CARSENSE – NEW ENVIRONMENT SENSING FOR ADVANCED DRIVER ASSISTANCE SYSTEMS

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Abstract

The CARSENSE programme, grouping together 12 major industrial and research partners[1] *and sponsored by the EC, is to develop a sensor system, the purpose of which is to provide sufficient information on the car environment at low speeds to assist in low speed driving in complex (urban) environments. This article describes the main objectives of the programme, these being the improvement of the individual sensors and the merger of the information from these sensors in a fusion unit.*

Introduction

After the introduction of Adaptive Cruise Control (ACC) into the market in 1999 all surveys and experimental assessments have shown a high interest and product acceptance for such systems. However, these first “advanced driver assistance systems” (ADAS) are very much limited to use on motorways or urban expressways without crossings. The traffic situations evaluated by these systems consist only of other vehicles, such as cars and trucks moving in simple patterns. Processing is restricted and can be focussed on few, well defined detected objects. Nevertheless, even for these relatively simple situations, these first systems cannot cope reliably with fixed obstacles. They also occasionally behave in an unexpected manner, causing surprise to the driver in 'cut-in' situations[2]. Here, the width of the sensor beam may not fully cover the area in front of the vehicle, resulting in a late response from the ADAS.

CARSENSE Objectives

When such ADAS are in wider use, it will be necessary to extend the operation envelope to cover more complex situations, such as dense traffic environments in sub-urban or urban areas. Traffic is characterised by lower speeds, traffic jams, tight curves, traffic signs, crossings and “weak” traffic participants such as motorbikes or bicycles. Very soon road scenarios become very complex and it is more and more difficult to operate an ADAS reliably. This is because those sensor systems currently available for monitoring the driving environment provide only a very small amount of the information which is necessary to manage these higher level driving tasks. It has been identified in previous R&D programmes, that one of the crucial requirements for achieving significant progress in ADAS technology is a considerable increase in the performance of the driving environment monitoring systems. This includes larger range, greater precision and higher reliability of the sensor information, as well as additional attributes. The way to reach this goal is to improve existing sensors, such as radar, laser and video, as well as to fuse the information/output of these different sensor systems.

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[1] Autocruise, BMW, CRF, Renault, IBEO, Jena-Optronik, Thales Airborne Systems, TRW Automotive, INRIA, INRETS-LEOST, ENSMP, LCPC-LIVIC

[2] The term 'cut-in' refers to other vehicles pulling in closely in front of the vehicle.

CARSENSE will develop a sensing system and an appropriate flexible architecture for driver assistance systems, with the aim being to advance the development of ADAS for complex traffic and driving situations, initially at low speeds. The ADASE (ref?) project identified that driver assistance at low speed is the next most feasible function after the introduction of ACC. However, this functionality requires two of the fundamental steps towards future ADAS: reliable information about stationary objects and a wider field of view, albeit only in the near range.

Based on these agreed scenarios, chosen to cover a large spectrum of low speed real-life situations, data from various sensors will be acquired simultaneously and recorded along with additional driving sequence description scripts. The scripts provide the partners with the means for calibrating their sensors and for testing their algorithms. LCPC (LIVIC department) will use it's own test tracks to achieve this task.

At the end of the project, a second set of tests will permit a study of the performance of each newly designed sensor. These will also help assess the benefits of sensor fusion and allow an evaluation of the detection performance of the entire system, and its capacity for coping with low speed driving situations.

System and Datalogging Architecture

The CARSENSE system is a multi-sensor data fusion system designed to detect objects in front of the host car. This multi-sensor data fusion system consists of a set of internal and external sensors from where information is fused within a single data fusion unit. Internal sensors give information about the host vehicle state, such as its velocity and steering angle information. External sensors (Laser, Radar, and image sensors) sense information outside the vehicle, such as obstacles and road information. All the sensors and the data fusion unit are connected via CAN busses. A system specification of CAN messages has been built according to external sensors constraints [1]. [2] shows a similar approach.

The development process, based on data collection and off-line processing, requires a reliable and powerful data logging equipment. The datalogger designated for this purpose has been developed by ENSMP. It is installed in the first architecture representing in addition an essential component for the control of the data flow within this architecture [10].

