Conference Paper

Conceptual Model for an Intelligent Persuasive Driver Assistant

Siam Yamsaengsung and Borworn Papasratorn

School of Information Technology, King Mongkut's University of Technology Thonburi, Thailand

Abstract

Traffic congestion is a serious issue for large cities. This is especially critical for cities that has insufficient mass transit system like Bangkok. Although transportation infrastructure projects and rail mass transit lines are being implemented, these efforts require major financial investment and take a long time to complete. This work proposes to help reduce traffic problems through influencing a change in driver behavior. In this initial stage, a model for an intelligent persuasive driver assistant is conceptualized as a voice-interactive smart assistant on a smartphone. The system uses information about the driver, his physical state, vehicle performance information, and geolocation information to form persuasive strategies to influence driver behavior and to adapt user interfaces and interactions to reduce driver distraction. Integrating these components together is expected to provide improved assistance in driving tasks and affect driving behavior changes.

Keywords: intelligent driver assistant, navigation, smart assistant, persuasive technology

Corresponding Author:
Siam Yamsaengsung
siam@sit.kmutt.ac.th

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1. Introduction

Traffic congestion is a serious problem in large cities where the number of cars far outpace the infrastructure. Some of the negative effects include air pollution, wasted fuel, lost time, and stress for drivers and passengers alike. These issues are especially critical for cities that are still developing its mass transit infrastructure like Bangkok. Although improved transportation infrastructure and mass transit systems will certainly help, but it will require significant financial investment and many years to implement and expand service areas to an adequate level. Meanwhile, alternate solutions must be explored. Insufficient infrastructure is certainly a major cause of traffic problems, but some of the problems can also be attributed to driver behavior. To provide some examples, previous works have reported that providing information and feedback (e.g. fuel consumption effects of aggressive driving) can affect behavioral changes in ecological driving [1] and providing information about headway (the time it takes a following vehicle to reach the position of the lead vehicle) can increase the distance from the lead vehicle [2]. Persuasive strategies have also been successful in influencing driver behavior [3]. It has also been suggested that matching feedback to driver goals could also enhance the behavioral changes effect [4]. To our knowledge, although previous works have demonstrated successful cases of influencing behavioral changes, but no work has integrated a smart assistant with persuasive strategies to influence driving behavior. It is with these observations that this work proposes an integrated model for an intelligent persuasive driving assistant that can customize its interactions with the driver based on his driving goals while providing suggestions for desirable driving behavior.

The next section provides a brief overview of key components for developing an intelligent persuasive driving assistant, followed by the proposed conceptual model and a conclusion section.

2. Components of a smart driver assistant

In aiming to address the issues noted above, the proposed conceptual model for an intelligent persuasive assistant in this work draws on a number of research areas including Traveler Information Systems, Advanced Driver-Assistance Systems, Smart Assistants and Persuasive Computing.

2.1. Navigation information and driver behavior

Many research works in advanced traveler information systems (ATIS) has explored how drivers make route choices when provided with various traffic information such as trip time, expected arrival time (ETA), and congestion level [5, 6]. Although research has shown that the overall traffic system performance would improve when drivers follow the recommended routes [5], but drivers do not always follow the suggested routes. There are many factors that have been reported to influence route choices including the perceived accuracy of the information (i.e. ETA, trip time) [7], trip purpose (work, school), and trip distance [8]. In a more recent work, Djukic [9] explored the use of navigation apps on smartphones, and reported that drivers follow the suggested route around half the time and tend to follow their habitual routes rather than the suggested detour or short cut.

Although the navigation services do have some inaccuracies in their estimates, in most situations, a few minutes difference from actual travel time is likely to be acceptable. As an anecdotal example, CNBC News [10] in the United States (www.cnbc.com) conducted an unscientific comparison of Apple Maps, Google Maps, and Waze navigation recommendations during a holiday weekend and found that the three services suggested different routes and estimated trip times. In the three legs of the trip, the three navigation systems produced estimates that differed from the actual trip time at a maximum of 14 minutes for a 50-minute drive. More advanced map services are expected to provide improved estimates and more detailed and accurate map information. For example, HERE HD Live Map utilizes crowdsourced vehicle sensor data from hundreds of thousands of cars and other sources such as satellite and aerial imagery, and mobile probes to continuously update map information [11].

As noted above, even if navigation systems could provide more accurate information about traffic conditions and recommend the best routes to use, it is unlikely that all drivers would follow those recommendations. Influencing drivers to change their habits could be addressed by persuasive technologies as further described in the next sections.

