

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



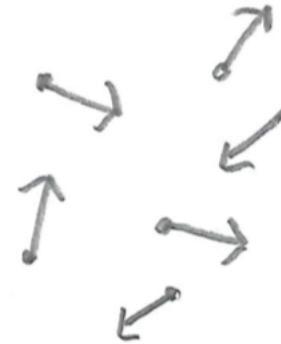
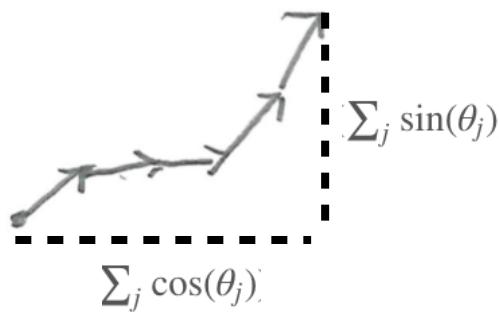
Low Polarisation



Measure of Alignment: Polarisation



High polarisation



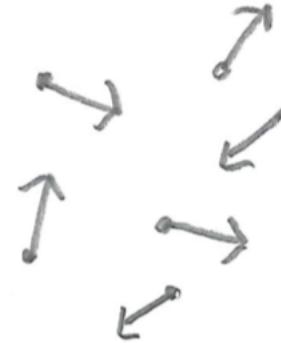
Low Polarisation



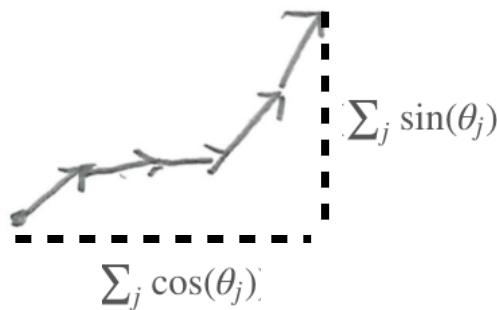
Measure of Alignment: Polarisation



High polarisation



Low Polarisation



$$\text{Polarisation of: } \theta_1, \theta_2, \dots, \theta_N = \frac{1}{N} \sqrt{(\sum_j \sin(\theta_j))^2 + (\sum_j \cos(\theta_j))^2}$$

Measure of Aggregation?

Definition -

a cluster of things that have come or been brought together

Vicsek Model

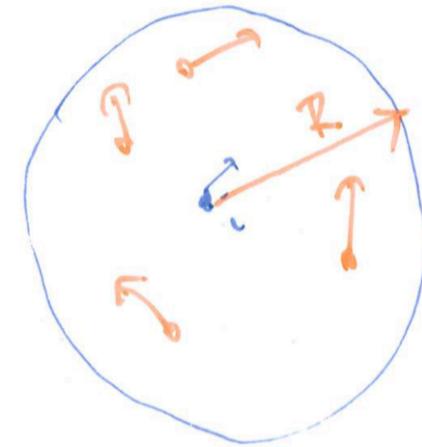
N: number of particles

η : noise parameter

L: size of domain

R : radius of interaction

v: speed

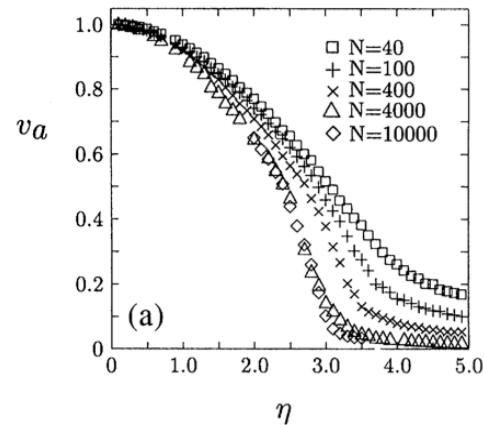
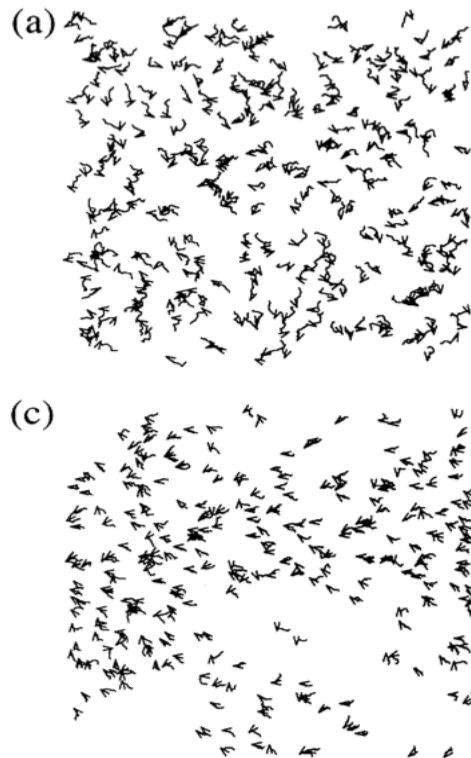


Angular update rule:

