CS166

Final Project - Crowd Egress

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Simulation Goal

The scenario being simulated in this project is crowd egress. It models how people exit a room when there is an emergency such as a fire and a fire alarm goes off. By running the simulation, I hope to compare how a specific number of exits and specific exit sizes are suitable for different room sizes and a different number of people in the room.

Simulation Parameters and Rules

The simulation is initialized by a randomly generated room, with randomly placed exits and randomly placed people. The size of the room can be specified by the user, so can the number of people in the room, the number of exits, and the size of each exit. The room size and the number of people can be specified to model specific types of rooms a user wishes to model, while the number of exits and the size of each exit determine the performance (how long does it take for people to evacuate) of the model parameters. After the simulation is initialized, it follows the following rules to progress during a single time step.

- For each person, check if they are adjacent to an exit, if they are, then they are removed from the room in the update step.
- For each person, choose an exit to go to based on the Mahalanobis distance to each exit. The distance is calculated by calculating the vertical distance to the edge of the room, and then calculating the horizontal distance to the exit. If there is a person in the vertical route, then add a +1 cost to the distance to compensate for the fact that there is someone in your route. If there is a person in the horizontal route, then add a +1 cost to the distance for the same reason.
    - For the sake of simplicity, the distance to an exit is the distance to its center i.e. if an exit is of size 5 then the center is at the 3rd cell of the exit, and if an

exit of an even size (say, 4) then the center is randomly chosen between the middle cells (3 or 2 in this case).

- For each person, calculate their optimal move in the time step and store it. If you can move straight, then your optimal move is going straight. If there is someone ahead of you, then you try to move horizontally. If there is someone ahead and on your side, you don't move in the time step. Lastly, you do not move horizontally if the exit closest to you is straight ahead of you i.e. you just need to move straight to exit the room.
- If multiple people have the same location as an optimal move, then randomly select one person to move to that location.

Assumptions:

Obviously, the simulation is a simplification of an actual room and how people would react to a fire alarm in real life, but I hope to list most of the key assumptions and simplifications here.

- There are no obstacles in the room such as chairs/pillars/tables etc. Although I could add another cost to the Mahalanobis distance if an obstacle was in the way to make a more realistic model, it would make the results much harder to analyze. Moreover, the goal of the simulation is to see which specific number of exits and exit sizes are suitable for varying room sizes filled with a different number of people.
- People go straight first, and move horizontally only if they can not move straight. In the real world, if a lot of people move towards an exit, people form a clogged 'line' that is almost perpendicular to the exit. However, people in this simulation clog the exit sideways i.e. they form a 'line' that is horizontal to the exit. I believe this parallel

clogging has a similar effect to the perpendicular real life clogging, but it just visually seems odd and unintuitive.

- Only one person moves to a spot if more than one person is moving to the same spot. In the real world, this would result in a collision between people but I found that particularly difficult to model since there is a lot of uncertainty involved. For example, is the collision strong enough to make someone fall down? Or where do people start moving to after a collision occurs? More importantly, people try to avoid collisions and in order to do that, would they sacrifice making the optimal move in a situation with a strong fire? Or will they risk a collision in hopes of getting closer to the exit?
- Not everyone has the same speed of movement. In the real world, some people would simply just be faster in reaching the exit. One could model that by randomly assigning each person a speed where they can move more than one cell per time step; however, the goal is to check which number of exits and exit sizes are suitable for different room sizes and I believe the simplification where everyone can move one cell is suitable for it.

Measurables:

The main output I am measuring is time taken for everyone to evacuate the room. The whole goal of the simulation is to identify in what cases (room sizes and number of people) are different number of exits and exit sizes not suitable. Hence, I run a monte carlo simulation for different parameters to calculate how long it takes for people to exit with different parameters so I can identify cases where it takes too much time.

Simulation Visualization:

