Stability Analysis of a Dual-Rate Haptics Controller Using Discrete-Time Root-Locus Method

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Abstract In this paper, the classical discrete-time root-locus method is extended for analyzing the stability of a dual-rate haptics controller. The given controller involves two closed-loop feedback gains, damping and stiffness (of the virtual wall), implemented at different sampling rates. Owing to the multi-variable and multi-rate nature of such controllers, analyzing their stability by the direct application of the root-locus method is not feasible. At the outset, the characteristic equation of the controller is thereby set up in a suitable mathematical form amenable to the root-locus analysis. Thereafter the analysis is carried out by sequentially considering the damping and stiffness as feedback gains. Besides helping in establishing the stability bounds readily, the classical discrete-time root-locus method provides qualitative information about the stability contours of the dual-rate haptics controller.

Keywords Haptics controller · Discrete-time root-locus · Multi-rate controllers · *Z-width*

1 Introduction

A haptic interface is a programmable mechatronic device that enables real-time physical interaction with virtual reality environments through touch. Devices that are configured to produce a force output for a given motion input are referred to as *impedance-type* interfaces. This class of interfaces is more prevalent than others in both the commercial as well as the research domain.

Simplified virtual walls modeled as a spring-damper in mechanical parallel, form the building block of most virtual environments. A region of virtual wall stiffness

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