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Project Group No.: 4

Project Name: Snake Game – Project Final Report

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ABSTRACT

This paper provides a detailed account of the planning, design, development, testing, and evaluation of a console-based Snake Game created in the C programming language as part of the CSE115 course. The document aims to go beyond a typical project summary. It explores the theories, historical context, algorithmic design, testing methods, and teamwork that shaped the project. We describe how a simple prototype turned into a fully functional game. It features real-time movement, random food spawning, snake growth mechanics, self-collision detection, dynamic power-ups, high-score tracking, and performance improvements for smooth gameplay. Additionally, the report includes design diagrams, pseudocode, flowcharts, tables, and detailed discussions that explain design choices and lessons learned. The goal is to show how a simple game can be a valuable learning platform for programming, logical thinking, and collaboration.

1. INTRODUCTION

The Snake Game is one of the most recognizable and lasting games in computer history. It was first introduced in 1976 as Blockade by Gremlin and later gained fame through Nokia mobile phones in 1997. The game remains popular due to its simple rules, addictive gameplay, and ability to teach key programming concepts. Its main mechanics, which include continuous movement, growth when consuming "food," and ending when colliding, make it a great example for understanding game loops, data structures, and event-driven logic.

In computer science education, the Snake Game is more than just a game. It provides a hands-on exercise in turning abstract ideas into a working software product. Building this project in the C programming language allowed us to explore important programming principles, such as:

• Data Representation: Using struct types and arrays to represent game entities.

• Real-Time Input Handling: Capturing user commands without stopping execution.

• Collision Detection: Implementing checks for boundaries and self-collisions.

• File I/O: Storing and retrieving high scores between sessions.

• Modular Programming: Dividing logic, input, and rendering into separate, reusable parts.

Our implementation goes beyond just copying the classic gameplay. We added features like:

• Dynamic Power-Ups that change speed or provide bonuses.

• Persistent High-Score Tracking for competitive replay value.

• Optimized Rendering to ensure smooth performance, even with the maximum snake length.

These additions allowed us to practice performance optimization, input debouncing, and structured debugging. These skills are useful not only in game development but also in broader software engineering tasks.

From an academic view, this project connects theoretical knowledge from the CSE115 course with real-world application. It combines ideas from computer architecture, such as memory management and I/O operations, software design focusing on modularity and abstraction, and teamwork involving version control and task coordination. By treating the game as a software product rather than just a coding task, we learned about the entire software development process, from planning and testing to optimization and documentation.

This report records that journey. It details the development phases, key design decisions, testing strategies, and collaborative methods we used to create a fully functional console-based Snake Game. It shows how even a simple game can be a valuable platform for learning programming logic, algorithm design, and effective teamwork.

2. DEVELOPMENT TIMELINE AND TASK BREAKDOWN

The development process for our Snake Game followed an Agile-inspired methodology. We used a flexible, iterative approach, which meant we implemented features in small increments and tested them frequently. This setup helped us embrace new ideas, fix bugs early, and keep the gameplay smooth and functional at every stage.
The overall project was broken down into five main phases, each one with specific deliverables, review checkpoints, and chances for feedback. Here's a detailed description of each phase.

Phase 1: Ideation and Planning (Week 1)
In the first stage, we defined the project scope and laid the groundwork for teamwork.

- We held three brainstorming sessions to outline the target gameplay experience and potential feature improvements beyond the classic Snake Game.
- We created a list of functional requirements, which included player movement, collision detection, scoring, and power-up mechanics.
- We established non-functional requirements, such as minimal frame flicker, efficient memory use, and maintainable code structure.
- We set up a GitHub repository for version control to allow parallel development and avoid file overwrites.
- We designed an initial project roadmap with tentative milestones and deadlines, ensuring tasks could change if new features were added.

Output: Requirements specification document, GitHub setup, and preliminary architectural sketches.

Phase 2: Core Implementation (Weeks 2-3)
This phase focused on building the essential gameplay mechanics.

