Scientific Report for Short Term Scientific Mission

Algorithms for Primate Movement Ecology: Analysis of Intergroup Movement Patterns

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Purpose of visit

The general purpose of the visit was to develop effective and efficient methods for analyzing primate movement data, which requires knowledge from spatial algorithms and from primate ecology. These methods are targeted towards intergroup movement analysis and applied to movement data of vervet monkeys. Set in a fairly narrow time frame, the specific purpose of the visit was to initialize this line of research and to set up a framework, which we can use as foundation of future collaboration.

Description of the main result obtained

During the STSM we focussed on developing tools for the exploratory analysis of interaction. We developed these tools in R a programming language for statistical computing and graphics. These tools can be used to

- obtain a list of time-frames (called *encounters* in the following) for which trajectories came close (i.e., are at a distance below a given threshold for the duration of the time-frame)
- visualize encounters in space with geographic context
- visualize encounters in a space-time cube
- better visualize Brownian bridges (which we in the future will use to analyze encounters)

Figure 1 shows two examples of (2d depictions of) encounters between groups of vervet monkeys. A previously used upper bound for encounters is 50m. In the data set used there are only 7 such encounters 6 of which are between the same two groups (BD, NH). Several observations that can be illustrated using these examples are the following.

- 50 meter does not seem to be a suitable upper bound for encounters in general. For instance the encounter between BD and NH seems to continue beyond the black symbols (and even to the next day).
- Without (geographic) context it seems difficult to say much about the type of encounter. For instance, one might assume that there is some natural boundary (a river) separating BD and NH during the encounter which is not the case.
- At least to some extent the movement pattern in some encounters show a repulsion (like in the encounter between AK and BD)

Indeed, adding geographic context shows that the groups BD and NH are not separated by a river in the encounter of Fig. 1 but move together through scrubland. So far we used as context the digital elevation model, the color bands from bands from a remotely-

sensed imagery, and as a derived variable the normalised difference vegetation index (see Fig.2 (left)). Our simple 2d representation of the trajectories is sometimes cluttered (as in Fig. 1 (left)) and we therefore also implemented a space-time cube representation in R. The example of Fig. 1 (left) in a space-time cube is shown in Fig. 2 (right).

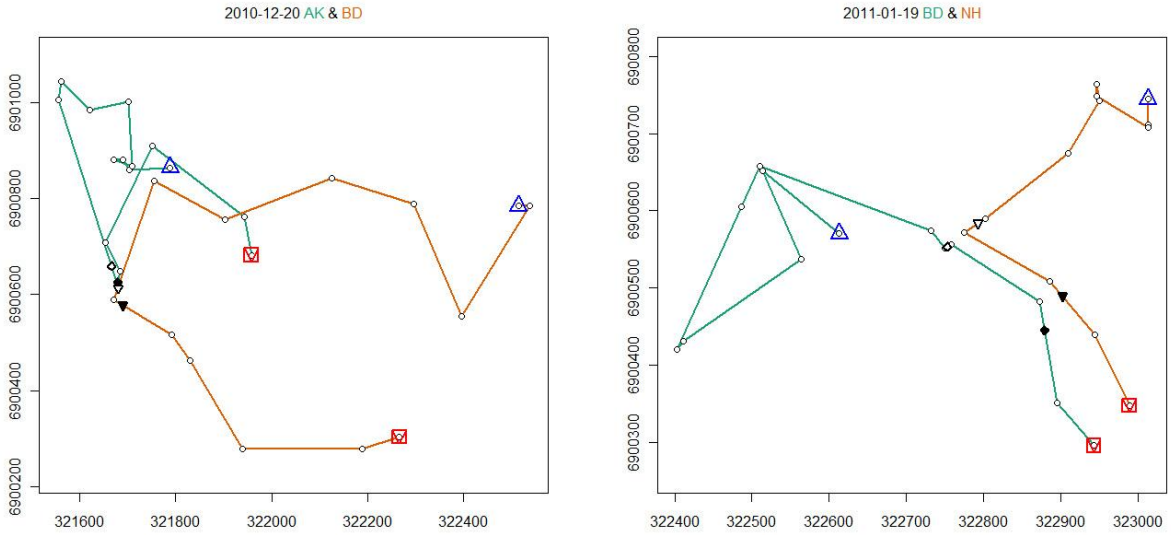

Fig. 1 Two examples of encounters using an upper bound of 50m. The blue triangle is the location of the morning sleeping tree, the red square of the evening sleeping tree. The white circles show the locations on the hourly GPS fixes. The white triangle and diamond show the beginning of the encounter and the black triangle and diamond the end of the encounter.

