Swarm Intelligence

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Flocking in Starlings

- Starlings form flocks of thousands of birds
  - These act as signposts and provide mutual protection

https://www.youtube.com/watch?v=QOGCSBh3kmM

Formation Flying in Geese

- Geese form V-shaped flocks when migrating
  - This it thought to make flying faster and more efficient

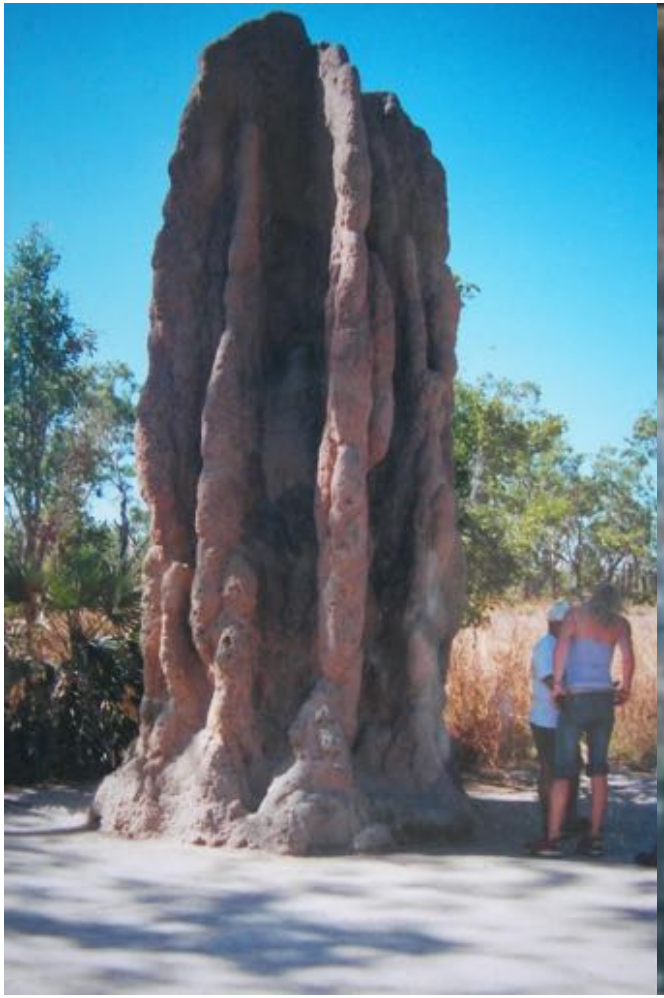
Fish Shoals

- Many species of fish also form swarms
  - For both predation and mutual protection from predation

https://www.youtube.com/watch?v=15B8qN9dre4

Ants and Termites

- Swarm intelligence is also common in insects
  - Ants and termites build collaborative structures



