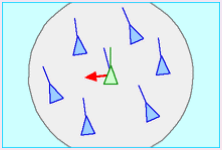
Pedestrians : Microscopic Models

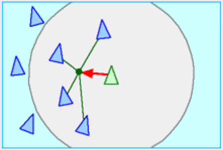
First Generation Models: Boids

[Craig W. Reynolds, Computer Graphics (1987)]

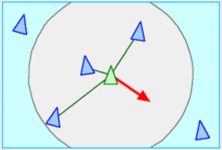
- Flocks, Herds, and Schools



Alignment

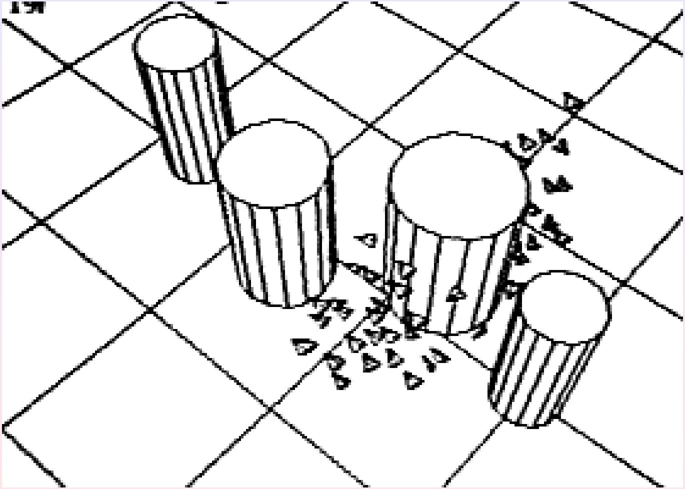


Cohesion



Separation

Boids model



Boids model

Pedestrians : Microscopic Models

First Generation Models: Social force model

[D. Helbing & P. Molnár, PRE (1995)]

- Position Based Model
- Multiple interactions: Sum of forces

Social force model

Repulsion force from [Helbing and Molnar 1995]

$$\mathbf{F}_\alpha^{rep} = -\nabla_{\mathbf{r}_{\alpha\beta}} V_{\alpha\beta}[b(\mathbf{r}_{\alpha\beta})]$$

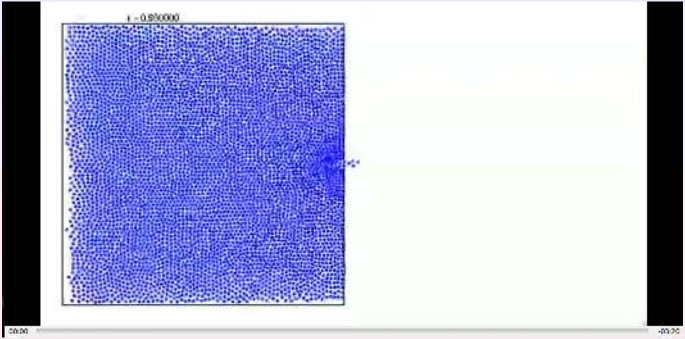
where

- $V_{\alpha\beta}$ = repulsive potential
  - decreasing function of b
  - equipotential lines have the form of an ellipse directed in the direction of motion.
- b = semiminor axis of the ellipse

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

where $v_\beta \Delta t$ is of the order of a stepwidth of pedestrian β.

Social force model



From Daishin Ueyama

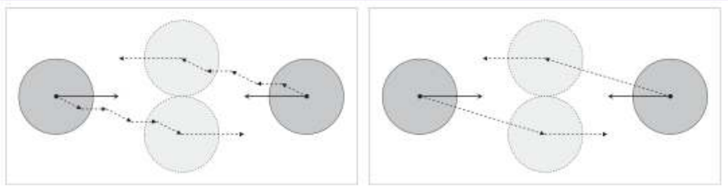
Pedestrians : Microscopic Models

Cellular automata model

- Floor field model

See next course on CAs.

