Ant Foraging Behavior, Combinatorial Optimization, and Routing in Communications Networks

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Overview

- Ant colony optimization (ACO)
  - Algorithms based on simulations of ant foraging behaviors
  - Often as good as other general purpose heuristics
- Artificial ants can be designed to solve combinatorial problems

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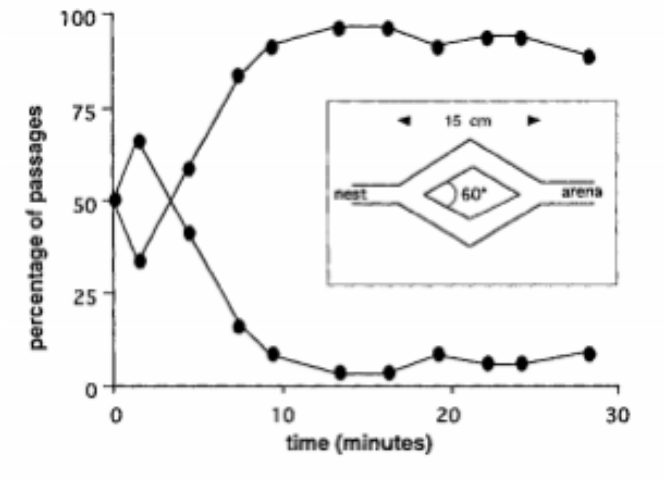
The Binary Bridge Experiment (Simple)



Percentage of ants on each of the two branches over time

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The Binary Bridge Experiment (Simple)

Probability of choosing path A

Degree of attraction of an unmarked branch

Degree of nonlinearity in choice function

Probability of choosing path B

$$P_A = \frac{(k + A_i)^n}{(k + A_i)^n + (k + B_i)^n} = 1 - P_B \,.$$

Number of ants that have used branch A after i ants

Number of ants that have used branch B after i ants

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The Binary Bridge Experiment (Simple)

$$A_{i+1} = \begin{cases} A_i + 1 & \text{if } \delta \leq P_A; \\ A_i & \text{if } \delta > P_A, \end{cases}$$

$$B_{i+1} = \begin{cases} B_i + 1 & \text{if } \delta > P_A; \\ B_i & \text{if } \delta \leq P_A, \end{cases}$$

$$A_i + B_i = i,$$

Random Variable uniformly distributed over [0, 1]

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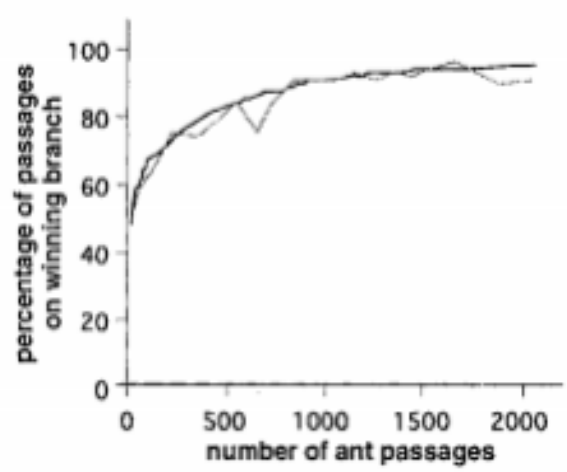
The Binary Bridge Experiment (Simple)



Percentage of passages on the dominant branch as more ants crossed the bridge

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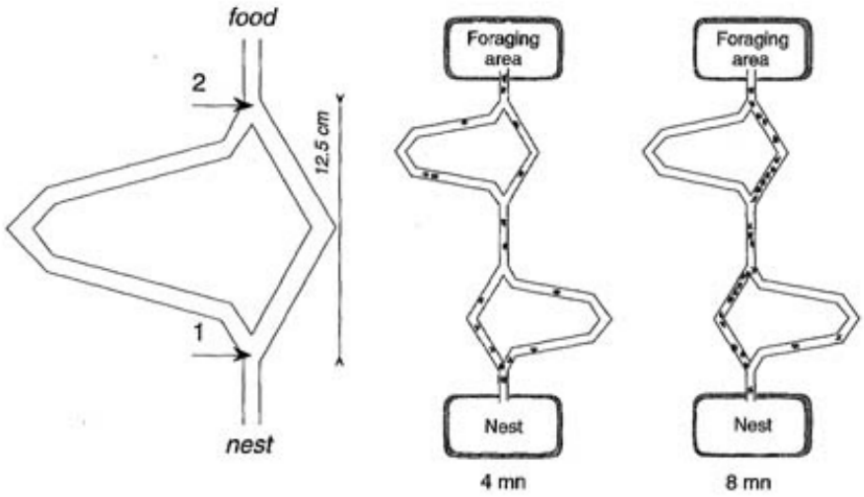
The Binary Bridge Experiment (Expanded)



