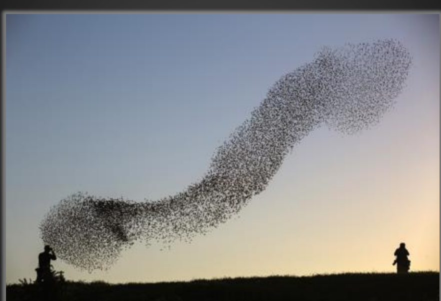
Collective behaviour

modelling perception

Murmuration

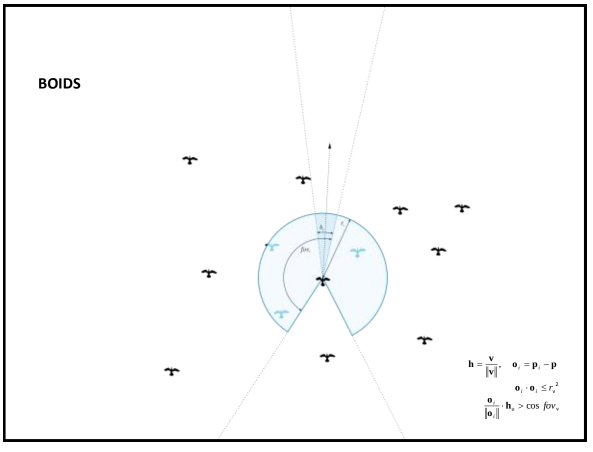


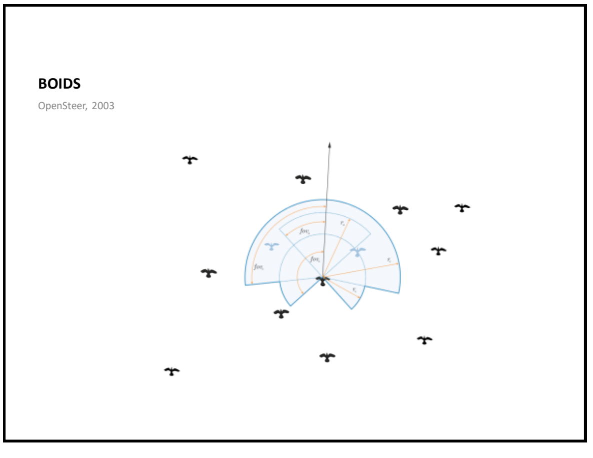
goo.gl/LnXW3k

Murmuration

vimeo.com/31158841, vimeo.com/58291553

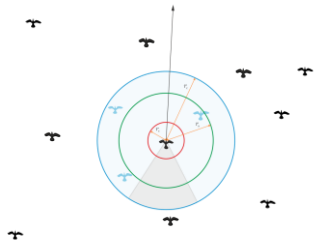

Murmuration
goo.gl/LnXW3k


BOIDS
$\mathbf{h} = \frac{\mathbf{v}}{\|\mathbf{v}\|}$, $\mathbf{o}_i = \mathbf{p}_i - \mathbf{p}$
$\mathbf{o}_i \cdot \mathbf{o}_i \le r_v^2$
$\frac{\mathbf{o}_i}{\|\mathbf{o}_i\|} \cdot \mathbf{h}_v > \cos fov_v$


BOIDS
OpenSteer, 2003

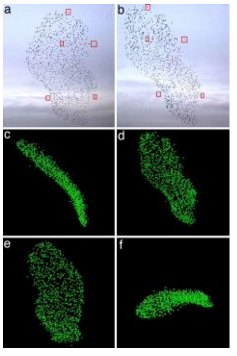
Zone based

Aoki I, 1982
Couzin I, *et al*, 2002



STARFLAG

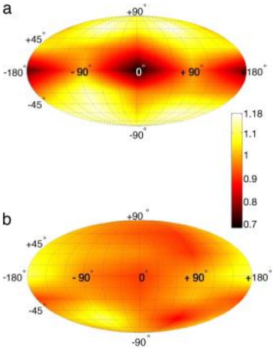
Ballerini M, *et al*, 2008



goo.gl/4gY3j9, goo.gl/3Ae5xp

STARFLAG

Ballerini M, *et al*, 2008

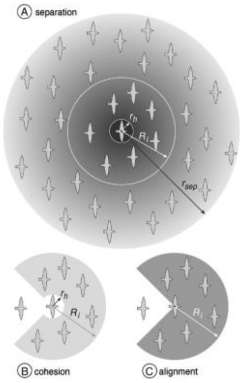


Topologic interaction

Hemelrijk CH & Hildenbrandt H, 2008

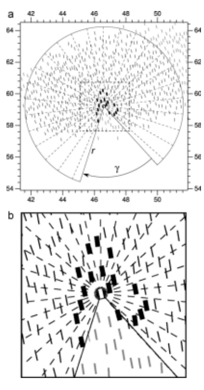
$$R_i(t+\Delta t) = (1-s)R_i(t) + s\left(R_{\mathrm{m}} - R_{\mathrm{m}}\frac{|N_i(t)|}{n_c}\right)$$