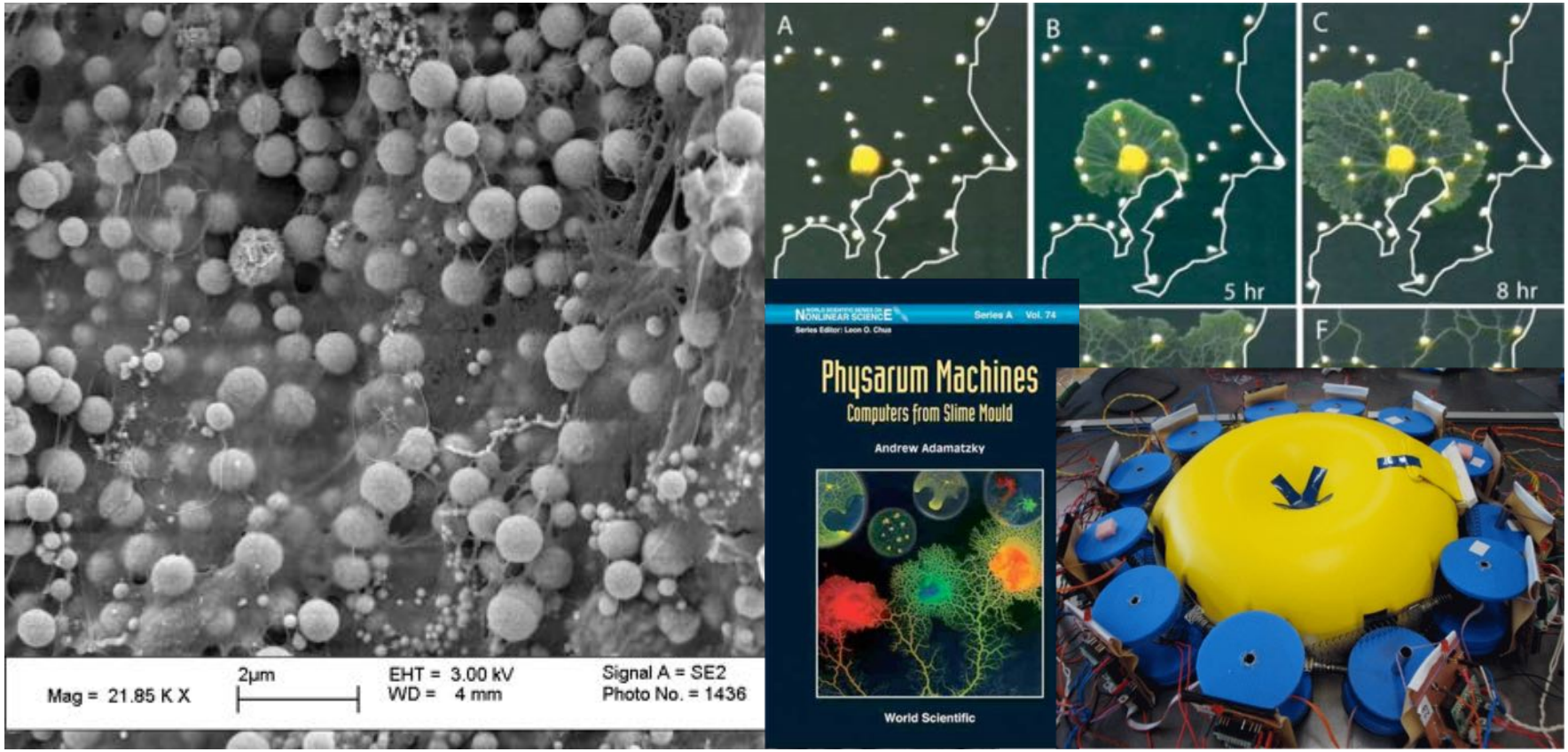
Foraging in Bees

- Swarm intelligence is also common in insects
  - Bees collaboratively forage for food in their environment

https://www.youtube.com/watch?v=-7ijl-g4jHg

Bacterial Swarms

- Even micro-organisms display collective intelligence
  - Bacteria engage in distributed collective decision making
  - Slime mold form collective structures



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  - Individual organisms are not aware of the bigger picture: they're only looking at what their **neighbours** are doing
  - Swarm behaviour is distributed amongst all its constituent organisms: this makes it **robust** to failure

Swarm Intelligence

- These observations have driven wider interest in the field of swarm intelligence
  - The study of how we can get **complex behaviour from simple interactions between simple things**
  - Which is quite different to the way in which human engineers usually go about producing complexity
  - And which leads to the important property of robustness, which is difficult to achieve in engineered systems

Collective Intelligence

- Humans also engage in collective behaviours
  - This is known as **collective intelligence**, rather than swarming, because humans like to be different
  - Examples include civilisation, society, and science, achievements beyond the ability of individual humans
  - Also simpler things like wisdom of crowds, juries, etc.

Adaptive Culture Model

- Sociologists study human collective behaviour
  - And have come up with some pretty simple models of the way in which ideas spread through populations
  - The **adaptive culture model** is one
  - It basically says that "*if you think your neighbour is good, then be more like them*"
  - And seems to predict many of the patterns we see in human culture.

