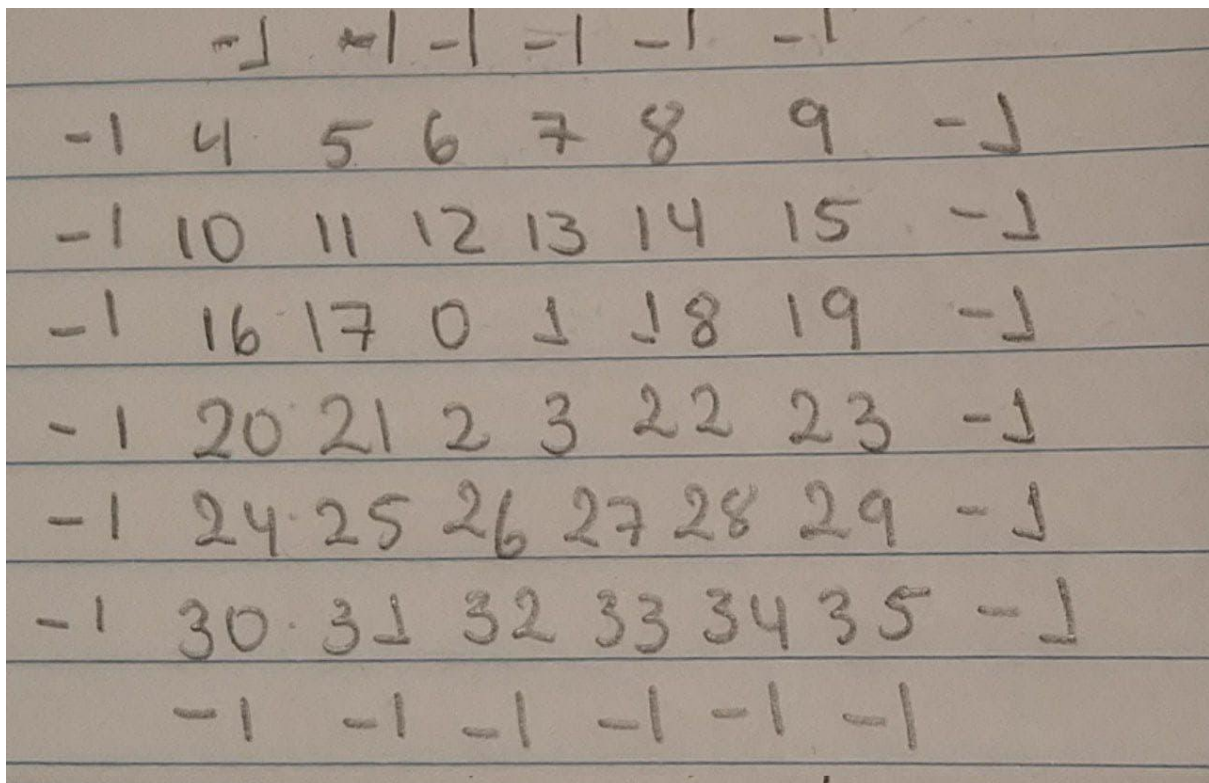


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Proyecto 2

Actividad 1

Se completó la representación del juego dentro de *othello_cut.h*, fue necesario incluir la validación de los outflanks de las diagonales, las cuales no estaban incluidas en la representación. De igual forma como con la validación de los outflanks fue necesario incluir en el método move el movimiento hacia las diagonales que están outflanked.



A photograph of a handwritten 8x8 grid on lined paper, representing an Othello board. The grid is filled with numbers and dashes. The top row contains dashes and numbers 4 through 9. The next six rows contain dashes and numbers 10 through 35. The bottom row contains dashes and numbers 1 through 6. The numbers are arranged in a way that suggests a mapping from a standard 8x8 grid to a 1D array of 36 elements (indices 0-35), with the board being 8 columns wide and 8 rows high. The numbers are: Row 1: -, 4, 5, 6, 7, 8, 9, -. Row 2: -, 10, 11, 12, 13, 14, 15, -. Row 3: -, 16, 17, 18, 19, 20, 21, -. Row 4: -, 22, 23, 24, 25, 26, 27, -. Row 5: -, 28, 29, 30, 31, 32, 33, -. Row 6: -, 34, 35, 36, 37, 38, 39, -. Row 7: -, 40, 41, 42, 43, 44, 45, -. Row 8: -, 46, 47, 48, 49, 50, 51, -. (Note: The numbers in the image are 1-6 in the last row, which may be a typo or a specific indexing scheme.)

