Offline 3 Report: Chain Reaction Game

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1. Experimental Setup

To evaluate AI behavior in the Chain Reaction game, I implemented one AI agents for AI vs HUMAN mode and two ai agents with different or same heuristic function for AI vs AI mode using the Minimax algorithm with Alpha-Beta pruning:

Human vs AI

- **Player 1 (AI)**: Maximizing player using heuristic H0/H1/H2/H3/H4
- **Player 2 (Human)**: Depends on move

AI vs AI

- **Player 1 (AI-Max)**: Maximizing player using heuristic H0/H1/H2/H3/H4
- **Player 2 (AI-Min)**: Minimizing player using heuristic H0/H1/H2/H3/H4

Each AI was allowed a limited depth(1/2/3) of search per move to simulate realistic performance constraints. The experiments were performed under the following settings:

- The board size is 9 by 6
- Three modes-
  - Human vs Human
  - Human vs AI
  - AI vs AI
- Five different Heuristics H0/H1/H2/H3/H4
  - BASIC ORB HEURISTIC
  - WEIGHTED ORB HEURISTIC
  - CELL CONTROL HEURISTIC
  - EVALUATE STABILITY
  - EVALUATE CLUSTER BONUS
- Fixed Depth
- PLayer 1 is Maximizing and PLayer 2 is minimizing

2. Results Summary

The outcome of the games between the AI vs human and two AI agents is summarized below:

Metric	Human	AI
Games Won	4	1
Average Runtime Time	33.49 games	
Max Evaluation Score	-131	
Grid Size	9x6	

Table 1: Performance Statistics Over 5 Games

Table 2: AI vs AI Battle Results

Heuristic A vs B	Winner	Runtime (s)	Max/Min Eval
Basic Orb vs Cell Control	Stability	36.98	71 / -134
Basic Orb vs Cluster Bonus	Basic Orb	1.99	inf / 10
Stability vs Cell Control	draw	17.45	N/A / -inf
Basic Orb vs Stability	Basic Orb	36.99	inf / -128
Weighted Orb vs Cell Control	Weighted Orb	20.77	135 / -57
Stability vs Basic Orb	draw	17.31	N/A / -inf
Cell Control vs Stability	Stability	26.46	448 / -114
Stability vs Stability	Stability(A)	33.74	inf / -160
Weighted Orb vs Cell control	Weighted Orb	20.66	inf / -57
Weighted Orb vs Stability	Weighted Orb	26.3	455 / -144

