EUROPEAN STANDARDS AT ITS TELEMATICS SYSTEMS RESEARCH ON THE BASIS OF COOPERS PROJECT

Tomasz Pałczyński, Zbigniew Pawelski

Technical University of Lodz
Department of Vehicles and Fundamentals of Machine Design
tel.: +48 42 6312392, +48 42 6312393, fax: +48 42 6312398
e-mail: tomasz.palczynski@p.lodz.pl, zbigniew.pawelski@p.lodz.pl

Abstract

At this paper there are presented methodology and selected information's about researches of OBU On Board Unit according to COOPERS project. There are information's about COOPERS and GALILEO projects integration. Presented research results documents write measurement equipment verification.

At this paper there was included description of Robust Positioning Unit, their communication with rest of ITS system, definition of COOPERS project services. There was described measurement vehicle and their basic elements with short work instruction.

According to Galileo description, there were presented GSSF (Galileo System Simulation Facility) program designed for simulation of their work. Secondly there was included methodology of systems Galileo and COOPERS integration.

Thanks to that, TU of Lodz learned, how to cooperate with multi partners team, how to exist at European project.

Experience acquired at this project shows, that ITS and their research have a big potential, needs a very precise procedures and equipment, there is possible to work at large teams with synergy of individual specialist.

Keywords: *ITS – Intelligent Transport System, OBU – On Board Unit*

1. Introduction

The market penetration of navigation systems for automotive applications has shown a tremendous growth over recent years. Nevertheless the utilization of the available positioning modules in many cars could not stimulate the development of new services to enhance safety on road networks. The focus of COOPERS project is on cooperative telematics systems that enable an Infrastructure to Vehicle (I2V) interaction, in order to improve road safety. The communication of safety relevant information on traffic, weather and road condition ahead, to driver via an adequate human machine interface (HMI) will be the main innovation, to contribute to the defined target to establish and demonstrate new services for eSafety on road networks.

In this regard, the functionality of position determination forms an essential part of the required information, to support the process of decision making of each driver, to gain a higher of safety. Therefore a robust positioning unit (RPU) has been developed by pwp-systems, to cope with advanced requirements of the COOPERS services for eSafety applications. A special developed environment called "virtual Galileo" has been set up to include Galileo signals into traffic applications and allows the user to get hands on the benefits generated for the individual operational constraints in the respective applications.

The above ideas were realized at following work plan:

- Task 1: Set up measurement acquisition system for the selected sensors spectrum, which is suitable for the road condition application.
- Task 2: Preparation for execution of representative simulation on the basis of existing software tools like Galileo System Simulation Facility (GSSF), which has been developed under the contract of ESA and forms a powerful tool.

- Task 3: Execute representative by using the capability of GSFF after the functionality has been extended according to COOPERS requirements. The specification of the simulation scenario as carried out within WP 4100 will be applied.
- Task 4: Develop optimal sensor fusion algorithms and implemented them into the multi sensor navigation unit, which forms a core part for the development of RPU.
- Task 5: Provide an implementation of enhanced navigation unit appropriate for this application, which delivers accurate data with high reliability and integrity, on the basis of the established scientific development platform. This target hardware platform should be the COOPERS OBU, which consist of different components.

2. The role of RPU for COOPERS services

The focus of COOPERS is on cooperative telematics system the enable an infrastructure to vehicle interaction, in order to enhance safety on road networks. The communication of safety relevant information on traffic, weather and road condition ahead, to the driver via an adequate HMI will be the main innovation, to contribute to the defined target. In this regard, the functionality of position determinations forms an essential part of the required information, to support the process of decision making in each driver, to gain a higher level of safety. Twelve services have been identified which could be based on or supported by COOPERS solutions. Some of the services will have a direct impact on driving safety by providing early warning of hazardous traffic conditions to make drivers better prepared and respond in a safe manner. Other services such as route navigation would provide drivers with navigation and route guidance information which can increase safety by allowing drivers to concentrate their resources on driving tasks (compared to paper map based guidance). Especially when driving on unfamiliar routes. Some of the services defined would have impacts on safety indirectly by reducing traffic demands and congestion, or providing continued service for international travellers [1]. These selected services for the COOPERS object are:

- Accident/Incident warning (S1),
- Road/Weather condition warning (S2),
- Road information (S3),
- Lane utilization information (S4),
- In-Vehicle variable speed limit information (S5),
- Traffic congestion warning (S6),
- Intelligent speed adoption (ISA) with infrastructure link (S7),
- Road charging to influence demand (S8),
- International service handover (S9),
- Estimated journey time (S10),
- Recommended next link (S11),
- Map information check to inform current update for digital maps (S12).