2.2. Vehicle information

Many technologies are available to help make driving safer and more convenient. Advanced Driver Assistance Systems (ADAS) rely on a multitude of sensors such as cameras, radar, infrared, and LIDAR to detect a vehicle's operating conditions and the surrounding environment. ADASs can perform many functions such as providing alerts if there is a vehicle in the blind spot when changing lanes (Blind Spot Monitoring), controlling the speed of a car to match with the vehicle in front (Adaptive Cruise Control), steering the vehicle to the middle of the lane if unintentional drift is detected (Lane Keeping Assistance) and apply the brakes to avoid collision or mitigate damage in an emergency (Automatic Emergency Braking) [12–14]. These systems can provide detailed information about how a car is driven; such information can be used to create a driver profile in order to provide more customized information, assistance, and appropriate persuasive strategies. Research has shown that providing safety information to the driver can change driving behavior. For example, [2] and [15] reported that providing temporal headway information to drivers caused them to increase the distance from the leading vehicle. Where such systems are not available as part of the vehicle equipment, smartphone sensors can be used to detect vehicle movement and infer driving style such as calm driving or aggressive driving [16, 17] which can also be used as the basis for forming persuasive strategies.

2.3. Smart assistants

Smart assistants such as Apple Siri [18], Google Assistant [19], and Amazon Alexa [20] have become a popular mode of interaction for many applications. The speech-to-text and natural language processing capabilities of these services allow users to talk to the assistants and ask them to do various things. This could be searching the Internet, setting an alarm, or adding an appointment to calendar. Voice interaction has been implemented in popular navigation services such as Google Maps, and Garmin Speak [21] since it offers hands-free operation and less distraction. Drivers could issue many different commands such as "navigate home," "show route over view," or ask "what's my ETA on this route" [22]. Additionally, smart assistants can use adaptive interface techniques to form strategies to interact with the driver. For example, a smart shopping assistant can adapt the presentation of product information based on observed (through sensors) user actions such as showing product details when a shopper looks closely at a product, or showing comparison information when the shopper picks up two items [23]. Machine learning also allows an intelligent agent like SARA [24, 25], a socially aware dialog system, to learn to classify human conversation. SARA can observe physical cues (eye gaze, smiling, and head nod) and conversation strategy (self-disclosure, reference to shared experience, praise, and violation of social norm) through the words being spoken by the interlocutor and use this to adapt its own communication strategy to match the conversation style. With this kind of technology, smart assistants could learn to observe driving behavior and recognize driving styles [16, 17] and dynamically adapt its voice and visual interaction strategies to suit the driver.

2.4. Persuasive systems

Some auto makers have equipped their cars with persuasive technologies to help drivers improve fuel efficiency. For example, Honda Eco Assist provides real-time feedback to the driver, by changing the color of the speedometer background, to indicate acceleration and braking efficiency. And Honda Eco Guide encourages 'ecological driving' by showing the number of 'leaves' a driver has earned for his driving efficiency on a trip along with a bar graph for a cumulative score [26]. In their review of 40 eco-driving research, Kurani et al. [1] reported that sixteen studies, which used various in-vehicle feedback strategies, produced an average fuel savings of 5.6%. Additionally, [4] also suggested that matching the feedback strategy to a driver's prior goal (e.g. get around faster, save fuel, save money, etc.) could further increase the fuel-reduction effect. This change in driver behavior is not only true for driving ecologically, but also for safe driving as well. Birrel et al. [15] used a smartphone connected to a modified forward collision warning system to provide headway feedback to the driver. Based on the recommended 2-second headway distance, the system would display an amber indication when the headway was less than 2 seconds and display a red indication when headway was less than 1.5 seconds. The resulting average headway was found to increase by 13.7% to 2.33 seconds compared to 2.05 seconds for the control condition. With many research showing that ecological and safe driving behavior can be affected by providing feedback, using a smart assistant that can employ a variety of persuasive strategies that aligns with a driver's mobility goals should be able to influence behavioral changes as well.

