CARLETON UNIVERSITY

Department of System and Computer Engineering

SYSC 5104

Methodologies For Discrete Event Modelling And Simulation

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Assignment Two

Report

- Background Information and Introduction

This paper introduced their CO_2 dynamic DEVS and Cell-DEVS. DEVS is defined as a math formalization of the system which is independent by using multiple tools and program languages. The paper uses Cell-DEVS model to simulate the diffusion of CO_2 in the apartment.

- Problem definition-Original Model from the Paper

In this paper, they used advanced techniques M&S and DEVS. They proposed two research questions:

1. Is it possible to determine the best CO_2 detector location for most accurate occupancy detection based on room configuration using M&S?
2. What is latency between the arrival/departure of an occupant and detection of change in CO_2 concentration level?

- Experimental Frame-Original Model from the Paper

In the paper, the researchers limited a closed scope 3.5m × 5.75m × 2.5m and set 1-2 occupants, presences of means for which CO_2 to escape and the placement of CO_2 sensors in constant locations. In Figure 1, the original model and inputs are shown. In the model of the paper, it's not clear to figure out whether distances between people will change the CO_2 or not.

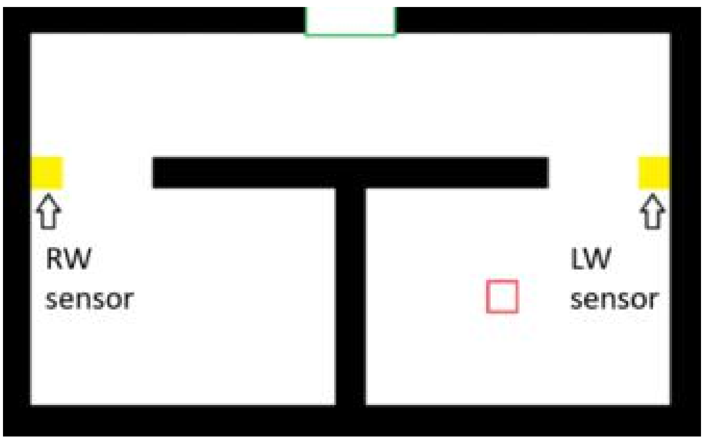

Figure 1. Original Model from the paper

- Conceptual Model-Original Model from the Paper

The researcher represented the closed space as a set of neighboring cells in a 2-dimensional Cell-DEVS model with different CO_2 levels. The system has many models(CO_2 and other gases) which are independent. For preliminary model, they averaged CO_2 levels of all cells in the local neighborhood including the center cell. The rate of diffusion is then controlled explicitly by the delay between each averaging event. The cell space should reflect the size of an average small office space or room. The conceptual model is shown in Figure 2.

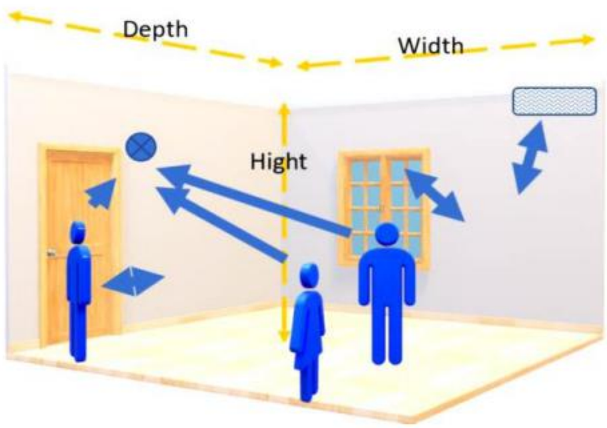

Figure 2. Conceptual Model from the paper

- Formal Model Specification-Original Model from Paper

The model in the paper can be considered as a two dimensional Cell-DEVS model with different CO_2 levels. The system has many models(CO_2 and other gases) which are independent. For preliminary model, they averaged CO_2 levels of all cells in the local neighborhood including the center cell. The rate of diffusion is then controlled explicitly by the delay between each averaging event.The cell space should reflect the size of an average small office space or room.

