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Spatio Temporal Analysis of Moving Objects in Supply Chain Networks using Semantic Clustering

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Abstract

Supply Chain Management (SCM) system regulates flow of products and services from its origin to the end user. It mainly focuses on the transportation and distribution of goods on demand. Among the different stages of SCM (Plan, Develop, Deliver and Return) the logistic and return phases are very much important as the speed of delivery mechanism will directly impact the end user. Choosing the best path for the delivery will positively affect the system. The growth of digital technologies and its seamless integrations with the network environment creates an exposure to big data management. Strategies in Supply Chain Management methodologies embrace the big transformations marking the information technology. Proper visualization of the consignment leads the decision makers to correct approaches. This study gives an overview on various pattern identification techniques that can be applied in Supply Chain Management.

Keywords: Big data, Data mining, Supply Chain Management, Spatio Temporal clustering, Semantic Trajectory Clustering.

INTRODUCTION

The supply chain management characterizes the movement of items from one point to another point. According to Stadtler [1] supply chain management is the conduct of sharing material, information and financial information within the organizational units to satisfy the customer needs and as a result, enhance the entire supply chain system. Much amount of time, effort and money are spent over the logistics of raw materials required for the production, delivery of finished goods and return of the defective items. Hence any measure that optimizes the physical

flow and information flow will positively influence the performance of the business.

Whether it is flow of information, financial transaction or transportation of materials mobility is the fundamental feature in the Supply Chain Management. Consequently mobility administration has become dominant and influential factors in supply chain management. Internal and external material flow is achieved by transportation of substances over a distribution network. The objective of any economical logistics is the cost effective transportation. This can be achieved only with the practice of a coordinated system that share precise, accurate and up to date information from each node of the supply chain.

Inefficient planning of distribution network can commence delay in shipments and it will interrupt the web of manufacturing and logistics management. Many snags can develop during the transportation phase including delay due to calamities, accidents or problems with the transportation network etc. At the time decisions are to be taken for alternative measures in order to temper damages. Uncertainty of the information about the shipped item can also lead to wrong or unhealthy settlements.

As mentioned above ensuring hassle free flow of items, whether it is finished products, raw material or return items, is the key constraint in the Supply Chain Management. The big trouble of transportation manager is route planning and formulation of distribution network. An intelligent analysis of the movement will help to facilitate effective transportation of items. Real time update of the locale of the object in transit is necessary to take measures to supplement the urgently needed items.

Surveys conducted among leading chief supply officers revealed that more and more companies are investing into the intelligent solutions to visualize the supply chain. The amalgamation of SCM with science, predictive analytics, and big data, collectively referred to as DPB [2].The study also point out the paucity of researches in the topic.

In this review paper some of the major thoughts in the area of spatio temporal data management in supply chain management domain are explored.

The remainder of the paper is organized as follows: next section presents mobility and tracking done in supply chain management in the light of advanced technologies. The third section presents the ways of managing the moving data in the database. The fourth section explains identification of mobility patterns from the stored data. The fifth section details route prediction techniques. Our contribution and perspectives related to this is briefed in section six. The seventh section concludes the topic.

Mobility and tracking

Outright tracking of freight movement will substantially scale down the delay in delivery of products and its chance of damages. The exponential growth, availability and use of location aware systems enable the tracking of objects in a better way. Rapid development of accurate context

aware systems made the traversal of mobile systems very easy and precise. The reduction in price of hardware devices characterized the popularity of Internet of Things (IoT), various range of products are now connected and are able to communicate its whereabouts to the station. Since, supply chain management system mainly comprises the management of containers and other carriers; context of the moving object is very important aspect, especially once its delivery is time bound. Location aware systems attached to the container constantly feeds data pertaining to position and time of the object in motion. Supply Chain Management exploits this advantage in the logistics domain.

Radio Frequency Identification (RFID) and barcodes are two existing prominent traceability solutions in the industry. RFID tags electronically stores information required for ascertaining the details of object in which it is attached [3]. Standard specifications are developed to ensure security and privacy of data stored in RFID chips. A detailed research conducted by IDTechEx [15] on the RFID market reveals that in 2015 total RFID market is worth $10.1 billion and forecast that to rise to $13.2 billion in 2020. This includes tags, readers and software/services for RFID cards, labels and all other form factors [15].
Another upcoming method of this genre is Mobile Supply Chain Management (mSCM). It is the use of mobile equipment and applications to assist various activities in the supply chain management. The mobile Supply Chain Management consists of the integration of logistics movement with connected devices such as mobile phones, PDAs, Pocket computers etc. [4]. This technology is getting wide acceptance as a cost effective approach in the supply chain management.
GPS enabled tracking technology provides greater visibility of the shipment during its journey. An article published in Forbes [16] lists some of the leading transport management solutions that provide real time visibility of the fleet movement across the network.

