iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** XI **Month of publication:** November 2025

DOI: https://doi.org/10.22214/ijraset.2025.75692

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XI Nov 2025- Available at www.ijraset.com

Neo NPC Using Deep Learning: Literature Review

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Abstract: ***This paper presents a novel approach to Non-Playable Character (NPC) design, exploring the integration of artificial intelligence to create dynamic, responsive, and evolving behaviors in virtual environments. We examine how Reinforcement Learning (RL) and Neural Networks (NNs) can be leveraged to develop intelligent NPCs capable of adapting to player interactions, retaining memory of past encounters, and evolving strategies over time. It details the implementation of a playable prototype featuring an AI-powered boss character, whose behavior dynamically adjusts based on player actions to offer a unique experience in every session. This paper aims to provide researchers and practitioners with a comprehensive understanding of how machine learning can transform traditional NPC systems. We review current literature on AI in gaming, compare various techniques for adaptive NPC behavior, and outline our system's design, emphasizing its ability to produce lifelike, interactive, and emotionally resonant characters***
Keywords: Adaptive NPCs, Reinforcement Learning, Neural Networks, Deep Learning, Game AI

I. INTRODUCTION

NPC behavior in video games has traditionally relied on scripted logic and static decision trees, resulting in predictable and non-adaptive interactions. With the rise of deep learning, particularly Reinforcement Learning (RL) and Neural Networks (NNs), intelligent and responsive NPCs have become feasible. The core objective is to develop adaptive NPCs that learn from player interactions, remember past events, and evolve strategies over time. By integrating machine learning techniques with game AI, this paper explores a modular framework for lifelike, context-aware characters. Applications span gaming, simulation, and interactive training environments.

II. LITERATURE REVIEW

The literature survey reviews recent advances in adaptive NPC design, emphasizing reinforcement learning (RL), deep learning, and hybrid AI frameworks in gaming. It highlights the transition from rule-based systems to intelligent, context-aware NPCs capable of evolving behavior dynamically based on player interaction.

A. Natalia Khan et al. (International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 2023). "AI Chatbots in Gaming Experience Transformation." [1]

This paper investigates the application of AI chatbots in gaming to enhance non-linear storytelling and interactive dialogue. It reviews implementations focusing on context awareness and dynamic narrative generation, identifying both computational limitations and potential integration with reinforcement learning systems. The study emphasizes how AI can offer richer gameplay through emotionally adaptive dialogues, though challenges remain in maintaining coherence over extended sessions. It also highlights the role of sentiment analysis in shaping dialogue responses and outlines avenues for integrating voice-based interactions.

B. Kun Shao et al. (Computational Intelligence and Neuroscience, 2022). "A Survey of Deep Reinforcement Learning in Video Games." [2]

This survey categorizes and analyzes Deep Reinforcement Learning (DRL) methods like DQN, PPO, and A3C across various game genres. It outlines algorithmic strengths, implementation challenges, and potential improvements in areas like sample efficiency and multi-agent coordination, but lacks original empirical benchmarks. The paper serves as a foundational reference by tracing the evolution of DRL in gaming and underlines the importance of transfer learning and real-time adaptability in future systems. It also reviews open-source toolkits used in DRL research and notes the scarcity of standardized evaluation environments. This gap affects reproducibility and makes performance benchmarking difficult across diverse gaming environments, limiting cross-study comparisons.

C. *Wemade Next Co. Ltd. et al. (NVIDIA Technical Report, 2025). "AI-Powered NPCs in MMORPG: Asterion Case Study." [3]*

This case study presents an adaptive AI boss character named Asterion from the MMORPG MIR5. It utilizes cloud-based learning and NVIDIA's Avatar Cloud Engine to dynamically adapt strategies based on player behavior, though its reliance on proprietary hardware limits broader access. The system demonstrates how real-time personalization of NPC actions can improve engagement but also highlights the trade-off between computational power and availability. Asterion's behavior evolves across player encounters, enhancing replay value and immersion.

D. *Tejal Kadam et al. (International Journal of Scientific Research in Engineering and Management, 2020). "Reinforcement Learning Bot for Mario." [4]*

This paper details the development of an RL-based bot for Super Mario, using reward shaping to navigate game levels. The bot demonstrates emergent behavior and learns effective strategies autonomously. Limitations include high variability and limited generalization. The authors suggest enhancements through hierarchical reinforcement learning to enable more structured task completion. The study also comments on scalability issues for more complex platforming environments. Additionally, it emphasizes the importance of balancing exploration versus exploitation in sparse-reward settings. The training process relies on episode-level feedback to optimize movement sequences. The implementation showcases how lightweight DRL frameworks can be applied to retro-style games with constrained action spaces.

