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A Trajectory Preprocessing Method Based on Angle and Velocity

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Abstract: The fusion of angle and velocity information allows for a more comprehensive description of object motion characteristics, which holds significant importance for trajectory data analysis and exploration. However, conventional trajectory data processing typically overlooks direction and velocity information between adjacent trajectory points. This paper's methodology involves initially collecting raw trajectory data, followed by assessing abnormal trajectory points through angle and velocity computations, and ultimately conducting filtering and refinement for integration. Experimental results demonstrate that preprocessing by integrating angle and velocity effectively enhances the accuracy and usability of trajectory data, offering richer information for trajectory analysis, behavior identification, and predictive modeling of motion patterns.

Keywords: Trajectory Data; Abnormal Detection; Data Mining

1. Introduction

Trajectory data, serving as crucial information that records the paths of object movements, is abundantly generated in modern society through mobile devices, sensor technologies, and geographical positioning systems[1]. These data not only play a significant role in scientific research but also find widespread applications in practical domains such as navigation[2], logistics[3], transportation planning[4], and more. Therefore, efficient and accurate preprocessing and analysis of trajectory data hold paramount importance.

However, trajectory data processing encounters a challenge known as the issue of outlier points. These outlier points may arise due to device malfunctions, signal interference, irregular motion patterns, among other reasons, adversely impacting the accuracy and reliability of the data. Particularly in vehicle sensor data, outlier points might stem from sudden events during travel, signal interference, or equipment failures.

Conventional methods for preprocessing trajectory data often resort to simple smoothing techniques or basic filtering methods to eliminate outlier points[5]. However, these methods are not highly effective in handling complex outlier situations. Moreover, these approaches disregard the directional and velocity information carried within the trajectory data, failing to comprehensively consider the characteristics of motion, thereby struggling to cope with the diversity and complexity of the data.

This study aims to address the limitations of traditional methods by proposing a trajectory preprocessing approach based on angle and velocity. This method combines directional and velocity information, achieving a more precise and comprehensive identification and treatment of outlier points through a holistic analysis of these two aspects. By considering the variations in motion direction and speed comprehensively, our method aims to enhance the accuracy and credibility of trajectory data, providing a more reliable foundation for trajectory data analysis.

2. Overview of trajectory preprocessing

2.1 Trajectory Data

Trajectory data comprises a spatiotemporal collection of geographic location records generated by moving objects over continuous time intervals[6]. Each location point within this data possesses multiple attributes, including timestamps, spatial positions, and semantic information. This type of data not only captures fundamental characteristics of moving objects but also provides insights into the characteristics of studied populations and their respective areas.

Commonly encountered trajectory data predominantly encompass human and vehicular trajectories, both originating from human activities[7]. Human trajectories refer to the records of individual movements, such as walking, running, or utilizing transportation modes, depicting spatial paths. These data can be obtained through mobile phone positioning, location sharing in social applications, or other mobile devices.

Vehicular trajectory data constitutes a dataset recording the movement paths of vehicles, often collected via in-vehicle navigation systems or smartphone navigation records[8]. Typical vehicular trajectory data includes timestamps, vehicle location information, and specific identification numbers for the vehicles. Vehicular trajectory data stands as a critical information source for improving transportation networks, optimizing resource allocation, and conducting traffic analysis. These data stem from diverse sources, including latitude and longitude information recorded by in-vehicle BeiDou navigation systems, trajectory data uploaded by users utilizing navigation features in mobile applications, and real-time vehicle passage information recorded in traffic monitoring systems.

The acquisition of such trajectory data typically involves recording and collecting individual movement trajectories, as well as documenting the movement paths of vehicles on roads. Both human and vehicular trajectory data hold significant importance for urban planning, traffic management, behavior analysis, and the development of intelligent transportation systems. They provide valuable foundational information for studying human behavior, predicting traffic flow, analyzing traffic congestion, and more.

2.2 Trajectory data characteristics

Trajectory data possesses three primary characteristics in the era of big data: voluminous data, real-time capability, and diversity. Influenced by various factors such as device technology, sampling frequency, and data storage methods, these data exhibit the following traits:

1. Spatiotemporal Sequencing: Trajectory data constitutes a series of sampled sequences that record position and time information. Each sampled point represents the dynamic changes of an object at different time and space locations. This spatiotemporal sequencing stands as one of the most fundamental and crucial traits of trajectory data.

2. Asynchronous Sampling: Due to the randomness of different activity trajectories and temporal differences, trajectory data exhibits significant variations in sampling intervals. For instance, navigation services might sample at intervals of seconds or minutes, while trajectories of social media activities may be sampled at hourly or daily intervals. This varying sampling frequency poses challenges for analyzing trajectory data.

