Collective behaviour

Simple tactics

Simulated predator attacks on flocks: a comparison of tactics

Demšar J & Lebar Bajec I, 2014
doi: 10.1162/ARTL_a_00135

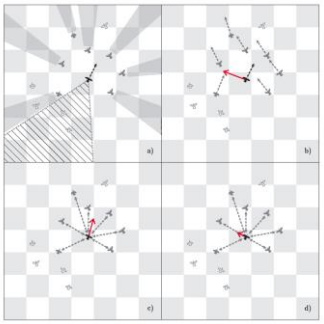

Fig. 1. Perception of nearby neighbours (a). The black bird is the observed individual. The dark grey birds are the perceived nearby birds that influence the observed bird's behaviour. The white and outlined birds are either occluded by nearer birds (shaded areas), outside of the observed bird's field of vision (dashed area) or outside the number-limited range. Red arrows represent the resulting force vectors of the three basic drives – alignment (b), cohesion (c), separation (d). The black bird is the observed individual, the dark grey birds are the influencing neighbours.

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separation


```
if (Closest is not_too_close) and (Dist is far) then (Hc is samedir)
if (Dist is near) and (Pos is infront) then (Hc is samedir)
if (Dist is near) and (Pos is behind) then (Hc is samedir)
if (Dist is near) and (Pos is left) then (Hc is right)
if (Dist is near) and (Pos is right) then (Hc is left)
if (Closest is not_too_close) and (Dist is far) then (Sc is samespd)
if (Dist is near) and (Pos is infront) then (Sc is slower)
if (Dist is near) and (Pos is behind) then (Sc is faster)
if (Dist is near) and (Pos is left) then (Sc is samespd)
if (Dist is near) and (Pos is right) then (Sc is samespd)
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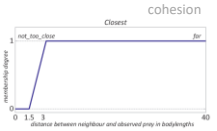
cohesion




```
if (Closest is not_too_close) and (Dist is near) then (Hc is samedir)
if (Closest is not_too_close) and (Dist is far) and (Pos is behind) then (Hc is samedir)
if (Closest is not_too_close) and (Dist is far) and (Pos is infront) then (Hc is samedir)
if (Closest is not_too_close) and (Dist is far) and (Pos is right) then (Hc is right)
if (Closest is not_too_close) and (Dist is far) and (Pos is left) then (Hc is left)
if (Closest is not_too_close) and (Dist is near) then (Sc is samespd)
if (Closest is not_too_close) and (Dist is far) and (Pos is infront) then (Sc is faster)
if (Closest is not_too_close) and (Dist is far) and (Pos is behind) then (Sc is slower)
if (Closest is not_too_close) and (Dist is far) and (Pos is left) then (Sc is samespd)
if (Closest is not_too_close) and (Dist is far) and (Pos is right) then (Sc is samespd)
```

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alignment


```
if (Closest is not_too_close) and (Dist is near) then (Hc is samedir)
if (Closest is not_too_close) and (Dist is far) then (Hc is samedir)
if (Closest is not_too_close) and (Dist is med) and (Hd is right) then (Hc is right)
if (Closest is not_too_close) and (Dist is med) and (Hd is samedir) then (Hc is samedir)
if (Closest is not_too_close) and (Dist is med) and (Hd is left) then (Hc is left)
if (Closest is not_too_close) and (Dist is near) then (Sc is samespd)
if (Closest is not_too_close) and (Dist is far) then (Sc is samespd)
if (Closest is not_too_close) and (Dist is med) and (Sd is slower) then (Sc is slower)
if (Closest is not_too_close) and (Dist is med) and (Sd is samespd) then (Sc is samespd)
if (Closest is not_too_close) and (Dist is med) and (Sd is faster) then (Sc is faster)
```

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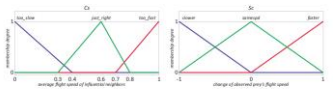
regulate speed




```
Rules:
  if (Cs is too_fast) then (Sc is slower)
  if (Cs is just_right) then (Sc is samespd)
  if (Cs is too_slow) then (Sc is faster)
```

Fig. 9. Detailed description of the regulate speed drive. On the membership function charts that describe speed the value 1 represents the prey's maximum speed while -1 represents the negative value of the prey's maximum speed. While these are the desired changes in speed, the action selection stage ensures that the current speed of the observed individual never falls under the appropriate minimum speed (predator's or prey's).

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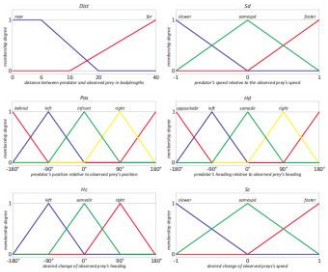

hide

