Humans and Flocking

Presenters:
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Papers:
"Social Force Model for Pedestrian Dynamics"
- Helbing, Molnar

"Simulating Dynamical Features of Escape Panic"
- Helbing, Farkas, Vicsek

Basis of the Model

- Movement of pedestrians is mostly automatic or reflex
- This motion is similar to particle motion, so it can be turned into an equation of motion
- The forces driving the motion are "social forces"
- A social force is ***NOT*** a physical force
- Instead it is something that motivates a person to act
  - i.e. taboo against violating personal space
- This motivation evokes the pedestrian to accelerate somehow, acting as if s/he is the subject of an external force

Mathematics of the Model

Destination Force: $$\vec{F}_\alpha^0(\vec{v}_\alpha, v_\alpha^0 \vec{e}_\alpha) := \frac{1}{\tau_\alpha}(v_\alpha^0 \vec{e}_\alpha - \vec{v}_\alpha).$$

$\vec{v}_\alpha$ is the actual velocity

v_α^0 is the desired speed

$\vec{e}_\alpha(t) := \frac{\vec{r}_\alpha^k - \vec{r}_\alpha(t)}{\|\vec{r}_\alpha^k - \vec{r}_\alpha(t)\|}$ s the desired direction

τ_α s the time the pedestrian takes to reach desired speed

Mathematics of the Model

Personal Space Repulsion: $\vec{f}_{\alpha\beta}(\vec{r}_{\alpha\beta}) := -\nabla_{\vec{r}_{\alpha\beta}} V_{\alpha\beta}[b(\vec{r}_{\alpha\beta})]$

b is the length of the semi-minor axis of ellipse given by:

$$2b := \sqrt{(\|\vec{r}_{\alpha\beta}\| + \|\vec{r}_{\alpha\beta} - v_\beta \Delta t\, \vec{e}_\beta\|)^2 - (v_\beta \Delta t)^2}$$

$V_{\alpha\beta}(b)$ s the repulsive potential with the form on an ellipse

Mathematics of the Model

Environment Repulsion: $\vec{F}_{\alpha B}(\vec{r}_{\alpha B}) := -\nabla_{\vec{r}_{\alpha B}} U_{\alpha B}(\|\vec{r}_{\alpha B}\|)$

$U_{\alpha B}(\|\vec{r}_{\alpha B}\|)$ s the repulsion potential

Environment Attraction: $\vec{f}_{\alpha i}(\|\vec{r}_{\alpha i}\|, t) := -\nabla_{\vec{r}_{\alpha i}} W_{\alpha i}(\|\vec{r}_{\alpha i}\|, t)$

$W_{\alpha i}(\|\vec{r}_{\alpha i}\|, t)$ s the attraction potential

Mathematics of the Model

The formulas for pedestrian repulsion and environmental attractions only hold if they are in the desired direction.
To correct this, multiply by a correction factor.

$$w(\vec{e}, \vec{f}) := \begin{cases} 1 \text{ if } \vec{e} \cdot \vec{f} \geq \|\vec{f}\| \cos\varphi \\ c \text{ otherwise.} \end{cases}$$

$0 < c < 1$
2*phi is the angle of sight

$$\vec{F}_{\alpha\beta}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_\beta) := w(\vec{e}_\alpha, -\vec{f}_{\alpha\beta})\vec{f}_{\alpha\beta}(\vec{r}_\alpha - \vec{r}_\beta)\,,$$

$$\vec{F}_{\alpha i}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_i, t) := w(\vec{e}_\alpha, \vec{f}_{\alpha i})\vec{f}_{\alpha i}(\vec{r}_\alpha - \vec{r}_i, t)\,.$$

Mathematics of the Model

The total force is just the superposition of all these forces:

$$\vec{F}_\alpha(t) := \vec{F}^0_\alpha(\vec{v}_\alpha, v^0_\alpha \vec{e}_\alpha) + \sum_\beta \vec{F}_{\alpha\beta}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_\beta) + \sum_B \vec{F}_{\alpha B}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}^\alpha_B) + \sum_i \vec{F}_{\alpha i}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_i, t)\,.$$