The **original** two-dimensional Cell-DEVS space of the CO_2 model is:

$\mathbf{CO_2 = < Xlist, Ylist, S, X, Y, \eta, N, \{t1, t2\}, C, B, Z >}$

Where:

Xlist = Ylist = {Ø}

S = *type*: {0, 1, 2, 3, 4, 5}

conc: {double}

X = Y = Ø; η = 5

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

t1 = 14; t2 = 20;

C = {Cij / i∈[0,14] j∈[0,20]}

B = {∅} the set of border cells : unwrapped cell space

Z = translation function, defines the internal and external function.

The cells have 2 distinct state variables: *type* and *conc*. *Type* has six possible numeric values which represent the type of cell. *Conc* is a double value that represents the CO_2 concentration in ppm within a cell. If a cell is impermeable, its *conc* variable is assigned a value of -10. All cells have a default delay of 1000ms except for CO_2 sources which represent human breathing.

The local computing function τ of the atomic model of each cell:

Table 1 Values of τ (N).

τ(N)	**N**
conc=average of neighbors	*type = 0*
conc=neighbors average+12.16ppm	*type = 1*
conc=−*10*	*type = 2*
conc=500 ppm	*type = 3*
conc=400 ppm	*type = 4*
conc=300 ppm	*type = 5*

Table 2 Values of D(S).

D(S)	**S**
*R*0+=1000	*type = 0*
*R*0+=5000	*type = 1*
*R*0+=1000	*type = 2*
*R*0+=1000	*type = 3*
*R*0+=1000	*type = 4*
*R*0+=1000	*type = 5*

- Original Model Results

From the original model, the researcher used Cell-DEVS concepts to get some rules: the change of CO_2 detector locations affected the ability of gasses diffusing in the room. Determining the latency for a sensor to detect significant CO_2 changes is also heavily dependent on the layout of the room.

- Third Step: Model with Change

For the third step, professor mentioned some choices that are related to this assignment:

- Design scenarios for people sitting at various distances. For example: the distance varies for different countries from 1.5 m to 2M. Taiwan is the only country that suggests 1m to 1.2m.

- Implement some mobility inside the rooms

In assignment two, I need to make some changes to the model. In this way, more factors that may be related to the sensor position and the concentration of CO_2 will be discussed and implemented. Meanwhile, the video of the simulation model will be created to show how CO_2 in the room diffused at the specific condition after changes. These two factors above will be discussed by adding changes of the original changes. The detailed changes are introduced below.

- Conceptual Model with Changes

In assignment 2, I put more people in the room and create some mobility in this room. As you can see from the Figure 3, we have two people in one room at the beginning. Then they will move from their room to other room as the time increases. The changes of the model can be concluded as:

- ✧ The distance between the people is 1.25m to 3.25m. They will move with the change of the time. As the distance changes, you can see the the CO_2 concentration level will be influenced as well. This factor will be illustrated by the video in the zip file and discussed in details in model variations part.
- ✧ In the paper, the original model doesn't have mobility in the room. Hence, the people in the room will move after changes.

Figure 3. The beginning situation of the model(After Changes by me)

The scope of the changed room is 20m × 10m. Each cell includes 25cm × 25cm × 25cm liters of air each. In Figure 3, we can see that:

- ✧ The black walls are impermeable walls.
- ✧ The red points represents people in the room.
- ✧ The green points represents the beginning positions of people. After 125 breaths, people in the room will move to positions of blue points.
- ✧ The distance between the green points is 1.25m. This shows the distance between people in the change I made is 1.25m. After people move in the room, the distance will be 3.25m(max). In this way, you can see whether the difference of distances will change the CO_2 diffusion by simulation video.
- ✧ The blue points represents the ventilation system which removes CO_2 and keep the concentration of CO_2 at 300ppm.
- ✧ The yellow point is duct of the room.

