Collective Animal Behavior

Analyses and models of animal movement and interaction

F. Ghanbarnejad & V. M. Eguíluz/ CCS 2018 / September 27, 2018 / Thessaloniki, Greece **collab2018.weebly.com**

Michele Tizzoni (INVITED)
Measuring and modeling animal social networks with sensors
One of the key technical challenges in studying animal social networks is determining the patterns of social contact among multiple individuals. Recent technological advances have enabled the automated collection of contact data from a broad range of free-ranging animals through the use of proximity loggers. However, large-scale deployments are often hindered by the unit cost of the devices. Here, I will present the application of a fully - distributed proximity sensing platform – originally developed to measure human proximity – in an animal social network study. The platform has been used during an extensive field deployment on free-ranging domestic dogs (*Canis lupus familiaris*) in two settlements in rural Chad. The proximity-sensing system has been integrated with GPS-based telemetry. I will give an overview of the contact patterns measured by the sensing platform and their implications for behavioral ecology and infectious disease dynamics, in particular for modeling the spread of rabies.

Joshua Garland, Andrew Berdahl, Jie Sun and Erik Bollt
Anatomy of Leadership in Collective Behaviour
Understanding the mechanics behind the coordinated movement of mobile animal groups (collective motion) provides key insights into their biology and ecology, while also yielding algorithms for bio-inspired technologies and autonomous systems. It is becoming increasingly clear that many mobile animal groups are composed of heterogeneous individuals with differential levels and types of influence over group behaviors. The ability to infer this differential influence, or leadership, is critical to understanding group functioning in these collective animal systems. Due to the broad interpretation of leadership, many different measures and mathematical tools are used to describe and infer "leadership", e.g., position, causality, influence, information flow. But a key question remains: which, if any, of these concepts actually describes leadership? We argue that instead of asserting a single definition or notion of leadership, the complex interaction rules and dynamics typical of a group implies that leadership itself is not merely a binary classification (leader or follower), but rather, a complex combination of many different components. In this talk we will develop an anatomy of leadership, identify several principle components and provide a general mathematical framework for discussing leadership. With the intricacies of this taxonomy in mind we will present a set of leadership-oriented toy models that should be used as a proving ground for leadership inference methods going forward. We believe this multifaceted approach to leadership will enable a broader understanding of leadership and its inference from data in mobile animal groups and beyond.

Gabriel Ramos-Fernandez, S. E. Smith Aguilar, D. C. Krakauer, Jessica C. Flack
Individual decision-making and collective fission-fusion dynamics
Fission-fusion dynamics, where a group of animals is divided in subgroups that change their size and composition continuously, is a collective pattern arising from individual decisions. These dynamics are adaptive, as they allow individuals to forage more efficiently in heterogenous environments, sharing information about the location of resources and flexibly adjusting the size of their subgroups to the current resource availability. In turn, fission-fusion dynamics also pose a challenge for the regulation of social relationships, as they increase the uncertainty that individuals will have about the identity of their associates. As such, they have been related to the emergence of cognitive abilities that reduce this social uncertainty.
In this study we aim at uncovering the rules by which individuals decide to join or leave subgroups, according to dyadic influences. We propose that these microscopic dynamics are integrated into a mesoscopic level, i.e. the network of all significant influences, together with the rules by which each each node in the network integrates all incoming influences. This mesoscopic level would then lead to the emergence of an adaptive macroscopic property: a distribution of subgroup size that successfully tracks the distribution and abundance of food resources in the environment. Data consist of 5780 scan samples of subgroup composition collected in 2013-2014 on a group of individually identified and habituated spider monkeys (Ateles geoffroyi) in natural conditions in the Yucatan peninsula, Mexico. For the same period, we registered the bi-weekly distribution and availability of fruiting trees of different size. For a continuous series of scans, we calculate the conditional probability that an individual is present (or absent) given another individual's presence (or absence) in the previous scan. These conditional probabilities of presence (or absence) are then compared to null probabilities obtained by permutation of the original data set. The dyadic influences that were significantly different from the null allowed us to construct networks of significant influence. In order to recover the macroscopic property that could be emerging from these networks, we simulate datasets assuming that each individual integrates all its incoming significant influences to decide whether to stay, leave or join a subgroup. By assuming different rules by which significant influences are integrated, we can give more weight to repulsive forces (as would occur when food is not plentiful) or attractive forces (when food is more plentiful), generating simulated datasets where the subgroup size distribution matches different conditions in the environment to different extents. The model can be validated by evaluating the actual match between the observed subgroup size distribution and that of the available tree distribution.

