Requirements of Traffic Telematics to Spatial Databases

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Abstract. Traffic telematics comprises services like traffic information, navigation, and emergency call services. Providers of such services need large spatial databases especially for the representation of detailed street networks. However, the implementation of the services requires a functionality which cannot be offered by a state-of-the-art spatial database system. In this paper, some typical requirements concerning the determination of a vehicle position, the traffic-depending computation of routes, and the management of moving spatial objects are discussed in respect to spatial database systems. It will be shown, that these tasks demand for the capability to handle spatio-temporal data and queries.

1 Introduction

One of the most challenging and encouraging applications of state-of-the-art technology is the field of traffic telematics. In the last few years, several new companies or new divisions have been founded in order to establish services concerning the collection, processing and transmission of data and information in respect to the road traffic[1]. This process was set off (1) by the urgent need of the road users for information and assistance and (2) by the development of new technologies: traffic telematics would not be possible without the availability of mobile (voice and data) communication techniques (e.g. the GSM standard including the short message service SMS) [3] and without satellite location (especially GPS). Typical services around traffic telematics are the following [4]:

- traffic information services via (mobile) telephones or special car terminals,
- on-board and off-board navigation services,
- breakdown and emergency call services,

[1] In Germany, some of the companies working in the field of traffic telematics are the Mannesmann Autocom GmbH (`http://www.passo.de`), the Tegaron Telematics GmbH (`http://www.tegaron.de`), the DDG Gesellschaft für Verkehrsdaten GmbH, and the automobile club ADAC (`http://www.adac.de`). Also most of the car manufacturers have founded special divisions or have commissioned subsidiaries in order to establish such services.

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- information and booking services, and
- fleet services.

In order to offer such services to customers, the service center of a provider needs the access to a large heterogeneous database storing alphanumerical data like customer records as well as spatial data. These spatial data consist of different vector and raster data sets: examples are administrative areas, postal code areas, and detailed topographical raster maps. Most important is the very detailed representation of the street network. Such street data are typically delivered according to the European GDF standard (“geographic data file” [2]) containing information like road names, house numbers, points of interest, and traffic restrictions.

Another typical aspect of the spatial database is the change of data: Some parts are relatively static (e.g. the street network) whereas other parts are permanently changing. For example, the information about traffic jams and the average speed on a road may change in intervals of only few minutes. A special motivation for using database systems in order to store changing or volatile data is the aspired robustness of the services: in a multi-computer and multi-process environment, the services can be synchronized best using a central database.

In the rest of the paper, some typical requirements are presented concerning spatial database systems in order to implement services around traffic telematics. Several of these requirements cannot be satisfied by state-of-the-art database systems.

2 Determining the Location of a Vehicle

In order to implement a breakdown and emergency call service, it is necessary to determine automatically the location of the customer’s vehicle and to derive the road name and the house number interval (or the names of crossing roads). But also for other services it is essential to locate a vehicle. Examples are off-board navigation services (see section 3), where the actual position of the vehicle is automatically used as starting point of the route computation, and the *"floating car data" technique (FCD)* [5] where speed changes combined with the location of the vehicle are used for the detection of traffic jams.

The actual position of the vehicle which has been transmitted to the service center is used for locating the vehicle. That sounds easy. However, the position delivered by GPS is imprecise because of jamming or/and because of the interference originated by buildings. In some cases, the accuracy is only several hundreds of meters. In order to solve this problem, not only the actual position of the vehicle, but also additional positions are transmitted to the service center [5]. At this positions, the vehicle performed special maneuvers. In addition, the accuracy of the positions, the distance which the vehicle drove between the positions, and the direction of the car at the positions (incl. accuracy) are transmitted. These data are called *string of pearls*, an example is depicted in figure 1.

To locate a vehicle means to determine of the road segment(s) where the vehicle could be, including a probability of the location. For performing such a computation, it is necessary

- to handle imprecise positions,

- to handle (imprecise) conditions between imprecise positions, and
- to take the underlying network including (time-dependent) traffic restrictions into account.

