SAVE-U

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Sensors and system Architecture for VulnerablE road Users protection

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Executive summary

- Eight work packages were running in the period from March 2003 to February 2004 where:
  - WP6, WP8 are finished and
  - WP9, WP10, WP11, WP12, WP13, WP14 are in progress.
- In WP6, the time to get the vision sub-system available was longer than planned initially. The work focused mainly on detection/classification integration and on overall optimization and validation. Extensive experiments in realistic traffic conditions has proved the final vision component in both SAVE-U Configuration A and B successful in bringing recognition performance within reach of specified overall SAVE-U targets as specified in Deliverable 7. All the due deliverables were submitted.
- WP8 is dedicated to the realisation of the sensor fusion ECU. The hardware was available at the end of the last period. The work done early this year consisted in the implementation of the communication protocol on the sensor fusion PC and its validation only at the physical layer level. After that, sub-systems were able to dialog together and with the vehicle network. This was a major step for fusion process at high and low levels. All the due deliverables were submitted to EC and approved by reviewers.
- Incremental delays in previous work packages and remaining problems of CAN communications (at application level) between sub-systems have not allowed WP9 (development of data fusion algorithms) to progress as much as expected. Nevertheless, it was possible to achieve a first full SAVE-U system running up to the High-Level Fusion on the Volkswagen test car. This first version still needs to be enhanced in order to achieve a better quality of the data sent to the vehicle ECU, which controls warning and brakes.
- In WP10, several technical meetings were organised by Faurecia with SiemensVDO and CEA in order to ensure that communications on CAN (at application level) were in accordance with specifications given in D18, especially after the implementation of upgraded software on radar and vision PCs due to progress made on fusion algorithms.

  Volkswagen modified the existing demonstrator vehicle (vehicle network architecture, bumper for IST The Hague).

  DC performed extensive tests with “HANS”, their pedestrian dummy, on the test track to evaluate and improve the driver warning and vehicle control strategy.

  The radar network is now integrated on the DC car.

  After a first use of the weather-proof housing, which showed undersized blocking systems for settings, Faurecia modified the system. The new mount was validated under severe conditions on sled to withstand strong decelerations.
- In WP11, the deliverable D23 was submitted and approved by reviewers. This document gives an overview of test rig design.

  The rig and the ground truth acquisition method were improved to take into account the problems encountered during the data collection phase. It is now ready for the evaluation of the full sensor platform alone scheduled in April 2005.
- The PMB came to ask for a project extension after consideration of the remaining work, which was not achievable with the end date of February 2005. The extension was agreed by the EC and an addendum to the technical annex was prepared. An amendment of the SAVE-U contract was sent

to partners for signature to make official the project extension by 7 months without modification of the initial budget.

- In Work package 13, D4 (Evaluation Plan) was submitted to EC and approved by reviewers.

  M2' and M2" successfully rolled up on Oct 2004. An internal milestone M3' was added end of March 2005 together with intermediate evaluations till there in order to evaluate closely the progress made in development of data fusion algorithms prior to the test phase at MIRA for the full platform evaluation on rig.

- In terms of dissemination activities (WP14), several conferences on SAVE-U progress and on sensors development have been given during the period. The DC car was presented in Parma for IV' 2004 and the Volkswagen one in The Hague in the framework of an EC IST event.

1 Introduction

This report is the public version of the third Periodic Report (PR3) of SAVE-U (IST-2001-34040). It covers the period from March 2004 till February 2005 (End of Year 3).

It will give to the reader a summary of the work performed all along year 3 for each Work Package that is still under progress or was finished during the period. It will remind the objectives, then will explain how the tasks were done and what are the main results issued from the work.

2 Overview

This section describes the work performed in each work package that is still under progress or was finished during the reporting period (year 3) and gives the related main results.

2.1 WP6: Image sensor and image processing development

2.1.1 DESCRIPTION

DaimlerChrysler is the WP leader.

D9: Evaluation of the embedded image processing (EIP) platform and associated sensors (Public)

D10 Prototypes of EIP platform and stereo vision sensors (Public)

D11 Algorithms for detection and classification of VRUs (Public)

2.1.1.1 Objectives

WP6 covers necessary developments for the entire image sensing part. Main objective is to develop a module able to process images and videos coming from visible and IR channels in order to assure the pedestrian detection.