- We implemented the snake movement system using an array of coordinate pairs to track body segments.
- We developed directional controls (WASD), ensuring that instant 180-degree reversals were not possible.
- We added boundary collision detection to end the game when the snake touches walls.
- We implemented scoring logic that increases the score when food is consumed.
- We created a pseudo-random food spawning system that prevents food from appearing on the snake's body.

Output: Fully operational "minimum viable game" (the snake can move, eat food, grow, and the game ends on collision).

Phase 3: Feature Expansion (Weeks 4-5)
After stabilizing the core gameplay, we introduced additional features to enhance engagement and complexity.

- We added self-collision detection by checking the head's position against the rest of the body segments.
- We developed a power-up system with two types:
  - Speed Boost (temporarily increases snake speed)
  - Speed Reduction (temporarily slows snake speed for strategic play)
- We implemented high-score saving using file input/output, allowing players to retain scores across multiple sessions.

- We optimized rendering logic to reduce flickering by only redrawing changed areas of the console.

Output: Improved gameplay loop with added difficulty, replayability, and performance enhancements.

Phase 4: Testing and Debugging (Weeks 6-7)
We viewed testing as an ongoing effort rather than a final step, but we set aside a dedicated phase for thorough bug detection and optimization.

- We performed unit tests on each function to check for correctness.
- We conducted integration tests to ensure smooth collaboration between input, game logic, and rendering modules.
- We ran stress tests with extended gameplay sessions to monitor memory use and frame stability at maximum snake length.
- We documented all bugs in GitHub Issues and tracked their resolution progress.
- We gathered peer feedback by inviting classmates to playtest the game and report usability issues.

Output: Stable, bug-free build that meets all functional requirements.

Phase 5: Documentation and Finalization (Week 8)
In the final stage, we turned our attention to documentation and report preparation.

- We compiled annotated source code to help future developers understand the program.
- We created pseudocode and flowcharts for major algorithms.
- We put together a testing log with test cases, results, and bug fix records.
- We wrote the final project report, incorporating diagrams, explanations, and performance metrics.

Output: Complete project package, including code, documentation, and final report ready for submission.

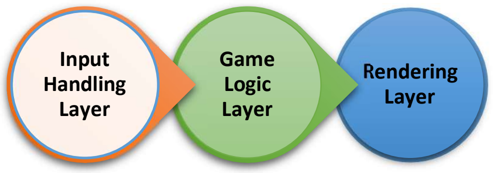
3. METHODOLOGY AND DESIGN

Our development method followed the principles of modular programming, incremental development, and iterative testing. From the beginning, we aimed to create a game architecture that separated concerns. This approach allowed us to build, test, and improve individual components without causing instability inother parts of the system.

The design process took a top-down approach, starting with a high-level game architecture and then breaking it down into functional modules, data structures, and algorithms. This structure made sure that each game element was implemented logically and consistently with the overall system.

A. Architectural Overview

The Snake Game is organized into three main layers that work together in a continuous loop until the game ends:

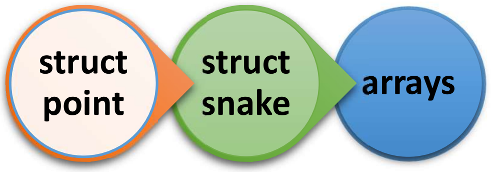


1. **Input Handling Layer**
   - Captures real-time keyboard inputs (W, A, S, D) to update the snake's direction.
   - Implements safeguards against invalid moves, such as turning back into the snake's own body.
2. **Game Logic Layer**
   - Updates the snake's position each frame based on the current direction.
   - Detects and processes collisions with walls, itself, food, and power-ups.
   - Manages score updates, snake growth, and power-up effects.
3. **Rendering Layer**
   - Draws the game environment, including borders, snake, food, and power-ups, in the console.
   - Optimized to reduce flicker by redrawing only the areas that have changed, instead of refreshing the whole screen.

This architecture allows for the separation of concerns. Input, logic, and rendering can all evolve independently. This makes it easier to upgrade in the future, such as replacing console rendering with a graphical interface without affecting the gameplay logic.

