

Contents

Symbols and Abbreviations	vii
1 Introduction	1
1.1 Validated Simulation and Estimation: State of the Art	2
1.2 The Goal and Contents of the Thesis	5
2 The Multibody Modeling Library MOBILE	6
2.1 Theoretical Aspects of MOBILE	7
2.2 MOBILE from the User's Point of View	10
2.2.1 Main Features of MOBILE	10
2.2.2 Main Classes of MOBILE	11
2.2.3 A Simple Usage Example	14
3 Validated Methods	16
3.1 Basic Principles of Interval Arithmetic	16
3.2 Enhanced Validated Arithmetics	18
3.3 An Algorithm for Solving Linear Systems of Equations	20
3.4 An Algorithm for Finding Zeros of a Non-Linear Function	21
3.5 Validated Algorithms To Solve IVPs	22
3.5.1 Validated IVP Solvers based on Interval Algorithms	22
3.5.2 A Validated IVPS Based on Taylor Models	28
3.6 Fundamentals on Algorithmic Differentiation	29
3.6.1 Assumptions and Basic Idea	30
3.6.2 Algorithms	31
3.6.3 Implementation Techniques	33
4 A Validated Modeling Tool Based on MOBILE	35
4.1 An Approach to Validation	35
4.1.1 Types of Interfaces	35
4.1.2 Types of Modeling Software	37
4.1.3 An Approach to Validation	37
4.2 Design	40
4.2.1 AD in MOBILE: Well Defined?	40

4.2.2	The Designing Problem. The Basic Data Type	42
4.2.3	Universality	45
4.2.4	An IIVPS Based on VNODE in SMARTMOBILE	53
4.2.5	Structure of SMARTMOBILE	62
4.3	A Usage Example	65
4.4	Functionality of SMARTMOBILE	68
4.4.1	Kinematics	69
4.4.2	Dynamics	73
4.4.3	Continuing Computations	75
4.5	Performance	76
4.5.1	Preliminaries	76
4.5.2	An Analytically Solvable System: Conical Pendulum	77
4.5.3	A Time-Varying System: Point-Tracking Manipulator	78
4.5.4	A Closed Loop System: One Axis Manipulator	81
4.5.5	Summary	84
4.6	Handling the Dependency Problem	85
4.6.1	Rotation Error Elimination	85
4.6.2	Employment of Taylor Models	86
4.6.3	Other Methods	91
5	Comparison	92
5.1	Validation of Kinematics	92
5.1.1	NICEMOBILE – A Validated Library for Kinematics	92
5.1.2	A Sloppy Joint: MoSloppyJoint	93
5.1.3	Comparison	93
5.2	Validation of Dynamics	94
5.2.1	Symbolic Counterparts to MOBILE	95
5.2.2	An Approach to Validation Based on Symbolic Modeling Tools	96
5.2.3	Comparison with SMARTMOBILE	96
6	Conclusions and Outlook	99
A	Software Choices	110
A.1	Software for Validated Arithmetic	110
A.1.1	PROFIL/BIAS	110
A.1.2	COSY INFINITY	111
A.2	Software for Algorithmic Differentiation	111
A.3	Software for Validated Solution of IVPs	111
A.3.1	VNODE	111
A.3.2	COSY VI	112
A.3.3	VSPODE	112
		112

B C++ Programming Language	113
B.1 Object Oriented Programming in C++	113
B.1.1 A Class and its Syntax in C++	114
B.1.2 Data Abstraction	114
B.1.3 Inheritance and Polymorphism	115
B.1.4 Operator Overloading	115
B.2 Templates in C++	115
B.2.1 Class Templates in C++	116
B.2.2 Organization of Template Code	117
C SMARTMOBILE Installation	120
C.1 Installation	120
C.2 make -Files for SMARTMOBILE Programs	123
C.3 Useful Flags	123
D Data format .help	126