15464 2019 Spring Final Project Final Report: Flock simulation

Name: Yi Ting Kristy Tsai (AndrewID: yitingts)

1 Project description

1.1 Motivation

Originally I have planned to do the hair simulation using mass spring model, however, after struggling to code the framework from scratch and set up hair rendered hair strands, I think I have overlooked the problem, and I am worrying that I might not be capable of achieving. Therefore, I would like to propose another topic which I have an initial result and it is one of my final project pitches. I am as well interested in the flock simulation and there are multiple resources and explanations which makes me more comfortable about. I have seen the simulated flock avoiding cylindrical obstacles video (1986) a long time ago, although it is an old topic, I feel like it would still be nice to implement one myself.

1.2 Goals

The project primary goal is to simulate how flock behaves using the boids algorithm, and design an interface to let user interactively see the result with different weights of parameter. Second goal is to test the implementation with different test cases of scenarios and compare the result. Third goal is to understand more of existing software of flock simulation nowadays.

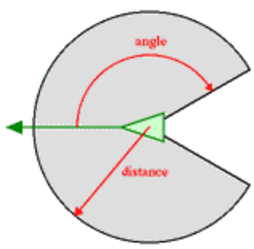
2 Approach

2.1 Implementation

My implementation is done in Unity3D using C#.

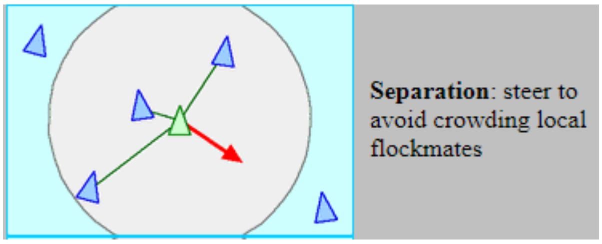
The boid algorithm is an artificial life simulation firstly introduced by Craig Reynolds in 1986 and the idea is that each entity is referred as a "boid" or "flock agent" and they move accordingly by certain rules. There are three basic rules: **separation/avoidance**, **alignment**, and the **cohesion**. The program manages to generate and display the flocking behavior.

Boid: Set up boids. Each boid has their own velocity, orientation and position and is calculated in each frame relative to its neighbor's. A neighborhood is a region to define where the other boids would be influenced. The neighborhood's distance and angle could be calculated from the boid's direction of flight.

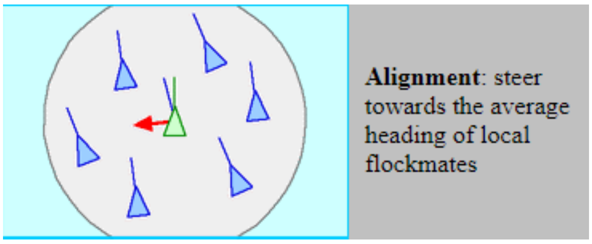


a boid's neighborhood

Separation: In order to prevent overcrowding, each boid applies a repulsive force in opposite direction to its neighbor. The force is scaled by the inverse of the distance.



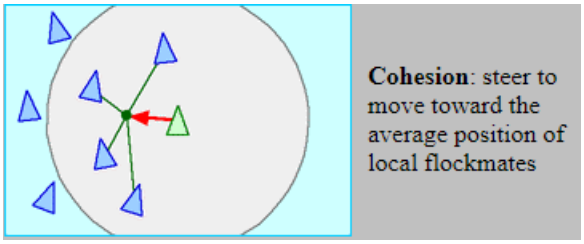
Alignment: In order to show boids align together, calculate average velocity of neighbors and apply this as a force on the boid.



Cohesion: In order to group the boids, compute the average position of its neighbors P_{AVG} and d is the direction vector pointing to P_{AVG}. To get d, simply subtract the average position with current boid position p. And compute the steer vector V_{Steer} with d and current velocity v and steer to the position.

$$d = P_{AVG} - p$$

$$V_{Steer} = d - v$$



Avoid obstacles: Filter the obstacle layer and physics layer in Unity3D.

If on the obstacle layer, boid will avoid the obstacle, and steer away.

Interface: Using the Unity3D's game object based UI system.

