

Handbook of Computer Vision and Applications

Volume 1

Sensors and Imaging

Editors

Bernd Jähne

Interdisciplinary Center for Scientific Computing
University of Heidelberg, Heidelberg, Germany

and

Scripps Institution of Oceanography
University of California, San Diego

Horst Haußecker

Peter Geißler

Interdisciplinary Center for Scientific Computing
University of Heidelberg, Heidelberg, Germany



ACADEMIC PRESS

San Diego London Boston
New York Sydney Tokyo Toronto

Contents

| | |
|---|-------------|
| Preface | xi |
| Contributors | xiii |
| 1 Introduction | 1 |
| <i>B. Jähne</i> | |
| 1.1 Components of a vision system | 1 |
| 1.2 Imaging systems | 2 |
| I Illumination and Image Formation | |
| 2 Radiation | 7 |
| <i>H. Haußecker</i> | |
| 2.1 Introduction | 8 |
| 2.2 Fundamentals of electromagnetic radiation | 9 |
| 2.3 Radiometric quantities | 13 |
| 2.4 Fundamental concepts of photometry | 24 |
| 2.5 Thermal emission of radiation | 28 |
| 2.6 Acoustic waves | 34 |
| 2.7 References | 35 |
| 3 Interaction of Radiation with Matter | 37 |
| <i>H. Haußecker</i> | |
| 3.1 Introduction | 37 |
| 3.2 Basic definitions and terminology | 39 |
| 3.3 Properties related to interfaces and surfaces | 43 |
| 3.4 Bulk-related properties of objects | 52 |
| 3.5 References | 61 |
| 4 Imaging Optics | 63 |
| <i>P. Geißler</i> | |
| 4.1 Introduction | 64 |
| 4.2 Basic concepts of geometric optics | 64 |
| 4.3 Lenses | 67 |
| 4.4 Optical properties of glasses and other materials | 78 |
| 4.5 Aberrations | 81 |
| 4.6 Optical image formation | 90 |
| 4.7 Wave and Fourier optics | 96 |
| 4.8 References | 101 |

| | |
|---|-----|
| 5 Radiometry of Imaging | 103 |
| <i>H. Haußecker</i> | |
| 5.1 Introduction | 104 |
| 5.2 Observing surfaces | 104 |
| 5.3 Propagating radiance | 112 |
| 5.4 Radiance of imaging | 115 |
| 5.5 Detecting radiance | 118 |
| 5.6 Concluding summary | 134 |
| 5.7 References | 135 |
| 6 Illumination Sources and Techniques | 137 |
| <i>H. Haußecker</i> | |
| 6.1 Introduction | 137 |
| 6.2 Natural illumination | 138 |
| 6.3 Artificial illumination sources | 141 |
| 6.4 Illumination setups | 157 |
| 6.5 References | 162 |
| II Imaging Sensors | |
| 7 Solid-State Image Sensing | 165 |
| <i>P. Seitz</i> | |
| 7.1 Introduction | 166 |
| 7.2 Fundamentals of solid-state photosensing | 168 |
| 7.3 Photocurrent processing | 175 |
| 7.4 Transportation of photosignals | 182 |
| 7.5 Electronic signal detection | 185 |
| 7.6 Architectures of image sensors | 189 |
| 7.7 Camera and video standards | 194 |
| 7.8 Semiconductor technology for image sensing | 204 |
| 7.9 Practical limitations of semiconductor photosensors | 207 |
| 7.10 The future of image sensing | 209 |
| 7.11 Conclusions | 218 |
| 7.12 References | 219 |
| 8 HDRC-Imagers for Natural Visual Perception | 223 |
| <i>U. Seger, U. Apel, and B. Höfflinger</i> | |
| 8.1 Introduction | 223 |
| 8.2 Log compression at the pixel site | 224 |
| 8.3 Random pixel access | 228 |
| 8.4 Optimized SNR by bandwidth control per pixel | 228 |
| 8.5 Data density in the log space | 230 |
| 8.6 Color constancy in the log space | 230 |
| 8.7 Development of functionality and spatial resolution | 231 |
| 8.8 References | 235 |
| 9 Image Sensors in TFA (Thin Film on ASIC) Technology | 237 |
| <i>B. Schneider, P. Rieve, and M. Böhm</i> | |
| 9.1 Introduction | 238 |
| 9.2 Thin-film detectors | 239 |

