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ScienceDirect

Procedia Technology 26 (2016) 570 – 579

Procedia Technology

3rd International Conference on System-integrated Intelligence: New Challenges for Product and Production Engineering, SysInt 2016

An Automotive Distributed Mobile Sensor Data Collection with Machine Learning Based Data Fusion and Analysis on a Central Backend System

Tim Tiedemann[a,*], Christian Backe[a], Thomas Vögele[a], Peter Conradi[b]

[a]*DFKI GmbH, Robotics Innovation Center, Robert-Hooke-Str. 1, 28359 Bremen, Germany*
[b]*ALL4IP TECHNOLOGIES GmbH & Co. KG, Berliner Allee 65, 64295 Darmstadt, Germany*

Abstract

One of the most extensive examples for ubiquitous computing today is automotion. The equipment of sensors and independent computing devices in current vehicles is vast if not endless. Furthermore, traffic infrastructure is realized using global and local computing devices. Communication initiated by the car itself (e.g., to an emergency hotline) will be obligatory in some countries soon. And finally, by using a smart phone the driver brings an additional powerful computing device and sensor set to the vehicle.

However, all these automotive sensors and computing devices are used just for fixed (and in most cases single) purposes. Data exchange between vehicles or vehicles and infrastructure is rarely done. And dynamic changes like compensating for a broken sensor with available other data, using old sensor equipment for new functions, or improving old driver assistance systems with new sensors is not possible, either.

The objective of the collaborative research project Smart Adaptive Data Aggregation (SADA) is to develop technologies that enable linking data from distributed mobile on-board sensors (on vehicles) with data from previously unknown stationary (e.g., infrastructure) or mobile sensors (e.g., other vehicles, smart devices). One focus of the project is the dynamic and fully-automated switching between different sensors or sensor configurations, including the adaptation of data fusion processes. Technically, one important component for some of the SADA use cases is a central backend system that (1) collects sensor data of the vehicles and/or the infrastructure, (2) fuses these data, and (3) carries out machine learning (ML) based analysis of the data to generate new information for the drivers (sometimes refered to by the term “virtual sensors”).

The article gives a short overview of the SADA project and describes in more detail the concept of the backend system architecture, the user interface, and the methods and processes needed for a demonstration use-case.

Peer-review under responsibility of the organizing committee of SysInt 2016
Keywords: Sensor Cloud; Pervasive Computing; Distributed ML; IoT; Big Data

* Corresponding author. Tel.: +49-421-17845-6640.
E-mail address: tim.tiedemann@dfki.de

Peer-review under responsibility of the organizing committee of SysInt 2016
doi:10.1016/j.protcy.2016.08.071

1. Motivation

The basis for dynamic data fusion in automotive applications has already been on the streets for years now. Sensor equipment and computing power are present in virtually every vehicle, as well as in the traffic infrastructure. And applications are obvious in the form of the advanced driver assistance systems (ADAS) offered by car manufacturers or community-driven social mobile apps guiding the driver through traffic or to parking spaces. What is missing is the possibility to dynamically adapt the system, e.g., adding or removing components, using data of local or remote sensors, for new and old applications.

The collaborative research project SADA consists of the partners SIEMENS AG (lead), NXP Semiconductors GmbH, fortiss GmbH, Baselabs GmbH, DFKI GmbH, and ALL4IP TECHNOLOGIES GmbH & Co. KG. Its objective is to develop technologies that enable dynamical linking of data from distributed mobile on-board sensors (on vehicles) with data from previously unknown stationary (e.g., infrastructure) or mobile sensors (e.g., other vehicles, smart devices). The sensors are connected independent of their brand, manufacturer, or application area in an intelligent and flexible way. SADA plans to provide interfaces and methods that enable the unrestricted dynamic integration and analysis of data from multiple heterogeneous sensors. One focus of the project is the dynamic and fully-automated switching between different sensor configurations, including the adaptation of data fusion processes. This is necessary, e.g., when, caused by the movement of the mobile sensor platform (vehicle), new sensor infrastructures become available or drift out of reach. The automatic adaptation of the system to new situations is made possible by semantic descriptions of sensor properties, the operational environment, and necessary algorithms, which are modeled explicitly and shall be provided along with the sensor data. With such a combination of (1) dynamic sensor configuration changes, (2) explicit support of heterogenous, brand/manufacaturer-independent and even cross-applicational data exchange, and (3) a consortium of scientific research institutes and industrial partners, SADA is unique.

Technically, one important component for some of the SADA use cases is a central backend system that (1) collects sensor data of the vehicles and/or the infrastructure, (2) fuses these data, and (3) carries out machine learning (ML) based analysis of the data to generate new information for the drivers. Ideally, crowd sensing (emergence of information by combination of data from spatially distributed sensors) may lead to so-called "virtual sensors" (generated in the backend system) that can be fed back into the SADA fusion process.

SADA technology could be used for example to support driving comfort functions, to increase driving safety, and to contribute to more efficient and environmentally friendly traffic (e.g., by preventing traffic jams and searches for parking space). An online data exchange from a user and their vehicle to other vehicles, to infrastructure, and back to the vehicle, its ADAS, and to the user is an intrinsic component. Therefore, ubiquitous computing, distributed data collection, and machine learning are central topics in the project.

It is planned to develop a micro-positioning use case for automotive applications where the exact location is required. Here, a sensor or a sensor cluster can be adapted instantly. Applications could be, for example, autonomous parking, autonomous fuelling of a combustion-engined vehicle, or positioning an electric vehicle over an inductive charging spot. For the intended use case, an improved localization is presented as the result of a dynamical sensor fusion process. As user interface in this positioning task a smartphone is planned to be used. An app on the smartphone shall read the coordinates and display dedicated control instructions for the user to position the vehicle precisely over the inductive charging station.

2. Related Research Projects

2.1. General Traffic-Related Research Projects

From 2007 to 2010, in the thematically wide-ranging research project "Aktiv", funded by German BMWi and BMBF, techniques were developed to help traffic-control systems collect and broadcast information, to improve the active safety in vehicles, and to improve the results by using Car2Car communication. Information was exchanged about traffic events and traffic situations [1,2].

In about the same period, from 2006 to 2010, the European research project "coopers" was conducted [3]. Its focus was on cooperative traffic management, supported in particular by car-to-infrastructure communication. A substantial