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‘Delay scheduling’, an unconventional use of time delay for trajectory tracking

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Abstract

A basic trajectory tracking exercise is conducted on a linear time invariant (LTI) dynamics with a fixed control law. The feedback considered here, however, is affected by a time delay, τ, which maybe uncertain. Interestingly, time delayed LTI systems may exhibit multiple stable operating regions in the space of the delay. However, systematic, exact and exhaustive determination of these regions is, mathematically speaking, still a challenging problem. The contribution of this paper is three fold. First, to deploy a recent framework called Cluster Treatment of Characteristic Roots (CTCR) and experimentally verify the stability regions. Second, to establish an unconventional control law, called the "*delay scheduling*" procedure, to use the time delay as a control parameter. Third, to determine the best ("optimum" in certain respect) time delay value(s) rendering the most desirable tracking characteristics.
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1. Introduction and problem statement

In this paper, a classical trajectory tracking problem is studied from a novel perspective. The novelty resides in the presence of feedback delays within the controlled dynamics. And our aims are to understand the influence of time delay on the system behavior, to validate the analytical findings using an experimental setup and very importantly to manage the time delay intelligently for stabilizing the experimental dynamics. With these objectives in mind, the motivation of the work is presented next.

Trajectory tracking has been an attractive research topic as it underlies the fundamentals of many realistic problems, such as vehicle guidance, robotic manipulations. The operation is successful if the dynamics follows a desired trajectory with zero (or desirably small) error. For the treatment here, the system is driven under a *fixed* and *predetermined* state feedback control law while the controller can only utilize the tracking error with a *fixed time delay*. The control law is designed based on a non-delayed feedback setting, which would result in a satisfactory performance. Common sense calls that the same feedback control law when implemented with delayed feedback information should hamper the tracking. As the delay increases the performance gets worse, or does it? This is the question, which leads us to the above objectives.

In this investigation, the delay is considered to be the only variable element altering the success in tracking. If the given controlled dynamics were asymptotically stable, a desirable tracking would be achieved. Thus, authors first address the stability of the system with respect to the time delay. It is clear that for a successful trajectory tracking, the controller should have the knowledge of the relative state error between the target trajectory and the system's output. Often times, however, this information is available with a delay, and even worse, with some partially delayed

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