**CARLETON UNIVERSITY**

**Department of System and Computer Engineering**

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**SYSC 5104**

**Methodologies For Discrete Event Modelling And Simulation**

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**Summary of CO2 Model - Part I**

1. **Introduction**

In order to reduce energy consumption in daily life, many studies have proposed the demand-driven HVAC control systems. These systems depend on sensers data for indoor occupancy detection. Among these sensors, carbon dioxide sensors are a good choice. Firstly, they do not need other special actions and costs, and secondly, it does not infringe on the privacy of occupants. However, when CO2 sensors detect CO2 levels, there will be a delay. In addition, the change of configuration parameters has a great impact on the accuracy of the sensor. In this study, the authors tried to use modeling and simulation (M&S) to determine the best placement of the CO2 sensors in the room and calculate the delay between the change in the number of occupants and the detection of the change in CO2 levels.

1. **Description**

The research used Cell-DEVS, the combination of Cellular Automata and DEVS, to model the change of CO2 levels in different environments. This is because Cell-DEVS are adaptable to different environment settings in the model and it allows simulation to skip periods of inactivity to save the simulation time.

1. *Basic Experimental Frame*

In this paper, (1) this 2- dimensional Cell-DEVS model has a closed space size 3.5m × 5.7m × 2.5m(width × length × height). Each cell represents 25cm × 25cm × 25cm spaces. Therefore, the model has 14 × 23 × 10 cells; (2) One to two occupants, and the average person produces 19mL carbon dioxide every 5 seconds which corresponds to 12.16 particle per minute(ppm); (3) outlets of model (an open door, a window and a ventilation port). The cells that represent open door, open window and ventilation keep concentration of CO2 at 500 ppm, 400 ppm and 300 ppm respectively; (4) The placement of CO2 sensors are at center of wall.

1. *Formal Model Specification*

The 2-D Cell-DEVS space of the CO2 model is: CO2 = < Xlist, Ylist, S, X, Y, η, N, {t1, t2}, C, B, Z >, where Xlist=Ylist={Ø}; S=type:{open-air, CO2sources, walls, open doors, open windows, ventilation} and conc:{CO2concentration}; 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]}; and B = {∅}. In addition, all cells have 1000ms delay except for cells representing CO2 sources which have additional 12.16 ppm of carbon dioxide added every 5000ms. Open-air cells need to check the local neighborhood to exclude the wall cells.

1. *Simulation Results*

In this paper, authors had 10 model variations. (1) An occupant in a closed space, (2) an occupants in a two cubical room, (3) two occupants in a two cubical room, (4) two occupants in an open-door room, (5) two occupants in a room with a window, (6) two occupants in a room with a vent, (7) two occupants in a room with a door, a window, (8) two occupants in a room with a door, a vent, (9) two occupants in a room with a window, a vent, (10) two occupants in a room with a door, a window and a vent. For the placement of sensor, authors placed one on the right wall and another on the left wall of room with an open door in which has one to two occupants.

From the models above, the simulation results showed that (1)the configuration of environment considerably affects the distribution of CO2 and (2)the latency for a sensor to detect CO2 changes is also influenced by placement of sensor and room.

1. **Conclusion**

In conclusion, although this model is a basic 2-D model which did not consider the height of closed base and did not use precise fluid dynamics methods to determine delay time, it can help us to estimate the number of occupants by using CO2 sensors for the demand-driven systems.

**Part II**

1. **Modification**

Based on the basic CO2 model, I designed a model about CO2 levels of grocery and I added three areas, which are daily use area, foods area and drinks area. Students will go to different areas according to what they want to buy.

The configuration of the model can be seen in Figure 1.

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Fig.1 configuration of grocery

The black area represents the wall (impermeable structure). Two windows are at yellow area. There are 6 vents which are blue, and the door is green. The red part is commodity area. The purple part is foods area. And the grey part is drinks area.

Students come in through the door and go to the area they want to go. Staying there for a random time and then leaving.

1. **Model specification**

CO2 = < Xlist, Ylist, S, X, Y, η, N, {t1, t2}, C, B, Z >

Xlist=Ylist={Ø};

S= type: {AIR=-100, CO2\_SOURCE=-200, IMPERMEABLE\_STRUCTURE=-300, DOOR=-400, WINDOW=-500, VENTILATION=-600, DAILYUSE=-700, FOODS=-800, DRINKS=-900} and conc: {CO2concentration};

X=Y=Ø; η=5; N= {(0,0), (-1, 0), (0, -1), (0, 1), (1, 0)}; t1 = 25; t2 = 30;

C = {Cij/ i∈[0,25] ˄j∈[0,30]}; and B = {∅} (unwrapped).