

Robot Hands and the Mechanics of Manipulation

Matthew T. Mason

J. Kenneth Salisbury, Jr.

Technische Universität Darmstadt FACHBEREICH INFORMATIK B I B L I O T H E K Inventar-Nr.: <u>W01-00315</u> Sachgebiete: _____ Standort: _____

The MIT Press
Cambridge, Massachusetts
London, England

CONTENTS

List of Figures	xi
List of Tables	xv
Series Foreword	xvii
Preface	xix
Acknowledgments	xxvii

SECTION I—*Kinematic and Force Analysis of Articulated Hands*

—J.K. Salisbury, Jr.

Nomenclature	2
------------------------	---

Chapter 1 Introduction

1.0 Robots - Fact and Fiction	3
1.1 Overview of Existing Hands	4
1.2 Preview	5

Chapter 2 Contact - Freedom and Constraint

2.0 Introduction	9
2.1 Contact	11
2.2 Types of Contact Between Bodies	12
2.3 Effect of Single Contacts Between Bodies	14
2.4 Screws, Twists and Wrenches	15
2.5 Geometry of Contact Twist and Wrench Systems	19

Chapter 3 Number Synthesis of Hands

3.0 Introduction	25
3.1 Mobility and Connectivity	26
3.2 Enumeration of Hand Mechanisms	27

Chapter 4 Contacts in Groups

4.0 Introduction	33
4.1 Constraint by Groups of Contacts	34
4.1.1 3-Freedom Contact	34
4.1.2 4-Freedom Contact	36
4.1.3 5-Freedom Contact	37

Chapter 5 Complete Restraint and Internal Forces

5.0 Introduction	39
5.1 Algebraic Approach	40

5.2	Geometric Approach	44
Chapter 6	Force Application and Velocity Analysis	
6.0	Introduction	49
6.1	The Grip Transform, G	50
6.2	Control and Sensing of External and Internal Forces	51
6.3	Control and Sensing of Velocities	52
Chapter 7	Stiffness Control and Sensing	
7.0	Introduction	55
7.1	Review of Force Control	56
7.2	Stiffness Control	59
7.3	Stiffness Sensing	63
7.4	Conclusions	64
Chapter 8	Force Error Analysis	
8.0	Introduction	65
8.1	Effect of Structural Stiffness on Force Accuracy	65
8.2	Force Error Propagation	68
8.3	Isotropic Points in a Two-link Mechanism	69
8.4	Isotropic Points in a Three-link Mechanism	74
8.5	Conclusions	76
Chapter 9	Conclusions	
9.0	Review	77
9.1	Stanford/JPL Hand	78
9.2	The Future	87
References	90
Appendix	94
	<i>Active Stiffness Control of a Manipulator</i>	
	<i>in Cartesian Coordinates</i>	95
	<i>Articulated Hands: Force Control and Kinematic Issues</i>	109
	<i>Interpretation of Contact Geometries</i>	
	<i>from Force Measurements</i>	133
	<i>Design and Control of an Articulated Hand</i>	151

SECTION II—*Manipulator Grasping and Pushing Operations*

—M.T. Mason

Chapter 1	Introduction	171
1.1	Analysis of an Example Grasping Motion	172
1.2	Discussion	179
1.3	Overview	183
1.4	Previous Work	184
Chapter 2	Theory of Pushing	189
2.1	Friction of Planar Motion	192
2.2	Pushing with Fixed or Rolling Contact	201
2.3	Pushing with Sliding Contact	221
2.4	Undetermined Contact Mode	236
2.5	On Quasi-static Analysis	244
Chapter 3	Application	253
3.1	Automatic Orientation	253
3.2	Automatic Planning of Grasping	261
3.3	Verification of Grasping	263
Chapter 4	Conclusion	271
Table 1		273
Appendix		275
References		287
Index		295