Mathematics of the Model

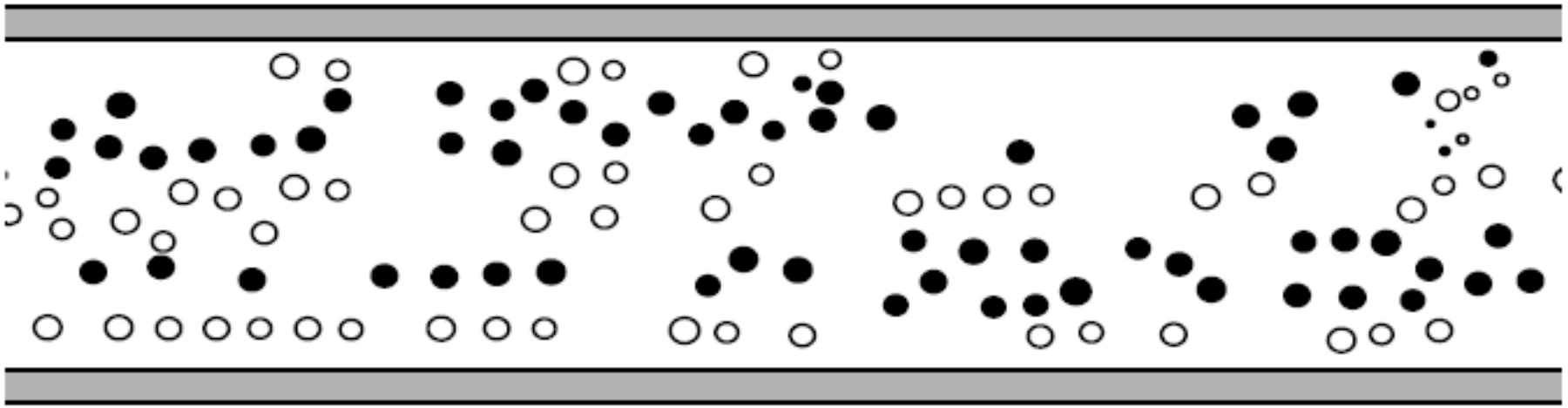
Finally, the model can be summarized with:

$$\frac{d\vec{w}_\alpha}{dt} := \vec{F}_\alpha(t) + fluctuations.$$

$$\frac{d\vec{r}_\alpha}{dt} = \vec{v}_\alpha(t) := \vec{w}_\alpha(t)\, g\left(\frac{v_\alpha^{\max}}{\|\vec{w}_\alpha\|}\right)$$

$$g\left(\frac{v_\alpha^{\max}}{\|\vec{w}_\alpha\|}\right) := \begin{cases} 1 & \text{if } \|\vec{w}_\alpha\| \leq v_\alpha^{\max} \\ v_\alpha^{\max}/\|\vec{w}_\alpha\| & \text{otherwise.} \end{cases}$$

