Sonia Ionescu (260665763)
COMP 424
January 30

Assignment 1

1.
    a.
        i. Breadth first search results in

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[1, 4, 2]
[5, 3, 0]
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[1, 4, 2]
[5, 0, 3]
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[1, 0, 2]
[5, 4, 3]
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[0, 1, 2]
[5, 4, 3]
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        ii. Uniform cost search results in the same thing as breadth first search, since all operators have unit costs.

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[1, 4, 2]
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[5, 0, 3]
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[1, 0, 2]
[5, 4, 3]
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[0, 1, 2]
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        iii. Depth first search results in

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[5, 4, 3]

iv. Iterative deepening (implemented as depth first search with a limit, which increases if the goal is not found) results in this, which is the same result as BFS:

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[1, 4, 2]
[5, 0, 3]

[1, 0, 2]
[5, 4, 3]

[0, 1, 2]
[5, 4, 3]

b. The Manhattan distance heuristic is still an admissible heuristic for A* search in this new variant. A* search evaluates $f(n) = g(n) + h(n)$ where $g(n)$ is the cost to reach the node and $h(n)$ is the estimated cost of the cheapest path from n to the goal. $h(n)$ as calculated by the Manhattan distance will always be less than the true cost, because the true cost for each movement will be multiplied by the value of the tile being moved; this is the definition of an admissible heuristic. In addition, the Manhattan distance still provides the optimal solution to a relaxed problem, it is just a further relaxed problem.

c. An admissible heuristic that dominates the heuristic from part b is $h(n) = Manhattan\ Distance\ \times value\ of\ piece$. For the puzzle in the initial state it would be $1 \times 1 + 2 \times 0 + 3 \times 1 + 5 \times 0 = 4$. This will always be lower than the actual cost, as pieces can only swap with a 0, not with any piece, as in the calculation for the $Manhattan\ Distance\ \times value\ of\ piece$. Thus, this is an admissible heuristic that dominates the Manhattan Distance.

d. The Manhattan distance heuristic from part A may no longer be an admissible heuristic, as the real cost may be lower. For example, in the puzzle

[5, 1, 2]
[, 4, 3]

has an $h(n) = 1$, but a real cost of 0.5. Thus, it is no longer admissible.

2.

a. If the branching factor is 1 and the depth limit for iterative deepening is 1 as well, Iterative deepening will take the triangular number of steps, which is equal to the $\Sigma \frac{n(n+1)}{2} = O(n^2)$. On the other hand, breadth first search will go straight down, which is $O(n)$.

b. Breadth-first search is a special case of uniform-cost search. This is true, as BFS is a special case of uniform-cost search when all operator costs are the same (or are unit cost).

c. Depth-first search is a special case of best-first tree search. This is true; best-first search run with the heuristic “negative depth of the node” will result in depth-first search.

d. Uniform-cost search is a special case of A* search. This is true, as A* search uses both cost-so-far and cost-to-go (heuristic function). If the cost-to-go produced by the heuristic function is the same for all nodes, then the only differing function is the cost-to-go, in which case it is uniform-cost search.

3.

a. Steps to convergence: the largest number of steps is done at start point 0 with step size .01 and is 196 steps. The other beginning positions and the number of steps can be seen in Appendix 1.
Final result (X*, Y*): The final (x, y) position is (1.74, .396016)

b. Steps to convergence:
Final result (X*, Y*): The final (x, y) position is (1.98, 0.358559)

