Turtle Ant Movement and Nest Choice on Modular Tree Branches

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Introduction

Arboreal ants build networks connecting nests and food sources along pathways constrained by tree branching patterns[1]. Little is known about arboreal ant networks and the mechanisms by which they are formed[2]. Here, we investigate (1) whether the arboreal turtle ant *Cephalotes varians* displays individual turning biases when navigating physical branches, and (2) whether such biases can explain which nesting cavities colonies choose to inhabit. We study how individual *C. varians* ants navigate a modular asymmetric branching structure, and how colonies explore the same structure to choose among multiple identical nests.

Questions

Do individual *C. varians* ants display turning biases based on the geometry of their tree structure?

Can we explain a colony's nest choice from individual biases?

Methods

Modular Tree Design

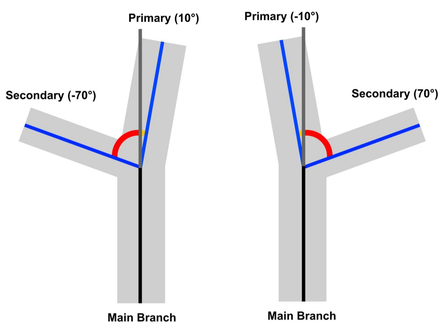

Figure 1: We constructed our tree branch maze out of 31 modular branching junctions of two types (left and right handed junctions). Each junction has a main branch, primary branch, and secondary branch. The main branch (one of four diameters) splits into a sharp and shallow turn: the primary branch (same diameter as main) at 10°, and the secondary branch (75% diameter) at 70°.

Experiments

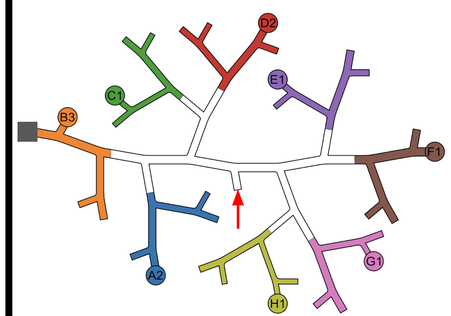

Figure 2: Eight nests (noted with alpha-numeric codes and colors) were placed equidistant from the ant's starting location on the maze — the short offshoot in the middle of the maze (red arrow). An equal amount of food and water was located near each nest. The maze is attached to a thick wooden block or "trunk" (grey square) adjacent to nest B3.

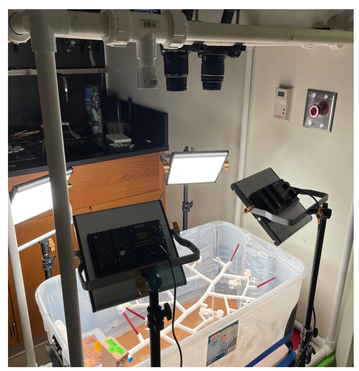

Figure 3: The maze was positioned in a box which also contained the ant colony's smaller, self-contained habitat. For 62 individual experiments, one ant at a time was brought via a string hanging from the starting branch. Then, the junctions the ant visited were recorded in sequential order. For four colony experiments, the string permanently connected the habitat to the maze, and the number of ants in each nest were recorded after 3 days.

Agent-Based Model

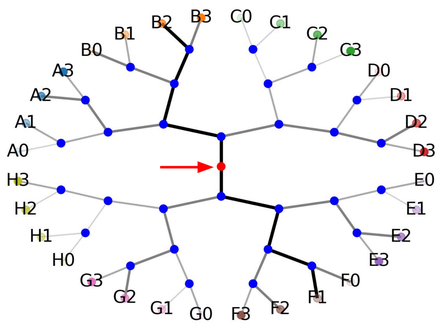

Figure 4: An agent based model was created in Python using the Mesa agent-based modeling framework on a NetworkX network environment. Ants in the model navigate this tree according to turning biases extracted from statistical analysis of the experiments. Probabilities of every turn type were calculated with a binomial GLMM in R where the probability of making a turn type was explained by the type of approach (see **Figure 6**). At each time step, ants make one move in any of three directions from their current node, until they reached a tip (labeled A1-H3), without interacting and with no goal or memory.

Results

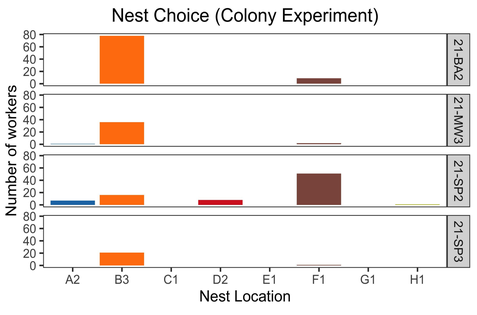

Figure 5: The number of worker ants in each nest at the end of each of the four colony experiments (colonies 21-BA2, 21-MW3, 21-SP2, 21-SP3).

