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Location Based Services,
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A HIGH INTEGRITY LOW COST POSITIONING SYSTEM FOR LOCATION BASED SERVICES

Actual user requirements concerning Location Based Services (LBS) involve not only a high integrity position, but also a low cost final product affordable for most of the drivers. Thereby, most recent researches have been focusing their efforts in decreasing the price of the final product without impoverishing the quality of the solution. In this paper, a study of different technologies and techniques to implement a positioning system for remote services on roads is presented.

WYSOKO ZINTEGROWANY TANI SYSTEM POZYCJONUJĄCY DLA USŁUG BAZUJĄCYCH NA LOKALIZACJI

Rzeczywiste wymagania użytkowników dotyczące Usług Bazujących na Lokalizacji (LBS) obejmują nie tylko wysoką spójność, ale również tani produkt finalny, na który może sobie pozwolić większość kierowców. Dlatego najnowsze badania koncentrują się na zmniejszeniu ceny produktu finalnego bez pogorszenia jakości rozwiązania. W niniejszym referacie zaprezentowano studium różnych technologii i technik wdrożenia systemu pozycjonowania dla zdalnych usług na drogach.

1. INTRODUCTION

Many of the current remote services for land vehicles such as traveler information, route guidance, automatic emergency calls, freight management or advanced driver assistance require a road side equipment (RSE) capable to offer a high available accurate position with

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low price. Wide communication availability is essential regarding most of the LBS. Specially, in applications where people security is involved, high integrity monitored positioning is absolutely required. With this purpose in mind, developers had been focusing their efforts on the combination of Global Navigation Satellite System and Cellular Networks (GNSS/CN). This solution allows low-cost positioning system, the possibility of increasing the accuracy and integrity by using the Satellite Based Augmentation Systems (SBAS), and bidirectional communication between the vehicle and the service provider. However, today the GNSS systems do not provide the availability, accuracy and integrity necessary and some other technologies must be used. Main desirable features for the On-Board Unit (OBU) are:

1. Low cost, including easy installation and maintenance.
2. Capacity for computing vehicle parameters like vehicle dimensions, truck class and weight.
3. Capacity for logging the trajectories, speed, time, etc., and management of geographical Information Systems (GIS), and compute distance traveled.
4. Integrate wireless communication for tasks such as e-pay and e-maintenance.
5. Interoperability with other systems.
6. Anti-cheating enforcement, difficulty to manipulate the OBU by non-allowed users.

As an example, just in the case of the electronic-fee-collection systems (EFC) in Europe, the results of the efforts of the EU for a technical standardization, harmonization of national projects, and negotiations between operators contrasting with the real situation are shocking. A charging system is implemented in Switzerland (LSVA-RPLP) using DSRC microwave 5.8 GHz. In Germany an approach based on GNSS/GPRS is already available in test-bed mode. In Italy, haulers may use the Telepass technology (a different DSRC microwave, technology not compatible with the Austrian one). In France and Spain, the possibility of a solution based on DSRC and compatible with the Austrian one “LIBER T” is attended. United Kingdom, Belgium, Netherlands and Czech Republic are interested in the deployment of a GNSS/GPRS solution [2-5] and [10]. Unfortunately, these are too many incompatible onboard equipments behind the windscreen.

According to the actual bibliography, the most reliable solution to the problem of terrestrial vehicle localization implements a positioning system based on the integration of a GNSS aided by autonomous positioning. Different approaches are being studied in order to guarantee the proper quality of positioning for remote applications. All of them rely on an accurate GNSS position, either as the leading positioning information input, or as an assistance system, to determine vehicle movements along roads. In [9], a GPS receiver is complemented with odometry information and an electronic compass to estimate the position of an autonomous vehicle. In that work, some assumptions concerning GPS availability and velocity limits are done. It is worth mentioning the different versions of the NabLab positioning systems equipped by a GPS receiver, odometry and supported with a vision system and a laser range scanner for avoiding collisions [7]. In [1], a GPS receiver and inertial units are used. In Europe, the European Space Agency (ESA) is encouraging the use of the EGNOS/SISNeT position corrections while private companies as BMW offer their localization systems based on a single GPS receiver.

