Universität Stuttgart Institut für Technische und Numerische Mechanik

Fatemeh Ansarieshlaghi

Nonlinear Control of a Very Flexible Parallel Robot Manipulator





Nonlinear Control of a Very Flexible Parallel Robot Manipulator

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von Fatemeh Ansarieshlaghi

geboren im Iran

Hauptberichter: Prof. Dr.-Ing. Prof. E.h. Peter Eberhard

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Preface

This dissertation was written as a part of my work as a research assistant from November 2015 to November 2020 at the Institute of Engineering and Computational Mechanics (name in German: Institut für Technische und Numerische Mechanik) at the University of Stuttgart. My research was partially funded by the German Research Foundation (Landesgraduiertenförderungsgesetz) via the Cluster of Excellence SimTech at the University of Stuttgart. This support is highly appreciated.

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Fatemeh Ansarieshlaghi Ehningen, June 2022 - Dedicated to my parents, family and my dear husband who always supports me.

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تقدیم به بمسرمهانم به پاس قدر دانی از قلبی آکنده از عثق و معرفت که محیلی سرباگد از سلاست و امنیت و آرایش برای من فرایم آورد و است.

وتقديم به خوامران نازينم كه عطرحضور ثان تكرار خوشي باي من است.

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Abstract

By growing usage of the robot manipulators specially of light-weight robots, a lot of researches are focused on their controlling. Interaction control with an environment is the most important and, at the same time, the most challenging task. Hence, this thesis investigates the model-based control of a flexible-links parallel manipulator. Here, the focus is on the dynamic modeling of a flexible multibody system and the use of this model to design a high-performance model-based controller. The main goal of this work is the interaction control of the flexible lambda-shaped robot with its environment.

To achieve this goal, we investigate the lambda robot modeling and validate the models on the robot hardware to determine the best trade-off between model accuracy and simplicity for use in real-time applications. The system's full states and end-effector position are estimated using three different observers based on the robot models. They are tested on the lambda robot to determine which one is the best observer. As a result, the nonlinear high gain observer is then used in an online controller loop for a real-time application to estimate the system's full states and end-effector position. To achieve high accuracy position control, three different controllers in the robot's joints space are designed and tested on the robot hardware and the lambda robot's simulated model. In hardware tests and simulation, the feedback linearization combination with a nonlinear observer and the reduced dynamics controller produce very close results. In the robot's workspace, two different controllers are also designed. The controllers are tested on the simulated model. The results show that the reduced dynamics controller performs best for the lambda robot in joint space and workspace.

To interact with unwanted effects of environments, a disturbance observer is designed and tested on the simulated model of the lambda robot. The lambda robot has no direct measurement of its deformation derivative, and estimations are not accurate and enough noise-free to test this approach on the hardware. Therefore, to have a desired interaction, a contact tool is designed to interact with the environment and to measure the contact force. This contact tool is modeled, and a force/position control using an impedance controller is designed to regulate interaction. Finally, the controller is validated on the simulation model of the lambda robot.

In this thesis, all of the proposed schemes are extensively tested in various scenarios and the results show that the modeling, observation, precise position control, and interaction controllers work successfully.