

Learning from the ups and downs of a multimodal hidden Markov model likelihood

Hidden Markov models (HMMs) are ubiquitous in the analysis of ecological time series data. In the application of HMMs to animal movement data, it is assumed that the observed movements are a result of the animal's underlying behavioral state. For example, modeling of overall dynamic body acceleration in sharks via HMMs can provide insights into activity states (low vs high activity) and GPS data can provide insights into behavioral states such as traveling, area-restricted search and resting behaviors in terrestrial animals. However, one of the challenges when fitting HMMs to data is that the likelihood surface, and subsequently joint posterior distribution, is multimodal. This aspect of model fitting is typically taken as a computational challenge. Multiple starting points are selected and convergence to local modes are expected. Once it is expected that all of the possible modes have been found, a selection of the 'global mode' with the highest value of the likelihood is taken to represent the most likely possible values of our parameters and construction of confidence/credible intervals (CIs) is done around this mode only. All other modes are disregarded in the final presentation of the HMM results. However, a multimodal surface is not only a computational challenge, but should also be seen as an inferential and ecological challenge as well. Construction of CIs that disregard all but one mode have lower coverage and are not theoretically guaranteed to converge to the true value of the parameters. From an ecological standpoint, the parameter values that correspond to the 'less likely' modes may contain important ecological information. For example, the multiple modes may provide evidence that there is uncaptured individual variation in the model construction or point to other degrees of model misspecification. As difficult as it is to collect ecological time series data, we do a disservice by ignoring the modes of an HMM likelihood when we can learn so much more. It's simply time to start learning from and embracing the ups and downs of a multimodal hidden Markov model likelihood.