Guest Editorial - Special Section on In-vehicle Embedded Systems

Françoise Simonot-Lion

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Over the past two decades, there has been a significant increase in the number of computer based functions embedded in vehicles. While automobile production is likely to increase slowly in the coming years, the part of embedded electronics and more precisely embedded software is growing. In 2006, the electronic embedded system represented at least 25% of the total cost of a car and more than 35% for a high-end model [1]. This trend has been driven by economical as well as technological factors. On the one hand, several local area networks were specifically developed for the automotive industry such as LIN [2], CAN [3], FlexRay [4][5], MOST and IDB-1394 [7][8]. This has led to the concept of multiplexing, whose principal advantage is a significant reduction in the wiring cost as well as the flexibility it gives to designers; data (e.g. vehicle speed) sampled by one microcontroller becomes available to distant functions that need them with no additional sensors or links. Furthermore, while the reliability and the performance of hardware components are increasing, their cost is decreasing. On the other hand, several new functions whose development would be costly or even not feasible if using only mechanical or hydraulic technology can be realized thanks to software technology, satisfying therefore the end user requirements in terms of performance, cost, safety and comfort. In short, thanks to these technologies, the customers can buy a safe, efficient and personalised vehicle while the carmakers are able to master the differentiation of product variants and the innovation (in 2002, analysts stated that more than 80% of added value, will be obtained thanks to electronic and software-based systems [9]). A new factor, multimedia and telematics in vehicles, is emerging. This domain includes systems that support information exchanges inside a vehicle, between vehicles or between vehicle and road infrastructures. Even if these kinds of applications have little to do with the vehicle's operation itself, they grow significantly the part of software embedded in a car and require a high level of real-time quality of service and an important increase of the computation power.

The development of an embedded electronic architecture is a cooperative work involving an OEM (Original Equipment Manufacturer, or carmaker) and several Tier 1 suppliers. The result of this work is a complex distributed system, integrating several heterogeneous communication networks, and subject to stringent safety requirements.

In the near future, the development process of in-vehicle embedded systems will be leaded by the safety concerns because of the emerging ISO 26262 standards [10] that are likely to influence the certification process for embedded systems of the automotive domain in terms of dependability guarantee. Nevertheless, in a highly competitive domain like the automotive industry, the design and production costs must be kept as low as possible. In this context, it is vital for the different stakeholders to master the complexity of the design of the embedded electronic architecture. One way to reach this goal is to use a modelling language capable of representing the system at all its design steps and common to all the actors involved in the design process (such languages have been developed: AIL_Transport [11], EAST-ADL [12], EAST-ADL2 [13].) These languages are mainly based on a reference architecture of the embedded systems. A reference architecture defines the overall organization and the models of computation and communication used to implement computer-based systems of a certain domain. A first study was carried out within the TTA project, which focused on time-triggered architecture [14]. The proposal was intended to ease "composability" and to provide a transparent implementation of fault-tolerance mechanisms. A similar target is the first objective of the international program AUTOSAR [15][16], which gathers the majority of the stakeholders of the automotive industry in the world. One of the goals of the AUTOSAR project is to make it possible to separate software from hardware in the design process of a complex distributed technical architecture, thus allowing the portability of application software components, the flexibility for product modification, upgrade and update, the scalability of solutions within and across product lines, and the improvement of the quality and reliability of embedded systems.

In this global context of standardization, the AUTOSAR reference architecture and the ISO 26262 safety standard, two problems have to be tackled simultaneously: the integration of components (hardware but mainly software) and the guarantee that the resulting global system will not jeopardize the safety of the vehicle while ensuring a low cost for the carmakers as well for the customers, and a high level of performance and comfort. Therefore, the keywords are "composability", portability, safety assessment, real-time assessment and schedulability analysis for tasks and messages.

This Special Section on "In-Vehicle Embedded Systems" presents four papers that deal with relevant aspects pertaining to the topics highlighted above, covering a spectrum of topics, ranging from schedulability and real-time Quality of Service analysis, thanks to deterministic as well to stochastic approaches, to the composability issues when components provided by different partners are to be integrated or when the designer wants to obtain preliminary results on end-to-end response time during earlier phases of the design process.

The paper "*A Synchronization Protocol for Temporal Isolation of Software Components in Vehicular Systems*", by Thomas Nolte, Insik Shin, Mikael Sjodin and Moris Behnam,

deals with the temporal interoperability issue when integrating functions that are developed independently. The problem is there to guarantee a predictable behavior of the whole system. The proposed technique is based on the temporal isolation of the different functions and is specifically well suited to the AUTOSAR context. A schedulability analysis completes the proposed mechanisms.

It can be difficult and even not possible to compute a tight upper bound for end-to-end response time of a complex function distributed onto several ECUs communicating through a network. Therefore a probabilistic approach [17] is a good way to obtain valuable information in the early stage of the architecture design. How to evaluate the probability distribution of the end-to-end latencies in a CAN-based architecture is the topic of the paper "*Stochastic Analysis of Distributed Real-time Automotive Systems*" proposed by Haibo Zeng, Marco Di Natale, Paulo Giusto and Alberto Sangiovanni-Vincentelli.

Several economic and technical reasons justify the introduction of multicore nodes in a vehicle. First a large amount of functions require an always increasing computation power (complex control laws or multimedia streams handling). Then, each core can be dedicated to specific functions such as, for example, the AUTOSAR communication stack or specific sensors handling functions. Finally, these new architectures can support the deployment of safety mechanisms (redundancy of components, active / passive control of software components, etc.). Safety and real-time assessment as well as deployment optimization are two problems that have to be taken into account in this new context [18]. The paper "*Response Time Analysis in Multicore ECUs with Shared Resources*" from Simon Schliecker, Mircea Negrean and Rolf Ernst shows how to ensure the predictability of real-time requirements. In particular it develops an analytical approach in order to determine the worst-case response time for tasks allocated on a multicore ECU with shared resources.

The paper "*Traffic Shaping for Resource-Efficient In-Vehicle Communication*" from M. Rahmani, K. Tappayuthpijarn, B. Krebs, R. Bogenberger and E. Steinbach investigates the impact of the introduction of IP-based network architecture in in-vehicle embedded architecture. More precisely, they propose to deploy multimedia applications onto a full-duplex switched Ethernet. For such application, the challenge is to guarantee the real-time Quality of Service for the transmission of audio and video stream. The authors propose a novel traffic shaping policy suited to these applications, evaluate its performance and detail how to implement it.

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