Publishable summary

Description of project context and objectives

The “Advanced Radar TRAcking and Classification for enhanced road safety” (ARTRAC) research project contributed to the Road Safety Programme 2011-2020 concerning improved safety for vulnerable road users (VRU). The main objective was to develop a novel 24 GHz radar sensor to protect VRUs in general and reduce the number of fatalities in particular.

The European commission described the ambitious goal in 2001 to reduce the number of fatalities by 50% in a ten years time frame. This requirement has not completely met so far, however a significant progress could be observed when the number of fatalities has been reduced by 25% in the last 10 years due to several technical assistance procedures and techniques. For the period from 2011 to 2020 again the goal is to reduce the number of fatalities on European roads by 50% [1]. The technical challenge of ARTRAC was to develop a 24 GHz radar sensor product in high volume series cars, as they are already applied in high-end limousines. Current sensor systems (cameras and radar sensors) show already excellent performance in target detection for driver assistance and comfort system functionality. However, the new ARTRAC radar sensor has also a target recognition feature integrated. This functionality distinguishes between radar echo signals from pedestrians, bicyclists, vehicles and static objects and is able to classify these different objects. Thereby as a reaction upon a critical situation an extended functionality like automatic deceleration, steering recommendation and driver warning is performed. This was the focus in this ARTRAC project. The system developed consists of a 24 GHz radar sensor, a risk assessment and a vehicle control procedure. This safety system has a high potential to be launched because the majority of all components belong already to standard equipment in series cars. This is the reason why the ARTRAC consortium is convinced that the ARTRAC research activity is a necessary step towards a modern VRU safety procedure.

The ARTRAC project is organized in eight different work packages, where the first WP covers management purposes and the other seven cover research and development tasks.

	Title	***Leader***
WP 1	Administrative and Financial Management	TUHH
WP 2	User Needs, Requirements and Application Scenarios	Volkswagen
WP 3	Specifications, Architecture and System Design	TUHH
WP 4	Sensor Development	Smartmicro
WP 5	System Actuation Control	CTAG
WP 6	Safety System Integration	CRF
WP 7	Testing and Validation	VTT
WP 8	Dissemination and Exploitation	TuTech

Description of work performed and main results

At the kick-off meeting at TuTech Innovation in Hamburg, Germany in November 2011 the project was initiated and since then has been running according to plan. During the 3 years of ARTRAC project all project members met regularly. Each partner was in close contact and had several telephone conferences and meetings with other partners contributing to the same work package.

Work package 2 has been focused on accident analysis in terms of vulnerable road user collisions based on existing analysis from related projects (e.g. RADARNET, FRICTION, INTERSAVE, AKTIV…), the CARE and GIDAS database. In WP 2 **specific scenarios** from these accident statistics have been derived to be are **addressed in ARTRAC**. Also the **state of the art in intelligent vehicles** such as actuators, driver vision enhancement and road friction estimation, including 24 GHz radar technology with pedestrian recognition has been covered. From this analysis, a consolidated view of **user needs and requirements** has been derived. The ARTRAC aim is to equip the vehicle volume market with an universally usable low-cost radar sensor to cover a high amount of new and already existing modern intelligent applications. Therefore **two demonstrator vehicles** (one from Volkswagen and a second from FIAT) has been described to be equipped with the ARTRAC sensor to perform a system-initiated deceleration by braking and/or a system-initiated steering recommendation as explained in deliverable D2.1. These systems are each representative to a system for the vehicle volume market. By the user needs, known approaches to enhance road safety, the **system proposal**, **assistance functionality** and **standardization radar requirements for VRU detection and protection** in general has been explained including antenna and signal processing requirements. These requirements also need **road friction estimation**, as the initiated reaction of the vehicle (steering or breaking) requests additional information about the road surface which has been also covered in the workpackage 2. The milestone “Scenarios and Requirements” has been completely fulfilled.

