Analyzing and Modeling Turtle Ant Movement Biases

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Introduction

Arboreal ants such as *Cephalotes varians* (turtle ants) have to navigate constrained geometry in order to find food, resources, and shelter.[1] The ways in which turtle ants specifically decide how to explore these environments — what turns they take; what they prioritize — are less well known than other ants. We study the decisions turtle ants make at varying junctions and how those decisions scale to colony-sized populations.

Questions

Do individual ants have turning biases based on geometry of junctions?

Can these biases explain which nests ants explored first, or ultimately chose to inhabit?

Methods — Experiments on ant movement and nest choice were conducted in the lab, and compared to an agent-based model of nest choice based on biased movement.

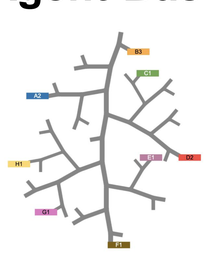
Individual + Colony Ant Experiments

Figure 1: the tree model from the ant tracking camera with annotations

Figure 2: the tree model from the observer's POV

The ants are placed at the black arrow one at a time for individual experiments and allowed to walk via string there for colony experiments. Their individual choices at junctions and arrivals at nests are examined by camera (also by eye for individual experiments). Their destinations were noted for data analysis.

Agent-Based Model



Network Representation of the Tree

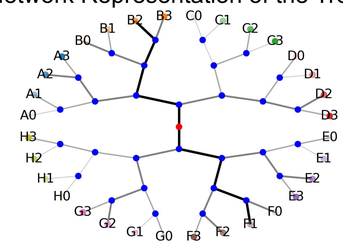


Figure 3: Ants in the individual model navigate this tree (left) according to turning biases (right vs. left, wide vs. narrow), with no goal or memory, and stop when they reach any tip (labeled A1-H3).

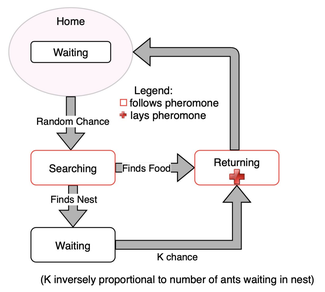


Figure 4: Ants in the colony model follow state changes according to this flowchart, beginning in their home nest.

Two models were used: an individual model in which ants would stop when they reached a tip of the tree and didn't interact with their environment or each other, and a colony model where food was present and ants could continue to explore after reaching a branch tip according to the model described in **Figure 4.** The ant biases included in the model are preferences between left and right turns and width biases.

Results

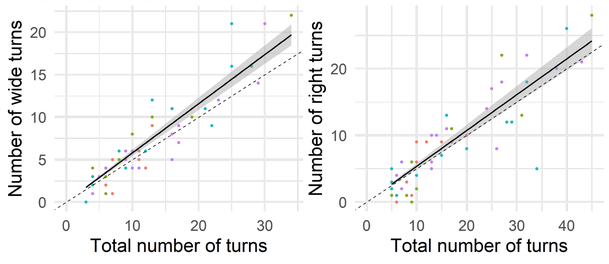


Figure 5 & 6: Scatter plots to examine the presence of left/right and narrow/wide biases, with each regression compared to a no-bias reference regression (0.5).

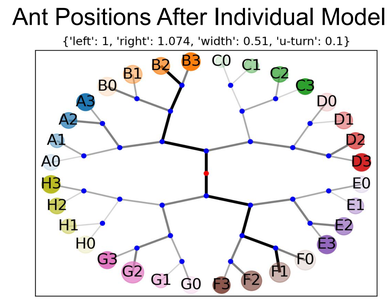


Figure 7: A simulation of 1000 ants over 50 time steps in the individual model parameterized with individual experiment data. Node size corresponds to number of ants present.

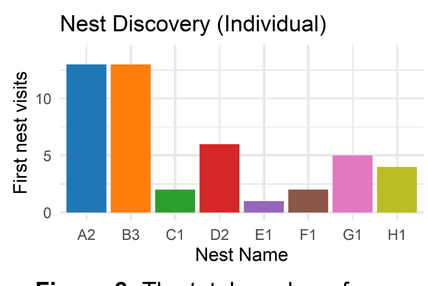


Figure 8: The total number of ants that went into each nest in individual experiments

Individual trial results suggested a slight right bias and moderate wide bias for outgoing ants. The parameters created from our analysis of individual ant walks informed the individual and colony models. The parameters used do not explain observed nest biases, as neither model matches experimental data.

Right: 53.7% Left: 46.3%
Wide: 57.9% Narrow: 42.1%

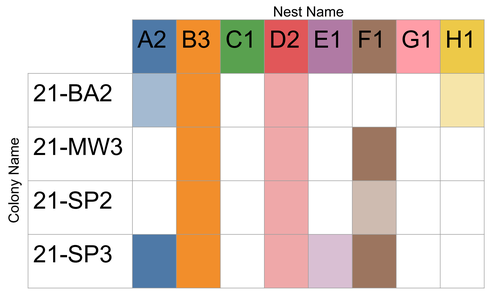


Figure 9: A table of how many ants went into each nest per colony, corresponding to transparency value. Solid is many, light is few, and white is none.

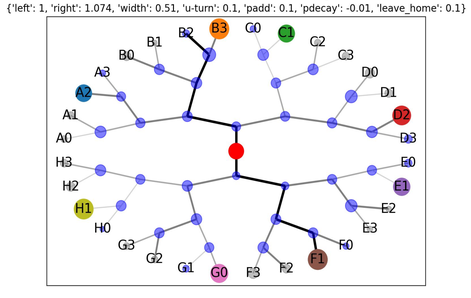


Figure 10: Similar to fig. 7, but in the colony model. Grey nodes are food sources, blue nodes are normal junctions, the red node is the ants' home nest, other colors are nests. Ant biases are informed by the experimental data.

Conclusion

Our model-informed design for the tree helped us design the experimental tree that facilitated data collection for understanding the presence of various biases. We observed that, on an individual level, ants tend to prefer right turns slightly, and wide branches slightly more. Our qualitative observations of the colony experiment corroborated our observed wide bias, as the ants primarily inhabited nests on thick branches.

However, our observed biases cannot explain nest choice observed in the colony experiments. The ants' apparent preference for nest B3 over F1, which slightly goes against the observed width bias, does not show up in our colony experiments. Furthermore, the colony model parameterized from individual experiments does not agree with the experiment results. This suggests that other biases which we did not analyze in our experiments or include in the model are at play. One possible bias could be directionality bias, since nest B3 is closer to the ants' nest box than nest F1.

Acknowledgements

Thank you to C. Wu for working with us on the computer-vision-tracking of the ants, J. Clinton for laying the groundwork and advising our design of the tree structure, and S. Powell, M. Adams for collecting our ants. Funding for this work was provided by Harvey Mudd College and the National Science Foundation.

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.