# Crowd Simulation of Predators and Preys in Packs

Chengyan Zhang*
National Centre for Computer Animation

## Abstract

This project is a crowd simulation for hunting behaviours of wolves coupled with the behaviour of preys such as elks and caribous. The herd behaviour from the preys, as well as the movement pattern of the predators, resemble a form of flocking patterns. This project seeks to present a simulation of such interaction.

## 1 Introduction

The steering system of an animal can also be described as a point-mass with a combination of states, forces and velocities driven by a set of instructions, see [Craig W. Reynolds 1999].

A predator or a prey, they can be seen as an autonomous agent with their own states. With a group of them, they will begin to communicate and access more information among one another (For instance - "when to flee from the incoming predators".). There may be some differences between different species but the concept of hunting and avoiding-the-hunters, can be somewhat described in a generic approach - a structured system to administrate agents' states. Simulations such as this may have its use certain games or as a subsidiary in a larger simulation. Unreal Engine 4 and C++ are used to build this simulation.

## 2 Related work

There have been a plethora of approaches to a crowd simulation, one of the notable publications is from GDC 1999 - Steering Behaviors For Autonomous Characters [Craig W. Reynolds 1999]. Craig W. Reynolds has presented various approaches to steering behaviours of autonomous agents. The paper has demonstrated key aspects of a steering system and their potential functionality when combined in addition to their alternatives. For example, the agent can be steered through direct force control from autonomous agent, a predetermined flow of movement pattern through a flow field or a combination of such approaches.

Since then, there are numerous implementations that follows this paper, such as [Daniel Shiffman 2012], the book explains the technical details of his implementations of [Craig W. Reynolds 1999]'s proposed simple steering components with code snippets and WebGL applications or diagrams. This source is an example that utilises the [Craig W. Reynolds 1999] methods to demonstrate its practicality, guiding me through the rough data structures and algorithms that is needed to perform certain actions on an agent.

Previous works of prey and predator relationship are also considered in psychological and observational pieces [Isaac M. Marks 1987]. The parts of interest suggest that anxiety and fear factor, which causes a group of prey to panic and flee, is often directly related to the difference in numbers, the distance between the prey and the predator and their orientations with respect to the group of preys. These observations can form a basic idea of how the agents would react or enact in the simulation of the hunting-ground.

Articles of [Dave Pottinger 1999] provides some direction on how a formation of units can be formed and transformed in a simulation. The source explains the relationship between the the leader agent and its subordinates. Dave Pottinger has also presented the necessary data structures for some examples of behaviours. This source is more specifically illustrating how agents can move knowing their positions in a group in a game development background, which is essential for the movement pattern of predators as it's needed to think about real-time strategy game tactics for a hunt, a predator's game.

Additionally, [S.-H. Lee 2006] and [Jaedong Lee 2018] illustrate ways of approach to handle states and formation changes of prey flocks where basic model of states are defined for predator detection, predator avoidance avoidance, predator's choice of preys and flocking reaction. The former article utilises different force models to steer the agents in each of prey states. The latter approach applies machine learning techniques to derive an increasingly optimal course of action in the given scenario of agent positions.

Aside from older observations, articles such as[Living with Wolves ] and documentary snippets [National Geographic ] have been considered. As most of the sources are quite recent compared the the previous publication [Isaac M. Marks 1987] and are focused on a few specific species in a specific environment - wolf packs hunting elks or deer in Yellowstone National Park.

There are also bird-eye captures of sheep herding by shepherd dogs[YouTube User - Caters Clips ], as the behaviour of dogs may correlate with the other species in the Canis Family. This source shows a more controlled situation of the interaction. It may not be as accurate compared to the scenes witnessed in wilderness, however, the formation of flocks can be quite apparent.

## 3 Method Overview

Firstly, I've implemented the necessary flocking behaviours and a basic state machine to test the interactions and determined that the maximum speed, used to limit an agent's speed increase in certain states, is a parameter to allow variations between individual prey or predator. This will also allow the predators to determine their target prey, since according to documentaries (see [Living with Wolves ], [National Geographic ]) predators usually only choose one easy target per hunt to conserve their energy and avoid confusion.

**For the individual agent, there are several states to handle:**

1. **Idle** - When the agent is not moving, symbolising that it may be dead, prey-only in this simulation.
2. **Pursuit** - When an agent chases after a target agent, predator-only for this simulation.
3. **Flee** - When the agent is running away, prey-only.
4. **Wander** - When an agent is not fleeing nor pursuing, they wander around.
5. **Regroup** - When an agent is wandering, they may wander too far from the group, this recalls them to head back into the group.

