Predator-Prey Simulation Using Boids Model

Matija Ojo, Miha Krajnc, Marko Adžaga, and Janez Kuhar

Problem overview

Original paper:

Emergence of splits and collective turns in pigeon flocks under predation, Papadopoulou et. al. (2022)

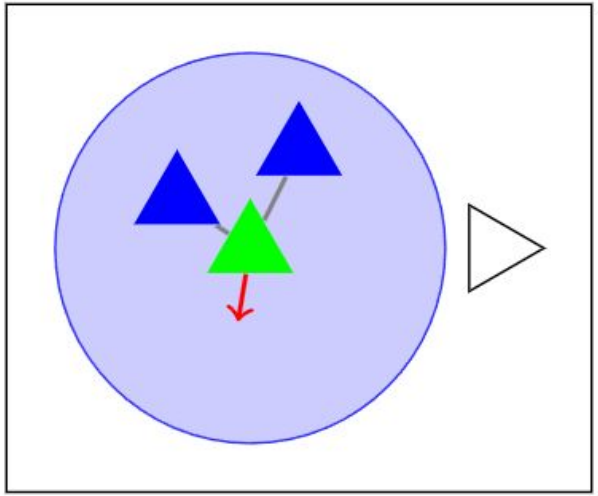
Interests:

- Faster results than empirical data
- Inspiration for autonomous systems (robotics, drones, …)

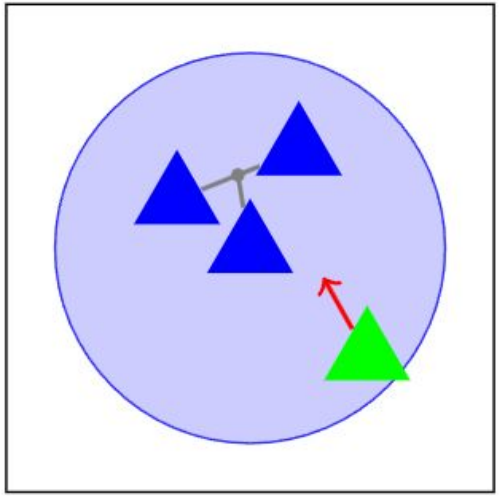
Improvements:

- Different predator strategies
- Enhance realism (occlusion, field of vision, predator confusion, …)
- Use a boundary instead of toroidal coordinates
- Analyze predator’s success

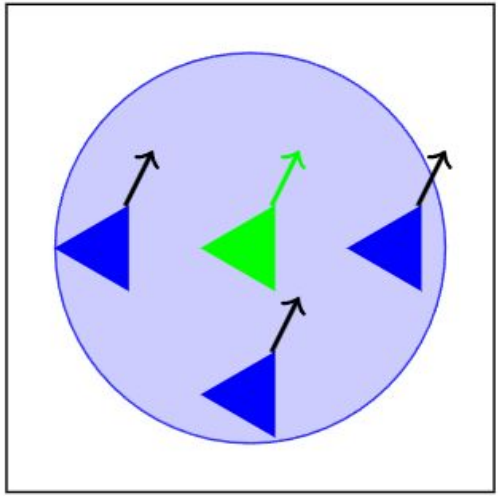
Boids algorithm



Separation



Cohesion



Alignment

Escape behaviours

Avoid position

$$direction = \sum_{i=1}^{n} position(B) - position(P_i)$$

Avoid direction

$$direction = \sum_{i=1}^{n} perpendicular(velocity(B)) \times sign(B, P_i)$$

$$sign(B, P_i) = \begin{cases} -1 & angleBetween(velocity(P_i), velocity(B)) > 0 \\ 1 & \text{else} \end{cases}$$

Escape behaviours

Avoid turn time

$$direction = \sum_{i=1}^{n} magnitude(velocity(B))^2 / \text{radius} \times perpendicular(velocity(B)) \times sign(B, P_i)$$

$$\text{radius} = magnitude(velocity(B)) / \text{angularVelocity}$$

$$\text{angularVelocity} = \text{escapeTurn} / \text{escapeTime}$$

Avoid turn random

$$\text{angularVelocity} = random(\text{MinEscapeTurn}, \text{MaxEscapeTurn}) / random(\text{MinEscapeTime}, \text{MaxEscapeTime})$$