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

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

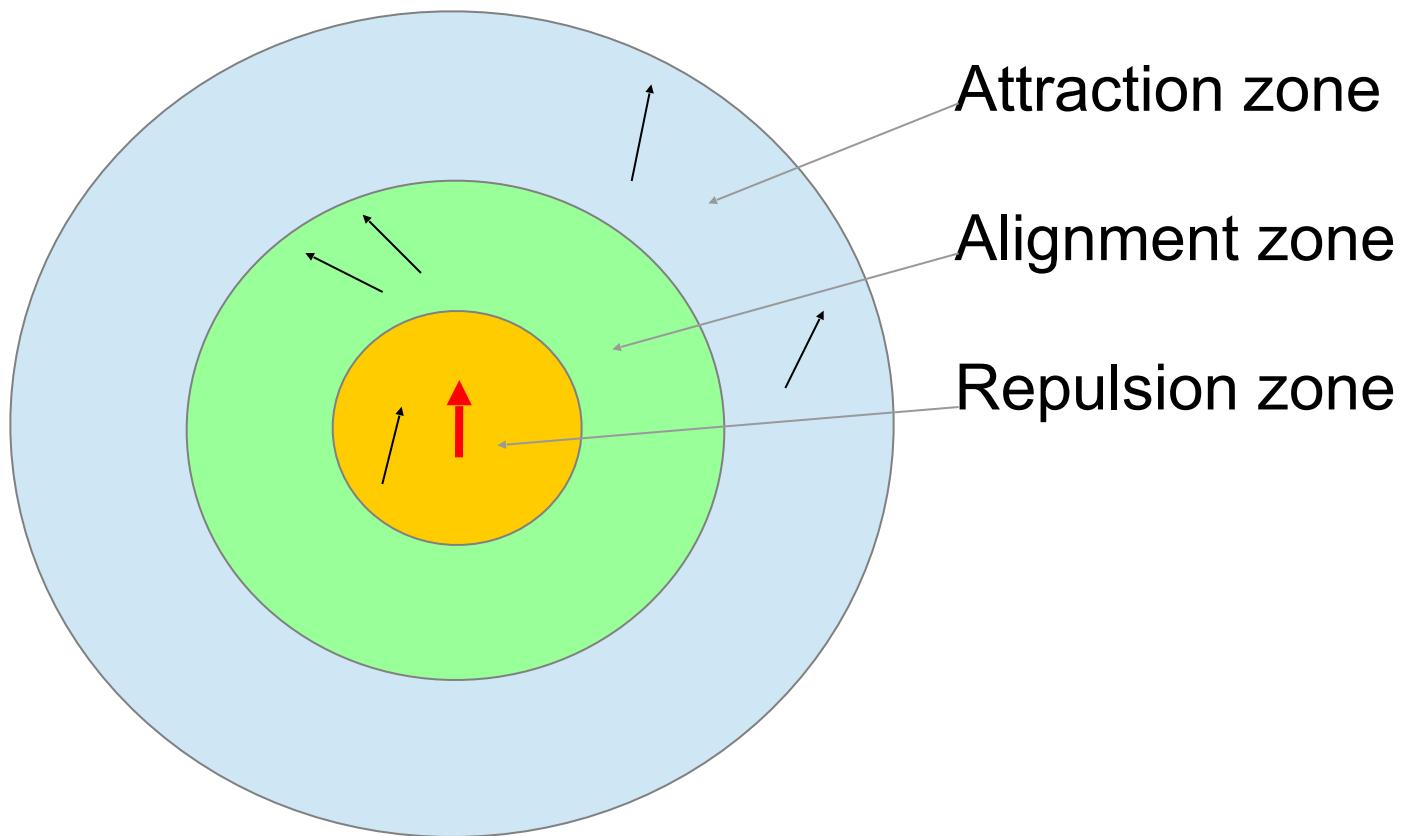
Vicsek Model



Vicsek et al., PRL 75 (1995)

