Modelling Complex Systems

Self-propelled particles II

This lecture is adapted from Vicsek, T. & Zafeiris, A. (2012) Collective Motion and previous slides of David Sumpter

See: arXiv:1010.5017v2

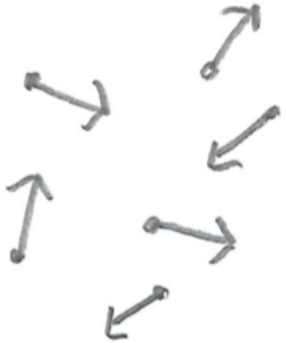
Vicsek Model

- Introduced in Lab 5, we now discuss the theory.

- Code: ‘Align2D.m’ or the python implementation on the course webpage.

Measure of Alignment: Polarisation

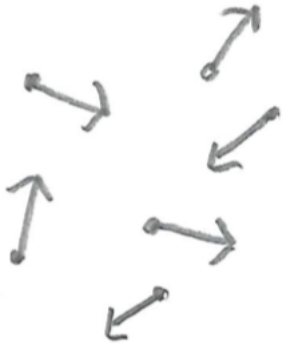
High polarisation



Low Polarisation

Measure of Alignment: Polarisation

High polarisation



Low Polarisation

Measure of Alignment: Polarisation

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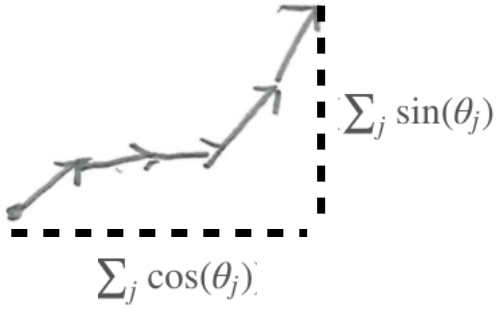

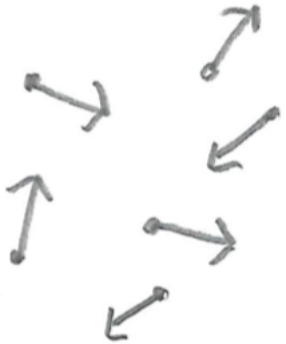

Low Polarisation

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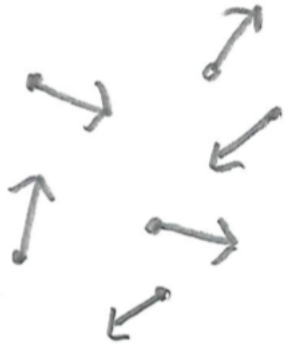
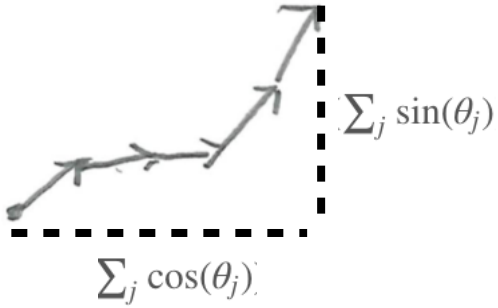


Low Polarisation



Polarisation of:

$\theta_1, \theta_2, \ldots, \theta_N$

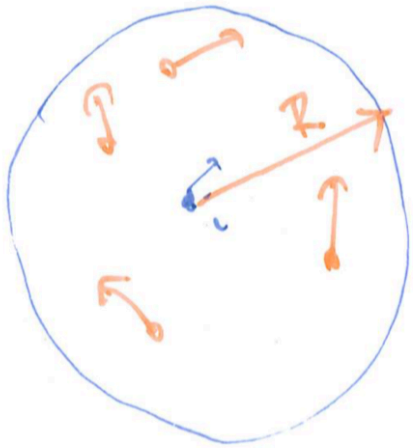
$$= \frac{1}{N}\sqrt{(\sum_j \sin(\theta_j))^2 + (\sum_j \cos(\theta_j))^2}$$

Measure of Aggregation?

Definition -

a cluster of things that have come or been brought together

Vicsek Model



N: number of particles
η: noise parameter
L: size of domain
R: radius of interaction
v: speed

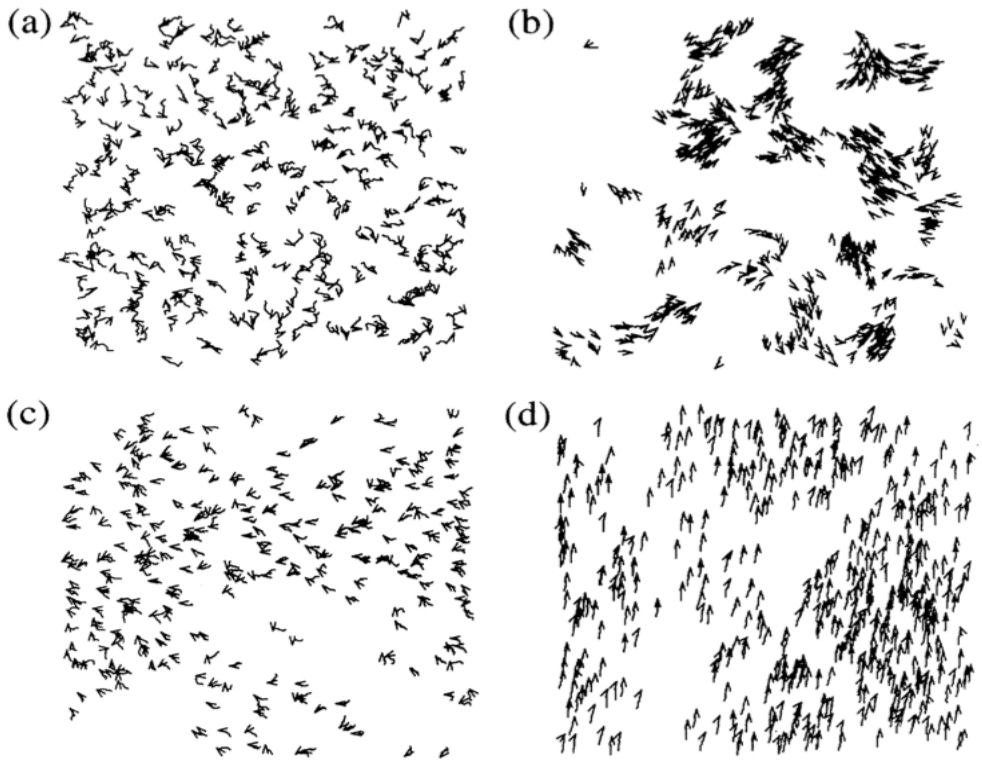
Angular update rule:

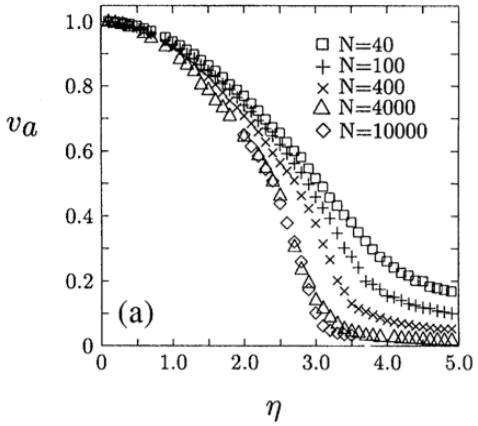
$$\theta_i(t+1) = \tan^{-1}\left(\frac{\sum_{j\in R_i}\sin(\theta_j(t))}{\sum_{j\in R_i}\cos(\theta_j(t))}\right) + e(t)$$

e(t) is a random number selected uniformly at random from a range $[-\eta/2, \eta/2]$

