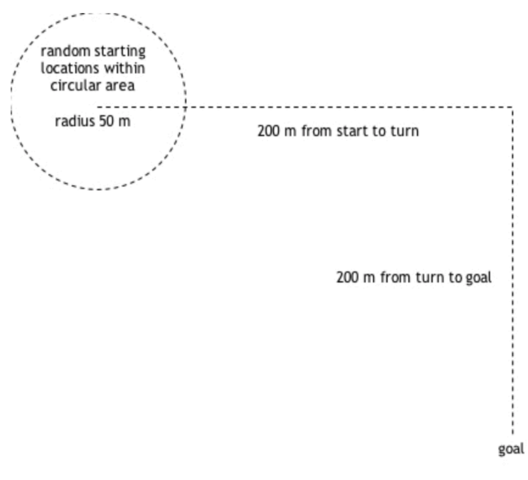
General setup

Basic Scenario: 25 holonomic circular robots of radius 0.25 m with 360-degree field of view sensors of range 50m form a flock and move together through a marked course to a goal location with minimal collisions between each other. The sensing of each robot is perfect, that they all may home toward both the line through the course and the goal location, but that each robot may not explicitly communicate with any other robot. The goal of robots is to minimize the average distance of each robot from the centroid of the distribution of robots without colliding and minimize the distance of the centroid from the closest point on the line at each time step while making progress toward the goal location.



This case study implemented three conditions of robot collectivity: Regular Case, Following Case and Herding Case. The regular case follows from the basic scenario described above. The following and herding case no longer assume that all the robots may home toward the line through the course and the goal location, but instead assume that only a fixed proportion of 25% or less of the robots may do so and the rest will only flocking and following, or flocking and being herded, respectively.

General robot settings: In all these cases, robots are initialized at random positions within the range of 50m circle centered at the start position. Each robot will move away from the others if other robots are detected in its “comfortable zone”. This collision avoidance behavior always has the **highest priority**. And each robot cannot communicate with any of the other robots directly but only can sense the robots within its sensor's range.

Regular case setup:

Video Link: https://youtu.be/-b35uZ_aXow

In this case, after initializing position, each robot will obey the following rules:

1. Collision detection always has the highest priority, all the other tasks need to be halted for avoiding collision until no robots are detected in the "comfortable zone".
2. If the collision avoidance part dose not in charge, each robot will keep moving right and calculating the centroid of surrounding robots that are in the sensor's range.
3. If the a robot's calculated centroid attain to the first check point, this robot will turn and keep going downwards to the final destination. This rule can effectively address the problem that robot will turn one by one, without flocking, at the first check point because the robot use the position of calculated centroid point deciding whether turn or not but not its own position. The figure below on the left shows the turning without flocking problem and the figure on the right solving this issue by following rule 3.

Figure: Without following Rule #3

Figure: Following Rule #3 can help robots keep flocking while turning

Following case setup:

Video Link: https://youtu.be/9Qxhwvmal_4

In this case, after initializing position, each robot will obey the following rules:

1. Collision detection always has the **highest priority,** all the other tasks need to be halted for avoiding collision until no robots are detected in the "comfortable zone".
2. After handling potential collision after setting the robot positions randomly, the group of "leading" robots will moving to the front of the group of "following" robots. Specifically, this action can be implemented by giving the incentive the centroid of

"leading" robots always in front of the centroid of "following" robots at least 5m. And this rule always have the **2nd highest priority.**

3. The "leading" robots calculate their centroid while moving and following the same turning rule as mentioned in rule 3 of regular case.
4. All the "following" robots only flocking or following the "leading" robots that are in their sensor's range.

Herding case setup:

Video Link: https://youtu.be/KKjPKfNI79A

In this case, after initializing position, each robot will obey the following rules:

1. Collision detection always has the **highest priority,** all the other tasks need to be halted for avoiding collision until no robots are detected in the "comfortable zone".
2. After handling potential collision after setting the robot positions randomly, the group of "herding" robots will moving to the back of the group of "herded" robots. Specifically, this action can be implemented by giving the incentive the centroid of "herding" robots always in back of the centroid of "herded" robots at least 5m. And this rule always have the **2nd highest priority.**
3. All the "herded" robots only flocking or avoiding the "herding" robots that are in their sensor's range. So they can be "pushed" by the herding robots.
4. The "herding" robots calculate their centroid while moving and following the same turning rule as mentioned in rule 3 of regular case.

