Animation & Simulation

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Behavioural Animation

- Another model-based animation
  - Key-framing
  - Parametric methods
  - Physically-based methods
  - Behavioural, cognitive processes
    - High-level, based on reliable animation techniques at lower levels
    - Relieve animators from not-so-important animations
    - A way of automating animation generation
    - Cognitive: individual and group levels

Behavioural Animation

- Cognitive modelling
  - Rule-based
    - <condition, behaviour> with motion databases
    - Logic and reasoning -> traditional AI
  - Machine learning
    - No specific rules but only data correlations
    - Causation detection (harder)
  - Deep learning
    - Brutal learning from a large amount of data
    - A working progress

Behavioural Animation

- Aggregate Behaviours

Type	Number of Elements	Incorporated Physics	Intelligence
Particles	10^2–10^4	Much—with environment	None
Flocks	10^1–10^3	Some—with environment and other elements	Limited
Crowds	10^1–10^2	Usually little physics, but depends on interaction with environment	Varies from little to much

Behavioural Animation

- Primitive Behaviours
  - Flocking
    - Fish schools, bird flocks, etc.
    - Highly coordinated low-level behaviours
    - Global behaviours can be approximated by local behaviours
    - [Reynolds 87]: avoid collisions and staying part of the flock
      - Each agent needs to avoid colliding with neighbouring agents
      - Each agent needs to follow the general formation

Behavioural Animation

- Primitive Behaviours
  - Flocking
    - Local control: physics, perception, reasoning and reaction
      - Physics: like particles
      - Perception: perceived environment
      - Reasoning and reaction: intelligence

Behavioural Animation

- Primitive Behaviours
  - Flocking
    - Perception

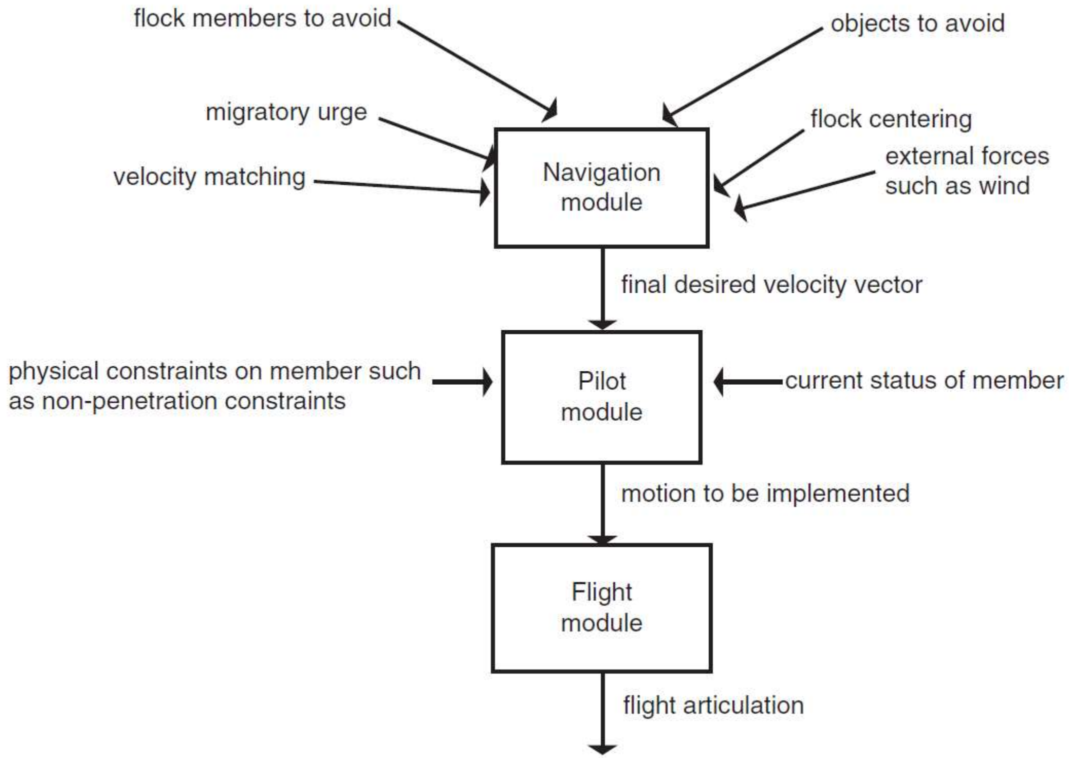
Be aware of itself and two or three of its neighbors
Be aware of what is in front of it and have a limited fov
Have a distance-limited fov
Be influenced by objects within the line of sight
Be influenced by objects based on distance and size (angle subtended in the fov)
Be affected by things using an inverse distance-squared or distance-cubed weighting function
Have a general migratory urge but no global objective
Not follow a designated leader
Not have knowledge about a global flock center

