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CSCE 420 – PA2

5 February 2014

Pentago AI Report

2.) This program was compiled and run in a Visual Studio solution with C++. (Most likely, it could also be compiled on a command line with `g++ *.cpp` and run with `./a.out`.)

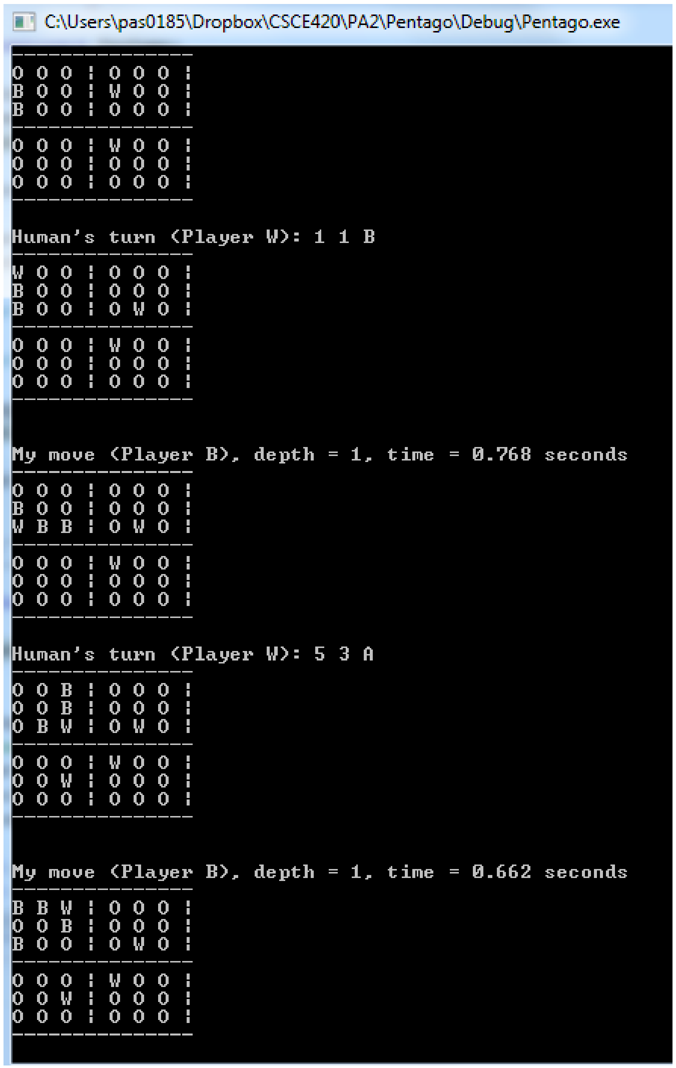
3.) The minimax algorithm was used with a utility function to attempt to make the best move. The function returns a child state that should be moved to, given the current state, player, and depth.

> Note: The state representation I used was a 64-bit integer because it has the capacity to enumerate all of the possible (but not probable) board states. Assuming every spot can have three different values (W, B, and empty), the 36 spots yields ~1.5e17 possible states. A 64-bit integer can hold ~1.8e19 different values, so I made a function that can allow a large integer to represent one of the states. This probably added computation time, but it made implementation easier, and it reduced reference-type errors.

In the recursive part of the algorithm, the child state was selected that had the highest utility value. The utility value was assumed to be the worst one out of the children. This choice between the max and min alternated down the state tree in accordance with the minimax theorem. When a leaf node or the maximum depth was reached, recursion ended, and the state of the current node was returned (for which the utility is observed when making decisions). The utility function, which is ultimately applied on a single state, admittedly has room for improvement in the future. Currently, it returns INT_MAX (~=positive infinity) if a goal state is reached; five marbles in a row. Otherwise, it returns an integer proportional to the number of consecutive marbles it has.

Improvements to this algorithm would include a data-based look-up table to help predict with opening and ending moves. To help make predictions when there are way too many states to choose from, or a concise way finish a game victoriously. One measure I took at attacking this was to search at a lower depth in the early moves, because they aren't as important and there are far more choices that make little difference. Once several moves had been taken, the depth was increased because the prediction accuracy is more critical.