E. *Natalia Curado Carneiro (International Journal of Advanced Computer Science and Applications, 2021). "FSM-Based Behavior Modeling for Mario." [5]*

The study models Mario's behavior using Finite State Machines (FSM), illustrating simple transitions between actions like walking and jumping. While effective for predictable behaviors, FSMs lack scalability for complex, adaptive decision-making in games. It also notes the rigidity in modifying FSMs when new states are added, making them less ideal for open-ended environments. The approach remains useful in constrained, highly controlled gameplay loops. This structure allows for clear debugging and deterministic outputs, which is advantageous during early-stage prototyping. However, the absence of memory or learning limits responsiveness to dynamic game contexts. The paper suggests FSMs are best suited for classic arcade or puzzle games with minimal player variability.

F. *Pedro Almeida et al. (Applied Sciences, 2024). "Reinforcement Learning as an Approach to Train Multiplayer First-Person Shooter Game Agents." [6]*

This paper evaluates deep reinforcement learning strategies—Curriculum Learning (CL), Behavior Cloning (BC), and hybrid models—for training FPS agents in Unity. Using systematic matchups between bot teams, it found CL outperformed BC by 23.7% in win rates. Hybrid approaches had inconsistent outcomes due to training instability, but the work presents clear pipelines for real-time AI development. It also emphasizes the role of spatial awareness and reaction latency in agent behavior modeling. The research highlights the challenge of balancing aggression and defense through adaptive reward structures. It proposes future refinement through multi-objective optimization and domain randomization. These insights contribute toward building robust, competitive agents suitable for commercial multiplayer environments.

G. *Shouren Wang et al. (arXiv preprint, April 2025). "Enhancing Player Enjoyment with a Two Tier DRL and LLM Based Agent System for Fighting Games." [7]*

This work introduces a Two-Tier Agent system combining DRL-based playstyle agents with an LLM-based hyper-agent that selects suitable opponents based on player feedback. The design enables adaptive matchups in Street Fighter II and boosts user experience, with gameplay showing up to 156% improvement in advanced technique execution. However, the setup adds complexity and lacks transparency in LLM decision-making. It further outlines the potential to scale this system into open-world or role-playing games. The authors emphasize the importance of continual learning cycles informed by player input to personalize difficulty and maintain engagement. The system also introduces a dynamic matchmaking layer, reacting to player proficiency trends in near real-time. Despite its promise, the hybrid approach raises questions about reproducibility, evaluation metrics, and ethical tuning of adaptive difficulty.

H. *Chen Zhang et al. (IEEE Transactions on Games, Early Access, 2024). "Advancing DRL Agents in Commercial Fighting Games: Training, Integration, and Agent-Human Alignment." [8]*

This paper presents Shūkai, a DRL agent deployed in Naruto Mobile, trained via Heterogeneous League Training (HELT) to generalize across 400+ characters. The system employs human-aligned reward mechanisms and diverse agent architectures. Results show a 22% boost in training speed and effective performance across characters, though the approach's complexity and reliance on manual tuning are noted as drawbacks. It also emphasizes the need for continuous feedback loops to maintain balance as new characters are added. Additionally, the work explores modular policy learning to facilitate incremental updates as the game evolves. The integration pipeline accounts for real-time combat variability, ensuring agents respond fluidly to unpredictable human inputs. However, scalability concerns emerge when extending the framework to less structured or procedurally generated combat environments.

I. *Iveta Dirgová Luptáková et al. (Sensors, 2024). "Playing Flappy Bird Based on Motion Recognition Using a Transformer Model and LIDAR Sensor." [9]*

This research replaces image-based input with LIDAR data in Flappy Bird and uses Transformer models to enhance temporal understanding. Performance improved dramatically over CNN baselines, aided by a risk penalty mechanism. The study, while innovative, is constrained by limited applicability in broader visual games and higher computational costs of Transformers. The findings suggest future integration with lightweight sensor fusion techniques. Additionally, the system demonstrates robustness to environmental noise, making it promising for accessibility-driven game adaptations. However, the setup requires precise calibration and stable input feeds, limiting ease of deployment. The work opens avenues for motion-controlled interfaces that bypass traditional visual pipelines.