In addition, there is also the spawning locations of the agents. As I don't want predators to initialise near the preys, the region of possible spawn location is defined by a radius and a centre position; this ensures that such artefacts do not happen.

*e-mail:s4903744@bournemouth.ac.uk

The detection of neighbourhood collisions is reported through bounding spheres provided by Unreal Engine 4 (see [Epic Games ]). The system flags collisions of spheres on agents enter or exit another agent's sphere, event can then be fired to respond to a change in the local environment. This simulates the sensory abilities of animals.

Initially, the design of agents are focusing purely on their local neighbourhood as behaviours such as separation and cohesion of a pack are maintained in an agent's local neighbours (see [Craig W. Reynolds 1999]). However, issues arise when a group is under pursuit from predators agents as the individual prey only react when a predator is close, rather than their peers affecting its motion. The predators are also disorganised as there are not coordination involved in the simulation at this stage.

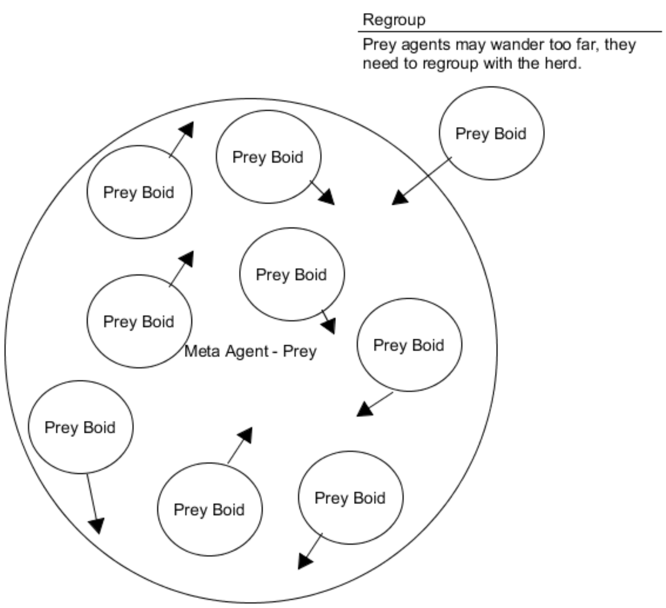



**Figure 1:** *A group of prey agents with the predators approaching and observing.*

The direct solution to this is to add additional access and processing on a container class level that maintains all preys or predators and allows the individual prey or predators to access these data to influence their states, essentially, a *meta-agent*. The structure of the hierarchy is similar to a section of the class model in [Simon Andrew Cooper 2005], refer to Figure 4.

**In addition to the individual states, the container class will be managing the following states:**

1. **Nervous** - Default states when the predators are approaching.
2. **Panic** - When the predators are getting too close to the group, the group starts to panic.
3. **Observing** - When the predator group is approaching the herd.
4. **Hunting** - When preys panic, this state triggers and starts the pursuit;.

Now how do predators select an ideal victim to chase after? During the documentary regarding wolves' hunting tactics, (see [Living with Wolves ], [National Geographic ]) it is very apparent that they tend to have the ability to quickly determine the weaker individuals when the herd starts to flee.

**To simulate this interaction, there are a few ways of approaching it:**

1. Predetermine the target prey at the Observation stage as predators can access prey data. This method is easier to implement and quicker but it assumes that the predators possess omniscience at all times, which isn't very realistic.
2. Only allow the pack to access the prey data when the preys are panicking or when the pack is ready to hunt. While it seems to be more realistic in principle, there are problems such as it being hard to determine when a predator agent has readied itself and it introduces a layer of complexity if the predators do not know where the preys are.
3. Allow predator agents to log each unique preys they've found in their neighbourhood and compare their potential weaknesses. This is quite logical as an animal knows about its preys through individual sensory and communication. However, there are many places where race conditions may occur as many agent try to access or write to the same data, it would have to be the meta-agent's role to collect and propagate such data across all predator agents.

In the end, the simplified method is chosen as the other methods would result in a similar behaviour with less added complexity on the meta-agent's level.

