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MODEL PREDICTIVE STATIC PROGRAMMING: A COMPUTATIONALLY EFFICIENT TECHNIQUE FOR SUBOPTIMAL CONTROL DESIGN

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Abstract. *Combining the philosophies of nonlinear model predictive control and approximate dynamic programming, a new suboptimal control design technique is presented in this paper, named as model predictive static programming (MPSP), which is applicable for finite-horizon nonlinear problems with terminal constraints. This technique is computationally very efficient, and hence, can possibly be implemented online. The effectiveness of the proposed method is demonstrated by designing an ascent phase guidance scheme for a ballistic missile propelled by solid motors. A comparison study with a conventional gradient method shows that the MPSP solution is quite close to the optimal solution.*
Keywords: Model predictive control, Approximate dynamic programming, Model predictive static programming, Ballistic missile guidance

1. **Introduction.** Many challenging real life problems can be formulated in the framework of optimal control theory. However optimal control formulations usually lead to *two-point boundary value problems*, which in turn lead to large computational requirements [1-2]. Moreover, the control solution becomes 'open loop', which is highly undesirable. Hence, optimal control theory is rarely used in online applications. An exception, however, is the infinite-time linear quadratic regulator (LQR) theory, which facilitates a feedback solution of the control variable after solving the associated algebraic Riccati equation [1].

There are some attempts in the recent literature to extend the idea of infinite-horizon LQR theory to nonlinear problems. Perhaps the most notable idea is the state-dependent Riccati equation (SDRE) approach [3]. However, the SDRE solution is usually suboptimal. Moreover, this approach assumes that the Riccati equation can be solved fast enough so that a control update can be carried out online, which may not always be feasible. A relatively recent alternate approach, named as $\theta - D$ method [4-5] partially overcomes this problem. However, the $\theta - D$ method suffers from the difficulty that the design parameters must be tuned carefully to avoid high transient control requirement (in general this tuning process is not trivial). It is also important to note that even though both SDRE and $\theta - D$ methods attempt to provide rapid solutions, their utility is limited only to infinite-horizon quadratic regulator problems for control affine systems (where the control variable appears linearly in the system dynamics).

Even though a good amount of attention has been focused in the literature to develop computationally efficient techniques for infinite-time regulator problems and their extensions, little literature is available for finite-time problems. However many methods are