Behavioural Animation

- Primitive Behaviours
  - Flocking
    - Interacting with other members
      - Attraction and repulsion
    - Interaction with the environment
      - Collisions
    - Global control
      - Direction, speed, etc.
    - Flock leaders
      - For others to follow
    - Negotiate the motion
      - Optimisation with respect to all afore-mentioned constraints

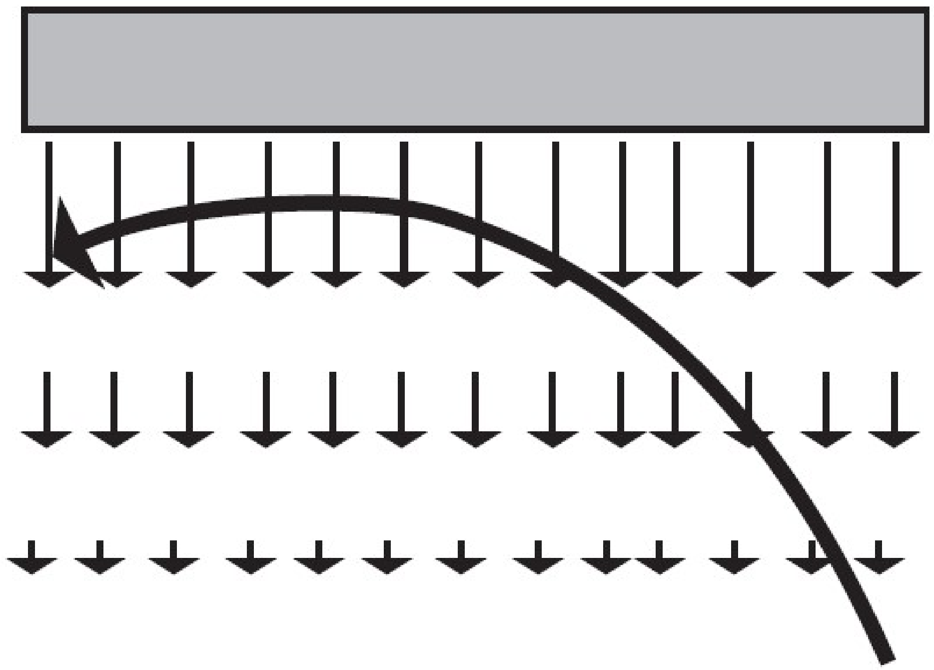
Behavioural Animation

- Primitive Behaviours
  - Flocking



Behavioural Animation

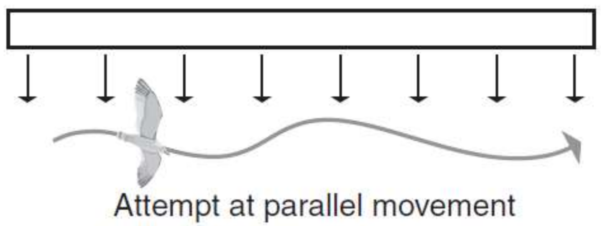
- Primitive Behaviours
  - Flocking
    - Collisions