Applications

Applications

- Swarm intelligence impacts on a number of fields
  - **Biology**: swarm models can be used to understand biological systems, and help us understand how to control these systems (e.g. could we control bee foraging?)
  - **Entertainment**: simulating crowds, such as in the battle scenes in Lord of the Rings, was an early driver behind the development of swarm models
  - **Optimisation**: organising search processes so that they collectively forage for optima in a fitness landscape is currently a major focus of swarm intelligence research

Robotic Swarms

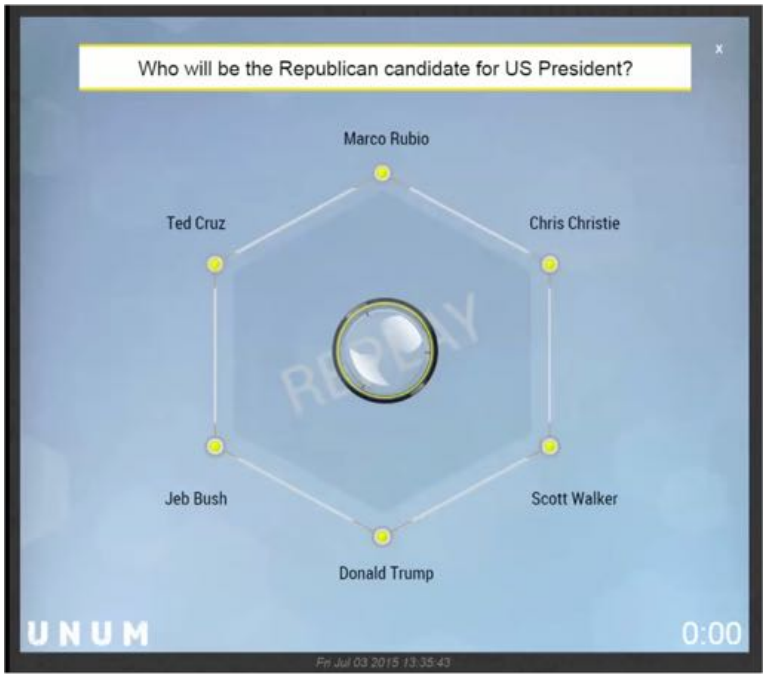
- Swarm/collective robotics is about getting lots of simple robots to do something useful
  - **Cost**: The robots are individually simple, so they are cheap to construct in comparison to traditional robots.
  - **Fault-tolerance**: If one robot stops working, the swarm still functions. Also, simpler robots are less likely to fail.
  - **Scalability**: We can easily increase the capacity of the swarm by buying more robots.
  - **Multitasking**: Different groups of robots can do different things in parallel.

Robotic Swarms

https://www.youtube.com/watch?v=z0n3J18N

Human Swarms

- Recently there's been interest in using technology to promote collective intelligence in humans
  - Amazon's recommender system is an early example
  - Unanimous AI have been developing a platform:
    - Using "human swarming" to predict outcomes
    - Successful at predicting sports results, Oscars etc.
    - http://unu.ai



https://youtu.be/8igWKuhsbFg

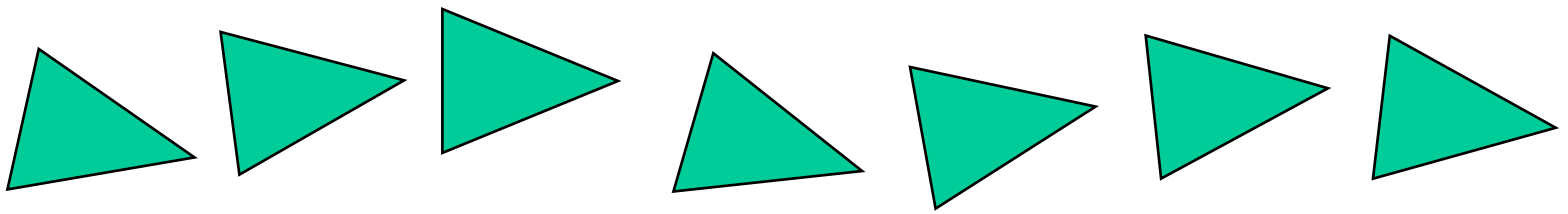
Swarm Optimisation

- New optimisation algorithms are probably the most useful thing to come out of swarm intelligence
  - These take inspiration from the ways in which biological organisms forage for food
  - This foraging taking place in fitness landscapes, with the aim of finding tasty optima to eat
  - These approaches have been very successful
  - I will be talking about two of them this week: **particle swarm optimisation** (motivated by birds) and **ant colony optimisation** (well, you can guess!)