Vicsek et al., PRL 75 (1995)

Vicsek Model

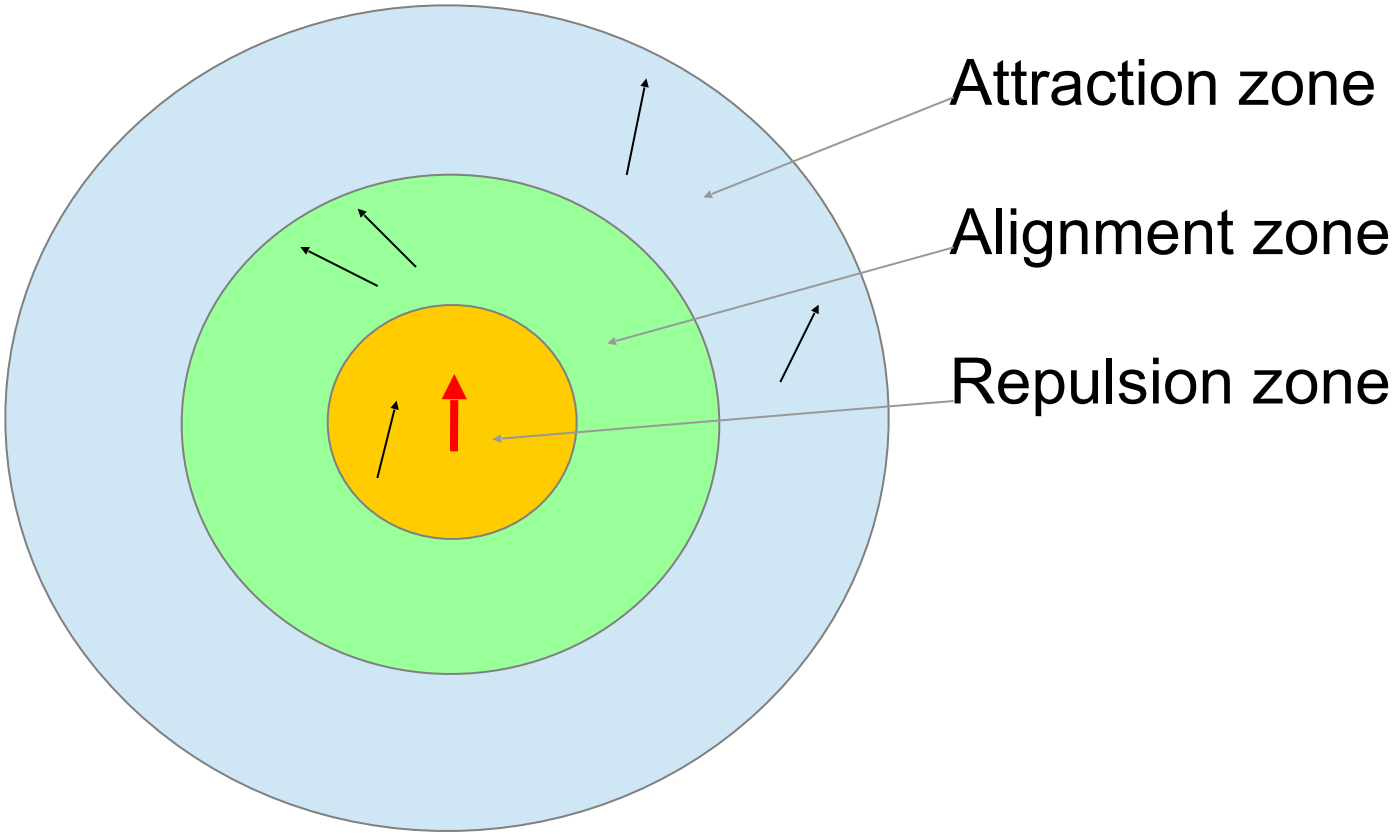




Vicsek et al., PRL 75 (1995)

