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P1: Final Project
Main Report (w/ Demos)

I. Introduction

Public places such as Concert Halls, Theaters, Bars, Malls, etc. are always crowded with people. Due to these buildings being able to host a high capacity of people, they must always be planned and built to ensure the safety of the people inside. Although drills are a great way to practice and prevent emergencies, they can only happen after the building has been created. Therefore, animated simulations of these buildings must be created to ensure that during an emergency or an evacuation everyone is able to leave the building in the shortest amount of time possible. Working off of this idea and using b4 Social Forces as the base of the project, I have designed a small concert hall/bar (think Terminal 5 in NYC) in Unity as an evacuation simulator with a Timer and a Single and Dual Exit configuration.

II. Controlled Variables

Throughout the course of these four experiments I conducted, many variables were manipulated. However, a lot of these variables were also kept at the same value. These controlled variables include: the size of the concert hall, size of the pillars (in single and dual exit), location of the pillars (in single and dual exit), width of the exit door, and the amount of agents.

Variable	**Value**
Size of Concert Hall	X: 10 units Y: 0 unit Z: 30 units
Size of Cylindrical Pillar (Single Exit)	X: 3 units Y: 5 units Z: 3 units
Size of Cylindrical Pillars (Dual Exit)	X: 2 units Y: 5 units Z: 2 units
Location of Pillar (Single Exit)	In Front of Exit Door

Location of Pillars (Dual Exit)	One Pillar In Front of Each Exit Door
Width of Exit Door(s)	3 units (Wide Door Configuration)
Amount of Agents	250 Agents (Large Capacity)

III. Experiment 1: Single Exit

The first experiment I conducted involved forcing the 250 agents to head towards one single exit. The exit door through which the agents were forced to go through was purposefully kept wide (see controlled variables) and a pillar was also placed in front of the wide door. In most theories and papers that have been formulated, it is said that placing a pillar, or any obstacle in front of the door can be helpful in streamlining a crowd allowing them to exit the room quicker. This has already been tested. However, I noticed that in most tests conducted, the door which was used could only accommodate 1 agent at a time. This is why having a pillar in front of the door ensured a better distribution of agents. Through experimenting with a wide door, I concluded that having a wide door which fits 2 (or more) agents has the same effect as putting a pillar in front of a smaller door (think double door exit). The reason for this is that a pillar can split a crowd up into two groups (the group left of the pillar and the group right of the pillar. Wide doors have the capability of allowing multiple streams of people/agents through the door. Essentially, the wide door and the pillar are performing the same function. Another interesting observation through this experiment was the fact that the Agent Force being applied to all agents actually prevents the agents from exiting the venue as quickly as they do without the Agent Force being applied. The time it takes agents to exit with the force applied is drastically higher than with the force not applied (in both cases of having a pillar there and not having a pillar). The reason for this is that with the Agent Force applied, the proximity and repulsion force prevents agents from touching each other and repels them from each other. Although this creates a more dispersed crowd, it also makes the agents stand further back and prevents them from leaving as groups from the wide door. Basically, the Agent Force prevents the agents from utilizing the wide door's capacity. In a real life emergency situation, most people would panic and attempt to bundle together as groups. This is especially true if families are present. In a research paper titled "Crowd Simulation Modeling Applied to Emergency and Evacuation Simulations using Multi-Agent Systems", it is mentioned that in emergency situations, people result to herding (following others and bundling up into groups). Thus, it is unlikely that people will act as the agents in the simulation do with Agent Force activated. This is a good thing to an extent. The cons of acting in this manner are that people could often lose their balance or be pushed causing them to fall. This would cause a much bigger delay and could be dangerous. The agents in the simulation are always upright and balanced. In conclusion, the optimal scenario in this situation would be to implement a wide door without pillars. Some data and demos are presented below.