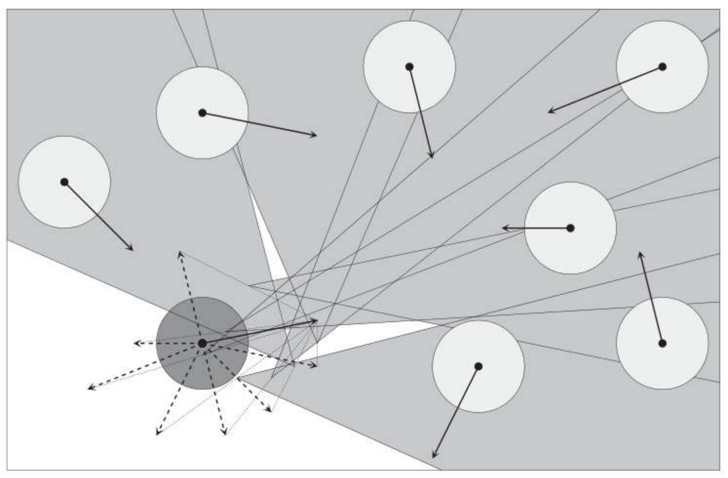
Pedestrians : Velocity based models



On the left, VO, we see oscillations in the velocity.
On the right, RVO, smoother.

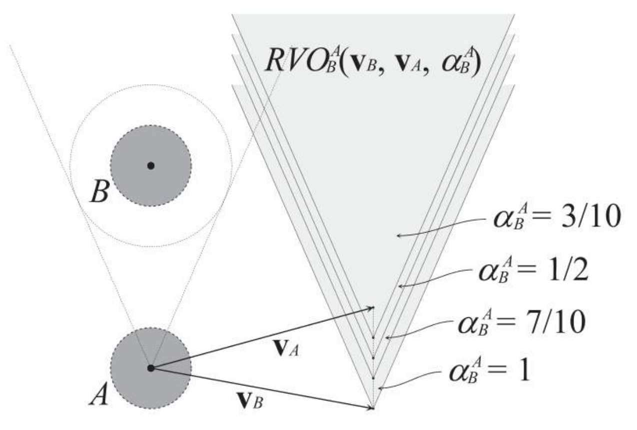
From [van den Berg, Lin, Manocha "Reciprocal Velocity Obstacles for Real-Time Multi-Agent Navigation" Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2008]

Pedestrians : Velocity based models



Multiple interactions with other pedestrians or obstacles.

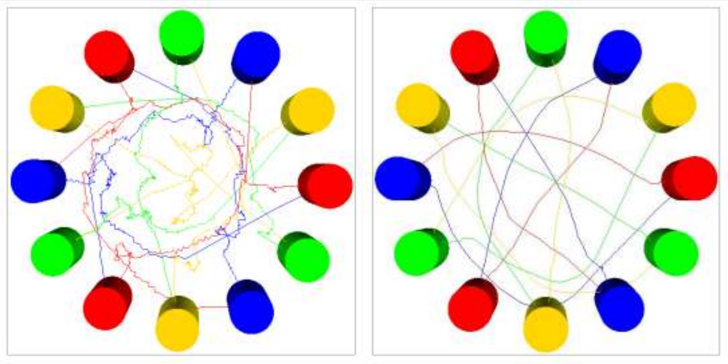
From [van den Berg, Lin, Manocha "Reciprocal Velocity Obstacles for Real-Time Multi-Agent Navigation" Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2008]



RVO with varying weights for $\mathbf{v}_A$ and $\mathbf{v}_B$

From [van den Berg, Lin, Manocha "Reciprocal Velocity Obstacles for Real-Time Multi-Agent Navigation" Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2008]

Pedestrians : Velocity based models

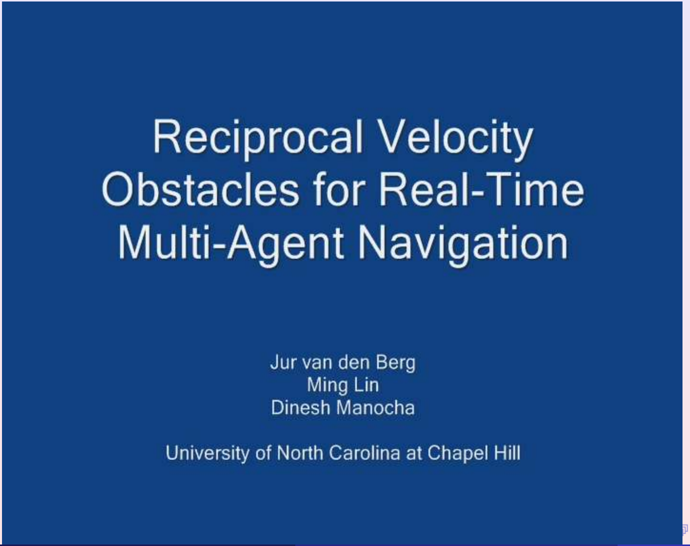


left: VO
right: RVO

From [van den Berg, Lin, Manocha "Reciprocal Velocity Obstacles for Real-Time Multi-Agent Navigation" Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2008]