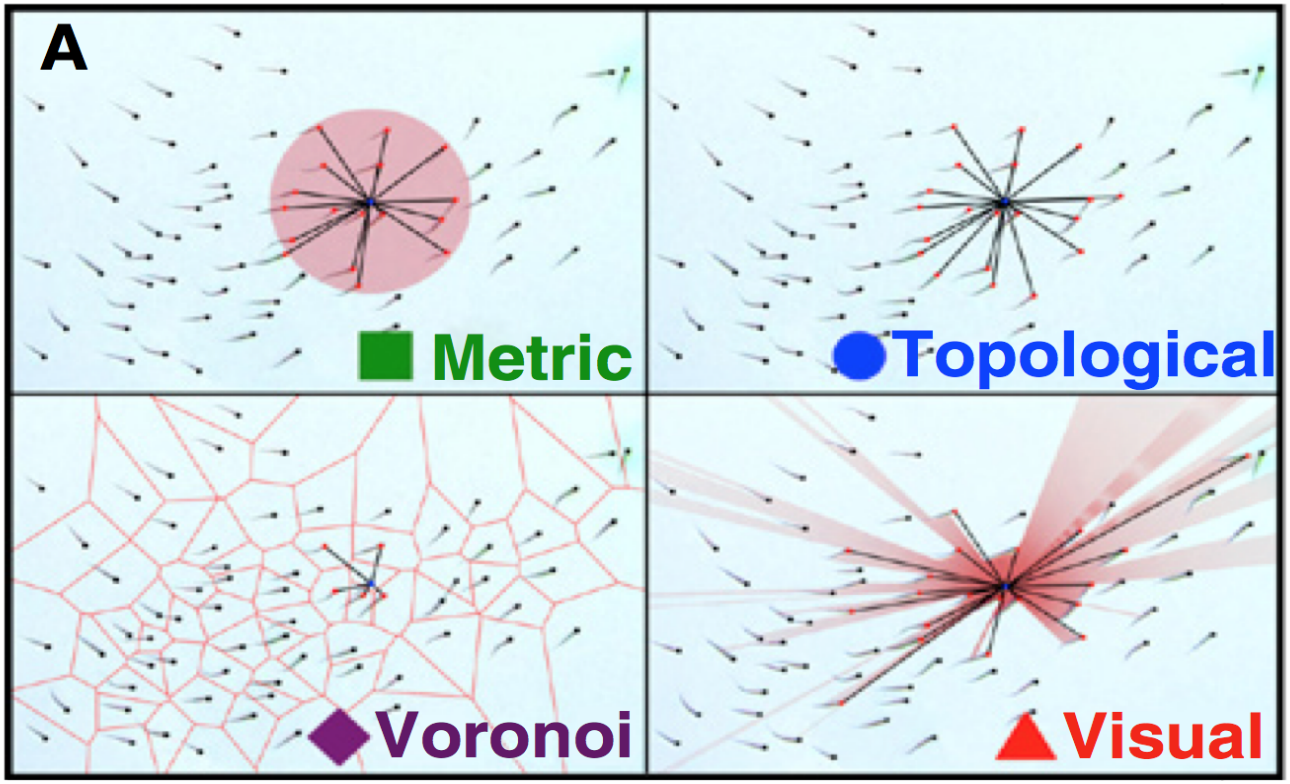
Attraction/Repulsion

"Boids" model



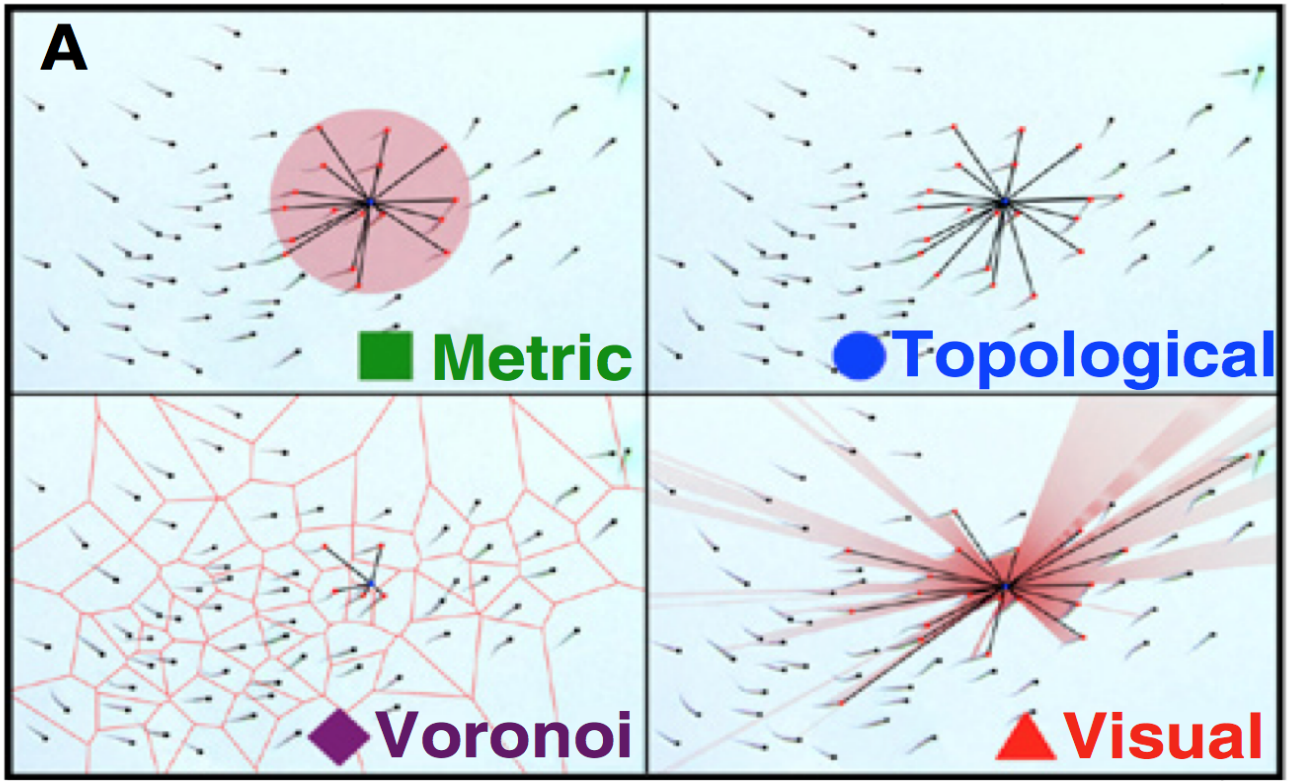
See: Couzin et al., J. Theor. Bio. (2002)

Alternative distance measures



Strandburg-Peshkin et al., Current Biology (2013)

Alternative distance measures



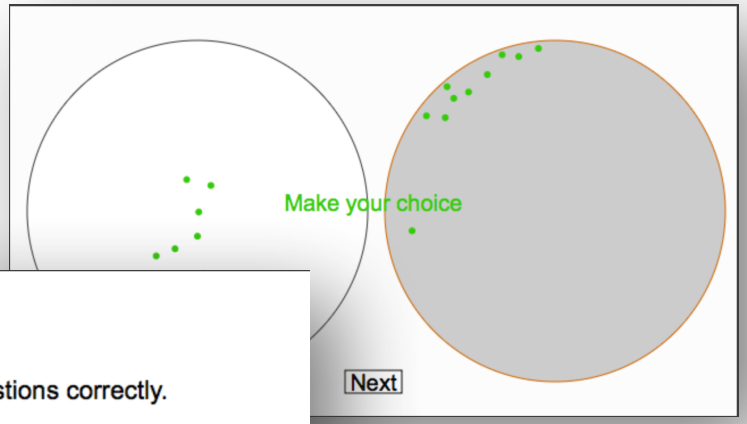
Metric: all individuals within a certain distance.
Topological: a fixed number of nearest neighbors.
Voronoi: those individuals sharing a boundary in a Voronoi tes-sellation of the group.
Visual: all individuals that occupy an angular area on the retina of the focal fish that is greater than a threshold value.

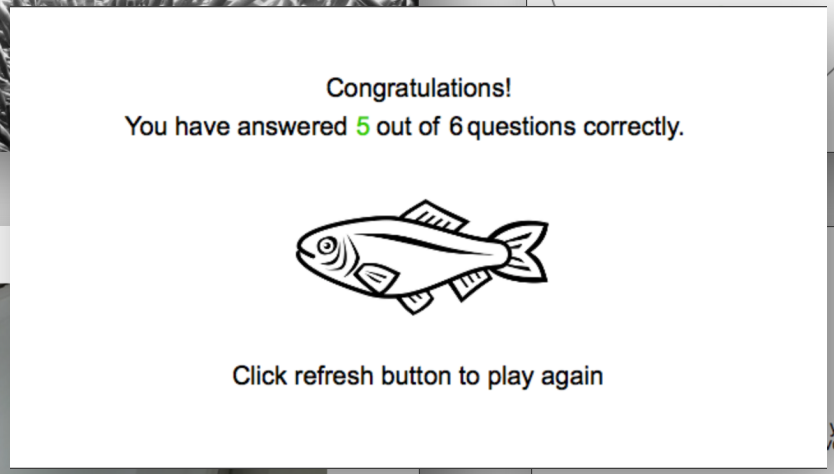
Strandburg-Peshkin et al., Current Biology (2013)

