Evacuation Behaviour From a Building Under Panic

CA4024: Building Complex Computational Models
Continuous Assessment: Agent Based Modelling

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Gitlab

1. Introduction

The safe evacuation of people from a building under threat is a complex and multifaceted problem. While the source of the danger such as a fire is often the main focus, other factors such as the layout of the building and the behaviour of people can have significant impacts on the likelihood of survival. Due to the variety of influencing factors, a system that can effectively simulate these emergency events could help building planners and safety regulators to prepare for the worst.

Agent-Based Models (ABMs), are systems that are represented as a multitude of individual decision-making units known as agents. Each agent independently assesses its circumstances and environment then makes its own decisions based on a set of predefined rules. Agent-based models provide a methodology for exploring systems of interacting, adaptive, diverse, spatially situated actors (de Marchi and Page, 2014). In this report we will model the evacuation behaviour from a building under panic as agent-based models can identify "psychological and physical factors that cause panic in such situations" (Trivedi and Rao, 2018).

In our case, the panic will be ensued by a fire. We have two types of agents in this model, "Fire" agents and "Worker" agents. The fire will spread and kill any worker agents it encounters. Worker agents will attempt to flee the building immediately however, physical factors such as walls and other workers may block their escape. As well as this, panic may be induced if surrounding workers are panicked or if their planned exit route is blocked. Panicked agents will move erratically. The effectiveness of the evaluation will be measured by the number of workers who successfully escape, and will be evaluated under several different parameters setups. These parameters will control the room layout, panic behaviours, agent awareness and fire properties.

2. Methodology

2.1 Layout

The layout of the office defines the environment that all of the agents react to and interact with. The office is defined by a 100*100 grid, with open space, wall, exit and fire tiles. By default the building contains 4 offices, with a central corridor in between them leading to the 4 exits at each of the cardinal directions. The offices each contain rows of desks which also impede worker movement.

There are 3 office layout parameters that can be used to examine how different design choices affect the likelihood of survival. The first parameter, **desks**, controls the presence of the desks within the offices. This can show how cluttered environments can impede escape efforts. The next layout parameter is **door width** which controls the size of the internal doors. Smaller doors can act as choke points, forcing groups of workers to form queues or to find alternative routes. Finally the **exit locations** parameter allows us to control which of the 4 exits are active.

2.2 Fire Agents

Fire agents are used to represent the start and spread of a fire in our building. The fire agents take several parameters which define how they behave. By default, the fire will start at a random location and begin to spread to any adjacent open tiles in the layout until every worker has either escaped or died. The fire's increase is exponential, as each fire agent can produce more fires, this simulates the escalation of the emergency over time.

The location parameters are the **fire x coordinate** and **fire y coordinate** which control where the fire begins. Different coordinates can be selected to see the effect of a fire starting in a corner versus a corridor. The other parameter you can pass to the fire agent is **fire spread** which is a probability that a fire agent at a certain grid location will spread to its adjacent grid locations. This parameter could potentially measure the effectiveness of implementing fire mitigation systems such as sprinklers into the building.

2.3 Worker Agents

Worker agents are meant to represent workers in the simulated building. At the start of the simulation, under the assumption of fire alarms, calm agents become immediately aware of the fire emergency and begin to head towards their nearest exit. However, certain rules and situations which we will outline below may cause these worker agents to enter a state of panic where they begin to move erratically. If the workers make it to the exit, they are counted as escaped and removed from the simulation. A worker's path to the exit can become blocked by the fire or other workers, in which case they will recalculate their path, Workers will become panicked based on the panic level of their immediate neighbours, additionally, if there is no possible escape route, they will automatically become panicked, which effectively simulates the panic induced by congested and cramped corridors. Workers who see an exit will become calm again.

The **number of workers** parameter controls the number of workers in the building. The **panic percent** parameter will set the default percentage of worker agents that are in a state of panic at the start of the simulation. This could possibly represent the amount of people who had not received emergency fire training and are unsure of the location of the exits, as a result they panic. At each step a worker agent will identify every other worker agent within a radius of five grid spaces. The worker will then look at the panic state of these workers and calculate the percentage of these workers who are panicked. If this percentage breaches the **panic change threshold** parameter that has been set, they will adopt the attitude of their neighbours. The **force calm** parameter removes panic from the system, for comparison.

