

Contents

1	Introduction	1
	Notes and References	20
2	Manifolds, Vectorfields, Lie Brackets, Distributions	23
	2.0 Survey of Section 2.1	24
	2.1 Manifolds, Coordinate Transformations, Tangent Space	29
	2.1.1 Differentiability, Manifolds, Submanifolds	29
	2.1.2 Tangent Vectors, Tangent Space, Tangent Mappings	37
	2.2 Vectorfields, Lie Brackets, Distributions, Frobenius' Theorem, Differential One-Forms	43
	2.2.1 Vectorfields, Lie Brackets, Lie Algebras	43
	2.2.2 Distributions, Frobenius' Theorem	55
	2.2.3 Cotangent Bundle, Differential One-Forms, Co-distributions	61
	2.3 Summary of Section 2.2	67
	Notes and References	69
	Exercises	70
3	Controllability and Observability, Local Decompositions	73
	3.1 Controllability	73
	3.2 Observability	93
	3.3 Invariant Distributions; Local Decompositions	101
	Notes and References	111
	Exercises	113
4	Input-Output Representations	117
	4.1 Wiener-Volterra and Fliess Series Expansion	118
	4.2 External Differential Representations	125
	4.3 Output Invariance	135
	Notes and References	143
	Exercises	145
5	State Space Transformation and Feedback	148
	5.1 State Space Transformations and Equivalence to Linear Systems	148
	5.2 Static and Dynamic Feedback	165
	Notes and References	172
	Exercises	173

6 Feedback Linearization of Nonlinear Systems	176
6.1 Geometric Conditions for Feedback Linearization	178
6.2 Computational Aspects of Feedback Linearization	194
Notes and References	205
Exercises	207
7 Controlled Invariant Distribution and the Disturbance Decoupling Problem	211
7.1 Controlled Invariant Distributions	211
7.2 The Disturbance Decoupling Problem	219
Notes and References	237
Exercises	239
8 The Input-Output Decoupling Problem	242
8.1 Static State Feedback Input-Output Decoupling for Analytic Systems	242
8.2 Dynamic State Feedback Input-Output Decoupling	255
Notes and References	270
Exercises	271
9 The Input-Output Decoupling Problem: Geometric Considerations	274
9.1 The Block Input-Output Decoupling Problem for Smooth Nonlinear Systems	274
9.2 The Formal Structure at Infinity and Input-Output Decoupling	286
Notes and References	294
Exercises	296
10 Local Stability and Stabilization of Nonlinear Systems	299
10.1 Local Stability and Local Stabilization via Linearization	299
10.2 Local Stabilization using Lyapunov's Direct Method	303
10.3 Local Stabilization via Center Manifold Theory	310
Notes and References	319
Exercises	321
11 Controlled Invariant Submanifolds and Nonlinear Zero Dynamics	323
11.1 Locally Controlled Invariant Submanifolds	323
11.2 Constrained Dynamics and Zero Dynamics	331
11.3 Interconnection of Systems and Inverse Systems	337

Notes and References	344
Exercises	346
12 Mechanical Nonlinear Control Systems	349
12.1 Definition of a Hamiltonian Control System	355
12.2 Controllability and Observability; Local Decompositions	363
12.3 Stabilization of Hamiltonian Control Systems	369
12.4 Constrained Hamiltonian Dynamics	376
12.5 Conservation Laws and Reduction of Order	385
Notes and References	392
Exercises	394
13 Controlled Invariance and Decoupling for General Nonlinear Systems	400
13.1 Locally Controlled Invariant Distributions	400
13.2 Disturbance Decoupling	414
13.3 Input-Output Decoupling	416
13.4 Locally Controlled Invariant Submanifolds	422
13.5 Control Systems Defined on Fiber Bundles	426
Notes and References	431
Exercises	433
14 Discrete-Time Nonlinear Control Systems	437
14.1 Feedback Linearization of Discrete-Time Nonlinear Systems	438
14.2 Controlled Invariant Distributions and the Disturbance Decoupling Problem in Discrete-Time	445
14.3 Input-Output Decoupling in Discrete-Time	451
Notes and References	455
Exercises	461
Subject Index	463