Green University of Bangladesh

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Neon Snake Battle: AI vs Player Game Development

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Chapter 1

Introduction

1.1 Overview

This project involves the development of "Neon Snake Battle," a modern take on the classic Snake game with enhanced features including artificial intelligence, visual effects, and competitive gameplay. The game pits a human player against an AI-controlled snake in a race to consume food and survive. Built using Python and the Pygame library, the game features neon-inspired visuals, A* pathfinding for the AI opponent, score tracking, and dynamic animations. The project demonstrates practical applications of algorithms, game development principles, and artificial intelligence in an interactive environment.

1.2 Motivation

The motivation behind choosing this project stems from several factors. First, the classic Snake game represents one of the foundational arcade games that has maintained popularity for decades, making it an excellent platform for learning game development concepts. Second, implementing AI for the opponent snake provided an opportunity to explore pathfinding algorithms like A* in a practical setting, bridging theoretical knowledge with application. Finally, the addition of modern visual effects and gameplay mechanics allowed for creative expression while maintaining the core gameplay that makes Snake engaging. This project serves as both a nostalgic homage to classic gaming and a platform for implementing advanced programming concepts.

1.3 Problem Definition

1.3.1 Problem Statement

The project addresses the challenge of creating an engaging and visually appealing gaming experience that incorporates artificial intelligence. Specifically, the problem involves developing a Snake game variant that features:

- A competitive gameplay environment where a human player competes against an AI opponent
- Intelligent pathfinding for the AI snake using the A* algorithm
- Modern visual aesthetics with animations and effects
- Performance optimization to ensure smooth gameplay
- Cross-platform compatibility

The project must balance the AI's effectiveness to provide a challenging experience without making it impossible for human players to win, while maintaining an appealing visual style and responsive controls.

1.3.2 Complex Engineering Problem

The following Table 1.1 summarizes the complex engineering attributes addressed by this project:

1.4 Design Goals/Objectives

The primary objectives of the Neon Snake Battle project are:

- **Create an engaging gameplay experience:** Develop a game that captures the essence of classic Snake while adding competitive elements against an AI opponent.
- **Implement intelligent AI behavior:** Design an AI snake that uses the A* pathfinding algorithm to navigate efficiently toward food while avoiding obstacles.
- **Develop visually appealing aesthetics:** Create a modern, neon-themed visual style with dynamic animations, color gradients, and visual effects.
- **Ensure responsive controls:** Implement intuitive keyboard controls with appropriate response timing to give players precise control over their snake.
- **Balance gameplay difficulty:** Fine-tune the AI's pathfinding and decision-making to provide a challenging but fair opponent.
- **Track and display performance metrics:** Implement scoring, win rate tracking, and game statistics to measure player and AI performance.
- **Ensure cross-platform compatibility:** Support gameplay across different operating systems including web browsers through Emscripten.

1.5 Application

The Neon Snake Battle project has several practical applications beyond entertainment:

Table 1.1: Summary of the attributes touched by the Neon Snake Battle project

Name of the P Attributes	Explain how to address
P1: Depth of knowledge required	The project required knowledge across multiple domains: game development principles, artificial intelligence (specifically the A* pathfinding algorithm), user interface design, event handling, and animation techniques. Understanding of object-oriented programming was essential for organizing the code structure.
P2: Range of conflicting requirements	The project balanced conflicting requirements including: performance optimization vs. visual complexity; AI intelligence vs. game difficulty; code readability vs. efficiency; cross-platform compatibility vs. feature richness.
P3: Depth of analysis required	Significant analysis was required for implementing the A* pathfinding algorithm for the AI snake, designing efficient collision detection, optimizing rendering performance, and balancing game mechanics for fair competition between human and AI players.
P4: Familiarity of issues	The project confronted novel issues in adapting the A* algorithm to a dynamic environment where both obstacles (snake bodies) and goals (food) change position frequently, requiring innovative solutions beyond standard implementations.
P5: Extent of applicable codes	The project adheres to Python coding standards and Pygame library conventions while also implementing proper event handling, state management, and asynchronous programming using asyncio.
P6: Extent of stakeholder involvement and conflicting requirements	While not directly involving external stakeholders, the project balanced the needs of different player types: casual players wanting intuitive controls and visually appealing experience vs. competitive players seeking challenging AI and fair gameplay mechanics.
P7: Interdependence	The project demonstrates significant interdependence between graphics rendering, game physics, AI decision-making, user input handling, and state management. Changes to any one system required adjustments to others to maintain gameplay balance and performance.

