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Cooperative Strategies for Agent Behaviour

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FIT3094 Artificial Life, Artificial Intelligence and Virtual Environments

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Learning Objectives

To know likely scenarios for using cooperative group behaviours to game agents.

To understand the components of a distributed flocking algorithm.

To know how to implement a distributed flocking algorithm.

To know how to extend the flocking algorithm to allow control of the group's direction.

To know how to extend the flocking algorithm and the boid model in different ways.

Why might game agents cooperate?

To form a group of animals: flock, school, herd, vehicle traffic.

To gang up on a player: alien invaders, enemy troops or monsters.

To build a structure or community: RTS opponent agents.

Halo Wars, Ensemble Studios

Cooperating game agents will appear intelligent and life-like.

Flocks, Herds and Schools

Movement of organisms in mass groups reduces the chance an individual animal may be singled out by a predator.

Specific characteristics of these behaviours:

- Aggregate, polarized, non-colliding motion of a group of animals
- Behaviour propagates rapidly through a large group
- Behaviour of the group is independent of the number of members
- Complex behaviour (difficult to animate manually)

Reynolds, C. "Flocks, Herds and Schools: A Distributed Behavioural Model"
Comp. Graph. Vol 21, No. 4 July 1987, (SIGGRAPH 87) p25-34.

Flocking, early models

- **Force-field model**: an early model (seen in *Eurythmy* by Michael Girard and Susan Amkraut) operated by constructing bound force-fields around each static or mobile object. Paths are calculated incrementally through these dynamic force fields.

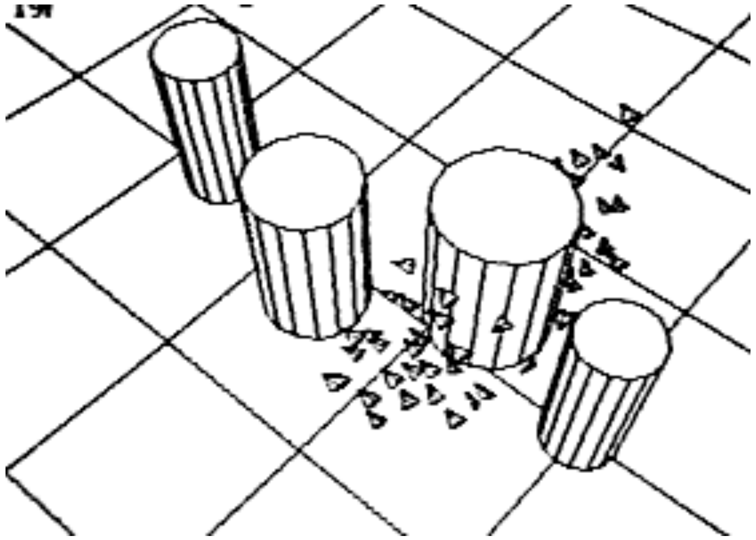
- **Follow the leader**: one flock member is designated the leader. The remainder adjust their velocity (magnitude and direction) to match / chase the leader. Due to different masses and turning ability of the flock members, the flock members have a slight variation in their flight paths.

- **Central force model**: flock members are drawn along by a force towards some moving point.

Girard & Amkraut, *Eurythmy* 1985/89

A *Distributed* Flocking Model

Craig Reynolds presented the first distributed model of flocking behaviour in which:



Each boid* follows its own set of behavioural rules that are applied according to its individual point of view.

Reynolds, *Stanley and Stella in Breaking the Ice*, 1987

* A *boid* is short for a bird-oid.

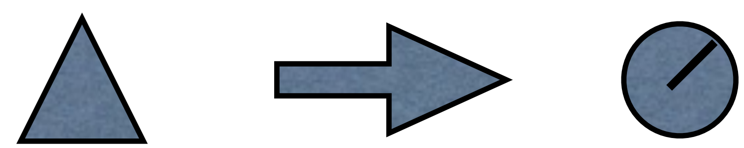
Reynolds, C. "Flocks, Herds and Schools: A Distributed Behavioural Model" Comp. Graph. Vol 21, No. 4 July 1987, (SIGGRAPH 87) p25-34.

A *Distributed* Flocking Model

Reynolds' boids can perceive only their immediate neighbours.

A boid is modelled visually as an "oriented particle".

particle (no directional indicator)



oriented particles

Reynolds' models' boid behaviours

In Reynolds' model, each boid follows these rules:

Collision avoidance (static object)

Collision avoidance (other boids)

