Assignment 1 (4%)
Magic Square Classifier

Deadline: Friday, 16 February 2024 at 23:59 on Submitty

Working individually, complete the assignment below. Submit your solution to Submitty (`https://submit.scss.tcd.ie`). Your mark will be the auto-graded mark assigned by Submitty. There is no manual marking for this assignment.

You are allowed to submit **10 attempts** for the assignment without penalty. Subsequent attempts will attract a 5 mark penalty each, up to a maximum penalty of 30 marks.

Submitty will allow you **eight "late days"** for CSU11022 assignments. For example, you can submit one assignment late by eight days or four assignments late by two days each, without penalty. Once your "late days" are used up, you will receive zero marks for any late submissions. Note that even 1 second after the deadline counts as one full late day. Late days do not apply to exercises that are not for credit.

By submitting your solution, you are confirming that you have familiarised yourself with College's policy on academic integrity (`https://libguides.tcd.ie/academic-integrity`).

Instructions

A *semimagic square* [1, 2] is an $N \times N$ 2D array containing each of the positive integers $1, 2, 3, \ldots, N^2$ arranged so the sum of the elements in each row and each column is equal. The following is an example of an $N \times N$ magic square where the rows and columns all sum to 15.

2	6	7
9	1	5
4	8	3

(a) **[60 marks]** Design and write an ARM Assembly Language program to determine whether a square 2D array of word-size values is a *semimagic square*, according to the definition above. (In other words, the array must contain the positive integers $1, 2, 3, \ldots, N^2$ and the sum of each row and column must be equal.)

The magic square is stored in RAM at the address in R1. The number of rows/columns in the array is in R2. Your program should store the result in R0 as follows:

- 0 if the 2D array is not a semimagic square or
- 1 if the 2D array is a semimagic square.

(b) **[10 marks]** Extend your program from part (a) to determine whether the 2D array is a *magic square* [1]. In addition to satisfying the properties of a semimagic square, the sum of the elements in each of the two major diagonals of a magic square must be equal.

The following is an example of an $N \times N$ magic square where the rows, columns and major diagonals all sum to 15.

8	1	6
3	5	7
4	9	2

Your program should now return:

- 0 if the 2D array is not a semimagic square,
- 1 if the 2D array is a semimagic square that is not also magic,
- 2 if the 2D array is a magic square.

(c) **[30 marks]** Further extend your program from part (b) to determine whether the 2D array is an *associative magic square* [3]. An *associative magic square* is a magic square (according to the definition in parts (a) and (b) above) in which pairs of numbers that are symmetrically opposite the centre of the square sum to N^2+1. In the figure below, pairs of symmetrically opposite numbers are given the same label A, B, C, ... M.

A	B	C	D	E
F	G	H	I	J
K	L	M	L	K
J	I	H	G	F
E	D	C	B	A

The following is an example of an associative magic square:

17	24	1	8	15
23	5	7	14	16
4	6	13	20	22
10	12	19	21	3
11	18	25	2	9

Your program should now return:

- 0 if the 2D array is not a semimagic square,
- 1 if the 2D array is a semimagic square that is not also magic,
- 2 if the 2D array is a magic square,
- 3 if the 2D array is an associative magic square.

References

[1] https://mathworld.wolfram.com/MagicSquare.html

[2] https://mathworld.wolfram.com/SemimagicSquare.html

[3] https://mathworld.wolfram.com/AssociativeMagicSquare.html