Cooperative partly automated and coordinated vehicles and transports

Invited Position Paper

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Abstract: Automation of vehicles and transports is rapidly evolving from a vision to reality due to systems for local situation awareness relying on advanced on-board vehicle sensors and software implemented intelligence. This evolution will be further supported by the capability to communicate and cooperate between vehicles and with important infrastructure to coordinate the traffic for both safe and environmentally efficient transports. To become accepted among vehicle drivers and other citizens this will require understanding of the problems involved and suitable methods to cope with these problems. This paper identifies some of the problems seen and methods needed.

Today many new cars and trucks are equipped with GPS or DGPS and several other advanced on-board sensors including radar and video based systems enabling them to detect lanes, road signs, vehicles, animals and pedestrians in their close vicinity. Soon new cars and trucks will be equipped with radio transceivers to allow wireless communication between each other. Important traffic system infrastructure such as traffic lights and other sources of space and time stamped information will also be made available either ad hoc or via the internet.

Automation in road vehicles have evolved rapidly during the last decades, from cruise control, electronic stability control and anti-lock-braking to systems that relate to the environment around the vehicle such as adaptive cruise control, automatic braking, lane-keeping aids and self-parking vehicles. With the help of on-board sensors the next step in automation is to let the vehicles drive for longer time without human intervention. In the beginning functions like e.g. “queue-assist” will automatically follow the proceeding vehicle within the current lane in low speed scenarios. Automation is rapidly evolving and these functions will soon be introduced in higher speeds as e.g. autopilots for highway driving. The final goal is to offer the driver fully automated driving for all situations which could include driverless vehicles.

Drivers will accept [Beg 13] the functions as long as they behave reliable and interpretable and this also by other road users and further the stepwise evolution will allow them to be used in a mixed traffic environment. However, the transition to highly automated vehicles, that autonomously take the vehicle passengers or goods to their destination, may require significant support from the infrastructure implying dedicated lanes reinforced by radio transmission. Since different vehicle manufacturers have different targets, the transition period will consist of not only a mix of automated and manual vehicles but the level of automation will also differ. This also calls for a broad legislation process to cover a large variety of automated functions.

This rapid evolution give rise to several new concerns, for example: what standardization and legislation is needed; is for example the Vienna 1968 Convention on Road Traffic, with amendments, as applied in [Van 13] enough? Is available modelling and test methods good enough to validate and verify system dependability? How should different automation mode transitions be handled, for example engaging or disengaging the human driver (that for legal reasons most likely is responsible for the driving on roads with mixed traffic including both old and new vehicles until new laws come into effect)? How should the infrastructure and road network be developed to support autonomous driving? How should a stepwise deployment in to a mixed traffic environment be supported and planned?

Seeing the overall vehicle-based transport system as an advanced cyber physical system (CPS) and controlling it as such, can bring large gains for society. Transport efficiency would increase, accidents decrease, time spent on roads decrease and thus the cost for society. A traffic CPS would need to include human behaviors and societal regulations influencing the development, there are many problems and questions that needs research to answer properly. For example: How far can the vehicle industry implement safe automation just from the perspective of a single vehicle detecting road lanes and seeing other vehicles mainly as obstacles? When is it time to include cooperative and coordinated behavior and how shall such behavior be specified, standardized and constructed to be safe and secure; are current traffic laws and regulations too fuzzy and dependent on human interaction and interpretation? Do current regulations act more as guidelines and thus do we need modernized formal and executable specifications? Will this help since in reality traffic regulations are not always followed by manually driven vehicles? How should these specifications be interpreted by the different road users and by the automated vehicles, and is it possible for them to coexist and interact in the traffic? Would it be necessary to make infrastructural changes not only to support the automated vehicles but also the humans interacting with them? These are relevant questions in a traffic system where vehicles are driving by themselves on their way to pick up their passengers or goods.

CPS research has been devoted to careful studies of mixed continuous/discrete or hybrid systems influenced by the mapping from the real continuous world to the computers discrete world and the reverse. Some research have also studied the effects induced by the cyber space including the effects or more unreliable and thus stochastic wireless communication, for example inducing information losses and delays in the loops of systems. Including also humans in the loops of a system means that the modelling and prediction of stochastic behaviors becomes even more important. This is not new and already considered in the design of advanced driving simulators but it must be emphasized that the engineering of many future systems require not only CPS engineers to understand and be able to handle these complexities. It also means that probabilistic models, hybrid models and mixed simulations including humans in the loop are needed for the analysis of many such systems and that these new aspects must be modelled; such as the cyberspace influence and also the mutual interaction effects among several drivers in more complex scenarios, e.g. in lane change [Ard 12].

