Using movement parameters to infer dynamic interactions between moving object pairs

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Abstract

'Interactions' between and among moving objects occur across widely varying spatial and temporal scales and are an important component for understanding spatial behaviours such as mating, predation, and territoriality as well as phenomena resulting from these behaviours such as disease spread. 'Dynamic interactions' refer to interactions that are defined based on proximity in both space and time and while social network analysis can be applicable for studying interactions among human individuals as well as among animal individuals, a 'dyad' (comprised of two individuals) is more often used as the unit for studying interactions between animal individuals. The two main approaches of quantifying dynamic interactions between two individuals involve treating the locations as discrete **points** or examining the **paths** that are inferred as trajectories between subsequent points. In this research I present results that use a hybrid approach of quantifying interactions using spatiotemporal point proximity and comparing movement path parameters to infer interaction behaviors. This new method is applied to thirteen black-backed jackal dyads in Etosha National Park, Namibia.

Key words: movement pattern analysis, spatiotemporal, trajectories, interaction

1 Introduction

'Interactions' between and among moving objects occur across widely varying spatial and temporal scales and are an important component to processes ranging from disease spread to information flow and technology diffusion. 'Dynamic interactions' refer to interactions that are defined based on proximity in both space and time and while social network analysis can be applicable for studying interactions among human individuals as well as among animal individuals, a 'dyad' (comprised of two individuals) is more often used as the unit for studying interactions between animal individuals

Interactions are measured using data representing the locations of two individual along with a time stamp and the two main approaches involve treating the locations as discrete points or examining the paths that are inferred as movement between subsequent points. Point-based metrics often depend on subjective inputs (temporal and distance thresholds, home range estimates), while path-based metrics do not involve spatial proximity. In this research I present results that borrow from both of these frameworks to test for interaction-related differences in parameters. I use a dataset on black-backed jackals (*Canis mesomelas*) in

Etosha National Park (Bellan and Getz 2017) to illustrate these methods. Black-backed jackals are monogamous and territorial and their social structure is comprised of solitary residents, transients, and pair/pack members. The individuals whose locations were tracked in this dataset show a range of different spatial interactions and make an excellent case study for these methods.

1.1 Modeling interactions

Dyad interactions are measured based on either the point data or the paths or trajectories that are inferred as connecting subsequent points. While these point-based dynamic interaction metrics involve the concept of two individuals occurring "together", path-based interaction metrics use movement trajectories as the basic unit of analysis and compare similarity in movement parameters such as speed, direction, and mean displacement (Calenge et al. 2009). These path-based metrics define interaction solely in terms of movement similarity and do not consider the distance between the two individuals or their location relative to designated spaces such as home range overlap. Since point-based metrics include explicit representations of proximity, they may be more appropriate for studying positive interactions such as direct contact related to mating or disease spread. Each of these approaches (point vs. path) has generally been considered separately when measuring interactions, although metrics that combine them are being introduced (Konzack et al. 2017, Zhang et al. 2018). The movement coherence quantified by path-based metrics may make them more appropriate for studying both positive and negative interactions related to, ex., predator-prey dynamics.

Both point- and path-based interaction metrics have limitations as well. Point-based interaction metrics typically require a subjective parameter such as home range delineation or a distance threshold. Distance thresholds can be based on previous research or observation while temporal thresholds are often a function of the data resolution. Path-based metrics involve fewer subjective decisions, but what they are measuring in terms of 'interaction' is really path similarity irrespective of spatial proximity and may not be appropriate for some applications.

In spite of the importance of measuring interactions, they have not been a main research focus in movement analysis. Few studies have tested different dynamic interaction metrics using the same data, and when they have been compared, the results have been quite incongruous (Long and Nelson 2013, Long et al. 2014; Miller, 2012; 2015). Most of the metrics that measure interactions range from -1 to 1 or 0 to 1 and either specify negative interaction or no interaction as the lowest value. However, it is unclear whether negative interaction can be measured using the same metrics as positive interaction. In fact, studies that have compared performance of these metrics using simulated data rarely find evidence of negative interaction (Long et al., 2015; Miller 2015). This research aims also to explore whether negative interaction can be identified with this hybrid point-path measure.

2 Methodology

The research presented here introduces a hybrid point-path approach to analyse interactions that harnesses the advantages of each approach. First, a point-based interaction ('contact') is identified based on appropriate spatial and temporal thresholds. The temporal thresholds used (4200 seconds) are a function of the temporal resolution and four distance thresholds were used: 100m, 500m, 1000m, and 5000m. The first three distances are intended to represent potential interactions between individuals, while 5000m is used as a null model since no meaningful ecological interactions between jackals would be expected to occur at that distance. Movement trajectory parameters for the step before, during, and after a 'contact' are considered here to be those that could potentially represent interactive behavior (eg., attraction, avoidance), and these contact-related parameters are compared to the distribution of non-contact related parameters ('other'). Movement parameters tested included relative and absolute angles, step length, velocity, persistence index, persistence velocity, and turning velocity. Results are compared across thirteen jackal dyads.

