Asiatic cheetah behavioral estimation from telemetry data using Bayesian statistics

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Abstract

In this paper we study the movement behavior of Asiatic cheetah (*Acinonyx jubatus venaticus*), a highly endangered cat found in Iran. At first, we fitted the differenced correlated random walk model to the data to estimate the probability of the behavior of the animal in two distinctive states. The moving state can be interpreted as the state when the animal had higher mobility and the resting state in which the animal had small step movements and constantly changes its direction.

We considered a movement and observation model; we used the observation model to model the error associated with the GPS sensors. We employed the Bayesian framework for the model fitting in which the Markov Chain Monte Carlo (MCMC) simulation enabled us to estimate as many parameters found in the posterior distribution.

The movement track was collected spanning four and a half months in 2007; probably, the cheetah was predated by a leopard after that period. The animal was monitored in Bafq area, a region in the central Iran with an arid environment.

Plotting the animal track symbolized by the two behavioral modes revealed that the cheetah had more mobility between four clusters of resting phases. Applying the k-means clustering to the cheetah's resting locations, revealed that the cheetah had more mobility between eight clusters of resting phases. One speculation was that, these resting clusters were associated with the highest likelihood of prey concentration as cheetahs major preys, wild sheep, and goat, reside in these regions.

Objectives

- Estimate the movement behaviors (resting and moving) of the cheetah only using the movement track.
- Look for any interesting pattern in the movement behavior i.e..
- Estimate the resting location clusters of the cheetah
- Find correlation between the behavior and the time of day associated with behaviors

Cheetah Data

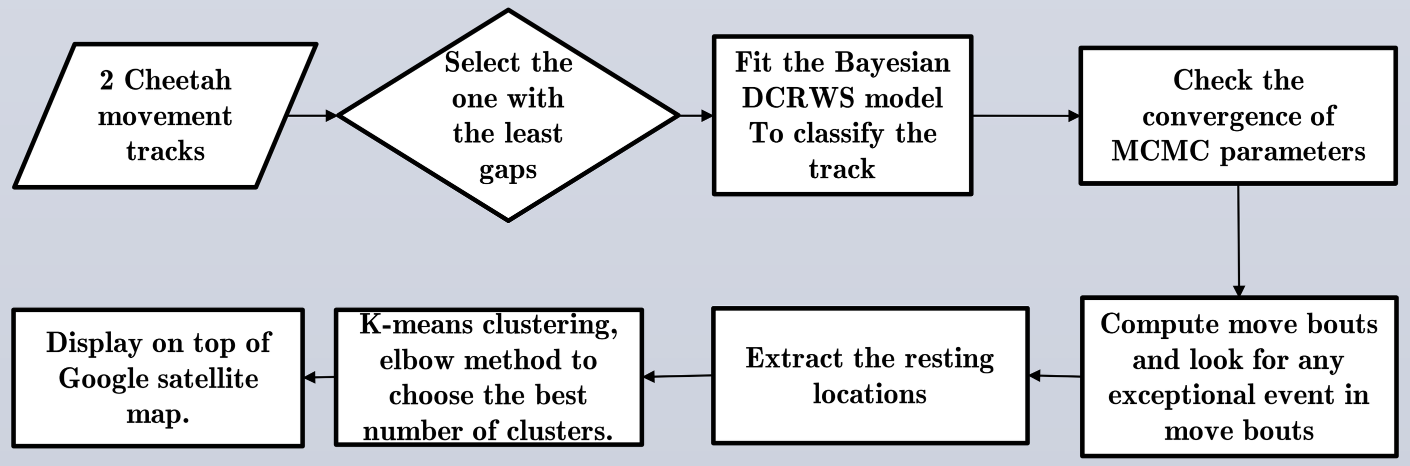
- Two male (brother) cheetahs (age 3-5) were captured using foot snares
- The collars were set to transmit locations every 8 hours (at 12 AM, 8 AM and 04 PM)
- As identified by their GPS tracks, movements of the two cheetahs were almost identical (median of 10 m)
- Almost all remotely sensed movement data exhibits some gaps
- Options to deal with the gaps include interpolating the consecutive missing points using weighted averaging, or sub-sampling the data to the largest gap (24 h). We employed the first approach to maximize the data available for analysis.