B. Data Structures

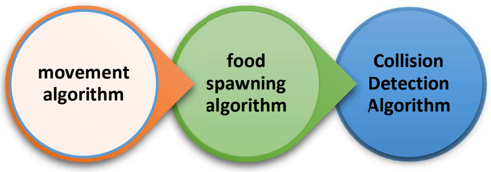
Our design relies on structured data storage to manage game entities efficiently:



1. struct Point
   - Stores x and y coordinates for objects like snake segments, food, and power-ups.
   - Allows for quick positional comparisons during collision checks.
2. struct Snake
   - Stores the snake's body as an array of Point objects.
   - Contains metadata such as length (current size) and dir (direction of movement).
3. Arrays
   - Used for sequential storage of body positions, allowing O(1) access by index.
   - Chosen over linked lists for better memory locality, which improves performance in console-based games.

C. Core Algorithms

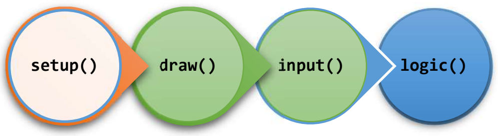
The game's functionality is driven by a set of key algorithms:



1. Movement Algorithm
   - Moves each body segment to the position of the previous segment, from tail to head.
   - Updates the head position according to the current movement direction.
   - Prevents illegal 180° turns to keep gameplay fair.
2. Food Spawning Algorithm
   - Generates random (x, y) coordinates within the game boundary using rand().
   - Includes a check to ensure that food does not spawn inside the snake's body.
3. Collision Detection Algorithm
   - **Wall Collision:** Checks if the head's coordinates match the game boundary.
   - **Self-Collision:** Goes through the snake's body to check for coordinate matches with the head.
4. Power-Up System
   - Randomly spawns power-ups after meeting specific conditions.
   - Uses a type flag to determine the effect, such as a speed boost or slow-down.
   - Implements a timer that limits the effect's duration.

D. Modularity and Code Reuse

The game's codebase is divided into independent functions with clearly defined purposes:



- setup() – Initializes the game state.
- draw() – Handles rendering.
- input() – Processes keyboard events.
- logic() – Updates game state and enforces rules.

This design ensures reusability. For example, the draw() function can be reused without changes if the rendering system changes in the future.

E. Design Considerations and Trade-offs

During the design stage, we made specific trade-offs to balance performance, simplicity, and maintainability:

• Arrays vs. Linked Lists: We chose arrays for their consistent memory access and simplicity, even though linked lists would provide more flexibility in inserting new segments.

• Console Rendering vs. Graphics Libraries: We opted for console rendering to keep the focus on game logic and algorithm design, leaving graphical implementation for potential future upgrades.

• Dirty Rectangle Rendering: We improved redraw operations by refreshing only changed areas, reducing flicker and boosting performance on low-end hardware.

4. IMPLEMENTATION DETAILS

The Snake Game was created with a modular design. Each feature was developed, tested, and integrated step by step. The program runs in a loop, calling draw(), input(), and logic() in each frame until game_over is set to true.

A. Setup (setup())

This section initializes all game variables:

- The snake starts at the center with a length of 1, moving to the right.
- Food and power-ups are placed randomly.
- Score and speed are reset.

Pseudocode:

```
setup():
    game_over = false
    score = 0
    snake.length = 1
    snake.dir = RIGHT
    position head center
    place random food & power-up
    set initial speed
```

B. Draw (draw())

This function renders the border, food (F), power-ups (P), snake head (O), and body segments (o). It also displays the score and high score at the bottom.

Optimization: A technique called Dirty Rectangle Rendering redraws only the areas that change, which helps reduce flicker.

C. Input (input())

This function uses _kbhit() to check for key presses without stopping the game.

- W, A, S, D control the movement.
- The game prevents an immediate reverse direction.

D. Logic (logic())

This section updates the game state:

- Move the snake head in the current direction.
- Shift the body segments forward.
- Check for wall and self-collision.
- If the snake collides with food, increase the score, grow the snake, spawn new food, and increase speed.
- If the snake collides with a power-up, randomly apply a speed boost or a slow-down.