```
Rules:
  if (Dist is near) and (Pos is left) and (Hd is left) then (Hc is samedir)
  if (Dist is near) and (Pos is left) and (Hd is right) then (Hc is right)
  if (Dist is near) and (Pos is left) and (Hd is samedir) then (Hc is right)
  if (Dist is near) and (Pos is left) and (Hd is oppositedir) then (Hc is right)
  if (Dist is near) and (Pos is right) and (Hd is right) then (Hc is samedir)
  if (Dist is near) and (Pos is right) and (Hd is left) then (Hc is left)
  if (Dist is near) and (Pos is right) and (Hd is samedir) then (Hc is left)
  if (Dist is near) and (Pos is right) and (Hd is oppositedir) then (Hc is left)
  if (Dist is near) and (Pos is infront) and (Hd is left) then (Hc is right)
  if (Dist is near) and (Pos is infront) and (Hd is right) then (Hc is left)
  if (Dist is near) and (Pos is behindb) and (Hd is right) then (Hc is left)
  if (Dist is near) and (Pos is behindb) and (Hd is left) then (Hc is right)
  if (Dist is near) then (Sc is faster)
  if (Dist is far) then (Sc is samespd)
  if (Dist is far) then (Hc is samedir)
```

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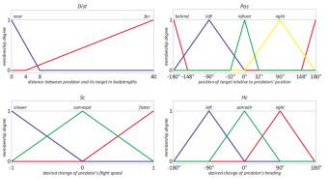
seek




```
Rules:
  if (Pos is infront) then (Hc is samedir)
  if (Pos is right) then (Hc is right)
  if (Pos is left) then (Hc is left)
  if (Pos is infront) then (Sc is faster)
  if (Pos is left) and (Dist is near) then (Sc is slower)
  if (Pos is right) and (Dist is near) then (Sc is slower)
```

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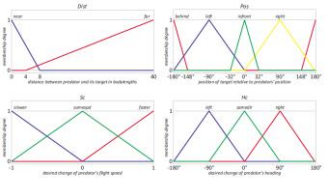
seek




