A TRAFFIC INFORMATION SYSTEM BY MEANS OF REAL-TIME FLOATING-CAR DATA

Ralf-Peter Schäfer, Kai-Uwe Thiessenhusen, Peter Wagner

German Aerospace Center (DLR), Institute of Transport Research
Rutherfordstr. 2, 12489 Berlin, Germany
phone: +49 30 67055-204
fax: +49 30 67055-202
{ralf-p.schaefer; kai-uwe.thiessenhusen, peter.wagner}@dlr.de

ABSTRACT

The paper outlines the architecture and applications of a real-time traffic information system using Floating Car Data (FCD). The proposed system uses synergies from the GPS (Global Positioning System) based fleet disposition exploiting position data of several hundred vehicles of a taxi companies in Berlin, Nuremberg and Vienna. In order to manage the client disposition each taxi has to send the GPS position to the taxi head quarters at least once per minute, therefore acting as a FCD–probe vehicle. The procedure leads to a nearly complete data coverage of all major roads in the above mentioned urban areas, at almost no costs. In that context, a FCD traffic information system were designed and implemented. In contrast to conventional systems, the FCD approach allows a realistic travel time and optimal route calculation for individual and commercial road users.
Since May 2001, the developed real-time traffic information system is in operation for the Berlin region. Further applications are running for the Austrian capital Vienna and the City of Nuremberg.

KEYWORDS

Floating Car Data (FCD), IST application, Online Traffic Information System; GIS; Global Positioning System (GPS); Network Communication

INTRODUCTION

Heavy traffic including congestion can be observed on urban roads all over the world. Since space for new roads is very limited, it is necessary to improve the exploitation of the existing network. In order to solve this problem the number of telematics applications has been rapidly grown over the last couple of years. New wireless communication and location-sensing technology mainly pushed this development. Consequently, traffic management and mobility services providing online travel information for road users were established over the last years. Traffic information for road users are usually broadcasted via radio or TV channels, via the Internet or cellular phone networks, as well. Conventional traffic data for mobility information are collected by stationary traffic volume measurements like inductive loops, infrared sensors or video observations. The major problem with this approach is a realistic reconstruction of travel time and the routes of the vehicles in the road network, because the velocity of the

vehicles is only locally measured. In case of higher distances between two measurement stations the traffic flow is strongly influenced by inflow and outflow on intersections.
An alternative, more reliable approach analyzing the travel time and routes of vehicles on urban roads are Floating Car Data (FCD) using the Global Positioning System (GPS). Nowadays, an increasing number of commercial and private vehicles are equipped with GPS devices. In that context, a project with a Berlin Taxi company was established. Several hundred taxis equipped with a GPS receiver and a wireless communication device are working as FCD data supplier. Once per minute each taxi sends its current position to the taxi headquarters, where the data are processed for the online taxi- disposition system. The data recorded are processed for the traffic situation analysis providing mobility services for private and commercial road users. In May 2001 the real time operation of the developed floating car data system was started in Berlin.

The FCD traffic sensor has several advantages. There are no additional on-board hardware and software costs. Furthermore, for the communication between the vehicle and the headquarters nothing has to be paid. The Taxi companies use its own communication infrastructure and frequencies.
Since May 2001, several millions of position data from the associated Taxi fleet have been collected. These data are an excellent basis for analyzing the daily variation of travel time on almost any major road of Berlin.
In the paper the architecture of the web-based traffic information system is described. Furthermore, the travel times on different types of roads are compared. For a variety of reasons, the travel time depends on time and location: demand for traffic, weather condition, and seasonal effects, events or roadwork influence behavior of the vehicles. With this input we are able to generate travel time maps for the underlying road network.

TRAFFIC INFORMATION AND FLOATING CAR DATA (FCD)

Currently, the data used for providing traffic information services are rather limited. In most cases the data are measured by point sensors (e.g. inductive loops, video observation, infrared and laser vehicle detection etc.). Additionally, traffic information is collected by messages from private individuals, from commercial flight services or information from traffic police departments. The data collected by point sensors are local variables like the velocity, the traffic flow and partly the classification of vehicles.