	Temporal Scale			# of Observations			
Animal	From	To	Days	8 hours	16 hours	24 hours	% of Gaps
Cheetah 1	2/27/2007	7/13/2007	136.7	358	26	-	7%
Cheetah 2	2/26/2007	7/6/2007	130	358	13	2	4.50%

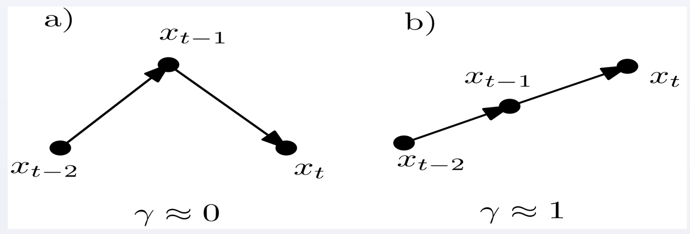
Study area

- The cheetah study was conducted in the Bafq protected area in central Iran, one of five protected areas identified by the Conservation of Cheetah Project (CACP, 2016) as the most important areas for cheetah
- Bafq is barren area of land characterized by desert with scarce rainfall, high temperature and degraded landscapes.
- It is surrounded by human infrastructure such as cities, villages and highways that exacerbate the situation for cheetah dispersal.
- A large number (7 out of 50-70) of Asiatic cheetahs have been lost due to vehicle collisions in the region over the last decade.

Method



Differenced correlated random walk

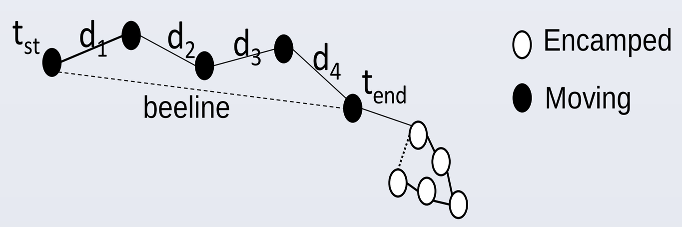


$$x_t = x_{t-1} + \gamma_{b_t} T(x_{t-1} - x_{t-2}) + N(0, \Sigma)$$
$$T = \begin{pmatrix} \cos\theta_{b_t} & -\sin\theta_{b_t} \\ \sin\theta_{b_t} & \cos\theta_{b_t} \end{pmatrix}$$
$$\Sigma = \begin{pmatrix} \sigma_x^2 & \rho\sigma_x\ \sigma_y \\ \rho\sigma_x\ \sigma_y & \sigma_y^2 \end{pmatrix}$$
$$\Pr(b_t = i | b_{t-1} = j) = \alpha_{ji}$$
$$\alpha = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} = \begin{pmatrix} a_{11} & 1 - a_{11} \\ a_{21} & 1 - a_{21} \end{pmatrix}$$
$$y_t = x_t + N(0, \Omega)$$

We considered just two states: a moving state consisting of relatively fast and more directionally persistent movement (also known as moving state), and a resting state consisting of relatively slow movement with frequent course reversals, also known as the encamped state

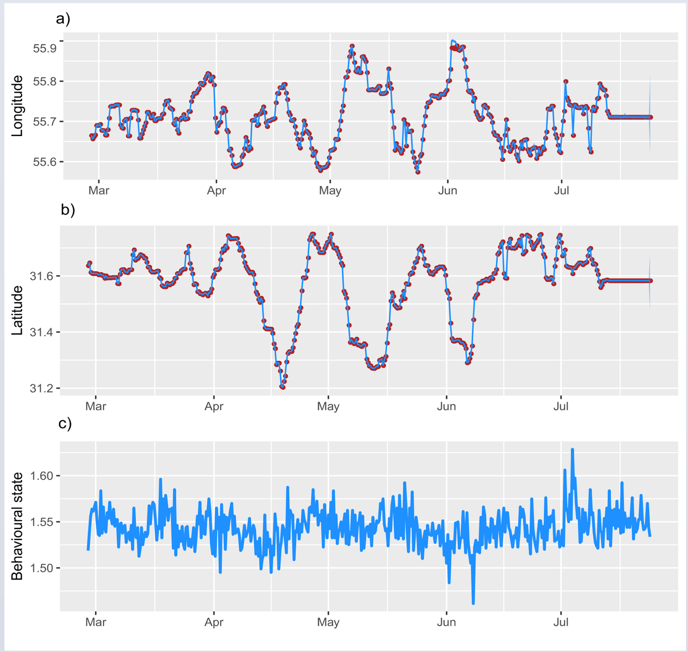
Behavioral bout summary

$$\text{displacement} = \mathrm{d}_1 + \mathrm{d}_2 + \mathrm{d}_3 + \ldots$$
$$\text{duration} = \mathrm{t}_{\text{end}} - \mathrm{t}_{\text{start}}$$
$$\sqrt{\Delta x^2_{(start,end)} + \Delta y^2_{(start,end)}}$$