The next two parameters control the pathfinding behaviour of the workers. The **vision** parameter defines how many steps along their path a calm worker can see obstructions, giving them more time to recalculate new paths. On the other hand, the **patience** parameter controls how long a worker will accept being stationary in a queue of workers, before they decide to try another path.

2.4 Metrics

The simulation tracks three key metrics: the percentage of escaped workers, the percentage of dead workers and proportion of panicked workers within the building. These metrics collectively aim to capture critical aspects of each simulation: the mortality rate, percentage of successful evacuations, and the correlation between panic levels and worker fatalities.

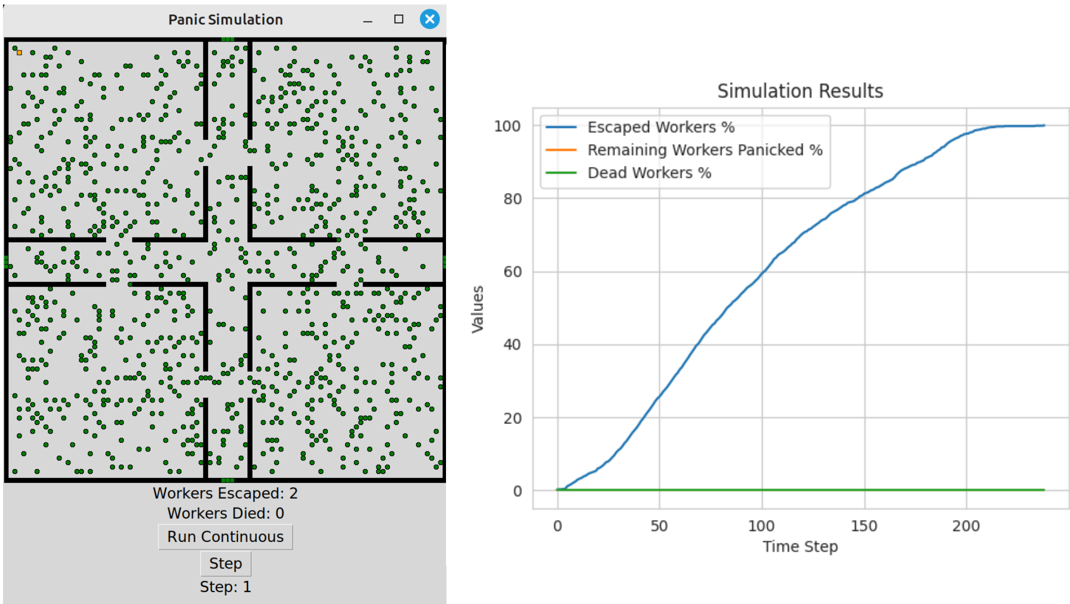
3. Results

Each experiment was run with 1000 workers, with a vision of 15 and a patience of 10.

Experiment 1

The first experiment was a baseline setup, just to ensure that everyone can escape under ideal circumstances. The layout was kept clear, the agents were set to remain calm and the fire started in the corner and spread slowly.

Door Width: 6	Fire (x, y): Corner (3, 3)
Desks: False	Fire Spread: 0.1
Exits: All	Force Calm: True



