LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

OCTOBER 22, 2024

MODEL AGENTS: SOCIAL BEHAVIOR THROUGH THE FORMAL LENS

FANTASTIC BOIDS AND WHERE TO FIND THEM

Adrian Haret
a.haret@lmu.de

Many organisms exhibit some sort of synchronized collective behavior.

MURMURATIONS

A large group of birds, usually starlings, that all fly together and change direction together.

EDMUND SELOUS (1857-1934)

They circle; now dense like a polished roof, now disseminated like the meshes of some vast all-heaven-sweeping net... wheeling, rending, darting... a madness in the sky.

Selous, E. (1931). *Thought Transference (Or What?) in Birds*, Constable and Company Ltd., quoted in Couzin, I. (2007). Collective minds. *Nature*, 445(7129), 715.

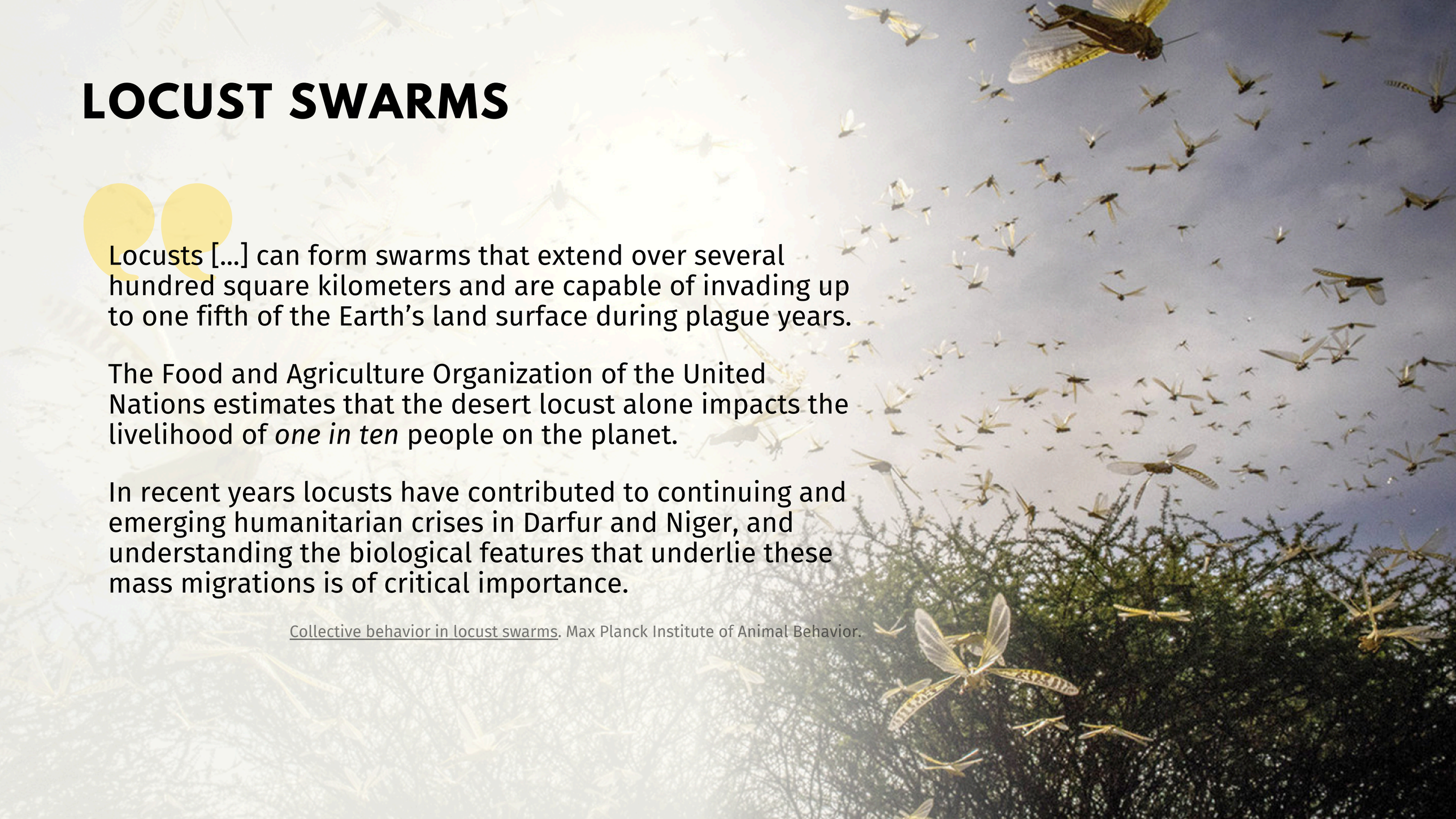
LOCUST SWARMS

Locusts [...] can form swarms that extend over several hundred square kilometers and are capable of invading up to one fifth of the Earth's land surface during plague years.

