(SYSC 5104) Methodologies for Discrete Event Modelling and Simulation

Fall-2017

Assignment 2: Truck Movement in Traffic Simulator using Cell-DEVS

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**Part 1:**

Traffic simulations are useful to test traffic policies, traffic signals measuring the consequences of collisions or accidents, controlling pollution, avoiding traffic jams etc. Due to the complex characteristics of these systems, a model reflecting a higher number of features can provide more accurate results. In this case, a truck movement model has been built to test different scenarios and to simulate traffic conditions and impact of truck movements on traffic.

The paper that is selected for this assignment is “Specifying Truck Movement in Traffic Models Using Cell-DEVS”. The paper presents a cellular automata model to simulate truck movement in different traffic conditions. The model is described in the two-dimensional system. The underlying structure is W x W cell grid, where W is the system size. Each cell can either be empty or occupied by exactly one truck. The update is synchronous for all trucks. Each truck can move only one cell per time-step.

In this case, the Von Neumann neighborhood is used (left/right/up/down). In the model, there are two types of movements of trucks including the upward truck movements from the bottom to the upper boundary and the downward movements of truck from the upper to the bottom boundary. The model uses a wrapped boundary.

Since the update is synchronous for all trucks at every time-step, there exist some problems at every time-step. One problem is the route choice for the trucks. Following Figure-1 shows all the possible configurations which the upward truck may encounter.



Figure-1: Different cases of truck behavior

In this model only one cell can be occupied by one truck at a single time-step. This is another problem which is the confliction when more than one truck is going for the same cell. To solve this problem and avoid collision of trucks, the neighborhood is increased from the previously stated Von Neumann neighborhood to a larger neighborhood as shown in Figure-2.

**(-2,-1)**

**(-2,0)**

**(-2,1)**

**(-1,-1)**

**(-1,0)**

**(-1,1)**

**(0,-1)**

**(0,0)**

**(0,1)**

**(1,-1)**

**(1,0)**

**(1,1)**

**(2,-1)**

**(2,0)**

**(2,1)**

**(0,-2)**

**(0,2)**

Figure-2: Neighborhood used in the Model

Rules:

This part defines the behavior of a truck movement. All the rules given below are pseudo code specified for the upward truck. The same logic applies to the downward truck. Also, there are other static vehicles to test different scenarios.

Rule 1: No truck/vehicle ahead, then move forward

If the upper adjacent cell is unoccupied, the upward truck will select it to move into whether his left or right adjacent cells are occupied or not. To avoid two trucks colliding, this rule is extended to: move to the upper adjacent cell if the upper adjacent cell is unoccupied, and the upper adjacent cell to that cell is not a downward truck. This allows the upward truck to move forward one cell if a vehicle lays in the cell two spaces ahead. This rule has the highest priority.

Rule 2: Truck/vehicle ahead and right lane available, then move to the right lane

The upper adjacent cell is occupied by another truck or vehicle, move to the right adjacent cell if that cell is unoccupied and another truck is not going to take that cell in the next time-step. This rule has the 2nd highest priority.

Rule 3: Truck/vehicle ahead and to the right, move to the left lane

The upper and right adjacent cells are occupied by other trucks or vehicles, move to the left adjacent cell if that cell is unoccupied, and another truck is not going to take that cell in the next time-step. This rule has the 3rd highest priority.

Rule 4: Move right if possible if two trucks are going for the same cell

When an upward truck and a downward truck are trying to go to the same cell in the next time-step, both trucks move to the right adjacent cell if that cell is unoccupied, and another truck is not going to take that cell in the next time step to avoid collision. If that cell is occupied or another truck is going to take that cell in the next time step, then don’t move. This rule has the 3rd highest priority.

Rule 5: Default

The truck does not move and wait where it is.

**Part 2:**

**Cell-DEVS Formal Specification:**

**Neighborhood**

Figure 2 is a graphical representation of the neighbourhood. As mentioned, the neighbourhood had been increased from the Von Neumann neighbourhood to the neighbourhood in Figure 2 to avoid collisions. Cell (0,0) represents the core cell where the truck can move to the adjacent cell either north, south, east or west based on the rules specified above.