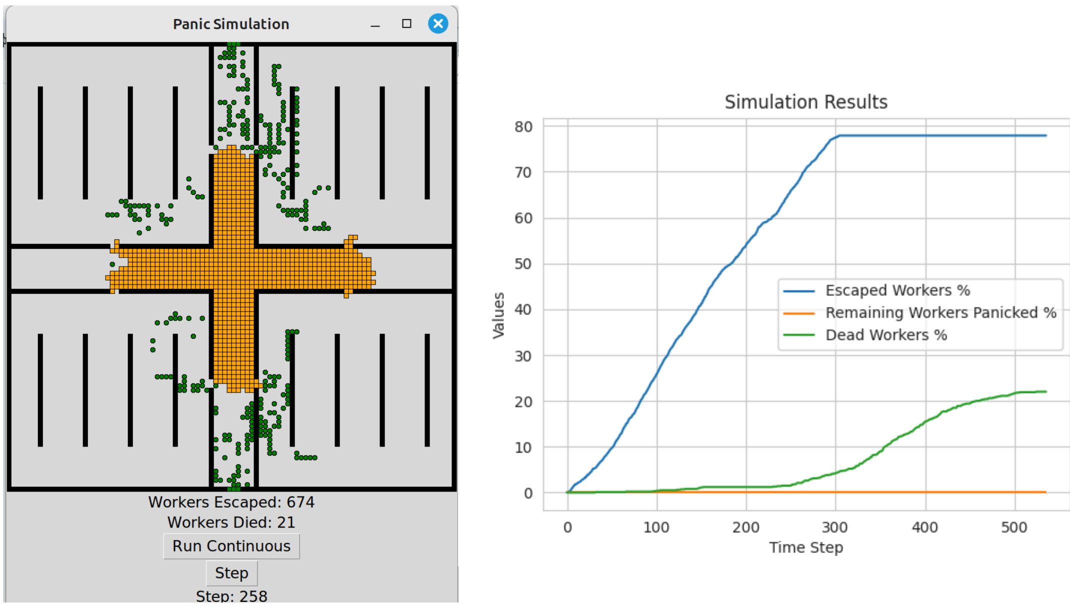
Experiment 1

All 1000 workers survived. This showed that all workers have the ability to escape under ideal circumstances.

Experiment 2

Door Width: 2
Desks: True
Exits: Top, Bottom

Fire (x, y): Center (50, 50)
Fire Spread: 0.1
Force Calm: True



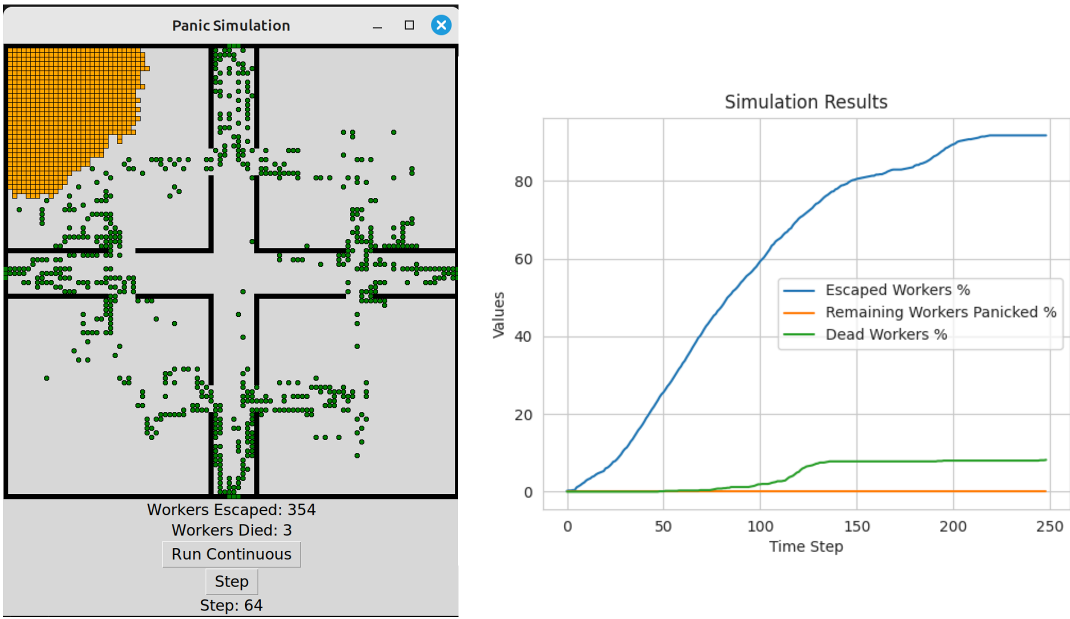
Experiment 2

The central location of the fire combined with the very thin doors, caused lots of congestion amongst the workers, resulting in 221 deaths. This shows how office layout and fire location can cause deaths, even when everyone knows where the exits are.