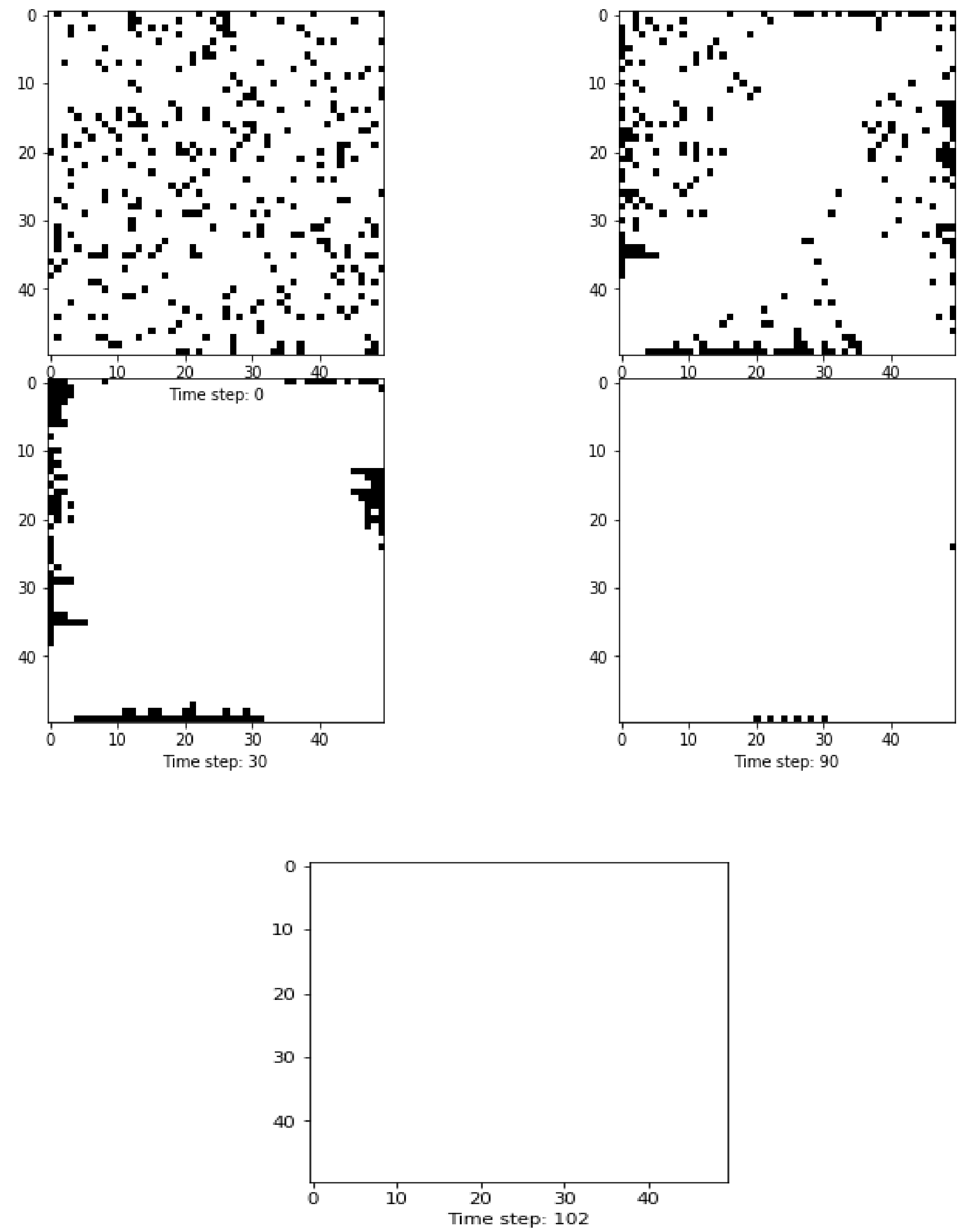


Fig 1. Figures showing how the simulation runs over time. The 'horizontal clogging' phenomena can be observed in the third and fourth figure.

Analysis:

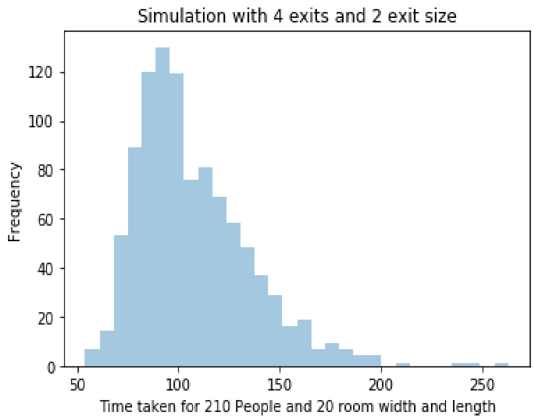
To analyze the simulation, I compared two cases with different parameter settings:

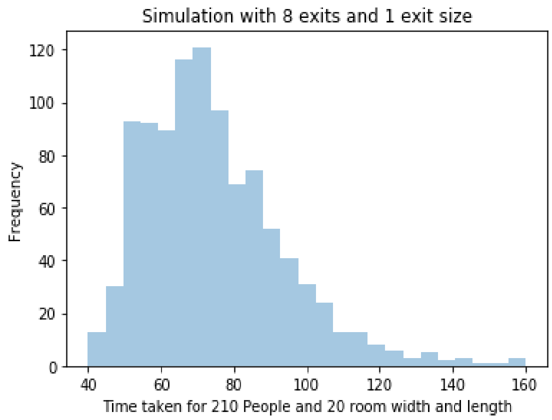
a) Have 4 exits with an exit size of 2 per exit. Test it on symmetrical rooms that are sized between 20 and 60, while also changing the number of people between 10 and 210.

b) Have 8 exits with an exit size of 1 per exit. Test it on symmetrical rooms that are sized between 20 and 60, while also changing the number of people between 10 and 210.

Although the model can be tested on multiple simulations, for this project, I shall be contrasting double the amount of smaller exits to half the amount of larger exits and see which performs better.

My Jupyter notebook has more histograms on different parameter results but for this paper, I will only show the results with the maximal number of people and different room sizes.





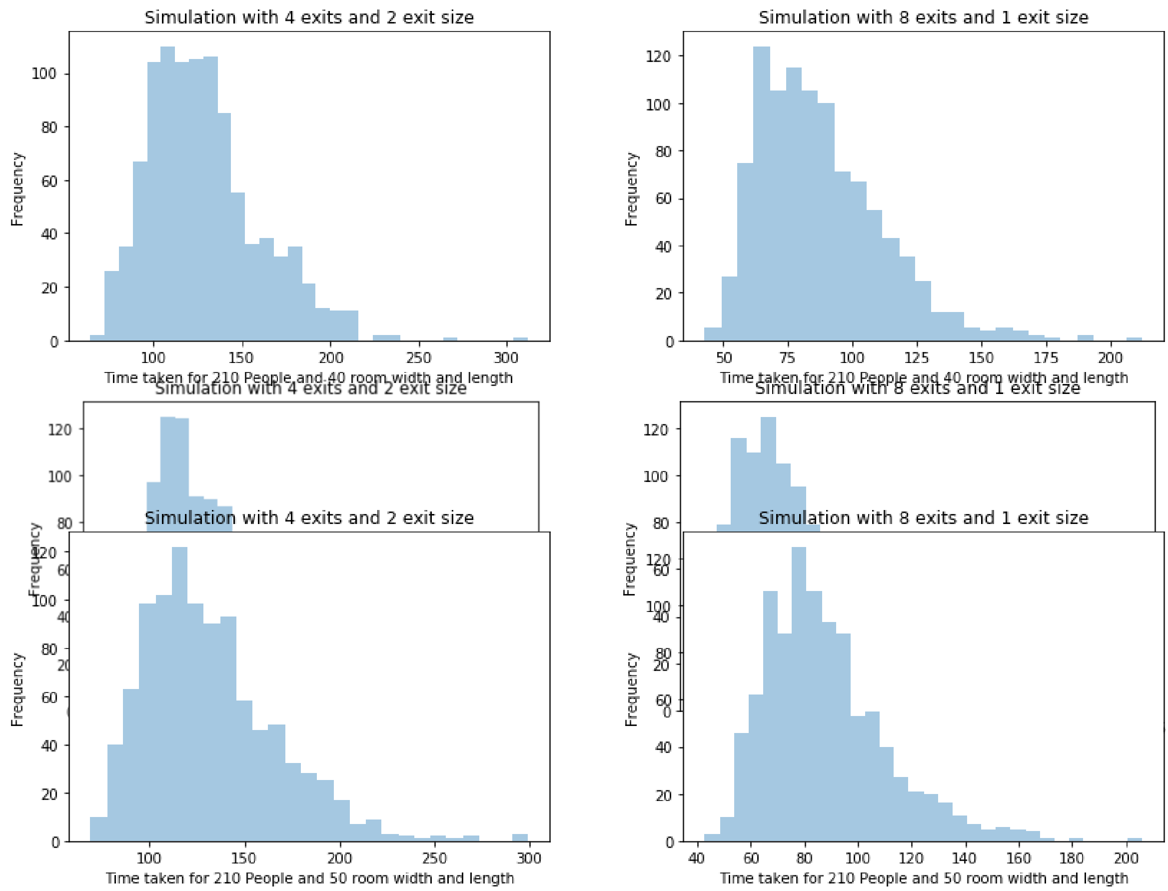
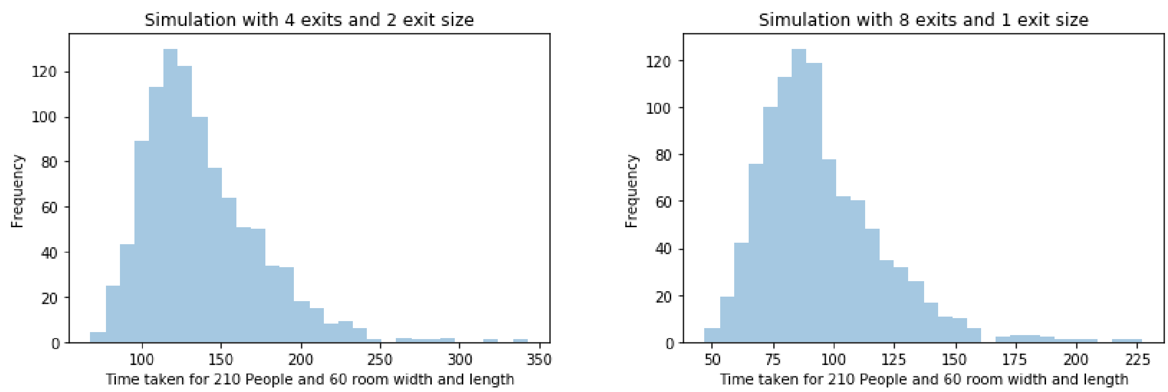