-	4	5	6	7	8	9	-
-	10	11	12	13	14	15	-
-	16	17	18	19	20	21	-
-	22	23	24	25	26	27	-
-	28	29	30	31	32	33	-
-	34	35	36	37	38	39	-
-	40	41	42	43	44	45	-
-	46	47	48	49	50	51	-

Además hicimos una validación de la representación del bitboard y cada elemento dentro de filas, columnas y sus dos diagonales cumple adecuadamente.

Actividad 2

Los algoritmos fueron implementados y se encuentran en el archivo *algorithms.cpp*.

Actividad 3

Dentro de la carpeta *results* se encuentran los resultados experimentales, a continuación se presentan el análisis de los mismos:

El algoritmo *Scout* tuvo un tiempo de ejecución bastante aceptable, pero al mismo tiempo es el que encontró la variación principal más larga, desde el movimiento 17 hasta el 34. Además encontró un total de 18 nodos que pertenecen a una variación principal, lo que refleja un 53% de acierto.

El algoritmo *Negamax* (versión minimax) tardó un tiempo exageradamente superior al resto, encontró una variación principal casi tan larga como *Scout*, desde el movimiento 18 hasta el 34. Además encontró un total de 18 nodos que pertenecen a una variación principal, lo que refleja un 53% de acierto.

El algoritmo *Negamax* (con alpha-beta pruning) tardó un tiempo similar a *Scout*, pero las variaciones encontradas no fueron muy sólidas, puesto que hubo jugadas equivocadas por parte de black, lo que rompe el concepto de variación principal donde ambos juegan óptimos. Además encontró un total de 14 nodos que pertenecen a una variación principal, lo que refleja un 41% de acierto.

El algoritmo *Negascout* fue el más rápido en tiempo, pero con resultados similares a *Negamax* (con alpha-beta pruning) el cual muchos de los valores de la variación principal no dieron el valor esperado para la jugada óptima.

Conclusiones

Dados los resultados y tras el análisis de los mismos hemos concluido que **el mejor algoritmo**, por ser el 2do mejor tiempo de ejecución, tener mejores resultados, mejor % de acierto y altura de la variación principal, es **Scout**. Atribuimos la mejora en resultados y tiempo de ejecución de Scout a TEST, que permite hacer poda de ramas cuyo valor del nodo se encuentren fuera de los rangos de alpha y beta, con una mejor aproximación y complejidad que la poda alpha-beta.

El uso de alpha-beta en este juego no es una buena estrategia, los 2 algoritmos que hacen uso de ella no se aproximaron a tan buenos resultados como los otros 2.