This CARSENSE system is implemented on a test vehicle (Fig. 1). The vehicle serves three main functions:

1. Collection of data with available sensors installed in the car and connected to the dataloger;
2. After having collected the scenario data, the car will be available for different individual tests and sensor verification until the final system is ready for installation;
3. In the final part of the project, the final system with improved hardware will be tested and its performance validated according to the scenarios.

Fig. 1: Test Vehicle Alfa 156 Sportwagon 2.0 Selespeed

The following paragraphs outline some new hardware and software developments being done within the framework of the CARSENSE project.

External Sensors and Data Fusion Hardware

Three kinds of sensors are embedded in the system (radar, laser and video sensors). Each one will have an intelligent processing unit and a CAN interface. A specific hardware is being developed for data fusion.

- **Radar Sensor**

Prototype radar sensors (Fig. 2) have been developed by Thales. They will later be commercialised by its subsidiary Autocruise. The technology used GaAs based Monolithic Microwave Integrated Circuits (MMIC). MMIC based radars have the potential to be produced at a low cost level that is acceptable to automotive customers [4].

The main technical characteristics of the radar are:

- Frequency: 76-77 GHz
- Range: <1 - > 150 m
- Search Area: 12°
- Speed meas. precision: < 0.2 km/h
- Angular Precision: < 0.3°

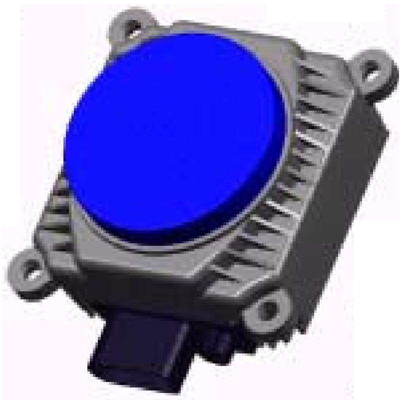

Fig. 2: Autocruise AC20 Radar Sensor

At the core of the radar is the transmitter / receiver module (T/R – Module). It contains all the microwave circuits necessary for the radar function.

Within the CARSENSE project, this radar sensor will be improved by Thales on two fronts:

- Widened field of view in the short range area (+/- 35 ° up to about 40 m) by use of a new optical part for the radar antenna
- Improved detection of fixed targets by use of a new waveform

In order to improve the later one, a digital FM radar waveform will be used that combines the advantages of frequency shift keying (FSK) with the advantages of Frequency Modulation (FMCW) (Fig. 3). This waveform has the following advantages:

- Allows a very high speed discrimination

- Allows fixed object detection and discrimination
- Ideal compromise for highway /road operations
- No distance nor speed ambiguity
- Low sensitivity to interference

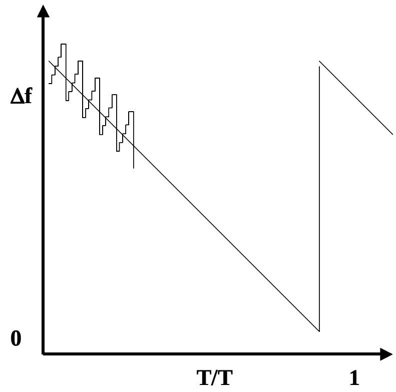

Fig. 3: Radar Waveform (Digital FM)

- **Laser Sensor**

The New IBEO laserscanner LD ML Automotive (Fig. 4) is a high resolution scanner with an integrated DSP for sensor-internal signal processing.

The laserscanner emits pulses of near infrared light and measures the incoming reflections of those pulses. The distance to the target is directly proportional to the time between transmission and reception of the pulse. The scanning of the measurement beam is achieved via a rotating prism. The measurements of one scan form a 2.5-D profile of the environment.

Expected characteristics (Prototype of the new laser sensor):

- Viewing angle: up to 270°
- Angle resolution: 0,35°
- Scan frequency: 10 Hz
- Distance measurements
  reflecting targets: up to 150 m
  dark targets (reflectivity 5 %): up to approx. 30 m
- Distance Accuracy: +/- 5 cm (1 sigma)
- Eye-safe: laser class 1

Fig. 4: New IBEO Laserscanner LD ML Automotive

The measurement control is done by a micro controller. The distances and corresponding angles result in 2.5D range raw data profiles, which are transmitted to the DSP where application-specific calculations are performed in real time. The raw data are divided into segments, which are assigned to objects on the street and of the boundary. Relevant objects are tracked using Kalman-filters. Object parameters like position, size and velocity are calculated in this process. They are transmitted to the host computer via a CAN bus.