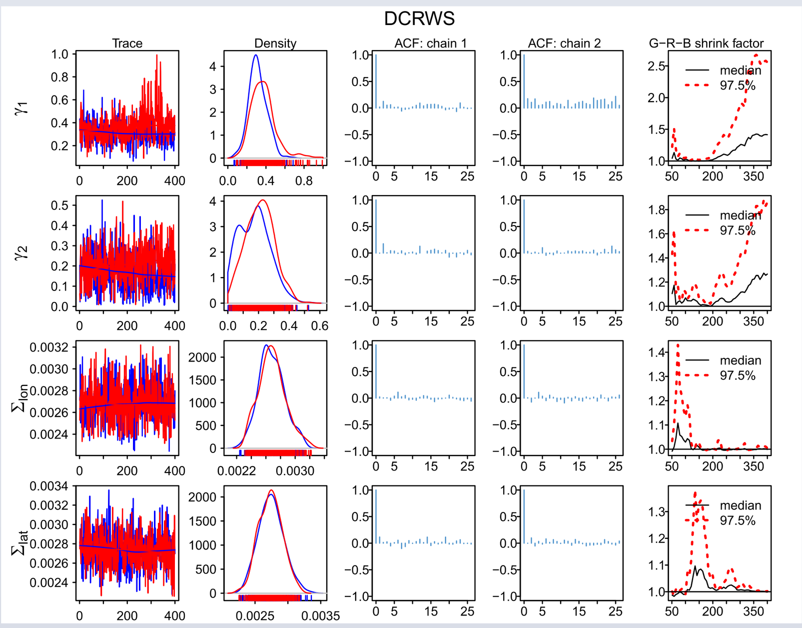


Result

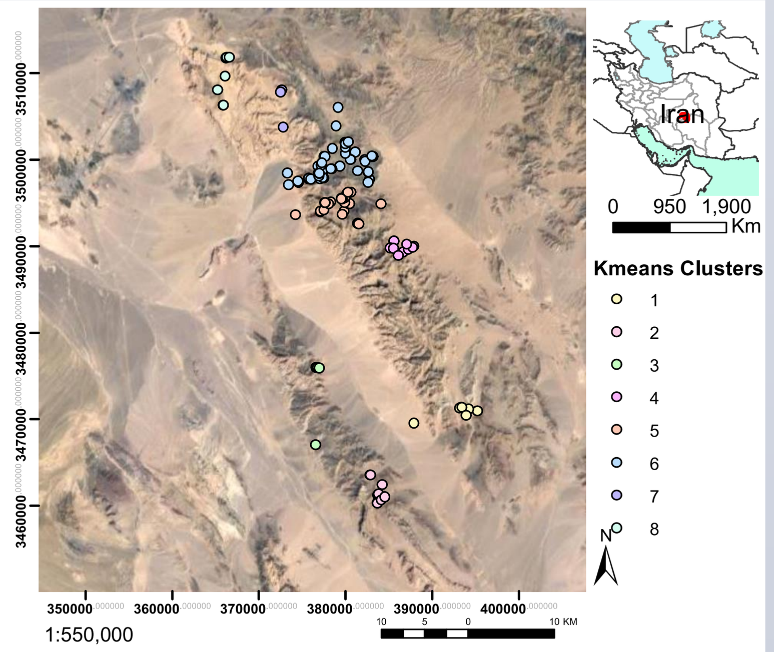
The longitude and latitude profiles could be used as a mean to visually inspect the changes in the both direction to check whether the animal is moving or resting.