Anexos

Negamax (alpha-beta version)

```
Extracting principal variation (PV) with 33 plays ... done!
Algorithm: Negamax (alpha-beta version)
Moving along PV:
34. White moves: value=-4, #expanded=0, #generated=1, seconds=1.00001e-06, #generated/second=999992
33. Black moves: value=-4, #expanded=1, #generated=2, seconds=2.99991e-06, #generated/second=666687
32. White moves: value=-4, #expanded=3, #generated=5, seconds=2.00002e-06, #generated/second=2.49998e+06
31. Black moves: value=-4, #expanded=3, #generated=4, seconds=2.00002e-06, #generated/second=1.99998e+06
30. White moves: value=-4, #expanded=9, #generated=13, seconds=4.99992e-06, #generated/second=2.60004e+06
29. Black moves: value=8, #expanded=4, #generated=5, seconds=2.00002e-06, #generated/second=2.49998e+06
28. White moves: value=-4, #expanded=21, #generated=27, seconds=8.99995e-06, #generated/second=3.00002e+06
27. Black moves: value=8, #expanded=21, #generated=26, seconds=9.99996e-06, #generated/second=2.60001e+06
26. White moves: value=-4, #expanded=153, #generated=194, seconds=6.1e-05, #generated/second=3.18033e+06
25. Black moves: value=-4, #expanded=689, #generated=895, seconds=0.000273, #generated/second=3.27839e+06
24. White moves: value=-4, #expanded=879, #generated=1145, seconds=0.000385, #generated/second=2.97403e+06
23. Black moves: value=0, #expanded=2492, #generated=3207, seconds=0.001095, #generated/second=2.92877e+06
22. White moves: value=-4, #expanded=2935, #generated=3714, seconds=0.001357, #generated/second=2.73692e+06
21. Black moves: value=14, #expanded=20993, #generated=27501, seconds=0.008359, #generated/second=3.28999e+06
20. White moves: value=-4, #expanded=70289, #generated=90887, seconds=0.029277, #generated/second=3.10438e+06
19. Black moves: value=-4, #expanded=163545, #generated=212976, seconds=0.067889, #generated/second=3.13712e+06
18. White moves: value=-4, #expanded=722468, #generated=947004, seconds=0.305402, #generated/second=3.10084e+06
17. Black moves: value=-6, #expanded=751024, #generated=1028714, seconds=0.334088, #generated/second=3.07917e+06
16. White moves: value=-6, #expanded=3582591, #generated=6711518, seconds=1.96006, #generated/second=3.42415e+06
15. Black moves: value=-2, #expanded=2355090, #generated=4879799, seconds=1.49471, #generated/second=3.26472e+06
14. White moves: value=-6, #expanded=137845, #generated=358980, seconds=0.109264, #generated/second=3.28544e+06
13. Black moves: value=12, #expanded=32607, #generated=51629, seconds=0.0235963, #generated/second=2.18801e+06
12. White moves: value=2, #expanded=569512, #generated=1552632, seconds=0.551015, #generated/second=2.81777e+06
11. Black moves: value=10, #expanded=17326, #generated=29140, seconds=0.0141349, #generated/second=2.06157e+06
10. White moves: value=0, #expanded=32011, #generated=87274, seconds=0.0342331, #generated/second=2.5494e+06
9. Black moves: value=6, #expanded=1754, #generated=2933, seconds=0.00161171, #generated/second=1.81981e+06
8. White moves: value=-2, #expanded=4087, #generated=13896, seconds=0.00560331, #generated/second=2.47996e+06
7. Black moves: value=4, #expanded=350, #generated=614, seconds=0.000397682, #generated/second=1.54395e+06
6. White moves: value=-4, #expanded=200, #generated=772, seconds=0.000322342, #generated/second=2.39497e+06
5. Black moves: value=0, #expanded=43, #generated=75, seconds=4.91142e-05, #generated/second=1.52705e+06
4. White moves: value=-2, #expanded=19, #generated=55, seconds=2.71797e-05, #generated/second=2.02357e+06
3. Black moves: value=-2, #expanded=6, #generated=13, seconds=8.10623e-06, #generated/second=1.6037e+06
2. White moves: value=0, #expanded=1, #generated=4, seconds=9.53674e-07, #generated/second=4.1943e+06
1. Black moves: value=0, #expanded=0, #generated=1, seconds=9.53674e-07, #generated/second=1.04858e+06
```