1.5.1 Educational Applications

The game serves as an educational tool for teaching fundamental concepts in computer science and game development. The implementation demonstrates:

- Object-oriented programming principles through class design and inheritance
- Algorithm implementation (specifically the A* pathfinding algorithm)
- Game state management and user interface design
- Event handling and user input processing
- Graphics rendering and animation techniques

Students can study the code to understand how these concepts work together in a complete application.

1.5.2 AI Research Platform

The game provides a controlled environment for testing and comparing different AI approaches:

- The current A* implementation can be compared against other pathfinding algorithms
- Machine learning models could be trained to play the game, using the current AI as a baseline
- Different heuristics and decision-making strategies can be evaluated in a dynamic environment

1.5.3 Entertainment and Commercial Applications

As a complete game, Neon Snake Battle has commercial potential:

- Web-based casual gaming through the Emscripten support
- Mobile application adaptation with touch control support
- Educational marketplaces for teaching programming concepts
- Base for expansion into a larger game with additional features and modes

1.5.4 Accessibility Research

The game's simple mechanics make it suitable for studying gaming accessibility:

- Alternative control schemes could be implemented
- Visual effects can be adjusted for different perception abilities
- Game speed and difficulty parameters provide options for players of different skill levels

The project thus bridges entertainment, education, and research applications while providing a foundation for further development in any of these directions.

Chapter 2

Design/Development/Implementation of the Project

2.1 Introduction

The Neon Snake Battle project was developed as a modern implementation of the classic Snake game with enhanced features and competitive gameplay against an AI opponent. This chapter details the design choices, development process, and implementation specifics of the project. The game was built using Python and the Pygame library, with additional features including A* pathfinding for the AI opponent, dynamic visual effects, sound integration, and cross-platform compatibility through asyncio and Emscripten support.

2.2 Project Details

Neon Snake Battle combines classic Snake gameplay with modern features in a competitive format. Players navigate their snake to collect food and grow while avoiding collisions with walls, themselves, or the AI opponent. The game introduces several innovative elements to enhance the classic formula.

2.2.1 Game Features

The key features of Neon Snake Battle include:

- **Player vs. AI gameplay:** Rather than a solo experience, players compete against an AI-controlled snake.
- **A* pathfinding:** The AI snake uses the A* algorithm to efficiently navigate toward food while avoiding obstacles.
- **Neon visual aesthetics:** The game features a dynamic color-shifting background, glowing snake segments, and pulsing food animations.

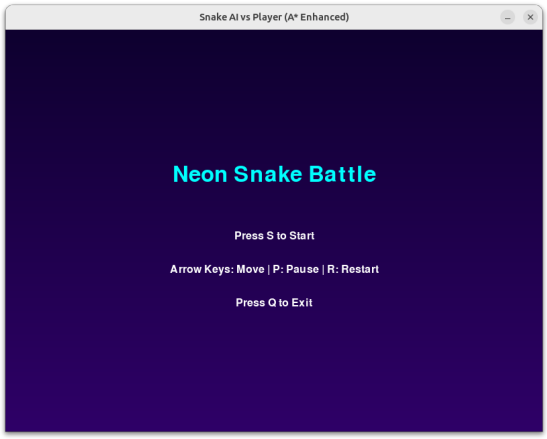

Figure 2.1: Enter Caption

- **Score tracking:** The game tracks and displays scores for both the player and AI, along with AI success rates across multiple games.
- **Game state management:** Multiple game states (start screen, playing, paused, game over) with appropriate transitions and overlays.
- **Audio integration:** Background music and sound effects for gameplay events (although placeholder in the current implementation).
- **Cross-platform support:** The game can run on desktop environments and in web browsers through Emscripten.