3 Deliverables

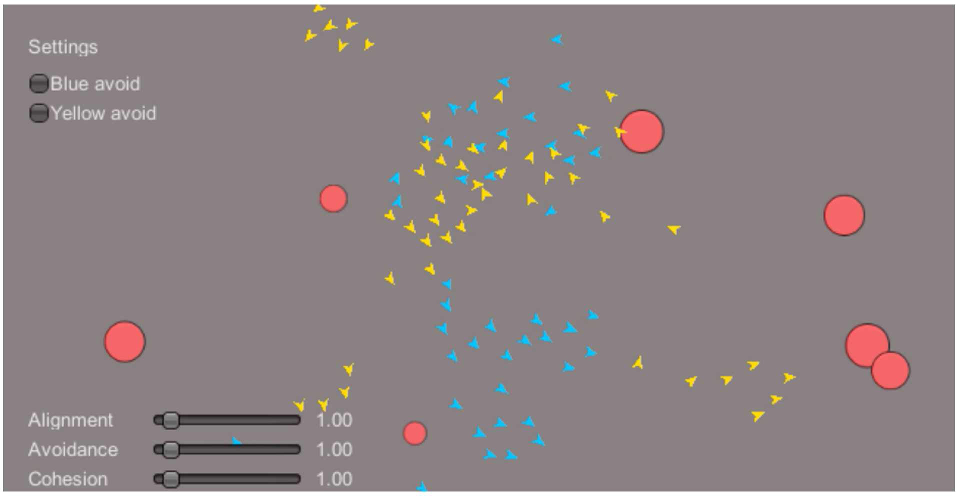
These are the deliverables I have made in the proposal stage and I revise it a bit after the goal has changed a little bit. I have been able to complete most of the part. I was not able to convert 2D to 3D since I want to focus more on how to evaluate the result I had right now. Instead, I tried the Mash plugin in Maya to create a flocking animation in 3D world.

	Deliverables	Expected date
Stage 1	~~Setup flock in Unity~~ ~~Complete flock behaviors~~	4/23
Stage 2	~~Add avoiding obstacles behaviors~~ ~~Create user interface for interactive adjustment of parameters to show results with different flock simulation~~	5/3
Stage 3	~~Compare different behaviors and run through test case~~ Convert 2D to 3D version of the flock simulation	5/10

4 Result

4.1 2D flock simulation with interface

This is the user interface for the 2D flock simulation built in Unity3D. The red circles are represented as obstacles. Blue and yellow arrow sprites represent two group of flocks. There are different iterations of the version. The red circles are adjusted to larger version so that the collide of the flock with red circle is more obvious. User could drag the slider bar at the left bottom and adjust different weights of the three rules. By clicking the toggle button, the blue and yellow flock will avoid the red circles accordingly.



4.2 Test case

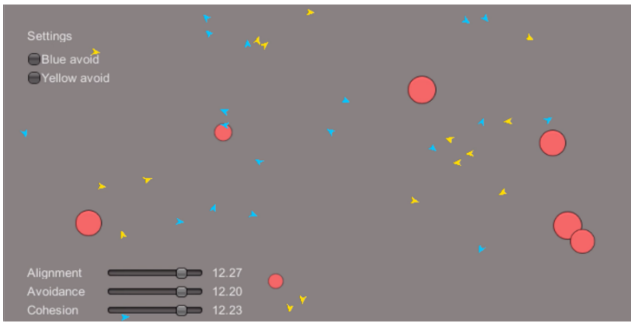
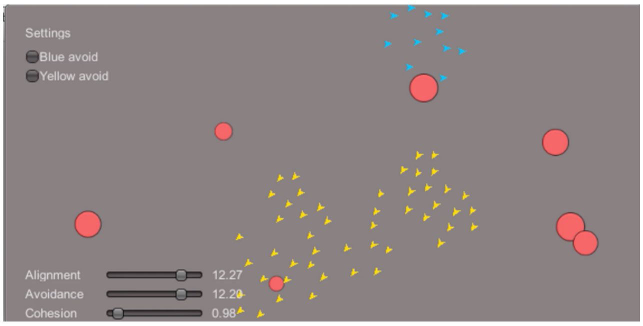
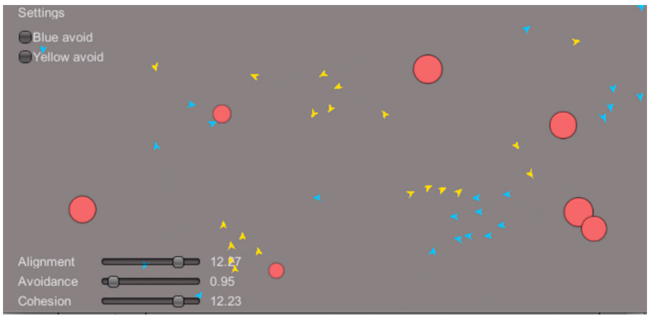
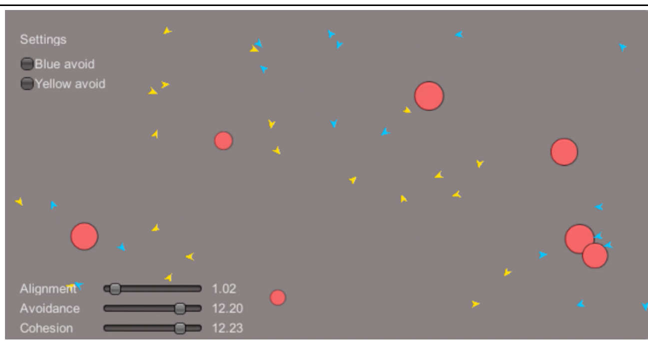
In total, I have separated the test case in two kinds of scenario and tested with different test cases. To see the result more clearly, all the video files are attached in the folder.

