Evacuations: A mathematical Modelling Experience

Note: In the study, these exercises were provided in German rather than English.

Introduction

The Niels Abel School in Firetown (Brandenburg) has trouble with the school inspection which considers the old sports hall to be a security risk. Especially the narrow hallway, in wich lockers are located, was evaluated critically:

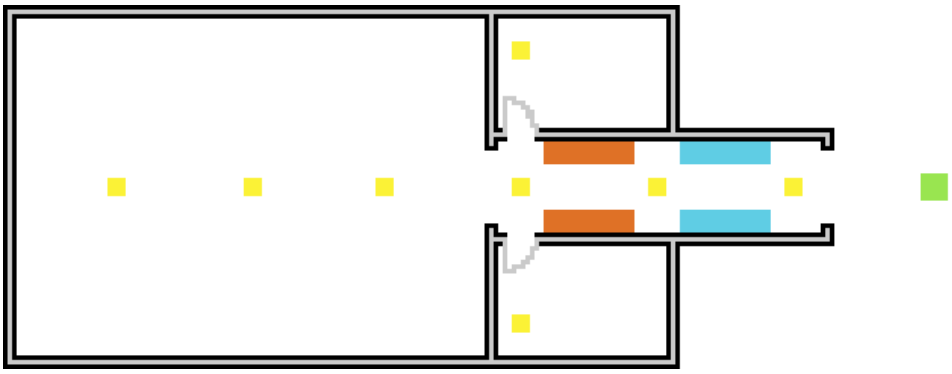

Figure 1: Building plan of the sports hall. Scale: 10px ≙ 1m

The inspection is not convinced that every student can leave the building in time if an evacuation happens. However, measuring the time with a test evacuation is currently not possible given the current restriction because of the Covid-19-pandemic.

For this reason, the mathematics teacher of the schools tries to estimate the evacuatability of the sports halls with a simulation. To prevent mistakes, the teacher utilizes two different programs that are able to simulate such a situation. Both programs are based on a different mathematical approach.

Simulation Environment 1: The Grid Automaton

This Environment is available online at https://evadid.it/eva2. Die sports hall is implemented in the following way:

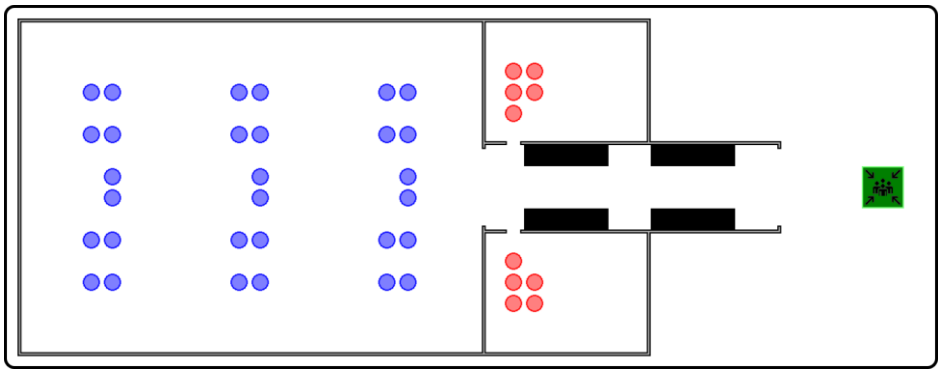

Figure 2: Implementation of the sports hall with a grid automaton.

In the model, every person takes up a grid of the size 50x50cm² and moves step-by-step towards the secure area outside of the sports hall. The number of steps can be used to estimate the duration of the evacuation. The sports hall is implemented in the scale 16x16 px² ≙ 50x50 cm² ≙ 1 cell in the automaton.

Simulation Environment 2: The Flow Network

This simulation environment is available as Java-program. The download is available under https://evadid.it/eva1. The sports hall is implemented in the following way:

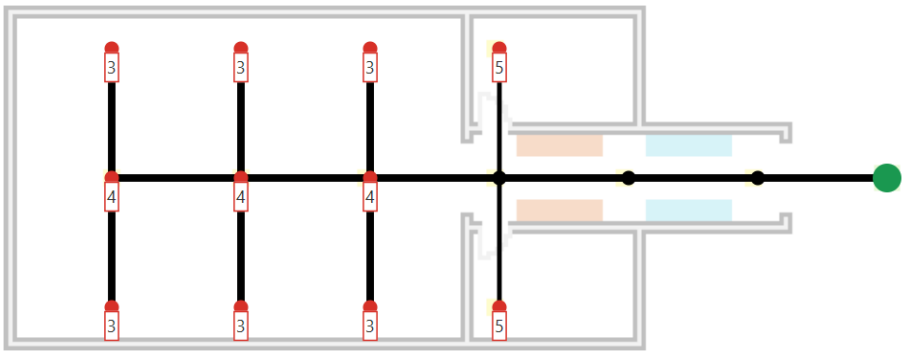

Figure 3: Implementation of the sports hall with a flow network.

In this model, every person is located at a node and moves over the edges towards the secure area outside of the sports hall. The simulated simulation duration, caused by the delay necessary to move alongside an edge, can be used to estimate the duration of the evacuation. The sports hall is implemented in the sale 1m ≙ 10px and persons are configured to move with a simulated speed of 50px/s.

Exercise 1: Determining the results of the simulation

Open both simulation programs, load the modelled scenario, and execute it.

a) Denote the duration of evacuation according to the 1st simulation in simulation steps
b) Calculate the duration of evacuation according to the 1st simulation in realistic time
c) Denote the duration of evacuation according to the 2nd simulation in simulation seconds
d) Calculate the duration of evacuation according to the 2nd simulation in realistic time

Hinweise:

- There is a button to load the sports hall implementation into the environment
- List all assumptions you used to come to your answer.

Exercise 2: Comparing the scenario implementations in the simulations

Compare the two implemented scenarios (e.g., according to the sizes of the rooms, width of hallways, moving speeds, …) by describing similarities and differences.

Exercise 3: Comparing the simulations to each other and reality

Compare both simulation approaches (e.g., by behavior of people during fleeing, representation of people in the environment, …) by describing similarities and differences between them. Additionally, describe realistic and unrealistic aspects in both simulations.

Exercise 4: Evaluating the realism of the results

Evaluate, whether the results of the simulations are realistic. Do so by also using your results from exercises 1-3.