A Machine-Learning Based Real-Time Analysis to Quantify the Effects of Gut Microbes in Social Insect Collective Behavior

Alessio Sclocco and Serafino Teseo

October 16, 2019

A Machine-Learning Based Real-Time Analysis to Quantify the Effects of Gut Microbes in Social Insect Collective Behavior

Alessio Sclocco[1†], Serafino Teseo[2]

[1]Netherlands eScience Center, Amsterdam, the Netherlands
(E-mail: a.sclocco@esciencecenter.nl)
[2]School of Biological Sciences, Nanyang Technological University, Singapore
(E-mail: steseo@ngu.edu.sg)

Abstract: Researchers in gastroenterology, microbiology and neuroscience employ animal models to investigate the role of gut microbes in socially relevant behavior. Surprisingly, despite being lab-friendly models for sociality-related questions, group-living insects receive little attention from this perspective. Nonetheless, insect social behavior research is currently undergoing a radical transition, thanks to the increasing availability of high-throughput video tracking systems. However, these video tracking systems have minimal behavioral pattern identification and perform data analysis only a posteriori on previously recorded videos. Our goal is to study how gut microbes of individual ants affect the emerging properties of the whole colony, and develop a machine-learning based behavioral pattern classifier, to help us recognizes individual behavior in real-time. This intelligent tracking system will be connected with a processing backend for simultaneous data harvesting and analysis. The device will be used to monitor laboratory ant colonies including artificially gut microbe-remodelled workers in differential proportions. Generated datasets will include individual behavior, social interactions and colony-level information. There are two main predictable scenarios: 1) microbe remodelling-mediated individual behavioral changes do not affect the emerging properties of the group; 2) colony-level properties vary based on the presence/proportion of microbe-suppressed individuals. This study would be the first attempt to investigate the role of gut microbes on whole animal societies, and the first to provide these results in real-time.

Keywords: Animal Behavior, Social Insects, Social Evolution, Video Tracking, Machine Learning

1. INTRODUCTION

Understanding the emerging properties of collective entities is a major challenge across scientific disciplines. Social insects like ants, wasps and bees live in complex societies that behave as single organisms, but are constituted of simple interacting modules (individual workers). Recently, some scholars implemented automated systems to measure interactions within insect societies, opening a window on their emerging properties [1] [2] [3]. In these systems, insects are tagged with individual QR codes and move on 2D artificial arenas, while top view cameras connected to computers record images of all individuals. After experiments, which can last from hours to weeks, data are harvested and dedicated software recognizes QR code positions over time, producing interaction matrices for each individual. These matrices are then integrated to establish whole-colony social network structures, and experimental vs control colonies are compared to identify responses to specific treatments. A limitation of systems based only on positional data is that they do not detect individual-level behavioral patterns (e.g., self cleaning, item transport) or behavior-relevant individual attributes (e.g., speed, trajectory patterns). Importantly, interactions among individuals are only identified using QR tag positions and orientation in each picture, for example assuming that two workers are interacting because the respective tags are close and oriented at a certain respective angle. Therefore, such systems cannot detect what individuals do at specific moments and locations, or how and how long individuals interact.

Using machine learning, it is not only possible to develop video tracking systems that are more accurate than the human eye, but also make these systems intelligent [4]. In this work, we exploit this intelligence to achieve automatic recognition and classification of social interactions in an insect colony, overcoming the technical limits illustrated above. However, simply being able to automatically recognize behavior is not enough. What is really interesting, is to be able to follow the interactions of individuals in a colony through time, and be able to quantify these simultaneously. Therefore, a machine-readable description of movement and interaction of individual insects will be fed to a real-time analysis backend. This high-performance backend would be able to quantify the interactions of multiple colonies in parallel, and produce real-time statistics on the social network of said colonies.

The developed technology will be of relevance for all social behavior scientists. It will potentially be adopted by other insect scientists and could be adapted to other lab model systems, such as mice. Moreover, the system will be used for further studies targeting any type of behavior, even in other insect species with completely different social systems. Deciphering the multidirectional crosstalk between gut microbes, guts, individuals and societies is paramount for understanding human behavior and treating behavioral disorders such as depression and autism. This study will shed light on how social groups influence and are influenced by individual gut microbes, helping us move our first steps in this direction.

† Alessio Sclocco is the presenter of this paper.

2. METHODOLOGY

Ant colonies (genus Camponotus) are currently kept in the laboratory at NTU. One month before experiments, ant workers will be microbe-suppressed via antibiotics injection (Rifampicin) in their first hours of adult life, a period corresponding to the peak of the target gut bacterium (Blochmannia). Treated and control workers (injected with a "dummy" solution) will be put together in differential proportions (0%, 33%, 66%, 100%) in 50-individual experimental colonies. Each ant will be marked with a QR code glued on the thorax, serving as an individual identifier throughout the experiment.

The experimental apparatus for video tracking will be constituted of four units installed on an anti-vibration table, each hosting a single ant colony. Each unit will include a foraging area and a closed nest protected from light, with an infrared camera placed on top. The nest will be exposed to infrared light in order to keep darkness while collecting images, whereas the foraging area will be exposed to visible light during the day and infrared light at night, to simulate day/night alternation; experiments will last for one-two weeks.

Cameras will be connected to a computer located in the laboratory, and all processing will take place on it; acquisition will take place through USB or other high-speed A/V cables, or through the network. Video capturing through a network stream makes the system suitable also for analyzing streams that are not produced locally, or to deploy the tracking and analysis software on the cloud. The video streams are saved for archival purposes, while at the same time being processed in real-time by our system.

The real-time processing system is divided into two parts: 1) tracking and 2) analysis. Instead of using standard feature recognition, the tracking subsystem will be based on machine learning; the advantages are resilience to partially obscured or damaged QR codes, and the enrichment of positional tracking with behavioral information. The analysis component will process the output of the tracker to produce real-time models of the behavior over time of single individuals, together with interaction models of subgroups and the whole colony. All software will be modular and reusable, to foster adoption by other researchers, and it will be distributed under a permissive open source license (e.g., MIT, Apache); the annotated data sets used for training and testing of the tracker will also be made available and distributed under a permissive open source licenses.

REFERENCES

[1] Stroeymeyt N. and Grasse A.V. and Crespi A. and Mersch D.P. and Cremer S. and Keller L., "Social network plasticity decreases disease transmission in a eusocial insect", *Science 362*, pp. 941-945, 2018.

[2] Ulrich Y. and Saragosti J. and Tokita C.K. and Tarnita C.E. and Kronauer D.J.C., "Fitness benefits and emergent division of labour at the onset of group living", *Nature 560*, 2018.

[3] Greenwald E.E. and Baltiansky L. and Feinerman O., "Individual crop loads provide local control for collective food intake in ant colonies", *eLife 7*, 2018.

[4] Mathis A. and Mamidanna P. and Cury K.M. and Abe T. and Murthy V.N. and Mathis M.W. and Bethge M., "DeepLabCut: markerless pose estimation of user-defined body parts with deep learning", *Nature Neuroscience 21*, pp. 1281-1289, 2018.