Table 3: Performance Statistics Over 10 Games

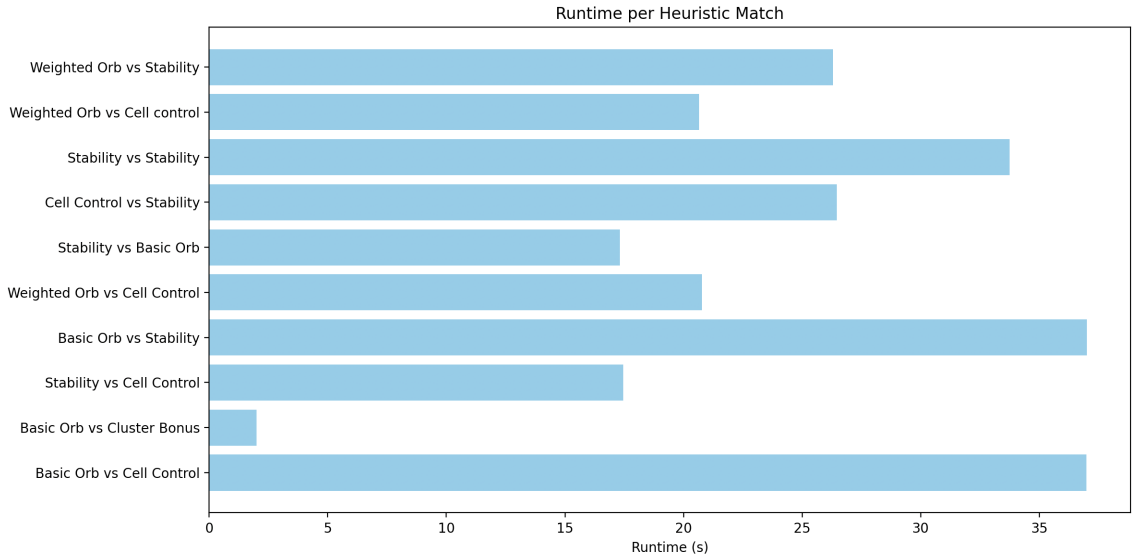

Figure 1: Run time for each ai vs ai match

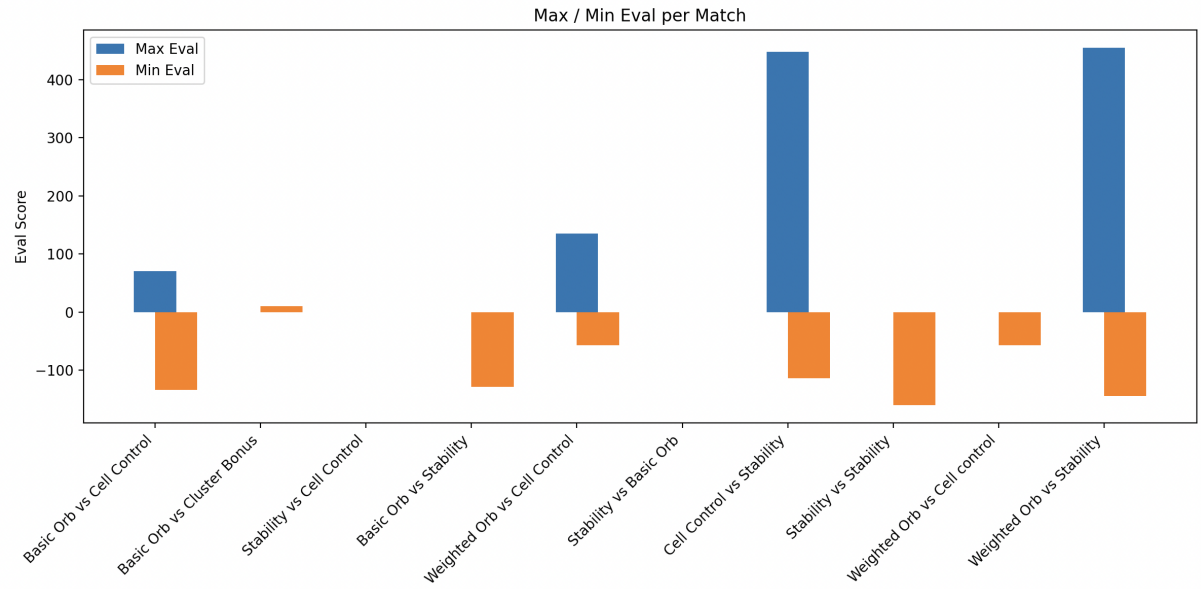

Figure 2: Max/Min val for each ai vs ai match

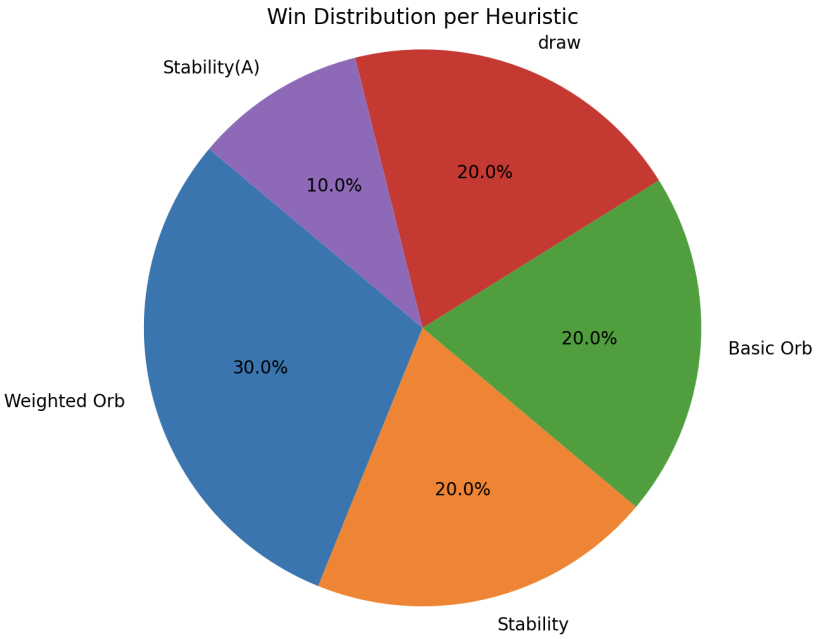

Figure 3: win percentage

3. Discussion and Analysis

Heuristic Performance

The performance of the heuristics shows that Weighted Orb is the most effective, winning all its matches with strong evaluation scores and reasonable runtimes.

Basic Orb also performed well in AI vs AI games but was less effective against human players, likely due to its simplicity.

Stability had mixed results, winning some games but often leading to draws or unstable evaluations, indicating inconsistency. Cell Control and Cluster Bonus were generally outperformed, suggesting weaker strategic impact.

Overall, heuristics that combine multiple factors, like Weighted Orb, tend to perform better than those focusing on a single aspect.

Trade-offs Observed

- **Computation Time**: some heuristic challenges take near minute to complete a match.The same heuristics can finish the game in just 2 second with the shortest move win game rule.Draw matches take much time to reach the final state.Increasing depth requires much time but improvement is not guarented always
- **Depth Sensitivity**: Sometimes Increasing depth improved both AIs' performance, but takes much more longer to have a new move

4. Conclusion

This experiment shows that AI strategies focused on gaining more orbs, like the Weighted Orb heuristic, work better than those that focus on controlling space or staying stable.

In Ai vs Human, I always tried to minimize the advantage of ai moves and thus I successfully won the most of the games.In one game, I intentionally invoked bad moves and AI eith basic heuristic could somehow made the game.

In AI vs AI games, aggressive heuristics won more often. Increasing the depth of thinking (how many moves ahead the AI looks) sometimes helped, but it also made the game much more slower without always making the AI smarter. Overall, smartly designed heuristics that balance different game factors perform best, and there is still room to improve AI by creating more useful domain specific heuristics and other evaluation functions with varryig depth.