3 Results

Figure 1 shows the distribution of absolute and relative turning angles for two jackals relative to when a spatio-temporal "interaction" occurred (based on 4200 second temporal and 500m distance threshold). These results suggest that both individuals use more tortuous movement (relative angles between 150-210 degrees) right before they are close in space and time compared to all of their other movements. Figure 2 shows the distribution of persistence velocity (velocity * cos(rel.angle)) (Gurarie et al. 2009) for contacts and other for jackal cm70 when it was near jackal cm72 (contacts) and when it was not (other). Parameters associated with contacts were higher, indicating direct movement, while the lower Vp values indicate less direct movement such as that associated with foraging (Teimouri et al., 2018).

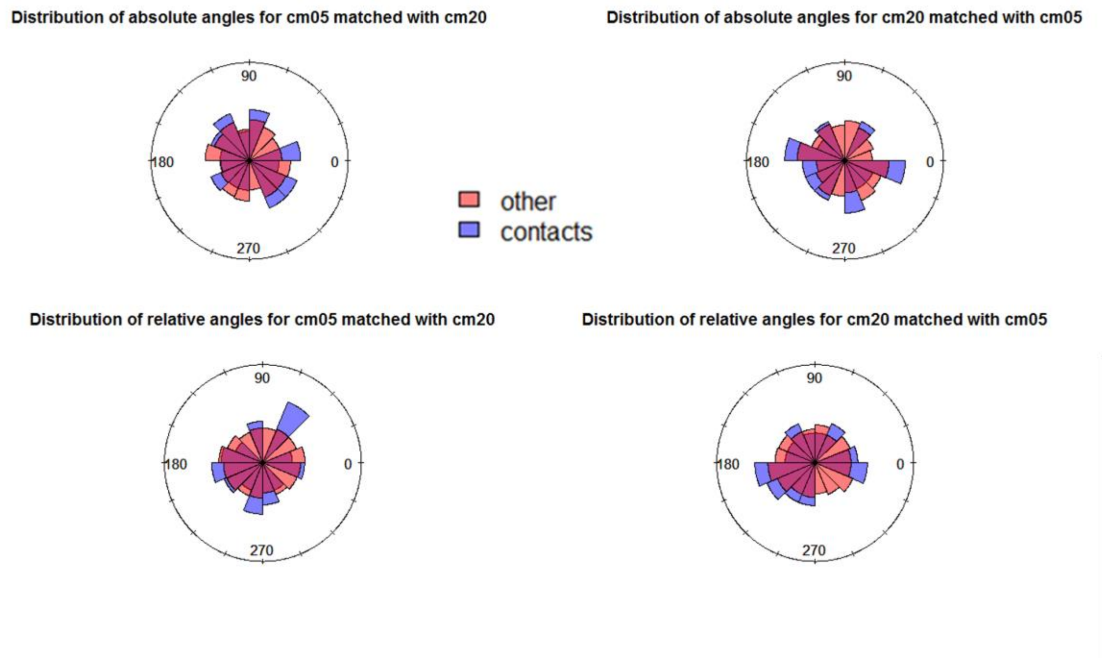

Figure 1: Distribution of absolute and relative turning angles for one jackal (cm05) matched with another jackal (cm20). Blue represents the angles before, during, and after an "interaction" occurred and red represents the angles for all other steps.

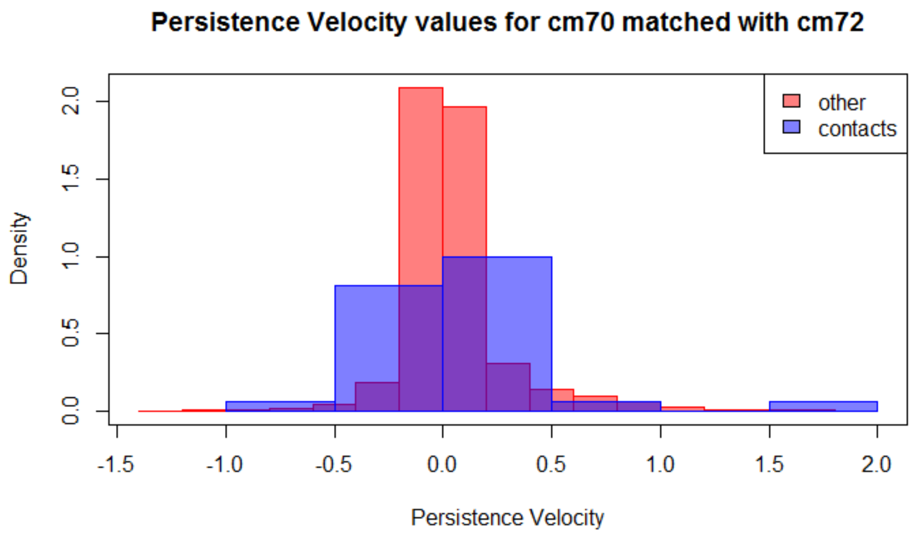

Figure 2: Distribution of persistence velocity for individual cm70 matched with cm72.

In general, the movement parameters associated with contacts were significantly different than those that were not. For most parameters, 1000m resulted in the greatest number of statistically significant differences, likely a function of the higher number of interactions within this distance threshold. There was also wide variation across individual jackal's results, suggesting that interactions measured this way are not symmetric. This is important as point- and path-based interaction metrics currently used are based on pair-wise measures, which assume interaction is symmetric.

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