2024; Carneiro and Cunha 2012).

Further issues associated with the development of adaptive AI include ethics and design aspects. Transparency, player agency, and fairness become critical ethical problems with adaptive AI. Adaptive technologies equipped with predictive capabilities can potentially be used for manipulating players or making decisions secretly (Melhárt et al. 2023). When dealing with stealth situations, adaptive AI might exploit psychological aspects, such as fear or frustration, to make the game more engaging. This issue leads to the problem of informed consent and emotional freedom. To address these ethical issues, explainable AI (XAI) models can be introduced to improve transparency in NPC behaviors and decisions (Abdullah et al. 2024). Thus, the integration of ethical approaches into the development of adaptive AI enables the technology to be a facilitator of immersive experience rather than a tool of deception. As research proves, the progress made within this field is limited both by technical difficulties and by the confrontation of realism, ethics, and playability.

FUTURE AND RESEARCH OPPORTUNITIES.

Further studies of adaptive AI in stealth NPCs are shifting to more extensive incorporation of machine learning, generative AI, and large language models (LLMs). Such technologies have started to redefine the behaviour of the NPCs by making them be able to reason contextually, create dialogue, and respond to the environment in a dynamic way (Zhou et al. 2024; Tang, Lee, and Xu 2023). Situational awareness and adaptive communication in stealth scenarios can be demonstrated by LLM-driven NPCs and corresponds to human deception and planning. Initial prototypes show that generative systems generate context-aware responses like improvising patrol dialogues or reading player intent, which provide new experiences of realism and unpredictability (Park et al. 2023; Laird and Duchi 2022). Nonetheless, such integrations bring issues of latency, interpretability, and narrative consistency, in cases where generative outputs do not align with the intent of the story (Torrado, Martínez, and Gómez 2025). A manageable creativity is still a key to the development of adaptive stealth AI.

The other prospective line is based on neuroscience, psychology, and human-AI interaction (HAI). NPC sensory systems that simulate human vigilance and decision-making have been designed using the neuroscientific models of attention and perception (Duchowski et al. 2021). The adaptive and affective systems are slowly integrated with the psychological frameworks

of empathy, cognitive load, and emotion of the player (Melhárt et al. 2023). This multi-disciplinary synthesis calls on emotionally intelligent NPCs who can act in subtly (like hesitation, fear, or cooperation) to reduce the gap in immersion. The combination of these understandings also contributes to the ethical reflection since an enhanced comprehension of human cognition and emotion will help to reduce manipulative or invasive adaptation (Zou 2024).

Ongoing challenges define the frontier of adaptive stealth AI research. These include scalability in multiplayer or cooperative environments where NPCs must coordinate across players with distinct strategies (Lin et al. 2024), the emergence of unscripted narrative through dynamic AI interaction (Koenig and Smith 2020), and explainable AI (XAI) models that preserve transparency without diminishing realism (Abdullah et al. 2024). Tackling these challenges involves innovation in efficiency and evaluation techniques, which must tie gameplay experience to design metrics. The evolution of adaptability in artificial intelligence for stealth games depends on the interplay between creativity and control, where generative and cognitive approaches will be used to create realistic NPCs without compromising player experience.

CONCLUSION & FUTURE WORK

This review reveals that adaptive AI significantly improves the quality of the stealth experience by making it more immersive, unpredictable, and engaging. In particular, various design techniques such as adaptive patrol, pursuit, and vigilance allow making NPCs more realistic and believable due to dynamic pathfinding alongside context-sensitive decision structure. Indeed, adaptive implementation of such classical approaches as FSM and algorithms like A* allows creating an illusion of autonomous behaviour and generating unexpected moves through incorporating adaptive design techniques (Hart, Nilsson, and Raphael 1968; Russell and Norvig 2021). Adaptive AI increases unpredictability and engages players' analytical skills thus contributing to the development of the gaming experience and its replayability.

However, despite the great potential of adaptive AI approaches such as reinforcement learning, hybrid AI and generative AI, their effectiveness is limited due to computational complexity and scalability issues, which are currently addressed insufficiently. Furthermore, there is still a lack of evidence confirming effectiveness of the described approaches in practice (Zheng 2025; Lin et al. 2024). For this reason, effective design and implementation of adaptive AI require finding an optimal balance between flexibility and computational efficiency without compromising the gaming experience or its story aspect. At the same time, in terms of players' experience, adaptivity is determined by such criteria as fairness, credibility, and emotional authenticity. Namely, AI agents should pose a challenging and immersive opponent without manipulating and misguiding the player. Incorporation of affective and behavioural aspects and ethical considerations can enhance the gaming experience through building empathy and making players feel like active participants of the game (Melhárt et al. 2023; Zou 2024).

Finally, looking into the future, it seems likely that AI-based stealth games would involve collaboration between experts from different fields. Particularly, the role of interactive storytelling, computer science, and even cognitive psychology will become more pronounced. In particular, advancements in natural language processing and generative AI might enable further advancement of emergent and context-sensitive narrative (Abdullah et al. 2024; Park et al. 2023). However, such advances should be developed and implemented in a manner that is interpretable and consistent with the ethical framework.

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