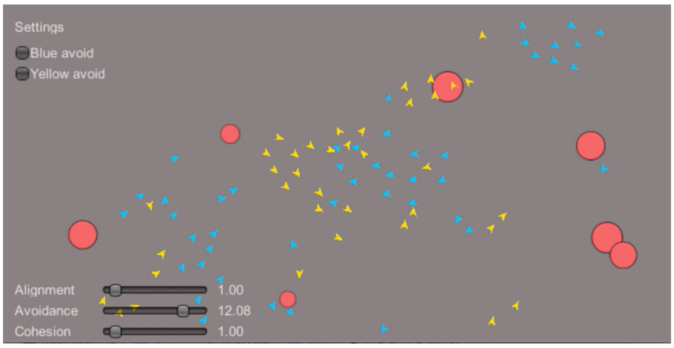
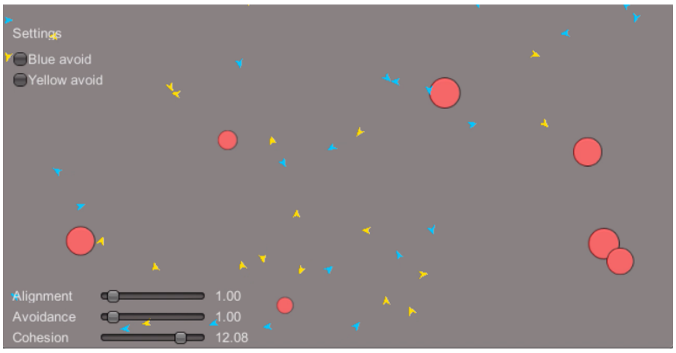
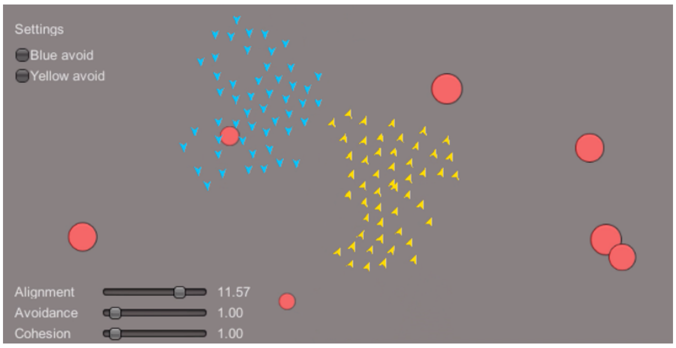
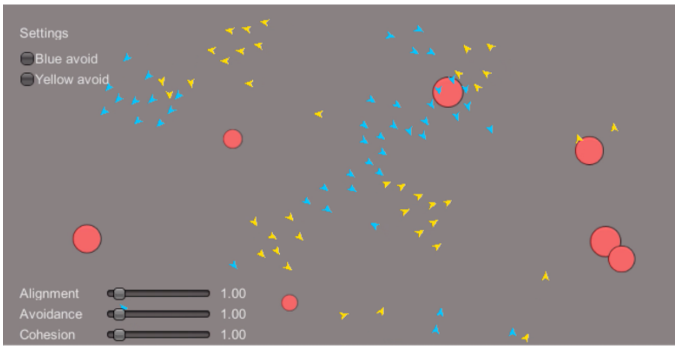
Scenario 1: Given Equal amount of two groups of flock

Preset: Blue has an amount of 50 boids in starting, Yellow has an amount of 50 boids in starting.