The Boids Model

The Boids Model

- Boids (1986) was one of the first swarm models
  - By Craig Reynolds, a computer graphics researcher, who revolutionised animation in games and movies
  - Prior to this, animations of flocks, swarms, groups, and so on, behaved nothing at all like the real thing
  - Reynolds solved the problem by trying a very simple approach, which was inspired by how animals swarm
  - See http://www.red3d.com/cwr/boids/



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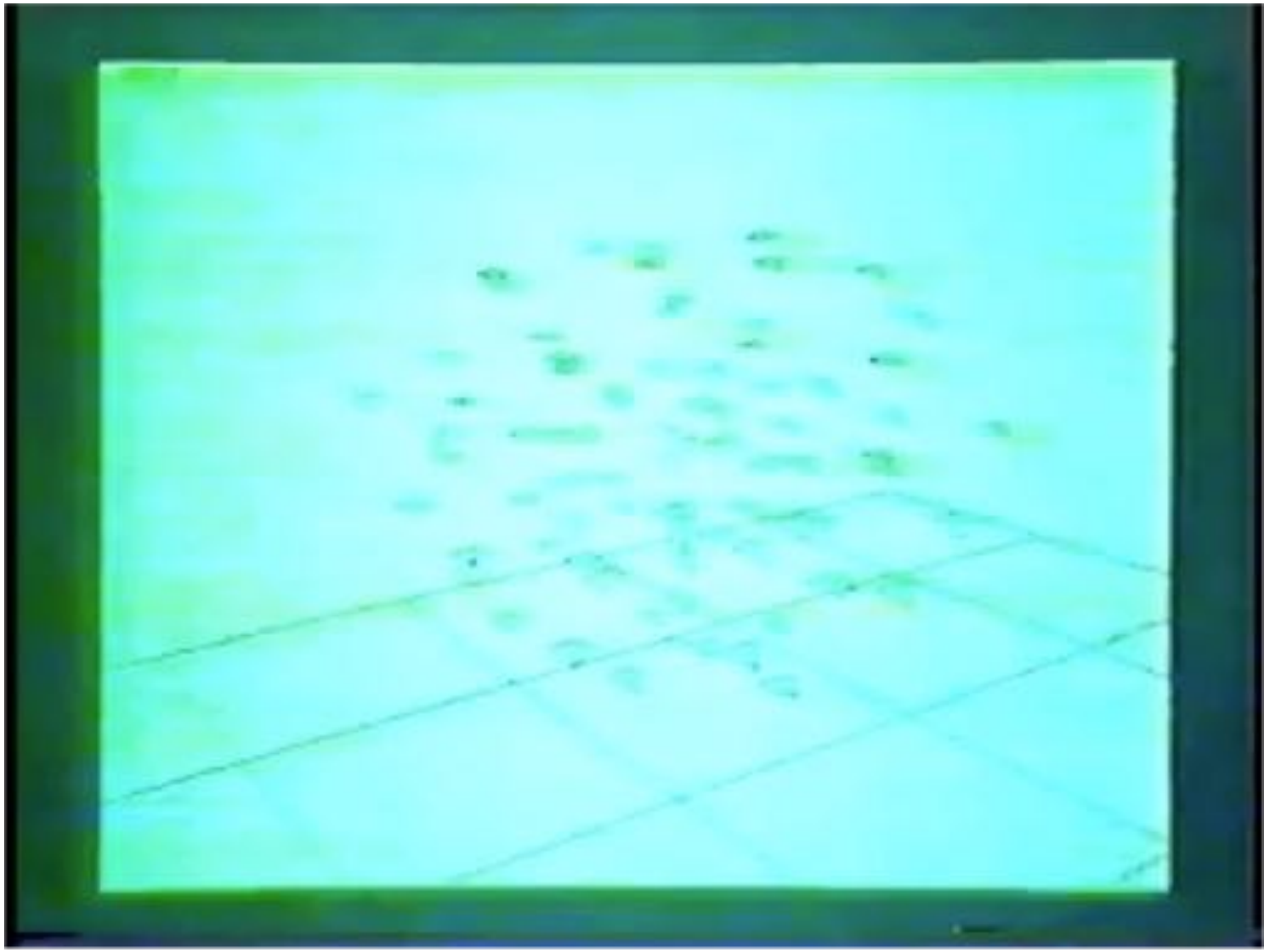
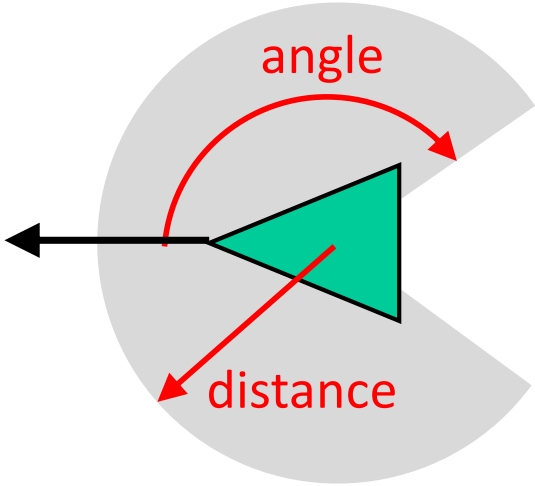


