

Artificial Intelligence: Local Search

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Contents

Introduction to the Graphical User Interface(GUI)	2
Basic Puzzle Evaluation	3
User Generated Puzzle Evaluation	5
Basic Hill Climbing	5
Hill Climbing with Random Restarts	7
Hill Climbing with Random Walk	8
Simulated Annealing	9
Population Based Approach	10
Puzzle Evaluation	11
Example Puzzle for $n = 5$	11
Example Puzzle for $n = 7$	14
Example Puzzle for $n = 9$	17
Example Puzzle for $n = 11$	20

Basic Hill Climbing Approach	23
Example Puzzle for $n = 5$	24
Example Puzzle for $n = 7$	26
Example Puzzle for $n = 9$	28
Example Puzzle for $n = 11$	30
Hill Climbing with Random Restarts	32
Example Puzzle for $n = 5$	32
Example Puzzle for $n = 7$	35
Example Puzzle for $n = 9$	37
Example Puzzle for $n = 11$	37
Hill Climbing with Random Walks	38
Example Puzzle for $n = 5$	38
Example Puzzle for $n = 7$	38
Example Puzzle for $n = 9$	38
Example Puzzle for $n = 11$	38
Simulated Annealing	39
Proposal and Implementation of a population based approach	40

Introduction to the Graphical User Interface(GUI)

When the Graphical User Interface starts up the user is able to select the type of puzzle evaluation through a drop down menu. The given options include: Basic Puzzle Evaluation, User Generated Puzzle Evaluation, Basic Hill Climbing, Hill Climbing with Random Restarts, Hill Climbing with Random Walk, Simulated Annealing, and Population Based Approach.

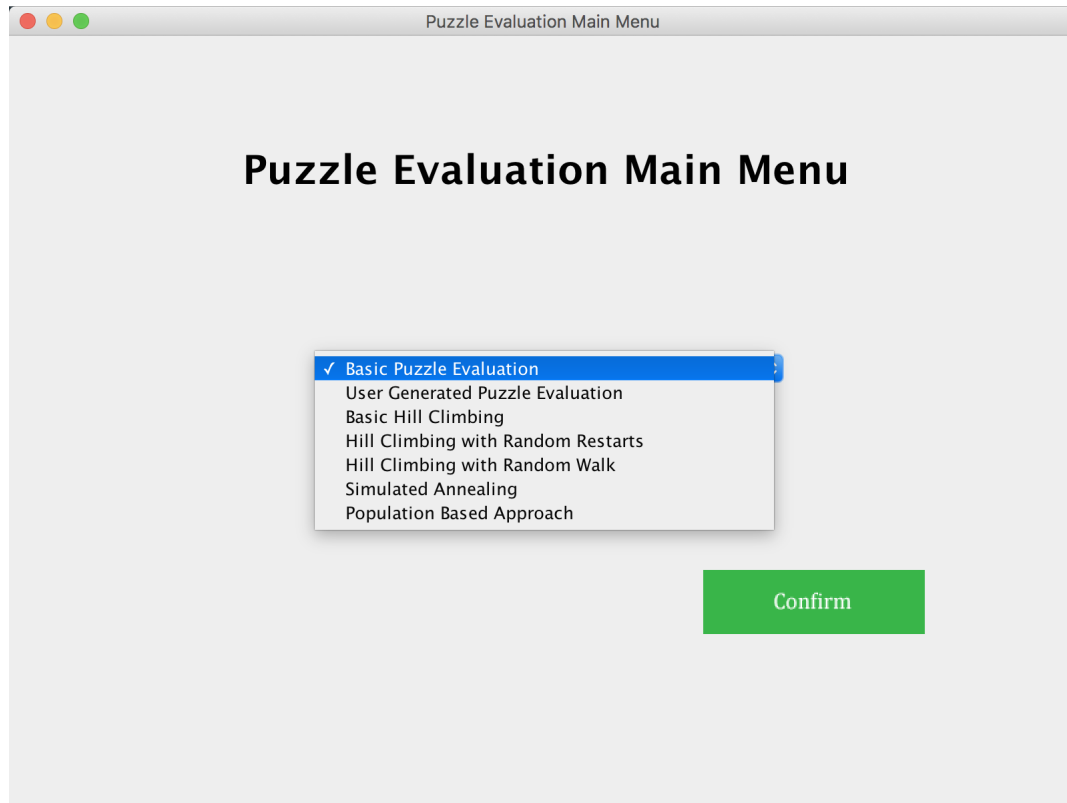


Figure 1: Main Menu of GUI

Each of the options then have their own corresponding window which is comprised of four main tabs: Puzzle Initialization, Puzzle, Puzzle Moves, and Data. The Puzzle Initialization tab is slightly different for each option in regards to the type of input received. The tabs Puzzle and Puzzle moves provide the user with a graphical representation of the generated puzzle as well as a graphical representation of the number of moves that it takes to get to each cell respectively.

Basic Puzzle Evaluation

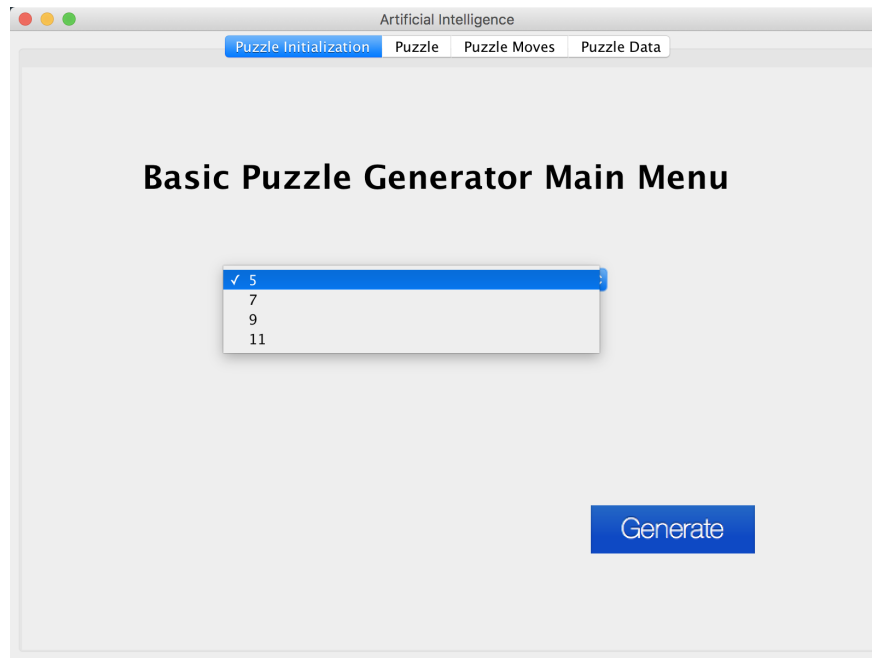


Figure 2: Puzzle Initialization of Basic Evaluation

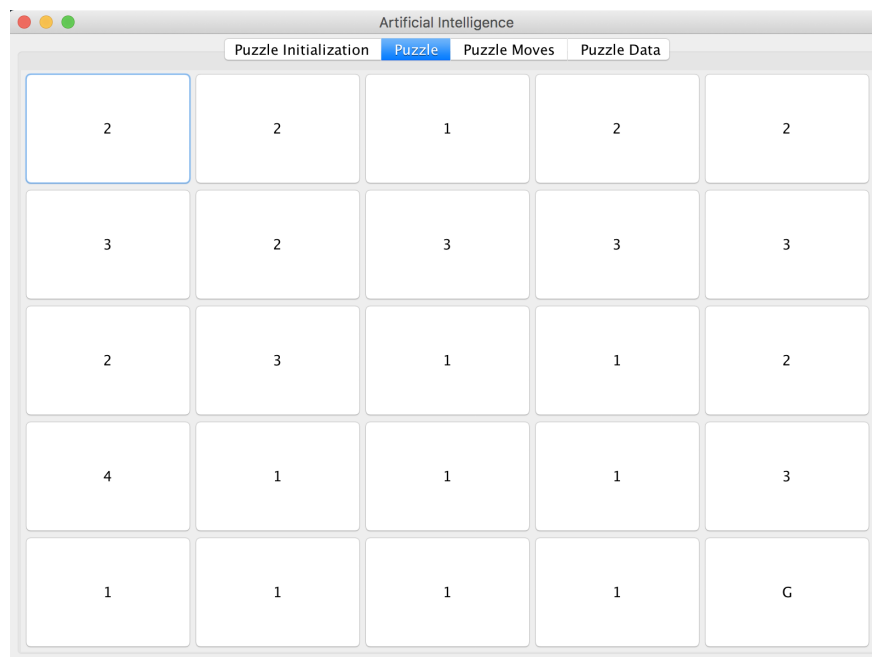


Figure 3: Puzzle Tab of Basic Evaluation

Artificial Intelligence				
Puzzle Initialization	Puzzle	Puzzle Moves	Puzzle Data	
0	2	1	2	5
5	X	2	4	X
1	3	2	3	4
3	4	3	4	4
2	3	3	4	5

Figure 4: Puzzle Moves Tab of Basic Evaluation

Artificial Intelligence				
Puzzle Initialization	Puzzle	Puzzle Moves	Puzzle Data	
<p>Evaluation function output: 5</p>				

Figure 5: Puzzle Data Tab of Basic Evaluation

User Generated Puzzle Evaluation

The User Generated Puzzle Menu starts up with the default file of `./userPuzzles/assignment.txt`, the user is able to change the file name to any location that they wish. The tabs Puzzle, Puzzle Moves, and Puzzle Evaluation are the same as the above examples for the Basic Puzzle Menu.

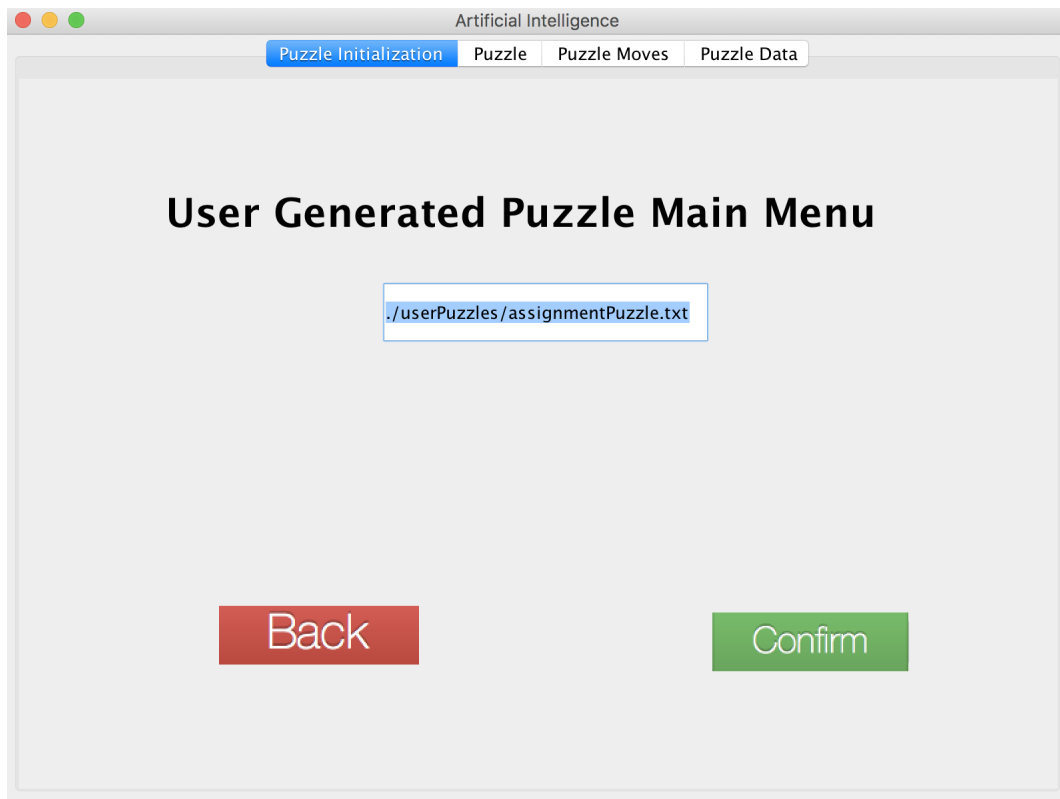


Figure 6: Puzzle Initialization Menu for User Generated Puzzle

Basic Hill Climbing

The Basic Hill Climbing Menu allows input for the size of the puzzle as well as a number of total iterations to perform the hill climbing algorithm. The data menu differs from the first two options in that it now shows a total evaluation time in addition to the evaluation function output.

