Enhanced Navigation System for Road Telematics

Gilliéron Pierre-Yves, EPFL – Topométrie / Géomatique
Konnen Jeff, INSER SA

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Enhanced Navigation System for Road Telematics

Gilliéron Pierre-Yves
ENAC - Laboratoire de Topométrie
EPFL
1015 Lausanne

Phone: 021-693 27 50
Fax: 021-693 57 40
e-Mail: pierre-yves.gillieron@epfl.ch

Konnen Jeff
INSER SA
Ch. De Maillefer 36
1052 Le Mont-sur-Lausanne

Phone: 021-643 77 11
Fax: 021-643 77 10
e-Mail: jk@inser.ch

Abstract

Navigation systems are becoming standard in-vehicle equipment. In the future these technologies will take place in new systems called Intelligent Integrated Road Safety Systems. Reaching this high level of integration and these requirements needs more precise digital map databases and advanced navigation technologies.

This paper presents the evolution of digital map databases, the new data capturing techniques and some tests of precise navigation.

Les systèmes de navigation sont des équipements standards de l'automobile. Dans le futur, ces technologies vont prendre place dans les systèmes intégrés pour la sécurité routière. Pour atteindre ce haut niveau d'exigences et d'intégration, les cartes routières numériques devront être plus précises et les systèmes de navigation plus performants.

Ce texte présente l'évolution des cartes routières numériques, les nouvelles méthodes de saisie des données ainsi que quelques tests de navigation précise.

Keywords

Digital Map databases – Navigation – GPS – Map Matching – ADAS – Road safety - 3rd Swiss Transport Research Conference – STRC 03 – Monte Verità

1. Introduction

1.1 Transport policy and road safety

The price paid in Europe and Switzerland for mobility is too high because of the excessive number of road accidents. In September 2001 the European Commission presented the White Paper on European Transport policy for 2010 (EU COM, 2001) and in 2002 the new Swiss federal guidelines for road safety have been launched with the VESIPO project (ASTRA, 2002). Both initiatives set an ambitious target for the reduction of road fatalities by 2010.

Until now, public authorities and the automotive industry have been involved in improving road safety through accident prevention and injury reduction. Most of the accident prevention measures have focused on the driver, while the ways to reduce the consequences of an accident have focused on the vehicle and on the road infrastructure. It's now time to include the benefits of the new developments of the information society technologies. An increasing number of vehicle control, safety and comfort functions are available on the market. These technologies will take place in new systems called **Intelligent Integrated Road Safety Systems** (EU COM, 2002). The use of new technologies cannot achieve the target to reduce road facilities alone, although it can make an important contribution.

An integrated road safety system will use information society technologies and intelligent transport systems. This global approach for safety will involve the interaction between the driver, the vehicle and the road environment. In this area, enhanced navigation systems and accurate digital map databases will offer a great potential for improvements, especially when combined with Advanced Driver Assistance Systems (ADAS).

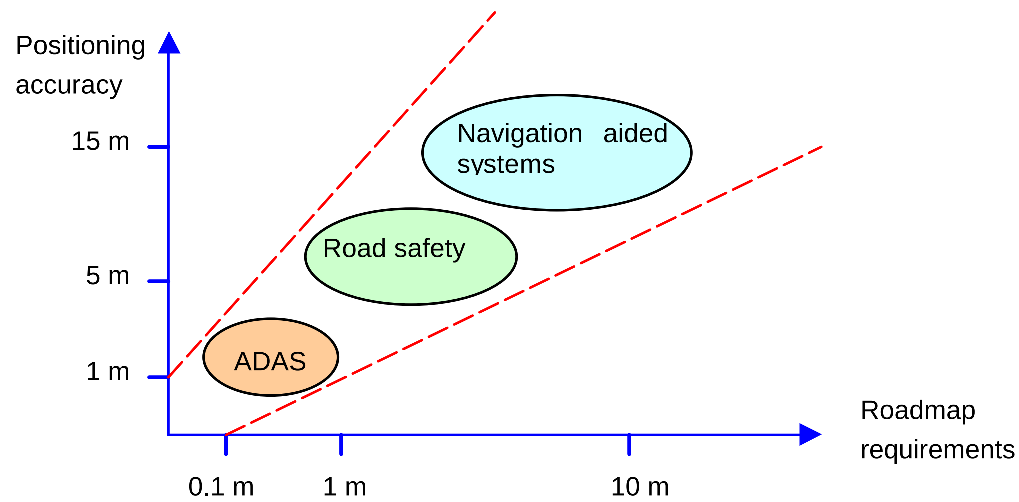
For the deployment of Intelligent Integrated Safety Systems, the public and private sectors should collaborate in order to define strategic, legal and economic goals. The introduction of these safety systems could only be based on a co-ordinated effort of the road authorities and the automotive industry.