https://www.youtube.com/watch?v=86iQiV3-3IA

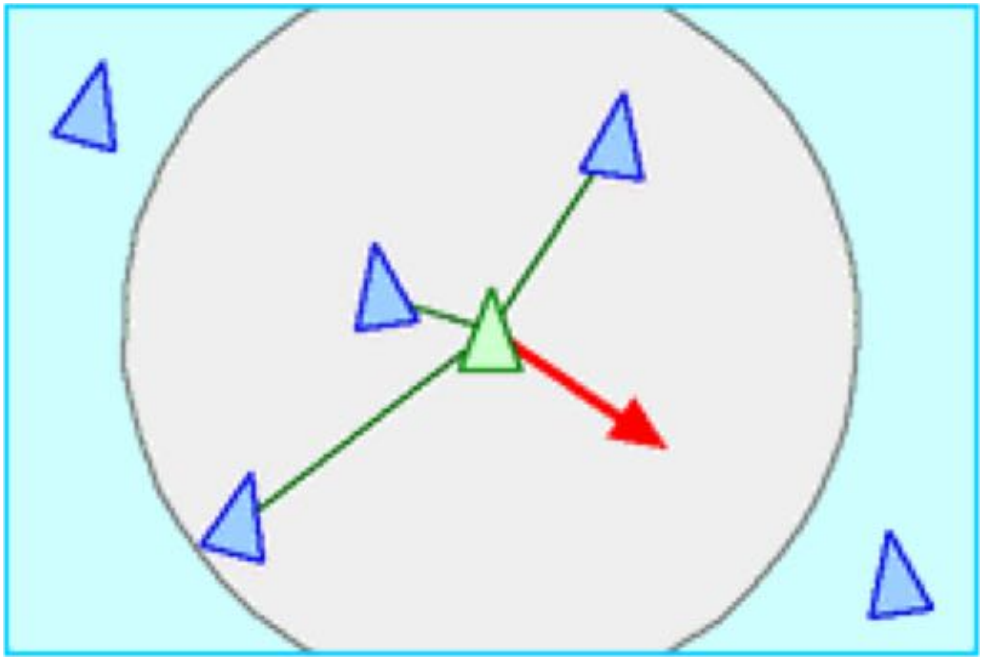
The Boids Model

- Reynolds came up with **three simple rules** that resulted in realistic flocking behaviour
  - To explain them, we first need to consider the perceptual system of an individual (which Reynolds called a boid)
  - For realistic movement, you need a realistic view of perception, i.e. what a single bird can see
  - Can see a certain amount ahead, and is also aware of any flockmates within limits on either side
  - It is only influenced by the angle and distance from other boids



