Optimal and Robust Control: Advanced Topics With MATLAB

Table Of Contents:

List of Figures xi
Preface xv
Symbol List xvii
1 Modelling of uncertain systems and the robust control problem 1 (8)
   1.1 Uncertainty and robust control 1 (5)
   1.2 The essential chronology of major findings into robust control 6 (3)
2 Fundamentals of stability 9 (18)
   2.1 Lyapunov criteria 9 (2)
   2.2 Positive definite matrices 11 (3)
   2.3 Lyapunov theory for linear time-invariant systems 14 (4)
   2.4 Lyapunov equations 18 (3)
   2.5 Stability with uncertainty 21 (3)
   2.6 Exercises 24 (3)
3 Kalman canonical decomposition 27 (16)
   3.1 Introduction 27 (2)
   3.2 Controllability canonical partitioning 29 (2)
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 Reduced order models for SISO systems</td>
<td>79</td>
<td>(2)</td>
</tr>
<tr>
<td>7.2 Properties of symmetrical systems</td>
<td>81</td>
<td>(2)</td>
</tr>
<tr>
<td>7.3 The cross-gramian matrix</td>
<td>83</td>
<td>(1)</td>
</tr>
<tr>
<td>7.4 Relations between $w_2c$, $w_2o$ and $w_\infty$</td>
<td>83</td>
<td>(6)</td>
</tr>
<tr>
<td>7.5 Open-loop parameterization</td>
<td>89</td>
<td>(2)</td>
</tr>
<tr>
<td>7.6 Relation between the Cauchy index and the Hankel matrix</td>
<td>91</td>
<td>(1)</td>
</tr>
<tr>
<td>7.7 Singular values for a FIR filter</td>
<td>92</td>
<td>(3)</td>
</tr>
<tr>
<td>7.8 Singular values of all-pass systems</td>
<td>95</td>
<td>(1)</td>
</tr>
<tr>
<td>7.9 Exercises</td>
<td>96</td>
<td>(3)</td>
</tr>
<tr>
<td>8 Linear quadratic optimal control</td>
<td>99</td>
<td>(22)</td>
</tr>
<tr>
<td>8.1 LQR optimal control</td>
<td>99</td>
<td>(6)</td>
</tr>
<tr>
<td>8.2 Hamiltonian matrices</td>
<td>105</td>
<td>(4)</td>
</tr>
<tr>
<td>8.3 Resolving the Riccati equation by Hamiltonian matrix</td>
<td>109</td>
<td>(1)</td>
</tr>
<tr>
<td>8.4 The Control Algebraic Riccati Equation</td>
<td>110</td>
<td>(1)</td>
</tr>
<tr>
<td>8.5 Optimal control for SISO systems</td>
<td>111</td>
<td>(6)</td>
</tr>
<tr>
<td>8.6 Linear quadratic regulator with cross-weighted cost</td>
<td>117</td>
<td>(1)</td>
</tr>
<tr>
<td>8.7 Finite-horizon linear quadratic regulator</td>
<td>117</td>
<td>(1)</td>
</tr>
<tr>
<td>8.8 Optimal control for discrete-time linear systems</td>
<td>118</td>
<td>(1)</td>
</tr>
<tr>
<td>8.9 Exercises</td>
<td>119</td>
<td>(2)</td>
</tr>
<tr>
<td>9 Closed-loop balanced realization</td>
<td>121</td>
<td>(14)</td>
</tr>
<tr>
<td>9.1 Filtering Algebraic Riccati Equation</td>
<td>122</td>
<td>(2)</td>
</tr>
<tr>
<td>9.2 Computing the closed-loop balanced realization</td>
<td>124</td>
<td>(1)</td>
</tr>
<tr>
<td>9.3 Procedure for closed-loop balanced realization</td>
<td>125</td>
<td>(2)</td>
</tr>
<tr>
<td>9.4 Reduced order models based on closed-</td>
<td>127</td>
<td>(4)</td>
</tr>
</tbody>
</table>
9.5 Closed-loop balanced realization for symmetrical systems

9.6 Exercises

10 Passive and bounded-real systems

10.1 Passive systems

10.1.1 Passivity in the frequency domain
10.1.2 Passivity in the time domain
10.1.3 Factorizing positive-real functions
10.1.4 Passification
10.1.5 Passive reduced order models
10.1.6 Energy considerations connected to the Positive-Real Lemma
10.1.7 Closed-loop stability and positive-real systems
10.1.8 Optimal gain for loss-less systems

10.2 Circuit implementation of positive-real systems

10.3 Bounded-real systems

10.3.1 Properties of bounded-real systems
10.3.2 Bounded-real reduced order models

10.4 Relationship between passive and bounded-real systems

10.5 Exercises

11 H∞ linear control

11.1 Introduction
11.2 Solution of the H∞ linear control problem
11.3 The H∞ linear control and the
uncertainty problem

11.4 Exercises 171

12 Linear Matrix Inequalities for optimal and robust control

12.1 Definition and properties of LMI 173
12.2 LMI problems 175
  12.2.1 Feasibility problem 175
  12.2.2 Linear objective minimization problem 176
  12.2.3 Generalized eigenvalue minimization problem 176
12.3 Formulation of control problems in LMI terms 176
  12.3.1 Stability 177
  12.3.2 Simultaneous stabilizability 177
  12.3.3 Positive real lemma 178
  12.3.4 Bounded real lemma 178
  12.3.5 Calculating the $H_\infty$ norm through LMI 178
12.4 Solving a LMI problem 179
12.5 LMI problem for simultaneous stabilizability 181
12.6 Solving algebraic Riccati equations through LMI 184
12.7 Computation of gramians through LMI 187
12.8 Computation of the Hankel norm through LMI 188
12.9 $H_\infty$ control 190
12.10 Multiobjective control 192
12.11 Exercises 198
13 The class of stabilizing controllers 201
13.1 Parameterization of stabilizing controllers for stable processes 201(2)
13.2 Parameterization of stabilizing controllers for unstable processes 203(3)
13.3 Parameterization of stable controllers 206(3)
13.4 Simultaneous stabilizability of two systems 209(1)
13.5 Coprime factorizations for MIMO systems and unitary factorization 210(1)
13.6 Parameterization in presence of uncertainty 211(3)
13.7 Exercises 214(3)

Recommended essential references 217(6)
Appendix A Norms 223(4)
Appendix B Algebraic Riccati Equations 227(4)
Index 231