- **High Dynamic Range Video System**

A video sensing system is being developed for sensing features such as stationary and moving obstacles and road information. This will consist of multiple cameras and a dedicated embedded processing unit. The cameras are being developed by Jena-Optronik GmbH, exhibiting a high dynamic range (to cope with ambient lighting conditions outside the vehicle) and a high resolution. The purpose of the processing unit is to enable image processing algorithms to operate at real time (frame rate ~ 25 Hz), while demonstrating a clear relationship between the development hardware and that which will go into production .

Fig. 5 : High Dynamic Range Video System

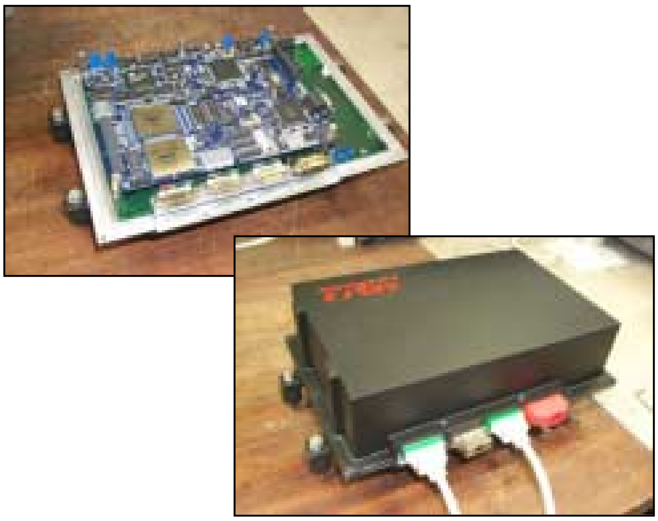

Fig. 6: Embedded Image Processing & Fusion Unit

TRW Automotive is developing a high performance platform (Fig. 6) which contains both a Field Programmable Gate Array (FPGA) and Digital Signal Processor (DSP) which is capable of processing raw video at a high data rate.The hardware will consist of an embedded micro controller to handle communication with the rest of the subsystems. It will have two CAN2.0B interfaces, each running at a maximum of 1Mbps. This micro controller has a low overhead dual-port RAM interface to the algorithm DSP which is capable of 800 million floating-point operations per second (Mflops). For visualisation of the data, the DSP has access to an SVGA frame buffer which can display the road scene as viewed by one of the CARSENSE cameras, with graphics overlaid by the DSP. The whole system will be housed as an embedded unit, with an internal automotive power supply unit[11].

The unit is modular and stackable, so that multiple algorithms can be tested on additional processing boards, and those algorithms that require more processing power than is provided by a single FPGA/DSP subsystem can make use of multiple processors, if necessary.

This development platform will demonstrate that complicated image processing algorithms can be realised using a cost effective embedded hardware solution.

- **Data Fusion Hardware**

The requirement for the architecture to be flexible has lead to an Object-Oriented approach being taken. This leads to an open hardware requirement, with the software design (developed by TRW) being platform independent. The choice of platform is driven by the requirement for enough processing power for the data fusion algorithms at least 2 CAN buses capable of the CAN2.0B specification.

Initially algorithm development will make use of a PC platform, for ease of implementation. The final solution will be implemented on an embedded platform. This leads to a split of the fusion CPU and the Comms CPU. Depending on the computational requirements of the data fusion algorithms, the system can be implemented on either a single CPU or a platform similar to that in development for real-time image processing. To enable an object orientated approach to be taken, a translation layer is currently required to convert the inputs from the various sensors into a standard object format. Ultimately this will be performed by the individual sensors themselves, reducing the Comms CPU processing load, and making possible the use of a single CPU for system implementation[12].

Algorithm developments

Video processing and data fusion algorithms will be developed by INRIA, LCPC (video and data fusion), INRETS-LEOST, and TRW (data fusion).

