Simulating Schooling Behavior of Fish with Unreal Engine 5

Bodong Wang* 005523428 **Penghai Wei*** 105726519 **Xiaoxiang Zhao*** 205059635 **Yuxin Wang*** 905129084

1 Introduction

Schooling is the behavior of a group of fish displaying coordinated motion, in which individuals exhibit attraction towards others while also having a tendency to align their direction of travel with near-neighbors. It is an effective group strategy that allows the shoal as a union to be more competitive in seeking food and less vulnerable to the attack of its predators. [Griffiths and Magurran, 1997] Schooling behavior of fish flock is a complex reaction process, especially when the prey flock is under attack of some predator. To survive in a predator rich environment, fish escape activities have led to a variety of behavioral and morphological adaptations.

In this project we use Unreal Engine 5 to simulate the schooling behavior of fishes when the predator exhibits different behaviors. The prey fish will also exhibit different escaping or defensing behavior in reaction of the predator's movement. The simulation is divided into multiple layers. The fundamental layers contain the basic rule of the prey flock under all circumstances, including collision detection and avoidance, prey-to-prey perception and communication system, and Boids algorithm to maintain the flock. On top of that, we then implemented eight different maneuvers of the prey fish in reaction to the three different predator behaviors, which are predator-present, predator-chase, and predator-attack.

2 Game Scene Design

With the ability of a modern game engine, we design a fully interactive scene where the player plays the role of the predator. An underwater scene is established using the unreal engine's rendering and postprocessing functionality. Several boulders are put on the scene for testing collision-avoidance functionality. The predator fish and prey fishes are rendered using unreal engine's Skeletal Mesh class, and their animations are played using AnimationBlueprint with keyframed animations.

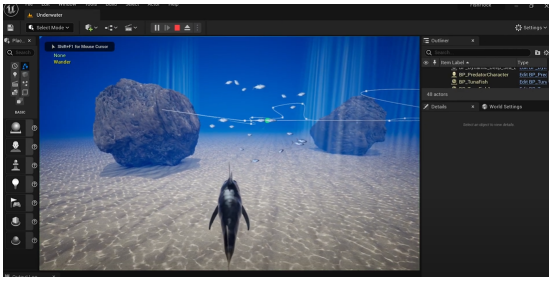

Figure 1: Underwater Scene

3 Predator Implementation

We design several keybindings for players to control the predator. Traditional WASD control is used for moving forward and moving right/left. Keyboard Q and E are for diving up/down. A left mouse click causes the action of attacking, where a special animation is played on the predator mesh; holding the mouse right button is for chasing, in which state the swimming speed of the predator is increased. A demo for controlling the predator is shown here https://www.youtube.com/watch?v=McvCW7zVCOE&list=PLifb_pFDC6_ycl9CPivZ-H2eX1SqB3lV-

4 Prey Sensing and Maneuver State Machine

Each prey has two primary sensors: a vision sensor for sight and a peripheral sensor for ripple force. The vision is simulated by a distance cone in front of the fish, which means the prey can see the predator if the predator is within a distance of the prey, and the angle between the predator-to-prey vector and the prey's forward

*Group members are listed in Alphabetical order

vector is within an angle. On the other hand, the ripple force is sensed if the predator is within another distance of the prey (no angle check), which is less than the vision distance. Since we simulate the behaviour of a fish flock as a whole, which means a group behaviour is picked based on the situation rather than individual behaviour, we decide that the flock sees the predator or senses the ripple force if any of the fishes in the group sees or senses the predator.

The maneuver-picking logic of the fish flock is designed to be a finite state machine, where states represent maneuvers and transitions represent when to choose that maneuver. A maneuver is a set of movement logic applied to every fish in a fish flock. In most cases, the purpose of the maneuver is to scare or run away from the predator in the most efficient way under the current situation. The transitions are mainly based on the predator's state, which are Presence, Chasing, and Attacking mentioned in the introduction. Predator is the Presence state if the fish group sees or senses the predator; predator is the Chase state if it's already in the Presence state and is chasing (controlled by the player by holding the right mouse button); predator is the Attack state if it's already in the Presence state and is attacking (controlled by the player by clicking the left mouse button). The overall picture of the maneuver state machine is shown in figure [figure placeholder], and the detail of each state will be explained in the following sections.

5 Fundamental Rules of the Prey Flock

This section describes the prey's fundamental movement rules applied under most maneuvers.

5.1 Boids algorithm

TODO.

5.2 Collision Avoidance

A simple collision avoidance scheme is implemented so prey won't swim into boulders. In each position update, we sample several points on the prey's forward hemisphere and do a ray cast from the prey's origin toward the sample point to detect any collision. [figure placeholder] The unreal engine's physics module handles the implementation of the ray cast. If no possible moving direction is found, which means obstacles surround the fish, then the fish's velocity is set to zero immediately. Otherwise, we pick the target direction as the no collision direction nearest to the desired moving direction produced by the current maneuver. Directions are compared using the angle metric. We interpolate the current prey's direction to the target direction to form a continuous velocity.

6 Prey Fish Maneuvers

In this section, we will describe in detail how the prey fish will behave in reaction to the three different predator states, which are Predator-Present, Predator-Chase, and Predator-Attack.

6.1 No Predator Exists

If the predator is too far away from the fish group to be sensed by the fishes, then the fishes will be in the Wander state. In the Wander state, fishes swim along a fixed spline. Many other implementations of the fish schooling system do a random swim if no predator exists. We choose to implement a spline following rather than a random swim because, in this way, the swim routine is much more controllable for game designers to make the fish interact with other gameplay logic.

