
Contents

Part I Iterative Learning Control Overview

| | | |
|----------|--------------------------------------------------------------------|----|
| 1 | Introduction | 3 |
| 1.1 | General Overview of the Monograph | 3 |
| 1.2 | Iterative Learning Control | 4 |
| 1.2.1 | What Is Iterative Learning Control? | 4 |
| 1.2.2 | Classical ILC Update Law | 7 |
| 1.2.3 | The Periodicity and Repetitiveness in ILC | 10 |
| 1.2.4 | Advantages of Using ILC | 11 |
| 1.3 | Research Motivation | 13 |
| 1.3.1 | Motivation for Robust Interval Iterative Learning Control | 13 |
| 1.3.2 | Motivation for H_∞ Iterative Learning Control | 16 |
| 1.3.3 | Motivation for Stochastic Iterative Learning Control ... | 17 |
| 1.4 | Original Contributions of the Monograph | 17 |
| 2 | An Overview of the ILC Literature | 19 |
| 2.1 | ILC Literature Search Methodology | 20 |
| 2.2 | Comments on the ILC Literature | 20 |
| 2.3 | IJC Special Issue | 23 |
| 2.4 | ILC-related Ph.D. Dissertations Since 1998 | 24 |
| 2.5 | Chapter Summary | 25 |
| 3 | The Super-vector Approach | 27 |
| 3.1 | Asymptotic Stability of Higher-order SVILC | 27 |
| 3.2 | Monotonic Convergence of Higher-order SVILC | 29 |
| 3.3 | Chapter Summary | 33 |

Part II Robust Interval Iterative Learning Control

| | | |
|----------|-----------------------------------------------------------------------------|-----------|
| 4 | Robust Interval Iterative Learning Control: Analysis | 37 |
| 4.1 | Interval Iterative Learning Control: Definitions | 37 |
| 4.2 | Robust Stability of Interval Iterative Learning Control | 41 |
| 4.2.1 | Asymptotical Stability of the Interval FOILC | 41 |
| 4.2.2 | Monotonic Convergence | 43 |
| 4.2.3 | Singular Value Approach | 48 |
| 4.2.4 | Robust Stability of Higher-order Interval Iterative Learning Control | 48 |
| 4.3 | Experimental Test | 49 |
| 4.4 | Chapter Summary | 51 |
| 5 | Schur Stability Radius of Interval Iterative Learning Control | 55 |
| 5.1 | Stability Radius | 56 |
| 5.2 | Optimization | 62 |
| 5.3 | Simulation Illustrations | 63 |
| 5.3.1 | Test Setup | 64 |
| 5.3.2 | Test Results | 64 |
| 5.4 | Chapter Summary | 68 |
| 6 | Iterative Learning Control Design Based on Interval Model Conversion | 69 |
| 6.1 | Interval Model Conversion in ILC | 69 |
| 6.2 | Interval Matrix Eigenpair Bounds | 71 |
| 6.3 | Markov Parameter Bounds | 75 |
| 6.4 | Robust ILC Design | 75 |
| 6.5 | Simulation Illustrations | 77 |
| 6.6 | A Different Approach for Interval Model Conversion | 79 |
| 6.7 | Chapter Summary | 80 |

Part III Iteration-domain Robustness

| | | |
|----------|--------------------------------------------------------------------------|-----------|
| 7 | Robust Iterative Learning Control: H_∞ Approach | 83 |
| 7.1 | Introduction | 83 |
| 7.2 | Problem Formulation | 84 |
| 7.2.1 | A Generalized Framework | 85 |
| 7.2.2 | Iteration-domain H_∞ Problem Formulation | 86 |
| 7.3 | Algebraic H_∞ Approach to Iterative Learning Control | 89 |
| 7.3.1 | Iteration-varying Disturbances | 89 |
| 7.3.2 | Model Uncertainty | 93 |
| 7.4 | Simulation Illustrations | 95 |
| 7.5 | Chapter Summary | 97 |