- Formal Model Specification with Changes

The **changed** model two-dimensional Cell-DEVS space of the CO_2 model is:

CO_2 = < Xlist, Ylist, S, X, Y, η, N, {t1, t2}, C, B, Z >

Where:

Xlist = Ylist = {Ø}

S = type: {-100, -200, -300, -400, -500, -600, -700,-800, -900, -1000}

Here, there are more types created than original model. The types created in the new model is listed here:

type -100: normal cell representing air with some CO_2 concentration

type -200: CO_2 source, constantly emits a specific CO_2 output

type -300: impermeable structure (Eg: walls, chairs, tables, solid objects)

type -400: doors, fixed at normal indoor background CO_2 level (500 ppm)

type -500: window, fixed at lower CO_2 levels found outside (400 ppm)

type -600: ventilation, actively removing CO_2 (300 ppm)

type -700: CO_2 sensor

type -800: ducts

type -900: movelable people

type -1000: destination

X = Y = Ø;

$\eta = 5$

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

t1 = 14; t2 = 20;

C = {Cij / i∈[0,14] j∈[0,20]}

B = {∅} the set of border cells : unwrapped cell space

Z = translation function, defines the internal and external function.

The local computing function τ of the atomic model of each cell:

Table 3 Values of τ (N).

τ (N)	N
conc = average of neighbors	type = -100
conc = neighbors average+12.66ppm	type = -200
conc = -10	type = -300
conc = 500 ppm	type = -400
conc = 400 ppm	type = -500
conc = 300 ppm	type = -600
conc = 500 ppm	type = -700
conc = average of neighbors	type = -800
conc = neighbors average+12.66ppm	type = -900
conc = average of neighbors	type = -1000

Table 4 Values of D(S).

D(S)	S
R0+=1000	type = -100
R0+=5000	type = -200
R0+=1000	type = -300
R0+=1000	type = -400
R0+=1000	type = -500
R0+=1000	type = -600
R0+=60000	type = -700
R0+=1000	type = -800

R0+=5000	type = -900
R0+=1000	type = -1000

- Rules of the Changed Model:

Type -100 :open-air spaces with constant 500ppm CO_2 level. Diffusion rules for open-air and source cells are performed by averaging the conc values of the center cell with the four neighboring cells. Open-air cells need to check the local neighborhood in case one or more wall/impermeable cells are present. If this is the case, the diffusion computation is adjusted to exclude the unwanted cells from the average calculation. There are 8 cases to consider for an open-air cell: 4 cases when the cell is directly against a wall and not in a corner, and 4 cases of being in a corner where walls meet. If the cell type is -100 and it's neighbors' CO_2 level

Type -200: CO_2 sources with a fixed level of CO_2 added at an interval to mimic breathing (people). Additional 12.16ppm of CO_2 is added every 5 seconds.(additional 2×121.6 ppm of CO_2 in added every 5 seconds in the model)

Type -300: walls that are impermeable and do not allow CO_2 to diffuse through them. Set the CO_2 level to maintain -10

Type -400: doors, fixed at normal indoor background CO_2 level. Set the CO_2 level to maintain 500

Type -500: window, fixed at lower CO_2 levels found outside. Set the CO_2 level to maintain 400

Type -600: ventilation, actively removing CO_2. Set the CO_2 level to maintain 300

Type -800: Ducts, the function is same as type -100

Type -900: moveable people. After 125 breaths. The cell will become a open-air spaces. Between 125 breaths, the function is same as type -200.

Type -1000: the destination of moveable people.

- Results of the changed model

After the changes of the original model, the simulation results are shown Figure 4. The simulation process duration is 6 hours. In the picture:

- ✧ The black walls are impermeable walls.
- ✧ The red points represents people in the room.

- ✧ The green points represents the beginning positions of people.
- ✧ The blue points represents the ventilation system which removes CO_2 and keep the concentration of CO_2 at 300ppm.
- ✧ The yellow point is duct of the room.