Escape behaviours

Avoid turn gamma

$$\text{turnAmount} = gammavariate(\text{TurnAlpha}, \text{TurnBeta})$$

$$\text{turnTime} = gammavariate(\text{TimeAlpha}, \text{TimeBeta})$$

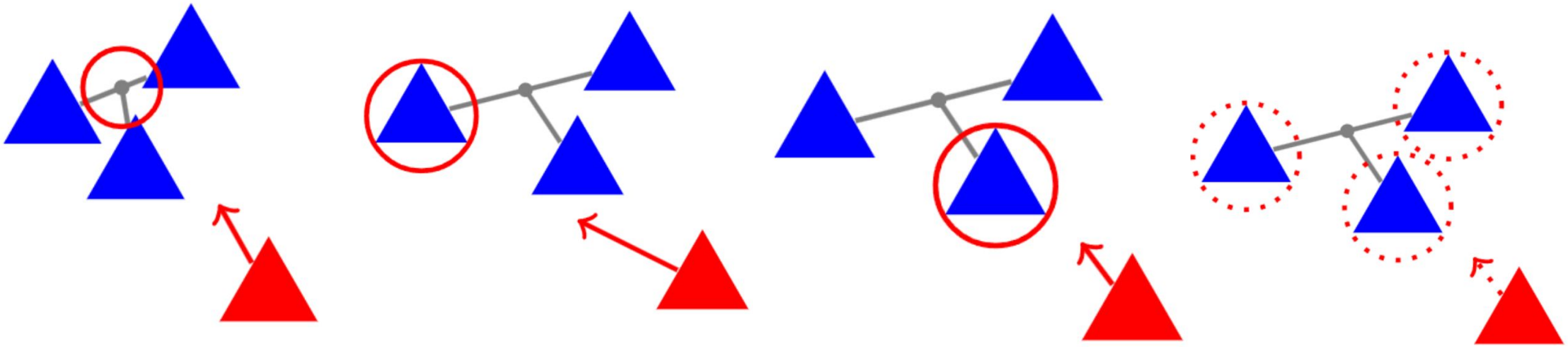
$$\text{angularVelocity} = turnAmount/turnTime$$

Avoid turn zig zag

$$\text{angularVelocity} = \text{EscapeTurn}/\text{ZigZagTime}$$

$$\text{sign} = \begin{cases} \text{sign} & \text{ZigTimer} < \text{ZigZagTime} \\ -\text{sign} & \text{else} \end{cases}$$

