Course: CS30A1570 Complex Systems

Assignment 1: What is Complexity?

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Task 1:

Study Question: How do variations in population size, maximum step size, and maximum turn angle affect the average time taken for ants to consume all available food in the MultipleAnts.nlogo simulation?

Sub-questions:

• Does doubling the population size from 50 to 100 significantly reduce the average time taken for ants to consume all available food?

• How does increasing the maximum step size from 4 to 8 impact the average time taken for ants to consume all available food?

• What effect does increasing the maximum turn angle from 60 to 120 have on the average time taken for ants to consume all available food?

Answer:

Based on the data (Appendix- Table 1) obtained from running the modified MultipleAnts.nlogo model (Appendix- Image 1 & Attachment 1) 5 times per configuration and taking the average time taken (as ticks), it is evident that the average time taken for the ants to consume all available food varies depending on the population size, maximum step size, and maximum turn angle.

Population Size: Increasing the population size from 50 to 100 decreases the average time (ticks) taken for ants to consume all available food.

Maximum Step Size: Increasing the maximum step size from 4 to 8 increases the average time for a population of 50 but decreases the average time for a population of 100.

Maximum Turn Angle: Increasing the maximum turn angle from 60 to 120 degrees decreases the average time for a population of 100 but increases the average time for a population of 50.

The observations suggest that the average time taken for the ants to deplete the food sources depends on all the parameters. However, further testing is needed to identify and understand the proper causes and the effects of each parameter. Moreover, the results vary due to the stochastic nature of the simulation.

Task 2:

Study Question: How does the introduction of a pheromone mechanism, where ants leave and follow pheromone trails while foraging, impact the efficiency and effectiveness of food gathering in the ant simulation model compared to the model without pheromones?

Answer:

The introduction of a pheromone mechanism in the ant simulation model appears to have some effect on the ant colony. Based on the data (Appendix – Table 2) obtained from running the modified MultipleAntsWithPheromone.nlogo model (Attachment 2) with incorporating the concept of pheromones (Appendix- Image 2) 5 times per configuration and taking the average time taken (as ticks), it is evident that the average time taken for the ants to consume all available food varies depending on the population size, maximum step size, and maximum turn angle. For this experiment, the diffusion rate and the evaporation rate of the pheromones were kept fixed in all the experiments.

Population Size: Increasing the population size from 50 to 100 decreases the average time (ticks) taken for ants to consume all available food (Appendix- Chart 4).

Maximum Step Size: Increasing the maximum step size from 4 to 8 increases the average time for a population of 50 but decreases the average time for a population of 100 (Appendix- Chart 5).

Maximum Turn Angle: Increasing the maximum turn angle from 60 to 120 degrees decreases the average time for a population of 100 but increases the average time for a population of 50 (Appendix- Chart 6).

When comparing the model without the concept of pheromone (Appendix- Table 3), the average time taken generally increases. It is observed that the incorporation of pheromones usually increases the average time taken with the exception of 2 cases where the (population, max-step-size, max-turn-angle) is (50, 8, 60) and (100, 8, 60). This demonstrates that the optimal value for max-step-size is 8 and for the max-turn-angle is 60.

This data suggests that while the introduction of a pheromone mechanism has an effect on the efficiency of foraging on the ant colony, the impact can vary depending on the factors such as population size, maximum step size, maximum turn angle, pheromone diffusion and evaporation rate. Further investigations are required to observe how these factors interact with each other to affect the efficiency of the model in terms of time taken. Genetic algorithm can be the best method to figure out the optimum values of the parameters.

Task 3:

Study Question: What are the optimal values of the pheromone parameters (diffusion rate and evaporation rate) for a fixed population size in the Ants Simple model, and how do these values impact the efficiency of food gathering by the ant population?

