Introduction to Symbolic AI
Coursework 2: Adversarial Search on Connect Four

Sunjin Kim, Charlize Yang

Department of Computing
MSc Artificial Intelligence

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The times measured in this report does not correspond to any real world unit of time, because it was measured by time.perf_counter().

1 Question 3

See Tables 1, 2, 3 and Figures 1, 2, 3, 4.

There is a significant increase in selection time for actions as each of m, n, k increases. Out of the three, increase in k brought the most dramatic increase (refer to the Tables and Figures). In Figure 1 and 2, each line looked almost linear (except for $k = 1$), suggesting that the running time is similar to exponential in both m and n.

Figure 3 looked very similar to Figure 4 for $k = 2$ and $k = 3$, suggesting that the running time of minimax and the number of states visited are highly positively correlated. However, they looked very different for $k = 1$.

2 Question 4

See Tables 4, 5, 6, and Figures 5, 6, 7 and 8.

Compared to the unpruned plots, the gradients of the lines in both the $Log(Time)$ and $Log(Count)$ plots are smaller (see Figures 7 and 8), suggesting that the change in running time with respect to m, n and k is much smaller than the unpruned game. Also, the lines aren't straight, but rather bend downwards, revealing the time is not truly exponential in m and n, but rather a little bit less than exponential.

Figure 5 looked very similar to Figure 6 for $k = 1, 2, 3$, suggesting that the running time of minimax and the number of states it visits are highly positively correlated.

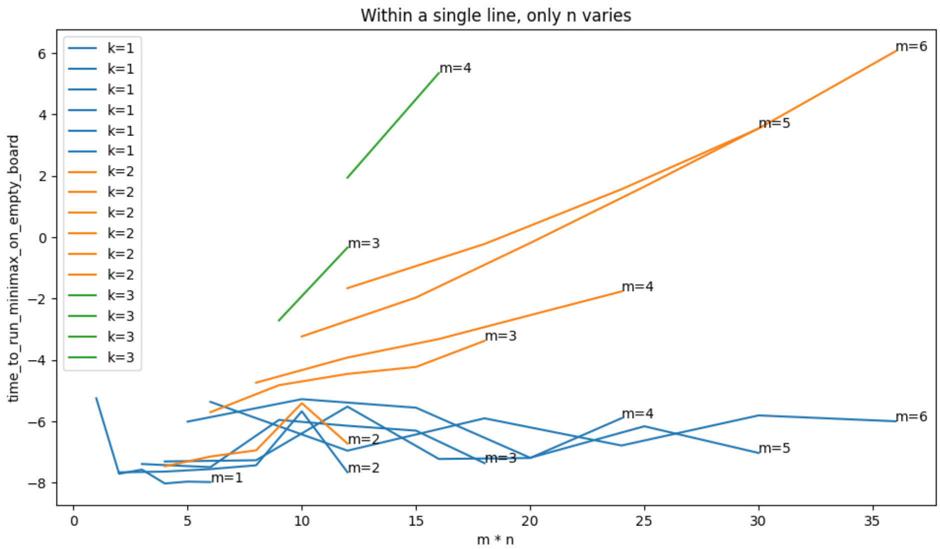

Figure 1: Log(time); Unpruned. Curves are parametrized with respect to n.

