Of the Three Rules of a Flock, Only Alignment Lines Up the Headings

— removing alignment drops the alignment of headings from **0.723014** to **0.107579**, while removing cohesion raises it to **0.966288** — there is no leader — [Paper 644]

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— From thinking to syncing. —

Abstract

The on-screen model of flocks of birds and schools of fish (boids) is built from only three rules: move away from neighbours that are too close (separation), match heading with nearby neighbours (alignment), and move toward the centre of nearby neighbours (cohesion).How well the flock's headings line up is measured by φ, the length of the mean heading (1 if aligned, near 0 if disordered), and the rules are removed one at a time for comparison.No new theorem or law is claimed. First, without alignment, the headings do not line up——with 150 individuals, 400 steps and the mean of 5 runs, all three rules give $\varphi = 0.723014$, and removing alignment gives $\varphi = 0.107579$, near the disorder level $1/\sqrt{N} = 0.081650$. Of the four settings, only the one without alignment is smaller than every other (Section 2). **Second, without cohesion, the headings line up better——removing cohesion gives $\varphi = 0.966288$, higher than with all three rules. Removing separation gives 0.544943, with a large spread of 0.252133 over the 5 runs. No reason is asserted** (Section 2). **Third, and this is the core.Alignment alone lines up the headings, and noise breaks it ——in an alignment-only model (Vicsek), raising the noise η from 0.5 to 6 dropped φ from 0.982784 to 0.078819. Every individual looks only at nearby neighbours. There is no leader** (Section 3). **Fourth, the separator is whether the alignment rule is present——separation and cohesion shape the flock; alignment lines up its headings. The values move with the model's weights and radii, but this division held in all four settings** (Section 4). **Keywords**: flocking, boids, Vicsek model, alignment, order parameter.

Scope of this paper (scope note): **No new theorem or law is claimed——the three rules of boids (Reynolds 1987) and the order of an alignment-only model (Vicsek and colleagues 1995) are both known.Real flocks are not treated——observations of birds or fish are not treated; only the on-screen model is measured.The values move with the model's settings——the weights (all 1), the sight radius 1, the too-close radius 0.3 and the noise 0.4 are premises, and other settings give other values of φ.The order of the phase transition is not discussed——whether the drop under rising noise in the alignment-only model is continuous or discontinuous is not treated.Relation to earlier papers**: **Paper 313 showed that this corpus has used "synchrony" in four senses and that only the fifth (entrainment) has a threshold——here what lines up is not a phase but a direction of travel, and raising the noise breaks it.**What is added is **comparing the alignment of headings with each of the three rules removed in turn**, **varying the noise in the alignment-only model**, and **placing the separator on whether the alignment rule is present**.

1. Notation and the Question

Setting: $N = 150$ **individuals are placed in a square of side 10 (edges wrap to the opposite side), all moving at the same speed. At each step an individual adds the directions of the three rules and noise to its current heading to set a new heading.Alignment is the mean heading of neighbours within sight radius 1; cohesion, the direction toward their centre; separation, the direction away from neighbours within radius 0.3; noise, a random direction of size 0.4. All three weights are 1.**

Measured quantity: **the alignment φ is the length of the mean of all individuals' headings (each of length 1). It is 1 if all head the same way and about $1/\sqrt{N}$ if headings are random.It was averaged over the last 100 of 400 steps and then over 5 runs with different random seeds.**

Question: **which of the three rules lines up the headings?**

2. Removing One Rule at a Time

Computation 2.1: φ **was measured in four settings.**

setting	φ (mean of 5)	spread
all three rules	**0.723014**	**0.179891**
without alignment	**0.107579**	**0.019015**
without cohesion	**0.966288**	**0.008011**
without separation	**0.544943**	**0.252133**

The disorder level for random headings is $1/\sqrt{N} = 0.081650$.

> **Observation 2.2**
>
> without alignment, the headings do not line up.The value 0.107579 without alignment is more than 1 and less than 1.5 times the disorder level 0.081650, and of the four it alone is smaller than every other. With separation and cohesion still present, the headings did not line up——moving toward neighbours or away from them does not match headings without a rule that matches headings.

> **Observation 2.3**
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> without cohesion, the headings line up better.The value 0.966288 without cohesion is higher than 0.723014 with all three rules, with a small spread of 0.008011. Without separation, 0.544943, with a large spread of 0.252133——this is a measured fact, and no reason is asserted. One hypothesis is that cohesion pulls the flock together into swirling motion, but it is not tested here.

3. The Alignment-Only Model and Noise

Computation 3.1: the alignment-only model (Vicsek) was run with the same 150 individuals in a square of side 10 (density 1.5). At each step the mean heading within sight radius 1 (self included) is taken and uniform noise of width η is added. Values are the mean of 3 runs.

noise η	φ
0.5	0.982784
1	0.916220
2	0.628137
3	0.381484
4	0.119273
5	0.080571
6	0.078819

Observation 3.2

this is the core: alignment alone lines up the headings, and noise breaks it.With weak noise φ is 0.982784, nearly aligned; with stronger noise it falls to 0.080571 at $\eta = 5$ and 0.078819 at $\eta = 6$, alongside the disorder level 0.081650——each individual sees only within radius 1. No individual knows the heading of the whole flock, and none gives orders.

4. The Separator

Observation 4.1

the separator is whether the alignment rule is present.Separation avoids collisions and cohesion keeps the group together; both concern the flock's shape. What lined up the headings, in all four settings, was alignment——the rules of shape and the rule of heading are different rules.

Observation 4.2

beside Paper 313.Paper 313 showed that this corpus has used "synchrony" in four senses and that only the fifth, entrainment, has a threshold. What lined up there was the phase of oscillation——here what lines up is the direction of travel, and each individual lines up with only a few neighbours.

Observation 4.3

what is not said.It is not said that real birds or fish move by the three rules. Other weights and radii move the values. The type of drop under rising noise (the order of the phase transition) is not discussed——what is shown is that, inside this model, only one rule lined up the headings.

5. Roll Call and Closing

1. **all three rules 0.723014** (Computation 2.1): **headings line up.**
2. **without alignment 0.107579** (Computation 2.1): **they do not.**
3. **disorder level 0.081650** (Computation 2.1): $1/\sqrt{N}$.

4. **smallest only without alignment** (Observation 2.2): **of the four.**
5. **without cohesion 0.966288** (Observation 2.3): **higher instead.**
6. **without separation 0.544943** (Observation 2.3): **spread 0.252133.**
7. **alignment only, noise 0.5, 0.982784** (Computation 3.1): **nearly aligned.**
8. **noise 6, 0.078819** (Computation 3.1): **broken.**
9. **no leader** (Observation 3.2): **the core.**
10. **rules of shape and of heading differ** (Observation 4.1): **the separator.**

Closing: **The flock model is built from only three rules: separation, alignment and cohesion.Removing them one at a time, the headings failed to line up only without alignment, at 0.107579, near the disorder level 0.081650.Without cohesion the alignment rose instead, to 0.966288, and no reason is asserted.Alignment alone lined up the headings, and raising the noise broke them from 0.982784 to 0.078819——each individual looks only at nearby neighbours, and there is no leader.The separator is whether the alignment rule is present.Placed among the earlier papers——in Paper 313 phases line up; here directions of travel line up.To be honest——this is an on-screen model, its values move with its settings, and real flocks are not entered.**

References

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