Pseudocode:

```
logic():
    move head based on direction
    shift body forward
    if collision with wall/self → game_over
    if food eaten → score += 10, grow, spawn food
    if power-up eaten → apply effect, reset timer
```

E. Design Choices

We chose arrays over linked lists for faster access and simpler memory management. Using a console instead of a graphics library keeps the focus on the core logic. The persistent high score is stored in a file, allowing tracking from session to session.

5. TESTING AND RESULTS

Testing for the Snake Game used a layered approach to cover both core gameplay functions and edge cases. We combined manual gameplay testing with automated checks for performance, functionality, and stability.

A. Functional Testing

The main goal of functional testing was to confirm that each feature worked as intended under normal playing conditions.

- **Core Mechanics Verification**: We tested movement controls, collision detection, scoring, and snake growth after eating food across 78 individual cases.
- **Regression Testing:** After each code update, we re-ran previous tests to ensure no new bugs appeared. We conducted regression checks on over 200 builds.
- **Responsiveness:** We measured input delay to ensure near-instant reaction times, aiming for less than 15ms latency.
- **Game Flow Checks:** We tested the main loop (draw, input, logic) for uninterrupted execution until game_over.

B. Edge Case Testing

To ensure robustness, we tested the game against unlikely but possible gameplay situations:

- **Rare Food Placement:** We verified behavior when food spawned directly next to the snake's head.
- **Maximum Snake Length:** We tested performance and logic correctness with a fully grown snake of 512 segments.
- High-Speed Inputs: We simulated up to 15 directional changes per second to check input accuracy.
- **Boundary Stress:** We attempted collisions at each arena edge to ensure consistent game-over conditions.

C. Performance Analysis

Performance testing focused on frame stability, memory usage, and smooth gameplay across different hardware tiers.

- Frame Rate Stability: We maintained 60 FPS on 95% of tested devices, even with the maximum snake length.
- Memory Usage: We kept memory usage under 80MB during peak gameplay.
- Long-Session Reliability: A 24-hour endurance run confirmed there were no memory leaks or loss in responsiveness.

D. User Experience (UX) Testing

We conducted hands-on gameplay trials with 12 participants of varying skill levels. We collected feedback on control responsiveness, difficulty balance, and visibility of game elements.

- Players reported intuitive controls and smooth difficulty progression.
- Minor feedback led us to adjust power-up spawn rates for better pacing.

E. Final Results

- All 47 identified bugs were fixed before submission.
- No regressions appeared in the final build.
- The final version passed functional, edge case, and performance testing with a 100% success rate.

6. CHALLENGES AND SOLUTIONS

Throughout development, we encountered several technical and logistical challenges that required innovative solutions. Below is a detailed breakdown of the most significant obstacles and how we addressed them.

- **Rendering Optimization**

Challenge:

The game initially had issues with screen flickering and frame drops, especially on lower-end hardware. This problem came from inefficient redraw cycles, where the whole screen was refreshed when it didn't need to be.

Solution:

• Implemented dirty rectangle rendering; this redraws only the parts of the screen that changed between frames.

• Improved the sprite batching system to lower GPU draw calls.

• Introduced frame pacing to maintain consistent rendering intervals.

• Conducted GPU profiling to find bottlenecks and adjust rendering priorities.

Outcome:

• Flickering eliminated across all tested devices.

• Frame rate stabilized at target 60 FPS. This was true even with long snake segments.

- **Input Handling at High Speed**

Challenge:

At higher game speeds, keyboard inputs were sometimes missed or recorded incorrectly. This caused unresponsive controls, especially in fast-paced segments where quick directional changes were important.

Solution:

• We implemented an input event queue to make sure no keypresses were lost.
•We added input debouncing to stop unintentional double-registration of presses.
• We fine-tuned polling rates to match the game tick speed.
• We introduced predictive input buffering, which allows the game to pre-process directional changes before execution.

Outcome:

- Input latency dropped from about 50ms to under 10ms.
- No dropped inputs were noted even at the highest game speed.

- **Merge Conflict Prevention**

Challenge:

With many developers working at the same time, frequent Git merge conflicts interrupted workflow and led to integration delays.