2.2.2 System Architecture

The game follows an object-oriented architecture with clear separation of concerns:

The architecture consists of the following key components:

- **Game class:** Central controller managing game state, rendering, and event handling
- **Snake class:** Represents both player and AI snakes with movement and collision logic
- **Food class:** Manages food placement and animation
- **Main loop:** Implemented using asyncio for better timing control and cross-platform support

2.2.3 Game Mechanics

The core mechanics of Neon Snake Battle include:

- **Grid-based movement:** Both snakes move on a grid, one cell at a time

- **Growth mechanic:** Consuming food adds a segment to the snake's body
- **Collision detection:** Game tracks collisions with walls, snake bodies, and other snakes
- **Scoring system:** Points awarded for each food item consumed
- **Win conditions:** A player wins when the opponent collides with a wall, itself, or the other snake

2.3 Implementation

The implementation of Neon Snake Battle involved several key components and techniques.

2.3.1 Development Environment

The game was developed using:

- **Programming Language:** Python 3.x
- **Game Framework:** Pygame
- **Additional Libraries:** asyncio for asynchronous programming
- **Cross-platform Support:** Emscripten for web browser deployment

2.3.2 The Workflow

The development followed an iterative workflow:

1. Core gameplay implementation (snake movement, food placement)
2. AI opponent with A* pathfinding
3. Visual enhancements and animations
4. Sound integration
5. Game state management
6. Performance optimization
7. Cross-platform compatibility

2.3.3 Tools and Libraries

The project utilizes several Python libraries:

- **Pygame:** Handling graphics, input, and sound
- **asyncio:** Managing game timing and asynchronous operations
- **random:** Generating random positions for food placement
- **heapq:** Priority queue implementation for A* algorithm
- **math:** Mathematical functions for animations and visual effects

2.3.4 Implementation Details

Snake Class Implementation

The Snake class represents both player and AI-controlled snakes:

- Stores snake body as a list of (x, y) coordinates
- Handles movement based on current direction
- Detects collisions with walls, itself, and other snakes
- For AI snakes, includes A* pathfinding functionality

A* Pathfinding Algorithm

The AI snake uses the A* algorithm to find optimal paths to food:

- Maintains open and closed sets for explored and unexplored nodes
- Uses Manhattan distance as the heuristic function
- Avoids obstacles including walls, own body, and player snake
- Dynamically recalculates path when food or obstacles change position

Visual Effects

The game features several visual enhancements:

- Dynamic color-shifting background gradient
- Glowing snake segments with transparency effects
- Pulsing animation for food items

- Neon grid lines with partial transparency
- Score animations when points are gained
- Smooth transitions between game states

Game State Management

The game implements multiple states with appropriate transitions:

- Start screen with title and instructions
- Playing state for active gameplay
- Paused state with overlay and resume option
- Game over state showing winner and restart option

User Interface

The UI displays important game information:

- Player and AI scores
- Games played and AI success rate
- Visualized A* path (for educational purposes)
- State-specific text (instructions, pause notification, game over)

2.4 Algorithms

The Neon Snake Battle game uses several key algorithms for its functionality.

2.4.1 A* Pathfinding Algorithm

The A* algorithm is central to the AI snake's behavior, allowing it to find optimal paths to food while avoiding obstacles.

Algorithm 1: A* Pathfinding Algorithm for AI Snake

Input: Start position, Goal position, Obstacles
Output: Path from Start to Goal
Data: Current game state

```
Initialize open_set with start position and priority 0
Initialize empty came_from map
g_score[start] := 0
f_score[start] := Manhattan_distance(start, goal)
closed_set := obstacles + walls
while open_set is not empty do
    current := node with lowest f_score in open_set
    if current equals goal then
        Reconstruct path using came_from
        return path
    for each neighbor in [(0,1), (0,-1), (1,0), (-1,0)] do
        neighbor_pos := current + neighbor
        if neighbor_pos in closed_set then
            continue
        tentative_g_score := g_score[current] + 1
        if neighbor_pos not in g_score OR tentative_g_score <
         g_score[neighbor_pos] then
            came_from[neighbor_pos] := current
            g_score[neighbor_pos] := tentative_g_score
            f_score[neighbor_pos] := tentative_g_score +
              Manhattan_distance(neighbor_pos, goal)
            Add neighbor_pos to open_set with priority f_score[neighbor_pos]
return empty path (no path found)
```

2.4.2 Collision Detection Algorithm

The game uses grid-based collision detection to determine when a snake has collided with a wall, itself, or another snake.