Answer:

For this task, the AntsSimpleModel.nlogo model was modified (Attachment 3) so that the experiment population remained constant at 100 and before stopping the ticks were stored in a global variable named experiment-result. Then, the tool "*Behavior Search"* was used (Appendix- Image 3 and Image 4). The "*Behavior Search"* experiment was setup with the following configurations:

Population: 100 fixed

Diffusion rate: initiated at 10 with increment 10, and maximum value was 100.

Evaporation rate: initiated at 10 with increment 10, and maximum value was 100.

Repetitions: 5

The total experimentation yielded 500 sets of data. From the data, it was evident that the minimum time achieved for a population of 100 was 980 ticks where the evaporation-rate was 40 and diffusion-rate was 70 (Attachment 4- ants-behavior-space-data.xlsx).

Running a python script (Attachment 5: ants.py) gives the following result:

Correlation between experiment result and evaporation rate: 0.03248875186228832

Correlation between experiment result and diffusion rate: -0.06614278294266314

Appendix:

Table 1: Average time (ticks) required to deplete all the food sources (without pheromones).

Population	Maximum Step Size	Maximum Turn Angle	Ticks	Average Ticks
50	4	60	360	**311.40**
50	4	60	251	
50	4	60	335	
50	4	60	362	
50	4	60	249	
100	4	60	145	**147.20**
100	4	60	170	
100	4	60	141	
100	4	60	117	
100	4	60	163	
50	8	60	401	**502.00**
50	8	60	534	
50	8	60	369	
50	8	60	697	
50	8	60	509	
100	8	60	207	**265.40**
100	8	60	214	
100	8	60	242	
100	8	60	395	
100	8	60	269	
50	4	120	198	**238.00**
50	4	120	211	
50	4	120	314	
50	4	120	221	
50	4	120	246	
100	4	120	219	**139.60**
100	4	120	121	
100	4	120	110	

100	4	120	113	
100	4	120	135	
50	8	120	185	**207.60**
50	8	120	225	
50	8	120	212	
50	8	120	198	
50	8	120	218	
100	8	120	81	**114.00**
100	8	120	125	
100	8	120	145	
100	8	120	133	
100	8	120	86	

Table 2: Average time (ticks) required to deplete all the food sources (with pheromones).

Population	Maximum Step Size	Maximum Turn Angle	Ticks	Average Ticks
50	4	60	484	**347.80**
50	4	60	304	
50	4	60	273	
50	4	60	394	
50	4	60	284	
100	4	60	181	**182.20**
100	4	60	191	
100	4	60	194	
100	4	60	166	
100	4	60	179	
50	8	60	248	**276.20**
50	8	60	330	
50	8	60	266	
50	8	60	223	
50	8	60	314	
100	8	60	160	**156.60**
100	8	60	152	
100	8	60	150	
100	8	60	175	
100	8	60	146	
50	4	120	403	**361.20**
50	4	120	351	
50	4	120	337	
50	4	120	348	
50	4	120	367	
100	4	120	251	**225.40**
100	4	120	202	
100	4	120	235	
100	4	120	215	

100	4	120	224	
50	8	120	353	**363.40**
50	8	120	339	
50	8	120	460	
50	8	120	373	
50	8	120	292	
100	8	120	170	**200.40**
100	8	120	208	
100	8	120	189	
100	8	120	245	
100	8	120	190	

Table 3: Comparison of the average time (ticks) required to deplete all the food sources (without pheromones and with pheromones).