The image processing module consists of the video sensor (to be bought from stock) including its Video Processor (VP), the IR sensor (to be developed up to simulation level) including its non-uniformity correction module (NUC), the Embedded Image Processor (EIP) and the general purpose computer (PC) used for target classification.

Developments in this work package concentrate on the EIP, low level image processing (segmentation) to be implemented on the EIP, high level image processing algorithms (e.g. classification of objects) and road detection algorithms to allow risk assessment.

2.1.2 SUMMARY

The following are the main results of the reporting period:

- The model of the IR camera being completed, the translation of real IR images - obtained from the present IR technology - into virtual images featuring the future technology has been developed (CEA).
- Optimization of the software was implemented on the vision PC to decrease the processing time. The gain is about 50% (CEA).
- Two main additional stages for the detection were added to improve it (CEA)
    - Merging of overlapping bounding boxes (to eliminate a large number of detections around a same pedestrian),
    - Adaptation of boxes around a detected pedestrian (to improve the position of the bounding box on the pedestrian).
- The feasibility of an industrial prototype intended to support the overall image sensing modules required for achieving a SAVE-U commercial prototype was studied (CEA).
- The parameters of the SAVE-U vision system in both Configuration A and B were optimized using a ROC convex hull technique (DC)
- Extensive experiments in realistic traffic conditions has proved the final vision component in both SAVE-U Configuration A and B successful in bringing recognition performance within reach of specified overall SAVE-U targets as specified in Deliverable 7 (CEA/DC)
- The validation procedure involved comparing ground truth with system output and associated data sets, on a per-image and per-trajectory level (DC).
- A number of additional research directions were explored, which hold promise in improving future performance: dense stereo, classification under occlusion and by heading direction (DC – by subcontracting to Univ. of Amsterdam).

After some delay, WP6 has now successfully been finished.

2.2 WP8: Development of the sensor fusion ECU

2.2.1 DESCRIPTION

SiemensVDO is the WP leader.

D16:	Prototype of sensor fusion ECU	(Public)
D17:	Interfaces to sensor ECUs and vehicle	(Public)
D18:	Report on Sensor fusion ECU development	(Public)

2.2.1.1 Objectives

The sensor fusion ECU is the heart of the SAVE-U sensor platform due to its interfacing function. It will allow the sensors of different technologies to interact and collect data from both image and radar processing. Having processed the high level data fusion algorithms and optimized tracking routines, in this ECU the relevant objects (classified unprotected traffic participants in front of vehicle, distance and time to impact, relative speed …) will be computed and transferred to the vehicle application (warning and control strategies to avoid a crash / active protection system in case the crash cannot be avoided) in order to suitably react.

In turn, the sensor fusion ECU will be directly linked to the vehicle network to acquire vehicle information (such as speed, inclination, steering angle). Some of these data will be transmitted to the image and radar processing ECUs to integrate them into calculations

This work package focuses on the development of the sensor fusion ECU including communication software to operate the image and radar sensing subsystems and to talk to the vehicle network.

2.2.2 SUMMARY

During this report period the implementation of the communication protocol of the sensor platform and vehicle was done and checked.

The validation of the protocol was done in three steps:

- Validation with a general purpose CAN-analyzer Tool (from Vector), in order to simulate the SAVE-U platform and vehicle,
- Validation with the application software coming from CEA (vision system) and SiemensVDO (radar-network, sensor fusion) and
- Validation with the VW demonstrator car (communication with the vehicle).

The validation of CAN-communication involved only the physical layer. Its purpose was to check that the protocol defined by the SAVE-U partners was correctly implemented by sending real or dummy data over the CAN-bus. At that time, the validation could not involve to check that all data structures to be transmitted over CAN were filled correctly with data of detected objects. The reason for this was that not all the corresponding algorithms were yet available. Such algorithms were under development in the framework of WP9.

The sensor fusion ECU fulfilled the functional requirements of

- Enabling communication over Ethernet between the radar gateway interface with the radar pre-processing algorithm

- Enabling communication between the gateway and the radar network over an own CAN-bus, and between the gateway and the Vision-PC over the SAVE-U CAN-bus

Currently two sensor fusion PCs are available, one for the test rig and the DC demonstrator car and one implemented in the VW demonstrator car.

