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SPATIL DATA MIING IN SPATIO-TEMPORAL DATA BASES

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Abstract

Spatial databases have been an active area of research for over a decade, addressing the growing data management and analysis needs of spatial applications such as Geographic Information Systems (GIS). This research has produced spatial data types and operators, spatial query languages and processing techniques, spatial indexing and clustering techniques. A spatial database management system aim to make spatial data management easier and more natural to users or applications such as urban planning, utilities, transportation and remote sensing. Even though traditional database technology has been evolving for last fourteen years, managing spatial data with database system poses many challenges. Spatio-temporal data bases are the latest developments in the field which stores spatial data at specified time stamps. This database technology made it possible to provide location-based services to web and mobile applications using data bases. The explosive growth of the use of intelligent mobile devices such as mobile phones and PDA's opens up new possibilities for delivering location information to the mobile devices, and delivering services to the mobile devices that are customized and tailored according to their current location. In order to provide on-line information to mobile devices, the location of the objects which are moving in space are to be recorded at real time in database which is spatio-temporal nature called moving object data base (MOD). A location based service is able to provide targeted spatial information to mobile workers and consumers. Geographical information System (GIS) and Global

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Key Words : *GIS, Spatio-Temporal data bases, Location aware services, Moving object data bases, Trajectory similarity.*

Positioning system (GPS) technologies are expanding their traditional applications to embrace a stream of consumer-focused location based applications. The technologies and applications of Location aware services can play an even increasingly important role in the modern, mobile, always connected world. This paper presents the basic concepts of the Spatial Database, a client-server architecture, its basic model with handling trajectory equation, its applications in commercial, scientific and location aware services.

1. Introduction

A spatial database management system aim to make spatial data management easier and more natural to users or applications such as urban planning, utilities, transportation and remote sensing. Earlier databases are traditionally used in business and administrative applications and such data bases needs the common data types such as integer, float, character etc. The modern applications requires advanced data types to store picture, sound and other such multimedia data. The recent developments in Geographical Information System stores both the picture and attribute data together in one database using Object relational database technology.

When we are interested in spatial data at various time stamps such as to study the rate of deforestation takes place for a period of time we need to store and manipulate pictures of the area at speficified time interval. Such databases are generally called spatio-temporal databases where time parameter also stored along with spatial objects. In most of this case the data base contain historical data capable of reproducing the object status at various points of time in the Past.

The explosive growth of the use of intelligent mobile devices such as mobile phones and PDA's opens up new possibilities for delivering location information to the mobile devices, and delivering services to the mobile devices that are customized and tailored according to their current location. In order to provide on-line information to mobile devices, the location of the objects which are moving in space are to be recorded at real time in database which is spatio-temporal nature called spatio-temporal data base. It allows the user of a portable computing unit to transfer data, via a wireless network, to and from a host computer.

Spatial Databases

A Spatial Databases model the movement of moving objects in space. The technology has been developing rapidly due to continuous improvements in the performance/price ratio in wireless communications and mobile computing devices. The positions of the moving objects change continuously with time. Sensor systems, such as the Global Positioning Systems (GPS), Geographic Information Systems (GIS) or even cell phones and Personal Digital Assistants (PDAs) provide only discrete points of information about the moving objects to the MOD. For any time t (whether correct or incorrect), there is a location for the moving object. Each moving object (a mobile client) is equipped with a GPS receiver, an onboard computing device and a GSM device. The GPS receiver obtains the moving objects location. The clients (moving objects) have wireless communications to the host server through the GSM device. A Typical client/server architecture used for Spatio-Temporal database application is shown in Fig 1.

