Computer Architectures
Exam of 28.02.2024 – part II

Question 1

A maze is saved in a NUM_ROW * NUM_COL matrix of bytes. The character ‘X’ indicates a wall, and the space indicates a passage. It is guaranteed that all the borders of the maze are walls. The entrance is represented with ‘e’ and the exit with the integer number 0.

Example: a maze matrix with NUM_ROW = 9 and NUM_COL = 8 is shown below:

X	X	X	X	X	X	X	X
X	0						X
X		X	X	X	X		X
X							X
X	X		X		X	X	X
X			X			e	X
X		X	X		X	X	X
X							X
X	X	X	X	X	X	X	X

Write the `shortestPath` subroutine in ARM assembly language to find the shortest path from the entrance to the exit. The subroutine receives the following parameters (in the order indicated):

- number of rows
- number of columns
- address of the *maze* matrix

The subroutine scans all the cells of the maze: if a passage is connected to the exit (i.e, it is at its right, left, top or bottom), then the content of the cell becomes the integer value 1. The loop is repeated: this time all neighbors of a cell with the value 1 assume the value 2. The loop is repeated again: it stops when the entrance becomes connected to a cell with an integer value.

Example: Iteration 1

X	X	X	X	X	X	X	X
X	0	1					X
X	1	X	X	X	X		X
X							X
X	X		X		X	X	X
X			X			e	X
X		X	X		X	X	X
X							X
X	X	X	X	X	X	X	X

Iteration 2

X	X	X	X	X	X	X	X
X	0	1	2				X
X	1	X	X	X	X		X
X	2						X
X	X		X		X	X	X
X			X			e	X
X		X	X		X	X	X
X							X
X	X	X	X	X	X	X	X

Iteration 3

X	X	X	X	X	X	X	X
X	0	1	2	3			X
X	1	X	X	X	X		X
X	2	3					X
X	X		X		X	X	X
X			X			e	X
X		X	X		X	X	X
X							X
X	X	X	X	X	X	X	X

Iteration 4

X	X	X	X	X	X	X	X
X	0	1	2	3	4		X
X	1	X	X	X	X		X
X	2	3	4				X
X	X	4	X		X	X	X
X			X			e	X
X		X	X		X	X	X
X							X
X	X	X	X	X	X	X	X

Iteration 5

X	X	X	X	X	X	X	X
X	0	1	2	3	4	5	X
X	1	X	X	X	X		X
X	2	3	4	5			X
X	X	4	X		X	X	X
X		5	X			e	X
X		X	X		X	X	X
X							X
X	X	X	X	X	X	X	X

…

Iteration 8

X	X	X	X	X	X	X	X
X	0	1	2	3	4	5	X
X	1	X	X	X	X	6	X
X	2	3	4	5	6	7	X
X	X	4	X	6	X	X	X
X	6	5	X	7	8	e	X
X	7	X	X	8	X	X	X
X	8						X
X	X	X	X	X	X	X	X

The procedure returns the length of the shortest path, i.e., the number of iterations executed. In the example, the return value is 8.

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Question 2

The following matrix of chars is declared in C:

```
char maze[9][8] = {"XXXXXXXX",
                   {'X', 0, ' ', ' ', ' ', ' ', ' ', 'X'},
                   "X XXXX X",
                   "X      X",
                   "XX X XXX",
                   "X  X  eX",
                   "X XX XXX",
                   "X      X",
                   "XXXXXXXX"};
```

Pass this matrix to the `shortestPath` subroutine to find the shortest path in the maze.

Then, show the sequence of movements to arrive to the exit using the leds. In details, you start from the entrance (represented with 'e') and look for the cell *x* containing the value *k* returned by the `shortestPath` subroutine:

- if *x* is at the right of the entrance, switch on led 4
- if *x* is at the bottom of the entrance, switch on led 5
- if *x* is at the left of the entrance, switch on led 6
- if *x* is at the top of the entrance, switch on led 7

Then, you look for the cell containing the value $k - 1$ and switch on the corresponding led. The loop continues as long as $k >= 0$.

In the example, the sequence of leds are: led 6, led 6, led 7, led 7, led 6, led 6, led 6, led 7, led 7.

Each led remains lit for 0.5 s. Then, you have to wait 0.5 s before switching on the next led.

(Suggestion: you need a timer generate interrupts every 0.5 s.)