# SIMULATING ESCAPE PANIC

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## Abstract

Simulating crowd dynamics using Cellular Automata is a well-known and widely used area of study. Those simulations allow us to infer some statistics about the dynamics of the human population in various contexts. For instance, the shopping behavior of the customers during BlackFriday in a shopping mall, the effect of the circulation of the people during a pandemic on the speed of the spread, or even the population changes of the species of animals across a certain area. Also, escape panic is one of them. During a disaster or a hazard, the behavior of the agents in a given area plays a critical role in the ratio of the survivors. Thus, in this study, it is focused on a scenario of a poisonous gas released from a point of a room full of people. Regarding the scenario, the gas propagates through the room and people try to escape from a narrow passage. During the simulation, the effect of the clogging of people (they can't move due to crowded), the toxicity of the gas, and the population density on the survivor ratio will be examined. Helbing et al.[1] showed that for the scenario people are walking instead of running, the ratio of the survivor increases. In this study, we extend the experiment parameters. In terms of cellular automata, each person in the simulation is represented as a cell. The wall is also a set of cells. Both the people and the walls are obstacles and people can not pass through them. The poisonous gas starts as a single cell and spreads to its neighbor cells. The gas cells can pass through the people and at each timestep, a poison is accumulated on the exposed people. Hence, people may die due to this poison depending on the level of exposure. After a person dies, it is counted as an obstacle and the other people can not walk through them. Since the results will affect human life, the inferences of the escape panic simulations are needed to be conducted.

**Keywords:** Cellular Automata, Escape Panic, Probabilistic Behaviour, Moving Cells

# Introduction

Cellular automata is a way of simulating agent based approaches. In this approach, the environment is divided into a grid and each atom of the grid is called as the **cell.** The form of the cell is called the state. All the possible states a cell can in it, is called **state set**. At each step, the state of the cell is changed based on a set of rules. This set is called the **ruleset**.

The grid can either be 2D or 3D. Each cell may represent a different type of component of the environment. A cell may be a rock, a tree, a piece of wall, or a person. The cell does not need to be a real object. For example in Wolfram Code[2], the ruleset is based on the state of the horizontal neighbor cells. After steady state, an obvious pattern is obtained. Thus, the cells are just the pixels of the pattern. Another very famous application is Conway's Game of Life[3]. In this automaton, each cell represents the existence.

The parameters of the cellular automaton vary in a wide range. For example, the cells do not need to be rectangular. They can be triangular or hexagon. Similarly, the transition rules may be based on a probability distribution or the state history. In this study, we exploited a probability based transition function. The details are going to be explained below.

On the other side, the escape panic scenarios can be represented with the cellular automaton. As explained above, a cell may correspond to the real world objects. In a very common escape panic scenario, where a plenty of people are placed in a room then a disaster happens, the components of the environment are well suited to the cellular automaton dynamics.

In escape panic scenarios, behaviour of and the way people escape, when a disaster happens are examined. For example in our scenario, we start with a crowded room and then a poisonous gas is released from a corner of the room. The people start to run towards the door of the room where only one person can pass through once at a time. The way people behave strongly determines the percentage of the survivors.

By simulating this setup, an optimal common behavior may be decided and can be tested in a drill. In the end, this practice may save the life of a lot of people. Of course, it is a hard problem to model since it includes the psychological issues. However, in this study, they are excluded.

In the following sections, the inspired paper will be mentioned in the Related Work section. The system parameters and techniques that are applied are explained in the System Model section and the experiments are added after that.

# Related Work

Helbing et al.[1] experimented the scenario we used. They mainly focused on the effect of velocity people have on the average leaving time of the room. They simulated the jamming and clogging at the door. The experiments showed that when people run faster than normal, they tend to leave room later.

We are inspired by that work but tested different features of the simulation. The details are explained in the following section.

