IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol-6, Special Issue-6, July 2018 E-ISSN: 2347-2693

Semantic based Exploration of Interesting Points of moving objects Trajectories

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Available online at: www.ijcseonline.org

***Abstract*—** The importance of analysing moving object data has increased significantly due to the increased acceptance of context aware devices such as Smartphones, GPS connected gadgets etc. Broad use of wireless context aware devices has accelerated the generation of mobility data in various formats.The vital component of moving object data constitutes of geographical coordinates and time. The analysis of space time points in mobility data gives deep knowledge about the movement pattern of the object. Because of the presence of rich semantic aspects in the moving object data, the mining of context related data requires special methods and attention. There are less number of reported works that primarily focuses on the spatial and temporal behavior of moving objects. This research paper concentrate on the methods of extracting Points of Interests from the moving object trajectories by considering its Spatial and Temporal aspects so as to mine useful knowledge from it. Along with the explicit mobility data the method also considers semantic attributes underlined in the travel trajectory.

***Keywords*—** Location Based Systems, Moving Objects Clustering, Semantic Trajectory, Spatio Temporal Data mining Clustering

I. INTRODUCTION

Mobility is an important aspect of the human life. Broad use of wireless context aware devices has accelerated the generation of mobility data in various formats. Premier source of mobility data are smartphones, travelling assistants, GPS traces of freight movements, cyclonic data which traces formation and progress of cyclones, traffic monitoring systems, forest fire etc. Context and time information are the fundamental attributes of the mobility data. It is also possible to extract such information from voluminous unstructured data as well. Social networking platforms and microblogging sites provide provisions for sharing the travelling information of individuals, in addition to that geo tagging of photographs, Zip code even the mobile number also can be used for exploring the space time related information of an individual. There are a number of online portals that facilitates sharing of riding routes and trekking points [1], [2]. The journey details are logged using GPS sensors and is uploaded in different formats such as gpx, plt and csv etc. Recently surfacing enterprise solution called Digital Experience Platform (DXO) aggregates various technologies and contents of transactions recorded in distinct data silos to provide personalized customer engagement [3]. Capturing of multidimensional mobility data attracts room for mining of useful patterns from the heterogeneous data.

By the term moving object, we mean the movement of objects in a constrained travel environment such as road networks, dedicated waterways etc. The movement of goods carriers and vessels, journey of a tourist etc. are examples for this. The main component in the mobility data consists of spatial and temporal information. Spatial information indicates geographical location of the object which is represented with latitude and longitude of the object in motion. Temporal data consists of the time at which object resides in a particular location. Depending on the update frequency of the GPS devises number of points in a travel session varies.

Since moving object provides continuous stream of spatio-temporal information traditional database system such as RDBMS is not good enough to represent the mobility data. Hence specially designed structures called moving object databases (MOD) or spatio-temporal databases are used for this purpose. Trajectories are the basic way of representing the mobility of the object. In order to represent the mobility of the object trajectories are used.

Identifying movement pattern of the object will give more outlook on the characteristics of the object. It is very helpful in the design of the transportation network, to understand the nature of movements of cyclone, forest fire etc. Location based Advertising is another key area in marketing which roughly depends in the contextual data of the moving object.

It is evident that researches and investment in the field of trajectory data gaining more and more attention due to the proliferation of pervasive systems and IoT in daily life. Due to the exclusive features of geographic and temporal information, specific approaches in the data mining techniques are required to extract knowledge. Majority of the trajectory exploration techniques in this field rely on the explicit data for the information extraction. Besides the obvious information such as latitude and longitude the trajectory holds underlying information about the movement. These semantic information like direction of movement, acceleration, important halt points can be consumed for the pattern extraction.

Rest of the paper is organized as follows, Section I contains the introduction of Semantic Trajectory processing, Section II reports major works related to the spatio-temporal data mining, Section III describes the key concepts and methodology, Section IV illustrates the architecture and essential steps of identifying Points of Interests of movement tracks, section V explains the proposed algorithm, Section VI outlines experimental data, results and discussion and Section VII concludes research work with future directions.

II. RELATED WORK

Moving Object Data analysis is becoming a popular area of research. Different works on Moving Object data span across diverse aspects of Bigdata such as representation, indexing, retrieval and analysis of trajectory data. Here we are examining notable works in the area of Points of Interest extraction. In a recent work [7], human mobility patterns are discovered from space time points recorded from the social networking sites. Here the context information also considered for the analysis which are obtained from the description of places that people move through. ST-Hadoop is a framework [8] that represents a system using popular distributed framework Map Reduce for processing spatio temporal data. This system is designed to load partitions and data records according to the temporal and spatial characteristics among the computational nodes. All these frame works are based on the direct spatial and temporal properties of the moving object, whereas exploiting the underlined information of the movement data is a different idea in the trajectory mining. Stop and Move of trajectories introduced by Spaccapietra et.al in [4] is one such approach, here a trajectory is considered a sequence of stops and moves. Stops are important locations of the movement track which are defined according to the application we are considering. It could be famous tourist destination in a tourism application, a garage in the case of fright movement, traffic junction in transportation etc. This method is one of the first reported works of semantic trajectory processing. Inspired by the Stop and Move method a few number of semantic trajectory processing techniques, called Stop and Move of Trajectories -SMoT, are developed. Some of them are IB-SMoT (Intersection Based SMoT) [9], CB-SMoT (Clustering-Based SMoT)[10] and DB-SMoT (Direction SMoT)[11]. All these methods identify important locations of single track movement.

