Nest structure influences colony relocation in harvester ants

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Background

- It has been shown that the physical structure of living spaces can influence the behavior of social groups and individuals occupying these spaces[1,2]
- Colonies of social insects in many ways resemble human societies, yet insects respond to clearer and simpler incentives which makes these colonies a great model for studying the effects that built environment has on societal organization[3]
- Here, we examine how nest relocation of harvester ants *Veromessor Anderi* is affected by the architecture of the nest

Goals

1. Verify that nest architecture affects collective behavior of harvester ants during nest relocation
2. Build a reliable computer simulation replicating the relevant features of the nest relocation event
3. Identify specific features of the nest architecture that correlate with changes in collective behavior

Materials and methods

Figure 1. Top-down view of an empirical nest relocation experiment. Ants move from one artificial nest to another driven by the uncomfortable environmental conditions (high heat level) in the occupied nest

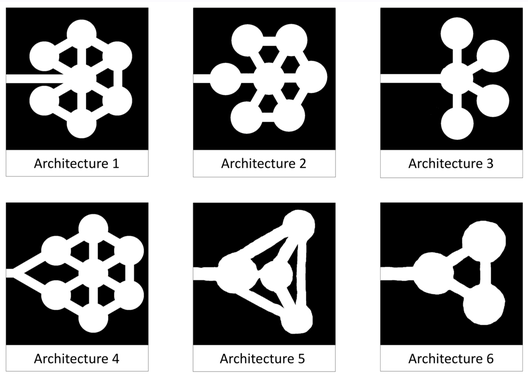

Figure 2. Architectures of the artificial nests. These structures were used both as "blueprints" for laser-cut physical nests and as arenas in the simulated experiments

Acknowledgments

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Computational agent-based model

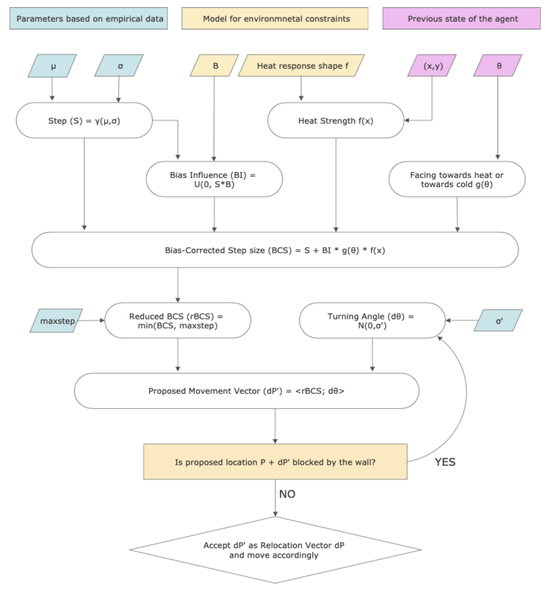


Figure 3. Flowchart of the relocation vector generation. Relocation vector defines movement of the agent at any given time step. It is generated independently for each agent at each time step

Quantifying space: PCI and ACI

Idea: measuring the curviness of the path to the nest exit

- **Point Curvature Index (PCI)** – scaled sum of turns on an optimal path from a given point *P* to the exit from the nest

$$c(p) = \frac{1}{\pi}\sum_{i}(\pi - \alpha_i(p))$$

- **Architecture Curvature Index (ACI)** – average path curvature from a point in a given architecture to the the exit from the nest

$$C_a = \left(\frac{\sum_{p\in A} c\,(p)}{|A|}\right)^{-1}$$

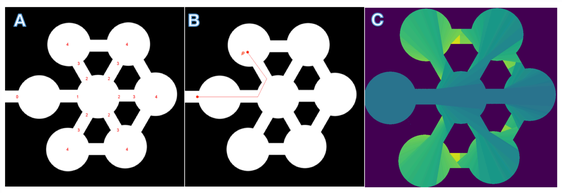
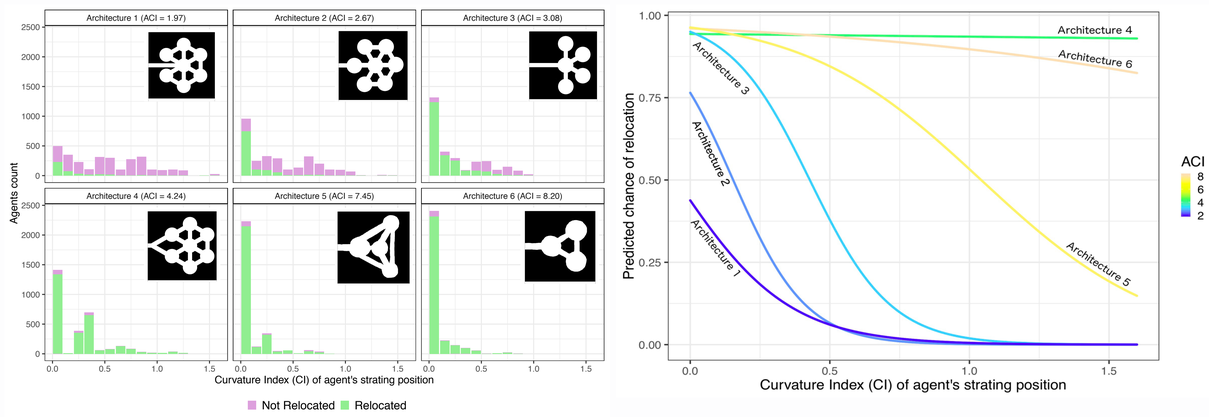