The Boids Model

- Rule 1: **Separation**

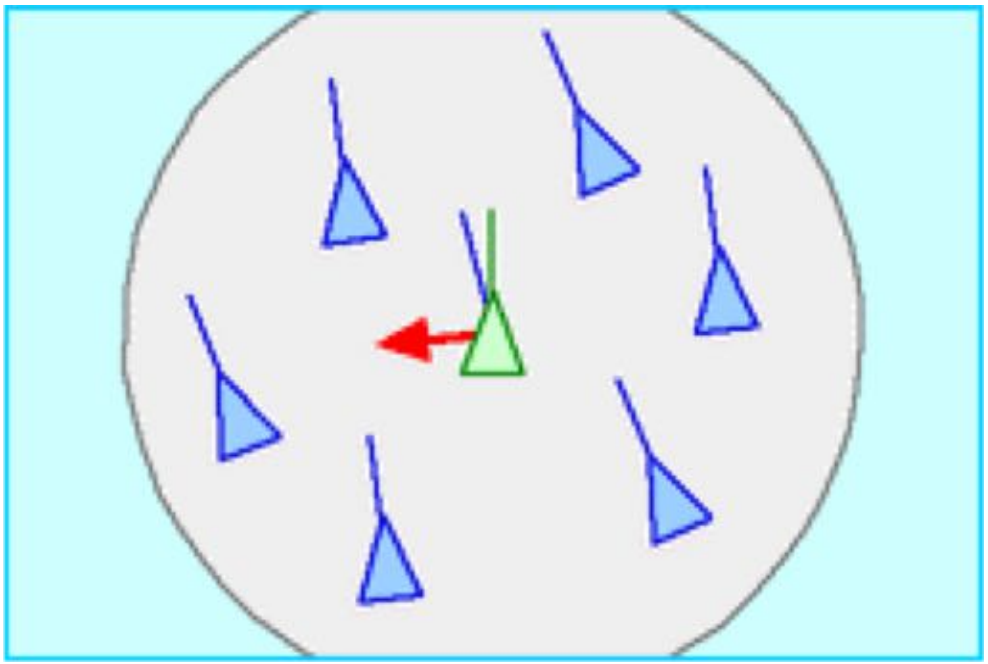


At each iteration, a boid makes an adjustment to its velocity according to the following rule:

Avoid getting too close to local (the ones it is aware of) flock mates.

The Boids Model

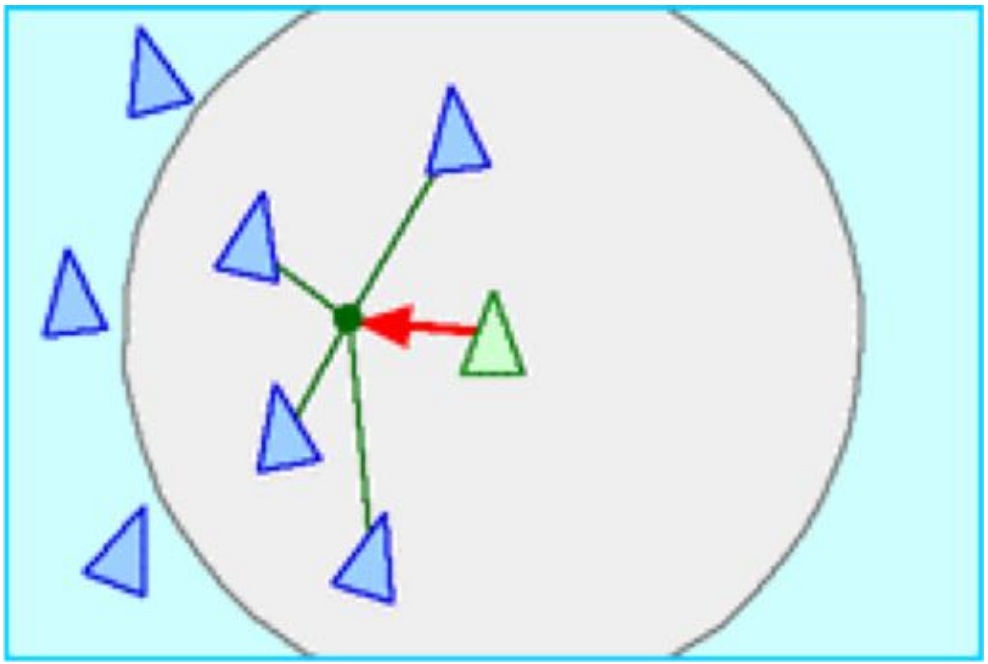
- Rule 2: **Alignment**



At each iteration, a boid makes an adjustment to match its velocity to the average of that of its local flock mates.