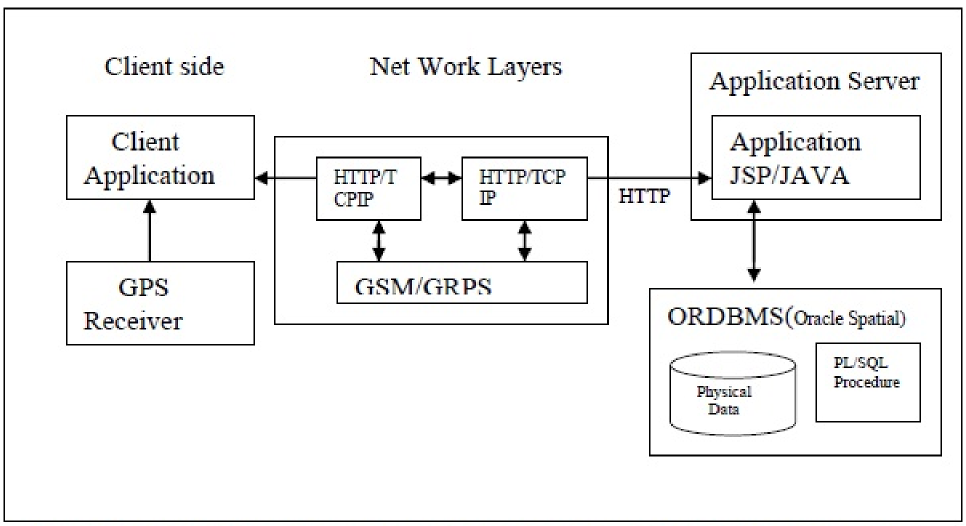
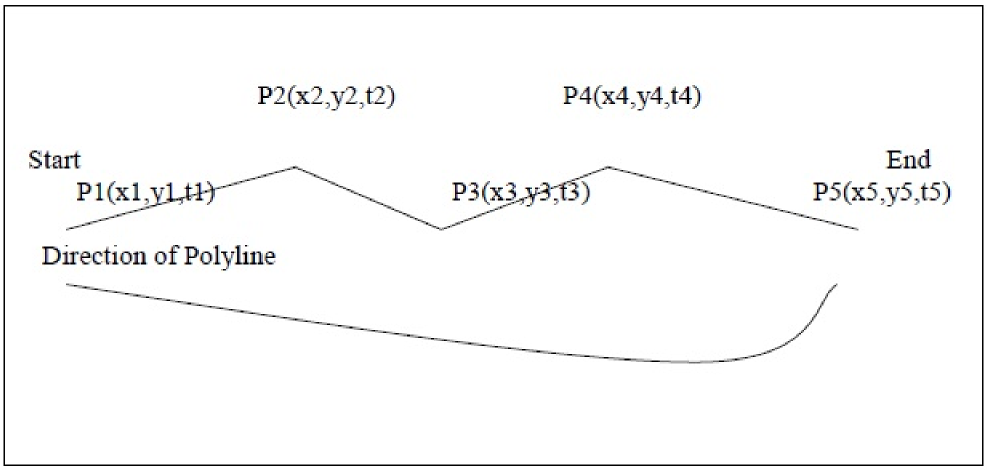


Fig 1: Client Server Architecture of Spatial Data Base for location aware services

MOD is emphasizing approaches which will be able to handle continuously changing geometries, or moving objects. For some objects only the position in space is relevant, hence they can be viewed as moving points; for others also the time dependent extent is relevant, hence we can speak of moving regions. Examples of moving points are people, vehicles or animals; examples of moving regions are hurricanes, forest fires, deforestation, or the spread of epidemic diseases. The goal of the database research is to represent such entities in databases, to be able to ask all kinds of queries about them, and to get these queries evaluated efficiently.

Basic Data Model for MOD

In a typical spatio-temporal database, the objects have no or very slow motion in space. MOD is an extended case of spatio-temporal database. It deals with the representation and querying of continuous, time-varying information on moving objects, usually in a large number and at higher speeds. The simplest form of a moving object trajectory in 2D space is usually represented by a polyline as shown in Following figure.



