ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Lecture with Computer Exercises:
Modelling and Simulating Social Systems with MATLAB

Project Report

Evacuation Bottleneck
Simulating a Panic on a Cruise Ship

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Agreement for free-download

We hereby agree to make our source code for this project freely available for download from the web pages of the SOMS chair. Furthermore, we assure that all source code is written by ourselves and is not violating any copyright restrictions.

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Contents

1 Abstract

This work takes a look into the evacuation mechanisms of a cruise ship in case of an emergency. A simple model is implemented which is used to simulate the dynamics of such a system. The main emphasis was on the limited capacity of the exits, since that is the key element for a rescue boat.

2 Individual contributions

The work on this project was split among us to fit our strengths the best way possible. Because of his knowledge in image editing and formats, Johannes Weinbuch focused on the image manipulation for the input and implemented the loading of the image into MATLAB, improving the existing solutions from the previous courses. He further took a large part of the writing for the report and executing the simulations, which were written by Benedek Vartok. He evaluated which code from previous semesters could and should be reused, and implemented the missing parts for our special case. Also, he wrote the output mechanisms for the simulation, so that the data could be used for analysis.

3 Introduction and Motivations

In January 2012, the Costa Concordia hit a rock and ran aground[1]. This event got great media attention for a long time so we decided to take a closer look at the evacuation of a cruise ship. The question is, what is the best stratgy to leave the ship? This question should for sure be answered with one of the emergency drills, but it is always good to have some background knowledge.

4 Description of the Model

The model is a big simplification of real life, otherwise it would be way too complex to simulate. It assumes that the ship is intact, that there is calm sea and that the passengers are obliged to leave the ship. A possible explanation for this could be a machine defect which leaks explosive gas in a badly ventilated room in the ship. Further, we assume that the rescue boats are like doors, which close after a certain amount of people going through them.

Since we also assume that the other doors, for example between the rooms or floors, are constantly open and working, we only simulate one deck, the one with the exits to the rescue boats. The evacuation of multiple floors in a static building has already been researched in [2].

After these simplifications, the task left to simulate was the evacuation of a single floor with some elements that can change. For this task, we chose a simple agend based modelling solution as described in [3]. A passenger is treated as a particle. It has a mass, and there are physical and social forces, accelerating that mass so that it cannot always follow its desired direction. The desired direction is implemented as the shortest path to the nearest exit. For the exact formulae for the forces see section 5.2.5.

5 Implementation

5.1 Input

Since we had some good projects which covered similar problems as ours, we could get some ideas from them, but at the same time improve them. Namely, there are [2] and [4]. As far as the input for the simulation is concerned, we see two approaches in these works for getting the map data into the simulation. In [2], a simple PNG image is used to get a map into the simulation. The problem here is that only a certain RGB color value can be read out of the image. This can lead to problems if the image is processed with automatic or semiautomatic image manipulation programs, since only a minor difference in color can prevent the generation of the desired data. In [4], the image format is even more simple. There is only a bitmap image read into MATLAB. Since the bitmap images can use a colormap, MATLAB doesn't use 3 channels but a unique number for each color in an image matrix to give every pixel its color. This has the same problem as the PNG solution regarding how exactly the colors have to be set, but the different parts of the image can be separated with less code.

We took the best of both solutions. We used the PNG-format with indexed colors. So we have the most flexibility with very little usage of disk space. There is no special "wall color" or anything like that, just a simple rule how the colormap is read: Color 0 of the map specifies walls, color 1 free space. Then, there can be any number of spawn zones. Spawn zones are the areas in the image, where new agents can be placed. With different spawn zones, it is possible to account for different situations: A ballroom is different from a staircase. The number of spawn zones is specified in the configuration file. At last, there is an arbitrary number of exits. Again, each exit can have its own parameters or can even be handled specially in the program's code.

To manipulate the colormap, any slightly sophisticated image manipulation program should suffice. We used the free software Gimp [5]. It has a very convenient command which allows the user to rearrange the colormap. This is shown in figure 1.

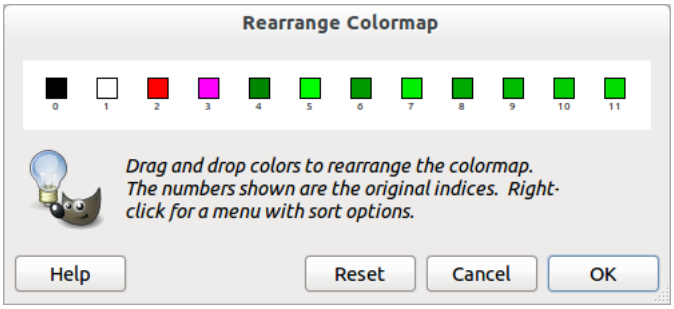

Figure 1: Screenshot of the Rearrange Colormap dialog in Gimp 2.6.11

5.2 The Simulation Routines

5.2.1 Code Reuse from Multilevel Evacuation

Since this project has very similar foundations as [2] (like the forces used in the model), we were able to use a lot of code from their repository. Some of the structure needed to be changed to implement our custom features, but for example the utility functions for the Fast Sweeping algorithm and the linear interpolation which the other group wrote in C were copied 1:1 into our code-tree.

5.2.2 General Structure

During the entire program run, one single big structure is used to hold and pass around the state of the simulation.

At first, this structure is initialized with the fields that are given in the configuration file by `loadConfig`. Then, `initialize` runs over the struct and calculates some data needed in the simulation, such as the vector fields needed for the wall and exit force fields using the `fastSweeping` method which we got from [2].

5.2.3 Main Loop

`simulate` is the routine we call when we do an entire simulation. It uses the `loadConfig` and `initialize` functions to initialize its runtime data, then it does the loop calculating forces, adding new agents, progressing the agents, updating the exit vector fields, potentially plotting and saving frames and collecting data.

These steps will be explained in detail in the following sections.

5.2.4 Agent Placement

As mentioned in section 5.1, our model of the ship has different spawning zones where new agents can start out at. The way we implemented it, in every step of the simulation loop it is checked whether there are any remaining agents that need to be placed (i.e. agents which are not in the simulation yet). If there are, then for every agent the program chooses a random point in the spawning zones and places him there, unless it detects that the agent would collide either with walls or other agents. In that case, the routine tries the placement for that agent up to five times, each time with a new random position. If the agent couldn't be placed, then he will have a chance to spawn in the next time step.

This method was implemented in `placeAgents`. In the same method, the basic properties of the agent get assigned, like the starting zero velocity and a random radius.

5.2.5 Agent Dynamics

To simulate the movement of the agents in this physical model, different forces need to be calculated in every step on every agent. These forces have been separated into the following functions which `simulate` calls:

`addDesiredForces` is responsible for making the agents seek the exits of the layout, in our case the rescue boats.

5.3 Output

6 Simulation Results and Discussion

7 Summary and Outlook

8 References

[1] `http://www.bbc.co.uk/news/world-europe-16563562`, 9.12.2012

[2] *Modelling Situations of Evacuation in a Multi-level Building* , Hans Hardmeier, Andrin Jenal, Beat Kng, Felix Thaler, Zurich, April 2012

[3] *Simulating dynamical features of escape panic*, Dirk Helbing, Illés Farkas, Tamás Vicsek, Nature, 28. September 2000

[4] *Pedestrian Dynamics Airplane Evacuation Simulation*, Philipp Heer, Lukas Bhler, Zurich, May 2011

[5] http://www.gimp.org/, 9.12.2012