

Contents

1.	Krein Space	1
1.1	Definition of Krein Spaces	1
1.2	Projections in Krein Spaces	3
1.3	Kalman Filtering Formulation in Krein Spaces	4
1.4	Two Basic Problems of Quadratic Forms in Krein Spaces	5
1.4.1	Problem 1	5
1.4.2	Problem 2	6
1.5	Conclusion	6
2.	Optimal Estimation for Systems with Measurement Delays	7
2.1	Introduction	7
2.2	Single Measurement Delay Case	7
2.2.1	Re-organized Measurements	9
2.2.2	Re-organized Innovation Sequence	11
2.2.3	Riccati Difference Equation	12
2.2.4	Optimal Estimate $\hat{\mathbf{x}}(t t)$	13
2.2.5	Computational Cost	15
2.3	Multiple Measurement Delays Case	17
2.3.1	Re-organized Measurements	18
2.3.2	Re-organized Innovation Sequence	19
2.3.3	Riccati Equation	20
2.3.4	Optimal Estimate $\hat{\mathbf{x}}(t t)$	22
2.3.5	Numerical Example	24
2.4	Conclusion	26
3.	Optimal Control for Systems with Input/Output Delays	27
3.1	Introduction	27
3.2	Linear Quadratic Regulation	28
3.2.1	Duality Between Linear Quadratic Regulation and Smoothing Estimation	29
3.2.2	Solution to Linear Quadratic Regulation	34

3.3	Output Feedback Control	41
3.4	Examples	44
3.5	Conclusion	50
4.	H_∞ Estimation for Discrete-Time Systems with Measurement Delays	53
4.1	Introduction	53
4.2	H_∞ Fixed-Lag Smoothing	54
4.2.1	An Equivalent H_2 Estimation Problem in Krein Space ..	55
4.2.2	Re-organized Innovation Sequence	58
4.2.3	Calculation of the Innovation Covariance	59
4.2.4	H_∞ Fixed-Lag Smoother	63
4.2.5	Computational Cost Comparison and Example	67
4.2.6	Simulation Example	69
4.3	H_∞ d -Step Prediction	69
4.3.1	An Equivalent H_2 Problem in Krein Space	70
4.3.2	Re-organized Innovation	73
4.3.3	Calculation of the Innovation Covariance	74
4.3.4	H_∞ d -Step Predictor	76
4.4	H_∞ Filtering for Systems with Measurement Delay	77
4.4.1	Problem Statement	77
4.4.2	An Equivalent Problem in Krein Space	78
4.4.3	Re-organized Innovation Sequence	80
4.4.4	Calculation of the Innovation Covariance $Q_w(t)$	82
4.4.5	H_∞ Filtering	84
4.5	Conclusion	85
5.	H_∞ Control for Discrete-Time Systems with Multiple Input Delays	87
5.1	Introduction	87
5.2	H_∞ Full-Information Control Problem	88
5.2.1	Preliminaries	89
5.2.2	Calculation of v^*	91
5.2.3	Maximizing Solution of J_N with Respect to Exogenous Inputs	96
5.2.4	Main Results	104
5.3	H_∞ Control for Systems with Preview and Single Input Delay ..	106
5.3.1	H_∞ Control with Single Input Delay	106
5.3.2	H_∞ Control with Preview	108
5.4	An Example	111
5.5	Conclusion	113
6.	Linear Estimation for Continuous-Time Systems with Measurement Delays	115
6.1	Introduction	115

6.2	Linear Minimum Mean Square Error Estimation for Measurement Delayed Systems	116
6.2.1	Problem Statement	116
6.2.2	Re-organized Measurement Sequence	117
6.2.3	Re-organized Innovation Sequence	118
6.2.4	Riccati Equation	119
6.2.5	Optimal Estimate $\hat{x}(t t)$	120
6.2.6	Numerical Example	121
6.3	H_∞ Filtering for Systems with Multiple Delayed Measurements	122
6.3.1	Problem Statement	123
6.3.2	An Equivalent Problem in Krein Space	124
6.3.3	Re-organized Innovation Sequence	126
6.3.4	Riccati Equation	127
6.3.5	Main Results	129
6.3.6	Numerical Example	130
6.4	H_∞ Fixed-Lag Smoothing for Continuous-Time Systems	132
6.4.1	Problem Statement	132
6.4.2	An Equivalent H_2 Problem in Krein Space	133
6.4.3	Re-organized Innovation Sequence	136
6.4.4	Main Results	137
6.4.5	Examples	140
6.5	Conclusion	141
7.	H_∞ Estimation for Systems with Multiple State and Measurement Delays	143
7.1	Introduction	143
7.2	Problem Statements	144
7.3	H_∞ Smoothing	145
7.3.1	Stochastic System in Krein Space	146
7.3.2	Sufficient and Necessary Condition for the Existence of an H_∞ Smoother	148
7.3.3	The Calculation of an H_∞ Estimator $\bar{z}(t, d)$	149
7.4	H_∞ Prediction	157
7.5	Conclusion	162
8.	Optimal and H_∞ Control of Continuous-Time Systems with Input/Output Delays	163
8.1	Introduction	163
8.2	Linear Quadratic Regulation	164
8.2.1	Problem Statements	164
8.2.2	Preliminaries	165
8.2.3	Solution to the LQR Problem	169
8.2.4	An Example	175
8.3	Measurement Feedback Control	178
8.3.1	Problem Statement	179

8.3.2	Solution	180
8.4	H_∞ Full-Information Control	185
8.4.1	Problem Statement	185
8.4.2	Preliminaries	187
8.4.3	Calculation of v^*	190
8.4.4	H_∞ Control	195
8.4.5	Special Cases	199
8.5	Conclusion	203
	References	205
	Index	211