Swarm Intelligence

NWI-IMC042 Natural Computing

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1 Experimental design

To execute the experiments, we created a circular racetrack, consisting of lines and arcs, as shown in the assignment, see Figure 1. A number of extra “forces” are added to make the boids roughly stay on the racetrack and follow its course in a clockwise circular motion. More details on that are described in section 1.1.

We do not use every individual boid’s passing of the measurement section to generate datapoints for the FD graph. Instead, we take a measurement every 10 timesteps and get the number of boids in the measurement section, as well as their speeds. In real life, the speed of a person cannot be measured by looking at only one timestep, but with the simulated boids, it is trivial.

We thus only take a subset of the boids going through the measurement zone. We find this reasonable, since it makes the computations and thus simulation speed much more manageable. Although there are quite a few “0-samples”, meaning that there were no boids in the measurement zone at this time, we still get more than enough valid data points, since we leave the simulation running for a while[1]. The stochasticity of whether a boid happens to be in the measurement zone at a given timestep is also taken care of by running the simulation for long enough, and the reasonable size of the zone.

1.1 Implementation details

We chose to implement the racetrack in terms of “soft” constraints by adding extra ”forces” pushing the boids onto the racetrack and creating a circular motion around it. This way, the randomly spawning boids naturally find their way onto the racetrack and follow its path. We found this implementation more interesting, also because the other forces acting on the boids can pull them off the racetrack for a moment, leading to more interesting interactions in the swarm.

It took us quite some time to fine-tune the boundaries and intensities of these extra forces to reach a satisfactory result. While the boids do not perfectly stay on the racetrack all the time (sometimes also because they are affected by the ablation forces), they roughly follow its shape and deliver, in our opinion, interesting results.

The code snippet for that is shown in the Appendix (section 5).

[1] 1000 timesteps was our standard setting, creating 100 samples with a varying number of boids.