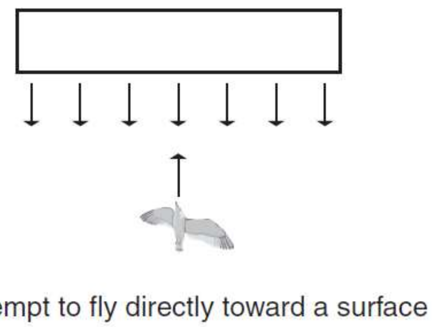
Behavioural Animation

- Primitive Behaviours
  - Flocking
    - Collisions
      - problems

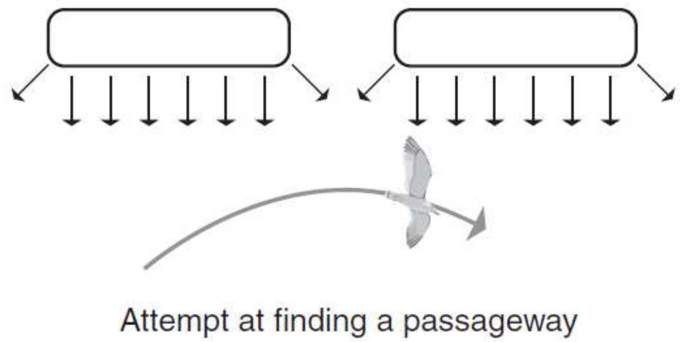
Cannot fly in parallel



Might give velocity singularity

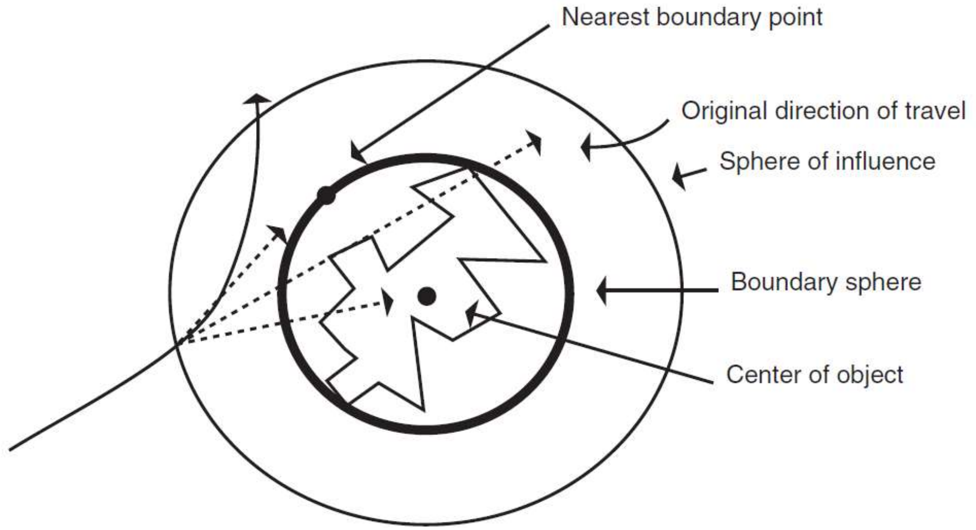


Cannot fly through a passageway