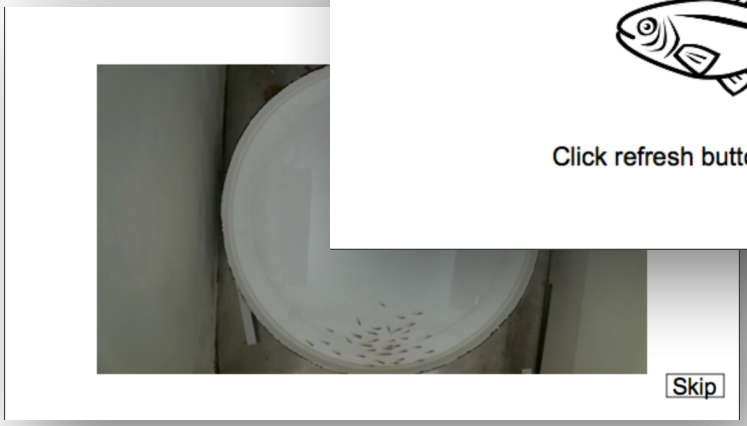
Even more options

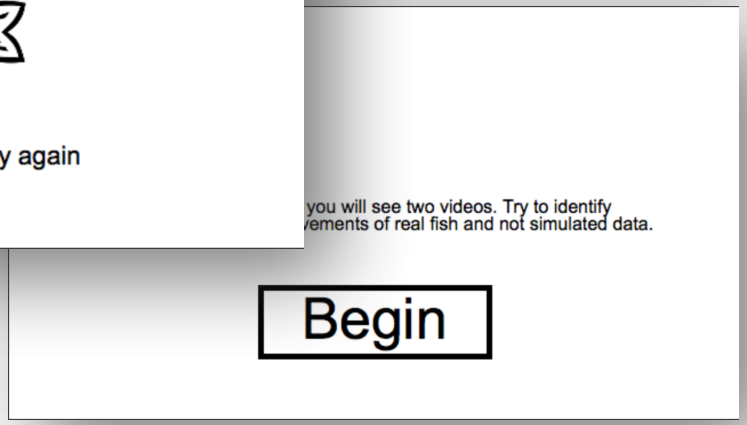
- Maximum turning angles
- Blind angles
- Attraction/repulsion potentials
- Reaction times
- Wall interactions
- Variable speed
- Variation in individuals
- Pheromone trails
- Etc....

Can you tell the difference between real and simulated fish?





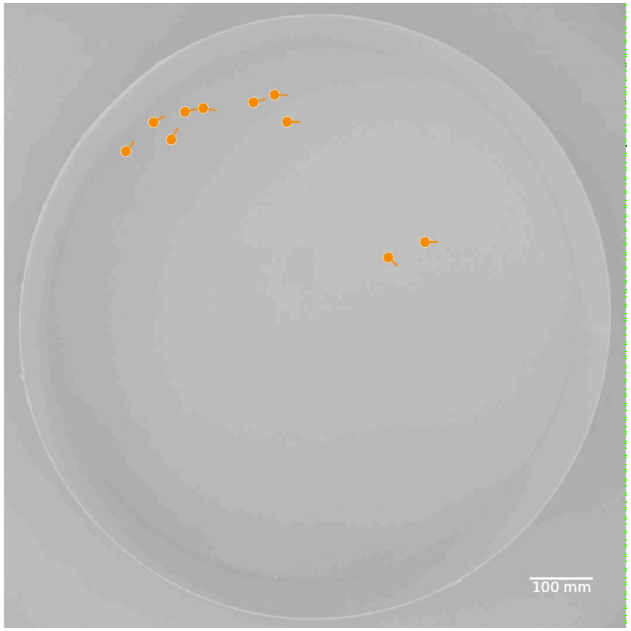


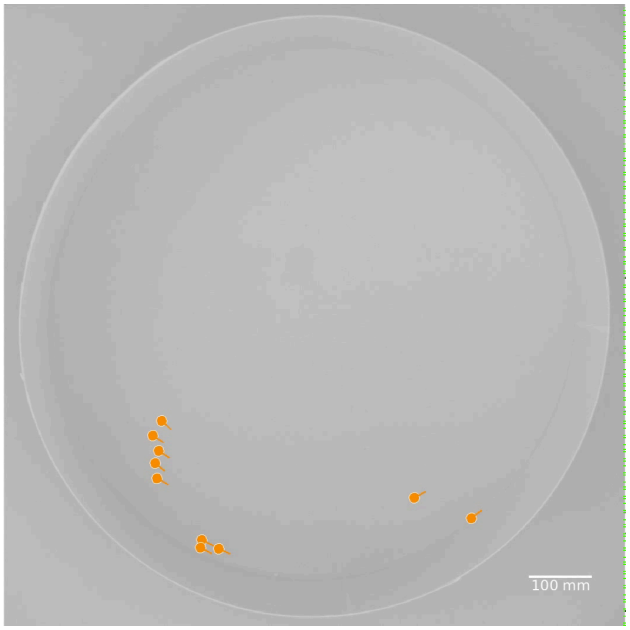


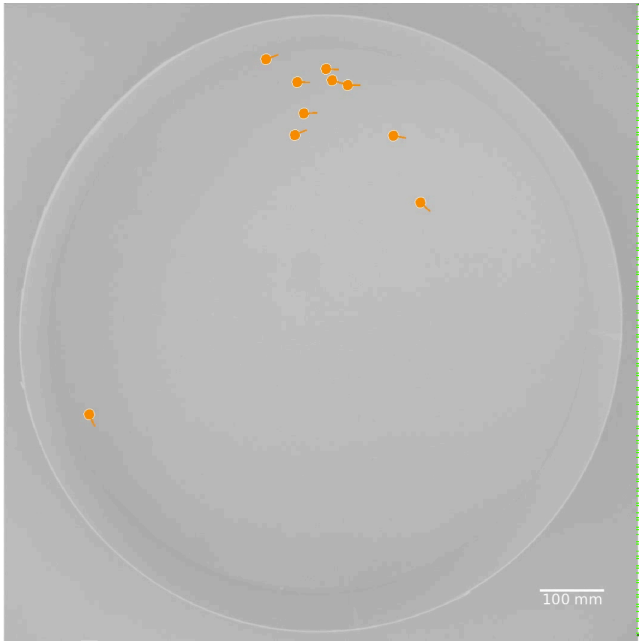
Get playing!