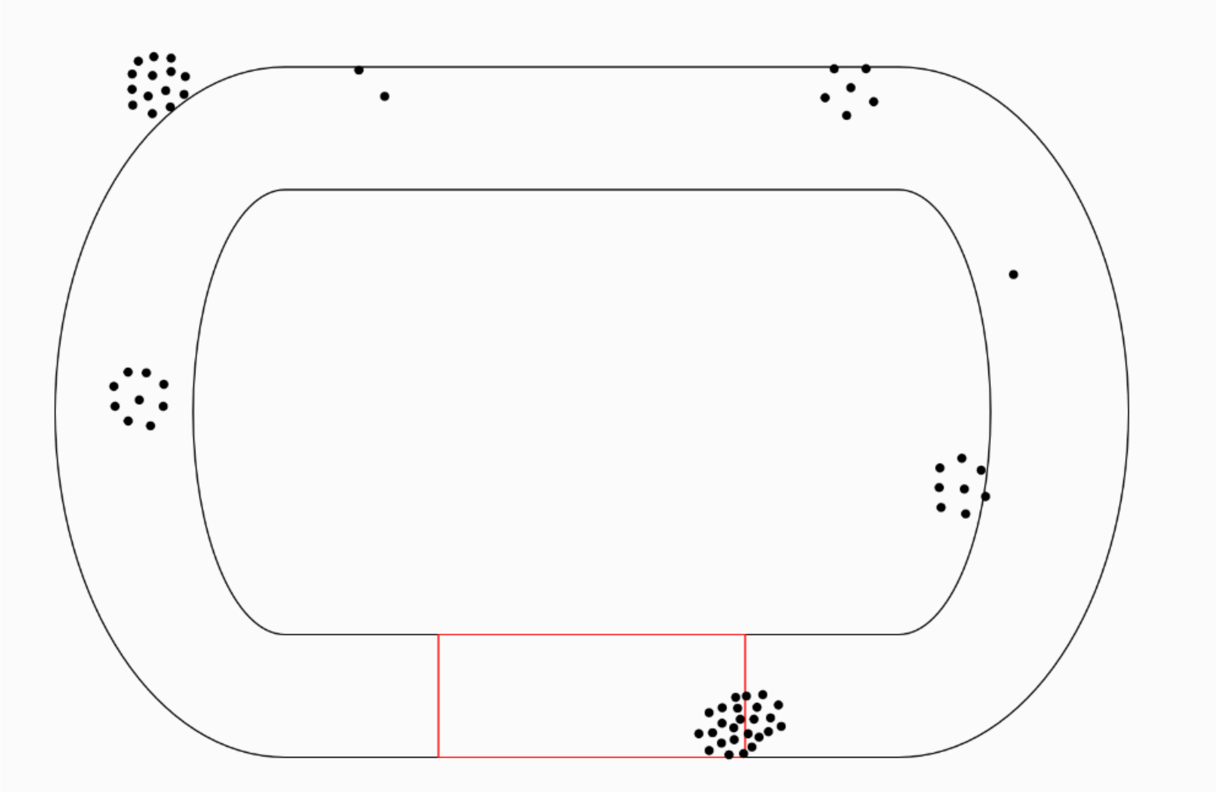

Figure 1: Experimental setup. The boids are following the circular racetrack. The measured section of the racetrack is shown in red.

2 Initial simulations

To simply answer the question whether "the fundamental diagram resembles that of human pedestrians", no it does not (see fig. 2). As seen in the figure, the slope does not resemble the same slope as in the aforementioned figure of human pedestrians. While the average speed varies for the different densities, it does not appear to systematically decrease with an increasing density.

3 Ablation study

For the ablation study the Alignment, Cohesion and Separation variables were switched off separately and afterwards in pairs. The results were plotted in scatter plots, where the density (in Boids/m^2) is plotted against the average speed (in m/s) of the boids.

3.1 Alignment

When the alignment variable is switched off there is no clear decrease in speed for the boids. However a notable change can be seen in this fundamental diagram (see fig. 3a) as opposed to the aforementioned standard fundamental diagram (fig. 2), namely the fact that the density varies greatly. In fig. 3a, the density varies between 0 and 12. This can be explained by the fact that without alignment the boids cannot move together as a group in the same direction, but whenever a group is formed they can stick together (due to the fact that cohesion is still active). So this movement becomes random and thus whether a higher density group forms becomes also more random.

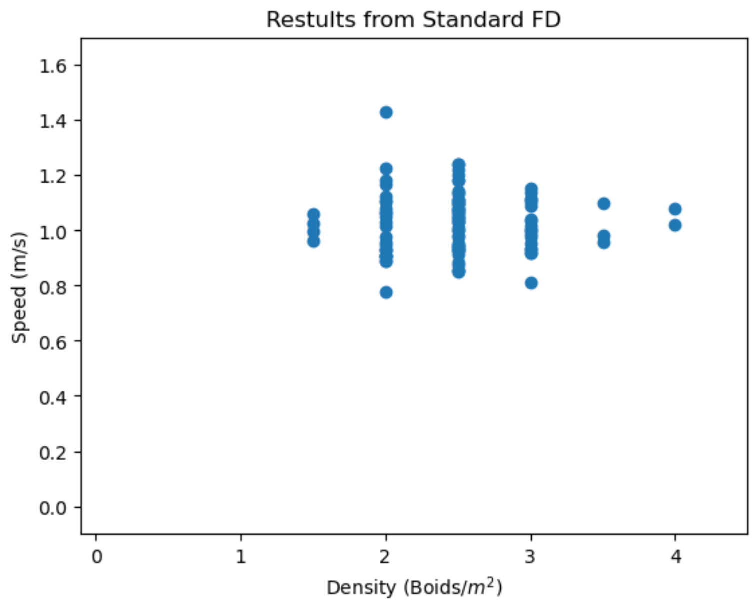

Figure 2: The fundamental diagram with alignment, cohesion and separation.

3.2 Cohesion

Without cohesion the results showed that the densities varied more than the standard fundamental diagram (fig. 3b). Where before they varied between 1.5 and 4 boids/m^2, they now vary between 0.5 and 6 boids/m^2. This change in density could be explained by the fact that without cohesion it is more likely that groups of boids separate. However the boids still have the same alignment to each other, so when they move around the track it is still likely that multiple boids cross the measurement area at the same time.

3.3 Separation

Without separation the results showed that the densities of the boids varied less than the standard fundamental diagram. Where before they varied between 1.5 and 4 boids/m^2, they now vary between 1.5 and 3.5 boids/m^2 (fig. 3c). This change in density can be explained by the fact that without separation it becomes more likely for groups of boids to form. Due to the nature of randomness in the initializing phase, it is likely that multiple smaller groups of boids have formed. Moreover, since there is no separation, the likelihood of breaking from the group is lower. Thus explaining that the density does not exceed 3.5 boids/m^2.

