ASSIGNMENT-2

(Part-1)

CELL DEVS

SYSC 5104. METHODOLOGIES FOR DISCRETE EVENT MODELLING AND SIMULATION

OPENING AND CLOSING IMAGE MORPHOLOGY USING CELL-DEVS

By: HARKISHAN SOHANPAL(101026577)

&

RAJ CHUNARA(101024657)

Part 1

General Idea

In this assignment we are planning to implement Morphological image processing methods using Cell DEVS. We are emulating two processes of Morphology namely Opening and Closing Morphology.

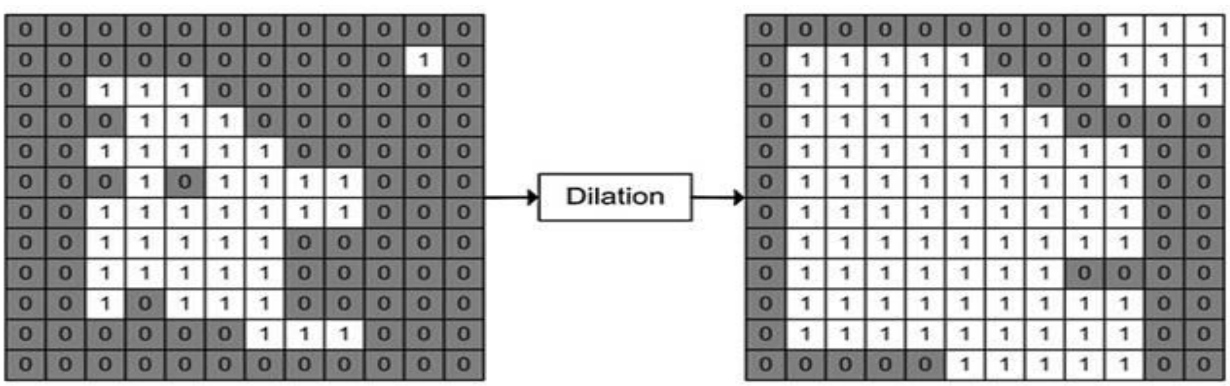
Morphology operates like the other neighbourhood processing methods by applying a kernel to each pixel in the input. In morphology, the kernel is denoted a structuring element and contains '0's and '1's. We can design the structuring element as we please, but normally the pattern of '1's form a box or a disk.

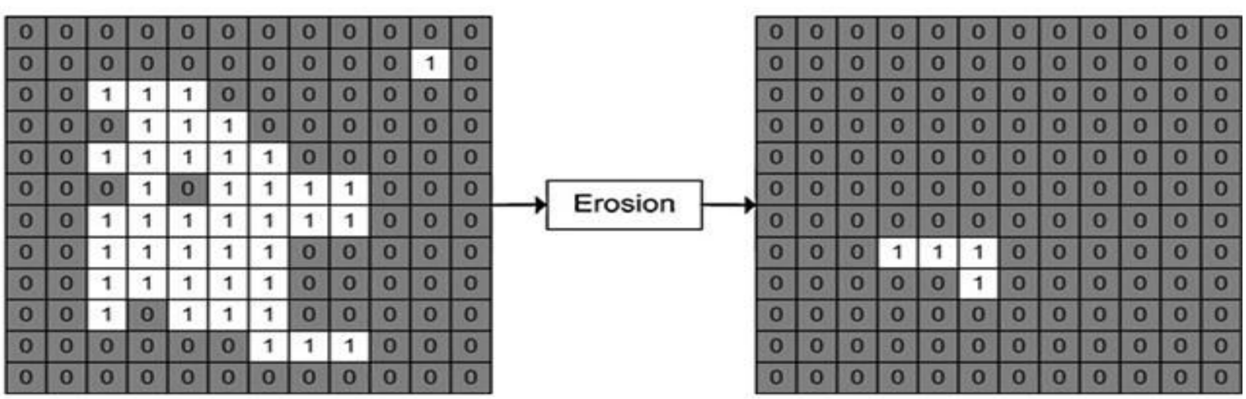
The process of Opening is erosion of image followed by dilation of the same image. The process of closing is dilation on the image followed by erosion on the same. Erosion and Dilation are also a part of morphological Image processing. In order to implement opening and closing operation we need to first implement the erosion and dilation filtering methods. These methods use binary representation of the data.

Erosion filtering is done on an image by taking a structure element which tests for adjacent cells (pixels) for a value of 1 to make the center cell of structuring element value as 0 and similarly the dilation filter checks the adjacent cells to make the center cell of structuring element value as 1.