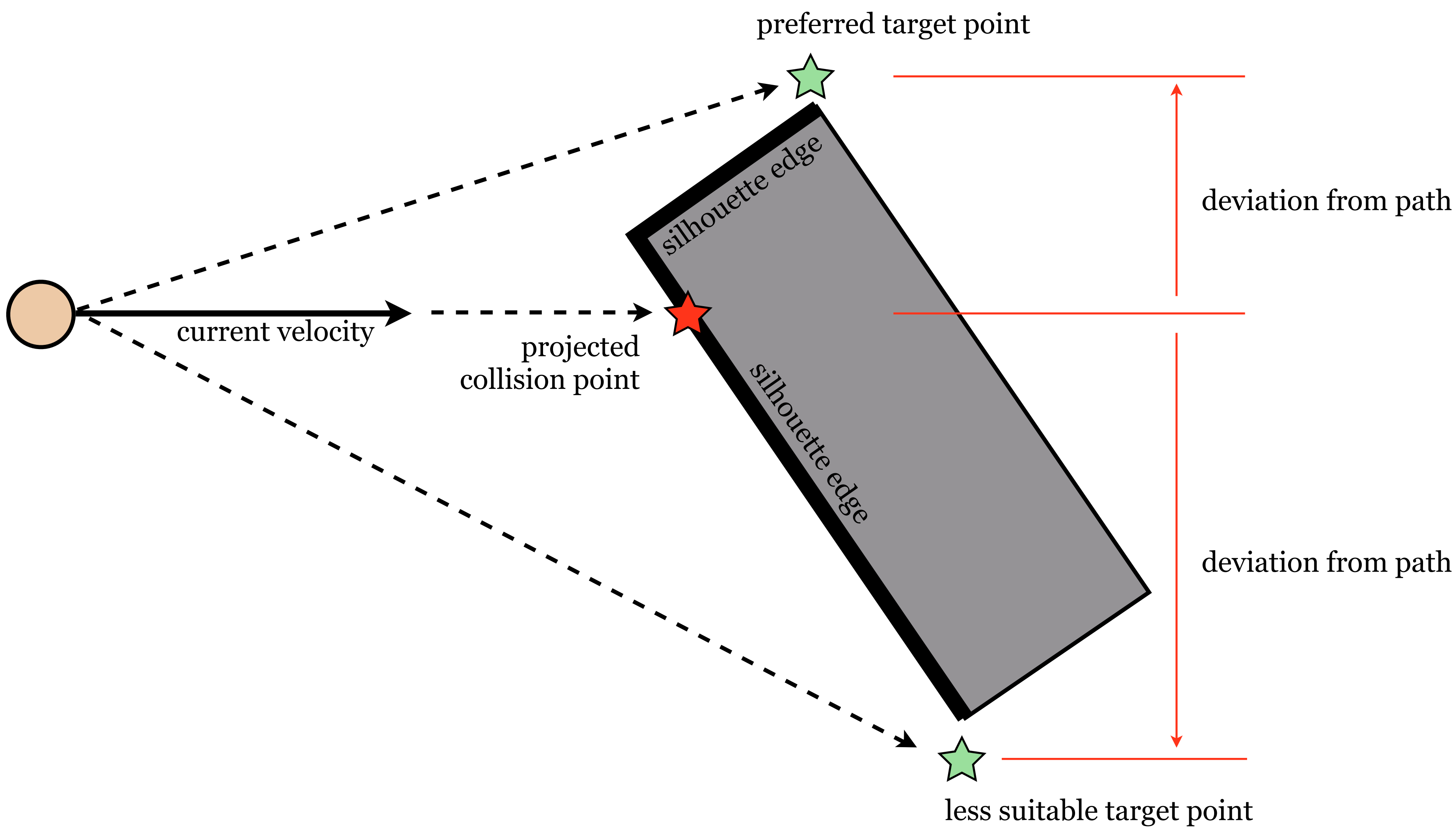
Velocity matching (other boids)

Flock Centering (other boids)

Boid collision avoidance (static object)

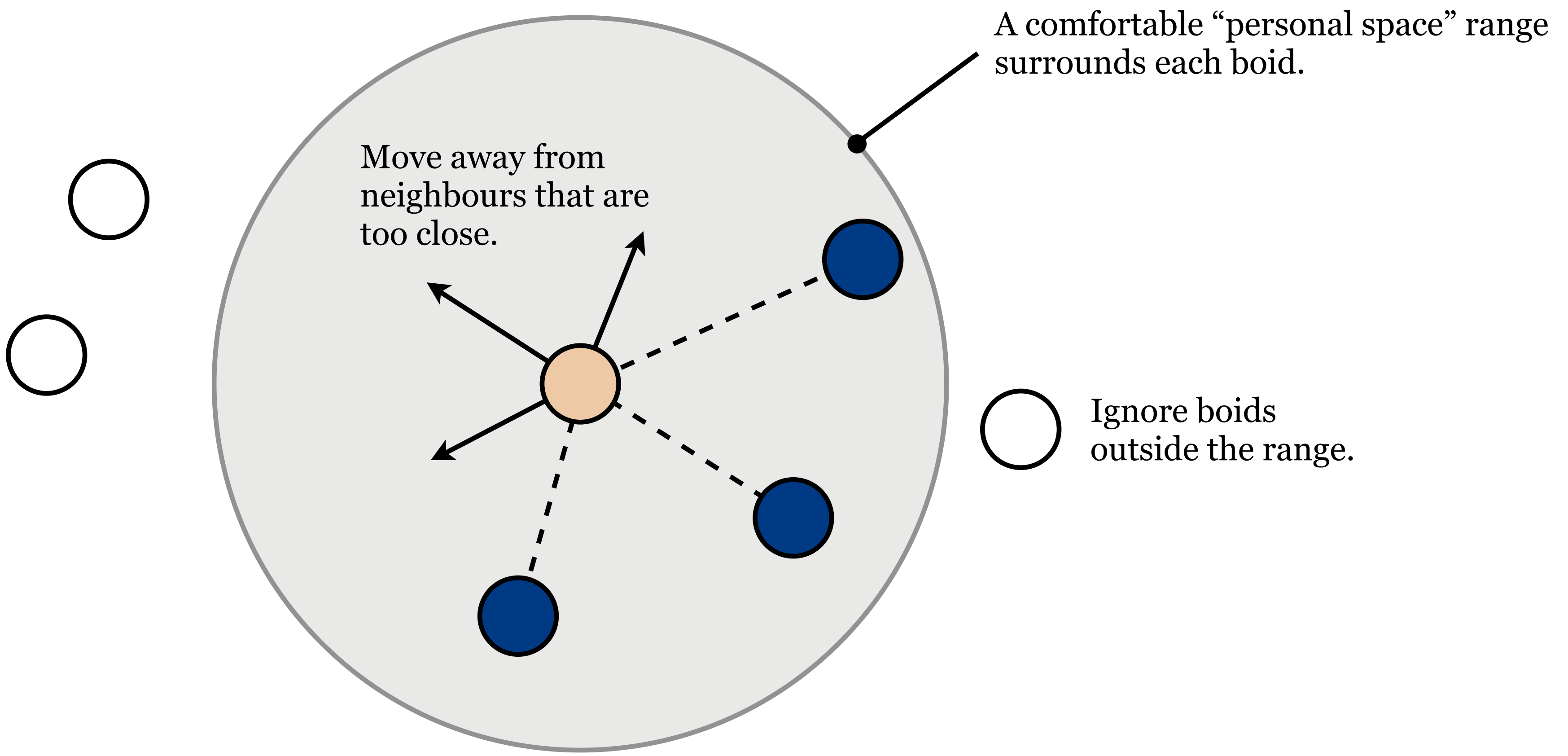
To avoid collisions, choose a new target point beyond the nearest “silhouette edge” of the obstacle.