Moving object data management
The volume of data generated from the sensors has exploded over the years as a result of connectedness. Stack of data cascaded to remote storage devices are of heterogeneous format. This growth of diverse and abundant data has given rise to the emergence of new approach called big data.
Data pulled out from the location aware sensors that are connected to the object in supply chain consists of object id, location (latitude and longitude) and time at which the object occupies the position. Making use of this information the supply chain can be visualized and more underlined information can be mined which will grease most of the uncertainties transpire during the shipment process. Normally, enterprises keep its data in various data silos using traditional database management system. Since, long established database management system such as RDBMS largely stores data having static nature, the

continuous stream of information generated by these moving objects requires an extension of the existing system. This leads to the development of Moving Object Database (MOD) or Spatio Temporal Database. Being a subsection in the big data, MOD is capturing attention by both researchers and management experts.

Queries formulated in the spatio temporal databases augments advanced, descriptive and predictive analysis processes. Continuous stream of spatio temporal data regarding the time stamped location of the container is stored in special form called trajectories. Trajectory is the sequence of time stamped locations and is the basic form of representing moving data. The movement is represented in the trajectory with two spatial components and one temporal dimension.

Given this scenario the size of moving object in supply chain is not considered for the convenience of computation. The entire properties of the object are confined into a point. In one of the noted work on the processing of spatio temporal trajectories Dieter Pfoser [8] has classified the moving object into following categories.

a. Constrained Movement

The steps of pedestrians over the path, ride of vehicles over the road and passage of trains etc. are examples for constrained movement. With reference to the SCM the constrained path represents the distribution network. Most of the traffic management frameworks developed are associated with the constrained network.

b. Unconstrained Movement

Movement of ships in sea, navigation of migrating birds, hurricanes etc. are example of unconstrained movement. Mobile Supply Chain application considers both constrained and unconstrained movements. Since change of position in constrained and unconstrained network characterizes different properties, they need to be treated accordingly.

Number of successful frameworks is in place for the management of these trajectory data. Ralf Hartmut Guting and colleagues developed a generic framework for representing spatio-temporal attributes of moving object [5] [6]. These works suggests data model and query language for handling the time dependent continuously moving objects.

Identifying feasible patterns of package movement

Analyzing the trajectory data will give the characteristics of moving object. Proper study of movement patterns will give more hidden information about the nature of mobility. Clustering is an effective approach for this; it is the process of grouping a set of objects into similar batch. Clustering discovers previously unidentified but potentially useful points from the trajectory. Being the fundamental data analysis component it has relevance in moving object data as well. Different clustering frameworks explore dataset to associate objects in units, such that the objects in each group have common characteristics [17].

Moving objects in SCM creates trajectory which contains location and time. The journey of finished products starts from the dispatch section of the factory, by assuming multiple mode of conveyance it proceeds to the destination. Different containers from the same source can take various lanes which will have diverse directions, speed, blockers, stops etc. For the computational purpose the size of the moving object is ignored here and each object in motion are treated as points. In this context spatial and temporal attributes of the moving points are important parameters for plotting the trajectory. Spatio temporal clustering on this trajectory builds groups of objects that are geographically and temporally close [6].

A competent clustering algorithm can discover common path of various carriers in the supply chain. Majority of the clustering techniques so far utilizes the density based algorithms; Density Based Spatial Clustering of Applications with Noise (DBSCAN) is the first member in this class [14]. This method traverses through the complete data set (here the package locations) and label each object as core object (object within the cluster), border object or noise (object outside of the cluster). In the second step core objects that are close each other are grouped to a cluster.

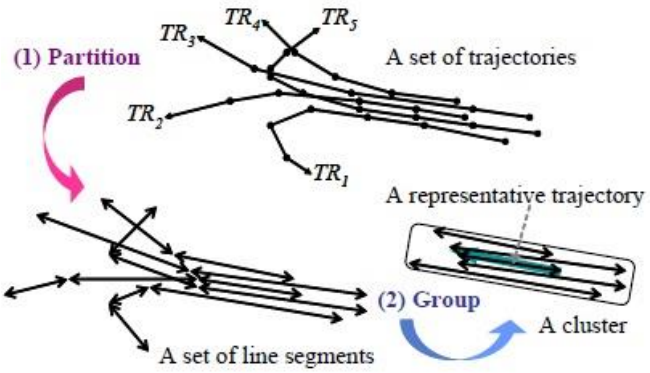

Figure 1: trajectory clustering in the partition and group framework [13]

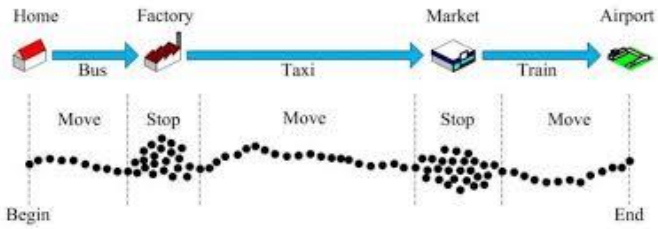

Figure 2:Trajectory that constitute stop and move [9]

Discovering common sub travel paths will be useful in fabricating the distribution network. Figure 1 pictures clustering techniques in partition and group framework proposed in [13].

