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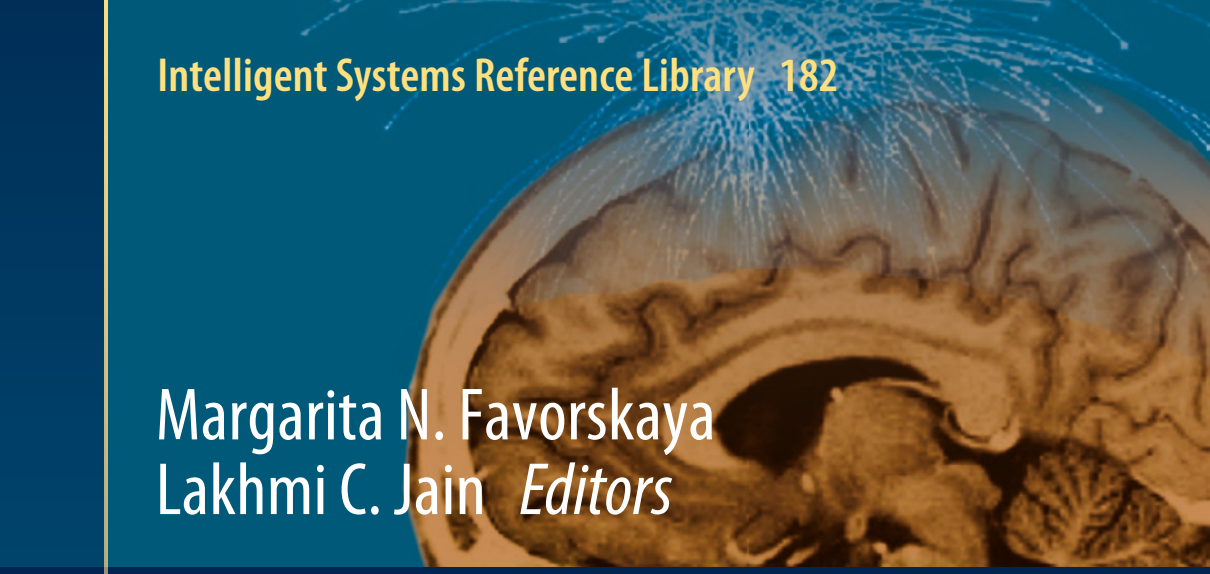

Margarita N. Favorskaya
Lakhmi C. Jain *Editors*

Computer Vision in Control Systems—6

Advances in Practical Applications

Springer

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Volume 182

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Editors

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Preface

The research book is a continuation of our previous books which are focused on the recent advances in computer vision methodologies and technical solutions using conventional and intelligent paradigms.

- *Computer Vision in Control Systems—1, Mathematical Theory*, ISRL Series, Volume 73, Springer-Verlag, 2015
- *Computer Vision in Control Systems—2, Innovations in Practice*, ISRL Series, Volume 75, Springer-Verlag, 2015
- *Computer Vision in Control Systems—3, Aerial and Satellite Image Processing*, ISRL Series, Volume 135, Springer-Verlag, 2018
- *Computer Vision in Control Systems—4, Real Life Applications*, ISRL Series, Volume 136, Springer-Verlag, 2018
- *Computer Vision in Control Systems—5, Advanced Decisions in Technical and Medical Applications*, ISRL Series, Volume 175, Springer-Verlag, 2020

The main aim of this volume is to present a sample of recent practical application of computer vision systems implemented by a number of researchers in Russian Federation.

The book is directed to the Ph.D. students, professors, researchers, and software developers working in the field of computer vision technologies and their applications.

We wish to express our gratitude to the authors and reviewers for their contributions. The assistance provided by Springer-Verlag is acknowledged.

Krasnoyarsk, Russia — Margarita N. Favorskaya
Broadway, Australia — Lakhmi C. Jain

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About the Editors

Dr. Margarita N. Favorskaya is a Professor and Head of Department of Informatics and Computer Techniques at Reshetnev Siberian State University of Science and Technology, Russian Federation.