In this work we are suggesting methods to identify Points of Interests from a group of trajectories by considering spatial, temporal and semantic features. V. Bogorny et.al in [12] proposed a semantic trajectory data conceptual model called CONSTAnT, which defines important aspects of semantic trajectories. This is claimed to be the first paper that provides an inclusive definition of various aspects of semantic trajectories. It elaborates the concept of sematic trajectory and introduced certain thoughts such as semantic sub trajectory, semantic points, geographical places, events goals etc. of moving objects. A practical system for storing and managing this semantic attributes are still could not be achieved. Since the huge and extensive proliferation of IoT and LBSs in all corners of life, a precise platform and software are necessary in the field of semantic processing. In a recent publication about the ongoing research [13] on semantic trajectory frameworks, authors describes a two dimensional trajectory representation method for including its additional features other than spatio-temporal attributes. It extracts and classifies Context and Semantic dimensions of the travelling object data to make the analysis meaningful. The contextual information indicates the surrounding information that associated to the moving object, while the semantic information describes the inspiration of the item to move.

III. KEY CONCEPTS AND METHODOLOGY

This section summaries basic concept behind trajectory processing that identifies interesting points of multiple travel paths. The notion of trajectory, Point of Interest, threshold values and semantic properties are discussed.

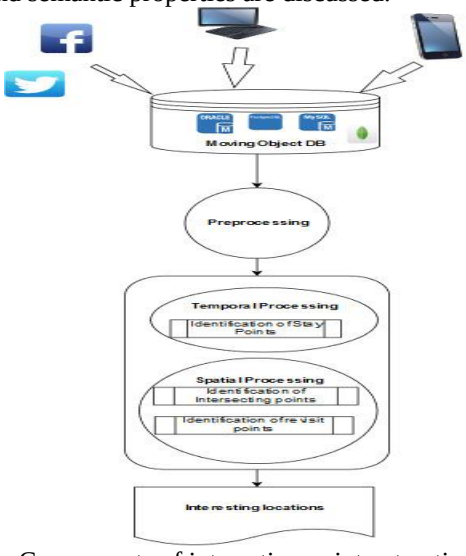

Figure 1 : Components of interesting point extraction system

A. Trajectory

A Trajectory, TR(x, y, t) , is a list of space time points $\{(x_0,y_0,t_0),(x_1,y_1,t_1),\ldots(x_n ,y_n ,t_n)\}$ where x_j ,y_j , $t_j \in R$ for j = 0,...,N and $t_0 < t_1 < t_2$.

Where (x, y) indicates latitude and longitude of the moving object and t_j is the time in which the object resides the location (x, y). The position (x, y) is called spatial value and t_j is called temporal value [5].

B. Threshold Values

Two threshold values used in the work are spatial threshold (MinVisit and MinIntersect) and temporal threshold (MinStay).

The temporal threshold, MinStay, is measured in seconds, if the object retains in a specific location beyond MinStay the location is be considered as a valid temporal point. If the count of revisits made by the object reaches above the spatial threshold, MinVisit that point is considered as a valid spatial point, SP_i. Another threshold for spatial threshold is, MinIntersect, which is the minimum number of intersecting points among different trajectories.

An interesting Point of Interest, PI_i, of a trajectory TR(x, y, t) is the location identified by accounting the temporal and spatial stay point counts.

$$PIi \in TR(x, y, t) \mid fn\ (TM_i ,\ SP_i).$$

Inputs:

1. $TR_{i..j} = \{(x_0,y_0,t_0),(x_1,y_1,t_1),\ldots(x_n ,y_n ,t_n)\}$, a set of trajectories
2. MinStay, minimum duration of time the moving object resides in a stop.
3. MinVisit , minimum number of counts the moving object performs stay and revisit
4. MinIntersect, minimum number of intersection points among different trajectories

Output:

1. Semantic Trajectory Points $P=\{P_1 , P_2 ,P_3,\ldots,P_n\}$, interesting points identified , each point is a member of TR_j

Method:

1. Accept row trajectories of moving objects in TR , initialize MinStay, MinVisit and MinIntersect
2. ***For j = 0 to n*** of all individual trajectories
   i. Calculate *stayTime* of individual trajectory TR and store it in *tempStayDuration*.
   ii. If (*tempStayDuration* > *MinStay*)
      1. Assign the points in to *sematicArray*
   iii. Identify the revisited locations of individual trajectory TR_i and store it in *tempRevisitPoints*
   iv. If (*tempRevisitPoints* > *MinVisit*)
      1. Assign the points in to *sematicArray*
3. ***For i = 0 to m***
   i. Find intersecting points among individual trajectories and store it in *tempIntersectPoints*
   ii. If (*tempIntersectPoints* > MinIntersect)
      1. Assign the points in to *sematicArray*
4. **END FOR**
5. Identify unique points of *sematicArray*.