At the beginning of the simulation, a fraction of fishes in the fish group are selected as leaders whose desired positions are given by the points on the spline. The desired position point moves along the spline at a constant velocity, computed by an inverse look-up table. Then all other follower fishes' velocities are updated using the three basic boid updating rules to follow the leader. Collision is checked for every fish to avoid swimming into obstacles, described in section 5.2. A demo of fishes following spline with collision avoidance is shown here https://www.youtube.com/watch?v=DskCWU9RzFY&list=PLifb_pFDC6_ycl9CPivZ-H2eX1SqB3lV-&index=2

6.2 Predator-Present State

TODO

6.3 Predator-Chase State

There are two possible maneuvers when the predator is in the Predator-Chase state: Fast Avoid and Skitter.

6.3.1 Fast Avoid

One pre-state of Fast Avoid is Compact, where the transition happens when the predator enters its Chase state. The movement logic of Fast Avoid is the same as Avoid state, except the only difference is that fish's swimming speed increases. Just as in the Avoid state, the fish pick its target velocity's direction to be the vector pointing from the predator to the fish's position so that it leaves the predator in the fastest way. Another pre-state of Fast Avoid is Skitter, which will be discussed below.

6.3.2 Skitter

The pre-state of Skitter is Fast Avoid. After a pre-fixed time amount in the state of Fast Avoid, the state transits to Skitter. The heuristic here is that fishes swim very fast in Fast Avoid, which means they consume lots of energy and need some rest. In the Skitter state, the swimming speed is a bit slower than Fast Avoid, and the target velocity direction is randomly picked in order to confuse the predator. After another pre-fixed time amount in the Skitter state, if the predator is still chasing, the then state transits back to Fast Avoid, forming a cycle.

A video demo of Fast Avoid and Skitter maneuvers is provided here https://www.youtube.com/watch?v=mWJpQPLezk4&list=PLifb_pFDC6_ycl9CPivZ-H2eX1SqB3lV-&index=3

6.4 Predator-Attack State

In the predator-attack state, the predator will perform an attack on the prey flock by doing a brief but fast forward burst towards the target. Depends on the...., the prey flock will exhibit different maneuvers.

6.4.1 Herd Maneuver

When the predator performs an attack near the fish group, the flock has a chance to perform a Herd maneuver. The target velocity direction of fishes in the flock is picked to be the direction from the predator's position to the centre of the fish flock, which is the average position of all fishes of that flock. This maneuver creates the effect of herding the fishes from the back. A video demo of the herd maneuver is provided https://www.youtube.com/watch?v=BvdJoIgQV8U&list=PLifb_pFDC6_ycl9CPivZ-H2eX1SqB3lV-&index=4

6.4.2 Fountain Maneuver

The prey fish exhibit fountain maneuver if...

In this state, the prey fish will firstly divide into two group, then they will turn around and join behind the predator in a semi circle like trajectory. The two escaping groups are determined by the position of the prey fish relative to the predator. Divided by the predator's heading direction, the left and right halves will turn left and right accordingly, and swimming circularly towards the direction opposite to the predator's heading direction. Once the prey fish is behind the predator, they will reunion as a group and run away from the predator straghtly.

6.4.3 Hourglass Maneuver

The prey fish exhibit hourglass maneuver if...

6.4.4 Flash Maneuver

The prey fish exhibit flash maneuver if...

Once the predator attacks, the prey school will explode into all directions and swiftly swimming away from the predator. The flashing direction of a fish is the optimal direction that allows them to run away fast from the predator, plus some randomness. After a short time of explosion (0.6 seconds), The prey fish will turn around and come back straightly towards their starting position to join again as a flock. The joining speed will be relatively slower than the explosion speed, as in the explosion stage the prey fishes consider themselves in a more dangerous situation than the joining stage.

6.4.5 Split Maneuver

Split is the maneuver the prey flock will exhibit when they receive consecutive attacks by the predator within a short time period. During the first attack, they prey fish will exhibit other escaping maneuver described above, such as fountain or hourglass. Even through the prey flock may divides into subgroup while escaping, they will try to maintain the shape of a single flock by quickly reunion together after avoiding the attack. However, if the predator attack again during the reunion, then the prey flock will consider themselves under an extremely unsafe environment. They exhibit split maneuver and divide into different subgroups. Firstly, similar as in the fountain maneuver, the prey flock will divide into sub-groups

based on their position relative to the predator. In the same time, a leader of each sub-group, who is the farthest fish from the predator, will be determined. And the leader will lead the subgroup to run away from the prey fish while separating away from other sub-groups, so that the chance of each sub-group been chased by the predator will be reduced.

6.4.6 Join Maneuver

Join maneuver is exhibit as a follow-up reaction to the division of the prey flock. After the prey flock divides into subgroup while avoiding the attack from the predator, the subgroups will join back as a single flock when the environment is less dangerous. Not only will the prey fish perform join behavior after the split behavior, but also they may perform join behavior after other maneuvers where the prey flock may split, such as fountain maneuver. In terms of implementation, join maneuver is an exhibition of the Boids algorithm among the whole prey community, where the Cohesion component is enhanced to encourage the reunion.

7 Conclusion

TODO.

References

Siân W. Griffiths and Anne E. Magurran. Familiarity in schooling fish: how long does it take to acquire? *Animal Behaviour*, 53(5):945–949, 1997. ISSN 0003-3472. doi: https://doi.org/10.1006/anbe.1996.0315. URL https://www.sciencedirect.com/science/article/pii/S0003347296903152.