A queuing model based on social attitudes

Conference on Traffic and Granular Flow '15

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Queuing in the real world

Most people encounter queues as part of everyday live. Queues are social systems (Mann (1969)) influenced by

- physical constraints,
- social norms & rules,
- culture,
- the goal,
- type (self-organized or controlled),
- ...

➥ Different queuing patterns can be observed.

The goal

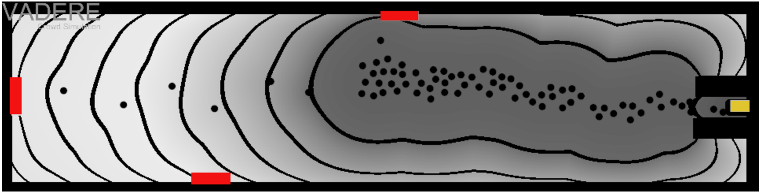
The goal is to extend ideas from (Köster and Zönnchen (2014)):

- Use different navigational floor fields to induce both, standing in line and competition for the best spot.
- Allow switching between floor fields to include queue jumping.

➥ Natural queuing patterns should emerge.

Floor fields guide pedestrians around obstacles towards their target along

- the shortest path (Burstedde et al. (2001); Blue and Adler (2001)), or
- the quickest path (Kirik et al. (2009); Kretz (2009); Kretz et al. (2011); Hartmann et al. (2014)), or
- an occupied path which induces loose queueing (Köster and Zönnchen (2014)).



The floor field encodes $T(\vec{x})$,

- the traveling time to the target
- of a wave front propagating from the target area Γ.

The wave front travels with traveling speed $F(\vec{x})$. T is computed by solving the eikonal equation

$$||\nabla T(\vec{x})|| = \frac{1}{F(\vec{x})}, \quad T(\vec{x}) = 0 \text{ if } \vec{x} \in \Gamma.$$

➥ Manipulate F to get different floor fields.

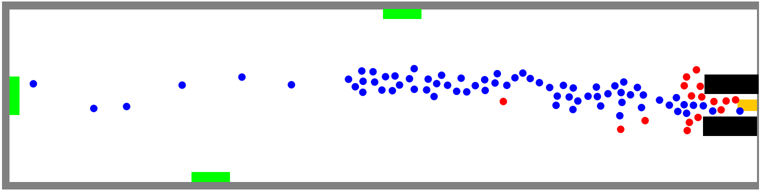
The model

We introduce two principles:

- We use multiple floor fields to model different pedestrian strategies.
- We allow switching between strategies according to a simple decision process.

What do we want to model?

- Pedestrians use one of two strategies.
  - (a) Competitive: walk directly to the target.
  - (b) Cooperative: get in line.
- Pedestrians change their strategy during the simulation.



Pedestrians walk to the yellow target on the right. Cooperative pedestrians get in line, competitive pedestrians cut the line.

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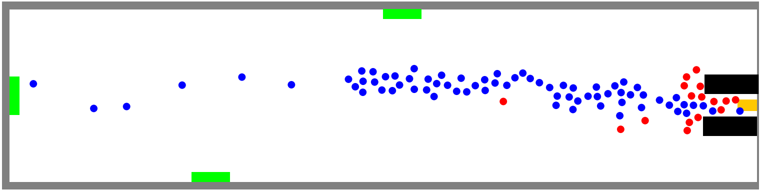

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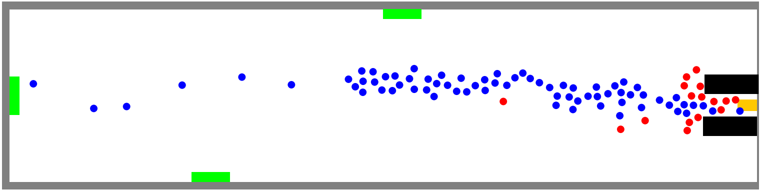

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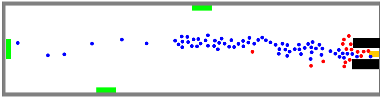
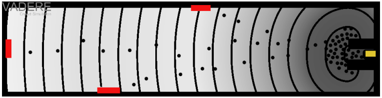
Modeling of different pedestrian strategies.

The model: strategies and floor fields

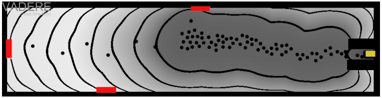
Pedestrians navigate according to the floor field that corresponds to their current strategy.



Queuing with queue jumpers.



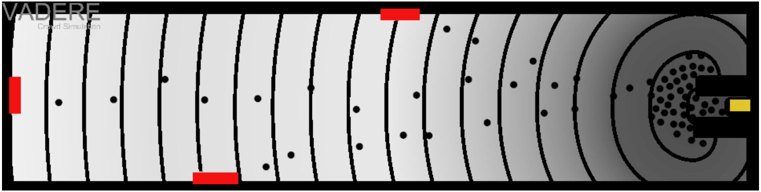
Floor field for competitive pedestrians.



