Course: CS30A1570 Complex Systems

Assignment 1: What is Complexity?

Completion Date: 10 March 2024

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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.

A screenshot of a video game

Description automatically generated

Image 1: Multiple Ants Model

A screenshot of a video game

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Image 2: Multiple Ants Model with pheromones

A screenshot of a computer

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Image 3: The “Behavior Space” experiment configuration

A screenshot of a computer

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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