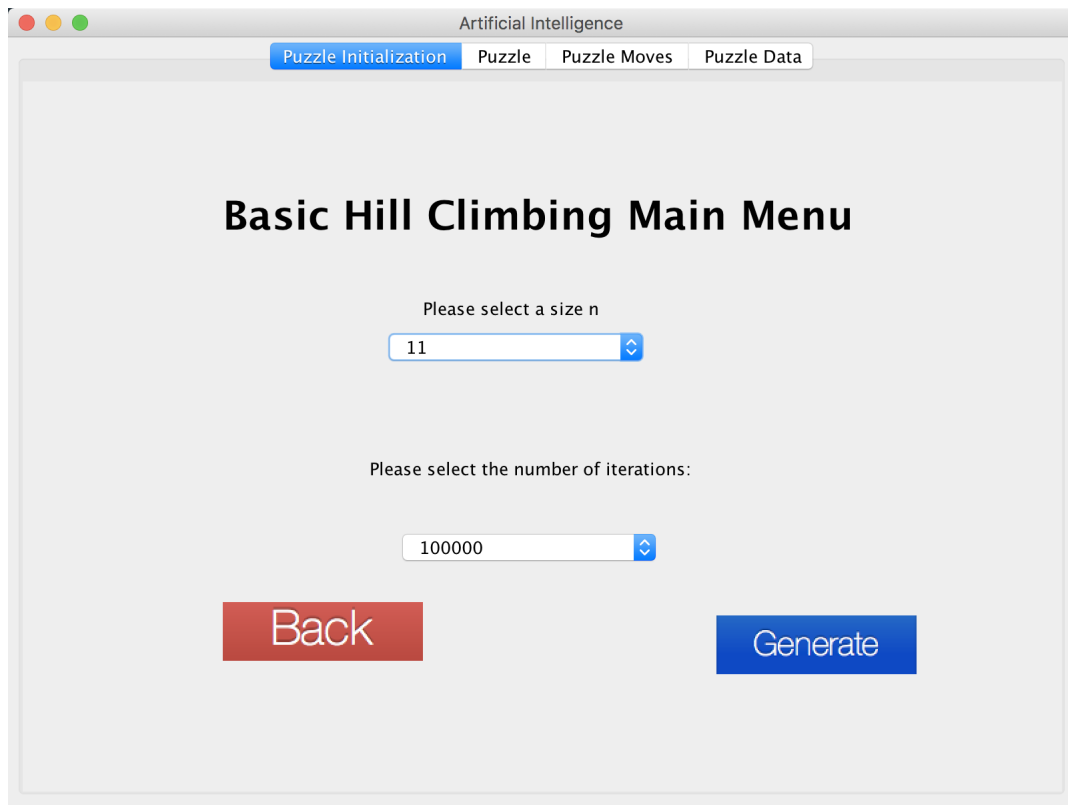


Figure 7: Puzzle Initialization Menu for Basic Hill Climbing

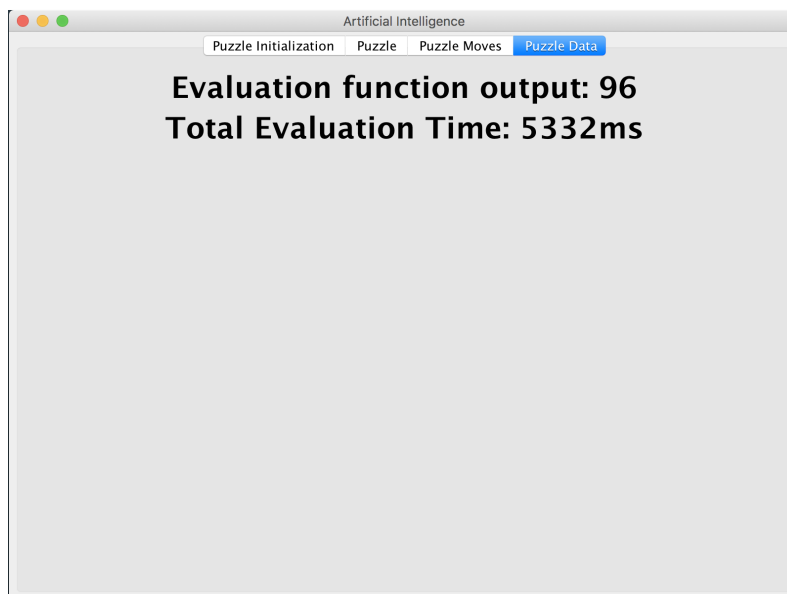
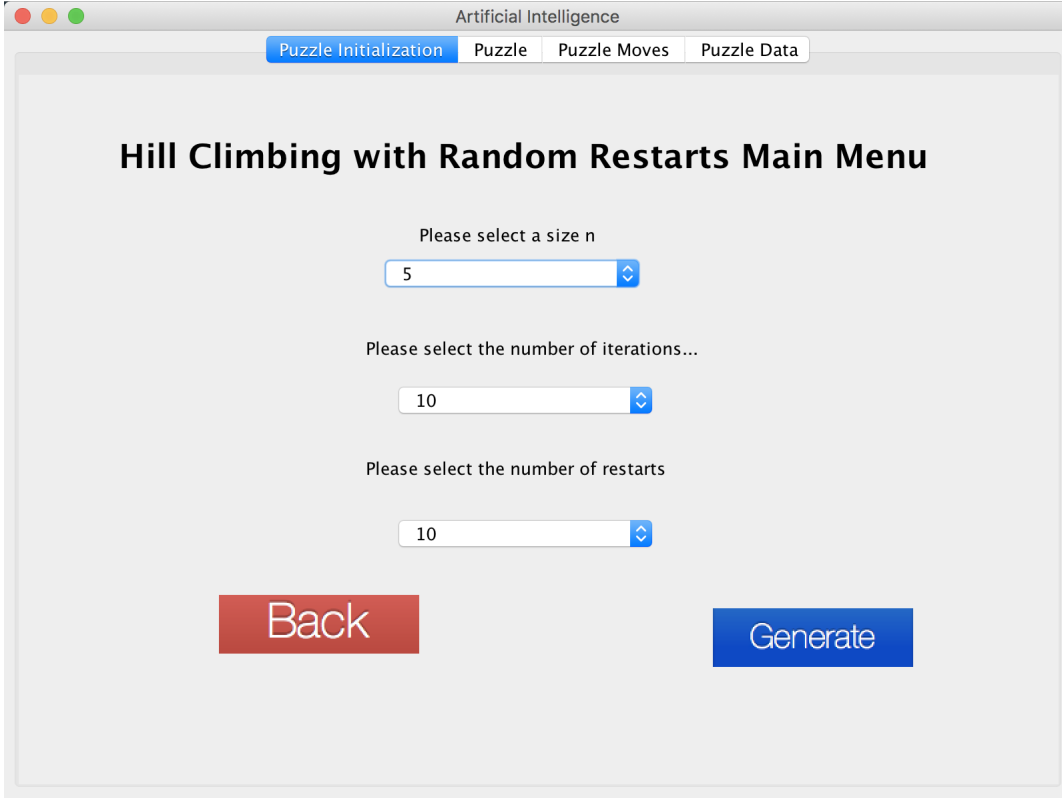


Figure 8: Puzzle Evaluation Tab for Basic Hill Climbing

Hill Climbing with Random Restarts

The Hill Climbing with Random Restarts Menu is similar to the Basic Hill Climbing menu, with the addition of an input option for the number of random restarts that should be performed. The Puzzle, Puzzle Moves, and Evaluation tabs remain unchanged from the previous example.



The screenshot shows a web application window titled "Artificial Intelligence". It has four tabs: "Puzzle Initialization" (active), "Puzzle", "Puzzle Moves", and "Puzzle Data". The main content area is titled "Hill Climbing with Random Restarts Main Menu". It contains three input fields, each with a label and a dropdown menu:

- Label: "Please select a size n", Value: "5"
- Label: "Please select the number of iterations...", Value: "10"
- Label: "Please select the number of restarts", Value: "10"

At the bottom, there are two buttons: a red "Back" button on the left and a blue "Generate" button on the right.

Figure 9: Puzzle Initialization Menu for Hill Climbing with Random Restarts

Hill Climbing with Random Walk

Hill Climbing with Random Walks Menu is the same as Hill Climbing with Random Restarts, but replaces the bottom input option of number of restarts, with the probability of down hill acceptance.

Artificial Intelligence

Puzzle Initialization Puzzle Puzzle Moves Puzzle Data

Hill Climbing with Random Walk Main Menu

Please select a size n

5

Please select the number of iterations...

1000

Please select the probability of restart

0
✓ 0
1
2
3
4
5
6
7

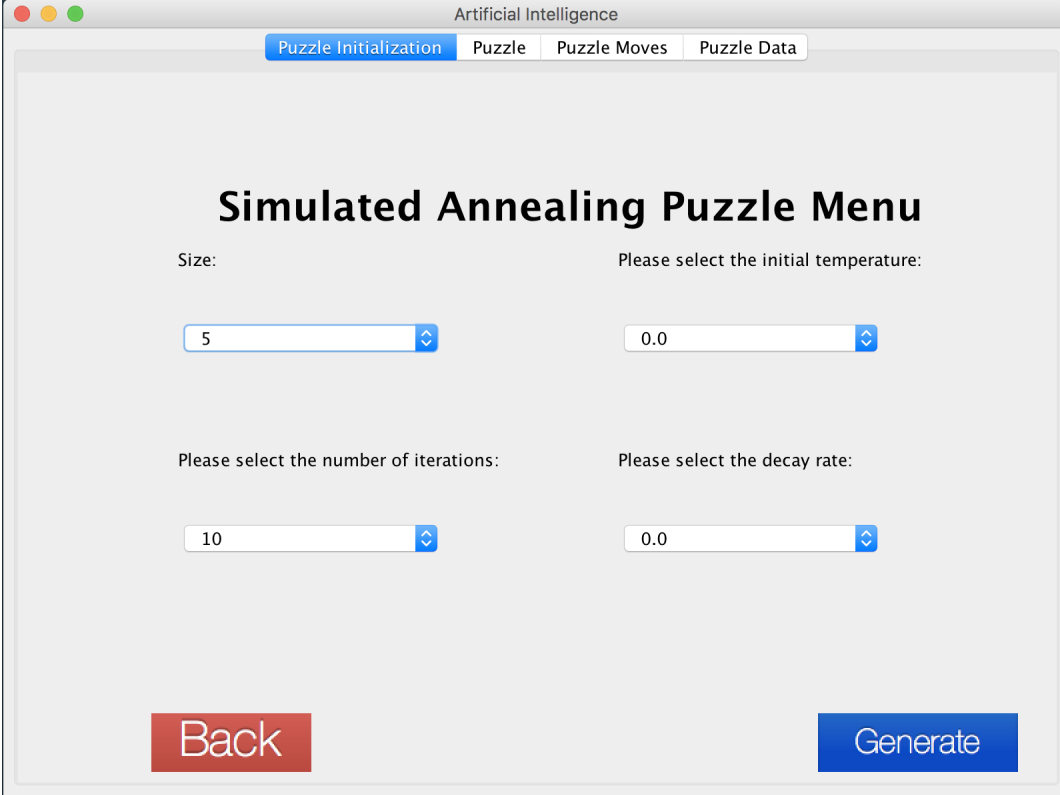
Back

Generate

Figure 10: Puzzle Initialization Menu for Hill Climbing with Random Walk

Simulated Annealing

The initialization menu for Simulated annealing includes 4 input options: the size n of the puzzle of the puzzle, the initial temperature T , the total number of iterations, and the decay rate.



The image shows a software window titled "Artificial Intelligence" with four tabs: "Puzzle Initialization" (selected), "Puzzle", "Puzzle Moves", and "Puzzle Data". The main content area is titled "Simulated Annealing Puzzle Menu". It contains four input fields arranged in a 2x2 grid. The top-left field is labeled "Size:" and contains the value "5". The top-right field is labeled "Please select the initial temperature:" and contains the value "0.0". The bottom-left field is labeled "Please select the number of iterations:" and contains the value "10". The bottom-right field is labeled "Please select the decay rate:" and contains the value "0.0". At the bottom left is a red "Back" button, and at the bottom right is a blue "Generate" button.

Parameter	Value
Size	5
Initial Temperature	0.0
Number of Iterations	10
Decay Rate	0.0

Figure 11: Puzzle Initialization Menu for Basic Hill Climbing

Population Based Approach

Puzzle Evaluation

In your report please include an example of 2 example puzzles for each size of n , where one of the puzzles is solvable and the other is not solvable.

You will be asked during the demo to execute the evaluation puzzle on example puzzles and present the corresponding visualization. INCLUDE OPTION FOR FILE SELECTION?

