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Human finger mechanical impedance modeling: Using multiplicative uncertain model

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Abstract

To design a controller for the purpose of control of hand exoskeleton force, the critical question is to model the human finger impedance properly. The difficulty is that the parameters of the impedance model are perturbative in different postures. In this paper, multiplicative uncertain models of human finger impedance are presented. We describe the impedance as a mass-spring-damping system. The experiments are set in extension, half-flexion, flexion and synthesis postures. The parameters of nominal model as well as their perturbation range are identified by the forgetting factor recursive least square method. The weighting functions are constructed accordingly. The results show that the uncertain model of synthesis posture can represent the magnitude-frequency characteristic at low frequency, while, for high frequency, the uncertain models composed by the weighting function of synthesis posture and the corresponding nominal model are feasible. These provide effective approaches for hand exoskeleton force control issues.

Keywords

Mechanical impedance, modeling, uncertain model, finger exoskeleton

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Introduction

Rehabilitation after stroke is very necessary for recovering the function of a paralysed limb. Some exoskeleton robots are developed to solve the problem in an automated and intelligent way, which have been proven to be effective.[1,2–5] Current robotic systems are capable of assisting movement in a number of different modes,[6] passive assist mode and active assist mode. In the latter mode, the control target is an interaction force. Since the force reflects the motion attempts, we can provide the effort for the movement by controlling the interaction force between the human and the exoskeleton.[7] However, the human hand is the most dexterous part of the human body, with five digits and 22 degrees of freedom (DOFs). Development of active force control of hand exoskeletons has proceeded slowly. As shown in Figure 1, the exoskeleton robots are nonlinear systems, and the exoskeletons contact human soft tissues associated with a rigid body using an interaction system. Since the performance of the soft tissue cannot be described in a formula, the parameters of the interaction system are uncertain. Thus we have to creat a mechanical impedance model to describe the relationship between haptic force and displacement accurately and properly for exoskeleton force control.

In previous researches, the mechanical impedance is considered in a certain posture, and based on that the LTI models are presented. Flash and Mussa-Ivaldi[8] investigated on the mechanical impedance of human arm when it holds in a defined posture. They treated it as a spring. The results indicated that the shape and orientation of the stiffness ellipse strongly depend on arm configuration. At any given hand position, the values of these parameters were found to remain invariant among subjects and over time.[8] Toshio Tsuji et al. did further research in which mass-spring-damp system was used to describe the mechanical impedance, when a subject maintains a given hand location, and small external disturbances are applied to his hand by a manipulandum. The corresponding force–displacement vectors are measured and sampled over time in order to estimate

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