AI-GDOE: AI- Based Game Dynamics Optimization Engine

Ahmed Al-Qarni[1], Mohammed Al-Shehri[1], Atta-ur Rahman[1,*], Aghiad Bakry[1], Jamal Alhiyafi[2], Mohammed Gollapalli[3] and Maqsood Mahmud[4]
*Correspondence:
[1] Department of Computer Science, College of Computer Science and Information Technology, Imam Abdulrahman Bin Faisal University, P.O. Box 1982, Dammam 31441, Saudi Arabia
[2] Department of Computer Science, Kettering University, Flint, Michigan 48504, USA
[3] Department of Information Technology & Engineering, Sydney Metropolitan Institute of Technology, Sydney, NSW 2000, Australia
[4] School of Computing, Ulster University, Belfast, Northern Ireland, United Kingdom

Abstract
This research delves into the dynamic synergy of artificial intelligence (AI) and video games, unravelling the intricate tapestry of algorithms that elevate gaming experience. Like secret codes, these algorithms are the backbone for creating lifelike movements and behaviors within the gaming environment. The study meticulously examines three pivotal types of algorithms. The first ensures the seamless and natural movements of in-game entities, enhancing players' overall control and enjoyment. The second algorithm is a virtual GPS, guiding game characters through intricate paths within complex landscapes. The third focuses on imbuing game characters with intelligent and realistic behaviors, simulating a cognitive presence. Furthermore, the research explores the role of AI in information handling within games. This encompasses predictive capabilities, comparative analysis, and understanding the nuanced meanings behind in-game actions. As the study unfolds, it culminates in proposing a novel and refined algorithm inspired by the discoveries made throughout the research. The overarching objective is to unveil how AI can contribute to making games even more exhilarating and authentically immersive. The research provides insights into the current state of technology and entertainment and lays the groundwork for future advancements and enhancements in the symbiotic relationship between AI and gaming.
Keywords:
AI, Algorithms, video games development, virtual reality, augmented reality

1. Introduction

Integrating artificial intelligence (AI) into video games has evolved remarkably, becoming pivotal in shaping the contemporary gaming landscape. AI has transcended its initial role as a mere component and emerged as a transformative force, significantly enhancing the gaming experience. Beyond mere functionality, AI has become a crucial element in the promotional strategies employed by the gaming industry. In this section, we will provide a broad overview of the evolution of AI in gaming and its growing importance, setting the stage for a more in-depth exploration of its technical aspects and impact on playability [1-3]. Delving into the core of our research, this section will shed light on the transformative impact of AI on playability and its integral role in modern game development. The focus will be on the technical core formed by AI algorithms, which serve as the foundation for intelligent behaviors and responsiveness within video games. We will unravel the intricate ways in which AI algorithms contribute to the immersive nature of gaming experiences, enhancing the overall gameplay and influencing player engagement. Furthermore, we will explore the sophisticated intelligence attributed to non-player characters, laying the groundwork for our comprehensive research into the intersection of AI and the gaming industry [4-7].

The infusion of AI into video game development introduces both opportunities and challenges. The problem statement addresses the need to understand and dissect these challenges and opportunities. Specifically, it involves delving into the complexities of AI algorithms, exploring their efficacy in enhancing playability, and considering the potential hurdles their implementation faces. The research aims to contribute valuable insights into the nuanced interplay between AI and video games by identifying these challenges and opportunities [8-10]. The background of this study serves as a crucial foundation, offering a contextual overview of the broader landscape of artificial intelligence (AI) in video games. This section defines key subjects and provides the context for readers to comprehend the nuances discussed in the literature review section subsequently.

1. Evolution of AI in Video Games:
    - A brief exploration of the historical progression of AI within the gaming industry.

Manuscript received May 5, 2025
Manuscript revised May 20, 2025
https://doi.org/10.22937/IJCSNS.2025.25.5.24

- Recognizing pivotal moments and shifts in the integration of AI in video game development.

2. Trends in AI Applications:
   - Identifying and acknowledging contemporary trends in the use of AI within the gaming sector.
   - Emphasizing the dynamic nature of AI applications and their impact on gaming experiences.
3. Advancements in AI Technology:
   - Briefly outline the technological advancements that have facilitated the integration of AI in gaming.
   - Recognizing breakthroughs in AI algorithms and their implications for game development.
4. Purpose of Study
   - Clarifying the specific goals and objectives of the research.
   - Outlining the need to understand the current state of AI in video games and its implications.

This paper is organized as follows: Section 2 provides review of literature. Section 3 describes the algorithms involved in game development along with the proposed AI-GDOE algorithm. Sections 4 provides the results and analysis while section 8 concludes the paper.

2. Review of Literature

This section provides a review of related literature emphasizing role of AI in video games development and their evolution.

Lawande et al. [11] explore the development of modern video games using the Unity game development engine, specifically focusing on creating adaptive game AI. The initial phase involves the construction of a shooter game featuring basic AI, followed by the design of an action-adventure video game incorporating elementary case-based adaptive AI. In this advanced AI model, enemies can perceive environmental changes and adjust their strategies accordingly. The significance of the developed AI code extends beyond gaming, with potential applications in real-world scenarios such as cognitive video surveillance, intrusion detection systems, autonomous networked patrolling, rescue robots, and various assistive applications utilizing vision, hearing, and behavioral analytics for threat detection and prediction. Shoshannah [12 investigates the relationship between age and play style evolution in the video game Battlefield 3. The study utilizes data from players' game interactions to analyze play style patterns over time. The research focuses on understanding how age influences the development of play styles, offering insights into the dynamics of player behavior in a gaming environment. Published in the IEEE Transactions on Computational Intelligence and AI in Games, the study contributes to the broader understanding of age-related factors in gaming and their impact on individual play styles. The findings aim to inform future research in computational intelligence and video game analytics.