http://www.collective-behavior.com/apps/

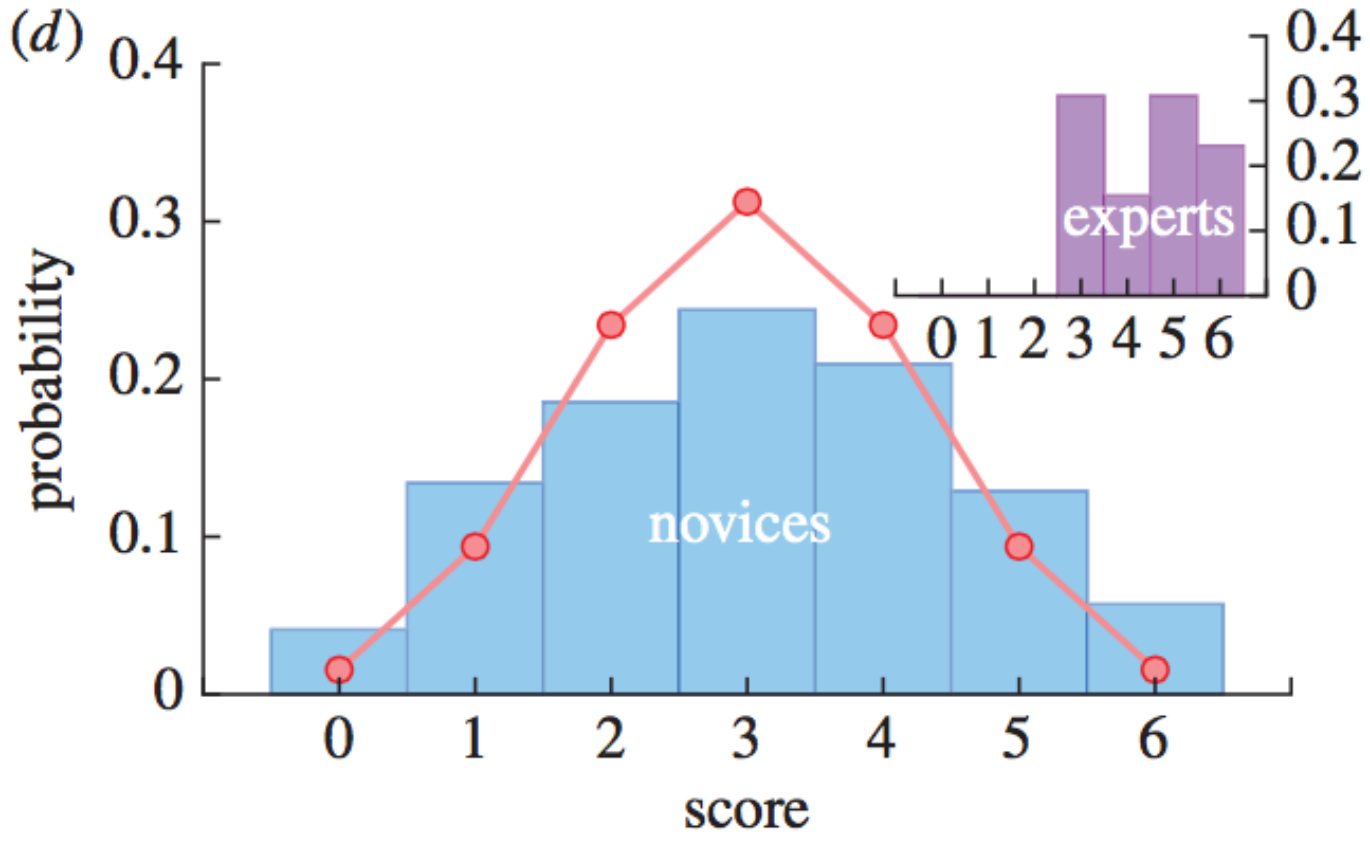

100 mm


100 mm

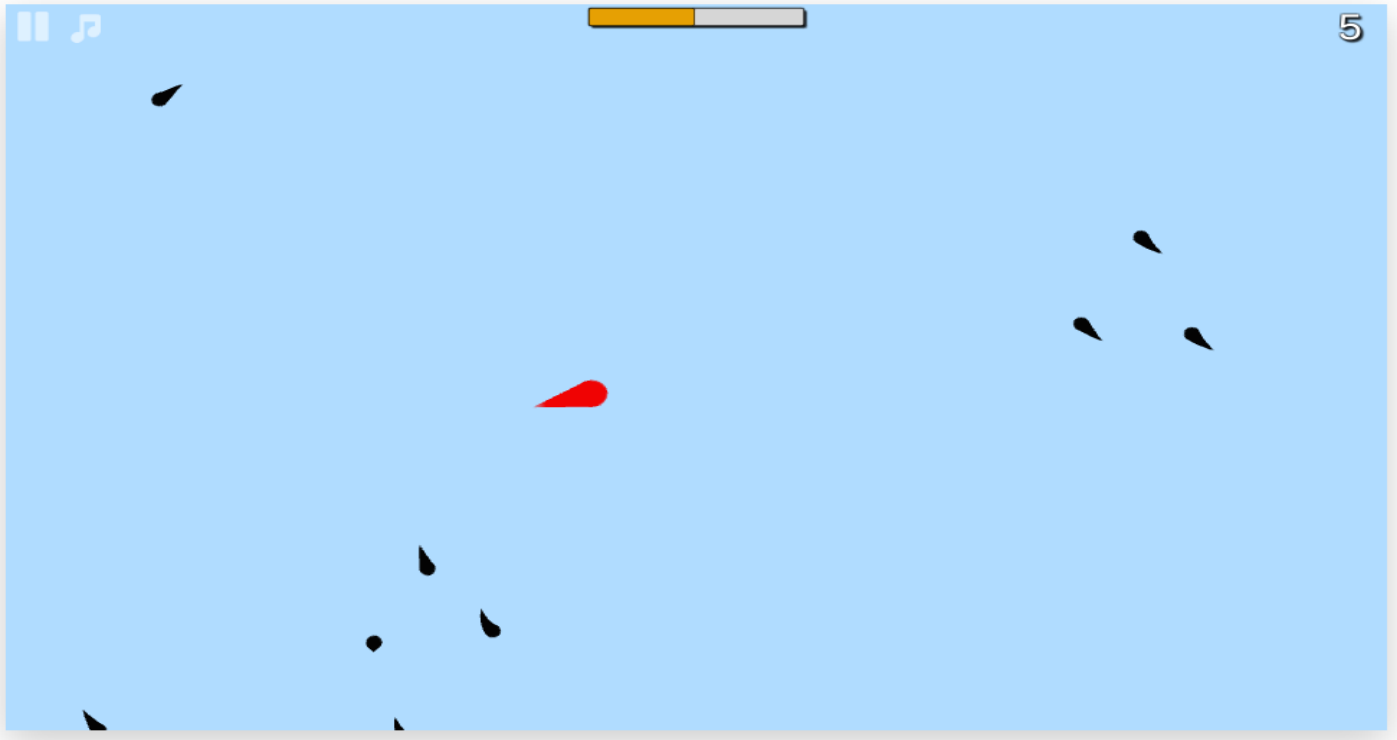

100 mm


100 mm

Can people tell the difference between real and simulated fish?