**M = <Xlist, Ylist, I, X, Y, ƞ, N, {r,c}, C, B, Z, SELECT>**

* Xlist = { Ø };
* Ylist = { Ø };
* I = { Ø };
* X = Y = {0,1,2,3};
  + 0 means unoccupied
  + 1 means upward truck
  + 2 means downward truck
  + 3 means static vehicle
* Ƞ = 17;
* N = {(0,0), (0,1), (0,-1), (1,-1), (1,0), (1,-1), (2,-1), (2,0), (2,-1), (-1,-1), (-1,0), (-1,1), (-2,-1), (-2,0), (-2,1),(0,-2),(0,2)};
* r = 30; c = 30;
* C = {Cij | i ϵ [0,29], j ϵ [0,29]};
* B = {Ø}; % wrapped
* Z = Inverse neighbourhood of N
* SELECT = {(0,0), (1,0), (0,1), (0,-1), (-1,0)};

**Part 3:**

**Simulation and Testing:**

This section will display the testing results. For testing purposes, the grid size was reduced to 8x8 to show specific scenarios. When describing the behaviors of the trucks, the directions mentioned are relative to the direction the truck is facing.

**Rule 1 Testing:**

These tests are carried out to verify that trucks move forward, provided that there are no vehicles or trucks directly in front of them. Figures 3 and 4 demonstrate different scenarios for this rule.

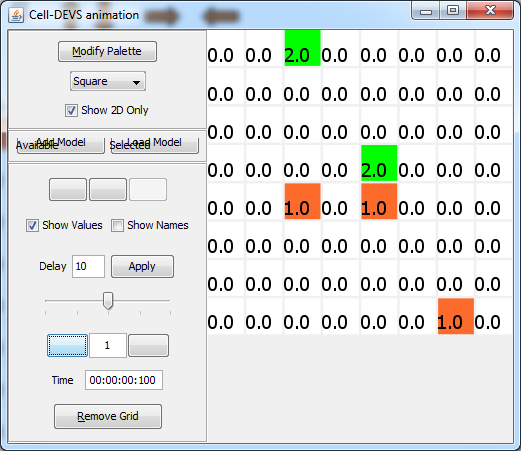
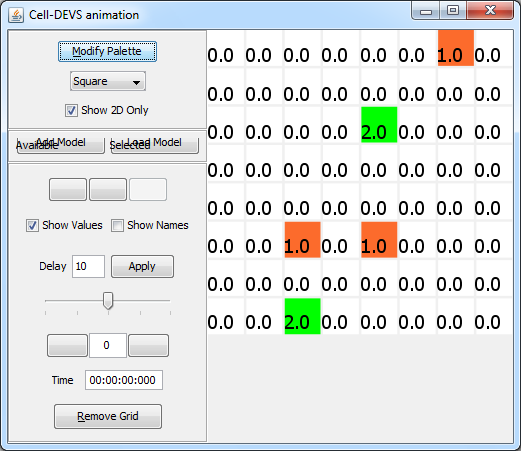


Figure-3: Rule 1 Test 1

Figure 3 displays that since there are no trucks or vehicles directly in front of them (within 2 cells ahead), they move to the cell in front of them. Figure 3 also demonstrates the behavior of the wrapped border (ie. when a downward truck(green) reaches the bottom of the grid, they reappear at the top of the grid).

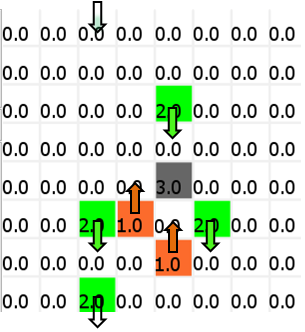
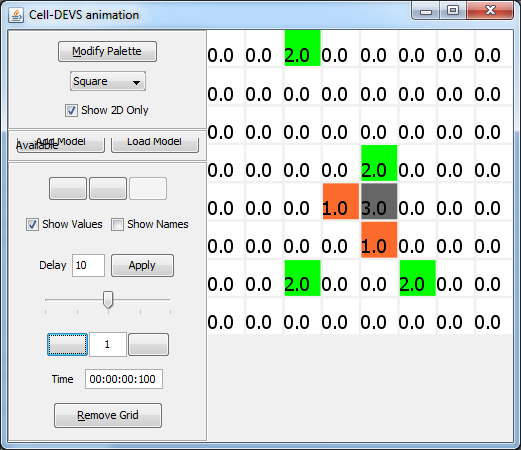


Figure-4: Rule 1 Test 2

As shown in Figure 4 since there are no two trucks going for the same cell in the next time-step, they move forward even though there are vehicles or trucks of the same type two cells ahead. This is as expected and no collisions result. Over the course of the simulation, the rule functions very well.