Negamax (minmax version)

```
Extracting principal variation (PV) with 33 plays ... done! Samuel, 4 days ago • Uploading results
Algorithm: Negamax (minmax version)
Moving along PV:
34. White moves: value=-4, #expanded=0, #generated=1, seconds=1.00001e-06, #generated/second=999992
33. Black moves: value=-4, #expanded=1, #generated=2, seconds=1.99996e-06, #generated/second=1.00002e+06
32. White moves: value=-4, #expanded=3, #generated=5, seconds=2.99996e-06, #generated/second=1.66669e+06
31. Black moves: value=-4, #expanded=4, #generated=6, seconds=2.00002e-06, #generated/second=2.99998e+06
30. White moves: value=-4, #expanded=9, #generated=13, seconds=4.00003e-06, #generated/second=3.24998e+06
29. Black moves: value=-4, #expanded=10, #generated=14, seconds=3.99997e-06, #generated/second=3.50002e+06
28. White moves: value=-4, #expanded=64, #generated=91, seconds=2.4e-05, #generated/second=3.79167e+06
27. Black moves: value=-4, #expanded=125, #generated=177, seconds=4.1e-05, #generated/second=4.31708e+06
26. White moves: value=-4, #expanded=744, #generated=1049, seconds=0.000253, #generated/second=4.14625e+06
25. Black moves: value=-4, #expanded=3168, #generated=4498, seconds=0.001113, #generated/second=4.04133e+06
24. White moves: value=-4, #expanded=8597, #generated=11978, seconds=0.002914, #generated/second=4.1105e+06
23. Black moves: value=-4, #expanded=55127, #generated=76826, seconds=0.020801, #generated/second=3.69338e+06
22. White moves: value=-4, #expanded=308479, #generated=428402, seconds=0.106138, #generated/second=4.03627e+06
21. Black moves: value=-4, #expanded=2525249, #generated=3478735, seconds=0.85135, #generated/second=4.08614e+06
20. White moves: value=-4, #expanded=9459570, #generated=13078933, seconds=3.3269, #generated/second=3.93127e+06
19. Black moves: value=-4, #expanded=65046365, #generated=90571445, seconds=22.5756, #generated/second=4.01192e+06
18. White moves: value=-4, #expanded=614228905, #generated=865108508, seconds=211.058, #generated/second=4.09891e+06
17. Black moves: value=-6, #expanded=3062019639, #generated=327695181, seconds=1099.38, #generated/second=298072
16. White moves: value=-6, #expanded=137178963, #generated=3477989201, seconds=4435.04, #generated/second=784207
15. Black moves: value=-2, #expanded=1138389157, #generated=4073281039, seconds=7051.66, #generated/second=577635
14. White moves: value=-2, #expanded=2497993600, #generated=2472868750, seconds=2342.11, #generated/second=1.05583e+06
13. Black moves: value=2, #expanded=669732144, #generated=3532379935, seconds=773.149, #generated/second=4.56882e+06
12. White moves: value=2, #expanded=167240952, #generated=997081568, seconds=224.051, #generated/second=4.45025e+06
11. Black moves: value=4, #expanded=78291537, #generated=519689751, seconds=118.932, #generated/second=4.36965e+06
10. White moves: value=0, #expanded=7171086, #generated=47175422, seconds=11.3311, #generated/second=4.16337e+06
9. Black moves: value=0, #expanded=2449841, #generated=18579536, seconds=4.24121, #generated/second=4.38072e+06
8. White moves: value=-2, #expanded=217468, #generated=1629187, seconds=0.389648, #generated/second=4.18117e+06
7. Black moves: value=-2, #expanded=28788, #generated=241264, seconds=0.0585938, #generated/second=4.11757e+06
6. White moves: value=-4, #expanded=3666, #generated=28333, seconds=0.00683594, #generated/second=4.14471e+06
5. Black moves: value=-4, #expanded=298, #generated=2281, seconds=0.000976562, #generated/second=2.33574e+06
4. White moves: value=-2, #expanded=29, #generated=165, seconds=0, #generated/second=inf
3. Black moves: value=-2, #expanded=6, #generated=27, seconds=0, #generated/second=inf
2. White moves: value=0, #expanded=1, #generated=4, seconds=0, #generated/second=inf
1. Black moves: value=0, #expanded=0, #generated=1, seconds=0, #generated/second=inf
```