A: Alignment weights S: Separation/Avoidance weights C: Collision weights

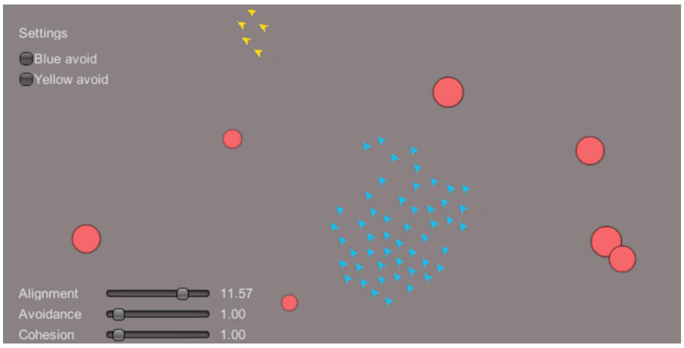
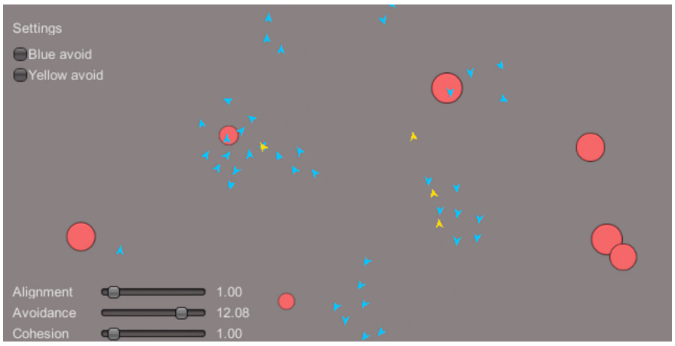
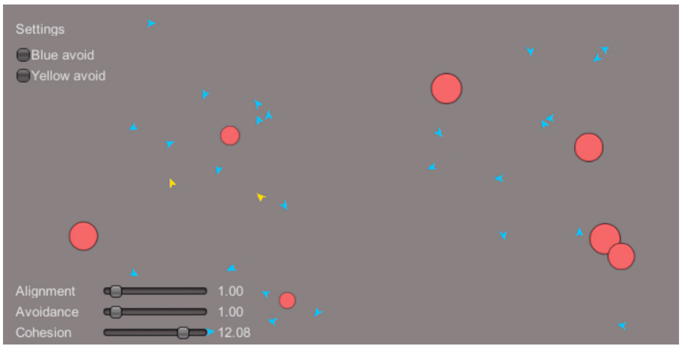
H: High influence (set to 12) L: Low influence (set to 1)

Test case 1: A->H, S->H, C->H		The boids behave more naturally like a flock, which since it takes in all the weights and stays at a balance stage.
Test case 2: A->H, S->H, C->L		The boids separate in the very beginning. They align well together and sometimes they separate and merge again.
Test case 3: A->H, S->L, C->H		The boids are separated into small amount of groups and each group still group together.
Test case 4: A->L, S->H, C->H		The boids are all separated, however since avoidance is influencing the system, small amount of boids still form small groups

Test case 5: A->L, S->H, C->L		The boids flock together and then separate and then flock again in cycle.
Test case 6: A->L, S->L, C->H		The boids do not group together at all.
Test case 7: A->H, S->L, C->L		The boids flocks into two group of boids and do not separate.
Test case 8: A->L, S->L, C->L		The boids behave more naturally like a flock and stays at a balance stage. The amount of a group of boids is larger when they group together than *test case 1*.