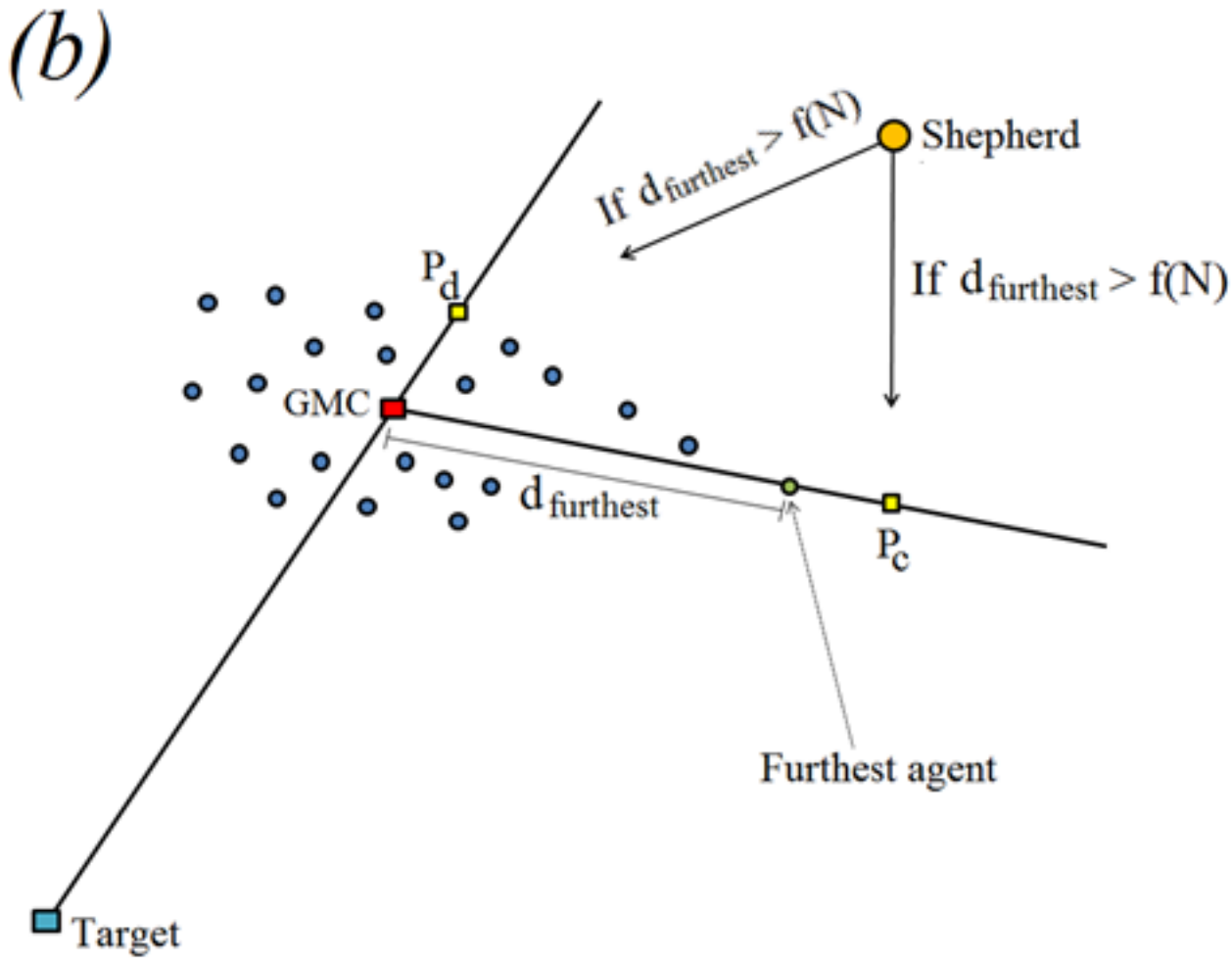
Evolving prey



http://collective-behavior.com/apps/fishindanger/webgl

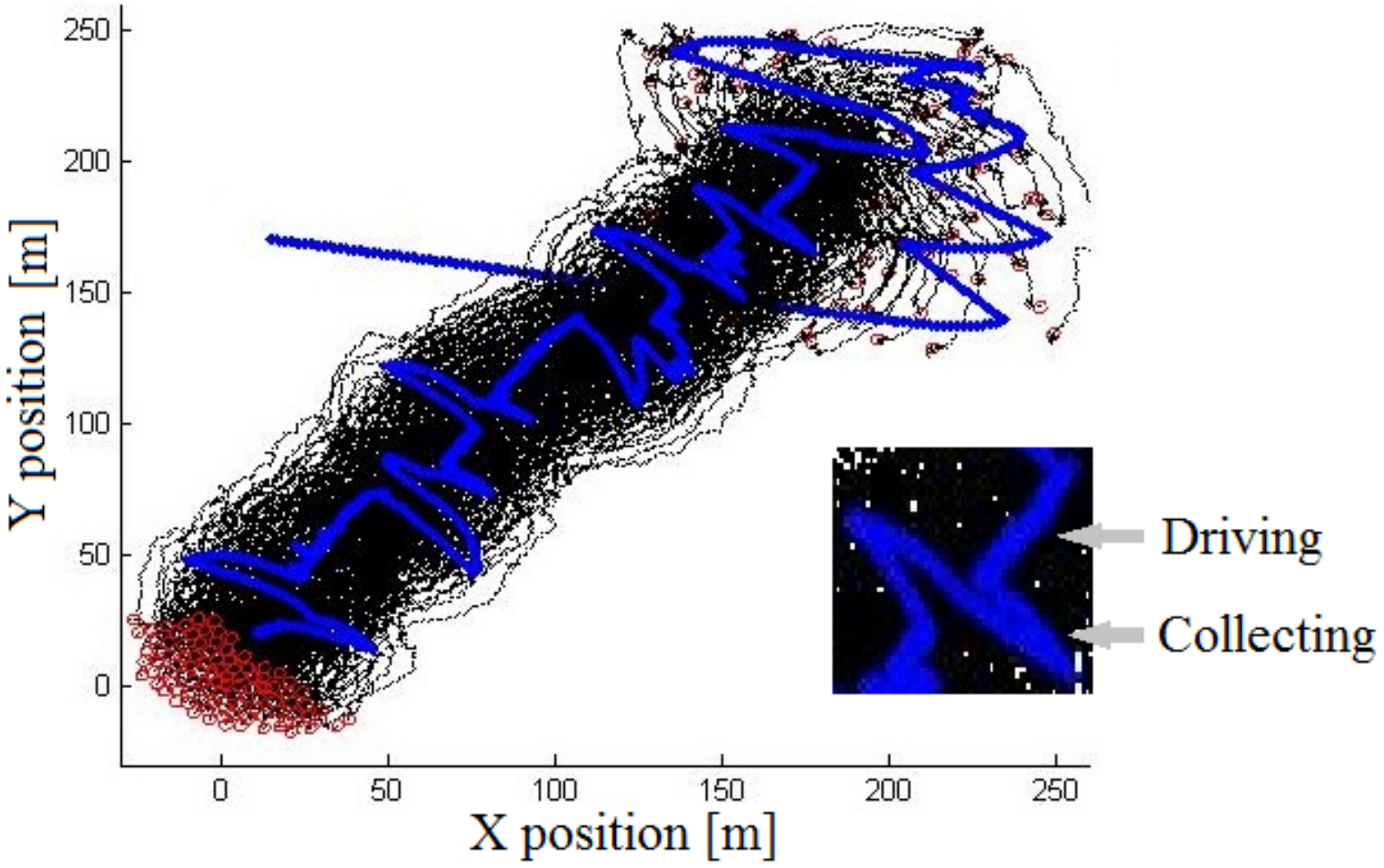
King et al. (2012) *Current Biology*

Sheepdog model



Strömbom et al., J. Royal Soc. Interface (2014)

Drive and collect



Next: when humans go ballistic

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Collective Motion of Humans in Mosh and Circle Pits at Heavy Metal Concerts

Jesse L. Silverberg,* Matthew Bierbaum, James P. Sethna, and Itai Cohen

Department of Physics and Laboratory of Atomic and Solid State Physics, Cornell University, Ithaca, New York 14853, USA

