

# Table of Contents

<b>Chapter 1 Introduction .....</b>	<b>1</b>
1.1 Problem Statement and Motivation .....	1
1.2 Purpose of This Monograph .....	3
1.3 Background and Literature Review .....	4
1.3.1 Rough Terrain Modeling and Estimation .....	4
1.3.2 Rough Terrain Motion Planning.....	7
1.3.3 Rough Terrain Control.....	11
1.4 Outline of This Monograph.....	13
1.5 Assumptions .....	13
<b>Chapter 2 Rough Terrain Mobile Robot Modeling and Estimation ...</b>	<b>17</b>
2.1 Introduction .....	17
2.2 Robot Kinematic and Force Analysis .....	18
2.2.1 Robot Kinematic Analysis.....	18
2.2.2 Robot Force Analysis .....	21
2.3 Terrain Characterization and Identification .....	24
2.3.1 Equation Simplification.....	27
2.3.2 Sensing and Implementation Issues.....	31
2.4 Results: Terrain Identification .....	33
2.4.1 Simulation Results.....	33
2.4.2 Experimental Results.....	35
2.5 Wheel-Terrain Contact Angle Estimation .....	39
2.5.1 Extended Kalman Filter Implementation.....	42
2.6 Results: Wheel-Terrain Contact Angle Identification .....	44
2.6.1 Simulation Results.....	44
2.6.2 Experimental Results .....	45
2.7 Summary and Conclusions .....	50
<b>Chapter 3 Rough Terrain Motion Planning.....</b>	<b>51</b>
3.1 Introduction .....	51
3.2 Rough Terrain Motion Planning .....	52
3.2.1 Step One: Rapid Path Search.....	52
3.2.2 Step Two: Model-Based Evaluation.....	57
3.2.3 Uncertainty in Rough Terrain Motion Planning.....	59

XII Table of Contents

- 3.2.4. Incorporating Uncertainty in the Rapid Path Search ..... 61
- 3.2.5. Incorporating Uncertainty in the Model-Based Evaluation.... 62
- 3.3 Simulation Results—Rough Terrain Planning ..... 65
- 3.4 Rough Terrain Articulated Suspension Configuration Planning .... 70
  - 3.4.1 Articulated Suspension Configuration Planning Problem Description ..... 70
  - 3.4.2 Mobility Analysis ..... 71
  - 3.4.3 Articulated Suspension Configuration Planning for Enhanced Tipover Stability ..... 72
- 3.5 Results—Rough Terrain Articulated Suspension Configuration Planning ..... 75
  - 3.5.1 Simulation Results ..... 75
  - 3.5.2 Experimental Results ..... 76
- 3.6 Summary and Conclusions ..... 79
  
- Chapter 4 Rough Terrain Control ..... 81**
  - 4.1 Introduction ..... 81
  - 4.2 Mobile Robot Rough Terrain Control (RTC)..... 82
  - 4.3 Wheel-Terrain Contact Force Optimization ..... 84
    - 4.3.1 Optimization Criteria ..... 84
    - 4.3.2 Problem Constraints ..... 86
  - 4.4 Results—Rough Terrain Control..... 87
    - 4.4.1 Simulation Results ..... 87
    - 4.4.2 Experimental Results ..... 92
  - 4.5 Summary and Conclusions ..... 96
  
- Chapter 5 Conclusions and Suggestions for Future Work ..... 97**
  - 5.1 Contributions of This Monograph..... 97
  - 5.2 Suggestions for Further Work ..... 98
  
- References..... 101**
  
- Index ..... 109**