Human-in-the-loop Control with Prediction of Driver Intention: Safe Driving Assistance For Beginners

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Modern transportation systems are usually operated by humans. In vehicles, drivers control the car based on their own sense and experience. The safety of such systems relies on the drivers themselves to make the right decisions. However, the driver and the car are both exposed to rapidly changing spatiotemporal context. Hazardous situations can occur if drivers fail to make the right decisions in real-time, and in the worst case, people may die in accidents. Technologies such as active safety have been developed to improve safety, but they are not enough to assist inexperienced drivers during their learning process. CPS technologies can help teach new human drivers safe techniques and help avoid accidents during learning. Perhaps these solutions would even be mandated for new drivers. While many of the CPS solutions would also benefit experienced drivers, such drivers are less likely to make use of the learning aspects of the technology. To accomplish this CPS control and teaching task requires work that aims at (i) establishing fundamental models for predicting human driving intention, (ii) proposing human in the loop control design to achieve safety as well as providing learning feedback to the drivers, and (iii) designing and implementing a driving assistant system as reference implementation to evaluate designs in real-world scenarios.

The greatest lifetime chance of crashing occurs in the first 6 months after licensure, according to National Highway Traffic Safety Administration [1][2]. Motor vehicle crashes are the leading cause of death for U.S. teens. In 2010, seven teenagers ages 16 to 19 died every day from motor vehicle injuries. The major reasons that cause these crashes include i) lack of scanning that is needed to detect and respond to hazards; ii) going too fast for undesirable road conditions, such as overtaking or changing lanes; and iii) being distracted by something inside or outside of the vehicle, such as passengers or smartphones.

To provide driving assistance for these dangerous situations, it is critical to capture user-specific driving behavior patterns at runtime. For example, inexperienced drivers may not have established a safe scanning habit before changing lanes. They will be notified when they fail to conform to the safe procedure for scanning and if a dangerous situation exists automated control will prevent the accident. The active safety controller will also be notified so that the control model is adaptive to a driver specific pattern. This dual loop approach incorporates driving behavior monitoring directly into the driving safety control loop.

The challenges of this work lie in: 1) Creating driving intention predictive models. This work focuses on intended driving behaviors, such as changing lanes and overtaking other cars. Due to the uncertainty in the environment as well as the human-specific decision process, wirelessly networked sensing technologies must provide reliable prediction results of driver intensions, which is extremely challenging [3]. 2) Human in the loop control. The needed human in the loop control is different from existing maneuver control systems, where systems passively receive control commands from drivers. Here drivers are monitored and the observed intentions are used for active safety control. To achieve that, we face several key research questions: a) quantify driver intention into a classic maneuver control loop; b) develop adaptive control models that prepare the safety of a car for incoming maneuvers; c) design safe and flexible control interfaces for driving. 3) Safe driving training and checking. To assist the training of inexperienced drivers, it is essential to provide them a learning experience in real scenarios and also protect their safety. Because of the limited understanding of interactions between inexperienced drivers and vehicular systems at a macro time scale, the safety training and checking processes are under-exploited.

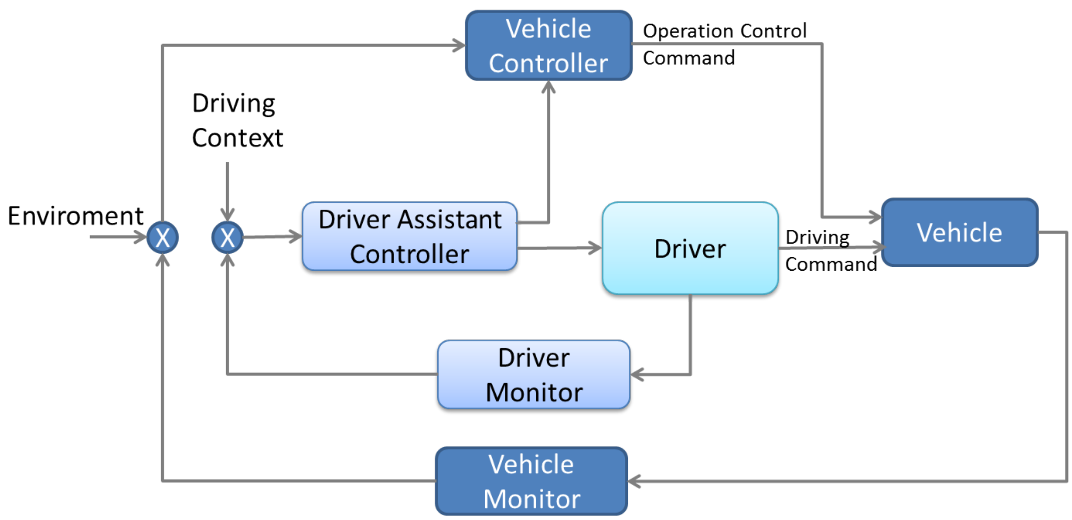

Figure 1. Driver in the loop Control for Safety

In our own work we use a human in the loop control approach. Our recent works on human in the loop control have been applied to cyber physical systems [4][5]. We believe that the safe driving behaviors can be modeled as a sequence of control actions under their specific context. The hazardous driving behaviors may not conform to the sequence of actions or timing of actions or corresponding context. The goal of our human in the loop control design is to monitor the driver, identify the difference between hazardous driving and safe driving behaviors as error, and compensate the maneuver control actions adaptively. The real-time driving context combined with the uncertainty in human driving behaviors, make this control design unique and challenging. A hierarchical control design might be necessary to account for the dynamics occurred at different timescales. We believe that human in the loop control approach is essential for maintaining stability of the maneuver with human errors.

Model predictive control shall be employed in the human in the loop design. Model predictive control (MPC) is nothing new, but how to apply human related contextual information into the

MPC framework for safety guarantees is indeed very new, because plant states (e.g. human intentions) are probabilistically changing instead of being sampled directly. Allowing real-time contextual information to correct the predictions from a plant model, we can avoid computing control trajectory over the entire prediction horizon with escalated uncertainty and computational complexity, instead we can correct the prediction (in a short horizon) using the correlated contextual information from driver specific behavior patterns.

References

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