Move towards this target point.

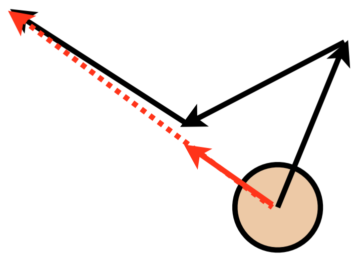


Boid collision avoidance (other boids)

An easy way to avoid collisions with a flock of other boids is by keeping your distance from them.

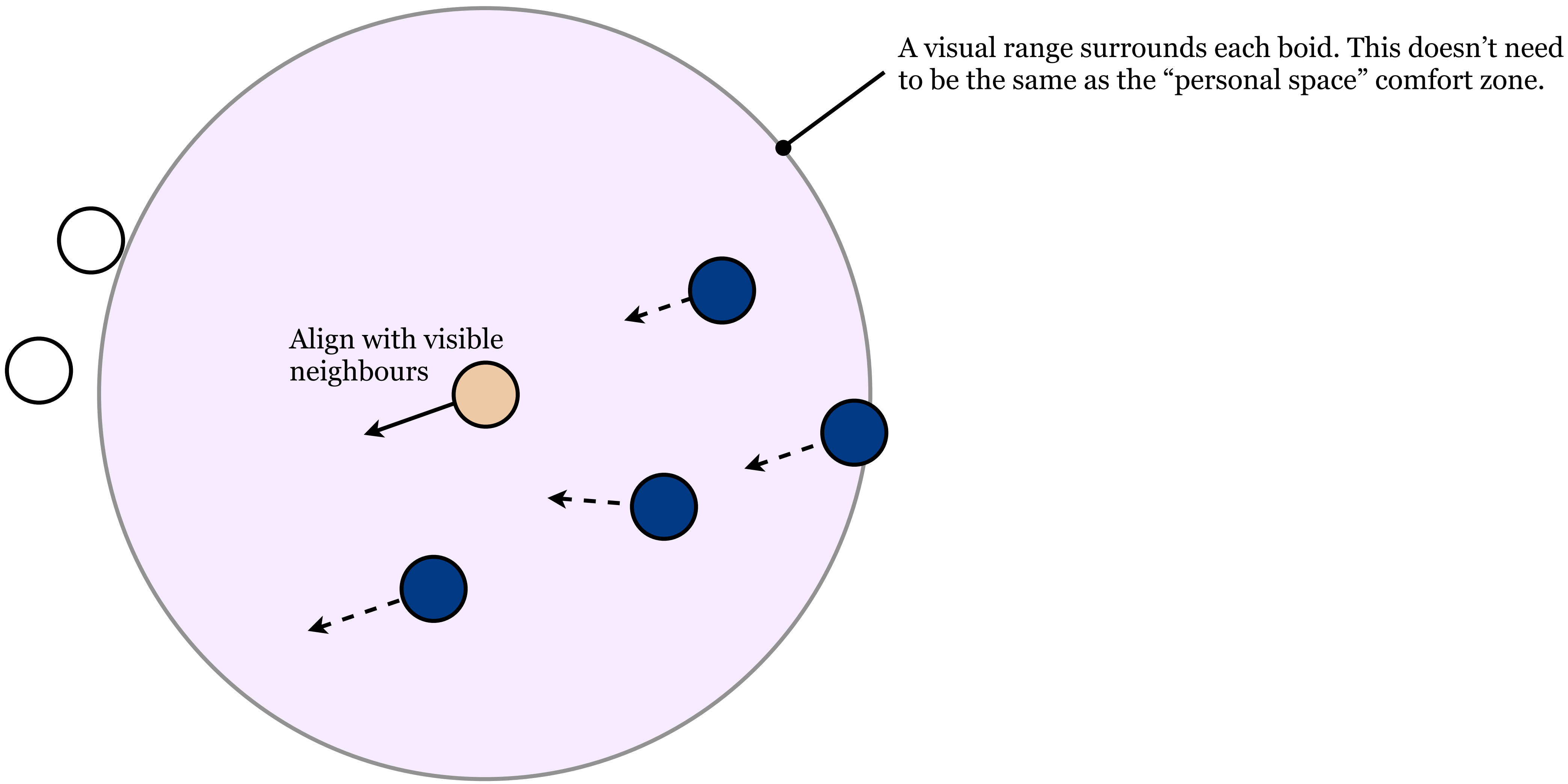


Add the "avoid vectors" to obtain a resultant vector that indicates the direction this boid should move to avoid being too close to others. Divide this vector by the number of vectors that were added to get an appropriate length.

