A Functional Decomposition of Eusocial Insect Parasite Resistance: A Tool for Biologically Inspired Design

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Abstract

Resilience is a vital component of multi-agent systems, as a lack of resilience can easily lead to system failure. Faulted agents are one of the many things that can impact a system. One aspect of resilience, resisting the effects of these faulted agents, can reduce system costs and downtime. Solving the problem of increasing system resilience is not an easy one, however, as some solutions require increasingly complex solutions that do not scale well. Eusocial insects face these challenges often, thus making them prime examples to find unique biological solutions to resilience. In this work the connection between eusocial insect behaviours and faulted agent resilience is explored, as well as the transfer of these behaviours to generalized functions for multi-agent systems. This work's primary contribution is the presentation of a functional decomposition of eusocial insect behaviours in relation to pathogen and/or parasite resistance. Additionally, functions and tactics based on these behaviours are identified and presented. These functions will provide the basis for future work in biologically inspired design and faulted agent resilience.

Research Question

How can we describe eusocial insect behavior to better understand naturally resilient systems?

Purpose

- Study current literature of eusocial insects to determine biological responses to faulted agents.
- Relate the biological responses to tactics in synthetic systems

Hypothesis

If we perform a functional decomposition on eusocial insect parasite resistance, *then* we can relate them to artificial systems, *because* both need resilience in unknown environments.

Why is this important?

- This work connects across disciplines, diversifying current resilience research.
- This work acts as a guide for engineers through biological literature and research.
- This work lays the groundwork for future resilience research.