Most of services indentified are expected to have a direct impact on safety by providing information/warning of abnormal events.

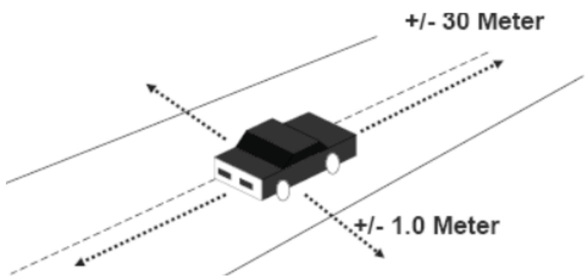

Fig. 1. Requirements for a lane specific positioning capability [2]

Through the analysis of the COOPERS services, which relate mainly to the domain of motorways, the following requirements could be derived as performance target for the robust positioning unit (RPU):

- In the longitudinal dimension along the driving path of vehicle, the required accuracy is not very high and value of +/- 30 meter seems sufficient for all coopers services.
- With respect to the lateral dimensions perpendicular to the driving path of the vehicle the requirements are much higher and have been specified with tolerable error +/- one meter.
- The knowledge about the own vehicle position needs to be present at any time during the tip, which leads to an availability requirement of 100%, which needs to be provided by the system.
- Furthermore the integrity of determined position is also an important aspect to provide correct information to the driver and was specified with 99.9%.

With the scientific development platform the PRU could be developed and implemented in the concept car. In order to support the overall COOPERS approach, the advanced positioning character had to be ported into the developed COOPERS – OBU. The general concept of the OBU hardware consists of elements from EFM, which extends a reliable automotive proof hardware platform for the interaction with the vehicle devices and interfaces and the automotive PC to provide high flexibility for the implementation of the COOPERS services on the basis of PC.

In Fig. 2 above a three dimensional model of OBU with its main modules is depicted. This version shows an intermediate stage of development concept OBU, which is based on the technical platform of the OBU for the German toll collect system. This approach advantages of the reliable hardware component from series production with the possibility to customize this device with respect to additional requirements from COOPERS.

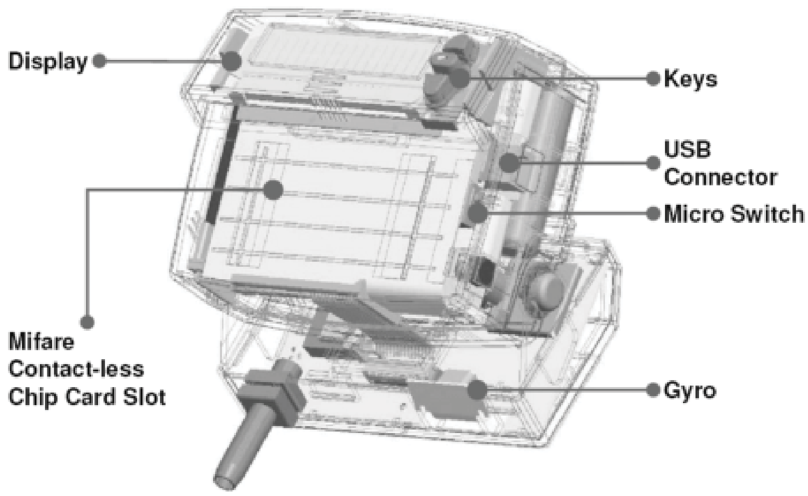

Fig. 2. 3D Model of the OBU

OBU provides access to most of the input data from the vehicle and the communication links, it provides the functionality of communication gateway (CGW) for the implementation of the services.

Information serviced by OBU:

- Massages from the OBD-II CAN, (currently the necessary input data for the RPU is not accessible through the OBU - interface),
- Traffic Control Massages (TPEG-RTM) from the COOPERS Service Centre sent over GSM/ GPRS,
- Traffic Control Messages from Road side Unit (RSU) my means CALM-IR (This I2V link provides valuable information for the task of position determination.),
- GPS data (NMEA - GGS and RMC Strings), (The GPS content could be used in principle by the RPU, but it was not possible to provide proper synchronization with synchronization with PPS signal).