Professor Favorskaya is a member of KES organization since 2010, the IPC member and the Chair of invited sessions of over 30 international conferences. She serves as an associate editor of *Intelligent Decision Technologies Journal*, *International Journal of Knowledge-Based and Intelligent Engineering Systems*, *International Journal of Reasoning-based Intelligent Systems*, a Honorary Editor of the *International Journal of Knowledge Engineering and Soft Data Paradigms*, Guest Editor, and Book Editor (Springer). She is the author or the co-author of 200 publications and 20 educational manuals in computer science. She co-authored and co-edited several books for Springer. She supervised nine Ph.D. candidates to completion and presently supervising four Ph.D. students.

Her main research interests are digital image and video processing, remote sensing, pattern recognition, fractal image processing, artificial intelligence, and information technologies.

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Professor Jain founded the KES International for providing a professional community the opportunities for publications, knowledge exchange, cooperation, and teaming. Involving around 5000 researchers drawn from universities and companies worldwide, KES facilitates international cooperation and generates synergy in teaching and research. KES regularly provides networking opportunities for professional community through one of the largest conferences of its kind in the area of KES.
http://www.kesinternational.org/organisation.php

Chapter 1
Image Processing for Practical Applications

Lakhmi C. Jain and Margarita N. Favorskaya

Abstract The chapter presents a brief description of chapters on image processing in different practical fields, from radar systems to medical applications. In spite of the fact that images can be multidimensional, additional dimensions extend the possibilities of methods and applications.

Keywords Object detection · Kalman filter · Video watermarking · Camera trap · Medical diagnostic · Data envelopment analysis · Landmarks descriptors

1.1 Introduction

Current technical achievements of humanity became possible due to the persistent work of scientists throughout the world. The main contribution of the book deals with the new techniques of forming and measurement of sub-pixel shift of digital images, characteristics of phase-energy image spectrum, detectors fields, comparative evaluation of algorithms for trajectory filtering, watermarking models of video sequences, experimental data acquisition and management software for camera trap data studies, two-stage method for polyps segmentation in endoscopic images, algorithms for markers detection in facies images of human biological fluids in medical diagnostics, research activities in intelligent data processing using data envelopment analysis, hybrid optimization modeling framework for research activities in intelligent data processing, non-local means denoising algorithm based on local binary patterns and object-oriented simultaneous localization and mapping on the spherobot platform.

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1.2 Chapters in the Book

Chapter 2 introduces new methods of forming digital images with sub-pixel shift and measuring this shift. Modification of discrete Chebyshev transformation is suggested to create the images with given sub-pixel shift [1]. The proposed algorithm allows to generate the digital images with a given sub-pixel shift and arbitrary scale without additional oversampling and interpolation. The exact distribution of estimations on the output of discriminator at the presence noise is obtained. This distribution is non-Gaussian and has got "heavy tails". Therefore, it was proposed to use restrictions such as Tukey, Huber, and Hampel at the output of the discriminator. In this case, the algorithm generates the robust and consistent estimations. Statistical modeling of proposed estimations is performed. It is established that the analytical law of estimation distribution coincides with experimental one.

Chapter 3 proposes a novel method to determine oscillation based on the analysis of one- and two-dimensional power spectra of the images or video sequences [2]. The authors assumed that one of the features confirmed object detection should be the determination of oscillation of the object or its parts in the image or videos. However, the information about oscillations mainly contain in 3D phase spectrum, which is difficult to extract. Nevertheless, phase-energy spectrum helps to solve this problem. The authors analyse complete information about amplitude and phase of image or video characteristics and obtain a real-valued function from phase-energy spectrum (i.e. weighted sum of cosines), which is convenient for the video analysis.

Chapter 4 introduces a new term—detectors fields as a set of two-zone structures (detectors). This approach is inspired by biological-like methods of video content analysis based on two-zone structures. Also, a drift mechanism of the detectors field is described. Use of the detectors fields allows to reduce the size of the processed image but keep all significant features. Thus, it is possible to reduce information flow to the next step of image processing. Detectors field is an adaptive computational environment for object detection. The distinguishing feature of detectors field is size reduction of the image. Detectors field consists of two-zone structures able to overlap and vary in size. The retinal receptive field can be considered as a prototype of the detectors fields. Redundancy reduction facilitated the implementation of quasi-optimal real-time filtering similar to Wiener–Hopf method. The practical tasks of motion blur and compensate can be solved using this approach.