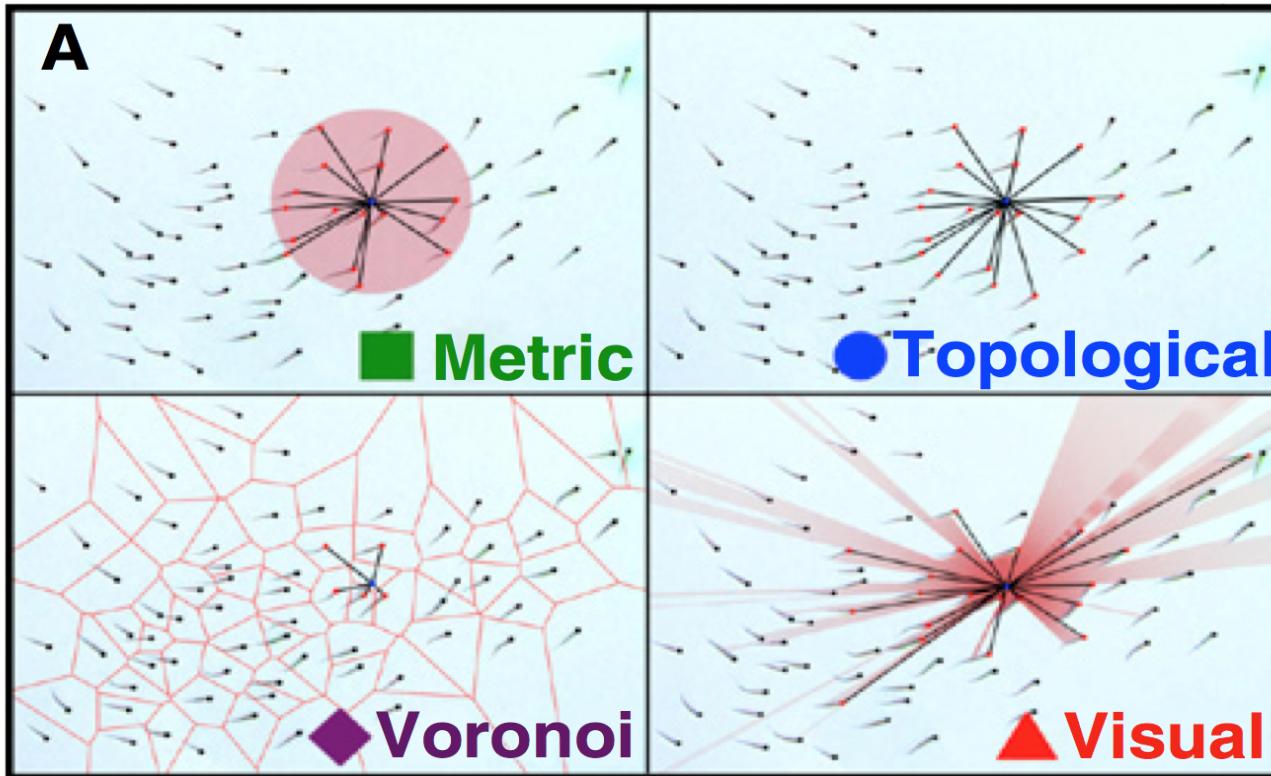
Attraction/Repulsion

“Boids” model

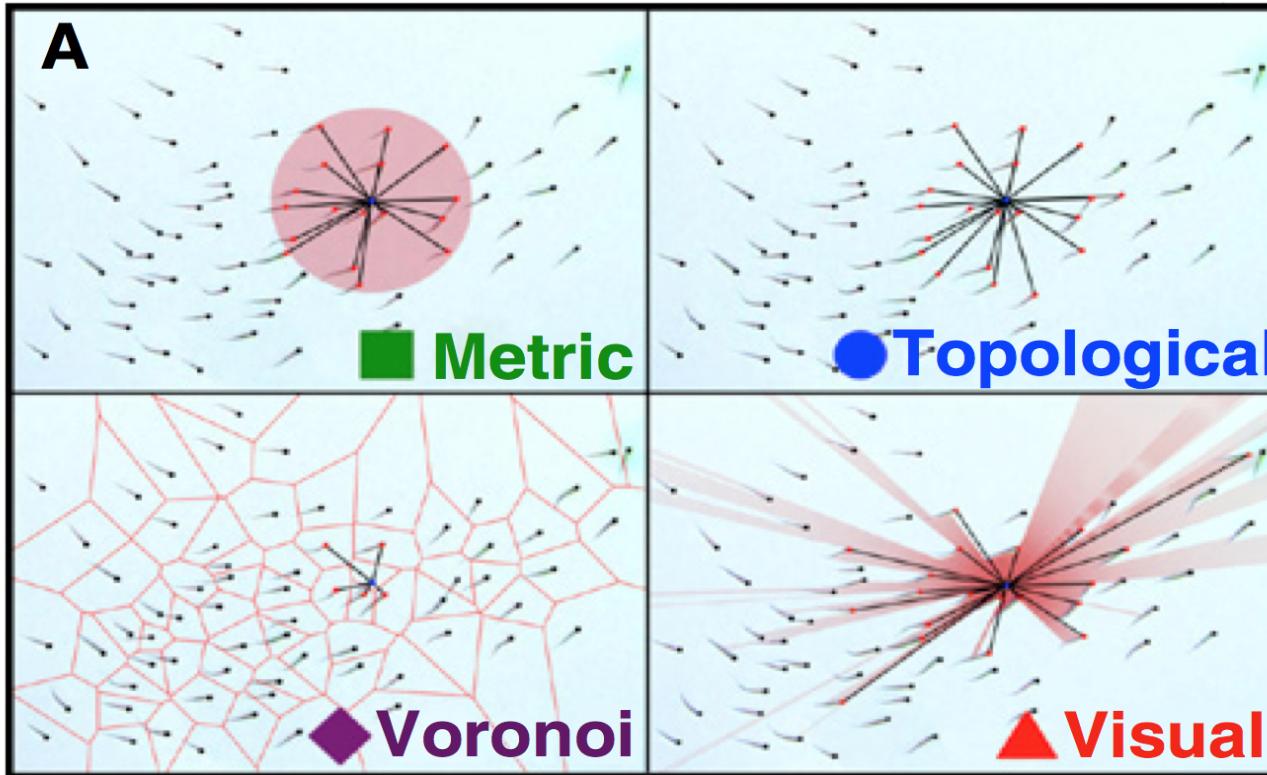


See: Couzin et al., J. Theor. Bio. (2002)

Alternative distance measures



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 tessellation 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.

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?

The image is a collage of screenshots from a computer application. At the top left is a grayscale video frame showing a dense school of fish, with a black rectangular button containing the word "Play". To its right is a circular interface with two sections: a smaller white circle on the left containing several green dots and a larger gray circle on the right containing a single green dot. The text "Make your choice" is positioned between them, and a "Next" button is at the bottom right. Below these is a white box containing the text "Congratulations! You have answered 5 out of 6 questions correctly." and a simple line drawing of a fish. To the left of this box is another video frame showing a white container with many small fish swimming in it, with a "Skip" button at the bottom right. At the bottom right is a large white box with a black rectangular button containing the word "Begin".

Play

Congratulations!
You have answered 5 out of 6 questions correctly.