The open architecture of this system enables certain upgrade properties, in order to adapt to requirements of navigation that may change in the future. This includes the feature of scalability, which allows the user to purchase a basic navigation unit for his intended application, in conjunction with the possibility for a later upgrade. Such an upgrade would not conclude a replacement of the whole navigation unit, but more a substitution or augmentation of a minimum of hardware and software components. Often, rather then listing general upgrade properties, one might mention future requirements that can be foreseen already, as for instance:

- The inclusion of GALILEO,
- The inclusion of enhanced observed time difference (E-OTD) trough cellular networks,
- The inclusion of any measurements or data base information from short range communication devices (I2V or V2V) besides CALM – IR, which already included in the COOPERS – RPU,
- The inclusion of a barometer,
- The inclusion of an accelerometer.

This upgrade properly might also be appropriate in case the operation constrains are different if the services have changed.

3. Reference equipment for the process evaluation

For the evaluation of the results from executed tests trials, it is necessary to know the true trajectory or at least a very accurate and reliable estimation of it. Therefore, the Technical University of Lodz (LOD) has combined a high precision inertial measurement unit (IMU), which was aided though an external wheel pulse transducer (WPT) with high resolution and dual frequency GPS receiver. The measurements are recorded in parallel but strictly independent to the other system of the COOPERS OBU and the scientific development platform inside the PWP concept car. In Fig. 3 below, the main modules are depicted, with its installation location inside the concept car.

Fig. 3. PWP concept car with COOPERS OBU and independent reference system

The modules of reference systems can be found at three locations, the special dual frequency antenna with advanced reception characteristic in the roof, the Corrsys Datron WPT at the outside of the back wheel and the additional reference sensors including recording laptop in the trunk of the vehicle. While the reference system does require the most installation space, the modules of the COOPERS OBU are rather small in size and have all been installed in the cabin of the vehicle. The assessment of technical performance of RPU will be executed by the LOD as a neutral instance for this task. In order to quality the remaining error behaviour of the RPU by measurements, hard facts will be generated for the process of the technical assessment. The applied hardware components of Corrsys, IMU, and dual frequency GPS are very costly (more than 50 000 EUR) and do not qualify for an economic solution with respect to the task of robust positioning with COOPERS.

For the correct and precise determination of the performance of RPU during kinematic test trials with the concept car reference systems is necessary that operates at the same time reference as the RPU. For this task SPAN system (Synchronized Position Attitude Navigation) has been applied by the TU of Lodz. While the SPAN operates in the basis of GPS time, most low cost GPS receiver does provide UTC time. The timing accuracy is in both systems sufficient, but by definition there exists a time drift between GPS time and UTC, which is currently determined with 15 lead seconds, that have to be compensated to achieve proper synchronization. The core of the SPAN system is an inertial measurement unit (IMU), which consist of fibre optic gyros (FOG) and three precise accelerometers. This sensor assembly can be percept the rotation and translation motion of the vehicle in all three axes, to cover the complete six degrees of freedom with respect to physical motion.

The measurements of all reference sensors are logged via the software tool from the SPAN unit, which is running on a separate laptop from LOD. The interface of the SPAN systems is kept quite simple and allows controlling the proper operation of the reference equipment during the test ride. In comparison to the PRU, the SPAN system has a quite long procedure for initialization, until all the single sensors are calibrated. The HMI of the SPAM has similarity with the view of cockpit instrumentation, which comes from the fact that costly equipped is rather used for aviation, than for land transport. This shows the high reliability that comes with inertial sensor systems and proofs again the high effort is appropriate, in order to generate a reliable reference trajectory for robust positioning applications like the COOPERS-services.

A typical example for the quality of the reference trajectory is visualized in Fig. 4 where 10 demonstration runs (5 for each direction) are overlapped in different colours. When the concept car was passing this section on motorway, the middle lane was used (see 2 red lines for direction of south-east and 2 green lines for the direction north-west). While the left was used after the exit (3 green lines) at this junction, always the right lane was used to enter the motorway (3 lines with orange to purple) again after the u-turn.

