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From Paths to Routes: A Method for Path Classification

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Many animals establish, learn and optimize routes between locations to commute efficiently. One step in understanding route following is defining measures of similarities between the paths taken by the animals. Paths have commonly been compared by using several descriptors (e.g., the speed, distance traveled, or the amount of meandering) or were visually classified into categories by the experimenters. However, similar quantities obtained from such descriptors do not guarantee similar paths, and qualitative classification by experimenters is prone to observer biases. Here we propose a novel method to classify paths based on their similarity with different distance functions and clustering algorithms based on the trajectories of bumblebees flying through a cluttered environment. We established a method based on two distance functions (Dynamic Time Warping and Fréchet Distance). For all combinations of trajectories, the distance was calculated with each measure. Based on these distance values, we grouped similar trajectories by applying the Monte Carlo Reference-Based Consensus Clustering algorithm. Our procedure provides new options for trajectory analysis based on path similarities in a variety of experimental paradigms.

Keywords: bumblebee, clustering, route, classification, clutter, navigation

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1. INTRODUCTION

Finding a location in an unknown environment can be a daunting time- and energy-demanding task. In contrast, returning to a known location is much easier than finding it for the first time. To return to an already known location, animals and artificial agents alike can move along habitual routes. Forming and following of routes has been observed in numerous taxa; from insects (Lihoreau et al., 2011; Woodgate et al., 2016; Buatois and Lihoreau, 2016; Woodgate et al., 2017) to mammals (Hurlebaus et al., 2008; Pfeiffer and Foster, 2013); thus, it is a wide-spread strategy to navigate in a familiar environment. Despite the large number of taxa following routes, it remains little understood how routes are established and followed.

Thanks to the rise of miniature embedded tracking devices (Nagy et al., 2010; Genzel et al., 2018; Greif and Yovel, 2019), and high-throughput computational methods, tracks of individual animals in various natural habitats (Graving et al., 2019) have become more wide spread in recent years. With this expanding collection of paths gathered by scientists, there is a growing need for efficient data-analysis pipelines to identify, classify, and compare different paths across taxa, species, or individuals.

There is a distinction to be made between an animal's path and a route. A path specifically describes the animal's trajectory of movement, while the route can be visualized as a string around which different paths meander. Depending of the consistency of the paths taken among different runs, a potential route may not easily be recognizable to an observer. However, when many paths