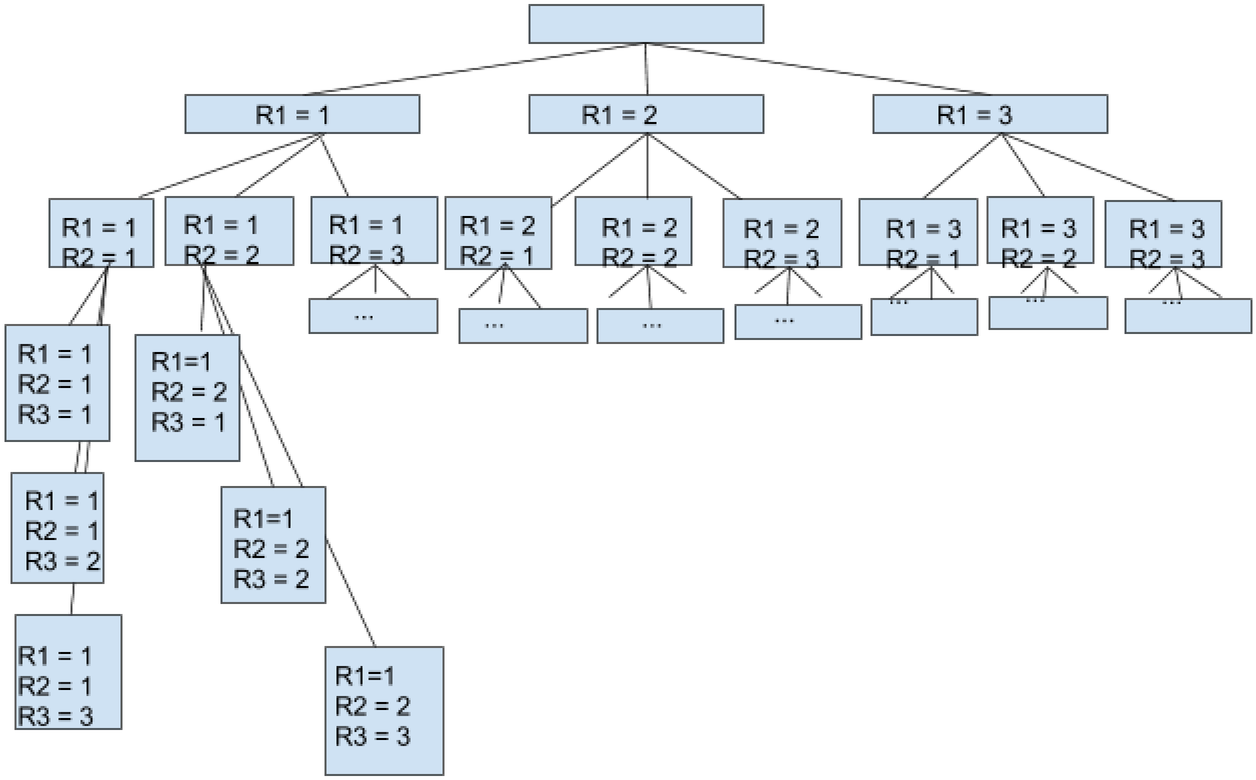
4.

a. If $k > n$, constraint satisfaction is not possible.
Put one rook per column in k leftmost columns. Let value indicate row of each rook

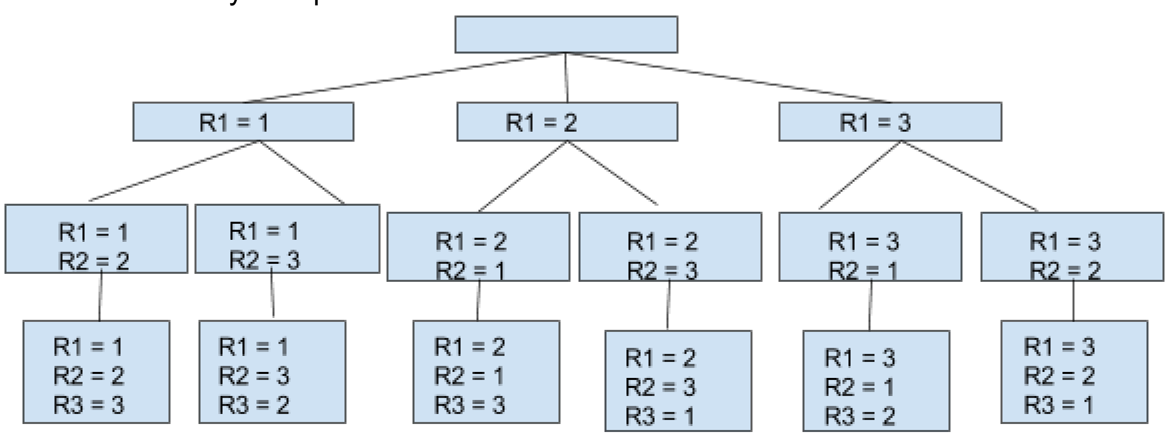
Variables: $\{R_{1,} R_2, ...R_k\}$
Domains: (same for all variables): $\{1,\ 2,\ ...,\ n\}$
Constraints:

$R_i \neq R_j$ (cannot be in same row)

b. Where the number after the R represents the column and the number after the equal represents the row. In this case, the domain is the entire board.



c. Where the number after the R represents the column and the number after the equal represents the row. In this case, the domain the board - the domains that are already occupied.