In three-dimensional space (two-dimensional geometry, plus time), represented as a sequence of points $(x_1, y_1, t_1), (x_2, y_2, t_2) \cdots, (x_n, y_n, t_n)$, with $t_1 < t_2 < \cdots < t_n$. Since the moving object is assumed to be moving on a straight line and at constant speed, the location and speed of the moving object at any time t_i can be interpolated from the end points of the polyline. [2]. The speed of the moving object along the line segment between (x_i, y_i) to (x_{i+1}, y_{i+1}) can be calculated as

$$V_i = \sqrt{}[(x_{i=+1} - x_i)^2 + (y_{i+1} - y_i)^2]/(t_{i+1} - t_i).$$

The end points of the polylines are also the locations of the moving object where location updates take place. These end points can also contain data other than location and time, such as the tuple P (oid, x, y, speed, azimuth, t) of the moving object (i.e. the object id, location, speed, azimuth and updating time).

Applications of Spatial Data Base for moving Object

Spatial Databases are used in commercial, environmental, civilian and military applications. The moving objects could be people, animals and vehicles on land, sea or in air. Spatial database allow efficient location tracking, monitoring and forecasting of moving objects. With the cost of on-board mobile computing and wireless communications becoming more affordable and reliable, the applications are not just limited to ocean liners, aircrafts or military vehicles. Some applications of such data bases include tracking and monitoring of:

- Self-owned vehicles for personal navigation, theft recovery, etc.
- Service vehicles such as taxis, delivery trucks, and ambulances and ships in the sea.
- Wild animals in scientific studies
- Senior citizens suffering from dementia
- People sentenced to alternative jail terms that restrict their movement
- Potential shoppers (with cell phones equipped with GPS) who come close to a shopping area. Sales promotion messages will be sent to their cell phones.

Spatial Data Mining for mobility based Applications

While the Trajectory Database analytical tools concentrate on presence of moving objects, mobility mining is aimed at analyzing movement. A method for mobility data mining tackles two different tasks: first, to define the format of spatiotemporal patterns and models to be extracted from trajectory data, and second, to design and implement efficient algorithms for extracting such patterns and models. The different mining tasks developed within GeoPKDD [5] focusing on trajectory similarity and pattern mining, trajectory clustering, and trajectory classification. The following section details on trajectory similarity and pattern mining.

Trajectory Similarity and Pattern Mining

Trajectory pattern is a novel notion of spatio-temporal pattern, which formalizes the idea of aggregated movement behaviors. A trajectory pattern, as defined in [5], represents a set of individual trajectories that share the property of visiting the same sequence of places with similar travel times. Therefore, two notions are central: (i) the regions of interest in the given space, and (ii) the typical travel time of moving objects from region to region. In this approach a trajectory pattern is a sequence of spatial regions that, on the basis of the source trajectory data, emerge as frequently visited in the order specified by the sequence; in addition, the transition between two consecutive regions in such a sequence is annotated with a typical travel time that, again, emerges from the input trajectories. For example a pattern may be interpreted as a typical behavior of tourists that rapidly reach a major attraction from the railway station and spend there about two hours before getting to the adjacent museum. It should be observed that a trajectory pattern does not specify any particular route among two consecutive regions, while a typical travel time is specified, which approximates the (similar) travel time of each individual trajectory represented by the pattern.

2. Methnodology

Here we concentrate our research on spatio-temporal similarity to mine tourist mobility data which comes under the area trajectory similarity and pattern mining.

Trajectory Similarity in Spatial Networks

Let T be a trajectory in a spatial network, represented as

$$T = ((b_1, t_1), (b_2, t_2), (b_3, t_3), \cdots, (b_n, t_n))$$

where n is the trajectory description length, b_i denotes a location in binary string [6] and t_i is the time instance (expressed in time units, eg. seconds) that the moving object reached node b_i and $t_1 < t_i < t_m$, for each $1 < i < m$.

It is assumed that moving from a node to another comes at a non-zero cost, since at least a small amount of time will be required for the transition.

We identify the following similarity types [7], [8] related to road network environment.

(i) Finding Objects moving through certain Points of Interest: This will be useful in finding out the movements of objects through known locations of interest, which may be terrorist locations, points of emergency or list of strategically important locations: Here we consider only spatial similarity measure.

(ii) Finding Objects moving through Certain Times of Interest: Useful for objects moving through known times of interest, which may be emergency time, explosion happened time or festival season time etc. Here we consider the temporal similarity measure only.