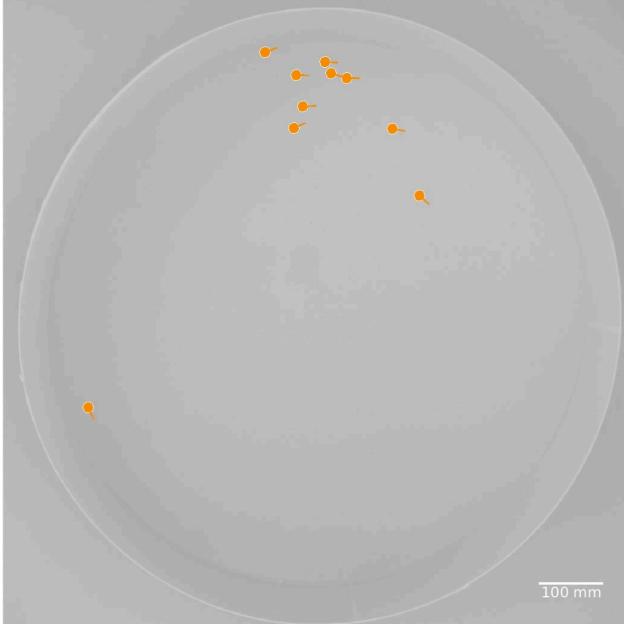
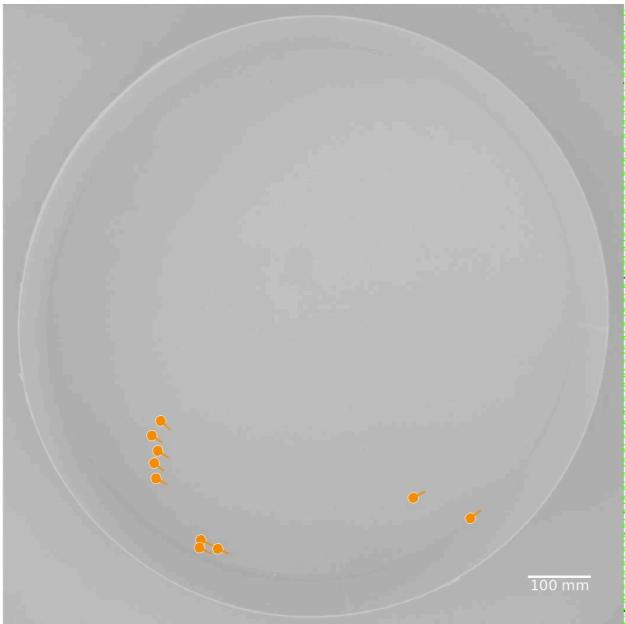
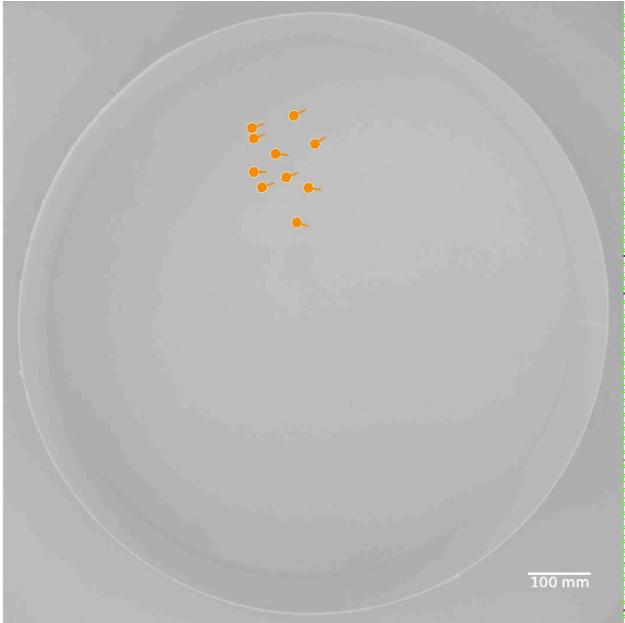
Next