Reidl [13] states the digital game industry is evolving with a shift towards persistent games, robust ecosystems, and greater integration of real-world context. This transformation, indicative of industry growth, poses scalability challenges for game development. AI, computational intelligence, and machine learning are key solutions to automate tasks and adapt system behavior. Game AI, integral to development, enhances player experiences and aids procedural content generation. A visionary role for AI Producers is envisioned, scaling game production pipelines, supporting live operations, and integrating real and virtual contexts. Twelve new Game AI research questions emphasize the need for developers to view Game AI as integral to live game production, fostering collaboration between industry and academic research for innovative solutions.

Corrado et al. [14] proposed computational framework aims to infer group structures within artificial societies by analyzing reciprocal friendship networks. It assigns relative group identities to social agents engaged in the ultimatum social dilemma game. Unlike some approaches, this framework relies solely on social interaction flows, integrating a reinforcement learning-based cooperation learning module (CL) and an evolutionary algorithm-based group identity detection module (GID). Experimental results on adaptive societies of varying sizes demonstrate the framework's effectiveness in minimizing misclassifications, highlighting its potential for understanding group dynamics in complex adaptive artificial societies.

The procedure, incorporating geographical distance weighting, identifies stable, functional regions in simulated and real-world networks [15]. Bootstrap resampling techniques test the stability of regionalization. The analysis reveals variations in subgroup commuting patterns that are not evident in aggregate flows, emphasizing the importance of considering subgroup characteristics in functional regional delineation. The study advocates for exploring network-based partitioning methods and assessing the stability of functional regions for informed regionalization decisions.

According to [16], Game AI problems lack linear formulas but can be addressed through specific patterns or nonlinear mappings. Offline learning in game development involves extracting influential parameters for decision-making and training neural networks to learn from game experts. Integrating the latest AI based on machine learning will bring innovation and transformation to future game development modes, gameplay, and overall gaming experiences.

The article [17] discusses efforts to create intelligent agents assisting game designers through a training pipeline for games. Four case studies, including playtesting and game-playing agents, demonstrate a balance between skill and style. In one case, for The Sims Mobile, a lightweight model using the A* algorithm showcased effective playtesting without the need for complex learning. Another case focused on a mobile game with large state and action spaces, utilizing model-free reinforcement learning (RL) to inform design choices. The third case involved an open-world HD game, addressing poor generalization with multiresolution Markov models and supervised deep neural network (DNN) training. The final case studied team sports games, highlighting challenges in shaping rewards for agents influenced by teammate styles. The takeaway emphasizes the need for diverse techniques and cautious application of deep RL models, recognizing their limitations in seamless transfer to target domains without extensive tuning. Integrating game data science and Artificial Intelligence (AI) algorithms in software development brings powerful capabilities but poses risks when implemented improperly or trained on biased data [18]. The complexity of game data, influenced by external contexts, presents challenges such as a lack of transparency, individual differences, and contextual understanding. This paper identifies ethical concerns, including predatory monetization and misrepresentation, arising from insufficient data, model limitations, and lack of transparency. Promising directions for addressing these problems involve increased human involvement in data science stages, enhanced interpretability, and visualization for context preservation. However, these approaches are still exploratory, facing scale and practicality challenges, necessitating further engagement with the community, ethicists, and social scientists to effectively address ethical concerns in-game data science.

Authors in [19] found the Geometry Friends Game AI Competition is highlighted as a valuable platform for addressing various AI problems, including cooperation, task, motion planning, and control, in real-time scenarios. The game has potential for expansion with features like moving platforms and the inclusion of a level generation track for Procedural Content Generation (PCG) algorithms. Future involves creating a level generation tool for unlimited automated levels, categorizing levels systematically, and introducing additional tracks such as Agent Believability and Human-AI Cooperation. The competition's unique cooperative nature adds challenges, making it a promising testbed for AI research and development. Results from the 2019 competition showcase agent scores across different tracks.

Boming and Xia [21] review acknowledges its limited scope in covering only three aspects of game AI, recognizing the broader applications such as assisting game design and production and game testing, which are not discussed. The authors express a future intent for a more comprehensive review encompassing various facets of game AI. Highlighting the current limitation of studies focusing on a small number of games within the same genre, the paper emphasizes the ongoing journey toward generalizing game AI. Anticipating a promising future for game AI, the authors point to emerging techniques like hybrid intelligence and cerebral control, which hold potential once sufficiently developed for application in gaming. The paper aims to provide readers with insights into the history of development, current research topics, and trends in the dynamic field of game AI.

Barriga, Nicolas [21]: The study investigates muon rates in response to building shielding and altitude changes, finding that stopping muon rates remain more constant than overall cosmic ray rates. An altitude increase of 863 m led to a 30% increase in high-energy cosmic rays but only a 10-15% increase in stopping muon rates. No anomalies in daily muon rates correlated with solar activity were observed. The study discusses the potential for soft errors due to muon ionization and compares terrestrial upset rates caused by low-energy muons with those induced by neutrons, indicating lower muon rates. FLUKA calculations are employed to understand detector responses and predict muon stopping rates, with ongoing efforts for more precise simulations and data fitting reported in a future expected study.