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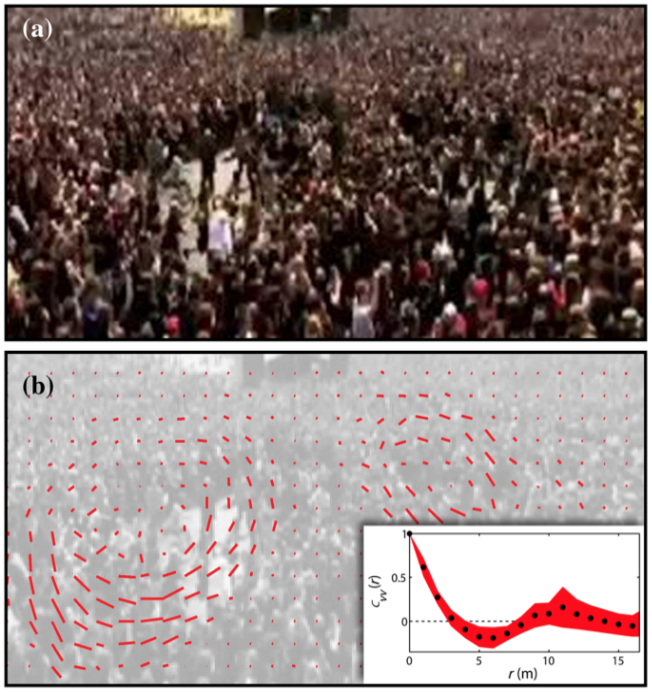
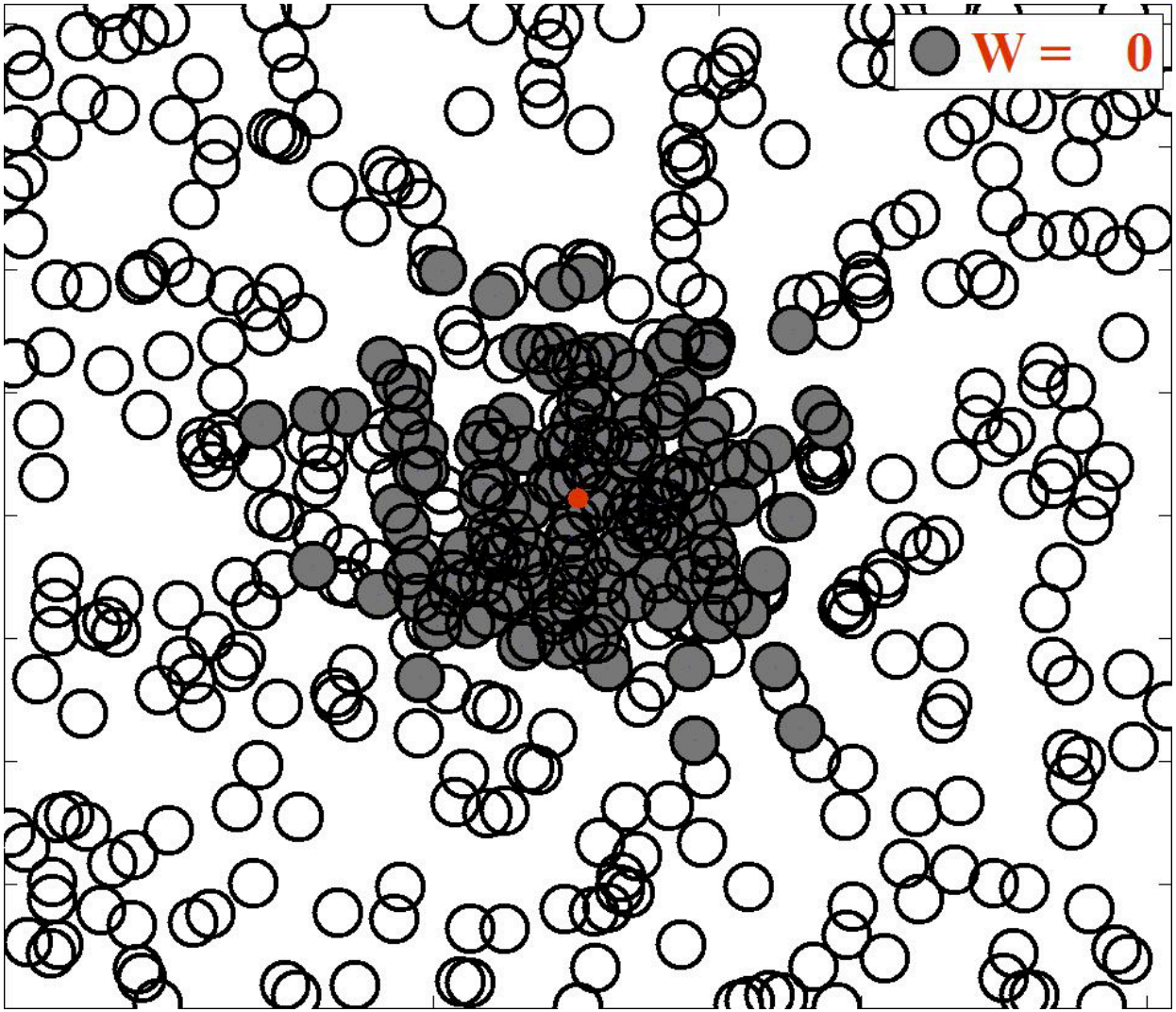
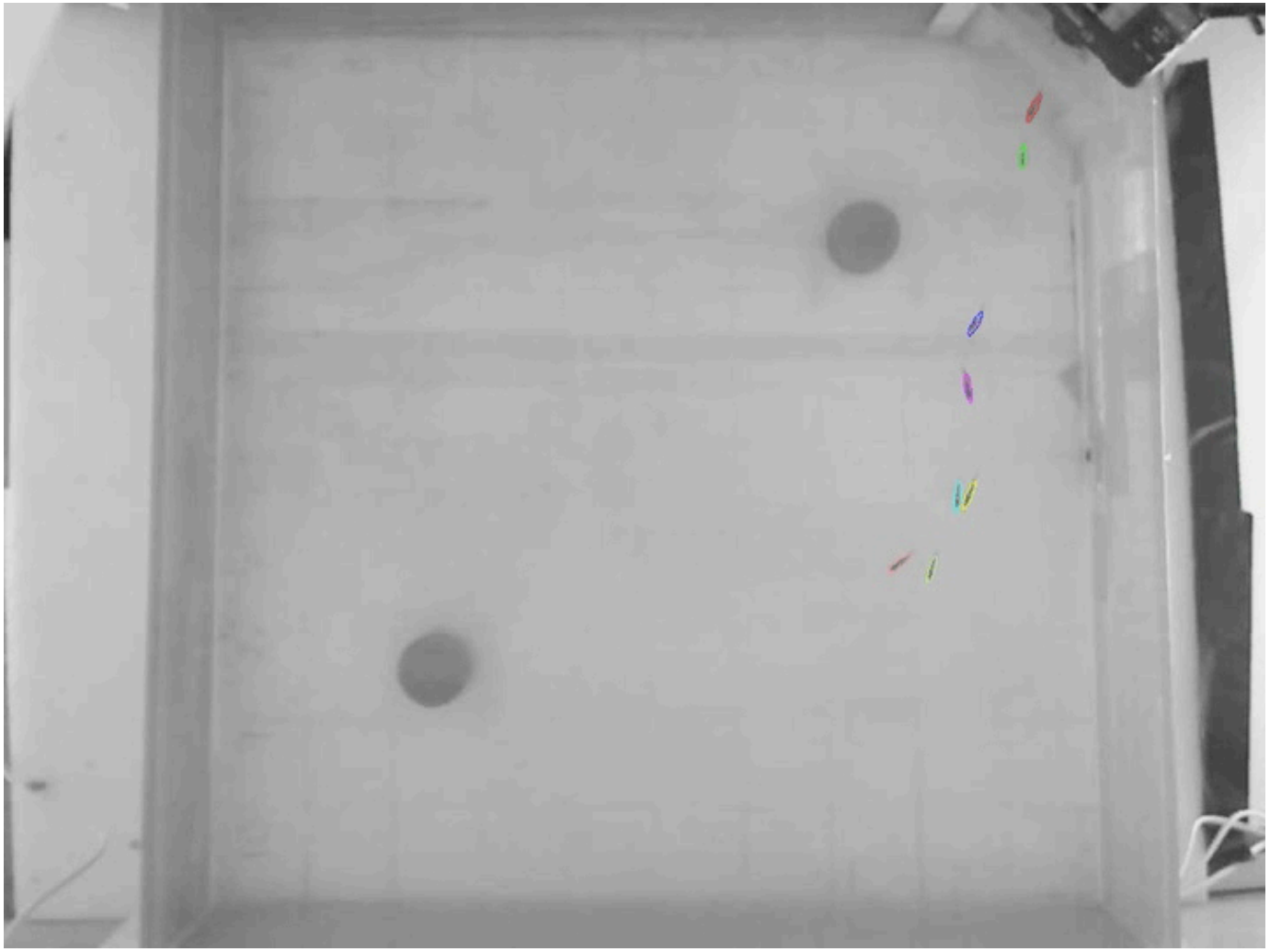