Begin

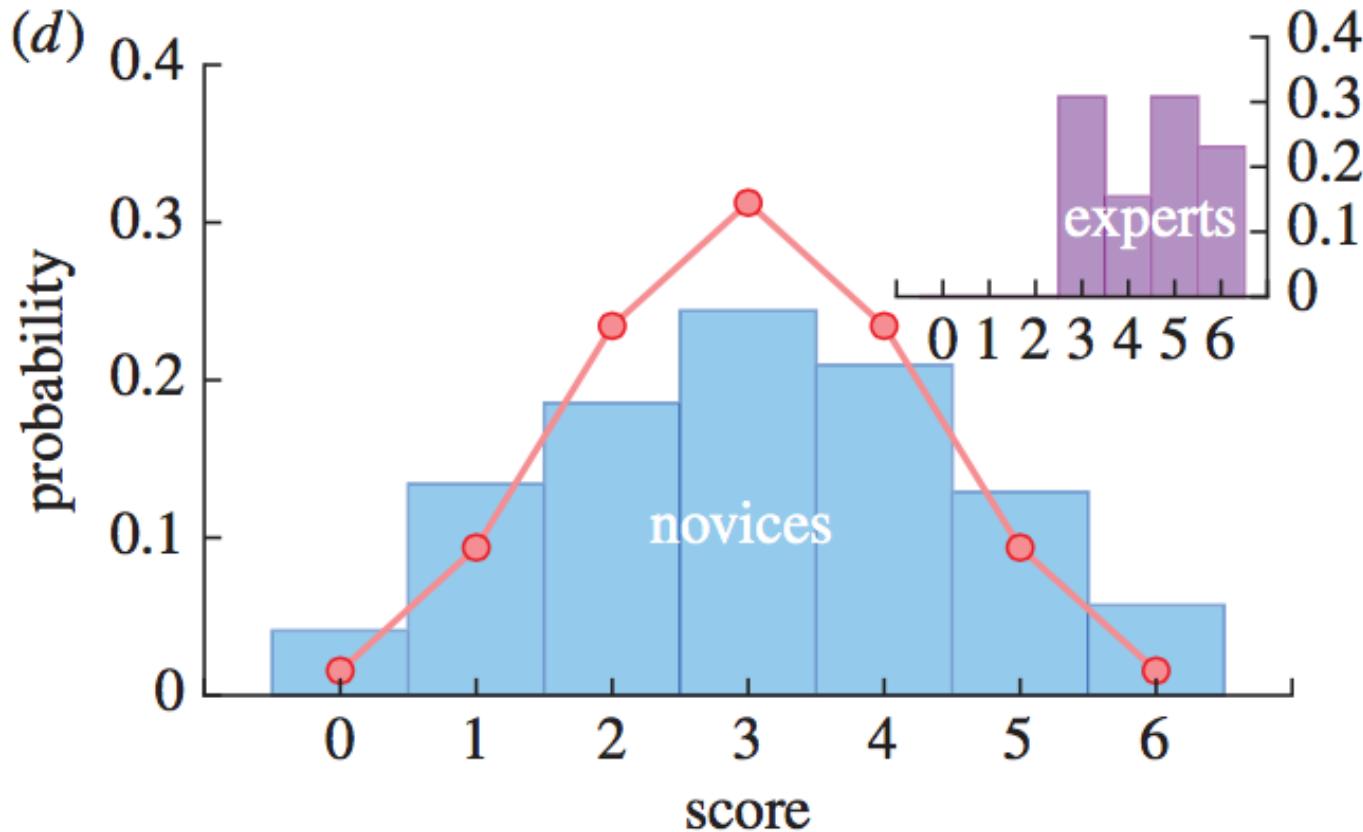
Skip

Get playing!

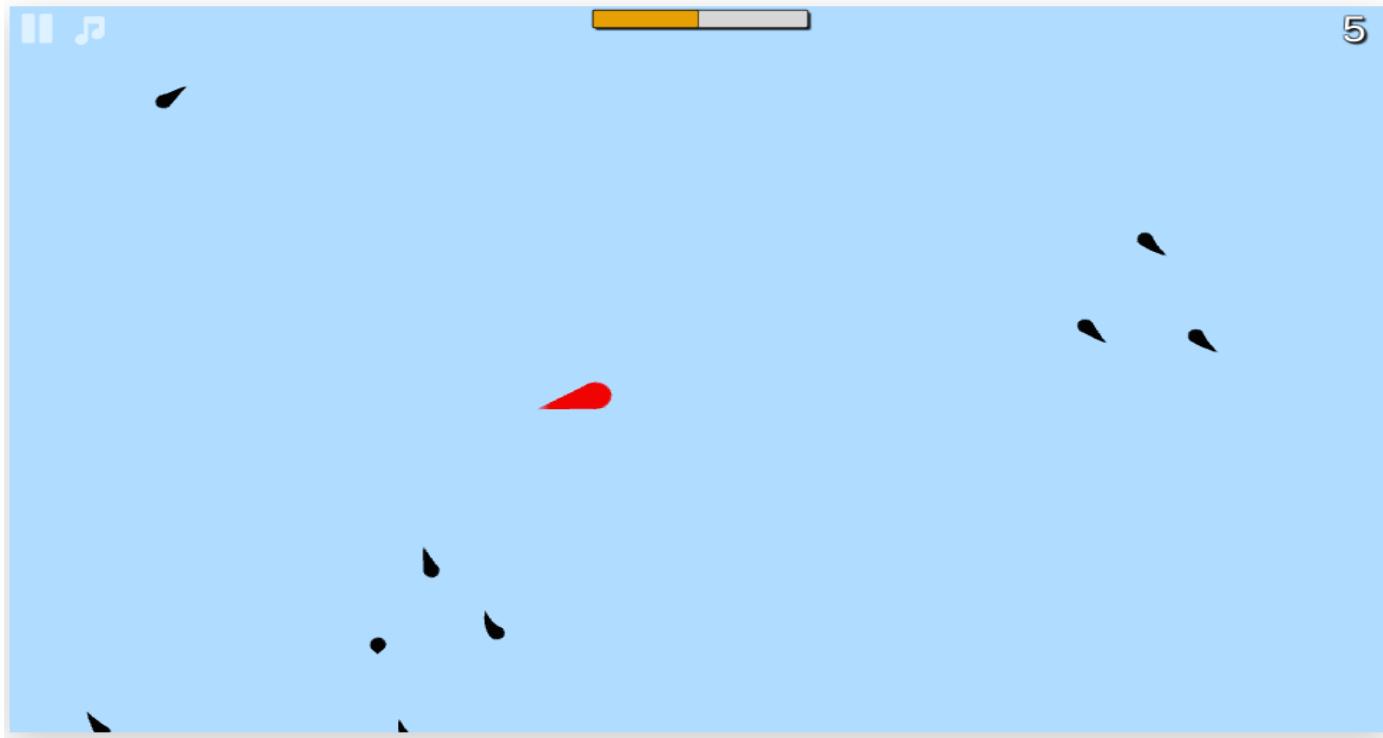
<http://www.collective-behavior.com/apps/>



Can people tell the difference between real and simulated fish?