Figure 4. Computation of an optimal path to the nest exit (A, B) and PCI heatmap (C) of a sample architecture

1. Bafna S, Chambers E. The influence of spatial organization of the home on inhabitant activity. AZ. 2014 Dec;11(2):31–46.
2. Cassiers T, Kesteloot C. Socio-spatial Inequalities and Social Cohesion in European Cities. Urban Studies. 2012 Jul 1;49(9):1909–24.
3. Pinter-Wollman Noa, Penn Alan, Theraulaz Guy, Fiore Stephen M. Interdisciplinary approaches for uncovering the impacts of architecture on collective behaviour. Philosophical Transactions of the Royal Society B: Biological Sciences. 2018 Aug 19;373(1753):20170232

Results

I. Effect of the starting position PCI



II. Spatial distribution of initial positions had no effect

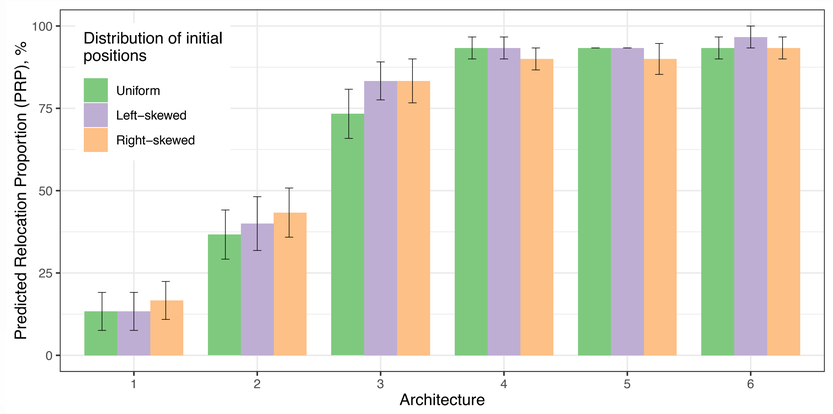


Figure 5 (Top left). Curvature index (CI) of the starting position of simulated agents that relocated (green) or did not relocate (lavender) into the new nest.

Figure 6 (Top right). Likelihood of simulated agents to relocate in relation to the CI of their starting positions.

Figure 7 (Bottom left). Average relocation proportion for a given combination of a nest architecture and agents' initial positions distribution

III. Effect of the architecture curvature

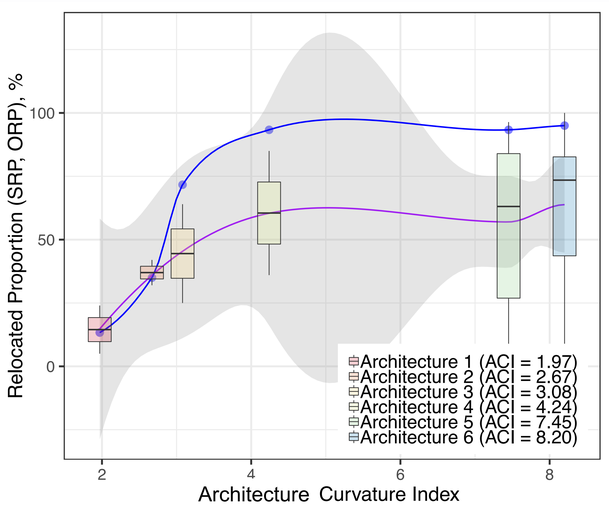


Figure 8. Simulated and observed proportions of individuals that relocated to the new nest in relation to the ACI of the architecture. Blue line is an interpolation of mean PRP values of simulations; boxplots aggregate results from empirical experiments. Purple line is an interpolation of ORP values of the empirical experiments.

Conclusions

- Both PCI and ACI are predictive of the colony relocation success
- Differences in PCI effect size (Fig. 6) in different architectures indicate that overall curviness of the architecture has an effect on relocation success that acts in parallel to the influence of the starting position conditions
- Computational model correctly predicts the shape of the trend in relocation proportion change, but overestimates relocation efficiency for simple (high ACI) architectures

Practical implications and future work

- A combination of PCI and ACI measures can be developed into a novel way of quantifying the complexity of living spaces
- Computational model of the nest relocation can be used to develop and test new hypotheses about the dynamics of nest relocation in *V. Andrei*
- Other space quantification measures should be tested for correlation with the effectiveness of collective behavior