Behavioural Animation

- Primitive Behaviours
  - Flocking
    - Collisions
      - solutions



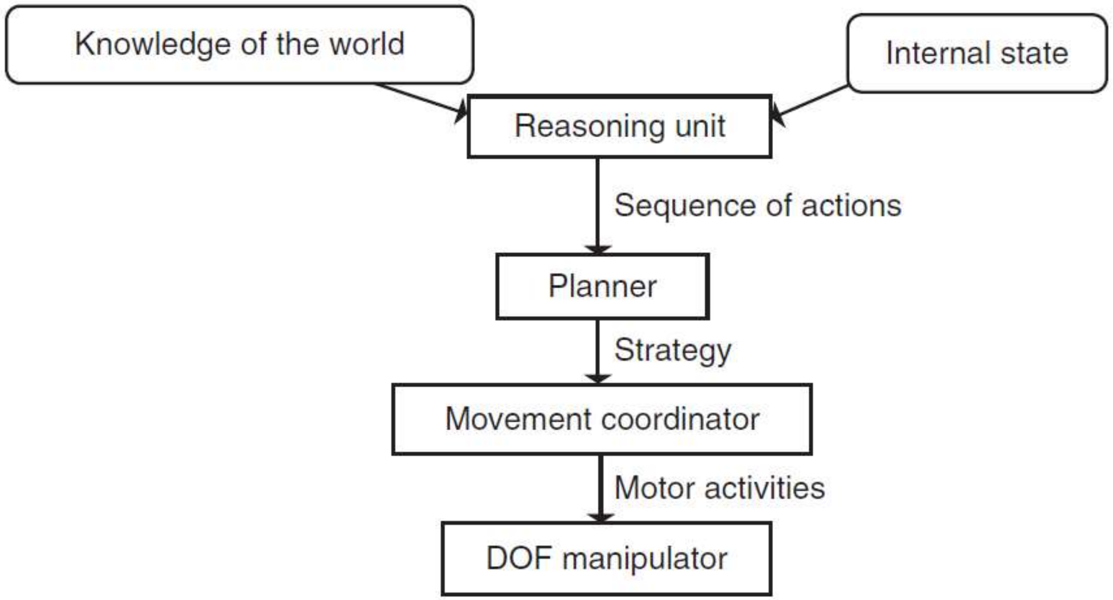
Behavioural Animation

- Primitive Behaviours
  - Flocking
    - Splitting and rejoining
      - No good automatic solutions
    - Formation Control