More satisfactory results arise from telematics applications that use the GPS (Global Positioning System) technology. The quality of the GPS-data has been highly improved after the U.S. Government in 2000/2001 has stopped the scrambling of the GPS-signals (for details: http://igscb.jpl.nasa.gov].
Over the last years the commercial market of telematics applications (e.g. Integrated Transport Information Systems) [4] – some of them based on GPS technologies – has been grown rapidly. Meanwhile, many transport companies use location technologies and wireless communication for fleet tracing and optimisation of their fleet management. In Taxi transport companies the use of the GPS has greatly improved the disposition of client travel orders. The Taxi disposition system by GPS results in synergies for Floating-Car Data (FCD) collection. Along with the on-board location-

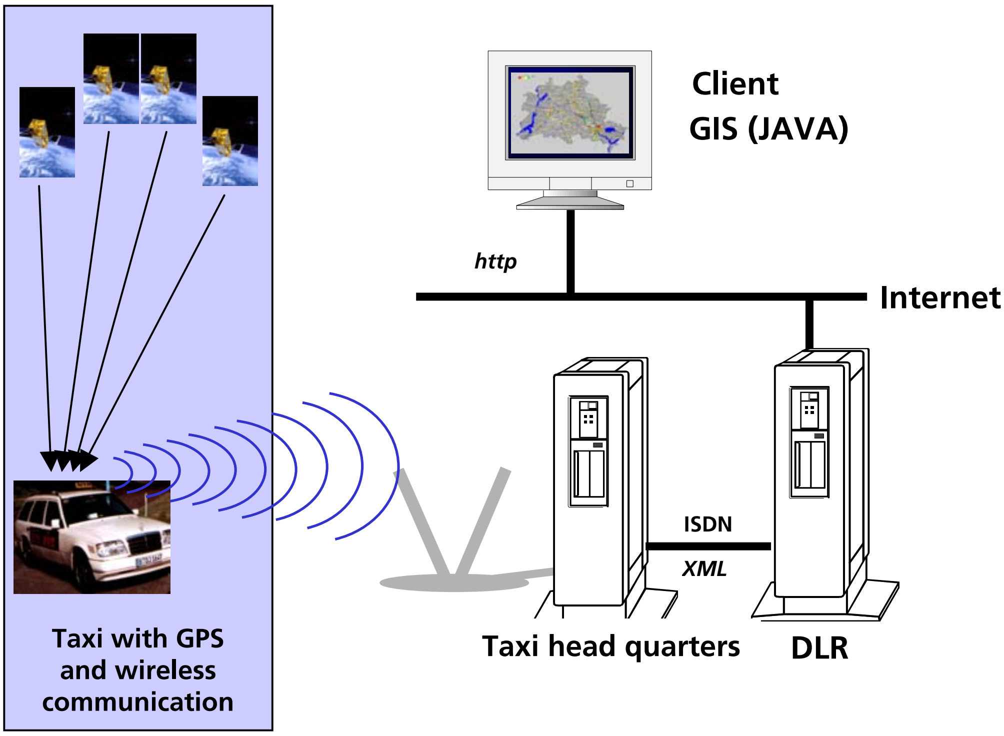

Figure 1. Architecture of the Traffic Information System

sensing technology and the cellular connection to the central data server, the Taxis can easily used as cheap data suppliers.
In our approach we use the Floating Car Data for traffic data management in real time, providing online information for road users. In general, Floating Car Data are classified in two types, active and passive FCD, respectively. The main scheme for active FCD is shown in the left part of Figure 1 while the scheme for passive FCD is shown in Figure 2.

In case of active Floating Car Data the vehicles are equipped with GPS or other location

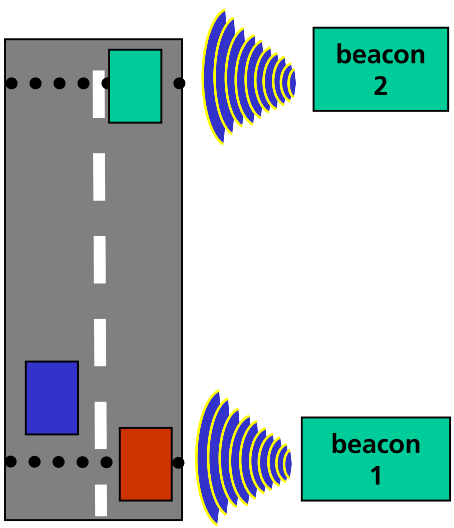

Figure 2. Scheme for the collection of passive Floating Car Data.

sensing devices. The data are transmitted via a wireless communication network to a server, where the data are processed. The main advantages of this system are investigations about continuous routing information and detailed specifications of travel times.

