Autonomous vehicles are expected to greatly transform the transportation domain in the near future. Some even envision that the human drivers may be fully replaced by automated systems. It is plausible to assume that at least a significant part of the driving task will be done by automated systems in not a distant future. Although we are observing a rapid progressive trend towards this goal, which gradually pushes the traditional human-based driving toward more advanced autonomy levels, but this full autonomy concept still has a long way before being completely fulfilled and realized due to numerous technical and societal challenges.

During this long transition phase, blended driving scenarios, composed of agents with different levels of autonomy, seems to be inevitable. Therefore, it is critical to design appropriate driving systems with different levels of intelligence in order to benefit all participants.

Vehicular safety systems and their more advanced successors, i.e., Cooperative Vehicular Systems (CVS), have originated from this perspective. These systems aim to enhance the overall quality and performance of the current driving situation by incorporating the most advanced available technologies, ranging from on-board sensors such as radars, LiDARs, and cameras to other promising solutions e.g. Vehicle-to-Everything (V2X) communications. However, it is still challenging to attain the ideal anticipated benefits out of the cooperative vehicular systems, due to the inherent issues and challenges of their different components, such as sensors’ failures in severe weather conditions or the poor performance of V2X technologies under dense communication channel loads.

In this research we aim to address some of these challenges from a Bayesian Machine-Learning perspective, by proposing several novel ideas and solutions which facilitate the realization of more robust, reliable, and agile cooperative vehicular systems. More precisely, we have a two-fold contribution here. In one aspect, we have investigated the notion of Model-Based Communications (MBC) and demonstrated its effectiveness for V2X communication performance enhancement. This improvement is achieved due to the more intelligent communication strategy of MBC in comparison with the current state-of-the-art V2X technologies. Essentially, MBC proposes a conceptual change in the nature of the disseminated and shared information over the communication channel compared to what is being disseminated in current technologies.

In the MBC framework, instead of sharing the raw dynamic information among the network agents, each agent shares the parameters of a stochastic forecasting model which represents its current and future behavior and updates these parameters as needed. This model sharing strategy enables the receivers to precisely predict the future behaviors of the transmitter even when the update frequency is very low.

On the other hand, we have also proposed receiver-side solutions in order to enhance the CVS performance and reliability and mitigate the issues caused by imperfect communication and detection processes. The core concept for these solutions is incorporating other informative elements in the system to compensate for the lack of information which is lost during the imperfect communication or detection phases. For proof of concept, we have designed an adaptive FCW framework which considers the driver’s feedbacks to the CVS system. This adaptive framework mitigates the negative impact of imperfectly received or detected information on system performance, using the inherent information of these feedbacks and responses. The effectiveness and superiority of this adaptive framework over traditional design has been demonstrated in this research.

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