We can see that it can be represented using the Cell DEVS formalism and Cellular Automata can be used to emulate the behaviour of these filters.

The following 2 figures show the effect of dilation filter and erosion filter on a binary image.

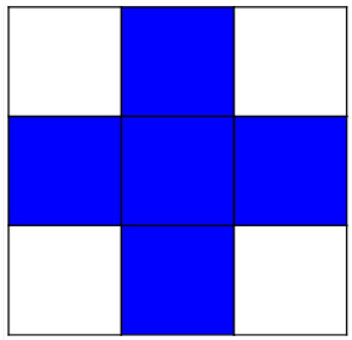




Part 2

We have assumed to analyze the image in binary format in CELL DEVS. After analyzing we devised algorithms for erosion and dilation which further can be implemented for opening and closing morphology.

Neighborhood
We have considered 5 neighborhoods as for most filters it simple application of a 4 connected window for filtering the image.The same window has been used for all the 4 implemented filters.



4 connected filtering window

Algorithm

1. **Erosion**

   Erosion is a process of disconnecting the connected components of an image depending on the window size.

In our algorithm we check neighbors of the center cell. If any of the neighbors of the center cell is greater than zero and the center cell itself is 1, we make the value of center cell zero. The rules look as follows:

[erosion-rule]

```
rule : 2 100 { (0,0) = 1 and trueCount = 5 }
rule : 2 100 { (0,0) = 2 }
rule : 0 100 { t }
```

2. **Dilation**

Dilation is the process of connecting the disconnected components depending on the window size.

In our algorithm we check neighbors of the center cell. If any of the neighbors of the center cell is greater than zero and center cell is zero. We make the center cell as one. The rule looks like as follows:

[dilation-rule]
rule : 1 100 { (0,0) = 0 and trueCount >= 1 }
rule : 1 100 { (0,0) = 1 and trueCount >= 1 }
rule : 0 100 { t }

3. **Opening**

Opening morphology is a process of erosion of image followed by dilation. It embolden separate parts of image.

In our algorithm we used the rules of erosion and dilation in the order defined as follows:

```
[opening-rule]
rule : 2 100 { (0,0) = 1 and trueCount = 5 }
rule : 3 100 { (0,0) = 0 and (-1,0)=2 }
rule : 3 100 { (0,0) = 0 and (0,-1)=2 }
rule : 3 100 { (0,0) = 0 and (0,1)= 2 }
rule : 3 100 { (0,0) = 0 and (1,0)= 2 }
rule : 3 100 { (0,0) = 2 }
rule : 3 100 { (0,0) = 3 }
rule : 3 100 { t }
```

4. **Closing**

Closing morphology is a process of dilation followed by erosion. It is used to embolden the connected parts of image.

In our algorithm we used the rules of dilation and erosion in the order defined as follows:

```
[closing-rule]
rule : 2 100 { (0,0) = 0 and (-1,0)=1 }
rule : 2 100 { (0,0) = 0 and (0,-1)=1 }
rule : 2 100 { (0,0) = 0 and (0,1)= 1 }
rule : 2 100 { (0,0) = 0 and (1,0)= 1 }
rule : 2 100 { (0,0) = 1 }
rule : 0 100 { (0,0) = 2 and (1,0)= 0 }
rule : 0 100 { (0,0) = 2 and (0,1)= 0 }
rule : 0 100 { (0,0) = 2 and (-1,0)= 0 }
rule : 0 100 { (0,0) = 2 and (0,-1)= 0 }
rule : 3 100 { (0,0) = 2 }
rule : 3 100 { (0,0) = 3 }
rule : 0 100 { t }
```

DEVS Formalism

External Coupling Definition

M = < X, Y, D, {Mi}, {Ii}, {Zij}, select>

we have no external coupling function as it is not required for the model.
Atomic Cell Devs Model

CD = < X, Y, I, S, θ, N, d, δint, δext, τ, λ, D >

X
Cell sees its 4 connected neighbor as input to evaluate its next state.

Y
There is no output from a cell. Each cell represents a pixel of image, and it evaluates its future state according to neighbor.

S = {Real}
The possible states of the cell are 0,1,2 and 3.

N = There is no input values for this model.

I = $<n,u,Px, Py > = \{none\}$
θ = (s,phase,σqueue, σ)
The state changed from 0 to 1,1 to 0,1 to 2,2 to 3 after a transport delay.

