Semester Project OOAD

Project Summary

Individual: Dieu My Nguyen

Project title: Agent-based model of firefly mating strategy

High-level overview: To make use of the concepts from this class for my PhD research, I aim to build an agent-based model to simulate firefly mating behaviors using an OOAD framework. Briefly, an agent-based model is a collection of interacting agents, each being an encapsulated bundle of data and methods that allow the agents to act in an environment. Notably, the agents typically have limited behaviors, i.e. they have knowledge of a small spatial area around them, but not of the global environment. Yet, complex global patterns emerge from the local interactions between individuals.

In the dark, during the process of firefly courtship and reproduction, males use flash signals as part of their courting ritual. A stationary female will need to perform some sort of tracking of different male flashes and select a mate, then respond to the chosen male's flash to signal her location. The environment contains dense number of male fireflies who are mating competitors. Further, to converse energy, males likely do not send continuously signals and instead send a limited number of flashes to convey their location and trajectory. Then, how does a female firefly maintain contact with a male she is signaling in this noisy environment? What can male fireflies do to optimize their chances at being recognized and successfully tracked? These questions are the driving force behind my exploration of this problem via computational modeling (and later in my research, experimental observations). (The equivalent phenomenon in humans is the cocktail party problem, which describes how people can distinguish and identify one conversation when surrounded by many people.)

In my model, fireflies will be the individual agents divided into different types based on attributes and behaviors (i.e. female, male, and finer distinction of males with different types of flash patterns and movement strategies) and they exist in some discrete 2D environment (i.e. a grid). The 2-D flying motion of male fireflies will be modeled as a correlated random walk. The female will track an individual male using a "lookup table," a distribution of anticipated positions stored in memory, to evaluate which signal comes from the male she is attempting to track.

To accomplish & Expected system: For the scope of this course, I will keep the model minimal as long as core theoretical concepts are sufficiently modeled. My goal is to implement a working agent-based model with parameters a user can vary to observe various emergent properties of the whole system. Specifically, I would like to be able to make some preliminary observations about the optimal flashing and moving strategies male fireflies can employ to mate with the female. If time allows, I would like to also explore different strategies females can use for the challenging tracking task.

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Project Requirements & Responsibilities

Functional capabilities:

- Model inputs: A set of model parameters from the user (e.g. number of male fireflies, velocity/step size, random walk turning angle, resting interval between flashes, etc.)
- Model outputs: A (graphic if possible) simulation of the courting process, female's success/efficiency in tracking a single male of interest
- Data to store: Time data of each male's motion trajectory and flashing pattern, of female tracking and final decision

Constraints & Non-functional requirements:

- Python 3 code for easy sharing with computational biology community
- Reproducible parameter searches: Use a random seed throughout
- Maintainability and enhancement: Because this will be ongoing research, the model should be flexible for future changes, such as additional strategies each firefly type may employ.

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Users and Tasks: Use Cases

Type of users, tasks they will accomplish with system:

1. Research Assistant: After building a working model, I will request assistance from an undergraduate mentee (or myself) to run parameter sweeps to heuristically explore the bounds and the optimal values of this biological-inspired model. The assistant will test various values and ranges and based on the model outputs, determine optimal values.
2. A Broad Audience: I will share the finished model on Github with other researchers and a broad audience. The user can input various parameters to observe how the system changes. A set of default parameters and suggested ranges will be available. Rather than trying many parameters as the research assistant would, this audience would simply run the model to reproduce certain parameter set results or to explore this biological phenomenon on a higher, curiosity-drive level.

The two types of users above also define the number of scenarios I will strive to make possible in the model for the scope of this class project. Below are the respective text use cases.

Use case 1:

- Name:
- Brief Description:
- Actor(s):
- Preconditions:
- Basic Flow:
- Alternative Flows:
- Exception Flow:
- Post Conditions:

Use case 2:

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Activity Diagram

- Pick the most complex use case and create activity diagram to document all paths through it.

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Architecture Diagram

- Show architecture of system
- Box and arrows

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Data Storage

- Where to store data
- How to store
- Classes needed to access this data at run time

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UI Mockups/Sketches

- Screen mockups for UI of various parts of the application

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User Interactions

- 3 interactions with user
- For each, how does system support it? Show sequence diagram of objects that will participate in interaction

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Class Diagram