Fig. 4. Example for the quality of the generated reference at the demonstration in Berlin

4. Galileo and GPS simulation

The European satellite navigation system Galileo is currently in the phase of the ‘in orbit validation’ (IOV), where in total four satellites for the future Galileo system shall be brought to orbit. During the IOV phase it will be possible for limited time windows a day, to gain first experiences with Galileo signals and executed individual benchmarking including position determination in first Galileo receiver prototypes.

Having greatest flexibility with a simulation based approach it has been decided within the research and developed work of COOPERS to deploy the Galileo System Simulation Facility (GSSF) as sound basis for the demonstration of the Galileo capability.

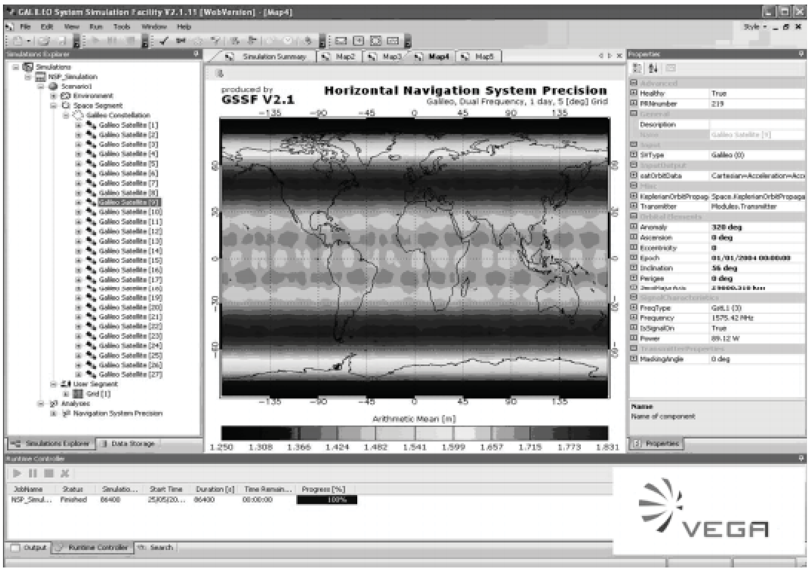

Fig. 5. Screen shot of the Galileo System Simulation Facility (GSSF)

5. Methodology for the integration of Galileo

Galileo, the first satellite positioning and navigation system specifically designed for civil purposes, will offer state-of-the-art services with outstanding performance in accuracy, continuity and availably. It will be more advanced, more efficient and more reliable than the current US GPS monopoly [3]. Even though the principle expectations towards Galileo are positive, the addressed user can hardly grasp the resulting benefits for this application. Therefore a unique approach has been designed by pwp-systems GmbH together with VEGA IT GmbH &Co. KG to test the benefits of Galileo within traffic and transport application, before the space segment of Galileo has been installed.

In this section the general principle of the newly designed methodology to integrate simulated Galileo signals into real life test trials will be described. In contrast to GPS, Galileo will broadcast integrity information for some critical applications, assuring the quality of positioning accuracy. The need for several service categories, in terms of accuracy, service guarantees, integrity and other parameters has been identified. Most requirements will be met solely with the satellite signal, in many cases in combination with auxiliary sensors that can, for instance, be in the user's vehicle.

The hereby introduced methodology takes up exactly this recommendation of Galileo Joint Undertaking, which motivation in several user workshops from 2003 to 2005, to start any innovative application idea on the basis of the available GPS and integrate the advance Galileo system at a later stage. This approach especially applies foe eSafety on road networks. The block diagram of this approach is depicted on Fig. 6. This approach has been developed by PWP together with VEGA. The focus is to enable an assessment process today of Galileo benefits that can be achieved in future for individual application in their domestic environment. Since real Galileo signals will not be available from the space segment within the coming years the main idea is an integration of simulate Galileo information into the obtained measurement from real life test trials. Thus the depicted block diagram from Fig. 6 shows two main paths, one for the processing of real measurements data, and the other for the generation and verification of simulated signals.

The methodology starts with the execution of a real test trial. The necessary test vehicle from pwp-systems is equipped with the prototype of RPU and with additional sensors from the TU of LODZ that can provide the reference trajectory. The reference trajectory is very important and represents the information of the true path of complete vehicle movement in a higher quality. The complete set of all documents from the whole spectrum of available sensors are recorded as raw data.

