

Lecture Notes in Computational Vision and Biomechanics

Volume 11

Series editors

João Manuel R. S. Tavares, Porto, Portugal
R. M. Natal Jorge, Porto, Portugal

Editorial Advisory Board

Alejandro Frangi, Sheffield, UK
Chandrajit Bajaj, Austin, USA
Eugenio Oñate, Barcelona, Spain
Francisco Perales, Palma de Mallorca, Spain
Gerhard A. Holzapfel, Stockholm, Sweden
J. Paulo Vilas-Boas, Porto, Portugal
Jeffrey A. Weiss, Salt Lake City, USA
John Middleton, Cardiff, UK
Jose M. García Aznar, Zaragoza, Spain
Perumal Nithiarasu, Swansea, UK
Kumar K. Tamma, Minneapolis, USA
Laurent Cohen, Paris, France
Manuel Doblaré, Zaragoza, Spain
Patrick J. Prendergast, Dublin, Ireland
Rainald Löhner, Fairfax, USA
Roger Kamm, Cambridge, USA
Thomas J. R. Hughes, Austin, USA
Yongjie Zhang, Pittsburgh, USA
Yubo Fan, Beijing, China

For further volumes:

<http://www.springer.com/series/8910>

The research related to the analysis of living structures (Biomechanics) has been a source of recent research in several distinct areas of science, for example, Mathematics, Mechanical Engineering, Physics, Informatics, Medicine and Sport. However, for its successful achievement, numerous research topics should be considered, such as image processing and analysis, geometric and numerical modelling, biomechanics, experimental analysis, mechanobiology and enhanced visualization, and their application to real cases must be developed and more investigation is needed. Additionally, enhanced hardware solutions and less invasive devices are demanded.

On the other hand, Image Analysis (Computational Vision) is used for the extraction of high level information from static images or dynamic image sequences. Examples of applications involving image analysis can be the study of motion of structures from image sequences, shape reconstruction from images and medical diagnosis. As a multidisciplinary area, Computational Vision considers techniques and methods from other disciplines, such as Artificial Intelligence, Signal Processing, Mathematics, Physics and Informatics. Despite the many research projects in this area, more robust and efficient methods of Computational Imaging are still demanded in many application domains in Medicine, and their validation in real scenarios is matter of urgency.

These two important and predominant branches of Science are increasingly considered to be strongly connected and related. Hence, the main goal of the LNCV&B book series consists of the provision of a comprehensive forum for discussion on the current state-of-the-art in these fields by emphasizing their connection. The book series covers (but is not limited to):

- Applications of Computational Vision and Biomechanics
- Biometrics and Biomedical Pattern Analysis
- Cellular Imaging and Cellular Mechanics
- Clinical Biomechanics
- Computational Bioimaging and Visualization
- Computational Biology in Biomedical Imaging
- Development of Biomechanical Devices
- Device and Technique Development for Biomedical Imaging
- Experimental Biomechanics
- Gait & Posture Mechanics
- Grid and High Performance Computing for Computational Vision and Biomechanics
- Image Processing and Analysis
- Image Processing and Visualization in Biofluids
- Image Understanding
- Material Models
- Mechanobiology
- Medical Image Analysis
- Molecular Mechanics
- Multi-Modal Image Systems
- Multiscale Biosensors in Biomedical Imaging
- Multiscale Devices and Biomems for Biomedical Imaging
- Musculoskeletal Biomechanics
- Multiscale Analysis in Biomechanics
- Neuromuscular Biomechanics
- Numerical Methods for Living Tissues
- Numerical Simulation
- Software Development on Computational Vision and Biomechanics
- Sport Biomechanics
- Virtual Reality in Biomechanics
- Vision Systems

M. Emre Celebi · Bogdan Smolka
Editors

Advances in Low-Level Color Image Processing

 Springer

Editors

M. Emre Celebi
Computer Science Department
Louisiana State University
Shreveport, LA
USA

Bogdan Smolka
Department of Automatic Control
Silesian University of Technology
Gliwice
Poland

ISSN 2212-9391

ISSN 2212-9413 (electronic)

ISBN 978-94-007-7583-1

ISBN 978-94-007-7584-8 (eBook)

DOI 10.1007/978-94-007-7584-8

Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2013953224

© Springer Science+Business Media Dordrecht 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law. The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Color perception plays an important role in object recognition and scene understanding both for humans and intelligent vision systems. Recent advances in digital color imaging and computer hardware technology have led to an explosion in the use of color images in a variety of applications including medical imaging, content-based image retrieval, biometrics, watermarking, digital inpainting, remote sensing, visual quality inspection, among many others. As a result, automated processing and analysis of color images has become an active area of research, which is witnessed by the large number of publications during the past two decades. The multivariate nature of color image data presents new challenges for researchers and practitioners as the numerous methods developed for single channel images are often not directly applicable to multichannel ones.