Scenario 2: Given one group of flock has larger amount than the other

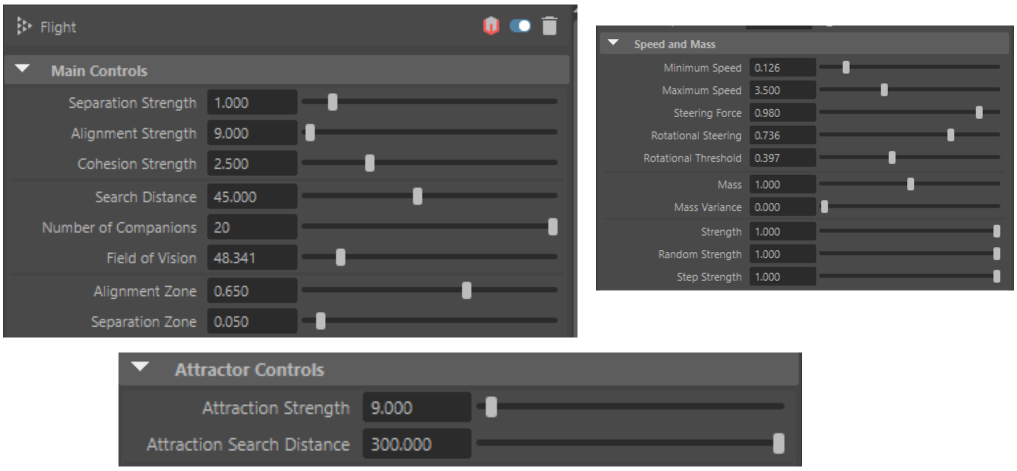
Preset: Blue has an amount of 50 boids in starting, Yellow has an amount of 5 boids in starting.

Test case 9: A->H, S->L, C->L		The boids flock into two group of boids and do not separate.
Test case 10: A->L, S->H, C->L		The boids are hard to flock together.
Test case 11: A->L, S->L, C->H		The boids do not group together at all.

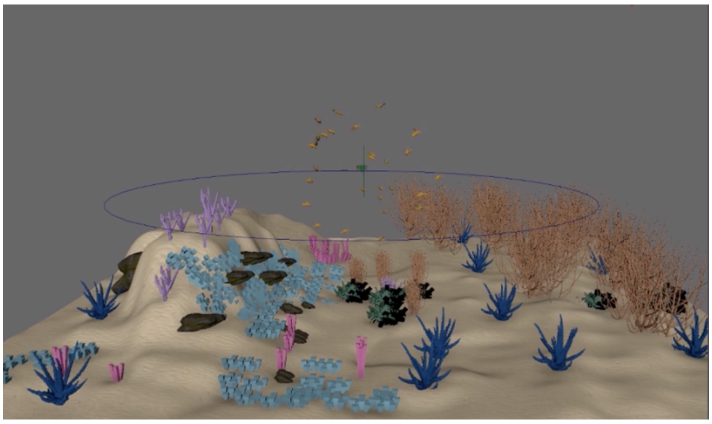
4.3 Existing software on flock simulation

4.3.1 Maya Mash fish swarming simulation

Mash is a Maya plugin, that artist could create flight node which is a multi-threaded simulation node that approximates flocking behavior by attaching objects to a number of points. Below is the setup for the first try of fish swarming simulation following a motion path.

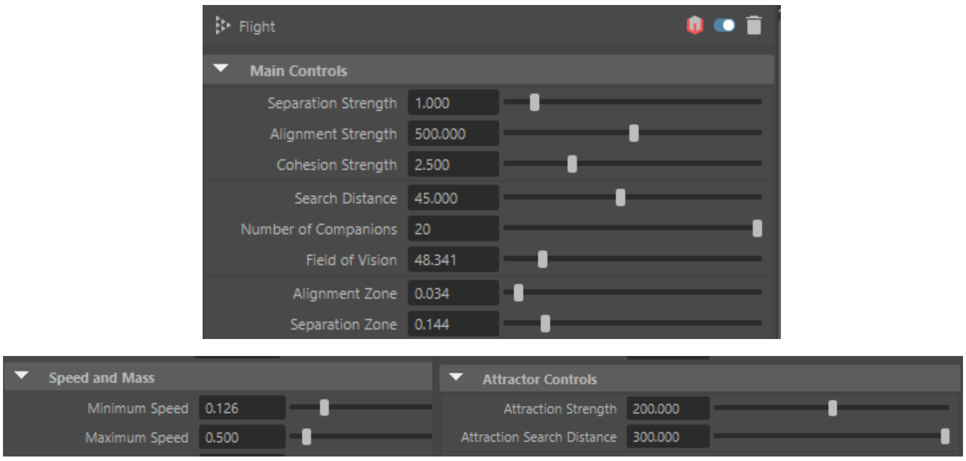


Separation is set to 1. Alignment is set to 9. Cohesion is set to 2.5.