Example Puzzle for $n = 5$

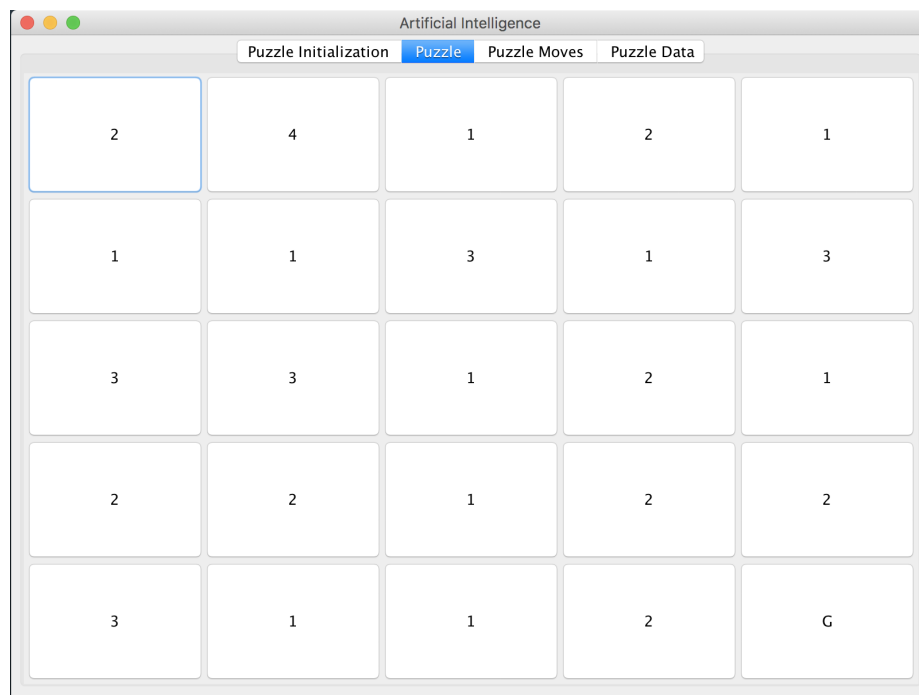


Figure 12: Reachable Goal Puzzle size $n = 5$

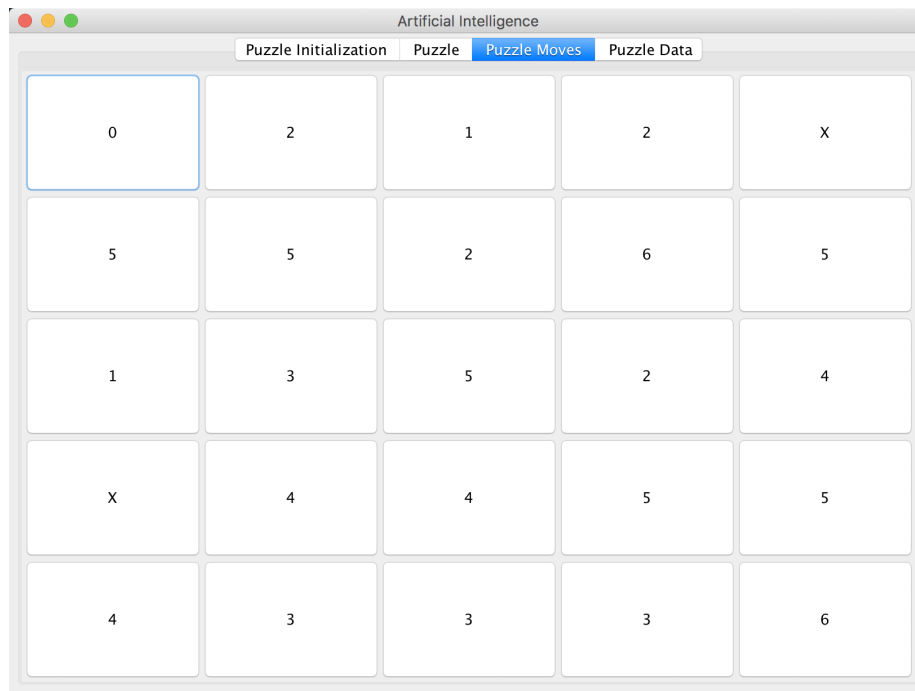


Figure 13: Reachable Goal Puzzle Moves size $n = 5$

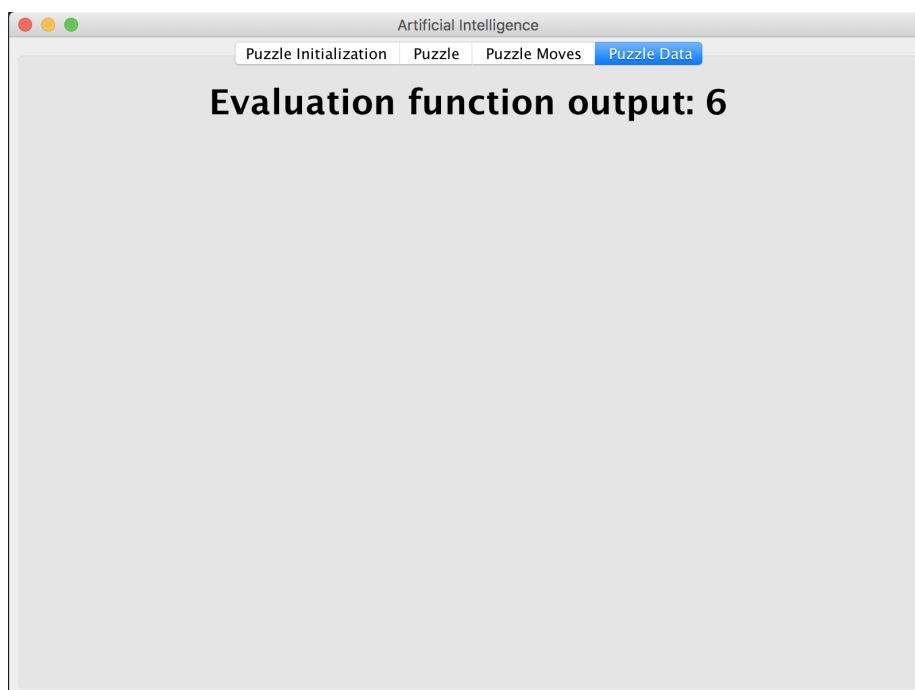


Figure 14: Reachable Goal Puzzle Evaluation size $n = 5$

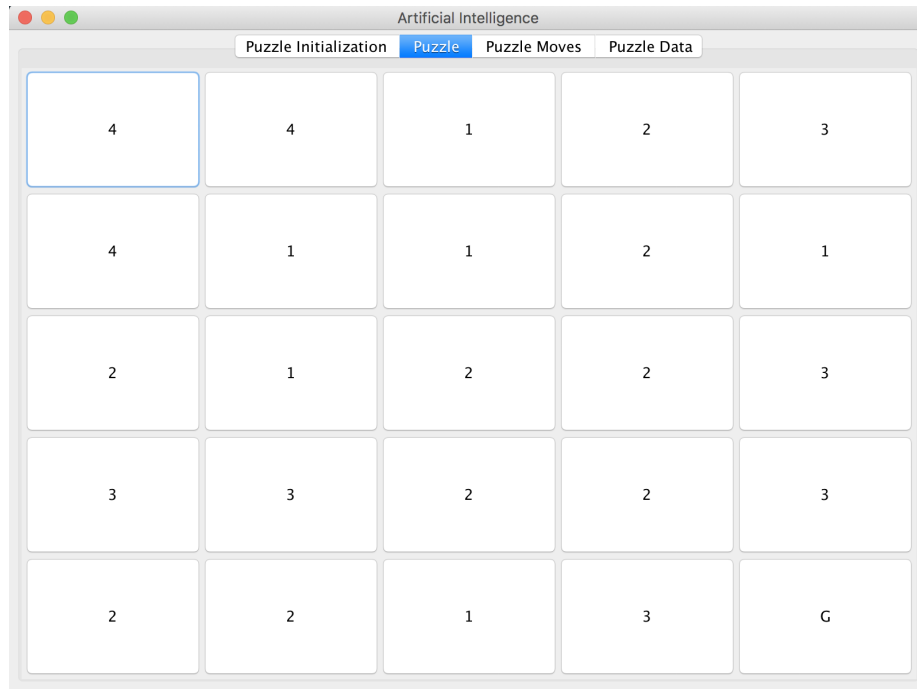


Figure 15: Unreachable Goal Puzzle size $n = 5$

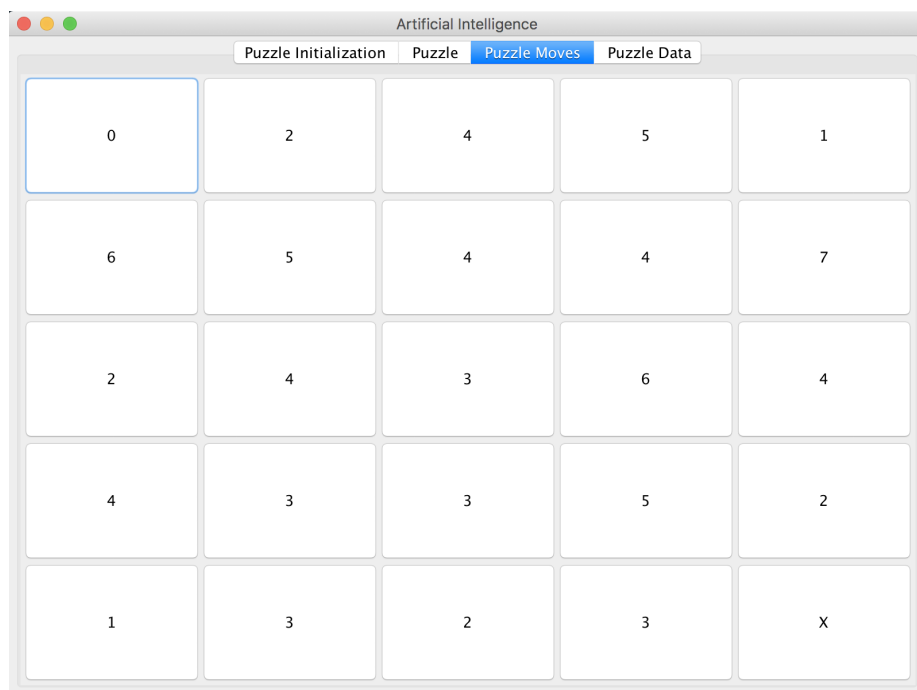


Figure 16: Unreachable Goal Puzzle Moves size $n = 5$

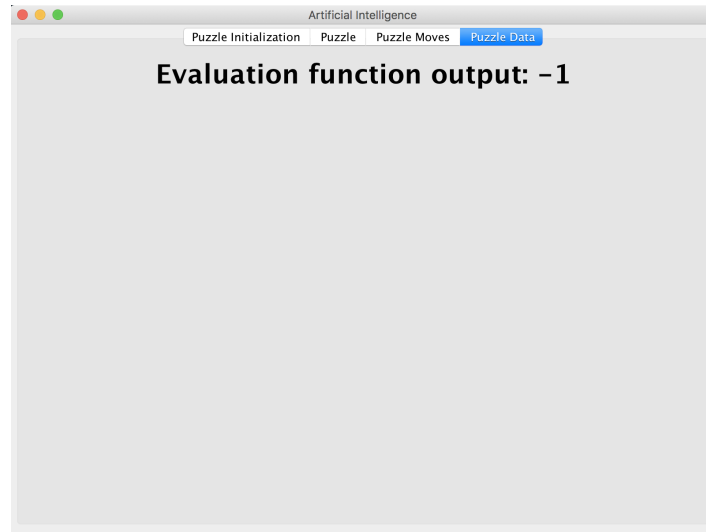


Figure 17: Unreachable Goal Puzzle Evaluation size $n = 5$

Example Puzzle for $n = 7$

The screenshot shows a window titled 'Artificial Intelligence' with four tabs: 'Puzzle Initialization', 'Puzzle', 'Puzzle Moves', and 'Puzzle Data'. The 'Puzzle' tab is selected. The main content area displays a 7x7 grid of numbers. The first cell (top-left) is highlighted with a blue border. The bottom-right cell contains the letter 'G'.

1	6	2	6	3	5	1
5	3	2	1	3	5	2
5	3	3	1	2	4	1
1	5	2	2	1	1	4
4	4	2	1	3	2	5
2	3	3	2	3	2	5
6	5	2	5	2	1	G

Figure 18: Reachable Goal Puzzle size $n = 7$

Artificial Intelligence						
Puzzle Initialization		Puzzle	Puzzle Moves	Puzzle Data		
0	1	X	8	8	X	X
1	3	8	7	4	2	9
9	7	7	8	7	6	8
8	7	7	6	6	5	6
7	4	6	6	5	5	X
X	6	8	5	7	4	X
2	2	5	9	4	3	3

Figure 19: Reachable Goal Puzzle Moves size $n = 7$

Evaluation function output: 3

Figure 20: Reachable Goal Puzzle Evaluation size $n = 7$

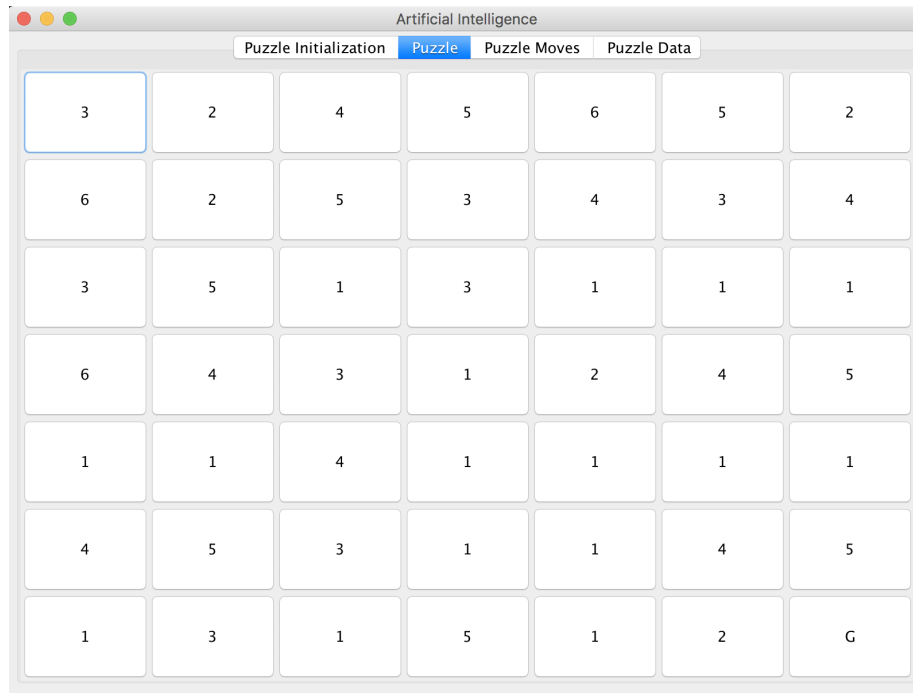


Figure 21: Unreachable Goal Puzzle size $n = 7$

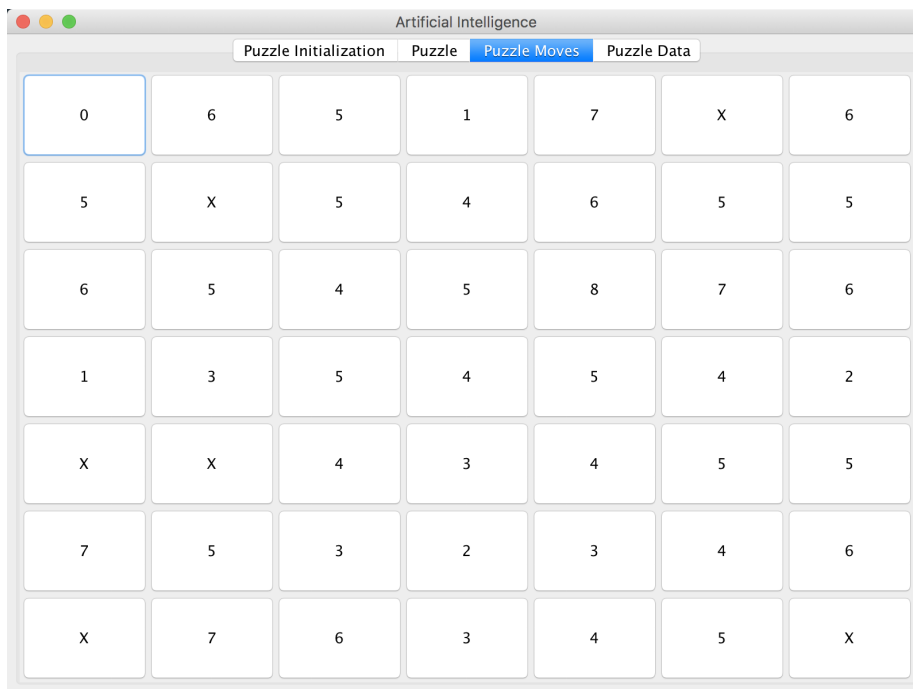


Figure 22: Unreachable Goal Puzzle Moves size $n = 7$

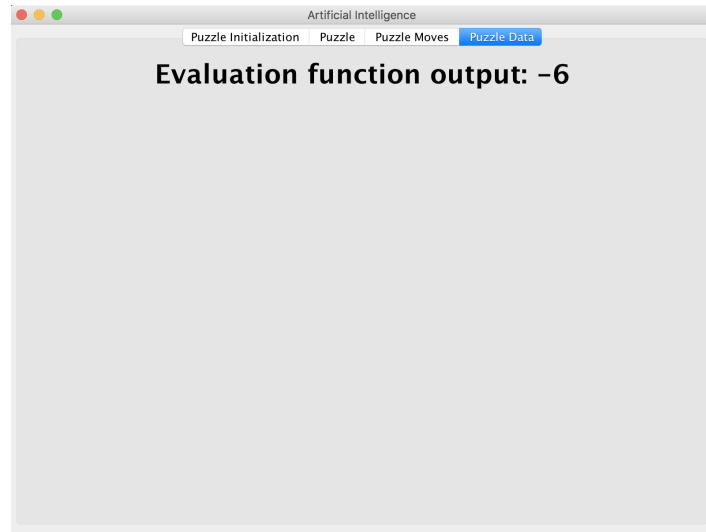


Figure 23: Unreachable Goal Puzzle Evaluation size $n = 7$

Example Puzzle for $n = 9$

The screenshot shows a window titled 'Artificial Intelligence' with four tabs: 'Puzzle Initialization', 'Puzzle', 'Puzzle Moves', and 'Puzzle Data'. The 'Puzzle' tab is selected. The main content area displays a 9x9 grid of numbers. The first cell (top-left) is highlighted with a blue border. The bottom-right cell contains the letter 'G'.