The Boids Model

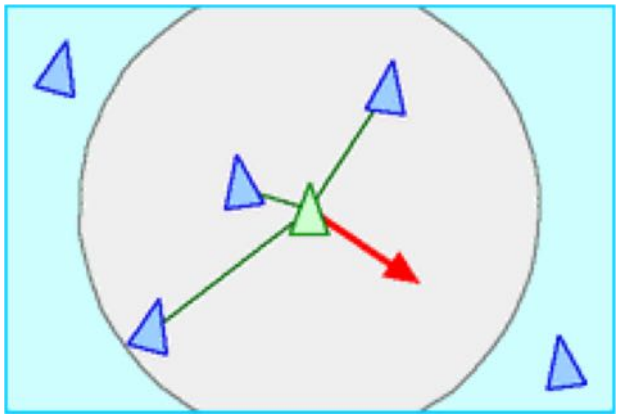
- Rule 3: **Cohesion**



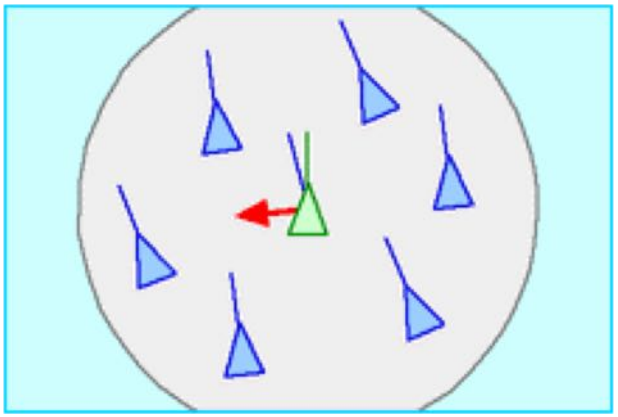
At each iteration, a boid makes an adjustment to its velocity towards the centroid of its flock mates.