```
Rules:
  if (Pos is infront) then (Hc is samedir)
  if (Pos is right) then (Hc is right)
  if (Pos is left) then (Hc is left)
  if (Pos is infront) then (Sc is faster)
  if (Pos is left) and (Dist is near) then (Sc is slower)
  if (Pos is right) and (Dist is near) then (Sc is slower)
```

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Parameter	Description	Default value
Δt	Time step	1 frame (1/30 s)
T	Maximum length of one simulation	900 frames (30 s)
v_{aM}	Maximum speed of the predator animat	22 m/s
v_{am}	Minimum speed of the predator animat	8.8 m/s
v_{pM}	Maximum speed of prey animats	18 m/s
v_{pm}	Minimum speed of prey animats	7.2 m/s
φ	Animat field of view	300°
n	Number of influential nearest neighbours	7
w_c	Weight for cohesion drive	5
w_s	Weight for separation drive	5
w_a	Weight for alignment drive	3
w_o	Weight for hide drive	4
w_{vs}	Weight for regulate speed drive	1
w_k	Weight for seek drive	1
l	Body length	0.2 m
	Fuzzification	singleton
	Fuzzy conjunction	product
	Fuzzy disjunction	probabilistic sum
	Fuzzy implication	product
	Fuzzy aggregation	probabilistic sum
	Defuzzification	centrer of gravity

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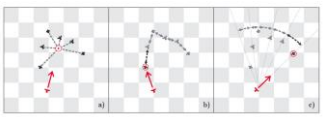

Fig. 2. The three attack tactics – (a) the predator attacks the centre of the seven perceived prey, (b) the predator attacks the nearest of the seven perceived prey, (c) the predator attacks the most isolated of the seven perceived prey. The red bird is the predator and the red arrow represents the resulting force vector of the predator's seek drive.

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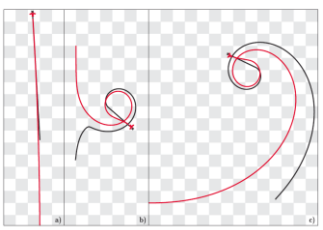

Fig. 5. Predator attacking a single prey from three main directions: (a) behind, (b) head on, (c) side.

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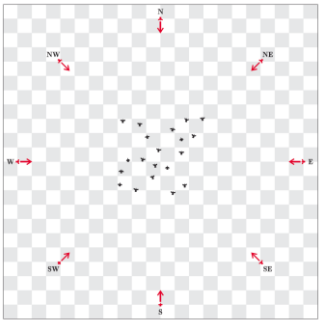

Fig. 3. One of the starting configurations along with eight bearings of the predator's attack.

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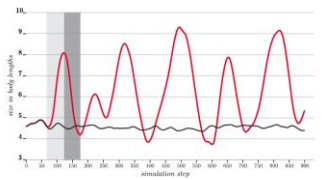

Fig. 7. Plot of the flock size of an artificial flock consisting 20 animats. The black line shows the flock size over 900 simulation steps when there is no predator nearby. The red line shows the flock size over 900 simulation steps when the flock is under predator attack. A clear example of flock expansion is marked with a light grey background, and dark grey is used to mark an example of flock compression. As predator attacks occur one after the other there is no clear example of flock relaxation.

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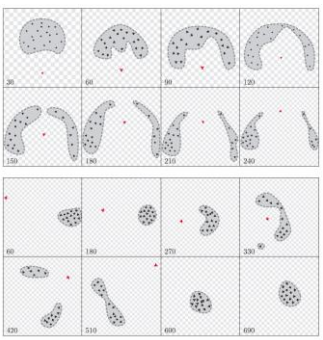

Fig. 6. Three common patterns in the artificial flock's response to a predator attack: (above) from *herd* (frames 30–120) to *split* (frames 120–240), (below) from *herd* (frames 60–330) to *fountain* (frames 330–510). In the below snapshots one can also notice the phases in the flock's response: before attack (frame 60), *compression* (frames 60–180 and 510–600), *expansion* (frames 270–510) and *relaxation* (frames 600–690). The red bird is the predator, black birds represent prey. For the sake of clarity the birds were scaled by 200% (above) and 300% (below).

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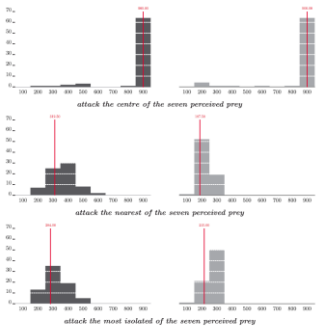

Fig. 4. The influence of the predator's attack tactic and prey's behaviour on survivability of prey. Presented are six histograms of the predator's time-to-catch in corresponding simulation runs ($n = 72$). Dark grey histograms present the time-to-catch in simulations with social prey, whereas light grey histograms present the time-to-catch in simulations with individualistic prey (cohesion and alignment drives not used). Red lines present the corresponding median time-to-catch.

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Our simulations show that the least successful predator is the one that attacks the centre of the flock. They suggest that with predators whose tactic tries to optimize the chance of a positive outcome, social behaviour is more advantageous than individualistic behaviour, which strengthens our belief in the hypothesis that cluster flocking can be a mechanism for protection from predators.

The behaviour of our artificial flocks appears to be comparable with that seen in flocks in nature. The average distance from nearest neighbour is around four body lengths (one body length equals 20 centimetres), the response of an artificial flock to a predator attack is similar to field observations, and similar escape patterns emerge as in nature. Our results also shows that the most successful predators attack from behind, and seek isolated targets.

Our results seem to suggest that cluster flocking around a roost is paradoxical because although its structure might provide some protection against a predator attack, its very existence invites a predator attack, and at least in nature, there are always isolated individuals that can be picked of. It suggests also that at least in some circumstances, which may or may not be common in nature, tight cluster flocking can be of benefit to the flock as a whole, although it does not provide absolute protection to individuals in the flock.

Predatory fish select for coordinated collective motion in virtual prey

Ioannou C.C., Guttal V. & Couzin I.D.

doi: 10.1126/science.1218919

SEMINARJI