The Food and Agriculture Organization of the United Nations estimates that the desert locust alone impacts the livelihood of *one in ten* people on the planet.

In recent years locusts have contributed to continuing and emerging humanitarian crises in Darfur and Niger, and understanding the biological features that underlie these mass migrations is of critical importance.

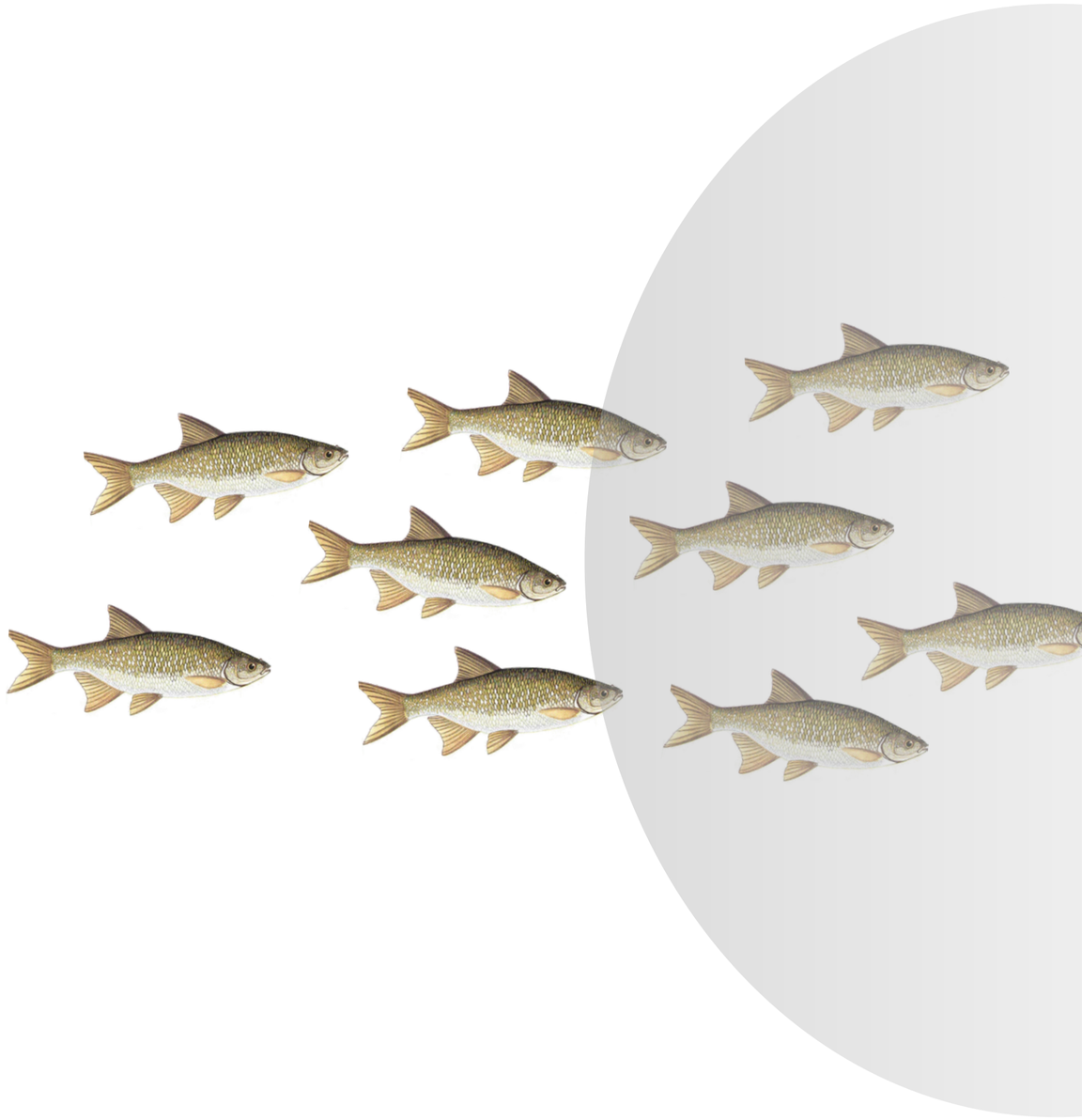
Collective behavior in locust swarms. Max Planck Institute of Animal Behavior.