3.4 Combinations

For the fundamental diagrams without combinations of the variables, we will firstly discuss alignment and separation, alignment and cohesion and lastly cohesion and separation.

Simulating the boids without the alignment and separation variables, results in a fundamental diagram (fig. 4a) that shows the same characteristics as the fundamental diagrams as shown in fig. 3a,c. The variation in density is similar to that of fig. 3c, while the average speed is more similar to that of fig. 3a.

Secondly, when simulating the boids without the alignment and cohesion variables, the resulting fundamental diagram (fig. 4b) represents a diagram, which is the combination of diagrams fig. 3a,b. The average speed again matches that of fig. 3a, while the variation in

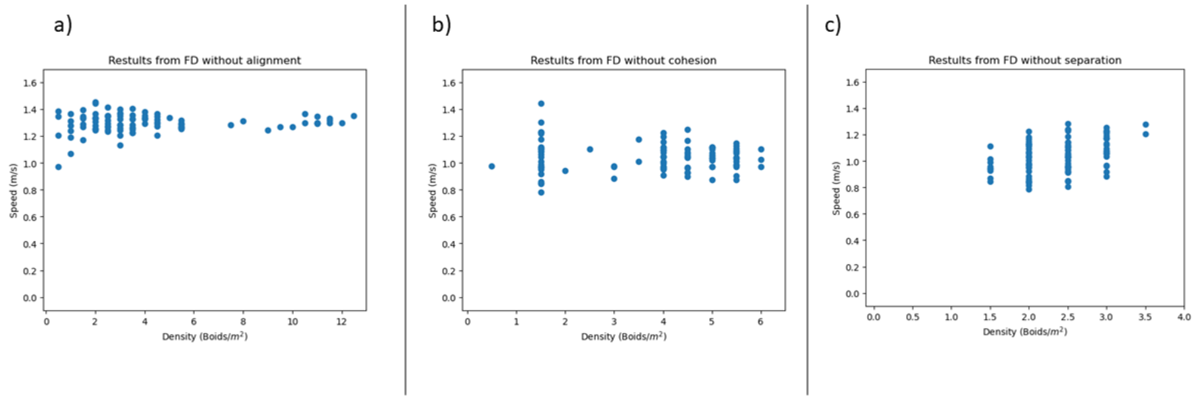

Figure 3: Fundamental diagrams without (a) Alignment (b) Cohesion (c) Separation.

density lies between fig. 3a and b.

Lastly, the resulting fundamental diagram of the simulation without cohesion and separation (fig. 4c), shows the combination of diagrams fig. 3b,c. The variation in density shown in fig. 4c resembles the variation in fig. 3c, while the variation in average speed resembles fig. 3b more closely.

3.5 Without everything

For the last simulation all the variables (alignment, cohesion and separation) are switched off. The resulting fundamental diagram shows large variation in both average speed and density (fig. 5), in contrast to the original fundamental diagram. The influence of the alignment variable can be seen in the variation of densities being spread between 0 and 12 boids/m^2. The influence of the cohesion variable can be seen in the spread of average speed. The influence of the separation variable can be seen in the larger group of densities around 0.5 and 5 boids/m^2.

4 Conclusion

So to conclude the general effects of Alignment, Cohesion and Separation on boids following a racetrack. The alignment variable affects the average speed and variation in density of the boids, generally increasing both when switched off. The cohesion variable affects the spread of average speed and increases the variations in density when switched off. Lastly the separation variable affects the group density, generally increasing the amount of smaller density groups when switched off.

