# Marmara University Faculty of Engineering



# **CSE 4082**Artificial Intelligence

# **Assignment 1**

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### Implementation

Our project starts with the main.java file. The main file activates the helper class related to the Knight's Tour and the initial node after receiving the necessary inputs from the user. Then, it runs the TreeSearch.java class to apply the Tree Search algorithm.

The Node.java class represents a square on the board. This class stores the x and y coordinates of the square, as well as the parent node and the visit order (visitedOrder) of the node.

The KnightTour.java class is designed as a helper class that contains all the auxiliary functions to be used during the Tree Search algorithm.

The TreeSearch.java class is where the Tree Search algorithm is implemented. In this class, frontier is defined as a LinkedList. Based on the selected method:

- If the BFS algorithm is chosen, frontier behaves like a queue using offer and poll operations.
- If the algorithm is DFS or one of the heuristic methods, frontier behaves like a stack using push and pop operations.

A loop runs as long as frontier is not empty, during which valid moves for the knight are appropriately added to the frontier. In heuristic methods, a temporary ArrayList is used, and moves are added to the frontier in the appropriate order determined by the heuristic.

Each time a node is removed from the frontier via pop or poll, it is checked whether the node is in the goal state. This check ensures that the visitedOrder value is equal to size x size (the square of the board size). If the values are not equal, the selected node is expanded.

#### Problem Definition and Environment

The Knight's Tour Problem (KTP) aims to move a knight across an n x n chessboard so that it visits every square exactly once, thereby completing a tour of the entire board.

The movement rules for the knight follow the L-shaped moves used in chess:

- 2 squares horizontally and 1 square vertically, or
- 2 squares vertically and 1 square horizontally.

This problem is classified as a deterministic, single-agent, and fully observable problem.

### Outputs:

We add all relevant outputs to the output file in a text file and image format.

Breadth-First Search (BFS)

n = 8

```
Search Method: Breadth First Search
Board Size: 8
Out of Memory.
```

n = 16

```
Search Method: Breadth First Search
Board Size: 16
Out of Memory.
```

n = 32

```
Search Method: Breadth First Search
Board Size: 32
Out of Memory.
```

n = 41

```
Search Method: Breadth First Search
Board Size: 41
Out of Memory.
```

n = 52

```
Search Method: Breadth First Search
Board Size: 52
Out of Memory.
```

## Depth-First Search (DFS):

#### n = 8

Search Method: Depth First Search Board Size: 8

A solution found.

Time Taken: 1.132 seconds Nodes expanded: 3242064

Solution written to knights\_tour\_solution.txt

Solution image was saved to knights\_tour\_solution.png

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

#### n = 16

Search Method: Depth First Search

Board Size: 16

Timeout.

Nodes expanded: 1027024630

#### n = 32

Search Method: Depth First Search

Board Size: 32

Timeout.

Nodes expanded: 359828918

#### n = 41

Search Method: Depth First Search

Board Size: 41

Timeout.

Nodes expanded: 231197247

Search Method: Depth First Search

Board Size: 52

Timeout.

Nodes expanded: 143265975

Depth-First Search with Heuristic h1b

n = 8

Search Method: Depth First Search with Heuristic h1b

Board Size: 8
A solution found.

Time Taken: 0.004 seconds

Nodes expanded: 63

Solution written to knights\_tour\_solution.txt

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

Search Method: Depth First Search with Heuristic h1b

Board Size: 16 A solution found.

Time Taken: 0.012 seconds

Nodes expanded: 255

Solution written to knights\_tour\_solution.txt

Solution image was saved to knights\_tour\_solution.png

56	39	42	9	106	103	44	11	142	117	46	13	120	17	48	15
41	8	97	102	43	10	105	116	45	12	141	118	47	14	121	18
38	39	40	107	104	115	134	143	140	157	132	127	160	119	16	49
7	96	101	114	135	144	133	156	133	103	161	158	131	128	19	122
100	37	103	95	112	153	146	187	202	155	216	119	126	159	50	129
93	6	113	136	145	138	201	154	215	193	235	162	241	130	123	20
36	109	94	111	152	147	195	203	234	217	242	239	236	125	164	51
5	92	87	148	137	200	151	214	191	238	233	246	163	240	21	124
86	35	110	91	150	185	192	231	204	243	218	237	254	245	52	165
75	4	149	88	179	90	199	194	213	232	251	244	247	166	253	22
34	85	76	83	184	193	182	206	230	219	224	227	252	255	248	53
3	74	67	178	89	190	195	198	223	212	229	250	167	226	23	256
66	33	84	n	82	183	206	181	210	197	220	225	228	249	54	171
71	2	73	68	177	78	81	196	207	222	211	168	173	170	57	24
32	65	70	79	30	63	176	269	28	61	174	221	26	59	172	55
1	72	31	64	69	80	29	62	175	208	27	60	169	56	25	58

#### n = 32

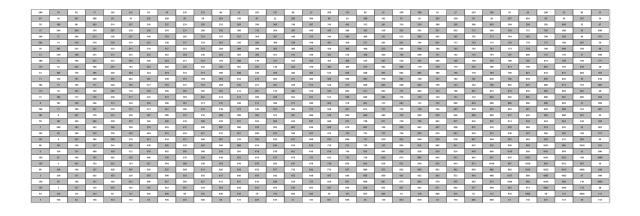
Search Method: Depth First Search with Heuristic h1b

Board Size: 32 A solution found.