Public deliverables: D2.1. User Needs and Requirements for VRU protecting systems based on multipurpose narrow-band radar

In **work package 3** the 24 GHz **radar sensor and system architecture** has been designed and specified. In this context actual sensor techniques such as radar sensors, camera systems and laser scanners used in automotive applications has been considered. **Two different system architectures of radar sensors have been specified, one radar for VRU protection and a second radar for road condition measurement.** In case of the VRU radar sensor the architecture description includes objects to detect, the specification of the hardware (multichannel receiver, DSP board) and the software part in the radar signal processing (waveform, antenna, tracking, feature extraction and classification). The same specification has been derived for the road condition radar sensor. In addition to the specification **on board integration** concerning the **conformity to standards and automotive constraints** as well as the **system architecture and safety functionality of the two demo vehicles** has been derived. The milestone “Architecture and specifications” has been completely fulfilled.

Public deliverables: D3.2 The ARTRAC Architecture

Workpackage 4 can be divided into three main parts. The first part is the development of the sensor hardware which had mostly been completed in the first report period. In the current report period the hardware of the sensor has been finalized so that the devices could be

delivered to Volkswagen and CRF for integration into the vehicle. For road condition estimation, a trial system based on 24 GHz radar has been set up and several field tests have been conducted to verify the results of the various simulation scenarios. The second part of this workpackage refers to data modelling and the development of tracking and classification algorithms, as well as implementing these algorithms on the sensor. A **novel waveform** based on linear continuous chirp sequences has been successfully implemented on the sensor. Based on the raw recorded data of the first measurement campaigns, the **tracking algorithm** and **classification scheme** that had been prepared in the first report period on simulated data could now be adapted and successfully implemented on the digital signal processor of the VRU ARTRAC sensor. In the third part of the work package, the performance of the sensors has been verified in laboratory tests.

Prototype:

D4.1 Multipurpose Radar Hardware – 10 Units of VRU Sensor manufactured

Public deliverable:

D4.5 The ARTRAC Sensor

In **workpackage 5**, the on board system software, actuation units and human-machine-interfaces for the Volkswagen and CRF demonstration car have been specified and designed. Based on selected scenarios and use cases, Global Control Strategies have been derived. Dependent on the observed situation, the on board system software decides to warn the driver visually and acoustically (CRF), to initiate evasive steering manoeuvres (VW) or trigger the braking system (CRF and VW). Algorithms for situation analysis and decision making have been developed based on physical assumptions and restrictions. Based on these algorithms, steering and braking control software has been designed and implemented. The ARTRAC Actuation Unit has been completed for integration into the demonstration vehicles of Volkswagen and CRF.

Public Deliverable:

D5.2 On-Board System Software

In **workpackage 6**, the ARTRAC sensors were successfully integrated onto the three vehicle demonstrators, one from VW, one from CRF and one from VTT. The communication links between sensors, actuation unit and on board system software could be successfully established. The demonstrator vehicles successfully implemented Frontal Collision Warning and Mitigation (CRF), automatic emergency braking and steering recommendation (VW) and road condition detection and friction coefficient estimation (VTT). All vehicles were equipped with demonstrational user interfaces to visualize sensor data and the actuation decision process. For CRF, a specially developed HMI has been integrated into the dashboard of the vehicle which allows a visual and acoustical warning for the driver in a danger situation.

Public Deliverable:

D6.2 Description of Integrated System

In **workpackage 7** an elaborate test catalogue has been developed for all components of the final ARTRAC systems. An overall test and evaluation concept has been developed based on the scenarios and use cases defined earlier in WP2. Then, every partner has created

dedicated test sets for their specific component. Smartmicro has specified and described their test measurement campaign with the ARTRAC sensor in a anechoic chamber for verifying the base performance of the sensor and for identify physical limitations of the sensing principle. TUHH designed unit tests and benchmarks in order to rate the classification algorithms. VW and CRF have agreed on a synchronous test catalogue exploring the defined scenarios with different vehicle speeds and parameters. VTT has created a series of tests involving the simulation of various dangerous road surface conditions, including ice, water and tree leaves on asphalt. In the next step, all partners have conducted the specified tests and documented the outcome. Finally, all developed systems have been demonstrated to the public including live demonstrations of selected scenarios on the Volkswagen proving ground in Ehra/Lessin.