Primary Functional Decomposition

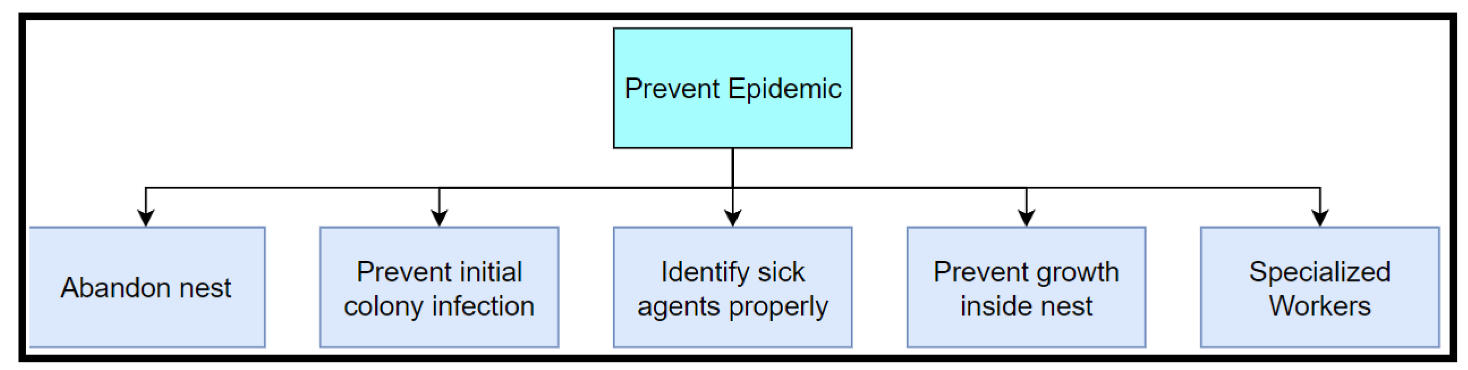


Figure 1: Five Primary Strategies

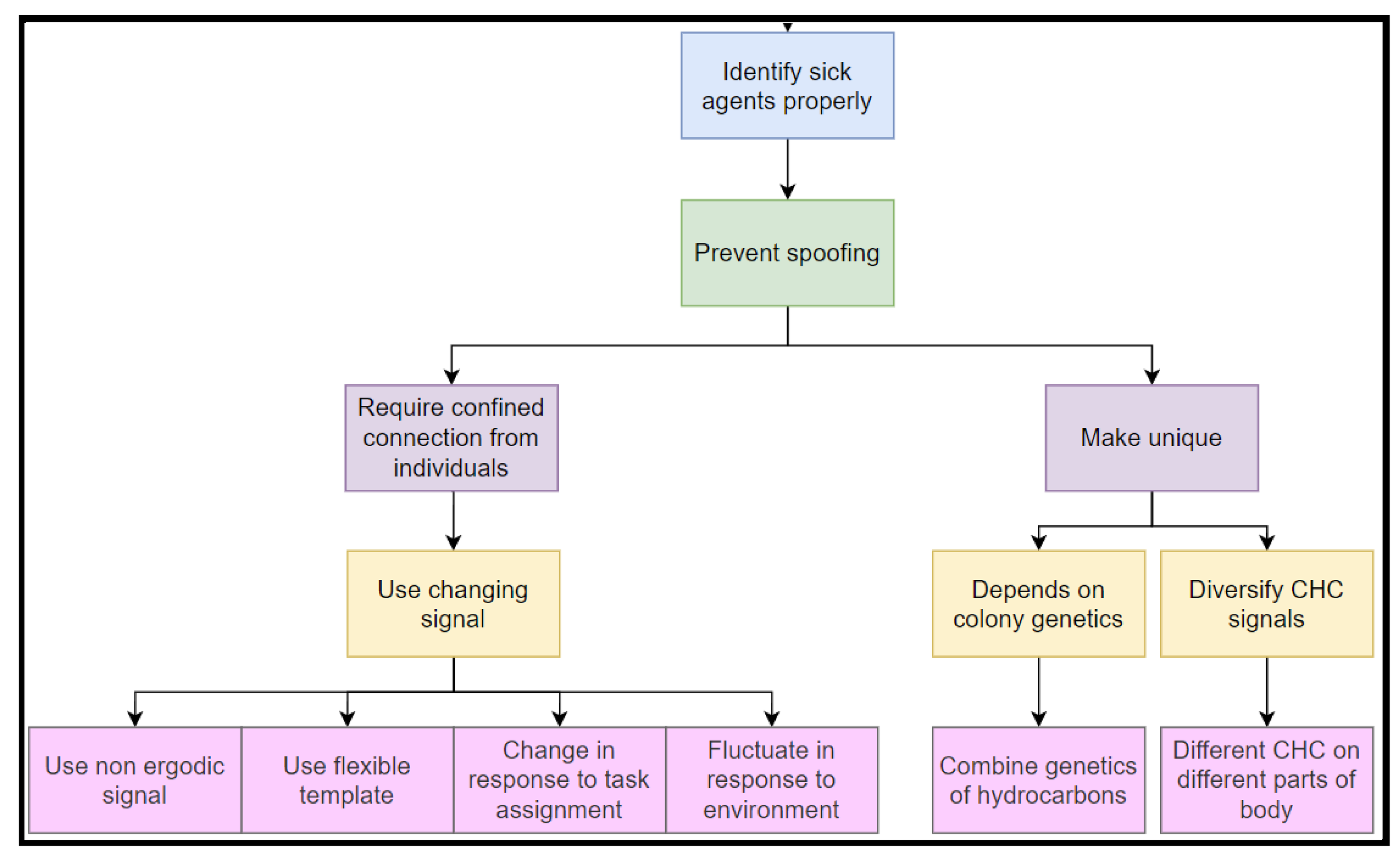
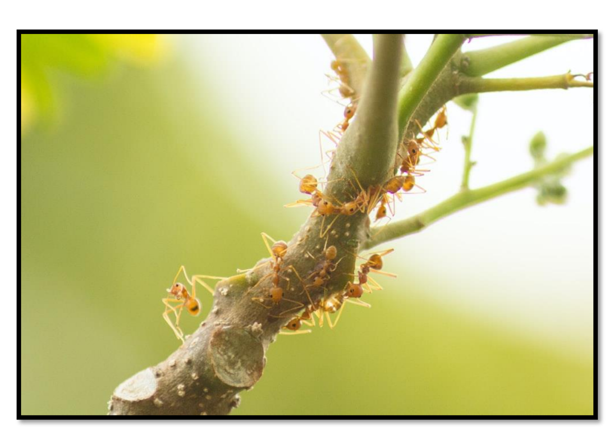


