The Vehicle as Pervasive Display – Potentials and Limitations

Stefan Diewald [1], Patrick Lindemann [2], Andreas Möller [1], Tobias Stockinger [2], Marion Koelle [2], Matthias Kranz [2]
[1] Technische Universität München, Arcisstr. 21, 80333 Munich, Germany, stefan.diewald@tum.de, andreas.moeller@tum.de
[2] Universität Passau, Innstr. 43, 94032 Passau, Germany, {firstname.lastname}@uni-passau.de

***Abstract*—Sharing information between traffic participants can improve traffic flow and safety. Currently, communication is mainly done via vehicle lighting such as brake lamps or turn signals. For enhanced information exchange, we propose using the exterior of vehicles as pervasive displays to present information that may be relevant to other traffic participants. The compilation of potential applications and limitations shall provide an introduction to further discussion in the community.**

I. Introduction and Background

Regular exchange of traffic-relevant information is essential for safe road traffic. Currently, the information exchange is mainly based on a broad variety of different visual cues. For example, traffic regulation is often realized by visual cues that are part of the road infrastructure (e.g., via street signs, traffic lights, or variable-message signs). In-vehicle visual cues are used to inform and warn the driver of vehicle-related issues, such as low tank fill level or slippery road. Advanced driver assistance systems (ADAS) may further use warning lights or present messages on in-vehicle displays to extend the situational awareness of drivers, for example, by warning of blind spot-driving vehicles, lane departure, or too short distance to the vehicle in front. Visual cues are also used for inter-vehicle communication. Turn signals inform other drivers of direction changes, brake lights indicate decreasing speed, reversing lamps warn of reversing vehicles, and head and tail lamps (incl. rear fog lamps) indicate the position of the vehicle in conditions of poor visibility. Some of these visual cues have a secondary meaning. For example, the hazard warning light is based on the turn signals and by flashing high beams drivers try to communicate with oncoming vehicles. Emergency vehicles and transport vehicles are using flashing alarm lamps to trigger higher attention.

Sometimes, the exterior of vehicles is used for presenting individual information. For example, buses use text display boards above the driver's cabin or at the sides to inform passengers about the bus line, destination, and the current schedule. Additional equipment attached to vehicles can also provide means of communication. For example, taxis use mounted light signs to indicate when they are free to take up passengers, and police cars use mounted text displays to signal other drivers to pull over.

In the last few years, the research on *pervasive displays* gained a huge momentum [1]. Researchers have explored the interaction with embedded displays in public and semi-public environments. The ongoing development of more flexible and better display technology [2] allows leveraging displays as a pervasive means of information presentation in many domains. In this paper, we address the automotive domain and take a look at the usage of vehicles as pervasive displays. We contribute a collection of possible applications as well as a look on current limitations as an introduction for further discussion.

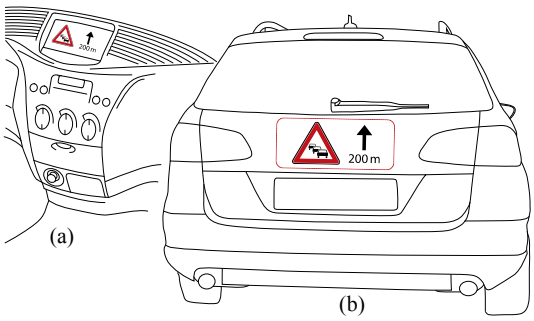

Fig. 1. Using displays on vehicles could boost the effectiveness of vehicle-to-x communication at low equipment rates. By using visual cues on V2X-equipped vehicles, even low penetration rates allow informing many possibly affected drivers [3]. We suggest that safety-relevant information, which is usually only displayed to the driver on in-vehicle displays (see (a)), is also displayed on the exterior of the vehicle to inform other drivers (see (b)).

II. Potential Applications

We can conceive of varied possible application scenarios for vehicles as pervasive displays. Our short collection includes cases with standalone information on the car as well as vehicle-to-x communication (V2X) scenarios that leverage data aggregated from connected vehicles or infrastructure. Some ideas describe using standing cars as pervasive displays, others are discussing potential applications during driving. A categorized selection of possible application is given in Table I.

Similar to indicator lights, displays on the exterior of vehicles could convey different kinds of warnings for other traffic participants, but with potentially more content and detail. By communicating with a navigation system, the displays could show prediction information for the behavior of the driver to others. If there is a left turn ahead for the current route, trailing drivers might be informed early on by a distance-to-turn visualization to avoid overtaking or sudden braking maneuvers. Acceleration or braking intensity could be visualized on the engine cover and the rear[1], e.g., to help pedestrians and cyclists estimate whether it is safe to cross

[1] http://apps.leg.wa.gov/rcw/default.aspx?cite=46.37.210, May 22, 2014.

TABLE I. POSSIBLE APPLICATIONS WHEN VEHICLES ARE USED AS PERVASIVE DISPLAYS. WE DISTINGUISH BETWEEN STANDING AND MOVING VEHICLES AS WELL AS STATIC AND DYNAMIC CONTENT.