SiemensVDO submitted the deliverable D18 (Report on sensor fusion ECU developments) end of May 2004. The prototype deliverables D16 (Prototype of sensor fusion ECU) and D17 (Interfaces to sensors ECUs and vehicle) were validated by partners too.

WP8 is finished.

2.3 WP9: Development of sensor fusion algorithms

2.3.1 DESCRIPTION

SiemensVDO is the WP leader.

D19: High and Low level data fusion algorithm (Public)

D20: Report on Sensor fusion algorithm (Public)

2.3.1.1 Objectives

Sensor fusion algorithms will be developed according to the detection strategy defined in work package 5.

There will be two levels of data fusion:

First, the so-called low level data fusion, by means of exchanging pre-processed data between sensor processing ECUs. Second, the so-called high level data fusion, by means of extracting the correct parameters from both sensor channels.

Low level data fusion algorithms will be implemented on the one hand on the EIP hardware of the image processing subsystem and on the other hand on the radar processing ECU to ensure the required raw data exchange between both ECUs in order to optimise detection of each technology.

High level data fusion concepts will be implemented on the sensor fusion ECU developed in WP8. The same applies for novel tracking algorithms taking into account the vehicle's path and the adapting of information for the vehicle application. The latter part of the software will be dependent on the vehicle specific and the warning and control concept.

In accordance with vehicle parameters, objects in the vehicle's path will be identified and tracked. These algorithms will be dependent on the vehicle network which changes versus vehicle trade mark. Related parts of the software, therefore, need to be adapted to the vehicle specific.

2.3.2 SUMMARY

In this section, the most relevant events and the main results of the reporting period are listed chronologically.

Early in the period, a newer radar sensor technology was introduced to enhance the results of detection through the radar system. It brought a benefit for all levels of fusion: Sensor Fusion (SF), Low-Level Fusion (LLF) and High-Level Fusion (HLF).

Volkswagen conducted a second workshop on sensor fusion techniques in Regensburg in July 2004. CEA and SV attended this workshop. The content covered scientific and technical topics like object tracking, modelling of sensor characteristics, Kalman filtering, data association techniques, probabilistic state vector description, asynchronous versus synchronous fusion concepts, high-level-fusion techniques, low-level-fusion methods, recommendations for a good operating SAVE-U system, and some practical aspects.

In November 04, a first version of the "Concept for Data Fusion in SAVE-U" was sent by SV to all partners. In the same time, a first version of low level fusion was developed by CEA.

The Configuration B (Radar System and B/W Stereo Camera System) was tested on the DC test car in December 2004. The LLRD delivered by the Radar System were validated using a simple scenario with one person.

Using a new version of the Vision application, which integrates the result of low level fusion in HLVD, it was possible for the first time to have HLVD and HLRD being provided to the HLF task on January 2005. However, high level sensor fusion and object tracking were still not operating.

A first complete version of the SAVE-U system was integrated and running on the Volkswagen Passat end of February 2005. Major enhancements were: Enhanced Radar Sensor Fusion

(through an enhanced radar peak detection and association); enhanced LLF using the radar range of objects detected; HLF using a one pass weighted mean approach. CAN communication at application level was operating successfully.

WP10: Building of prototypes and fitting on cars

2.3.3 DESCRIPTION

DaimlerChrysler is the WP leader.

D21: Demonstrator vehicles (Public)

D22: Driver warning and vehicle actuator concepts (Confidential)

2.3.3.1 Objectives

Prototypes of the SAVE-U sensor platform developed in the previous work packages will be integrated on vehicles in order to show the improvements brought by the new sensors and the associated ECUs. Two test vehicles will be equipped for realising and evaluating two different driver warning and vehicle control strategies identified in work package 3 to show the efficiency of the integrated protection systems developed. System evaluation will take place in various European countries - in particular in the scenarios defined in work package 1.

Realisation of two systems on the one hand requires duplication of the SAVE-U sensor platform. On the other hand, it necessitates the development of two different warning and control concepts. As mentioned earlier, warning and control concepts realised in the experimental cars will not include deployment of active protection devices. Instead, for verification of the SAVE-U concept, warning strategies, collision avoidance measures (by means of braking) and/or graphical animations will be implemented by the car manufacturers in the consortium.

2.3.4 SUMMARY

Recall that the VW demonstrator is a blue VW Passat B5/00 (see Figure 1) and the DC demonstrator is a Mercedes-Benz E-Class Limousine, see Figure 2.