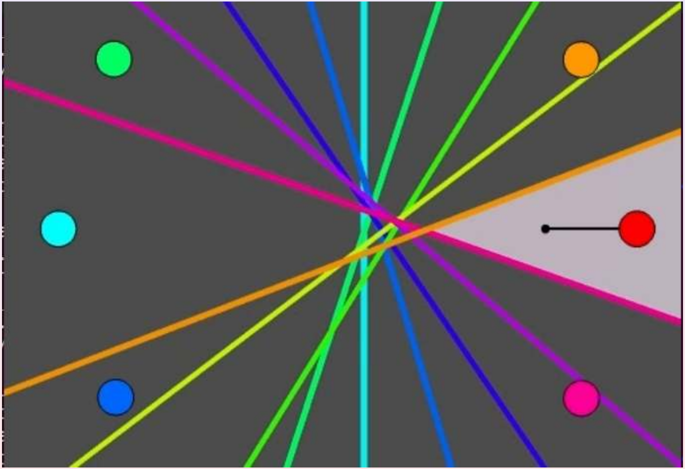
RVO

- Illustration of the RVO approach



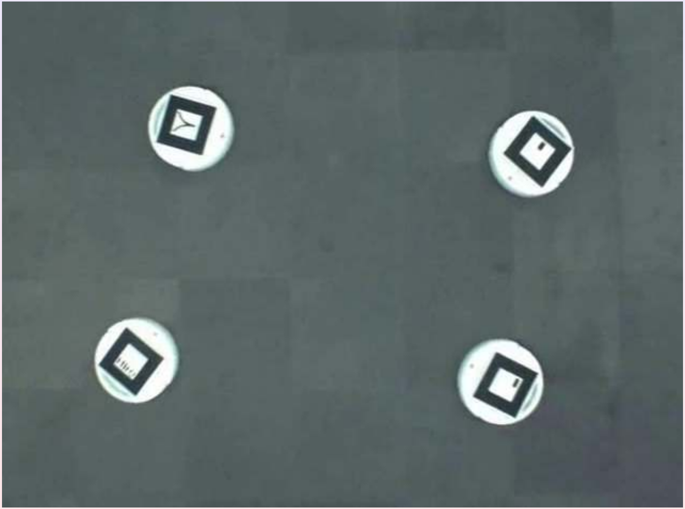
ORCA

- Illustration of the ORCA approach with ten agents.



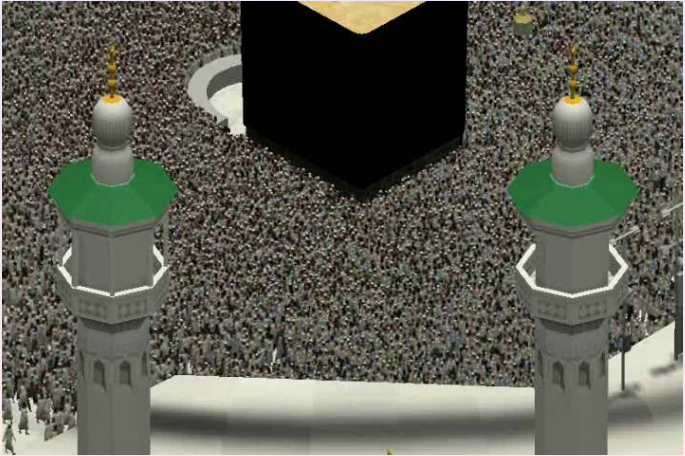
ORCA

- Robotics: ORCA with four iRobot Create differential-drive robots.