J. *Maciej Świechowski et al. (Artificial Intelligence Review, 2023). "Monte Carlo Tree Search: A Review of Recent Modifications and Applications." [10]*

This survey covers enhancements in MCTS, such as UCT variants, parallelization, and neural integrations. It is especially useful for planning-intensive games like Go but has limited direct application in NPC control. The review is comprehensive but lacks empirical comparison across different games. The paper also identifies challenges in real-time deployment—such as latency constraints in RTS games—and emphasizes the need for memory-efficient modifications like dynamic node pruning to enable broader applicability. It also highlights hybrid approaches that combine MCTS with deep learning for better generalization. Moreover, the authors point to growing interest in using MCTS within procedural content generation. Despite the theoretical focus, the paper outlines several future research paths for adaptive and scalable search systems.

K. *Muhammad Bambang Firdaus et al. (Journal of Physics: Conference Series, 2023). "FSM for Retro Arcade Fighting Game." [11]*

The paper designs an FSM-based combo system in Godot for the game Brawl Tale. It highlights predictable transitions and responsive controls, validated through structured development cycles and user testing. However, its deterministic nature restricts adaptability. The study recommends FSMs primarily for games emphasizing mechanical precision over emergent behavior. It also notes that FSMs simplify debugging and maintenance in tightly scoped environments. The system's modular state design improves clarity for developers working in collaborative teams. Despite limitations, FSMs remain practical for latency-sensitive arcade-style combat systems.

L. *Natalia Curado Carneiro et al. (International Journal of Interactive Multimedia and Artificial Intelligence, 2022). "Integrating FSM and Reinforcement Learning for Hybrid NPCs." [12]*

A hybrid framework combines FSM for high-level behavior control and RL for fine-tuned decision-making. The platformer testbed demonstrates faster training and context-aware behaviors, though managing boundaries and reward shaping introduces design complexity. This framework shows promise for balancing predictability and adaptability in commercial games, particularly in genres like stealth or RPGs where nuanced agent responses and structured progression are vital. The study highlights how FSM structures can guide exploration, reducing erratic RL behavior during early training. It also outlines how state transitions can be dynamically adjusted based on learned patterns. However, achieving smooth coordination between FSM logic and RL policies requires careful architecture design and testing.

M. Afzal Hussain et al. (Indonesian Journal of Electrical Engineering and Computer Science, 2023). "A Survey on Unity Game Engine: Architecture, Features, and Its Applications." [13]

This survey outlines Unity's system architecture, component model, and cross-platform deployment. It covers core areas like scripting, rendering, and asset workflows, but lacks discussion on AI or RL integration. The paper serves as a foundational reference for Unity's structure and capabilities. It also includes comparisons with Unreal Engine in terms of toolchain modularity and learning curve. Additionally, it notes Unity's strengths in mobile game development, lightweight runtime efficiency, and superior integration with VR/AR platforms.

III. CONCLUSIONS

The literature reviewed highlights the progressive shift in NPC behavior modeling from rule-based systems such as Finite State Machines to adaptive learning techniques including Deep Reinforcement Learning and hybrid AI architectures. While FSMs remain useful for deterministic control and simplicity, they fall short in dynamic or player-responsive scenarios. Reinforcement learning methods have demonstrated strong potential in developing agents capable of emergent, human-like behaviors, though they often face issues related to training complexity, generalization, and computational cost.

Hybrid approaches—combining FSM structure with neural adaptability or integrating LLMs for contextual reasoning—represent a promising direction for developing scalable and intelligent NPCs. Commercial implementations such as NVIDIA's Asterion and HELT-trained agents in Naruto Mobile provide evidence that adaptive NPC systems are no longer just academic exercises but viable in large-scale game environments.

Overall, the surveyed works establish a foundation for modular, memory-augmented, and context-aware NPC frameworks, positioning them as central to the future of game AI.

