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Application of the MPC strategy to nonholonomic vehicles and vehicle formations in a point-to-point motion

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Abstract:

Model Predictive Control (MPC) is an optimization-based control technique that has received an increasing research interest and has been widely applied in industry. Thousands of applications have been reported [9], especially in the chemical processes industry, making MPC being classified as the only advanced control technique with a substantial impact on industrial control problems [6].

Research in MPC has been very active in the recent years. There has been an intense and increasing research effort addressing a wide range of fundamental issues such as stability, robustness, performance analysis and state estimation [8]. We have also been witnessing to a widening of the application range, to include the so-called fast systems, such as robotic systems, automobile and aeronautics applications [10]. These new applications are possible not only due to technological developments (increasing computational power at lower cost), but also due to theoretical developments, in specific dynamic optimization algorithms [11] and at a more fundamental level (e.g. enabling MPC to use discontinuous feedbacks and address nonholonomic systems) [1, 2, 3, 4, 5, 13].

The framework proposed in [1] describes how a continuous-time MPC framework using a positive inter-sampling time, combined with the use of an appropriate concept of solution to a differential equation, can address nonholonomic systems. An implementation of an MPC strategy to control a wheeled mobile robot using the results above is reported in [4, 5, 13].

In the article [12], the control scheme proposed is for a set of vehicles moving in a formation. There are two intrinsically different control problems: one is the trajectory control problem, to devise a trajectory, and corresponding actuator signals, for the formation as a whole; and the other is to maintain the formation, the change of the actuator signals in each vehicle to compensate for small changes around a nominal trajectory and maintain the relative position between vehicles. So the control methodology is a two-layer control scheme where each layer is based on model predictive control (MPC). Control of multi-vehicle formations and/or distributed MPC schemes have been proposed in the literature. See the recent works [14,15] and references therein.

These control problems are intrinsically different because on the one hand most vehicles (cars, planes, submarines, wheeled vehicles) are nonholonomic. On the other hand, while the vehicles are in motion, the relative position between them in a formation can be changed in all directions (holonomic behavior).

Model Predictive Control was shown to be an adequate tool to control vehicles in a formation [12]: it deals explicitly and effectively with the constraints that are an important problem feature; recent results on parameterized approaches to the optimal control problems allow addressing fast systems as well as allowing efficient implementations.

Keywords
Model predictive control; stability analysis; nonholonomic systems, vehicles in a formation

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