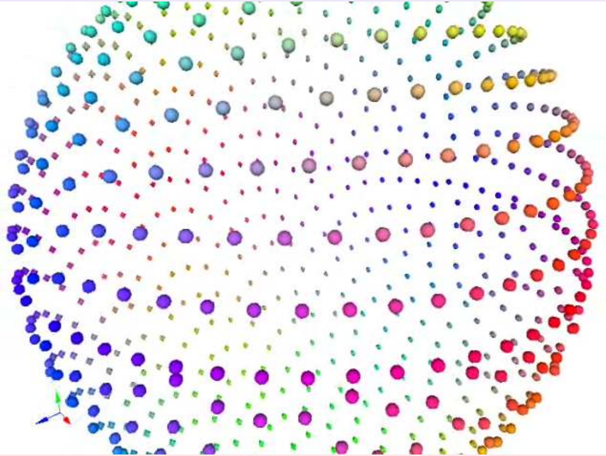
ORCA

- Crowd simulation: ORCA with 25,000 agents in a virtual Hajj.



ORCA

- 3D: ORCA with 812 agents on a sphere moving to their antipodal positions.

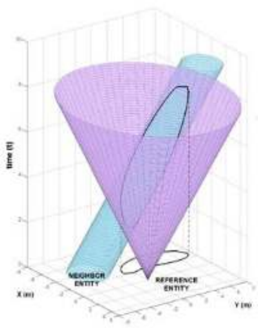


Pedestrians : Microscopic Models

Velocity based models

- Determination of admissible velocities (to avoid collision in the next few seconds)
- Optimal choice among this set of velocity

➥ Automatic composition of interactions

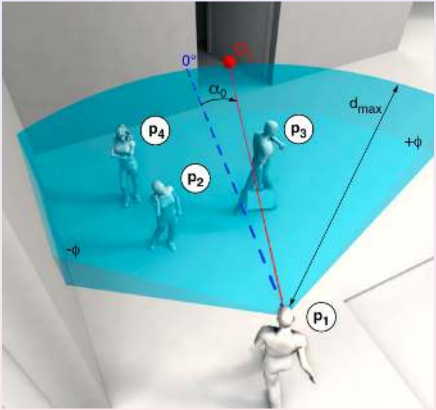


[Paris *et al* (2007)]

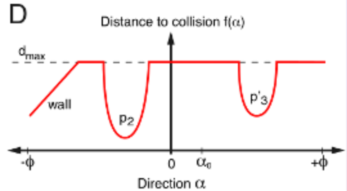
- [Paris, Pettré, Donikian (2007)]
- [RVO (2008)]

Decoupling between velocity angle and modulus

- [Ondrej et al (2010), Moussaïd et al (2011)] ➥ Decoupling of velocity modulus and angle



From [Moussaid et al, PNAS (2011)]



- first choose angle to optimize
- then modulus to avoid collision

Vision based model

- Determination of velocities ?

➥ visual information

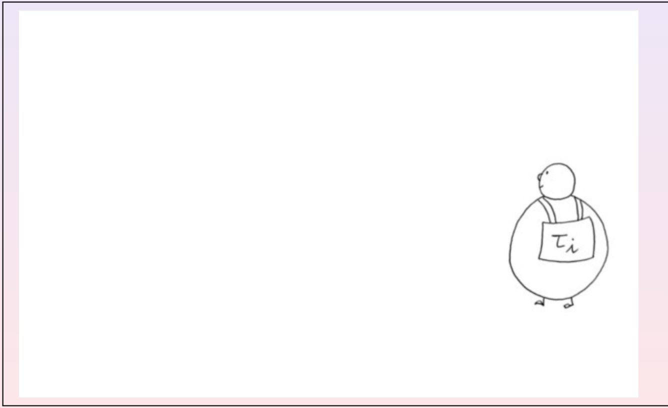
➥ cognitive process

- Vision based model [Ondrej et al, SIGGRAPH 2010]

Vision based model

[Ondrej et al, SIGGRAPH 2010]
[Cutting et al, 1995]

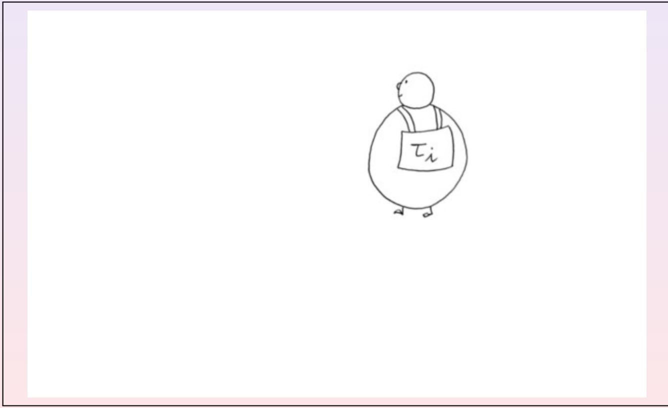
- Movement



Vision based model

[Ondrej et al, SIGGRAPH 2010]
[Cutting et al, 1995]