2. THE LOCATION BASED SERVICES PROBLEM

There are different technological problems regarding Location Based Services. In this work, we have mainly considered the areas of Telematics and High Integrity Positioning.

2.1. THE GNSS INTEGRITY

There are many factors to be considered when we talk about GNSS integrity. The selection of the proper integrity index can be crucial to obtain the desirable performance. Thus, DOP (Dilution of Precision) values are usually offered by the GNSS sensors. However, none of them takes into account, neither the propagation signal errors, nor the satellite constellation operability. Some other integrity indexes are required. In order to avoid the problems connected with a bad satellite constellation, the HPL (Horizontal Protection Level) and the VPL (Vertical Protection Level) are being used by some sensors. The RAIM (Receiver Autonomous Integrity Monitoring) Algorithm [6] allows the rejection of those satellites that do not fulfill the integrity requirements. The SBAS includes integrity information into the geostationary satellites messages. The European SBAS service, the EGNOS (European Geostationary Navigation Overlay Service) offered by the ESA brings two meters error thresholds and the HPL_{WAAS} integrity index for the GNSS/SBAS navigation systems [8].

2.2. TELEMATICS TO LBS

Navigation systems are just the first step of the LBS. The application of the telematic technology to the ITS (Intelligent Transport Systems) bring us new applications for a safer, more comfortable driving. The communication hardware has been settled into a customized personal computer strapped to our vehicle prototype. WLAN via GPRS/UTMS allows real time video and audio access from the Internet. An 802.11 transceiver allows high-speed communications with the vehicle through a LAN net where available. Short distance communications are also available via the Bluetooth link added to the computer.

3. THE POSITIONING SYSTEM

Nowadays, the most popular global positioning system is the American GPS (Global Positioning System). Both the GPS and the Russian GLONASS (GLObal Navigation Satellite System) are called the GNSS. Typical GPS and GLONASS error thresholds (around ten meters depending on the quality of the sensors) are not enough to achieve lots of the LBS objectives. The SBAS bases its architecture into the geostationary satellites and terrestrial installations to transmit the GNSS position corrections. In Europe, the EGNOS signal is also broadcasted via the Internet by the SISNeT (Signal In Space through the InterNeT) [12], which allows us to bring the EGNOS corrections to our GNSS sensor, even during the outages of the geostationary satellite.

3.1. THE GNSS/SBAS/INS INTEGRATED SYSTEM

Despite the improvements in the quality of the sensors, the GNSS/SBAS systems, cannot guarantee the proper solution for high integrity demanding applications. In order to achieve a most desirable performance of our positioning system we have implemented a solution based on a GNSS/SBAS/INS integrated system. The nature of the inertial measurements (accelerations and rates of turn in the three coordinated axes of the body frame) complements perfectly the deficiencies of localization systems based on the GNSS solution. However, the need of a double integration process to obtain the position from the acceleration measures is the principal source of error in an INS/GNSS integrated system. Often updates should be taken to zero the solution drift. The odometry option avoids the double integration, but new problems such as glides, uncertainty of the effective wheelbase, unequal wheel diameters, etc. are presented. A low cost inertial navigation unit based on MEM (Micro-Electro-Mechanical) technology has been installed in our vehicle. To diminish the effects of the INS drifts, odometry measurements are also collected. In our vehicle, the ABS encoders give us information about the wheel speed. Thus, no further installations are required, and the system price is not increased. Further details about the filter can be found in [11].

