VIET NAM NATIONAL UNIVERSITY HO CHI MINH CITY
UNIVERSITY OF SCIENCE
FACULTY OF INFORMATION TECHNOLOGY

LAB 1 REPORT
SUBJECT: PROGRAMMING TECHNIQUES

THE KNIGHT'S TOUR PROBLEM

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I. KNIGHT'S TOUR PROBLEM

1. What is Knight's Tour?

- On a chessboard, a knight's tour is a series of movements in which the knight visits each square precisely once. The tour is closed if the knight ends on a square one knight's move from the beginning square (such that it can instantly tour the board again, following the same path); otherwise, it is open.

II. IMPLEMENT

- **Programming language:** Python
- **Percentage of completion:** 100%

A. BACKTRACKING

1. Introduction

- **Backtracking:** Backtracking is an algorithmic strategy for recursively solving problems by attempting to develop a solution progressively, one piece at a time, and discarding any solutions that do not satisfy the problem's criteria at any point in time (by time, here, is referred to the time elapsed till reaching any level of the search tree).

2. Statistics

Size	**n = 8**		**n = 15**		**n = 25**	
Initial position	**Running time(ms)**	**Number of moves**	**Running time(ms)**	**Number of moves**	**Running time(ms)**	**Number of moves**
(1, 1)	32099.20	8250733	3600003.36	1028900345	5285318.68	655435466
(n, n)	674107.12	251825408	3600002.76	904374742	3879324.71	187671806
(1, n)	7332.68	3242065	3600009.05	1007783107	4199719.75	419321086
(n, 1)	101281.64	27241113	3600002.80	902453984	3914681.56	193827599
(4, 6)	843263.15	343234829	3600007.03	553709582	3903787.01	191345815
Average	331616.79	126758830	3600005	879444352	4236566.34	329520354

Time: $O(8^{n^2})$, where n is the size of the matrix

Space: $O(n^2)$

- **Comments:**
  - Because time complexity of backtracking is $O(8^{n^2})$ – very huge giant number in real time. Therefor, in size 15x15 and 25x25 we compute the statistics based on 1-hour-long runs.

B. WARNSDORFF'S HEURISTIC

1. Introduction

- **Warnsdorff's Heuristic:** According to the Warndorff's Rule, we can start from any initial location of the knight on the board and move to a neighboring, unvisited square with a minimum degree (minimum number of unvisited adjacent squares). This approach can be used to any graph in a broader sense.

2. Statistics:

Size	n = 8		n = 15		n = 25	
Initial position	**Running time(ms)**	**Number of moves**	**Running time(ms)**	**Number of moves**	**Running time(ms)**	**Number of moves**
(1, 1)	0.92	63	7.60	224	17.69	624
(n, n)	1.37	63	10.34	224	9.88	624
(1, n)	1	63	4.99	224	10.08	624
(n, 1)	0.92	63	4.10	224	15.05	624
(4, 6)	1.99	63	8.61	224	10.39	624
Average	1.24	63	7.13	224	12.62	624

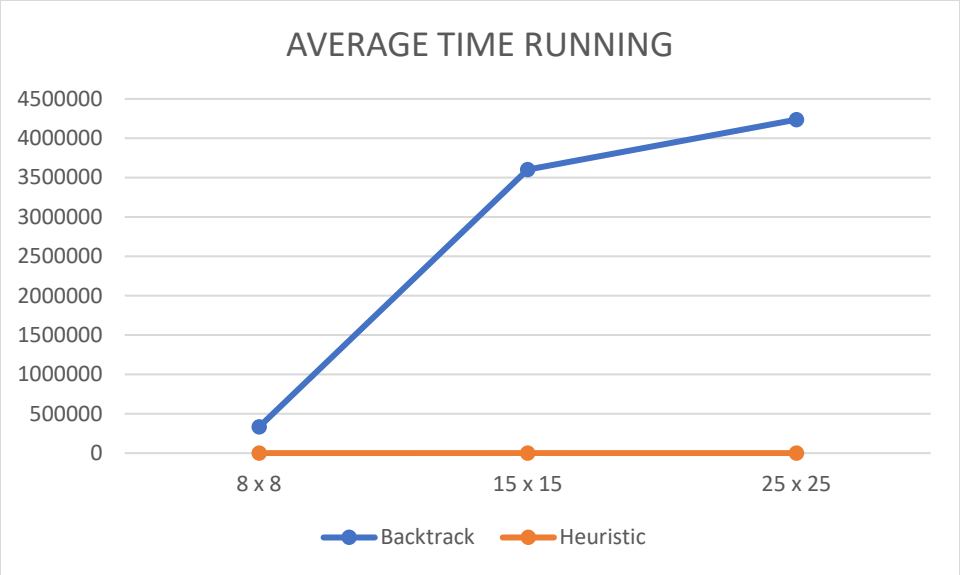
Time: **O(n)**

Space: **O(n.n)**

- **Comments:**
  - Warnsdorff's heuristic successfully finds a solution in linear time (O(n)).
  - The majority of cases will find solutions exceptions the existence of solutions in teacher's file.

