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主　論　文　の　要　旨

論文題目　Realization of Safe Autonomous Driving using Randomized Model Predictive Control
(サンプルベースモデル予測制御を用いた安全な自動運転の実現)

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論　文　内　容　の　要　旨

Safety levels required by autonomous driving (AD) are consistently rising as AD is targeting a wider range of driving tasks. This research has realized higher safety levels in challenging AD tasks using randomized model predictive control (RMPC). We start with the identification of major bottlenecks in the application of RMPC to address challenging navigation problems in AD. We address all such bottlenecks in chapter 3. This includes the noisiness of input signals since they are originating from the random sampling. This has been addressed with a smoother frequency domain sampling. RMPC was also not useful at higher sample counts because of the computational burden. This was addressed by a parallel implementation running on GPU. RMPC adds complexity to normal MPC in terms of extra variables such as the number of samples. We propose an efficient method of parameter selection for RMPC. We also demonstrated that RMPC could safely perform high-speed obstacle avoidance driving with an RC car.

In chapter 4, we present an interaction problem between a crossing pedestrian and a self-driving car. The pedestrian being modeled by a novel PrARX model, this framework enabled human-like considerate driving. We achieve this using our novel method of representing stochastic constraints in an RMPC framework. Considering the entropy of pedestrian's decision-making in the cost function, this framework achieves early motion consensus and hence enables safer interaction. While being human-like in comparison to traditional control solutions, the behavior of the proposed RMPC is also tunable to suit the driving style of different drivers.

Even though RMPC can handle most of the non-linear control problems well, there are certain tasks where a gradient-based optimization provides a smoother solution reliably. In chapter 5, we propose a combination of such a commonly used nonlinear MPC framework with the proposed RMPC. The base controller being gradient-based, violates safety constraints under discontinuity. We present a method of supplementing such discontinuous cases with RMPC to guarantee safety in all conditions. The sudden switching to RMPC at discontinuity and the switch back once the situation is stable are both addressed.

Along with expanding the usage of RMPC as a powerful solution for nonlinear optimal control problems, we believe that the proposed tools and methods will hasten the achievement of improved safety levels in autonomous driving.