GOLDEN SHINER SHOALS

Golden shiners move around in groups, and they live shady areas.

And, as a group, they’re good at finding shady areas.



How do all these organisms know how to organize themselves?

One way to synchronize behavior: someone tells you what to do.

DNC 2024 GROUP PHOTO

At the Democratic National Convention, 2024, the announcer instructs the audience to stay perfectly still.

Otherwise, the photo captured by century-old camera will be blurry.

Dowling, S. (2024). Democratic National Convention crowd freezes for 110-year-old panoramic camera. Kosmo Foto.

Maybe birds communicate with each other telepathically.

EDMUND SELOUS (1857-1934)

They must think collectively, all at the same time, or at least in streaks or patches — a square yard or so of an idea, a flash out of so many brains.

Selous, E. (1931). *Thought Transference (Or What?) in Birds*, Constable and Company Ltd., quoted in Couzin, I. (2007). Collective minds. *Nature*, 445(7129), 715.

IAIN COUZIN

Decision-making by individuals within such aggregates is so synchronized and intimately coordinated that it’s tempting to think they’re all part of a ‘collective mind.’

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Couzin, I. D. (2009). Collective cognition in animal groups. *Trends in Cognitive Sciences*, 13(1), 36–43.

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Each organism typically has only relatively local sensing ability (further limited in large aggregates by crowding).

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Why does any of this matter?

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Understanding the dynamics of such organisms can provide some insight into the workings of neurons.

But also decision-making in groups of people!

Couzin, I. D. (2009). Collective cognition in animal groups. *Trends in Cognitive Sciences*, 13(1), 36–43.

Couzin, I. D. (2023). On Fish, Fascists and the power of collective behaviour. Science & Cocktails, on YouTube.

To understand something complex, like a flock of birds, let’s start simple.

PAUL E. SMALDINO

Modelling involves doing some ‘violence to reality.’

We have to aggressively simplify.

Smaldino, P. (2023). *Modeling Social Behavior. Mathematical and Agent-Based Models of Social Dynamics and Cultural Evolution, Chapter 1*. Princeton University Press.

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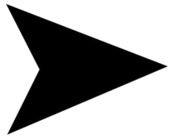

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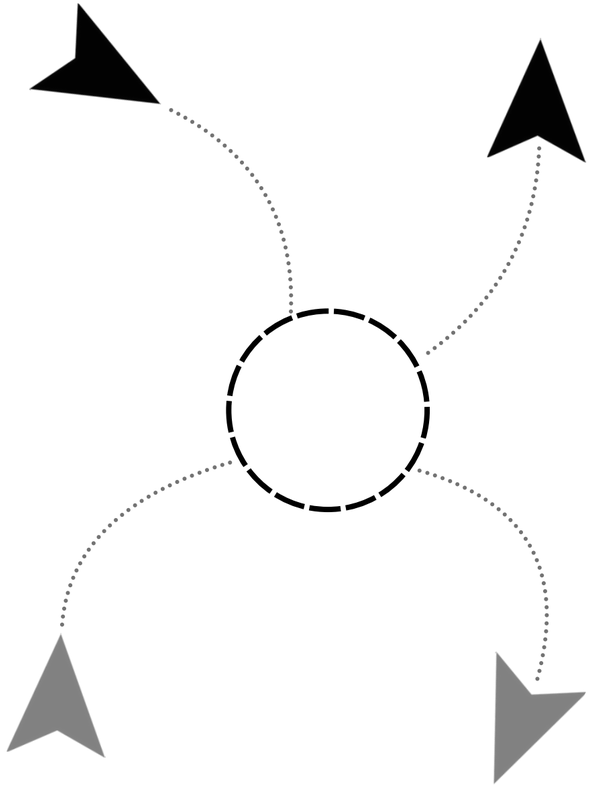
STEP 1: AVOIDING COLLISIONS

PAUL E. SMALDINO

Start with a simple model in which agents move around randomly in an environment.

When agents are about to ‘bump’ into each other, they change direction.