**Rule 2 Testing:**

These tests are carried out to verify that when a truck has a vehicle or truck directly in front of them, they move to the right lane if it is possible. Figures 5 and 6 demonstrate different scenarios for this rule.

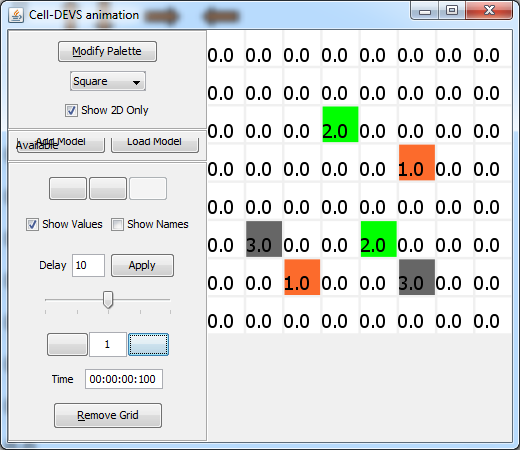
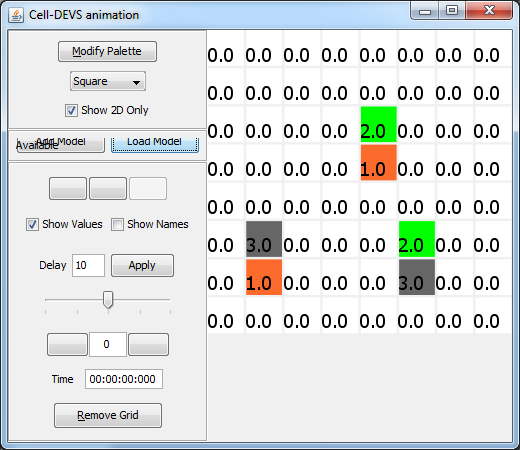


Figure-5: Rule 2 Test 1

As seen in Figure 5, the trucks move right when they are blocked by either another truck or vehicle directly ahead of them.

Figure 6 demonstrates a more complex test for this rule. In the scenario on the bottom left of the figure, the orange cell (upward truck) has another truck in front of it. However, since the downward truck (green) will be going to the right of the orange cell in the next time-step, the orange cell waits because the downward truck has the right of way. Another collision is avoided.

Similarly, in the upper scenario on Figure 6, the green (downward truck) cell has a truck in front of it, and an opening to its right. However, since the upward truck has precedence and will take that cell in the next time-step, it waits.

Finally, even though there are two vehicles NE, and SE of the other orange cell, they pose no threat to a collision in the next time step, so the upward truck moves right, in between them.

Over the course of the simulation this rule behaves accurately.

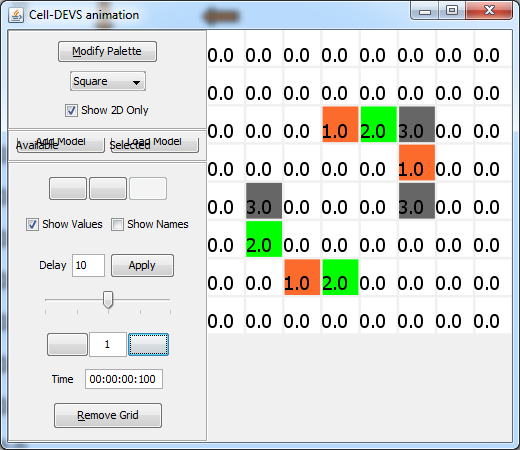
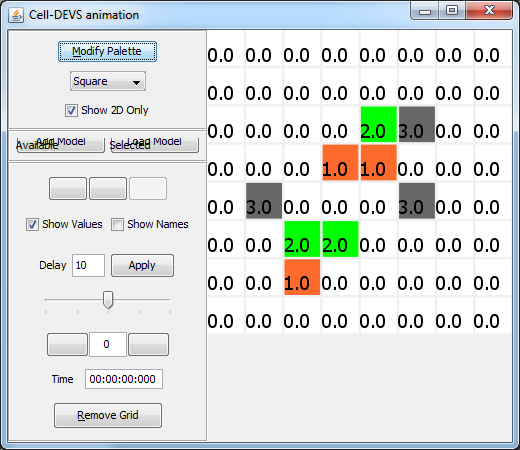