Population	Maximum Step Size	Maximum Turn Angle	Average Time without Pheromones	Average Time with Pheromones
50	4	60	311.4	347.8
100	4	60	147.2	182.2
50	8	60	502	276.2
100	8	60	265.4	156.6
50	4	120	238	361.2
100	4	120	139.6	225.4
50	8	120	207.6	363.4
100	8	120	114	200.4

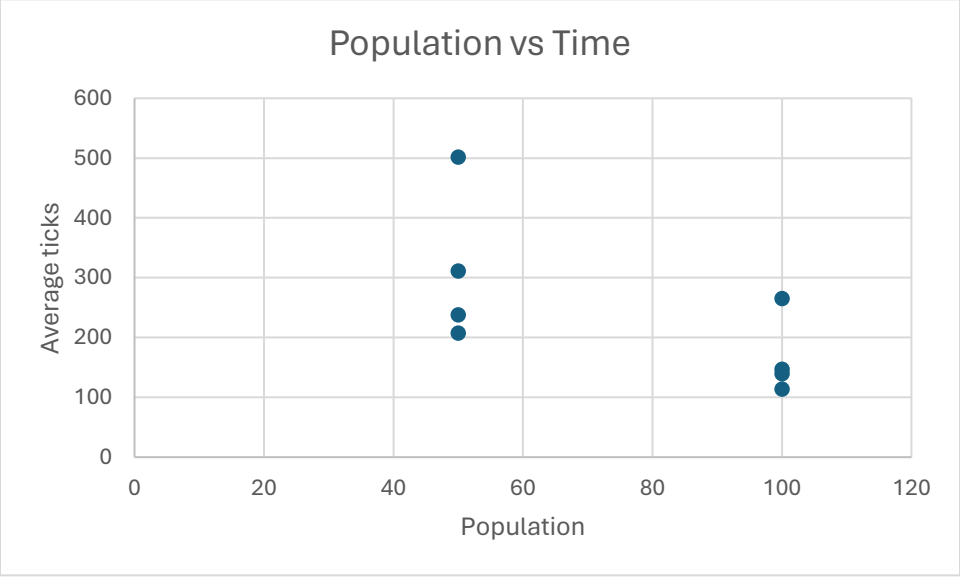

Chart 1: Varying population (50 and 100) vs Average ticks required.

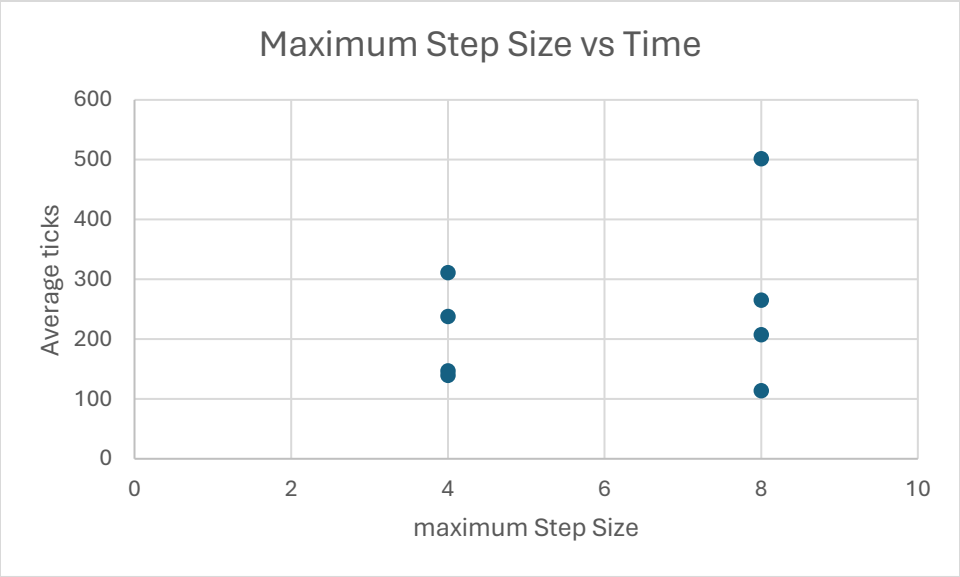

Chart 2: Varying maximum step size (4 and 8) vs Average ticks required.