Figure 1: the VW demonstrator vehicle

Figure 2: the DC demonstrator vehicle

Volkswagen Demonstrator was modified according to requests from partners during integration on the vehicle and software testing. All technical environment in the Passat is fully operating. The automatic brake system and its deployment was installed, programmed and tested with synthetic data.

DC vehicle demonstrator: Improved warning and control strategy based on experiments with “Hans”, the pedestrian dummy, with vehicle speeds up to 40 km/h. System is demonstrable.

DC vehicle demonstrator: SiemensVDO radar network integrated in bumper. CAN communication with sensor subsystem implemented (still needs testing)

After a first use of the weather-proof housing, which showed undersized blocking systems for settings, Faurecia modified the system. The new mount was validated under severe conditions on sled to withstand strong decelerations.

This work package is **on schedule** to be completed July 2005.

2.4 WP11: Development of test method, evaluation

2.4.1 DESCRIPTION

MIRA is the WP leader.

D23: Test rig (Public)

D24: Tests and evaluation of the integrated system (Public)

2.4.1.1 Objectives

The main objective is the evaluation of the SAVE-U sensor platform including the driver warning and vehicle control concepts. It is very important for proving the efficiency of the entire approach. As mentioned above, no crash-active protection devices shall be installed on the experimental cars used in this proposal. Full evaluation of such integrated systems to protect vulnerable road users would require impacting real people (not dummies) due to the required real behaviour with respect to the 3 sensor technologies deployed. Such kind of testing is clearly unacceptable.

A test methodology will be developed in this work package based on the list of main scenarios related to vulnerable road users established in work package 4 from data gathered in work package 1.

The evaluation strategy will be split into two main points. The first is the evaluation of the quality of the detection and classification of vulnerable road users. The second is the evaluation of the driver warning and vehicle control strategies.

2.4.2 SUMMARY

The test rig was manufactured during this period and was used at first on April 2004. Twenty tests were conducted as part of the data collection phase. These tests were intended to give synchronized data recordings from both sensor sub-systems in order to help in the development of sensor fusion algorithms.

The scenario for the tests is that the rig, mounted with the SAVE-U system, would approach the VRU at a speed approaching 40km/h and then be brought to rest in a distance of approximately 5 meters. The performance of the SAVE-U system at speed and close range, using various staged pedestrian scenarios, could be developed. The VRU scenarios for the test program included stationary, walking, running, VRU from occlusion, multiple VRU's walking, cyclists and a moving vehicle.

The test set up comprised of the test rig vehicle, the stopping rig and the overhead camera system. The test rig is a remote controlled vehicle purposely designed and built to withstand the

severity of the test programme. The test rig housed the SAVE-U system that comprised of two computers, an infrared camera, a colour camera and five radar sensors.

The stopping rig consisted of high strength rope tethers connected to a drum and brake system used to bring the test rig vehicle to a controlled halt and two energy absorbers that would bring the vehicle to a stop should the braking system fail.

The overhead camera system comprised of a 13m platform that enabled an overhead camera view to film the approach of the test rig vehicle towards the VRU.

The test rig vehicle is described fully in the SAVE-U project deliverable D23. Figure 3 shows the rig at speed during a test with all of the sensors mounted.

Figure 3: Test rig equipped with SAVE-U platform

The generation of the ground truth data (relative positions and speeds of the VRU's and vehicle) was issued to partners during this period.

The detailed test plan for the next evaluation phases was discussed and agreed. It is broken into three sections:

- System Evaluation on the Test Rig – Tests evaluating the performance of SAVE-U system. Approximately 20 tests.
- System Evaluation on the vehicles. Approximately 30 tests.
- System Evaluation on Urban Road. Approximately 3 tests.

2.5 WP12: Project management

2.5.1 DESCRIPTION

Faurecia is the WP leader

2.5.1.1 Objectives

WP12 covers the entire work for optimum co-ordination of the project. It mainly covers three areas: Administrative, technical and financial co-ordination.

2.5.2 SUMMARY

Twelve work packages were running in the period from March 2004 to February 2005 where:

- WP6, WP8 are finished.
- WP9, WP10, WP11, WP12, WP13, WP14 in progress.