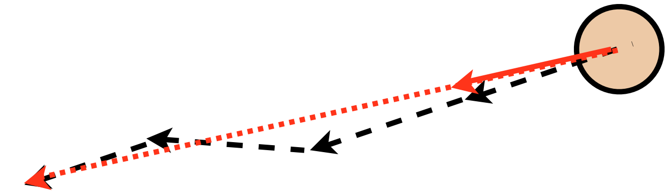


Boid velocity matching (other boids)

Another way to avoid collisions with a flock of other boids is by flying in the same direction as your visible neighbours.



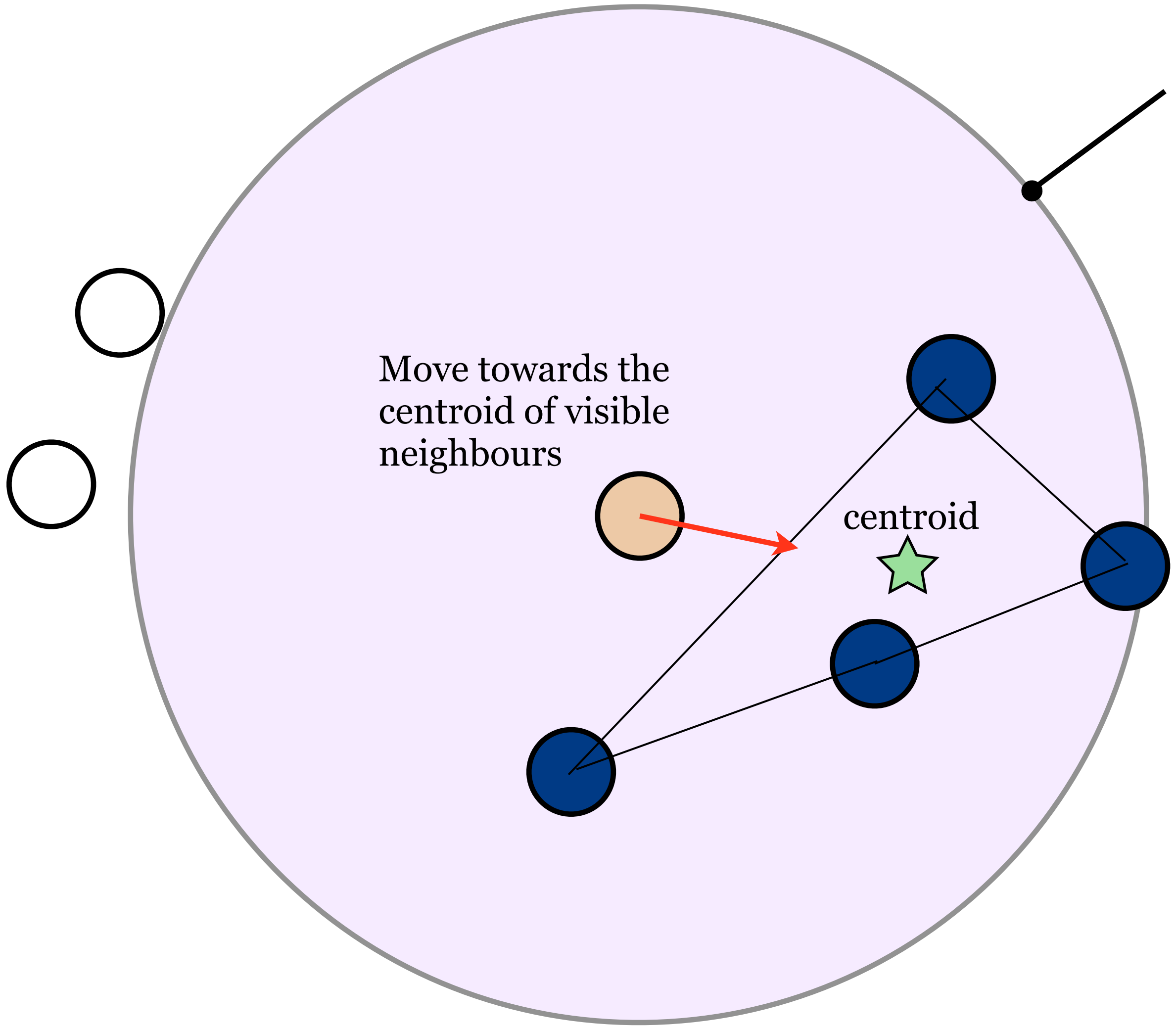
To align with a set of neighbours, add up their velocity vectors and adjust your velocity to steer towards this average direction and at the average speed.



Boid flock centering (other boids)

A flock is a group flying together. We don't want the birds to fly too far apart so we add a localised flock centering tendency.

A visual range surrounds each boid. This doesn't need to be the same as the "personal space" comfort zone.



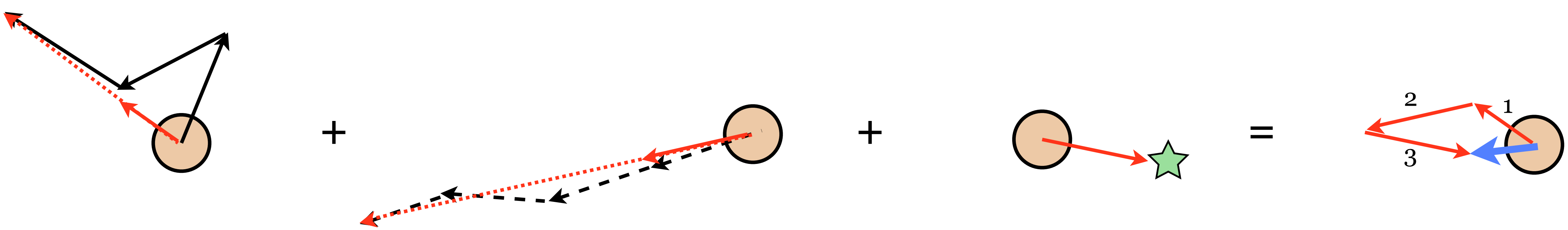
To find the centroid of the local neighbourhood, add up the positions of each visible neighbour, and find the average x and y coordinates. Move towards this point.