Passive Floating Car Data are characterised by getting information through road beacons (Figure 2). This system has very cheap on-board the hardware (e.g. transponder tag) whereas the infrastructure investments for the beacons along the roads are quite high.

In contrast to active FCD, the vehicle position is only detected at the location of the beacons. In case of higher distances between the beacons, there could be a lack of necessary information about the actual traffic situation (bypass problem).

The FCD TRAFFIC INFORMATION SYSTEM

In order to exploit Floating Car Data for online traffic information systems GPS data from the fleet dispositions are used. In contrast to other traffic sensors there are no additional expenses on-board of the vehicles as well as for software at the server site of the taxi head quarters. A first pilot application was established in 2001 in the German capital Berlin where GPS data from 300 taxis were integrated in an information system at the Institute of Transport Research of the German Aerospace Centre (DLR).

The data acquisition from the taxi data base server is done in real-time. After the successful transfer the data are processed analysing the positions, velocity, travel time and routes of the taxis. The travel time calculation for each link of the underlying road network is done with the help of a map-matching algorithm, where the GPS positions are linked to the network layer. The bias of the GPS signal is eliminated by a given reliability band around each road edge.

Since 2001 in Berlin every month approximately two million of GPS position data are collected from the associated fleet. That's an excellent basis for a travel time analysis covering the whole Berlin area and the daily variations, as well.

Each vehicle transmits frequently once or twice per minute the current positions to the central data server of the Taxi Company, where the data are being used by the fleet disposition system.

The Taxi Company uses its own broadcast infrastructure and frequencies. Therefore, no additional transfer expenses for the data communication have to be paid.

THE SYSTEM ARCHITECTURE

The traffic information system is implemented in a client-server based on Java technology. Figure 1 outlines the concept collecting and distributing the traffic data.
On the *server* site a database management system deals with the data storage of the positioning data as well as different kinds of static data describing the traffic network, waiting zones for Taxis or identification data of involved Taxis. Furthermore, weather data, events or roadwork areas are collected on the DLR server in order to identify the correlation between traffic and external conditions.
The server of the Taxi head quarters is connected with the server at the German Aerospace Center (DLR) via ISDN or the Internet, respectively. The data exchange between the two servers is handled by an uniform XML protocol (Figure 1).

The *client* site of the traffic information system consists of different layers representing a geographic map of the underlying area as well as various layers with traffic information. Such layers are real-time information about the current positions and velocities of the associated fleet, travel time and route visualisation of the vehicles or warnings for congested roads, as well.
The classification of velocities by colour maps allows an easy recognition of congested roads or areas with higher velocities, as well (Figures 3, 4 and 5).

ANALYSIS OF TRAFFIC CONDITIONS IN THE REGIONS OF BERLIN, NUREMBERG AND VIENNA

Since 2001, when the first application of the FCD traffic information system was installed further cities has been integrated into the environment. Until now, floating car data from fleets in different cities of Germany like Berlin, Nuremberg, Munich or Regensburg and the Austrian capital Vienna are available. The FCD from the Berlin and Vienna test site are running in real-time. In Berlin site with 300 taxis of the associated fleet the complete inner city is usually covered within a one-hour timeframe, whereas the outer districts have lower GPS data density according to the location of the client orders. In contrast to Berlin the positioning data from the associated vehicles in Vienna and Nuremberg is almost equally distributed because the number of taxi is higher (500 in Nuremberg, 400 in Vienna) and the size of the urban area in both areas is much smaller than Berlin.

The analysis of the GPS positioning data in terms of velocities and the daily variations has been shown that strong differences between the cities can be observed. Especially in the Vienna inner city regions with a centralised road structure and many narrow roads the mean speed is quite lower, especially during the rush hours (Figure. 4).

In all regions from the historical database of several millions of GPS data a routing service using the travel times has been implemented. Based on Dijkstra's algorithm, and in contrast to existing router systems where static road type dependent travel times are used, we used the "experiences" of the associated fleets. In order to calculate weekly and daily variation of the mean velocity for each link a map-matching algorithm was used.