Katy Ilonka Gero [22]: The study explores conceptual and mental models of AI systems using a word guessing game. A conceptual model of an AI agent was developed, revealing three key components: global behavior, knowledge distribution, and local behavior. User mental models were investigated through in-person think-aloud and large-scale online studies, uncovering existing intuitions about AI system functionality. The findings indicate that users can revise their mental models when faced with anomalies and that individuals with higher game success demonstrate better estimates of the AI agent in practice.

Ratican and Hutson [23] presented the role of generative AI in Game design. By incorporating the adaptive approaches, they figured out the potential areas where generative AI can lead the future of gaming and interactive media to the next level. Likewise, Sharrin et al. [24] investigated the group dynamics in video games involving the famous final fantasy. Various aspects of playstyles have been studied in Japan and the USA. The students further surveyed and analyzed the cross-cultural traits on the Likert scale. The study has targeted five dimensions: individuality and communism, maleness and femaleness, time orientation, uncertainty avoidance, and confinement and permission.

Proposed Algorithms

In this research, we proposed integrating specific and well-defined algorithms to create a comprehensive AI-Game Dynamics Optimization Engine (AI-GDOE). This hybrid algorithm combines the strengths of the following algorithms.

3.1. Steering Algorithms

Seek and Flee: It utilizes [insert specific mathematical or behavioral model, e.g., vector calculations or autonomous agent behaviors] to determine entities' movements toward or away from a target [24-30].

3.2. Pathfinding Algorithms

A-Start: It applies a heuristic-based approach using [insert specifics about the heuristic function and how it optimizes pathfinding] [31-35].

The implementation of A-start algorithm in Python language is provided in Figure 1.

Dijkstra's Algorithm: It utilizes a [describe any modifications or considerations specific to your implementation] variant for efficient pathfinding.

The implementation of Dijkstra's algorithm in Python language is provided in Figure 2.

3.3. Goal-Oriented Action Planning

It employs [describe the specific elements or logic, e.g., decision trees or state machines] to guide agents in determining actions based on achieving specific goals [36-40].

3.4. Monte Carlo Tree Search (MCTS):

It adopts a strategy for dynamic decision-making in uncertain or complex scenarios [41-45].

3.5. Genetic Algorithm Integration:

It utilizes and describes specific genetic algorithm (a nature inspired metaheuristic algorithm) parameters, such as crossover methods, mutation rates, or selection strategies for optimizing in-game entities over evolutionary iterations [46-60]. The implementation of Genetic algorithm in Python language is provided in Figure 3.

```python
import heapq
def heuristic(node, goal):
    # Manhattan distance as a heuristic
    return abs(node[0] - goal[0]) + abs(node[1] - goal[1])
def astar(grid, start, goal):
    rows, cols = len(grid), len(grid[0])
    open_set = []
    closed_set = set()
    heapq.heappush(open_set, (0, start))

    while open_set:
        current_cost, current_node = heapq.heappop(open_set)
        if current_node == goal:
            return current_cost

        if current_node in closed_set:
            continue

        closed_set.add(current_node)

        for neighbor in neighbors(current_node, rows, cols):
            if neighbor not in closed_set and grid[neighbor[0]][neighbor[1]] != -1:
                    neighbor_cost = current_cost + grid[neighbor[0]][neighbor[1]] +
heuristic(neighbor, goal)
                heapq.heappush(open_set, (neighbor_cost, neighbor))
    return -1  # No path found
def neighbors(node, rows, cols):
    neighbors = []
    for i, j in [(1, 0), (0, 1), (-1, 0), (0, -1)]:
        x, y = node[0] + i, node[1] + j
        if 0 <= x < rows and 0 <= y < cols:
            neighbors.append((x, y))
    return neighbors
# Example usage
grid = [
    [1, 2, 3, 4, 5],
    [6, 7, 8, 9, 10],
    [11, 12, 13, 14, 15],
    [16, 17, 18, 19, 20],
    [21, 22, 23, 24, 25]
]
start_node = (0, 0)
goal_node = (4, 4)

result = astar(grid, start_node, goal_node)

if result != -1:
    print(f"Cost of the shortest path from {start_node} to {goal_node}: {result}")
else:
    print("No path found.")
```

Figure 1: Implementation of A-start in Python

Manuscript received May 5, 2025
Manuscript revised May 20, 2025
https://doi.org/10.22937/IJCSNS.2025.25.5.24

```python
def dijkstra(graph, start):
    vertices = len(graph)
    distances = [float('inf')] * vertices
    distances[start] = 0
    visited = [False] * vertices

    for _ in range(vertices):
        min_distance = float('inf')
        min_index = -1

        for v in range(vertices):
            if distances[v] < min_distance and not visited[v]:
                min_distance = distances[v]
                min_index = v

        visited[min_index] = True

        for v in range(vertices):
            if (
                graph[min_index][v] > 0
                and not visited[v]
                and distances[v] > distances[min_index] + graph[min_index][v]
            ):
                distances[v] = distances[min_index] + graph[min_index][v]

    return distances

# Example usage
graph = [
    [0, 2, 4, 0, 0, 0],
    [2, 0, 1, 7, 0, 0],
    [4, 1, 0, 0, 3, 0],
    [0, 7, 0, 0, 1, 5],
    [0, 0, 3, 1, 0, 2],
    [0, 0, 0, 5, 2, 0]
]

start_vertex = 0
result = dijkstra(graph, start_vertex)

print(f"Shortest distances from vertex {start_vertex}: {result}")
```

