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Personalised assistance for fuel-efficient driving

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ABSTRACT

Recent advances in technology are changing the way how everyday activities are performed. Technologies in the traffic domain provide diverse instruments of gathering and analysing data for more fuel-efficient, safe, and convenient travelling for both drivers and passengers. In this article, we propose a reference architecture for a context-aware driving assistant system. Moreover, we exemplify this architecture with a real prototype of a driving assistance system called Driving coach. This prototype collects, fuses and analyses diverse information, like digital map, weather, traffic situation, as well as vehicle information to provide drivers in-depth information regarding their previous trip along with personalised hints to improve their fuel-efficient driving in the future. The Driving coach system monitors its own performance, as well as driver feedback to correct itself to serve the driver more appropriately.

1. Introduction

The number of cars is increasing. Cars make our lives more convenient but have shortcomings as well. First, it is well known that car emissions have high effects on air pollution (European Environment Agency, 2011). Another worrying issue is that, among transport accidents, passenger car accidents have one of the leading positions (Eurostat, 2009). Different factors affect both of these characteristics, like driver experience, car model, traffic situation, and weather conditions. Often, a driver cannot understand or distinguish all these factors in order to optimise his driving. Our research aims to deliver to the driver information on his driving behaviour and instructions for safer and more environmentally-friendly driving.

Many researchers have investigated what affects fuel usage and emissions of a car, can the driver affect these parameters and how. Sivak and Schoettle (2012) classify the driver decisions which affect fuel consumption into strategic (vehicle selection and maintenance), tactical (route selection and vehicle road), and operational (driver behaviour). The authors discovered that vehicle selection has a dominating effect on fuel economy, but the remaining factors can contribute, in total, to about 45% reduction in fuel consumption. Ericsson (2001) has investigated the factors of driving behaviour which affect fuel consumption. From her findings, the most influential factors include stops during run, extreme acceleration, and late change from 2nd to 3rd gear. In turn, driving behaviour depends on many factors, among others are street and traffic environment (Brundell-Freij and Ericsson, 2005). For instance, the density of junctions controlled by traffic lights seems to have a high effect on driving behaviour and hence on fuel consumption and car emissions. Thus, route selection is an important factor having influence on fuel efficiency (Sivak and Schoettle, 2012; Brundell-Freij and Ericsson, 2005). Route selection refers to

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planning a trip in such a way that the number of stops, high speeding, etc. are minimised. Ericsson et al. (2006) have calculated that a fuel-efficient route can save about 8% of fuel. Also, their study demonstrated that a fuel-efficient route is about the same as the shortest one. No significant fuel reduction effect was found for the fastest route option. Aggressive driving is another factor affecting fuel-consumption (Sivak and Schoettle, 2012; Brundell-Freij and Ericsson, 2005). Aggressive driving means certain actions increasing the risk of road accident, like excessive speeding and improper turning. In fact, aggressive driving is found to be one of the main causes of car accidents (The AAA Foundation for Traffic Safety, 2009). Based on the related work, we may conclude that it is possible to minimise fuel consumption by discovering the most relevant factors and informing drivers how to improve their driving behaviour with respect to these factors.

On the other hand, drivers vary a lot. They have different driving experience, preferences, and habits. Hence they require tailored solutions to explain what can be improved in their driving style and how (Gonder et al., 2011). Moreover, different external factors, like traffic fluency situation, road quality, and weather may affect performance of drivers. Hence, the overall situation should be assessed to promote more fuel-efficient driving. This information is referred as context, and systems able to capture the context and react on its changes are called context-aware (Dey, 2001). In this article, we argue that context-aware driving assistant systems provide more adequate feedback to drivers regarding fuel-efficient driving.

In this article, we propose a reference architecture for context-aware driving assistance systems. This architecture is aligned with a Meta-level control framework presented by Gilman and Riekki (2012). Their framework emphasises the necessity for self-introspective functionality for personalised and adaptive systems. This framework adds a controlling and monitoring layer to such systems. Moreover, it emphasises monitoring the overall interaction to gather feedback about how well the system supports its users in their tasks. For instance, with this kind of functionality, the system would notice that a driver constantly ignores certain advice and would perform actions to resolve such cases.

The proposed architecture is exemplified with a driving support system called Driving coach. This system teaches a driver to drive better. Better driving in this context means: (1) avoiding aggressive driving, (2) trip planning, and (3) driving in a fuel-efficient manner. The system is based on real-time information, obtained from on-board sensors and external services. The driver gets feedback about his driving after each trip: comments and recommendations what to do differently in order to drive better. The key characteristics of our system are:

1. Fusion of on-board information and real-time information from third party services.
2. Identification of personal driving factors affecting the fuel use in certain situations.
3. Adaptation of the system's decision-making with respect to a driver's progress and responses to recommendations.

Although many applications have been developed for driver assistance, our application is unique in combining these three characteristics.

The contribution of this article can be summarised as follows: First, we apply the Meta-level framework to create a reference architecture for context-aware driving assistance systems. Second, we propose Driving coach, which serves as the implementation use case for this reference architecture. Driving coach is a fully implemented and functional prototype which gathers diverse data from real trips (driving data, weather data, traffic situation data, and digital map data), analyses these data and presents feedback to the driver after the trip.

The rest of the article is structured as follows: First, we present a review of related research in Section 2. Section 3 presents our vision to equip driving assistance systems with Meta-level control. Section 4 discusses the big picture of Driving coach. Then, we provide details on data used in Section 5. Section 6 describes Driving coach core. Web interface of the system is presented in Section 7. Finally, we conclude the paper with Section 8.

2. Related work

Recently, keeping in mind that driving behaviour affects fuel consumption significantly, car manufacturers have started to invest in the development of on-board systems that provide drivers feedback about their driving (e.g., SmartGauge[1], ECO ASSIST[2]). These systems provide visual feedback about whether driving is fuel-efficient together with statistics about fuel consumption and possible savings. Another illustrative approach is ECO Pedal[3] from Nissan, which provides physical feedback with a pedal push-back control mechanism when a driver accelerates too heavily. More detailed analysis of trips is provided by Fiat eco:Drive[4] system. This solution gathers statistics about trips and provides explanatory feedback about how to drive more fuel-efficiently. On-board diagnostic scanners are becoming the most common tools for monitoring driving behaviour, as they can be bought separately and plugged into on-board diagnostic ports. Kiwi Drive Green[5] system serves as an example of such a tool. Kiwi device plugs into an on-board diagnostic port to obtain sensor information about the vehicle. The device analyses driving behaviour and delivers this information to the driver. The systems listed above are oriented for real-time driver awareness about fuel consumption and hence car emissions. Only eco:Drive system from Fiat provides explanatory feedback.

[1] http://en.wikipedia.org/wiki/Ford_Fusion_Hybrid#SmartGauge_for_eco_driving.
[2] http://world.honda.com/INSIGHT/eco/index.html.
[3] http://www.nissan-global.com/EN/NEWS/2008/_STORY/080804-02-e.html.
[4] http://www.fiat.com/ecodrive/.
[5] http://www.plxdevices.com/product_info.php?id=SCANKIWI.