3. Data Quality Variability: As continuous movement trajectories are discretely recorded, the quality of data can be affected by factors such as sampling accuracy, positional uncertainty, and preprocessing methods. These elements can influence the accuracy and credibility of the data, presenting challenges for analyses based on trajectory data.

3. The trajectory preprocessing algorithm integrating speed and angle.

The article introduces the Speed and Angle-based Trajectory Preprocessing (SVATP) method as a solution to the overlooked speed and direction information in traditional trajectory data processing. SVATP aims to enhance the accuracy of trajectory recognition and prediction by analyzing the trajectory characteristics of moving objects at various speeds and angles.

Vehicle trajectory data often contains numerous redundant points, including those generated during stationary and constant-speed movements. Instances where vehicles remain in specific positions for a particular duration are termed as stop points. Moreover, noise points represent a significant feature in vehicle trajectory data, resulting from erroneous sampling due to software or hardware anomalies. For instance, GPS signal reception anomalies caused by a vehicle entering an underground parking lot or encountering signal interference environments can lead to positioning errors. These noise points significantly impact the analysis and exploration of trajectory data, hence effective handling during data processing and cleansing is essential to ensure the accuracy and reliability of analytical results.

3.1 Speed based trajectory preprocessing method

The algorithmic concept of the speed-based trajectory point preprocessing method involves several key steps. Firstly, it gathers trajectory data of vehicles or objects and then computes the distance and time difference between consecutive trajectory points to derive speed information. Subsequently, based on predefined thresholds or rules, the obtained speed data undergoes filtering and screening, such as eliminating outliers or unreasonable speed values, to ensure data quality. Finally, this process yields a set of trajectory points filtered based on speed, providing an accurate and reliable data foundation for subsequent road information analysis and map construction.

The speed-based trajectory point preprocessing method encompasses three crucial steps:

1) To calculate distance: Compute the spatial distance between trajectory points to determine the movement distance of a vehicle or object during motion.For speed-based trajectory point preprocessing, distance and time intervals need to be calculated. The following formula represents the computation:

2) Calculate Speed: Calculate the time interval between trajectory points, and compute the speed based on distance and time data to determine the velocity information of a vehicle or object at different time points.

3) Speed Filtering: Filtering trajectory points based on calculated speeds to remove those with abnormal velocities, ensuring that the trajectory point data aligns with the expected motion state and requirements.

The algorithm pseudocode is shown in Algorithm 1.

Algorithm 1 Trajectory Point Preprocessing Method based on Speed

```
Obtain trajectory data Trajectory
for each adjacent trajectory point p_i, p_{i+1} in Trajectory do
    Calculate distance distance ← CalculateDistance(p_i, p_{i+1})
    Calculate time difference time ← CalculateTime(p_i, p_{i+1})
    Calculate speed speed ← distance/time
    if speed is not within a reasonable range then
        Remove or flag p_{i+1} from Trajectory
    end if
end for
Return processed trajectory data ProcessedTrajectory
```

3.2 Angle based trajectory preprocessing method

Algorithm Concept: The algorithmic concept of angle-based trajectory point preprocessing involves obtaining trajectory data of a vehicle or object and calculating the directional motion or turning angles between adjacent trajectory points using positional coordinate information. Subsequently, the calculated angle data undergoes filtering and processing based on pre-defined thresholds or rules to exclude trajectory points with abnormal angles. The angle-based trajectory preprocessing method comprises the following two key steps:

Angle Calculation: Calculate the directional or turning angles between trajectory points to determine changes in the movement direction of a vehicle or object during motion.

Angle Filtering: Utilize the calculated angle data to filter out anomalies or segment them into subsets within different angle ranges, ensuring that the trajectory point data adheres to the expected requirements for movement direction or turning.

The algorithm pseudocode is shown in Algorithm 2.

Algorithm 2 Trajectory Point Preprocessing Method based on Angle

```
Obtain trajectory data Trajectory
for each pair of adjacent trajectory points p_i, p_{i+1} in Trajectory do
    Calculate angle angle ← CalculateAngle(p_i, p_{i+1})
    if angle is not within an acceptable range then
        Remove or flag p_{i+1} from Trajectory
    end if
end for
Return processed trajectory data ProcessedTrajectory
```

4. Experimental Result

In the experiment, this study initially employed a smoothing technique to denoise the trajectory data. Subsequently, using positional coordinates, it calculated the speed and angle changes between adjacent points. By setting thresholds, it identified and removed outliers in both speed and angle changes to ensure data accuracy and stability. Finally, employing visualization methods, it plotted curves illustrating the changes in speed and angle over time, showcasing the characteristic features of the data after preprocessing.

