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The TranQuyl language for data management in intelligent transportation ☆

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ABSTRACT

Intelligent Transportation Systems envision a networked environment consisting of vehicles, the infrastructure, and hand-held devices (e.g., smart-phones). The environment will enable numerous safety, mobility, and environmental improvement applications. For example, drivers can be warned of dangers in their local environment or when risking to leave their lane. Furthermore, their visibility range can be expanded by providing highly up-to-date information from areas that are currently invisible. For another example, the road weather—up-to-the-minute visibility, precipitation, and pavement condition information—can be provided at high spatial resolution.

Intelligent Transportation efforts are currently being undertaken throughout the world. In addition to the IntelliDrive initiative of the US Department of Transportation, similar efforts exist in Europe, Japan, and China. But these efforts are largely decoupled from, and often incognizant of, the advances in spatio-temporal information management.

This paper outlines a spatio-temporal data management language, Transportation Query Language (TranQuyl), which will facilitate the specification of a wide variety of queries of interest to travelers, to transportation agencies, and to industry. Queries in TranQuyl may be processed in either client server mode, or mobile peer-to-peer (P2P) mode, or both. TranQuyl will provide support for the specification of uncertainty either quantitatively or qualitatively as fuzzy queries, for example: "retrieve safety/emergency information around me". In response, query processing should avoid overloading the traveler with information, and instead present only the most relevant answers to the query.

1. Introduction

The impact of Computer Science (CS) and Information Technology (IT) on transportation systems is not as dramatic as the one on science, finance or business in general. But in the last few years we have witnessed significant penetration of IT in surface transportation. Navigation systems with real-time traffic information and route planning capability, color coded traffic maps, and real-time information displays about public transport vehicles (e.g. nextbus and CTA's bus-tracker) are some examples of the improvements in urban transportation brought by IT. The rapid advances in mobile and ubiquitous computing and sensor networks are opening opportunities to revolutionize large complex systems, including transportation. Indeed, the purpose of the IntelliDrive[SM] initiative of the US Department of Transportation is "advancing connectivity among vehicles and roadway infrastructure in order to significantly improve the safety and mobility of the US transportation system" (RITA, 2010). A related development is the emergence of increasingly more sophisticated geospatial and temporal information management capabilities. These factors have the potential to dramatically alter traveler services, and the provision and analysis of related information.

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In the envisioned environment, travelers and billions of sensors, both embedded within the infrastructure and in vehicles and smartphones, will generate vast amounts of data whose interpretation could be exploited to spur the formulation of innovative transportation services and policies. Advances in social networking, crowd-sourcing, and data mining research are increasingly creating new sophisticated mechanisms which can foster seamless information integration among travelers, provide alternatives, and support sustainable economic and social policies.

In addition to technological advances, novel applications are driven by the following factors (Winter et al., 2011):

- Ever increasing mobility demand leading to congestion with dramatic effects on public safety, on the environment, and on the economy.
- Real infrastructure is expensive and laborious to build and maintain; furthermore, it is aging and has to be replaced by modern, new concepts and systems.

Most novel applications are included in the following classes (Winter et al., 2011):

1. Shared transportation resources: a better exploitation of the resources is achieved by sharing, with benefits for the users (reduced prices), the infrastructure (less congestion), and as a consequence also the environment (less pollution).
2. Collaborative traveling, for example by platooning, i.e. the virtual coupling of vehicles to form larger units like virtual trains. These structures can get priorities e.g. when crossing junctions. Within a platoon, autonomous driving is possible. Also, intelligent traffic lights enable a more adaptive giving right of way depending on the current traffic situation instead of fixed schedules.
3. Infrastructure is replaced by virtual infrastructure: in this way, the real infrastructure, which has several disadvantages like aging and expensive maintenance, can be replaced. Examples are virtual traffic lights where vehicles negotiate right-of-way, virtual signs; it is also relevant for highly temporal and ad-hoc warnings like construction sites or aquaplaning or slippery roads.
4. Driver assistance: drivers can be warned of risks in their local environment or when risking to leave their lane. Furthermore, their visibility range can be expanded by providing highly up-to date information from areas that are currently invisible.
5. Evacuation planning: highly temporal information is provided to support and calibrate simulations
6. Autonomous driving: as a long-term goal, highly dynamic maps of the environment have the potential to support autonomous driving.
7. Dynamic road pricing: the knowledge about the current usage of roads can be used to manage traffic, e.g. by reducing prices for collaboratively used cars or platoons.
8. Smart grid, electric cars: sharing resources opens the way to extend the flexibility of using and sharing electric cars, e.g. by dynamic planning of the electric grid resources, and of routes by considering charging facilities.
9. Road and traffic planning can be greatly enhanced by precise, high resolution travel information, which leads to adaptive traffic systems. For example, the road weather—up-to-the-minute visibility, precipitation, and pavement condition information—can be provided at high spatial resolution.

Indeed Intelligent Transportation efforts are currently being undertaken throughout the world. In addition to the IntelliDrive initiative of the US Department of Transportation (RITA, 2010) mentioned above, similar efforts exist in Europe, Japan, and China. But these efforts are largely decoupled from, and often incognizant of, the advances in spatio-temporal information management and ubiquitous sensing. Indeed, the potential of crowd-sourcing through the billions of mobile sensors in vehicles and smartphones that currently exist in the transportation system is largely untapped. But things are starting to change in the sense that the Civil Engineering community, which is driving the Intelligent Transportation efforts, becomes aware of the potential of spatio-temporal information tools to facilitate the large scale deployment of Intelligent Transportation applications.

Towards this end, i.e. facilitating Intelligent Transportation applications, we propose three objectives, corresponding to query-language design, query-processing, and answer filtering.

1.1. Language and tools for data management

In the Intelligent Transportation environment there will be a large amount of data being collected and stored. This data will typically be collected in a distributed network (e.g., traffic sensor network or probe vehicles) and stored locally or on a central server. The data will then be disseminated through peer-to-peer, client–server, or web-based mechanisms and may be accessed in real-time. In other words, there will be numerous distributed data sources co-existing in the network. This requires a novel database management system (DBMS) that effectively identifies the data sources and integrates the queried data from these sources. As part of the DBMS platform, we need to develop data models for storing such data, user friendly languages for querying the data, and tools for efficient processing of the queries. The data model should be spatio-temporal, storing moving object data as well as graph based data that captures the transportation network and its facilities. The system should provide language mechanisms for querying all such data including trips in a multi-modal (e.g. car, bus, and train) transportation network. It should allow queries about available resources, traffic conditions, dynamic route planning, etc.