Figure-6: Rule 2 Test 2

**Rule 3 Testing:**

These tests are carried out to verify that when a truck has a vehicle or truck directly in front and to the right of them, they move to the left lane if it is possible. Figures 7 and 8 demonstrate different scenarios for this rule.

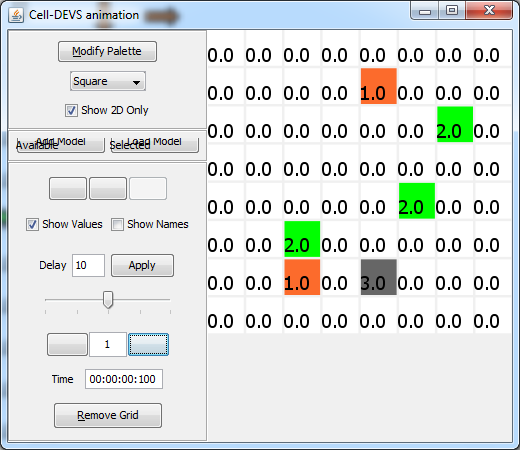
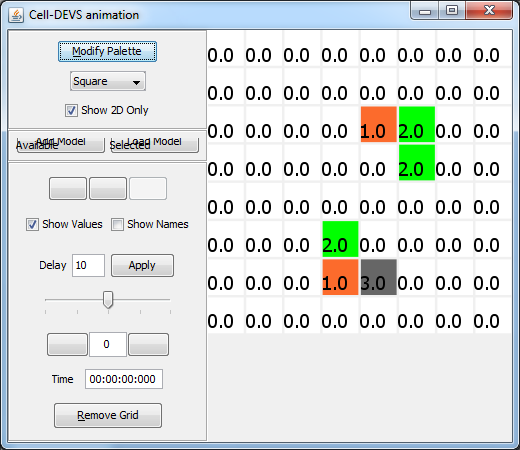
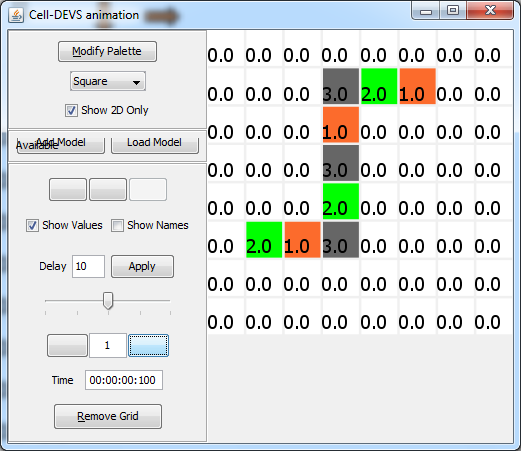
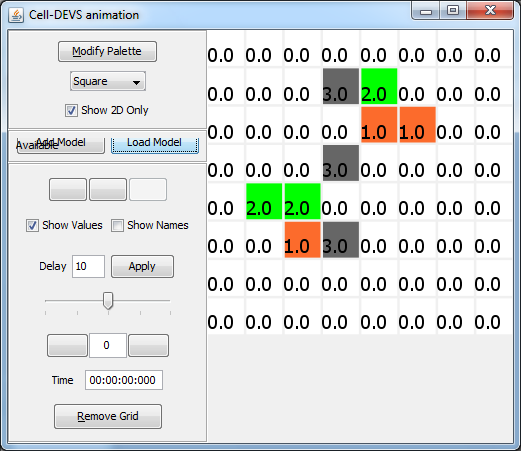


Figure-7: Rule 3 Test 1

As seen in Figure 7, the trucks that have vehicles and/or trucks in front of them, and to their right, move to the left when the left cell is available and not going to be taken by another truck in the next time-step.