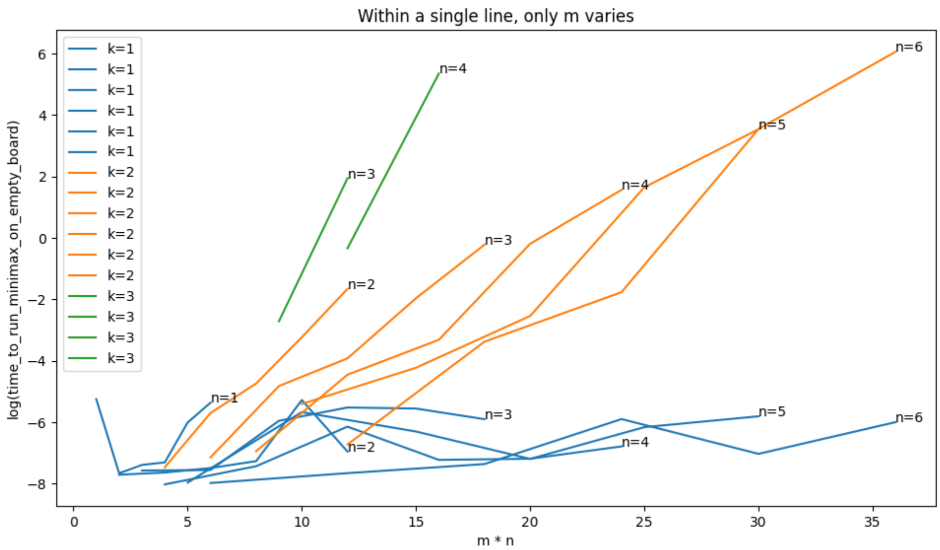

Figure 2: Log(time); Unpruned. Curves parametrized with respect to m.

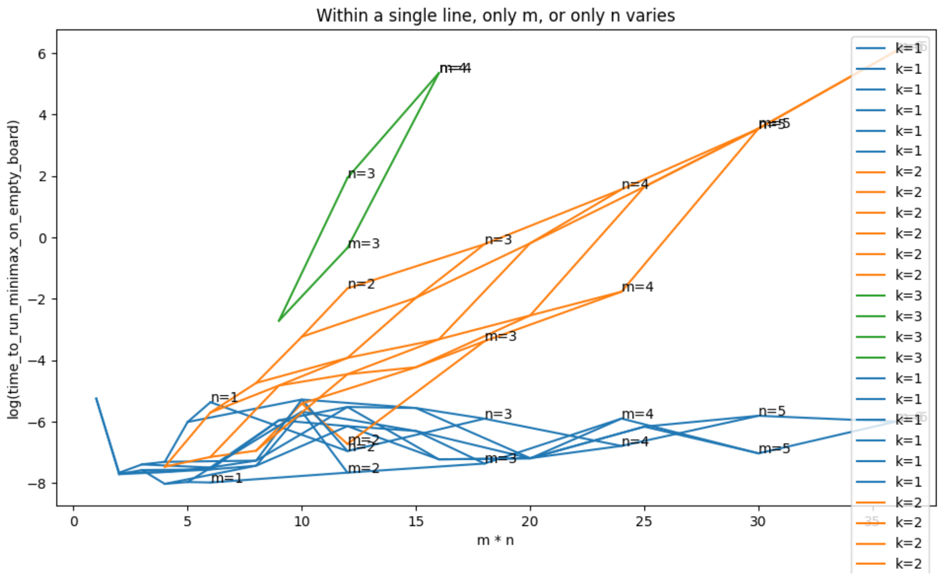

Figure 3: Log(time); Unpruned. (Figure 1 and 2 combined.)

