Evacuation of Ships and Buildings based on a CA model

www.traffgo-HT.com
„Bilderbuch Duisburg“

Bilderbuch Duisburg.avi
Topics

1. Model Characteristics
2. Calibration: Experiments and Observations
3. Alternative Methods: „Hand calculations"
4. Validation: Exercises, Reports, Field Studies
5. Technical Aspects: CAD etc.
6. Assessment based on simulation results
7. Limits (in principle, time, memory)
TraffGo
TraffGo HT, Background

- *Physics of Transport and Traffic*, Universität Duisburg-Essen
- Started in 2001
- Support from „Pfau“ (now: „Exist“)

„Since I‘m a member of the Green Party and not catholic, this is the most attractive position available.“
TraffGo HT, References

- Cooperation Germanischer Lloyd AG
- Maritime Industry (FSG, Meyer, Kvaerner)
- Built Industry (Stadiums, WYD, Hajj)
- Guideline (www.rimea.de) – open project
- www.ped-net.org
- „Last-mile evacuation“
Data
Introduction – Groups

Panic is a controversial concept.
# Influence of Group Size

<table>
<thead>
<tr>
<th>Group Size</th>
<th>Number</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>95</td>
<td>1.38</td>
</tr>
<tr>
<td>2</td>
<td>149</td>
<td>1.28</td>
</tr>
<tr>
<td>3</td>
<td>59</td>
<td>1.24</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>1.24</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>1.22</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>1.10</td>
</tr>
<tr>
<td>sum</td>
<td>332</td>
<td>1.30</td>
</tr>
</tbody>
</table>
Distribution of Walking Speeds

Anzahl

Daten | 6 | 8 | 4 | 16 | 25 | 23 | 24 | 35 | 34 | 25 | 30 | 30 | 17 | 18 | 9 | 5 | 11 | 4 | 0 | 2 | 2 | 0 | 1 | 0 | 1 | 0

Gauß | 2.6 | 4.2 | 6.6 | 9.8 | 14 | 18 | 22 | 13 | 9.4 | 6.3 | 4 | 2.4 | 1.4 | 0.7 | 0.4 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0

Gauß abgeschn. | 1.8 | 3.5 | 6.4 | 11 | 16 | 23 | 30 | 35 | 38 | 35 | 30 | 23 | 16 | 11 | 6.4 | 3.5 | 1.8 | 0.8 | 0.4 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0

Geschwindigkeit m/s
Individual Strategies

- bed bound
- sedated
- confused
- young, fit
- alert
- egress
- slow egress
- move to refuge
- defend in place
- decreasing mobility
- increasing complexity
- single storey
- simple building
- multi storey
- multi function building
Formation of Lanes

a) 

b)
Movement on Stairs

specific flow [P/ms]

1.5
1.0
0.5

30°

38°

density [P/m²]

1.0  2.0  3.0
Film Evakuierungsübung FL
Models
Classes of Models

```
<table>
<thead>
<tr>
<th>Space</th>
<th>Continuous</th>
<th>Fine Networks (CA)</th>
<th>Coarse Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Individual Perspective</td>
<td>Individual Perspective</td>
<td>Global Perspective</td>
</tr>
<tr>
<td>Behavior</td>
<td>Implicit</td>
<td>AI Based</td>
<td>Rule Based</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AI Based</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Functional Analogy</td>
<td>Implicit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Implicit</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Space</th>
<th>Coarse Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Global Perspective</td>
</tr>
<tr>
<td>Behavior</td>
<td>No Rules Applied</td>
</tr>
<tr>
<td></td>
<td>Functional Analogy</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk Assessment</th>
<th>Coarse Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Perspective</td>
<td>Individual Perspective</td>
</tr>
<tr>
<td>Implicit</td>
<td>Rule Based</td>
</tr>
</tbody>
</table>
```
Model

- Cells 40cm x 40cm
- Cells are accessible or walls
- At most one person per cell
Simulation, Influences

- Speed
- Body Height
- Stamina
- Mobility Impairments
- Age
- Sex
Movement Algorithm

$\Delta t = 1s$

Conflict solution:

$v_{\text{free}} = 3$

$v_{\text{free}} = 2$

$v_{\text{free}} = 3$
Potential Spread
Transition probabilities

Transition probabilities:

\[ p_i = e^{-\frac{(P_i - P_0) + S}{S}} \]

Inertia:

\[ p_i, \text{ current direction} \rightarrow p_i, \text{ current direction} \cdot \Theta \]
Update Strategies

1. Hop or stop
2. Move as far as possible
3. Sub-steps
4. No crossing paths

Strategy 3 – Sub-Steps
Discretization
Non-local Conflicts
Clogging at the Exit
Higher Flow for \( a = 20 \text{cm} \)
Flow Models, Assumptions

- Flow = f(Density)
- No overtaking
- Identical Persons
- Unhindered Movement
- Safety or Correction Factors
Flow Models, Basics

Floor 1
Floor 2
Floor 3

Other Decks

Floor 1
Floor 2
Floor 3

M
Exit
Flow Model, Example

Predtetschenski/Milinski

- Calculation of initial density in sqm/sqm
- Take flow value from list
- Calculate flow time $\rightarrow t_{\text{Flow}}$
- Calculate walking time $\rightarrow t_{\text{Walk}}$
- Total time: $t_{\text{Total}} = t_{\text{Flow}} + t_{\text{Walk}}$
Flow Models, Assumptions

