Project Proposal for CSCI 5423, Spring 2019

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PROJECT DESCRIPTION/SIGNIFICANCE

Adult fungus gnats play a healthy role in the decomposition of organic matter (e.g. mulch, mold, grass clippings, fungi, etc.) and are primarily harmless. Their larvae, however, can be damaging to a plant's survival. A single fungus gnat larvae is less than 1cm in length; but in large numbers, their tendencies to chew on plant roots (a characteristic unique to larvae) can be catastrophic to the growth and survival of a garden, greenhouse, or other plant landscapes [1].

This project will evaluate the unique movement of a group of fungus gnat larvae as seen in a video published to the web [2]. The group of larvae appears to be solid three-dimensional shape with individual movement from back to front by agents located on the top layer. Their movement is like a slow-motion game of leapfrog, except the agents are not leaping over one another; instead, they maintain a single mass as they are crawling over one another and using a base group as support.

An interesting observation to note is a point at which the group splits into two legs, where each leg starts a trajectory in a unique direction. The two legs work the same as the original, but now have less mass. As there is little observation of this species, it is unknown if this splitting behavior is the case with all fungus gnat larvae movement, or unique to the instance captured in the aforementioned video.

This project seeks to design a model that will provide insight in the understanding of two distinct features of this behavior: **(1) the decision to split**; and **(2) the decision to travel by stacking mass, as a three-dimensional group**. For the first, we will explore ideas of informed decision making. Projecting the larvae movement in two-dimensional space, we will investigate what parameters of informed decision making that must exist in a group of larvae in order to induce a split. It is likely that the gnat larvae preference toward a wet environment will play a role in this task. Secondly, we aim to expand this model into three-dimensional space to explore the leapfrog-like collective movement in which these fungus gnat larvae chose to move. This behavior is likely significant in providing protection against possibly much larger prey.

RELATED WORK

Due to the lack of experimental data of the larva movement behavior, we aim to understand the aforementioned 2 features using theoretical means. There are two papers [3, 4] that attracted our attention.

In Ref. [3], the authors studied the phase transition to the emergence of self-ordered motion in a system of self-driven particles. The order parameters of the model are a random perturbation and a varying density among individuals during the course of the particles' motion. In the phase diagram, the rotation symmetry breaks spontaneously, and the state of motion for the particles changes. We expect to gain hints from the work, which acts on a two-dimensional space, to our three-dimensional modeling of the splitting behavior of larva aggregate.

In Ref. [4], the authors modeled the aggregate motion of birds by treating the flock as a particle system, where each particle determines its next-step reaction by sensing the dense interaction of the relatively simple behaviors of neighboring particles. This work simulates the flock in the three-dimensional space. With the investigation of the model, it might inspire us a simple "force-field" among particles that explains the stacking mass, leapfrog-like, traveling behavior.

SCHEDULE

All dates listed are Mondays beginning each week. The task accompanying the date is to be done during that week (or before the deadline of that week).

March 18: Read the 2 papers [3, 4] sent to us by Dr. Peleg. Complete project proposal (deadline: March 21).

March 25:

1. Continue search for possible similarities between existing problems (either in the literature or ongoing research among labs).
   (i) Looking for further motivation.
   (ii) Searching for some evidence of rules that we might want to implement.
   (iii) Look for more experimental evidence with these kinds of behaviors (e.g. other videos)
2. Download and install NetLogo (optional).

(i) Become familiar with functionality and tools.
(ii) Videos to reference:
    a. https://www.dailymail.co.uk/sciencetech/article-2737816/Snakes-No-writhing-mass-hundreds-fungus-gnat-LARVAE-searching-shelter.html (DailyMail article with video and some discussion)
    b. https://www.youtube.com/watch?v=P5XhSSaHtgM (YouTube video)
(iii) Brainstorm some ideas for modeling this system.
    a. What kinds of rules do the agents follow?
    b. What world do the agents live in?
    c. How can we represent a 3D structure in 2D space? (Do we need to look at 3D modeling tools?)

April 1: Working on model

1. Have a very minimal model to represent a 2D space of these animals moving in this motion.
2. Flush out basic rules and know what kinds of tools we will need to implement for our model

April 8: Working on model

1. Complicate our model.
    (i) Look to move to 3D space and add further functionality.
    (ii) Test end cases.
    (iii) Add noise/perturb the model and see how it responds.
2. Draw new inferences from our results and see how they compare to our initial thoughts on the behavior of these agents.

April 15: Assuming our model has been flushed out (or at least minimally is working)...put together presentation flow. Continue working on the model.

April 22: Practice for presentation (deadline: presentation on April 24)

April 29: Continue work on the model and start the paper.

1. If the model has been converted to 3D space and complicated (unlikely), think of further ways to increase complexity or play with the rules.
2. If the model needs work on its correctness or complexity (likely), made further progress here.
3. Start writing the paper.

May 6: Make final revisions to paper (deadline: final paper due on May 9th).

BIBLIOGRAPHY

1. J. A. Bethke, S. H. Dreistadt, “How to Manage Pests: Pests in Gardens and Landscapes.” *UC-IPM*, Pest Notes Publication 7448, August 2013, http://ipm.ucanr.edu/PMG/PESTNOTES/pn7448.html (accessed 21 March 2018).
2. S. Griffiths, “Snakes? No, this writhing mass is made from hundreds of fungus gnat LARVAE searching for shelter.” *DailyMail*, Associated Newspapers Ltd, 29 August 2014, https://www.dailymail.co.uk/sciencetech/article-2737816/Snakes-No-writhing-mass-hundreds-fungus-gnat-LARVAE-searching-shelter.html (accessed 21 March 2018).
3. T. Vicsek, A. Czirok, E. Ben-Jacob, I. Cohen, & O. Shochet. “Novel type of phase transition in a system of self-driven particles.” *Physical Review Letters*, *75*(6), 1226–1229 (1995).
4. C. W. Reynolds. “Flocks, herds, and schools - A distributed behavioral model.” *Siggraph*, 25–34 (1987).
5. Wikipedia contributors, "Fungus gnat," *Wikipedia, The Free Encyclopedia,* https://en.wikipedia.org/w/index.php?title=Fungus_gnat&oldid=886383814 (accessed March 22, 2019).