ICSP Final Presentation

Development of an Interactive Combinatorial Game Platform

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7th Group

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Project Overview

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Objective
Develop an interactive platform for playing and analyzing Impartial Combinatorial Games (ICGs) with automated winning strategy computation.

Key Features

- Support multiple classic ICG games (Nim, Kayles, etc.)
- Real-time strategy analysis and optimal move suggestions
- Interactive graphical user interface
- Extensible framework for new games

Technical Challenges

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- **State Space Explosion**: Exponential growth of possible states
- **Real-Time Requirements**: Need for sub-second response time
- **General Framework Design**: Supporting diverse game rules
- **UI/UX Design**: Creating intuitive interface with no prior experience

Our Solutions

System Architecture

Three-Tier Architecture

Game Logic Layer Implements rules and state transitions for each game

AI Engine Layer Optimized recursion with memoization for strategy analysis

User Interface Layer Pygame-based interactive graphical interface

Modular Design

- Each game implements standardized interfaces
- Core engine independent of specific game logic
- Easy to add new games

Core Algorithm

Optimized Recursion with Memoization

$$\text{win}(S) = \begin{cases} \text{False} & \text{if } S \text{ is terminal} \\ \neg \bigwedge_{S' \in \text{moves}(S)} \text{win}(S') & \text{otherwise} \end{cases}$$

Key Optimizations

- **State Hashing**: Efficient state representation
- **Memoization**: Avoid redundant calculations
- **Early Termination**: Prune search space

Performance

- Solves medium states in < 1 second
- Scales to complex game configurations
- Memory efficient

Progress & Results

Completed Work

Implemented Games

- **Nim** with multiple pile configurations
- **Kayles** (bowling pins game)
- Two additional ICG variants
- All with complete rule validation

System Features

- Fully functional graphical UI using Pygame
- Three gameplay modes: PvP, PvC, Analysis
- Real-time strategy analysis display
- Move history and undo functionality

Team Contributions

Member	Contributions
J. T. Xue	Core algorithm design and implementation, Nim & Kayles game logic, system architecture design
J. H. Liu	Test case design, performance testing, state representation optimization, documentation
X. Yang	UI components implementation, user interaction flows, system integration testing

Table 1: Team member contributions and responsibilities

Significance & Applications

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Educational Value

- Interactive learning of game theory
- Visual demonstration of winning strategies
- Research tool for combinatorial games

Technical Applications

- AI decision-making systems
- Algorithm design patterns
- Framework for game analysis

Research Contribution

Bridges abstract mathematical theory with practical computational implementation, making combinatorial game theory accessible and applicable.

Future Directions

Future Directions

- **Algorithm Optimization**: Parallel computation, heuristic evaluation
- **Game Expansion**: Support for more complex ICG variants
- **AI Integration**: Machine learning for strategy prediction
- **Cloud Deployment**: Web-based platform for broader accessibility
- **Quantum Computing**: Exploration of quantum algorithms for game solving

Conclusion

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Key Achievements

- Successfully developed a functional ICG analysis platform
- Implemented efficient algorithm using memoization and state hashing
- Created intuitive graphical interface for multiple games
- Demonstrated practical application of combinatorial game theory

The platform provides valuable tools for education, research, and AI development

Questions?

Thank You!