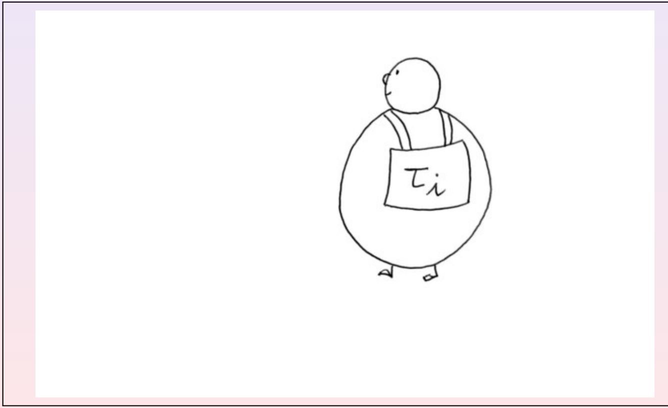
- Movement
- Size



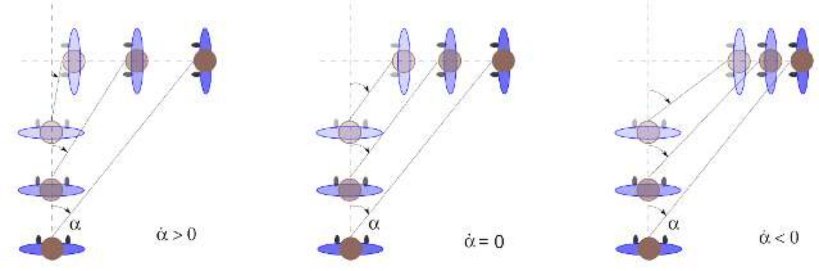
Vision based model

[Ondrej et al, SIGGRAPH 2010]
[Cutting et al, 1995]

- Movement
- Size

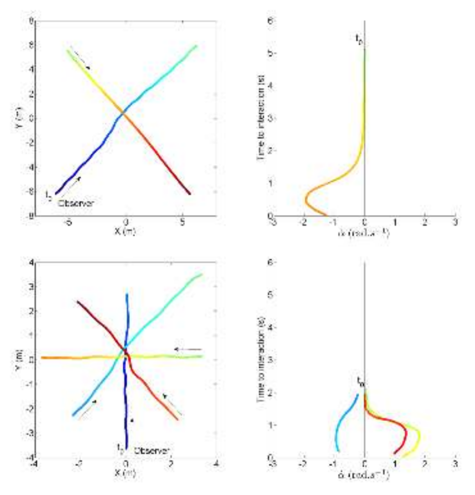


Vision based model: Perception



From [Ondrej et al, SIGGRAPH (2010)]

Vision based model: Perception

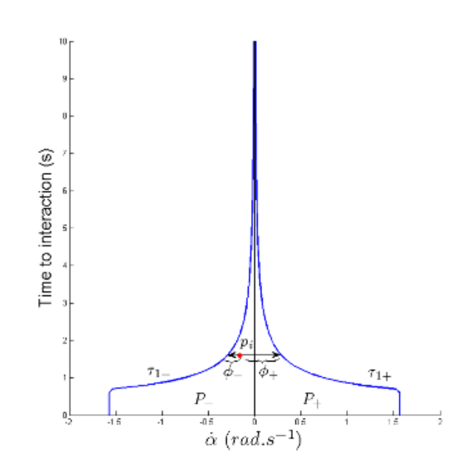


From [Ondrej et al, SIGGRAPH (2010)]

"Two examples of real interactions between (top) two walkers and (bottom) four walkers. Motion captured trajectories projected on the ground are shown (plots on the left), as well as in the $(\dot{\alpha}, \text{tti})$-space (plots on the right), as perceived by one of the participant called 'observer'. Trajectories are colored in order to enable matching between the two representations."

Vision based model: Perception of a risk of collision

Perception of a neighbor *i*



From [Ondrej et al, SIGGRAPH (2010)]

"Future collision is detected when $p_i(\dot{\alpha}_i, \mathrm{tti}_i)$ is below τ_1 and $\mathrm{tti}_i > 0$."