Appendix

1.

Hill climbing				

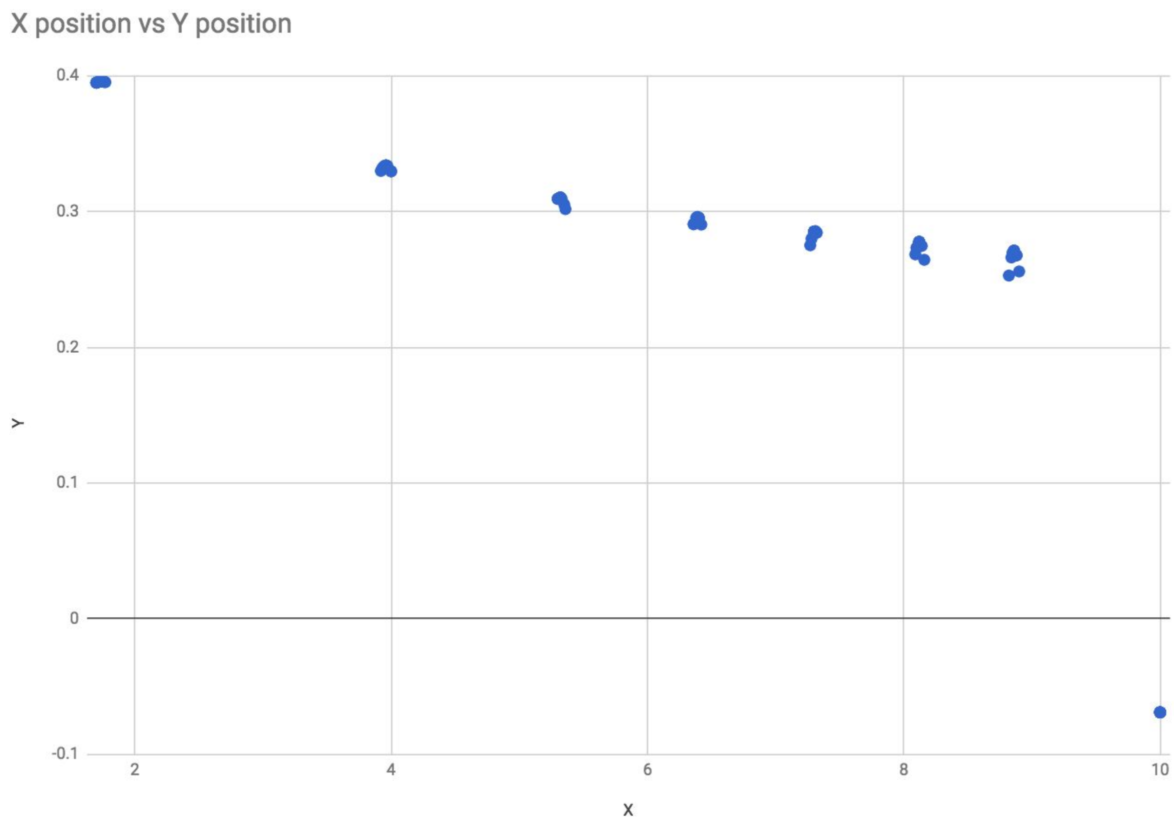
start point	step size	number of steps	current x	current y
0	0.01	175	1.74	0.396016
0	0.02	88	1.74	0.396016
0	0.03	59	1.74	0.396016
0	0.04	44	1.72	0.395788
0	0.05	36	1.75	0.395955
0	0.06	30	1.74	0.396016
0	0.07	26	1.75	0.395955
0	0.08	23	1.76	0.395776
0	0.09	20	1.71	0.395503
0	0.1	18	1.7	0.395107
1	0.01	75	1.74	0.396016
1	0.02	38	1.74	0.396016
1	0.03	26	1.75	0.395955
1	0.04	19	1.72	0.395788
1	0.05	16	1.75	0.395955
1	0.06	13	1.72	0.395788
1	0.07	12	1.77	0.395477
1	0.08	10	1.72	0.395788
1	0.09	9	1.72	0.395788
1	0.1	8	1.7	0.395107
2	0.01	27	1.74	0.396016
2	0.02	14	1.74	0.396016
2	0.03	10	1.73	0.395959
2	0.04	8	1.72	0.395788
2	0.05	6	1.75	0.395955
2	0.06	5	1.76	0.395776
2	0.07	5	1.72	0.395788
2	0.08	4	1.76	0.395776