1.2 Requirements for road data

Navigation systems are becoming standard in-vehicle equipment. Based on the positioning capability of the vehicle, location-based information for the driver could be implemented. These systems may participate to road safety by informing the driver in advance of safety issues related to the road section. Implementing map based safety systems requires appropriate digital maps which contain safety related data and accurate geometry and topology of road sections.

The future development of ADAS applications in the road safety field will benefit from enhanced digital map databases (Pandazis, 2002). The map requirements identified for ADAS in the NextMap project are based on the geometric accuracy and the new attributes and features to be collected. Figure 1 shows the evolution of in-vehicle ITS applications towards the accuracy of navigation systems.

Figure 1 Evolution of in-vehicle ITS applications



The Geodetic Eng. Laboratory (TOPO) is currently developing integrated systems for the positioning of people and vehicles. The context of road safety is a challenging domain for the deployment of navigation technologies for precise vehicle positioning and for automated road data capture. The first part of this paper is focused on the architecture of navigation systems based on sensor integration for specific ADAS functions like lane detection. The second part is dedicated to the evolution of digital map databases with the purpose of including new attributes and a highly accurate geometry. The third part illustrates the new technologies of mobile mapping to facilitate the collection of road data.

2. Architecture of Navigation Systems

Navigation Systems have nowadays become standard in-vehicle equipment, especially in high standard cars. They are often falsely designated as “GPS Systems”, but they are much more than a simple GPS receiver. A state-of-the-art navigation system can be divided into two components:

- The positioning sensors
- The map database

The positioning block combines several sensors to compute the most accurate and reliable instantaneous position of the vehicle. The most famous part is certainly the GPS receiver, computing positions out of range measurements to a minimum of 4 satellites flying at a height of about 20200 km above sea level. As the reception of these signals is however difficult, or even impossible, in urban areas or tunnels, the signal of a digital gyroscope, measuring angular rates, and of an odometer, measuring travelled distance, are added. By integrating the angular rates and travelled distance information over time, a local position can be calculated. This technique is called “dead reckoning” (DR). To obtain reliable positioning information all over the time, GPS and DR measurements are integrated using a digital filter. Thus, the accuracy of GPS and the availability of the dead reckoning measurements are combined to guarantee a certain position accuracy, which is today lying between 10m and 100m.

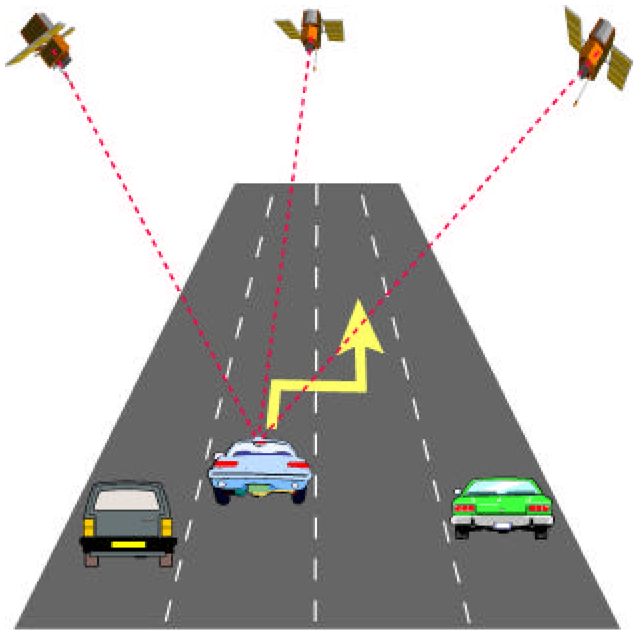
The second component of a navigation system is the digital map, a geographical database, which describes the road network. It contains geometrical as well as attributive data. In order to harmonize the content and the formatting of these data, the major manufacturers of navigation systems and map databases have created an international ISO standard, the GDF – Geographic Data File. This standard defines how roads have to be described in order to be correctly interpreted by navigation systems.