$$N_i(t) = \{j \in \mathrm{N};\, j \neq i;\ d_{ij} \leq R_i\}$$



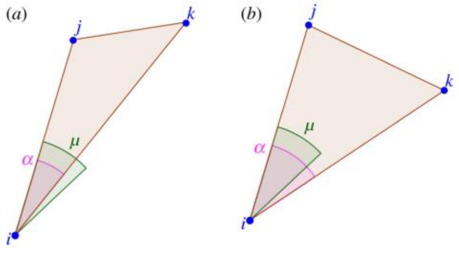
Vision with occlusion

Kunz H & Hemelrijk CH, 2012



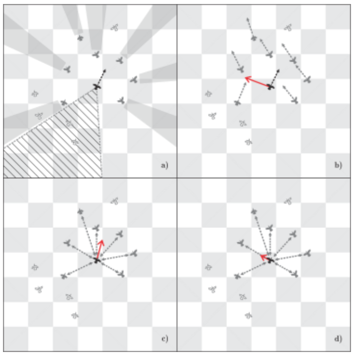
Spatially balanced topological interaction

Camperi M, *et al*, 2012



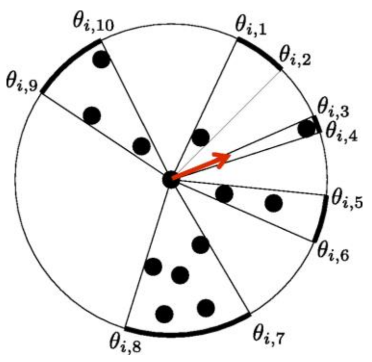
Topologic vision with occlusion

Demšar J & Lebar Bajec I, 2014



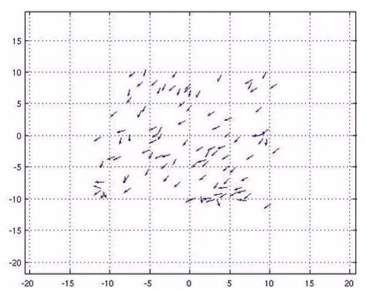
Projective interaction

Pearce DJG, *et al*, 2014



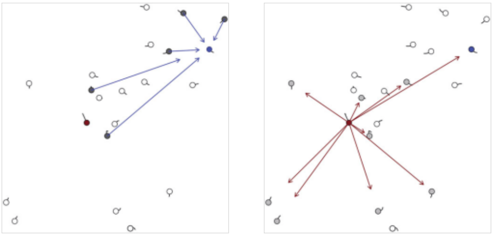
Projective interaction

Pearce DJG, *et al*, 2014



Motion-guided attention

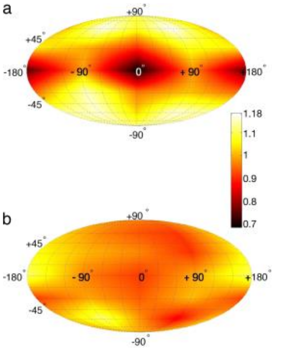
Lemasson BH, *et al*, 2013



Random interactions

Bode NWF, *et al*, 2011

$$p_j = \frac{1}{d_j} / (\Sigma_k \frac{1}{d_k})$$



Schooling Fish:
A Multisensory Approach

Larsson M, 2014

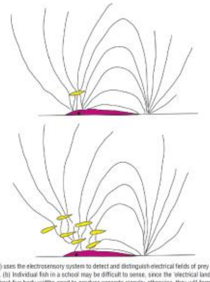
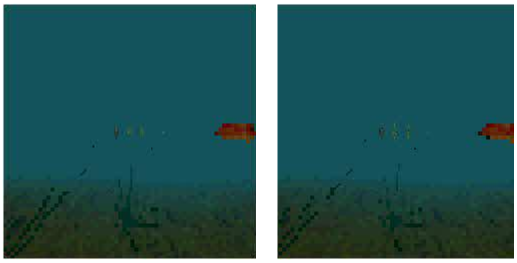


Figure 6 A predatory fish (purple) uses the electrosensory system to detect and distinguish electrical fields of prey during an attack. (a) A solitary fish may be easy to detect and localize. (b) Individual fish in a school may be difficult to sense, since the 'electrical landscape' will be more complicated. Individual prey (yellow) must be about five body widths apart to produce separate signals; otherwise, they will form a blurred image (Babineau et al., 2007). Reproduced from Larsson, M. (2012). Why do fish school? *Current Zoology*, **58**, 116–128, with permission from *Current Zoology*.