Floor field for cooperative pedestrians.

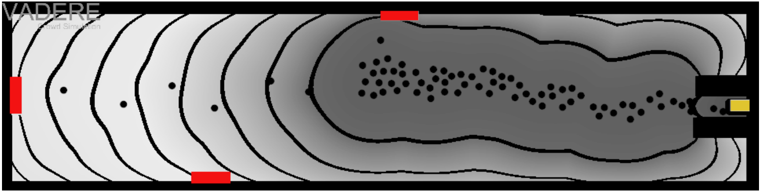
Competitive strategy

Pedestrians walk directly to the target.



Cooperative strategy

Pedestrians get in line.



Modeling decision process.

The model: decision process

A pedestrian's decision on whether to start or stop queue jumping is influenced by:

- the time t a pedestrian has been using a certain strategy, (e.g. loosing patience, satisfied with new position)
- the absolute or relative queue position of a pedestrian, ('Should I risk my position?')
- the progress of the service point,
- social norms,
- the culture,
- shared social identity (e.g. football fans waiting together.)
- ...

The model: decision process

We assume that the decision process is similar to a birth process with a memory-less exponential distribution.

Let τ be the time a pedestrian p changes strategy. Then

$$P(\tau \leq t) = \begin{cases} 1 - \exp\left(-\frac{1}{\mu_{comp}} \cdot t\right) & \text{if } p \text{ is competitive} \\ 1 - \exp\left(-\frac{1}{\mu_{coop}} \cdot t\right) & \text{if } p \text{ is cooperative,} \end{cases}$$

The parameters μ_{comp} and μ_{coop} are the expected time a pedestrian sticks to the competitive and the cooperative strategy respectively.

Our algorithm is independent of the underlying locomotion model.

Here we use

- Optimal Steps Model: Seitz and Köster (2012); von Sivers and Köster (2013),
- Gradient Navigation Model: Dietrich and Köster (2014).

Pedestrians spawn from the green areas and try to reach the yellow target on the right. Some pedestrians cut the line.

Medium level of patience: $\mu_{comp} \to \infty, \mu_{coop} = 300s$

Low level of patience: $\mu_{comp} \to \infty, \mu_{coop} = 100s$

Pedestrians spawn from the green areas and try to reach the yellow target on the right. Some pedestrians start queue jumping and get back in line after a short time.

Short queue jumps: $\mu_{comp} = 2s, \mu_{coop} = 100s$

Longer queue jumps: $\mu_{comp} = 20s, \mu_{coop} = 100s$

Conclusion

Floor fields in combination with a simple decision process can be used to induce a variety of natural looking queues in pedestrian motion models.

Future work

We have to find heuristics based on findings from psychology that realistically model the decision process.

Blue, V. J. and Adler, J. L. (2001). Cellular automata microsimulation for modeling bi-directional pedestrian walkways. *Transportation Research Part B: Methodological*, 35:293–312.

Burstedde, C., Klauck, K., Schadschneider, A., and Zittartz, J. (2001). Simulation of pedestrian dynamics using a two-dimensional cellular automaton. *Physica A: Statistical Mechanics and its Applications*, 295:507–525.

Dietrich, F. and Köster, G. (2014). Gradient navigation model for pedestrian dynamics. *Physical Review E*, 89(6):062801.

Hartmann, D., Mille, J., Pfaffinger, A., and Royer, C. (2014). Dynamic medium scale navigation using dynamic floor fields. In Weidmann, U., Kirsch, U., and Schreckenberg, M., editors, *Pedestrian and Evacuation Dynamics 2012*, pages 1237–1249. Springer.

Kirik, E. S., Yurgelyan, T. B., and Krouglov, D. V. (2009). The shortest time and/or the shortest path strategies in a CA FF pedestrian dynamics model. *Mathematics and Physics*, 2(3):271–278.

Köster, G. and Zönnchen, B. (2014). Queuing at bottlenecks using a dynamic floor field for navigation. In *The Conference in Pedestrian and Evacuation Dynamics 2014*, Transportation Research Procedia, pages 344–352, Delft, The Netherlands.