      https://www.youtube.com/watch?v=bFU0kK306u4&feature=youtu.be

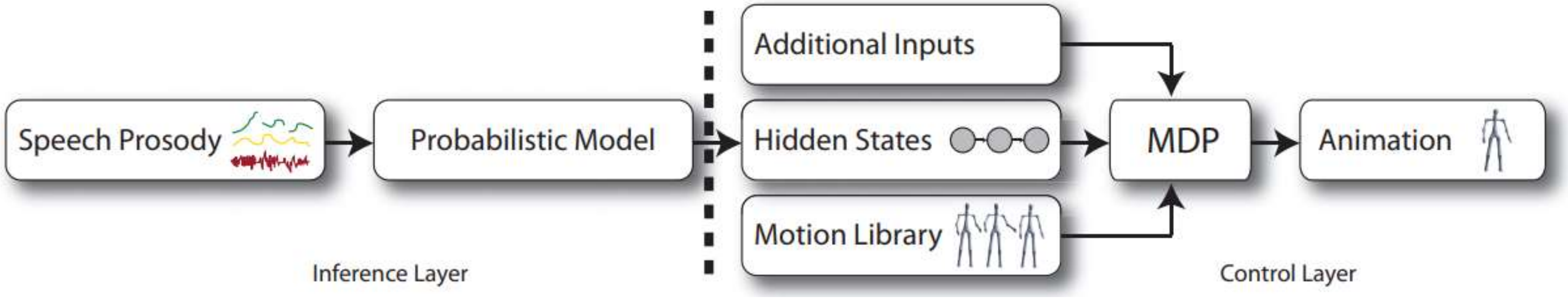
Behavioural Animation

- Modelling intelligent behaviours



Behavioural Animation

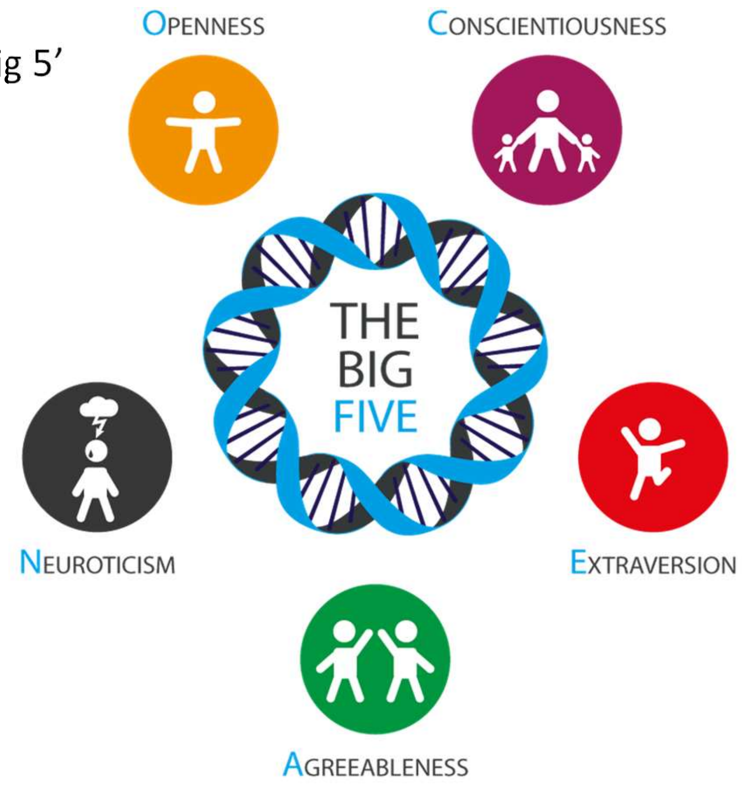
- Modelling intelligent behaviours
  - Expression and gestures
    - [Levine et al. SIGGRAPH 2010]



https://www.youtube.com/watch?v=k140CcKUirc

Behavioural Animation

- Modelling intelligent behaviours
  - Personalities and emotions
    - OCEAN or Five-Factor Model or ‘big 5’