Experiment 3
Next we repeated experiment 1, with a higher rate of fire spread.

Door Width: 6
Desks: False
Exits:All

Fire (x, y): Corner (3, 3)
Fire Spread: 0.5
Force Calm: True



Experiment 3

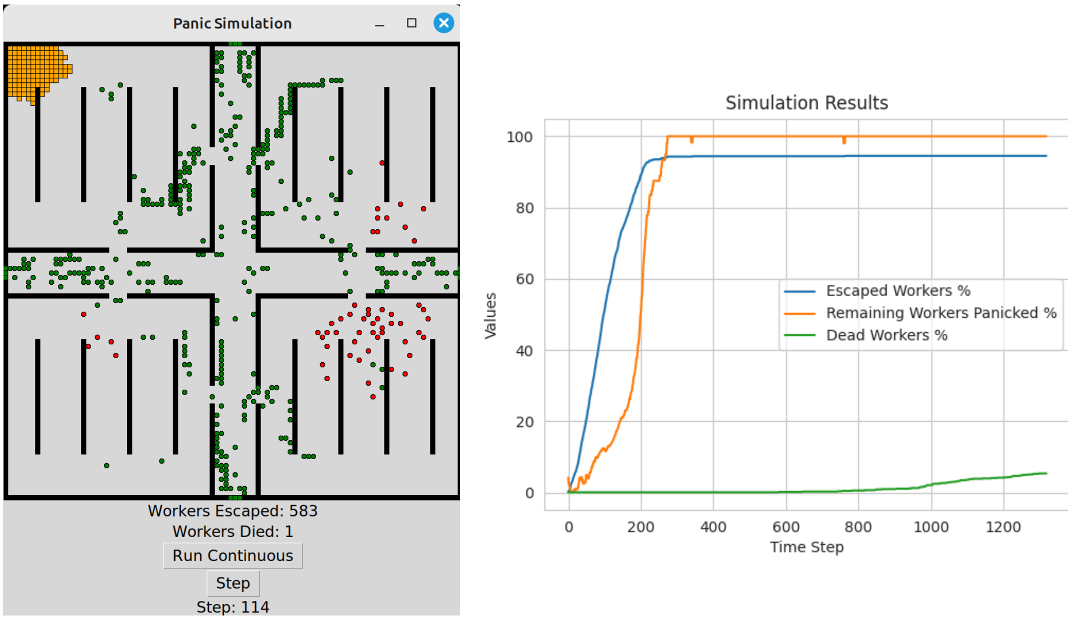
Despite the safer layout 83 workers died as they could not outrun the exponentially growing fire.

For the remaining experiments we selected a balanced office layout, including desks, setting the door width to 4 and using all 4 exits.

Experiment 4
We then introduced panic into the simulation, to show how it affects the escape. In experiment 4 there are a low initial number of panicked people, and they will be resistant to the moods of their neighbours, however they will panic when trapped.

Door Width: 4
Desks: True
Exits:All
Panic Percent: 0.1

Fire (x, y): Corner (3, 3)
Fire Spread: 0.1
Force Calm: False
Panic Change Threshold: 0.9



