ETH zürich

Simulation of Escape Panic: Bottleneck Effect

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Introduction

Introduction

Goals:

- Simulate evacuations of arbitrary rooms filled with may people
- Analyze the effect of additional barriers on the evacuation scenario
- Test our program on a real life tragedy: Evacuation of Madrid Arena in 2012

Model

- Social-force model
- Based on the paper: *Simulating dynamical features of escape panic* by Dirk Helbing et al.
- $m_i \frac{d\boldsymbol{v_i}}{dt} = m_i \frac{v_i^0(t)\boldsymbol{e}_i^0 - \boldsymbol{v}_i}{\tau_i} + \sum_{j \neq i} \boldsymbol{f}_{ij} + \sum_W \boldsymbol{f}_{iW}.$

Implementation

N-body problem:

- Each agent is treated independently
- Time independent Hamiltonian
- Differential equation determines the time evolution of the system
- As soon as initial positions and initial velocities are determined, the system becomes completely deterministic

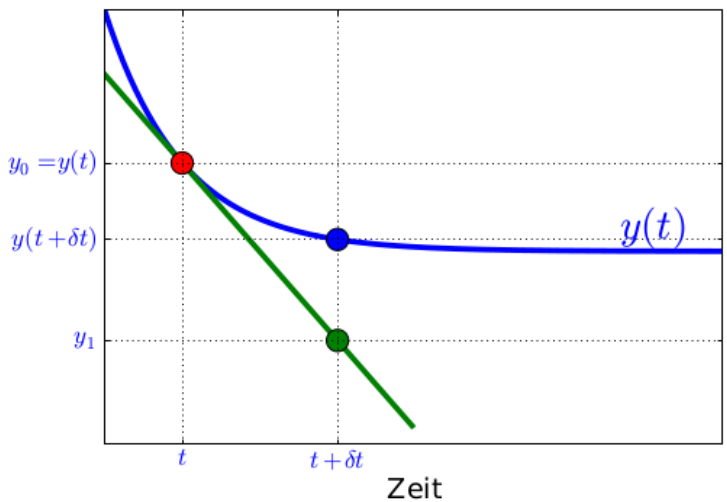
The positions have been implemented using a $n \times j \times k$-array, where n is the number of agents used, j is the number of coordinates and k is the number of timesteps. The velocities have been implemented using a similar array

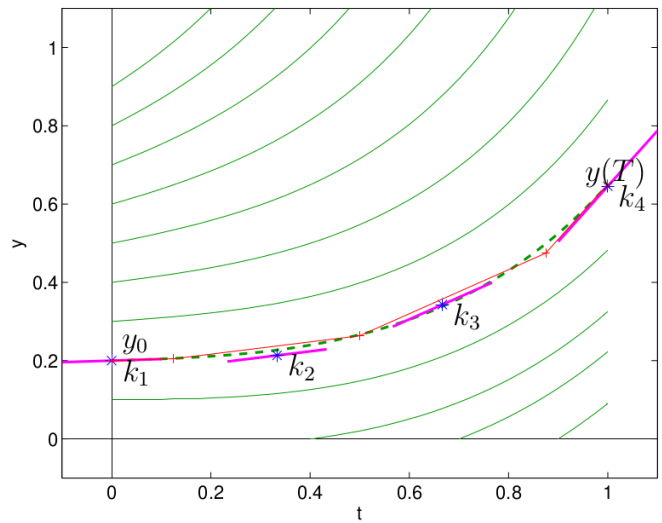
Time evolution

Numerical solution of the differential equation:

- $y_{...,...,k+1}, v_{...,...,k+1} = odestep(y_{...,...,k}, v_{...,...,k})$

What is actually odestep?





Dormand-Prince ode45

- 4th and 5th order methods
- Adaptive methods
- Yield the most accurate results
- Each iteration costs 7 function iterations => running times at EULER exceeded three days
- Lower order integrators "exploded" due to stiffness $\Longrightarrow$ ode45 is necessary

Additional Wall Model

In addition to the Helbing model, we have implemented the ability of people to overcome wall obstacles.
Implementation structure:

- Obstacle's recognition
- Taking the shortest path

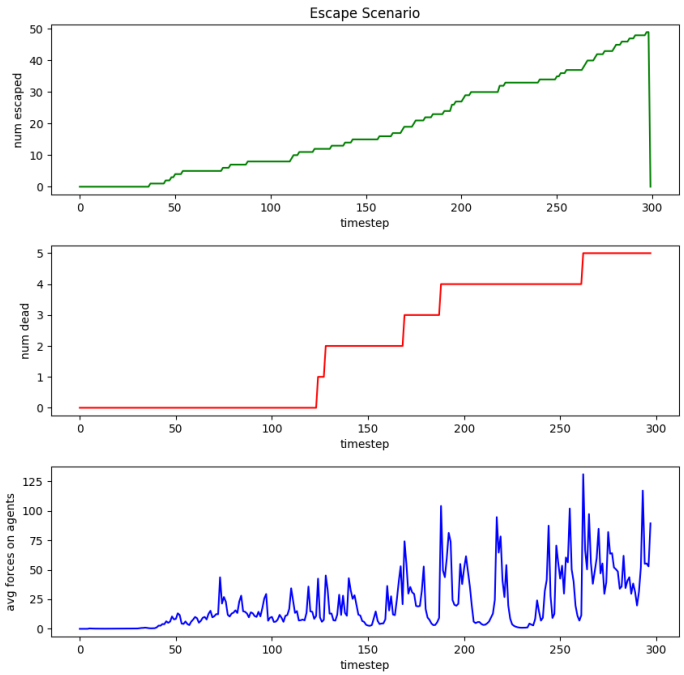
Simulation Videos

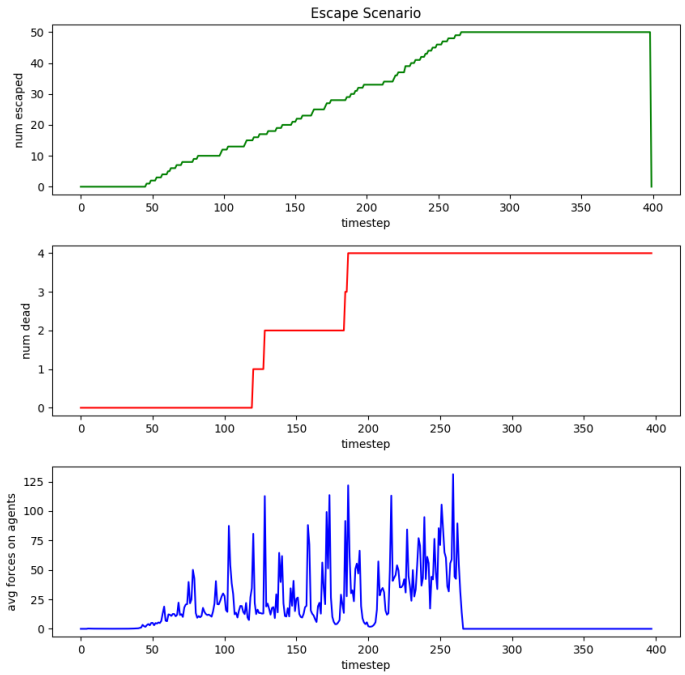
Results

- The run time was around 30-60 hours even with EULER
- Were not able to run more than a few simulations
- Therefore the results are of limited validity

Results - Square Room

- Room of size 25*m* x 25*m* with one exits of size 1.7*m*
- 50 people inside



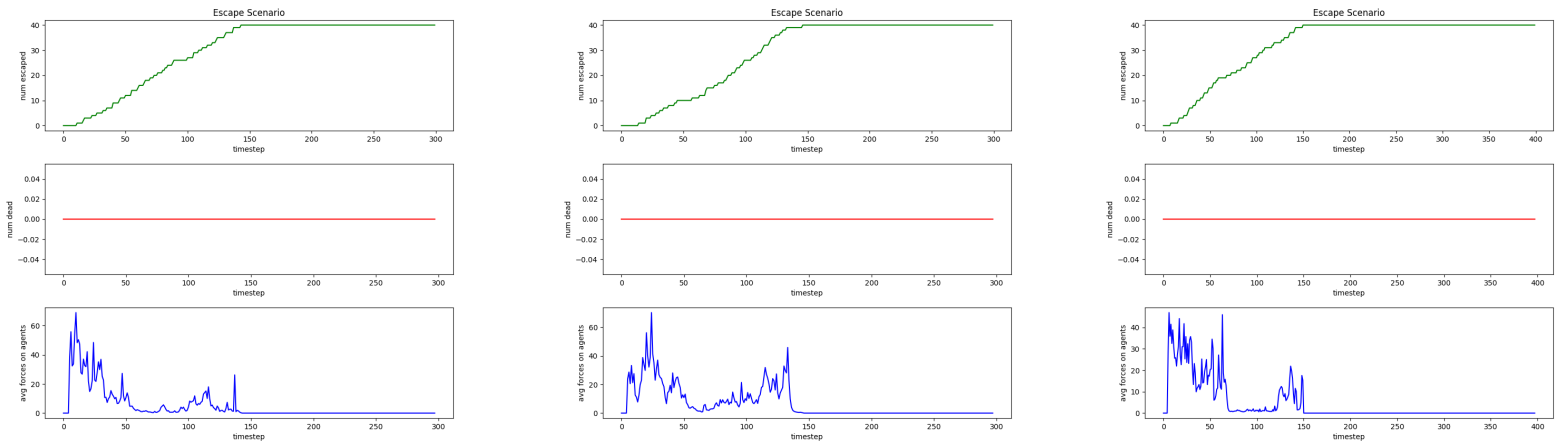


Results - Square Room

- 4-5 people died in this evacuation scenario
- One exit of size 1.7 meters is too small for the amount of people

Results - Rectangle Room

- Room of size 25*m* x 5*m* with two exits of size 1.7*m*
- 40 people inside, each half goes to one of the exits



Results - Rectangle Room

- Modelling the incident in Madrid in 2012 where four girls died
- In our simulations there were no casualties
- This suggests that if the people split up, two exits of size 1.7 meters are enough to evacuate 40 people in an $25m$ x $5m$ corridor.

Bibliography

V. Gradinaru, *Numerische Methoden* Lecture Notes, 2017, ETH Zürich.

Dirk Helbing, et al., *Similating dynamical features of escape panic*, Nature, 200, 407, Jg., Nr. 6803, S. 487