Figure 8 shows a more complex scenario for this rule. In the bottom left scenario of the figure it shows both an upward truck (orange) and a downward truck (green) with vehicles / trucks in front of them and to their right. The orange cell does have the left cell available, but it also has to check if there will be another truck going for that cell as well in the next-time step. In this case a downward truck will be going for it, so the orange cell will wait since the downward truck has priority. The green cell has two vehicles in the cells NE, and SE of it and the left cell proportional to it is available. Since these obstacles pose no threat of collision in the next time step, the downward truck is able to move left. The upper scenario behaves the same way except with the roles reversed. Over the course of the simulation this rule behaves as expected.



**Figure-8: Rule 3 Test 2**

**Rule 4 Testing:**

These tests are carried out to verify that trucks that are going for the same cell in the next-time step move right if it is possible to avoid collisions. Figures 9 and 10 demonstrate different scenarios for this rule.

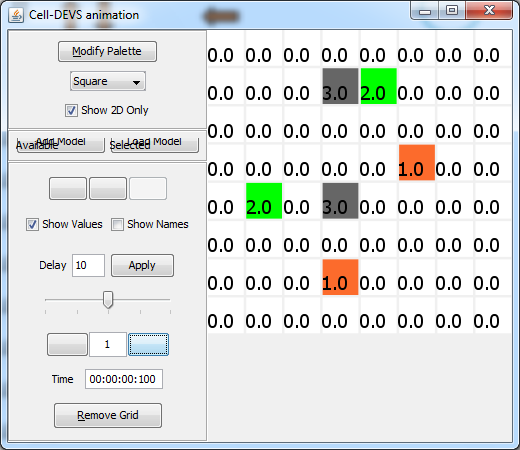
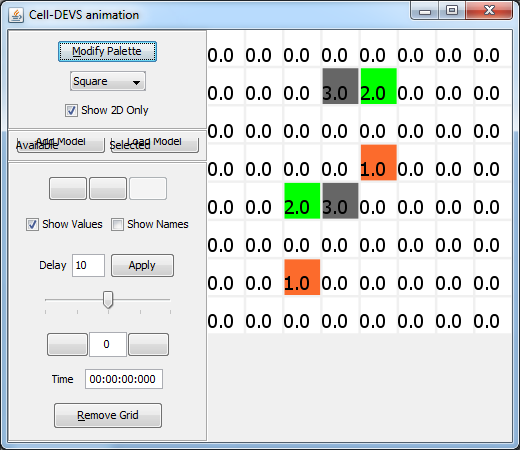


Figure-9: Rule 4 Test 1

Figure 9 shows two different scenarios. The first scenario involves two trucks that have empty cells in front of them, but if they both move forward, there will be a collision. In the bottom left of the figure it shows that the cells to the right of the trucks are available, so they move right to avoid collision. In the upper portion of the figure the downward truck (green) has a vehicle to the right so it waits and stays where it is.

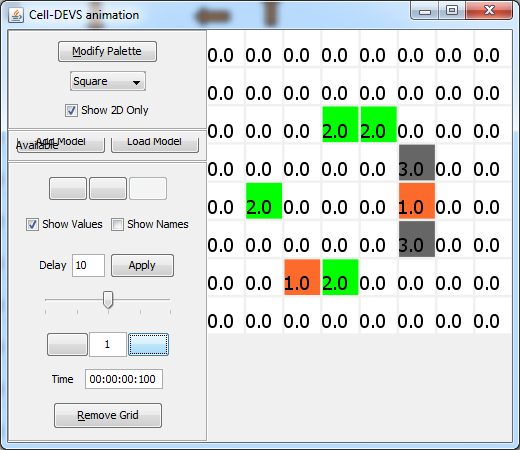
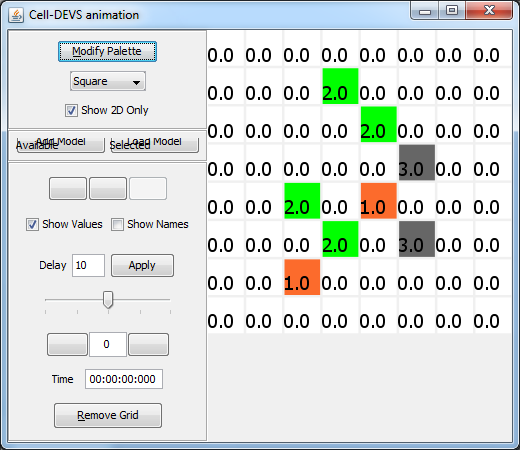