Listing 1 : Pseudo code for interesting points extraction system.

IV. ARCHITECTURE

A. Methodology

Different components used in the proposed system are given in Figure 1. As explained before mobility data are generated from different sources and in various formats. The pre-processing step consists of making the data in a uniform format and checking its continuity. Once pre-processing is over spatial and temporal operations are carried out. The spatial processing consists of identification of intersection points and revisited locations. Appropriate threshold values are used for the inclusion of points. Followed by spatial operation the temporal processing considers points where the object reside for specific period of time.

B. Algorithm

According to the basic definitions and concepts detailed in section III, we are proposing a novel algorithm for extracting the interesting semantic points of multiple user trajectories. It accepts moving object trajectories of various users in a geographic area. Each trajectory may have varying number of trajectory points. The output of the algorithm is the set of semantic points or interesting points. The Point of interest P_i is the location in the trajectory path that is having special attention. The significance of interesting point is quantified by considering spatial, temporal and semantic features of the trajectory.

The pseudo code of the algorithm is given in Listing 1. The method accepts different parameters such as trajectory of m different users, threshold minimum duration of stay in a location, threshold value of number of visits made by respective trajectories in a location and minimum number of intersecting points of different trajectories. Once the preprocessing phase is over each trajectory is examined for the presence of stay point.

If the stay time is above the threshold value for stay time, MinStay, the location will be considered as a valid temporal point. The spatial factor is measured by verifying the revisit of the object and intersection of different trajectories. The revisit values above spatial threshold, *MinVisit*, will be accounted for the calculation of Semantic Points. Similarly the threshold value for intersection of different trajectories are limited by the value set in MinIntersect. The identification of stay point duration and revisited location are performed by evaluating trajectories one by one (line 2 and subsections of the listing). All the qualified points are updated in *sematicArray*, finally de duplication is done to eliminate the presence of same locations from any one of the three phases.

V. EXPERIMENT AND EVALUATION

The experiment is performed on Microsoft Geolife [6] Trajectory set which is a trajectory set of movement data of 182 different users collected using GPS devices in a period of five years. For the purpose of our work we have considered 716377 trajectory points of five different users. A Point of Interest is a location in the travel path of the object that is having some priority. Table 1 shows the number of stay points and number of revisits identified from the trajectory of selected users by applying our algorithm.

Our method is compared with an existing related approach for extracting the Stop Points called IB-SMoT. Since IB-SMoT is designed for single trajectory we modified it for multiple

users. An additional 189 POIs are extracted from the six user travel sessions compared to the IB-SMoT method. Figure 2 shows trajectories connecting the interesting points of different users. These are points identified as a function valid stay points and revisit locations.

Table 1: Sematic points identified from multiple user movement trajectories

UserId	No. Trajectory Points	Stay Point Count (IB-SMoT*)		Revisited locations		Total valid interesting locations
		Total	Valid	Total	Valid	
6	31830	1051	0	13	5	5
153	62209	543	51	26	8	59
5	91649	4985	0	75	23	23
1	108607	5576	1	374	128	129
0	173865	8429	2	0	0	2
2	248217	8325	0	56	25	25
Total Interesting Locations			54		189	243
*IB-SMoT Modified for multiple trajectories						

Table 2 : Interesting locations identified using intersecting points of different user tracks

Meeting Users	No. intersecting locations
1,2	3
1,5	7
5,6	2
2,5	2

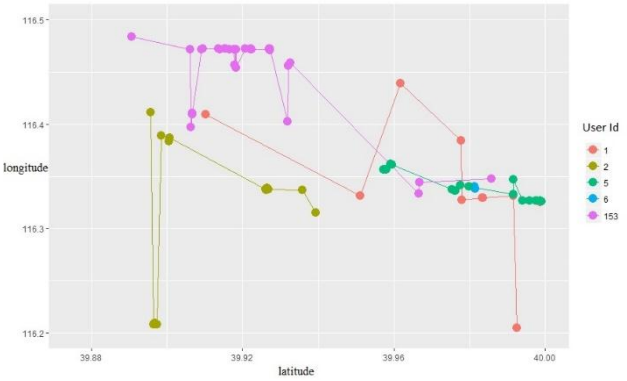

Figure 2 : Interesting points identified from movement trajectories of different users

VI. CONCLUSION AND FUTURE SCOPE

Widespread use of context aware devices generates large amount of movement data from plethora of sources. Identifying interesting locations from voluminous movement traces of objects is useful in many applications. In this paper we propose a method to identify interesting points from these movement tracks of multiple objects. Compared to existing methods of semantic point extraction our approach identifies more meaningful locations since it simultaneously considers spatial and temporal behaviors of the moving object simultaneously.

In future we would like to extend the model by including various semantic properties such as direction of movement, change in the velocity etc. Once the interesting points are identified it will undergo clustering process for the mining the similarity patterns.

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