# System Model

In our model, there are three main types of cells: The wall, the person and the gas. The room is bounded by the walls and there is a door that only one person can pass through at once. People are distributed in the room randomly. The gas starts to spread from one of the opposite corners of the door. (See Figure 1)

People can not walk through each other. This guarantees that only one person can pass through the door. Every person tries to reach the closest possible cell to the door. If a person can not move in a step, s/he tries to move in a vertical direction randomly once more. This allows us to have more equality distributed clogging around the door, rather than long narrow queues. Hence, we obtained a more natural distribution of the people. A shortest path algorithm may be used here but behaving optimally would not represent the conditions of a panic behaviour. (See Figure 2)

The gas poison the people at each timestep when they are in the area of the gas. The gas has a toxicity level and at each time step, it is accumulated on the people exposed. This accumulated poison ranges from 0 to 1 and represents the probability of dying in that step. For demonstrative purposes, the color of the people cell is changed based on the level of toxicity accumulated on that person. If a person dies, the cell turns to red completely. Dead people can not move anymore and other people still can not walk through them. (See Figure 3)

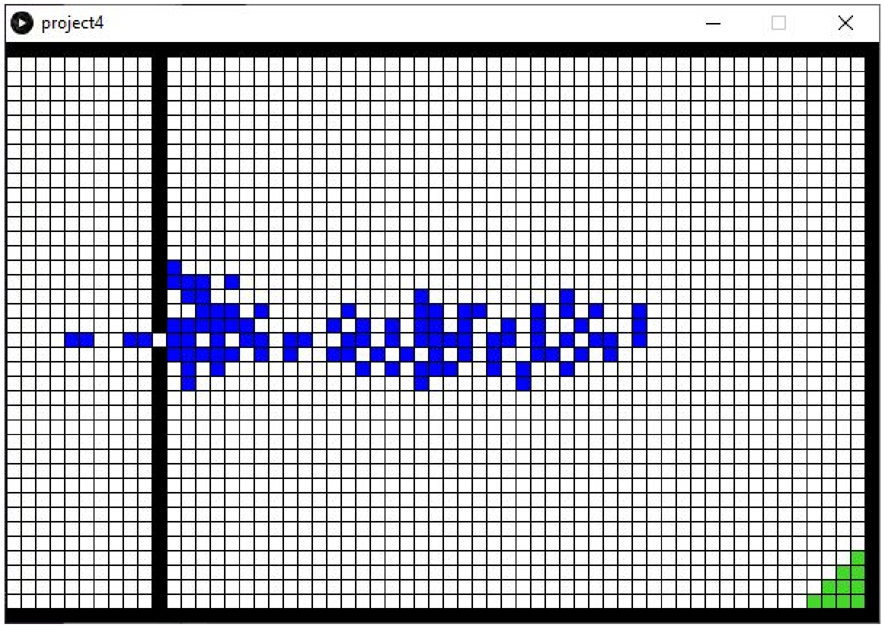


*Figure 1 : Black cells represent the walls, the blues represent the people and the green cells are the gas. The gas spreads slower in the figure for the demonstrative purposes.*

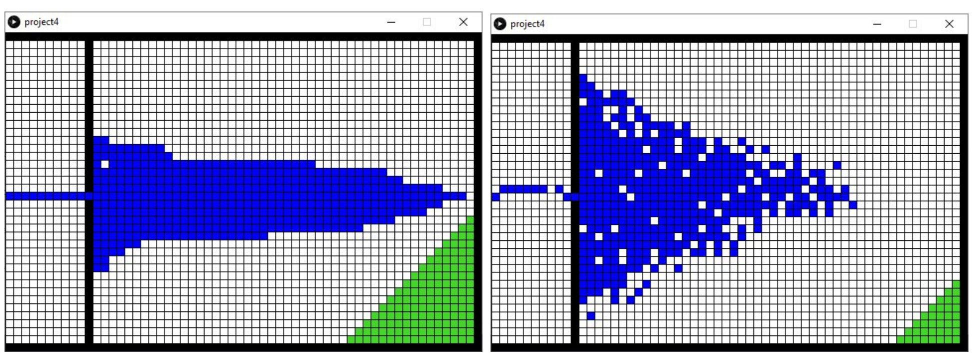


*Figure 2 : When random vertical movements are removed (on left) versus when random vertical movements are enabled (on right)*