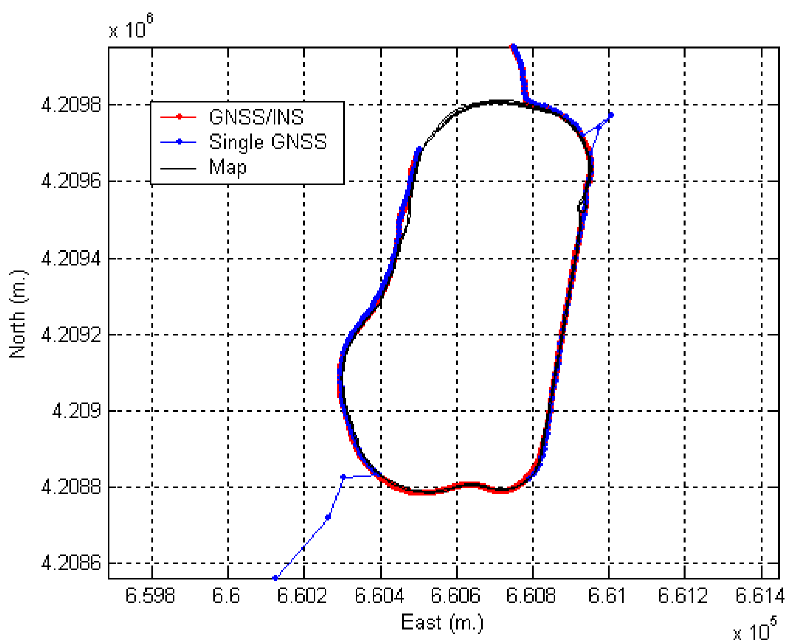

Fig.1. Trajectory through the Campus of Espinardo, Murcia, Spain. A typical situation where the GNSS/SBAS/INS solution is highly recommendable.

Fig.1 shows the results obtained by our positioning system in built-up environments, where GNSS signals are poor and deficient. The integration of an autonomous unit by using odometry and inertial navigation systems can guarantee a reliable, accurate positioning during the periods of GNSS lack of coverage. However, the GNSS outages are not the only (maybe not even the main) problem in city environments. Spurious GNSS data as a consequence of the multipath signal problem are extremely usual, and no removal via map matching (usual solution for wide open areas when multipath is due to trucks, crossing roads, etc.) is possible when roads are so nearby. In order to improve this undesired behavior, a Nyquist validation filter has been implemented. Fig.1 presents how our positioning system guarantee accurate positioning avoiding the spurious problems, and during GNSS outages of 30 seconds, with no significant drifts in the solution.

4. A ROADPRICING APPLICATION

The roadpricing systems are one of the most important applications regarding the LBS. As we have seen during the introduction of this paper, many European countries are preparing solutions to this problem, and none wants to be out of the topic. In our work, we have developed a preliminary prototype for a roadpricing system. The onboard unit prototype consists of the positioning unit (leaded by the GNSS/SBAS), a CN modem and the onboard computer. On one hand, onboard units should guarantee a high integrity solution minimizing at maximum the toll charging errors. On the other hand, onboard units should be affordable for all the EFC users. For this reason, different sensors and positioning architectures has been implemented. Regarding GNSS sensors we have tested a Novatel Millennium OEM3 (GPS/SBAS), an ASHTECH Thales GG24 double constellation (GPS/GLONASS), a Trimble Geoexplorer XT (GPS/SBAS) and a low cost GPS/SBAS Sensor.