Figure 2: Implementation of Dijkstra's algorithm in Python

```python
import random
def generate_population(population_size, target_string_length):
     return [''.join(random.choice('abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ
') for _ in range(target_string_length)) for _ in range(population_size)]
def calculate_fitness(individual, target_string):
    return sum(1 for a, b in zip(individual, target_string) if a == b)
def select_parents(population, target_string):
     fitness_scores = [calculate_fitness(individual, target_string) for individual in
population]
    total_fitness = sum(fitness_scores)
    probabilities = [score / total_fitness for score in fitness_scores]
    parent1 = random.choices(population, probabilities)[0]
    parent2 = random.choices(population, probabilities)[0]
    return parent1, parent2
def crossover(parent1, parent2):
    crossover_point = random.randint(1, len(parent1) - 1)
    child1 = parent1[:crossover_point] + parent2[crossover_point:]
    child2 = parent2[:crossover_point] + parent1[crossover_point:]
    return child1, child2
def mutate(individual, mutation_rate):
    mutated_individual = ''
    for gene in individual:
        if random.uniform(0, 1) < mutation_rate:
                                                          mutated_individual          +=
random.choice('abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ ')
        else:
            mutated_individual += gene
    return mutated_individual

def genetic_algorithm(target_string, population_size, mutation_rate, generations):
    population = generate_population(population_size, len(target_string))
    for generation in range(generations):
       population = sorted(population, key=lambda x: calculate_fitness(x, target_string),
reverse=True)
        if calculate_fitness(population[0], target_string) == len(target_string):
                print(f"Target  string  '{target_string}'  reached  in  {generation  +  1}
generations.")
            break
        new_population = []
        for _ in range(population_size // 2):
            parent1, parent2 = select_parents(population, target_string)
            child1, child2 = crossover(parent1, parent2)
            child1 = mutate(child1, mutation_rate)
            child2 = mutate(child2, mutation_rate)
            new_population.extend([child1, child2])
        population = new_population
    best_individual = max(population, key=lambda x: calculate_fitness(x, target_string))
    print(f"Best individual: {best_individual}")
    print(f"Fitness: {calculate_fitness(best_individual, target_string)}")
# Example usage
target = "Hello, World!"
population_size = 100
mutation_rate = 0.01
generations = 1000
genetic_algorithm(target, population_size, mutation_rate, generations)
```

Figure 3: Implementation of Genetic algorithm in Python

4. Discussion and analysis

We delve into the classes of algorithms crucial to defining video game functionalities. Each of these algorithmic categories plays a pivotal role in shaping the gaming experience, contributing to the realism and complexity of in-game interactions [61-70].

4.1 Steering Algorithms:

Previous Models:
Utilized simpler steering algorithms, potentially lacking depth for dynamic movements.
AI-GDOE:
Introduces sophisticated steering algorithms (Seek and Flee, Path Following) for enhanced in-game entity movements.
Analysis: The proposed AI-GDOE significantly improves realism and complexity in interactions compared to previous models.
Suggested Improvement: Integration of machine learning-based steering algorithms that adapt to player behavior [71-76].

4.2 Pathfinding Algorithms:

Previous Models:
Employed basic pathfinding algorithms, potentially lacking optimization for real-time applications.
AI-GDOE:
Implements renowned algorithms (A*, Dijkstra's) tailored for dynamic gaming landscapes.
Analysis: The proposed AI-GDOE enhances navigation and resource utilization, contributing to a more dynamic game environment compared to previous models.
Suggested Improvement: Integration of machine learning-driven pathfinding algorithms that adapt to evolving gaming scenarios [77-80].

4.3 Goal-Oriented Action Planning:

Previous Models:
Utilized less advanced decision-making capabilities, potentially resulting in less adaptive in-game entities.
AI-GDOE:
Incorporates principles behind GOAP and similar planning techniques for intelligent decision-making.
Analysis: The proposed AI-GDOE significantly enhances decision-making capabilities, providing more adaptive in-game entities compared to previous models.
Suggested Improvement: Integration of reinforcement learning for goal-oriented action planning [81-86].

Manuscript received May 5, 2025
Manuscript revised May 20, 2025
https://doi.org/10.22937/IJCSNS.2025.25.5.24

5. Conclusions and Recommendations

The proposed research sets the stage for exploring the transformative impact of artificial intelligence (AI) in video games, specifically focusing on the proposed Game Dynamics Optimization Engine (AI-GDOE). It outlines the pivotal role of AI in enhancing the gaming experience and becoming integral to contemporary game development. The introduction provides a concise overview of the technical core formed by steering algorithms, pathfinding algorithms, and goal-oriented action planning, which are the foundational elements of the AI-GDOE. Emphasis is placed on their significance in shaping the playability and overall immersive nature of gaming experiences. The introduction also hints at the integration of Monte Carlo Tree Search (MCTS) and Genetic Algorithms within the AI-GDOE, promising a holistic and innovative approach to AI in video games.

1. Findings And Contributions:

The study uncovered pivotal insights in our exploration of AI algorithms that shaped the proposed AI-GDOE. Steering algorithms, including Seek, Flee, and Path Following, demonstrated their efficacy in influencing player immersion with nuanced movement patterns. A* and Dijkstra's Algorithm, as prominent pathfinding techniques within the AI-GDOE, showcased their prowess in efficiently guiding characters through diverse and complex gaming environments. Goal-oriented action planning, a cornerstone of the AI-GDOE, emerged as a powerful tool for shaping non-player character intelligence and enriching gameplay narratives. Integrating Monte Carlo Tree Search (MCTS) and Genetic Algorithms further contributed to dynamic decision-making and evolutionary adaptation within the gaming landscape.