IV. ACKNOWLEDGMENT

On presenting the Major Project Phase-1 report on "NEO NPC using Deep Learning". We feel great to express our humble feelings of thanks to all those who have helped us directly or indirectly in the successful completion of the project work. We would like to thank our respected guide Dr. Sankhya N Nayak, Associate Professor, Dept. of CS&E, and our major project phase 1 coordinators Mr. Vedananda D E, Assistant Professor, Dept. of CS&E and Mrs. Radhika S K, Assistant Professor, Dept. of CS&E, who helped us a lot in completing this task, for their continuous encouragement and guidance throughout the project work. We would like to thank Dr. Jalesh Kumar, Professor and Head of the Dept. of CS&E, JNNCE, Shivamogga and Dr. Y Vijaya Kumar, the Principal, JNNCE, Shivamogga for all their support and encouragement. We are grateful to the Department of Computer Science and Engineering and our institution Jawaharlal Nehru New College of Engineering and for imparting us the knowledge with which we can do our best. Finally, we would also like to thank the whole teaching and non-teaching staff of Computer Science and Engineering Department.

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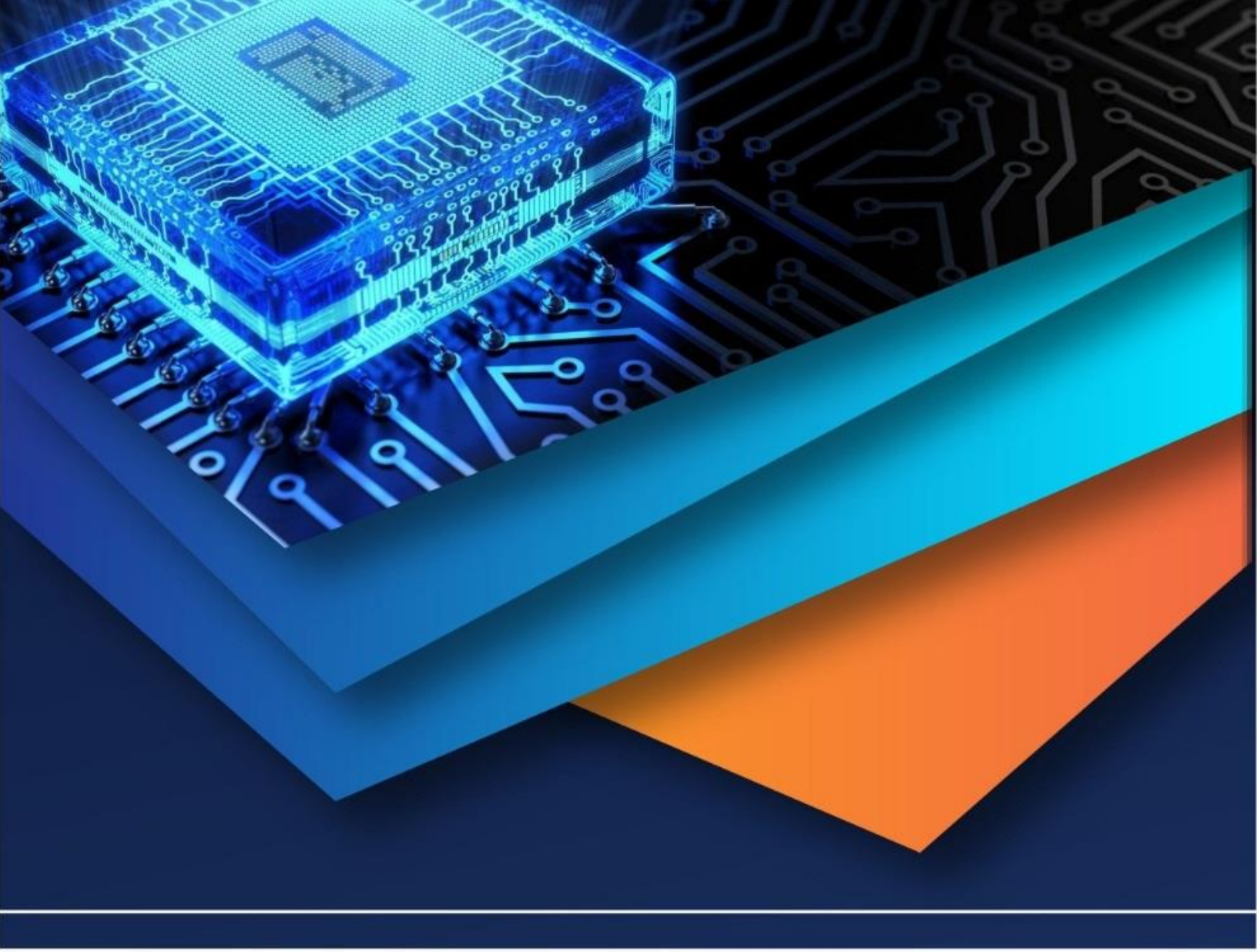

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