Testing Evacuation Strategies

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1 Background

1.1 Context

You will model the behaviour of building users during an emergency situation, in this case the library building at TU Delft campus. (Figure 1). This building will be needing an evacuation when the fire alarm goes off. We will prepare the floor plan of the building and a base NetLogo model skeleton and announce it in Brightspace when available.

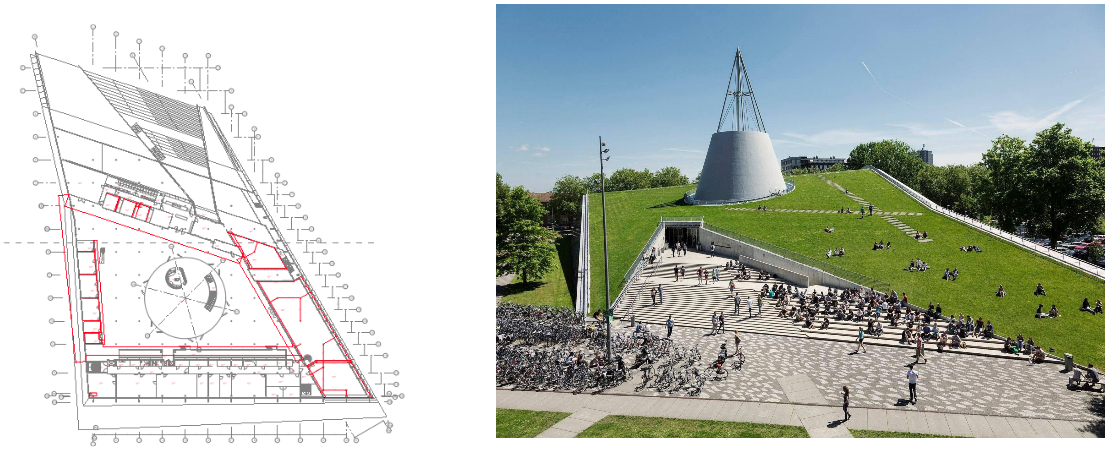

Figure 1: TU Delft library (right) and floor plan 1st floor (left)

The people in the building need to evacuate the building when the fire alarm goes off. The safest thing to do is to stop what you were doing and immediately leave the building through the nearest exit. Not using the elevators, but the stairs.

In reality, however, people tend to be slow to respond to fire alarms. This is due to many reasons, for example because of normative and informational social influence. Normative social influence is following the social norm, for example: “nobody is doing something, I shouldn’t do something or else I will stand out". Informational social influence is when there is no visible sign of danger and people are looking at each other about what is happening and what to do. We tend to think others know more than us and if nobody does something, there is a big chance we don't do anything as well. Other reasons for a slow response can be that you have to stop a task that you are performing. For example borrowing a book, sending an email, typing your assignment. In observational studies different response times have been observed for different tasks that were performed and stopped during an evacuation; for example up to 25 minutes in WTC Tower 2 during 9/11 disaster and up to 10 minutes in a retail store evacuation drill). Another reason for delayed response can be picking up belongings or persons before you leave the building. This could be keys or a coat, but it can also be a colleague, spouse, friend or child you need to stay together with.

Another influence on the response time is the emergency communication. When a fire alarm goes off, it is more effective to have another communication with it than a fire alarm by itself. This can be a message over the PA system, such as "There is an emergency, please leave the building through the nearest exit." It can also be a similar message that is communicated live from a control room or the building manager. Sometimes this will contain a bit more specific information and you can hear it is spoken live by a person at the scene, which can make building users more compliant. Another option is when staff members instruct the other building visitors what to do. This can be very effective, as building users tend to put the responsibility of safety with building managers and employees in the building. Building visitors tend to expect the staff members to tell them what to do in case of emergency. Visitors assume the staff members should know what to do in case of emergency and they should know the building (and its exits) better.

1.2 Actors

There are two different type of building users: staff members and visitors. Staff members are employees of the library and visitors tend to be TU Delft students, but can also include other people of the general public.

The building users can perform different tasks. Staff members can help visitors at the desk or perform library duties in an office. Visitors can stand at the desk for questions or borrowing books, walk to find a book, or sit at a desk to study. Each task will have a different amount of time it takes to stop this task when the fire alarm goes off.

Each building user has different knowledge about the building, based on their familiarity (experience) with the building. Each user has a default walking speed, based on their gender and age. Their walking speed is also influenced by the environment, such as congestion due to others being close by or walking on a horizontal plane versus stairs.

The staff members have followed a training on what to do when the fire alarm goes off. They will be stopping their current task immediately, go into their allocated position (which they know form their training) and tell visitors what to do. The majority of the visitors does not know what to do and show delayed responses due to the many reasons explained before. A minority of visitors is knowledgeable and will stop their task immediately and go to the nearest exit.

