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Mining Partners in Trajectories

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ABSTRACT

Spatiotemporal data is everywhere, being gathered from different devices such as Earth Observation and GPS satellites, sensor networks and mobile gadgets. Spatiotemporal data collected from moving objects is of particular interest for a broad range of applications. In the last years, such applications have motivated many pieces of research on moving object trajectory data mining. In this article, it is proposed an efficient method to discover partners in moving object trajectories. Such a method identifies pairs of trajectories whose objects stay together during certain periods, based on distance time series analysis. It presents two case studies using the proposed algorithm. This article also describes an R package, called TrajDataMining, that contains algorithms for trajectory data preparation, such as filtering, compressing and clustering, as well as the proposed method Partner.

KEYWORDS

Data Mining, Moving Objects, Pattern, R, Trajectory

INTRODUCTION

Recent advances on sensors and communication technologies have produced massive spatiotemporal data sets that allow scientists to observe the world in novel ways. Earth observation satellites capture changes over time in cities and forests. Environmental sensors measure the variation of air pollution, temperature and humidity in specific locations. GPS satellites and devices collect locations of animals, vehicles and people over time. Mobile gadgets, sensor networks, social media and GPS tools create useful data for planning better cities, capturing human interactions and improving life quality.

Spatiotemporal data collected from moving objects is of particular interest for a wide range of applications. Moving objects are entities whose spatial positions or extents change over time (Erwig, Gu, Schneider, Vazirgiannis et al., 1999). Examples of moving objects are cars, aircraft, ships, mobile phone users, polar bears, hurricanes, forest fires, and oil spills on the sea. Trajectories are countable journeys associated to moving objects (Spaccapietra et al., 2008).

Nowadays, moving object trajectories have been used in a broad range of applications, such as location-based social networks, intelligent transportation systems, and urban computing (Wang, Zheng, & Xue, 2014; Zheng, 2011). These applications have motivated research on novel data mining techniques to discover patterns in trajectories, attracting attention from many areas including computer science, sociology, and geography (Zheng, 2015). Taniar and Goh (2007) propose an approach to extract movement pattern from mobile users through transforming user movement database to location movement database.

Along the years many patterns have been proposed to extract information from trajectories. These patterns range from those that take into account semantically enhanced trajectories, such as CB-SMoT

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(Palma, Bogorny, Kuijpers, & Alvares, 2008), to those that analyze trajectories based solely on their geometries, like Convergence or Flock (Laube, van Kreveld, & Imfeld, 2005).

This work focuses on a specific group of trajectory pattern called Moving Together Patterns (Y. Zheng, 2015). A new approach called Partner is proposed to discover objects that move or stay together during certain periods, based on trajectory distance time series analysis. Next section presents related work, the main differences between the existing moving together patterns and the proposed Partner as well as its main advantages.

This paper extends the previous one presented by Monteiro et al. (2017), bringing more examples, definitions, results and implementations. It includes the description of an R package implemented by the authors, called TrajDataMining, that contains algorithms for trajectory data preparation, such as filtering, compressing and clustering, as well as the proposed method Partner.

TRAJECTORY PATTERN MINING

Recently, the research area on trajectory data mining has grown a lot. Studies on this area consist in analyzing the mobility patterns of moving objects and in identifying groups of trajectories sharing similar patterns. In last years, many methods and techniques for trajectory pattern discovering have been proposed to meet a broad range of applications. Zheng (2015) presents a systematic survey on the major research into trajectory data mining and classifies existing patterns in four categories: (1) Moving together patterns; (2) Clustering; (3) Frequent sequence patterns; and (4) Periodic patterns. This work focuses on the first category and propose a new approach to identify moving together objects.

Examples of patterns that discover a group of objects that move together for a certain period are flock (Gudmundsson & van Kreveld, 2006; Tanaka, Vieira, & Kaster, 2015; Vieira, Bakalov, & Tsotras, 2009), group (Taniar & Goh, 2007; Yida Wang, Lim, & Hwang, 2006), convoy (Jeung, Yiu, Zhou, Jensen, & Shen, 2008), swarm (Li, Ding, Han, Kays, & Nye, 2010), traveling companion (Tang et al., 2012), gathering (Zheng, Zheng, Yuan, & Shang, 2013; K. Zheng, Zheng, Yuan, Shang, & Zhou, 2014) and co-movement (Fan, Zhang, Wu, & Tan, 2016). Moving together patterns are useful for a high number of applications, such as monitoring of delivery trucks (Jeung et al., 2008) and identification of vessels that fish together.

The flock pattern has attracted a lot of interest from the community with many studies being published over the years regarding this pattern. A flock is a group of objects that stay together within a disk with a user-defined radius for at least K consecutive time stamps. Vieira et al. (2009) propose a framework and polynomial-time algorithms, called basic flock evaluation (BFE), to discover such pattern in streaming spatiotemporal data. Tanaka et al. (2015) present variations of the BFE algorithm, employing the plane sweeping technique, binary signatures and/or an inverted index. Similar to flock, group pattern identifies moving objects that travel within a radius for certain timestamps that are possibly nonconsecutive (Yida Wang et al., 2006). The main difference between both is that group considers relaxation of the time constraint.

According to Y. Zheng (2015), a major concern with flock and group patterns is the predefined circular shape, which may not well describe the shape of a group in reality. Since they use a disk with rigid limits, they miss objects that are close to a group but outside the disk limits. This drawback is called the lossy-flock problem. The chosen disk size has a substantial effect on the results of the discovery process. The selection of a proper disk size is very difficult. Besides the lossy-flock problem, for some data sets, no single appropriate disc size may exist that works well for all parts of the space and time domain (Jeung et al., 2008).

The convoy pattern uses density-based clustering in order to capture groups of arbitrary extents and shapes. Instead of using a rigid size disk as flock, such pattern requires a group of objects to be density connected during k consecutive time points. While both flock and convoy have a strict requirement on consecutive time period, Z. Li et al. (2010) propose a more general type of trajectory pattern, called swarm, which captures the moving objects that move within arbitrary shape of clusters

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