Time Taken: 0.108 seconds

Nodes expanded: 1023

Solution written to knights\_tour\_solution.txt



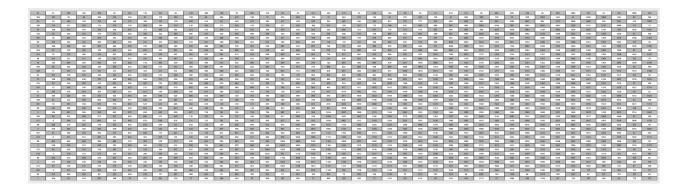
Search Method: Depth First Search with Heuristic h1b

Board Size: 41
A solution found.

Time Taken: 12.131 seconds Nodes expanded: 1061528

Solution written to knights\_tour\_solution.txt

Solution image was saved to knights\_tour\_solution.png



#### n = 52

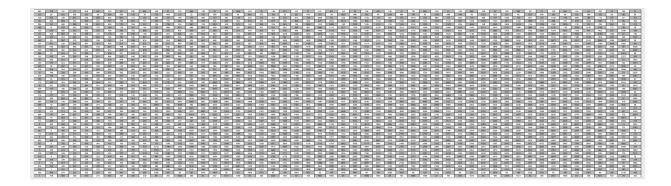
Search Method: Depth First Search with Heuristic h1b

Board Size: 52 A solution found.

Time Taken: 1.495 seconds

Nodes expanded: 2703

Solution written to knights\_tour\_solution.txt



# Depth-First Search with Heuristic h2

#### n = 8

Search Method: Depth First Search with Heuristic h2

Board Size: 8

A solution found. Time Taken: 0.005 seconds

Nodes expanded: 63

Solution written to knights\_tour\_solution.txt

Solution image was saved to knights\_tour\_solution.png

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

#### n = 16

Search Method: Depth First Search with Heuristic h2

Board Size: 16 A solution found.

Time Taken: 0.013 seconds

Nodes expanded: 255

Solution written to knights\_tour\_solution.txt

68	11	140	177	70	13	96	107	72	15	86	89	74	17	78	81
139	176	69	12	141	106	71	14	97	88	73	16	85	80	75	18
10	67	174	183	178	95	188	105	108	93	98	87	90	77	82	79
175	138	179	142	181	184	223	94	187	104	109	92	99	84	19	76
66	9	182	173	222	189	186	211	254	231	208	103	110	91	100	83
137	62	143	180	185	224	253	232	247	210	251	230	207	102	111	20
8	65	172	221	190	233	212	243	252	255	248	209	240	113	160	101
63	136	61	144	213	244	225	256	237	246	241	250	229	206	21	112
60	7	64	171	220	191	234	245	242	249	236	239	200	161	114	159
53	40	135	58	145	214	219	226	235	238	217	228	205	202	155	22
6	59	54	51	170	133	192	215	218	227	204	201	162	199	158	115
41	52	39	134	57	146	167	196	193	216	163	198	203	154	23	156
38	5	42	55	50	169	132	147	166	197	194	151	164	157	116	127
33	2	31	36	45	56	49	168	195	150	165	124	153	128	119	24
4	37	34	43	30	47	148	131	28	123	152	129	26	121	126	117
1	32	3	46	35	44	29	48	149	130	27	122	125	118	25	120

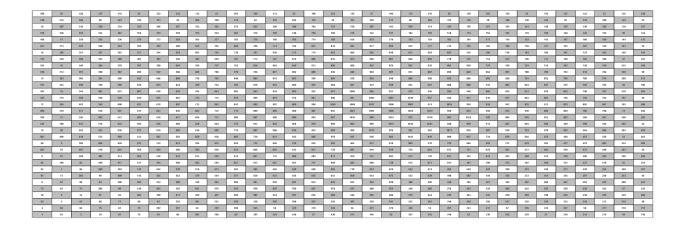
Search Method: Depth First Search with Heuristic h2

Board Size: 32 A solution found.

Time Taken: 0.133 seconds Nodes expanded: 1023

Solution written to knights\_tour\_solution.txt

Solution image was saved to knights\_tour\_solution.png



#### n = 41

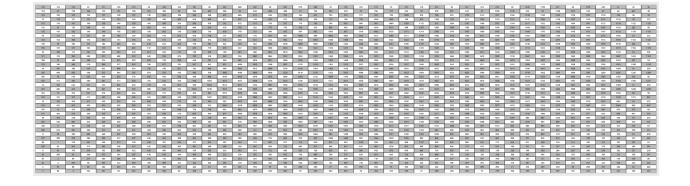
Search Method: Depth First Search with Heuristic h2

Board Size: 41
A solution found.

Time Taken: 0.452 seconds

Nodes expanded: 1680

Solution written to knights\_tour\_solution.txt



Search Method: Depth First Search with Heuristic h2

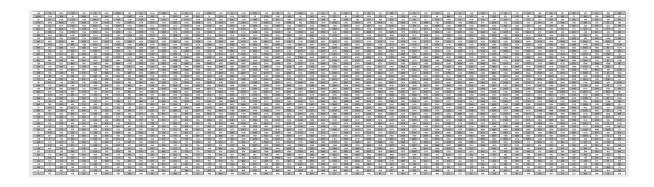
Board Size: 52 A solution found.

Time Taken: 1.653 seconds

Nodes expanded: 2703

Solution written to knights\_tour\_solution.txt

Solution image was saved to knights\_tour\_solution.png



#### n = 273 (maximum board size that can be toured in 15 minutes)

Search Method: Depth First Search with Heuristic h2

Board Size: 273 A solution found.

Time Taken: 897.376 seconds

Nodes expanded: 74528

Solution written to knights\_tour\_solution.txt