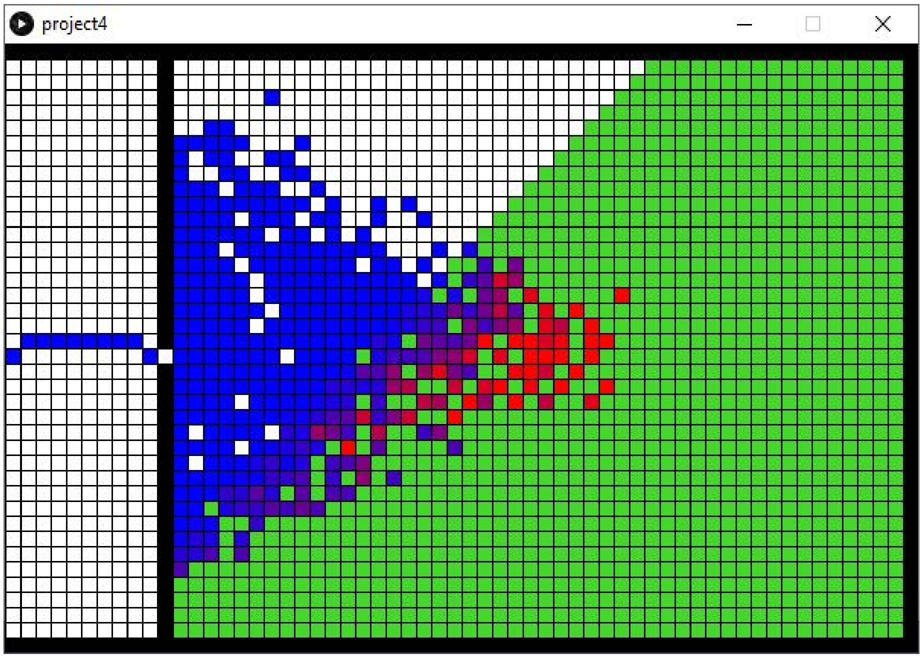


*Figure 3 : The color of the cells representing the people change as they are exposed to the gas.*

# Experiments

## 1. Effect of Clogging:

One of the reasonable behaviours that can be observed is the clogging. Since people tend to rush to the door, which is the only gateway, a clogging occurs around the door. In the simulation clogging is represented as follows; the number surrounded cells of a cell represents the clogging rate for that person. This rate is used as the probability of **not** moving at that step. If all four of the directions are closed of a cell, then this cell can not move for sure, which is consistent with our obstacle topology.

The results of the experiment shown in Figure 4. Clogging affects negatively the percentage of the survivors.

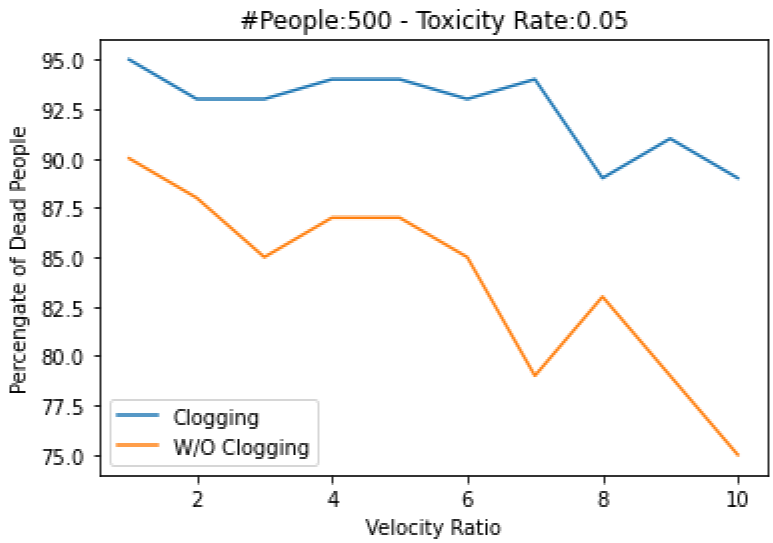


*Figure 4 : When clogging is enabled, more people tend to die. (Velocity Ratio: People Velocity/Smoke Velocity)*

## 2. Effect of Toxicity:

Toxicity rate affects the rate of the dead people directly. The accumulated toxicity rate of a person represents the probability of dying of that person in that step. We examined the effect in the range from 0.01 to 0.5. It is observed that the percentage of dead people stayed the same after some threshold, which is around 30%. This means after around the toxicity rate 0.1, the main reason of death is other reasons.