| | | |
|------------------------------------|--|------------|
| 9.3 | TFA properties and design considerations | 249 |
| 9.4 | TFA array prototypes | 256 |
| 9.5 | TFA array concepts | 262 |
| 9.6 | Conclusions | 267 |
| 9.7 | References | 268 |
| 10 | Poly SiGe Bolometers | 271 |
| | <i>S. Sedky and P. Fiorini</i> | |
| 10.1 | Overview | 272 |
| 10.2 | Principle of operation of bolometers | 274 |
| 10.3 | Microbolometer focal plane arrays | 280 |
| 10.4 | Bolometer materials | 284 |
| 10.5 | Poly SiGe bolometers | 288 |
| 10.6 | Characterization of poly SiGe bolometers | 292 |
| 10.7 | Conclusions | 302 |
| 10.8 | References | 303 |
| 11 | Hyperspectral and Color Imaging | 309 |
| | <i>B. Jähne</i> | |
| 11.1 | Spectral signatures | 309 |
| 11.2 | Spectral sampling methods | 310 |
| 11.3 | Human color vision | 315 |
| 11.4 | References | 320 |
| III Two-Dimensional Imaging | | |
| 12 | Dynamic Fluorescence Imaging | 323 |
| | <i>D. Uttenweiler and R. H. A. Fink</i> | |
| 12.1 | Introduction | 323 |
| 12.2 | Fluorescence | 324 |
| 12.3 | Fluorescent indicators | 328 |
| 12.4 | Microscopic techniques | 332 |
| 12.5 | Analysis of fluorescence images | 342 |
| 12.6 | Summary | 343 |
| 12.7 | References | 344 |
| 13 | Electron Microscopic Image Acquisition | 347 |
| | <i>H. Stegmann, R. Wepf, and R. R. Schröder</i> | |
| 13.1 | Introduction | 348 |
| 13.2 | Electron-specimen interactions | 349 |
| 13.3 | Transmission electron microscopy (TEM) | 350 |
| 13.4 | Scanning transmission electron microscopy (STEM) | 359 |
| 13.5 | Analytical transmission electron microscopy | 361 |
| 13.6 | Scanning electron microscopy (SEM) | 364 |
| 13.7 | Preparation techniques | 368 |
| 13.8 | Digital image processing of electron micrographs | 369 |
| 13.9 | Imaging examples | 370 |
| 13.10 | References | 383 |

| | |
|--|------------|
| 14 Processing of Ultrasound Images in Medical Diagnosis | 387 |
| <i>W. Albert and M. Pandit</i> | |
| 14.1 Introduction | 387 |
| 14.2 Ultrasound imaging systems | 390 |
| 14.3 Processing the B-mode image | 399 |
| 14.4 Examples of image processing of B-mode images | 404 |
| 14.5 Conclusions and perspectives | 411 |
| 14.6 References | 412 |
| 15 Acoustic Daylight Imaging in the Ocean | 415 |
| <i>M. J. Buckingham</i> | |
| 15.1 Introduction | 415 |
| 15.2 The pilot experiment | 416 |
| 15.3 ADONIS | 418 |
| 15.4 Acoustic daylight images | 420 |
| 15.5 Concluding remarks | 422 |
| 15.6 References | 423 |
| 16 The Multisensorial Camera for Industrial Vision Applications | 425 |
| <i>R. Massen</i> | |
| 16.1 Image segmentation with little robustness | 425 |
| 16.2 Sensor fusion and multisensorial camera | 426 |
| 16.3 A feature vector with every pixel | 428 |
| 16.4 A real-time three-dimensional linescan camera | 429 |
| 16.5 A real-time linescan scatter camera | 430 |
| 16.6 The multisensorial color-height-scatter camera | 433 |
| 16.7 Compressing the multisensorial camera signals | 435 |
| 16.8 The one-chip multisensorial camera | 435 |
| 16.9 Conclusion | 436 |
| 16.10 References | 437 |
| IV Three-Dimensional Imaging | |
| 17 Geometric Calibration of Digital Imaging Systems | 441 |
| <i>R. Godding</i> | |
| 17.1 Definitions | 442 |
| 17.2 Parameters influencing geometrical performance | 442 |
| 17.3 Model of image formation with the aid of optical systems | 444 |
| 17.4 Camera models | 445 |
| 17.5 Calibration and orientation techniques | 450 |
| 17.6 Photogrammetric applications | 457 |
| 17.7 References | 460 |
| 18 Principles of Three-Dimensional Imaging Techniques | 463 |
| <i>R. Schwarte, H. Heinol, B. Buxbaum, T. Ringbeck, Z. Xu, and K. Hartmann</i> | |
| 18.1 Introduction | 464 |
| 18.2 Basic principles | 465 |
| 18.3 Some criteria and specifications | 467 |
| 18.4 Triangulation | 469 |
| 18.5 Time-of-flight (TOF) of modulated light | 474 |