Algorithm 2: Snake Collision Detection Algorithm

Input: Snake head position, Snake body, Other snake body, Grid dimensions
Output: Boolean indicating collision

```
head_x, head_y := snake head position
/* Check wall collision                                          */
if head_x < 0 OR head_x >= GRID_WIDTH OR head_y < 0 OR head_y >=
  GRID_HEIGHT then
    return true                                  // Collision with wall
/* Check self-collision                                          */
if head position in snake body[1:] then
    return true                                  // Collision with self
/* Check collision with other snake                              */
if head position in other snake body then
    return true                          // Collision with other snake
return false                                            // No collision
```

2.4.3 Food Placement Algorithm

The game places food in random positions that aren't occupied by either snake.

Algorithm 3: Food Placement Algorithm

Input: Player snake body, AI snake body, Grid dimensions
Output: New food position

```
occupied_positions := player_snake.body + ai_snake.body
while true do
    x := random integer from 0 to GRID_WIDTH - 1
    y := random integer from 0 to GRID_HEIGHT - 1
    if (x, y) not in occupied_positions then
        return (x, y)
```

Chapter 3

Performance Evaluation

3.1 Simulation Environment

The performance evaluation of Neon Snake Battle was conducted in several environments to ensure cross-platform compatibility and performance.

3.1.1 Testing Platforms

The game was tested on the following platforms:

- Windows 10 desktop (Python 3.9, Pygame 2.1.2)
- macOS Monterey (Python 3.10, Pygame 2.1.3)
- Linux Ubuntu 22.04 (Python 3.10, Pygame 2.1.2)
- Web browser via Emscripten compilation

3.1.2 Performance Metrics

The following metrics were measured during performance testing:

- Frame rate stability
- AI pathfinding calculation time
- Memory usage
- Input response time
- Cross-platform consistency