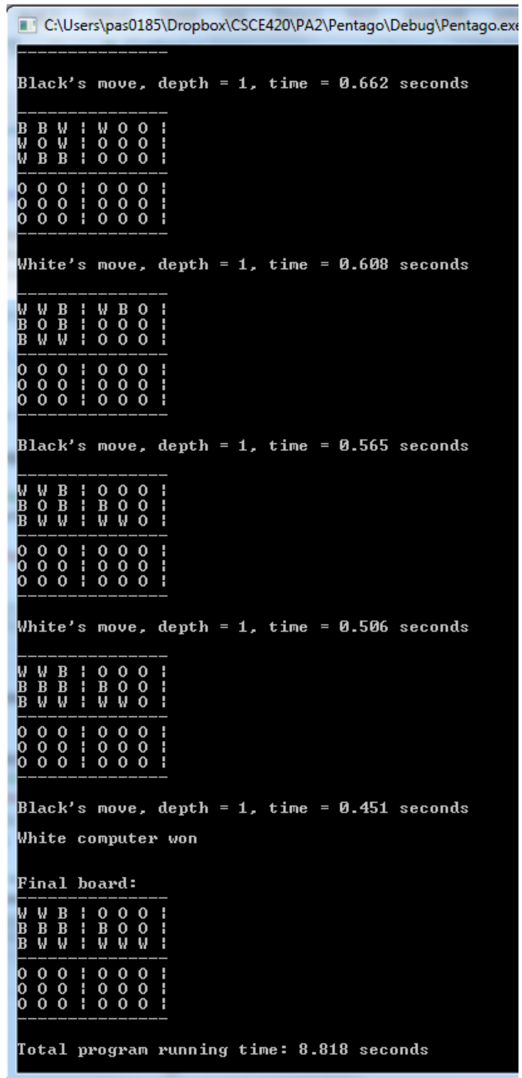
4.) The program is capable of allowing a human to play the computer (on the left), or for the computer to play itself (on the right). (Since it's not randomized, the computer always plays the same game)



```
C:\Users\pas0185\Dropbox\CSCE420\PA2\Pentago\Debug\Pentago.exe
---------------
O O O ¦ O O O ¦
B O O ¦ W O O ¦
B O O ¦ O O O ¦
---------------
O O O ¦ W O O ¦
O O O ¦ O O O ¦
O O O ¦ O O O ¦
---------------
Human's turn (Player W): 1 1 B
---------------
W O O ¦ O O O ¦
B O O ¦ O O O ¦
B O O ¦ O W O ¦
---------------
O O O ¦ W O O ¦
O O O ¦ O O O ¦
O O O ¦ O O O ¦
---------------

My move (Player B), depth = 1, time = 0.768 seconds
---------------
O O O ¦ O O O ¦
B O O ¦ O O O ¦
W B B ¦ O W O ¦
---------------
O O O ¦ W O O ¦
O O O ¦ O O O ¦
O O O ¦ O O O ¦
---------------
Human's turn (Player W): 5 3 A
---------------
O O B ¦ O O O ¦
O O B ¦ O O O ¦
O B W ¦ O W O ¦
---------------
O O O ¦ W O O ¦
O O W ¦ O O O ¦
O O O ¦ O O O ¦
---------------

My move (Player B), depth = 1, time = 0.662 seconds
---------------
B B W ¦ O O O ¦
O O B ¦ O O O ¦
B O O ¦ O W O ¦
---------------
O O O ¦ W O O ¦
O O W ¦ O O O ¦
O O O ¦ O O O ¦
---------------
```



```
C:\Users\pas0185\Dropbox\CSCE420\PA2\Pentago\Debug\Pentago.exe
---------------
Black's move, depth = 1, time = 0.662 seconds
---------------
B B W ¦ W O O ¦
W O W ¦ O O O ¦
W B B ¦ O O O ¦
---------------
O O O ¦ O O O ¦
O O O ¦ O O O ¦
O O O ¦ O O O ¦
---------------
White's move, depth = 1, time = 0.608 seconds
---------------
W W B ¦ W B O ¦
B O B ¦ O O O ¦
B W W ¦ O O O ¦
---------------
O O O ¦ O O O ¦
O O O ¦ O O O ¦
O O O ¦ O O O ¦
---------------
Black's move, depth = 1, time = 0.565 seconds
---------------
W W B ¦ O O O ¦
B O B ¦ B O O ¦
B W W ¦ W W O ¦
---------------
O O O ¦ O O O ¦
O O O ¦ O O O ¦
O O O ¦ O O O ¦
---------------
White's move, depth = 1, time = 0.506 seconds
---------------
W W B ¦ O O O ¦
B B B ¦ B O O ¦
B W W ¦ W W O ¦
---------------
O O O ¦ O O O ¦
O O O ¦ O O O ¦
O O O ¦ O O O ¦
---------------
Black's move, depth = 1, time = 0.451 seconds
White computer won

Final board:
---------------
W W B ¦ O O O ¦
B B B ¦ B O O ¦
B W W ¦ W W W ¦
---------------
O O O ¦ O O O ¦
O O O ¦ O O O ¦
O O O ¦ O O O ¦
---------------
Total program running time: 8.818 seconds
```

5.) As the numbers above show, the state tree can only reach a depth of one within 0.5 seconds. When playing a human (and the game isn't the same every time), a depth of two can be reached in roughly 1 second.

6.) **Resources**: piazza.com, stackoverflow.com, cplusplus.com, cppe.ru, wikipedia.org

7.) "An Aggie does not lie, cheat, steal, or tolerate those who do"