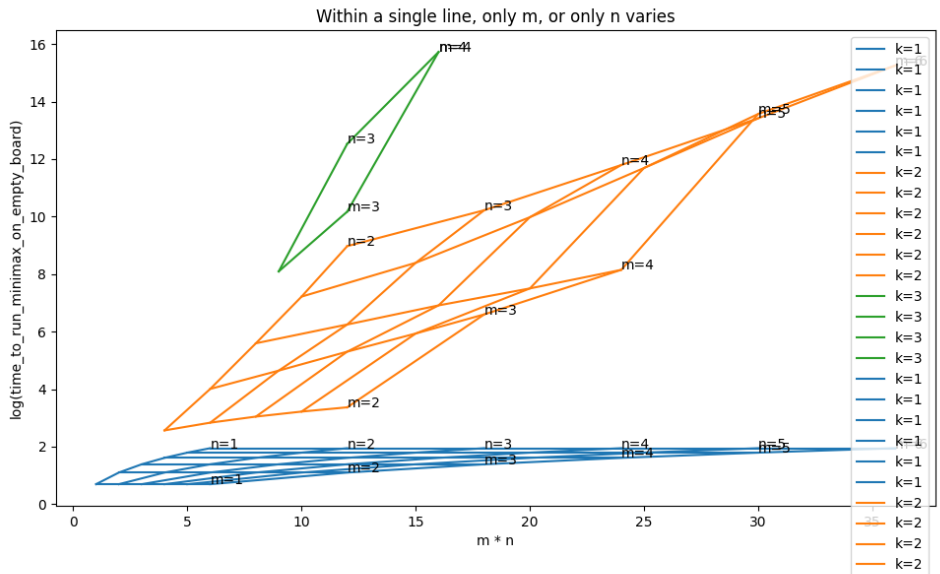

Figure 4: Log(count); Unpruned. (the y-axis is mislabelled)

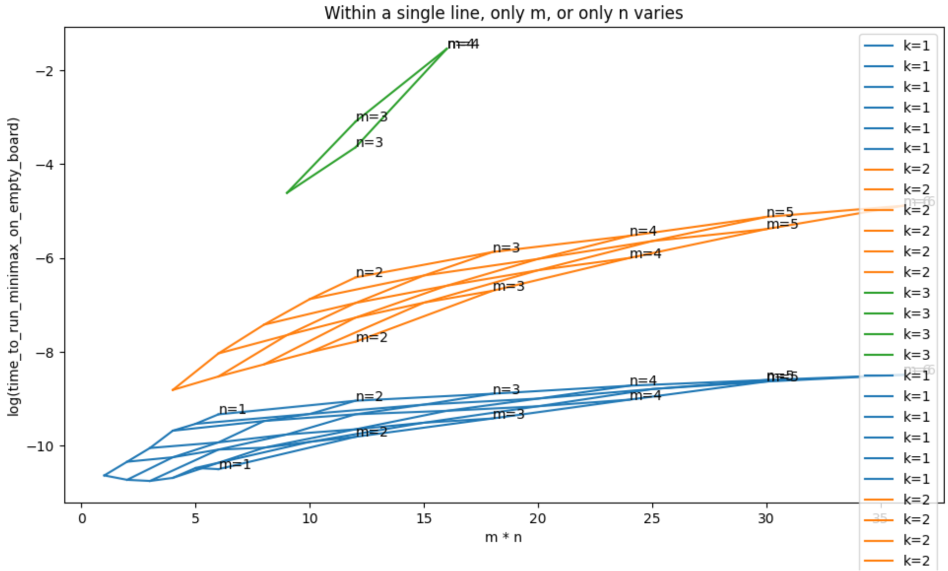

Figure 5: Log(time); Pruned.