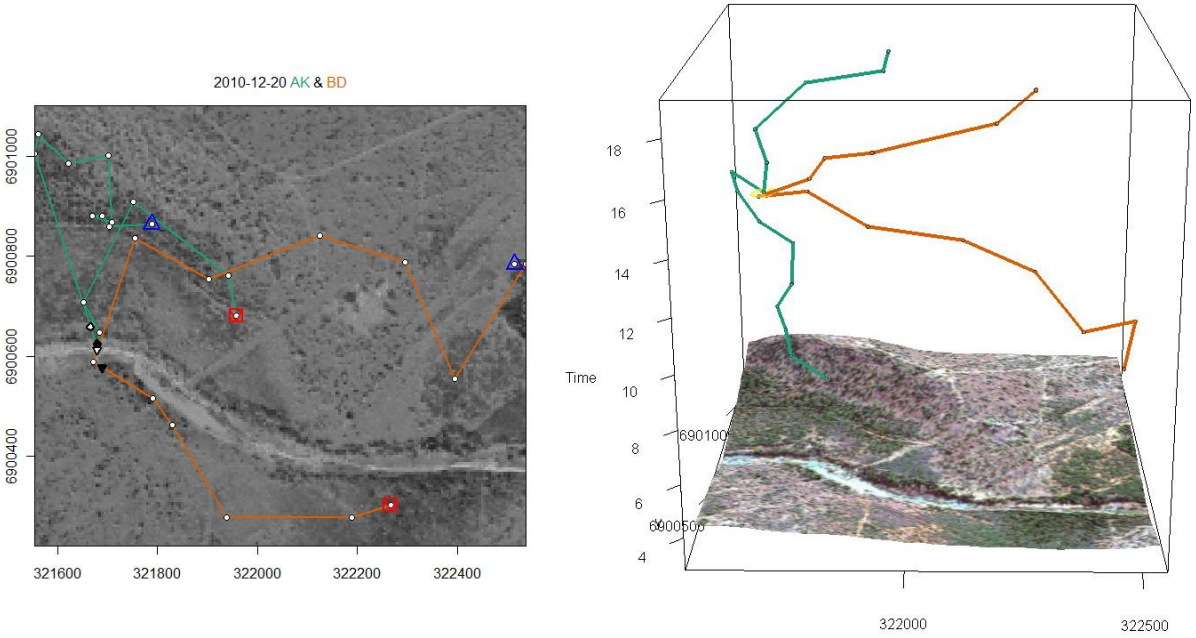

Fig. 2 Example of an encounter with context added and visualized in a space-time cube. Left: the background map shows the normalised difference vegetation index to explore the relation between encounters and food resources. Right: Space-time cube with digital elevation model.

The next step that we are taking is to make use of motion models, in particular Brownian bridges. For this we started implementing additional tools to show Brownian bridges. We currently use the Brownian bridge computation of the R library *adehabitat* as a basis but are planning to also use related motion models. In particular, we set the daily motion into the context of the monthly motion as a frame of reference. We are currently only using a 2d representation but are planning to move to a 3d representation.

We explored some potential indicators like relative turning angles for repulsion or attraction between groups. Such indicators would be of interest to explore dominance between groups. However, we did not detect suitable indicators yet. The goal of this research is the development of (semi-)automatic methods to analyze movement patterns related to inter-group interaction. In this STSM we laid some foundations for this analysis by providing some tools to explore encounters visually. We expect these tools to prove useful in our future research on (semi-)automatic analysis methods.

Future collaboration with host institution

We plan to continue our joint research and see this visit as a first step of this collaboration. The next step is to complete the integration of movement models into our analysis. This will provide a tool for the analysis of avoidance between groups: We can compute the expected total duration of encounters based on utilization distributions using Brownian bridges. But we can also compute this expected duration using simultaneous computation of Brownian bridges. The difference of these numbers gives us an indication of avoidance. Besides the analytical component we will also develop suitable visualizations.

We also want to detect a radius of influence. Here we essentially foresee two strategies. First, we can find suitable descriptors for repulsion and for instance use a maximum likelihood approach to detect the radius where repulsion takes place if at all. We did not succeed in this approach yet, which might also be due to not sufficiently dense data. Future data will have a higher sampling rate (every 30 minutes) which will extend our possibilities. Second, we will try to measure sudden change of movement/behavior in terms of acceleration data, which is more densely sampled. We also plan to integrate visibility into this analysis.

Beyond the topics mentioned above, we established further topics on which we would like to collaborate in the future (e.g., hotspot analysis in particular sleeping trees, context-aware Brownian bridges, changes over time).

Projected publications/articles resulting or to result from the STSM

Currently we do not yet know in which form we will publish our results. We plan to publish our results on the analysis of encounters using Brownian bridges as soon as we have finished the corresponding research. We are also planning to make our R scripts available as an R package, about which we then will also write an article.