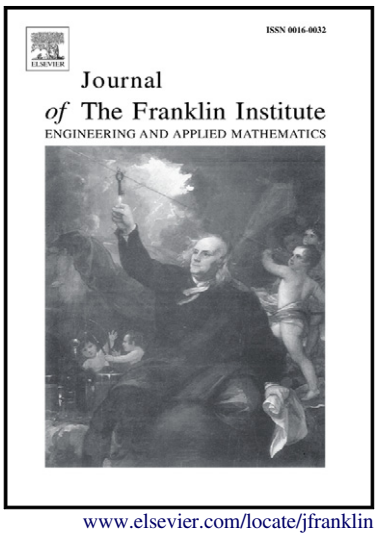

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Guaranteed Cost Control Design for Delayed Teleoperation Systems☆

Yuling Li[a,*], Rolf Johansson[b], Kun Liu[c], Yixin Yin[a]

[a]*School of Automation and Electrical Engineering, University of Science and Technology Beijing, Beijing, 100083, China*
[b]*Department of Automatic Control, Lund University, P.O. Box 118, 22100 Lund, Sweden*
[c]*ACCESS Linnaeus Centre and School of Electrical Engineering, KTH Royal Institute of Technology, SE-100 44, Stockholm, Sweden*

Abstract

A procedure for guaranteed cost control design of delayed linear bilateral teleoperation systems with nonlinear external forces is proposed. The assumption that the external forces are nonlinear functions of velocities and/or positions of local devices, and one part of these forces satisfies a sector condition has been made. A virtual tool system is introduced to 'observe' the forces at the remote sides, the position and velocity information of the master, the slave and the virtual tool are feedbacked to the controllers, hence the proposed control scheme actually has a four-channel architecture. A delay-dependent stability criterion is formulated, and then a sub-optimal guaranteed cost controller is obtained by solving a convex optimization problem in the form of linear matrix inequalities (LMIs). The behavior of the resulting teleoperation system is illustrated in simulations.

Keywords: Teleoperation, guaranteed cost control, LMI, delayed systems, stability

1. Introduction

Teleoperation systems enable humans to extend their capacity to manipulate remote interfaces with better safety, at less cost, and even with better accuracy. Its rich applications vary from nuclear operations, space and underwater exploration, to medical surgery, see [1], [2] and references therein.

Two main issues discussed about the control design of bilateral teleoperation systems are stability and transparency. The position/velocity tracking performance between the master and the slave and the accuracy of the haptic display of the environmental force to human operator are two criteria to indicate the "degree" of the transparency. However, due to the very nature of teleoperation, time delays associated with communication between the local and the remote sites are inevitable, and it is well-known that these communication time delays

*Corresponding author
Email addresses: lyl8ustb@gmail.com (Yuling Li), Rolf.Johansson@control.lth.se (Rolf Johansson), kunliu@kth.se (Kun Liu), yyx@ies.ustb.edu.cn (Yixin Yin)