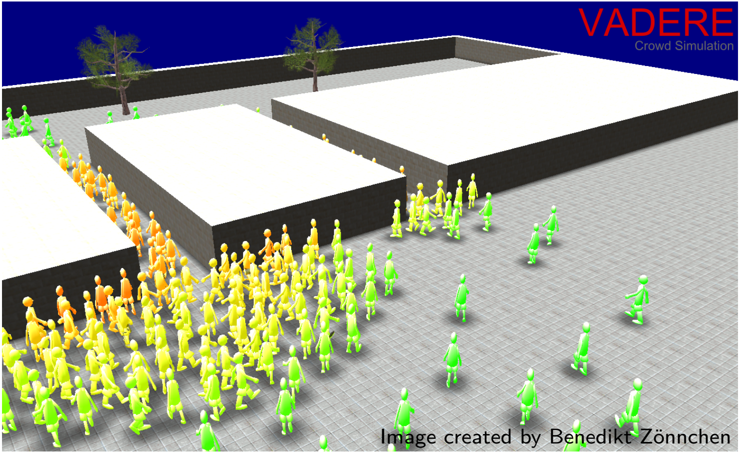
Kretz, T. (2009). Pedestrian traffic: on the quickest path. *Journal of Statistical Mechanics: Theory and Experiment*, 2009(03):P03012.

Kretz, T., Große, A., Hengst, S., Kautzsch, L., Pohlmann, A., and Vortisch, P. (2011). Quickest paths in simulations of pedestrians. *Advances in Complex Systems*, 10:733–759.

Mann, L. (1969). Queue culture: The waiting line as a social system. *American Journal of Sociology*, 75(3):340–354.

Seitz, M. J. and Köster, G. (2012). Natural discretization of pedestrian movement in continuous space. *Physical Review E*, 86(4):046108.

von Sivers, I. and Köster, G. (2013). Realistic stride length adaptation in the optimal steps model. In *Traffic and Granular Flow'13*, Jülich, Germany.



VADERE soon to be open source!

Add influencing properties (Example)

Let $T(\vec{x})$ the travelling time of the propagating wave starting at the queue tail and stopping at the border of the queue. Let further

$$T_{max} = \max_{\vec{x}} T(\vec{x}).$$

Replace μ_b by

$$\mu_b \cdot \frac{T_{max}}{T(\vec{x})},$$

where $\vec{x}$ is the current position of the pedestrian.

Decision process algorithm

Algorithm 1: Decision process algorithm.

Data: random generator $random$

for $i \leftarrow 0$ **to** n **do**
    $\Delta t \leftarrow t_{i+1} - t_i$;
    for *all pedestrians* p **do**
        if p *is cooperative* ***and*** $random.next() < \exp((-1/\mu_{coop}) \cdot \Delta t)$ **then**
            change the strategy of p to competitive
        else if p *is competitive* ***and*** $random.next() < \exp((-1/\mu_{comp}) \cdot \Delta t)$ **then**
            change the strategy of p to cooperative

Tail detection algorithm

Algorithm 2: Queue tail detection algorithm.

Data: $r > 0$

Result: target polygon $\Gamma \subset \Omega$ with $\forall q \in \Gamma : ||p - q|| < r$

calculate the pedestrian density $\rho_{ped}(\vec{x})\ \forall \vec{x} \in \Omega$;

mark each position $\vec{x}$ with $\rho_{ped}(\vec{x}) < \epsilon$ as unreachable $(\epsilon > 0)$;

solve the eikonal equation by starting the propagating wave from the target of interest, with $F = 1$;

sort the list $L \subset \Omega$ of reachable position according to descending travelling time;

$p \leftarrow L.pop()$ (remove the point with the highest travelling time form the sorted list);

$P.add(p)$ (add the point to the set of points);

while L *is not empty* ***and*** $||p - L.peak()|| < r$ **do**

  $P.add(L.pop())$

return Γ, the convex hull of P;

Each floor field corresponds to a specific travelling speed function F:

$$F_{coop}(\vec{x}) = \frac{1}{1 - \min\left(c_{queue} \cdot \rho_{ped}^{b}(\vec{x}), 1 - \epsilon\right) + c_{ob} \cdot \rho_{ob}(\vec{x})}, \tag{1}$$

$$F_{aggr}(\vec{x}) = \frac{1}{1 + c_{ob} \cdot \rho_{ob}(\vec{x})} \tag{2}$$

where $(1-\epsilon), c_{queue}, c_{ob} \geq 0$, $\rho_{ob}(\vec{x})$ is the obstacle density (see Köster and Zönnchen (2014)) and $\rho_{ped}^{coop}(\vec{x})$ is the pedestrian density of pedestrians using the cooperative strategy.

Equations

$$\rho_{ped}(\vec{z}) = S_{ped} \cdot \sum_{\vec{x} \in Ped} \left[\rho_{ped}^{partial}(\vec{x}, \vec{z}) \right] \tag{3}$$

$$\rho_{ped}^{partial}(\vec{x}, \vec{z}) = \frac{1}{2\pi R^2} \exp\left(-\frac{1}{2R^2} ||\vec{x} - \vec{z}||^2 \right) \tag{4}$$

$$\rho_{ob}(z) = \sum_{i=1}^{m} \int_{O_i} \left[\frac{1}{2\pi R^2} \exp\left(-\frac{1}{2R^2} ||\vec{x} - \vec{z}||^2 \right) \right] dx \tag{5}$$