Flocking: putting it all together.

To make the boids flock, for every boid in the flock, you need to prioritise and sum the vectors obtained for its individual behaviours.

Top priority	Collision avoidance (static object)
High priority	Collision avoidance (other boids)
Moderate priority	Velocity matching (other boids)
Moderate priority	Flock Centering (other boids)

Assuming no static object collisions are imminent*...



1. Collision avoidance

2. Velocity matching

3. Flock Centering

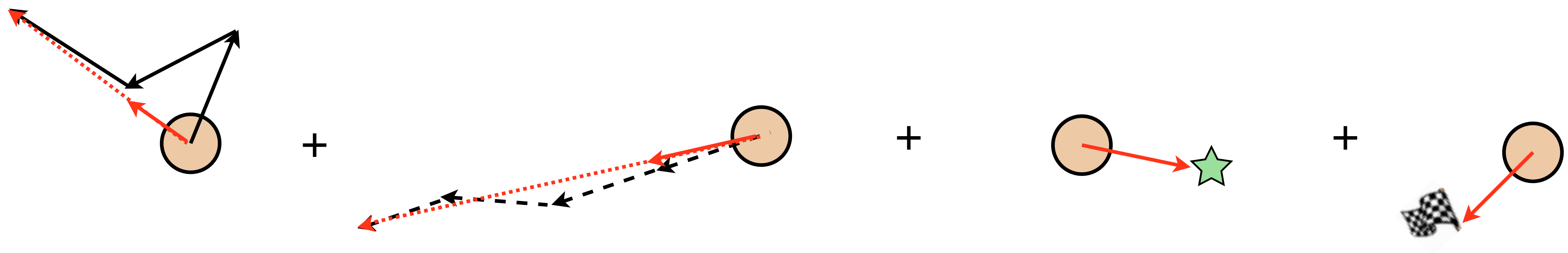
Resultant vector to apply to this boid.

* If a collision with an obstacle is imminent, it is usually best to give the boid's collision avoidance vector priority. It is not realistic (usually) for birds to go crashing into obstacles, but you can get away with birds flying slightly too close, not quite in alignment or slightly too far apart.

Boid extra behaviours.

How do you make the animated flock move where *you* want it to go?

Add an extra behaviour: Migratory urge toward some point

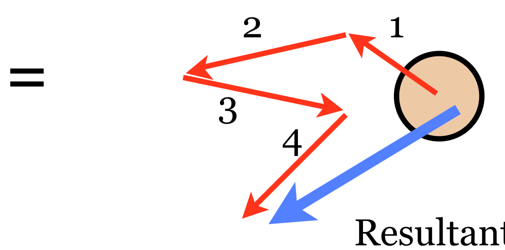


1. Collision avoidance

2. Velocity matching

3. Flock Centering

4. Migratory Urge



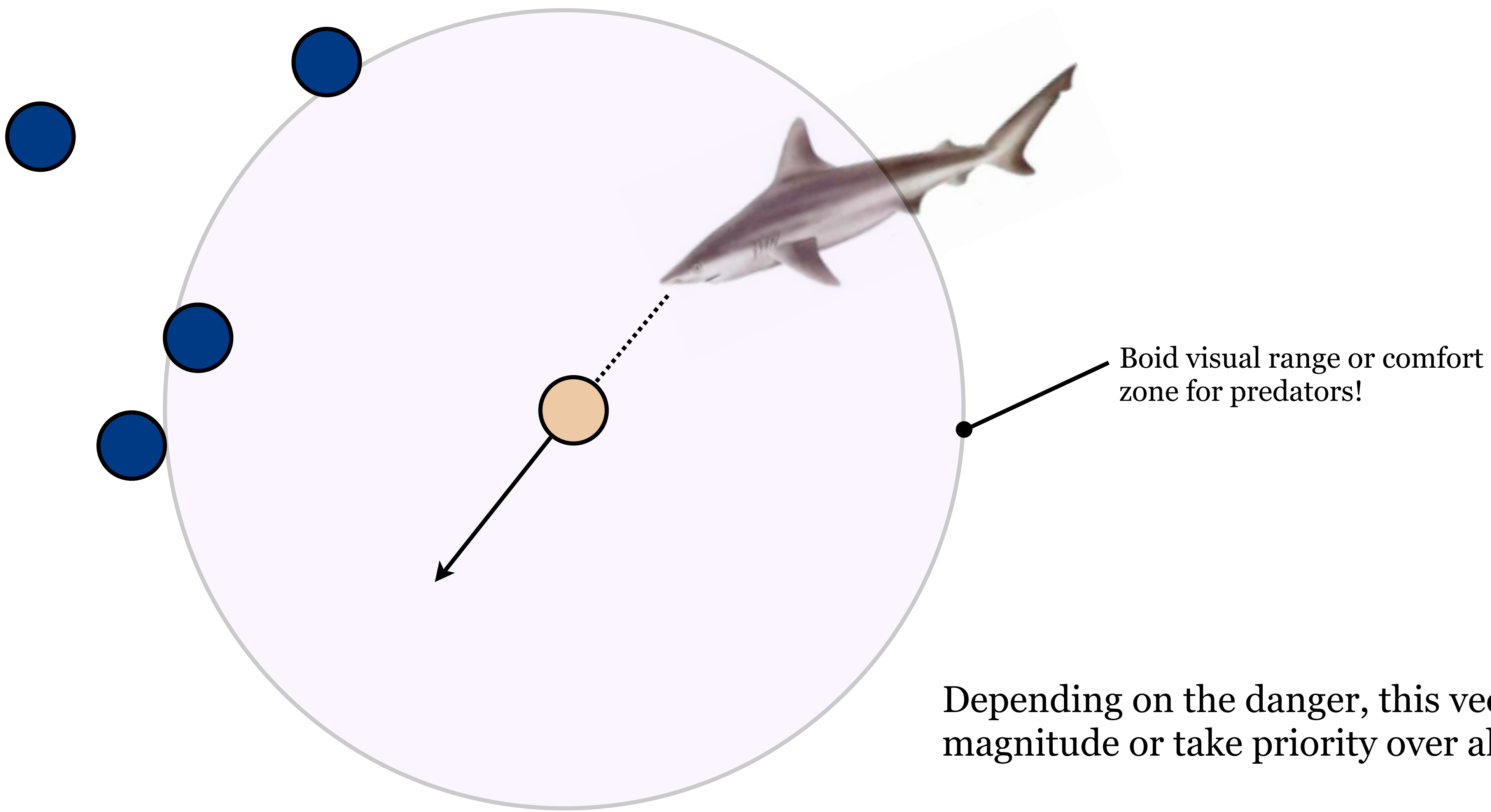
Resultant vector to apply to this boid.