Experiment 4

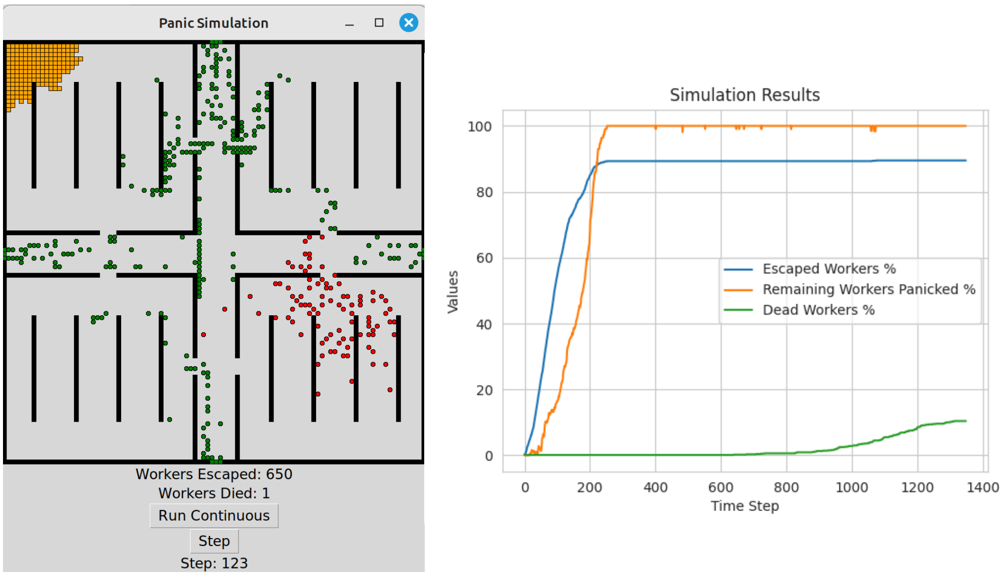
54 workers died. The simulation and results show that after the calm workers escape, the panicked ones remain moving randomly until they happen to find the exit, or the fire kills them.

Experiment 5

Now lets see what happens when their panic state is more volatile

Door Width: 4
Desks: True
Exits:All
Panic Percent: 0.1

Fire (x, y): Corner (3, 3)
Fire Spread: 0.1
Force Calm: False
Panic Change Threshold: 0.6



Experiment 5

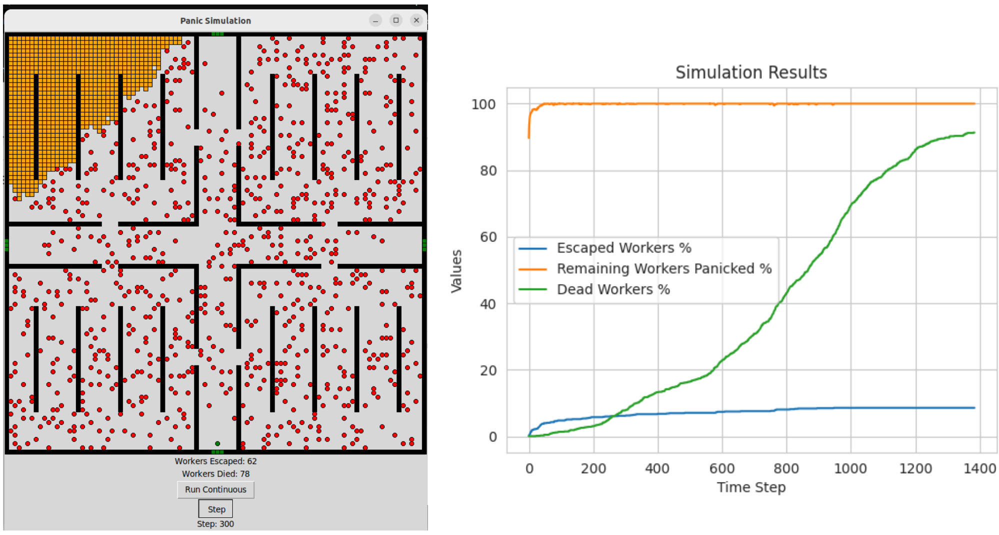
105 died this time. Initial panic levels were actually lower, as the workers adopted the majority calm state, however the panic spread much faster as escape routes became blocked.

Experiment 6

In this experiment we explore what happens when the majority of people are initially panicked.