Negascout

```
Extracting principal variation (PV) with 33 plays ... done!
Algorithm: Negascout
Moving along PV:
34. White moves: value=-4, #expanded=0, #generated=0, seconds=1.00001e-06, #generated/second=0
33. Black moves: value=-4, #expanded=1, #generated=1, seconds=1.99996e-06, #generated/second=500011
32. White moves: value=-4, #expanded=3, #generated=4, seconds=2.00002e-06, #generated/second=1.99998e+06
31. Black moves: value=-4, #expanded=3, #generated=3, seconds=1.99996e-06, #generated/second=1.50003e+06
30. White moves: value=-4, #expanded=14, #generated=17, seconds=5.99999e-06, #generated/second=2.83334e+06
29. Black moves: value=8, #expanded=4, #generated=4, seconds=2.00002e-06, #generated/second=1.99998e+06
28. White moves: value=-4, #expanded=26, #generated=31, seconds=1e-05, #generated/second=3.09999e+06
27. Black moves: value=8, #expanded=19, #generated=22, seconds=9.00001e-06, #generated/second=2.44444e+06
26. White moves: value=-4, #expanded=258, #generated=321, seconds=9.4e-05, #generated/second=3.41489e+06
25. Black moves: value=-4, #expanded=1153, #generated=1472, seconds=0.000429, #generated/second=3.43124e+06
24. White moves: value=-4, #expanded=1498, #generated=1910, seconds=0.000551, #generated/second=3.46642e+06
23. Black moves: value=0, #expanded=1059, #generated=1326, seconds=0.000476, #generated/second=2.78572e+06
22. White moves: value=-4, #expanded=4524, #generated=5628, seconds=0.00184, #generated/second=3.0587e+06
21. Black moves: value=14, #expanded=11667, #generated=15076, seconds=0.004835, #generated/second=3.1181e+06
20. White moves: value=-4, #expanded=42461, #generated=54035, seconds=0.018104, #generated/second=2.9847e+06
19. Black moves: value=-4, #expanded=94007, #generated=120390, seconds=0.039496, #generated/second=3.04816e+06
18. White moves: value=-4, #expanded=278843, #generated=360804, seconds=0.120101, #generated/second=3.00417e+06
17. Black moves: value=-6, #expanded=414799, #generated=562610, seconds=0.187407, #generated/second=3.00208e+06
16. White moves: value=-6, #expanded=1143693, #generated=2018479, seconds=0.627514, #generated/second=3.21663e+06
15. Black moves: value=-2, #expanded=1582418, #generated=3259735, seconds=1.02773, #generated/second=3.17178e+06
14. White moves: value=-6, #expanded=46571, #generated=104709, seconds=0.0348291, #generated/second=3.00636e+06
13. Black moves: value=12, #expanded=31611, #generated=49678, seconds=0.0232, #generated/second=2.14129e+06
12. White moves: value=2, #expanded=519001, #generated=1380052, seconds=0.50136, #generated/second=2.75262e+06
11. Black moves: value=10, #expanded=17244, #generated=28964, seconds=0.0141521, #generated/second=2.04663e+06
10. White moves: value=0, #expanded=17472, #generated=45280, seconds=0.01864, #generated/second=2.42918e+06
9. Black moves: value=6, #expanded=1783, #generated=3029, seconds=0.00165009, #generated/second=1.83565e+06
8. White moves: value=-2, #expanded=3469, #generated=10335, seconds=0.00436187, #generated/second=2.3694e+06
7. Black moves: value=4, #expanded=350, #generated=613, seconds=0.00037384, #generated/second=1.63974e+06
6. White moves: value=-4, #expanded=190, #generated=694, seconds=0.000277996, #generated/second=2.49644e+06
5. Black moves: value=0, #expanded=43, #generated=74, seconds=4.79221e-05, #generated/second=1.54417e+06
4. White moves: value=-2, #expanded=19, #generated=48, seconds=2.5034e-05, #generated/second=1.9174e+06
3. Black moves: value=-2, #expanded=6, #generated=12, seconds=8.10623e-06, #generated/second=1.48034e+06
2. White moves: value=0, #expanded=1, #generated=3, seconds=1.90735e-06, #generated/second=1.57286e+06
1. Black moves: value=0, #expanded=0, #generated=0, seconds=0, #generated/second=-nan
```