Road vehicles can be more or less easily detected and tracked if made more easy to observe and distinguish for example by the help of traditional means such as: lights, reflexes or protocols such as use of strong lights indicating braking or blinking light indicating turning intentions. As we know, these simple forms of help are used also at sea and in the air. In the context of cooperative and automated vehicles it is possible that the need for both human and machine readable markings and signalling is even more important although as already encountered cooperative awareness messages sent via radio provides a similar function. One such reason is to allow human drivers, pedestrians and cyclists to see and interpret each others' intentions and if needed adapt their behavior to a signal indicating that an approaching vehicle operates in an automated mode. To solve coordination problems at for example pedestrian crossings humans are currently able to cooperate by seeing each others' body, face and eye expressions as important signals. Can we replace or complement this kind of interaction used in cooperative coordination by machine detection, situation and intention awareness via sensors and wireless communication of suitable signals/messages in sufficiently dependable manners? What are and how do we validate and verify the necessary detector and intention awareness threshold levels needed to take a safety critical decision? Vehicle traffic is often very dynamic and observed situations change rapidly over time. Automated driving solutions must thus in real-time be able to detect and discriminate important logical states of the system and also handle transitions to new states including undetermined intermediate intervals between logically clearly separable states. Are there technical challenges in implementing all this? How are we to evaluate risks for unintended interaction between different functions or feedback coupled systems implementing different safety critical functions?

Already today it is difficult to verify and validate system safety for vehicle systems that use on board environmental sensors [Cam 10]. The current possibility to achieve high level of safety integrity in such systems limits their performance and scope. Research on methods for specification and validation of CPS behaviors and related tests are essential both to control the development and the verification of cooperative and automated driving systems, systems that are far more complex and dependent on external actors, [Jac 10]. In this context, what are the most critical factors and use cases to specify and how should these systems be tested and proven with respect to these factors and use cases? To validate and verify specified behaviors the test methods as such and related test environments need to be enhanced. For example, they need to handle the many boundary condition cases induced by function use cases including when communication channels and sensors are faulty or disturbed in different ways.

All vehicles have brand specific features and the manufacturers spend a significant amount of resources to maintain and develop these features. Although the human machine interfaces and instrument panels in most vehicles are unique they share some fundamental functionality, the position of the pedals, steering wheel and the spokes for windshield-wipers and indicators. However several other controls differ to various degrees. How should the guidelines for engaging/disengaging automated control be made? To what extent may different manufacturers design their own interfaces and what interfaces and functionality should be standardized? How are the brand specific features preserved in fully automated vehicles? Is this only a problem in the transition period when the control needs to be shifted between the driver and the vehicle and vice versa? Can we allow a mix of vehicle driving styles like: fast, aggressive, polite, friendly, economical, comfortable etc. or are there significant benefits if all show similar behaviors in cooperative and automated driving? The final concern is how these systems should be harmonized in order to qualify in standardized test and verification procedures?

References

[Ard 12] Ardelt M., Coester C. Kaempchen N., "Highly Automated Driving on Freeways in Real Traffic Using a Probabilistic Framework", *IEEE Transactions on Intelligent Transportation Systems*, vol.13, no.4, pp.1576,1585, Dec. 2012.

[Beg 13] Beggiato M., Krems J. F., “The evolution of mental model, trust and acceptance of adaptive cruise control in relation to initial information”, *Transportation Research Part F: Traffic Psychology and Behaviour*, Volume 18, May 2013, Pages 47-57.

[Cam 10] Campbell M., et al., "Autonomous driving in urban environments: approaches, lessons and challenges", *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 368.1928 (2010): 4649-4672.

[Jac 10] Jacobson J., Grante C., et al, "Functional Safety in Systems of Road Vehicles", SP Report 2010:07, ISBN 91-7848-978-91-86319-43-4, ISSN 0284-5172.

[Van 13] Vanholme B., Gruyer, D. Lusetti, B. Glaser S., Mammar S., "Highly Automated Driving on Highways Based on Legal Safety", *IEEE Transactions on Intelligent Transportation Systems*, vol.14, no.1, pp.333,347, March 2013.