(iii) Finding Objects moving through certain Points of Interest and Time of Interest. Here we consider both spatial and temporal features together coming as spatio-temporal distance measure.

Spatial Similarity Matrix based on POI

We introduce the similarity measures between two moving object trajectories in a constrained network incorporating concepts discussed in [8]. Here the spatial similarity is measured based on three concepts as explained in fig 2.

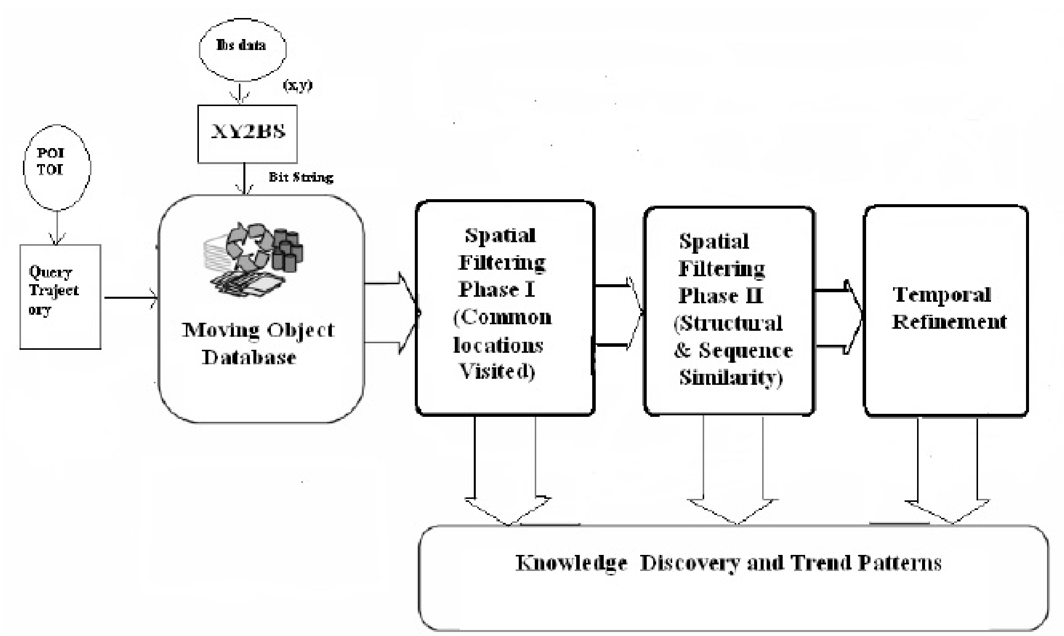


Fig 2. Similarity based Knowledge recovery Process

(a) Common URL's Visited by Two Trajectories

Let T_i and T_j be two trajectories. We introduce a Spatial Similarity measure $Sim_c(T_i, T_j)$ which attempt to incorporates number of common locations in trajectories. This similarity matrix measures the number of common locations passed through during the two trajectories relative to the total number of locations in both trajectories.

(b) Structural Similarity

Here structural similarity we mean how geographically the points are closed to each other. In order to measure Structural similarity we consider each of the four strings, separately and for each bit string, weightage will be assigned from left to right in the order 1, 2, 3 etc. Then we compare each corresponding bit of the two token strings bit by bit from the beginning until the first pair of bits is different. The similarity between two token strings is defined as the sum of the weight of those matching tokens divided by the sum of the total weights.

(c) Sequence Similarity of Web Sessions

The above spatial similarity measures consider the number common locations visited by two trajectories and their geographical neighborhood as a measure of structural similarity. The spatial similarity is checking only the percentage of common locations visited by each input trajectory with the query trajectory made by points of interest. As we consider important individual locations in Point of interest, the sequence in which these locations visited by an input trajectory is also to be considered in finding the actual similarity. For example in the field of security informatics if POI contains strategic locations and then the sequence of locations a moving car crosses will also have to be considered in finding how a user movement trajectory matches with the query trajectory created with the given set of POI. Here we consider the original trajectory data as a set of sequences, and apply sequence alignment method to measure similarity between trajectories.