2	0.09	4	1.73	0.395959
2	0.1	4	1.7	0.395107
3	0.01	127	1.74	0.396016
3	0.02	64	1.74	0.396016
3	0.03	43	1.74	0.396016
3	0.04	33	1.72	0.395788
3	0.05	26	1.75	0.395955
3	0.06	22	1.74	0.396016
3	0.07	19	1.74	0.396016
3	0.08	17	1.72	0.395788
3	0.09	15	1.74	0.396016
3	0.1	14	1.7	0.395107
4	0.01	5	3.96	0.33411
4	0.02	3	3.96	0.33411
4	0.03	2	3.97	0.33382
4	0.04	2	3.96	0.33411
4	0.05	2	3.95	0.333877
4	0.06	2	3.94	0.333124
4	0.07	2	3.93	0.331857
4	0.08	2	3.92	0.330079
4	0.09	1	4	0.329786
4	0.1	1	4	0.329786
5	0.01	33	5.32	0.310497
5	0.02	17	5.32	0.310497
5	0.03	12	5.33	0.309676
5	0.04	9	5.32	0.310497
5	0.05	7	5.3	0.309507
5	0.06	6	5.3	0.309507
5	0.07	6	5.35	0.305394

5	0.08	5	5.32	0.310497
5	0.09	5	5.36	0.301937
5	0.1	4	5.3	0.309507
6	0.01	40	6.39	0.296107
6	0.02	20	6.38	0.295544
6	0.03	14	6.39	0.296107
6	0.04	11	6.4	0.295462
6	0.05	9	6.4	0.295462
6	0.06	7	6.36	0.290826
6	0.07	7	6.42	0.290543
6	0.08	6	6.4	0.295462
6	0.09	5	6.36	0.290826
6	0.1	5	6.4	0.295462
7	0.01	32	7.31	0.285723
7	0.02	16	7.3	0.285368
7	0.03	11	7.3	0.285368
7	0.04	9	7.32	0.284552
7	0.05	7	7.3	0.285368
7	0.06	6	7.3	0.285368
7	0.07	5	7.28	0.280115
7	0.08	5	7.32	0.284552
7	0.09	4	7.27	0.275255
7	0.1	4	7.3	0.285368
8	0.01	13	8.12	0.277777
8	0.02	7	8.12	0.277777
8	0.03	5	8.12	0.277777
8	0.04	4	8.12	0.277777
8	0.05	3	8.1	0.273437
8	0.06	3	8.12	0.277777

8	0.07	3	8.14	0.27481
8	0.08	3	8.16	0.264568
8	0.09	2	8.09	0.268567
8	0.1	2	8.1	0.273437
9	0.01	15	8.86	0.271329
9	0.02	8	8.86	0.271329
9	0.03	6	8.85	0.269865
9	0.04	4	8.88	0.267871
9	0.05	4	8.85	0.269865
9	0.06	3	8.88	0.267871
9	0.07	3	8.86	0.271329
9	0.08	3	8.84	0.266291
9	0.09	3	8.82	0.252961
9	0.1	2	8.9	0.255978
10	0.01	1	10	-0.068913
10	0.02	1	10	-0.068913
10	0.03	1	10	-0.068913
10	0.04	1	10	-0.068913
10	0.05	1	10	-0.068913
10	0.06	1	10	-0.068913
10	0.07	1	10	-0.068913
10	0.08	1	10	-0.068913

2.



3.

