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Optimal Control in Teleoperation Systems with Time Delay: A Singular Perturbation approach

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Abstract

The main goal of controller design in teleoperation systems is to achieve optimal performance, transparency and stability in presence of factors such as time delay in communication channel and modeling uncertainties. The teleoperation systems usually have complex dynamic, consequently differential equations solution of optimal control problem is difficult and complex for them. This paper presents a novel method for designing optimal controller based on singular perturbation framework for these systems. Firstly, we use the Taylor expansion to model the time delay, with considering time delay term; we derive a singular perturbation formulation for the teleoperation system. Using singular perturbation model and Chang decoupling transformation, singularly perturbed differential equations of optimal control problem is decomposed into the reduced order slow and fast differential equations. A formula is obtained that produces the solution of original differential equations of optimal control problem in terms of solutions of the slow and fast reduced order matrix differential equations. The reduced-order differential equations decrease the complexity of the optimal control problem for teleoperation systems. The simulations verify the effectiveness of the proposed control method and excellent performances tracking with high speed and small control signal.

Keyword: Teleoperation system, Time delay, Optimal control, Singular perturbation, Transprancy

1. Introduction

Time delay in many engineering systems is a source of poor performances and instability. For this reason, many efforts have been done on the stability analysis and control design problems of time-delay systems. One of the most well-known types of such systems is teleoperation systems, which are widely applied to carry out complex tasks in remote or hazardous environments. Such remote systems have applications that include space and undersea exploration [1], robotic surgery [2] and handling of toxic and

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