Cap the resultant vector's magnitude to a *maximum* speed that is reasonable for the agent.
If the agent is flying, set a *minimum* speed below which the agent would fall out of the sky.

Boid extra behaviours.

How do you make the flock escape a predator (such as the player who is trying to catch a boid)?

Add an extra behaviour: Flee from agent

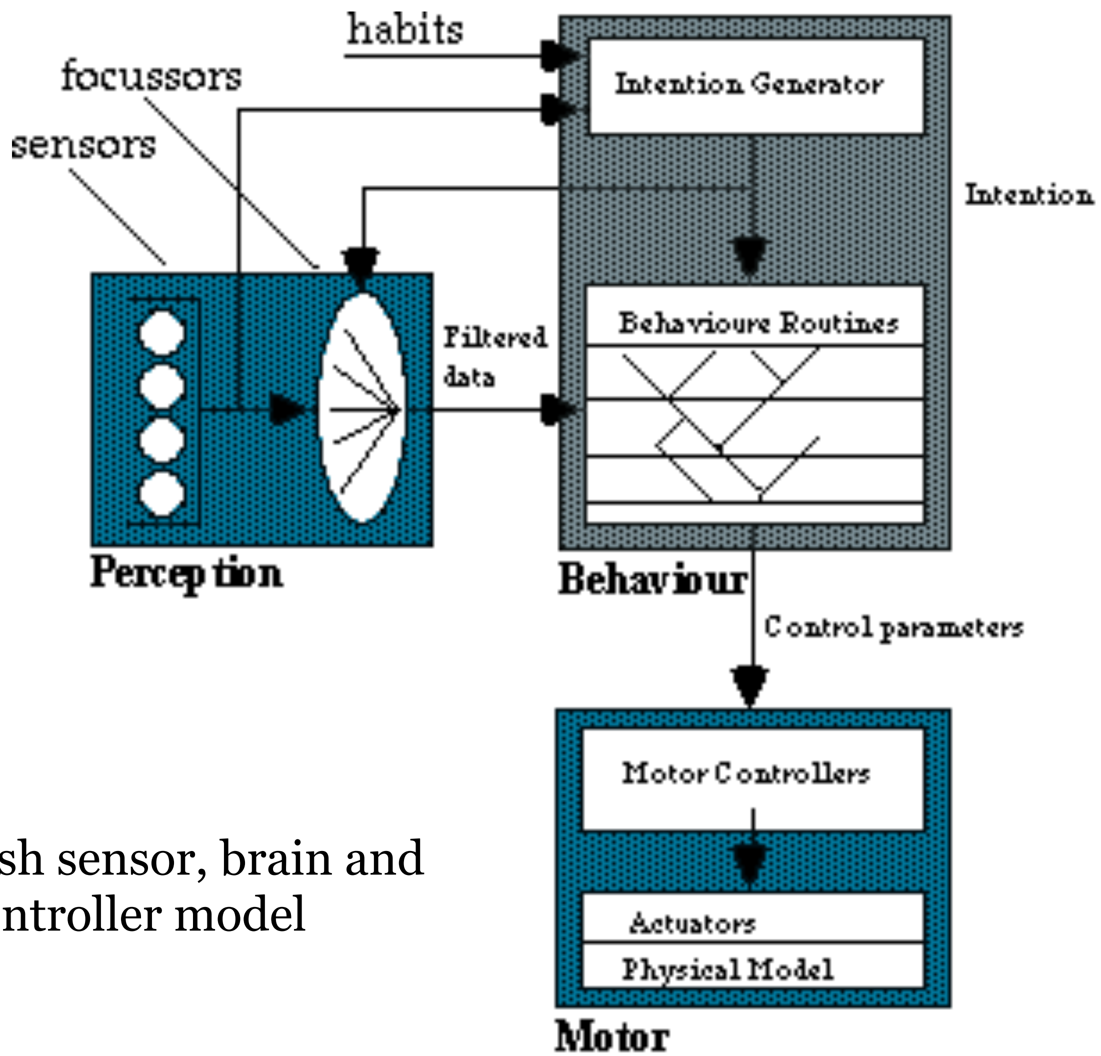


Depending on the danger, this vector could be large in magnitude or take priority over all other flocking behaviours.