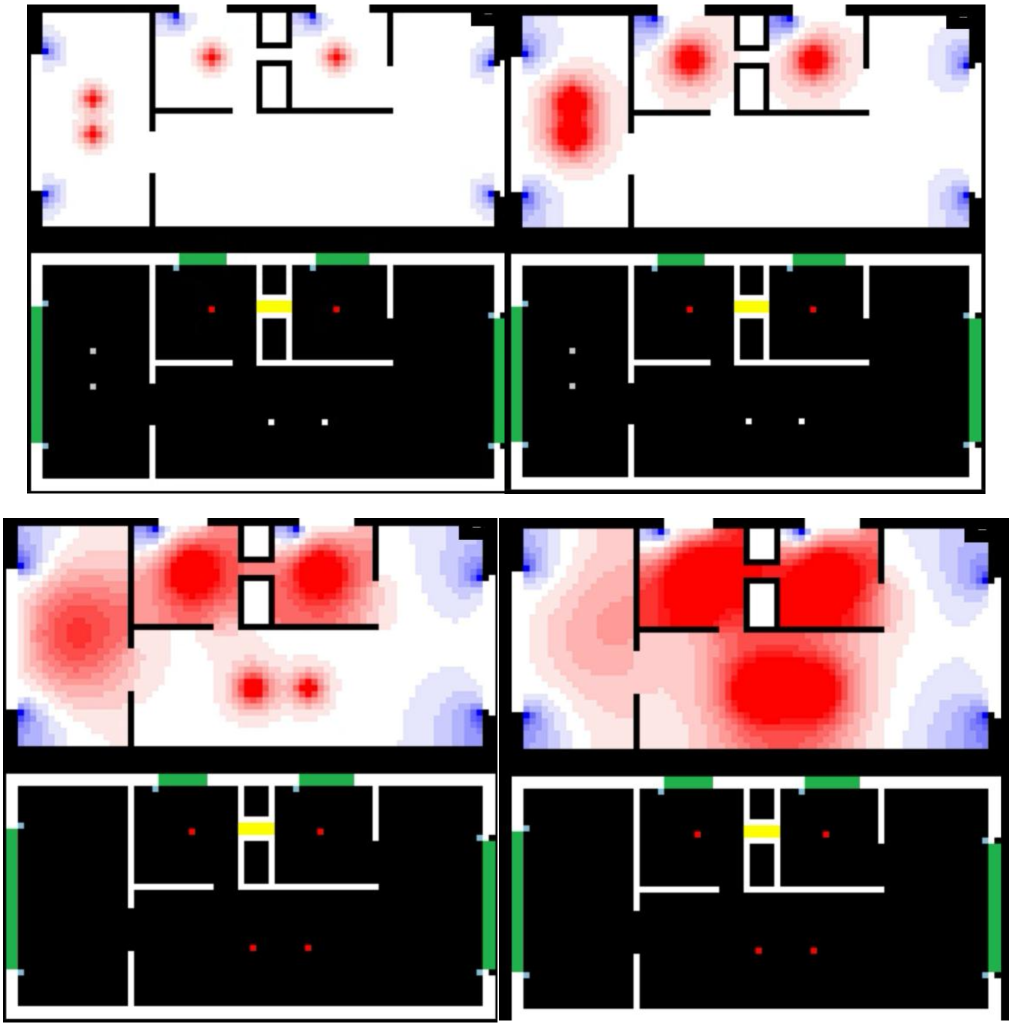

Figure 4. The simulation results

- Model Variations

The whole model is shown in Figure 3. The whole model can show the changes I made including mobility, more people involved in the model and setting of the distance between people. However, it's not clear to see how the distance between people change the CO_2 diffusion. Therefore, I established a model of Figure 6. As you can see, it's a model of the single room with two people at difference distances. The size of each room is 7.5m × 5m.