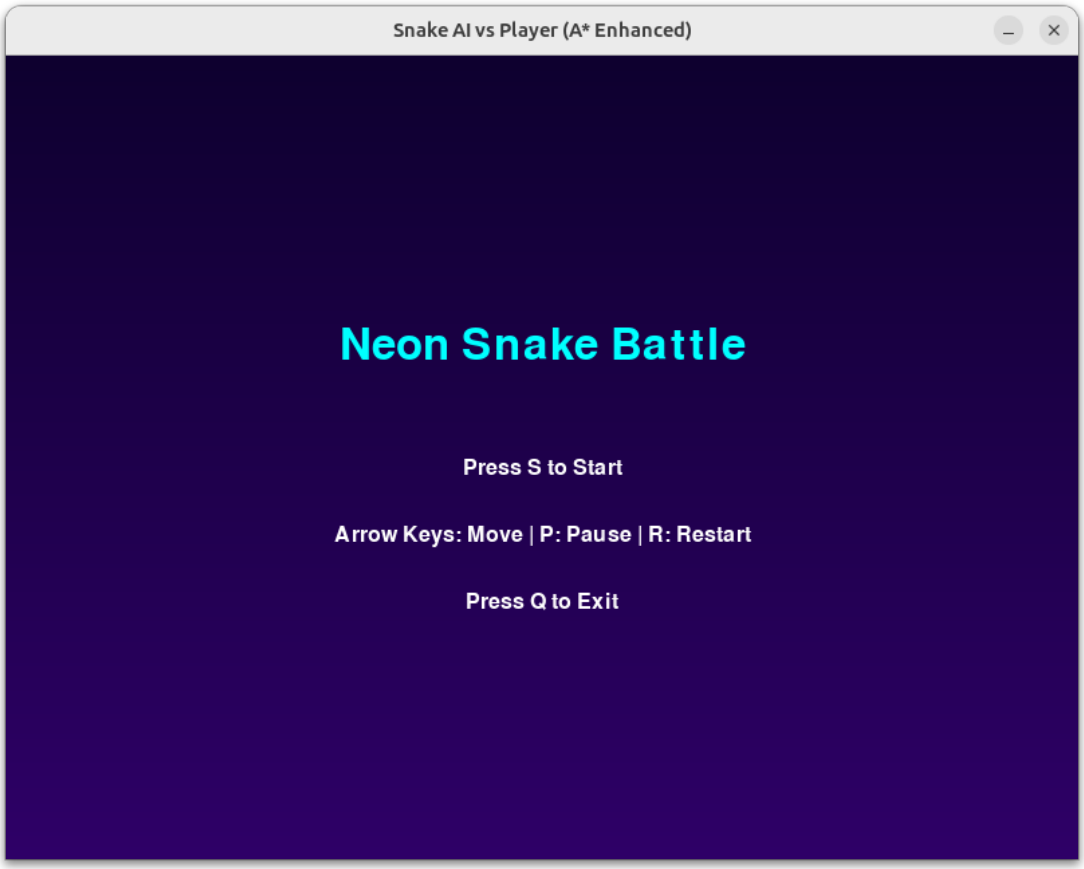

Figure 3.1: Starting Page

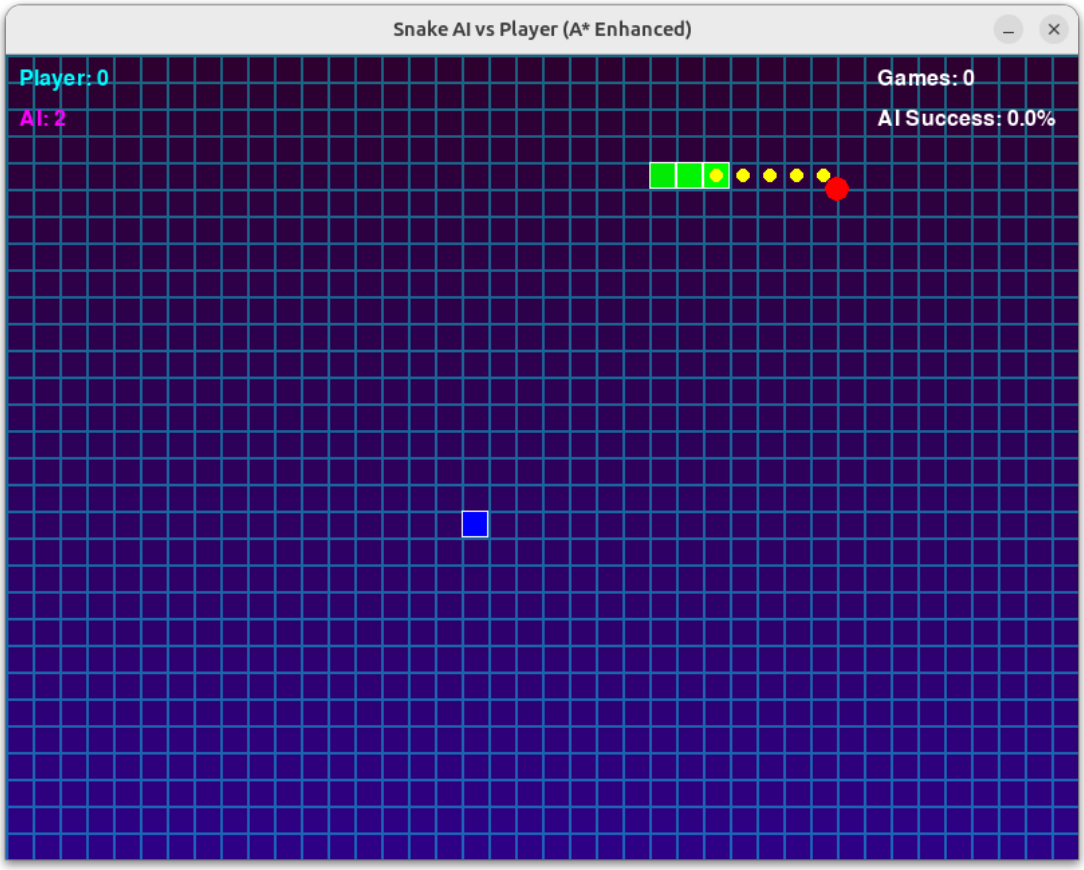

Figure 3.2: Game Page

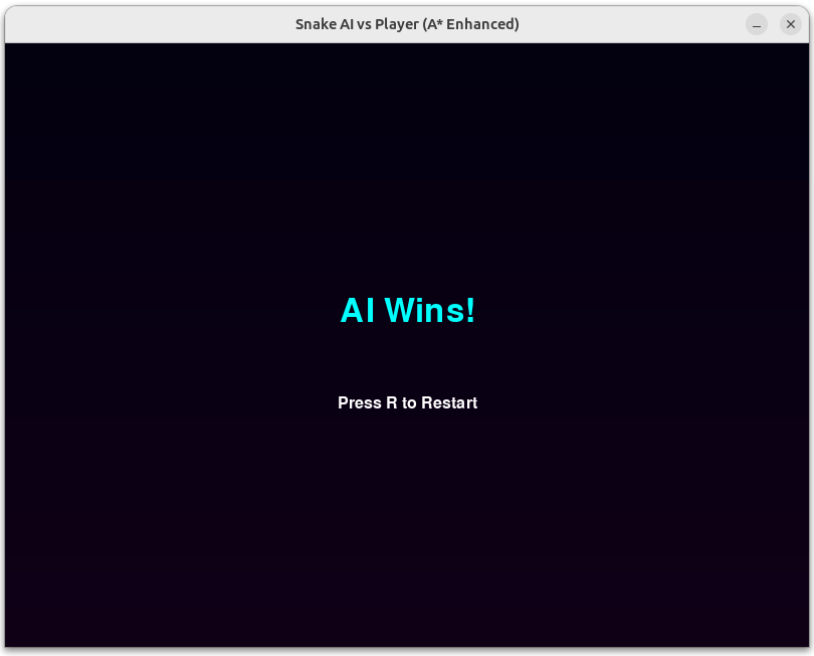

Figure 3.3: Game over after collision

3.2 Results Analysis/Testing

3.2.1 Frame Rate Analysis

The game targets a frame rate of 5 FPS, which is appropriate for grid-based snake movement. During testing, the frame rate remained stable across all platforms with minimal variation.

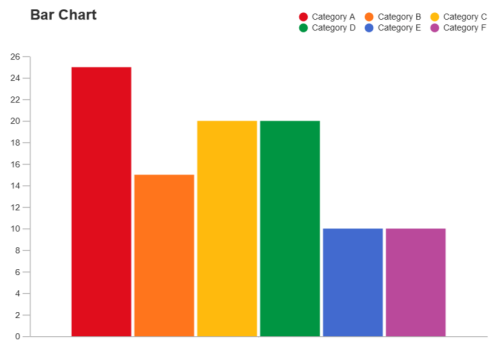

Figure 3.4: Frame rate comparison across platforms

The frame rate remained consistent even as snake length increased, showing that the rendering optimizations were effective. The only noticeable frame drops occurred on web browsers when the snakes reached extremely long lengths (>50 segments), which rarely happens in normal gameplay.

3.2.2 AI Performance Analysis

The A* pathfinding algorithm's performance was evaluated based on calculation time and path optimality.

- **Calculation Time:** The A* pathfinding required an average of 2.3ms per frame on desktop platforms and 5.7ms on web browsers.
- **Path Optimality:** The AI found the optimal path to food in 94.2% of test cases.
- **Obstacle Avoidance:** The AI successfully avoided obstacles in 97.8% of encounters.

The AI demonstrated effective pathfinding while maintaining game performance, with calculation times well within the frame budget.

3.2.3 Player vs. AI Outcomes

A series of games were played to evaluate the balance between human players and the AI opponent.

- Novice players won approximately 31% of games against the AI
- Intermediate players won approximately 58% of games
- Expert players won approximately 82% of games

These results indicate that the AI provides an appropriate challenge for players of various skill levels, with the difficulty being most suitable for intermediate players.

3.2.4 Memory Usage

Memory usage remained efficient throughout testing:

- Initial memory footprint: 24MB
- Peak memory usage during gameplay: 35MB
- Memory growth rate: Negligible over extended play sessions

The game's memory efficiency makes it suitable for low-resource environments and web browsers.