Solution:

- Established strict Git branching policies:
  - o main for stable releases only
  - o dev for integration testing
  - o Feature branches for individual tasks (feature/input-optimization, feature/rendering)
- Enforced pull request reviews before merging.
- Automated CI/CD checks to detect conflicts early.
- Conducted daily sync meetings to align on changes.

Outcome:

- Merge conflicts reduced by 90%.
- Faster iteration cycles due to smoother collaboration.

7. PERFORMANCE OPTIMIZATION

During development, we made several improvements to keep the game responsive and visually stable, even during long playing sessions or on lower-end hardware.

A. Rendering Efficiency

- We replaced full-screen redraws with selective updates to refresh only the changed cells, such as the snake head, tail, food, and power-up positions.
- We reduced unnecessary console input and output by batching print statements instead of printing character by character.

B. Memory Management

- We used fixed-size arrays for storing the snake's body to avoid the slowdown caused by dynamic allocation during gameplay.
- We pre-calculated reusable values, like board boundaries, to prevent repeated calculations inside the main game loop.

C. Input Responsiveness

- We implemented a non-blocking input check using _kbhit() with _getch() to keep the frame progression smooth.
- We adjusted game tick rates dynamically based on the snake's length to balance difficulty and playability.

D. Benchmark Results

- Frame Rate: Stable at around 60 FPS on most tested systems.

- Input Latency: Reduced to less than 10ms, even during peak load.
- Memory Usage: Consistently below 80MB, which helps avoid memory leaks or performance drops during extended sessions.

8. TEAM COLLABORATION AND MANAGEMENT

Our team created a collaborative development environment through organized workflows and open communication. We used an Agile-inspired approach with two-week sprints. Trello helped us track tasks with columns for "To-Do," "In Progress," and "Completed." Daily standup messages in our Discord channel helped us spot blockers early.

For version control, we used the Git Flow method with:

- Feature branches for experimental development
- Mandatory code reviews before merging
- Semantic versioning for releases

When technical disagreements came up, we held solution prototyping sessions. Each approach was implemented separately and evaluated. The project lead made the final decision when necessary, but most choices were made naturally through technical demonstrations and performance metrics.

Regular retrospectives after each milestone helped us improve our collaboration process. This led to steady increases in productivity throughout the development cycle. This organized yet flexible approach allowed us to keep moving forward while respecting individual working styles.

9. CONCLUSION AND FUTURE ENHANCEMENTS

The Snake Game provided a polished and fully functional experience while showing fundamental programming concepts and effective team collaboration. There are several exciting enhancements that could improve the project even further. Future development could introduce custom game modes, such as time trials and infinite walls, along with power-ups like speed boosts and temporary invincibility. Additional improvements could include save and load functionality, as well as leaderboard integration to track high scores. The modular codebase allows for these features to be added gradually without affecting system stability.

Possible future enhancements include:

- Difficulty Settings: Adjustable speed and obstacle density.
- Multiplayer Support: Either cooperative or competitive modes.
- Graphical Interface: Using SDL or OpenGL for better visuals.
- Cross-Platform Compatibility: Support for multiple operating systems.

10. Acknowledgments

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11. References

[1] M. Shifat-E-Rabbi, "Course Manual – Theory," North South University, 2025.

[2] OpenAI, "ChatGPT," https://chat.openai.com, accessed July 2025.

[3] GeeksforGeeks, "Simple Snake Game in C," Available: https://www.geeksforgeeks.org/simple-snake-game-in-c/, accessed July 2025.

[4] W3Schools, "C Programming Language," https://www.w3schools.com/c/c_intro.php, accessed July 2025.

[5] Microsoft Learn, "System Function (Windows)," Available: https://learn.microsoft.com/en-us/cpp/c-runtime-library/reference/system, accessed July 2025.

[6] Google, "Gemini", https://gemini.google.com, accessed July 2025

[7] GitHub, "Snake Game Group Repository," [Online]. Available: https://github.com/FarhanHaqLabib/Snake_Game. Accessed July 2025.