- Flow = f(Density)
- No overtaking
- Identical Persons
- Unhindered Movement
- Safety or Correction Factors
PedGo
Film RTL Supertrend

RTL Future Trend
Software Package

PedGo

- Simulation
- Analysis

PedGo Editor

- Import DXF-Files
- Model scenario
Personal Parameters
Routes

• Define different routes for different groups
• Crew and passenger routes
Flow-Density-Relation

Density [P/m²]

Specific Flow [P/ms]

Empirical

PedGo v2
Simulation, Results

- Statistical Distribution of Total Times
- Interaction of Persons
- Different Behavior
- High Calculation Speed
- Variation of Scenarios (Sensitivity Analysis)
- Fast Implementation of Geometrical Changes
Simulation, Results

Density plots (integrated over time):
Red Areas: congestion ($\rho > 3.5$ /sqm, 0.1 T)
Yellow Areas: medium congestion (0.01 T)
Green Areas: little congestion (1 second)

Animations/Screenshots:
Red dots: people standing
Yellow dots: medium speed
Green dots: free walking speed ($v_{max}$)
New Jamarat Bridge
Film Mekka

National Geographic.wmf
Simulation Jamarat Bridge

Assessment of the new design with respect to evacuation via side-towers.
Westfalenstadion Dortmund

Level 7  rot:  Walls
Level 6  Barriers
Level 5
Level 4
Level 3
Level 2
Level 1  grün:  Stairs
Egress

Exits

Level 1

Level 2

Congestion on the stairway → no congestion at the exits.

Hubert Klüpfel
Steps

Pruning

Coloring

Modeling

Scenarios

Simulation

Evaluation
St Evakuus, Floor-plan

Gallery
226 Persons
(202: seats, 24: choir)

Ground floor (exit)
793 Persons
(788: seats, 5: wheelchairs)
Work-flow

CAD-drawing → Preprocessed CAD → Grid-based Floor-plan → Simulation → Evaluation

TraffGo HT
Preprocessing
Pruning
Preprocessing, Pruning

Remove numbers and dimension lines
Preprocessing, Pruning

Remove text
Preprocessing, Pruning

Remove hatches and similar lines
Preprocessing, Pruning

Remove irrelevant equipment (like faucets)
Preprocessing
Coloring
Preprocessing, Coloring

Color = Information (door, stair, ignore, ...)

TraffGoHT
Modeling
Preprocessing, Modeling

Import the pre-processed files (dxf)
Preprocessing, Modeling

Automatically superimpose grid
Preprocessing, Modeling

Automatically project to grid
Preprocessing, Modeling

Definition of colors (mapping to function)
Preprocessing, Modeling

Automatically assign cell information
Assessment based on Simulation Results
Scenarios
Scenarios, Case 1 (standard)

Persons leave the building via the main egress routes.
Scenarios, Case 2 (peripheral)

Persons leave the building via the external stairs and exits.
Persons leave the building via the inlaying stairs and exits.
Scenarios, Case 4 (only main)

All persons leave the building via the main exit.
Population

Standard Population:

Wheelchairs:

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Simulation - Animation
Simulation - Cases

- 500 simulation runs per case
- Simulation speed:
  - Celeron; 450 MHz → 20 min
  - Pentium IV; 2.2 GHz → 5 min
- Additional variation of reaction time for Case 1 (equally distributed):
  - 0-10 s
  - 0-60 s
  - 0-120 s
## Results, Egress times

<table>
<thead>
<tr>
<th>Case</th>
<th>Significant time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 (0-60 s)</td>
<td>5:16 min</td>
</tr>
<tr>
<td>1.2 (0-10 s)</td>
<td>5:03 min</td>
</tr>
<tr>
<td>1.3 (0-120 s)</td>
<td>5:38 min</td>
</tr>
<tr>
<td>2 (outdoors)</td>
<td>5:42 min</td>
</tr>
<tr>
<td>3 (indoors)</td>
<td>5:21 min</td>
</tr>
<tr>
<td>4 (main exit)</td>
<td>9:33 min</td>
</tr>
</tbody>
</table>

**Conclusion:**

- Reaction time influences egress time only insignificantly.
- Route choice may have a major influence on egress time.
Results, Congestion

Case 1.2 (0-10 s)  Case 1.1 (0-60 s)  Case 1.3 (0-120 s)

Conclusion:

• The size of the jams increases with decreasing reaction time.
• There is hardly congestion on the gallery due to the low initial density.
Results, Identification of congestion

Case 1.1 (standard) | Case 2 (outside) | Case 3 (inside) | Case 4 (only main)

Conclusion:
- Hardly congestion on the gallery due to low initial density.
- There is always congestion in the central corridor (ground floor) and in front of the main exits.
Conclusion:

- Cases 1-3 are similar to each other.
- Case 4 is the worst case.
Limits
Principal, Time, Memory
Restrictions

Geometry: 100m x 100m
Population: 100,000
Many Psychological Aspects
Details of Deployment and Embarkation
Aker Genesis

~ 8,000 persons
21 decks
> 360 m long

Editor (pg2)
(show decks)
PedGo - Program

Night case

Open PedGo
PedGo - Simulation

Night case

Animation Decks 3 to 7
The end

Presentation, Publications, Manual, Information, Links

www.traffgo-ht.com