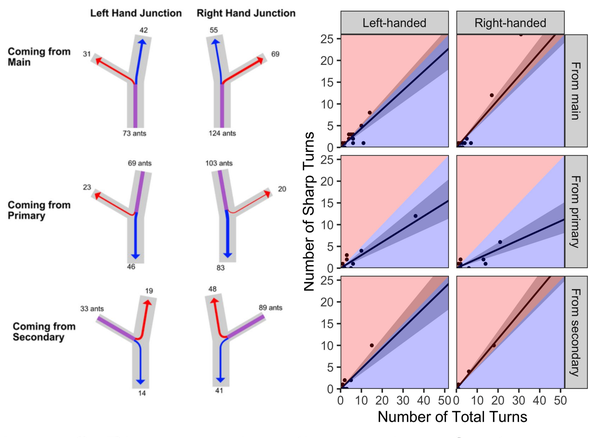

Figure 6: Diagrams show the number of ants making turns on left and right handed junctions coming from either the main, primary, or secondary branches. Scatter plots illustrate bias for sharp turns (red) versus shallow turns (blue) from different incoming directions (purple).

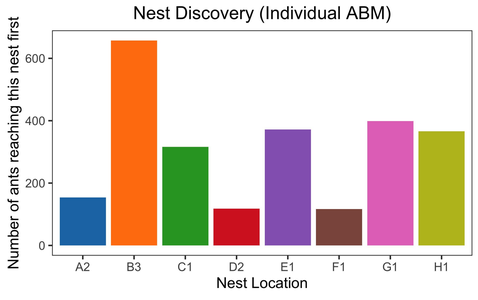

Figure 7: The total number of ants that went into each nest in a over 10,000 ants for 50 time steps in the agent-based model.

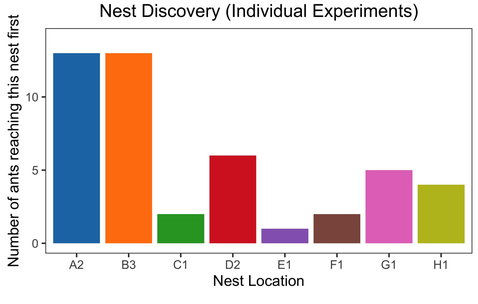

Figure 8: The total number of times a nest was the first one visited by an ant in the individual experiments.

In the colony experiments, nests B3 and F1 were most likely to be chosen (**Figure 5**). These nests lie at each end of the branching structure with a thicker, nearly straight path between them. In the individual experiments, ants approaching a junction from the main branch were equally likely to to take either path, as were ants approaching from a secondary branch. However, ants approaching from the primary branch were more likely to continue straight down the main branch, rather than making a sharp turn onto the secondary branch (binomial GLMM, odds ratio 0.35, 95% CI 0.22-0.56). The ABM based on these biases projects that most individual ants will visit B3 first (**Figure 7**), which is one of the nests individual ants were most likely to visit first (**Figure 8**).

Conclusion

In the individual experiments, we observed that ants approaching from the primary branch tend to continue straight onto the main branch. Because the trunk is at the end of a series of such turns, this could explain why the ant colonies consistently chose to congregate in nest B3 which is adjacent to the trunk. However, while the ABM does project a bias for B3 visitation, there are other discrepancies in first-nest visitation between the ABM and the experimental data. Because the model assumes that turning biases are only influenced by junction handedness and the direction of approach, this discrepancy suggests that real ants' turning choices could be influenced by some other factor, such as the branch size or the position of the junction in the overall structure.

Examining the colony level data, we see that while nest B3 is often heavily occupied, F1 was also frequently occupied and in one case even had the most ants. Nest F1 is not predicted to be heavily occupied according to the model or the individual first nest visits, so individual turning biases cannot directly explain this. However, the route leading back from nest F1 to the starting point, which leads to the colony's original nest, may be particularly easy to navigate due to individual turning biases. This could make any potential recruitment to nest F1 particularly efficient.

Acknowledgements

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References

[1] Chang, Joanna, et al. "Nest Choice in Arboreal Ants Is an Emergent Consequence of Network Creation under Spatial Constraints." *Swarm Intelligence*, Apr. 2021.
[2] Gordon, Deborah M. "The Dynamics of Foraging Trails in the Tropical Arboreal Ant Cephalotes Goniodontus." *PLOS ONE*, vol. 7, no. 11, Nov. 2012.