Smaldino, P. (2023). *Modeling Social Behavior. Mathematical and Agent-Based Models of Social Dynamics and Cultural Evolution, Chapter 2*. Princeton University Press.



STEP 1: AVOIDING COLLISIONS

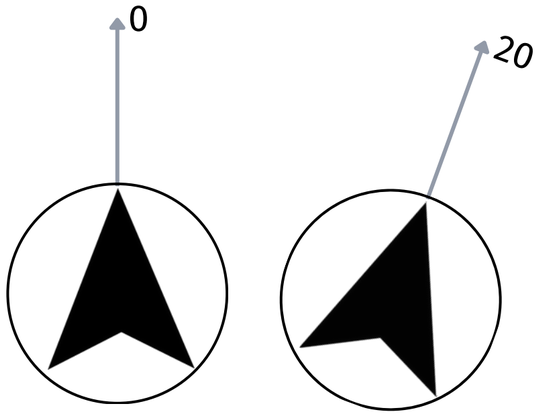
PAUL E. SMALDINO

In Netlogo agents have a direction, called a *heading*.

Their movement is determined by their *speed* and a random parameter for direction, called *whimsy*.

To avoid collisions, we can calculate when agents get close to each other, i.e., within a certain radius.

Add a plot to keep track of the number of (near) collisions!



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This only gives us a Brownian motion of agents. No flocking yet.

STEP 2: FLYING TOGETHER

PAUL E. SMALDINO

To get agents to flock, have them adapt their direction in response to their neighbors.

Endow agents with a *vision-radius v*, which determines birds' field of vision.

At every time-step (tick), an agent changes its heading to *the average heading of the other agents in its vision-radius.*

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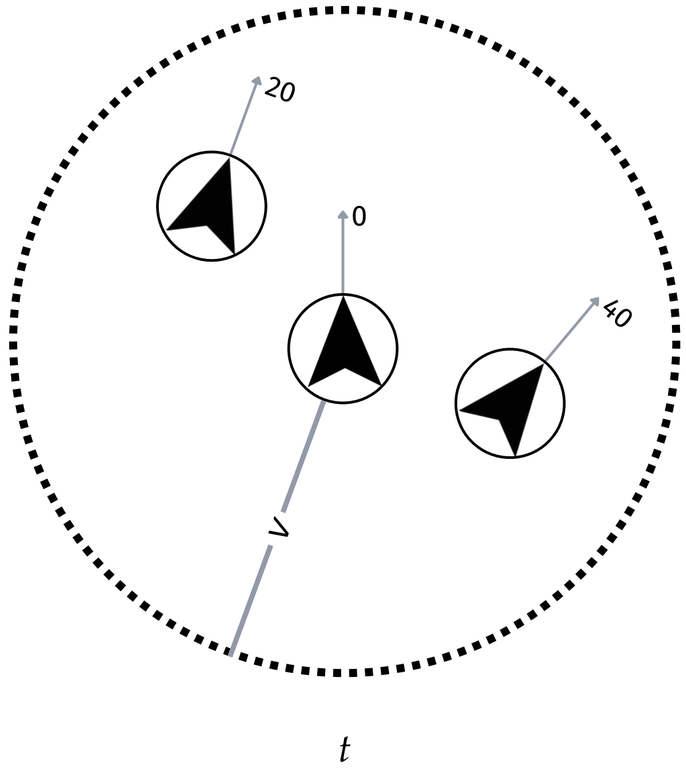

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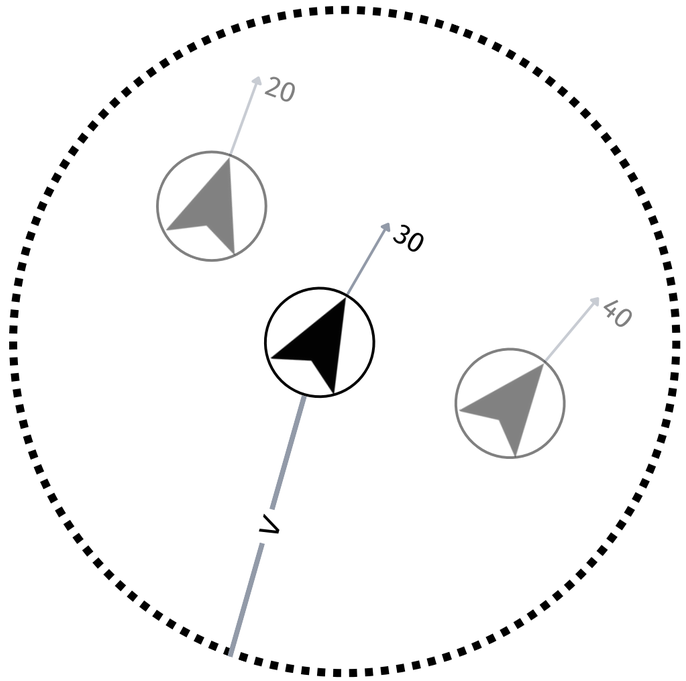