Figure-10: Rule 4 Test 2

In the lower scenario on Figure 10, the downward truck (green) with a potential collision has an available cell to the right with no one fighting for it, so it moves there in the next time step. However, the upward truck (orange) has an available cell to its right, but a downward truck in its NE cell that will move to its right cell in the next-time step. As observed, to avoid collisions, the orange cell waits, and does not move right.

In the upper scenario on Figure 10, the upward truck has vehicles to its NE and SE cell. Since these vehicles pose no threat of collision in the next-time step, the upward truck is able to move to the right cell. The downward truck has an available right side, but since it knows that its fellow downward truck is going to take that cell in the next time step, it waits to avoid collisions.

Over the course of the simulation this rule behaves as expected.

**Rule 5 Testing:**

This test is carried out to verify the default case that when none of the other rules apply, the truck does nothing and waits where they are. This also covers the behaviour for static vehicles.

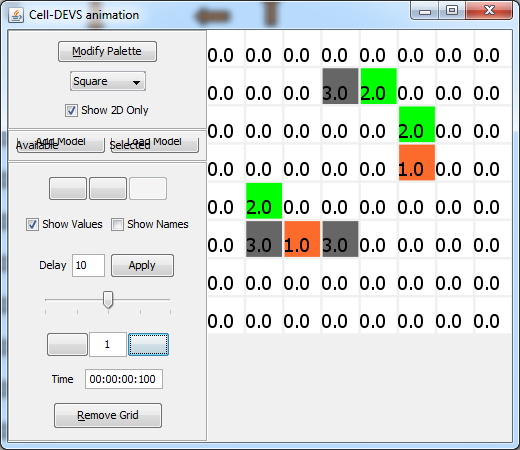
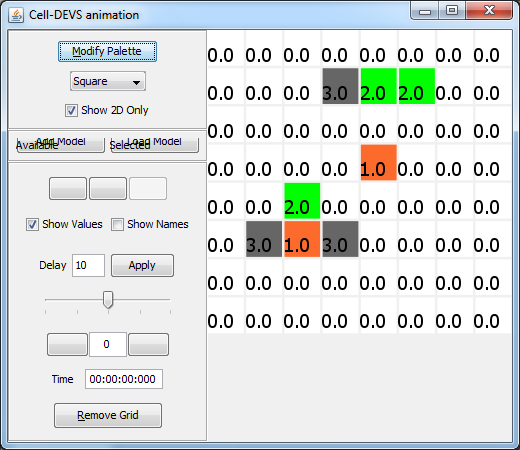


Figure-11: Rule 5 Test 1

The lower scenario on Figure 11 shows an upward truck (orange) who has vehicles / trucks to its right, left, and front adjacent cells. Since none of the other rules apply, the upward truck remains where it is until to coast is clear. The upper scenario demonstrates two trucks that will collide if they both move forward. In this case they move to right lane if possible. The upward truck does just that, but the downward truck has a vehicle to its right, so it waits where it is.

For the purposes of this simulation, the vehicles are meant to be permanently configured to the ground and not moved. This rule provided this. Over the course of the simulation this rule behaves as expected.

**Conclusion:**

The set of rules behaves as expected in this case. Multiple simulations were done and there were no collisions or traffic jams observed. The trucks moved very naturally. Different simulations provided expected results for different case scenarios. Overall the accuracy of the model was satisfactory.

**References:**

[1] Alejandra Davidson, Gabriel Wainer. “Specifying Truck Movement in Traffic Models Using Cell-DEVS”, 2000.

[2] F. Weifeng, Y. Lizhong, F. Weicheng. “Simulation of bi-direction pedestrian movement using a cellular automata model”, 2002.