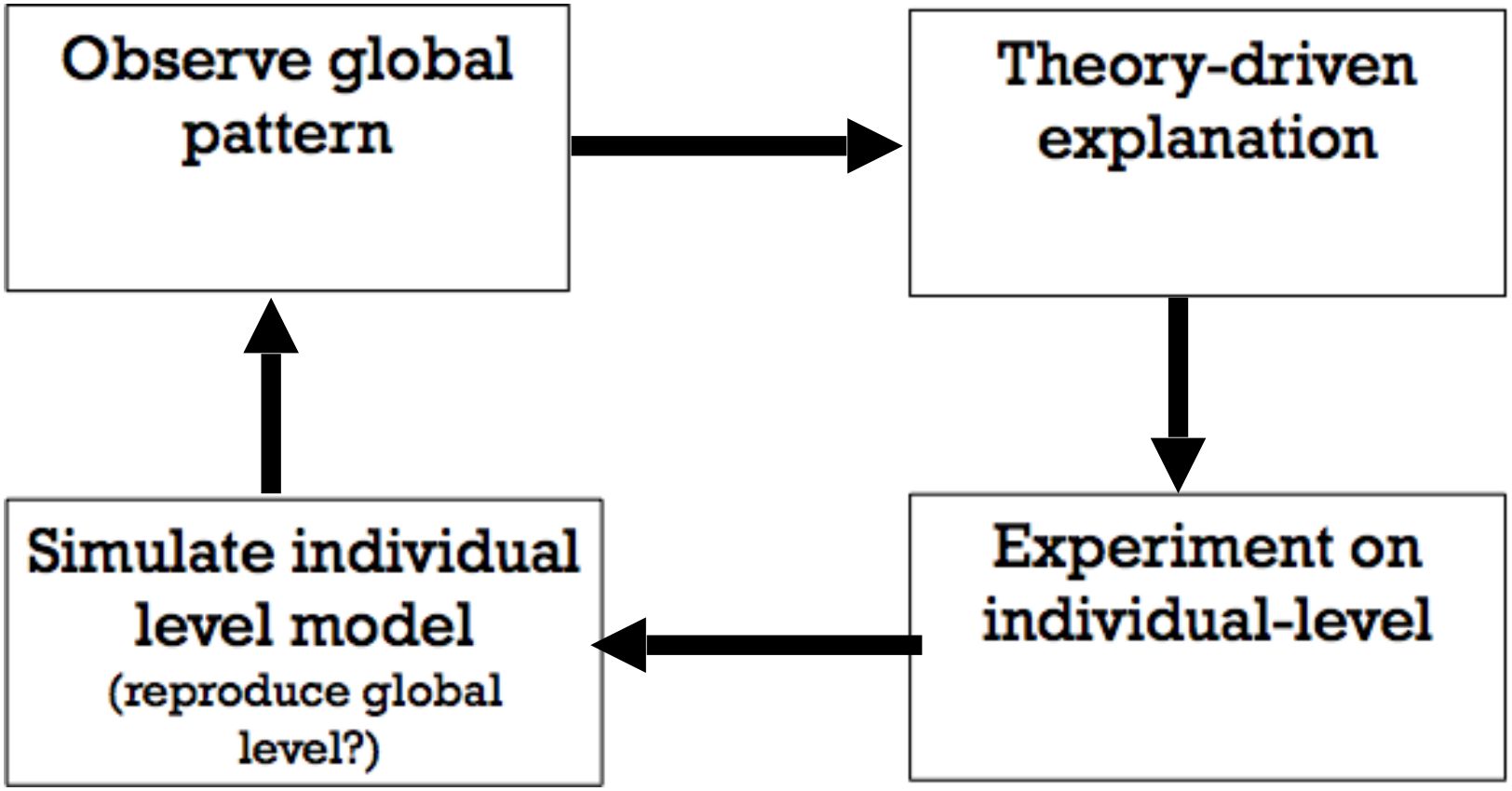
Moshpit model

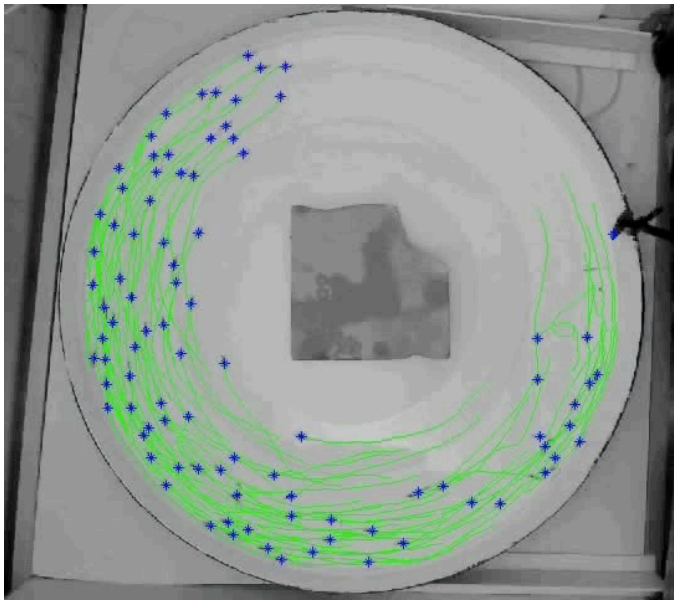


Rules of motion



The modelling cycle





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