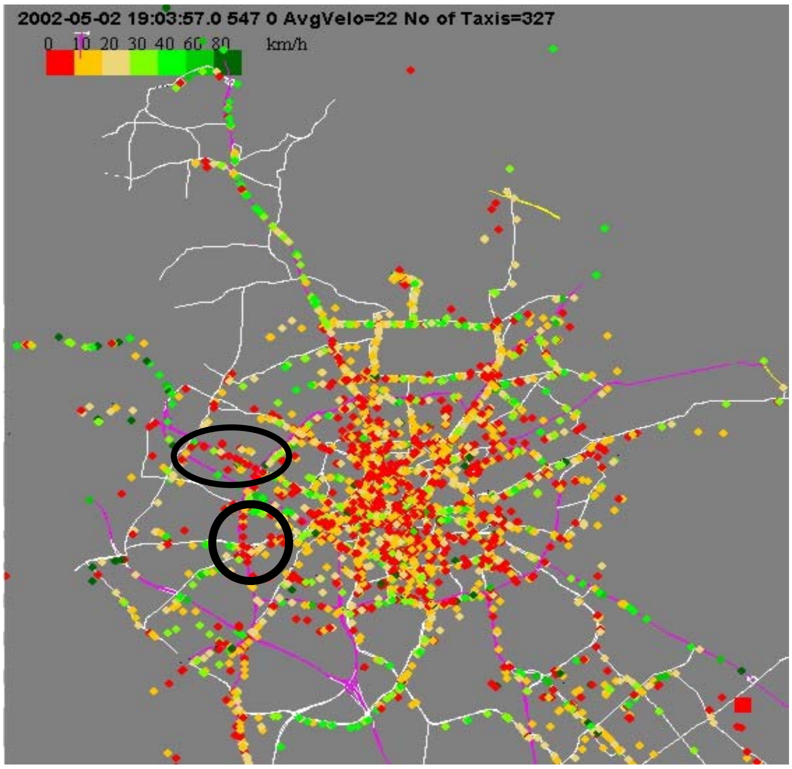

Figure 3. Visualisation of traffic conditions in Nuremberg, Germany, on May 5, 2002, 7:00 p.m. including detected congestion with velocities below 10 *km h*$^{-1}$ (marked areas) (Scale: 1:400,000), 327 taxis are registered.

Figure 4. Mean velocities in Berlin (l.); Vienna/Austria (r.a.) on a typical weekday morning rush hour (grid representation) and daily inner-city travel time variations (r.b.)

In case, that the velocity significantly deviates from normal conditions, there is a high probability for a congested road. In order to avoid misinterpretations, the observation time slots should be well conditioned. E.g. when vehicles come to a complete stop, this does not mean that there is a traffic jam, because taxis frequently wait for new clients. In order to neglect such unrealistic data each taxi has various status messages. Such statuses are for example "occupied", " waiting" or "running to the client".
After the correction of the data and the integration into the GIS a spatial survey of the actual road conditions is possible. For the area of Nuremberg, this is shown in Figure 3. This plot is based on the data of 324 operating taxis. In Figure 3 – which represents the view on the online screen – congested areas could be pointed out immediately. Other visualisation modes are available for grid representation as shown in Figure 4 or link based velocities.

The FCD system gives also very good representation of traffic situation in case of special events like demonstrations, sport events or worse weather conditions.
An example for a situation with blocked streets and a multiplicity of traffic jams in the inner city district of Berlin is shown in Figure 5. The plot represents the situation during the event "Love Parade" (with nearly 500,000 participants) in July 2002. The main East-West axis ("Street of the 17th June") was closed on a length of approximately 4 km for the whole traffic. For this reason a huge number of traffic jams in the surrounding areas (southern parts of the inner city district of Berlin) were detected. Furthermore, velocities and exact travel times through the congested roads has been evaluated during this time period. In addition, it was possible to detect rapid changes of the traffic situation *online*.