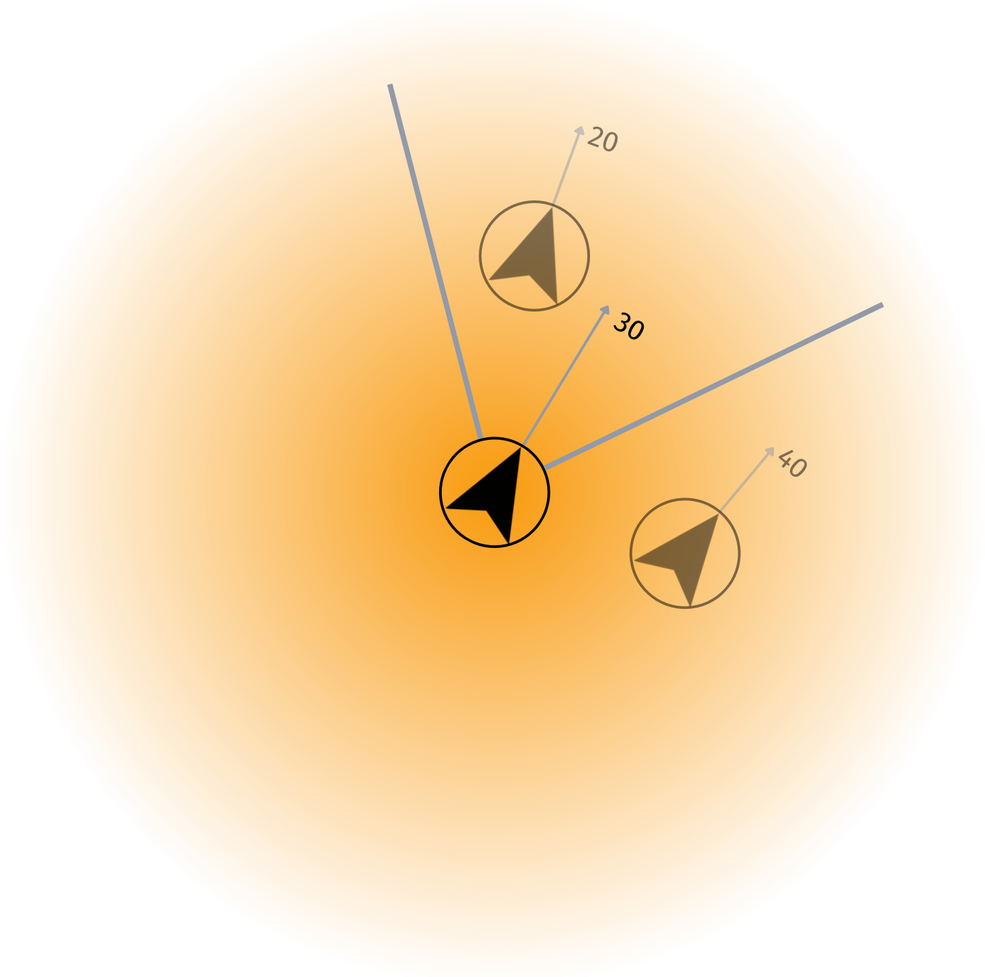
$t+1$

What further refinements would make sense?

STEP N: FLOCKING TOGETHER (?)

We’re assuming uniform speeds. But if speeds can be different, it could make sense that agents adapt that as well...

Perhaps agents’ vision should be more like a funnel...