Door Width: 4
Desks: True
Exits:All
Panic Percent: 0.7

Fire (x, y): Corner (3, 3)
Fire Spread: 0.1
Force Calm: False
Panic Change Threshold: 0.7



Experiment 6

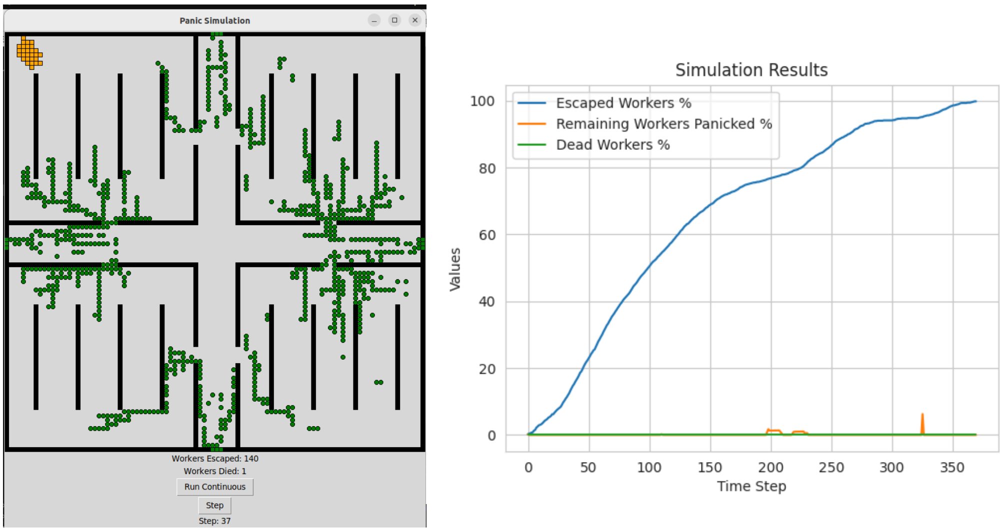
In this simulation almost all of the workers died. The only workers that managed to escape were the ones who got close enough to the exit to see it and leave. This simulation possibly models what happens when people have not properly been taught the layout of the building, or scenarios where visibility is so low that the exits are invisible.

Experiment 7

Up to now the patience has been set to 10, which means that workers will look for a new escape route if they are stationary in a queue for 10 steps. We repeated experiment 5 with the patience set to 100 allowing workers to queue for longer.

Door Width: 4
Desks: True
Exits:All
Panic Percent: 0.1
Patience: 100

Fire (x, y): Corner (3, 3)
Fire Spread: 0.1
Force Calm: False
Panic Change Threshold: 0.6



Experiment 7

This resulted in a dramatic improvement as only one worker died. This simulation showed that waiting in a queue to get out induced less panic amongst the workers and led to less erratic movements where they continuously look for open paths. Instead, when they wait their turn they are much more likely to live.

4. Conclusion

From our experiments we learned that anything that can reduce the rate at which fires spread, such as sprinklers, should be prioritised as a fast spreading fire is more deadly. Additionally the location of a fire has a large impact on its lethality. Stronger mitigation techniques, such as fire resistant materials should be used in central locations to reduce the spread across the building.

Furthermore, wider doors and more exits can reduce congestion during the escape and should be implemented. We found that an initial panic state can have a major effect on the effectiveness of the building evacuation, suggesting that fire training and building familiarity are also significant factors in this simulation. Finally, we found that patience is also key in a successful evacuation, as changing routes and attempting to overtake other workers lead to inducing panic amongst workers and less people escaping the building.

Further improvements could be made to improve the panic behaviour, by making panicked workers swarm instead of randomly moving, or by providing more dynamic ways for them to calm down. Additionally the fire spreading could be environmentally based on the materials that surround it, to more realistically depict the fire's growth.

Reference list

de Marchi, S. and Page, S.E. (2014). Agent-Based Models. *Annual Review of Political Science*, 17(1), pp.1–20. doi:https://doi.org/10.1146/annurev-polisci-080812-191558.

Trivedi, A. and Rao, S. (2018). Agent-Based Modeling of Emergency Evacuations Considering Human Panic Behavior. *IEEE Transactions on Computational Social Systems*, 5(1), pp.277–288. doi:https://doi.org/10.1109/tcss.2017.2783332.