2 Purpose of the model

2.1 Goal

You have two research aims:

1. Create a artificial society of agents evacuating a building and analyse the total evacuation time. The total evacuation time is the time between the onset of the alarm and the last person to exit the building. *You can also analyse the response time. The response time is the time between the alarm and the moment an agent starts to move towards an exit.*

2. Test effects of different evacuation strategies and populations on total evacuation times. Perform structured simulations, varying the gender or age, number of people in the building, type of emergency communications and evacuation strategies (like which exits are open/closed, one way direction, having no staff members tell visitors what to do). Choose at least three of these factors that influence the evacuation time and analyse their effects.

2.2 Your Task

1. Build the model

2. Explore crowd evacuation behaviour and the total evacuation time
3. Answer the research questions
4. Report your modelling process

The minimum required elements in your model are the model assumptions, mechanics and metrics. Your model must have these implemented to be considered complete. Optional *nice to have features* are (much) more challenging model elements for those groups that have previous ABM experiences or want to dive deeper and are denoted in *italics*. Adding *nice to have features* to your model has a positive but limited effect on your grade. They are meant to provide a greater challenge if you are already experienced in programming.

3 Model elements

3.1 Staff members

Number of staff. By default, there are 50 staff members.

Location at start of simulation. Randomly spread the visitors through the building. *If you have groups, make sure they are at the same patch at the start.*

Familiarity. Staff members are familiar with the building: they know all the exits.

Tasks. Employees can be helping a visitor at the desk or performing library duties in an office. Employees stop their tasks immediately when the fire alarm goes off.

Walking speed. Each building user has a default walking speed and running speed, depending on the gender. A man walks 1 m/s and runs 1.5 m/s by default. A woman walks 0.9 m/s and runs 1.4 m/s by default. *You can refine these defaults further with age and gradient/type of floor, like horizontal plane or stairs, looking at the handbook for fire safety engineering or other research studies looking at these speeds.* The default walking speed reduces non-linearly as the space around the staff member gets fuller/congested. The more agents per square meter, the slower the staff members will walk. There can be no more than 8 building users on a square meter. *You can refine the* *relation between crowd density and movement velocity by looking at research studies, for example [1]. You can also refine the simulation by making sure agents are not allowed to overlap each other in the space when they share a patch.*

Default behaviour. When the fire alarm goes off, all staff members immediately stop their task and tell visitors within visible distance to leave the building via the nearest exit. The visible distance can be a circle around the agent. *You can also refine this based on how far you can see looking forward or how far your head can turn to the side.* When all visitors within visibility have left, the staff member will also leave via the nearest exit.

3.2 Visitors

N. By deafult there are 450 visitors.

Location at start of simulation. Randomly spread the visitors through the building.

Familiarity. The majority of visitors only know the main entrance of the building as entrance/exit and are not aware of other exit locations, while some of them know the other exits as well.

Tasks. Visitors can be standing at the desk for questions or borrowing books, walking to find a

book, or sitting at a study desk to study. Each task will take a different amount of time to be stopped, when the fire alarm goes off.

Walking speed. Same as staff member.

Default behaviour. By default, visitors will first look around at what other agents do and it will take some time for the visitor to stop their task. If a visitor sees the majority of other visitors within their visibility leaving, the tend to also leave the building. If a visitor is being told to leave by a staff member, the visitor will stop the task (by default, with the default amount of time it takes) and then leave for an exit. The majority of visitors will choose the entrance through which they came. Only a small number of visitors will immediately stop their task and exit through the nearest exit, because they had fire safety training. These visitors will tell other visitors where the nearest exit is and then these visitors will follow them to the nearest exit. *If a visitor is with a group (e.g. friends/family) the visitor will always stay with* *their group (12 meter away) and one person of the group will decide when and where to leave the building and the other group members will follow this leader. The speed of the group is based on default speed of the slowest agent.*

3.3 Emergency communication, notification and danger

Alarm. Start the alarm at 30 ticks into the simulation. Make sure all agents can hear the alarm going off.

Signs. *Place static or dynamic signs in the building which a probability with which agents will see them. Once an agent sees the signs, the agent will follow the direction of the sign towards the exit.*

Danger. *Represent danger in your simulation by letting this randomly happen in the library (at a random location) not too close to an exit. When an agent sees the danger, the agent will leave immediately and also tell other agents there is danger. If other agents hear this news they will also immediately stop their task, leave for the exit and tell other agents that they come in contact with.*

Fear. *You can also spread the news of the real danger via fear. If every agent has a level of fear between 0 and 1, the level of fear can increase to 1 when the agent sees the danger itself or it slowly goes up towards 1 when the agent comes into contact with other agents that have a fear level that is higher than 0. Fear can spread via agents that come into contact with each other. At each tick, calculate the amount of fear in the neighbourhood of the agent let the aggregated amount influence how much the fear level goes up (or down).*

3.4 Time and space

By default, the model will run for as long as it takes for all agents to evacuate the building. Otherwise, you can stop a run after a reasonable amount of minutes, for example 5 minutes. (but that should also be dependent on the amount of agents at the start of the simulation, what is a reasonable amount of time for the agents to reach safety?). One tick is 1 second. Patch to distance relation will be specified in the skeleton model.