In this assignment, the variations are the different distances between people in the room. Hence, I changed the input, and then each model variation (M1, M2 and M3) screenshot is shown below. The CO_2 sensor is put in the middle of the room. The whole simulation process is 3 hours duration, I collected data per hour. The color legend for CO_2 levels is listed below.

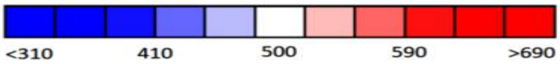

Figure 5. The color legend for CO_2 levels

Figure 6. Sensor displacement

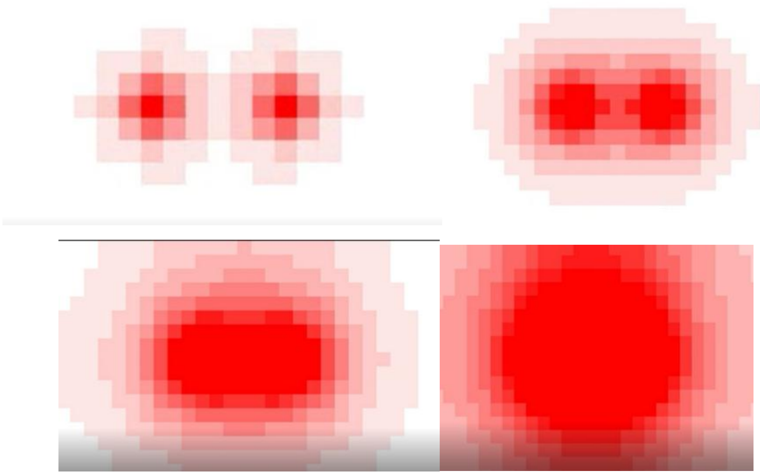

Figure 7. M1-1.25m distance between people

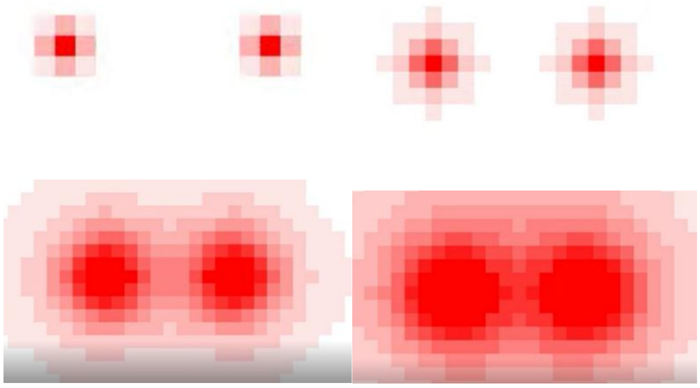

Figure 8. M2-2.25m distance between people

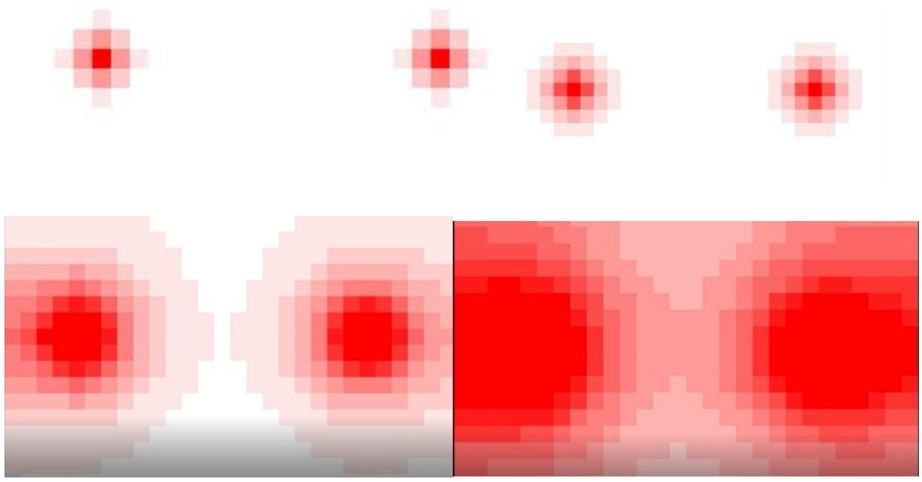

Figure 9. M3-3.25m distance between people

As shown in Figure 7, CO_2 diffusion occurs in all directions, spreading out from the central source cell. CO_2 levels continue to steadily rise over time. The next model variation M2 changes the distance of people. As we can see, the distance of two red points enlarged. The CO_2 concentration levels increased slower than the M1. The simulation of Figure 6 shows the distance of 3.25m between people in the room. The CO_2 concentration levels changed slowly compared to M1 and M2. Therefore, we can conclude that the distance between people will influence the CO_2 concentration levels when people move. The detailed simulation results will be illustrated in next part of the report.

- Simulation Results