The goal of this volume is to summarize the state-of-the-art in the early stages of the color image processing pipeline. The intended audience includes researchers and practitioners, who are increasingly using color and, in general, multichannel images.

The volume opens with two chapters on image acquisition. In [Chap. 1](#) Chen et al. focus on the problem of color artifacts generated by line-scan cameras. They propose a method that enables automated correction of the color misalignment in multi-line CCD images for rotational and translational scans. The chapter presents the experimental results achieved using a close-range multi-line CCD imaging system for inspection applications and a long-range camera intended for surveillance tasks. The results confirm that the two imaging systems enable the acquisition of hyper-resolution images with effective color misalignment adjustment.

In [Chap. 2](#) Lee and Park propose a novel adaptive technique for color image demosaicking that exploits the characteristics of the CFA pattern. Comparative experiments performed on a large set of test images show the effectiveness of the proposed interpolation algorithm in terms of peak signal-to-noise ratio, structural similarity, and subjective visual quality. The new algorithm outperforms conventional algorithms especially in the case of natural images containing many image structures such as lines, edges, and corners.

The volume continues with two chapters on color constancy. In [Chap. 3](#) Lee and Plataniotis et al. present a comprehensive survey of color constancy and color invariance. The color of an object recorded in image data is not only a function of an intrinsic property of the object itself, but also a function of the acquisition

device and the prevailing illumination. When these factors are not properly controlled, the performance of color image processing applications can deteriorate substantially. The Authors review two common approaches to attain reliable color description of image data under varying imaging conditions, namely, color constancy and color invariance, where the former is based on scene illuminant estimation and image correction, while the latter is based on invariant feature extraction.

In [Chap. 4](#) Lecca describes applications of the von Kries model of chromatic adaptation to color correction, illuminant invariant image retrieval, estimation of color temperature and intensity of light, and photometric characterization of a device. The von Kries model describes the change in image colors due to illuminant variation. Lecca first illustrates the theoretical foundations of the von Kries model. The Author then presents a method for the model parameter estimation and derives a mathematical relationship between the parameters of the von Kries model and the color temperatures and intensities of the varied illuminants. The chapter concludes by showing a model relating the von Kries parameters to the photometric properties of the acquisition device. Through this model, it is possible to estimate the light wavelengths for which the camera sensors are maximally responsive. These wavelengths are used for finding an illuminant invariant image representation. The chapter reports various experiments carried out on publicly available real-world datasets.

In [Chap. 5](#) Baljovic et al. propose a novel algorithm for removing impulsive or mixed noise from color images based on the halfspace depth function. The resulting multichannel filter maintains the spectral correlation between the color channels and does not depend on the nature or distribution of the noise. The Authors compare the performance of their filter against a large number of state-of-the-art noise removal filters on a diverse set of images.

The volume continues with three chapters on mathematical morphology. In [Chap. 6](#) Debayle and Pinoli present a spatially adaptive image processing framework based on the General Adaptive Neighborhood Image Processing (GANIP) concept. The Authors extend the GANIP approach to color images and define a set of locally adaptive image processing operators. Special emphasis is given to adaptive fuzzy and morphological filters, which are compared to their classic counterparts in restoration, enhancement, and segmentation of color images.

In [Chap. 7](#) Velasco and Angulo investigate the applicability of recent multivariate ordering approaches to morphological analysis of color and multispectral images. The Authors survey supervised learning and anomaly based ordering approaches and present applications of each.

In [Chap. 8](#) Lefèvre et al. review morphological template matching using the Hit-or-Miss Transform (HMT) operator. The Authors review the application of HMT to binary, grayscale, and color images. They also discuss several case studies illustrating practical applications of HMT in different application domains.

The volume continues with two chapters on segmentation. In [Chap. 9](#) Moreno et al. propose two powerful color edge detection methods based on the tensor

voting concept, which extracts structures from a cloud of multidimensional points. The proposed edge detection techniques are evaluated based on measures of completeness, discriminability, precision, and robustness to noise. Experimental results on a database with ground-truth edges reveal useful properties of the new methods, especially in the case of color images distorted by a Gaussian noise process.