Active vision

Terzopoulos D & Rabie TF, 1997

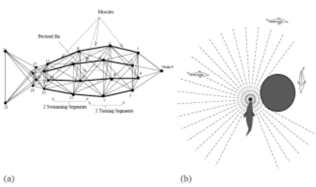


goo.gl/thBuW4

Active vision

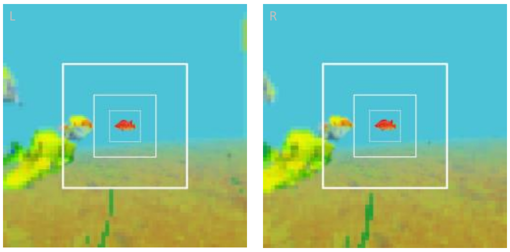
Terzopoulos D & Rabie TF, 1997

Figure 3. Biomechanical fish model (a) Nodes denote lumped masses. Lines indicate springs (shown at their natural lengths). Bold lines indicate muscle springs. Artificial fishes perceive objects (b) within a limited field view if objects are close enough and not occluded by other opaque objects (only the fish towards the left is visible to the animat at the center).



Active vision

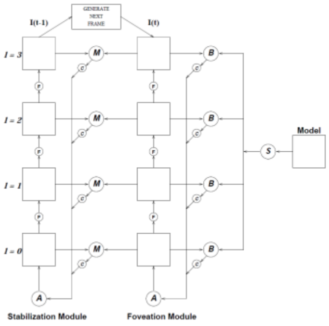
Terzopoulos D & Rabie TF, 1997



goo.gl/thBuW4

Active vision

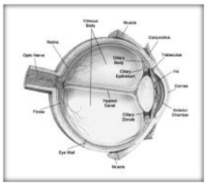
Terzopoulos D & Rabie TF, 1997



goo.gl/thBuW4

Active vision

Terzopoulos D & Rabie TF, 1997



$$\Delta\theta = \tan^{-1}\frac{x_c}{2^l f_c}, \qquad \Delta\phi = \tan^{-1}\frac{y_c}{2^l f_c}$$

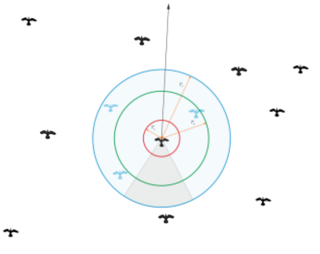
$$d = b\frac{\cos\theta_R \cos\theta_L}{\sin(\theta_L - \theta_R)\cos\big((\theta_L + \theta_R)/2\big)}$$

$$\theta_P = \frac{\theta_L + \theta_R}{2}, \qquad \phi_P = \frac{\phi_L + \phi_R}{2}$$

goo.gl/thBuW4

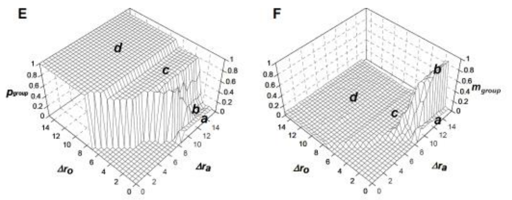
Collective behaviour of animal groups

Couzin I, *et al*, 2002



Collective behaviour of animal groups

Couzin I, *et al*, 2002



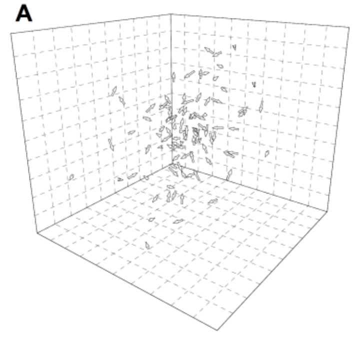
$$p_{group} = \frac{1}{N}\left|\sum_{i=1}^{N}\vec{v}_i\right|$$

$$m_{group} = \frac{1}{N}\left|\sum_{i=1}^{N}\vec{r}_{ic}\times\vec{v}_i\right|$$

$$\vec{r}_{ic} = \vec{p}_i - \vec{g}, \quad \vec{g} = \frac{1}{N}\sum_{i=1}^{N}\vec{p}_i$$