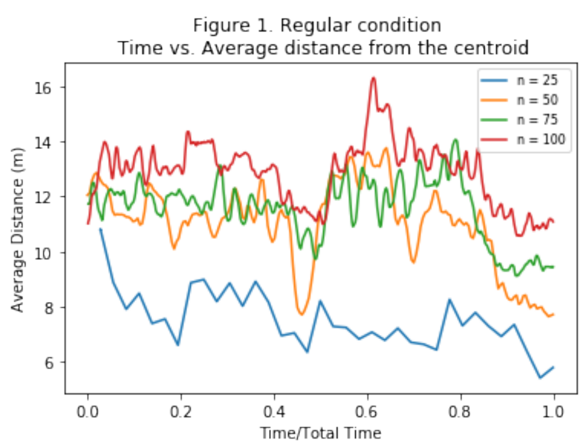
Experiment setup and Result

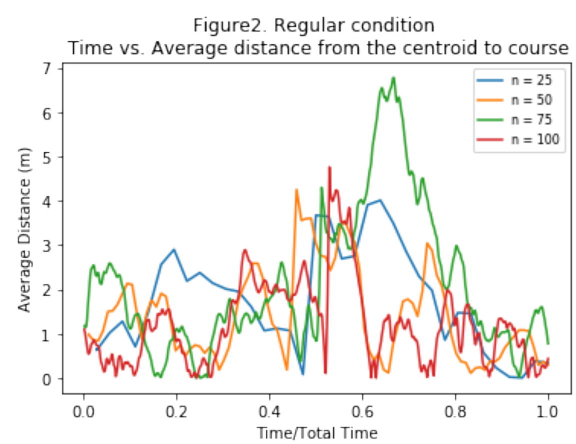
This report analyze the relationship between time and the average distance from each robot to the flock centroid and the average distance from the flock to the predetermined course with varying number of robots in different condition (regular, following and herding). Please notice that because of the slowness when running 75 and 100 robots on herding case, these two experiments has been aborted and only 25 and 50 robots in herding case will be discussed.

All the x-axis in the following figures refer to the current time divided by the total time, so it can reflect how much proportion to the overall progress has been accomplished. For example, 0.6 refers to 60% overall progress.

Regular Case:

As shown in the Figure 1, the average distance will ascend as the number of robots increasing. This is because when we experiment with more robots, the size of flock will become relatively larger and it is reasonable to have larger average distance from the flock centroid when we have more robots. And several peaks around 60% overall progress have been observed while experiment with 50, 75 and 100 robots and they both appeared in Figure 1 and Figure 2. Notice that 60% of overall running time is approximately the point where the robot flock need to turn. And because turning has higher priority as described in the algorithm above, both the average distance to the centroid and the average distance deviated from the desired course will increase while perform turning.





Following Case:

When comparing Figure 3 with Figure 1, the average distance to the centroid vibrate substantially. This is because the robot flock are partitioned into two separate groups and the attractive force between these two groups could increases the instability.

Figure3. Following condition
Time vs. Average distance to the centroid

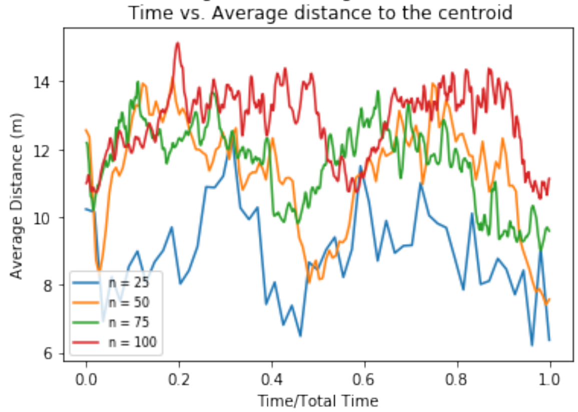
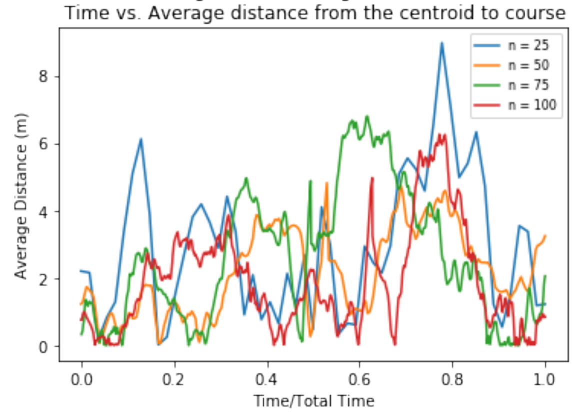


Figure 4. Following condition
Time vs. Average distance from the centroid to course



Herding Case and Other Results:

Figure 5 and Figure 6 shows the difference between three experimental cases with 25 and 50 robots. In herding case, robots always have relatively lower deviation from the centroid because the herding group is “pushing” the herded group and they still tend to forming on flock. Conversely, in the following case, robots tend to have a larger distance to their centroid because the leading group is alway ahead of following group and there are always two separate flock until attained to the final goal.

Figure5. Regular vs Following vs Herding n=25
Time vs. Average distance to the centroid

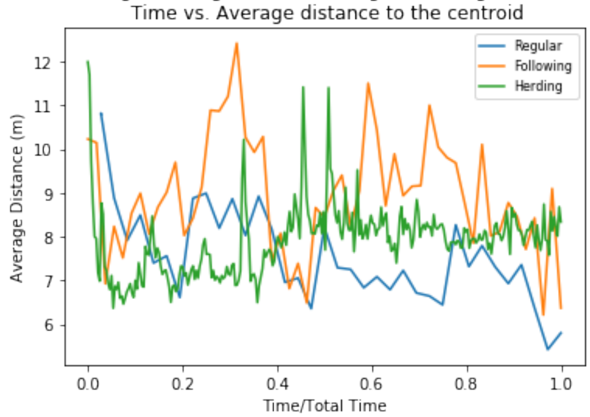


Figure6. Regular vs Following vs Herding n=50
Time vs. Average distance to the centroid