δint , δext , τ, λ, D = There is no such functions. Please refer to erosion.ma, dilation.ma, opening.ma, closing.ma files for these values.

Couple Cell-DEVS

GCC = < XList, YList, I, X, Y, n, N, {e,f }, C, B, Z, select >

XList = { (m,n,) where m and n belongs to N, 0 <= m <= 8, 0 <= n <= 8}

YList = { none }

I = $<P^x, P^y>$ = {none}

N = { (-1,0), (0,-1), (0,0), (0,1), (1,0)}

X = {none}

Y = {none}

n = 5

e = 8

f = 8

C = $\{ C_{ij} / i \ \varepsilon \ [0,8], j \ \varepsilon \ [0,8]\}$, where $C_{ij} = < I_{ij}, X_{ij}, Y_{ij}, S_{ij}, N_{ij}, d_{ij}, \delta_{intij}, \delta_{extij}, \tau_{ij}, \lambda_{ij}, D_{ij}>$ is an atomic component.

B = {none} (wrapped)

Z = There is no coupling in our case.

Select = there is no priority in this case

All the coupled models follow the same size and neighborhood. The only difference is in the function they evaluate and output they produce.

Testing and Results on Modeler

After defining and compling the rules for the simulation, following results were obtained for each function:

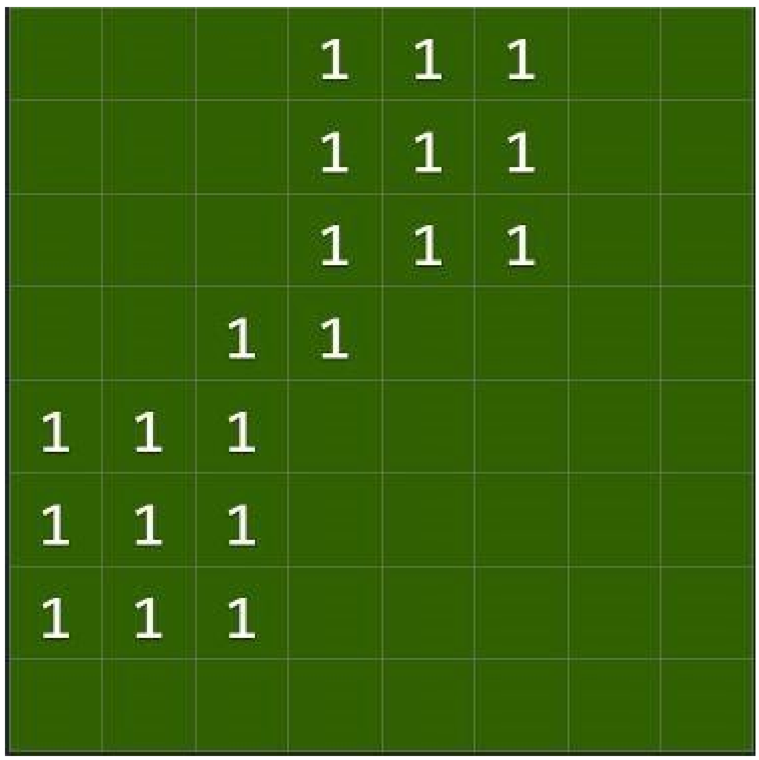


Fig1. Initial State of the erosion function

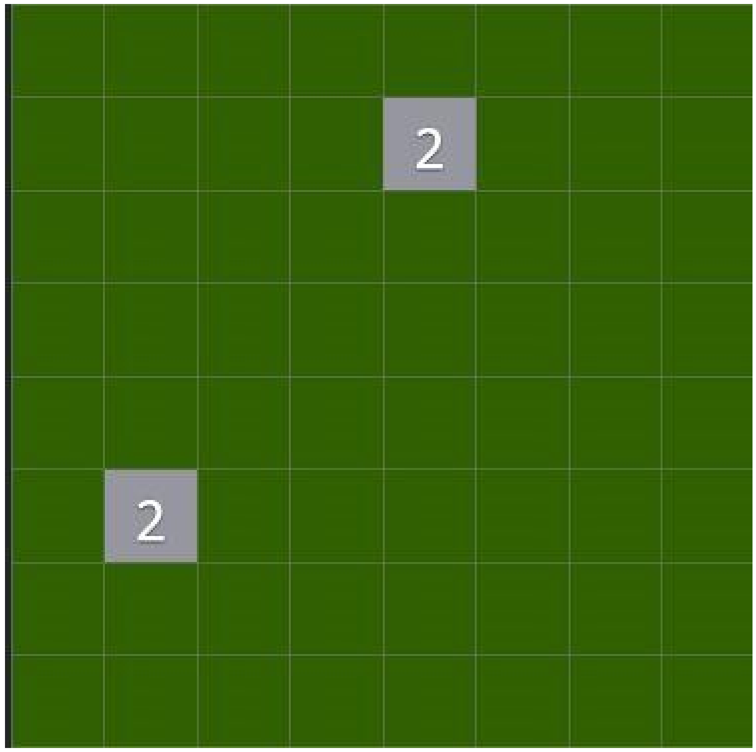


Fig 2. Final state of Erosion Function

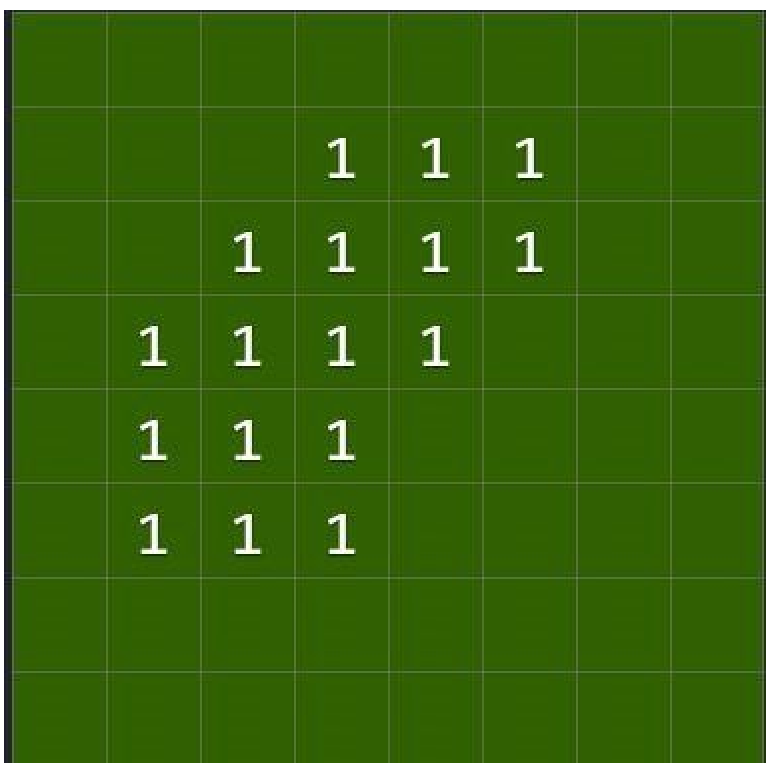


Fig 3. Initial State of dilation

			2	2	2		
		2	2	2	2	2	
	2	2	2	2	2	2	
2	2	2	2	2	2		
2	2	2	2	2			
2	2	2	2	2			
	2	2	2				