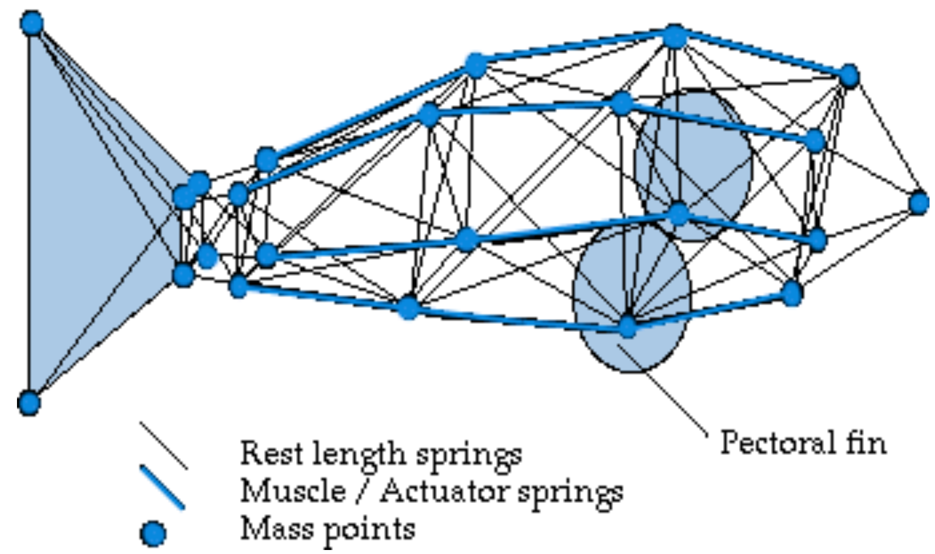
If the fear-flee vector is strong enough, it will cause the boids to collide with obstacles and with one another. It will cause them to bunch up too tightly or swim too far away... realistic behaviour for panicking fish!

Schooling and fish, an alternative model.

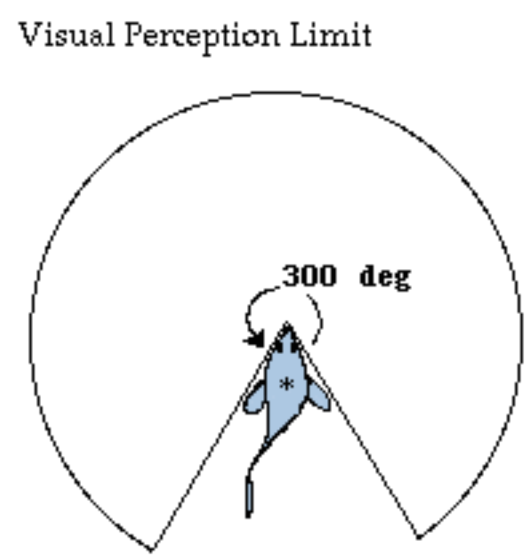
Tu and Terzopoulos introduced an alternative, more complex fish model that allowed for all kinds of fish-specific behaviour, including schooling.