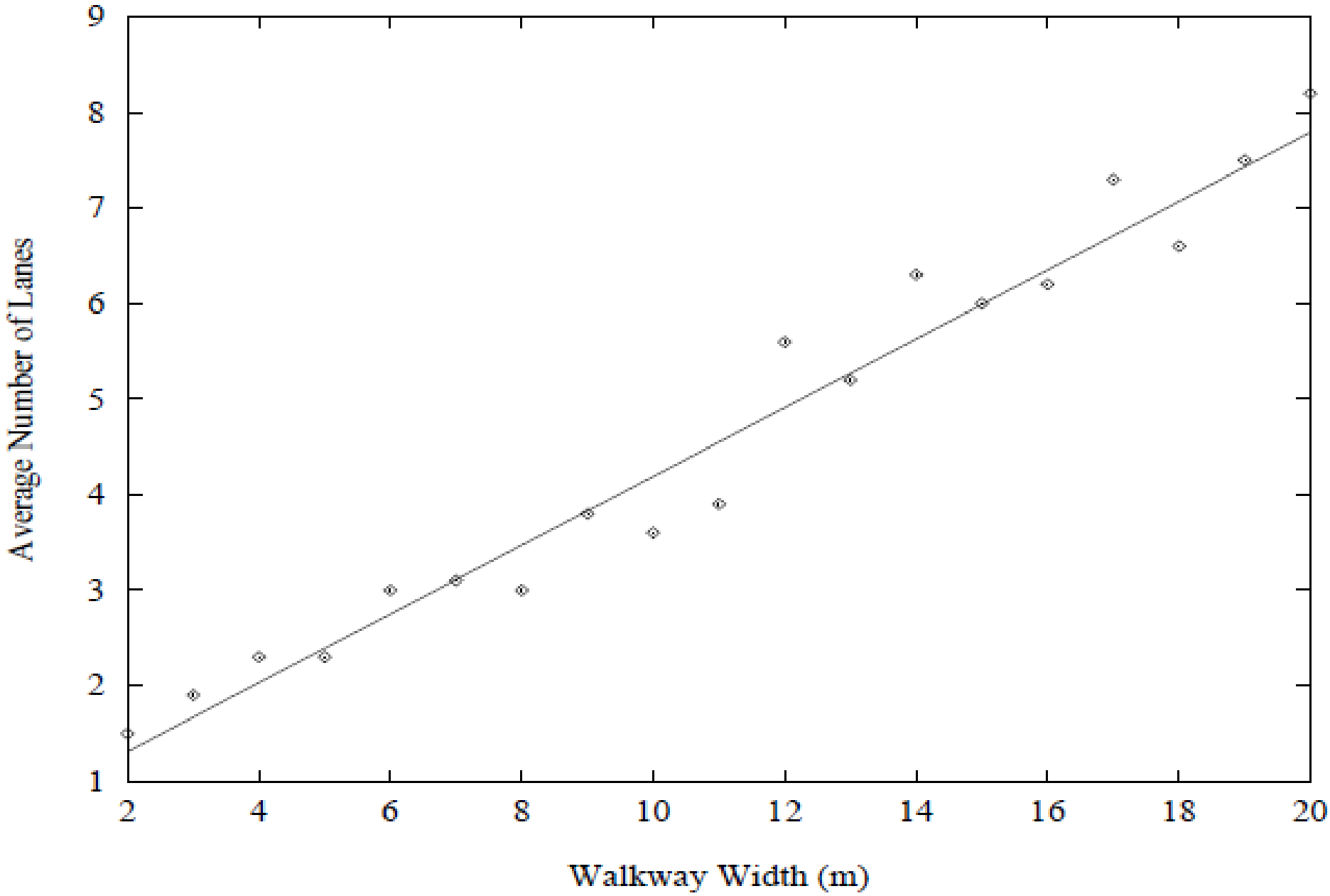
Spontaneous Lane Formation



Black : moving to the right
White : moving to the left
Diameter : actual speed

10 m wide path
4 lanes

Spontaneous Lane Formation

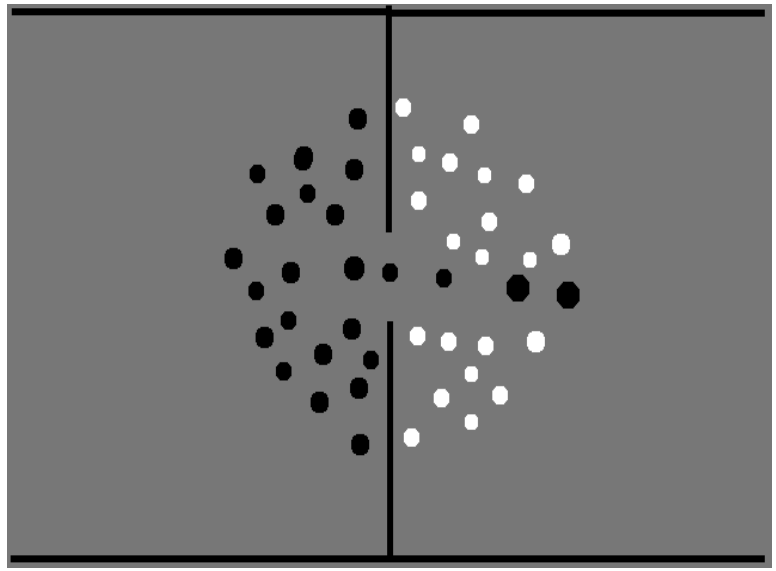


Doorway Passing Direction

Stream of people from a group passes through doorway

Stopped by pressure of opposing group

Role reversal



What is Panic?

http://en.wikipedia.org/wiki/File:1857_panic.PNG

Panic is a sudden fear which dominates or replaces thinking and often affects groups of people or animals. Panics typically occur in disaster situations, or violent situations which may endanger the overall health of the affected group. ...