| | | |
|-----------|--|------------|
| 18.6 | Optical Interferometry (OF) | 479 |
| 18.7 | Outlook | 482 |
| 18.8 | References | 482 |
| 19 | Three-Dimensional Sensors—Potentials and Limitations | 485 |
| | <i>G. Häusler</i> | |
| 19.1 | Introduction | 485 |
| 19.2 | Why three-dimensional sensors? | 486 |
| 19.3 | Some important questions about three-dimensional sensing | 488 |
| 19.4 | Triangulation on optically rough surfaces | 489 |
| 19.5 | White-light interferometry on rough surfaces | 495 |
| 19.6 | Summary | 503 |
| 19.7 | Conclusion | 504 |
| 19.8 | References | 505 |
| 20 | High-Performance Surface Measurement | 507 |
| | <i>R. W. Malz</i> | |
| 20.1 | Introduction | 508 |
| 20.2 | Close-range photogrammetry | 511 |
| 20.3 | Sequential light processing and information theory | 517 |
| 20.4 | Advanced self-calibration of three-dimensional sensors | 526 |
| 20.5 | Hybrid navigation of three-dimensional sensors | 529 |
| 20.6 | Mobile measuring system “Ganymed” | 532 |
| 20.7 | Conclusions | 536 |
| 20.8 | References | 538 |
| 21 | Three-Dimensional Light Microscopy | 541 |
| | <i>E. H. K. Stelzer</i> | |
| 21.1 | Three-dimensional microscopy | 542 |
| 21.2 | Telecentricity | 543 |
| 21.3 | Theory of three-dimensional imaging | 547 |
| 21.4 | Confocal microscopy | 548 |
| 21.5 | Index mismatching effects | 555 |
| 21.6 | Developments in confocal microscopy | 556 |
| 21.7 | Resolution versus distance | 557 |
| 21.8 | Perspectives of three-dimensional light microscope | 558 |
| 21.9 | References | 559 |
| 22 | Magnetic Resonance Imaging in Medicine | 563 |
| | <i>W. G. Schreiber and G. Brix</i> | |
| 22.1 | Introduction | 564 |
| 22.2 | Basic magnetic resonance physics | 564 |
| 22.3 | Image acquisition and reconstruction | 574 |
| 22.4 | Image contrast | 587 |
| 22.5 | Fast imaging methods | 591 |
| 22.6 | Overview of quantitative applications | 596 |
| 22.7 | References | 598 |

| | |
|---|------------|
| 23 Nuclear Magnetic Resonance Microscopy | 601 |
| <i>A. Haase, J. Ruff, and M. Rokitta</i> | |
| 23.1 Introduction | 601 |
| 23.2 Methodology | 603 |
| 23.3 Applications to plant studies | 605 |
| 23.4 Applications to animal studies | 609 |
| 23.5 Discussion | 611 |
| 23.6 References | 612 |
| Index | 613 |