In order to combine the computed positioning information and the digital map data, so called “map matching” algorithms have to be implemented. They project the calculated vehicle position to the most probable position on the modelled road network. These algorithms allow route guidance. Knowing the destination of the vehicle and its actual position, the system can calculate the best way to destination and issue route guidance tips during the trip. The latest models integrate traffic perturbation messages spread over RDS-TMC to optimise the route calculation depending on the real-time traffic conditions.

3. Evolution of Navigation Systems and Road databases

With the increased needs for safety, much hope lies in the development of new technologies, in particular in Advances Driver Assistance Systems (ADAS). These are systems like Automated Cruise Control, Lanekeeping or headlights that are directed into an upcoming curve. Navigation systems are only a part of the sensors that will be used for the realisation of such systems, but they will certainly play a major role. Building these systems requires the two components of navigation systems to be improved. ADAS applications need position accuracy between 1m and 4m under all conditions and the precision of the map database should be comparable.

Figure 2 Future Navigation Systems could give lane change advices in order to increase traffic flow and safety



The European ITS Research Organisation, ERTICO, has realised a project on the evaluation of future map requirements for ADAS applications. This project, called Nextmap (Pandazis, 2002), issued in a catalogue of improvements to be made and a proposal of an extension to the ISO-GDF 4.0 standard for in-vehicle ITS applications.

In 2002, a diploma thesis was realised at the Swiss Federal Institute of Technology, Lausanne to evaluate the precise car navigation in the context of the enhanced map database (Konnen, 2002). Two particular aspects were analysed: the adaptation of GDF/Nextmap data for accurate positioning issues and the accuracy of a high level DGPS[1]/DR sensor integration system.

During this project, a few tests were realised in order to demonstrate the capability of a high precision navigation system to detect which lane the car is driving on and when a car is changing lanes.

Figure 3 A view of the high precision measurement vehicle equipped with several GPS receivers and a dead reckoning system

[1] DGPS=Differential GPS, using a terrestrial correction signal to improve positioning accuracy (~1m)

4. New Data Capturing Techniques

4.1 Steps of surveying

A road database consists of an inventory of features, topology and attributes. Most of this information can be collected using different surveying techniques. The following steps are usually used to gather geo-information:

- Positioning of features in a spatial reference system. This geo-referencing operation is based on land survey techniques (GPS, theodolite) and aerial techniques (photogrammetry, remote sensing);

- Building the topology of objects (road network, nodes, crossings);

- Capturing attributes and information such as the direction of traffic, a signpost, a street name…

Collecting and managing all the geo-information and its related attributes in a map database requires a good co-ordination in the field surveying process. The whole process is monitored in order to reach the desired quality of the database. The merging of different information (aerial imagery, GPS, maps) can affect the database if the quality of the original data is poor. New techniques for capturing geo-information are developed with the target to warrant accuracy and reliability in dynamic applications.

4.2 Concept for Mobile Mapping

Mobile Mapping Systems (MMS) represent an advanced technique for the dynamic surveying of road networks and all their surrounding objects. MMS provide a fast and accurate method to carry out digital maps including both road geometry and road features. MMS integrate most of the current surveying techniques, i.e. GPS, inertial sensors, digital imagery, laser ranging.