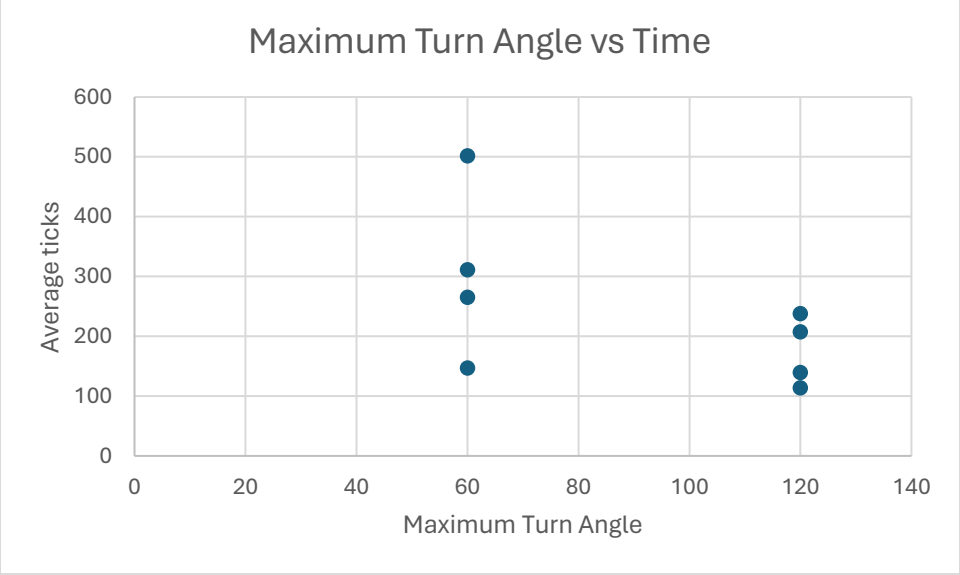

Chart 3: Varying maximum turn angle (60 and 120) vs Average ticks required.

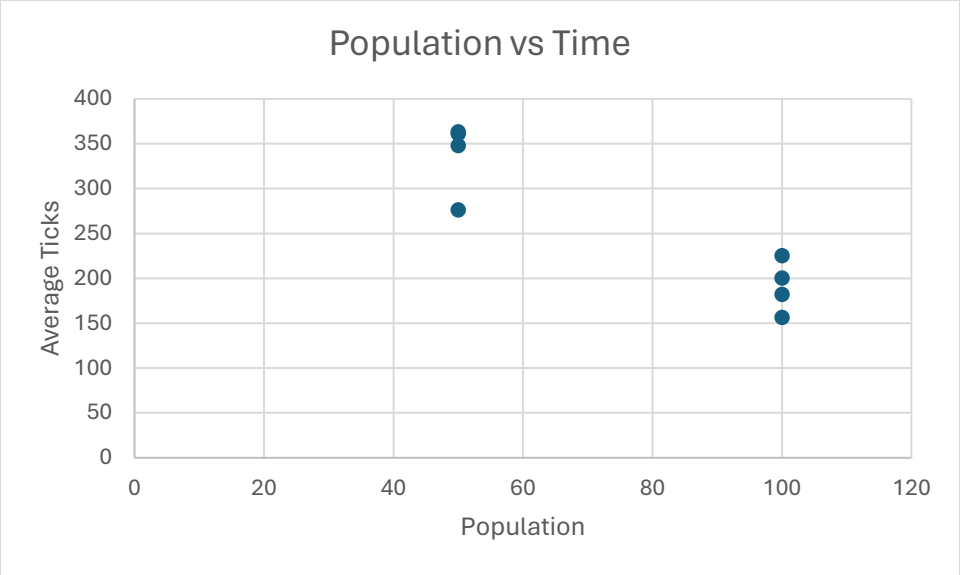

Chart 4: Varying population (50 and 100) vs Average ticks required.