(d) Temporal Refinement

The similarity measure defined in the previous section takes into consideration only the spatial concept, which consists of structural similarity and sequence similarity. In real applications, the time information associated with each trajectory is also very important. So to measure the similarity we have to consider the concept of space and time together. Here we are considering the temporal distance by taking the difference in web page request time as shown in Fig 3.

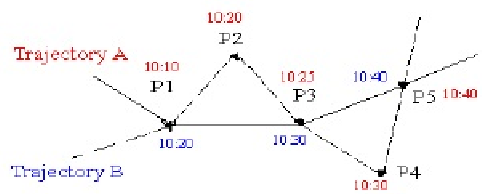


Fig 3: Temporal Distance of Two Trajectories

Temporal distance between Trajectory $A(T_A)$ and Trajectory B (T_B) will be $dist_T(T_A, T_B)$ = Differences in time at common

URL's visited $P_1, P_3, P_5 = 10 + 5 + 0 = 15$.

3. Experimental Evaluation and Results

We have taken a real-world data of tourist movement for experimentation purposes, namely a fleet of tourist cabs that make trajectory data set. The data set consists of 576 trajectories of 150 cabs moving places around Athens metropolitan area in Greece for 30 distinct days. The structure of each record is as follows:

{obj-id, traj-id, date(dd/mm/yyyy), time(hh:mm:ss), lat, lon, x, y}, where (lat, lon) is in WGS84 reference system and (x, y) is in GGRS87 reference system.

All experiments have been conducted on a Intel Core 2 Duo machine running Windows XP, with 2 GB of RAM, and a 320 GB SATA2-16 MB hard disk using the visual Programming Language Visual.

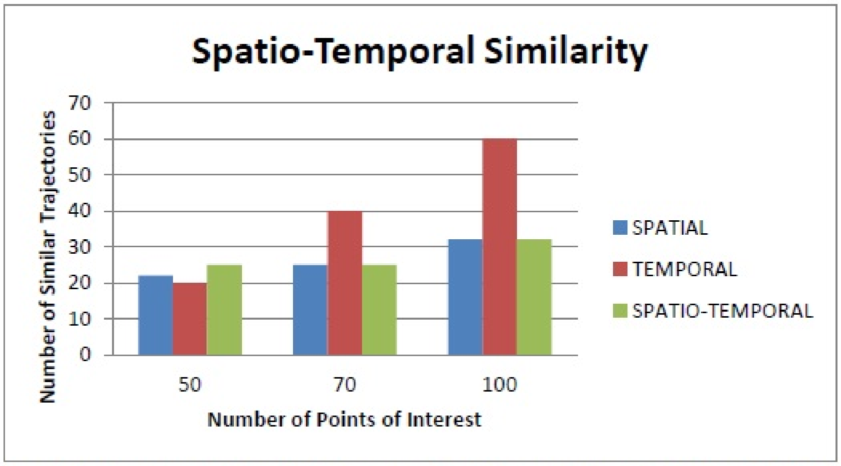


Fig 4. Comparison of Spatial, Temporal and Spatio-Temporal Similarity Search

Basic. Each of the three methods generate knowledge based on the methods proposed which can be used for mining tourist's movement profiles. The results of experiments confirm that (Fig 4) the spatio-temporal similarity search is more consistent than other two types of similarity search.

4. Conclusion

Mobile computing has been receiving significant attention in the past few years due to advances in personal mobile communications and wireless technology. The development of Spatial Database for location aware applications is still progressing research area. The similarity problem in trajectory database for moving objects on road networks has many applications in Transportation Network like tourist security, identification of traffic congestion and re-routing etc. In this paper we have proposed a method to measure the spatio-temporal similarity of moving object trajectories. As a continuation work we are planning to use the spatio-temporal similarity measures in the extraction of semantic location and activity knowledge from GPS traces, possibly augmented with other information such as web-sites visited by tourists and tourist behavior patterns.

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