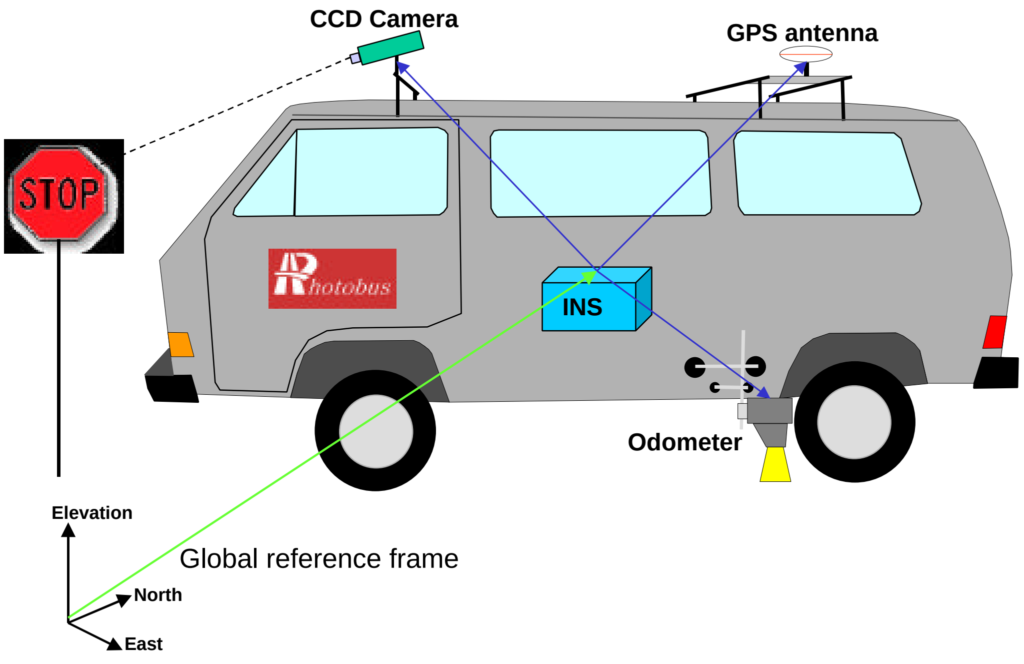
A mobile mapping system involves a vehicle that is equipped with:

- **A positioning system,** i.e. a high precision GPS (Carrier phase differential GPS), associated with a strapdown inertial navigation system (INS) that ensures the accuracy of measurements even without receiving satellite signals. An odometer (wheel sensor) could be added to measure the covered distance.

- **An imaging acquisition module,** composed of one or more CDD cameras to record the road surroundings. The imaging module is synchronised with GPS time in order to get position and attitude for each image.

- **A data processing module** that combines positioning data and images in order to define precise and reliable position of the desired objects.

Figure 4 Architecture of a Mobile Mapping System



4.3 Development of a MMS for road geometry acquisition

Photobus is a mobile mapping system for road data base management. Several devices are mounted on a mobile terrestrial vehicle that performs an automated survey of specific road features such as centerline, marks and roadsigns at speeds up to 100 km/h.

These devices include Global Positioning System (GPS) receivers, an Inertial Navigation System (INS) and Charge-Coupled Device (CCD) camera. The system is user-friendly and has a fast setup time, which facilitates its portability between different vehicles. Its development is conducted at the Geodetic Engineering. Laboratory (TOPO), Swiss Federal Institute of Technology Lausanne (EPFL).