Fig 2. Shows the various distributions between the two settings, and different parameters.

Note: All distributions were plotted by simulating the model 1000 times.



There are two important observations that can be made from the simulation results shown above. First, the number of time steps taken to exit a room follows a strong trend of normal distributions. Secondly, 8 exits of size 1 consistently perform better than 4 exits of size 2 which might indicate that more, yet smaller, exits are better than less, yet larger, exits. For more insight on this hypothesis, I plotted the mean time taken for each parameter setting for 4 exits of size 2, and for 8 exits of size 1. The results are shown in the figures below.

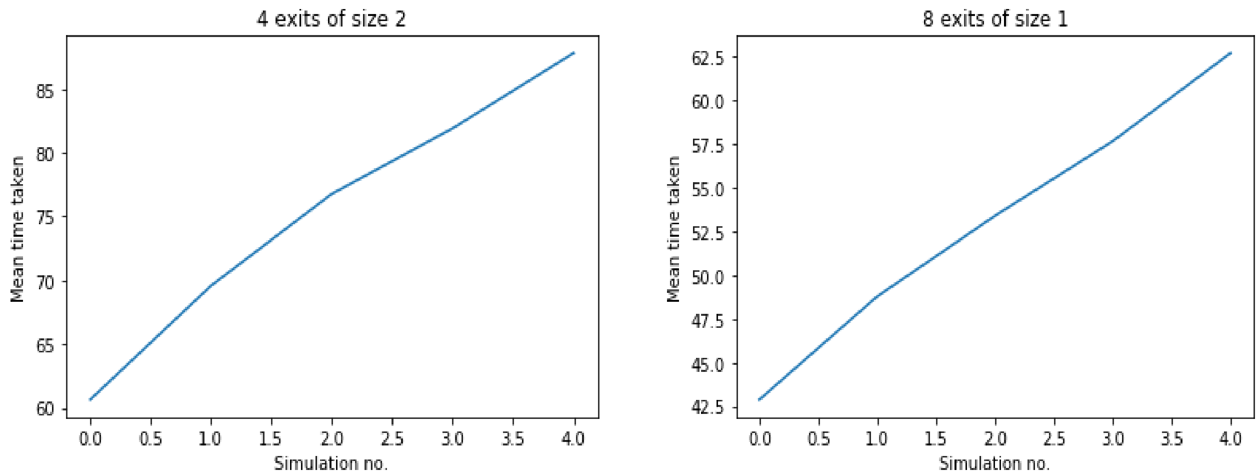


Fig 3. Plot showing the trend of how the mean time taken increases.

The figures suggest that the time taken for people to exit the room increases linearly with the number of people at all different types of room sizes. However, the Y-axis of the graph with 8 exits of size 1 is considerably smaller than that of the graph with 4 exits of size 2 which supports the hypothesis that more, yet smaller, exits are better than less, yet larger, exits.