Majority of the existing classification works are concentrated with the geometric properties of the travel path, which considers only geographic location and time.

Excavating implicit information about the movement was a thought in different dimension that is introduced by Spaccapietra et.al in [7]. In this concept the trajectories of package movement are observed as a set of Stop and Moves. The stops are interesting points of objects in motion [7] [11]. It can be the stoppage of container in garage, customer endpoint, check posts, stops due to traffic jams etc. Considering the need of the application stops can be defined. This approach is also called semantic clustering, which will give meaningful information of the transportation networks in use. We can extend this concept into the sphere of supply chain management. The stops are identified using clustering techniques for this additional attributes of the object in motion such as acceleration, direction of movement, rotation etc. can be utilised. A move is the travel path between two consecutive stops.

Prediction of best distribution path

Smart traffic technologies provide real time road traffic prediction that are useful to the container drivers to find alternative routes in case of adverse conditions. The trajectory database keeps the history of object movement under given time. Wani Min et. al [9] put forwards a precise one hour advance traffic prediction technique by utilizing spatio temporal data generated from the sensors. Normally trajectory data can be treated as a repository and it can be used for prediction of routs. Intelligent systems powered with Artificial Neural Network algorithms can learn multiple conditions from the real data .Using this better paths can be suggested.

As explained in section 4, clustering of trajectory using some of the semantic properties such as speed of the object, direction of movement will lead to better inferences. The direction of object movement is important, while clustering the trajectory path apart from the speed of the container movement the direction of the path is also considered. This is very much particular if the movement is through unconstrained network.

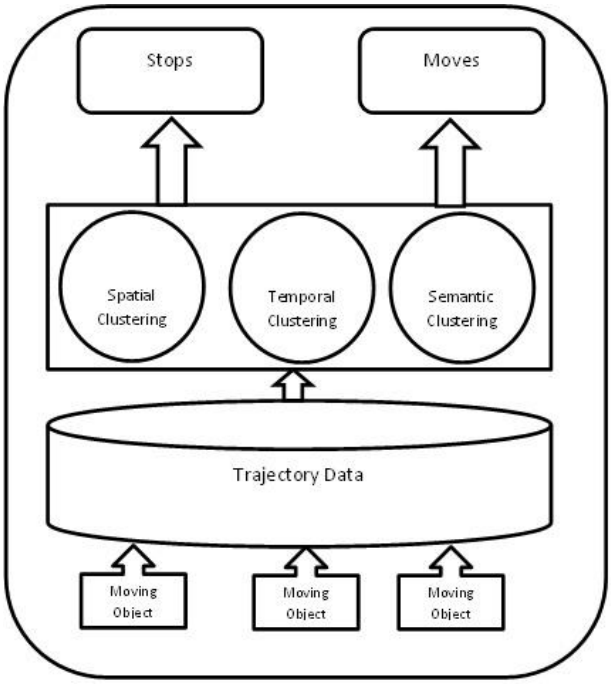

Figure 3: Logical architectural diagram for spatio temporal semantic clustering

The semantic clustering uses speed and direction of the object movement. Well accepted DBSCAN algorithm modifies accordingly. Figure 3 shows the architectural diagram of the proposed model. Movement data obtained from the container are stored in the trajectory database. The resulting information is a set of stops and moves. Spatial, temporal and semantic classification of the data is carried out in a phased manner.

If multiple trajectories of freight movement are analyzed using the semantic clustering system, it will provide the potential stops. The stops identified from various trajectories implies areas where the container system spends more time, travels in reduced speed, different containers opt for same path etc. These data are valid inputs for the design of distribution network and route prediction in supply chain management.

Microsoft's GeoLife GPS Trajectories is GPS trajectory set collected in (Microsoft Research Asia) Geolife project by 182 users [12]. Since this data set represents broad range of customer movements it can be used as a convenient test data for applying the clustering algorithm. The proposed implementation platform is the popular statistical and data mining Tool R programming.

Conclusion

By the introduction of the spatio temporal processing of trajectory in the data rich environment some of the existing practices of traditional supply chain management can be re-engineered. We are mainly focusing on the clustering of trajectories of moving object that occupies its path over a constrained network based on direction and speed. In addition to the explicit information available from the trajectory, mining of hidden information

helps gathering more useful knowledge on the travel pattern. The same concept can be extended to the areas where mobility is a key factor.

During the grouping process the objects that don't fall in any of the groups need to be treated accordingly. These partial objects can be grouped using Fuzzy Clustering technique. The analysis will be very much helpful for route planning of the container movement, route suggestion and identification of the delay points. With the addition of Artificial Neural Network modules considering different parameters such as acceleration, direction of movement, traffic congestion better alternative distribution network can be set. Since the amalgamation of ANN technology and spatio temporal clustering is still in infancy more researches has to take place in this area. Querying of information from the moving object database is another area that needs attention.

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