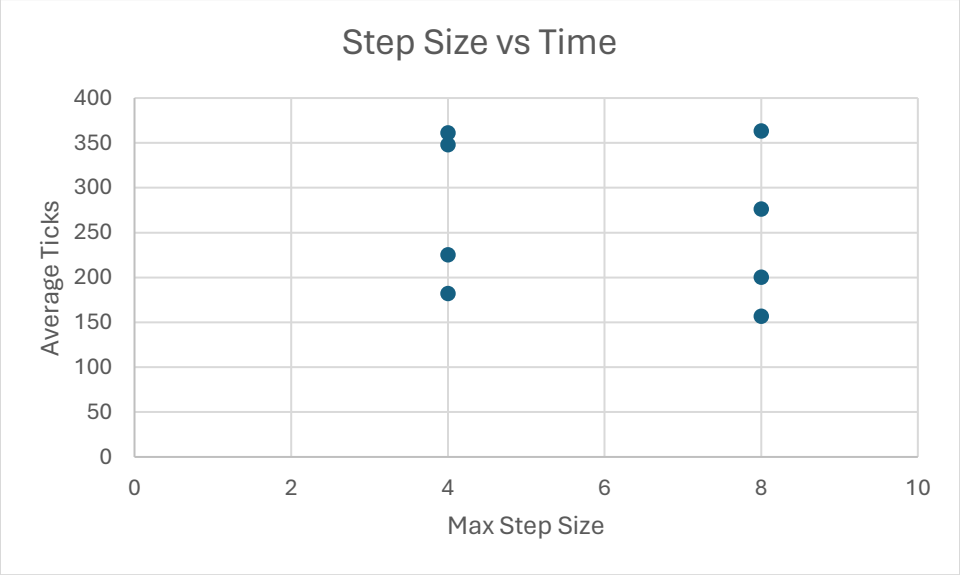

Chart 5: Varying maximum step size (4 and 8) vs Average ticks required.

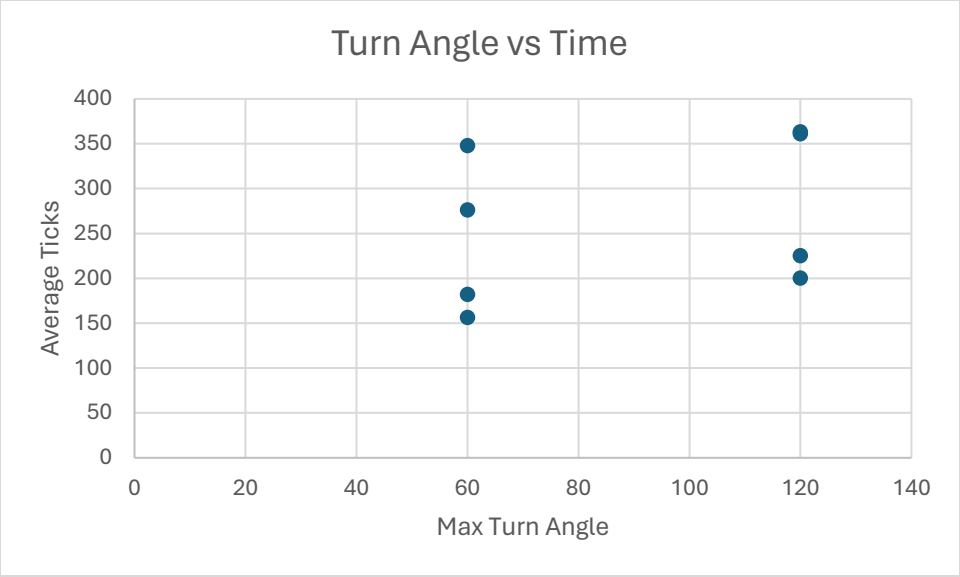

Chart 6: Varying maximum turn angle (60 and 120) vs Average ticks required.