Ariana Strandburg-Peshkin (INVITED)
Collective movement in animal societies
Group-living animals face a wide array of coordination challenges, from coming to consensus with group mates about when and where to move, to avoiding competition when searching for food, to collectively defending shared resources from external threats. For animals that live in stable social groups, social relationships are often multi-faceted and can persist over an individual's lifetime. These complexities may introduce heterogeneity into the rules individuals employ when making decisions, with potential consequences for group-level outcomes. Furthermore, many species have evolved sophisticated communication systems that can play a key role in shaping the processes of group coordination. Employing technologies such as lightweight GPS tags, accelerometers, and audio recorders enables us to monitor of the movements, behaviors, and vocalizations of multiple individuals simultaneously within wild animal groups, offering a new window into the mechanisms underpinning collective behaviors in natural contexts. In this talk, I will present recent and emerging collaborative work exploring the mechanisms by which animals living in stable social groups coordinate collective behaviors, focusing on three systems of social mammals: olive baboons, meerkats, and spotted hyenas.

Romualdo Pastor-Satorras and M. Carmen Miguel Lopez
Effects of heterogeneous social interactions on flocking dynamics
Social relationships characterize the interactions that occur within social species and may have an important impact on collective animal motion. Here, we consider a variation of the standard Vicsek model for collective motion in which interactions are mediated by an empirically motivated scale-free topology that represents a heterogeneous pattern of social contacts. We observe that the degree of order of the model is strongly affected by network heterogeneity: more heterogeneous networks show a more resilient ordered state; while less heterogeneity leads to a more fragile ordered state that can be destroyed by sufficient external noise. Our results challenge the previously accepted equivalence between the static Vicsek model and the equilibrium XY model on the network of connections, and point towards a possible equivalence with models exhibiting a different symmetry.

J. Fernández-Gracia, J. P. Rodríguez, L. Peel, K. Klemm, M. Meekan, V. M. Eguíluz
Inferring intraspecific tracing behaviour in animal movement
We propose a method for detecting following connections between individuals from their presence time series. We measure the inter-event times associated with each detection and the next, focusing on the consecutive detection of two different individuals, and study the statistical distance between the distributions of inter-event times of one individual after another and vice versa. High distances represent an asymmetry, as shorter inter-event times are more likely for the case in which one individual follows another than in the reversed case. From these distances, we build a directed network with links pointing towards the followees. We illustrate this method using the sequence of presence reports of 24 manta rays, reported as the detection on an acoustic receiver of the signal from a transmitter device brought by each individual, and analysing the follower-followee network taking into account the sex and size of each individual.

Ewan Colman, Andreas Modlmeier, David Hughes and Shweta Bansal
Spatial and social organization of an ant colony
Ant colonies exhibit a remarkable social dynamic in which each ant specializes in one particular function. The roles that have been observed are often analogous to human activities, there are nurses, workers, foragers, guards and so on. To perform these tasks effectively there must be sufficient communication between ants of different types; the foragers need to react when other ants are in need of food, the guards need to be called to arms when a threat appears, and each ant needs must be aware of what the others are doing in order to decide what she herself should do. By observing interactions and mapping their communication networks we can begin to understand how ants self-organize to achieve balance and efficiency.
One way to find out how ant society is structured is to manipulate its environment and observe how the colony adapts. In a laboratory experiment we introduced a colony into an artificial nest box that was barely large enough to contain them, then, after observations had been made, the box was extended to four times its original size. We tracked the locations of all 80 ants and recorded each trophallaxis (food-sharing) interaction over a 4-hour period. At first it seemed like the ants changed their behaviors in response to the changes in nest space; they adapted to the larger nest box by segregating into two distinct spatial regions, prompting the question: how does their spatial organization affect communication and food distribution throughout the colony?
To answer this we constructed two types of network. In the first, ants are nodes and the weight of each edge represents how similar they are in regards to their movement patterns. The second is a temporal network constructed from the trophallaxis interactions. We analysed community structure, path lengths, path durations and communicability. We also developed a mathematical model that considers the heterogeneity in contact rates between different pairs of nodes and fit the model to the trophallaxis data and to several other animal and human contact networks.
We conclude that ants exhibit a remarkable consistency in their social structure even when tested by extreme changes to their environment, in particular: The spatial and social structure of the ant colony is robust against changes to their nest size. Spatial structure and social structure, as observed in the trophallaxis network, are co-dependent. The rate at which food and information spreads through the network of trophallaxis interactions is not affected by the size and density of the nest. Ant populations are more homogeneously mixed than human and other animal populations. This aspect of their behavior is not affected by the nest size.