Evolving prey

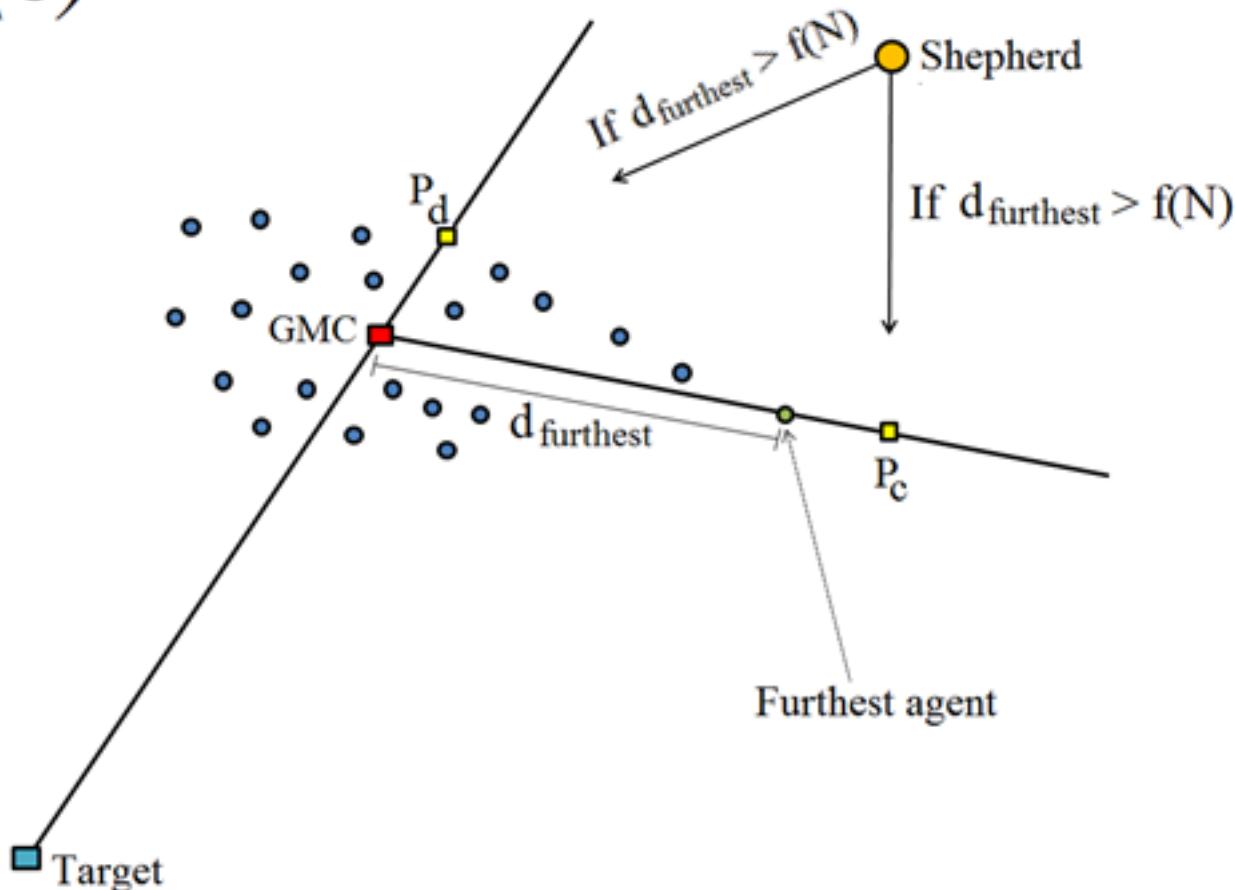


<http://collective-behavior.com/apps/fishindanger/webgl>

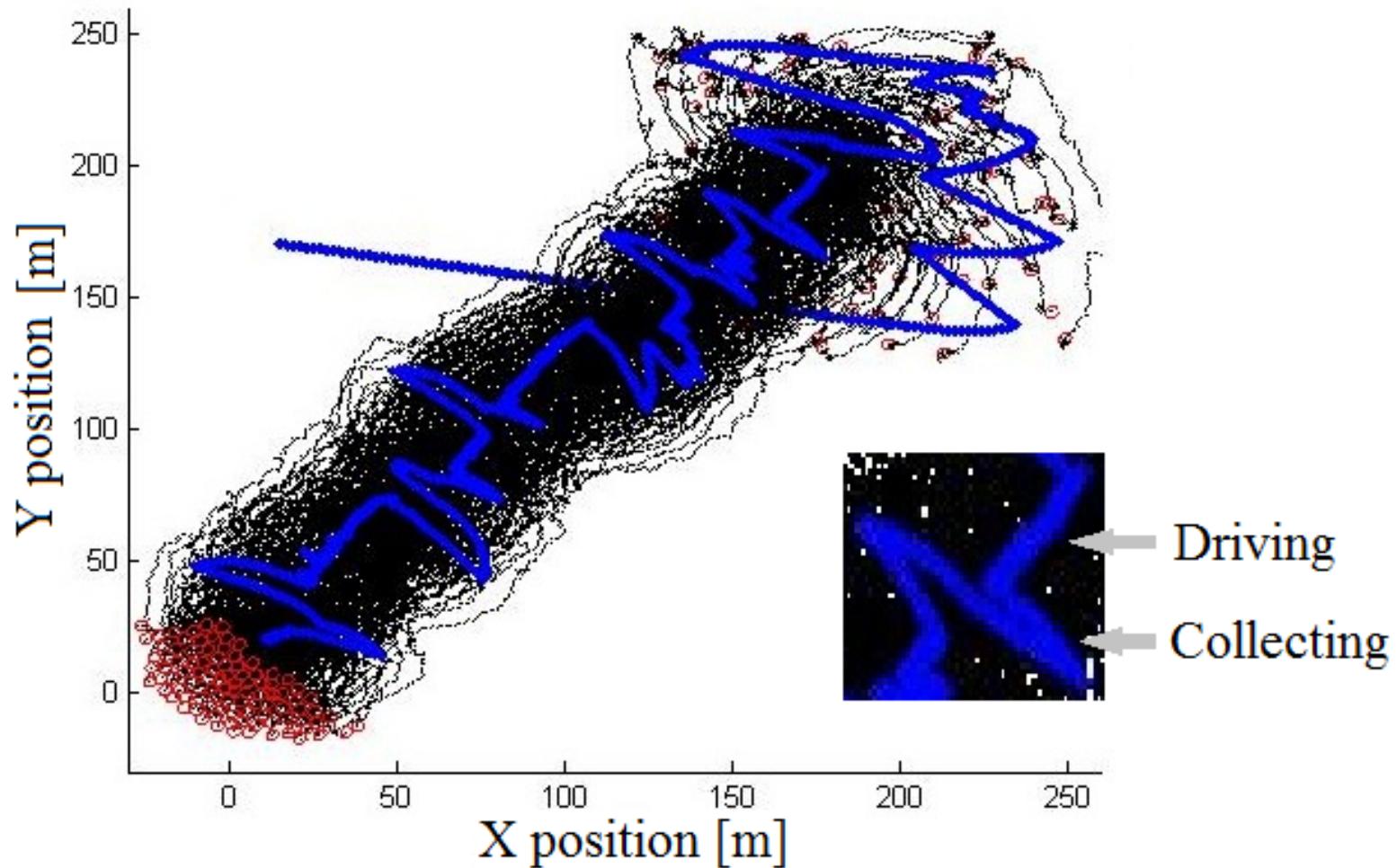


Sheepdog model

(b)



