

## Homework Assignment

### 3 Cellulitis

A *cellular automaton* consists of a grid of cells, each containing a symbol from a finite set of symbols. The content of the whole grid, called a generation, changes in one step, according to some rules.

The automata we consider in this assignment satisfy the following requirements.

1. The rules use only the current generation to compute the next one.
2. The rules are the same for each cell.
3. The grid is a single row of cells (so no rectangular grid as in the Game of Life).
4. The new value of a cell is based on the value of the direct neighbours (1 for a cell at the end of the row and 2 for the others) and of the cell itself; this set of cells is referred to as the *neighborhood* of the cell.
5. a cell can have only two values. it is either *occupied* or *empty*

The assignment is to implement two automata and an universal automaton. The description concerning the universal automaton can be found at the end of this text.

The number of cells in the row is specified in the input, as well as the initial configuration and which automaton has to be executed.

Your program should display the consecutive generation of the automaton, each generation is displayed as one line of output. An occupied cell is displayed as a star `*` and an empty cell as a space. The number of generations to be displayed is read from input.

Your program has to implement two automata defined by the following two rule sets.

#### A

1. if the cell is currently occupied, it remains occupied only if exactly one neighbour is occupied;
2. if the cell is currently empty, it remains empty only if both neighbours are empty.

#### B

1. if the cell is currently occupied, it remains occupied only if the right neighbour is empty;
2. if the cell is currently empty, it becomes occupied if exactly one neighbour is occupied.

### 3.1 Implementation requirements

The row of cells should be implemented an array of booleans, where `true` represents an occupied cell and `false` represents an empty cell.

## 3.2 Implementation and development suggestions

It may be convenient to have on both ends of the array an extra element that is always `false`. This way, every row cell has two neighbours, which simplifies the calculations. Note that in the formulation of the rules above it is already assumed that the outer cells of the row have two neighbours, of which one is empty.

Start with a simple automaton, e.g., one where an occupied cell remains occupied and an empty cell becomes occupied if one or both of the neighbour cells is occupied.

To calculate the next generation, you will probably need an extra array to store the new values. When the calculation is finished and Note that an array assignment such as `row1 = row2` does not copy all the values of `row2` into `row1`. It only makes `row1` refer to the space where the elements of `row2` are stored. In fact only the internal name of the array is copied.

The initial configuration is a sequence of integers followed by the word `*init_end*` (see below). The number of integers is not specified. You may use here the expression `scanner.hasNextInt()`, that is `true` if the next word on input is an integer and `false` if the next word is not an integer or there is no next word (in the case of keyboard input, the latter will never hold).

## 3.3 Input

1. the letter A, B, or U, signifying the automaton that should be executed: A and B are defined above and U stands for the universal automaton that is defined below.
2. a positive integer  $L$  representing the length of the row of cells (not counting the extra border cells you may add in your implementation);
3. a positive number  $G$  representing the number of generations that should be displayed, including the initial generation;
4. the word `*init_start*` followed by one or more positive integers, followed by the word `*init_end*`; the integers designate the position of the cells in the row that are initially occupied; the first cell in the row has position 1. All cells not specified are initially empty. When an integer is higher than the number of cells  $L$ , it should be ignored.
5. in the case of the universal automaton: 8 numbers (0 or 1), representing the rule sequence (see below).

## 3.4 Output

A sequence of  $G$  lines ( $G$  defined above) representing the successive generations. The first line is the initial generation, as specified in the input.

Each line consists of  $L$  characters, each character represents one cell. An empty cell is displayed as a space, an occupied cell as the character `*`.

Newlines are not significant in the input. In other words, don't use `scanner.nextLine()`.

### Example 1

#### Input

```
A 11 10
init_start 6 init_end
```

#### Output

```
  *
 * *
 * * *
 * * * *
 * * * * *
* * * * * *
 * * * * *
 * * * * * *
  * * * * *
 * * * * * *
```

### Example 2

#### Input

```
B 61 20
init_start 20 40 init_end
```

#### Output

```
          *          *
        ***          ***
      *  **        *  **
    ***** **    ***** **
  *   *  **      *   *  **
 ***** ***** ** ***** **
 *  *      *  **  *  **
***** ** ***** ** ***** **
 *      ***  *  ** *  ** *  **
***  *  ** ***** ** ***** *  ** ***** **
 *  ** ***** *  *  ** ***** *  **
***** *  *  ** ***** ** *  ** ***** **
 *  *  **  ** ***** *  *  ** *  ** ***** *  **
*** ** ***** ** ** ** *  ** ***** ** ***** **
 *  *  ***  *  ***** ** *  *  ** *  ** *  **
***** ** ***** *  *  ** ***** *  ** ***** **
```

```

      *           ***      * ***** * * * *      * *****   ***      *   **
    ***      *   **   **                * *   * **   **      ***   ** ***** **
  *   **   ***** ** **                ** *****   ** **   *   *** *      *   **
***** ** *   *   **   * *           *** *   *****   * **   ***** **

```

## Universal automaton

Besides executing two specific automata, your program should be able to implement any automaton. This will be achieved by reading the rules of the automaton from input. These rules are described in a compact format which is given below.

Remember that the next state of a cell depends only on the current state of the three cells in the neighbourhood cells: its left neighbour, the cell itself and its right neighbour. There are 8 such state combinations, called *patterns*. We give them in the following table. 1 means occupied, 0 means empty. For cells at the ends of the row, the missing neighbour is considered to have the value 0.

- pattern 0: 000 (all three cells are empty)
- pattern 1: 001 (right neighbour is occupied, other two cells are empty)
- pattern 2: 010 (etc.)
- pattern 3: 011
- pattern 4: 100
- pattern 5: 101
- pattern 6: 110
- pattern 7: 111

For each pattern, we give the value of the cell in the next generation. So we have 8 rules that completely define the behaviour of the automaton. What is needed on input are only these 8 values (0 or 1, where again 0 represents empty and 1 represents occupied), given in the order of the patterns of the table above. We call these 8 values the *rule sequence*.

So what the automaton should do for each cell is the following. If the neighbourhood pattern of a cell in the current generation is found at number  $n$ , give value number  $n$  of the rule sequence to the cell in the next generation. Numbering of the rule sequence starts at 0.

### Example of a rule sequence

Suppose the rule sequence is 0 1 0 1 1 1 0. The automaton will then behave as follows. An empty cell with empty neighbours stays empty, since the neighbourhood 000 is the first entry in the table and 0 is the first value in the rule sequence. An empty cell with an empty left neighbour and an occupied right neighbour will change to occupied, since 001 is the second entry in the table and 1 is the second number in the rule sequence. Etc.

More concisely:

1. if a cell's both neighbours are empty, the cell will become (or stay) empty;
2. if a cell is occupied and so are both neighbours, the cell will become empty;
3. in all other cases, the cell will become (or stay) occupied.

## Hints

To see which pattern applies for a cell, a sequence of 8 if-statements could be used. However, the numbering of the patterns is chosen in such a way that the number of the pattern can also be *calculated* in a much shorter piece of Java.

## Example of the universal automaton

### Input

```
U 11 5
init_start 5 init_end
0 1 0 1 1 1 1 0
```

### Output

```
  *
 * *
* * *
* * * *
* * * * *
```