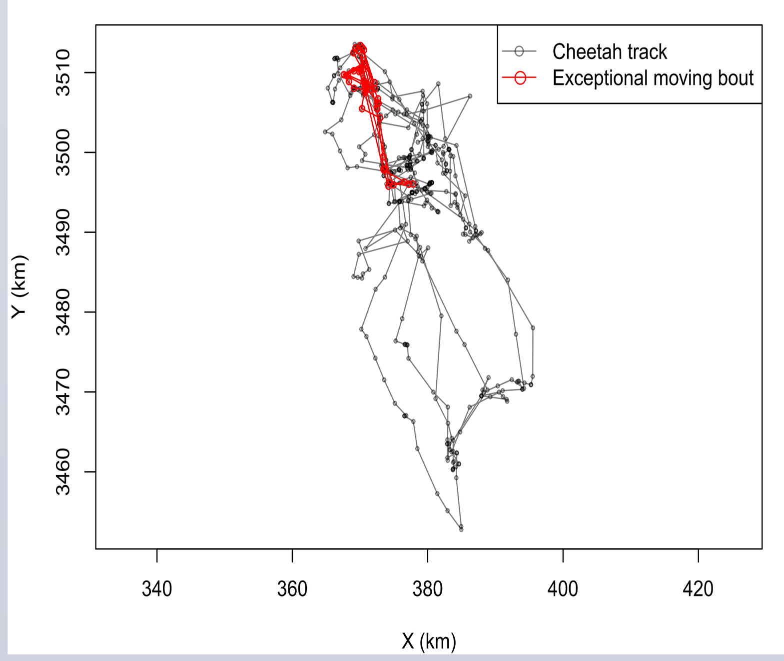
The diagnostics plots of the estimated parameters of the DCRWS model from the posterior distribution of MCMC sampler.

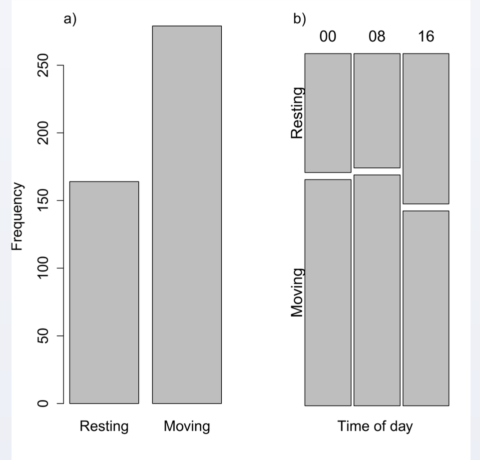


The estimated resting clusters, using k-means clustering, superimposed on top of Google satellite imagery.



In a very exceptional event, the cheetah entered into moving phase for straight 14.5 days and traveled 130 km within the same reserve.





a) The cheetah was more in the moving mode rather than the resting mode; this could be due to the harsh situation in the arid environment of Bafq desert and the pursuit of prey by the cheetah. b) The frequency of being in each behavioral state indicated that the cheetah tended to be in moving phase from 00:00 to 16:00, although the frequencies of being in both movement phases are roughly equal in the evening (16:00 to 00:00). The Chi-square goodness of fit test was not significant.

Discussion and Conclusion

Asiatic cheetah is a very agile and mobile animal. It tends to walk hundreds of kilometers to find a suitable habitat. The data at hand, was for a relatively short period of time (4.5 months), however the cheetah still showed significant mobility. This was evident from the classification of the track of the cheetah into two distinctive behaviors; the cheetah was more in moving state. The central region of Iran, Bafq, has a very harsh and arid environment. The cheetah's mobility could be related to this situation, which forces the animal to move, in order to find food and water. The steps that the cheetah took to find a convenient location for resting was important, however the locations where the animal selected for resting, were of interest.

In a very exceptional event, the cheetah entered into moving phase for straight 14.5 days and traveled 130 km within the same reserve. A detailed examination of this move bout showed that the cheetah was commuting between 3 hotspots multiple times in the north-west and central parts of its home-range, likely looking for hunt, though without any success. This is another evidence of an unsuitable habitat for cheetah, and the shortage of sufficient prey.

We also superimposed the classified track on the satellite imagery to add context to the cheetah's movement and superficially showed that the resting clusters of the cheetah locations were associated with the mid-range elevation habitat. The habitat features of the identified 8 resting clusters in this study should be explored to see why the cheetah is attracted to these locations.

The next step to this analysis is to link the estimated behaviors to environmental data and find the significant drivers of the movement and individual behavior.

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Acknowledgements

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