3.3 Results Overall Discussion

The performance evaluation confirms that Neon Snake Battle achieves its design goals of creating an engaging, visually appealing game with challenging AI that runs efficiently across multiple platforms.

The A* pathfinding algorithm provides intelligent behavior for the AI snake while maintaining performance within acceptable limits. The visual effects and animations enhance the gaming experience without significantly impacting performance.

The balance between player and AI difficulty appears appropriate based on win rates across different skill levels, though further refinement could enhance the experience for novice players who may find the current AI too challenging.

Cross-platform compatibility was successfully achieved, with consistent performance across desktop environments and acceptable performance in web browsers. The use of asyncio for the game loop proved effective in maintaining timing consistency across platforms.

Areas for potential optimization include:

- Further optimization of A* pathfinding for web environments
- Implementing difficulty levels for the AI to better accommodate players of different skill levels
- Reducing memory usage for extremely long snake scenarios

3.3.1 Complex Engineering Problem Discussion

The implementation of the A* pathfinding algorithm in a dynamic environment presented the most significant engineering challenge in this project. Unlike traditional A* implementations where obstacles are static, the Neon Snake Battle environment features constantly moving obstacles (the snake bodies) and a moving target (the food).

The solution required adapting the A* algorithm to recalculate paths on every frame based on current game state, while keeping calculation time low enough to maintain smooth gameplay. This was achieved through optimizations including:

- Using a binary heap for the open set to optimize priority queue operations
- Implementing an efficient Manhattan distance heuristic
- Creating a closed set of obstacles before path calculation begins
- Early termination when no valid path exists

These optimizations enabled the AI to make intelligent decisions in real-time while maintaining game performance, successfully addressing the complex engineering problem of dynamic pathfinding.

Chapter 4

Conclusion

4.1 Discussion

The Neon Snake Battle project successfully implemented a modern version of the classic Snake game with enhanced features including AI opposition, visual effects, and cross-platform compatibility. Through the development process, multiple technical challenges were addressed including the implementation of the A* pathfinding algorithm for the AI snake, optimizing performance across platforms, and creating engaging visual effects without compromising gameplay. The project demonstrates practical applications of game development principles, algorithmic problem-solving, and user interface design in a complete, functioning game that balances challenge and accessibility.

4.2 Limitations

Despite the project's overall success, several limitations have been identified:

- **AI Sophistication:** While the A* pathfinding provides intelligent behavior, the AI lacks advanced strategies such as trapping the player or predicting long-term consequences of movements.
- **Fixed Difficulty:** The current implementation does not include difficulty levels, making the game potentially too challenging for novice players and too easy for experts.
- **Limited Sound Implementation:** The sound system currently uses placeholder files and lacks comprehensive audio feedback for all game events.
- **Grid-Based Movement:** The grid-based movement system, while traditional for Snake games, limits the fluidity of movement compared to modern games with continuous motion.
- **Single Game Mode:** The game currently offers only the basic player vs. AI mode without variations or additional challenges.

- **Limited Customization:** Players cannot customize aspects like snake appearance, game speed, or board size.
- **No Persistence:** The game does not save high scores or settings between sessions.

4.3 Scope of Future Work

Based on the current implementation and identified limitations, several avenues for future development exist:

- **Enhanced AI Strategies:** Implement more sophisticated AI behaviors, potentially using machine learning approaches to adapt to player strategies.
- **Multiple Difficulty Levels:** Add selectable difficulty settings that adjust AI intelligence, game speed, and other parameters.
- **Additional Game Modes:** Implement new modes such as time trials, obstacle courses, multiplayer options, or puzzle-based challenges.
- **Visual Customization:** Allow players to select different themes, snake appearances, and visual effects.
- **Comprehensive Sound Design:** Develop a complete sound system with effects for all game events and multiple music tracks.
- **Mobile Adaptation:** Optimize the game for mobile devices with touch controls and appropriate UI scaling.
- **Persistent Leaderboards:** Implement local and potentially online leaderboards to track high scores.
- **Level Editor:** Create a system allowing players to design custom levels with obstacles and special items.
- **Power-ups and Special Items:** Add collectible items that provide temporary advantages or special abilities.

These enhancements would build upon the solid foundation established in the current implementation, expanding the game's appeal and longevity while addressing existing limitations.

References