Active Road Management Assisted by Satellite

ARMAS Phase II
Overview, Findings and Conclusions

IV Congresso Rodoviário Português
April 2006
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- Overview
- System Architecture
- Road Usage and Charging Determination
- Field Trials
- Conclusions
- Project Achievements and Future
Overview of ARMAS

- Technical Feasibility;
- High-Level Architecture;
- Legal Issues (Privacy, Liability);
- “Rough prototypes” developed for main entities;

ARMAS Phase I

Feasibility Study

ARMAS Phase II

Test-bed development focused on “EFC based in Satellite Positioning”

Time Frame

Phase I
Mar 03 - Dec 03

Phase II
Mar 04 - Dec 05

Detail analysis of key issues identified in Phase I;
Development of a demonstrator for the selected functionalities:
- “EFC based on Satellite Positioning”;
- “Warnings Provision”;
- “SOS Request”;
Overview of ARMAS

• “EFC based on Satellite Positioning”
  - Corridor Pricing/Passage Tolling;
  - Congestion Zones/Cordon Pricing;
  - Distance Based Pricing;
  - Combination;

• “Warnings Provision”
  - Provide information about hazards on the road ahead to the driver.

• “SOS Request”
  - Electronic SOS request from inside the car:
    • By the driver;
    • Triggered automatically by car sensors.
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System Architecture

GPS, EGNOS → Galileo

GSM, GPRS → UMTS

DSRC

Road-Side and Central Equipment
ARMAS Fixed-Part
AFP

On-Board Unit
In-Car System
ICS
System Architecture

- EGNOS SiS
- GPS SiS
- EGNOS over GPRS
- GPS + EGNOS
- Inertial Sensors
- Kalman Filter
- DSRC
- Map Matching
- Feature Matching
- Road Usage
- Route Matching
- Map Matching
- DSRC Road Usage
- Charge Calculation
ARMAS: ICS Prototype
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ARMAS: Charging Concepts - Integrity

- Integrity is measured by the Protection Level (PL)

- The Protection Level bounds the error in meters in the positioning given by the GNSS receiver;

- Defines a circle with center in the given position with radius equal to PL;

- The real position is within the circle with 99,9999% certainty.

- The PL is determined by the receiver depending on:
  - Satellite geometry
  - Pseudo-Range errors
HPL and Road Usage Determination

Collected Positions

Map-matching selects final route

Crossed Gantry with High HPL
Less Probable Candidate

Crossed Gantry with Medium HPL
Probable Candidate

Crossed Gantry with Low HPL
Very Likely Candidate

Edge of Gantry with High HPL
Unlikely Candidate
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Field Trials

- The trials were conducted covering a large area of Lisbon city and greater Lisbon area, methodically covering the same ground day after day, having established three different scenarios:
  - **Dense Urban ("Baixa Pombalina")**: Driving through downtown narrow streets and avenues having dense foliage;
  - **Urban**: Driving through large avenues and wider streets.
  - **Rural**: Following highways around Lisbon and passing places with a low or none density of buildings/trees.

- Three different times of the day were also established in order to prove the system against different ionosphere activity periods and in different traffic density situations:
  - **Afternoon**: Highly charged ionosphere. Medium traffic density.
  - **Evening**: Transitional period of the ionosphere. Heavy traffic situation.
  - **Night**: Lowest state of the ionosphere activity. Low traffic density.
Field Trials: Congestion Zone in Dense Urban Scenario
Field Trials: Congestion Zone in Urban Scenario
Trial Run Result Example: Dense Urban Scenario
Trial Run Result Example: Urban Scenario
Trial Run Result Example: Bridge “Vasco da Gama”
## Road Centreline Truth Source: Accuracy

<table>
<thead>
<tr>
<th>ICS ACCURACY (COMPAARED AGAINST ROAD CENTRELINE) (metres)</th>
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</thead>
<tbody>
<tr>
<td><strong>Geographic Scenario</strong></td>
</tr>
<tr>
<td>--------------------------</td>
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<tr>
<td><strong>AVERAGE</strong></td>
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<tr>
<td><strong>STD DEVIATION</strong></td>
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<tr>
<td><strong>PERCENTILE 75</strong></td>
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<tr>
<td><strong>PERCENTILE 95</strong></td>
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<tr>
<td><strong>PERCENTILE 99</strong></td>
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<tr>
<td><strong>MAXIMUM</strong></td>
</tr>
<tr>
<td><strong>MINIMUM</strong></td>
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</tbody>
</table>
## Road Centreline Truth Source: Latency

<table>
<thead>
<tr>
<th>ICS LATENCY (COMpared AGAINST ROAD CENTRELINE) (seconds)</th>
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</thead>
<tbody>
<tr>
<td><strong>Global</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Error &lt; 3m</td>
</tr>
<tr>
<td>Error &lt; 8m</td>
</tr>
<tr>
<td>Error &lt; 20m</td>
</tr>
<tr>
<td>Error &lt; 50m</td>
</tr>
</tbody>
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Conclusions: Overview

- As expected, the “GPS+EGNOS+INS” positioning solution is appropriate for the tested tolling situations. Accurate charging was produced although an extensive trial with a large number of vehicles is necessary for statistical validity.

- The only environment where the results are not optimal is the Dense Urban where, as expected, the performance of the system becomes heavily dependant on the performance of the INS, Map-Matching Algorithms and if applicable, tolling scenario (e.g. the definition of the “Charging Zone” boundaries).

- The other two system functionalities, “SOS Request” and “Warnings Provision” were easily implemented using the base tolling platform which proves that the approach followed is valid for providing more service and business oriented functionalities to the end customer.

- Besides being the basis of the “Integrity concept” of the system, EGNOS improved also the accuracy of the positioning.
Conclusions: Overview

- GPRS proved to be enough for uploading the charge-related data gathered in the OBU.

- However, for the dissemination of EGNOS based on SISNeT, the GPRS communication channel showed some problems:
  - High latency;
  - Low bandwidth;
  - Coverage problems;

- We concluded that in order to be able to have a reliable and complete EGNOS feed the ideal solution would be transmission based on radio broadcast such as RDS or DAB although UMTS should already bring a very noticeable improvement.
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Project Achievements

- ICS prototypes + AFP prototype (with COTS hardware) made available for further testing and trials;

- Platform able to test several different scenarios and applications;

- Hands-on knowledge of the problems/benefits of the use of ISO 17575 and MISTER;

- Field Trial data that raised several issues but overall confirmed the validity of the project choices;

- Comprehensive body of knowledge about all the technical issues related with EFC based in GNSS;

- Enabling the consortia members to engage with key industry stakeholders;
ARMAS Phase III

- Downscale ICS equipment in cost and size;
- Extensive User Trials in Portugal, Ireland and The Netherlands (30+ vehicles during 3 months in Portugal for instance);
- Comparison of performance of ARMAS against today’s leading toll technologies;
- Demonstration of Secondary Services:
  - Traffic Management;
  - Children and Youth Transportation;
  - Dangerous Goods Transportation;
  - PAYD insurance
  - Incident management
Thank you. Questions?

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