In the second block of the simulation path these simulated GPS signals are compared with the measured GPS signals. The good equivalence of the GPS data from the simulation with the reality

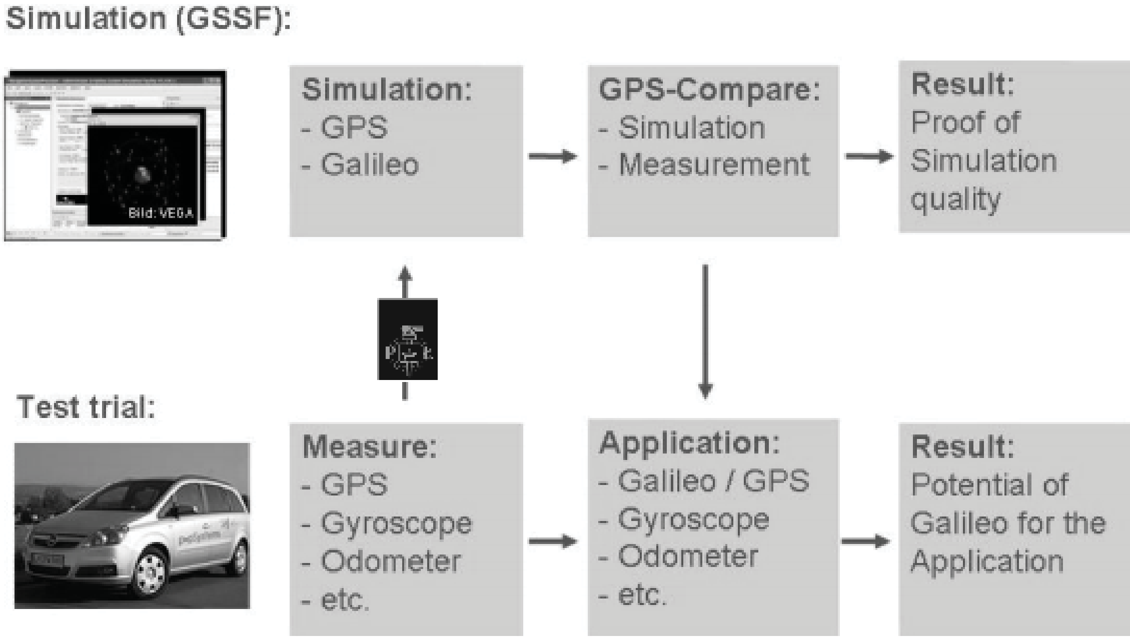

Fig. 6. Block diagram of the designed methodology to integrate Galileo signals

provides the proof for high quality simulation. The achieved position solution during the test trial has to match the processing of the recorded data exactly. This principle is called forcing tape and works the following way. The achieved position solution during the test trial is re-computed in the laboratory with the same sensor selection. Now the results from the lab have to provide the same numbers' as recorded from the executed test trail. This gives a second approval for the correct data handing and enhanced the reliability of the achieved results with the integrated Galileo signals.

6. COOPERS demonstration campaign

The emphasis is on the new validation of the developed RPU through the scientific development platform and the deployment of the new methodology for the integration of Galileo signals. The corresponding demonstration phase was executed from 2 of June 2009 until 13 of July on the basis of complete COOPERS OBU and including the reference system from LOD. During this time window the developed approach for robust positioning and Galileo has been applied in Berlin, Innsbruck, Trento and region Darmstadt, showing the flexibility of this system.

7. Summary

The market penetration of navigation for automotive applications has show a tremendous growth over recent years. Nevertheless the utilization of the available positioning modules in many cars could not stimulate the development of new services to enhance safety on road networks. Within the COOPERS project new series for eSafety are established with high demands on the positioning module. Therefore a robust positioning unit RPU (RPU) has been developed by PWP, which enables lane specific positioning through the exploration of I2V communication. Furthermore a unique approach has been presented to test the benefits of Galileo within traffic and transport application, on the basis of sophisticated simulation process.

In general the presented results from the conducted test with the scientific test vehicle already have been very promising. Within the activities of the COOPERS demonstration these achievements could be continued with the availability of hardware components for the COOPERS OBU. An extensive measurements campaign has been conducted at Berlin, Innsbruck, Trento and close to Frankfurt in summer 2009.

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