Scout

```
Extracting principal variation (PV) with 33 plays ... done! Samuel, 4 days ago • Uploading results
Algorithm: Scout
Moving along PV:
34. White moves: value=-4, #expanded=0, #generated=1, seconds=1.00001e-06, #generated/second=999992
33. Black moves: value=-4, #expanded=1, #generated=2, seconds=2.00002e-06, #generated/second=999992
32. White moves: value=-4, #expanded=2, #generated=3, seconds=2.00002e-06, #generated/second=1.49999e+06
31. Black moves: value=-4, #expanded=3, #generated=4, seconds=2.00002e-06, #generated/second=1.99998e+06
30. White moves: value=-4, #expanded=8, #generated=11, seconds=6.99994e-06, #generated/second=1.57144e+06
29. Black moves: value=-4, #expanded=9, #generated=12, seconds=6.00005e-06, #generated/second=1.99998e+06
28. White moves: value=-4, #expanded=10, #generated=13, seconds=1.1e-05, #generated/second=1.18182e+06
27. Black moves: value=-4, #expanded=11, #generated=14, seconds=2.70001e-05, #generated/second=518517
26. White moves: value=-4, #expanded=42, #generated=52, seconds=0.000122, #generated/second=426230
25. Black moves: value=-4, #expanded=152, #generated=192, seconds=0.000564, #generated/second=340426
24. White moves: value=-4, #expanded=199, #generated=249, seconds=0.000775, #generated/second=321290
23. Black moves: value=-4, #expanded=245, #generated=306, seconds=0.001413, #generated/second=216560
22. White moves: value=-4, #expanded=580, #generated=727, seconds=0.004152, #generated/second=175096
21. Black moves: value=-4, #expanded=1520, #generated=1909, seconds=0.017588, #generated/second=108540
20. White moves: value=-4, #expanded=1777, #generated=2250, seconds=0.02898, #generated/second=77639.8
19. Black moves: value=-4, #expanded=2238, #generated=2822, seconds=0.065977, #generated/second=42772.5
18. White moves: value=-4, #expanded=6419, #generated=8355, seconds=0.203483, #generated/second=41059.9
17. Black moves: value=-4, #expanded=5601, #generated=7692, seconds=0.353254, #generated/second=21774.7
16. White moves: value=0, #expanded=14126, #generated=21429, seconds=1.51546, #generated/second=14140.3
15. Black moves: value=3, #expanded=10472, #generated=16420, seconds=1.58265, #generated/second=10375
14. White moves: value=2, #expanded=31936, #generated=51020, seconds=2.55547, #generated/second=19965
13. Black moves: value=6, #expanded=17944, #generated=29264, seconds=2.84084, #generated/second=10301.2
12. White moves: value=4, #expanded=8248, #generated=13870, seconds=1.11565, #generated/second=12432.3
11. Black moves: value=6, #expanded=17961, #generated=30563, seconds=2.17436, #generated/second=14056.1
10. White moves: value=6, #expanded=2294, #generated=3977, seconds=0.176134, #generated/second=22579.4
9. Black moves: value=6, #expanded=460, #generated=801, seconds=0.0329981, #generated/second=24274.1
8. White moves: value=-4, #expanded=670, #generated=1191, seconds=0.0385456, #generated/second=30898.5
7. Black moves: value=0, #expanded=470, #generated=838, seconds=0.0261679, #generated/second=32024
6. White moves: value=0, #expanded=50, #generated=87, seconds=0.0017643, #generated/second=49311.4
5. Black moves: value=0, #expanded=42, #generated=73, seconds=0.00126934, #generated/second=57510.2
4. White moves: value=0, #expanded=8, #generated=14, seconds=0.000106812, #generated/second=131072
3. Black moves: value=-2, #expanded=6, #generated=11, seconds=4.673e-05, #generated/second=235395
2. White moves: value=0, #expanded=1, #generated=2, seconds=3.8147e-06, #generated/second=524288
1. Black moves: value=0, #expanded=0, #generated=1, seconds=9.53674e-07, #generated/second=1.04858e+06
```