Drive and collect



Next: when humans go ballistic

PRL 110, 228701 (2013)

PHYSICAL REVIEW LETTERS

week ending
31 MAY 2013

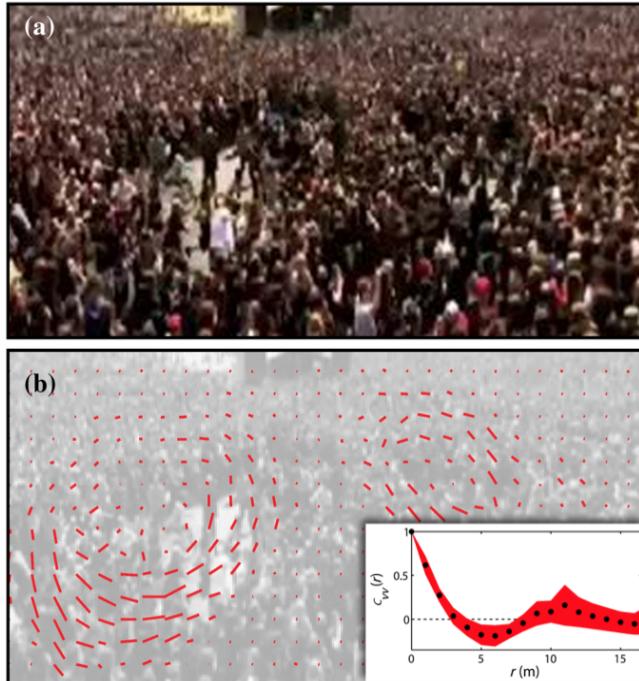


Collective Motion of Humans in Mosh and Circle Pits at Heavy Metal Concerts