5	7	6	7	7	6	3	2	7
5	4	2	6	7	5	7	3	6
4	5	1	3	3	6	6	5	6
2	7	6	5	2	3	1	4	3
2	4	3	4	1	1	4	6	3
4	6	5	2	3	3	3	6	2
4	4	3	4	2	3	1	4	1
2	7	5	1	6	3	1	1	7
7	3	7	7	6	3	5	2	G

Figure 24: Reachable Goal Puzzle size $n = 9$

Artificial Intelligence								
Puzzle Initialization			Puzzle	Puzzle Moves		Puzzle Data		
0	6	9	7	X	1	8	X	5
2	X	6	8	7	3	X	X	X
4	4	5	6	3	8	5	4	X
X	X	4	7	6	3	7	8	4
X	8	8	6	5	6	7	7	X
1	3	8	6	2	7	5	3	4
3	X	3	5	4	2	5	4	3
X	5	8	7	8	7	6	5	4
X	7	8	7	3	7	6	6	8

Figure 25: Reachable Goal Puzzle Moves size $n = 9$

Evaluation function output: 8

Figure 26: Reachable Goal Puzzle Evaluation size $n = 9$

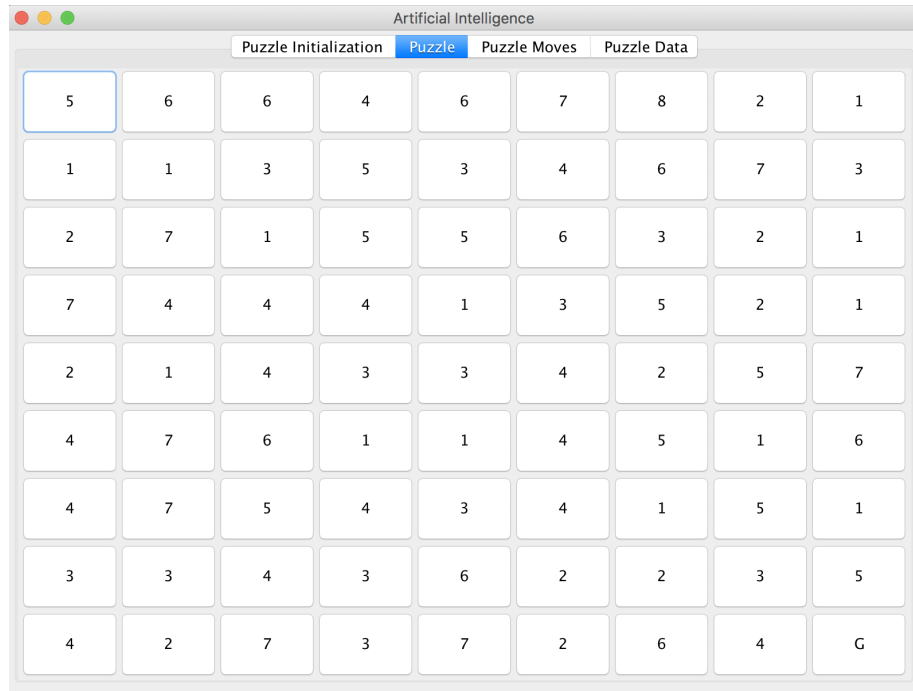


Figure 27: Unreachable Goal Puzzle size $n = 9$



Figure 28: Unreachable Goal Puzzle Moves size $n = 9$

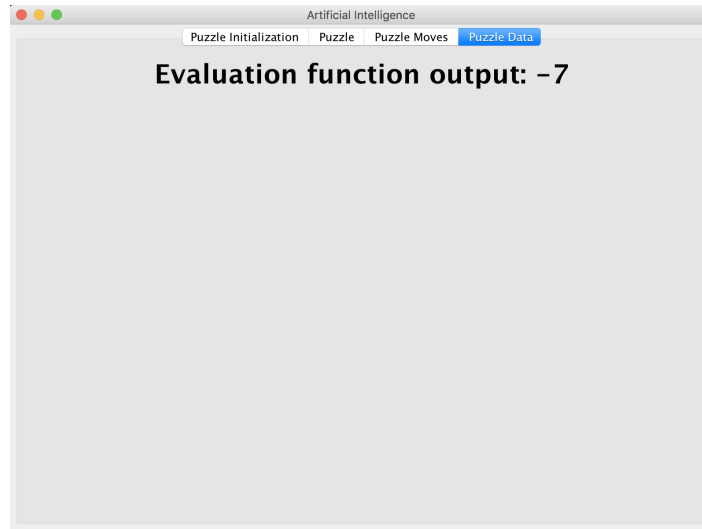


Figure 29: Unreachable Goal Puzzle Evaluation size $n = 9$

Example Puzzle for $n = 11$

The screenshot shows a window titled 'Artificial Intelligence' with four tabs: 'Puzzle Initialization', 'Puzzle', 'Puzzle Moves', and 'Puzzle Data'. The 'Puzzle' tab is selected, and an 11x11 grid of numbers is displayed. The first cell (row 1, column 1) is highlighted with a blue border.

1	6	3	8	9	1	1	4	8	1	5
7	5	4	9	8	6	6	3	8	9	8
1	3	1	3	6	6	8	8	6	1	3
3	8	8	2	4	4	5	7	6	8	3
7	6	5	2	5	3	3	5	7	6	9
9	8	6	4	4	1	1	6	2	3	4
4	3	5	3	1	5	2	3	2	7	5
9	5	2	4	2	6	4	5	7	4	6
8	8	3	2	1	2	3	2	3	1	8
1	6	7	1	2	2	3	1	6	3	2
4	2	7	7	8	9	2	4	8	3	G

Figure 30: Reachable Goal Puzzle size $n = 11$

Artificial Intelligence										
Puzzle Initialization			Puzzle		Puzzle Moves			Puzzle Data		
0	1	X	3	10	9	10	2	6	X	8
1	X	4	6	3	5	5	2	X	8	3
6	7	6	7	8	X	8	9	8	7	8
7	3	6	5	X	6	6	7	5	4	7
X	8	4	7	X	7	6	3	7	7	X
5	7	5	6	4	6	5	6	4	6	5
5	2	8	4	3	4	5	6	6	7	5
6	6	5	X	4	6	5	X	5	7	5
2	5	8	4	9	4	6	5	3	6	7
X	3	5	5	4	X	5	4	5	6	4
6	9	X	5	7	5	9	5	10	8	6

Figure 31: Reachable Goal Puzzle Moves size $n = 11$

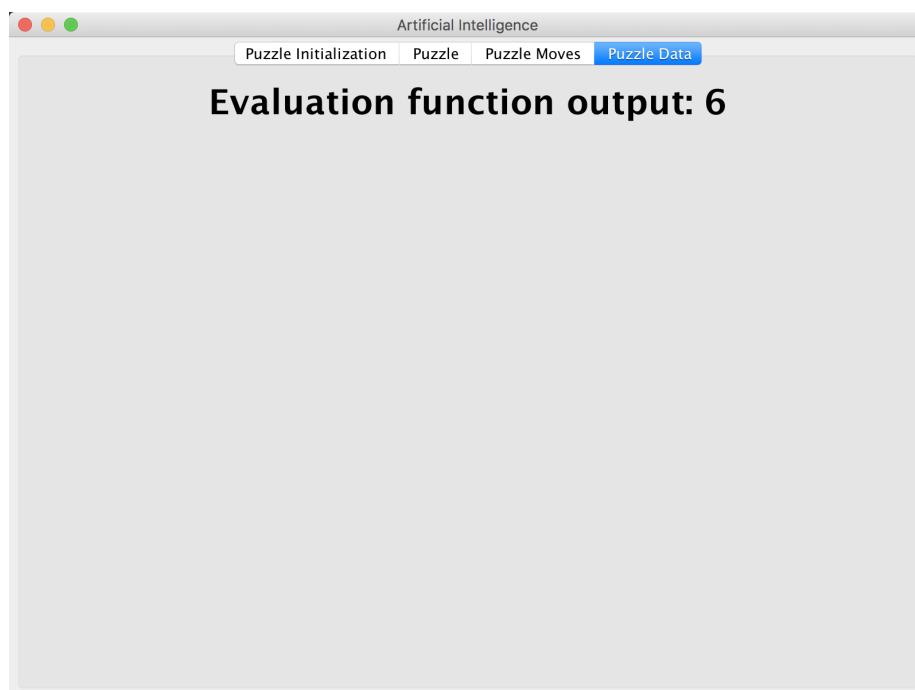


Figure 32: Reachable Goal Puzzle Evaluation size $n = 11$

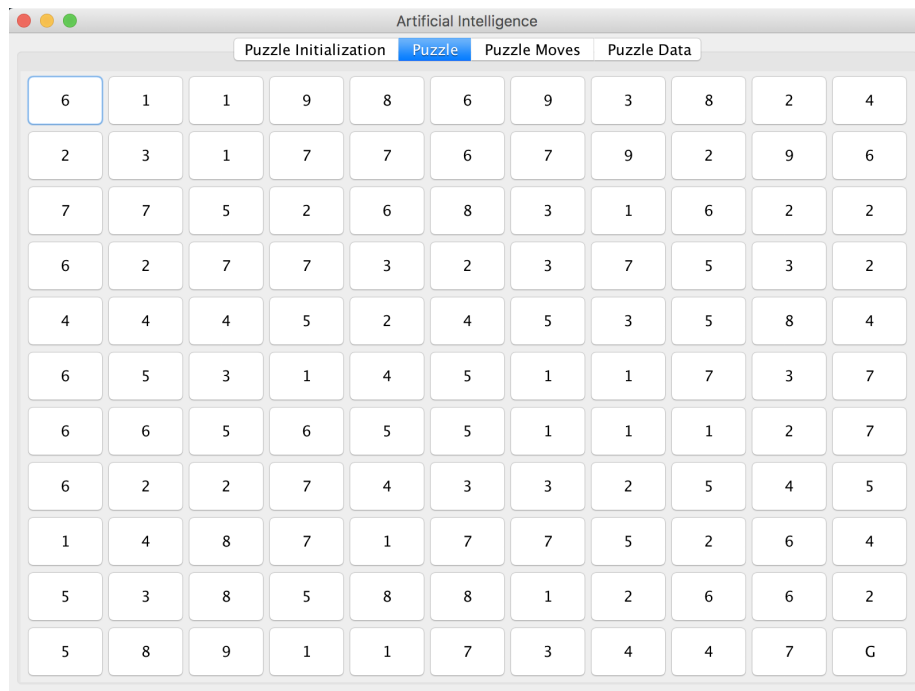


Figure 33: Unreachable Goal Puzzle size $n = 11$

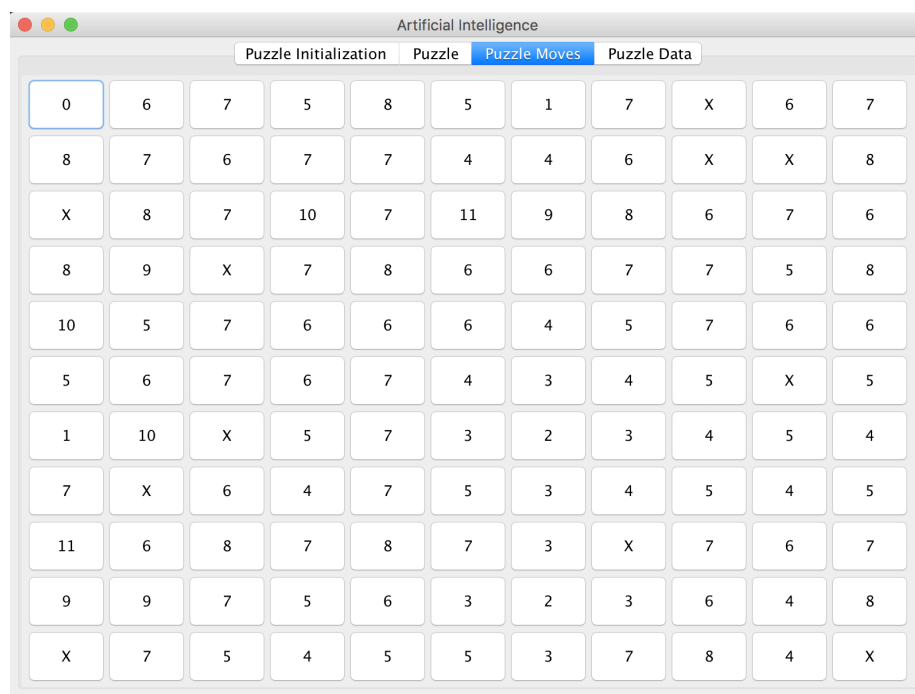


Figure 34: Unreachable Goal Puzzle Moves size $n = 11$

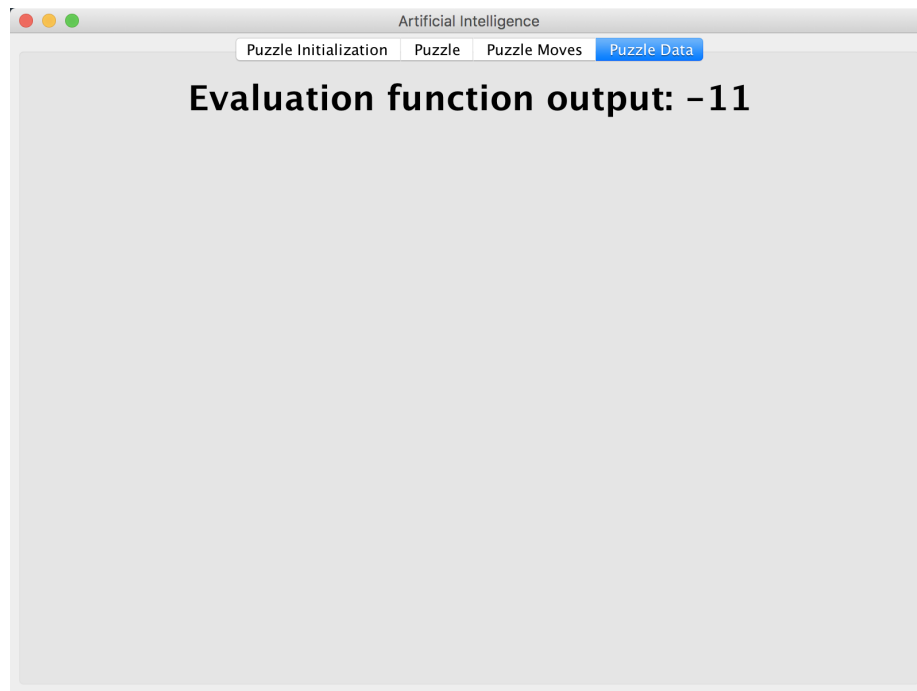


Figure 35: Unreachable Goal Puzzle Evaluation size $n = 11$

Basic Hill Climbing Approach

Your software should receive the number of iterations for the hill climbing approach as input and visualize the final optimized puzzle configuration, its value and the time it took to compute it.