In [Chap. 10](#) Alarcon and Dalmau first review various discrete and fuzzy-based color categorization models and then they focus on a new framework which provides a probabilistic partition of a given color space. The proposed approach combines the color categorization model with a probabilistic segmentation algorithm and generalizes it including the interaction between categories. The effectiveness of the proposed approach is illustrated using various applications including color image segmentation, edge detection, video re-colorization, and object tracking.

In [Chap. 11](#) Kawulok et al. present an overview of skin detection. The Authors focus on approaches based on pixel classification and present a comparative study of various state-of-the-art methods. They give an overview of techniques which model the skin color using a set of fixed rules, as well as those based on machine learning. In the latter case, the Authors report an experimental study which shows the sensitivity of commonly used methods to the number of samples in the training set. Not only are the techniques for skin color modeling explored, but also important approaches toward reducing skin detection errors are presented and validated empirically. In particular, the Authors outline the possibilities of adapting the skin color models to specific lighting conditions or to an individual, whose skin regions are to be segmented. In addition, the Authors present how the textural features and spatial analysis of the skin probability maps can be employed for skin detection.

In [Chap. 12](#) Lee et al. address the issues connected with the employment of skin color as a feature in automatic face detection systems. After providing a general overview of face detection methods utilizing color information, the Authors discuss approaches for modeling skin color distribution in various color spaces, focusing on the influence of illumination conditions on the skin detection results and describe practical applications of skin color classification in high-level image processing systems. The effectiveness of color cues in terms of detection performance and computational efficiency is addressed using two distinct case studies.

[Chapter 13](#) by Jiang et al. completes the volume. The Authors describe a very interesting application of color-based visual saliency in the design of video games. They provide an overview of several state-of-the-art saliency estimation methods and propose novel methods which are evaluated and compared with previously published techniques on an image saliency dataset. The proposed saliency estimation frameworks are applied to the visual game design process. The results demonstrate that the incorporation of color saliency information improves the visual quality of the video games and substantially increases their attractiveness.

As Editors, we hope that this volume focused on low-level color image processing will demonstrate the significant progress that has occurred in this field in

recent years. We also hope that the developments reported in this volume will motivate further research in this exciting field.

M. Emre Celebi
Bogdan Smolka

Contents

Automated Color Misalignment Correction for Close-Range and Long-Range Hyper-Resolution Multi-Line CCD Images	1
Zhiyu Chen, Andreas Koschan, Chung-Hao Chen and Mongi Abidi	
Adaptive Demosaicing Algorithm Using Characteristics of the Color Filter Array Pattern.	29
Ji Won Lee and Rae-Hong Park	
A Taxonomy of Color Constancy and Invariance Algorithm	55
Dohyoung Lee and Konstantinos N. Plataniotis	
On the von Kries Model: Estimation, Dependence on Light and Device, and Applications.	95
Michela Lecca	
Impulse and Mixed Multichannel Denoising Using Statistical Halfspace Depth Functions	137
Djordje Baljuzović, Aleksandra Baljuzović and Branko Kovačević	
Spatially Adaptive Color Image Processing	195
Johan Debayle and Jean-Charles Pinoli	
Vector Ordering and Multispectral Morphological Image Processing.	223
Santiago Velasco-Forero and Jesus Angulo	
Morphological Template Matching in Color Images	241
Sébastien Lefèvre, Erchan Aptoula, Benjamin Perret and Jonathan Weber	
Tensor Voting for Robust Color Edge Detection.	279
Rodrigo Moreno, Miguel Angel Garcia and Domenec Puig	
Color Categorization Models for Color Image Segmentation.	303
Teresa Alarcon and Oscar Dalmau	

Skin Detection and Segmentation in Color Images 329
Michal Kawulok, Jakub Nalepa and Jolanta Kawulok

Contribution of Skin Color Cue in Face Detection Applications 367
Dohyoung Lee, Jeaff Wang and Konstantinos N. Plataniotis

Color Saliency Evaluation for Video Game Design 409
Richard M. Jiang, Ahmed Bouridane and Abbes Amira

**Erratum to: On the von Kries Model: Estimation, Dependence
on Light and Device, and Applications** E1
Michela Lecca

Erratum to: Skin Detection and Segmentation in Color Images. E3
Michal Kawulok, Jakub Nalepa and Jolanta Kawulok