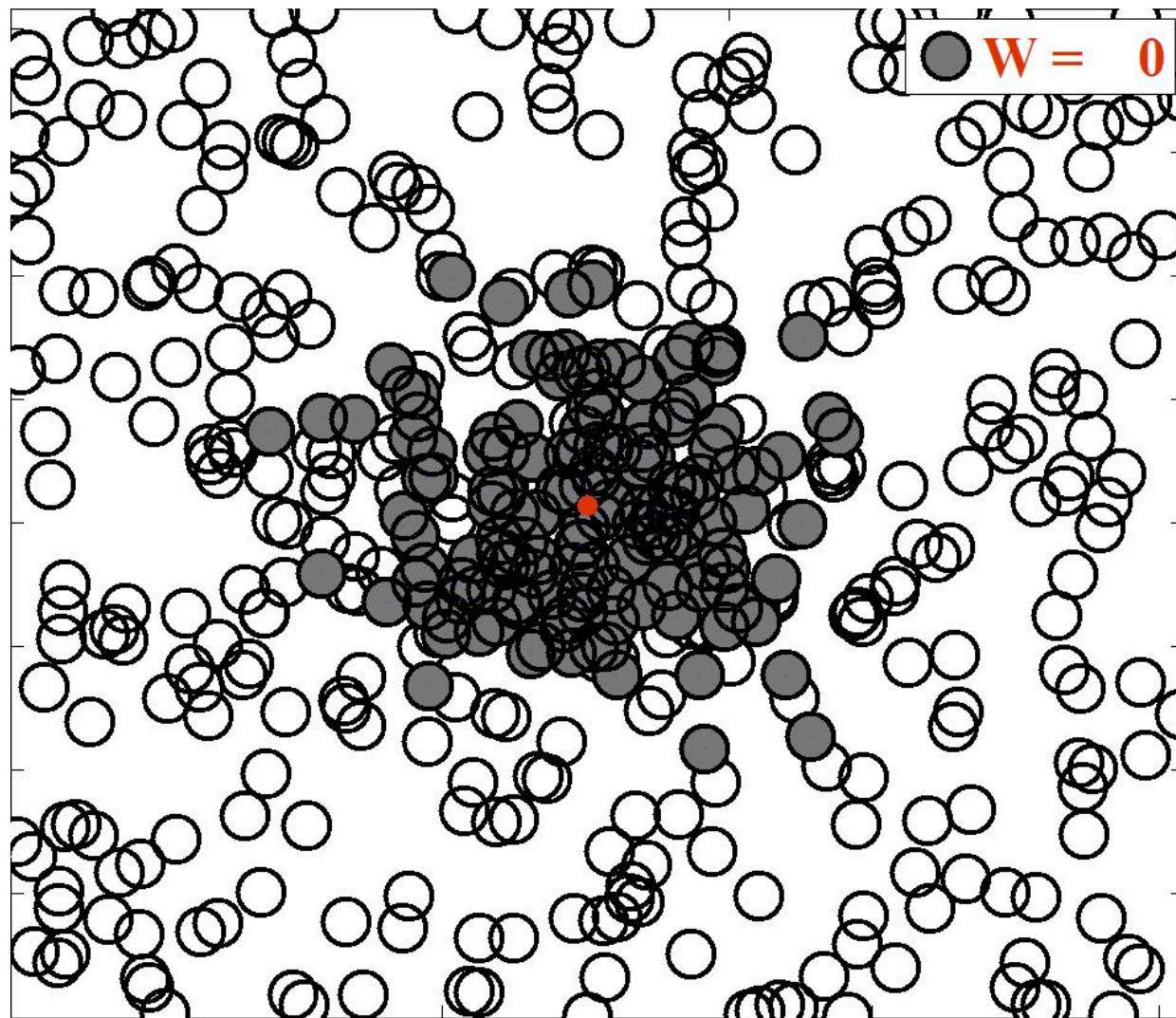
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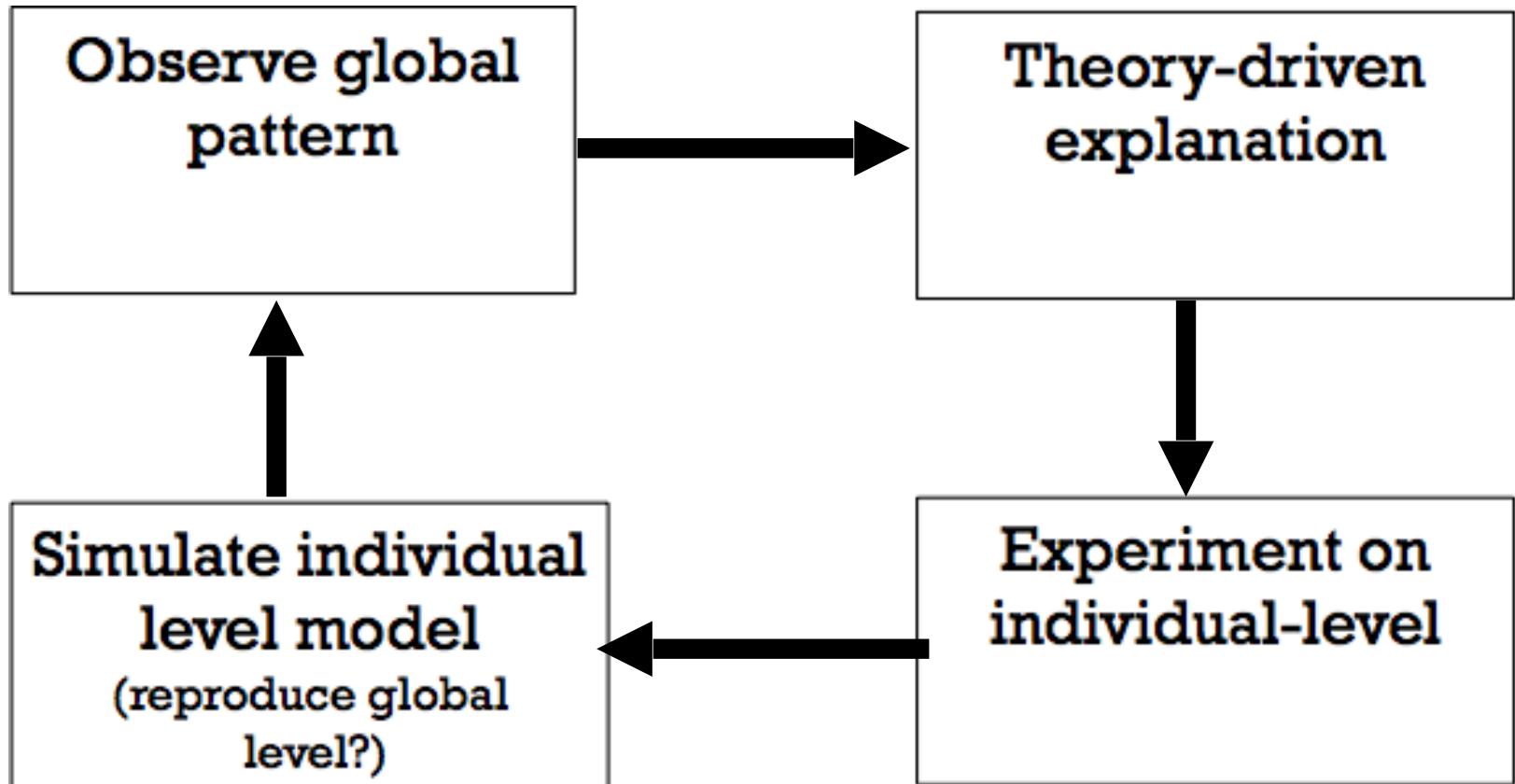
Moshpit model

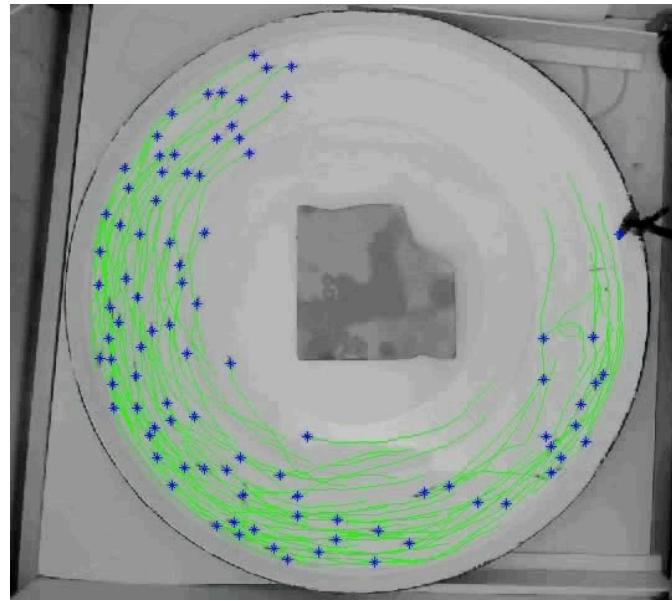


Rules of motion



The modelling cycle





COUGGEL BEHAVIOR