Fig 4. Final State of Dilation

			1	1	1		
			1	1	1		
			1	1	1		
		1	1				
1	1	1					
1	1	1					
1	1	1					

Fig 5. Initial State of Closing function

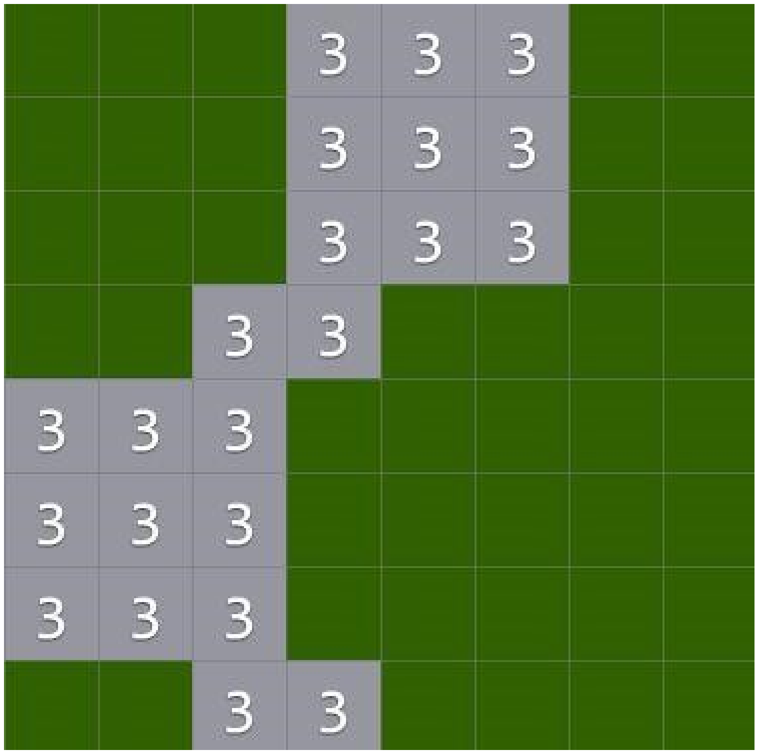


Fig 6. Final State of Closing

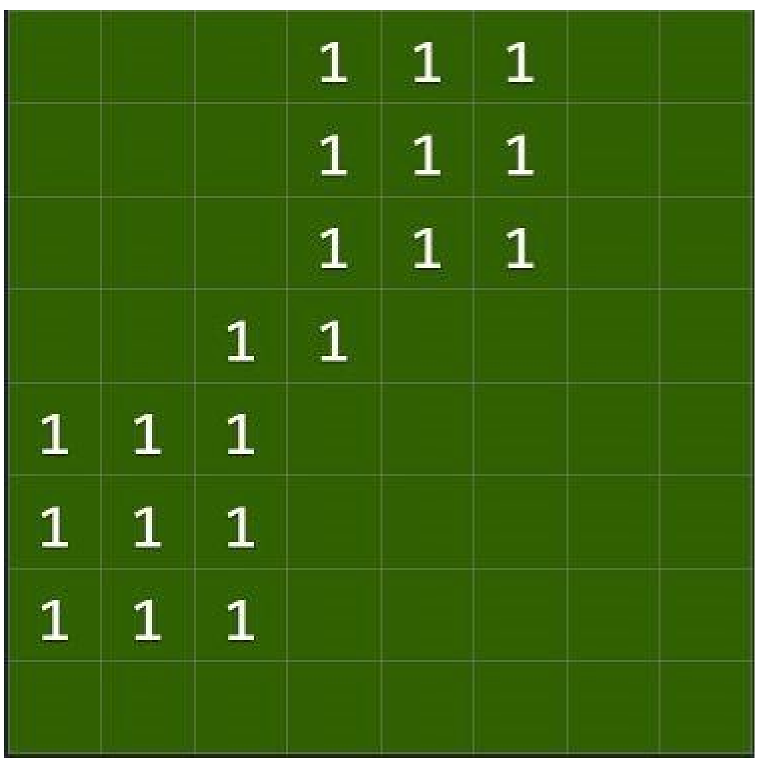


Fig 7. Initial State of Opening

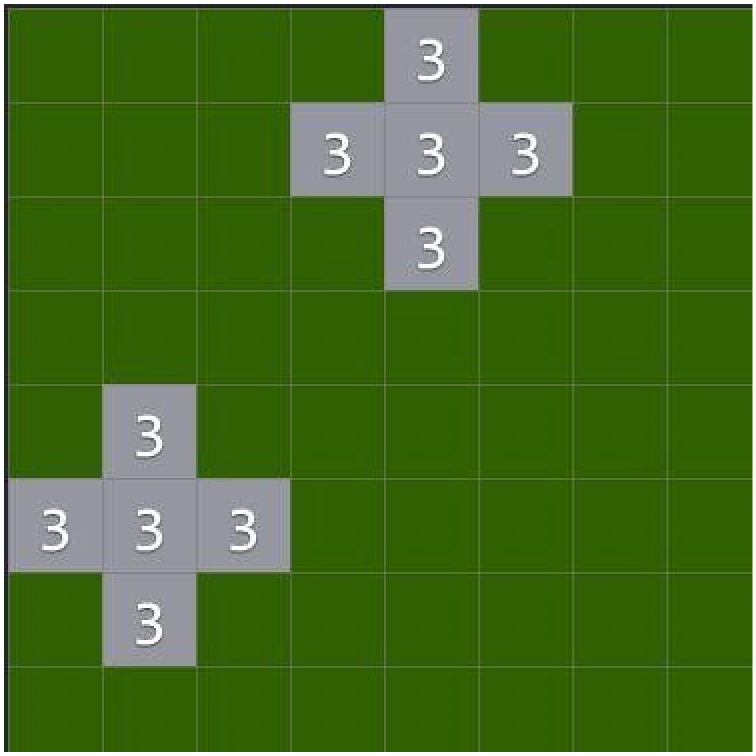


Fig 8. Final State of Closing

Download files

The download files contains the project folder containing the ma files for erosion, dilation, opening and closing.