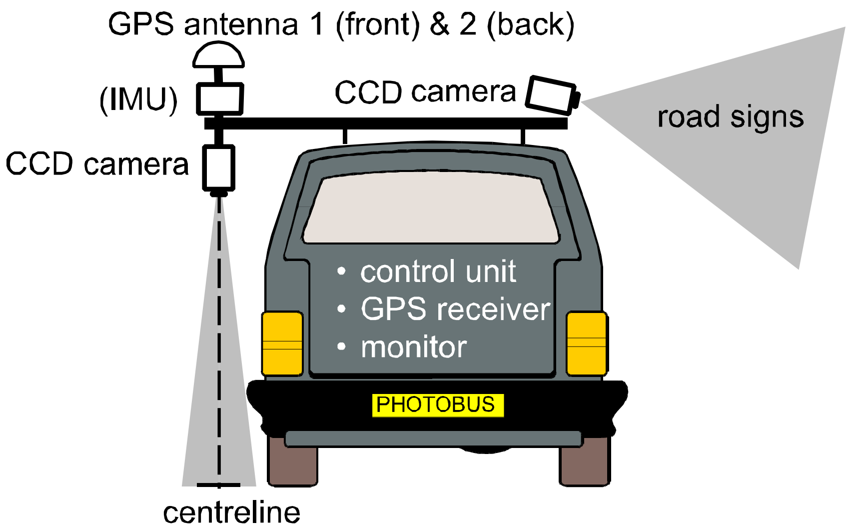
Road geometry

Photobus extracts the **road geometry** using a monoscopic view from a vertically oriented camera. This task-dedicated setup brings considerable advantages over forward-looking cameras and their stereoscopic feature extraction, since it:

- allows employing digital cameras of lower resolution, optical quality and stability;
- reduces calibration complexity and completing time;
- improves target visibility in dense traffic;
- permits highly automated and reliable feature extraction, possibly in real-time;
- reduces the cost while keeping the optical precision at a cm-level.

The combination of navigation data and images results in a set of 3D points. The sequence of these points describes a spatial curve that models the centre of the road. 3D cubic splines are used as a mathematical model of the road that is compatible with most of CAD (Computer Assisted Designed) systems.

Figure 5 Design of the *Photobus* System

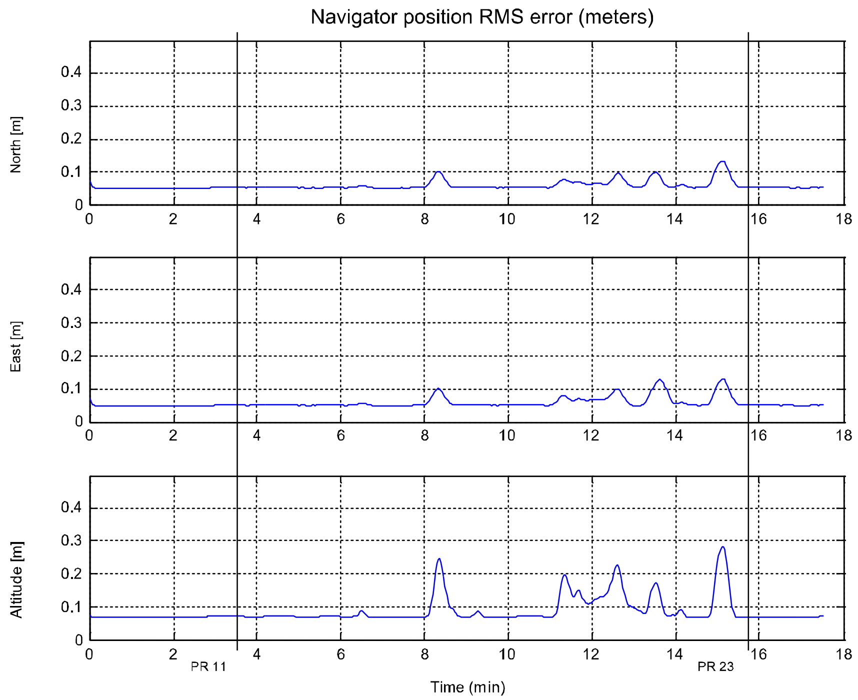


A correct topological representation of the road and a geometric accuracy are essential for the deployment of new in-vehicle ITS applications, especially ADAS. In the project *Photobus* we have evaluated the performance of the system in extreme conditions to monitor the quality of data during the process of acquisition. The following results demonstrate the geometric quality of data.

System Tests

The *Photobus* system has been used in different areas for the monitoring of centerline. The following figure gives an overview of the positioning efficiency of the system in the mountainous region of Neuchâtel. In this example, GPS signals were not always available due to natural obstacles (mountains, trees). The position and orientation of the vehicle were given by the INS system during these GPS gaps. The level of positioning accuracy was always better than 20 cm.