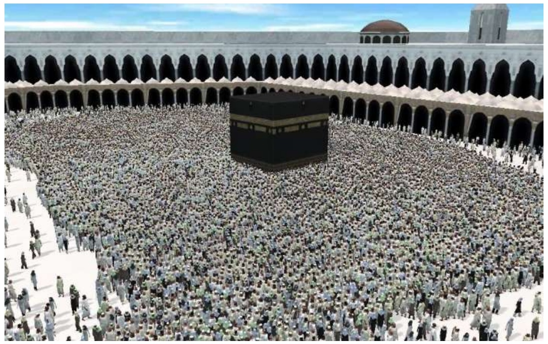


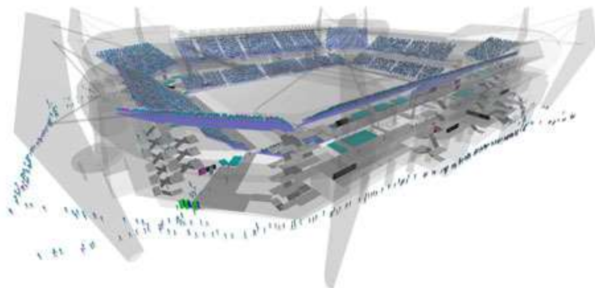
Behavioural Animation

- Crowds

Behavioural Animation

- Crowds

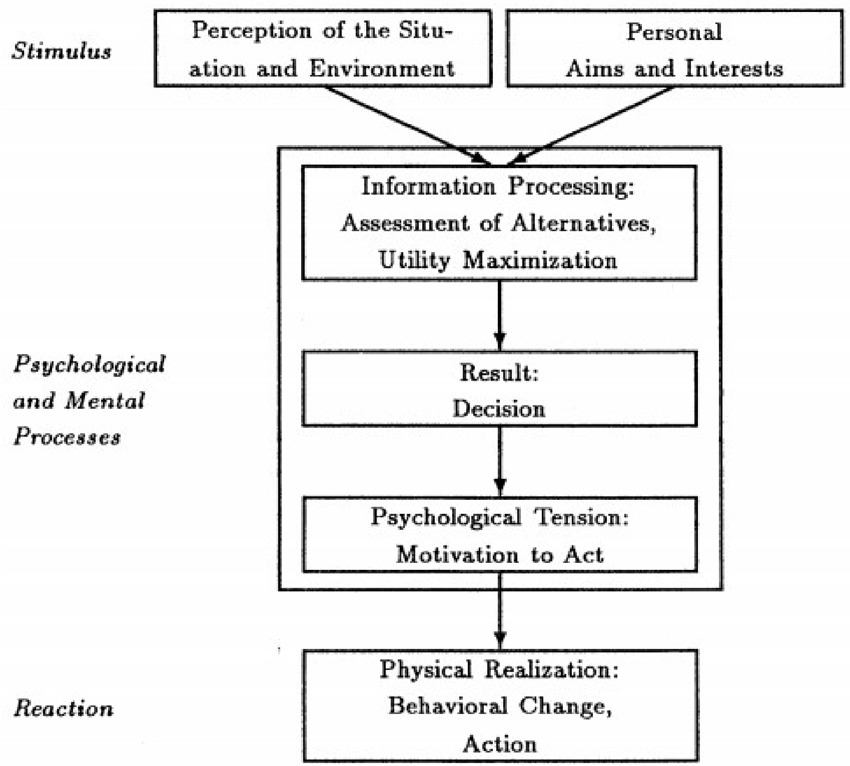




Behavioural Animation

- Crowds
  - [Helbing and Molar 1995]

Stimulus	simple or standard situations	complex or new situations
Reaction	automatic reaction, reflex	result of evaluation, decision process
Characterization	well predictable	probabilistic
Modeling concept	social force model, etc.	decision theoretical model, etc.
Example	pedestrian motion	destination choice by pedestrians



Behavioural Animation

- Crowds
  - [Helbing and Molar 1995]: social force
  - Particle systems

Target position Current position

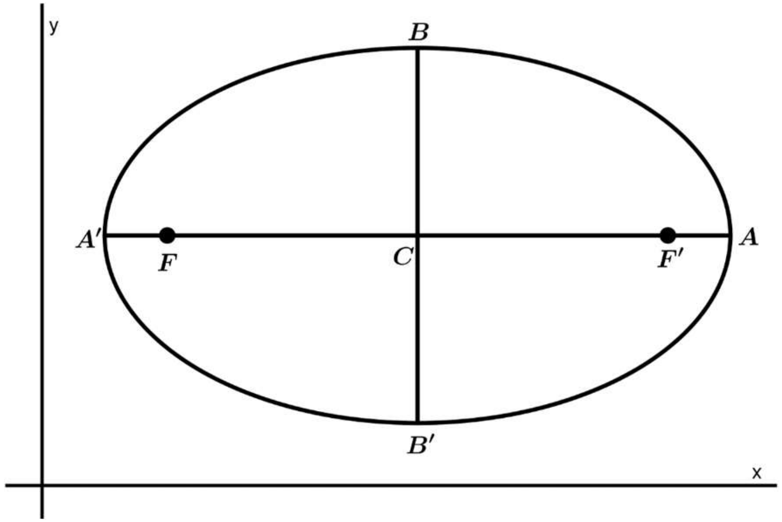
$$\vec{e}_\alpha(t) := \frac{\vec{r}_\alpha^k - \vec{r}_\alpha(t)}{\|\vec{r}_\alpha^k - \vec{r}_\alpha(t)\|}$$