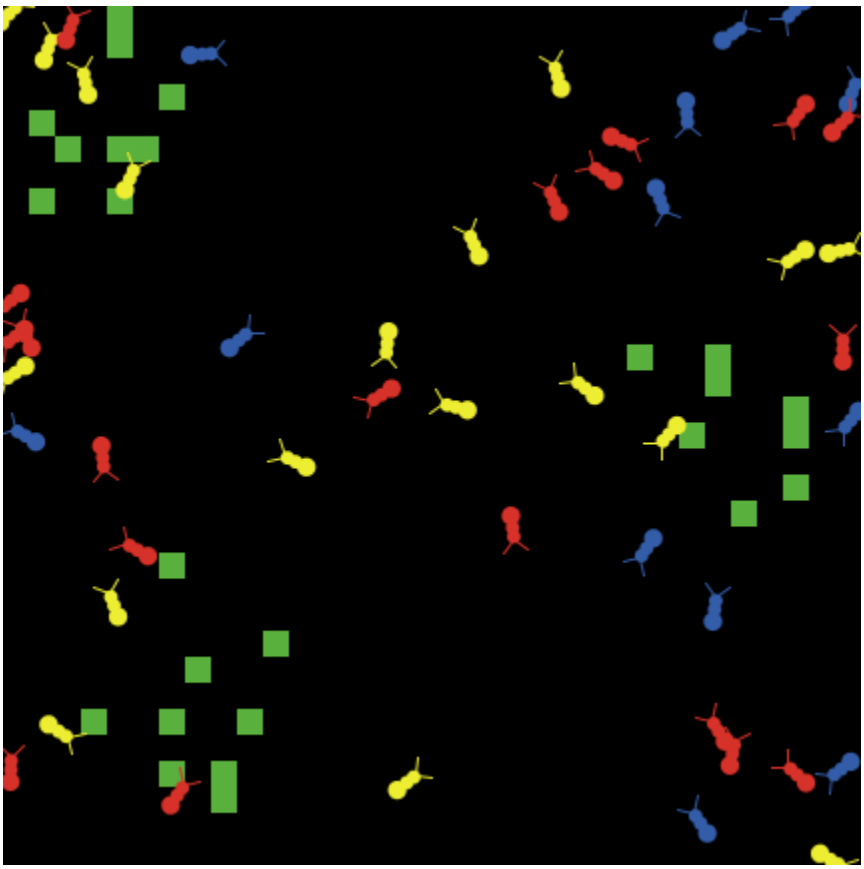

Image 1: Multiple Ants Model

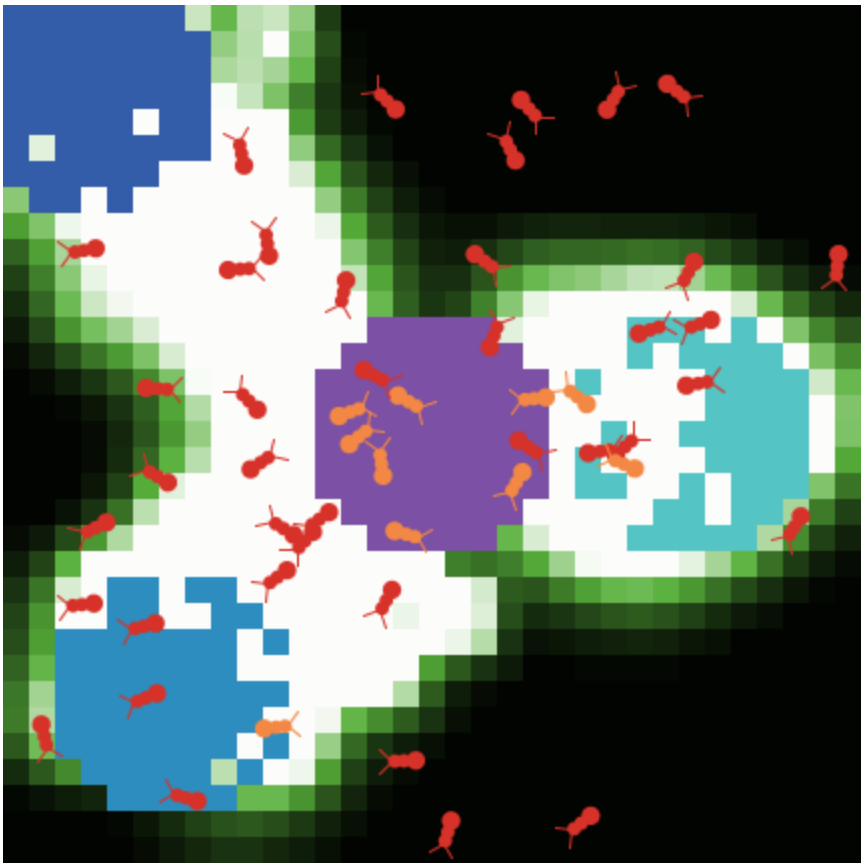

Image 2: Multiple Ants Model with pheromones