All Forces Activated (Goal, Agent, Wall):

Configuration	**Average Time To Exit (min:sec)**	**Demo Video**
Single Exit - No Pillar (Wide Door)	1:28	https://www.youtube.com/watch?v=EuRcNeJ5EoI
Single Exit - With Pillar (Wide Door)	1:34	https://www.youtube.com/watch?v=-9_O4Z-FRL0

No Agent Force Activated:

Configuration	**Average Time To Exit (min:sec)**	**Demo Video**
Single Exit - No Pillar (Wide Door)	0:59	https://www.youtube.com/watch?v=93bzC3PLOU0
Single Exit - With Pillar (Wide Door)	1:04	https://www.youtube.com/watch?v=Q0ekKbU2A9Y

IV. Experiment 2: Dual Exit

This experiment was similar to the previous one with the key difference being that the agents had the option of using two exits vs. only one. For this configuration, I attempted to place two pillars in front of the wide exits to confirm the fact that pillars in front of a wide door, which is already made for streamlining large crowds, is not beneficial in emergency situations. If the door is wider than the pillar (which it was in this case), the pillar actually becomes an obstacle and prevents agents (that would have normally gone through that area occupied by the pillar) to pass. The results regarding the use of Agent Forces were also similar to Experiment 1. The time it took for the agents to evacuate was greatly increased with the introduction of the Agent Force. Overall, the time it took the agents to exit was, on average, much lower than the time it took them to exit in the single exit configuration. Thus, it is definitely true that more exits mean a quicker exit time. However, going back to the research paper "Crowd Simulation Modeling Applied to Emergency and Evacuation Simulations using Multi-Agent Systems”, in realistic scenarios, people would prefer to herd instead of use both exit doors equally. In my simulation, they use both doors equally because the destination is in the middle of the two doors and in the middle of the plane in general. Data and demos are presented below.

All Forces Activated (Goal, Agent, Wall):

Configuration	**Average Time To Exit (min:sec)**	**Demo Video**
Dual Exit - No Pillar (Wide Doors)	1:06	https://www.youtube.com/watch?v=sTBzDTYdbys
Dual Exit - With Pillars (Wide Doors)	1:27	https://www.youtube.com/watch?v=sKVEqGxbqv4

No Agent Force Activated (Goal, Agent, Wall):

Configuration	**Average Time To Exit (min:sec)**	**Demo Video**
Dual Exit - No Pillar (Wide Doors)	0:58	https://www.youtube.com/watch?v=2IB3QGDxMkA
Dual Exit - With Pillars (Wide Doors)	1:05	https://www.youtube.com/watch?v=WidB-Cw7bjU

V. Experiment 3: Varied Agent Radius

The third experiment I conducted required varying the radius of the agents. In real life scenarios, crowds consist of people with varying body sizes. With the third experiment I varied the size of the agents to test whether this would affect the time taken to exit. I decided to use the same wide door. I chose to not enable Agent Forces for this experiment to keep it more realistic. The size of variance was between 0.2f and 0.5f. As per the results, varying the size of agents definitely causes huge delays in exiting. The pillar, in this case, was a bit helpful as it reduced the time of exit by 11 seconds on average. In conclusion, varying agent size negatively affects exit time. Data and demo below.

Configuration	Average Time To Exit (min:sec)	Demo Video
Varied Agent Size - Single Exit- No Pillar (Wide Doors)	2:03	https://www.youtube.com/watch?v=t8A_7OWUzvA

VI. Experiment 4: Realistic Scenario

For the fourth experiment, the goal was to create the most realistic scenario possible. At this point, I knew a few things. The first was that having Agent Force active is definitely unrealistic but having it disabled is also a bit unrealistic. The second was that the physical size of people can often vary and although incorporating this into the simulation affects exit time negatively, it is necessary to do so. Therefore, I ran a test in which the Agent Force is not disabled completely but is only 75% the strength of the original Agent Force. The agents were also of varying size in this scenario. The size of variance was between 0.2f and 0.5f. This configuration led to an Average exit time of 1:54.

VII. Conclusion

Overall, I was able to learn a lot from my research. The first thing I learned was that more exits mean a quicker exit time. This one is a no brainer since it has been proven before. The next thing I learned was that wide (or double) doors have a similar effect as placing an obstacle in front of a smaller door. If the door is wide enough, the same streamlining effect takes place in which the agents are able to divide themselves into two or more lines. The last thing I learned was that the Agent Force being applied actually delays the process of exiting. This has been confirmed by other research papers as well.