Advisory Paragraph:

To whom it may concern,

Laying out the design of a room during construction is imperative; however, one important aspect that architects may neglect is how many emergency exits should be placed for a room, and how wide/big the exits should be. To answer that, we modeled crowd egress on a room with a different number of exits, and different exit sizes, and then ran monte carlo simulations on the model. The results suggest that during an emergency, people exit a room faster if the exits are smaller in size, and larger in number. The smaller exits are almost 30% faster in helping people exit the room compared to larger sized, yet smaller number of exits.

Computational Limitations:

I have plotted all the 95% confidence intervals on the Jupyter Notebook; however, I will only show a few in this paper since all of them follow a trend of being too wide (as shown in the figures below).

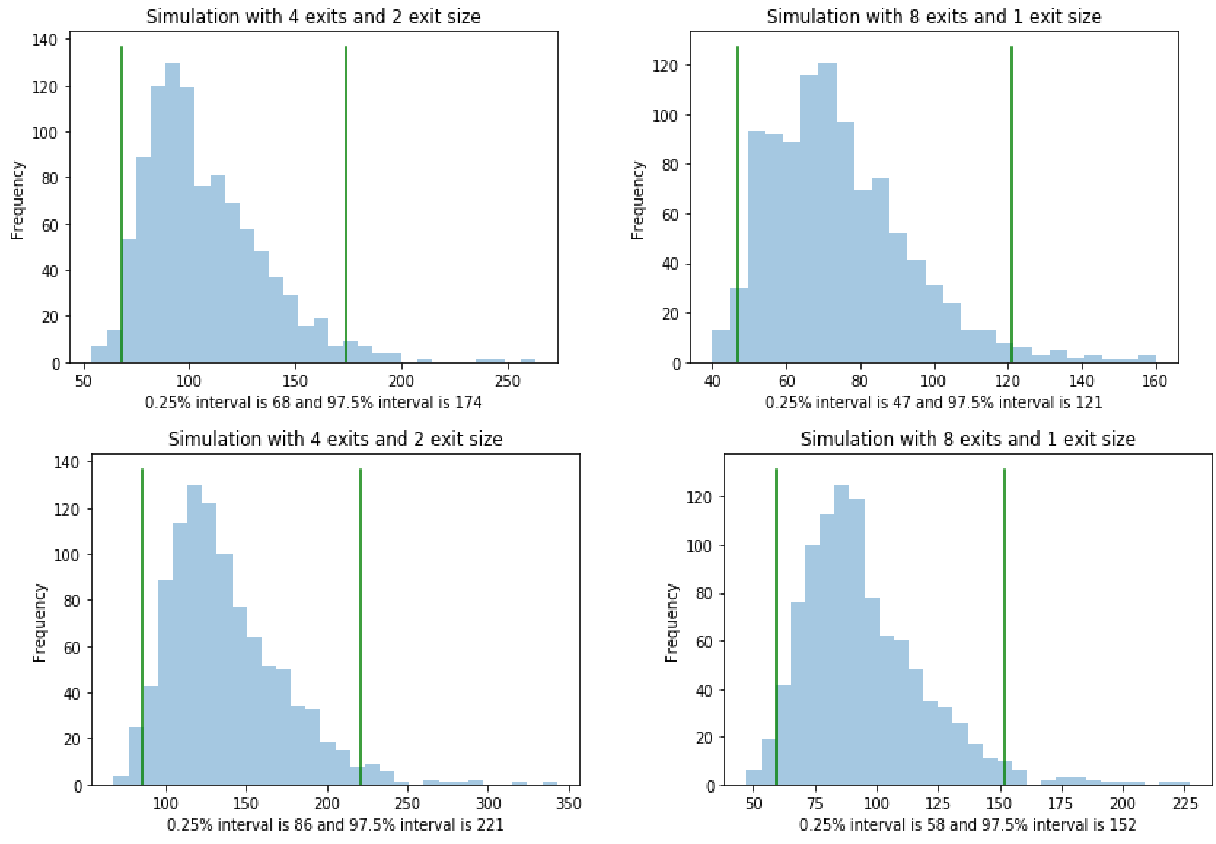


Figure 3. Histograms with confidence intervals plotted for various simulation results

From observing the 95% confidence intervals, the range of values where our true mean (for the time taken to exit the room) is too wide. In a life or death situation, it is imperative to get accurate results; however, due to time limitations, I could not run the simulation for a large number of trials. For each configuration, I only run the simulation 1000 times to get an estimate of the distribution of time taken. Ideally, it should run around 100000 times to get a much narrower distribution of time taken.