2.5. Driver information

In order to provide improved feedback that will better align with a driver's goals and actions, a system would need to know something about the driver. Similar to [25], a smart driving assistant can have a conversation with the driver to elicit mobility goals such as fuel efficiency, safety or ecological driving. The driving style could be observed by the smart driver assistant through ADAS sensors, the vehicle's Controller Area Network (CAN) bus or even with smartphone sensors [16, 17, 27]. Although there are various classifications of driving styles, but in general they could be characterized as calm driving (avoid harsh acceleration and braking), normal driving (moderate acceleration and braking) or aggressive driving (sudden acceleration and heavy braking) [27]. The physical state of the driver could be detected through wearables with heart rate sensors in order to estimate cognitive workload [28]. If wearables that can monitor heart rate were not available, an approach used by Tchankue, et al. [29] to develop an adaptive in-car communication system that uses a neural network to detect driver distraction level from the car speed and steering wheel angle could also be employed. The system, called MIMI, was designed to manage phone calls and text messages through voice commands. When the driver is classified as under medium distraction or higher (e.g. driving and high speed, making sharp turns), the system would automatically silence incoming calls and postpone alerts for messages. Alerts about incoming communications would then be delivered to the driver when he is experiencing low stress. The adaptive system was rated as safer and less frustrating to use than the non-adaptive version. Driving movements when using the adaptive system was also reported to have exhibited less lateral deviation than the non-adaptive version (though the difference was not significant). The driver profile, real-time driving style and the driver's physical state can then be used to select appropriate persuasive and interaction strategies to help make driving safer and improve fuel economy. The smart assistant could adopt a strategy to become less distracting to the driver when difficult driving situations were detected by reducing interactions (voice, audio alerts, visual) and unnecessary feedbacks. And when the driver is not performing difficult driving tasks, then more feedback about how his driving is affecting fuel efficiency could be presented.

3. The conceptual model of an intelligent persuasive driving assistant

By integrating the above concepts together, a holistic approach to an intelligent driving assistant can be developed. The intelligent assistant can first learn about the driver through a conversation [24, 25] and obtain initial information about his driving styles and driving goals. The assistant might ask about where he works, what time should he arrive there, his views on ecology, and so on, to form an initial driver profile. Ongoing interaction with the assistant and machine learning of vehicle movement during actual driving can be used to classify driving style in different driving situations. The assistant would then use this information to select appropriate persuasive strategies and modes of interaction to influence driver behavior.

For example, when a trip is made, the assistant can ask about the trip purpose (e.g. drive home for dinner by 7 PM) and form a strategy for routes to offer. If the driver fit the profile for an ecological driver and had indicated a preference for driving in light traffic, then the assistant could check whether there is sufficient time for taking a longer but less congested route and offer that route as one of the choices instead of simply showing the fastest routes. The assistant would also provide CO_2 emissions information for each route to raise drivers' awareness of the ecological impact of the routes and thus influence route choice [3, 30]. During the drive, providing visual and audio feedbacks about driving behavior (acceleration, braking, gear shifting suggestions) could be used to guide the driver towards a more ecological driving style [15].

However, if the driver had an aggressive driving style, providing feedback about how ecologically inefficient his driving was may be perceived as nagging and he could become irritated with such feedback. In such situations, a safe-driving strategy maybe more suitable in the beginning. For example, the assistant could provide visual information about when forward collision avoidance, blind spot monitoring and other preventive safety systems have activated through aggressive driving behavior. The assistant could also provide post-trip feedback comparing the driver's trip time and ecological performance to other trips that used the same route under similar traffic conditions. Trips with similar times but different driving styles and ecological results might help convince the driver that saving a few minutes may not be worth the safety risks from aggressive driving.

And through sensing the physical state of the driver (e.g. heart rate) [28], the system can infer cognitive load and adjust voice interactions and visual display to an appropriate level [29]. If the driver was performing a difficult driving maneuver, the system could reduce or delay non-safety related feedback. Then, when the driver was under a low cognitive load and able to safely interact with the system (driving at moderate speed on a fairly straight road segment) ecological driving persuasive strategies could be resumed. If the driver was detected as being drowsy or having driven for an extended period of time, the assistant could suggest a rest stop. Persuasive strategies related to other aspects of driving, such as safety and reducing traffic violations are also to be used at the appropriate time. For example, information from the forward collision avoidance system could be used to nudge the driver to maintain appropriate temporal headway and lane keeping during a drive [2, 15]. And if the assistant detects that the car is being parked on the street during no parking hours, then it could suggest a nearby parking location within walking distance. However, if the driver ignored such suggestions a few times, then these strategies could be marked as ineffective and other strategies could be tried instead.

As the driver continues to use the system, preferences obtained through the initial conversation with the driver can be supplemented by the system's records of how the car was actually driven and whether the driver had been responsive to the various persuasive strategies. This can be used to change or further refine the strategy for future trips. A simplified architecture of the intelligent driving assistant is shown in Fig. 1.