Example Puzzle for $n = 5$

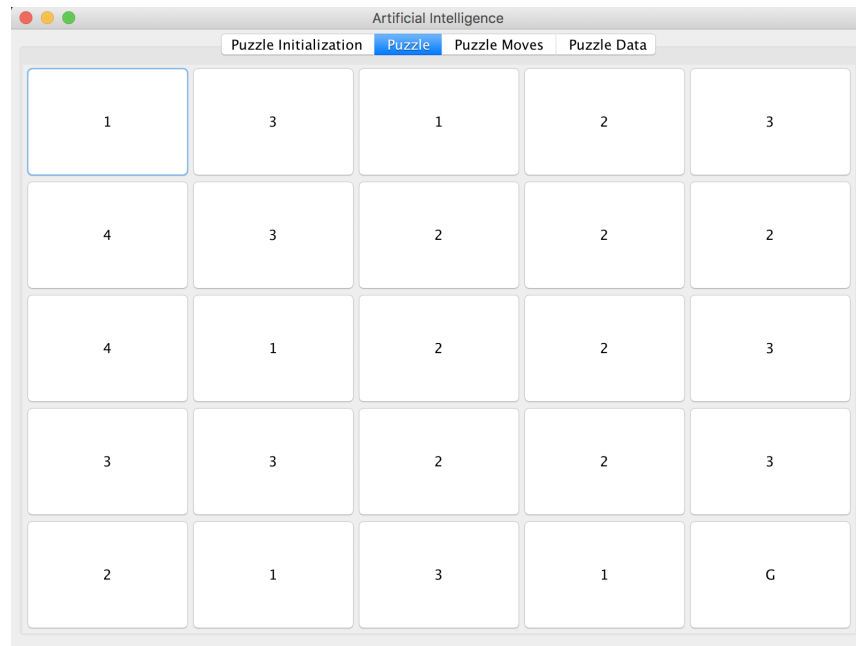


Figure 36: Basic Hill Climbing Best Puzzle after 100,000 iterations for $n = 5$

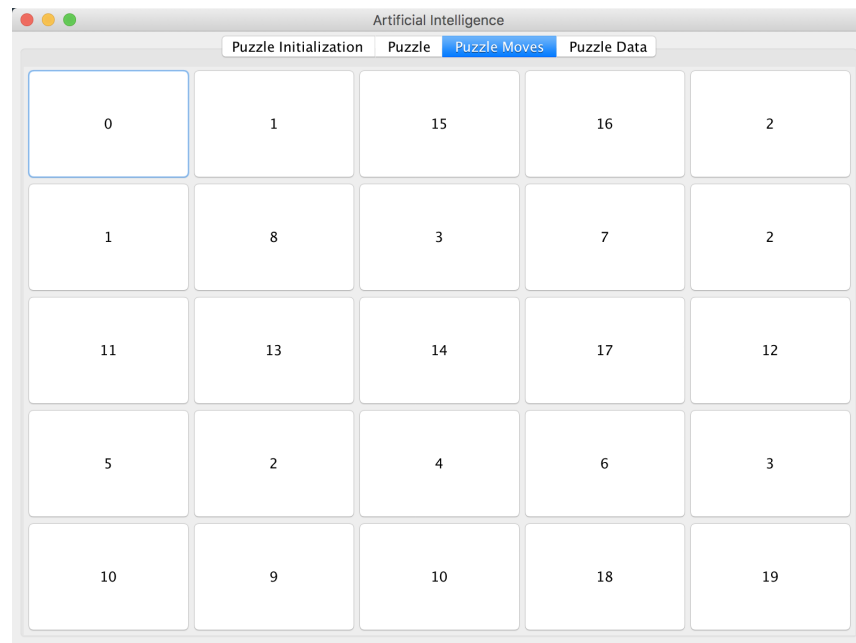


Figure 37: Basic Hill Climbing Puzzle Moves after 100,000 iterations for $n = 5$

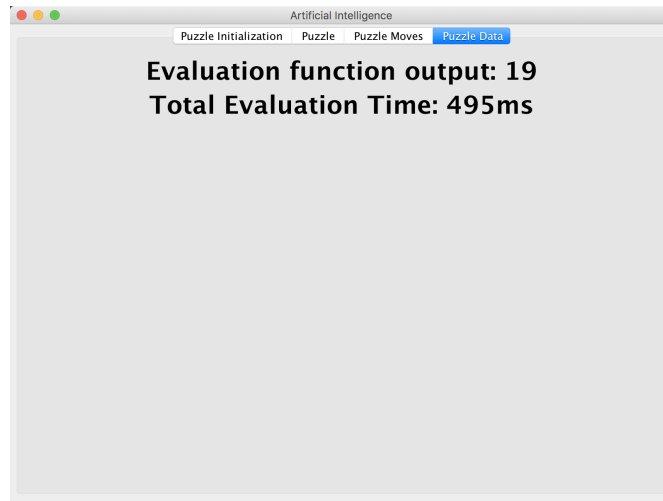


Figure 38: Basic Hill Climbing Puzzle Evaluation after 100,000 iterations for $n = 5$

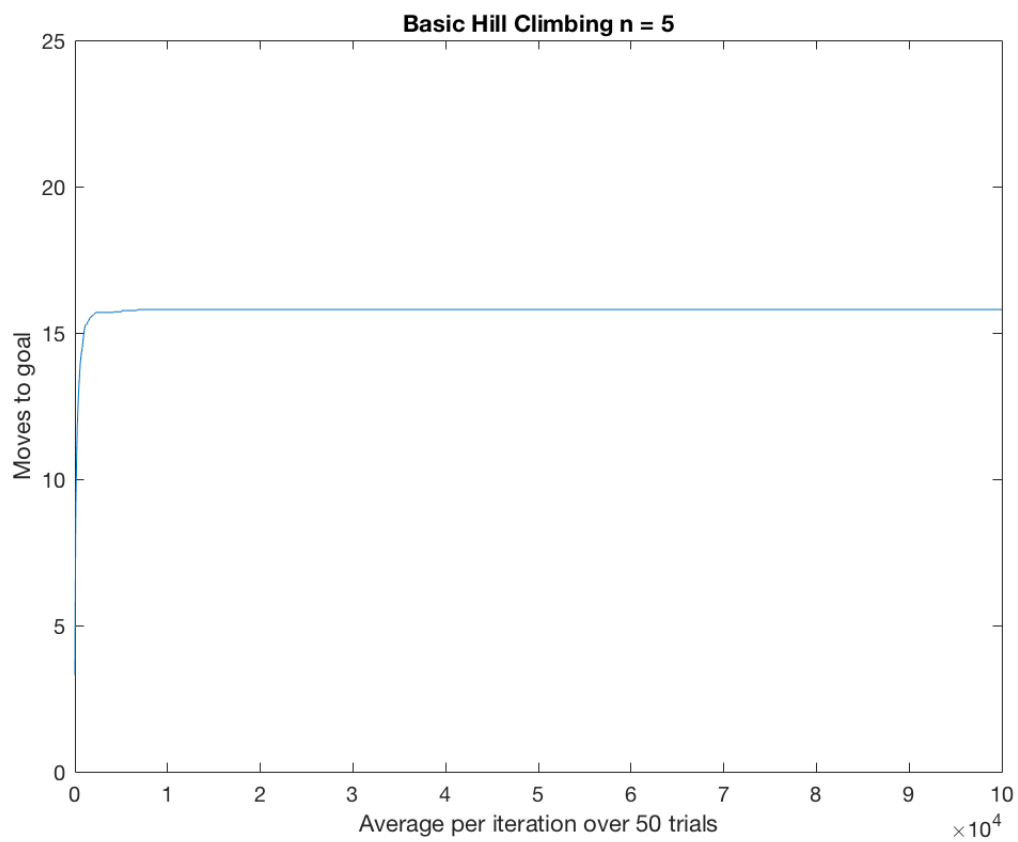
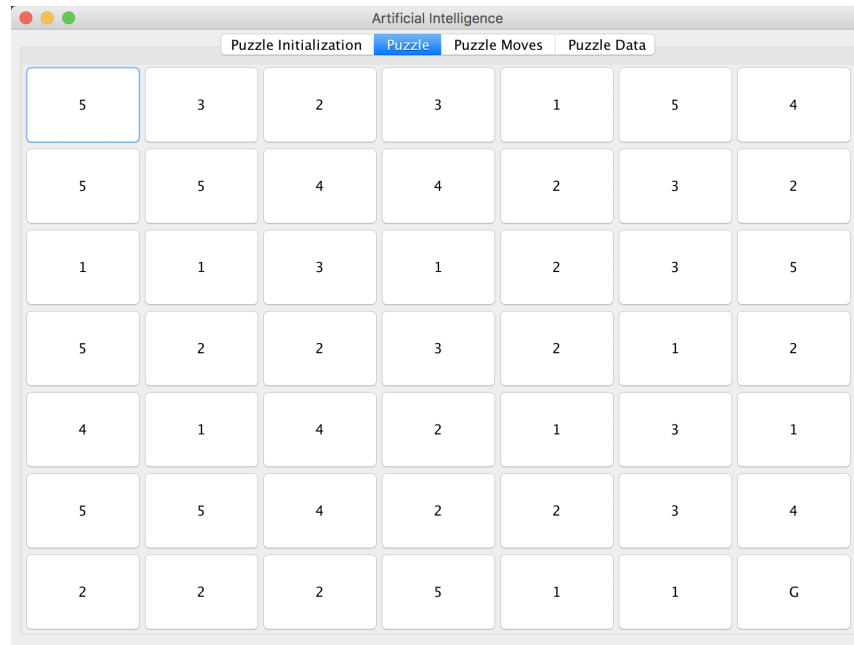


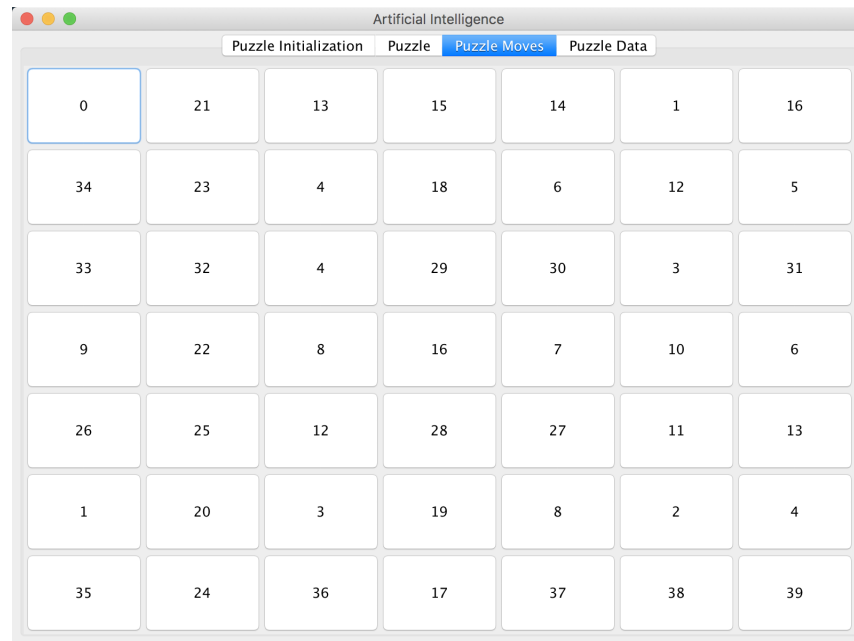
Figure 39: Plot of 100,000 iterations averaged over 50 runs for $n = 5$

Example Puzzle for $n = 7$



Artificial Intelligence						
Puzzle Initialization	Puzzle	Puzzle Moves	Puzzle Data			
5	3	2	3	1	5	4
5	5	4	4	2	3	2
1	1	3	1	2	3	5
5	2	2	3	2	1	2
4	1	4	2	1	3	1
5	5	4	2	2	3	4
2	2	2	5	1	1	G

Figure 40: Basic Hill Climbing Best Puzzle after 100,000 iterations for $n = 7$



Artificial Intelligence						
Puzzle Initialization	Puzzle	Puzzle Moves	Puzzle Data			
0	21	13	15	14	1	16
34	23	4	18	6	12	5
33	32	4	29	30	3	31
9	22	8	16	7	10	6
26	25	12	28	27	11	13
1	20	3	19	8	2	4
35	24	36	17	37	38	39

Figure 41: Basic Hill Climbing Puzzle Moves after 100,000 iterations for $n = 7$

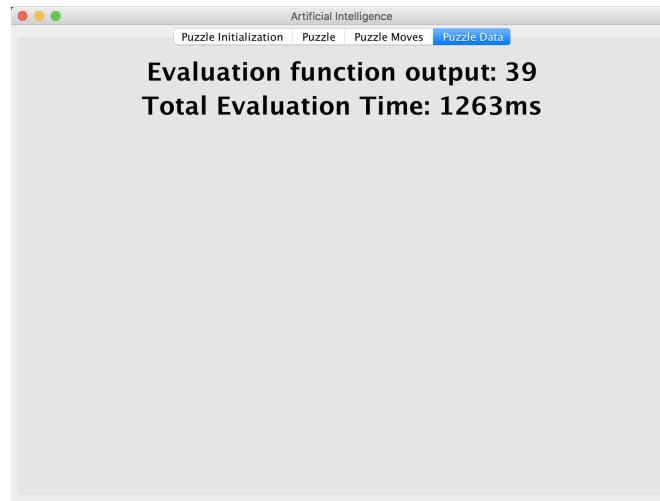


Figure 42: Basic Hill Climbing Puzzle Evaluation after 100,000 iterations for $n = 7$