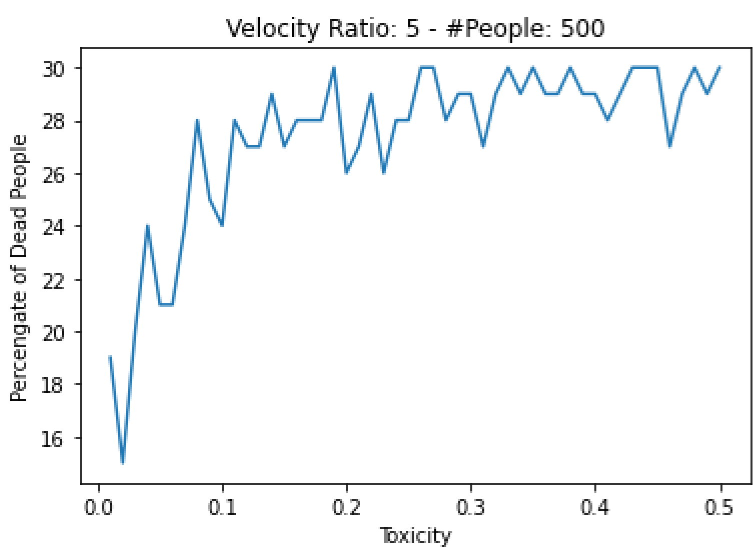


*Figure 5 : The percentage of dead people converges to a ratio in steady state*

### 3. Effect of Density:

The effect of the density is as expected. As the number of people increases, the density also increases, since the area of the room is fixed. Density triggers the effect of clogging. Since people can not walk through each other, the crowd obviously makes it harder to leave the room.

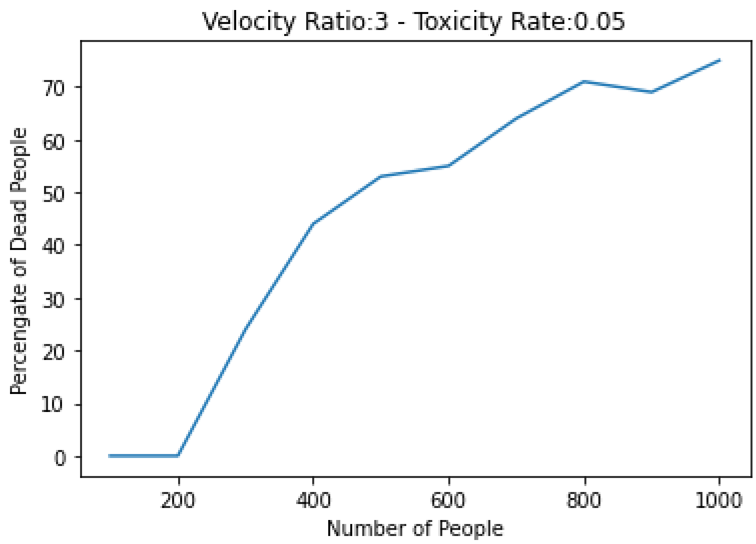


*Figure 6 : Number of people died increases as the total number of people so the density increases*

## Conclusion

Disaster scenarios are a very crucial topic to be investigated thus life of various number of people is affected. It is also hard to conduct real life drills due to lack of adrenaline and panic behaviour that emerges in a real case. Simulations are one of the well suited forms to test the parameters of such disasters. Agent oriented approaches, like cellular automata can be used in such problems. The experiments reported above satisfy the real world expectations and our proposition.

# References

1. 1. Helbing, D., Farkas, I. & Vicsek, T. Simulating dynamical features of escape panic. Nature 407, 487–490 (2000). https://doi.org/10.1038/35035023
2. Wolfram, Stephen (July 1983). "Statistical Mechanics of Cellular Automata". *Reviews of Modern Physics*. **55**: 601–644.
3. https://en.wikipedia.org/wiki/Conway%27s_Game_of_Life