Vision based model: Strategy

$$\phi_+ = min(\dot{\alpha}_i - \tau_{1+}(tti_i)), \quad \text{for all } p_i \in P_+$$
$$\phi_- = max(\dot{\alpha}_j - \tau_{1-}(tti_j)), \quad \text{for all } p_j \in P_-$$

We want $\dot{\alpha}_g = 0$.

• When $\phi_- < \dot{\alpha}_g < \phi_+$, "we choose the change of direction $\dot{\theta}$ that leads to the smallest deviation from the goal":

$$\dot{\theta} = \begin{cases} \phi_+ & \text{if } |\phi_+ - \dot{\alpha}_g| < |\phi_- - \dot{\alpha}_g| \\ \phi_- & \text{otherwise} \end{cases}$$

• Else, we take

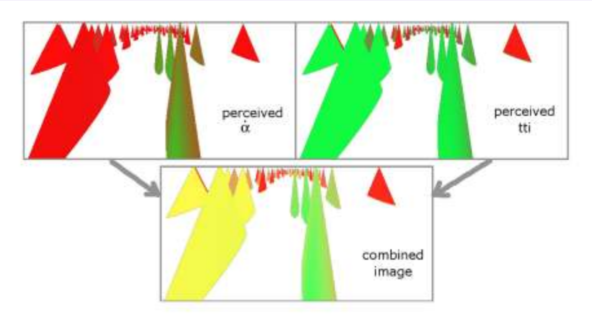
$$\dot{\theta} = \dot{\alpha}_g$$

• Velocity modulus is only adapted in the case of a risk of imminent collision.

From [Ondrej et al, SIGGRAPH (2010)]

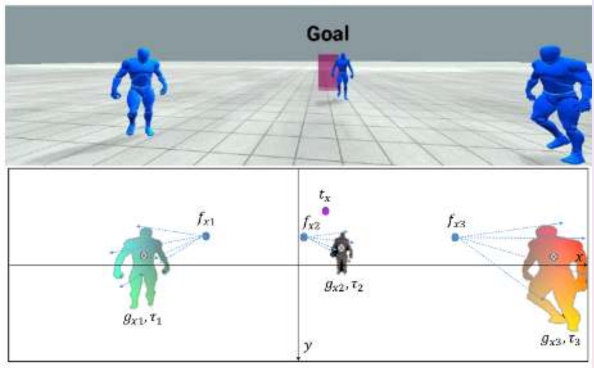
Vision based model:

Computing $\dot{\alpha}_i, \mathrm{tti}_i$ from the visual information:



From [Ondrej et al, SIGGRAPH (2010)]

Vision based model (2)

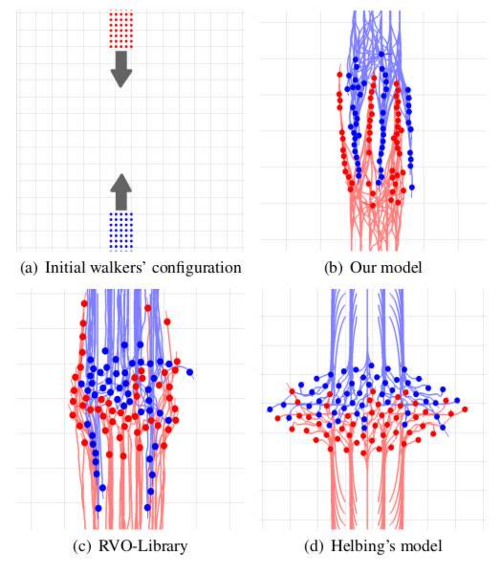


[López et al, EUROGRAPHICS (2019)]
Top: seen by the observer
Bottom: Informations reconstructed from image by the observer

Vision based model: comparison

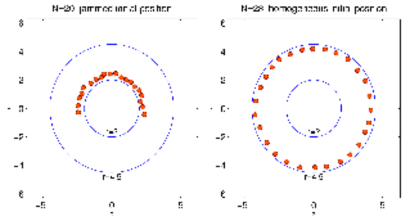
From [Ondrej et al, SIGGRAPH (2010)]

Vision based model: comparison



From [Ondrej et al, SIGGRAPH (2010)]