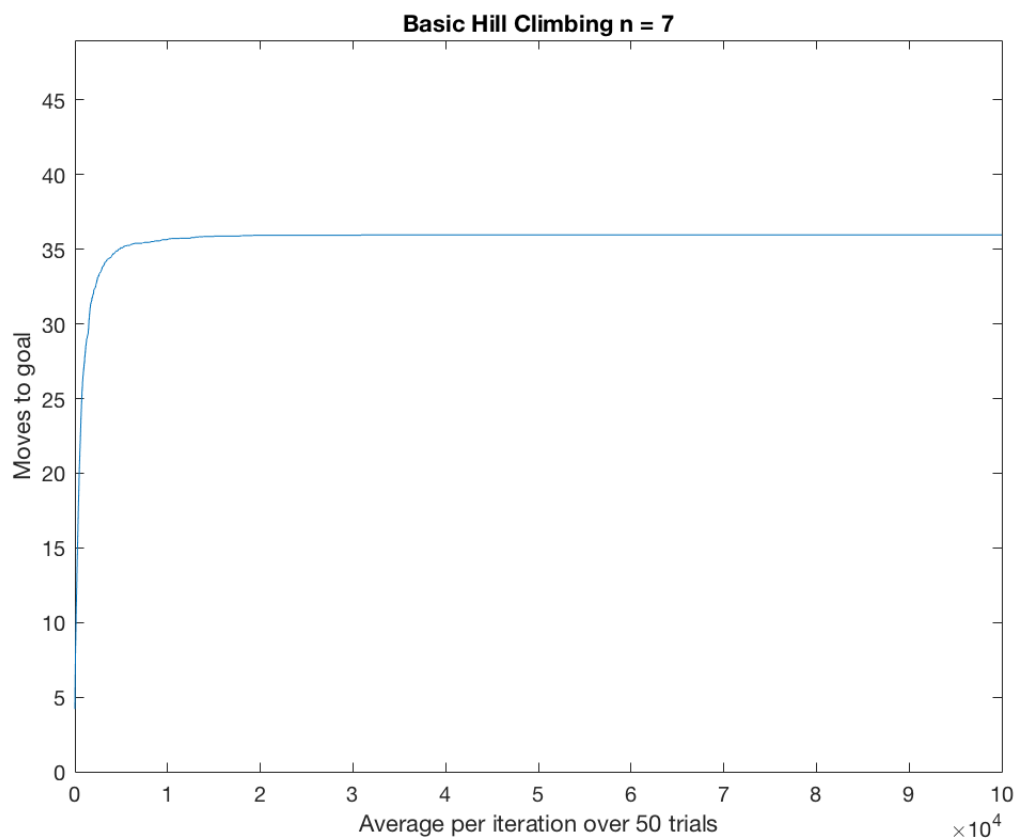
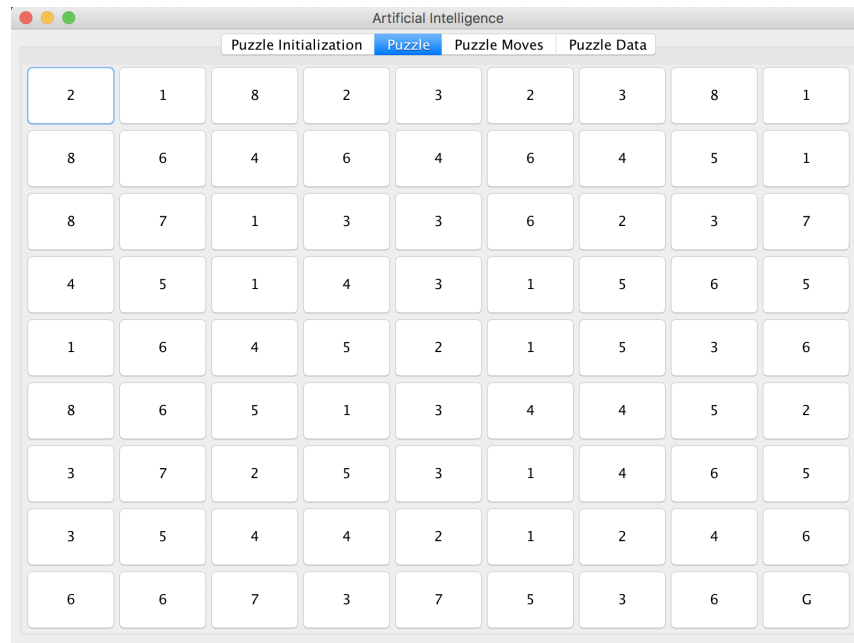


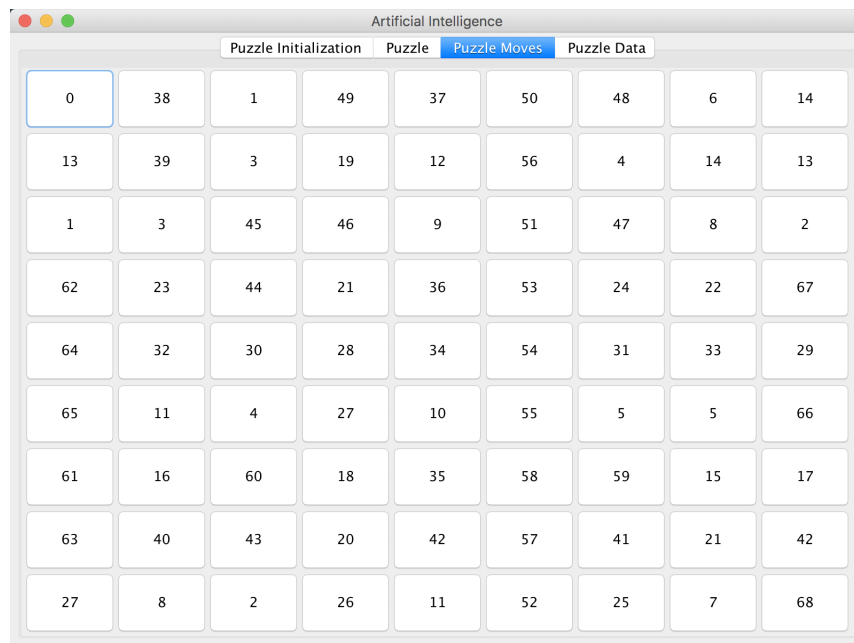
Figure 43: Plot of 100,000 iterations averaged over 50 runs for $n = 7$

Example Puzzle for $n = 9$



Artificial Intelligence								
Puzzle Initialization	Puzzle	Puzzle Moves	Puzzle Data					
2	1	8	2	3	2	3	8	1
8	6	4	6	4	6	4	5	1
8	7	1	3	3	6	2	3	7
4	5	1	4	3	1	5	6	5
1	6	4	5	2	1	5	3	6
8	6	5	1	3	4	4	5	2
3	7	2	5	3	1	4	6	5
3	5	4	4	2	1	2	4	6
6	6	7	3	7	5	3	6	G

Figure 44: Basic Hill Climbing Best Puzzle after 100,000 iterations for $n = 9$



Artificial Intelligence								
Puzzle Initialization	Puzzle	Puzzle Moves	Puzzle Data					
0	38	1	49	37	50	48	6	14
13	39	3	19	12	56	4	14	13
1	3	45	46	9	51	47	8	2
62	23	44	21	36	53	24	22	67
64	32	30	28	34	54	31	33	29
65	11	4	27	10	55	5	5	66
61	16	60	18	35	58	59	15	17
63	40	43	20	42	57	41	21	42
27	8	2	26	11	52	25	7	68

Figure 45: Basic Hill Climbing Puzzle Moves after 100,000 iterations for $n = 9$

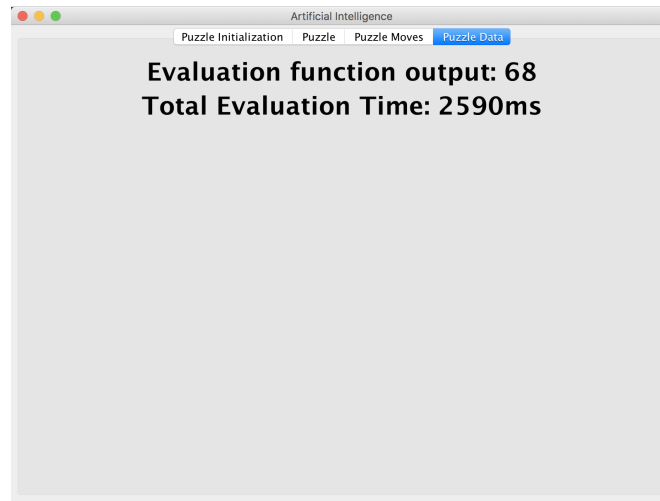


Figure 46: Basic Hill Climbing Puzzle Evaluation after 100,000 iterations for $n = 9$

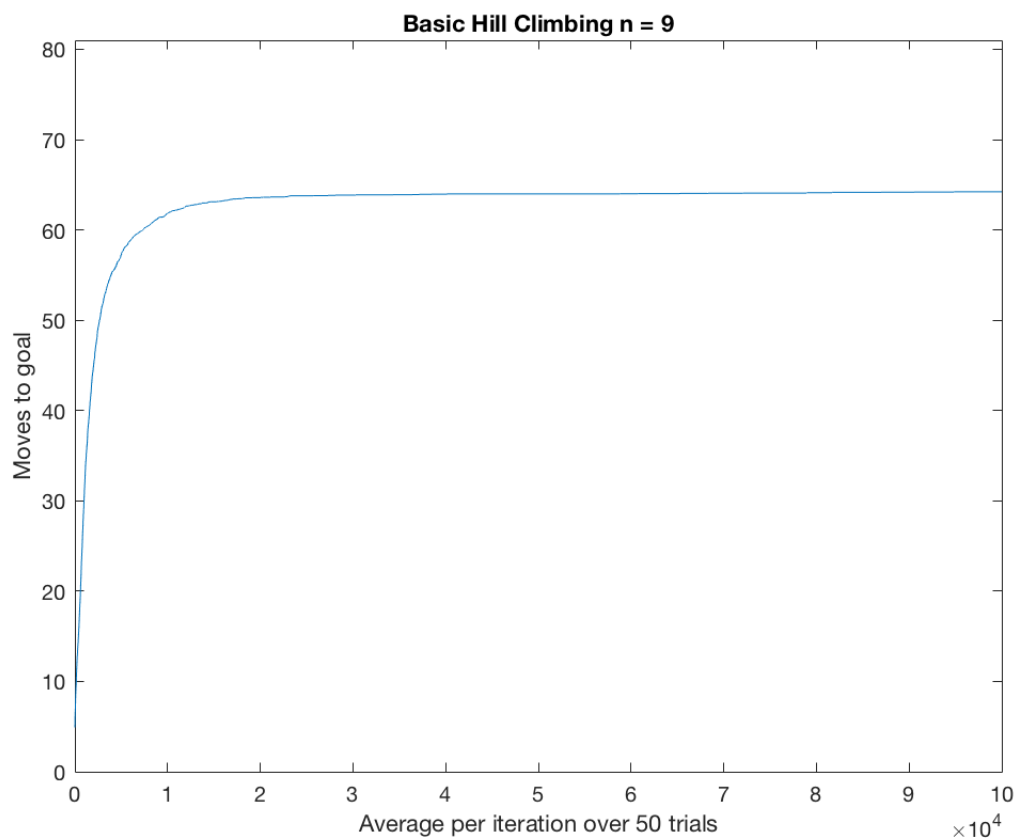
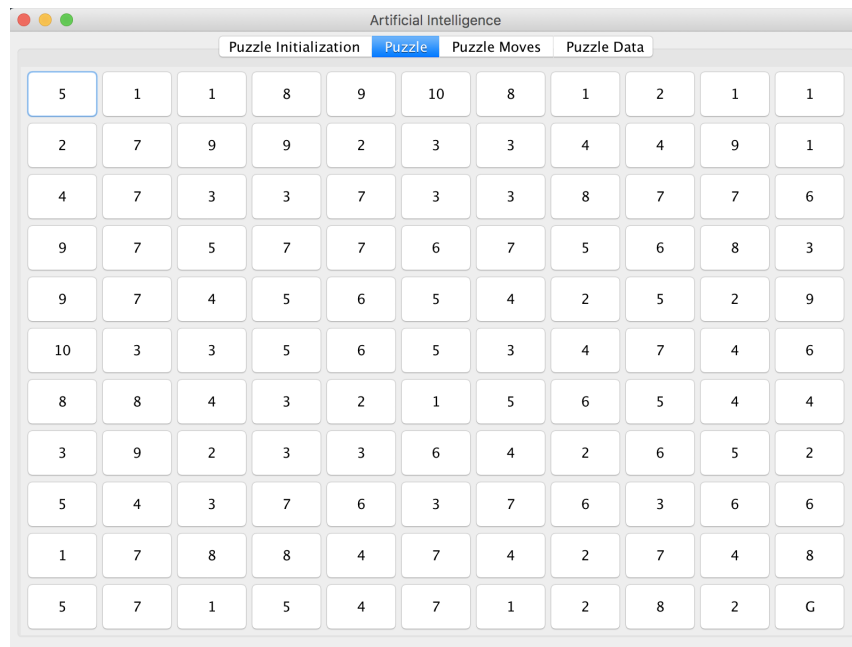


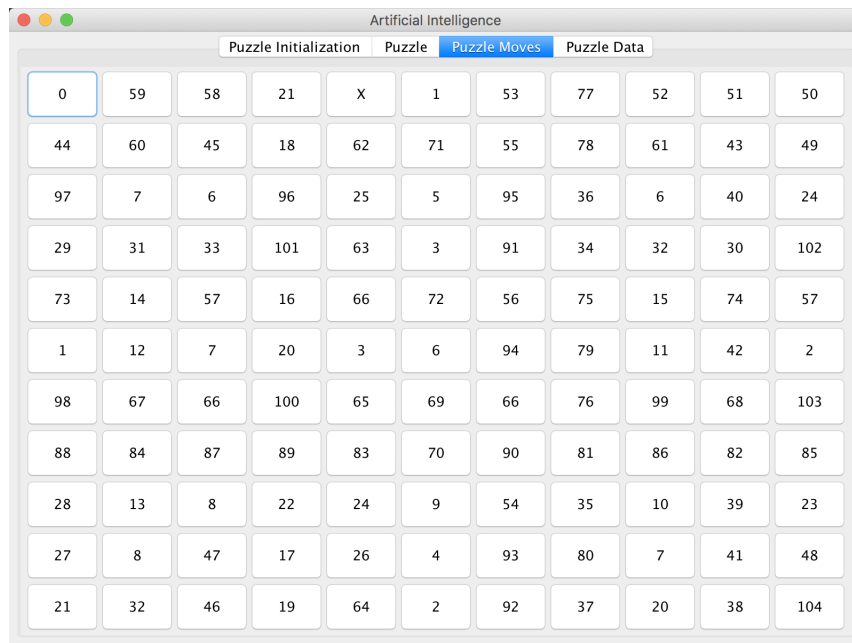
Figure 47: Plot of 100,000 iterations averaged over 50 runs for $n = 9$