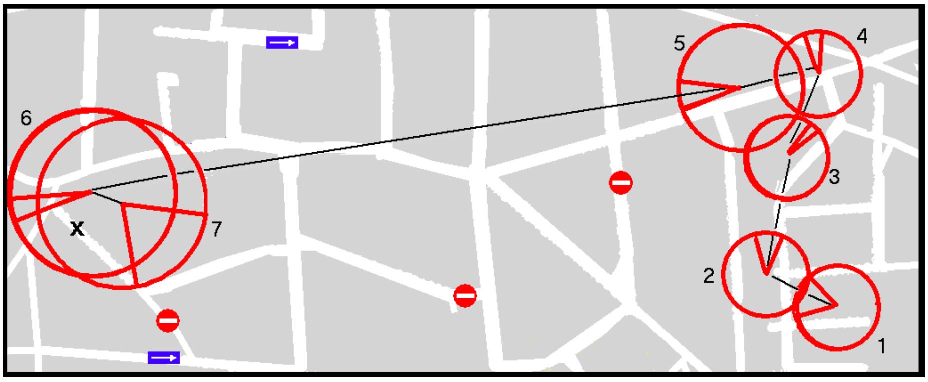

Fig. 1. String of pearls: seven pearls where the oldest pearl has number “1” and the most actual pearl is provided with number “7”. The sectors of the pearls represent the direction of the vehicle including the possible error. The order of the pearls is illustrated by the line which connects the pearls. The small cross shows the real position of the vehicle. In the background, the street network is depicted; the symbols represent traffic restrictions.

The computation of the location can be done outside of the database system by a program using standard spatial queries. Because of performance and maintenance issues, it seems to be reasonable to locate the vehicle by a query which can be performed and optimized by a spatial database system. However, state-of-the-art database systems are not able to perform such queries.

3 Traffic-depending Route Computation

On-board navigation terminals, which allow to compute the shortest route and to navigate the driver to the destination, are state of the art. The map is generally stored in the car on a compact disk. However, these terminals do not consider the actual traffic situation. A route computation which takes the traffic situation into consideration can be performed best in a service center where the (complete) traffic situation is known and where the current street network and the current traffic restrictions are maintained. Such an approach is called *off-board navigation*.

The computation of a route which takes the actual traffic situation into account is time-dependent. In order to compute the weight of a road segment used by the routing algorithm, (1) the time when this road segment is expected to be passed must be determined and (2) the expected speed at this road segment at the expected time must be computed. For performing such a spatio-temporal query, the database system must be able:

- to handle time,
- to perform updates efficiently,

- to compute routes efficiently, and
- to handle different times in one query depending on the route computed in the same query.

Especially, the last requirement is hard to fulfill.

4 Moving Objects

For fleet services, it is necessary to keep track on the positions of the vehicles. Also other (future) traffic telematics services such as toll charging via GPS/GSM, theft protection, and the integration of individual and public transport need the management of large sets moving spatial objects.

The support of motion requires that the spatial database system stores moving objects efficiently and supports spatial queries with time conditions in respect to the actual time, in respect to the past and, especially, in respect to the (near) future. The larger the number of moving objects, the more important performance issues will become.

The motion of vehicles (or other means of transport) is influenced and restricted by different factors:

– *the street network:* the street network channels the traffic. In consequence, no traffic can be observed outside of the network and most of the vehicles use mainly a small set of the network, i.e. they drive on major roads and motorways. This observation is also valid for public transport systems.
– *the traffic*: in the rush hour or in traffic jams, the average speed decreases. For example, this effect is used by the FCD technique in order to detect traffic jams.
– *time schedules:* the motion in public transport systems but also - on special parts of the network (e.g. ferry lines) - of individual vehicles is controlled by time schedules.
– *other conditions*: weather, day time, week day, holiday periods, etc. have influence on the average and the individual behavior of the vehicles.

For storing moving vehicles in a spatial database system, these factors have to be taken into consideration: First, the type of motion is correlated to performance issues: in order to support the storage of moving objects, the database system has to offer adequate data models and efficient access structures. For example, the structure of the network has to be taken into account in order to achieve high performance. Second, the motion influences the query processing process, especially if queries in respect to the (near) future are considered. This affects also the design of query languages. Furthermore, the integration of a knowledge base storing rules about the typical movement of vehicles could be useful in order to answer queries about moving vehicles.

These requirements illustrate that state-of-the-art (spatial) database systems need considerable improvements for an adequate support of moving objects.

5 Conclusions

Several requirements resulting from the field of traffic telematics were presented in this paper. Some of them could be solved by a state-of-the-art database (e.g. the storage of imprecise positions), others are topic of actual research activities (e.g. the CHOROCHRONOS project for spatio-temporal database systems [1]). For the efficient management of moving objects, for example, many questions are not solved [6]. Also the use of a spatio-temporal database system for the computation of traffic-dependent routes (see section 3) seems to be an unsolved problem.

A special problem is the integration of different techniques and solutions into one database system. Due to maintenance and operating reasons, it is an urgent need to use one standardized (spatial) database system to store the spatial data and implement the applications which are used by the different services. The use of several special-purpose systems and algorithms for fulfilling the requirements presented in this paper is extremely expensive (in respect to time and money). This observation will be strengthened by the expected transition of the static street network (actual update rate: quarterly) into a permanently updated network. In this case, an on-line update will be required which makes the maintenance of several databases and special-purpose systems more difficult and more expensive.

References

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