Desired velocity current velocity

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

Behavioural Animation

- Crowds
  - [Helbing and Molar 1995]: social force
  - Particle systems



Inter-agent Repulsion

Inter-agent distance

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

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

Elliptic potential

Semiminor axis

$$\vec{r}_{\alpha\beta} := \vec{r}_\alpha - \vec{r}_\beta$$

Env-agent Repulsion

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

Behavioural Animation

- Crowds
  - [Helbing and Molar 1995]: social force
  - Particle systems

$$\textit{attractive effects } \vec{f}_{\alpha i} \text{ at places } \vec{r}_i$$

$$(\vec{r}_{\alpha i} \;:=\; \vec{r}_\alpha - \vec{r}_i)$$

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

$$\text{monotonic increasing potentials } W_{\alpha i}(\|\vec{r}_{\alpha i}\|, t)$$

Behavioural Animation

- Crowds
  - [Helbing and Molar 1995]: social force
  - Particle systems

    Modified repulsion and attraction (decay in time)

Situations located behind a pedestrian

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

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

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

Situations located behind a pedestrian will have a weaker influence c with $0 < c < 1$.

Behavioural Animation

- Crowds
  - [Helbing and Molar 1995]: social force
  - Particle systems

    Add everything up

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

The *social force model* is now defined by

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

Behavioural Animation

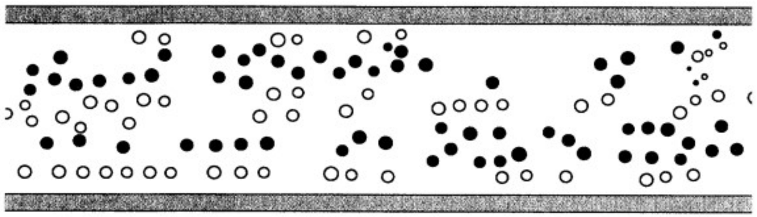
- Crowds
  - [Helbing and Molar 1995]: social force
  - Particle systems-implementation details

$$V_{\alpha\beta}(b) = V^0_{\alpha\beta} \mathrm{e}^{-b/\sigma}\,, \qquad U_{\alpha B}(\|\vec{r}_{\alpha B}\|) = U^0_{\alpha B} \mathrm{e}^{-\|\vec{r}_{\alpha B}\|/R}$$

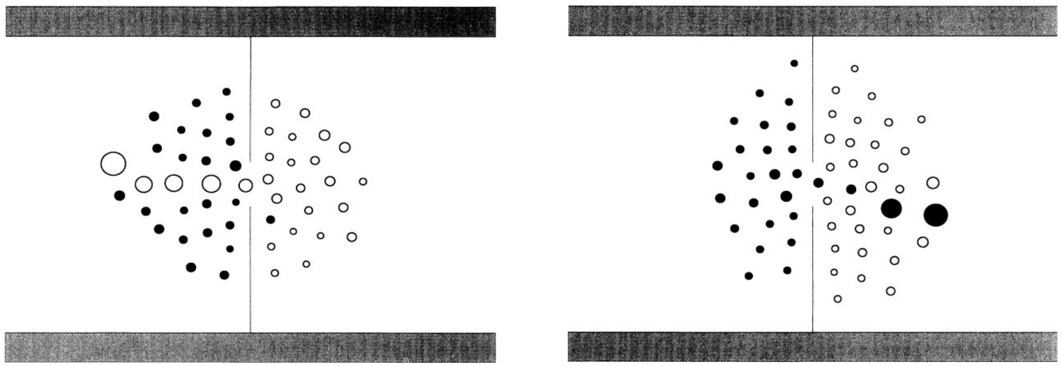
with $V^0_{\alpha\beta} = 2.1\mathrm{m}^2\mathrm{s}^{-2}$, $\sigma = 0.3\mathrm{m}$ and $U^0_{\alpha B} = 10\mathrm{m}^2\mathrm{s}^{-2}$, $R = 0.2\mathrm{m}$

Behavioural Animation

- Crowds
  - [Helbing and Molar 1995]: social force
  - Particle systems-simulations



Two-way corridor



Two-way door, alternating in capturing the door