Example Puzzle for $n = 11$



Artificial Intelligence										
Puzzle Initialization			Puzzle	Puzzle Moves			Puzzle Data			
5	1	1	8	9	10	8	1	2	1	1
2	7	9	9	2	3	3	4	4	9	1
4	7	3	3	7	3	3	8	7	7	6
9	7	5	7	7	6	7	5	6	8	3
9	7	4	5	6	5	4	2	5	2	9
10	3	3	5	6	5	3	4	7	4	6
8	8	4	3	2	1	5	6	5	4	4
3	9	2	3	3	6	4	2	6	5	2
5	4	3	7	6	3	7	6	3	6	6
1	7	8	8	4	7	4	2	7	4	8
5	7	1	5	4	7	1	2	8	2	G

Figure 48: Basic Hill Climbing Best Puzzle after 100,000 iterations for $n = 11$



Artificial Intelligence										
Puzzle Initialization			Puzzle	Puzzle Moves	Puzzle Data					
0	59	58	21	X	1	53	77	52	51	50
44	60	45	18	62	71	55	78	61	43	49
97	7	6	96	25	5	95	36	6	40	24
29	31	33	101	63	3	91	34	32	30	102
73	14	57	16	66	72	56	75	15	74	57
1	12	7	20	3	6	94	79	11	42	2
98	67	66	100	65	69	66	76	99	68	103
88	84	87	89	83	70	90	81	86	82	85
28	13	8	22	24	9	54	35	10	39	23
27	8	47	17	26	4	93	80	7	41	48
21	32	46	19	64	2	92	37	20	38	104

Figure 49: Basic Hill Climbing Puzzle Moves after 100,000 iterations for $n = 11$

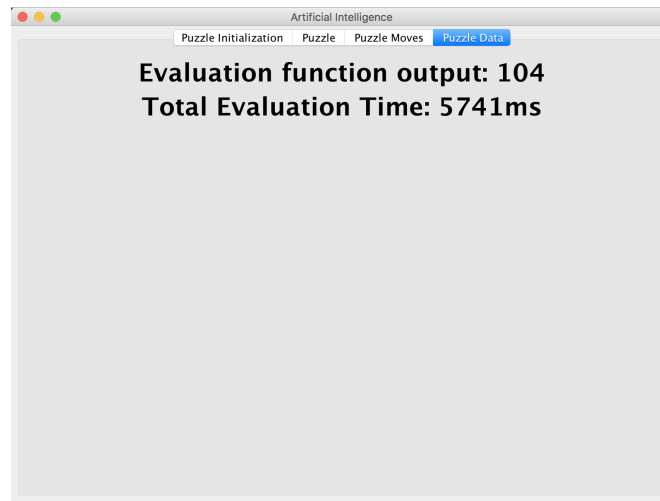


Figure 50: Basic Hill Climbing Puzzle Evaluation after 100,000 iterations for $n = 11$

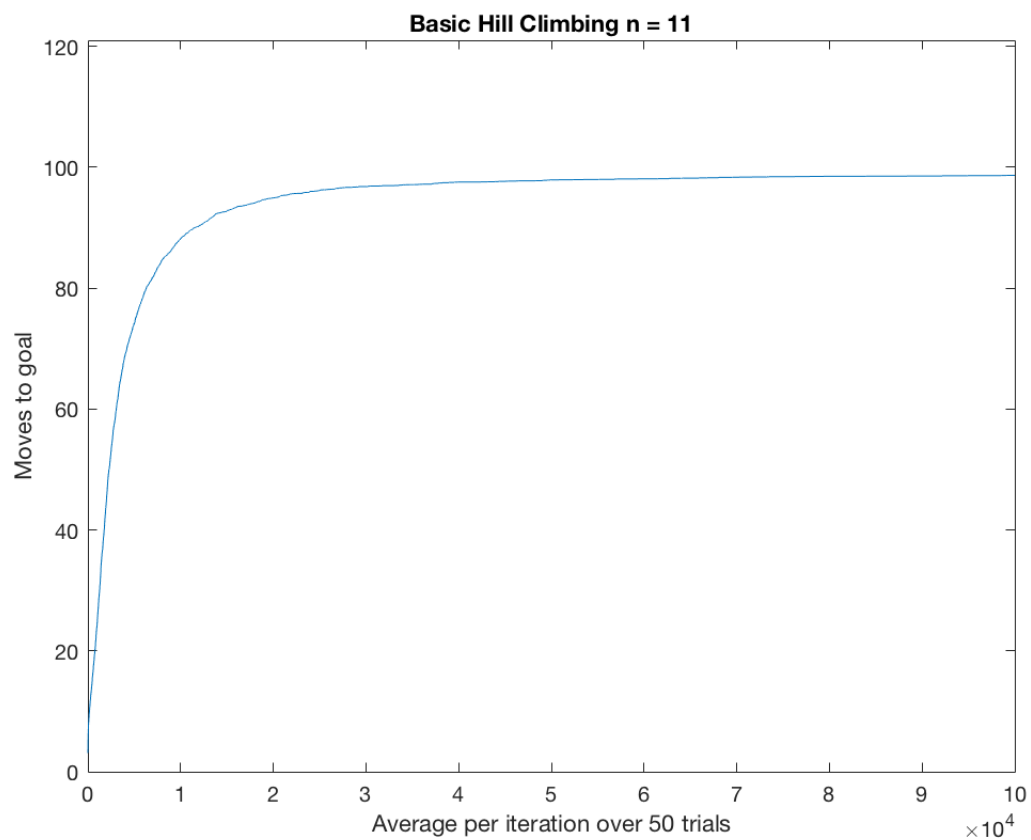


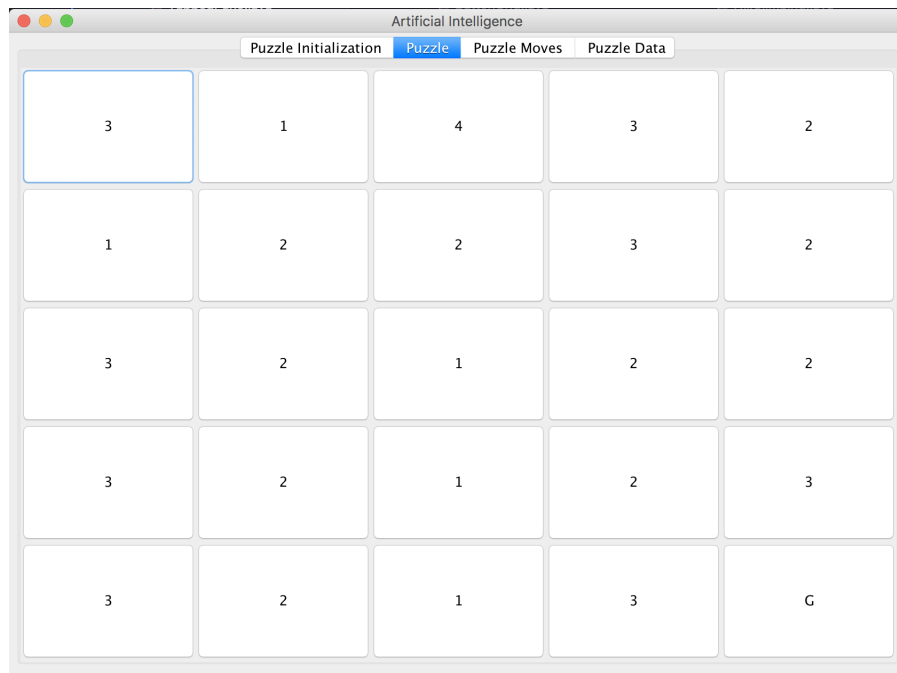
Figure 51: Plot of 100,000 iterations averaged over 50 runs for $n = 11$

Hill Climbing with Random Restarts

The following puzzles were generated with 10,000 iterations and 10 restarts for a total of 100,000 iterations.

The results are relatively similiar to those of

Example Puzzle for $n = 5$



Artificial Intelligence				
Puzzle Initialization	Puzzle	Puzzle Moves	Puzzle Data	
3	1	4	3	2
1	2	2	3	2
3	2	1	2	2
3	2	1	2	3
3	2	1	3	G

Figure 52: Hill Climbing with Random Restarts Best Puzzle after 100,000 iterations for $n = 5$

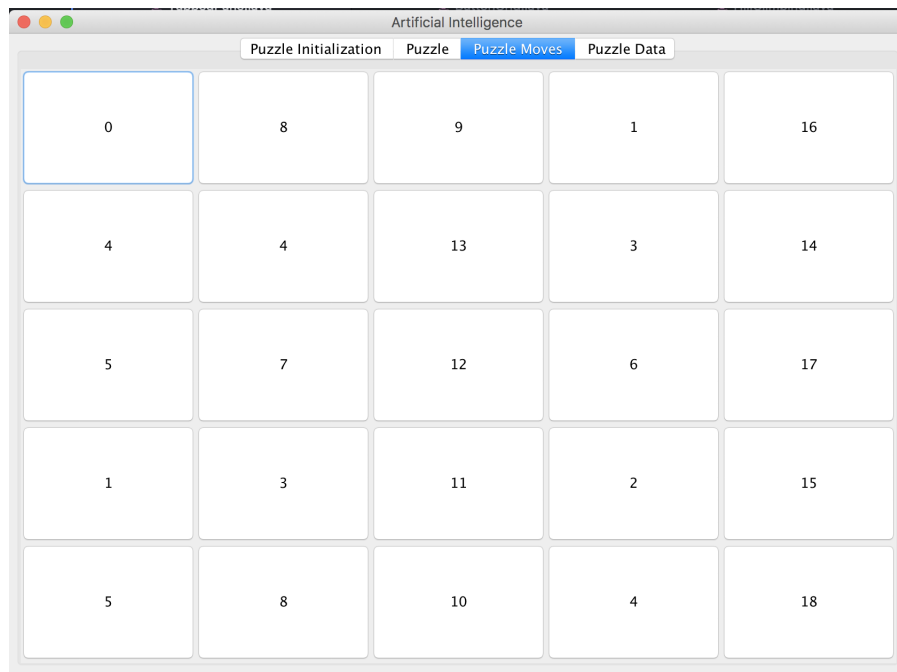


Figure 53: Hill Climbing with Random Restarts Best Puzzle after 100,000 iterations for $n = 5$

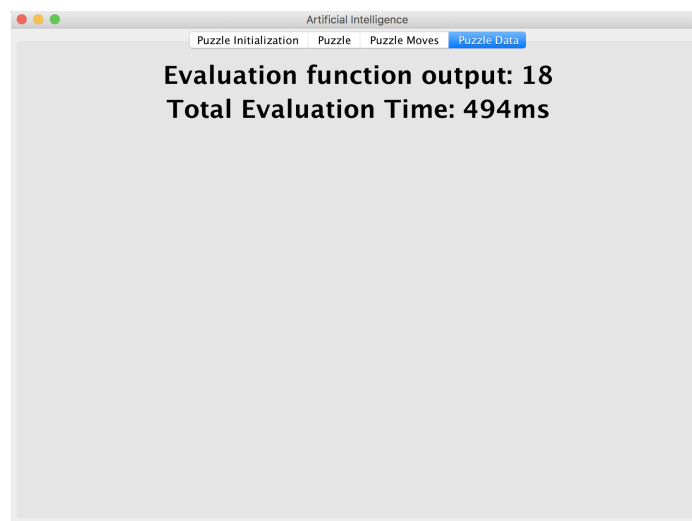


Figure 54: Hill Climbing with Random Restarts Best Puzzle after 100,000 iterations for $n = 5$

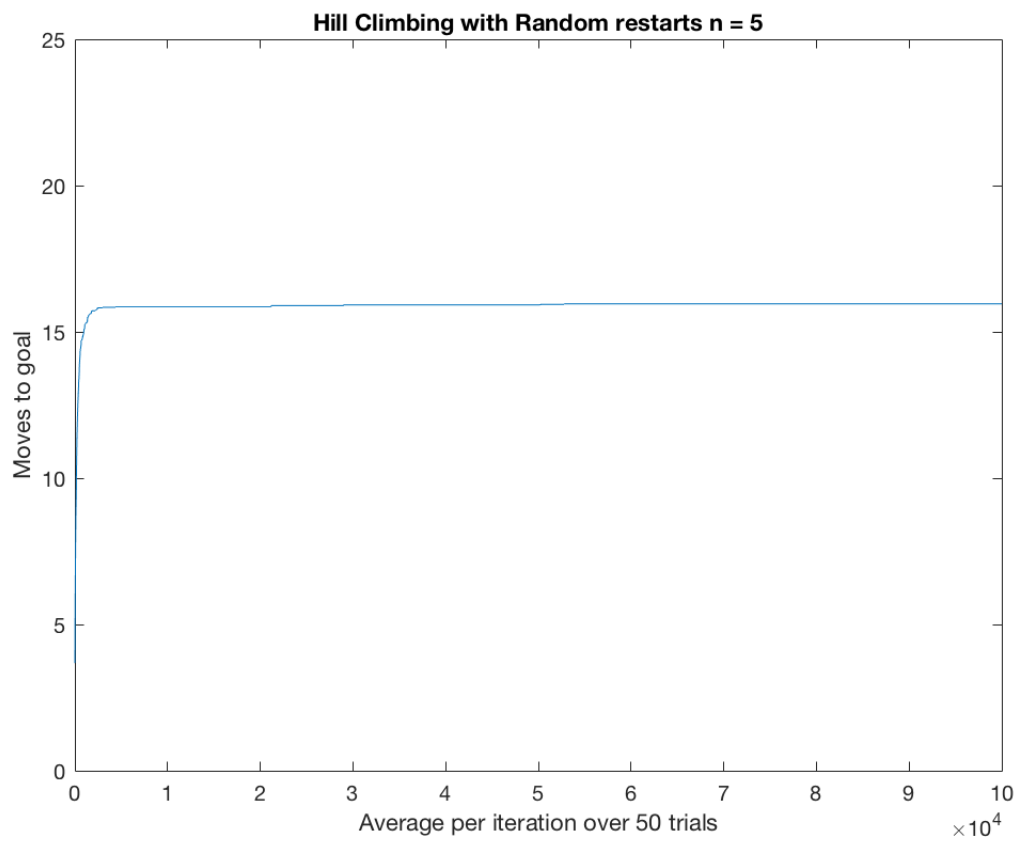
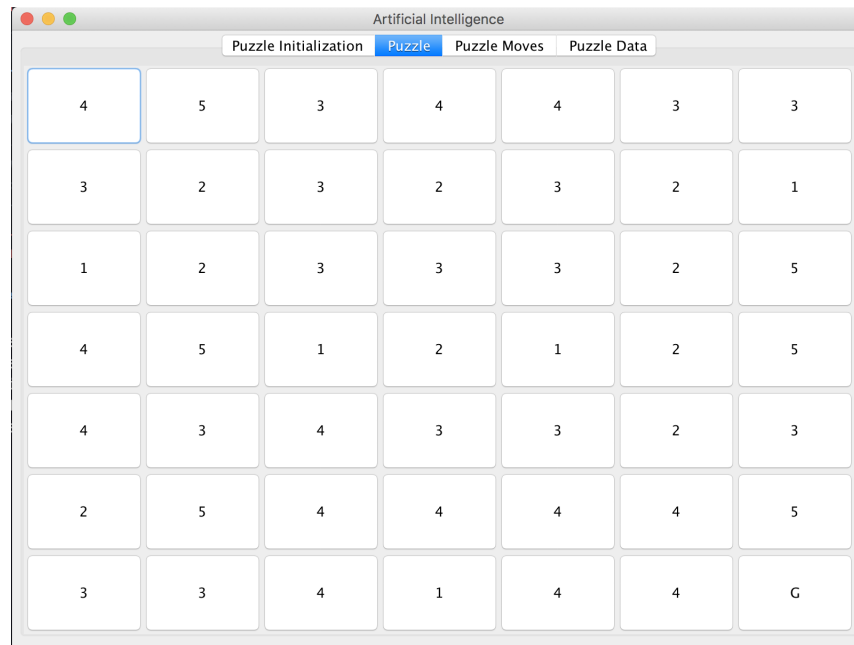


