Modeling Ants on Uneven Terrain

Matthew Moreno[1], Jason Graham[2], Simon Garnier[3]

[1]University of Puget Sound, [2]University of Scranton, [3]New Jersey Institute of Technology

Mathematical Biosciences Institute

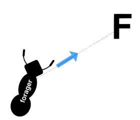
Summary

Ant foraging behavior is a collective decision making process in which, through pheromone deposition and individual interactions between ants, a colony of ants selects and exploits a path between their nest and a food source. Research into the collective decision making strategies of ants, in addition to characterizing the biological mechanisms and emergent properties of the foraging process, has the potential to be leveraged into applications such as swarm robotics and commercial logistics management. Although ant foraging behavior has been extensively studied on flat terrains, ant foraging over uneven terrains is not well studied. This research presents an individual-based set of differential equations to model ant foraging behavior over uneven terrain in an enclosed arena. This model is employed to investigate the characteristics of foraging paths that ants tend towards when foraging over simple inclines of varying magnitudes. Numerical solutions of the model predict that, over most inclines, ants tend to favor the direct path between nest and food, with the direct path typically being more strongly favored when foraging over steep inclines.

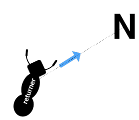
Tetramorium caespitum (Photo courtesy Alexander Wild.)

Model Components

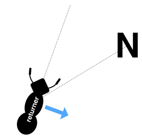
Constant Power Propulsion ants move fastest on slight decline



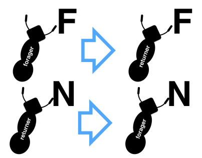
Food Attraction magnitude increases exponentially with proximity to food



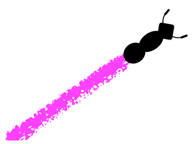
Nest Attraction returner ant accelerates towards nest with constant magnitude



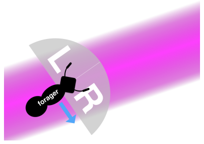
Near Nest Attraction magnitude increases with nest proximity; acts ⊥ to heading



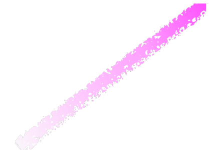
Role Switching occurs 1cm from food (forager → returner) or nest (returner → forager)



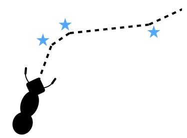
Pheromone Deposit rate proportional to ant speed (i.e. uniform per unit distance)



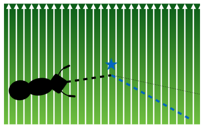
Pheromone Response difference in pheromone between L and R determines magnitude



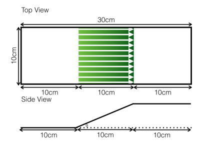
Pheromone Evaporation rate proportional to pheromone concentration



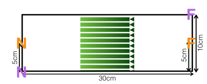
"Boltzmann walker" ant heading modified at occasional random reorientation events



Reorientation on Incline random reorientation biased to alignments parallel to gradient



Arena Terrain comprised of two flat sections joined by a simple incline



Nest/Food Placement center-to-center shown in orange, corner-to-corner shown in purple

Conclusion

Duration of foraging trips was found to increase with the severity of incline traversed, with uphill foraging trips taking longer than downhill ones. It was also found that foraging paths that traverse severe inclines, both uphill and downhill, tend to be more direct, more stable, and more tightly constrained than foraging paths that traverse gentle inclines or no incline. These effects were observed in the corner-to-corner setup, where the direct path crosses the incline at an angle, and–to a lesser degree–in the center-to-center setup, where the direct path is aligned with the incline.

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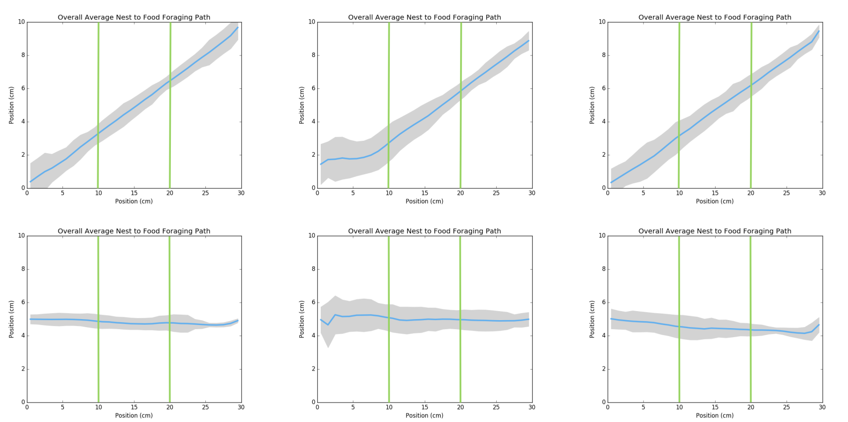
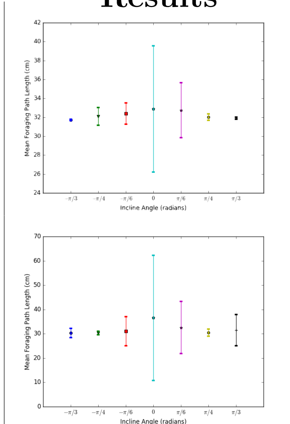
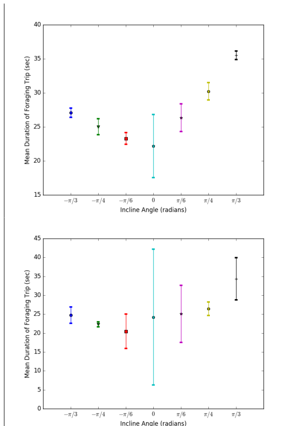
Results



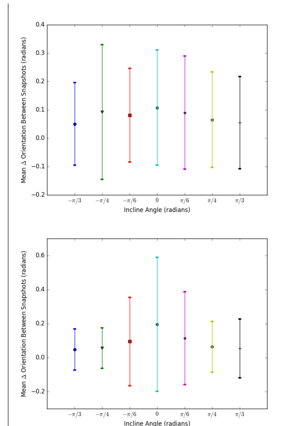
Comparison of overall average nest to food foraging path for, left to right, $-\pi/3$, 0, and $\pi/3$ radian inclines on corner-to-corner arenas (top) and center-to-center arenas (bottom). The blue line indicates the mean path and the gray shading indicates the magnitude of one standard deviation at each x value.



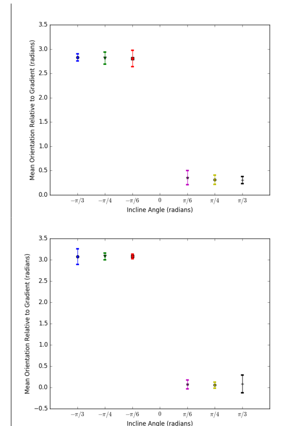
Comparison of nest-to-food path lengths over several incline angles; corner-to-corner arena top and center-to-center arena bottom.



Comparison of nest-to-food trip durations over several incline angles; corner-to-corner arena top and center-to-center arena bottom.



Comparison of changes in heading over half second intervals during nest-to-food travel over several incline angles; corner-to-corner arena top and center-to-center arena bottom.



Comparison of orientation relative to gradient over incline angles; a direct path would be oriented at 2.82/0.32 radians for the corner-to-corner arena (top) and at 0/3.14 radians for the center-to-center arena (bottom).