## Contents

Preface

|                  | Abk   | previations and Significant Notation                       | χv |
|------------------|-------|--|----|
| Part I<br>INTROI | DUCT  | ION  |    |
| 1                | 1 Ima | nging  | 3  |
|                  | 1.0   | Introduction 3   |    |
|                  | 1.1   | Digital Versus Optical Processing 5                        |    |
|                  | 1.2   | Concepts, Definitions, Notation, References 6              |    |
| 2                | 2 Ima | ge Formation and Recording                                 | 8  |
|                  | 2.0   | Introduction 8   |    |
|                  | 2.1   | Image Formation 8  |    |
|                  | 2.2   | Optical Systems 12   |    |
|                  | 2.3   | Penetrating Radiation Systems 13                           |    |
|                  | 2.4   | Image Detectors and Recorders 17                           |    |
|                  | 2.5   | Detector/Recorder Noise 20                                 |    |
|                  | 2.6   | Canonic Model for Image Formation, Detection, Recording 23 |    |
| VII              |       |  |    |

хi

viii Contents

| 3                 | Ima   | ge Representations and Models  | 26 |
|-------------------|---|--|----|
|                   | 3.0<br>3.1<br>3.2<br>3.3<br>3.4<br>3.5<br>3.6<br>3.7<br>3.8 | Introduction 26 Sampled Pictures 26 Image Representations in Orthogonal Bases 30 Examples of Image Representations 33 Separability, Kronecker Products, and Stacking Operators Parametric Statistical Models 42 Nonparametric Statistical Models 50 Parametric Deterministic Models 54 Nonparametric Deterministic Models 57 | 38 |
| Part II<br>DEGRAD | ATI   | ONS  |    |
|                   |   |  |    |
| 4                 | Sou   | rces and Models of Degradation   | 61 |
|                   | 4.0<br>4.1<br>4.2<br>4.3<br>4.4<br>4.5<br>4.6<br>4.7        | Introduction 61 Nonlinear Systems 61 Linear Systems 65 A Priori Imaging Constraints 68 Characterizations 75 Degrees of Freedom in Imaging Systems 83 Eigenanalysis of Imaging Systems 86 Stochastic Point-Spread Functions 88  |    |
| 5                 | ΑР  | osteriori Determined Degradation Parameters  | 90 |
|                   | 5.0<br>5.1  | Introduction 90 Point-Spread-Function Measurements 91  |    |

5.2 Noise Measurements 1015.3 Scanner Evaluation 705

Contents

## Part.III RESTORATION

| 6 | Preliminary Concepts in Image Restoration |  |     |  |
|---|---|--|-----|--|
|   | 6.0                                       | Introduction 113   |     |  |
|   | 6.1<br>6.2                                | The III-Conditioned Nature of Restoration 113  Discrete Formulation of Restoration 116 |     |  |
|   | 6.3                                       | Deterministic Versus Stochastic Approaches to Restoration 118                          |     |  |
|   | 6.4                                       | Theoretical Versus Practical Aspects of Image Restoration 120                          |     |  |
|   | 6.5                                       | An Overview of Image Restoration Methods 723   |     |  |
| 7 | Nor                                       | niterative Methods Implemented by Fourier Computation                                  | 126 |  |
|   | 7.0                                       | Introduction 126   |     |  |
|   | 7.1                                       | Least-Squares Restoration 126  |     |  |
|   | 7.2                                       | Minimum Mean-Square-Error Restoration 132  |     |  |
|   | 7.3                                       | Homomorphic Filter Restoration 140   |     |  |
|   | 7.4                                       | Concluding Comments 144  |     |  |
| 8 | Line                                      | ear Algebraic Restoration  | 147 |  |
|   | 8.0                                       | Introduction 747   |     |  |
|   | 8.1                                       | Discrete-Discrete Model: Least-Squares Techniques 747                                  |     |  |
|   | 8.2                                       | Properties of [H] 161  |     |  |
|   | 8.3                                       | Pseudo-Inversion Techniques 164  |     |  |
|   | 8.4                                       | Continuous-Discrete Model: Least-Squares Techniques 182                                |     |  |
|   | 8.5                                       | Conclusions 186  |     |  |
| 9 | Non                                       | linear Algebraic Restoration   | 187 |  |
|   | 9.0                                       | Introduction 757   |     |  |
|   | 9.1                                       | Positivity Constraints 188   |     |  |
|   | 9.2                                       | Bayesian Methods and Sensor Nonlinearities 193   |     |  |
|   | 9.3                                       | Random-Grain Models 189  |     |  |
|   | 9.4                                       | Optimal Recursive Processing 203   |     |  |
|   | 9.5                                       | Nonlinear Eigenspace Computations 206  |     |  |

## Contents

## **APPENDICES**

|   | Subject Index                                  | 23 |
|---|--|----|
|   | Author Index                                   | 23 |
|   | References                                     | 22 |
| В | Circulants and Fourier Computations            | 22 |
| Α | Space-Invariant Point-Spread-Function Matrices | 21 |