Chapter 5 is dedicated to the study of trajectory filtering algorithms based on the use of Kalman filter. A new algorithm for estimating trajectory parameters was synthesized based on the model in the body-fixed frame during observations in the spherical coordinate system. A mathematical modelling was performed using the known linear and nonlinear Kalman filters and proposed algorithm. The proposed approach consists in the quasi-linearization of the equations for the projections of new coordinates onto the axis of the Cartesian system [3]. Mathematical model constructed in MATLAB environment performs a comparative analysis and research of

the effectiveness of the proposed modifications of linear and nonlinear Kalman filters. It was clarified that the use of filtering with adjustment in body-fixed coordinates is more effective than the algorithm based on the known Kalman filters.

Chapter 6 covers the models for multilevel adaptive watermarking schemes [4, 5] of the uncompressed and compressed video sequences in the highlights of H.264/SVC standard. The architecture of SVC encoder is analyzed, and three strategies for watermark embedding using H.264/SVC standard are proposed. They are classified as the watermark embedding before video encoding (Strategy 1), integrated watermark embedding and coding (Strategy 2), and compressed-domain embedding after encoding (Strategy 3). Also, different criteria for embedding in videos as the recommendation measures for the multilevel protection are proposed. Some objective functions are considered and their linear combination with the weighed coefficients can serve as the generalized criterion for evaluation of the extracted watermark.

Chapter 7 presents experimental data acquisition and management software for camera trap data studies. The study and preservation of biodiversity and regulation of the impact of human activity on ecosystems involves the analysis of big data, which cannot be implemented without intelligent software tools. Workflow of typical camera trap data management system includes three distinct stages: file management, data annotation, and data extraction. Analysis that follows data extraction is specific to a study and can be conducted by specialists. However, software system can prepare data for the analysis in automated ways. Since uneven illumination has a great influence on the background model formation and visual understanding of images, the modified Multi-Scale Retinex (MSR) algorithm, which utilizes wavelet transform to speed up the calculations [6], was used. In order to automate annotation, modules for automatic image importing with metadata extraction, semi-automatic background model formation module [7, 8], and sematic builder, which utilizes CNNs data, are introduced. The convolutional neural network training module, which allows to extend dataset by augmentations [9], is also included in system.

Chapter 8 develops a method for early detection of pathology changes in the stomach, which makes it possible to ensure timely treatment and avoid more serious consequences. The authors combine the traditional approach based on the geometric primitives, color features, and texture descriptors with CNN approach, which is able to capture various features and can be used including the segmentation of polyps. Thus, an algorithm for segmentation of polyps that takes into account the characteristics and specificity of the problem of segmentation of polyps in endoscopic images is propose. The main idea of the proposed algorithm is to combine the advantages of both the above approaches under conditions of a substantially limited training base. The implementation of the algorithm includes two consecutive steps. Binary classification step provides a preliminary analysis of global image features using traditional machine learning technologies. The result of the preliminary classification is the decision about the presence of a polyp in the image. Segmentation step is based on the use of CNN with the purpose of segmentation of one or several polyps if their presence in the image was confirmed at the previous stage. The main experimental result is in that the use of binary classification as a preliminary segmentation

stage increases Dice score more than 10% in conditionals of small database in CNN training.

Chapter 9 describes a method for precise early diagnostics of different diseases based on examination of human biological liquids (blood, tears, cervical mucus, urine, etc.,) [10, 11]. A small drop of liquid is drawn on an object-plate and dried out slowly, thus a thin dry film (facies) remains. In the process of fluid crystallization there appear characteristic patterns (markers) in the facies. Each marker is a highly definite sign of some pathology even at an early stage of a disease development. The authors develop the algorithms for detecting several markers on facies images. First, the characteristic features (location, geometry, brightness, variation, spectrum, etc.) are revealed by means of their visual analysis of markers. Then, the methods of these features' detection are applied. The decision about the presence of the marker is made using a set of necessary characteristics. Tests of algorithms showed that accuracy of correctly identified images achieves 86–98%.

Chapter 10 reports the opportunities of intelligent data processing in object-based image analysis for location-based social networks. The intelligent transport systems and infrastructure technology solutions are of direct research interest. A pervasive space is characterized by the physical and informational interaction between the users and designed environment. The concept of the work is to present implements a vision of intelligent data processing task and elaboration of the efficiency evaluation using data envelopment analysis in research activities discussions on the problem investigations of advanced technology precursors. The core approach is a nonparametric method in operations research for the estimation of production frontiers for intelligent data processing tasks [12, 13]. The target setting corresponds to an initiative focused on a comprehensive discussion of geosocial networking formation issues and assessment of the quality of intelligent data processing on the basis of conceptual models of integration advanced technology of computer vision and location-based social networks, and innovative potential of distributed computer vision and collaborative innovation network.