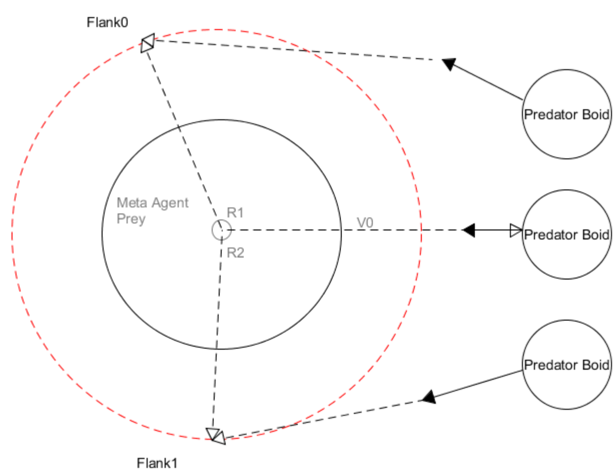



**Figure 2:** *A basic formation of three predator agent.*

The tactical formation for the predator agents are defined as target positions to reach for an agent. The target position itself is updated with a dynamic position of the preys as a group. The position of a group of preys is updated by calculating the average position of all preys in the group. The predators have access to the prey's data and therefore, is able to track the target prey.

With these data the predator can now define their target positions to flank their target prey. As I have mentioned above, the flanking predators have to know their position with respect to the prey's position. Since I've defined the prey group (meta-agent)'s boundary as a sphere, it is somewhat easy to find a relative position using vector rotations driven by values from a uniform distribution.

## 4 Results

With the proposed methods, the quality of results varies between each session as there are cases where unwanted artefacts appear.

For instance, if the predators predetermines their idle target before the chase by choosing the slowest prey agent in the group (see Section.3), there are cases where the slowest can be farther then other fleeing prey at the time of the pursuit, making the predators ignore some of the closer target.

The original idea of a bigger sphere region (see Figure.3) becoming a region where the predators would lose interest as preys leave the world sphere. This idea has been abandoned as it restricts the room for the simulation and appears to be overly-forceful to be carried out explicitly. Although this will result in eventual success for the predators compared to the reality.

The behaviour of the preys under pursuit, however, benefits from the inherent properties of the flocking system (see [Craig W. Reynolds 1999]) where they scatter into multiple groups as they recognises the predators' general direction. This interaction fits quite well with some of the description of fleeing preys in [Isaac M. Marks 1987]. Although, the transition between "Nervous" and "Panic" (see 3) are somewhat too spontaneous and synchronised, making this feel quite artificial.

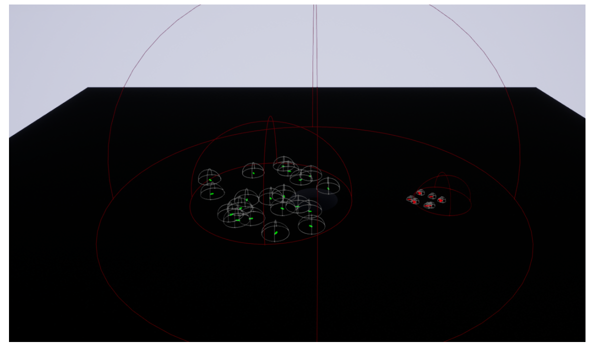
## 5 Evaluation

Due to time constraint, the artefact itself seems to lack the depth as the simulation lacks a gradual change in the psychology of the agents in play. When all preys immediately react to a Panic state change, the simulation looks too mechanical. Possible solutions to this may have been an additional "anxiety meter" where each prey are distributed with a range of limits. This properties can both drive the psychological state machine and result in a gradual spread of the fleeing behaviour, similar to behavioural models proposed in [S.-H. Lee 2006].

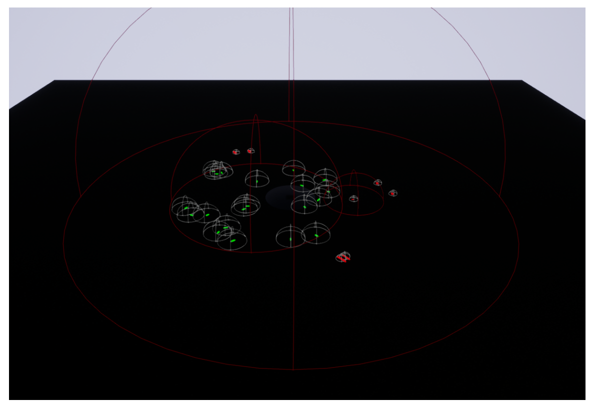
The preys are also somewhat too passive compared to their realistic counterpart as well as the lack of protection of the weaker prey members. Preys usually move as a group towards a direction at a quicker pace whilst keeping the group centred around their young calves. With more time, this behaviour pattern can possibly be implemented in the meta-agent in the way that it becomes a guidance zone for which the preys seek and regroup.