Distribution of *Linepithema humile* on the dual 4 and 8 minutes after introduction

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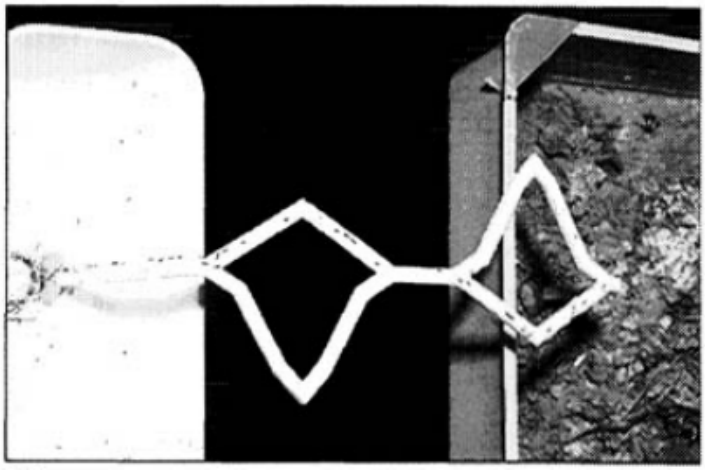
The Binary Bridge Experiment (Expanded)



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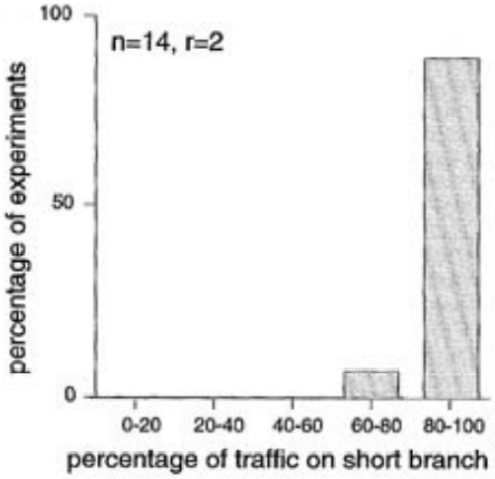
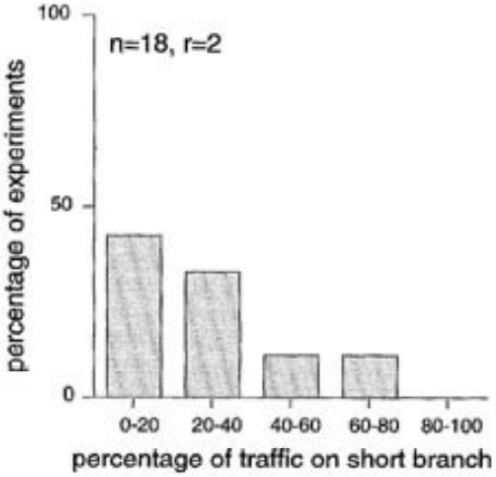
The Binary Bridge Experiment (Expanded)