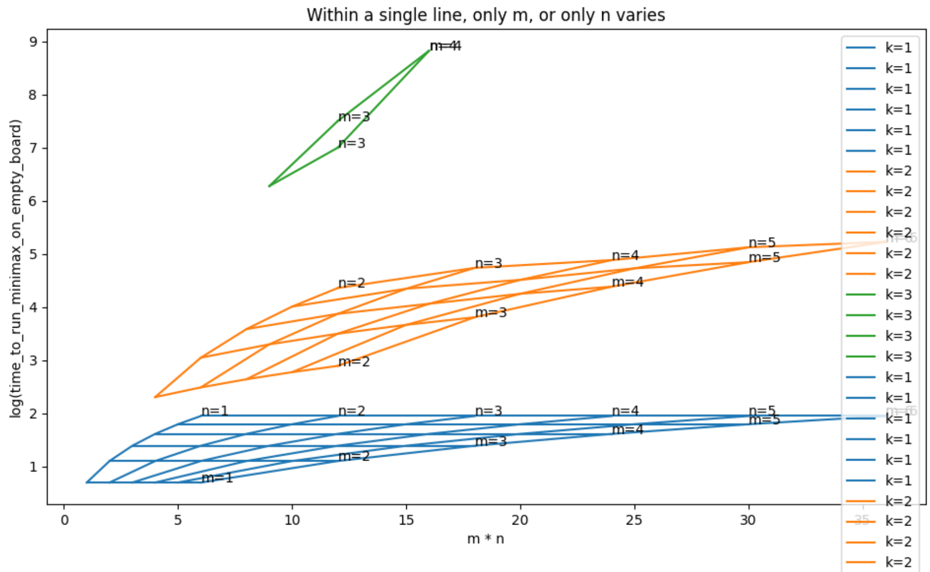

Figure 6: Log(count); Pruned. (the y-axis is mislabelled)

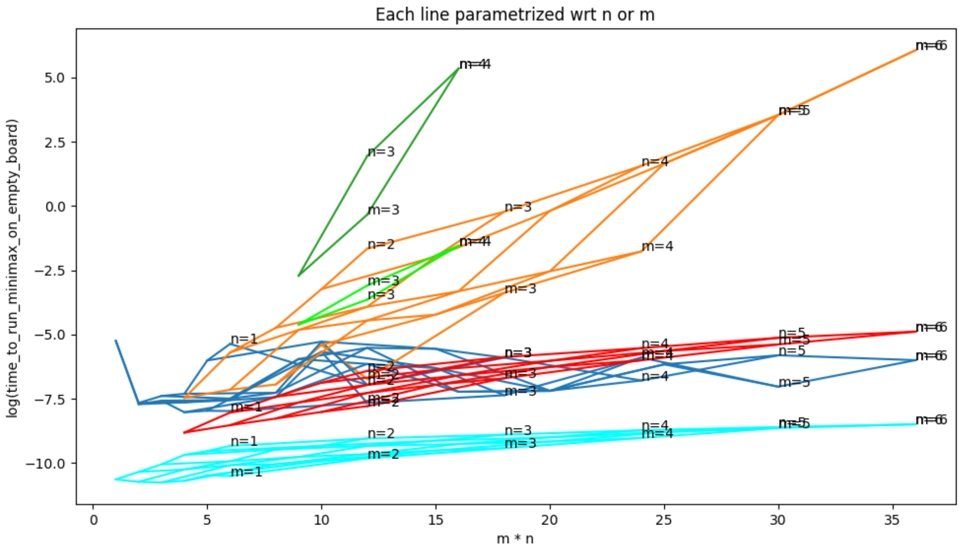

Figure 7: Log(time) plots combined (Figure 3 and 5). The brighter colors indicate the pruned version.