Figure 6 Geometric accuracy of the road centerline



Test Neuchâtel : Horizontal and vertical accuracy

The extraction of **road geometry** using *Photobus* methodology was proven to work reliably. Current research strives to achieve a complete automation and a real-time implementation of the feature extraction.

The employment of a mobile mapping system for road management seems to be essential for a fast acquisition of the road geometry. The undertaken development responds to the demand of data for ITS applications. The presented system is designed to map the road centerline with a sub-decimeter positioning accuracy, a feature that satisfies the demands of most agencies involved with road management.

5. System Tests: Geometric accuracy

The positioning tests realised in 2002, combining differential GPS and DR technologies showed that a position accuracy of about 1.5m can be achieved with a high cost system under good conditions. At Figure 7, one can see that the computed trajectory of the vehicle lies always within the boundaries of the modelled lanes.

Figure 7 The computed trajectory of the vehicle is always within the modelled lane

A much promising technology for future applications lies in the evolution of satellite based augmentation systems (SBAS). In Europe, this project is called EGNOS[2] and will be operable in 2004. This system augments the performance of GPS by broadcasting differential correction and integrity information to the user. This service is free of charge and doesn't require an additional communication link.

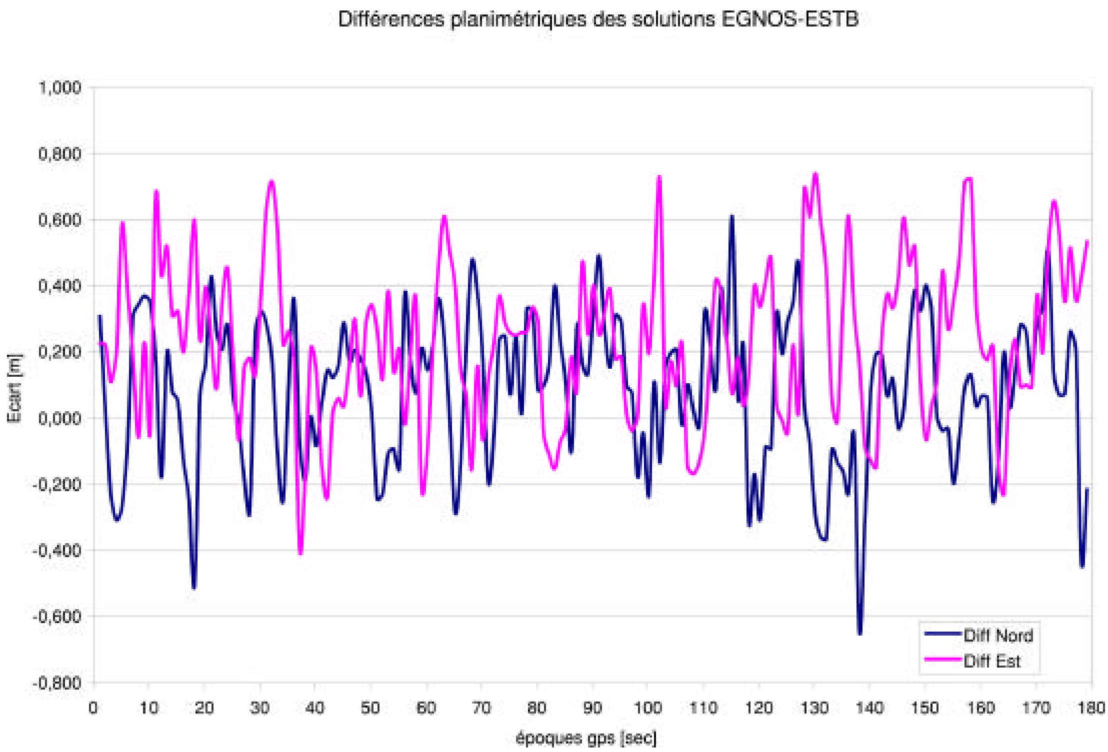
The Geodetic Eng. Laboratory takes part to several tests in collaboration with Skyguide (air traffic control in Switzerland). During these trials we used the EGNOS System Test Bed

[2] EGNOS : European Geostationary Navigation Overlay System (

(ESTB) which is a prototype system for the future EGNOS System (Gilliéron & Ladetto,2002).