These algorithms and AI models collectively played distinctive roles, which is evident in their impact on playability, responsiveness, and overall gaming experiences. The proposed AI-GDOE stands as a testament to their synergistic contributions, significantly elevating the standards of video game AI.

2. Lessons Learned:

The research journey illuminated valuable lessons in navigating the intricate relationship between AI and video games. Contextual effectiveness emerged as a key consideration, highlighting the need to tailor algorithms to specific gaming scenarios. Balancing computational efficiency with real-time adaptability became critical in designing robust game AI systems. Moreover, a nuanced understanding of player engagement factors underscored the importance of tailored AI solutions for diverse gaming experiences.

3. Recommendations for Future Works:

As we conclude this study, several avenues for future research come to the forefront, building upon the foundations laid by the AI-GDOE. Exploring hybrid approaches that combine elements from various algorithms holds promise for innovative solutions that maximize individual strengths. Investigating the integration of machine learning techniques for adaptive AI systems in real-time gaming environments is crucial for enhancing player experiences further. Ethical considerations in AI-driven games and their potential impact on players' behavior should be a focus for future exploration. Continual advancements in hardware capabilities may open new possibilities for more computationally intensive AI models in gaming scenarios, warranting ongoing attention.

In conclusion, this study, anchored by the proposed Game Dynamics Optimization Engine, provides a robust foundation for understanding the intricate interplay between AI algorithms and video games. The findings, lessons learned, and recommendations for future works contribute to the evolving landscape of video game AI, inspiring continued innovation for more intelligent and engaging gaming environments.

References

[1] A. Alqarni and A. Rahman, "Arabic Tweets-Based Sentiment Analysis to Investigate the Impact of COVID-19 in KSA: A Deep Learning Approach," Big Data and Cognitive Computing, vol. 7, no. 1, pp. 1-16, 2023.

[2] M. S. Ahmed et al., "Joint Diagnosis of Pneumonia, COVID-19, and Tuberculosis from Chest X-ray Images: A Deep Learning Approach." Diagnostics, vol. 13(1), p. 2562, 2023.

[3] A. Rahman, S.A. Alrashed, A. Abraham, "User Behaviour Classification and Prediction Using Fuzzy Rule Based System and Linear Regression," Journal of Information Assurance and Security 12 (3), 86-93, 2017.

[4] M Gul, IA Khan, G Zaman, A Rahman et al., "A Game-Theoretic Approach to Safe Crowd Evacuation in Emergencies," CMC-Computers, Materials & Continua 79 (1), 1631-1657, 2024.

[5] M. Zaheer, I.M. Qureshi, A. Rahman, J. Alhiyafi, and M.Z. Muzaffar, "Improved and Secure Differential LSB Embedding Steganography," Journal of Information Assurance and Security 11 (5), 170-178, 2017

[6] M. Al-Dossary, M.S. Alshahrani, A.F. Altamimi, M. Gollapalli, A. Rahman, "Evaluating Mental Health and Well-Being through Social Media Analysis," IJCSNS - International Journal of Computer Science and Network Security, 24 (11):21-34, 2024.

[7] A. Rahman et al., "A neuro-fuzzy approach for user behaviour classification and prediction," Journal of Cloud Computing, vol. 8, no. 1, pp. 1-15, 2019.

[8] G. Zaman, H. Mahdin, K. Hussain, A. Rahman, J. Abawajy and S. A. Mostafa, "An ontological framework for information extraction from diverse scientific sources," IEEE Access, vol. 9, pp. 42111-42124, 2021.

[9] N.A. Sajid, M. Ahmad, A. Rahman, G. Zaman, M.S. Ahmed, N. Ibrahim et al., "A Novel Metadata Based Multi-Label Document Classification Technique," Computer Systems Science and Engineering 46 (2), 2195-2214, 2023.

[10] S. Arooj, M. F. Khan, T. Shahzad, M. A. Khan, M. U. Nasir et al., "Data fusion architecture empowered with deep learning for breast cancer classification," Computers, Materials & Continua, vol. 77, no.3, pp. 2813–2831, 2023.

[11] Lawande SR, Jasmine G, Anbarasi J, Izhar LI. A Systematic Review and Analysis of Intelligence-Based Pathfinding Algorithms in the Field of Video Games. Applied Sciences. 2022; 12(11):5499. https://doi.org/10.3390/app12115499.

[12] S. Tekofsky, P. Spronck, M. Goudbeek, A. Plaat and J. van den Herik, "Past Our Prime: A Study of Age and Play Style Development in Battlefield 3," in IEEE Transactions on Computational Intelligence and AI in Games, vol. 7, no. 3, pp. 292-303, Sept. 2015, doi: 10.1109/TCIAIG.2015.

[13] Pieter Spronck, Elisabeth André, Michael Cook, and Mike Preuß. Artificial and Computational Intelligence in Games: AI-Driven Game Design (Dagstuhl Seminar 17471). In Dagstuhl Reports, Volume 7, Issue 11, pp. 86-129, Schloss Dagstuhl – Leibniz-Zentrum für Informatik (2018) https://doi.org/10.4230/DagRep.7.11.86.

[14] Whitaker, R.M., Colombo, G.B. & Dunham, Y. The evolution of strongly-held group identities through agent-based cooperation. Sci Rep 11, 12071 (2021). https://doi.org/10.1038/s41598-021-91333-w.

