**2105029 Report**

The UI was made using Node and React JS. Game Engine (Backend) was implemented using C++. The implementation was made versatile so that it can receive command line arguments to select heuristic, depth of search and which color to play for.

**Experimental Setup:**

Minimax algorithm with alpha-beta pruning was implemented. The following heuristics were developed:

1. **Tile Count:** The agent prioritizes filling the board in such a way that maximum number of tiles are filled with its playing color.
2. **Orb Count:** Similar to tile count, but it considers the total number of orbs that are of its playing color. Intuitively, this is expected to perform better than tile count (and it does so).
3. **Boundary Control:** As orbs in the boundaries and corners are more likely to react quickly (their critical masses being low i.e. 2 for corners and 3 for boundaries compared to 4 for other tiles), the agent prioritizes to gain control over those tiles, while trying to fill more tiles with its playing color.
4. **Stack Control:** Stacking orbs are crucial to cause a reaction, and this agent prioritizes having more chances of causing reaction up its arsenal (interesting data observed).
5. **Orb Boundary Mix:** This agent uses both orb count and the boundary control heuristics. A formidable opponent.
6. **Random Move:** This agent randomly places orbs in the board where it can. Weakest agent. Is not influenced by AI depth.

**Statistics:**

Performance: AI Depth = 2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Against->  Win rate of: | Tile Count | Orb Count | Boundary Control | Stack Control | Orb Boundary Mix | Random |
| Tile Count | - | 25.5% | 29.4% | 18.87% | 19.35% | 100% |
| Orb Count | 74.5% | - | 62.75% | 38.6% | 39.9% | 93.33% |
| Boundary Control | 70.6% | 37.25% | - | 15.7% | 32.7% | 100% |
| Stack Control | 81.13% | 61.4% | 84.3% | - | 61.7% | 97.06% |
| Orb Boundary Mix | 80.65% | 60.1% | 67.3% | 38.3% | - | 100% |
| Random | 0% | 6.67% | 0% | 2.94% | 0% | - |

Ranking after comparative strength analysis: (High to Low)

1. Stack Control
2. Orb Boundary Mix
3. Orb Count
4. Boundary Control
5. Tile Count
6. Random

Average Match Duration: AI Depth = 2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Against->  Time taken by: | Tile Count | Orb Count | Boundary Control | Stack Control | Orb Boundary Mix | Random |
| Tile Count | - | 17.82s | 18s | 21.6s | 17.75s | 11.61s |
| Orb Count | 17.82s | - | 19.08s | 21.53s | 19.39s | 11.55s |
| Boundary Control | 18s | 19.08s | - | 21.98s | 18.78s | 11.48s |
| Stack Control | 21.6s | 21.53s | 21.98s | - | 21.89s | 11.76s |
| Orb Boundary Mix | 17.75s | 19.39s | 18.78s | 21.89s | - | 11.28s |
| Random | 11.61s | 11.55s | 11.48s | 11.76s | 11.28s | - |

**No. of matches Simulated:**

* Tile Count vs Orb Count: 51
* Tile Count vs Boundary Control: 51
* Tile Count vs Stack Control: 53
* Tile Count vs Orb Boundary Mix: 124
* Tile Count vs Random: 29
* Orb Count vs Boundary Control: 51
* Orb Count vs Stack Control: 101
* Orb Count vs Orb Boundary Mix: 188
* Orb Count vs Random: 30
* Boundary Control vs Stack Control: 51
* Boundary Control vs Orb Boundary Mix: 52
* Boundary Control vs Random: 43
* Stack Control vs Orb Boundary Mix: 141
* Stack Control vs Random: 34
* Orb Boundary Mix vs Random: 30

Total Time taken = 5hrs 17mins 50s

**Statistics:**

Random was not included in this depth test as it was the worst before.

Performance: AI Depth = 3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Against->  Win rate of: | Tile Count | Orb Count | Boundary Control | Stack Control | Orb Boundary Mix |
| Tile Count | - | 38.1% | 41.67% | 40.38% | 27.08% |
| Orb Count | 61.9% | - | 36.78% | 62.96% | 29.5% |
| Boundary Control | 58.33% | 63.22% | - | 64.4% | 37.5% |
| Stack Control | 59.62% | 37.04% | 35.6% | - | 41.27% |
| Orb Boundary Mix | 72.92% | 70.5% | 62.5% | 58.73% | - |

Ranking after comparative strength analysis: (High to Low)

1. Orb Boundary Mix
2. Boundary Control
3. Orb Count
4. Stack Control
5. Tile Count

Average Match Duration: AI Depth = 3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Against->  Time taken by: | Tile Count | Orb Count | Boundary Control | Stack Control | Orb Boundary Mix |
| Tile Count | - | 2m 32s | 1m 57s | 5m 3s | 2m 17s |
| Orb Count | 2m 32s | - | 2m 43s | 3m 2s | 2m 42s |
| Boundary Control | 1m 57s | 2m 43s | - | 2m 46s | 2m 36s |
| Stack Control | 5m 3s | 3m 2s | 2m 46s | - | 2m 56s |
| Orb Boundary Mix | 2m 17s | 2m 42s | 2m 36s | 2m 56s | - |

**No. of matches Simulated:**

* Tile Count vs Orb Count: 63
* Tile Count vs Boundary Control: 51
* Tile Count vs Stack Control: 52
* Tile Count vs Orb Boundary Mix: 48
* Orb Count vs Boundary Control: 60
* Orb Count vs Stack Control: 54
* Orb Count vs Orb Boundary Mix: 61
* Boundary Control vs Stack Control: 59
* Boundary Control vs Orb Boundary Mix: 53
* Stack Control vs Orb Boundary Mix: 63

Total Time taken = 1d 2hrs 48 mins 35s

**Analysis:**

* Since random is not intelligent at all, we conclude that Tile Count heuristic is the weakest, even across varying depths. But is challenging as an opponent when played against as human.
* Stack control is the strongest at depth 2, but is the 2nd weakest at higher depth (3).
* Orb Count is the generally strong heuristic, securing 3rd place in both depths.
* Boundary Control proves to be better than Orb Count at higher depth.
* Orb Boundary Mix is always better than its constituent separate heuristics: Orb Count and Boundary Control, and it is the bests at higher depth.