Figure 2: Excerpt from Functional Decomp showing all levels of decomposition

Decomposition to Functions



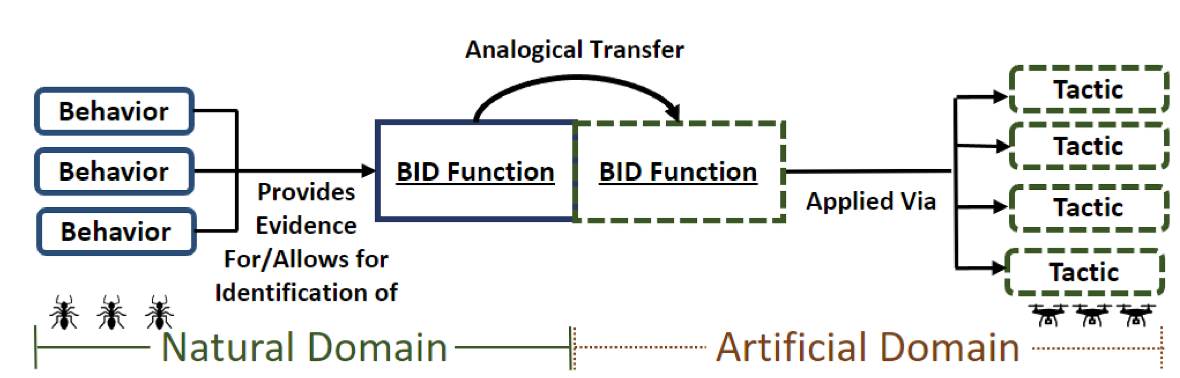


Figure 3: BID4R Standard Process for function transfer

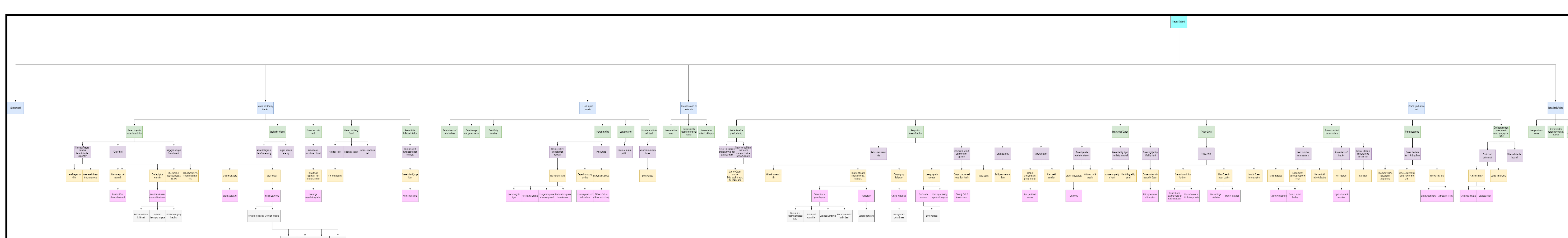


Figure 4: Full Functional Decomposition

Example Functions

Eusocial Insect Function	Generalized BID Function
Control nest environment	Control local environment
	Secure communication network
Respond to Invasion/Infection	Remove faulted agent from network
	Secure network from faulted agents
	Identify compromised agents
	Reduce fault propagation rate
Enhance individual immune systems	Share successful security measures between agents
	Improve individual security measures overtime
	Communicate in resilient networks
Protect Queen	Protect central node(s)
	Secure central node(s) from transmission vectors
	Improve central node(s) resilience and response
Protect role of Queen	Protect central node(s) signal
	Ensure central node(s) authority
	Ensure central node(s) signal authenticity

Quick Metrics

- 25 biological papers sourced
- 5 primary strategies
- 23 supporting functions of primary strategies
- 110 total functions supporting primary goal

Conclusion

- An in-depth literature review of over twenty peer reviewed biological paper sources used to create a functional decomposition of eusocial insect behavior in relation to parasitic resilience.
- Five primary strategies were identified that bolster eusocial insect resilience to parasitic influence.
- Over one hundred individual behaviors identified to support the goal of protecting the colony.

Future Work

- Translate identified behaviors into system functions.
- Model and simulate system functions to characterize their importance.
- Future work currently under review for NSF grant.

Biologically Inspired Design-for-Resilience Lab

Contacts

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