The Boids Model

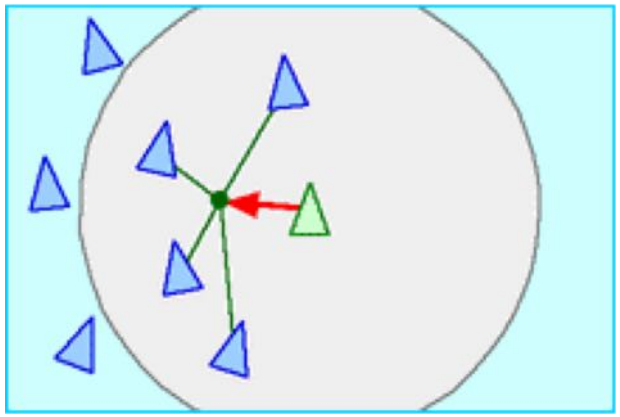
Don't get too close

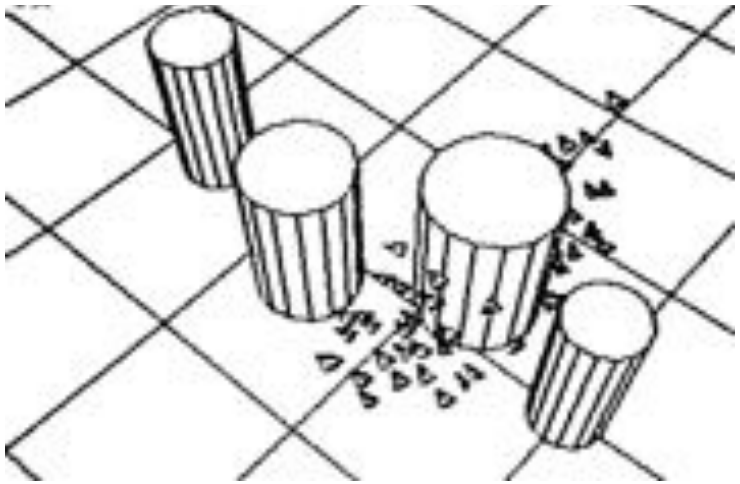


Stay aligned



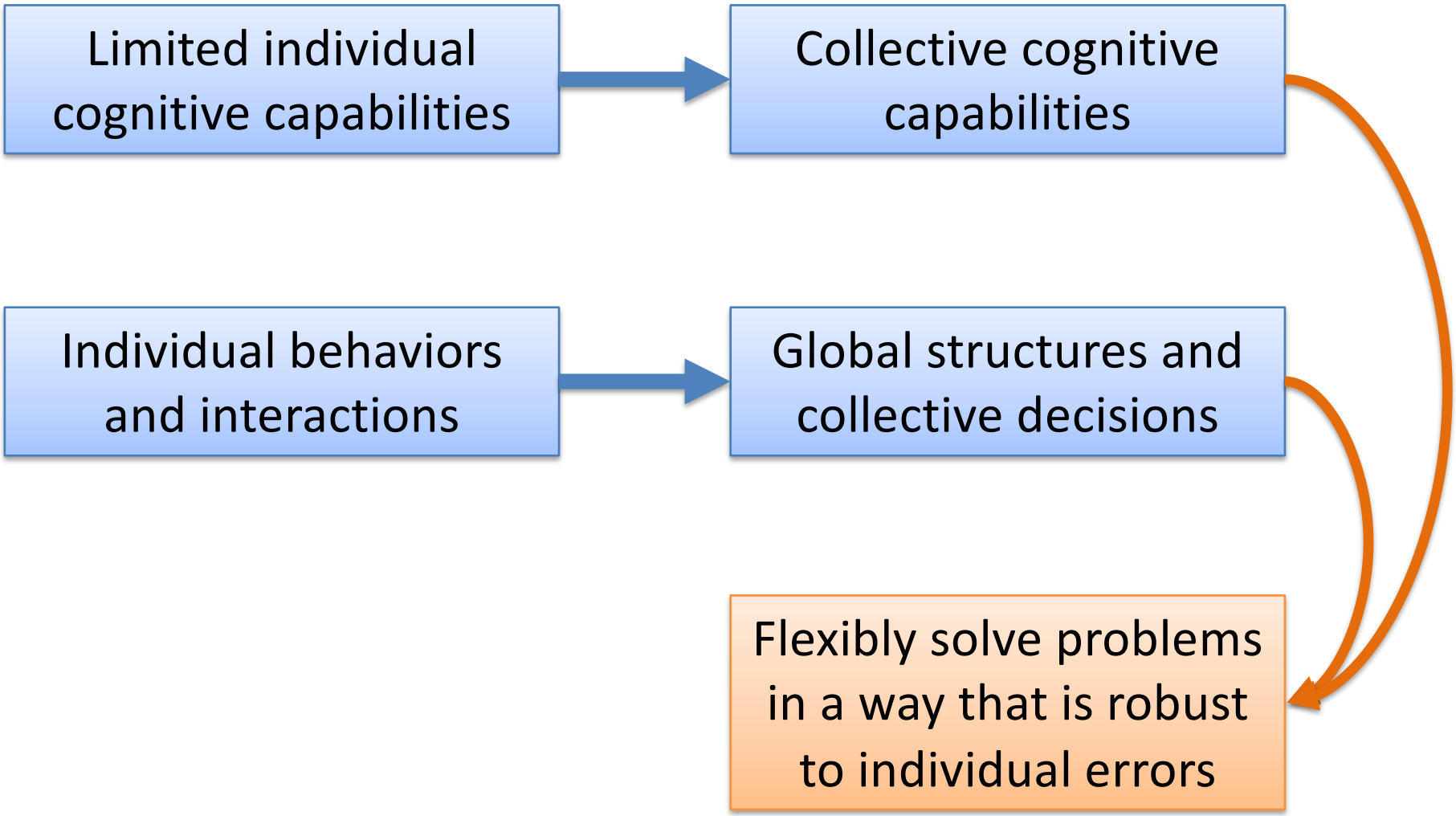
Remain cohesive





Seemingly complex avoidance behaviours

Summary


Limited individual cognitive capabilities
Collective cognitive capabilities
Individual behaviors and interactions
Global structures and collective decisions
Flexibly solve problems in a way that is robust to individual errors