EECS 3216 Project Proposal: Snake Royale using VGA Output on the DE10-Lite Board

Team Members:

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Project Description

Our project aims to design and implement the classic Snake game using the DE10-Lite FPGA board, with real-time VGA output to display the game on an external monitor. The project will integrate both hardware and software components, leveraging the FPGA's capabilities for combinational and sequential logic. The game will feature interactive gameplay, including snake movement, collision detection, score tracking, and progressive difficulty levels.

This project will demonstrate the integration of FPGA-based hardware design with software-driven control systems, showcasing our ability to combine digital logic, embedded systems, and real-time data processing. Additionally, we will explore advanced techniques such as adaptive difficulty algorithms and real-time analytics to enhance the gameplay experience.

Project Objectives

1. Hardware Implementation:
    - Design combinational logic for real-time snake movement based on user inputs (initially using onboard buttons/switches).
    - Implement sequential logic for game state management, including collision detection, score tracking, and level progression.
    - Develop a VGA controller module to display the game at 640x480 @ 60Hz resolution on an external monitor.
2. Software Integration:
    - Utilize Verilog on the DE10-Lite board to handle game logic.
    - Implement a state machine to manage different game states (start screen, gameplay, game over).
3. System Integration:
    - Integrate FPGA-based hardware modules (e.g., VGA controller, movement logic) with onboard controls initially.
    - Develop a modular and scalable design to support future enhancements.
    - If time permits, add PS2 keyboard integration for improved controls.
4. Advanced Features:
    - Implement adaptive difficulty algorithms that adjust game speed and complexity based on player performance.
    - Add real-time data analytics to track and display player statistics (e.g., score trends, reaction times).

Methodologies

- Hardware Design:
    - Use Verilog to design and implement FPGA modules for VGA output, movement logic, and collision detection.
    - Optimize resource utilization on the FPGA to ensure efficient operation within the DE10-Lite's constraints.
    - Implement separate clock domains for game logic updates (slower) and display refresh (faster).

- Memory Management:
    - Represent the game grid using a 2D array structure in FPGA memory.
    - Store snake segments as coordinates in an array, with the head at index 0.
    - Optimize memory usage by only tracking occupied grid cells.

- Software Development:
    - Implement efficient algorithms for game logic and collision detection.
    - Develop communication protocols between different game modules.

- Testing and Validation:
    - Create testbenches for each hardware module to verify functionality and performance.
    - Develop incremental testing milestones:
        - Test VGA controller with static patterns first
        - Verify movement logic with a single moving pixel
        - Test collision detection with simple obstacles
        - Integrate full snake mechanics and food generation
    - Conduct system-level testing to ensure seamless integration between components.

- Advanced Techniques:
    - Implement real-time data analytics to enhance gameplay and provide insights into player behavior.

Expected Deliverables

1. Functional Snake Game:

    - A fully playable Snake game with real-time VGA output (640x480 @ 60Hz), user controls, and score tracking.
    - Basic features: snake movement, growth, collision detection, food generation.
    - Multiple game states: start screen, gameplay, and game over screen.
    - Support for multiple difficulty levels if time permits.

2. Hardware and Software Code:
    - Verilog code for FPGA modules (e.g., VGA controller, movement logic, game grid representation).
    - Well-commented and modular code organization for maintainability.

3. Documentation:
    - A detailed design document outlining the system architecture, module descriptions, and integration process.
    - A user manual explaining how to play the game and customize settings.
    - A final report summarizing the project's objectives, methodologies, results, and challenges.
4. Demonstration:
    - A live demo showcasing the game's features, including VGA output, user controls, and advanced functionalities.
    - A technical poster summarizing the project's key achievements and innovations.

Key Components of the System

- FPGA Modules:
    - VGA Controller: Handles real-time display output with proper synchronization signals for 640x480 @ 60Hz.
    - Movement Logic: Processes user inputs and controls snake movement at a game-appropriate rate.
    - Collision Detection: Detects collisions with walls, food, and the snake itself using grid-based checking.
    - Game Logic: Manages game states, scoring, and level progression with a clear state machine approach.
    - Memory Manager: Efficiently tracks snake position, length, and food location.

- 2. Clock Management:
    - Main system clock (50 MHz from DE10-Lite)
    - VGA refresh clock (25.175 MHz for 640x480 @ 60Hz)
    - Game update clock (lower frequency, ~10 Hz initially for snake movement)

Roles and Responsibilities

- Kanwarjot Singh Bharaj: Hardware designer, responsible for FPGA modules (VGA controller, movement logic) and system integration.
- Fares Trad: Lead software developer, responsible for ARM HPS programming (game logic, analytics).
- Joshua Keppo: Testing and validation lead, responsible for creating testbenches, conducting system-level testing, and debugging.
- Kyle Williamson: Documentation and presentation lead, responsible for writing the design document, user manual, and preparing the final demo.

Project Timeline and Milestones

Week 1 (March 10-16):

- Set up development environment and tools
- Implement basic VGA controller and test with static patterns
- Design initial game architecture and module interfaces

Week 2 (March 17-23):

- Implement basic movement logic and controls
- Develop grid-based game representation
- Create simple sprite rendering for snake and food

Week 3 (March 24-30):

- Implement collision detection
- Add food generation and scoring system
- Integrate game state management (start, play, game over)

Week 4 (March 31-April 6):

- System integration and debugging
- Performance optimization
- Implement stretch goals if time permits
- Prepare documentation and demonstration materials

Risk Assessment and Mitigation

Potential Challenges:

- **Timing Issues**: VGA synchronization might be challenging
    - **Mitigation**: Use established VGA controller implementations as references
    - **Fallback**: Reduce resolution if needed
- **Memory Limitations**: Representing the full game state might strain FPGA resources
    - **Mitigation**: Optimize data structures, use efficient encoding
    - **Fallback**: Reduce game grid size or simplify graphics
- **PS2 Keyboard Integration**: May be complex to implement within timeframe
    - **Mitigation**: Implement and test early
    - **Fallback**: Use onboard buttons/switches exclusively
- **Advanced Features**: May not have time for adaptive difficulty and analytics
    - **Mitigation**: Implement core functionality first
    - **Fallback**: Focus on polishing the basic game mechanics

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Tools and Resources

- Quartus Prime Lite (for FPGA programming)
- ModelSim (for simulation and verification)
- DE10-Lite development board
- VGA monitor
- PS2 keyboard (if time permits)
- Reference implementations of VGA controllers and existing FPGA game projects

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Conclusion

This project will demonstrate our ability to design and implement a complex system that integrates FPGA-based hardware with software-driven control systems. By

incorporating advanced techniques like adaptive difficulty and real-time analytics, we aim to create an innovative and engaging Snake game that showcases our skills in digital design, embedded systems, and cross-disciplinary problem-solving. We seek approval for this ambitious project and look forward to delivering a high-quality implementation.