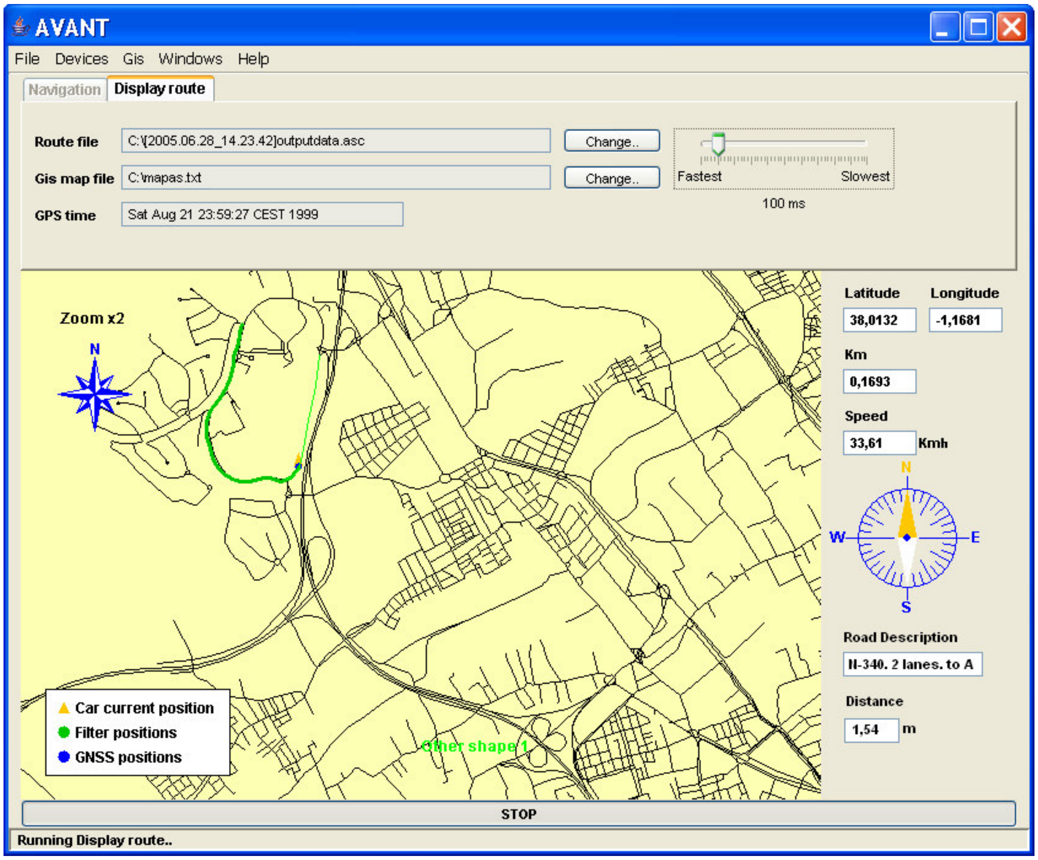

Fig.2. The AVANT Application.

Fig.2 shows the software application developed at the University of Murcia. This application saves the position data before transmitting them to the base station via GPRS, and the calculation of the charging fee. A GIS map is used to detect the road the vehicle rides and the database is checked to obtained the road charge. According to our researches, and taking into account just the vehicle positioning, the main problems are featured in city environments. Wide open areas problems can be easily solved by virtual gantries [13]. However, in built-up areas a solution based on a GNSS sensor is not enough to guarantee the precision required. The frequent outages of the GNSS signal encourage us to implement the GNSS/SBAS/INS solution previously described.

5. CONCLUSIONS

The Global Navigation Satellite Systems are presented as an useful tool to develop LBS applications. The Cellular Network technology applied to the GNSS, the GNSS/CN systems, enhances the quality of this GNSS solution. According to our tests, the EGNOS system is able to improve the precision of the positioning. SISNeT, a broadcasted position correction sent by the Internet, is proven to be a practical solution when the geostationary satellite is out of view.

However, in high integrity demanding applications, this solution does not fulfill all the requirements regarding reliability, robustness, and integrity. According to our research, an increase of the number of satellites in view, achieved by the use of a GLONASS/GPS receiver, can not deal with the lacks of a GNSS/CN system. A positioning systems based on the integration of the GNSS/SBAS systems with the speed information coming from the ABS system of the vehicle and low cost inertial sensors has been tested. The results present our GNSS/SBAS/INS positioning system as a low cost high integrity solution for the positioning problem, dealing with applications such as the implementation of a roadpricing system in city environments.

6. ACKNOWLEDGEMENTS

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