Ants initially introduced to both paths



Ants introduced to the short path after 30 minutes

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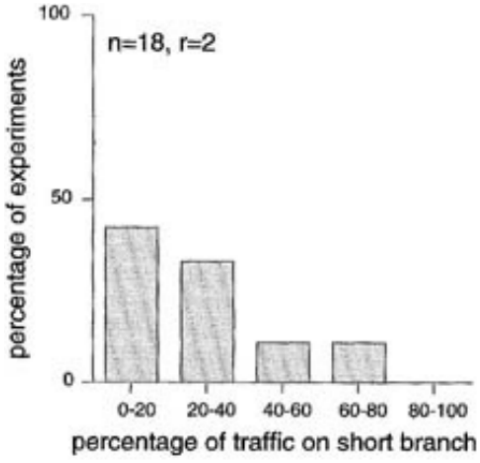
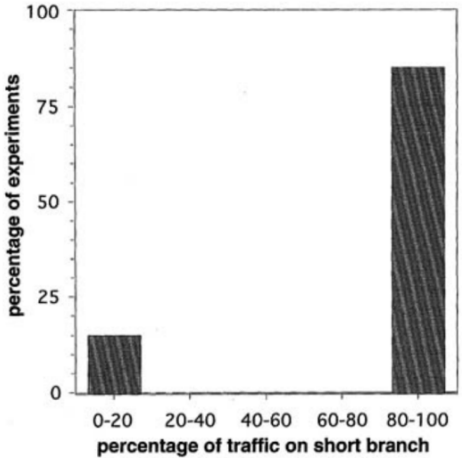
The Binary Bridge Experiment (Expanded)



Linepithema humile (Argentine ant)



Lasius niger (black garden ant)

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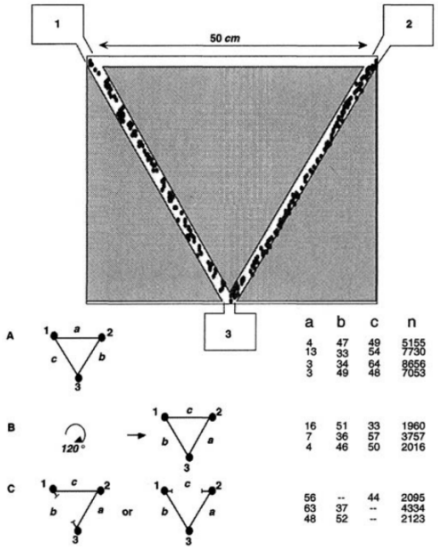
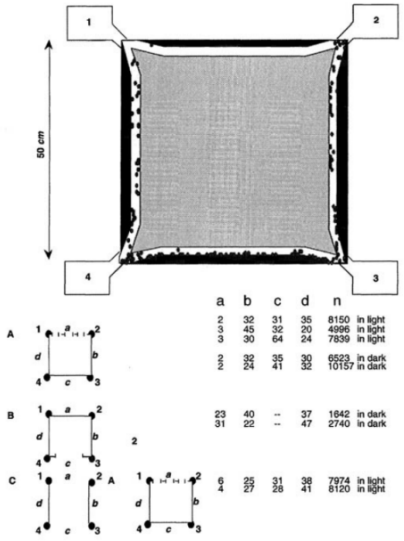
The Case of Inter-nest Traffic



	a	b	c	n
A	4	47	49	5155
	13	33	54	7730
	3	34	64	8656
	3	49	48	7053
B	16	51	33	1960
	7	36	57	3757
	4	46	50	2016
C	56	--	44	2095
	63	37	--	4334
	48	52	--	2123



	a	b	c	d	n	
A	2	32	31	35	8150	in light
	3	45	32	20	4996	in light
	3	30	64	24	7839	in light
	2	32	35	30	6523	in dark
	2	24	41	32	10157	in dark
B	23	40	--	37	1642	in dark
	31	22	--	47	2740	in dark
C	6	25	31	38	7974	in light
	4	27	28	41	8120	in light

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The Case of Inter-nest Traffic

Network of interconnected nests of *Formica lugubris*

Circles represent nests and lines represent permanent trails

Though not formally analyzed it is reasonable to expect some similarity to minimum spanning trees