Simmulated Annealing				
start point	step size	number steps	current x	current y
0	0.01	2	-0.01	2.50E-05
0	0.02	2	0.02	1.00E-04
0	0.03	2	-0.03	2.26E-04
0	0.04	2	-0.04	4.03E-04
0	0.05	2	-0.05	6.31E-04
0	0.06	2	-0.06	9.10E-04
0	0.07	2	-0.07	0.001241
0	0.08	2	-0.08	0.001624
0	0.09	2	-0.09	0.002059
0	0.1	2	0.1	0.002456

1	0.01	1	1	0.206477
1	0.02	2	1.02	0.21354
1	0.03	2	1.03	0.217082
1	0.04	1	1	0.206477
1	0.05	1	1	0.206477
1	0.06	1	1	0.206477
1	0.07	2	1.07	0.231296
1	0.08	2	1.08	0.234856
1	0.09	2	1.09	0.238416
1	0.1	2	1.1	0.241975
2	0.01	1	2	0.351764
2	0.02	2	1.98	0.358559
2	0.03	1	2	0.351764
2	0.04	1	2	0.351764
2	0.05	1	2	0.351764
2	0.06	1	2	0.351764
2	0.07	1	2	0.351764
2	0.08	1	2	0.351764
2	0.09	1	2	0.351764
2	0.1	1	2	0.351764
3	0.01	1	3	-0.348203
3	0.02	2	2.98	-0.343599
3	0.03	2	2.97	-0.340845
3	0.04	2	2.96	-0.337798
3	0.05	2	2.95	-0.334462
3	0.06	2	2.94	-0.330843
3	0.07	1	3	-0.348203
3	0.08	2	2.92	-0.322778
3	0.09	1	3	-0.348203

3	0.1	2	2.9	-0.31365
4	0.01	2	3.99	0.33166
4	0.02	2	3.98	0.333004
4	0.03	2	3.97	0.33382
4	0.04	2	3.96	0.33411
4	0.05	2	3.95	0.333877
4	0.06	2	3.94	0.333124
4	0.07	2	3.93	0.331857
4	0.08	1	4	0.329786
4	0.09	1	4	0.329786
4	0.1	1	4	0.329786
5	0.01	1	5	-0.020922
5	0.02	2	5.02	0.010659
5	0.03	1	5	-0.020922
5	0.04	1	5	-0.020922
5	0.05	1	5	-0.020922
5	0.06	2	5.06	0.073364
5	0.07	1	5	-0.020922
5	0.08	1	5	-0.020922
5	0.09	1	5	-0.020922
5	0.1	1	5	-0.020922
6	0.01	2	6.01	-0.21364
6	0.02	2	6.02	-0.200429
6	0.03	1	6	-0.22607
6	0.04	2	6.04	-0.171845
6	0.05	2	6.05	-0.15657
6	0.06	1	6	-0.22607
6	0.07	1	6	-0.22607
6	0.08	2	6.08	-0.107462

6	0.09	2	6.09	-0.090192
6	0.1	2	6.1	-0.072573
7	0.01	1	7	-0.170941
7	0.02	2	7.02	-0.136586
7	0.03	2	7.03	-0.118339
7	0.04	2	7.04	-0.099496
7	0.05	1	7	-0.170941
7	0.06	2	7.06	-0.060388
7	0.07	1	7	-0.170941
7	0.08	2	7.08	-0.020025
7	0.09	1	7	-0.170941
7	0.1	1	7	-0.170941
8	0.01	2	8.01	0.171874
8	0.02	1	8	0.153817
8	0.03	1	8	0.153817
8	0.04	1	8	0.153817
8	0.05	1	8	0.153817
8	0.06	1	8	0.153817
8	0.07	2	8.07	0.253618
8	0.08	2	8.08	0.261945
8	0.09	1	8	0.153817
8	0.1	1	8	0.153817
9	0.01	2	8.99	0.112849
9	0.02	2	8.98	0.134475
9	0.03	1	9	0.0903
9	0.04	2	8.96	0.174282
9	0.05	2	8.95	0.192149
9	0.06	1	9	0.0903
9	0.07	2	8.93	0.223118

9	0.08	1	9	0.0903
9	0.09	2	8.91	0.246962
9	0.1	2	8.9	0.255978
10	0.01	1	10	-0.068913
10	0.02	2	10.02	-0.017125
10	0.03	1	10	-0.068913
10	0.04	2	10.04	0.035394
10	0.05	2	10.05	0.061269
10	0.06	2	10.06	0.086538
10	0.07	1	10	-0.068913
10	0.08	1	10	-0.068913
10	0.09	2	10.09	0.156172
10	0.1	2	10.1	0.176532

4.