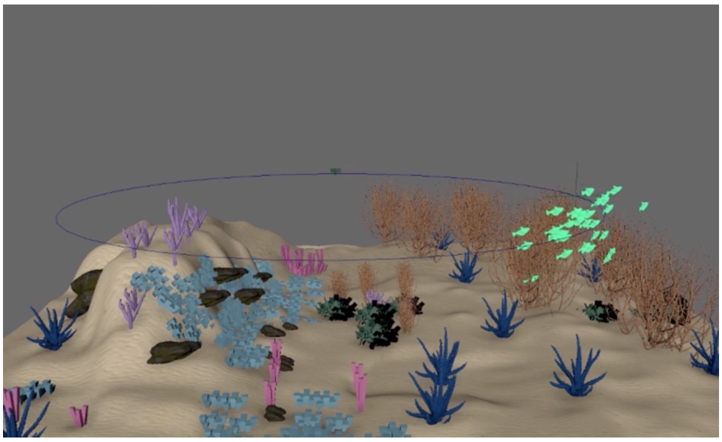


The result of the first try is too dynamics and it seems more like a bird or butterfly flocking simulation than the fish swarming.

For the second try, I adjust the alignment strength to extremely high and slow down the maximum speed and increase a new parameter called attract strengths which helps with grouping the flock together more to follow the path given.



Alignment is 500. Maximum speed is reduced to 0.5. Attraction strength is 200.



The result of the second try is still slightly dynamics during some time frames, however, they are more align to the path and looks more like a school of fish.

5 Discussion

5.1 Discussions

From the test case, we could conclude a few things.

Compare *test case 3* and *test case 7*, once the cohesion weights have been set to high, the cohesion factor will overcome alignment weight and results in a total separation of boids. Cohesion is a relatively strong factor for steering. Moreover, compare *test case 9* and *test case 11*, the smaller amount of flock compared to larger amount of flock is easy to flock together when the alignment is strong, and harder to flock together when the cohesion is strong.

To do a self-evaluate, I think the system of 2D flock simulation I implemented is standard and good for quick visualization of result for larger amount of flock. The cons about this system is that since every boid is flying around the scene, it is hard to tell the difference sometimes and to find the specific behavior that user is looking for.

To create different species of flocking, not only the weights are different, the neighborhood radius of how many neighbors are going to affect the boid or the maximum speed will result in big difference. For example, Fish swarms focusing more on alignment and grouping and butterfly or birds have less influence from the neighbors, so that they would fly dynamically.

5.2 Difficulties

The boid model itself is intuitive to understand the math and implementation. However, the system is hard to evaluate the correctness or different behaviors with various control. Since they are flying all around the scene and it's difficult to see if the result is correct or what is the difference between different weights of the rules. Therefore, I decided in the end after the consultation to do a quick test case with different weights or different amounts of boids. I still feel like the comparison is not very accurate and it is more like an observation of the behaviors. However, I think definitely listing out all the possibilities of different weight focuses could help me understand more how each rule influences and affects each other.

Another difficulty that I have encountered is when using the Mash tool, I thought it will be intuitive to simulate real life scenario, however, there are more factors to consider which lead to a more complicated situation. To get the correct result is not that easy for the artist.

5.3 Rooms for improvement

If I had more time, first I would like to explore more on different behaviors, for example: goal seeking or fleeing from predators. Since the tool in Maya from what I have tried out is not that intuitive, I would like to create my own script for it with different behaviors of species preset for the artist. Last, I would like to look into the steering optimization, since in some situation the arrow sprite in my implementation will have jittering effect when steering, this situation which might have some influence from the steering force.

6 Conclusion

Although the idea of boid algorithm is introduced a long time ago, and I am implementing the basic model of it, however, I have understand how the three rules work with mathematical background and I have tried out the existing software as well and at first I am amazed that solely three basic rules could simulate birds fly, and now I understand there are more than the base rules and it is sometimes hard to control the flock in the existing software still.

Resources

- Flocks, herds and schools: A distributed behavioral model Reynolds, C. W. (1987). (Vol. 21, No. 4, pp. 25-34). ACM.
- An improved fast flocking algorithm with obstacle avoidance for multiagent dynamic systems. Wang, J., Zhao, H., Bi, Y., Shao, S., Liu, Q., Chen, X., ... & Ha, L. (2014). *Journal of Applied Mathematics*, *2014*.
- Boids Pseudocode (http://www.kfish.org/boids/pseudocode.html)
- Maya flight node (https://knowledge.autodesk.com/support/maya/learn-explore/caas/CloudHelp/cloudhelp/2016/ENU/Maya/files/GUID-94DB481F-FFD5-4C5D-B2CF-8011DCD8C547-htm.html)