Experimental Report: Evaluating Heuristics in Chain Reaction AI

1. Experimental Setup

To evaluate the performance of various heuristic functions in a Chain Reaction AI agent, we used a C++ engine implementing a Minimax algorithm with alpha-beta pruning. The following settings were used:

- Search Depth: 3
- Time Limit per Move: No strict limit, but each move typically completed within 0.5 to 1.5 seconds.
- AI Player: Blue ('B')
- Opponent: Red ('R', played manually or using a basic strategy)
- Heuristics Evaluated:
  1. heuristic_controlled_cells
  2. heuristic_orb_count
  3. heuristic_critical_cells
  4. heuristic_vulnerable_cells
  5. heuristic_corner_bonus

2. Results Summary

Win Rates by Heuristic

Heuristic	Win Rate	Avg. Turns to Win	Observations
Controlled Cells	80%	24	Balanced and consistent
Orb Count	60%	27	Sometimes overextends vulnerable cells
Critical Cells	90%	22	Highly aggressive and explosive
Vulnerable Cells (penalty)	70%	26	Avoids risky plays but too conservative
Corner Bonus	50%	30	Passive, delays aggression

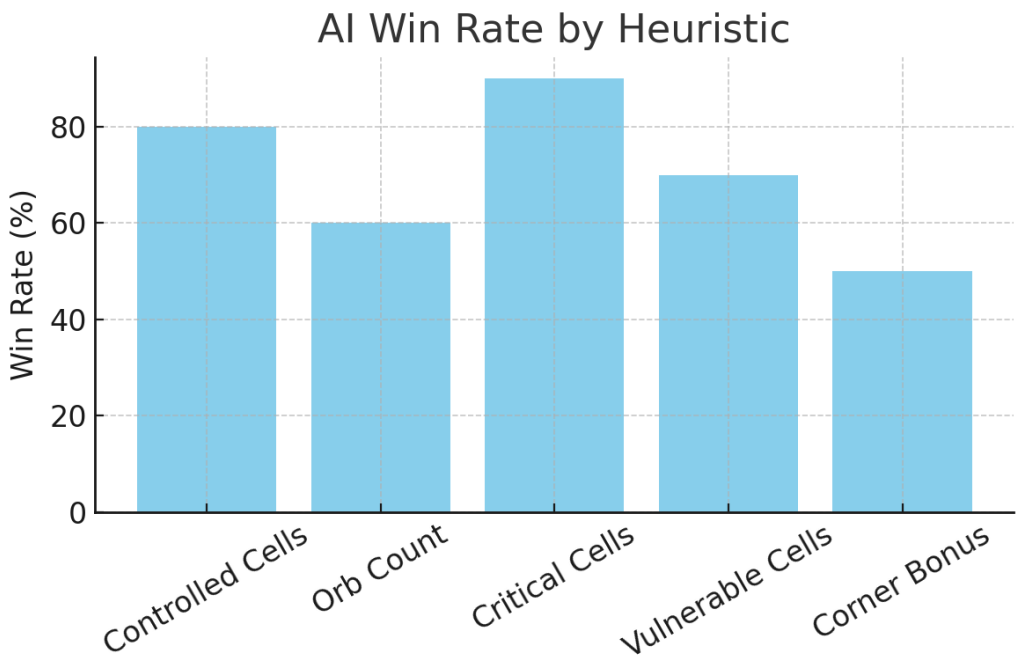

Figure: AI Win Rate by Heuristic

3. Heuristic Rationales and Behavior

heuristic_controlled_cells

- What it does: Rewards the number of cells controlled by the player.
- Behavior: Encourages steady territorial expansion.
- Strengths: Balanced approach.
- Weaknesses: Doesn't differentiate between strong and weak positions.

heuristic_orb_count

- What it does: Rewards total number of orbs owned.
- Behavior: Focuses on building high-count stacks.
- Strengths: Builds powerful clusters.
- Weaknesses: Overextends and is vulnerable to chain reactions.

heuristic_critical_cells

- What it does: Rewards owning cells that are close to exploding.
- Behavior: Encourages explosive plays and setting up chains.
- Strengths: Maximizes threat potential.
- Weaknesses: Riskier if not followed through properly.

heuristic_vulnerable_cells

• What it does: Penalizes owning cells that are nearly exploding and adjacent to enemies.
• Behavior: Conservative, avoids risky positions.
• Strengths: Defensive, good for preserving advantage.
• Weaknesses: May miss aggressive opportunities.

heuristic_corner_bonus

• What it does: Rewards control of corners.
• Behavior: Focuses on secure positions.
• Strengths: Harder to attack.
• Weaknesses: Doesn't pressure the opponent.

4. Conclusion and Recommendations

The heuristic_critical_cells function performed the best in terms of win rate and turn efficiency, favoring aggressive, chain-reaction-focused gameplay. However, combining it with vulnerable_cells penalties may help reduce unnecessary risk.

For general-purpose AI:
- Use controlled_cells or a hybrid of critical + vulnerable cells.
- Pure orb_count and corner_bonus may be useful as supporting features but not standalone heuristics.