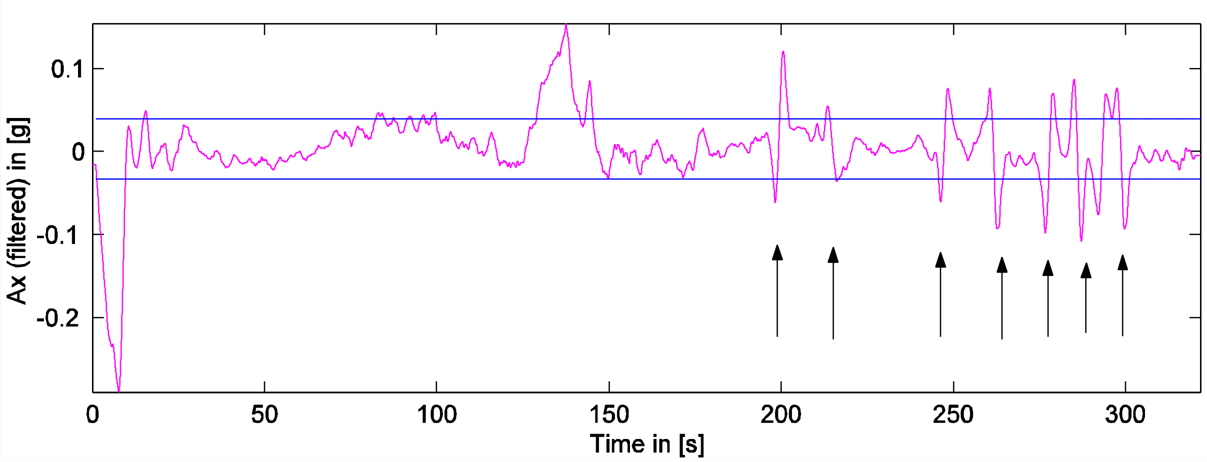
One of these trials was carried out at the EPFL. An EGNOS receiver was installed in a car for collecting data around a test-track. The accuracy of EGNOS is between 2 and 3 meters when the vehicle runs in a non-obstructed area. Under these conditions EGNOS guaranteed that the vehicle could be localised within each separate lane.

Figure 8 Precise positioning using EGNOS-ESTB



Additionally, some algorithms for lane change detection were tested in order to allow a correct lane positioning of a vehicle even when the positioning accuracy is not high enough. These algorithms use the signals of a lateral accelerometer and analyse the variation of these signals to detect a lane change. The results can be seen at Figure 9, where one can observe that every lane change is described by a sort of a sinusoid which can be detected using two constant thresholds.

Figure 9 The results of a lane change detection



6. Conclusion

The role of future navigation systems will increase the interaction between the driver, the vehicle and the environment. The potential contribution of Intelligent Integrated Road Safety Systems for enhancing road safety has already been demonstrated by the industry in several research projects. The new navigation technology is available but the costs are still high. The penetration of new technologies to all vehicles will also take a long time but is very promising.

Security applications require high level certification and standardisation for the development of navigation systems and for building digital road maps. The strategy of road safety shows that public authorities and industries together have an important role to play in the deployment of new technologies. A future public-private partnership could be a solution to produce, maintain and certify digital road map data. Map and car industries have to join efforts for investigating the technical and economical feasibility of enhanced map database and precise navigation systems.

Trials on precise navigation have demonstrated that high cost technology is available for the implementation of integrated positioning algorithms. These tests have illustrated that some ADAS applications can be achieved, e.g. lane detection. Satellite based augmentation systems are very promising for the precise positioning of land-mobile. EGNOS receivers will probably be a master component of the next generation of navigation systems developed in Europe. Forthcoming ADAS applications will integrate the EGNOS technology and other navigation sensors to improve the performance and the reliability of in-vehicle ITS applications.

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