Content type	Parked Vehicle	Moving Vehicle
Static	• Advertisement (replacement of foil coatings) • Carpooling information (e.g., when is a ride going to start, are seats left?) • Repair and maintenance instructions (e.g., display required tire pressure or tread depth above wheel casing)	• Advertisement (e.g., ads could be updated to match with the closest branch) • Warning signs (e.g., depending on vehicle payload's properties)
Dynamic	• Maintenance information and support (e.g., sensory data such as fill levels, pressures, or status of electric components) • Distance information for other parking vehicles (e.g., red flashing of car with increasing frequency on approach) • Estimated left parking time (e.g., to allow short-term second row parking)	• Vehicle-to-X information (such as warnings of ahead incidents, cf. Fig. 1) • Detected road sign information (such as restrictions on passing) • Navigation information (e.g., when will a truck leave the current road) • Social context (such as the driver's mood [4]) • Moving state (e.g., indication of acceleration, braking, floating) • Virtual traffic lights for right of way indication [5]

the street in front of an approaching car. It might also help to identify cars that are accelerating in reverse gear out of driveways despite approaching people or traffic.

Typical stressful situations on highways are overtaking maneuvers between trucks or buses, especially on two-lane sections. The trailing driver feels the need to pass because even small speed differences can make a difference for the arrival time on long routes. However, such maneuvers take a comparatively long time due to the small speed differences. They can also force approaching vehicles to slow down abruptly, possibly creating dangerous situations and stress. With a rear display on trucks, there would be the option of showing route information that might be relevant to others, e.g., the distance or time to the next exit, planned breaks, or the time of arrival. We believe other drivers might then forgo an overtaking process because it would not be worthwhile. The consequence is the prevention of a potentially dangerous situation and a general improvement of the traffic flow.

An obstacle for the implementation of vehicle-to-x communication is the penetration rate. At low equipment rates, there will only be a low gain of safety, as only few drivers are aware of the information. By using visual cues on V2X-equipped vehicles, even low penetration rates allow informing many possibly affected drivers [3]. Safety-relevant information that is usually only displayed to the driver on in-vehicle displays (see Fig. 1 (a)) could also be displayed on the exterior of the vehicle to warn other drivers (see Fig. 1 (b)).

Research has also shown that drivers often behave more cautiously and indulgently when they know more about the social context of other drivers [4]. Information about drivers' current condition, capability, and mood could be displayed on the vehicles' surfaces. Also shared interests and other social network information influence interpersonal interactions.

III. CURRENT LIMITATIONS

Added driver distraction is the most limiting factor for us. For dynamically changing content, principles for the design of in-vehicle displays are applicable [6]. Information presentation principles demand that continuously spatially moving images should be avoided. However, during driving, the information shown on the exterior of other moving vehicles will be in most cases spatially moving as the whole display is moving. This especially limits the presentation of text, as moving text is hard to read. Other technical limitations are glare effects and reflections that may cause difficulties in recognizing displayed information. When conveying detailed information, the content may be too small to be identifiable from distance.

There are also legal aspects that need to be considered. As defined by the 1968 *United Nations Convention on Road Traffic* and confirmed by most countries' legislation, only certain colors of light may be emitted by vehicles for specific purposes. For that reason, backlit displays are not allowed on vehicles. However, non-light emitting displays such as e-paper may be used. In addition, liability issues may occur when wrong information leads to accidents. As with all public displays, also privacy concerns need to be considered. Especially when trip details or social context is shared, privacy may be violated. In any case, the driver needs to have control about the shared information.

IV. CONCLUSION AND FUTURE WORK

This paper provides some ideas for using vehicles as pervasive displays. Although many applications do not comply with the current legal situation in most countries, we think that displaying certain pieces of information on the exterior of vehicles can improve the traffic flow as well as driving safety. We are currently creating prototypes based on different visualization technologies (multiple LEDs to HD displays). Key aspects of the evaluation will be the estimation of driver distraction when observing displayed static and dynamic content on standing and moving vehicles while standing or driving, and a comparison to retrofittable in-vehicle V2X solutions [7].

REFERENCES

[1] S. Schneegaß and R. Calderon, "Pervasive Displays 2013," *IEEE Pervasive Computing*, vol. 12, no. 4, pp. 58–61, 2013.

[2] B. Yoon, C. White, G. Wease, L. Honnappa, S.-T. Tsai, X. Wang, and T. U. Daim, "Technology Roadmap for Automotive Flexible Display," in *Planning and Roadmapping Technological Innovations*, ser. Innovation, Technology, and Knowledge Management. Springer, 2014, pp. 159–175.

[3] M. Boban, T. Vinhoza, O. Tonguz, and J. Barros, "Seeing is Believing – Enhancing Message Dissemination in Vehicular Networks Through Visual Cues," *IEEE Communications Letters*, vol. 16, no. 2, pp. 238–241, Feb. 2012.

[4] R. Schroeter, A. Rakotonirainy, and M. Foth, "The Social Car: New Interactive Vehicular Applications Derived from Social Media and Urban Informatics," in *Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI '12. New York, NY, USA: ACM, 2012, pp. 107–110.

[5] H. Conceicao, M. Ferreira, and P. Steenkiste, "Virtual Traffic Lights in Partial Deployment Scenarios," in *IEEE Intelligent Vehicles Symposium*, ser. IV '13, Jun. 2013, pp. 988–993.

[6] Driver Focus-Telematics Working Group, "Statement of Principles, Criteria and Verification Procedures on Driver Interaction with Advanced In-Vehicle Information and Communication Systems," Alliance of Automobile Manufacturers, Tech. Rep., Jun. 2006.

[7] S. Diewald, A. Möller, L. Roalter, and M. Kranz, "DriveAssist – A V2X-Based Driver Assistance System for Android," in *Mensch & Computer 2012 - Workshopband*. Oldenbourg Verlag, 2012, pp. 373–380.