Predator behaviours



Attack centroid

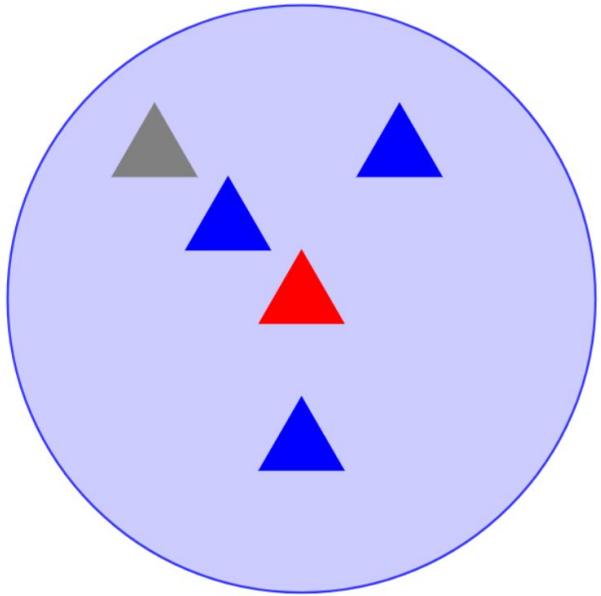
Attack most peripheral

Attack nearest

Attack random

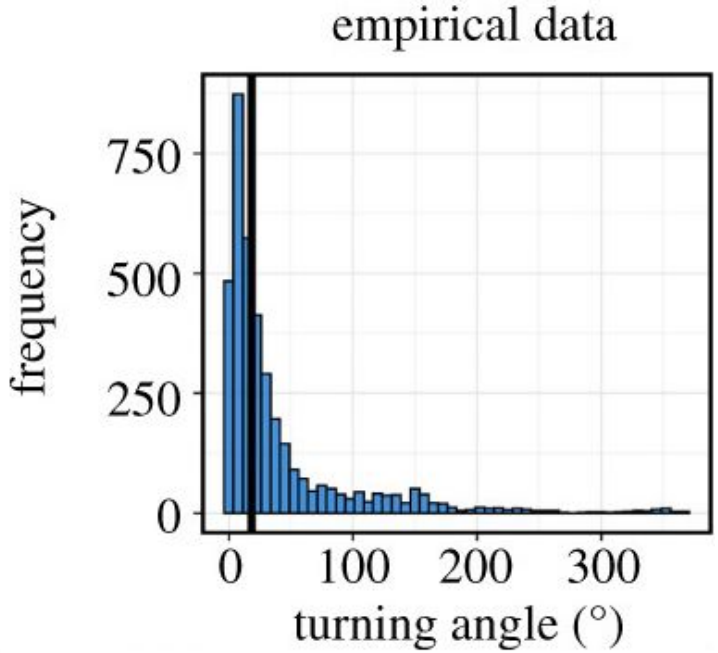
Improvements

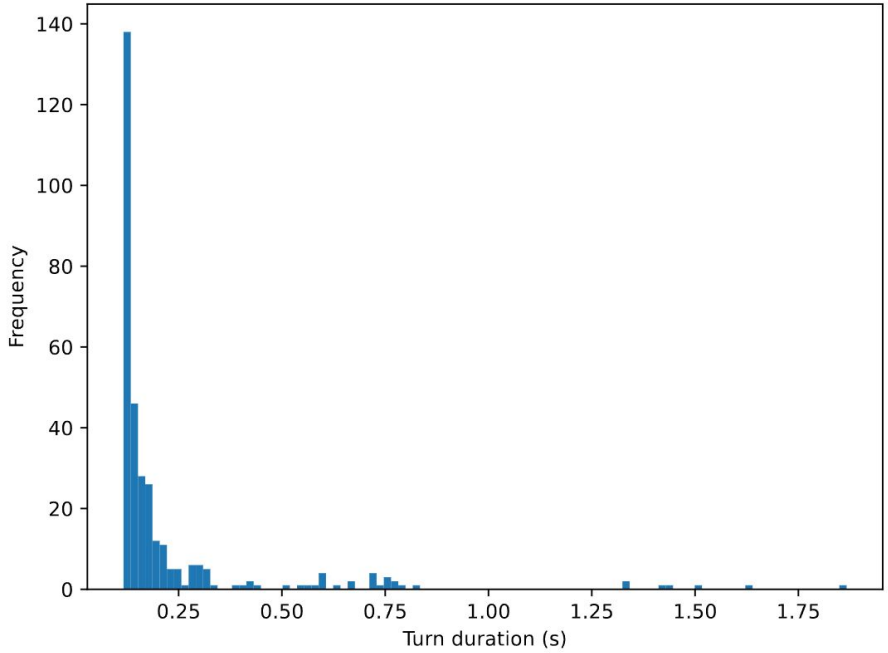
- 300 degree FOV
- Boid occlusion
- Predator confusion
- Prey reaction time
- Toroidal coordinates and boundary
- Multiple predators



Results (Empirical data)

- Testing whether the simulation works
- Empirical data assures objective comparisons





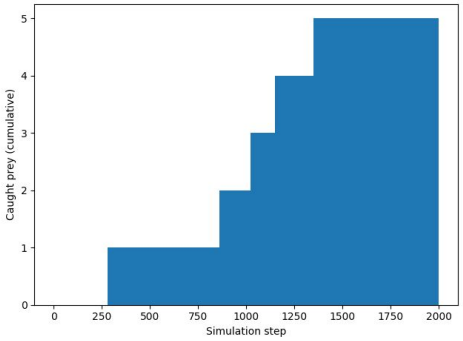
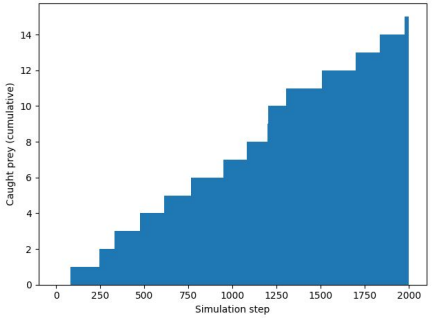
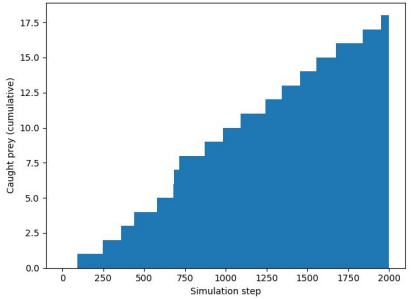
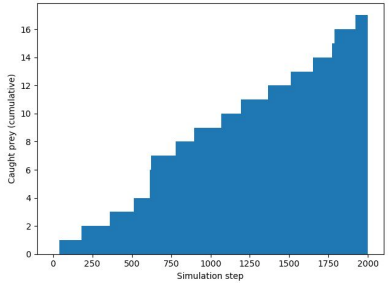
Results - measuring predator success (average caught prey over 10 simulations, 2000 steps, 20 prey, 1 predator)

Predator attack \ Escape behaviour	Centroid	Most peripheral	Nearest	Random
Avoid position	5.2	14.1	17.5	16.7
Avoid turn time	4.5	10.7	16.6	12.4
Avoid turn gamma	5.8	13.5	16.3	14.5

Results - measuring predator success (average caught prey over 10 simulations, 2000 steps, 20 prey, 2 predators)

Predator attack \ Escape behaviour	Centroid	Most peripheral	Nearest	Random
Avoid position	14.2	18.2	20	20
Avoid turn time	11.4	14.5	20	18.2
Avoid turn gamma	13.5	16.3	20	19.2

Results (predator's success)

Predator attack \ Escape behaviour	Attack centroid	Most peripheral	Nearest	Random
Avoid position				
Avoid turn time