The main user interface for the system is that of a smart assistant like Apple Siri, Google Assistant or Amazon Alexa. Most of the interaction with the system should be done through natural speech. Machine leaning techniques can be used to train the assistant to have domain knowledge related to vehicles, driving, traveling, ecology, driving safety and driving violations. The Driver Model is based on both domain knowledge and historical driving behavior. The assistant is expected to be able to predict certain driving behaviors and provide appropriate feedbacks specifically aimed at motivating the driver to make simple changes to his driving style. The Persuasive Strategies are expected to be used adaptively based on the driver's receptiveness. If a strategy has been rejected several times, it may be marked as ineffective and abandoned. Many works have explored how drivers respond to ecological driving feedbacks such as driving style effect on fuel economy and emissions, but much additional work is needed in developing strategies for safe driving and lawful driving. The Interaction Strategy is used to adapt the interaction mode and interaction level mainly for safety, but the assistant will also record the effectiveness of which interaction mode (voice, audio, visual, etc.) has affected behavior change towards the driving goals. Those interaction strategies that have been more effective could be used more often in other similar situations. With driver permission, anonymous data about the effectiveness of each strategy could be collected from drivers and used to fine tune the assistant in future updates.

In order to make the system a more complete mobility assistant, the Traffic and Map Information module could interface with other travel and entertainment recommendation systems to suggest restaurants, shopping and other points of interests. Information on other modes of transportation (other than driving) should also be included in route suggestions. For example, park-and-ride routes for getting to highly congested areas, or information from ride sharing systems.

As previously explained, the system requires information about the driver and vehicle to adapt its interaction and persuasive strategies. Driver information is concerned with the physical state of the driver such as stress, heart rate, or drowsiness. It is expected that this information can be collected through fitness-related wearables or ADAS sensors such as those used for driver in-attention detection or drowsiness detection.

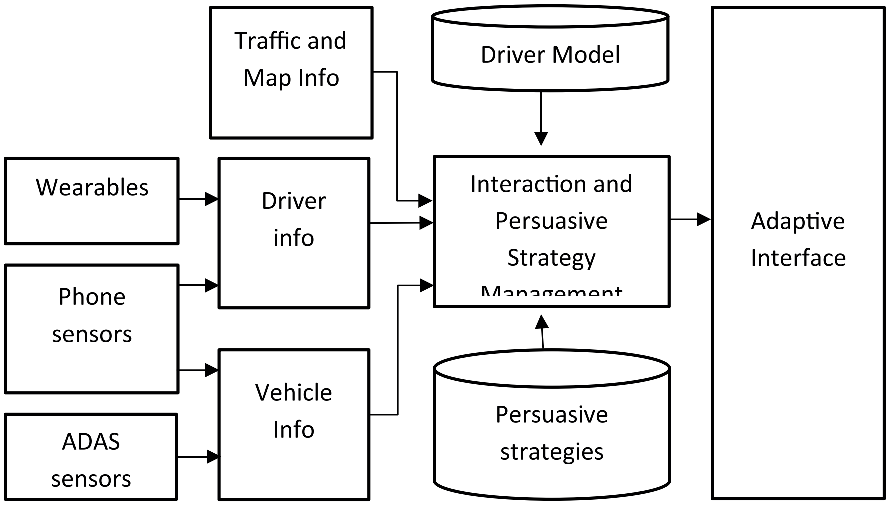

Figure 1: Architecture of an intelligent persuasive driver assistant.

4. Conclusions and further work

This work has presented an initial conceptual model for an integrated persuasive intelligent driving assistant. Driver information such as driving style and driving goals can be elicited from the driver through voice interactions. Real-time driving behavior can be monitored through integration with vehicle sensors or through smartphone sensors. The driver physical state and cognitive load could be monitored through wearables with heart rate sensors or inferred through the difficulty of the driving maneuvers being performed. By integrating the various contextual information together, the assistant can form appropriate persuasive strategies to influence the driver towards his driving goals and at the same time moderate the level of interaction to ensure that the driver's cognitive load is not overly burdened by the persuasion techniques being used. Safe, ecological and lawful driving behaviors are included as goals of the persuasive strategies. This novel combination of smart assistant, persuasion, and adaptive interface is expected to help drivers be more effective in achieving their driving goals. Further work is planned to develop specific details of the system in the next stages. In particular, research on developing specific persuasive strategies and user interactions that are suitable for lawful driving behaviors is needed. Different types and multiple levels of persuasion that are appropriate for each driver profiles also need to be developed. And user acceptance research on their willingness to accept and use such an encompassing system is also essential.

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