- **Video Processing**

The vision task (LCPC) can be split into two main topics : Lane Marking Detection and Obstacle Detection :

- **Lane Marking Detection**

The robust detection and tracking of lane markings and lane boundaries, using on-board cameras, is of major importance to the CARSENSE project. Lane boundary detection can assist the external sensors in identifying whether obstacles are within (or out of) the host vehicle's lane. Road boundary detection must at least provide, with high accuracy, estimates of the relative orientation and of the lateral position of the vehicle with respect to the road.

Two approaches, based on different road model complexity, will be tested:

- First, a real-time algorithm [7] will allow computation of the orientation and lateral pose of a vehicle with respect to the observed road. This approach provides robust measures when lane-markings are dashed, partially missing, or perturbed by shadows, highlights, other vehicles or noise.
- The second approach [8], contrary to usual approaches, is based on an efficient curve detector, which can automatically handle occlusion caused by vehicles, signs, light spots, shadows, or low image contrast. Shapes in 2D images are described by their boundaries, and represented by linearly parameterised curves. We do not assume particular markings or road lightning conditions. The lane discrimination is based only on geometrical considerations.

- **Obstacle detection through stereovision and fusion**

Here, the aim is to detect obstacles located at less than 50 metres in front of the test vehicle. For CARSENSE, an obstacle is a vehicle (car, truck), a motor bike, a bicycle or a pedestrian cutting into the host vehicle's trajectory.

A binocular vision and multi-sensor fusion approach is proposed, which allows the detection and location of such objects. Thus, the matching of data from the two cameras makes it possible, via triangulation, to detect objects located above the roadway and to locate them relative to the host vehicle. The matching process may use results obtained from other types of sensors (range-finders) in order to make reliable detection and increase the computational speed (co-operative approach).

- **Data Fusion processing**

Multiple sensors, apart from providing different coverage, can detect the same object, but with differing accuracy of the parameters describing that object (for instance, range and angle). This information is complimentary, and leads to a measurement of higher integrity, accuracy and confidence. In addition to this, certain sensors may see information 'invisible' to other sensors, such as video's ability to locate road markings. This assists in improving the positioning of objects with respect to the real-world, rather than the subject vehicle.

Data Fusion involves, as its name implies, the merging of the information provided by different sensors in order to get a better picture of the environment in front of the vehicle.

The different sensor units deliver processed information about the road geometry (curvature, etc.). They also deliver information about relevant objects detected in the vicinity of the CARSENSE vehicle, in the form of a list of objects. Each object is characterised by a certain number of attributes, such as position, velocity, etc., the quality of which depends on the sensor / processing unit under consideration.

The goal is to develop vision algorithms in order to detect obstacles on the road and to produce the trajectories of the various object of the scene (other vehicles as well as static obstacles). To achieve this goal INRIA will develop algorithms based on motion analysis, that enable to compute the dominant image motion component, assumed to be due to the car motion. The principle of this algorithm is to determine the polynomial model (constant, affine, and quadratic), which closest describes the image motion in a specified zone of the image by statistical multi-resolution techniques. Detection of obstacles can then be done by because the apparent image motion is not compatible with the computed dominant motion. The trajectories of these objects, as well as the time to collision, can then be computed and provided as input to the car system.

LIVIC will also be involved in the development of algorithms for combining the outputs of the various sensors in order to improve performance and robustness. A map of the object locations in the front of the equipped vehicle will be provided, so their relative speeds and an estimation of the confidence and precision over the detection will be computed. LCPC (LIVIC) will focus on the fusion of the vision and telemetry systems.

Summary and Conclusion

The CARSENSE project is an important step on the way to high performance perception systems in future ADAS. The combination of multiple sensor information will improve object detection reliability and accuracy over that derived from today's sensors. With the development of new sensor functions, such as detection of fixed obstacles and wider field of view, the systems will be capable of use in urban areas, and high integrity (and comfort) ACC systems. Ultimately these sensing systems may be used in safety applications such as Collision Mitigation or even Collision Avoidance.

Acknowledgments

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The CARSENSE programme is planned to finish at the end of 2003. The objective of the partners is to use the obtained results, and their benefits, in their own product development. Serious application of such systems is hence not far away.

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