Increases with number and mass size of events

Panic Features

try to move much faster than normal

pushing/physical interaction occurs

uncoordinated movement

arching and clogging

jams

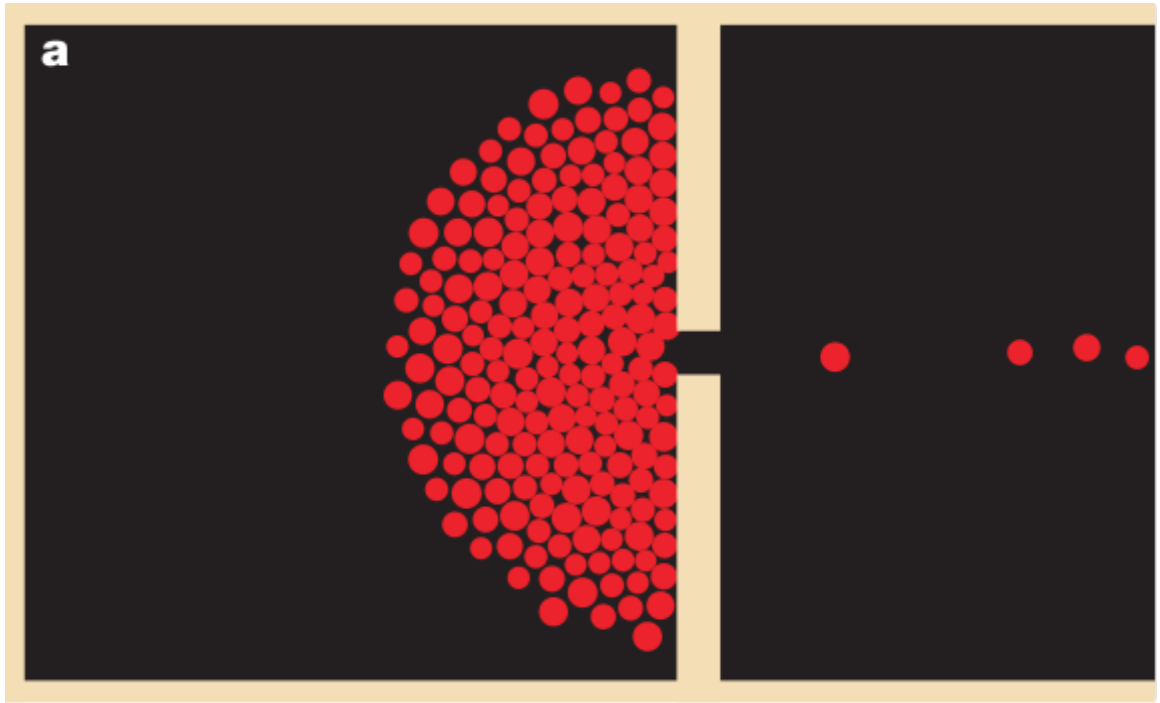
dangerous pressures

fallen obstacles

mass behavior

inefficient use of passages/exits

Clogging at Bottlenecks

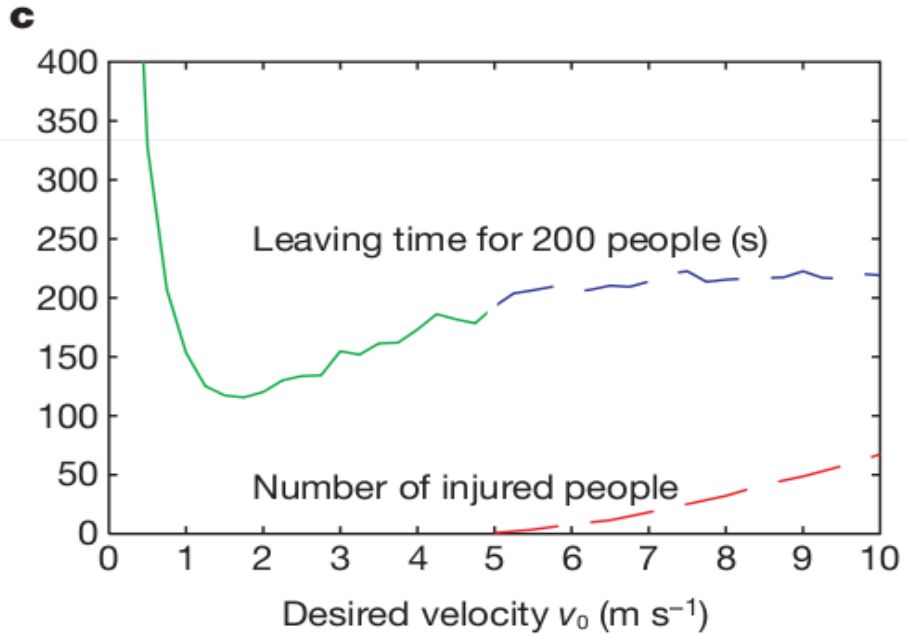


outflow is regular when velocities are normal

during rushing (1.5 ms-1) arching occurs

pedestrians leave sporadically

Faster is Slower

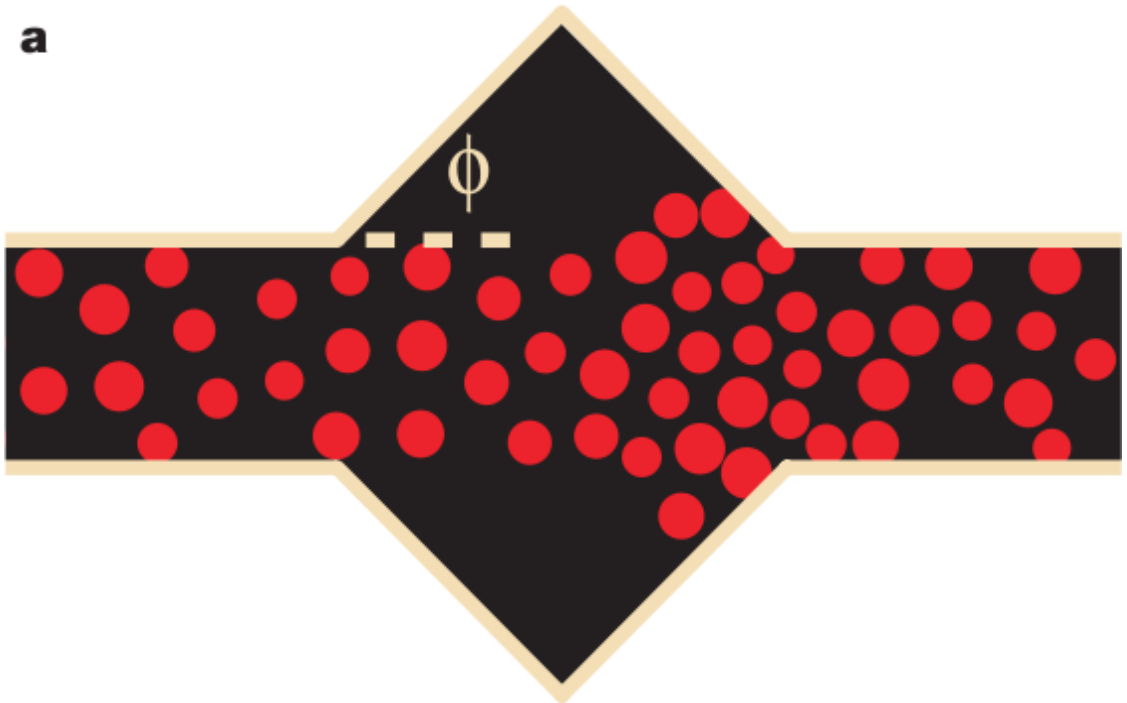


caused by impatience

desired velocity increases with delays

2 primary factors: bottlenecks and inter-personal friction

Reverse Bottleneck Clog



20% decrease in efficiency

pedestrians spread out and try to overtake each other

attempt to squeeze back together at bottleneck

Amplification of Effect

wide section at location of most irregular pedestrian flow

hallway is narrow

greater diversity amongst desired velocities

high desired velocities

pedestrian density is high

Individualistic Behavior vs Group Behavior

smoky room simulation

$$\mathbf{e}_i^0(t) = \mathrm{Norm}[(1 - p_i)\mathbf{e}_i + p_i \langle \mathbf{e}_j^0(t) \rangle_i]$$

individualistic behavior: each pedestrian finds exit accidentally

group behavior: entire group will eventually move towards same exit and blocking will occur