Chapter 11 is aimed at the implementation of effective commons-based peer production of the geosocial networking in the progressive movement of pervasive informatics based on investigation of geosocial networking using data envelopment analysis [14, 15]. The hybrid optimization modeling system includes a number of algorithms for efficiency analysis and multidimensional frontier visualization with the help of construction of two- and three-dimensional sections. In order to enhance effect from geosocial networking analysis, a projection system was applied, where 3D-sections of the frontier are generated using virtual reality. To create a visual stereo effect, two projectors with polarizing filters are used. On a special screen, two images for the left and right eyes are simultaneously formed. The screen has a special metallic surface that preserves the polarization of the images to be presented to each eye. Among the priority proposals on the use of the results of system integration in research activities and in the innovations of distributed computer and telecommunication networks based on the use of DEA technology, a generalization in the field of advanced computer vision for cyber-physical systems is outlined [16].

Chapter 12 describes an algorithm for converting old documents to digital format greatly simplifies their archiving and searching. This algorithm is a filter that divides an input image into fragments and then processes each fragment separately using a block-based method. Each image fragment contains many blocks. The blocks are processed separately, and the similarity of the blocks inside the fragment is measured by the basis of Euclidean distance between the centers of the blocks and the brightness distance between the blocks. Comparison of blocks is implemented in a fragment window, but not between adjacent pixels. In the course of this comparison, blocks with similar brightness levels have more weight when averaging a pixel value. This proposition allows to call this algorithm as a non-local method.

Chapter 13 describes an extraordinary robot, which looks like a ball and controlled by Wi-Fi communication. One can find a detail construction of this robot called as spherobot. By the wireless protocol, the robot streams the video data and data from encoders to the server. The sensors data broker on the robot is the Raspberry Pi Zero W. The robot is used fisheye lens with 260° on the camera for the getting much information as possible forming by a camera. The axis of the camera is directed vertically up. The displacement map of the environment is obtained using two consecutive images from different viewpoints. In such manner, 3D scene reconstruction can be achieved using special lens of robot camera.

1.3 Conclusions

This chapter provides a brief description of the chapters included in the book with original algorithms and practical implementations in the field of image processing for multiple tasks such as technical, control, medical, and so on. The contents of this book reflect the main directions of investigations carried out at present time which form the basis of future intelligent systems.

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Chapter 2
New Methods of Forming and Measurement of Sub-pixel Shift of Digital Images

Yuriy S. Radchenko and Olga A. Masharova

Abstract Methods of forming digital images with sub-pixel shift and measuring this shift are developed. Modification of discrete Chebyshev transformation is suggested to create the images with given sub-pixel shift. Optimal net of Chebyshev samples (secondary readings) in digital images is calculated. Samples are calculated in zeros of Chebyshev polynomials. Indicators of non-integer shift in a form of discriminators are suggested. Discriminators algorithms approximate Newton–Raphson method of estimating maximum likelihood. Estimation distribution for some types of discriminators in the presence of noise is obtained. We found that the estimation distribution is non-Gaussian, with "heavy tails". Limiters producing the stable estimations in order to subdue big output signal values are presented. Theoretical distributions of stable estimations are obtained. By means of statistical modeling, a coincidence between experimental and theoretical characteristics is established. The suggested algorithms are easy to calculate.

Keywords Sub-pixel image shift · Discrete Chebyshev transformation · Image position estimation · Discriminators · Non-Gaussian distribution of statistics · "heavy tails" of distribution · Statistical modeling

2.1 Introduction

The problem of synthesis and analysis of algorithms for estimating the shift of images or visual objects in frames is relevant and demanded in practice. First, it is an important part of signal compression and recovery algorithms in video coding problems [1]. Second, these problems are the main ones when estimating the position in a frame in video surveillance systems [2, 3]. Also, these problems arise in digital compensation of camera shakes and correction of turbulent distortions of visual objects in images [4, 5]. In these algorithms, estimation is non-integer. In modern systems, an image shift should be estimated with sub-pixel accuracy [1, 4, 5].

Recently, the problem of super resolution of images has been actively studied [6–11]. In this task, it is necessary to reconstruct a frame with a higher resolution

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