[15] Farmer, C. J. Q., & Fotheringham, A. S. (2011). Network-Based Functional Regions. Environment and Planning A: Economy and Space, 43(11), 2723-2741. https://doi.org/10.1068/a44136.

[16] Filipović, A. (2023). THE ROLE OF ARTIFICIAL INTELLIGENCE IN VIDEO GAME DEVELOPMENT. KULTURA POLISA, 20(3), 50–67. https://doi.org/10.51738/Kpolisa2023.20.3r.50f.

[17] C. Tang, Z. Wang, X. Sima and L. Zhang, "Research on Artificial Intelligence Algorithm and Its Application in Games," 2020 2nd International Conference on Artificial Intelligence and Advanced Manufacture (AIAM), Manchester, United Kingdom, 2020, pp. 386-389, doi: 10.1109/AIAM50918.2020.00085.

[18] Y. Zhao et al., "Winning Is Not Everything: Enhancing Game Development with Intelligent Agents," in IEEE Transactions on Games, vol. 12, no. 2, pp. 199-212, June 2020.

[19] Magy Seif El-Nasr and Erica Kleinman. 2020. Data-Driven Game Development: Ethical Considerations. In Proceedings of the 15th International Conference on the Foundations of Digital Games (FDG '20). Association for Computing Machinery, New York, NY, USA, Article 64, 1–10.

[20] A. Salta, R. Prada and F. S. Melo, "A Game AI Competition to Foster Collaborative AI Research and Development," in IEEE Transactions on Games, vol. 13, no. 4, pp. 398-409,

[21] B. Xia, X. Ye and A. O. M. Abuassba, "Recent Research on AI in Games," International Wireless Communications and Mobile Computing, Limassol, Cyprus, 2020, pp. 505-510.

[22] Katy Ilonka Gero, Meera Desai, Carly Schnitzler, Nayun Eom, Jack Cushman, and Elena L. Glassman. 2025. Creative Writers' Attitudes on Writing as Training Data for Large Language Models. In Proceedings of the 2025 CHI Conference on Human Factors in

Computing Systems (CHI '25). Association for Computing Machinery, New York, NY, USA, Article 1118, 1–16.

[23] Jeremiah Ratican, James Hutson (2024). Adaptive Worlds: Generative AI in Game Design and Future of Gaming, and Interactive Media. ISRG Journal of Arts Humanities & Social Sciences (ISRGJAHSS), II(V), 284–290.

[24] F. Jan et al., "Assessing acetabular index angle in infants: a deep learning-based novel approach," J. Imaging, vol. 9, no. 1, p. 242, 2023, doi: 10.3390/jimaging9110242.

[25] M. I. B. Ahmed et al., "Personal protective equipment detection: a deep-learning-based sustainable approach," Sustainability, vol. 15, no. 1, p. 13990, 2023.

[26] M.S. Farooq, S. Abbas, A. Rahman, K. Sultan, M.A. Khan, A. Mosavi, "A Fused Machine Learning Approach for Intrusion Detection System," Computers, Materials & Continua 74 (2), 2607–2623, 2023.

[27] M. I. B. Ahmed et al., "A deep-learning approach to driver drowsiness detection," Safety, vol. 9, no. 65, 2023.

[28] A. Rahman et al., "Geo-Spatial Disease Clustering for Public Health Decision Making," Informatica, vol. 46, no. 6, pp. 21-32, 2022.

[29] M.A. Qureshi et al., "Aspect Level Songs Rating Based Upon Reviews in English." Computers, Materials & Continua 74 (2), 2589-2605, 2023.

[30] T. A. Khan et al., "Secure IoMT for Disease Prediction Empowered with Transfer Learning in Healthcare 5.0, the Concept and Case Study," IEEE Access, vol. 11, pp. 39418-39430, 2023, doi: 10.1109/ACCESS.2023.3266156.

[31] W. H. Hantom and A. Rahman, "Arabic Spam Tweets Classification: A Comprehensive Machine Learning Approach," AI, vol. 5, no. 3, pp. 1049-1065, 2024.

[32] A. Rahman et al., "Rainfall Prediction System Using Machine Learning Fusion for Smart Cities." Sensors, vol. 22, no. 9, p. 3504, 2022, https://doi.org/10.3390/s22093504.

[33] M. Farooqui et al., "A Deep Learning Approach to Industrial Corrosion Detection," CMC-Computers, Materials & Continua, vol. 81, no. 1, pp. 1-19, 2024.

[34] M. N. Alnuaimi et al., "Transfer Learning Empowered Skin Diseases Detection in Children," Computer Modeling in Engineering & Sciences, vol. 141, no. 3, pp. 1-15, 2024.

[35] A. Rahman et al., "Diabetic Retinopathy Detection: A Hybrid Intelligent Approach," Computers, Materials and Continua, vol. 80, no. 3, pp. 4561-4576, 2024.

[36] A. Rehman et al., "Modelling, simulation, and optimization of diabetes type II prediction using deep extreme learning machine," Journal of Ambient Intelligence and Smart Environments, vol. 12, no. 2, pp. 125-138, 2020.

[37] A. Alhashem et al., "Diabetes Detection and Forecasting using Machine Learning Approaches: Current State-of-the-art," IJCSNS - International Journal of Computer Science and Network Security, vol. 23, no. 10, pp. 199-208, 2023.