Public Deliverable:

D7.3 Vehicle Presentation

In **workpackage 8**, intensive public relations work has been done. Besides taking continuously care of the **project website** www.artrac.org, five **project newsletters** have been published. The **International Radar Symposium 2013** in Dresden was used as a publication platform for the ARTRAC project, including the demonstration of the Volkswagen demonstration vehicle and a scientific session dedicated specifically to the ARTRAC project. On that event, about 300 experts in the field of radar could be targeted and informed about the good progress in pedestrian safety that could be achieved in this project. Additionally, **two project workshops** have been held. The first workshop was targeted at **VRU specialists**, while the second had a focus on **Sensor Specialists**. In these well visited events, all project partners presented their view and contribution to VRU safety and gave insights into the technology developed in the project to a variety of interested experts and students. Subsequently, intensive and fruitful discussions were possible between the participants and the ARTRAC partners. The partners have documented their dissemination activities and declared their plans to exploit the project results.

The ultimate highlight of the project was the Final Event held at the proving ground of Volkswagen in Ehra near Wolfsburg. About 50 persons, many of whom were from the production sector in addition to research oriented participant were presented with an overview of the work in the project and subsequently had the chance to take a test ride on the two demonstration cars, a Volkswagen Golf GTI and a Fiat 500L. A video of the event and the test rides is available on the project web site.

Public Deliverables:

D8.1 Project Website

D8.2 Project Brochure

D8.4 ARTRAC Workshop 1

D8.5 ARTRAC Workshop 2

D8.7 International Radar Workshop

D8.8 Newsletter No.1

D8.9 Newsletter No.2

D8.10 Newsletter No.3

D8.11 Newsletter No.4

D8.12 Newsletter No.5

Expected final results and potential impacts

The key of the ARTRAC project is a safety system to protect vulnerable road users (VRU) designed to be economically available in the volume vehicle market to decrease the number of fatalities on European streets. ARTRAC therefore combines actuators to control vehicle driving dynamics and active sensor technology measuring the vehicles environment. Critical safety situations may completely be avoided and passive safety elements, such as airbags, will be much more effective.

Therefore a new ARTRAC radar sensor measures range, radial velocity, azimuth angle in multi target situations and with high resolution. It has also a target recognition feature integrated, which distinguishes between radar echo signals from pedestrians, bicyclists, vehicles and static objects and is able to classify these different objects. A second ARTRAC sensor measures the road friction. As a reaction of a critical safety situation an extended functionality like automatic deceleration, steering recommendation and driver warning is performed in the vehicle adapted to the traffic situation and road surface is performed to safe the VRU. This safety system has a high potential to be launched because the majority of all components belong already to standard equipment in series cars.

It is obvious that following the idea to introduce pedestrian safety systems into compact class cars requires low-cost systems. In contrast to the high class car segment in the compact class car which represent the high volume the cost-sensitivity is much higher. To enhance pedestrian safety is both, a social/ ethical request as well as a request by customer protection organizations (like EuroNCAP). This fact is exactly addressed by the ARTRAC project. The research direction of ARTRAC is to enable pedestrian safety systems with only one cheap 24 GHz radar sensor. This would be a great benefit in terms of safety for pedestrians on European roads.

[1] European Commission, Towards a European road safety area: Policy orientations on road safety 2011-2020, Brussels, (2010).
[2] AUTOTECH CAST Europe, Harris Interactive 2006, European Consumer Advanced Automotive Technologies Report