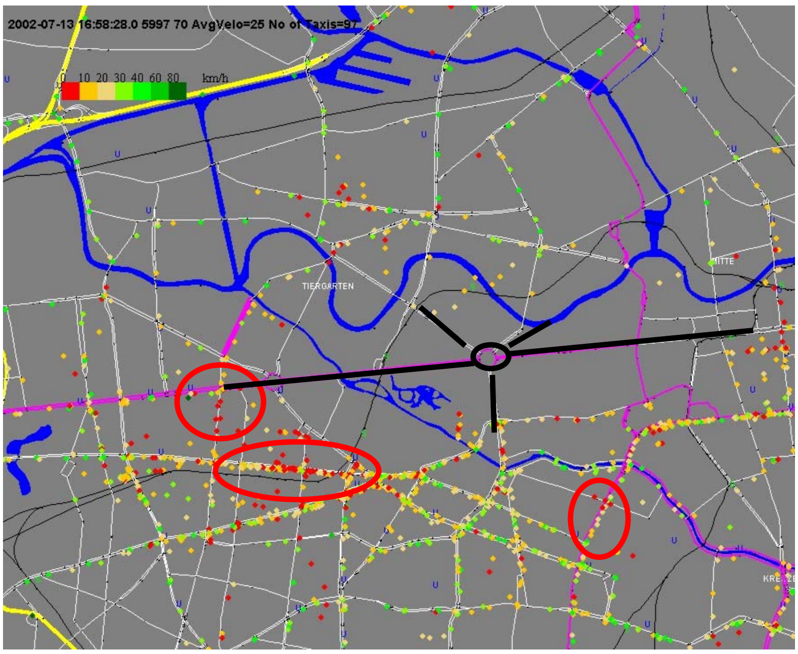

Figure 5. Visualisation of road conditions in the inner city district of Berlin during the event "Love Parade 2002", July, 12, 2002, 4-5 p.m. Closed roads ("Street of the 17th June") are marked with thick black lines, and the congested areas with red circles. In these areas the mean velocity is less 10 *km h*$^{-1}$ (Scale: approx. 1:50,000).

CONCLUSIONS

It could be shown that Taxi-Floating Car Data is a low-cost traffic sensor for inner city applications. There are a lot of synergies from the Taxi disposition using the GPS technology. It is easy to evaluate velocity profiles and exact mean travel times together with their distributions in urban areas. In different German cities and the Austrian capital the FCD traffic information system is already in use. The data analysis has been shown that the velocities can vary by several factors. Most significant decreases of velocities are connected with special events like demonstrations, bad weather conditions or roadwork.

Beside the preparation of online traffic information the Floating Car Data could be widely used. Such applications are the online fleet management in commercial transport companies or a dynamic routing of the fleet in case of congestion. The recording of the Floating Car Data (active and passive FCD) helps to build up historical travel time data bases as a base to forecast the traffic conditions.

ACKNOWLEDGEMENTS

The authors wish to thank the companies Taxiruf "CITYFUNK", Berlin, Germany, WIHUP Vienna, Taxiruf Nuremberg 19410 and Austrosoft, Vienna, Austria, for the kind collaboration.

REFERENCES

Buziek, G., D. Dransch, and W.-D. Rase, *Dynamische Visualisierung*, Springer, Berlin, Heidelberg, New York, 234 pp., 2000.

Cartwright, W, M. Peterson, and M. Gartner (Eds.), *Multimedia Cartography*, Springer, Berlin, Heidelberg, New York, 1999.

Eissfeldt, N., M. Luberichs and F.-N. Sentuc, *Investigating emissions of traffic by simulation*, Kerckhoffs, E.J.H., and M. Snorek [Eds.]: *Modelling and Simulation 2001*, Proceedings of the 15th European Simulation Multiconference Prague, SCS Publication, 961-965, 2001.

Etches, A., *A Temporal Geo-Spatial Database in support of an Integrated Urban Transportation System*, Zagel, B. (Ed.), *GIS in Transport und Verkehr*, 33-44, 2000.

Gordillo, S., F. Balaguer, C. Mostaccio, and F. des Neves, Developing GIS Applications with Objects: A Design Pattern Approach, GeoInformatica 3(1), 7-32, 1999.

Guptill, S.C., and J.L. Morrison, *Elements of spatial data quality*, Elsevier, Oxford, 1995.

Klein, L.A., Vehicle Detector Technologies for Traffic Management Applications, Part 1, 1997.