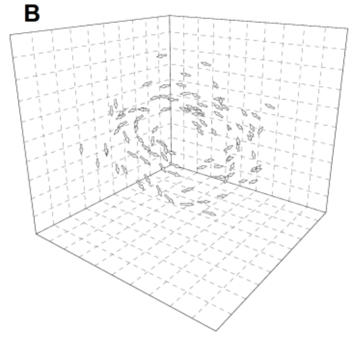
Collective behaviour of animal groups

Couzin I, *et al*, 2002



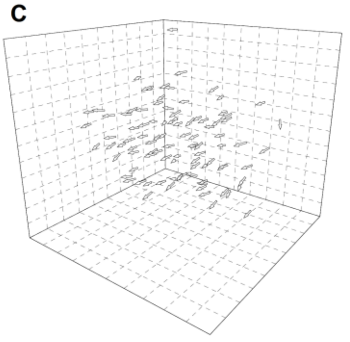
Collective behaviour of animal groups

Couzin I, *et al*, 2002



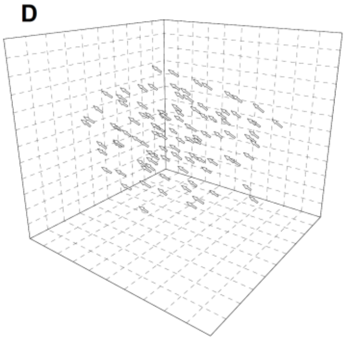
Collective behaviour of animal groups

Couzin I, *et al*, 2002



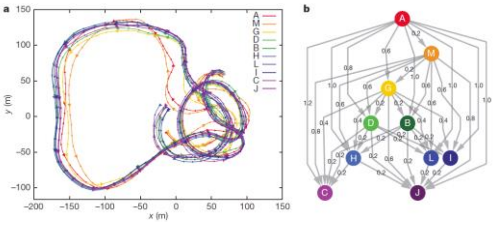
Collective behaviour of animal groups

Couzin I, *et al*, 2002



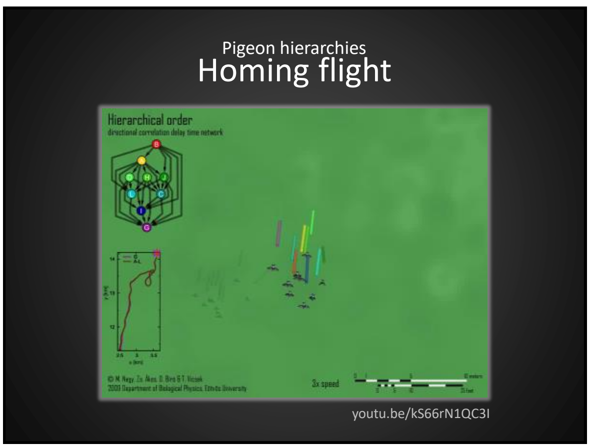
Pigeon hierarchies

Nagy M, *et al*, 2010, 2013



goo.gl/UIMg0R, goo.gl/OGGFSj


Pigeon hierarchies
Free flight
Hierarchical order
directional correlation delay time network
3x speed
youtu.be/UFF74jWZmM4


Pigeon hierarchies
Homing flight
Hierarchical order
directional correlation delay time network
3x speed
youtu.be/kS66rN1QC3I


Pigeon hierarchies
Free flight with landing
2x speed
youtu.be/FVBiR7pl71U

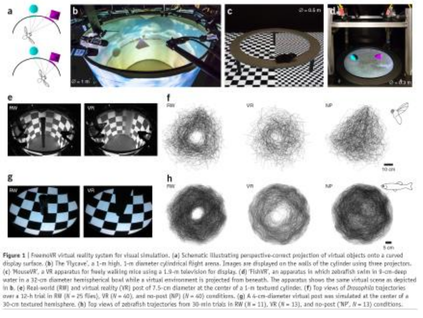
Pigeon hierarchies

Pecking order

youtu.be/QMpIvlKPk3k

Virtual reality for freely moving animals

Stowers JR, *et al*, 2017



MIT
Soft robotic fish

goo.gl/Jd4Ojl