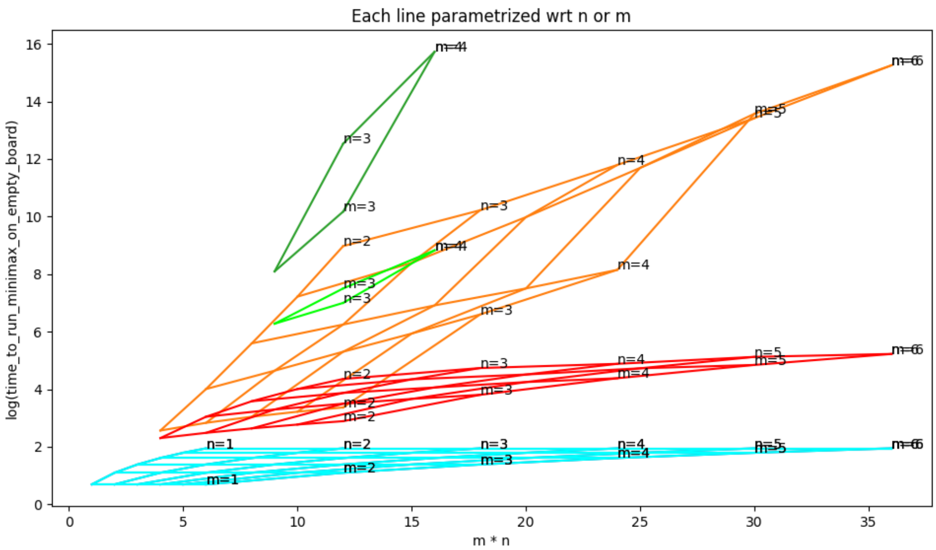

Figure 8: Two Log(count)(The y-axis is mislabelled) plots combined (Figure 4 and 6). The brighter colors indicate the pruned version. The cyan actually completely obscures the unpruned version's darker blue lines here.

n\m	1	2	3	4	5	6
1	4.050×10^{-3}	4.261×10^{-4}	3.748×10^{-4}	4.171×10^{-4}	2.464×10^{-3}	4.690×10^{-3}
2	3.509×10^{-4}	4.377×10^{-4}	3.317×10^{-4}	4.555×10^{-3}	5.121×10^{-3}	9.571×10^{-4}
3	3.034×10^{-4}	4.438×10^{-4}	3.795×10^{-4}	3.185×10^{-4}	3.882×10^{-3}	2.745×10^{-3}
4	2.780×10^{-4}	3.692×10^{-4}	1.474×10^{-3}	3.549×10^{-4}	7.584×10^{-4}	1.131×10^{-3}
5	3.493×10^{-4}	3.455×10^{-3}	1.838×10^{-3}	7.534×10^{-4}	2.118×10^{-3}	3.017×10^{-3}
6	3.439×10^{-4}	4.741×10^{-4}	6.375×10^{-4}	2.755×10^{-3}	8.881×10^{-4}	2.492×10^{-3}

Table 1: Unpruned game: the running times for minimax for different values of m and n, when $k = 1$.

n\m	2	3	4	5	6
2	5.748×10^{-4}	3.354×10^{-3}	8.772×10^{-3}	3.950×10^{-2}	1.906×10^{-1}
3	7.903×10^{-4}	8.082×10^{-3}	1.986×10^{-2}	1.406×10^{-1}	8.042×10^{-1}
4	9.677×10^{-4}	1.167×10^{-2}	3.635×10^{-2}	8.293×10^{-1}	4.783×10^{-0}
5	4.500×10^{-3}	1.464×10^{-2}	7.908×10^{-2}	5.211×10^{-0}	3.449×10^{-1}
6	1.205×10^{-3}	3.422×10^{-2}	1.712×10^{-1}	3.480×10^{-1}	4.290×10^{-2}

Table 2: Unpruned game: the running times for minimax for different values of m and n, when $k = 2$.

n\m	3	4
3	6.664×10^{-2}	6.974×10^{0}
4	7.152×10^{-1}	2.106×10^{2}

Table 3: Unpruned game: the running times for minimax for different values of m and n, when $k = 3$.

n\m	1	2	3	4
1	2.58864375e-05	2.95562500e-05	4.20523750e-05	5.36285000e-05
2	2.15188750e-05	3.24377500e-05	4.95180625e-05	6.64923750e-05
3	2.17856875e-05	3.66650625e-05	5.59633125e-05	8.79735625e-05
4	2.19276875e-05	4.20060625e-05	6.41628125e-05	8.88194375e-05

Table 4: Pruned game: the running times for minimax for different values of m and n, when $k = 1$.

n\m	2	3	4
2	0.00014108	0.00032122	0.00059654
3	0.00019683	0.00049385	0.00094588
4	0.00026159	0.00069692	0.00137228

Table 5: Pruned game: the running times for minimax for different values of m and n, when $k = 2$.

n\m	3	4
3	0.00994167	0.02623095
4	0.04536541	0.21473945

Table 6: Pruned game: the running times for minimax for different values of m and n, when $k = 3$.