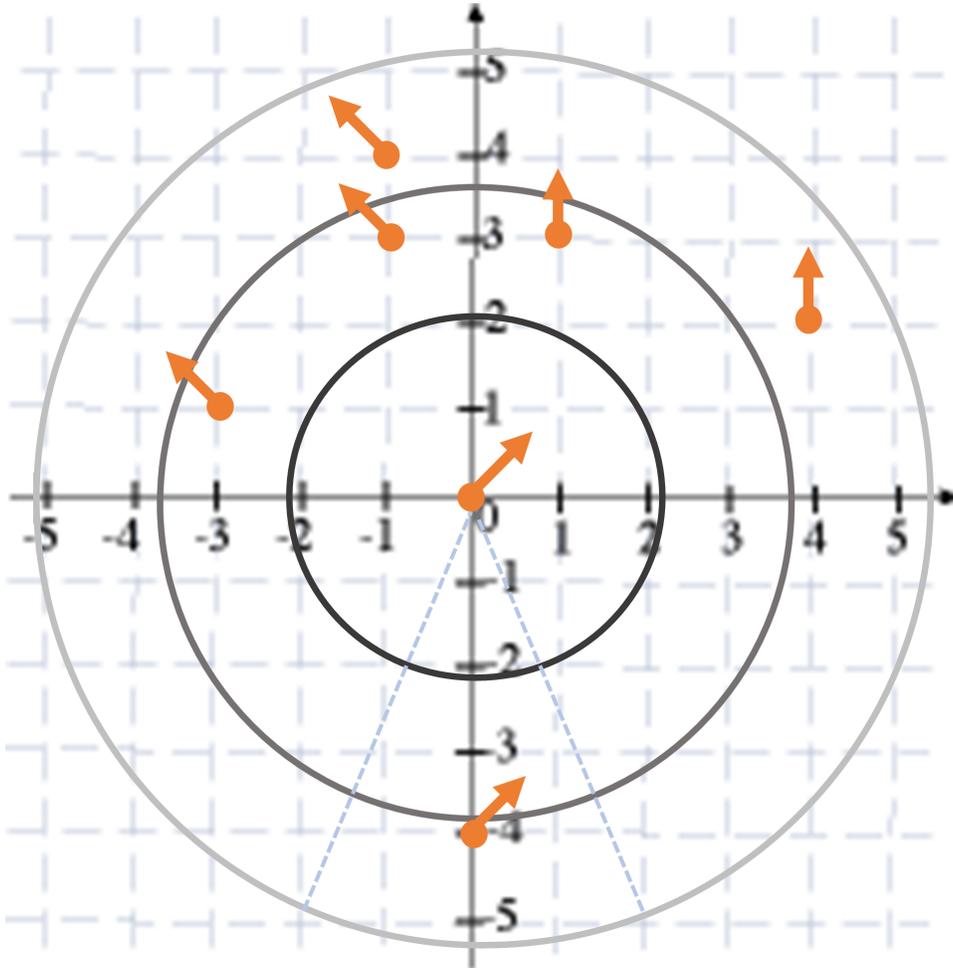1. **Which Way:**

Figure 1: Three zones model (repulsion, orientation, attraction, blind region) with positions $\vec{c}_i(t)$ and current headings $\vec{v}_i(t)$ indicated for $i = 1, \ldots, 7$.

(a) Figure 1 indicates the position of 7 fish at time t. Fish number $i = 1$ is at the origin $(x, y) = (0, 0)$. What is its desired heading at the next time step $\vec{d}_1(t + \tau)$?

(b) Fish $i = 2$ is the one located at $(x, y) = (1, 3)$. What is its desired heading at the next time step $\vec{d}_2(t + \tau)$? Assume the radii of the 3 regions are the same as shown for fish $i = 1$.

(c) How would you implement this swarming model in an actual robot swarm. What sensors would you use? How many messages would have to be sent in the network? The main goal here is to get you think in practical terms about how one moves from computer simulations and biological swarms into the world of robot swarms.

(d) The Couzin model we studied let's swarms move, but they do so without trying to find a target (source of food, water, warmth etc.). Detail explicitly how you would update this math model to incorporate the swarm moving toward a specific location toward a desired target. Justify in lay language how your math model achieves this. You may consult any resources, as needed.

2. **Fish food:** In class, we had a brief play with a matlab implementation of the Couzin-Ballerini mixture model. In addition, predators can attack in the simulation.

Now, it's time to choose your own adventure! Your task is develop and test a hypothesis about how flocks form (or not). There are many, many possibilities. Just to get the juices flowing: How does swarming depend on the inherent variation (standard deviation) of swimming speeds? How does noise in the system affect the ability to school? How does the preference for orientation vs. attraction affect whether coherent swarms form or not? How does coherent swarming depend on the ratio of the percent of individuals each agent interacts with (n_c/N_{swarm}, in terms of matlab simulation parameters)?

(a) Clearly state what question are investigating

(b) Clearly state how you investigated it. What exactly did you measure and why? Detail what parameters you varied, which stayed constant, how many trials you performed for each parameter combination?

(c) Describe your findings. A graphic or plot of some sort would be helpful here.

(d) Interpret your results. Did the results make intuitive sense given the models and parameter value settings? What do they mean in terms of biological fitness?

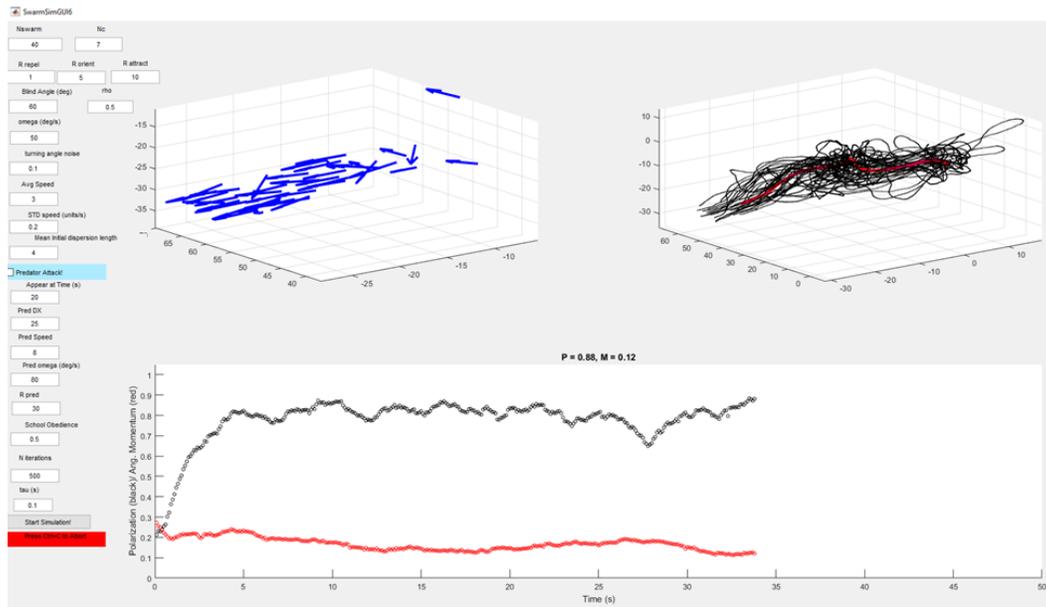(e) Discuss any shortcomings of the models, limitations with your study, and state any final conclusions.

You may work as a group on this!

Figure 2: Matlab software simulation screen shot