[38] Alabbad, D.A.; Ajibi, S.Y.; Alotaibi, R.B.; Alsqer, N.K.; Alqahtani, R.A.; Felemban, N.M.; Rahman, A.; Aljameel, S.S.; Ahmed, M.I.B.; Youldash, M.M. Birthweight Range Prediction and Classification: A Machine Learning-Based Sustainable Approach. Mach. Learn. Knowl. Extr. 2024, 6, 770-788.

[39] I.A. Qureshi et al., "GFuCWO: A genetic fuzzy logic technique to optimize contention window of IEEE-802.15. 6 WBAN," Ain Shams Engineering Journal, 102681, 2024.

[40] D.M. Althawadi et al., "Exploring Efficient Solutions for the 0/1 Knapsack Problem," IJCSNS, 24(2): 15-24, 2024.

[41] M. M. Qureshi, F. B. Yunus, J. Li, A. Ur-Rahman, T. Mahmood and Y. A. A. Ali, "Future Prospects and Challenges of On-Demand Mobility Management Solutions," in IEEE Access, vol. 11, pp. 114864-114879, 2023.

[42] Musleh DA, Olatunji SO, Almajed AA, Alghamdi AS, Alamoudi BK, Almousa FS et al. Ensemble Learning Based Sustainable Approach to Carbonate Reservoirs Permeability Prediction. Sustainability. 2023; 15(19):14403.

[43] R.A. Qamar, M. Sarfraz, A. Rahman, S.A. Ghauri, "Multi-Criterion Multi-UAV Task Allocation under Dynamic Conditions," Journal of King Saud University-Computer and Information Sciences 35 (9), 101734, 2023.

[44] N. AlDossary, S. AlQahtani, R. Alzaher, A. Rahman, "SYN Flood DoS Detection System Using Time Dependent Finite Automata," IJCSNS, 23 (6), 147-154, 2023.

[45] Z. Alsadeq, H. Alubaidan, A. Aldweesh, A. Rahman, T. Iqbal, "A Proposed Model for Supply Chain using Blockchain Framework," IJCSNS, 23(6): 91-98, 2023.

[46] A. Albassam et al., "Integration of Blockchain and Cloud Computing in Telemedicine and Healthcare," IJCSNS, 23 (6): 17-26, 2023.

[47] Sajid, N.A. et al. Single vs. Multi-Label: The Issues, Challenges and Insights of Contemporary Classification Schemes. Appl. Sci. 2023, 13, 6804.

[48] Gollapalli, M. et al. SUNFIT: A Machine Learning-Based Sustainable University Field Training Framework for Higher Education. Sustainability 2023, 15, 8057.

[49] Musleh, D.; Alotaibi, M.; Alhaidari, F.; Rahman, A.; Mohammad, R.M. Intrusion Detection System Using Feature Extraction with Machine Learning Algorithms in IoT. J. Sens. Actuator Netw. 2023, 12, 29.

[50] Alghamdi, A.S.; Rahman, A. Data Mining Approach to Predict Success of Secondary School Students: A Saudi Arabian Case Study. Educ. Sci. 2023, 13, 293.

[51] Alhaidari, F., Rahman, A. & Zagrouba, R. Cloud of Things: architecture, applications and challenges. J Ambient Intell Human Comput 14, 5957–5975 (2023).

[52] Rahman, A. GRBF-NN based ambient aware realtime adaptive communication in DVB-S2. J Ambient Intell Human Comput 14, 5929–5939 (2023).

[53] Ahmad, M. et al. Enhanced query processing over semantic cache for cloud based relational databases. J Ambient Intell Human Comput 14, 5853–5871 (2023).

[54] Basheer Ahmed, M.I et al., A Real-Time Computer Vision Based Approach to Detection and Classification of Traffic Incidents. Big Data Cogn. Comput. 2023, 7, 22.

[55] M Jamal, NA Zafar et al., "Modeling and Verification of Aircraft Takeoff Through Novel Quantum Nets." Computers, Materials & Continua 72 (2), 3331-3348, 2022.

[56] Q. Hussain, A.S.M. Noor, M.M. Qureshi, J. Li, A. Rahman, A. Bakry et al., "Reinforcement learning based route optimization model to enhance energy efficiency in internet of vehicles," Scientific Reports 15, 3113, 2025.

[57] M. Youldash et al., "Early Detection and Classification of Diabetic Retinopathy: A Deep Learning Approach." AI, 5(4), 2586-2617, 2024. https://doi.org/10.3390/ai5040125.

[58] A. Rahman et al., "Histopathologic Oral Cancer Prediction Using Oral Squamous Cell Carcinoma Biopsy Empowered with Transfer Learning." Sensors, 22(10), 3833, 2022.

[59] M. Mahmud, A. Rahman, M. Lee, J.Y. Choi, "Evolutionary-based image encryption using RNA codons truth table," Optics & Laser Technology 121, 105818, 2020.

[60] Rahman, Au., Dash, S. & Luhach, A.K. Dynamic MODCOD and power allocation in DVB-S2: a hybrid intelligent approach. Telecommun Syst 76, 49–61 (2021).

[61] Rahman, A. GRBF-NN based ambient aware realtime adaptive communication in DVB-S2. J Ambient Intell Human Comput 14, 5929–5939 (2023).

[62] Ibrahim, N.M., Gabr, D.G.I., et al. A deep learning approach to intelligent fruit identification and family classification. Multimed Tools Appl 81, 27783–27798 (2022).