4 Metrics

You are expected to provide at least these KPIs as model outputs and to use them in the analysis.

Total evacuation time. The total evacuation time is the time between the onset of the alarm and the last person to exit the building. *if you model danger, the total evacuation time is the time from the onset of danger until the last person exits the building.*

Response time. *The response time is the time between the alarm and the moment an agent starts to move towards an exit. In case you model danger or spreading of information between agents, you can choose a different starting point.*

Number of agents that have reached safety. Track at each tick how many agents have reached safety, show this in a figure while the simulation is running.

Average evacuation time. This is the average evacuation time over an X amount of simulation runs for a specific setting of your parameters.

5 User interface

Please make sure your model has at least these user interface elements, next to the visual representation of the building.

Event duration. The current time in minutes and seconds from the start of the simulation.
Alarm. Make a button you can press to make the alarm go off. (For your simulations let it go off automatically at tick 30).

6 Parameters

Please implement the following model parameters, and make them settable via the user interface:

Number of agents at start of simulation. Make a slider with the amount of agents at the start of the simulation. Think of what the maximum amount of building users can be in the library, based on the space and maximum crowd density (of 8 people per square meter)

Gender. Make a slider with the % of females in the simulation.

Age. Make a slider or input box with % of agents that are children or adults.

Familiarity. Make a slider to indicate what the percentage is of people with familiarity (knowing all exits and choosing the nearest one when the fire alarm goes off) or no familiarity (not knowing the exits and taking the familiar route)

7 Research questions

Run structured simulations, where you vary only one parameter and keep the values for other parameters the same. These are your research questions:

1. What is the difference in total evacuation time if all agents exit via the main entrance versus all agents exit via the nearest exit?
2. Systematically vary which exits all agents will exit the building through (only A, only B, only C, A or B, B or C, A or G, etc.). What are the differences in evacuation time?How many time should you run each variation?
3. *What is the difference in total evacuation time if there are signs in the building that lead the visitors to the nearest exit, compared to a building with no signs? Which assumptions do you need to make?*
4. *How does gender or familiarity influence total evacuation time?*
5. *Which parameter influence response time most?*

8 Guidelines, submission and grading

8.1 Guidelines

Most important thing is to cover all steps of the modeling cycle, from initial conceptualization to reporting on the model. When short on time, make the model (much) less complex, but make sure you do all the steps, like verification, analysis etc. Specially when you are not very experienced in programming, make it simple but sane.

The project description **is incomplete**, there are many things you will have to decide yourselves and make your own assumption. Make those assumptions and choices very clear, especially when significantly deviating from the base project description. Make it clear what the assumption is, and why did you make it. "We had no idea what else to do, this seemed reasonable" is a valid reason. Keep in mind, this is a modeling course, not a evacuation behaviour course.

Keep the report short and to the point. It is OK for it to be quite mechanical, you are demonstrating your ability to design a model, make choices, implement, analyses etc, not write pretty and long reports.

8.2 Submission

You will individually submit your final report during the exam, as an answer to a question. Each member of the group needs to upload the file as an answer to their own exam.

Please follow the requirements for the submission format carefully!

A zip file, with the name and student number of every group member as a filename. No spaces in the filename. e.g. **Van_Der_Wal_314159_Nikolic_424242.zip**

Inside the zip there is a :

- A directory with the same name.
- In that directory :
  - Report in PDF format with the name and student number of every group member in the file name : **Report_Van_Der_Wal_314159_Nikolic_424242.pdf**

- Please make sure you use the **"embed all fonts"** options, which is the same as as using the PDF/A format, when you generate the pdf.
- NO code in the report
- a **model/** directory, containing the .nlogo file(s) of the model and all data needed to run the model.
- a **output/** directory, containing all the generated result files. Please **zip these files** before adding them to the package
- a **analysis/** directory, containing all code (R/python/Excel/whatever) that you have used to generate your report, and all output images that you created.

Maximum file size is 100 MB. If you have generated more than that you need to reconsider your modeling practices.

8.3 Grading

The grading will be determined based on the following criteria :

- Does your model run?
- Does it break if the parameters are changed?
- Does it generate recognizable criteria?
- Which elements of the compulsory behaviors have you lest out, which of the advanced behaviors did you put in.
- Did you perform a verification step, and how thoroughly ?
- How did you set up the experiments?
- How well did you do the analyses? How well are you interpreting the data?
- Did you answer the research questions?
- How well are you using the Netlogo language
- Is the report complete, clear and readable?

9 References

[1] Z Fang, S.M Lo, J.A Lu, On the relationship between crowd density and movement velocity, Fire Safety Journal, Volume 38, Issue 3, 2003, Pages 271-283, ISSN 0379-7112, https://doi.org/10.1016/S0379-7112(02)00058-9.