Figure 1 and Figure 2 illustrates the processed trajectory data, where considering both speed and angle changes allowed the successful identification of outlier points, resulting in a clearer and smoother trajectory path.

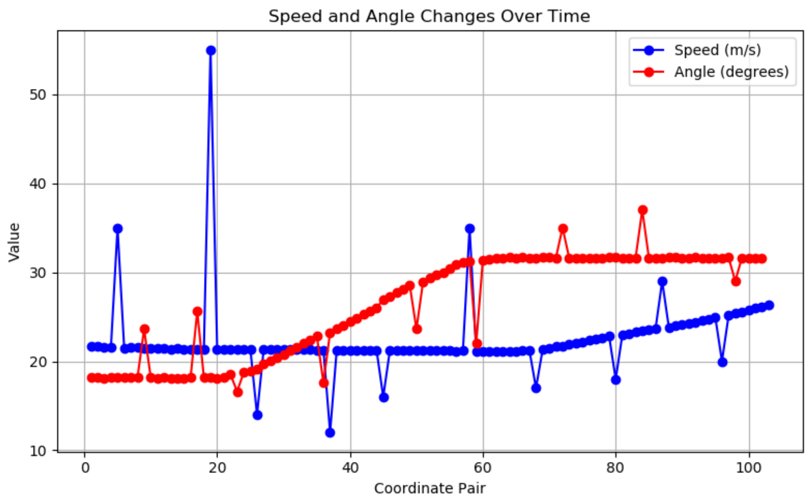

Figure 1 Before using the method

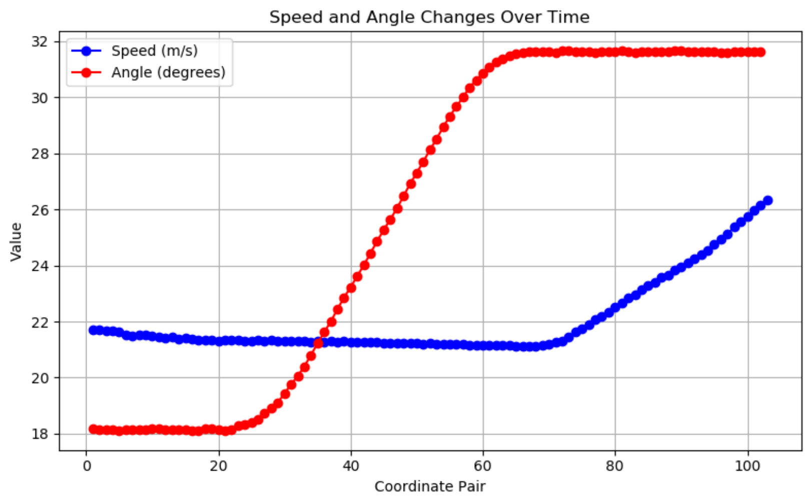

Figure 2 After using the method

Upon analyzing Figures 1 and 2, it is evident that despite undergoing conventional smoothing and denoising methods, the trajectory data still inevitably contains anomalies. However, with the approach proposed in this paper, some of these anomalies have been distinctly identified. This signifies limitations in traditional methods when handling trajectory data, whereas the method presented in this paper offers a more effective means of identifying and addressing anomalies. This holds promise for enhancing the accuracy and reliability of data processing.

5. Conclusion

Trajectory preprocessing refers to the process of cleaning, transforming, or reducing dimensions of trajectory data before analysis to facilitate subsequent analysis effectively. The angle and speed-based trajectory preprocessing method aims to extract useful features from the direction and rate of object movement, providing more accurate and efficient data for subsequent analysis and model construction.

Within trajectory data, angle information can be derived by computing the direction of an object's movement at different time points. Angle-based preprocessing methods calculate angle change rates to eliminate noise or extract more precise directional features. This aids in identifying the path and direction of object movement, forming the foundation for behavioral analysis and pattern recognition. On the other hand, speed-based preprocessing methods capture variations in movement speed at different time points, enabling the detection of rapid or slow-motion changes, identifying irregular motion, or specific motion patterns. This is crucial for predicting motion trends, identifying abnormal behavior, or performing trajectory classification.

Future exploration could delve into more complex preprocessing methods that combine angles and speeds. Combining these two factors can offer richer motion information, leveraging angle and speed features for trajectory prediction, motion pattern recognition, or abnormal behavior detection. Furthermore, with ongoing advancements in sensing technology and data collection, the quality and quantity of trajectory data will increase, providing more possibilities for research into angle and speed-based trajectory preprocessing methods.

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