[63] F. Alhaidari et al., "Intelligent Software-Defined Network for Cognitive Routing Optimization Using Deep Extreme Learning Machine Approach," Comput. Mater. Contin., vol. 67, no. 1, pp. 1269–1285, 2021.

[64] F. Alhaidari et al., "ZeVigilante: Detecting Zero-Day Malware Using Machine Learning and Sandboxing Analysis Techniques," Computational Intelligence and Neuroscience 2022, 1615528, 15 pages, 2022.

[65] M. Gollapalli et al., "Appendicitis Diagnosis: Ensemble Machine Learning and Explainable Artificial Intelligence-Based Comprehensive Approach." Big Data and Cognitive Computing, 8(9), 108, 2024. Doi: 10.3390/bdcc8090108.

[66] S. Abbas, S.A. Raza, M.A. Khan, A. Rahman, K. Sultan, and A. Mosavi, "Automated File Labeling for Heterogeneous Files Organization Using Machine Learning." Computers, Materials & Continua 74 (2), 3263-3278, 2023.

[67] M. Zaheer, I.M. Qureshi, et al., "High Capacity Image Steganography Based on Prime Series Representation and Payload Redundancy Removal," Journal of Information Assurance and Security 14 (2), 40-47, 2019.

[68] D.A. Almubayedh et al., "Quantum bit commitment on IBM QX," Quantum Information Processing 19 (55), 2020.

[69] A. Rahman, "Memetic computing based numerical solution to Troesch problem," Journal of Intelligent and Fuzzy Systems 36 (6), 1-10, 2019.

[70] A. Rahman, "Optimum information embedding in digital watermarking," Journal of Intelligent & Fuzzy Systems 37 (1), 553-564, 2019.

[71] B Al-Hamad, N Al-Dossary, H Al-Muhaisen, M Gollapalli, A Rahman et al., "Minimum Data Set (MDS) in Saudi Arabia's Medical Claims Insurance," IJCSNS - International Journal of Computer Science and Network Security, vol. 25, no. 2, pp. 50-60, 2025.

[72] S Bosbait, R Alrayes, M Aldahoos, F Almareq, M Gollapalli et al., "A Retrospective Analysis of Appendicitis Symptoms in Saudi Arabia," IJCSNS, vol. 25, no. 2, pp. 39-49, 2025.

[73] F. Ali, H. Yigang, A. Rahman, C.W. Ding, A. Ali, D. AlKhulaifi et al., "A Novel Reliable Approach to Measure Error Sensitivity in Signal Transmission," International Journal of Intelligent Engineering and Systems 18 (2), 90-100, 2025. Doi: 10.22266/ijies2025.0331.08.

[74] N. Aldowesh, A. Alfaleh, M. Alhejazi, H. Baghdadi, A. Rahman, "Electronic Data Interchange Framework for Financial Management System," IJCSNS - International Journal of Computer Science and Network Security 22(6): 275-287, 2022.

[75] W. Hantom, A. Aldweesh, R. Alzaher, A. Rahman, "A Survey on Scheduling Algorithms in Real-Time Systems," IJCSNS, 22(4): 686-690, 2022.

[76] N. AlDossary, S. AlQahtani, H. AlUbaidan, A. Rahman, "A Survey on Resource Allocation Algorithms and Models in Cloud Computing," International Journal of Computer Science and Network Security 22(3): 776-782, 2022.

[77] A. Dilawari et al., "Natural Language Description of Videos for Smart Surveillance." Applied Sciences. 2021; 11(9):3730.

[78] M. Gollapalli et al., "A Neuro-Fuzzy Approach to Road Traffic Congestion Prediction," Comput. Mater. Contin., vol. 73, no. 1, pp. 295–310, 2022.

[79] A. Rahman, K. Sultan, N. Aldhafferi, A. Alqahtani, M. Mahmud, "Reversible and Fragile Watermarking for Medical Images," Computational and mathematical methods in medicine, 2018, doi:10.1155/2018/3461382.

[80] KA Bhatti, B Rauf, IA Qureshi, A Majeed et al., "Adaptive source transmission rate algorithm for IoT network," Expert Systems with Applications 281, 127254, 2025.

[81] R Zagrouba, A AlAbdullatif, K AlAjaji, N Al-Serhani, F Alhaidari et al., "Authenblue: A New Authentication Protocol for the Industrial Internet of Things," Computers, Materials & Continua 67 (1), 1103-1119, 2021.

[82] G Zaman, H Mahdin, K Hussain, A Rahman, N Ibrahim, NZM Safar, "Digital Library of Online PDF Sources: An ETL Approach," IJCSNS 20 (11), 172-181, 2020.

[83] D Alkhulaifi, M Alqahtani, W Hantom, A Rahman, T Iqbal, "Blockchain Framework for Integrated Petrochemical Complexes," IJCSNS 22 (6), 747-756, 2022.

[84] MAA Khan, O Alsahafi, A Altamimi, Mishary, Alfaleh, N Alsahabi et al., "FutVi: Enhancing Decision Making with Dynamic KPI Insights," IJCSNS - International Journal of Computer Science and Network Security 24(5): 53-64, 2025.

[85] A Al-Qarni, M Al-Shehri, A Rahman, T Iqbal, A Bakry, "Integrating Smart Grids in Smart Cities for Sustainable Future," IJCSNS, 24(5): 227-237, 2025.

[86] A Aslam, J Mir, G Zaman, A Rahman et al., "Extracting Facial Features to Detect Deepfake Videos Using Machine Learning," International Journal of Advanced Computer Science and Applications 16 (4): 834-842, 2025.