Two project reviews were performed during the reporting period:

- in Saclay, on April 22, 2004

  This was the occasion to show to reviewers the status of VRU detection with the vision sub-system (configuration A) and to present the VW car fully equipped of the hardware.

  Concern was raised at this review meeting by the EC project officer Mrs Holmberg about MIRA's commitment to the project because of the cost incurred. As requested MIRA issued a formal undertaking to complete their obligations to the project

- in Brussels on Nov. 29, 2004

  Partners have mainly presented the final performance achieved by the vision sub-system and have indicated that it will not be possible to end the project on time.

  The project management board came to ask for a project extension after consideration of the remaining work, which was not achievable with the end date of February 2005. The main objective of the work plan extension is to develop and still to improve the VRU recognition performance thanks to data fusion between the radar and the vision sub-systems (the main focus of SAVE-U). Extension of WP9 is the main impact on the new project ending date.

  Subsequent tasks, which are WP10 (equipment of vehicles) and evaluation of the sensing platform and evaluation of vehicles done in the framework of WP11 are shifted in consequence.

The extension was agreed by the EC and an addendum to the technical annex was prepared. An amendment of the SAVE-U contract was sent to partners for signature to make official the project extension by 7 months without modification of the initial budget.

During period n°3, four consortium meetings have been organised (respectively by CEA-LIST, Faurecia, SiemensVDO and VW).

2.6 WP13: Assessment and evaluation of project progresses

2.6.1 DESCRIPTION

Faurecia is the WP leader.

D4: Evaluation and validation Plan (Confidential)

2.6.1.1 Objectives

WP13 deals with the continuous internal evaluation of the project to monitor the project progress and the achievable results. Evaluation will cover the technical progress according to the time plan, but also cover issues such as manufacturability, cost, safety and economic impacts. Due to the high relevance of evaluation, 5 key milestones have been defined.

2.6.2 SUMMARY

D4 (Evaluation plan) was finalized on May 2004 and was submitted in its version 1.2 to EC on July 22 after last minor MIRA comments.

Milestone 2' was evaluated the first time on June 2004. However, M2' was not rolled up during at this time because:

- The 1st evaluation of the vision sub-system in June 04 has shown that locations of RoIs around VRUs still need to be improved.
- High Level Vision Data (HLVD) examples in the right CAN format (results of detection from synchronised data recordings performed at MIRA on the rig) were not available. This would allow SiemensVDO to evaluate for the first time the performance of the low-level fusion strategy.

Milestone 2' was re-examined on October 2004 and was rolled up thanks to the following conditions, which have been all achieved:

- Availability of the sensor fusion ECU (radar ECU included)(HW) --- Done (See D18)
- Availability of the radar network (HW) --- Done (See D13 - D14)

- Availability of the vision sub-system (HW) --- Done (Refer to data collection phase at MIRA)

- Performance of radar network in accordance with D7 requirements --- Done (See D15)

- Communication between sub-systems and between each sub-system and vehicle network checked --- Done (Technical meeting in Regensburg on Oct 5-6)

- 1st version of detection SW on radar and vision sub-systems in operation --- Done (Technical meeting in Regensburg on Oct 5-6).

This important step has allowed to pursue deeper in the development of data fusion algorithms.

Validation of Milestone 2" was strongly linked to the evaluation of the vision sub-system performance, which was only possible on November 2004 due to additional runs of optimization both in detection and in classification:

- Configurations (IR and color) and B (stereovision) have roughly the same performance. Configuration A has a correct recognition rate of 74-95% with a false positive rate of 1 each 17.7-19.7s. Configuration B scores a correct recognition rate of 78-88% with a false positive rate of 1 each 17s. Both configurations comply with the boundary conditions set within the SAVE-U project listed in Deliverable 7 as to sensor coverage area, vehicle speed, processing rate, etc. Related to recognition performance, one notes that obtained results are above the targeted 70% correct recognition performance for the overall SAVE-U system. The false positive rates are still up to a factor of 3 below the targeted values, but this performance gap is relatively minor and can be expected to be closed by the addition of the SAVE-U radar component and sensor fusion (Work Package 9, a main focus within SAVE-U) while still keeping the correct recognition rate above 70%. See D9 for details.

These encouraging results have led to us to validate Milestone 2", considering the other requirements that were fulfilled earlier.