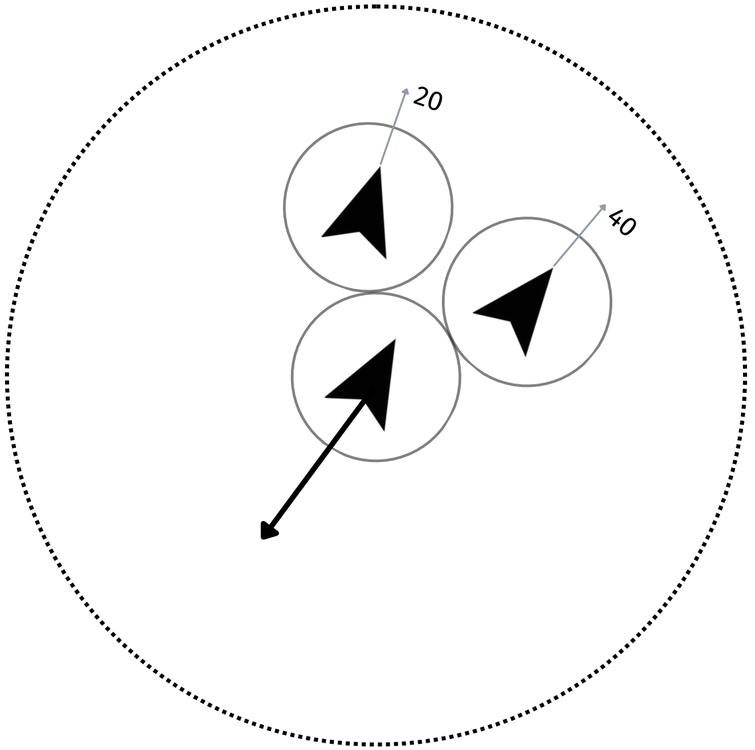
BOIDS

CRAIG REYNOLDS

In the 80s I started thinking about this problem.

In the Boids model I came up with, agents follow three basic rules.

Separation: avoid collisions, by steering to avoid local flockmates.



SEPARATION

Reynolds, C. W. (1987). Flocks, herds and schools: A distributed behavioral model. *Computer Graphics*, 21(4), 25–34.

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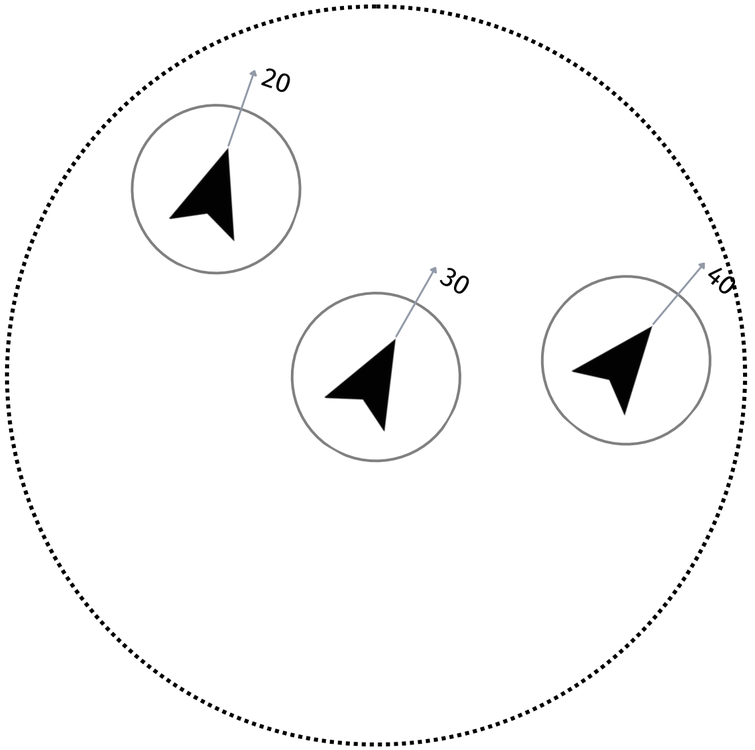