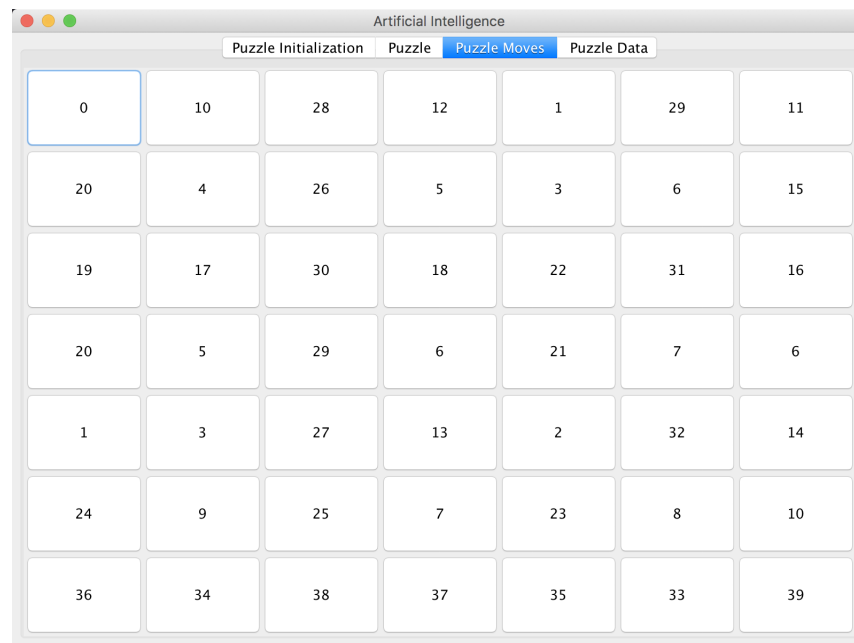
Figure 55: Plot of 100,000 iterations averaged over 50 runs for $n = 5$

Example Puzzle for $n = 7$



4	5	3	4	4	3	3
3	2	3	2	3	2	1
1	2	3	3	3	2	5
4	5	1	2	1	2	5
4	3	4	3	3	2	3
2	5	4	4	4	4	5
3	3	4	1	4	4	G

Figure 56: Hill Climbing with Random Restarts Best Puzzle after 100,000 iterations for $n = 7$



0	10	28	12	1	29	11
20	4	26	5	3	6	15
19	17	30	18	22	31	16
20	5	29	6	21	7	6
1	3	27	13	2	32	14
24	9	25	7	23	8	10
36	34	38	37	35	33	39

Figure 57: Hill Climbing with Random Restarts Best Puzzle after 100,000 iterations for $n = 7$

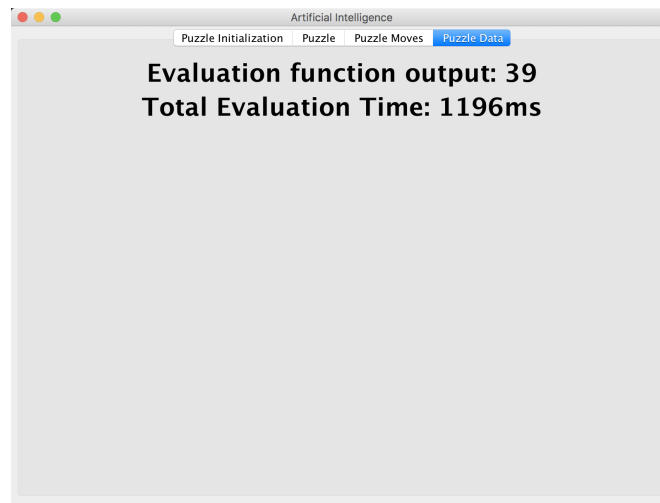


Figure 58: Hill Climbing with Random Restarts Best Puzzle after 100,000 iterations for $n = 7$

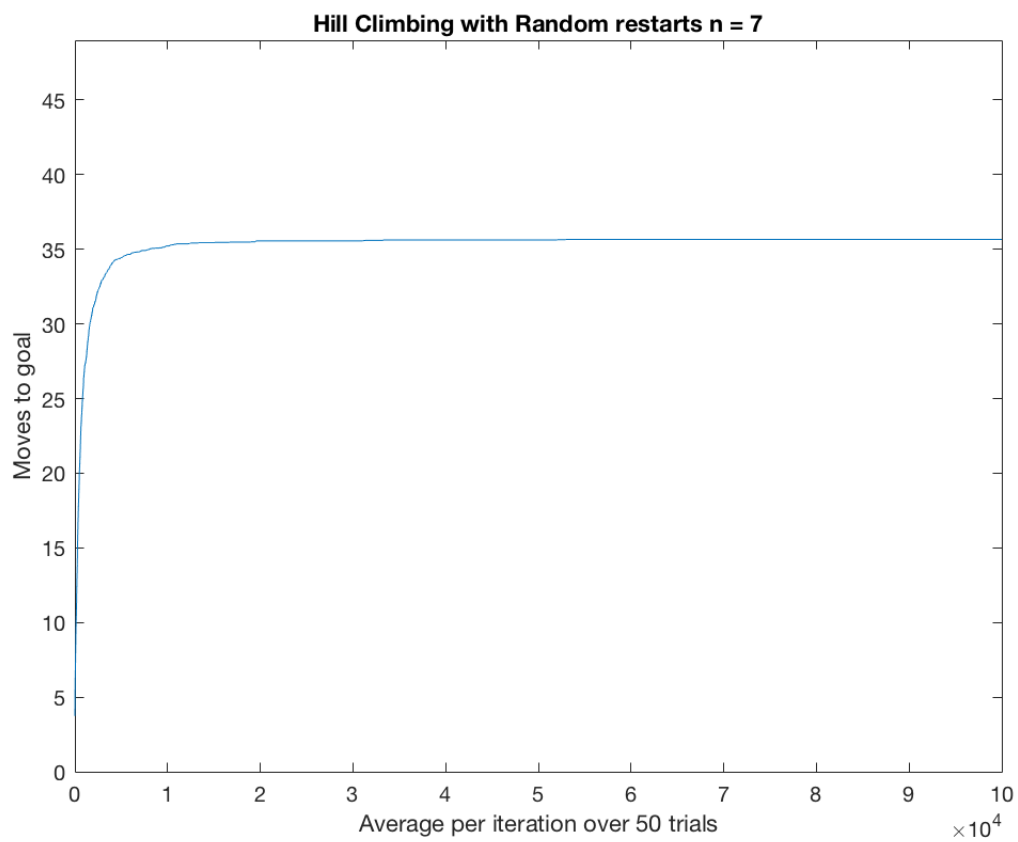


Figure 59: Plot of 100,000 iterations averaged over 50 runs for $n = 7$

Example Puzzle for $n = 9$

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Example Puzzle for $n = 11$

Artificial Intelligence

Puzzle InitializationPuzzlePuzzle MovesPuzzle Data

5	7	2	2	1	7	7	2	2	7	4
10	2	3	9	1	8	7	3	2	8	3
9	6	7	5	7	8	5	7	5	5	8
1	6	2	7	1	4	7	6	7	8	4
5	5	3	6	3	3	5	6	5	5	9
8	4	6	7	2	2	4	5	6	8	8
2	3	5	7	5	1	3	6	3	2	3
1	8	6	2	2	6	5	4	2	6	9
7	6	1	7	4	1	6	6	7	7	5
2	6	6	4	8	7	8	2	7	6	7
2	3	3	8	5	7	5	7	4	5	G

Figure 60: Hill Climbing with Random Restarts Best Puzzle after 100,000 iterations for $n = 11$

Artificial Intelligence										
Puzzle Initialization			Puzzle		Puzzle Moves			Puzzle Data		
0	33	74	32	31	1	35	72	34	73	35
43	16	51	17	30	3	40	45	95	15	44
26	24	75	19	28	5	23	25	20	27	104
78	8	77	61	60	7	63	9	96	8	62
79	37	52	55	57	53	38	46	54	56	36
1	69	3	13	59	70	60	71	2	68	14
82	85	83	101	86	99	100	84	98	87	102
81	13	50	12	58	2	22	11	21	14	22
42	25	89	90	93	92	41	26	94	88	91
80	9	76	12	29	4	39	10	22	11	103
48	65	49	18	66	6	64	47	97	67	105

Figure 61: Hill Climbing with Random Restarts Best Puzzle after 100,000 iterations for $n = 11$

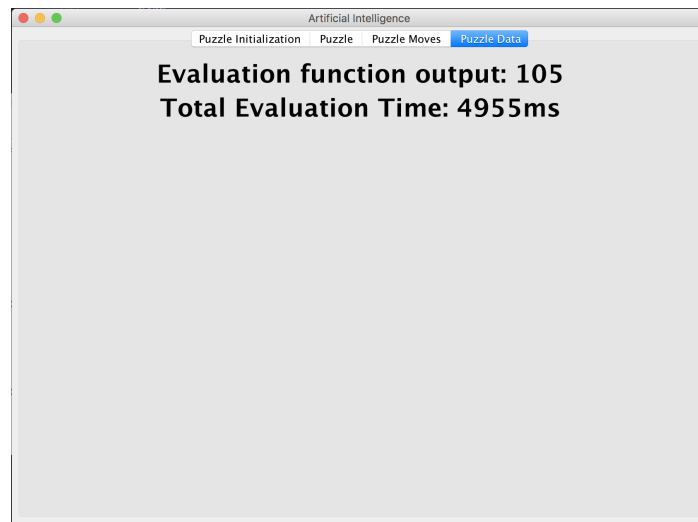


Figure 62: Hill Climbing with Random Restarts Best Puzzle after 100,000 iterations for $n = 11$

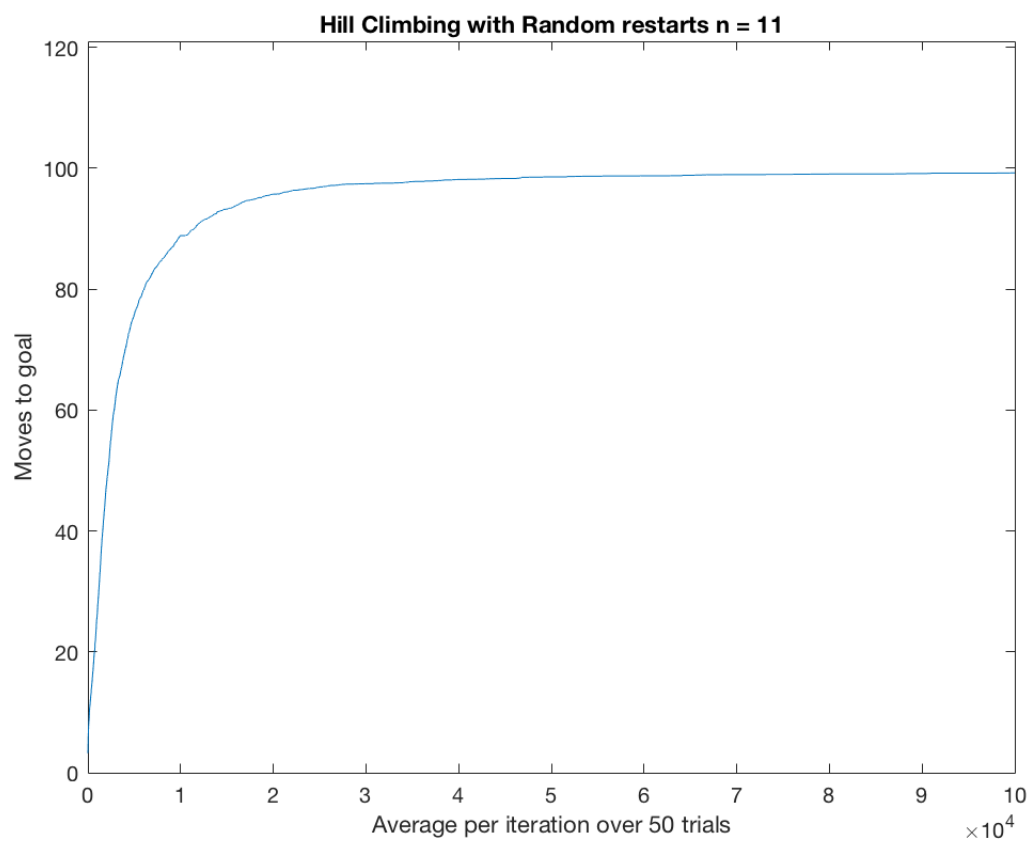


Figure 63: Plot of 100,000 iterations averaged over 50 runs for n = 11

Hill Climbing with Random Walks

Compare the output of the above two processes against the one that utilizes random walks for the same number of total iterations. i.e. again again visualize the final optimized puzzle configuration, its value and time it took to compute it.

Your input in this case will be two numbers a) the total number of iterations for hill climbing and b) the probability of the acceptance of a downhill move

Evaluate the effects of different values for probability p and select the one that works best for this problem and preferred number of total iterations

Example Puzzle for $n = 5$

Example Puzzle for $n = 7$

IMAGES

Example Puzzle for $n = 9$

IMAGES

Example Puzzle for $n = 11$

IMAGES

Simulated Annealing

Proposal and Implementation of a population based approach