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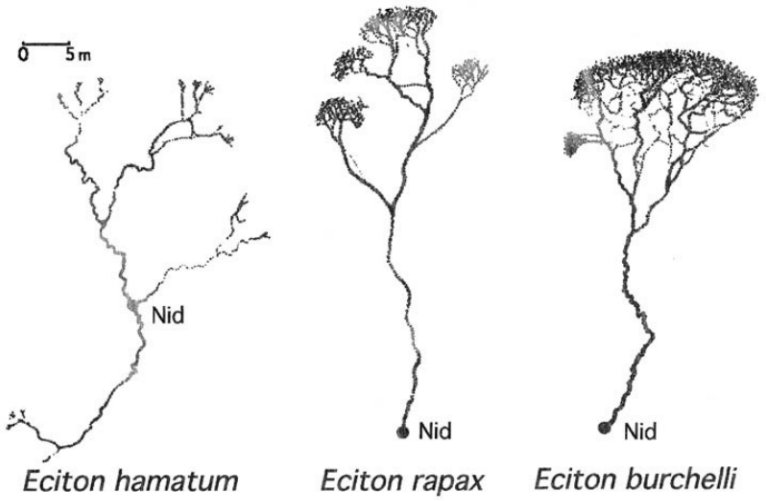
The Raid Patterns of Army Ants



It was noted that the behaviors of all three species are similar

However their food sources have different frequencies and sizes

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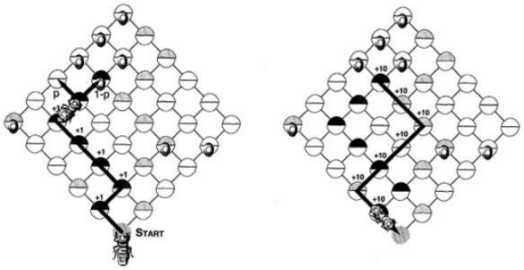
Simulation of Army Ant Raid Patterns



Monte carlo simulation of ants was done on a diagonal grid such that all navigation decisions are binary.

$$p_m = \frac{1}{2}\left[1 + \tanh\left(\frac{\rho_l + \rho_r}{100} - 1\right)\right]$$

Probability an individual ant will chose to move

$$p = \frac{(5+\rho_l)^2}{(5+\rho_l)^2 + (5+\rho_r)^2}$$

Probability a moving ant will chose to move left

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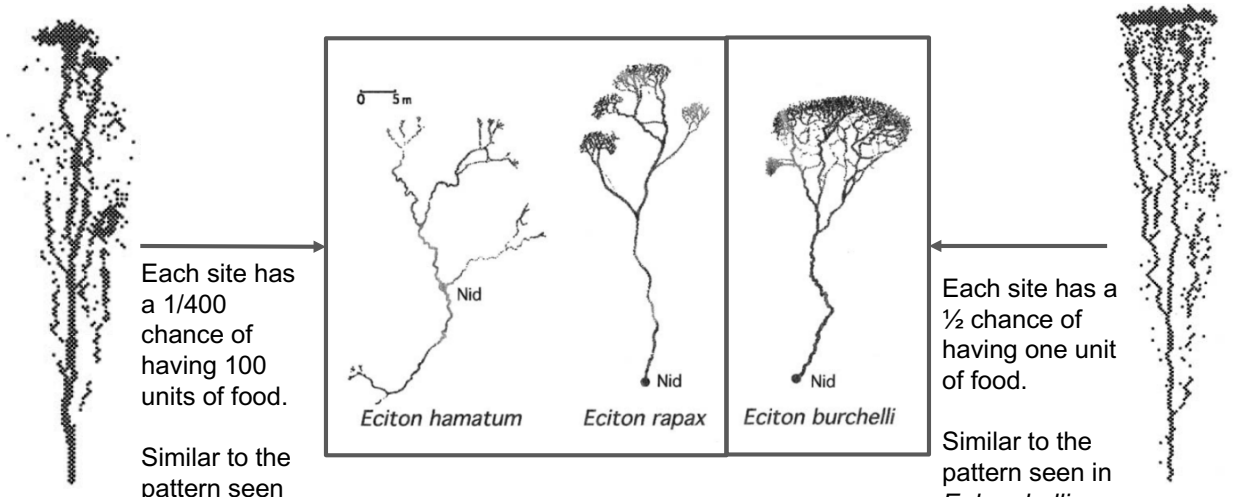
Simulation of Army Ant Raid Patterns



Each site has a 1/400 chance of having 100 units of food.

Similar to the pattern seen in *E. rapax*

Each site has a ½ chance of having one unit of food.

Similar to the pattern seen in *E. burchelli.*

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Questions?

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