Fish sensor, brain and controller model



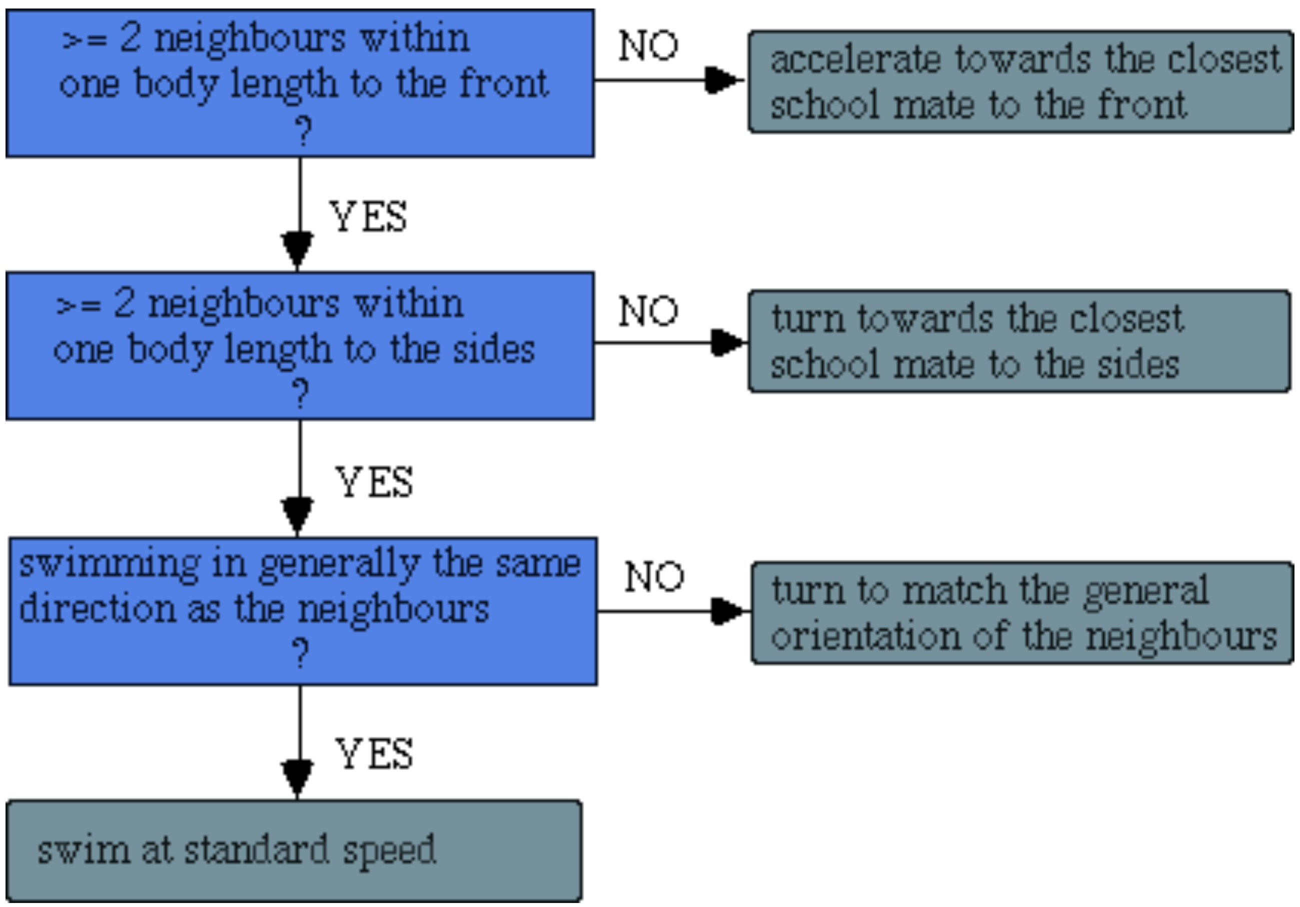
Fish physical model

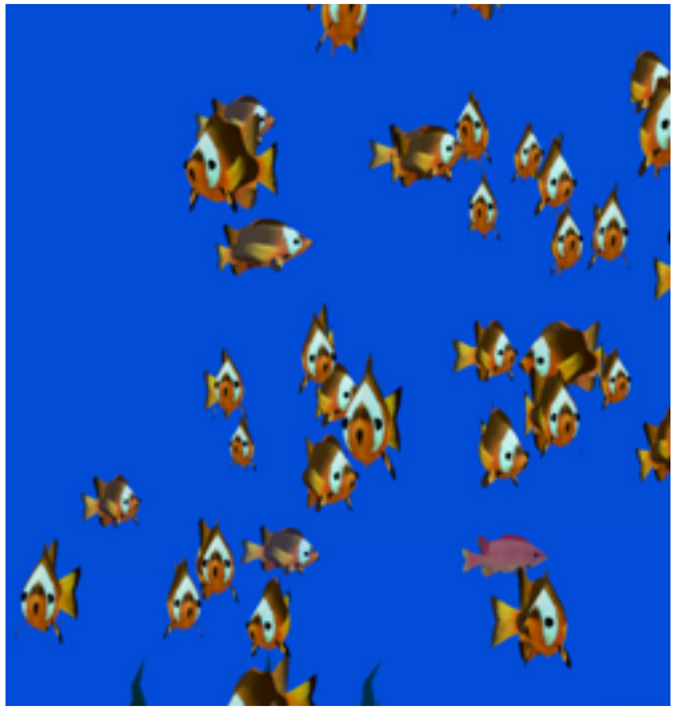


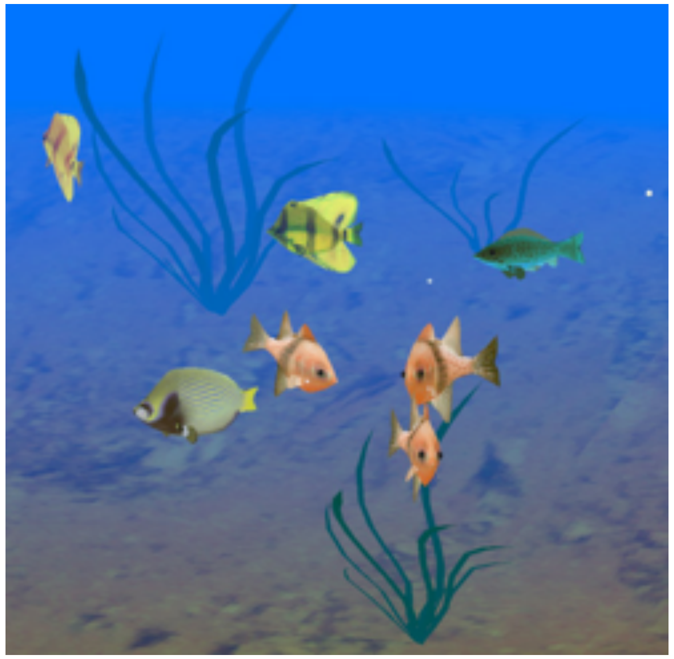
Tu, X., Terzopoulos, D. "Artificial Fishes: Physics, Locomotion, Perception, Behaviour" Comp. Graph. Proc. 1994, (SIGGRAPH 94) p43-50.

Schooling and fish, an alternative model.

Tu and Terzopoulos's schooling algorithm.







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Have you met the learning objectives?

Do you know the components of Reynolds' basic flocking model? Could you implement it?

Could you implement the additional behaviours described in the notes for Reynolds' model?

Do you understand the components of Tu and Terzopoulos' fish model?

What kinds of differences would there be between the swarming of bees or flies and the schooling of fish?

How could the algorithm be applied to model herds of cattle or people escaping from a burning building in a game?

What other applications can you think of for these algorithms?