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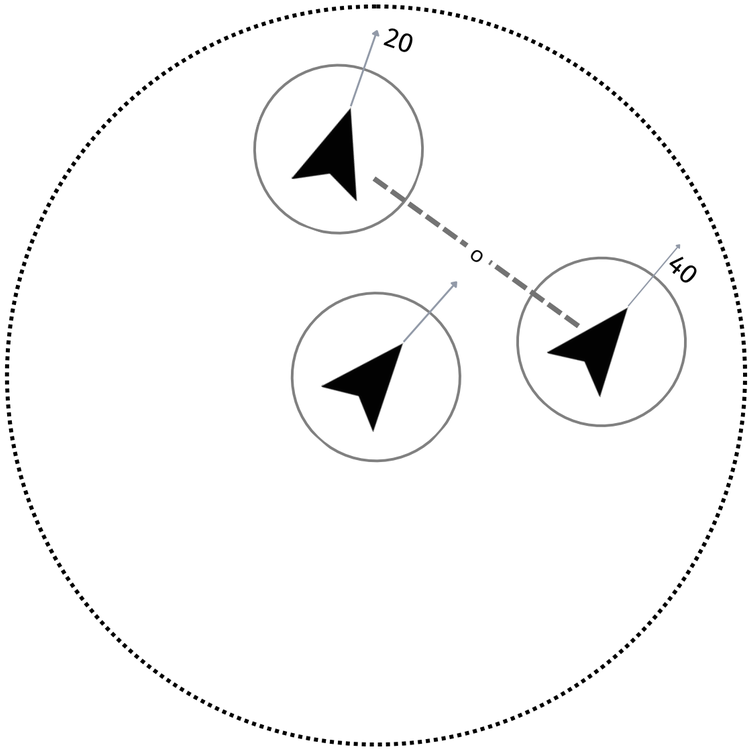

COHESION

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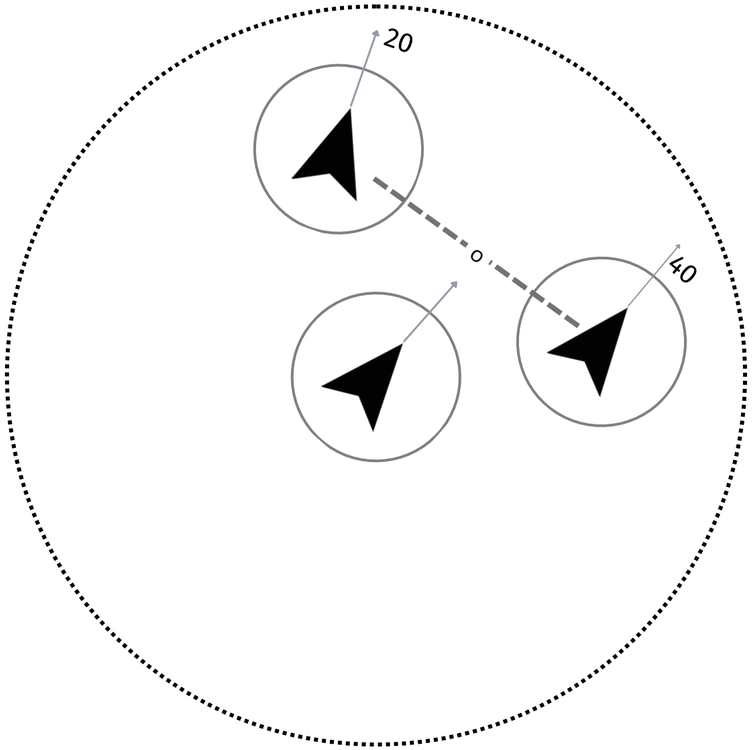
Check out this video!



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Variations of the Boids algorithm are behind most CGI flocks in movies and video games.

LOCUST, REVISITED

IAIN COUZIN

Despite being well understood on the individual level, we didn’t really know why locusts form swarms.

Is it cooperative?

Bazazi, S., Buhl, C., Hale, J. J., Anstey, M. L., Sword, G. A., Simpson, S. J., & Couzin, I. D. (2008). Collective motion and cannibalism in locust migratory bands. *Current Biology*, 18(10), 735–739.

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Is it cooperative?

No! It turns out that locusts are cannibalistic, and frequently bite off each other's limbs.

Swarms, then, arise from locusts trying to avoid getting eaten by the locust behind you.

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GOLDEN SHINER SHOALS

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Shiners like the shade, but individually they're bad at finding shady spots.

However as a group, they do better.

That's because they follow two rules.

First, they tend to stay close to each other.

Second, they slow down when they're in the shade.

As a result, once one shiners finds a shady spots, the others quickly join it.

Berdahl, A., Torney, C. J., Ioannou, C. C., Faria, J. J., & Couzin, I. D. (2013). Emergent sensing of complex environments by mobile animal groups. *Science*, 339(6119), 574–576.

IAIN COUZIN

There’s a lot of work happening in this area.

New stuff all the time!