| | | |
|----------|-------------------------------------------------------------------|-----|
| 8 | Robust Iterative Learning Control: Stochastic Approaches | 101 |
| 8.1 | Baseline Error Estimation in the Iteration Domain | 102 |
| 8.1.1 | Modeling | 103 |
| 8.1.2 | Analytical Solutions | 106 |
| 8.1.3 | Simulation Illustrations | 111 |
| 8.1.4 | Concluding Remarks | 112 |
| 8.2 | Iteration-varying Model Uncertainty | 115 |
| 8.2.1 | Basic Background Materials of Model Uncertain Super-vector ILC | 116 |
| 8.2.2 | ILC Design for Iteration-varying Model Uncertain System | 117 |
| 8.2.3 | Parameter Estimation | 121 |
| 8.2.4 | Simulation Illustrations | 123 |
| 8.2.5 | Concluding Remarks | 123 |
| 8.3 | Intermittent Iterative Learning Control | 124 |
| 8.3.1 | Intermittent ILC | 125 |
| 8.3.2 | Optimal Learning Gain Matrix Design for Intermittent ILC | 127 |
| 8.3.3 | Concluding Remarks | 133 |
| 8.4 | Chapter Summary | 134 |
| 9 | Conclusions | 135 |

Appendices

| | | |
|----------|--------------------------------------------------------------------------|-----|
| A | Taxonomy of Iterative Learning Control Literature | 143 |
| A.1 | Taxonomy | 143 |
| A.2 | Literature Related to ILC Applications | 143 |
| A.2.1 | Robots | 144 |
| A.2.2 | Rotary Systems | 144 |
| A.2.3 | Batch/Factory/Chemical process | 144 |
| A.2.4 | Bio/Artificial Muscle | 145 |
| A.2.5 | Actuators | 145 |
| A.2.6 | Semiconductor | 145 |
| A.2.7 | Power Electronics | 146 |
| A.2.8 | Miscellaneous | 146 |
| A.3 | Literature Related to ILC Theories | 146 |
| A.3.1 | General (Structure) | 147 |
| A.3.2 | General (Update Rules) | 147 |
| A.3.3 | Typical ILC Problems | 148 |
| A.3.4 | Robustness Against Uncertainty, Time Varying, and/or Stochastic Noise | 148 |

| | | |
|----------|-------------------------------------------------------------------------|------------|
| A.3.5 | Optimal, Quadratic, and/or Optimization | 149 |
| A.3.6 | Adaptive and/or Adaptive Approaches | 149 |
| A.3.7 | Fuzzy or Neural Network ILC | 149 |
| A.3.8 | ILC for Mechanical Nonlinearity Compensation | 150 |
| A.3.9 | ILC for Other Repetitive Systems and Other Control Schemes | 150 |
| A.3.10 | Miscellaneous | 150 |
| A.4 | Discussion | 152 |
| B | Maximum Singular Value of an Interval Matrix | 153 |
| B.1 | Maximum Singular Value of a Square Interval Matrix | 153 |
| B.2 | Maximum Singular Value of Non-square Interval Matrix | 156 |
| B.3 | Illustrative Examples | 157 |
| B.3.1 | Example 1: Non-square Case | 157 |
| B.3.2 | Example 2: Square Case | 157 |
| B.4 | Summary | 159 |
| C | Robust Stability of Interval Polynomial Matrices | 161 |
| C.1 | Interval Polynomial Matrices | 161 |
| C.2 | Definitions and Preliminaries | 162 |
| C.3 | Stability Condition for Interval Polynomial Matrices | 163 |
| C.3.1 | The Stability of Polynomial Matrices: Part 1 | 164 |
| C.3.2 | The Stability of Polynomial Matrices: Part 2 | 165 |
| C.3.3 | The Stability of Interval Polynomial Matrices | 168 |
| C.4 | Illustrative Examples | 171 |
| C.4.1 | Example 1 | 171 |
| C.4.2 | Example 2 | 172 |
| C.5 | Summary | 173 |
| D | Power of an Interval Matrix | 175 |
| D.1 | Sensitivity Transfer Method | 176 |
| D.2 | Illustrative Examples | 178 |
| D.2.1 | Example 1 | 179 |
| D.2.2 | Example 2 | 180 |
| D.3 | Condition for Proposition D.2 | 181 |
| D.4 | Summary | 186 |
| | References | 187 |
| | Index | 229 |