As the extension of the project (see WP12) results mainly of the extension of WP9 (because of incremental delays in previous work packages), an internal milestone M3' was added end of March 2005 together with intermediate evaluations till there in order to evaluate closely the progress made in development of data fusion algorithms prior to the test phase at MIRA for the full platform evaluation on rig.

In addition, partners have also attached the validation of the test procedure to this milestone.

2.7 WP14: Dissemination and implementation

2.7.1 DESCRIPTION

Faurecia is the WP leader.

D3: Project presentation (Public) Due date: End of August 2002

D5: DUP (Public) Due date: End of August 2002

D26: TIP (Confidential) Due date: End of February 2005

2.7.1.1 Objectives

Dissemination and implementation activities are considered very important to prepare the industrialisation of the achieved components and of the entire protection system subsequent to the SAVE-U research project. Due to the high importance of pedestrian protection for the community, several measures have been defined in order to prepare the exploitation of results as far as possible.

2.7.2 SUMMARY

The web site www.save-u.org is updated by Faurecia on a 3-months basis mainly in the areas "news, confidential documentation".

The area "Library", which provides all the public documentation about SAVE-U is updated after each project review with public deliverables that reviewers have approved.

SAVE-U is now referenced in several web sites (MIRA, Passive Safety Network, CEA, www.prismproject.com, www.cardesignonline.com/safety/, www.gavrila.net). At the end of 2004, the SAVE-U web site received more than 1000 visitors a month, where universities are well represented.

“Live” vehicle demonstrations by DaimlerChrysler (Stereovision only) at the Intelligent Autonomous Systems Conference in Amsterdam (10-13 March).

2-pages article about SAVE-U in MIRA publication 'Technology 2004'.

Article in "Les Défis du CEA" prepared by CEA on new safety devices, in particular SAVE-U, which will fit our tomorrow's vehicles. The article was on line in French on the CEA website, www.cea.fr, from 25th of September, for the opening of the motor show in Paris.

During the IST Exhibition in The Hague / Nederland, November 15-17, 2004 Volkswagen, supported by Faurecia, has presented their SAVE-U car equipped with the full sensor platform in

configuration A. A project overview was also presented to visitors. About 3400 participants have visited the exhibition.

CEA-LIST presented the vision sub-system at the congress “Les Maires de France” in Paris, on Nov. 16-18. "Live" detection of visitors in the hall was operating.

3 Conclusion

SAVE-U project is now running since March 1st, 2002.

This third year was dedicated mainly:

- to finalise the development of the vision sub-system,
- to develop the sensor fusion algorithms.

WP6, which is the WP in charge of the development of the vision sub-system has requested more effort than expected. The evaluation of the vision sub-system was done in November and showed that configurations A (IR and colour) and B (stereovision) have roughly the same performance.

Configuration A has a correct recognition rate of 74-95% with a false positive rate of 1 each 17.7-19.7s. Configuration B scores a correct recognition rate of 78-88% with a false positive rate of 1 each 17s. Both configurations comply with the boundary conditions set within the SAVE-U project listed in Deliverable 7 as to sensor coverage area, vehicle speed, processing rate, etc. Related to recognition performance, one notes that obtained results are above the targeted 70% correct recognition performance for the overall SAVE-U system. The false positive rates are still up to a factor of 3 below the targeted values, but this performance gap is relatively minor and can be expected to be closed by the addition of the SAVE-U radar component and sensor fusion (Work Package 9, a main focus within SAVE-U) while still keeping the correct recognition rate above 70%.

Equipment of both demonstrator vehicles is well advanced. The Passat is already completely equipped with configuration A and was intensively used by SiemensVDO for tests of the high level sensor fusion. The car was shown in The Hague on November 2004. The DC car (already equipped with stereovision system) is ready to receive the configuration A as soon as tests on rig are finished. The car was demonstrated in Parma with automatic braking and detection done with stereovision cameras only.

The development of sensor fusion algorithms, which started later than scheduled due to incremental delays in previous WPs was more difficult than expected. The PMB came to ask for a project extension after consideration of the remaining work, which was not achievable with the end date of February 2005.

The extension till September 05, approved by the EC, will be focused on the optimisation of the fusion algorithms together with the evaluation of the sensing platform on rig and on cars.

This extra time will be welcome to improve VRU detection at the platform level, which is confirmed to be a tough task anyway in real world conditions.