CMPUT 657 Heuristic Search
Assignment 1 Report
Part 2

Talha Ibn Aziz
Student ID: 1669108

February 15, 2021

Enhancements

The search mode 2 utilizes the reduction of memory consumption due to use of bit-wise operations and optimized representation of states to improve the Transposition Table performance. The given memory limit is 200 MB, which allows the use of larger Transposition Tables as the table takes up the largest amount of memory of the entire program.

Considering that all the white pieces of the board can be represented using only one unsigned long long integer (8 bytes), the total required memory for storing the board states in an increased transposition table of size 6000119 can be approximated as follows:

$$memory = 6000119 \times (8 + 8 + 4 + 4 + 4 + 4) = 186,003,689\ bytes$$
$$= 181,644\ kilobytes = 177.387\ megabytes$$

Here, the size 6000119 is selected as it is the highest possible prime number that can be selected without crossing the 200 MB memory limit. A prime number works better when performing a modulus and storing in the attained index value. The size is multiplied by different values representing the state parameters including information of white pieces (8 bytes), information of black pieces (8 bytes), best score (4 bytes), height of search tree (4 bytes), generation counter (4 bytes), best move, flag, and turn information (4 bytes when combined). Including other variables of the program and the transposition table of the mentioned size, the memory taken by the program while running is 190 MB (approx.). The remaining 10 MB is kept as a safeguard so that the memory limit is not exceeded. Besides change in memory, the comparison and storing of states is also faster.

Although, the bit-wise operation enhancement is part of Deliverables Part 2, it is difficult to exclude it from search mode 1 as the memory limit is exceeded when the entire transposition table is represented using character array states of same size. Therefore, the search mode 1 is implemented using the same transposition table and only the smaller sized indexes are accessed.

Furthermore, the initial search window of $-\infty$ and ∞, which is represented by -70 and 70 in my program is changed in search mode 2. Initially I used the limits $(-70, 70)$ as the maximum achievable score in an 8×8 board is 64 (without any obstacles). However, if there are obstacles, the maximum and minimum achievable score changes, and if any opposite piece count is somehow decreased to zero, the search window changes even more. I have decreased the window size accordingly when searching for the best possible move in search mode 2.

Experimental Section

The two search modes applied in the same state are show in figures 1a and 1b for mode 1 and mode 2, respectively. For the shallow-depth searches, there is no apparent change in terms of performance (depth 1, 2,..,5). However, the improvement becomes evident from depth 4 and onwards. In search mode 2 the Alpha-Beta calls decrease by only about $\frac{1}{2000}$th for search depth 6 (Table 1). The calls decrease much more further into the search tree, and decreases by about half at depth 10. The improvement in Alpha-Beta calls also improves the time required for each iterative deepening step making the search about 44% faster at depth 10.

The transposition table queries keep decreasing at each step due to lesser calls being made. On the contrary, even though queries are decreased, query matches are increased significantly due to larger transposition table size. The tree-cuts created due to transposition table matching also increases a lot at each step. Therefore, the slight increase in transposition table size improved the performance by manifolds.

Table 1: Improvement in terms of parameters for Search Mode 2

Depth	Time (s)	Alpha-Beta Calls	TTQ (-ve)	TTF (+ve)
6	0.0	10	0	10
7	0.0	8,720	90	563
8	0.2	140,612	9,361	24,069
9	2.0	8,423,799	205,422	398,921
10	69	301,463,842	15,592,824	10,514,936

```
Search Mode changed to 1
g
Search Depth: 10 Search Time Limit: 1000
CTM DDD Time        Calls     Speed       TTQ       TTF       TTC  CBF    [P-Variation] Val
WHT   1  0.0           15       ---         1         0         0 ---- [a8a7 ---- ----]   1
WHT   2  0.0           42       ---        16         1         0  1.0 [a8a7 h8h7 ----]   0
WHT   3  0.0          375       ---        58        16         0  1.0 [a8a7 h8h7 a8b8]   1
WHT   4  0.0          905       ---       433       186       130  1.0 [a8a7 h8h7 a8b8]   0
WHT   5  0.0         7562       ---      1377       704       414  1.7 [a8a7 h8h7 a8b8]   1
WHT   6  0.0        18582 1237150.5      8307      4631      3846  1.5 [a8a7 h8h7 a8b8]   0
WHT   7  0.3       893851 3010106.1     96823     33272     29329 10.1 [a8a7 h8h7 a8b8]   1
WHT   8  1.3      3164324 2457578.5    641670    214464    202122  6.0 [a8a7 h8g7 a8b8]  -1
WHT   9 11.1     41788330 3774720.8   3598581    805191    763027 13.4 [a8b7 h8g8 b7c7]   3
WHT  10 156.0    605305805 3879457.2  54592761   2163975   2047711 10.7 [a8b7 h8g8 b7c7]  -2
move: a8b7
```

(a) Search Mode 1

```
Search Mode changed to 2
g
Search Depth: 10 Search Time Limit: 1000
CTM DDD Time        Calls     Speed       TTQ       TTF       TTC  CBF    [P-Variation] Val
WHT   1  0.0           15       ---         1         0         0 ---- [a8a7 ---- ----]   1
WHT   2  0.0           42       ---        16         1         0  1.0 [a8a7 h8h7 ----]   0
WHT   3  0.0          375   24747.6        58        16         0  1.0 [a8a7 h8h7 a8b8]   1
WHT   4  0.0          905   59724.1       433       186       130  1.0 [a8a7 h8h7 a8b8]   0
WHT   5  0.0         7562  499043.1      1377       704       414  1.7 [a8a7 h8h7 a8b8]   1
WHT   6  0.0        18572  602204.9      8307      4641      3856  1.5 [a8a7 h8h7 a8b8]   0
WHT   7  0.3       885131 3338907.4     96733     33835     29776 10.1 [a8a7 h8h7 a8b8]   1
WHT   8  1.1      3023712 2845372.6    632309    238533    223933  6.2 [a8a7 h8g7 a8b8]  -1
WHT   9  9.1     33364531 3671620.3   3393159   1204112   1073466 13.2 [a8b7 h8g8 b7c7]   3
WHT  10 87.0    303841963 3494270.3  38999937  12678911  12136759 10.6 [a8b7 h8g8 b7c7]  -2
move: a8b7
```

(b) Search Mode 2

Figure 1: Search Results for different search modes applied on the same state