1D Circle



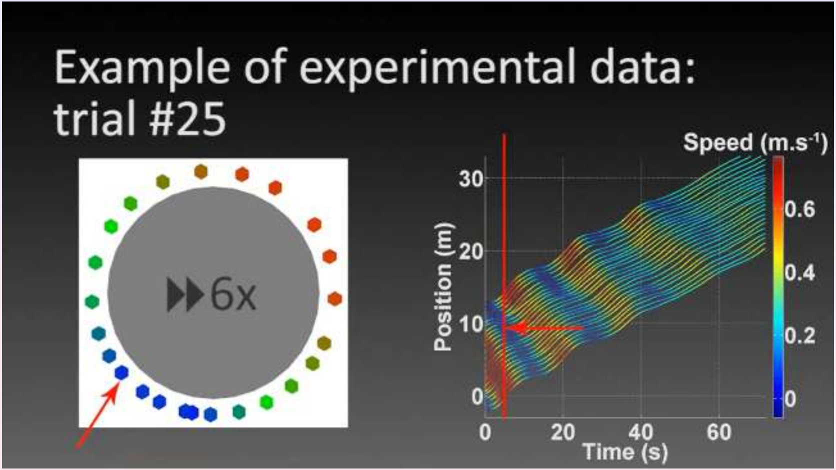
Density varying from 0.31 to 1.86 ped/m.

[S. Lemercier et al, *A realistic model of following behavior for crowd simulation*, EUROGRAPHICS (2012)]

1D Circle

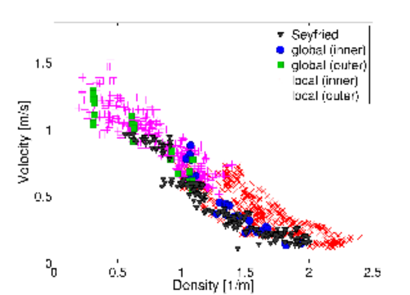
1Dcircle_pietons_qui_marchent.wmv

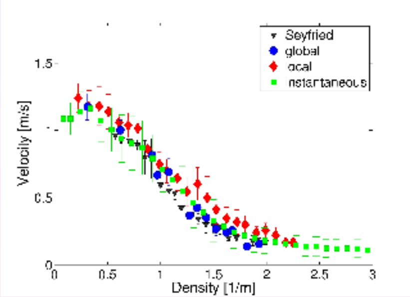
1D Circle



1Dcircle_stop_and_go_wave.wmv

1D Circle - Fundamental diagram





Instantaneous density:

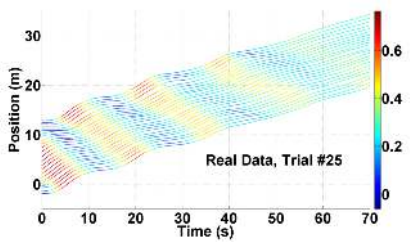
$$\rho_{instant} \equiv \frac{1}{h}$$

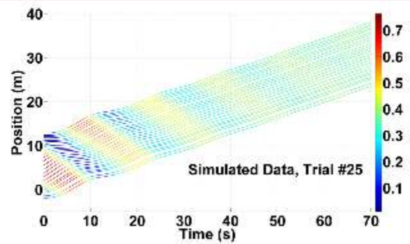
Following behavior

Ped-following

The acceleration of a pedestrian depends on

- the distance to his predecessor
- the speed difference with the predecessor





[S. Lemercier et al, *A realistic model of following behavior for crowd simulation*, EUROGRAPHICS (2012)]

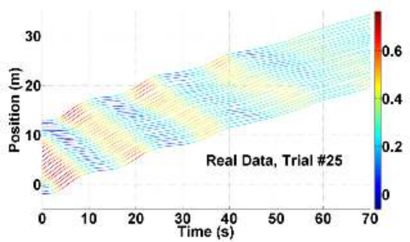
Following behavior

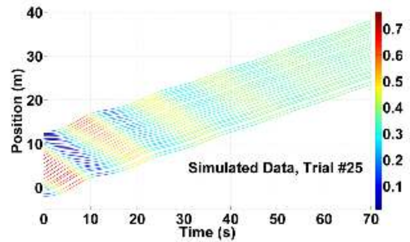
Ped-following

The acceleration of a pedestrian depends on

- the distance to his predecessor
- the speed difference with the predecessor

➥ speed difference evaluated with a delay





[S. Lemercier et al, *A realistic model of following behavior for crowd simulation*, EUROGRAPHICS (2012)]

1D Circle

[S. Lemercier et al, EUROGRAPHICS (2012)]