In figure 10, the relationship between the distance of people and CO_2 level is shown. As we can see, the blue line represents the distance between people is 1.25m, the orange line represents the distance between people is 2.25m and the gray line is the distance between the people is 3.25m. It's evident that CO_2 level increases as the time increases.

As we can see in Figure 10, These three line has the same tendency. However, if we increases the distance of people, the increasing speed of CO_2 diffusion will decrease. The conclusion is reasonable since we are limited to have at least 2m during COVID 19 in Canada. In this way, the possibility to get COVID 19 will be decreased.

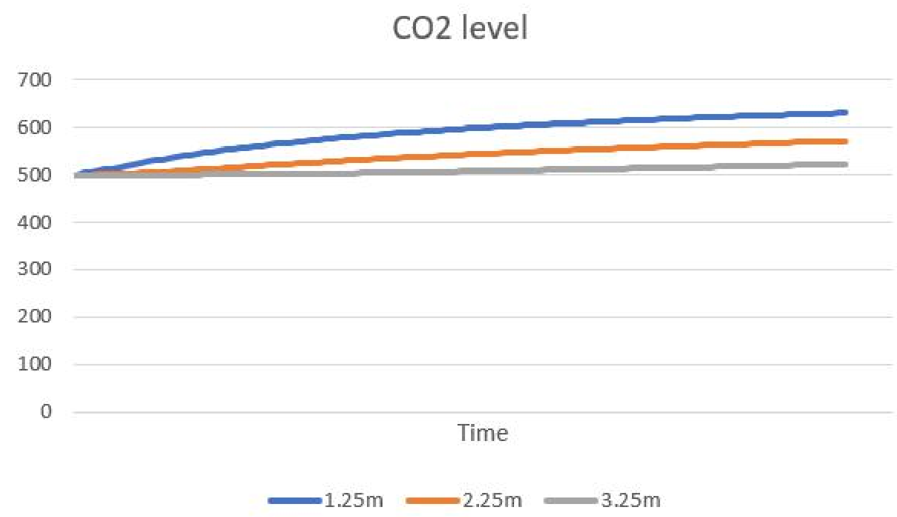

Figure 10. Simulation Results CO_2 Vs. Time plot (x axis: time (minutes) /y-axis: CO2 (ppm))

Acknowledgement

Assignment two includes two parts

- ✧ The summary of the original model and model
- ✧ The changes of the model

These two parts are gathering together in the final report, I made some comparisons of the original and changed model. Hence, some graphs of the summary in Part one might change the turn, but the contents are correct.

During the process of assignment 2, I learned the concept of Cell-DEVS and the process of how to visualize the results of DEVS. Meanwhile, the changes of the model has evident results that distance and mobility of people in the room will influence the CO_2 concentration level.

I got confused about the assignment 2 at first, and I communicates with professor several times. It's a good process for me to learn and improve my hard skills. Sorry for the bothering, it's really helpful and informative. All in all, I did make lots of efforts for this assignment and gained knowledge from it.