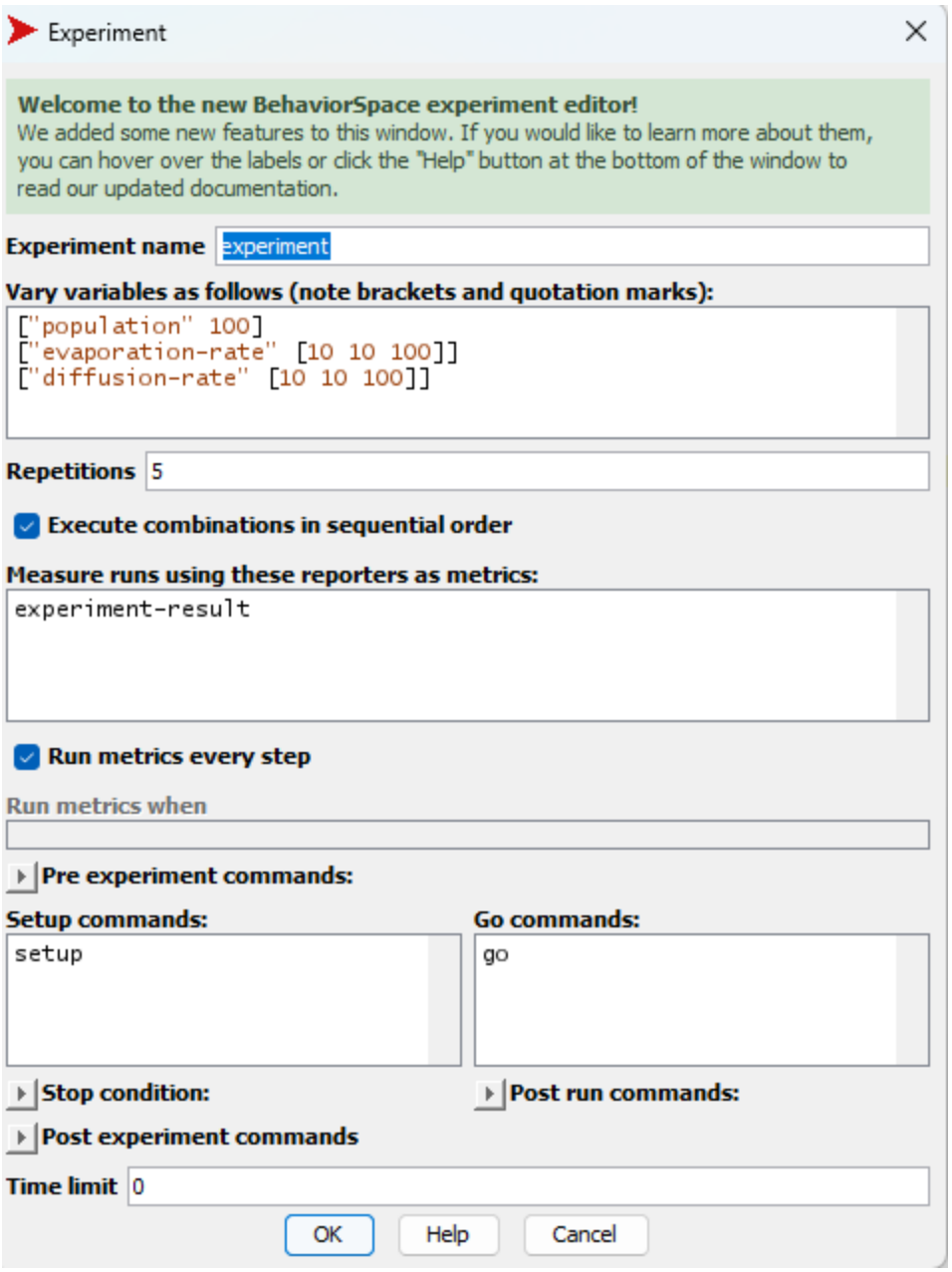

Image 3: The “Behavior Space” experiment configuration

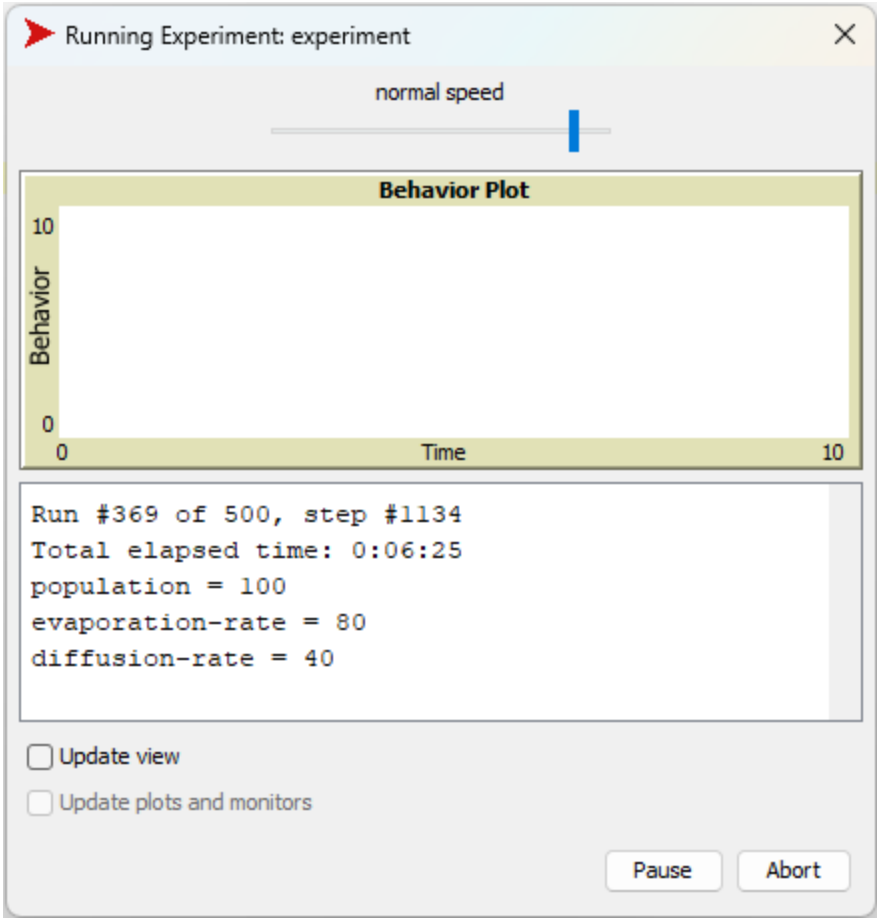

Image 4: “Behavior Space” experiment running

Attachments:

1. MultipleAnts.nlogo
2. MultipleAntsWithPheromones.nlogo
3. AntsSimpleModel.nlogo
4. ants-behavior-space-data.xlxs
5. ants.py