Context-Aware similarity measure of trajectories based on MOPSO algorithm and Fuzzy theory

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Extended Abstract

Introduction

With the developments in navigation, positioning, and tracking technologies, a large amount of moving point data (e.g., human, vehicle, animal) have been produced. Through moving an object in the course of time, a sequence of its position is recorded which is known as trajectory. Studying the behaviors of point objects and analyzing their trajectories have recently received great attentions among researchers in different fields of science, especially in geographic information science. Such studies contribute to better understanding of movement-behavior patterns of moving objects. Data mining, as one of the main approaches in geographic knowledge discovery, is normally used in moving databases to extract information from moving point objects' trajectories. Analyzing the similarity of trajectories as one of the frequently used approaches in geographic data mining, is of great importance, which is normally performed by distance functions.

The way an object moves is highly influenced from the condition and situation (known as context) where movement takes place. Therefore, merely analyzing trajectories from their spatiotemporal dimension may not clearly reflect the conditions and situations (contexts) during the move, and may lead to unrealistic results. Accordingly, most of the present distance functions are only able to measure the similarity of trajectories at spatial and spatiotemporal dimensions and neglect the underlying context during the move. Therefore, developing a new trajectory similarity measure approach, capable of handling a wide range of context information in conjunction with spatiotemporal dimension becomes crucial.

Materials & Methods

According to the complexity and variety in the moving objects' datasets, especially in their context parameters, in this research, a fuzzy model is developed which is able to exploit a wide range of internal and external context information in similarity measure process of multi-length trajectories. Specifically, a fuzzy inference system (FIS) is used for measuring the similarity between trajectories based on qualitative and quantitative context information. To enhance the effectiveness of the system, a subjective hierarchical fuzzy inference system (HFIS) is designed and the membership functions and rules are generated and adjusted based on learning. The HFIS controls the rules by dividing a FIS into several simple sub-systems that are hierarchically connected to each other. The Multi-Objective Particle Swarm Optimization (MOPSO) algorithm is used for defining and adjusting the FIS.

The performance of the system is assessed by applying it on real trajectories of pedestrians' and cyclists' datasets in the Central Park of Manhattan, New York, USA, while accounting contextual information. The movement parameters and context information were recorded in qualitative and quantitative formats. Two types of context information are used: 1) internal context (i.e., all of the properties that directly relate to the moving object, such as eagerness), and 2) external context (i.e., any factor that extrinsically influences the process of movement, such as slope). According to the nature of data, four models of spatial, spatiotemporal, spatiotemporal-internal context, and spatiotemporal-internal-external context are applied on the dataset to see the added value of each parameter.

Results & Discussion

The achievements of the implementations can be discussed from two main perspectives: 1) system performance, and 2) similarity results. From the system performance aspect, the control surface plots indicate the consistency of the rules in the developed fuzzy inference systems. In addition, the Pareto diagrams for both pedestrians' and cyclists' models cover the Pareto fronts in all four models in an appropriate manner.

From the similarity results aspect that are shown in boxplots, the commonalities between both pedestrians' and cyclists' trajectories are very high at the spatial dimension in the first model, while by adding the temporal dimension as the second model, the similarity range at the spatiotemporal dimension increases. This issue is directly related to the traversed paths and the elapsed times of the moving objects. By importing the internal contexts (i.e., speed, direction, length, eagerness) as the third model, the similarity range again increases but the median decreases. However, the distribution in the pedestrians' similarity values is much more than the cyclists' values. The fourth model is composed of all the previous parameters plus the external contexts (i.e., path difficulty and slope). The same as previous trends, the similarity range increases but the median decreases. Although the number of trajectories that share common characteristics are low when taking into account all the spatial, temporal, internal contexts, and external contexts in the implementation, the results become much more realistic and close to reality for both datasets.

In addition, to assess the influence of the internal and external contexts on the similarity output, a one-way analysis of variance (ANOVA) test, with a 95% confidence level, is applied on the results. Furthermore, a number of sensitivity analyses are applied on the datasets. The outcomes demonstrate meaningful influence of contexts on the similarity results of trajectories.

Conclusion

In this research a novel approach based on fuzzy systems is developed for multi-dimensional similarity measure of trajectories while accounting both internal and external context information. This approach enhances the previous similarity functions that only use spatial and temporal data. The developed models were applied on two real trajectory datasets, which were capable of handling both quantitative and qualitative information. The results indicate the effectiveness of the proposed context-aware similarity measure approach in revealing the commonalities between trajectories in multi dimensions.

Keywords: Trajectory; Similarity measure; Context-awareness; HFIS; Multi-objective optimization