Abstract

Swarming behavior is universally observed across species in biology. Various adaptive functions of swarming behavior have been discussed, such as an efficient foraging, increasing encounter with potential mates, and protection against predators. In this study, I focus on the evolution of swarming behavior of the primitive prey as a protection against predators. In the protective behavior against predators, I especially focus on the predator confusion effect in which higher density of the prey's swarm decreases the predation rate of the predator because it cannot concentrate the target prey due to too many prey in its field of vision.

Swarming behavior may also cause disadvantages, such as increased risk of infected with pathogens or increased competition for limited resources. The widespread observation of swarming behavior in the biological world suggests that the benefits of swarming outweigh such disadvantages. Not enough is known, however, about how the cost of swarming behavior is reduced. By representing disadvantages in swarm behavior as abstracted individuals with "internal threats," this study investigates how the disadvantages can be avoided. Here, an internal threat is an individual with two properties: "internality," which means that it is the same species as other group members, and "threat," which means that it negatively affects other group members. This study aims at clarifying whether prey swarming behavior evolves when "internal threats" are present in the prey population under an evolutionary scenario taking into account the predator confusion effect.

To achieve the goal, I construct a model of evolving prey interacting with other prey and a predator, and conduct experiments using agent-based simulation. The prey behavior is controlled by a neural network whose input is the visual information of other agents, and the output is the actuators' power determining its own movement. The neural network is evolved by Neuroevolution of Augumenting Topology (NEAT). Using this model, two conditions were compared: with internal threats in the prey population ("threaten condition") and without them ("no-threaten condition"). The results showed that swarming behavior of prey agents is not evolved in the case of "threaten condition" while it can be evolved in the case of "no-threaten condition".

The results suggest that the group of prey containing "internal threats" is hard to evolve swarming behavior because they tend to avoid "internal threats" rather than the predator. They also suggest that other adaptive functions than the predator confusion effect may be important to evolve swarming behavior in the case with "internal threats". Additionally, considering the possibility that prey can avoid "internal threats" through communication by exchanging information of "internal threats" to avoid them, evolving the communication ability may be necessary to evolve swarming behavior even in the case with "internal threats".