The formation of the flanking mechanisms may also become too restrictive in how the predators are moving. A possible approach is to separate a group of predators temporarily during observation, each subgroup will have a region of space to fulfil as oppose to a series of defined angle of approach, which, very often, causes crowding amongst the predators on the same flank.

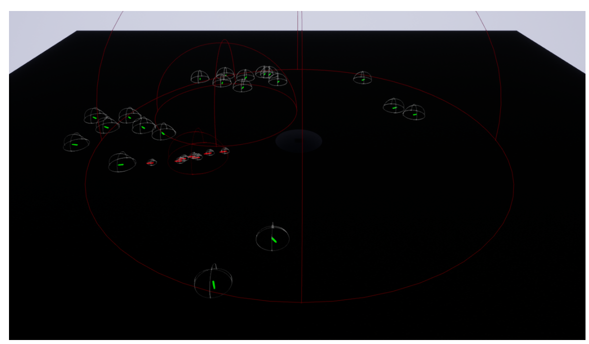
However, in general, the behaviour of the prey and predator interaction during a hunt has been described somewhat sufficiently as the predators are able to observe, take position to flank their target and take pursuit as the preys are panicking.



**(a)** *Approaching Prey*



**(b)** *Formation Setup*



**(c)** *Pursuit*

**Figure 3:** *Stages of the hunting simulation in snippets.* ***Green dots*** *are* ***preys*** *and* ***Red*** *are* ***predators***

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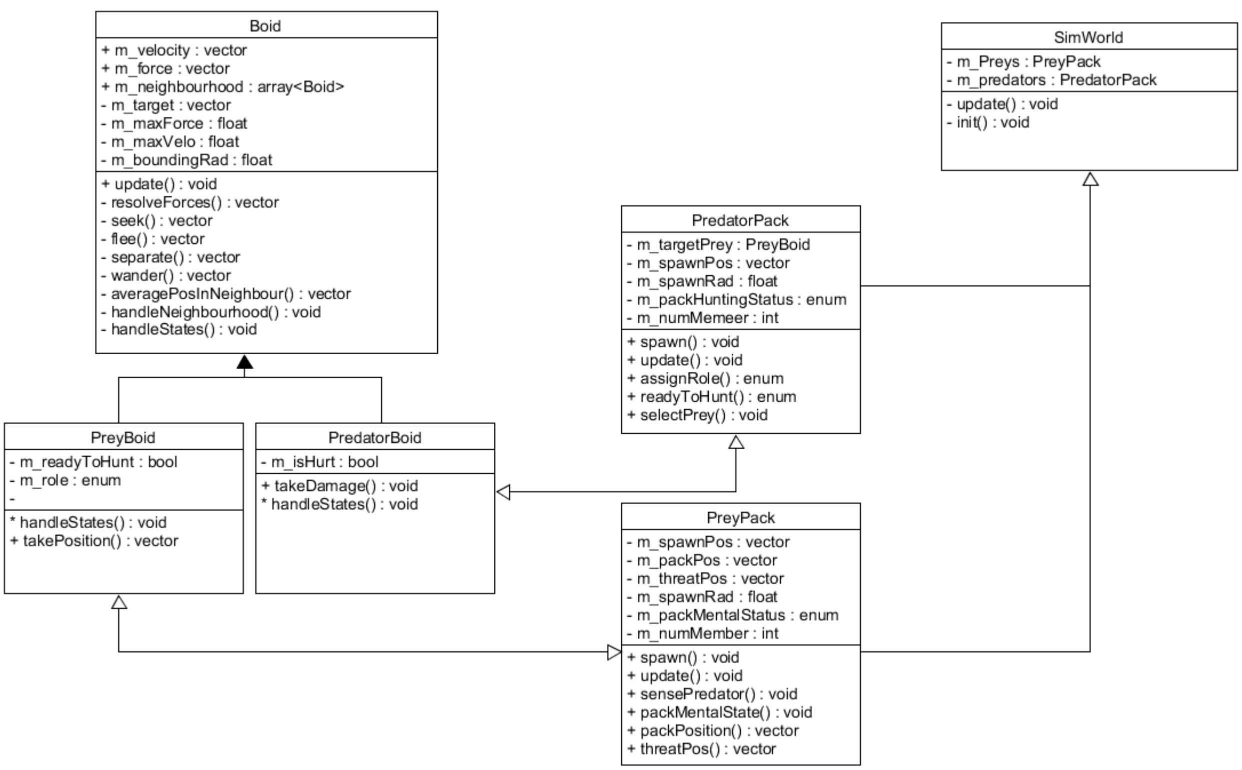


**Figure 4:** *Designed Class Structure guide.*