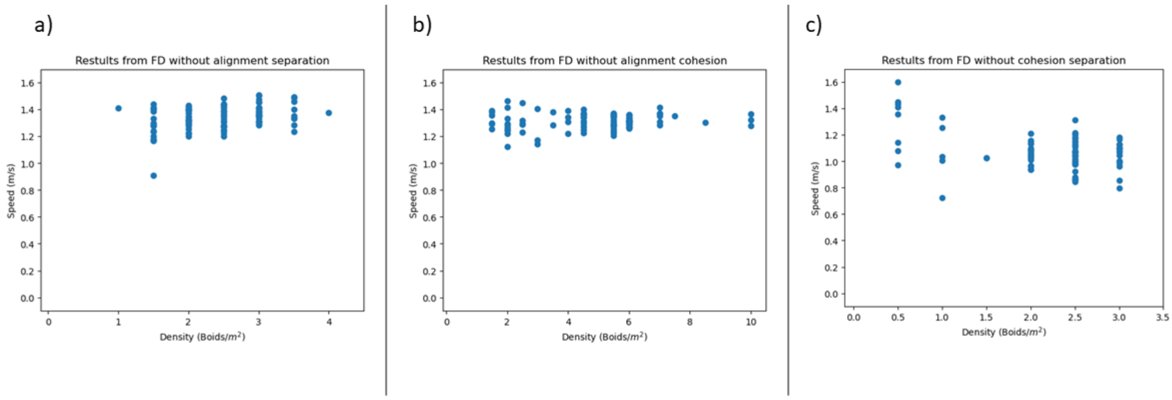

Figure 4: Fundamental diagrams without (a) Alignment and Separation (b) Alignment and Cohesion (c) Cohesion and Separation.

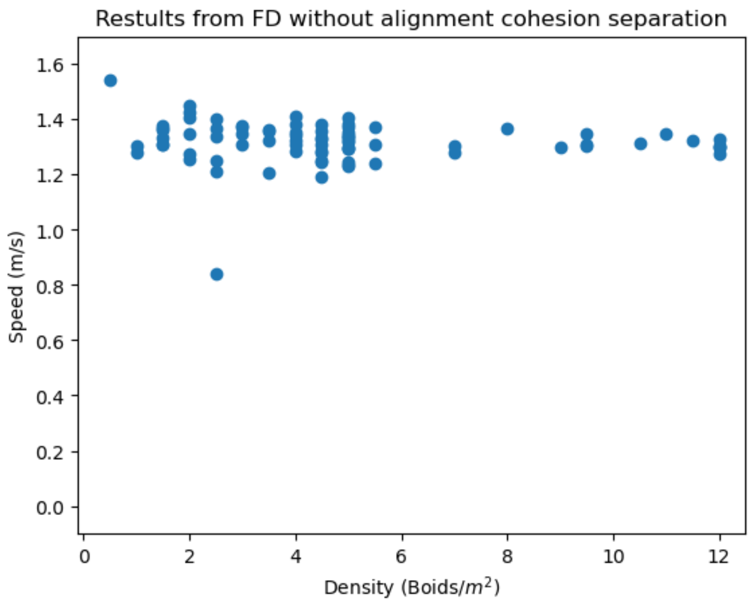

Figure 5: Fundamental diagrams without Alignment, Cohesion and Separation.

5 Appendix

The following code is used to steer the boids onto the racetrack and make them move in a circular movement around it.

```
// circular motion
if (150 < this.pos.x && this.pos.x < 650){
  if(230 < this.pos.y){
      this.dir.add(createVector(-0.3, 0))
  }
  if(this.pos.y < 420){
     this.dir.add(createVector(0.3, 0))
   }
}

if(100 < this.pos.y && this.pos.y < 550){
  if(this.pos.x < 200){
    this.dir.add(createVector(0, -0.1))
  }
  if (this.pos.x > 600){
    this.dir.add(createVector(0, 0.1))
  }
}

// push particles onto racetrack
if (100 < this.pos.x && this.pos.x < 700){
  // straight lines
  if (this.pos.y < 100){
    this.dir.add(createVector(0, 0.1))
  }
  if(180 < this.pos.y && this.pos.y < 325){
    this.dir.add(createVector(0, -0.1))
  }
  if(325 < this.pos.y && this.pos.y < 470){
    this.dir.add(createVector(0, 0.1))
  }
  if(550 < this.pos.y){
    this.dir.add(createVector(0, -0.1))
  }
}else{
  // curves
  let middle = createVector(400, 325)
  let dist = abs(p5.Vector.dist(middle, this.pos))

  if(this.pos.x < 400){
    // left half
    if(dist < 280){
      this.dir.add(createVector(-0.3, 0))
    }else if(dist > 330){
      this.dir.add(createVector(0.3, 0))
    }
  }else{
    // right half
    if(dist < 280){
```

```
      this.dir.add(createVector(0.3, 0))
    }else if(dist > 330){
      this.dir.add(createVector(-0.3, 0))
    }
  }
}
```