C. AVERAGE VALUES

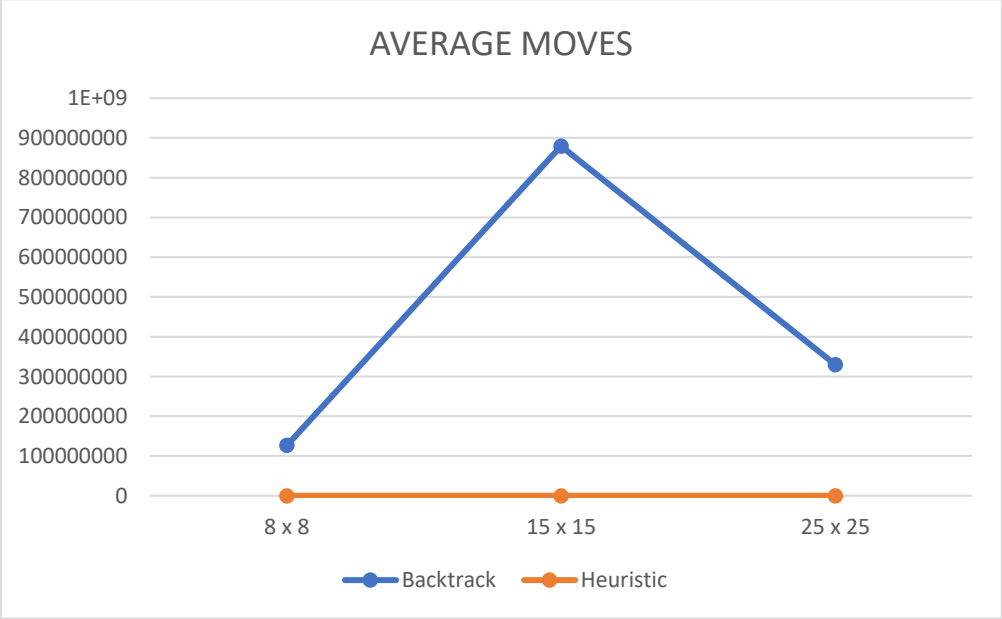
AVERAGE TIME(ms)			
	8 x 8	**15 x 15**	**25 x 25**
Backtrack	331616.79	3600005	4236566
Heuristic	1.24	7.13	12.62



Comments:

- Time running in Warnsdorff's heuristic is less than 15ms while Backtrack algorithm is over 1 hour running.
  ⇨ Warnsdorff's heuristic is more efficient than Backtracking, save a lot of execution time.

AVERAGE MOVES			
	8 x 8	**15 x 15**	**25 x 25**
Backtrack	126758830	879444352	329520354
Heuristic	63	224	624



Comments:

- The chart did not show correctness of average moves in practice. Because in 15 x 15 and 25 x 25, we enforced running in just 1 hour. Therefore, the completion of program is not 100 %.
- Number of moves in Warnsdorff's heuristic alogrithm is $n^2 - 1$ while Backtracking is over than 8 billions in 15*15. (maybe more than because this number just analysis in 1-hour running.
  ⇨ Backtracking alogrithm is more complex than Warnsdorff's in many times.

D. PROJECT ORGANIZATION

- **Input**: 20127680.py -px 1 -py 1 -s 8
- **Output**: 2 files text in OUTPUT folder which name:
  - 20127680_heuristic.txt
  - 20127680_backtrack.txt

E. CHECK LIST

#	Criteria	% credits	Done
1	Manipulate the input and output	10	X
2	Implement the backtracking	10	X
3	Implement the Warnsdorff's Heuristic	10	X
4	Provide valid results for the backtracking strategy	20	X
5	Provide valid results for the Warnsdorff's Heuristic	20	X
6	Provide all evidential files in the OUTPUT folder	10	X
7	Report sufficient information in the document	20	X

III. REFERENCES

[1] https://www.youtube.com/watch?v=Ntoyq5TinD8
[2] https://www.youtube.com/watch?v=D8KFwjohDNg
[3] https://www.geeksforgeeks.org/command-line-arguments-in-python/
[4] https://nguyenvanhieu.vn/doc-ghi-file-trong-python/#doc-toan-bo-file-ra-list